EAGLE TALK

McDonnell Aircraft Company

MCDONNELL DOUGLAS

1 APRIL 1989

P.S. 1257

A History of the

F-15 EAGLE

Volume III

(REPRINTS FROM MCAIR PRODUCT SUPPORT DIGEST)

MCDONNELL DOUGLAS

not for public release

P.S. 1257 - VOLUME III

INTRODUCTION

Welcome to Volume III of "Eagle Talk." With this book MCAIR continues to offer collections of F-15 articles previously published in the Product Support DIGEST. Volume I was published in 1984 and was aircrew oriented. Volume II followed shortly thereafter and contained the more technically oriented articles from the same period. This volume contains all articles published subsequent to those contained in the two earlier volumes. In addition we have sprinkled some F-15 related "Features" throughout the book.

To repeat the cautions stated with the two earlier reprints, there has been no attempt to "update" any of the articles to reflect the latest systems or possible modifications to the airplane. The Table of Contents contains the issue of the DIGEST in which the article appeared: 88/3 means year published/third issue. If you read something that sounds obsolete or conflicts with current manual coverage, the official USAF manual applies. This book contains good information and is intended to be of use to Eagle drivers and fixers alike, but remember it is for information only and is not directive in nature.

In case you have not seen the first two volumes of this series, they should be available from the MCAIR representative at your base. If no MCAIR representative is at your base, a direct request can be made to the address printed with the restriction notice on the inside front cover. We have a limited supply of these volumes and will provide copies upon request until they are exhausted.

We again apologize for the visual appearance of many of the pages in this book. The original test pages and artwork are no longer available so reproduction is done from a two-color copy of the appropriate articles in the DIGEST.

Volume II ended with two articles on the "Dual Role Fighter." This volume ends with the delivery of the first F-15E to Luke AFB. We didn't plan it that way but are struck with the coincidence. Who knows what is in store for Volume IV? Meanwhile we hope that this volume is a valuable addition to your store of Eagle knowledge.

The Staff, Product Support DIGEST

FOREWORD

Time flies when you're having fun! How often do we hear that? Sure is true though. The 17 years since we got the first Eagle airborne on July 27, 1972 have gone by very fast, due in part to the interest and excitement of this business. There can't be much to equal the fun of seeing an airplane and program of which you've been a part since its inception progress to such a successful stage.

For a guy like me, who has lived and breathed airplanes since single digit age, how could you top the thrill of being in on the design phase of a new airplane; being part of the first test pilot team; helping show the airplane off at Farnbrough the first time; and finally, watching (and hopefully contributing) from a management perspective as the program moves forward through successive stages of improvement.

In my view, the F-15 program has been a classic success. We had a great test program back in the 70s in concert with the Air Force test team. We've had good and timely mods to the Eagle culminating in the present F-15E. We've had a fine relationship with our customers. And, its a wonderful airplane with great capability and a superb safety record.

The names and faces change - some of you lucky Eagle drivers were youngsters when the program kicked off with the first contract award on January 1, 1970, almost 20 years ago. Lots of people who were key to the activity back then are out of the business now. But one thing doesn't change - the MCAIR/USAF dedication to keeping the F-15 in the pink of condition and upgraded, when necessary, so that it will continue to be the premier fighter airplane in the world. The multi-stage improvement program (MSIP), now underway, and the newly fielded F-15E version are testimony to that.

At MCAIR, we're awfully proud of this airplane. We want to help you keep it shiny, capable, and airborne. I hope the articles in this volume will be helpful toward that end.

Irv Burrows
Eagle Driver #1
Summer 1989

ENGINE

ENVIRONMENTAL

FLIGHT

FUEL SYSTEMS

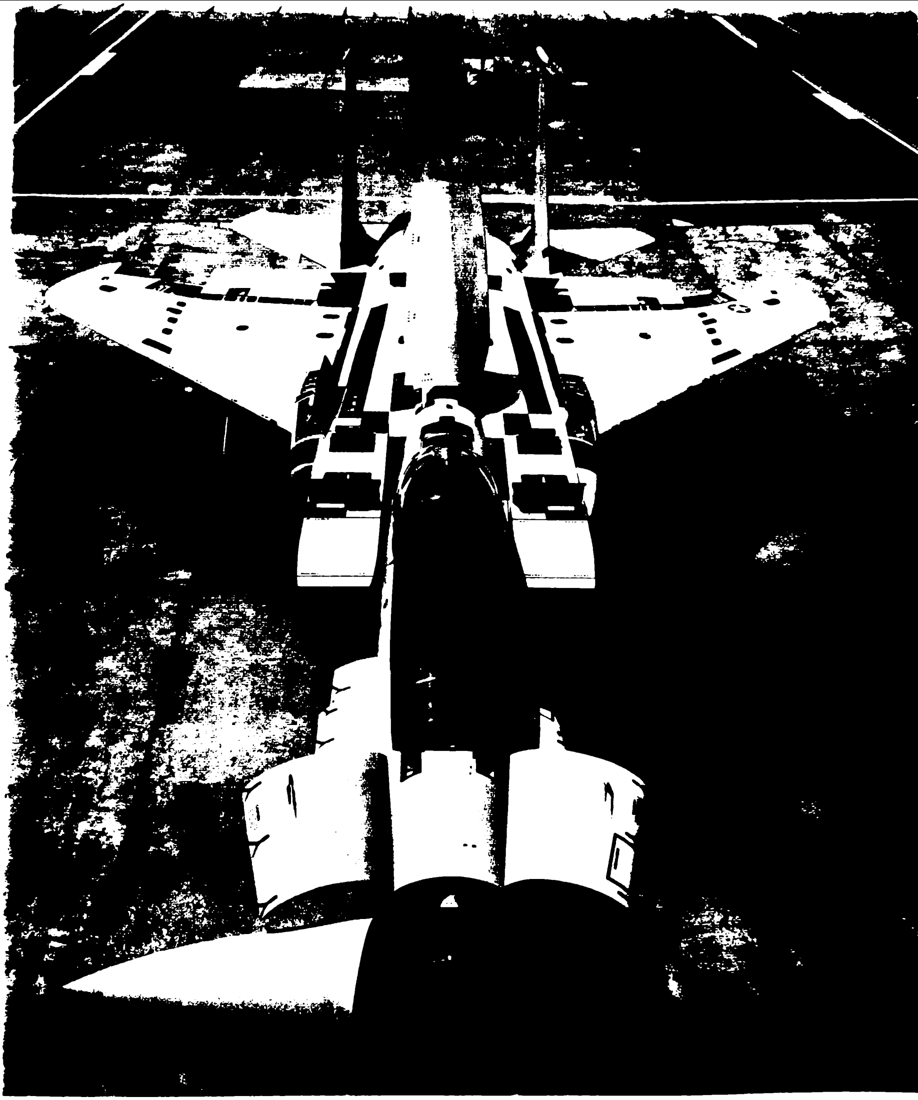
LOGISTICS

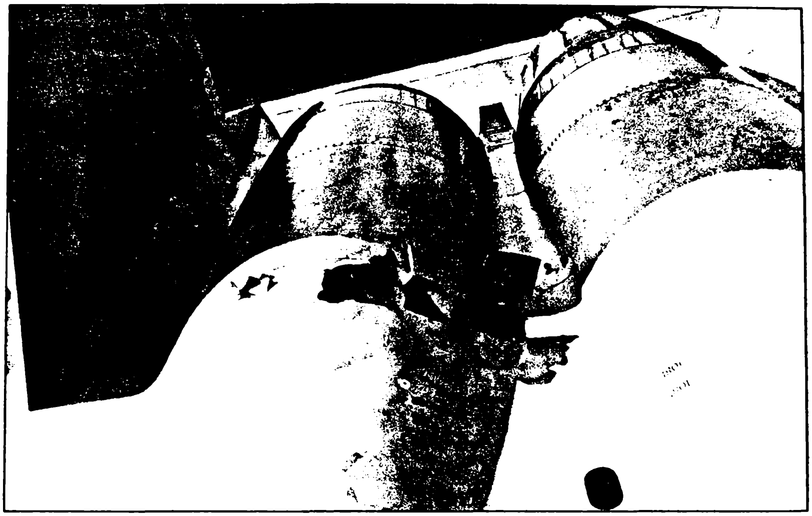
PNEUDRAULICS

SAFETY AND SURVIVAL

MAINTENANCE, GENERAL

FEATURES





WOUNDED EAGLE FLIES AGAIN

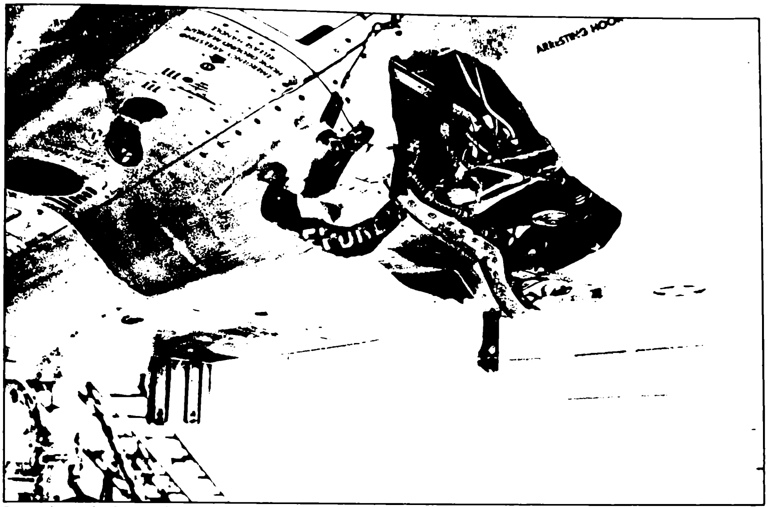
By DICK DOTY/*Service Engineer, Kadena Air Base, Okinawa, Japan*

"Most people would think fear would have come over me first, but mine was a feeling of bewilderment - that this was really happening to me. Fear wasn't a player for me because pilots go through extensive emergency procedures training intended to desensitize one to fear and permit rational, level-headed reactions."

The words above are by Lieutenant Steven W. Schmidt, a pilot with the 12th Tactical Fighter Squadron, 18th Tactical Fighter Wing, at Kadena Air Base, Japan; and he was referring to the hectic moments immediately after experiencing a serious inflight emergency with his F-15 Eagle. That this story has a "happy ending" is a direct tribute to the USAF fighter pilot training offered to new young officers like Lt Schmidt and to the rugged design of the F-15 air superiority fighter aircraft. A pilot with less effective training probably could not have overcome the operational problems; an airplane with less survivability probably could not have withstood the mechanical shocks which occurred so suddenly on this day back in March of 1981. Written by one of the MCAIR reps involved, this article presents an interesting account of some outstanding airmanship which resulted in safe recovery of a badly injured Eagle, followed by an equally interesting report of some outstanding "repairmanship" which resulted in eventual return to full operational status of F-15C S/N 78-0481.

Flying a training mission out of Kwang Ju Air Base, South Korea as a part of Exercise Team Spirit 1981, Second (now First) Lieutenant Steven W. Schmidt's F-15 flight turned rapidly from routine to a very serious inflight emergency. His first indication of trouble was illumination of the master caution light, followed almost immediately by a right engine oil pressure low light and a loud explosion. By the time he had retarded the throttle from military to idle power, leveled off the aircraft, and started to analyze the problem, the right engine fire warning light was flashing and the aural warning system had activated.

Following emergency procedures, Lt Schmidt shut down the right engine and discharged the fire extinguisher into the right engine bay. There were a few more anxious moments when the fire light did not go out, but his flight leader, in an accompanying F-15, verified that the fire was actually out. After making certain that the aircraft was controllable and could be safely landed, the lieutenant returned to Kwang Ju. On the way, flight control transients resulting from hydraulic switching valves kicking in and out



Damage photographs of upper surface (left) and lower surface (above) of F-15 78-0481 give some indication of extent of problems faced – first by pilot of this aircraft and later by repair crews – after inflight engine failure during Exercise Team Spirit in PACAF early in 1981.

shook the aircraft perodically; and landing at Kwang Ju was another test of flying skill because of a severe crosswind at the time. Despite engine, flight control, and hydraulic problems, he eased the damaged airplane onto the runway for a safe landing. (In recognition of his flying skills and systems knowledge, which were instrumental in recovery of a valuable Air Force combat aircraft, Lt Schmidt received the Pacific Air Forces "Aircrew of Distinction" award from Lieutenant General Arnold Braswell, PACAF Commander in Chief, during a meeting with Kadena pilots in August of 1981.)

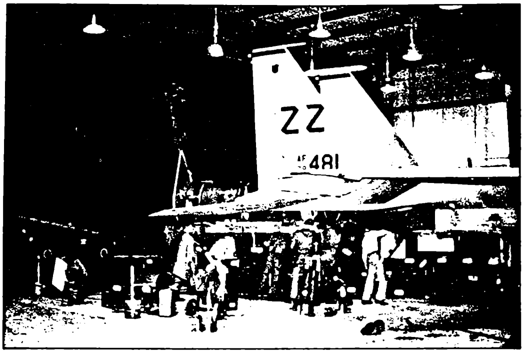
However, notwithstanding all of the lieutenant's good work, the Air Force now had a badly singed Eagle on its hands, some 600 miles from home base at Kadena. The aircraft was impounded and an investigation of the damage was started to determine what might be done next. As Lt Schmidt had already suspected, things looked pretty bad "under the hood;" and as the airplane was further checked out, it only got worse. It was obvious that 78-0481 was not ready for a quick turnaround.

There were many holes in the airframe on top of the engine bay and through the keel into the left engine bay as well as into the right primary heat exchanger bay. Some ten inches of the bottom of the main bulkhead at FS (Fuselage Station) 712.0 had been completely torn away. The engine bay itself had sustained extensive heat damage from just under the front of the engine all the way aft up on the bay outboard side wall. The right engine was so severely damaged that it was for all practical purposes broken into two parts, with only the main engine shaft holding them together.

With all this damage, it was obviously a job for a major repair team, but Kwang Ju was not suitable for such an effort. While the right engine was being removed for further damage analysis, engineers from MCAIR and Warner Robins AFLC were flown to the site to develop a temporary repair plan – something that would at least get the stranded Eagle back to Kadena for permanent rework. McDonnell engineer Ed Booker and WRALC engineer Crawford Battle not only came up with temporary fixes to make the aircraft one-time flyable, but also developed permanent repairs for later installation by a Depot team! They were joined at Kwang Ju by Pratt & Whitney engineer James Moore, who supervised removal of the damaged engine in what can only be described as an heroic inch-by-inch epic of make-do and bloody fingers!

As you all know, F-15 engine removal is normally a 30-minute maintenance job; this one took five days. First, the containment shield, which had been forced away from the engine so badly that it was meshed into the aircraft

LT Steve Schmidt



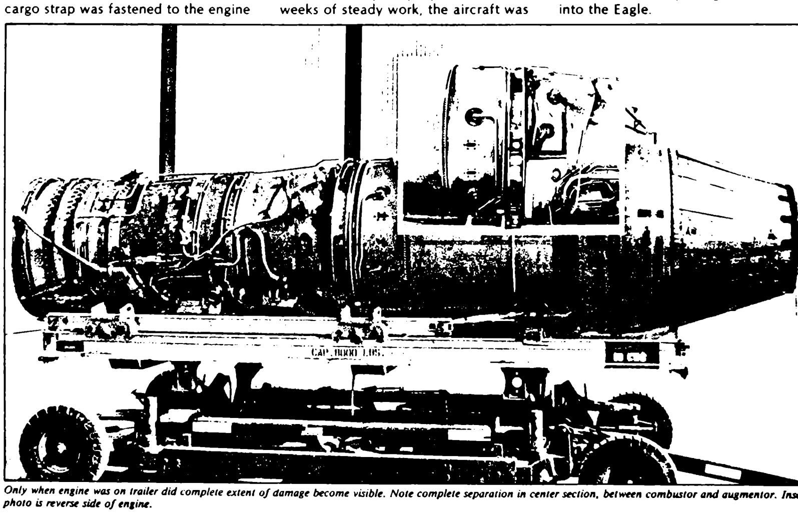
Damaged engine had to be inched out of airframe by equipment available at Kwang Ju AB, Korea.

skin, had to be cut into pieces and worked out through jagged holes in the airframe. This is what produced the bloody fingers. The make-do came with actual removal of the engine, through a setup of which Rube Goldberg would have been proud!

In order to keep the broken engine halves together and not cause further damage, the engine was removed an "inch at a time" by a novel looking but safe and effective combination of equipment on hand. A crane with a cargo strap was fastened to the engine augmentor section; an aircraft jack supporting wooden blocks was positioned under the center of the engine; and an MJ-4 bomb loader was placed under the front. After each inch or so, all of this equipment was repositioned for the next inch — actual removal of the engine took ten long, hard hours.

Colonel Ronald N. Hoelzer, 18th TFW Deputy Commander for Maintenance, then sent a special maintenance team up from Kadena to install the temporary repairs. After two weeks of steady work, the aircraft was considered fit for its one-time flight back to home base. Upon landing at Kadena Air Base, the first part of this major repair effort was now done; and a MCAIR Field Repair Team already at Kadena working on another aircraft assumed responsibility for the next part. They removed the temporary repairs, made "splashes" (exact patterns made of tooling plaster) of the damaged FS 712.0 bulkhead, sent the splashes back to St. Louis for fabrication of permanent repair parts, and cleaned up the remaining damage. By the time the permanent repairs were installed, more than eight months had elapsed from the day of Lt Schmidt's in-flight emergency; but on its first flight after repair, the aircraft returned with no major write-ups and ready to resume its duties with the 18th Tactical Fighter Wing in defense of the Pacific.

Many dedicated people must share in the congratulations for this amazing record of "can-do" performance, beginning with First Lieutenant Steven W. Schmidt for getting the damaged airplane back to Kwang Ju in the first place. Then there were the men and women of the 18th TFW maintenance organization who worked both at Kwang Ju and Kadena; and the engineers and technicians from Warner-Robins AFLC, Pratt & Whitney, and MCAIR. And then there was F-15C S/N 78-0481 itself — one more example of the survivability designed and built into the Eagle.

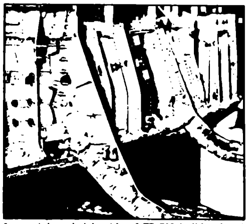


Only when engine was on trailer did complete extent of damage become visible. Note complete separation in center section, between combustor and augmentor. Inset photo is reverse side of engine.

"SPLASHES" HEAL WOUNDED EAGLE

By KEN PERCIVAL/*Unit Chief, Technology*

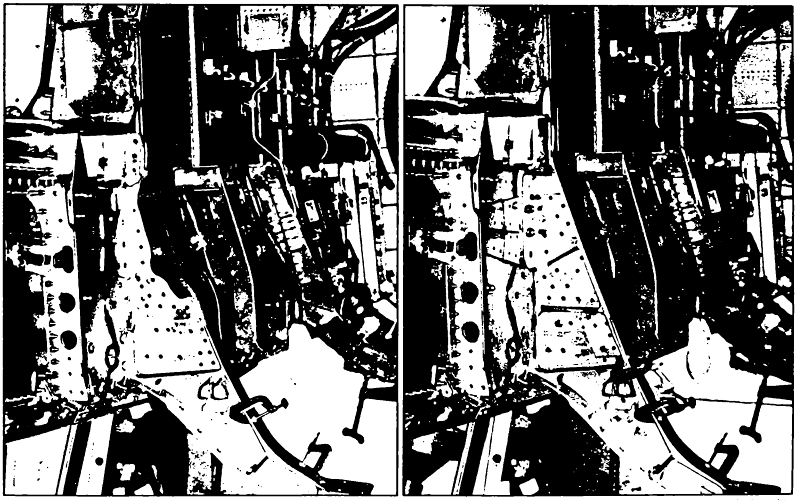
The article you have just read is only "half the story" on USAF F-15 78-0481 and its return to PACAF duty. While there were some novel methods used to remove the damaged engine from this airplane at Kwang Ju and prepare for a one-time flight back to Kadena, there were some equally novel — and extremely long distance — techniques used for permanent repair of this Eagle. Ken Percival was a member of the MCAIR Field Repair Team at Kadena and was responsible for the engineering effort involved. His half of our "Wounded Eagle" story summarizes these efforts.



Lower inboard right side of FS 712 bulkhead as it appears during manufacture and assembly of new aircraft in St. Louis. Compare with photographs below, taken during repair of F-15 78-0481 at Kadena AB, Japan.

I don't know how many standard "part-numbered" parts there are on a typical F-15 Eagle, but I do know that on F-15 78-0481, there are now some decidedly "non-standard" part numbers! If sometime in the future, you should ever do maintenance in the right engine bay of this particular airplane, you will run across several "one-of-a-kind" parts like a 68R093570-2009 or 68R093568-2017 Bulkhead Fitting. No other Eagle has them, and all of them resulted from what you might call a "customized" repair job we did recently on a badly damaged F-15 at Kadena Air Base Japan. Each of these peculiar parts started with a "splash."

It is usually possible to repair damaged or broken aircraft components by removing the bad part and replacing it with a new one. Sometimes, because of the nature of the part or its location, that simpler procedure won't work and more sophisticated methods must be used. Such was the case with Kadena's wounded Eagle. Among other structural injuries suffered during the in-flight incident, major damage occurred to the main bulkhead at FS 712. This is the main support bulkhead for the engines in the F-15 and is so integrated with other aircraft structure that its

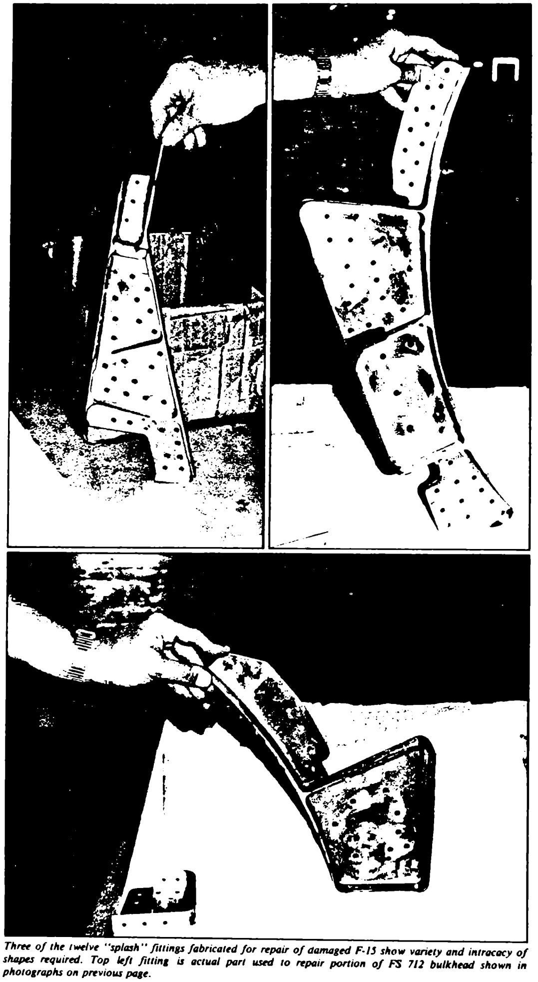


Note amount of material removed from damaged bulkhead (left) to prepare for installation of repair fitting. Right photograph shows repair fitting partially bolted in place. Fittings were secured to bulkhead with Hi-lok fasteners and epoxy bonding material. For added strength, a reinforcing strap was installed on inside circumference of bulkhead.

▶

removal and replacement was out of the question; to restore the bulkhead, repair fittings made by the "splash" method were the only feasible solution.

"Splash" is the term applied to the use of a wet plaster material spread on a surface to obtain a pattern for reproduction. It is not a new technique, but is invaluable in the aerospace industry in obtaining an accurate tooling pattern from which repair fittings can be machined. In our particular case, it was the *only* way, since the broken parts were in Kadena, Japan and the repair parts were to be machined 10,000 miles away, in St. Louis, Missouri.



Three of the twelve "splash" fittings fabricated for repair of damaged F-15 show variety and intracacy of shapes required. Top left fitting is actual part used to repair portion of FS 712 bulkhead shown in photographs on previous page.

The tooling plaster used in the splash technique is similar to what we all know as "plaster of Paris," but is specially formulated to have a controlled drying time and zero shrink properties. The area of the aircraft component to be splashed is first prepared by trimming away the damaged material per engineering direction. The splash technician then decides whether he can make the pattern in one piece or must segment it because of its size or to facilitate removal after drying. The raw plaster is mixed with water to form a paste, which is gradually applied to fill the damaged area. During this stage, reinforcing wires may be used to give added strength to the pattern. When dry the splash is removed, mounted on a board, and then sprayed with a plastic hard coat.

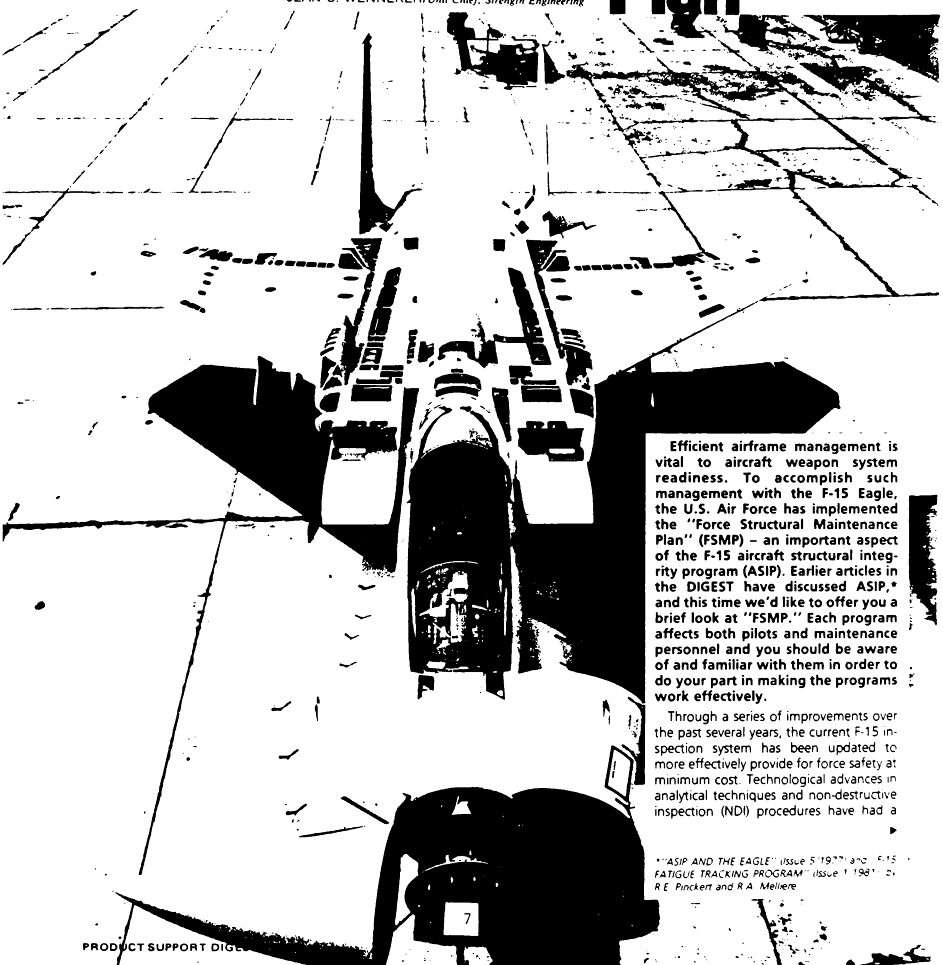
Twelve plaster patterns were required for the Kadena repair job. After careful packaging, the splashes were airlifted back here to MCAIR. The repair parts were then fabricated on a milling machine equipped with a special sensing device. This sensor traverses the surface of the pattern and causes the machine cutting head to produce an exact replica of the pattern in titanium, aluminum, or other required material. After expedited machine shop work here, the blank repair parts were returned to Kadena. Each part was carefully hand fitted to the bulkhead while working to a surface-to-surface tolerance of .010 of an inch. Attach holes for fasteners were drilled as necessary, and the repairs were completed.

F-15 78-0481 is once again as good as new and, while it may look a little different inside, is fully operational — thanks to a dozen plaster "splashes." In closing, I'd like to thank the Kadena base dental officer, and apologize to any dental patients who may have been inconvenienced by my own emergency "visit to the dentist" during our time on base. You see, there were so many splashes required that our supply of tooling plaster ran very low. There was nothing suitable available on the Okinawan economy so we asked the base dental office for help, since denture impression plaster is quite similar to tooling plaster. We took all they had available, mixed it with what we had left, and got enough of the combination to finish up the repair job. So, while it may have taken longer to get your new dentures back, we hope you will be pleased to know that Eagle 78-0481 is also "flying with a smile" again! ■

Eagle Fleet Management Program...

F-15 Force Structural Maintenance Plan

By JEFFREY C. MCFARLAND/*Senior Engineer and*
JEAN C. WENNEKER/*Unit Chief, Strength Engineering*



Efficient airframe management is vital to aircraft weapon system readiness. To accomplish such management with the F-15 Eagle, the U.S. Air Force has implemented the "Force Structural Maintenance Plan" (FSMP) – an important aspect of the F-15 aircraft structural integrity program (ASIP). Earlier articles in the DIGEST have discussed ASIP,* and this time we'd like to offer you a brief look at "FSMP." Each program affects both pilots and maintenance personnel and you should be aware of and familiar with them in order to do your part in making the programs work effectively.

Through a series of improvements over the past several years, the current F-15 inspection system has been updated to more effectively provide for force safety at minimum cost. Technological advances in analytical techniques and non-destructive inspection (NDI) procedures have had a ▶

*"ASIP AND THE EAGLE" (Issue 5/1977) and "F-15 FATIGUE TRACKING PROGRAM" (Issue 1/1981), by R.E. Pinckert and R.A. Melliere

F-15 FSMPlan

great impact on inspection criteria. The end result has been a revamping of when and where inspections are to be performed and a significant reduction in the number of inspections required.

FSMP is a maintenance-directed program used to establish the inspection, maintenance, and modification or replacement of key structural items of the F-15 throughout the service life of the aircraft. The two most significant aspects of FSMP are that it is based on a "damage tolerance assessment" of the aircraft structure and that it is tied to the F-15 fatigue damage tracking program. This latter program will be used to determine inspections for most of the fatigue-critical locations on the F-15 airframe, based upon individual aircraft usage, and thus provide a more accurate basis for inspections.

FSMP consists of a series of steps (tasks), the performance of which has been delegated to either MCAIR or an appropriate arm of the U.S. Air Force. While many of these tasks are part of the existing maintenance system – USAF data collections for the fatigue damage tracking program, performance of inspections, etc., a number of new tasks were created specifically under FSMP:

- Review of existing F-15 fatigue-critical locations.
- Establishment of damage computation procedures for determining inspection intervals.
- Incorporation of revised damage computation procedures into the fatigue damage tracking program.
- Establishment of NDI procedure for each location.
- Revision of inspection manuals to incorporate the new system.
- Institution of an inspection feedback system.

FATIGUE-CRITICAL LOCATIONS

The first step taken under the FSMP was to review known F-15 fatigue-critical locations, using three sources of information – fatigue damage analyses; full scale fatigue test results; and reported service failures. Locations were classified according to whether they were safety-of-flight critical and whether they could be tracked under the fatigue damage tracking program.

INSPECTION INTERVAL DETERMINATION

Prior to incorporation of FSMP, all airframe inspections had been based upon "average" use. This meant that some aircraft flew more severely and should have had shorter inspection intervals while others subjected to milder usage were inspected too frequently. Under FSMP, forty-four "fatigue-critical" locations on every aircraft will be monitored by the damage tracking program, and inspections will be keyed off the damage calculated at each of these locations. "Damage" is defined as a percent of crack growth life, where crack growth life is the life of a part from an assumed initial flaw to failure.

The benefits of such a plan are obvious. Fleet safety is improved because individual aircraft inspections are performed based on actual rather than average usage. Overall fleet management is more efficient since aircraft are only scheduled for inspection when necessary. Ordering of spare parts, more efficient use of personnel, and rotation of aircraft between bases are other aspects of fleet management that are also improved by FSMP.

FATIGUE DAMAGE TRACKING PROGRAM

A major revision has been made to the damage computation procedure of the fatigue damage tracking computer program. Originally, the damage analysis approach was based on crack initiation life. "Crack initiation life" is defined as the number of flight hours required to develop a crack 0.010 inch deep. Signal data recorder set (SDRS) and exceedance counter data from individual aircraft were used to determine the fraction of crack initiation life expended (i.e., fatigue damage) at critical locations for those aircraft.

The current methodology still employs signal data recorder and exceedance counter data to predict fatigue damage, but now determines the "fraction" of crack growth life expended. "Crack growth life" is defined as the number of flight hours required to grow an assumed initial flaw (usually greater than 0.010 inch deep) to failure. This philosophy was chosen for two reasons –

- It is easier to monitor the growth of the crack during inspections than to predict when a crack will initiate under actual usage.
- Analysis per MIL-A-83444 (Airplane Damage Tolerance Requirements) now assumes that every part has a "rogue" flaw in the most critical location. A rogue flaw is defined as any manufacturing defect, tool mark, or material defect that degrades material properties of the part. By implication, presence of a rogue flaw in a part eliminates the crack initiation portion in the total fatigue life of the part.

The fatigue damage tracking program will continue to track individual aircraft usage as SDRS and counting accelerometer (CA) data are collected. The flight data will be used to increment the fatigue damage for each critical location. And, as before, information on the individual aircraft damage will be published in SAFE (service aircraft fatigue estimate) reports for use by USAF in scheduling inspections, repairs, and/or replacement of parts.

NDI PROCEDURES

Non-destructive inspection procedures for new critical aircraft locations have been developed, and existing procedures have been reviewed. The goal is to ensure that flaws are detected with the greatest possible reliability and in a cost-effective manner. All NDI procedures are tested and verified by MCAIR for reliability before release to the Air Force. Incorporation of the newly developed inspection criteria and NDI procedures in the technical manuals is currently being accomplished.

A new NDI inspection procedure – low frequency eddy current – has been developed to facilitate inspections on sub-surface structure. This new procedure makes it possible to perform inspections on, for example, wing spars without removal of wing skin panels, a time consuming and costly process. The new method will be included in future inspection manuals.

INSPECTION MANUAL CHANGES

The 1F-15A/C-6 (Inspection and Maintenance Requirements) and 1F-15A/C-36 (Non-Destructive Inspection) manuals will undergo major revisions to incorporate fatigue damage tracking program changes and implement FSMP.

Inspection & Maintenance Requirements Manuals

Inspections controlled by the fatigue damage tracking program will be removed from the -6 manuals and placed in a newly-developed special section consisting of a table of required inspections for critical locations on individual aircraft. Each aircraft serial number will be shown at the last known base, and newly-based aircraft will have to be cross-referenced with their old bases to determine inspection requirements. A sample of this tabulation is shown in figure 1.

FIGURE 1 - SPECIAL SECTION INSPECTION MATRIX

TO 1F-15A-6

TABLE 2-6 (CONTINUED)

INDIVIDUAL AIRCRAFT TRACKING INSPECTION MATRIX

49TH TFW (HOLLOMAN)

AIRCRAFT S/N /1/	PAST DUE	PENDING /2/	QUARTER/YEAR INSPECTION DUE (BASED ON CALENDAR YEAR)				
		4-85 THRU 2-86	3-86	4-86	1-87	2-87	3-87
770061		IAT-17					
770062			IAT-17	IAT-16			
770062			IAT-19				
770063							IAT-17
770065		IAT-19	IAT-16		IAT-17		
770066		IAT-16					
770066		IAT-17					
770066		IAT-19					
770067		IAT-16		IAT-17			
770067		IAT-19					
770069						IAT-17	
770070		IAT-16				IAT-17	
770070		IAT-19					
770071		IAT-19	IAT-16	IAT-17			
770074	NO INSPECTIONS REQUIRED DURING THIS TIME FRAME						
770075	NO INSPECTIONS REQUIRED DURING THIS TIME FRAME						
770077			IAT-19	IAT-16	IAT-17		
770078	NO INSPECTIONS REQUIRED DURING THIS TIME FRAME						
770079		IAT-01					
770081		IAT-17					
770082	NO INSPECTIONS REQUIRED DURING THIS TIME FRAME						
770083					IAT-19		IAT-16
770085		IAT-16					
770085		IAT-17					
770085		IAT-19					
770086					IAT-17		
770087			IAT-19	IAT-16			
770088							IAT-19
770089	NO INSPECTIONS REQUIRED DURING THIS TIME FRAME						
770091							IAT-17

NOTE /1/
AIRCRAFT REASSIGNMENTS OCCURING AFTER SEPTEMBER 1985 ARE NOT REFLECTED IN THIS TABLE. TO OBTAIN INSPECTION REQUIREMENTS FOR RECENTLY REASSIGNED AIRCRAFT, REFER TO LISTING FOR SQUADRON (WING) AT WHICH AIRCRAFT HAS PREVIOUSLY ASSIGNED.

NOTE /2/
PENDING INSPECTIONS ARE THOSE INSPECTIONS (4-85 THROUGH 2-86) FOR WHICH FEEDBACK DATA HAS NOT YET BEEN RECEIVED.

Change 41 2—A—035

Inspections will be projected one year in advance. Every six months this section will be updated to show revised inspection requirements as well as those inspections not reported by the Air Force as having been completed to date. Inspections will be grouped by calendar quarters, with a "one-quarter early" inspection provided to allow for convenient aircraft docking.

Although a significant number of inspections currently listed by flight hours in the -6 manuals will be moved into the new section, some inspection requirements will continue to be specified by flight hours since they apply to aircraft locations that cannot be tracked by the fatigue tracking program. Also, because of an inherent lag in the collection and processing of data under the tracking system, inspection requirements that occur on an average frequency of under 600 flight hours will be called out by flight hours to insure that they are performed when required.

Another major change to the -6 manuals is the deletion of several locations that will now be inspected on a "sampling" basis since they have been determined to be not safety-of-flight critical (failure would not cause loss of the aircraft). Landing gear parts in this category will be inspected at Hill AFB as they are routed through the depot for normal maintenance. Airframe structure will be inspected at Robins AFB during analytical condition inspection (ACI), where eleven high-time aircraft from various bases are annually given a thorough inspection. If any fatigue cracking is detected at either base, a review of the location will be performed and inspections conducted on a force-wide basis if warranted.

Non-Destructive Inspection Manuals

The -36 manuals will also undergo some major format changes. A system has been developed to number every fastener hole in the aircraft to aid maintenance personnel in locating areas to be inspected and in reporting damage found. Figure 2 shows a typical example of the structural illustrations with numbered holes, as they will be presented in a newly created special section. In the first revised manual, only the wing, vertical stabilizer, and selected fuselage locations will be numbered, but eventually all holes will be included. Inspection procedures directly related to the fatigue tracking program will also utilize the hole numbering system.

FEEDBACK SYSTEM

Information that an inspection has been performed (and that repairs have been made, if appropriate) must be entered into the fatigue damage tracking ▶

FIGURE 2 - NDI PROCEDURES WITH HOLE NUMBERING SYSTEM

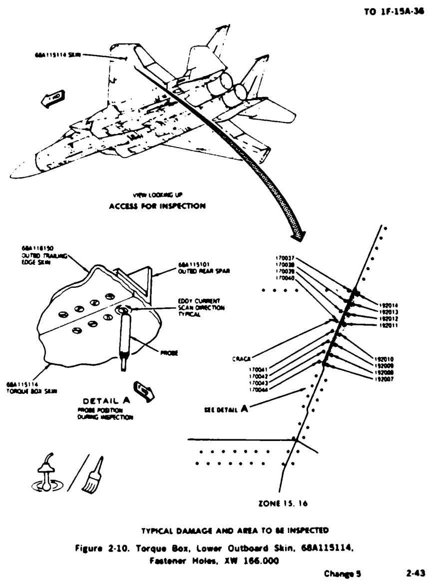
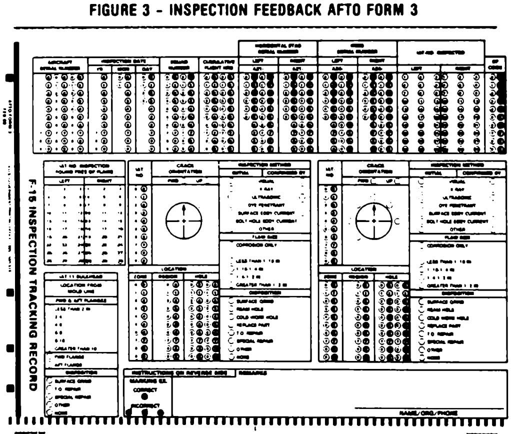


FIGURE 3 - INSPECTION FEEDBACK AFTO FORM 3



computer program if the inspection information loop is to be completed. This is accomplished through an inspection feedback system, using the newly created AFTO form shown in figure 3.

Maintenance personnel will record necessary information such as aircraft serial number, wing and stabilator serial numbers, cumulative flight hours, base location, and inspections performed. If a fatigue crack has been detected, the form has spaces to record the hole identification number, crack length and orientation, and any maintenance action that may have been performed. This inspection and repair data is then used to update the fatigue tracking program inspection accounting system. It will also be useful as a field report showing possible fatigue problem areas for further investigation.

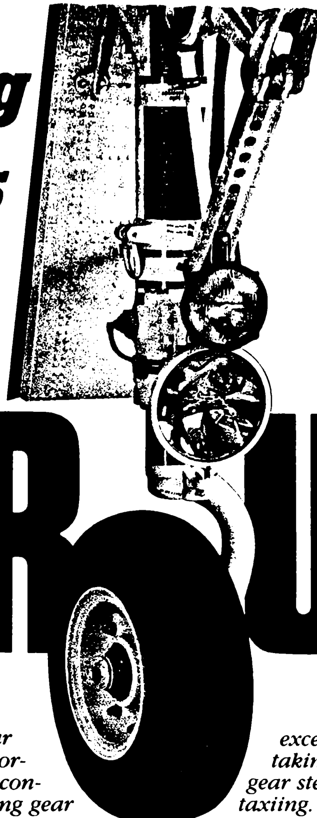
This has been a summary of the major changes and improvements to the F-15 aircraft inspection system - changes which will help management of the Eagle fleet and make your job more efficient. But in order to help you, you must help the system. Success of FSMP depends upon a reliable data collection effort, which means that the quantity and quality of data incorporated in the tracking program are directly dependent upon the F-15 using commands. It's up to you to record and process exceedance counter data properly; maintain and process SDRS tapes; provide correct maintenance on the recorder systems; perform inspections in a timely manner; and accurately record feedback of the NDI procedures conducted.

FSMP is a new program, with a specific chain of operations, and you are the most important link in the chain. Any break in the chain - mechanical or human - will compromise the system and degrade the Eagle fleet. We know the mechanical parts of ASIP and FSMP are good, but the rest is up to you. Please do your part - the program can't succeed without you.

an Eye to the Future...

Aircraft life cycle costs could be lowered greatly if repair measures were to be developed which would reduce or eliminate the need for structural inspections. McDonnell Aircraft Company has conducted tradeoff studies to compare the cost of modifying structure versus continuing to perform existing inspections, and a summary of this work has been presented to the Air Force, with recommendations on each analyzed location. ■

Servicing the Eagle's STRUTS



BRUCE BECKER

Servicing the landing gear shock strut is just as important as rigging the flight control system. Proper landing gear servicing cannot be overemphasized. Problems resulting from improper servicing can run the gamut from excessive runway roll when taking off to the loss of nose gear steering during rollout or taxiing. Improper servicing has been known to cause damage to the aircraft structure and/or the landing gear struts.

By STEVE SCHIMSA/*F-15 Landing Gear Senior Technical Data Engineer*
and
BRIAN EDWARDS/*F-15 Landing Gear Unit Chief Design*

Recent field reports have mentioned that landing gear malfunctions have been traced to improper servicing – not following the technical order servicing procedures. The DIGEST discussed this same topic on the F-4 Phantom, "Understanding F-4 MLG Strut Servicing," in Vol. 19, No. 3, 1972.

This time our discussions will center around the F-15 Eagle's landing gear struts having insufficient hydraulic fluid and over- and under-pressurized chambers.

First of all, we would like to explain the reason why the Eagle's struts are designed and serviced the way they are. Hopefully, through these discussions you will gain an insight into why it is so important that the landing gear struts be serviced correctly. ▸

What the Strut Does

The Eagle's struts, like all landing gear struts, absorb the energy of the aircraft during landing or taxiing. The energy that the struts must absorb is a function of two factors: aircraft gross weight and vertical velocity of the aircraft. One of the most critical phases of flight for Eagle pilots is the landing and rollout phases, which hinge upon how you, as maintainers, do your job – especially how the landing gear shock struts are serviced.

The majority of the landing shock load is absorbed by metering fluid through tiny internal orifices as the strut compresses (See Figures 1 and 2). The ability of the strut to absorb the landing shock load directly relates to the strut containing the proper amounts of hydraulic fluid and nitrogen (or air). A properly serviced strut will provide plenty of shock-absorbing capability for all normal conditions such as towing, taxiing, takeoff roll, and landing rollout.

The strut has one chamber at the top of the strut for nitrogen only, and it has a second chamber at the bottom of the strut for nitrogen and hydraulic fluid. The low pressure (lower) chamber helps absorb energy during the initial impact upon landing and taxiing. The air in the low pressure chamber is compressed to a higher pressure during strut compression. But if the low pressure chamber is overserviced, the air can't compress until a higher load is achieved, and the shock-absorbing feature is impaired. The strut becomes stiffer and acts more and more like a rigid link. The end result is added stress throughout the airframe and a rough landing. The Eagle will feel like you are driving a truck and may bounce side-to-side.

Up to this point we have discussed all struts in general. Now let's complicate the situation further by landing on uneven terrain or a rough surface with an overpressurized nose landing gear (NLG)

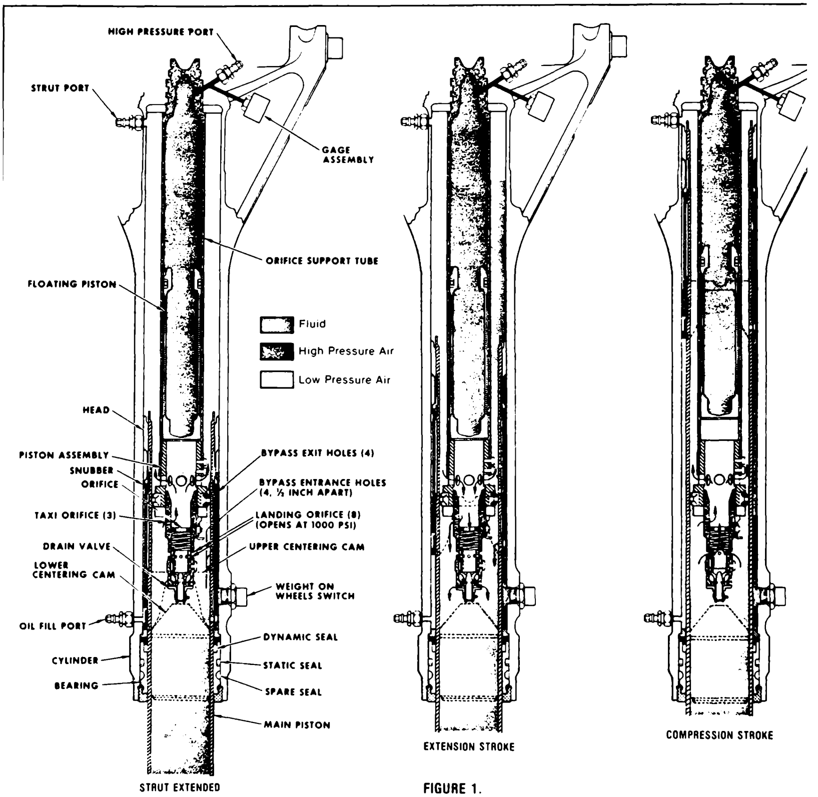


FIGURE 1.
NOSE LANDING GEAR SHOCK STRUT SCHEMATIC

strut low pressure chamber. The end result, excessive NLG bounce may cause the NLG WOW (weight-on-wheels) switch to energize. Whenever this switch is energized the pilot will experience loss of nosewheel steering. With a combination of over-serviced struts, and weather that is less than ideal, wet runway, cornering tail wind, plus on again, off again nose wheel steering, the pilot is in real trouble. Now that you know the impact of strut servicing on the Eagle's operation, let's get down to the basic facts of how to service landing gear.

To prevent any confusion, we will center on the F-15A/B/C/D NLG and MLG shock struts. In an upcoming issue of the DIGEST, our discussions will center around the changes, functions, and servicing of the F-15E struts. This article provides an overview on how to service the landing gear. Technical order TO 1F-15( )-2-12JG-10-2 must be followed step-by-step when actually servicing a strut.

Servicing MLG Struts

First of all, with the weight of the aircraft on the gear, let all of the air charge out of both the upper and lower chambers (See Figure 2). Then add hydraulic fluid through the lower filler valve until clear fluid, free of air bubbles, flows from the low pressure chamber air charge valve.

It is very important that the fluid is free of air bubbles, otherwise you will end up with the incorrect amount of fluid in the low pressure chamber. The only way to check the fluid is to try to get more fluid in, as there is no other indication of fluid level short of an ultra-sound inspection.

Upon completion of hydraulic servicing, close the lower filler valve and attach a calibrated air pressure gage to the low pressure chamber air charge valve. Then, inflate the lower chamber to the pressure called out in the technical order procedure (12-10-20). If nitrogen is not available, air can be used, but it is impor- ▶

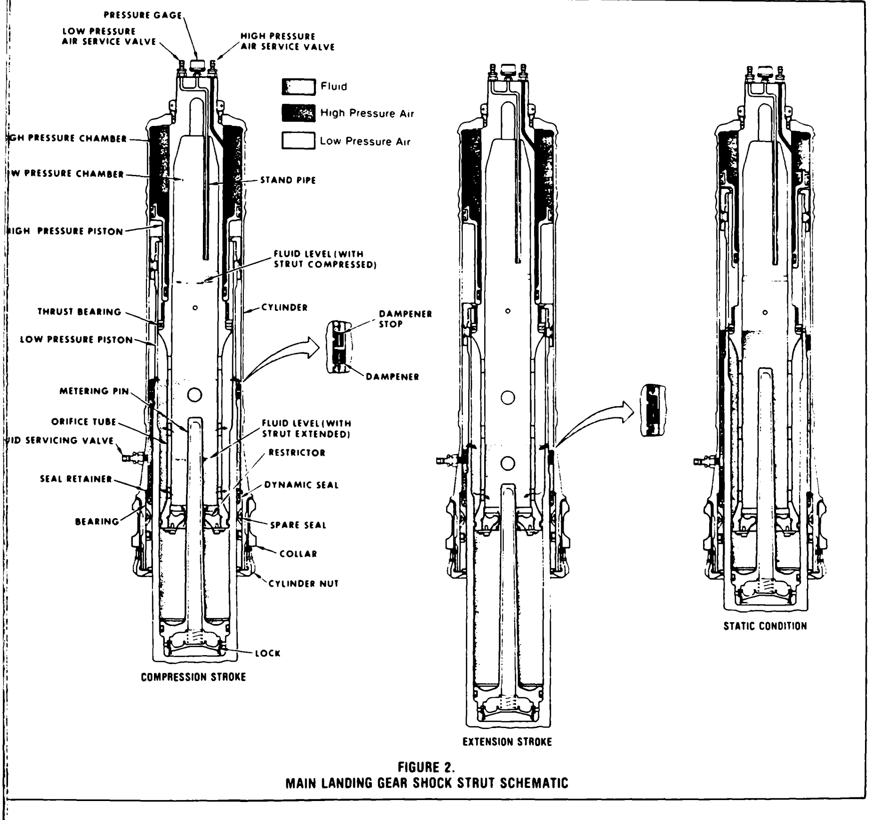
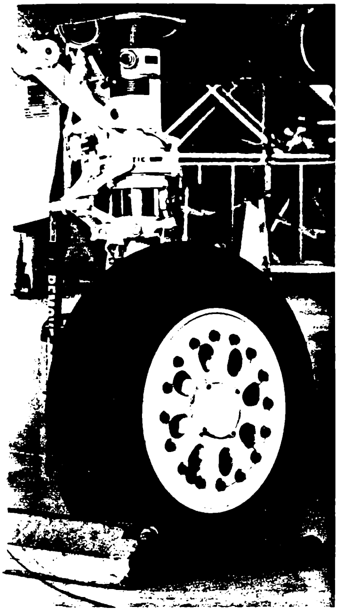


FIGURE 2.
MAIN LANDING GEAR SHOCK STRUT SCHEMATIC

BRUCE BECKER



tant that only clean dry air, filtered through a 10 micron filter with a dew point of -65° or lower, be used.

Do not use the small indicator gage mounted near the top of the strut for servicing. That gage is to give the crew chief a day-to-day idea of any air leakage in the strut – it is NOT a servicing gage.

When you have the right amount of fluid and the correct nitrogen (or air) pressure in the lower chamber, close the low pressure chamber air charge valve, then move over to the high pressure (upper) chamber. This is where you get the proper strut extension ("X" dimension) during servicing.

Once you get enough pressure in the upper chamber to start the strut extending, and until it bottoms out at the fully extended position, the pressure inside the upper chamber will remain the same no matter how much air you put in! What? You keep putting more air into the strut, but the pressure does not increase? That's right! Only one thing determines this pressure: the weight of the aircraft.

After the strut receives the pressure (psig) needed to lift the aircraft, no increase in pressure is required to continue lifting – only an increase in volume is needed. When you read the pressure in this chamber, you are really weighing the airplane (indirectly) so you can tell how much strut extension there should be. The theory used is that for any given aircraft weight, there must be a corresponding amount of extension. Remember: you control the "X" dimension through the volume of nitrogen (or air) in the upper chamber.

Due to the climatic extremes encountered by the Eagle, hydraulic leakage of struts in cold weather led to the development of oversized inner seals. One drawback to these seals is that they greatly increase the friction between the strut piston and outer cylinder. If pressure (psig) is increased to overcome this friction, it will cause you to put more pressure into the strut than is needed for actual aircraft weight. To prevent this, bounce the aircraft wings. This allows the struts to adjust themselves so they will continue to extend under the proper pressure as you add more volume. So, as the technical order says, extend the strut by adding nitrogen (or air) through the air charge valve on the upper chamber until the proper "X" dimension is reached.

It is interesting to note that it makes no difference where you end up on the chart as long as the "X" dimension matches the aircraft gross weight. For a light airplane, you will have a low pressure and a high "X" dimension. For a heavy airplane you will have a high pressure and a short "X" dimension. The most important thing is that the numbers on the chart correspond to the aircraft gross weight.

For example, on an F-15C aircraft with a gross weight of 59,400 pounds, the MLG shock struts require 2050 psig in the high pressure chambers to support that weight. To allow the strut to operate throughout its range, we have determined that the proper "X" dimension is 1-7/8 inches. Once properly serviced, the struts should maintain proper pressure and "X" dimension for all weights for that aircraft from that point forward.

Let's continue with the same example: if we would defuel the aircraft down to a gross weight of 48,000 pounds, the struts would have an "X" dimension of 2½ inches and the high pressure chamber would have 1650 psig. Why? Because at the lighter weight (48,000 pounds), 2050 psig was too high, causing the struts to extend, creating more room (cubic inches) in the lower chamber. As the volume (room) within the strut increases, the pressure subsequently decreases until it reaches the pressure required to support 48,000 pounds. Of course, while the volume within the strut increased, the "X" dimension was getting larger. The "X" dimension will now be 2½ inches, and the strut is properly serviced. No re-servicing is required for the new aircraft gross weight.

This is why at any given aircraft weight, it is imperative that the struts be serviced precisely so they can operate throughout the aircraft's gross weight capabilities.

Servicing NLG Shock Struts

On the NLG shock strut, the servicing process is basically the same as the MLG with a few exceptions. The differences are that on the NLG (Figure 1), the low pressure (lower) chamber controls the "X" dimension and the high pressure (upper) chamber is serviced to a given pressure. Also the NLG gage reads high pressure chamber pressure instead of the low pressure chamber.

The high pressure piston inside the NLG shock strut must be moved to the top of the stroke before servicing. This is done to provide room for the correct amount of hydraulic fluid. To accomplish this, completely deflate the strut and apply nitrogen (air) pressure to the low pressure chamber air charge valve as stated in the technical order procedure (12-10-21). After the piston moves to the top of its stroke, turn off air/nitrogen trailer and remove the servicing hose.

Attach a drain hose to the low pressure chamber air charge valve. Add hydraulic fluid through the lower filler valve until fluid, free from bubbles, flows freely from the drain hose. Close the lower filler valve, then remove the servicing and drain hoses.

Connect the air/nitrogen trailer and gage assembly to the low pressure chamber air charge valve. Inflate the low pressure chamber until an "X" dimension of approximately six inches is obtained. Close the low pressure chamber air charge valve and remove the servicing hose.

Next, connect the servicing hose and gage assembly to the high pressure chamber air charge valve. Inflate the high pressure chamber to the pressure listed on the inflation table in the technical order for the ambient air temperature. Close the high pressure chamber air charge valve and remove the servicing hose.

Now connect the servicing hose and gage assembly to the low pressure chamber. Slowly open the low pressure chamber air charge valve and inflate the NLG strut to the required "X" dimension. Bounce the aircraft to allow the strut to adjust and overcome seal friction. Close the charge valve and remove the servicing hose. Here again, as with the main gear, the weight of the aircraft determines the pressure required.

In conclusion, don't take shock strut servicing lightly. A full understanding of how shock struts function and are serviced will ensure that they will operate as designed. A lot depends on the accuracy and care you take in maintaining the finest fighter aircraft in the world. ■

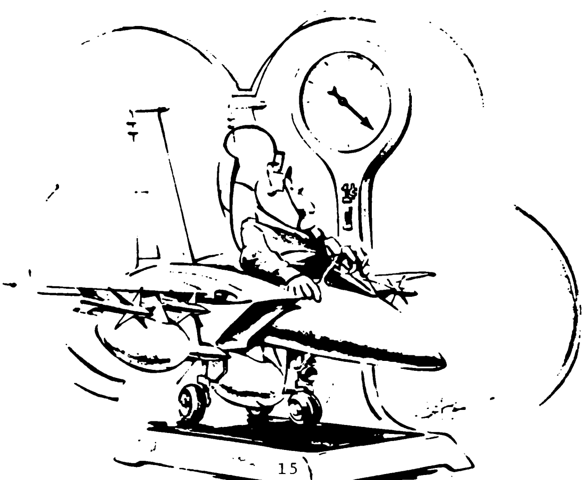
F-15A/B Aircraft Weights

Q ***Our OIC of quality assurance has some concern in the area of total aircraft weights. He states that with three external fuel tanks, four AIM-7s, four AIM-9s, and a full gun system, all of our F-15s are 1000 to 2000 pounds over the DASH ONE TAKEOFF limits. He has several questions concerning this: (a) What specifically has caused this weight increase? (b) Will this weight affect landing gear reliability? (c) Does MCAIR engineering feel it OK to increase DASH ONE weight limits, and if so, to what values?***

A The basic weight of the F-15A/B aircraft has increased approximately 750 pounds over the years as a result of TCTO incorporations and aircraft repairs. Weight & balance records must be carefully checked to insure that a specific aircraft does not exceed flight manual forward and aft CG limits and the maximum gross weight limit. If the aircraft gross weight exceeds max allowable, fuel and/or stores must be removed to bring gross weight down to max allowable for ground operation and takeoff.

The F-15A/B was initially designed and tested for operation at weights up to 53,300 pounds. Additional analysis was performed to extend max weight limit to 56,000 pounds. This is the max allowable if appropriate margins of safety are to be maintained in the landing gear and backup structure. There are no structural problems related to takeoff within the flight manual limits and air refueling to a maximum weight. High gross weight flight operation of the aircraft should be within the limits of the flight manual. If a waiver is required to meet a specific mission requirement or for alert aircraft, I suggest the squadron contact WRALC/MMEDF.

(Norm Tupper
Engineer – APG Group)



"GENERAL" MANUALS

The first of the two "general" manual categories is the *General Vehicle* (GV) manual. This single document is an invaluable aid to the technician who wants to have a good general understanding of the Eagle. It provides an aircraft description and maintenance orientation and is designed to give the technician a broad view of the F-15 and the maintenance manuals needed to support it.

The GV manual introduces the "Organizational Maintenance Manual Set" by identifying the various manuals that make up the set; by designating their structure and arrangement; and by explaining how to use the data. Explanation of the new Technical Order numbering system and the all-important System/Subsystem/Subject Number (S/S/SN) concept is also given. In addition, there is a record of all current Time Compliance Technical Orders (TCTO) applicable to the F-15.

The GV manual next presents a general description of the aircraft and then focuses in on its individual systems, outlining their functions, locations, and components — all of which are amplified by illustrations.

The remaining chapters of the GV manual provide a list of all abbreviations and symbols used in the maintenance manual set, including mathematical signs and symbols; graphic symbols used in electrical and electronic diagrams; graphic symbols used in fluid and mechanical diagrams; general maintenance procedures with detailed information on potential hazards (e.g. flammable liquids, gases, explosive devices, and radiation); and information on special torque values for fittings and tubing. There is also general information on dimensions and areas, jacking and lifting, leveling, and aircraft towing.

The second "general" manual category is the *General Systems* (GS) manuals, wherein the major aircraft systems are segregated into separate volumes that include system theory and principles of operation. They also contain complete lists of consumable supplies and support equipment for the system and (if needed) simplified schematics.

"FAULT" MANUALS

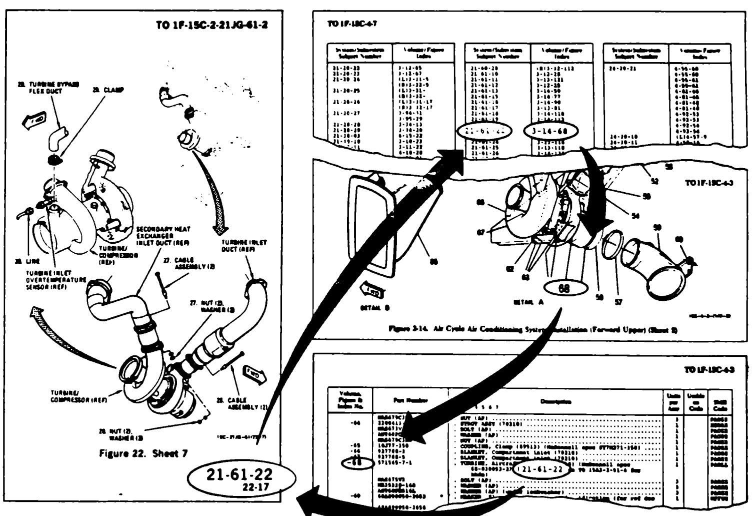
The next two categories of manuals are concerned with how the Eagle has performed in flight and with helping to achieve improve operations/maintenance communications for the correction of problems. MIL-M-83495 has placed great emphasis on the benefits of cooperative problem analysis; and the new "Fault Manuals" place much more responsibility in the debriefing room. These manuals help both the pilot and the maintenance debriefer develop an efficient, no-guesswork solution to any maintenance problem that may have appeared during a flight.

The first of the fault manuals is the *Fault Reporting* (FR) manual and is of major concern to both the pilot and maintenance debriefer since it defines aircraft malfunctions and thereby develops the "fault codes." It is the careful development of these fault codes during a comprehensive and conscientious debriefing process which will ensure that proper maintenance procedures are followed.

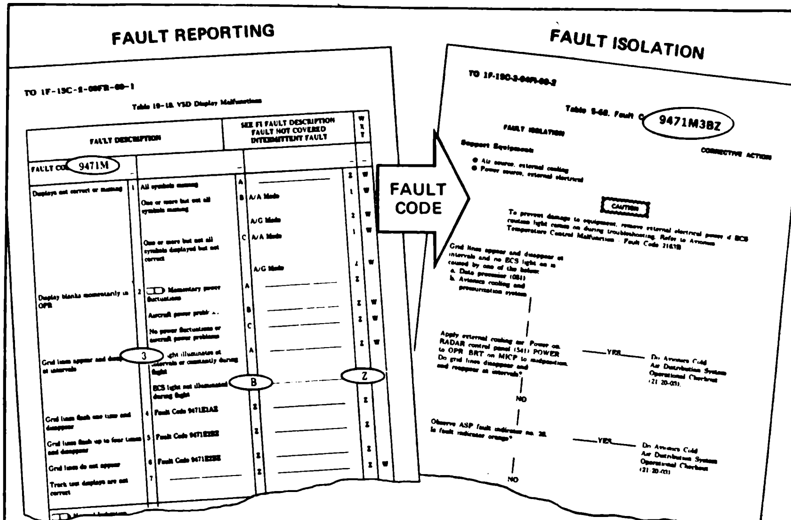
The FR manual has a three-part Master Symptom Index which correlates malfunctions to "fault description" tables:

(1) An alphabetical index with precise statements of possible malfunctions for every major aircraft system and subsystem.

(2) A built-in test (BIT) fault indications index keyed to the avionics status panel fault indicator numbers.



Note how "S/S/SN" number (color) tracks through various maintenance manuals, and cross-references to IPB index numbers (black).



"Fault Code" number ties fault reporting and fault isolation procedures together.

(3) A pictorial index which is an illustrated view of the cockpit with all gages and indicators fully detailed.

All three indexes lead directly to the heart of the FR manual — the fault description tables. Once the pilot and the debriefer identify the system that is malfunctioning (using any of the three indexes), they have only to turn to the fault description table identified. There they will find statements tailored to direct them to additional pilot observations to help pinpoint the fault.

The second "fault" manual category is the *Fault Isolation* (FI) manuals, one of which is provided for each of the major aircraft systems. FI manuals are normally used after the pilot and maintenance debriefer have developed "fault codes" through identifying those statements which most resemble malfunctions experienced during the flight. The shop technicians then work with the fault codes, which lead them to the appropriate "yes/no" logic trees. By following these logic trees, technicians can troubleshoot the system and pinpoint the specific item causing the malfunction. In other cases, the fault codes guide the technician to a direct fix contained in a Job Guide.

OTHER MANUALS

Two other types of manuals have been included in the new Organizational Maintenance Manual Set, but do not represent such major changes to format as the GV, GS, and JG T.O.s. *Schematic Diagram* (SD) manuals (one for each major system) provide integrated electrical/mechanical/hydraulic schematics of varying complexity to aid troubleshooting the aircraft. They have been identified per the new T.O. numbering system and contain troubleshooting information such as connector pin numbers and notes on operating ranges, values, and test points. The *Wiring Data* (WD) manuals have not changed internally from their previous arrangement, but they, too, have been numbered per the new numbering system.

MIL-M-83495 has not been applied to other related manuals, such as the IPB, Inspection Requirements, Work Cards, etc., except that those documents will be compatible with the keyed reference numbering system.

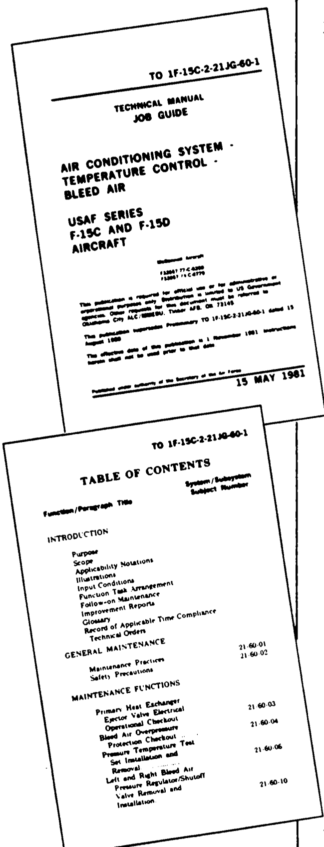
"JOB GUIDE" MANUALS

As noted earlier, "last is not least" with the new MIL-M-83495 publications, and we are now ready for a look at the documents whose name has become synonymous with the new maintenance manual system. The *Job Guide* (JG) manuals represent the biggest break with the past, from every standpoint including size, concept, and format. It will be the JG that the maintenance specialists will most often reach for to "get the job done" (see next two pages for examples).

These manuals are small (5 inches x 8 inches), compact, and easy to carry and use on the flightline. They are written in easy to understand, clear, and direct language. For every maintenance task written procedure, there is a corresponding "picture" description — the words on one side and the illustration on the other side of facing pages. Each numbered step in the written procedure is matched by the same number on the illustration, identifying the part or area to be worked on. Experienced technicians may use the illustrations more as a "check list," but the combination of words and pictures is intended as a carefully planned, step-by-step guide for performance of a specific job, usable and understandable regardless of the technician's experience level.

JG manual procedures can cover such flightline maintenance activities ▶

F-15 "JOB GUIDES"


TO 1F-15C-2-21JG-60-1

TECHNICAL MANUAL
JOB GUIDE

AIR CONDITIONING SYSTEM -
TEMPERATURE CONTROL -
BLEED AIR

USAF SERIES
F-15C AND F-15D
AIRCRAFT

15 MAY 1981

TO 1F-15C-2-21JG-60-1

TABLE OF CONTENTS

Function/Paragraph Title | System/Subsystem Subject Number

INTRODUCTION

Purpose
Scope
Applicability Notations
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Glossary
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Bleed Air Overpressure Protection Checkout 21-60-04
Pressure Temperature Test Set Installation and Removal 21-60-06
Left and Right Bleed Air Pressure Regulator/Shutoff Valve Removal and Installation 21-60-10

TO 1F-15C-2-21JG-60-1

REMOVAL.

NOTE

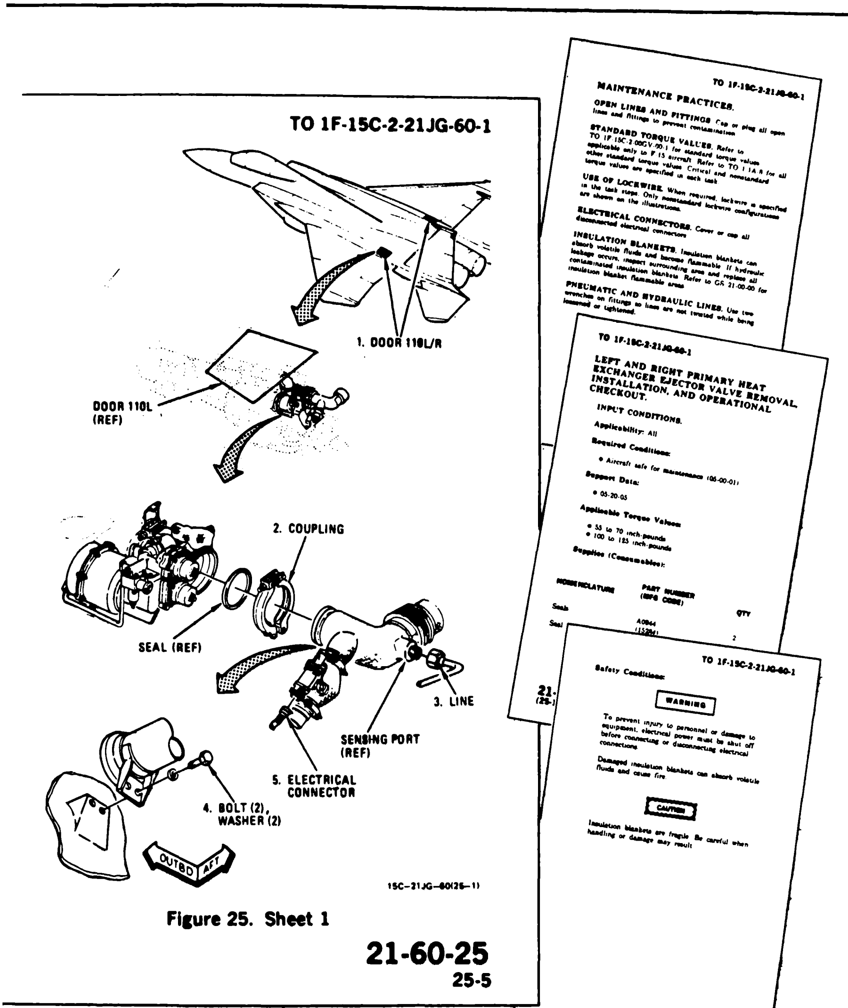
Left component is shown, right component is similar.

During normal operation of primary heat exchanger ejector valves, a continuous venting of air can be detected from vents in base of solenoid and should not be cause for replacement.

1. Open door 110L/R.
2. Remove coupling.
3. Disconnect line from sensing port.
4. Remove bolts and washers.
5. Disconnect electrical connector.

21-60-25
25-4

Two pages above are actual-size reproductions of typical Job Guide "task" pages and show how written (left) and picture (right) descriptions complement each other. (Note S/S/SN at bottom of both pages.) Other reduced size illustrations here are examples of key information pages of typical Job Guide, including title page, table of contents, maintenance practices, safety conditions, and a typical function "input conditions" page.



Heart of the New Eagle Maintenance Manual System

as removal, installation, bleeding, rigging, cleaning, adjustment, calibration, and operational checkout. The required work is arranged in a "function, task, step" sequence for each LRU of a system or subsystem. A "step" is a single and separate maintenance action; a "task" is composed of a series of steps leading to accomplishment of one of the procedures noted above; a "function" is composed of one or more tasks.

Each "function" begins with an "Input Conditions" page which provides information needed before starting the job — aircraft applicability, safety equipment and conditions, number of personnel recommended to accomplish the job, support equipment and data, applicable torque values, and consumable supplies which must be on hand. Where there are common maintenance activities required as a part of all functions in a Job Guide (connector capping, line plugging, lockwiring, etc.,) these common requirements are listed only once, under the heading of "General Maintenance Practices."

HOW TO "UNLOCK" THE SYSTEM

The crucial element to your successful use of the new F-15 maintenance manuals will be a good understanding of the numbering system. MIL-M-83495 establishes *three* types of identification numbers to tie the whole set of manuals together. There are T.O. numbers, S/S/SN numbers, and FR/FI numbers. Once you unlock the master numbering system and see the common-sense numerical relationships between all the manuals, we think you will be pleasantly surprised at how usable the system is and how quickly you will be able to track down or follow a specific part or procedure through all the books.

The "key" to unlocking the numbering system lies in the fact that MIL-M-83495 has assigned two groups of numbers (containing two digits each) to identify each of an aircraft's systems *and* subsystems. These two sets of numbers remain with a given system/subsystem throughout the maintenance manual set, becoming the common "clue" digits that are immediately identifiable wherever they appear. They can be prefixed or suffixed or separated by additional numbers and/or letters assigned by the contractor for various purposes, but the two basic number sets remain constant.

Let's look at a typical example. The Air Conditioning SYSTEM is assigned the two-digit number "21" (on the F-15, F-16, or any other new aircraft). The Bleed Air Temperature Control SUBSYSTEM of the Air Conditioning system is identified by the number "60."

Those two permanently assigned sets of numbers (21-60) will follow "Air Conditioning — Bleed Air Temperature Control" wherever it may wander — into the General Vehicle, General Systems, Fault Reporting, Fault Isolation, Job Guide, Wiring Data, Schematic Diagram, IPB, Work Card, etc., manuals. Regardless of whether you are installing, removing, checking, servicing, fault isolating, troubleshooting, or cross-referencing, "21-60" will always identify only the Air Conditioning Bleed Air Temperature Control subsystem.

Remember — every system/subsystem in the airplane bears its own unique set of four numbers and there is no duplication and no confusion. So let's look at how those four key numbers are used to integrate the entire MIL-M-83495 system as applied to the F-15 Eagle.

• T.O. Number — System/Subsystem numbers are built into the identification number of each type of manual in the set.

• Fault Reporting/Fault Isolation Number — Identification and troubleshooting of system/subsystem problems are aided by this special numbering plan. Called a "Fault Code," this number always includes the System and Subsystem numbers. It is developed in the Fault Reporting manual and utilized in the Fault Isolation manuals.

• System/Subsystem/Subject Number— this is the famous "S/S/SN" or "Triple SN" as you may hear it referred to. "System" and "Subsystem" portions have already been discussed. The "Subject Number" (SN) is a third two-digit number assigned by the contractor to identify specific *subjects* (component, maintenance practice or procedure, etc.) associated with a particular system/subsystem. S/S/SN is a firm and fixed six-digit number, established in the JG (Job Guide) series of manuals and usable throughout the maintenance manual set for research and cross-referencing.

Let's end with a review of how all of these "digits" arrange themselves into a typical T.O. number, S/S/SN number, and FR/FI (Fault Code) Number —

(TO) 1F-15C-2-21JG-60-1

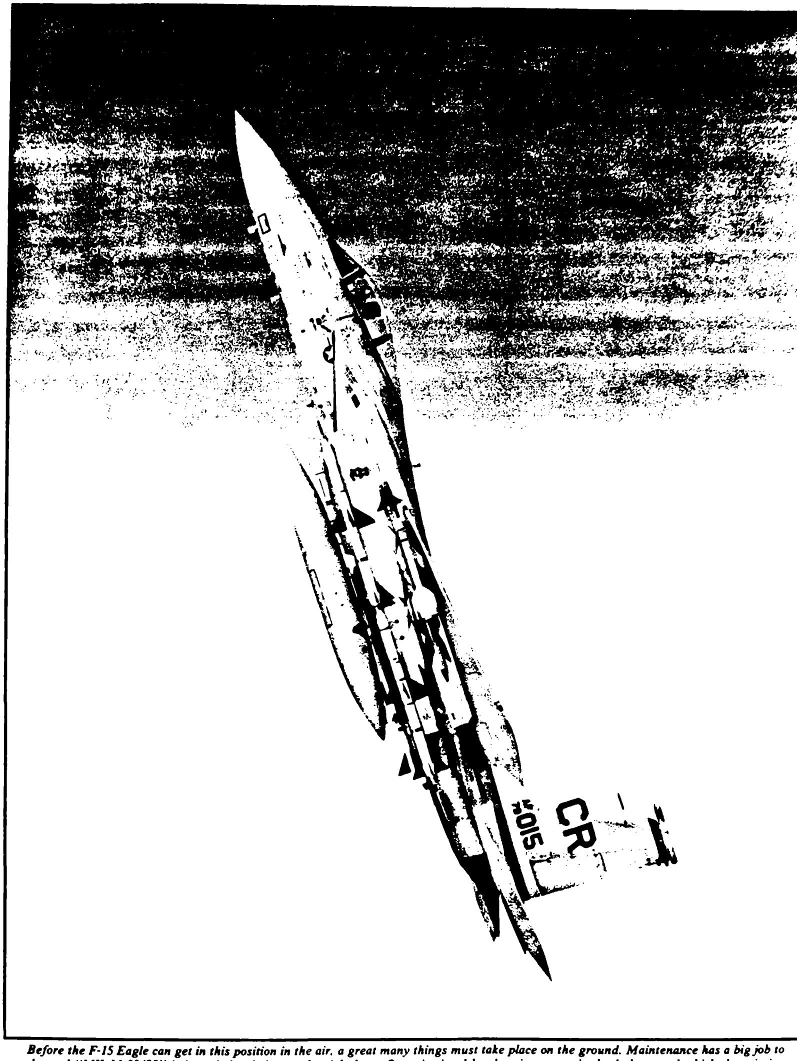
1 . . . Weapon system identifier (Aircraft)
F . . . Specific type aircraft (Fighter)
15 . . Air Force model designation series number
C . . . Specific model in series (could also be A, B, or D)
2 . . . Applicable maintenance level (Organizational)
21 . . . Aircraft system covered (Air Conditioning)
JG . . Type of manual (Job Guide)
60 . . . Aircraft subsystem (Bleed Air Temperature Control)
1 . . . Manual volume number

(S/S/SN) 21-60-25

21 . Aircraft system (Air Conditioning)
60 . Aircraft subsystem (Bleed Air Temperature Control)
25 . . Subject or function (Removal, installation, and operational checkout of Left and Right Primary Heat Exchanger Ejector Valves)

(FR/FI) Fault Code 2160B1C1

21 . Aircraft system (Air Conditioning)
60 . Aircraft subsystem (Bleed Air Temperature Control)
B . . .
1 . . .
C . . .
1 . . .
Digits assigned according to specific malfunctions identified



Before the F-15 Eagle can get in this position in the air, a great many things must take place on the ground. Maintenance has a big job to do, and "MIL-M-83495" is intended to help get that job done. Organizational level maintenance is the hub around which the mission revolves; careful use of the new MIL-M-83495 O-Level publications will insure that those missions are effective and successful. ■

Edwards unit establishes unique record...

F-15 CTF - 10,000 Accident-Free Hours

(Excerpted from article by Don Haley, Public Affairs Office, in "DESERT WINGS" newspaper, Edwards AFB, California, 5 August 1983.)

A significant milestone in the aviation test arena was achieved here recently when the F-15 Eagle became the first fighter aircraft in Air Force history to log 10,000 hours of flight test time without the loss of an aircraft.

The majority of the 10,000 test hours were flown by the Air Force Flight Test Center's F-15 Combined Test Force (CTF) here, along with additional hours flown at Eglin AFB, Florida, and by the contractor, McDonnell Douglas Corporation, in St. Louis, Missouri.

"This is a great credit to the Air Force and contractor personnel with the F-15 test force, not only now but to everyone who has been connected with the aircraft's test and development program since it began here 11 years ago," said Lt Colonel John Hoffman, who has headed the F-15 CTF for the past year. "This is an accomplishment based on teamwork and reflects the professionalism continually displayed at this CTF over the past years."

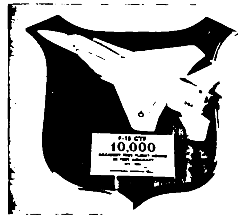
First flight of the aircraft was at Edwards on 27 July 1972. Since then, the majority of Air Force development flight testing has been carried out by the F-15 CTF, a unit made up of military and contractor personnel who work side-by-side to jointly test, evaluate, and develop the aircraft and its systems.

The CTF, presently flying six F-15s dedicated to test work, has on its personnel roster — in addition to nine test pilots — 20 Air Force and government civilian engineers; 30 uniformed, government, and civilian aircraft maintenance specialists; and about 70 contractor employees filling a variety of engineering, maintenance, and support jobs.

One of the major programs the F-15 CTF has been involved in over the past two years has been evaluating F-15 potential as a "dual role" fighter. CTF personnel logged over 340 hours of flight time, with nearly 100 hours devoted to realistic tactical flying. A spin-off from this dual role evaluation was the certification of conformal fuel tanks for Air Force use. Conformal tanks are low-drag external tanks that attach to the sides of the left and right engine inlets under the wings and give the aircraft a greater range, payload, and deployment capability.

CTF personnel are currently conducting several other programs to evaluate improvements to the F-15: F100 engine performance and durability upgrades; testing on advanced radar systems; refinements in the electronic countermeasures system; and work on a digital electronic flight control system.

Congratulations!



McDonnell Aircraft Company would like to add its congratulations to those already offered the F-15 Combined Test Force on its achievement of this magnificent flight safety record. For many years, MCAIR has recognized operational squadrons for accident-free flight performance, beginning at the 20,000 hour level (and repeating at 10,000 hour increments thereafter). We have presented small plaques attesting to these superior performances to one-hundred five squadrons, dating back to 1968. Illustrated above is the single exception to our own "20,000 hours first" rule, a trophy awarded recently to the Eagle CTF team at Edwards, for the record described at left. If ever there was an exception to prove a rule, 10,000 hours of accident-free *flight test* time is it!

CTF team members celebrate accident-free record setting flight by Col Mike Hall in F-15A 77-084. (L to R) Chuck Williams, RAF Sq Ldr Nigel Wood, Maj Geno Arnold, Maj Harry Strittmatter, Karl Richter*, Dick Bauer*, Lt Col John Hoffman, Col (now BGen) Hall, Capt Mike Deloney, MSgt Bob Rice, Maj Phil Filburn, Lt Col Billy Brooks, Col Jim Thomas, Maj Dave Spencer, Ron Beldo. (* - MCAIR).*

a better mouse trap...

AIM-9 RECYCLE ADAPTER

By CURT OBERG/*MCAIR Field Service Engineer, Eglin AFB, Florida*

Ask F-15 flightline armament system specialists what their biggest headache was in maintaining the Eagle weapon system and the "AIM-9 Recycle Cable" would surely be mentioned in short order.

Use of the locally-manufactured recycle cable had become a fact of life in the everyday F-15 training environment and the device was considered vital for an effective aircrew training program when using a captive AIM-9P/L pilot training missile (PTM) or the Cubic Corporation ACMI pod. However, while this cable was a valuable training aid, reliability and operational problems were reported by virtually every F-15 unit. Some of the problems were:

- Premature deterioration of ADU-407/A launcher adapter 531 door in the fastener countersink area, caused by excessive door removal and reinstallation.
- Broken wiring caused by cable flexure during installation into the limited amount of stowage space for the recycle cable beneath the 531 door.
- Failure to recycle, caused by release of Stores Release button prior to recycle time out.
- Recycle cable was compatible with captive missile carriage only and had to be removed for live missile carriage. The requirement to recertify the missile station with an A/E 24T-140 test set after removal of the recycle cable generated a tremendous workload.
- Recycle cable momentarily interrupted primary electrical power to the launcher power supply during recycle. A large number of newer launcher power supplies with internal overload protection were found to be incompatible with this power interruption and were restricted for captive missile carriage when a recycle cable was installed.
- Time delays in the recycle cable were not strictly controlled which occasionally resulted in a "partial" recycle, i.e., the armament control system recycled (verified by a "RDY" indication on the armament control panel after Stores Release button actuation) but the LAU-114A/A launcher power supply did not. This caused loss of AIM-9 missile seeker head control following recycle, a condition that could be corrected in flight by repositioning the Master Arm switch from "Arm" to "Safe" and then back to "Arm," *if* the pilot was aware of what had caused loss of head control.

In an effort to correct these deficiencies, several new recycle device concepts and designs were proposed by individuals from the F-15 community. After considering pros and cons of all proposed designs, representatives from the various agencies involved decided to develop the design that offered solutions to the largest number of problems. The "68D150083-1001 Recycle Adapter" is the result of these efforts, and provides the following features:

- Permanent installation, compatible with live missiles as well as captive missiles and ACMI pod, single or multiple store carriage.
- Circuit board and wiring are enclosed in a compact, machined-aluminum housing to prevent wiring damage caused by handling and flexure.
- "Latch in" circuit eliminates need to hold Stores Release button depressed until recycle time out is complete.
- Recycles without interrupting power to launcher power supply or missile/ACMI pod, and compatible with *all* present LAU-114A/A power supplies.
- Three-second time delay on recycle is compatible with all AIM-9 system test sets.
- Recycle time delays are controlled to ensure a complete recycle of all Armament Control System (ACS) and missile launcher circuitry.
- Disassembles easily for repair.

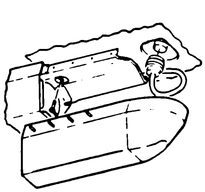
Validity of the new recycle adapter concept was proven operationally during a captive and live missile firing program conducted at Eglin AFB, Florida. Aircrews and aircraft assigned to the 33rd TFW at Eglin performed the captive carriage testing; while aircrews and aircraft assigned to the 36th TFW at Bitburg, Germany and the 32nd TFS at Camp New Amsterdam, the Netherlands, performed the live missile testing during a Weapon System Evaluation Program deployment to Eglin. Personnel from the 4484th FWS at Eglin evaluated aircraft and missile performance during the live AIM-9P/L missile launches. The five prototype recycle adapters used for the test program performed flawlessly, recycling reliably in well over 100 sorties with captive AIM-9P/L PTMs/ACMI pods and remaining "invisible" during the 10 live missile launches.

ADAPTER UTILIZATION

Use of the recycle adapter is quite simple. Permanently install a minimum of one recycle adapter in each F-15 and certify the missile station for live missile carriage by testing with the A/E 24T-140 test set. After testing, the recycle adapter-configured station may be used for any live or captive store presently cleared for carriage on the LAU-114A/A missile launcher. The recycle adapter will permit multiple practice launches of any captive store and will not interfere during live missile launches.

Aircrew Operation

When the aircraft is configured with a single AIM-9L PTM, in-flight operation of the recycle adapter will vary, depending on the type of umbilical cable used with the PTM. Two different configurations of AIM-9L PTM umbilical cables are presently in use. The first, and most common, is the standard training umbilical cable with a blue retaining strap. This training umbilical cable has an internal caging relay that positions and cages the AIM-9L seeker head to the boresight position during the three-second recycle interval. Usually, the AIM-9L PTM seeker head is off boresight in self-track from the radar slaved mode during practice intercepts. Because of the training umbilical cable internal relay, the AIM-9L seeker head will drive off-target to boresight position following recycle time out. The AIM-9L seeker



Job Guide illustrations show before (above) and after (right) installation of recycle adapter.

AIM-9 Recycle Adapter installed in pylon receptacle and connected to launcher adapter. Adapters are being manufactured by 4950th Test Wing (Mod Center) at Wright-Patterson AFB, Ohio and delivery to F-15 units is scheduled for completion in August of this year. According to reports from squadrons using the new device, reliability and system performance is greatly improved over old recycle cables, and life should become easier for Eagle weapons maintenance technicians. Tape wrap shown in photograph is recommended to guard against wire bundle chafing against inside of door 531. (USAF photo by SSgt L. Vaughn, 33rd EMS Armament Shop).

head *must* be recaged manually by depressing the Cage/Uncage button or by changing weapon mode.

The second type of AIM-9L PTM umbilical cable in use is a modified tactical cable (usually painted orange) which does not have an internal caging relay. When launching in self-track with the modified tactical umbilical cable, the AIM-9L PTM will actually remain in self-track if seeker head gimbal limits are not exceeded during the recycle interval, even though the missile seeker head position circle on the HUD display takes a boresight position. Following recycle, the seeker head position circle will give a real-time display of seeker head position and will return to the target heat source.

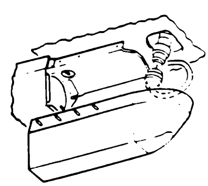
During the test program, most pilots voiced a preference for operation with the modified tactical umbilical cable since no extra action is required to return the missile seeker head to the target heat source, following recycle time out. The disparity in operation between the two types of umbilical cables will be rectified eventually; steps are being taken to eliminate the standard AIM-9L training umbilical cable with the internal caging relay because of a persistent moisture intrusion problem. The disparity can also be eliminated by configuring the aircraft with multiple recycle adapters and AIM-9L PTMs. During multiple carriage, station priority will transfer normally in sequence during firing through all loaded stations; recaging of the AIM-9L PTM seeker head will take place automatically with station transfer.

Maintenance

The recycle adapter connects in series between inboard pylon 60J-W026 or 60J-W027 receptacle and launcher adapter 60P-W004 connector, behind the ADU-407/A launcher adapter 531 door. To preclude the possibility of wire bundle chafing against 531 door when installing the new recycle adapter, it is advisible to add a protective wrap of silicone rubber tape, covering the 60P-W004 connector backshell clamp as well as the open mesh expando sleeve on the ADU-407/A wire bundle. The wire bundle should then be anchored to the recycle adapter with a plastic tie wrap.

SOME QUESTIONS AND ANSWERS

Numerous questions concerning operation of the new recycle adapter have arisen since its introduction. Some of the more commonly asked questions



AIM-9 Recycle Adapter installs between connector under door 531 and receptacle in door 525.

▶

and the answers provided should be of interest to all users of the new recycle adapters:

Q. If the recycle adapter is permanently installed and used for live as well as captive missile carriage, how does the recycle adapter differentiate between captive and live missiles?

A. It doesn't. When the Stores Release button is depressed, recycle adapter timer operation initiates regardless of the type store carried on the LAU-114A/A launcher. When a live missile is carried, missile launch sequence will be completed well before the three-second recycle time interval has completed. Recycle adapter timer operation is terminated and further inhibited when the live missile umbilical cable separates from the missile during launch. When a captive missile with an inert motor or an ACMI pod is carried, timer operation is not interrupted by umbilical separation and the recycle adapter will return the captive store to priority for additional practice launches.

Q. Will the recycle adapter have to be removed from the aircraft during maintenance such as ACS BIT checks, AN/AWM-75 firing circuit, or A/E 24T-140 test set checks?

A. No. The recycle adapter will not interfere with or affect ACS BIT checkout and is designed to be compatible with AN/AWM-75 and A/E 24T-140 test sets.

Q. If the aircraft is configured with four live AIM-9 missiles and an attempt to launch from a station with a recycle adapter installed results in a "hang fire," will the "recycled" live missile interfere with launching of remaining missiles?

A. During a live missile "hang fire," the "hung" missile would be recycled and placed back into firing order. During the three-second recycle interval however, the ACS will transfer station priority to the next missile in firing sequence, stepping over the "hung" missile. The ACS will place all remaining unfired missiles in priority before returning to the previously "hung" missile. The only way the "hang fire" missile could be placed into priority before all remaining unfired missiles would be in the remote case of a fuselage masking situation while in radar-slaved mode.

Q. In case of a "hung" live missile with a recycle adapter installed, is there any way to deliberately take the "hung" missile out of fire sequence permanently to preclude the possibility of it being placed into priority inadvertently?

A. There are two methods of deliberately removing a store from firing sequence when a recycle adapter is installed. The first and recommended method is to select the appropriate AIM-9 station with the Armament Control Panel Select Jettison switch and then depress the red jettison button. This procedure is completely safe and will not actually jettison the "hung" missile, since AIM-9 jettison circuitry has been deactivated by TCTO 11L1-2-14-502 *and* by interrupting jettison voltage at the recycle adapter by omitting the feedthrough wire at pin "X."

The second method is to step the appropriate store into priority with the AIM-9 Missile Reject switch, depress the Stores Release button, and then position the Master Arm switch to "Safe" before the three-second recycle interval is completed. This method was used successfully by several 33rd TFW pilots to deliberately remove an ACMI pod from firing sequence during a multiple captive missile/ACMI pod test. (When carrying a mix of AIM-9L PTMs and ACMI pods, 33rd TFW pilots normally "hang" the ACMI pod deliberately and use AIM-9L PTMs for running intercepts on the ACMI range. The ACMI pod is used for aircraft data downlink only; AIM-9L shots are called in manually over the UHF radio.) During the test, the aircraft was configured with a recycle adapter at each AIM-9 station, an ACMI pod at station 2A, and captive AIM-9L PTMs at stations 2B and 8B.

Use of the Select Jettison switch would be preferred when attempting to remove *any* live missile from firing order because of the possibility that the missile could launch when the Stores Release switch is actuated, even though it may have "hung" during a previous attempt.

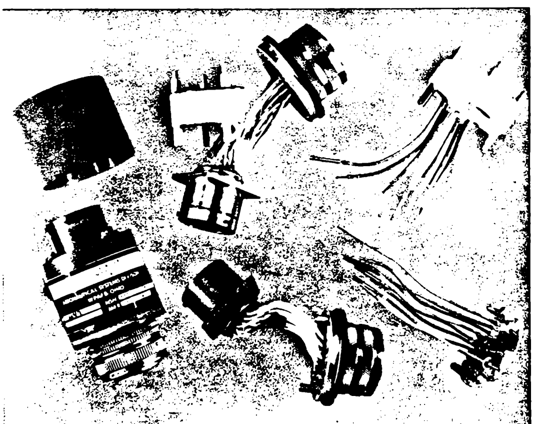
Q. There have been a few cases of delayed missile launches reported during live missile launch attempts from LAU-114A/A missile launchers. What effect would the installation of a recycle adapter have in this situation?

A. The launcher power supply has a "latch" circuit that keeps motor fire circuitry energized after a launch attempt until the Master Arm switch is positioned to "Safe." When a recycle adapter is installed, launcher power supply motor fire circuitry will be "safed" three seconds after stores release actuation, limiting delayed launches caused by an electrical malfunction to three seconds. The recycle adapter would have no effect on delayed launches caused by slow-burning motor igniters.

Q. If the recycle adapter reduces time during which a delayed launch could occur because of a missile/launcher electrical malfunction to three seconds, wouldn't a shorter recycle interval be desirable since an AIM-9 missile clears the launcher in less than a second during a normal launch?

A. The three-second recycle interval was selected to allow checkout of AIM-9 system with the A/E 24T-140 test set after recycle adapter installation. A shorter recycle interval would create an incompatibility with the A/E 24T-140 test set, which is the primary AIM-9 missile system test set.

If you have additional questions about the recycle adapter, contact your local MCAIR Field Service Rep or call MCAIR's St. Louis office at (314) 232-9363. ■



Exploded view shows internal components during various stages of manufacturing. Adapter prototypes were designed and manufactured by Curt Oberg, while MCAIR Department 321 provided component packaging and engineering drawings for fabrication of production version shown. (USAF photo by Tom Richards, 4950th TFW)

ALE-45 COUNTERMEASURES DISPENSER SET ACCELERATED RETROFIT (TCTO 1F-15-923/ECP 1795)

This document supports post-production installation of the countermeasures dispenser (CMD) into F-15C/D aircraft. The CMD consists of a programmer and four dispensing switch assemblies (DSA's). The CMD interfaces with the CMD control panel, TEWS telelight panel, manual program switches, afterburner ON switch, aircraft safety switches, weight-on-wheels circuits, avionics status panel, BIT control panel, and aircraft electrical subsystem and structure. The dispensing switch assemblies interface with GFE AN/ALE-40 dispensing magazines and associated expendable payloads and with dummy magazines. Two magazines are mounted on each DSA.

TCTO 2JA12-9-507 modifies the throttle quadrant by the installation of new throttle grips so that the full avionics control capability on the CMD aircraft can be utilized. Electrical switches and switch functions are installed on the new throttle grips for the improved avionics. TCTO 8D24-2-513 adds 18 fault indicators to the avionics status panel to monitor new equipment installed for the CMD.

CONFORMAL FUEL TANKS WITH TANGENTIAL WEAPON CARRIAGE ON FIXED ARMAMENT STATIONS (ECP 1652)

Design is currently in work to increase the weapons carrying capacity of the F-15E through use of the LCT-4 and RCT-4 conformal fuel tanks. Each tank can carry and deploy air-to-ground weapons from six stations mounted in two rows of three, or two AIM-120 or AIM-7 air-to-air missiles instead of the air-to-ground weapons. The central inboard station on each tank can carry a nuclear weapon. (The Dash-4 tanks are an integral part of the F-15E weapon system and can be installed on F-15C/D aircraft with minor kit part changes.)

With the new Dash-4 tanks, the forward and aft inboard air-to-ground stations have a combined 2,200-pound capacity; the center inboard air-to-ground station has a 3,300-pound capacity; and each of the three outboard air-to-ground stations has a 1,100-pound capacity. The new tanks are interchangeable with the current Dash-2 and Dash-3 conformal fuel tanks, each of which has only one air-to-ground station and two air-to-air stations.

Three photos show progress of CFT/weapons carriage capabilities - (top) original design in 1974; (middle) - 1981; (bottom) - current.

ARMAMENT SYSTEMS

(CURT JOHNSON/*Senior Engineer*)

Mixing AIM-9 Weapons Loads on the F-15

An AIM-9 missile is an AIM-9 missile. Or is it? The answer is yes up to a point. As all armament technicians know, there has been a whole series of heat-seeking missiles with the AIM-9 designation, but with different letter suffixes. They are all air-to-air heat seeking weapons and have been nicknamed "Sidewinder." They are all lean and mean and have four wings and four canards. But at that point the similarities begin to fade and complications to occur.

We'd like to talk a bit about the differences between AIM-9s because an F-15 unit in the field has asked a question concerning the use of AIM-9L and AIM-9J/P Sidewinders on the same Eagle. There are no physical restrictions to mixing the two types of missile and they can be loaded on the same weapons stations on the aircraft. So, our answer to the question is that, yes they *can* be mixed together, but that, no we *don't* recommend it. Here's why . . .

The AIM-9L has a "slaveable" seeker head which provides it with increased ability to "see" airborne targets when compared with earlier generation missiles. The AIM-9J/P is not equipped with the slaveable head feature and has a limited field-of-view. If the two versions are loaded on the same aircraft, the non-slaveable seeker head of the AIM-9J/P has the nearly impossible task of trying to duplicate its more sophisticated brother missile.

The F-15 armament control set (ACS) identifies to the aircraft, the central computer, and the radar that indeed an AIM-9L is loaded aboard and desires to be recognized to perform its mission as an AIM-9L. This allows the weapons integration system of the aircraft to give the AIM-9L with its slaveable seeker head the "authority" to look along the radar line-of-sight in an attempt to acquire and track a target. An AIM-9J/P in the same load would receive the same authority from the weapons integration system, but would lack the capability to carry out the order. The results could be, and most likely will be, catastrophic with damage to the missile seeker assembly if not complete failure.

We suggest you avoid giving the AIM-9J/P the severe headache that results from forcing it to live in the environment created by an AIM-9L. Don't use mixed Sidewinder loads on the Eagle - your missiles will show their appreciation by performing as designed, and the missile build-up folks will appreciate their reduced workload!

Flying the F-15 at

By LtCol WILLIAM A. THOMAS /*F-15 Chief Test Pilot-Flight Test Branch, Aircraft Division, Directorate of Maintenance, Air Logistics Center, Robins AFB, Georgia*

When I first decided I wanted to learn to fly, I had never been in an airplane of any sort. From that beginning to where I am now - flying the greatest fighter in the world during one of the most interesting assignments in the United States Air Force - has been quite a personal experience. The editor of the MCAIR magazine seems to think some of you might like to read a little about those experiences, and about what we do here at Warner Robins Air Logistics Center with their F-15 Eagle, so here goes.

Flying got into my blood quickly and it's obviously never gotten out. And where but in Uncle Sam's Air Force could a guy fly a multi-million dollar, multi-faceted fighter aircraft, and get paid for the enjoyment? I've been flying for over eighteen years, including seven in the test business after starting with the 4485th Test Squadron at Eglin, and have been at Robins for nearly three years. I've accumulated some 4450 flight hours, with 1500 of them in one of McDonnell's other fine airplanes, the F-4, but the 650 I've logged in the Eagle have been the best, by far! In my opinion, MCAIR really did it right with the F-15; it's the Cadillac of the fleet, and nothing can match it on either side. I've long felt that there are only two types of aircraft - fighters and targets, and the F-15 is one sweet fighter. MCAIR gives a shoulder patch to F-15 pilots that says "Eagle Driver" on it, but pilots assigned to this airplane have been called "Ego Drivers" because flying the F-15 is a real boost to your ego. I obviously feel extremely fortunate to have upgraded into this marvelous weapons system.

The flying here at Robins may not have the pure excitement you get in an air-to-air squadron, but our type of work means that you do learn your aircraft from every conceivable standpoint. You soon learn to recognize symptoms and to accurately evaluate to a greater degree what's going wrong, what a malfunction may actually be forecasting, what potential problems may be showing up. With the assistance of our maintenance people, the pilot here can prevent many problems from developing; and then through the excellent rapport we have with the MCAIR tech reps there aren't many questions on the F-15 that go unanswered. We are very highly maintenance-oriented at the Center, and that takes some getting used to for a pilot, but very worthwhile if you want to find out how an airplane really ticks.

Major Thomas G. Ylikopsa and I are assigned to test F-15s as they come off the Directorate of Maintenance "Speedline." With Speedline, the Air Logistics Center changes out the foam in the fuel tanks, modifies the brakes to the pulser system, adds the overload warning system, fuel pressure control valves, and about 15 other lesser modifications. Last year, we put 92 aircraft through Speedline, and eleven through validation and verification ("validate" is to test a technical order for technical accuracy and adequacy; "verify" is the actual performance, where we test and prove changes to be adequate for operational use). In addition, we have been running "Foam Express," just changing out the fuel cell foam on the aircraft. There were 73 aircraft programmed for this year.

Robins is also tasked with crash damage repair. For example, late in 1979, aircraft 77-061 was involved in a mid-air collision, with resulting extensive damage to the aircraft left side fuselage, wing, flaps, aileron, and vertical stabilizer. Our people did an absolutely outstanding repair job, and when I flew 061 on its airworthiness flight and full profile check flight, it came back discrepancy-free - not bad for a rebuild job! The aircraft is now back with the squadron, and the Depot can be proud of the money the Air Force saved with this effort. It never fails to amaze me - the amount of teardown an aircraft goes through here, yet our civilian work force gets it back together almost discrepancy-free each time.

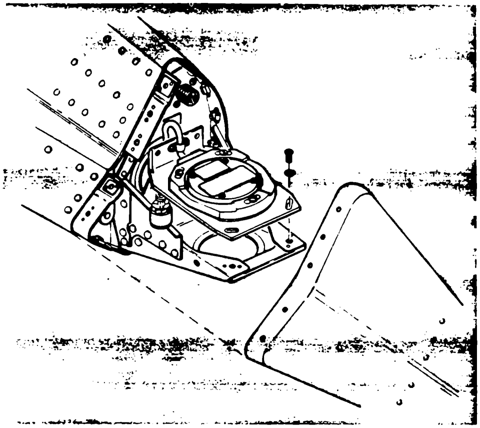
People who are used to seeing a flight ramp full of Eagles would probably laugh at the size of the "Robins Air Force" - we have only one F-15 assigned full time here, but S/N 77-068 is a pretty unique bird with full instrumentation for the various tests that occur. It's a typical test airplane in that it doesn't have a high number of flight hours for its age (some 440 hours in about 6½ years), but each hour has been spent doing something different. Currently, we are involved in vibration tests on the stabilator and we also check new radar tapes and are doing validation and verification of another new video tape recorder. I probably average 10 to 15 sorties a month and have the opportunity for more if I deliver aircraft back to their home stations.

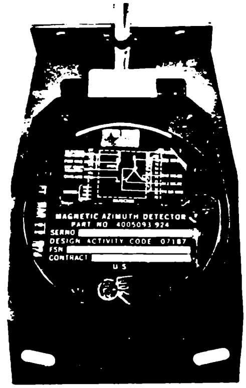
I remember several years ago that Irv Burrows, (then) MCAIR's chief test pilot, said in a DIGEST article that "he never met an airplane he didn't like - that he didn't enjoy flying," and that's exactly the way I feel about the F-4. With 1500 hours in "old double ugly," I have a real soft spot in my heart for the Phantom, but the F-15 is just so much more capable that it's hard to compare the two. The Eagle is definitely a product of its times - a highly complicated, very sophisticated technological machine that demands strong mental agility to keep up with. Even so, the F-15 is a more forgiving airplane flightwise than the F-4; you really have to "ham-fist" it to put it out of control. It has fantastic capabilities at both high G and low airspeeds. The radar is excellent now and still being improved upon continually. Of course, the HUD is great - I don't know how we managed without one in the F-4. Human engineering has produced a large, comfortable cockpit with controls such as radio and IFF well located for ease of change. Another major difference between the Eagle and Phantom is engine thrust - the F-15 is a real performer, without smoke! In fact, I don't know of any needs the Air Force might have as far as fighters are concerned that the Eagle could not be adapted to meet.

Every time I go out to fly, and light the afterburners on takeoff, it's a new thrill, regardless of how routine the mission might be. The pilot must be alert - you don't go out for a sunday afternoon drive in the F-15; but if you feel about airplanes like I do, your first flight in the Eagle jet will be the beginning of a genuine love affair! ■

CAUTION

Don't Make the MAD MAD...





MAGNETIC AZIMUTH DETECTOR SENSITIVITY

By BILL HOLMES/*Electronics Engineer and* GLEN SEGANFREDO/*Senior Engineer, Avionics Laboratory*

Technology, or applied science, is constantly changing. This is particularly true in the aerospace field where the changes are rapid and at times overwhelming. So much so that one may lose sight of the fact that there are basic and often simple scientific principles behind all the sophisticated systems in even the most modern of fighter aircraft. For example, the F-15 navigation system is a highly complex combination of black boxes that do wondrous things for the pilot and the mission, but buried deep within those complexities lies the simple physical principle of "earth magnetism." If something is done in maintenance to upset that principle, your Eagle is headed, not for the target, but for trouble. This is why . . .

Recently, an aircraft maintenance unit was confronted with an Attitude Heading Reference System (AHRS) problem on an F-15 aircraft. An investigation of the components of this system led to the discovery of ferrous (magnetic) fasteners located near the Magnetic Azimuth Detector (MAD) in the right tail boom fairing under access door 129R. Since the MAD operates magnetically, it was reacting to the magnetic distortion produced by the fasteners, which was much stronger than earth's normal magnetic field, and the MAD was in effect lost in a sea of conflicting magnetic "instructions." These MAD errors then delivered incorrect heading information to other components of the AHRS.

Replacing the ferrous fasteners with non-ferrous (non-magnetic) ones remedied the problem. Several other aircraft at the same base were checked, and revealed similar magnetic hardware installations. Since this indicates that people may be overlooking the caution notes in the maintenance manuals, let's quote from Job Guide 1F-15C-2-34JG-22-1 . . .

> Do not use magnetic screws or hardware to install Magnetic Azimuth Detector (MAD) or door 129R.

Any magnetically operated system in the aircraft requires the same precautions — keep (ferrous) workstands and ground carts away from the work area; use only nonmagnetic adjustment tools; make sure there are no loose ferrous materials around. Perhaps some basic information relating to operation and function of the Magnetic Azimuth Detector and the effects upon it of ferrous materials, will help keep this important little device always "headed in the right direction."

The MAD is an electromagnetic sensor used to detect the position of earth's horizontal magnetic field component with respect to the aircraft longitudinal axis, thus generating the magnetic heading of the aircraft. The sensing element inside the MAD housing is gimballed (suspended) to provide two degrees of freedom (30 degrees in pitch and 30 degrees in roll) so that the average position of the element is in the horizontal plane. The unit housing is filled with a silicon fluid which dampens oscillation of the gimballed sensing element during flight.

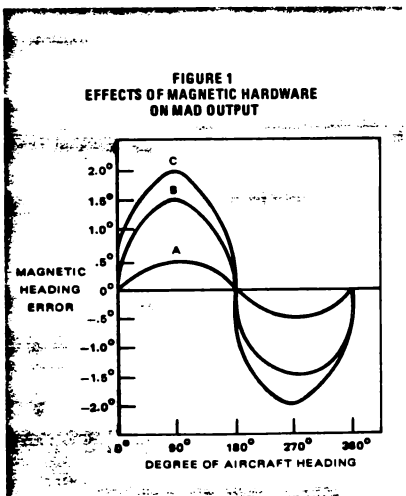
The interface for the MAD is contained in the AHRS Electronic Control Amplifier (ECA) which processes the magnetic heading and sends it to the Inertial Navigation System (INS), Central Computer Complex (CCC), and the Horizontal Situation Indicator (HSI). The INS uses magnetic heading for Best Available True Heading (BATH) alignment and a one degree error in magnetic heading to an INS (which is BATH aligned) can produce as much as 15 nautical miles per hour navigation error. Magnetic heading is continuously displayed on the HSI compass card and used by the CCC in conjunction with other inputs to provide bearing and steering information to the HSI. In addition, the CCC uses magnetic heading for heading display on the Head Up Display (HUD) in the Attitude Director Indicator (ADI) and Air-to-Ground modes and for computation of magnetic variation (MAG VAR). If the INS is inoperative and/or the Navigation Control Indicator (NCI) is not in INS NAV or TACAN NAV position, the CCC uses magnetic heading in computing true heading.

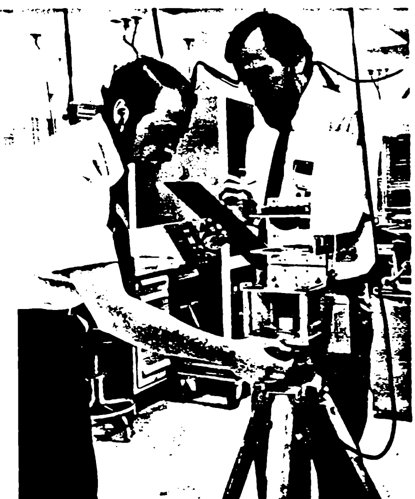
From the above it is quite evident that the MAD-generated magnetic heading plays a significant role in much of the F-15 avionics performance and justifies every effort to maintain its accuracy. However, the MAD has one weakness that must be respected in order for it to dispense accurate information — it is constantly allergic to anything that has the slightest tinge of magnetism, or that can become magnetized.

Figure 1 shows results of tests made in the MCAIR Avionics Laboratory to evaluate the effects ferrous metal fasteners could have on MAD output. Plot A shows a one cycle error, maximum amplitude of 0.5 degrees, resulting from random placement of ferrous fasteners in a full scale modeled envelope of the MAD access cover in door 129R. Plot B indicates a one cycle error, maximum amplitude of 1.4 degrees, caused by ferrous hardware which was momentarily placed in contact with a small permanent magnet and then randomly placed in the access cover model. Finally, Plot C displays a one cycle error, maximum amplitude of 2.0 degrees, produced by randomly picked ferrous hardware, magnetized as previously described, and placed in the MAD mounting bracket. An error of this amplitude could be very difficult to compensate out.

If these induced errors were stable (would not change in time), there would be no problem in compensating for them. However, aircraft environmental conditions (such as electrical storms, temperature, shock, and vibration) can cause the magnetism in ferrous hardware to change significantly. This produces unstable magnetic errors which allow a compass calibration to be effective only until a significant change in the magnetic state of the ferrous hardware occurs. Incidentally, it is probably this phenomenon that makes some technicians think magnetic hardware will not cause system operational problems, for they have seen ferrous materials used in a correctly functioning system. What had actually happened was that the error induced by the material had been compensated for in a calibration that would be good only until the next magnetic "upset." Using magnetic hardware in the MAD mounting bracket, access door, or surrounding structure is a guarantee of eventual AHRS problems.

If you are in doubt as to whether the hardware you want to use is appropriate, the simplest way to differentiate between magnetic/non-magnetic material is to touch it with a magnet. If it has the slightest attraction to, or adheres to, the magnet, it is ferrous and must not be used. Your Eagle is carefully trained to be attracted by Mother Earth's magnetic personality; don't let its head be turned by the passing fancy of a ferrous fastener! ■





(Photograph) MCAIR Avionics engineers Glen Seganfredo (left) and Bill Holmes (right) perform laboratory tests to demonstrate effects of ferrous (magnetic) hardware on Magnetic Azimuth Detector.

INERTIAL NAVIGATION SYSTEM

(DON STRAUSS/*Senior Engineer*)

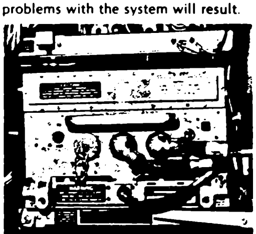
Preventing Damage to the F-15 IMU

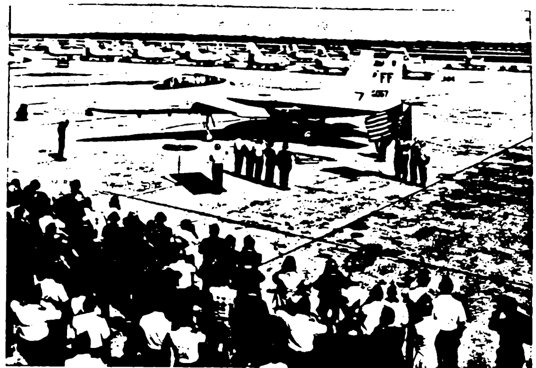
Two articles on the F-15 inertial navigation system (INS) recently appeared in the DIGEST (Issues 2/83 and 1/84). Both articles pointed out some practical problems with the system and areas in which care and caution were necessary, including handling of the inertial measurement unit (IMU). These articles are valuable reading for aircrewmen, flightline personnel, and avionics shop technicians, but overlooked a potential problem area when it becomes necessary to hand-carry the IMU from one place to another.

The IMU handle (see photograph) is NOT intended to be used for carrying the unit - its only purpose is to assist maintenance personnel in maneuvering the IMU when installing it in the aircraft. Serious personal and equipment damage can occur if this handle is used to transport the unit. There are reports of the handle breaking loose and allowing the IMU to fall to the ground. The unit weighs approximately forty pounds and, in most cases, it requires two people to remove it from the aircraft.

Inside the IMU there are two gyros worth about $14,000 each and two accelerometers that are also very expensive. Internal and external damage in excess of $30,000 has occurred to IMUs dropped as a result of broken handles. A safety hazard also exists in that a falling forty-pound IMU could cause bodily injury.

The IMU is very sensitive to shock. If the handle is used as a carrying tool, the unit guide pins could strike the ground, causing shock to the unit and damaging the gyros. So, please take extra caution when handling this vital unit of the INS - better accuracy and fewer problems with the system will result.





Millionth-hour aircrew - General Jerome O'Malley and Lieutenant Colonel Paul Hester - shut their F-15 down in preparation for "red carpet" reception on flight ramp at Tyndall AFB.

EAGLE OVER MILLION MARK

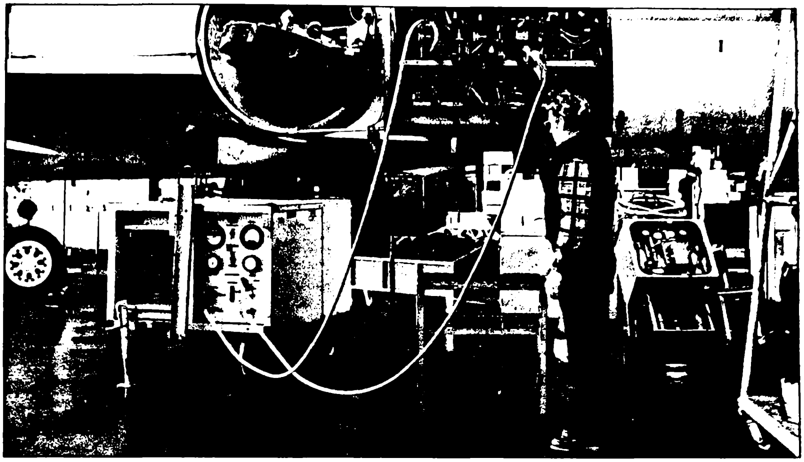
26 October 1984 was a red-letter day for McDonnell Aircraft Company and the United States Air Force. It was on that bright, sunshiny day at Tyndall Air Force Base, Florida, that the F-15 Eagle air superiority fighter officially became a "millionaire" - reached a million hours in the air!

When General Jerome F. O'Malley, new commander of the Air Force Tactical Air Command, and Lieutenant Colonel Paul Hester, 94th Tactical Fighter Squadron operations officer, landed F-15D S/N 80-057 at Tyndall, they were fifteen minutes into the second million hours, after a one hour fifteen minute flight from Langley Air Force Base, Virginia. With more than 800 aircraft operating from 14 locations around the world, Eagle flight hour # one million could actually have occurred at any number of places, but what more appropriate location and symbolic situation than Tyndall AFB and the concluding ceremonies for "William Tell 1984"?

F-15's have been operational at Tyndall for approximately a year, and are being flown there by the 325th Tactical Training Wing. F-15's from around the world were temporarily at Tyndall to participate for just the second time in a William Tell air-to-air weapons competition. Attention of the entire fighter aircraft community was therefore focused on the aerial event underway at this northern Florida base; and on this particular day all eyes at Tyndall were on the big red "apple" painted on the ramp as General O'Malley expertly brought his Eagle to a stop at that exact point, for a formal color guard reception.

It took just one month short of ten years of operational service for the F-15 to reach its millionth flight hour; November 1974 saw the airplane dedicated to squadron service with the 555th TFTS at Luke AFB, Arizona. In its first decade of utilization, the Eagle has become the "safest" fighter in aviation history - only four aircraft have been lost per 100,000 flight hours. In accepting a plaque from MCAIR in recognition of its accomplishments, General O'Malley said, "The F-15 a super performer. It has exceeded every goal we set for the airplane and is the safest fighter aircraft we've ever flown. It is a testament to the high state of Air Force readiness today, and a centerpiece of american technology and know-how." ■

General O'Malley accepts "million hour" plaque from William S. Ross, MCAIR vice president and general manager, F-15 program.



When the Wright brothers made their first powered aircraft flight on 17 December 1903 at Kitty Hawk, North Carolina, they had concern for just three fluids — gasoline to power a twelve horsepower engine, oil to lubricate its internal parts, and water to keep it cool. Since that eventful day aircraft have come a long way, and to keep pace with that progress many special fuels, lubricants, and fluids have been developed for various system functions. Keeping track of the characteristics, hazards, and proper use and handling of these sophisticated aircraft "consumables" can be a confusing task to personnel involved with maintenance and support.

The DIGEST has published several articles over the years to help make that task easier. For example, in issue 3/77 we gave you a look at that fascinating fluid, liquid oxygen. In issues 6/77 and 1/84 we examined jet fuels and their interchangeabilities. And in issue 6/79 we looked at the consumable that makes so much happen on an airplane — hydraulic fluid. Now, in our continuing effort to help you better understand the consumables used in aircraft manufactured by McDonnell Aircraft Company,

Let's Look at...
Heat Transfer Fluids

Since the dawn of aviation, a prime and constant objective of aircraft design engineers has been to lessen the weight of an aircraft. Development of miniaturized electronic equipment was a big step in that direction. However, with the inevitable increase in power output of miniature electronic units, more heat was created which had to be dissipated for safe and reliable operation of the units. With more electric power being designed into less space, electronic components had to function effectively even though exposed to widely fluctuating, often extreme environmental conditions. Because of the high and low temperature extremes involved, air and petroleum and water-based fluids were no longer effective as efficient coolants. For these advanced electronic packages, the search was on for a reasonably stable cooling fluid containing acceptable lubricating and dielectric (high voltage insulation) properties.

The first to appear was a synthetic fluid (originally known as OS-45 but later named Coolanol 45 dielectric heat transfer fluid), developed jointly by the Douglas Aircraft and Monsanto Chemical companies in 1954 (see editor's note).* Though developed originally as a hydraulic fluid operable in a temperature range of −65°F to +400°F, it was soon found that OS-45 fluid had excellent heat transfer characteristics. This, combined with good electrical properties, led to its use as a dielectric coolant in advanced weapons systems. MCAIR's first employment of an electronic cooling fluid

**Editor's Note: "Coolanol" seems to have become the standard term by which to identify the heat transfer fluid used in the F-15 and F/A-18 radar systems. However, "Coolanol" is a registered trademark of the Monsanto Chemical Company, and "Coolanol 25R" is the specific Monsanto brand used in the Eagle and Hornet. "Flo-Cool 180" is the registered trademark assigned by Chevron International Oil Company to identify its brand of heat transfer fluid used in the same aircraft*

(OS-45) was in 1959 when it was used in the APQ-72 XN1 radar system of the first Phantoms for the U.S. Navy.

During the early space programs, another fluid known as Coolanol 15 was developed. Because of its capacity to provide efficient, precise, and safe temperature control, Coolanol 15 fluid was used in the heat transfer system of the NASA/McDonnell Gemini space capsule. This same fluid was also used as the hydraulic medium for hatch actuation on the Spacelab. Today the Monsanto family of Coolanol dielectric heat transfer fluids consists of five fluids numbered 20, 25R, 35R, 40, and 45R. Monsanto also manufactures another electronic coolant fluid called OS-59. These fluids are used as cooling agents in components for fire control systems, missile guidance systems, air navigation systems, and communication systems.

After introduction of Monsanto's Coolanol, several other dielectric heat transfer fluids began to appear in the market place. Bray Oil Company produced Brayco 760 fluid. The Commercial Chemical Division of 3M Company turned out a series of dielectric coolants known as Fluorinert Brand Electronic Liquids. E.I. DuPont DeNemours & Company manufactured a fluid known as Freon E-2. General Electric Company produced a coolant called SF 1050 fluid. Chevron International Oil Company produced Oronite 8786 Dielectric Fluid, which is known today as Flo-Cool 180. Because Coolanol 25R and Flo-Cool 180 are the only authorized coolants for use in aircraft currently manufactured by MCAIR, this discussion will be confined to those two fluids.

FLUID DESCRIPTION & CHARACTERISTICS

Coolanol 25R and Flo-Cool 180 are inert, non-corrosive liquids. They are clear to light amber in color as manufactured and have a slight, characteristically sweet odor. The base fluid in each is tetra (2-ethylbutyl) orthosilicate which may contain additional amounts of other constituents to improve viscosity index and stability to oxidation. The results are low volatility fluids having excellent viscosity-temperature characteristics and outstanding thermal stability. Silicate ester base fluids have good lubricating features and are rated fair in their resistance to fire. (As such, they should not be considered fire-resistant fluids.)

Silicate ester base fluids, without additives, have only a fair oxidation stability. They are similar to hydrocarbon fluids in their susceptibility to attack by oxygen. The silicate esters respond well to oxidation inhibitors added to the finished fluid. The major disadvantages of these fluids are that they are "hygroscopic" (open containers can absorb water from ambient air) and have marginal resistance to hydrolysis (decomposition of the fluid by reaction with water).

Silicate esters will chemically react with even minute quantities of moisture to form a black, jelly-like (silica gel) contaminant known in avionic maintenance circles as the "black plague." Contaminated with water, the orthosilicate molecules can undergo total hydrolysis, and this process is accelerated with the addition of heat. The hydrated silica gel ($SiO_2 - 2\ H_2O$) can act as a sponge to absorb some of the parent fluid. If an extraction is done to the gel, the results will show approximately 80% parent fluid and 20% hydrated silica gel. If the original gel contaminant is recovered from an operating system, the solids that can be filtered may be dark gray to black due to wear debris particles from the system.

The contaminant acts as a thermal insulator and prevents optimum heat transfer. It clogs coolant passages and causes thermal interlock switches to stick, thereby causing system overheat and shutdown. It is a cause in the reduction of volume resistivity where system electrical properties are degraded by an order of one to three magnitudes. Contamination decreases the dielectric strength of the coolant, which precipitates high voltage arcs. This can damage vital system components and even cause piercing of metal housings and system plumbing.

Another by-product of coolant moisture contamination and exposure to high voltage is an alcohol (2-ethylbutanol). Because it is a flammable substance having a much lower flash point than the silicate esters, 2-ethylbutanol can contribute to fire hazards. This alcohol has a COC (Cleveland Open Cup) flash point of only 137°F. Under extreme thermal and/or oxidative stresses, the alcohol can oxidize or dehydrate to form other molecular fragments with even lower flash points. The combination of metal puncture from high voltage arcing and alcohol then leaking through the hole to impinge on a hot surface has been the cause of substantial damage to aircraft systems. Obviously, contamination of silicate ester base cooling fluids cannot be taken lightly and must be avoided.

FLUID QUALITY

Coolanol 25R and Flo-Cool 180 are both manufactured to the requirements of Military Specification MIL-C-47220 (Dielectric Cooling Fluids). This spec identifies five types (I, II, III, IV, V) of silicate ester cooling fluids, all of which are suitable for a low temperature range beginning at −65°F. The high temperature range for Type I is 350°F, Type II 400°F, Type III 550°F, Type IV 300°F, and Type V 700°F. *Coolanol 25R and Flo-Cool 180 are Type IV cooling fluids.*

In addition to the requirements of the general military specification governing quality of the heat transfer fluid as originally manufactured, there are several military and contractor specifica-

Quality of heat transfer fluid in aircraft radar systems is assured through particulate and moisture contamination testing of samples from each new Hornet or Eagle. In photo on opposite page, MCAIR Flight Test electrical & electronic mechanic Glen Flaugher checks hose connection from coolant supply cart to F-15 Eagle. In photo above, Annette Schuetz, assistant engineer in MCAIR Quality Control Laboratory, uses a "Karl Fisher Tritometer" to test coolant sample for moisture content.

tions applicable to the fluid after it has been installed in a radar system and used to cool the system. For example, MIL-C-47220 requires originally delivered fluid to contain no more than 100 ppm (parts per million) of water. USAF T.O. 33D7-35-39-1 (F-15 Antenna Test Station Operation Instructions) stipulates that coolant supplied to the radar transmitter by the AIS (Avionics Intermediate Shop) antenna test station may contain no more than 150 ppm water content. Neither the McDonnell (aircraft manufacturer) nor the Hughes (radar system manufacturer) internal specifications permit water content of cooling fluids in installed radar systems to be above 150 ppm. Limitations in the various specifications are equally specific concerning the amount and size of particulate contamination permissible. USAF T.O. 1F-15-2-21JG-80-1 (Avionics Liquid Coolant System Servicing) cautions that liquid coolant deteriorates quickly when exposed to contamination. USN A1-F18-LMM-000 (Line Maintenance Procedures) requires that flushing and bleeding of the radar liquid cooling system be performed when coolant contamination is suspected. USAF T.O. 12P2-2APG63-22 (Radar Transmitter Intermediate Maintenance Instructions) contains the listing above of "properties and requirements applicable to liquid coolant to determine its useability in the unit."

Properties	Requirements
Volume Resistivity	4×10^4 ohm cm (min)
Dielectric Strength	300 volts/mil (min)
Water Content	150 ppm (max)
Particulate Contamination (100 ml sample)	
10 — 200 microns	28,000 particles (max)
Over 200 microns	60 particles (max)

From all of this it can be concluded that "quality" of the installed cooling fluid is very important to satisfactory functioning of the radar system and that the system servicing advice presented below be followed closely.

Earlier in this article, it was noted that these heat transfer fluids were clear to light amber in color as delivered in original containers. Several inquiries from the field have questioned the significance of a change in this color, after the fluid has been in an operating radar system for a while. When fluid has been removed from transmitters, it has been noted as being everything from a light yellow, "dingy" yellow, light brown, to an almost dark gold. Why is this, what does it indicate, is it a problem? Some shops have also noted that the fluid can be "unusually" dark when changing out a transmitter that has failed or when a coolant low fault was flagged. According to the fluid manufacturer, these changes in color are caused by an amine additive contained in the fluid. This discoloration does not affect the performance of the coolant. Fluids currently being manufactured do not contain the additive and will discolor only slightly with use. So don't worry when you see fluid colors of the shades noted.

Coolanol 25R and Flo-Cool 180 are compatible and interchangeable with each other, and may be inter-mixed in any proportions (Revision B to Mil-C-47220 deletes a previous prohibition against mixing fluids of the same "type"). However, under no circumstances should either of these fluids be mixed with any of the other four "type" dielectric cooling fluids; the Hughes APG-63 radar system in the F-15 Eagle and the APG-65 radar system in the F/A-18 Hornet will not tolerate heat transfer fluid other than Type IV.

You may receive either Coolanol 25R or Flo-Cool 180 when ordering under the assigned National Stock Numbers (NSN). There are three NSN's, according to the size and shape fluid container required for servicing units. The 2001MC fluid make-up unit used in the F/A-18 system requires a one-gallon rectangular container. The 68D240006-1001 servicing unit used in the F-15 system accepts round containers of either one-quart or one-gallon size. Applicable stock ordering numbers are —

- NSN 6850-00-935-9774 — one gallon rectangular can
- NSN 6850-00-138-9794 — one quart round can
- NSN 6850-00-138-9799 — one gallon round can

RADAR SYSTEM SERVICING

When servicing or purging the radar liquid cooling system on the F-15 or F/A-18, several common-sense precautions will guarantee a satisfactory job. Compliance will assure that dielectric, thermal, chemical, and physical proper-

SSgt Bruce C. Schreiber
1 AGS, 1 TFW
Langley AFB, Virginia

(Reprinted with permission from August 1985 issue of TAC ATTACK magazine.)

SSgt Bruce C. Schreiber was servicing an F-15 accessory drive with oil. While checking the oil level, he noticed that the new oil was almost clear and had separated from the old oil. A further check revealed that the oil from the cart was very thin and had a sweet smell. Sergeant Schreiber immediately declared the aircraft unsafe for flight due to oil contamination and informed the production supervisor.*

Remembering that the same oil cart had been used on another aircraft that was about to begin an engine run, he ran over and informed the crew chief before the engines were started. Acting on his own initiative, Sergeant Schreiber then visually checked the oil in all aircraft on the flying schedule including four with pilots already present at the aircraft. He then checked every other aircraft in the AMU.

Sergeant Schreiber found five aircraft with contaminated oil; one aircraft was within minutes of engine start for a practice functional check flight (FCF). ■

**AMAD/engine oil contaminated with what? If you guessed electronic heat transfer fluid, you're right! Read the RADAR SYSTEM SERVICING section above to find out why this potentially catastrophic situation most likely occurred. Our congratulations to SSgt Schreiber for his alert action in recognizing the situation and averting what could have been a lot of very bad news for several engines, airplanes, and pilots.*

ties of the heat transfer fluid are maintained, thereby avoiding damage to costly radar system components.

- Be absolutely positive you are servicing the radar system with only Coolanol 25R or Flo-Cool 180 dielectric heat transfer fluids. Read the labeling on the fluid container carefully and verify the exact NSN prior to installing it in the servicing unit. This point cannot be overemphasized. Because of a similarity in packaging (one quart round cans) of MIL-C-47220 cooling fluid and MIL-L-7808 turbine engine lubricating oil, both products have been mistakenly used in place of each other. (See "Crew Chief Safety Award" on previous page.) Putting engine oil in the radar system or coolant fluid in the engine and/or an airframe mounted accessory drive is a costly mistake, with dangerous and potentially catastrophic results. Sad experience has proven that jet engines and accessory drives do not run well when "lubricated" by radar coolants and radar systems do not function well when "cooled" by engine oil. Store these two products in completely separate areas.
- Use only servicing equipment designed for the particular radar system being serviced. Make-shift bowsers or standard servicing equipment used for hydraulic, fuel, and engine lubricating systems cannot do the job properly.
- All servicing equipment must be clean. Servicing equipment and aircraft quick disconnects, couplings, caps, and servicing unit receptacle (particularly the receptacle piercer) must be free of moisture, dust, dirt, grime, lint, or any other particulate matter.
- Prior to installing the coolant container in the servicing unit, wipe off the container with a soft, dry, clean, lint-free cloth.
- Small cans of cooling fluids should be emptied completely after opening and any excess disposed of as noted below. Do not use fluid from a previously opened can.
- Because heat transfer fluids have a high coefficient of expansion when hot, a hot radar transmitter should be allowed to cool down for at least thirty minutes prior to final service. Servicing a hot transmitter will result in a low coolant state when the unit cools down. (An expanded discussion of this important servicing point is presented in the article on page 16.)

HEALTH AND SAFETY ASPECTS

Both Coolanol 25R and Flo-Cool 180 heat transfer fluids are classified by the U.S. Department of Transportation as non-hazardous materials. There are no restrictions to their transportation by air or other means, as long as they are in sealed containers. However, as with any other industrial chemical, standard safety practices should be followed when working with them. Eye protection and rubber gloves should be worn. Adequate ventilation should be provided in enclosed areas. Fluid spills should be contained and picked up by vacuum or absorbed onto clay or sawdust, which should then be incinerated. Do not dump, spill, rinse, or wash these fluids into sewers or public waterways.

These fluids are only slightly irritating to the eyes and skin (the eye irritation "score" in tests with rabbits was only 1.8 on a scale of zero to 110.0). If eye irritation does occur, it can be eliminated by flushing with large amounts of water. Prolonged or repeated contact with unprotected hands can remove natural oils from the skin and can result in chapped hands or "irritation dermatitis." This skin effect can be avoided by using nitrile gloves. If prolonged skin contact does occur, wash the contaminated area immediately with soap and water.

The vapor pressure of these fluids is quite low and usually presents no inhalation problem at room temperature. However, when working with the fluids at elevated temperatures or in areas with restricted ventilation a respirator should be used if a strong odor is detected or if irritation occurs.

The flash point of these fluids is 325°F and hot vapors from burning fluids may be harmful. Breathing apparatus should be worn during exposure to these vapors. Burning coolant is considered as a Class "B" fire, and should be extinguished with water spray, foam, dry chemical, or a carbon dioxide fire extinguisher.

It is important to repeat that Coolanol 25R and Flo-Cool 180 fluids as received from the manufacturer and stored in sealed containers will not present vapor inhalation problems during storage, transport, or actual use conditions in properly operated aircraft electronic equipment. (Your attention is invited to the article titled "Cargo Care is Critical," on page 17 which discusses a recent incident in this area of concern.)

Coolanol 25R and Flo-Cool 180 are products born of the space age. As a heat transfer medium they work well over a wide range of operating temperatures. However, it must be understood that with exposure to moisture or humid air and particulate contamination, both fluids deteriorate rapidly. The more they deteriorate, the less effective they become. A final point to keep in mind is that due to their chemical nature, these fluids begin to deteriorate the moment their container is opened and they are exposed to the atmosphere. Don't accelerate their deterioration by contamination.

ACKNOWLEDGEMENTS

Total amount of heat transfer fluid carried aboard the F-15 Eagle is 2.77 gallons, which weighs approximately 22 pounds. For the F/A-18 Hornet, the figures are 3.46 gallons, 26 pounds. How come – for something which takes up such a small amount of space and adds so little to the overall aircraft weight, we are asking you to read a six-page discussion about the stuff? Two reasons:

- A finely tuned and satisfactorily functioning radar system is vitally important to successful operation of both the Eagle and the Hornet. High quality, contamination-free radar liquid coolant is vitally important to successful operation of the radar system. Sort of like the old "for want of a nail" story, it isn't so much the size of our subject as it is its critical nature. In other words, the importance of radar coolant is far larger than its purely physical attributes.
- The more we looked into this subject of radar cooling fluids, the more questions were uncovered and points of confusion revealed. And the more this occurred, the more we realized that additional help and technical expertise were required. What started out to be a minor bit of editorial research into a couple pieces of tech data soon developed into a major investigation involving MCAIR engineering, safety, and materials specialists; product vendor representatives; and government specification experts. Therefore, much of the credit for the final scope and depth of the resulting discussion is due to the following people:

Department of Defense – George Morris, materials engineer at Wright-Patterson AFB, Ohio.

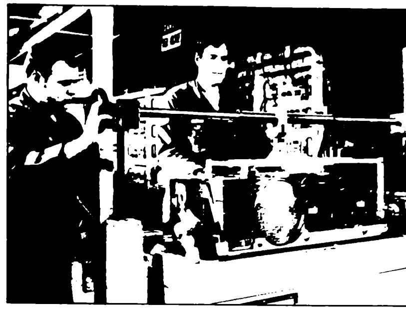
Monsanto Industrial Chemical Company – Dr. Craig Farr, toxicologist; Charles Farley, product acceptability manager; Anders Johnson, hydraulics and specialties business manager; David McCollum, senior research engineer; Ronald Zielinski, technical services manager.

Chevron International Oil Company – Mark Keller, aviation fuels and functional fluids manager; John Laurent, functional fluids manager; Frank Mandel, supply specialist.

Hughes Aircraft Company – Robert Harding, F-15 radar systems resident representative at MCAIR; Walter Lang, F-15 radar physical design program manager; Donald Smith, materials application department consultant.

McDonnell Aircraft Company – Frank Bruey, Bob Dickey, and John Simmons, technical support group engineers; Terry Bartels, laboratory unit chief; Mark Clay, design engineer; Bruce Dumont, lead electronics engineer; Marybeth Easley, laboratory engineer; Richard Evertowski and Robert Majesky, technical specialists; Wayne Matthews, field service engineer. ■

Effects of Temperature on Heat Transfer Fluids



BY BRUCE DUMONT/*Lead Electronics Engineer*

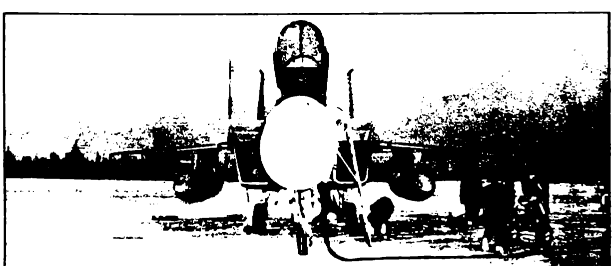
Both the F-15 and the F/A-18 contain coolant reservoirs that permit thermal expansion of coolant fluids under extreme temperature changes. Coolant reserve capacity includes enough volume for thermal expansion over a temperature range of −65° to +165°F, plus an additional reserve. On the F-15, this additional reserve is 15 cubic inches, to allow for minor leakage.

The radar transmitter in the F-15 provides a coolant volume capacity of 640 cubic inches. Coolant will expand (or contract) by approximately 7.3 cubic inches for every 20°F rise or fall in ambient temperature. For example, if an RFI (ready for installation) radar transmitter is removed from the AIS (Avionics Intermediate Shop) station, and the temperature at the aircraft is 40°F lower than at the AIS, the coolant in the transmitter will have contracted by approximately 15 cubic inches, enough to cause a partial vacuum and partially drain the coolant reservoir. Under these conditions, coolant system servicing will likely be necessary. When temperature differences are even greater, or transmitters are repeatedly changed, the coolant reserve becomes excessively over-taxed and servicing becomes even more critical.

In most situations such as described here, checkout of the radar system will result in a coolant low flow indication. This occurs because the flow sensor is located near the "RETURN" (exit) of the transmitter. Coolant flowing into a cold, partially evacuated, transmitter may take some time to fill all the voids. Flow will not exit until the transmitter is full and pressurized. This condition would be corrected by coolant servicing. Without servicing, the low flow condition will likely clear itself as the coolant warms and expands, temporarily allowing normal radar operation. However, the reservoir will not contain enough reserve to allow normal contraction when the system cools down again. This condition will likely cause repetitive low flow failures, and the failures will likely be mislabled as "BIT FALSE ALARMS."

Coolants should never be subjected to extremely high temperatures, even in storage. Due to temperature alone, coolants begin to degrade at temperatures above 400°F. Thermal expansion could cause containers to rupture and leak or to bleed through pressure relief valves in radar transmitters. Leaks in cans of new coolant will allow moisture contamination to enter, due to contraction of the fluid as it cools. Also, the "Open Cup" flash point in new fluid is 324°F but can be lower in used, degraded fluid. In unusual circumstances, this could become a hazard.

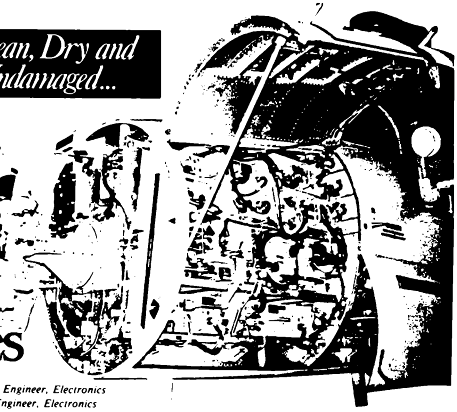
To conclude this brief analysis, let's look at an example scenario on the F-15. If a radar transmitter is removed from the AIS station after passing all tests, its coolant temperature is likely to be 120°F. Upon delivery to an aircraft parked on a ramp where the temperature is 30°F, there will be a coolant deficiency of approximately 33 cubic inches (approximately 0.15 gallons). When the transmitter is installed and the system checked, this volume will be filled by the reserve fluid in the aircraft. If the same cold aircraft had received a transmitter that had been subjected to a high temperature of 192°F during storage, the drain of the aircraft coolant would be doubled. In either case, the aircraft coolant would be deficient. Since the reservoir, heat exchanger, etc., have a total volume of approximately 155 cubic inches, repeated transmitter replacements under these conditions could effectively drain the entire aircraft reservoir. ■



Temperature effects on radar system heat transfer fluid vary greatly between "shirt sleeve" environment in shop testing of radar transmitter shown above and the "hooded parka" setting of the F-15 Eagle illustrated at left. Coolant will expand (or contract) by approximately 7.3 cubic inches for every 20°F rise or fall in ambient temperature.

Clean, Dry and Undamaged...

Radar
coax/triax cables & waveguides



By BRUCE DUMONT/*Lead Engineer, Electronics*
CHRIS LAFATA/*Senior Engineer, Electronics*
BOB STEVENS/*Senior Engineer, Logistics*

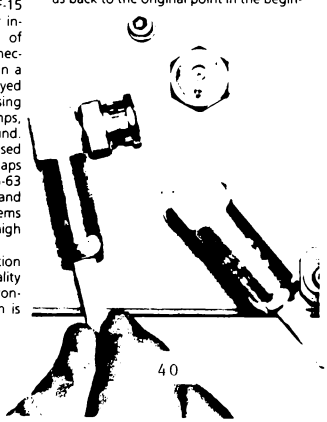
Whose maintenance job is most important to upkeep of a fighter aircraft? Yours, mine, his, or hers? Deciding might lead to an argument that would never end, so instead of deciding on one, we'd prefer to say that "everybody's" job is important, and look at a typical task for an example. How about the radar technician? Airborne electronics provides much of an aircraft's "intelligence," and the radar technician's job is very important to maintaining these avionics systems. Technicians in this field must work extensively with special RF (radio frequency) conductor materials known as coaxial and triaxial cables and with "waveguides" (special metal conduits for propagation of electromagnetic wave signals). What are some of the problems a radar tech faces with these special materials during day-to-day performance of his or her assignment?

Before a recent special exercise, MCAIR was asked to evaluate the condition of the radar hardware in some of the F-15 Eagles scheduled to participate. Our inspection revealed a surprising level of physical damage to coax/triax connectors/cables and waveguide sections in a majority of the aircraft. Broken or frayed shields, broken conductors, missing parts, cracked flexguides, bent clamps, and internal contamination were found. Conditions like these could have caused intermittent radar operations, perhaps even complete failure of the AN/APG-63 radar set. Fortunately, the inspection and associated repair corrected the problems and helped these Eagles attain very high scores during the exercise.

Our conclusion from this inspection was that the importance of high quality waveguides, coax/triax cables, and connectors to successful radar operation is not very well understood. The first, and probably most important, thing to understand is that these installations are *not* like ordinary signal wire harness assemblies used elsewhere in the aircraft. Coax/triax assemblies are by design not as mechanically strong as interconnect harness assemblies. They require special care and handling, whether you are working in comfortable conditions in the avionics shop or in the cold, rain, and dark out on the flight line.

Any avionics wiring with loose or intermittent connections or shields; or dirty, arced, pitted, or corroded waveguides will allow false data or signals – even during BIT (built-in test). BIT will use these signals and data (good or bad) in its fault isolation logic. With bad inputs, BIT will very likely isolate the fault to a good LRU (line replaceable unit). In order for BIT to assure accurate LRU fault isolation, all aircraft coax/triax connectors, cables, wiring, and waveguides must be carefully and properly maintained. Which brings us back to the original point in the beginning of this article – to offer some advice on problems experienced by radar technicians. And by the way – while we're talking here specifically about F-15 radar field operations, the checks and inspections described are in many cases applicable to other aircraft and avionic subsystems, so we hope you Hornet, Harrier, and Phantom radar techs will follow along with us also.

All of the radar set/indicator group maintenance manual procedures concerning installation and removal specify that coax/triax and electrical connectors and waveguides must be "clean, dry, and undamaged" prior to being connected. Inspections to insure this should be accomplished during the LRU removal sequence as well as prior to LRU installation. After LRU installation, all connections need a quick recheck for proper alignment. In amplification of the procedures in the technical manuals, there are several things the technician can do to detect and identify damage, and thus improve cable, connector, and waveguide maintenance and repair.



As with any other visual check, you've got to be able to see what it is you're looking for – sufficient light is required. Good flashlights or drop lights are very helpful. There are almost 30 coax/triax connector sets for F-15 radar LRU's and cables. Each connector is subject to some or all of the problems identified below. Any of these problems can be the cause of intermittent radar operation and must be corrected properly. What do we mean by *properly?* Taping the connector to the cable, for example, is not a fix for a frayed, loose, or broken shield – this might stiffen the joint superficially, but will only disguise the failure symptoms caused by the incomplete shield.

• All metallic contacts must be "shining" clean. Connectors with finger grease, dirt, metallic particles, or dust must be cleaned or repaired.

• Center pin must be straight and centered (sockets must also form a circle of tight contact for the pin). Many of the radar coax connectors are 90° "dogleg" types, allowing easy screw-on replacement of the contact end. Simple care must be taken to assure proper alignment of the center contact.

• Inner shield of triax must have a full circle of contacts.

• Outer shield of a cable must form a full circle of tight mechanical contact with the connector. Misunderstanding in this critical area is very common, and loose shields are suspected as one of the most frequent causes of intermittent radar operation. There is a simple method to visually check the integrity of a cable shield – *gently* try to twist the cable in the connector; any relative movement is an indication of a shield failure.

• Cables must not have any sharp bends, kinks, or deformations set into shield/dielectric casings. Any of these discrepancies can cause a variety of intermittent radar operational problems. All repairs must be tested for continuity and proper isolation of the conductors. Repairs involving shields should also be tested for proper SWR (standing wave ratio).

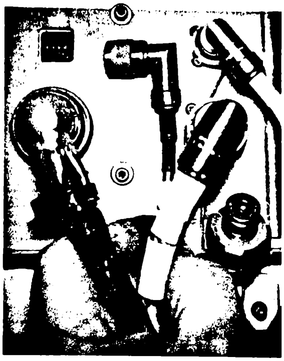
• Most coax/triax cables are assembled with enough length to allow two or three connector repairs. However, the radar IF cables (W52022 and W52002) have a special length tolerance and extra effort is required to maintain each length within 2.5 inches of the other. All cables must also be maintained with enough length to provide sufficient strain relief.

WAVEGUIDE VISUAL CHECKS

Since waveguides appear sturdy and therefore not prone to failure, they are often overlooked as the real cause of a radar problem. Therefore, a good radar technician will learn to look for several things during waveguide removal and installation.

• Before disconnecting a waveguide clamp, check that the waveguide is flush, properly aligned, and fits snuggly against its mate. Similar checks should be made after the waveguide is reconnected.

• After a waveguide is removed and the ends are open, inspect the interior of the wave channel. It must be clean and free of corrosion, black arcing residue, or other contamination. Any contamination could cause problems. Flexguides should be inspected for cracks, which will cause pressure loss, RF leakage, reflections, and arcing. Waveguide arcing causes degraded performance and/or destruction of components. After inspection, be sure ends are capped to keep them clean and dry until ready for reconnection.



• Waveguide sealing devices (preformed packing, gaskets, interface seals) must be only those authorized by the technical manuals, and must be free from nicks, cuts, or breaks. Unauthorized substitutions (red o-rings, cardboard cutouts, and similar strange items have been discovered) can only cause trouble – first in the inevitable pressure leaks and reflection problems they will cause, and second in ferreting them out because they were hidden in the system.

COAX TRIAX MATING

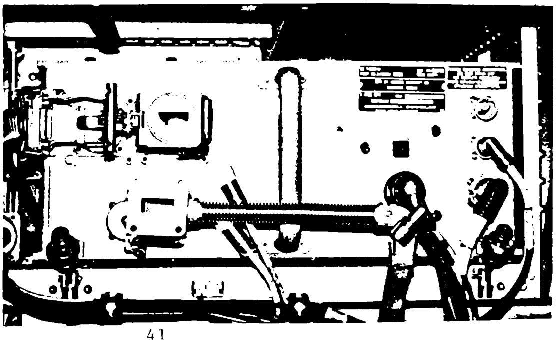
Coax/triax connectors are easier to connect and disconnect than all other aircraft wiring, but as with all connection devices there are some peculiar mating problems to be aware of. Handling coax/triax connectors with care will significantly reduce replacement maintenance and improve overall radar system performance. For example, if the center pin and socket are not properly aligned, the mismatch will usually cause enough resistance to be felt by an experienced technician. If this resistance is ignored and the connector is engaged anyway, connector damage could result in intermittent failures and subsequent repairs.

Keying baskets (used to assure each connector mates only with its correct receptacle) are secured with retaining rings. Before installing the LRU, the technician must visually check these rings, which must be below the end of the threads and tight around the receptacle body. Occasionally, these rings become spread and lodged in the threads of the receptacle. If the connector mates in this situation, the connector threads will jam on the ring, causing it to feel and look satisfactory, but it will not be properly engaged.

To wrap this up, we'd like to quote from a recent activity report by Ralph Day, MCAIR field service engineer with the 159th TFG of the Louisiana Air National Guard in New Orleans. They are flying high time F-15A/B aircraft, but even so, Ralph reports that "*. . . radar system operation continues to improve, primarily due to the concerted effort of radar shop maintenance personnel. One-by-one, each F-15 will have all of the coax and triax cables and connectors changed between each LRU. We have already done this on a few aircraft, and have seen a marked improvement in both system operation and troubleshooting time. We also continue inspection of all waveguides, and replace all that are pitted, corroded, or just "suspicious.' This process is time consuming, but it is really paying off. . . .*"

To us here in St. Louis, the key phrase in the rep's report is the "concerted effort of radar shop personnel." Well-trained, conscientious, and highly motivated technicians are required to bring out the best in the Eagle radar system. It's happening down in Louisiana – how about where you are? ■

Smaller photographs on these two pages show typical coax/triax cables and connectors and waveguide installations in the F-15 radar system pictured at top of opposite page. Importance of careful handling practices and skilled maintenance techniques are obvious from the densely packed components and amount of wiring in avionics compartments. Good communications between flightline and AIS personnel are also required.

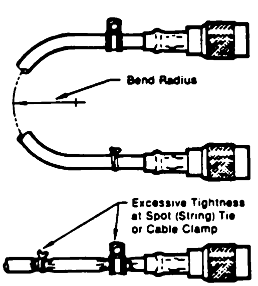


Coaxial/Triaxial Cable Maintenance

Sometimes even the simplest of aircraft maintenance procedures can cause a lot of frustration – particularly when working in tight places. The coax/triax cables used on the MCAIR F-4, F-15, F/A-18, and AV-8 are no exception, especially when securing these cables with clamps and string ties. Ordinarily a routine task, incorrect handling and installation techniques can result in improper bend radii, twisted and kinked cables, insufficient rain drip loops, and overly tight string ties and clamps. The shield of the cable can then be forced into the conductor, resulting in degraded system operation. To help you avoid these maintenance problems, here are some helpful tips on coax/triax cable clamping and spot (string) tieing procedures.

Clamping is usually not a difficult job; however, there are some basic techniques to keep in mind:

- When installing a clamp (after making sure you're using one that is approved), take care it does not compress or pinch the insulation on the cable. If this is about to occur, stop right then and install the next larger size clamp. Clamps with a rubber insert must be snugged up just enough to prevent the cable from being pulled through the clamp. In applications calling for clamps with a nylon insert, a small amount of slippage can be expected (less friction from nylon than rubber) and is permissible.
- During clamping, always maintain sufficient slack in the cable to allow for a proper bend radius or drip loop. When a bend is made after coming through a clamp or bulkhead opening, the bend radius must be a minimum of six times the diameter of the cable. If the bend radius is not observed, the cable will indent when pulled taut, resulting in internal damage. Make sure each drip loop is oriented toward the bottom of the aircraft to prevent water intrusion into the connector.



- Component installation/removal "envelopes" should be strictly observed during clamping of a new cable. A trial-fit check prior to completion of all clamping will ensure that components can be installed and removed without exceeding the bend radius.

String ties can be an effective preventive maintenance tool when working with numerous wire bundles and cables. When several cables are routed through the same area, string ties aid in cable retention and reduce the mechanical strain on cables within a bundle. They also help prevent chafing (frictional contact) between the cables and components or aircraft structure. However, as with improper clamping techniques, poor spot tieing procedures can create havoc with systems you are maintaining.

- A string tie should be snug but never excessively tight. Any time the outer surface of the cable begins to deform (crush), the string is too tight.
- String ties should never be used as a primary support or device to attach the cables to the aircraft structure. They can not support the cable correctly and will create a high stress area, eventually cutting into the cable.
- When string ties must be removed, always use caution to prevent a hidden break in the cable insulation. Sharp tools (such as pocket knives) are very likely to cause this type of damage to the cable. Diagonal wire cutters should be used for removal of ties. ■

F-15 Pitot Static Tubes

Q ***In their desire to have a nice looking aircraft, some of our crew chiefs have started a practice which does not appear to me to be very good. They are sanding and polishing the 68A815754 pitot static tube. The tubes polish up to a nice shine and look very nice, but I feel this is not a good practice, although I have not been able to find anything about it in the T.O.s. How does MCAIR feel about this practice?***

A In a word – "S-T-O-P"! Both MCAIR engineering and the manufacturer of these tubes strongly disapprove of the practice of sanding and polishing them. Pitot static tubes are machined to extreme accuracies for the particular aircraft and position on the aircraft, and it is very important to maintain that specific profile.

Contamination from the sanding and polishing process is very likely, with dust, grit, and who knows what else filling the static ports and drain holes in the tubes. Tube material properties are such that polishing and sanding will have an adverse impact, and the polished surface would tend to change dimensions as the probe heater raises the temperature of the tube.

Finally, and if the above reasons are not sufficient, all warranties on the tubes are negated if changes such as these are performed. So once again, tell your well-meaning but misguided crew chiefs to "S-T-O-P"!

(Dale Cattoor
Technical Specialist – Avionics Group)

F-15 ELECTRONIC FLIGHT CONTROLS
Roger L. Smith
18 TFW, Kadena AB, Japan

Two CAS (control augmentation system) problems caused many hours of work this month. In the first one, aircraft 78-565 flew numerous missions with pitch and roll CAS falling off line repeatedly. After each flight, FLTS (flight line test set) checks failed to indicate any problem. Actuator resistance checks were performed and numerous LRUs were changed out.

The aircraft was finally impounded, and after a complete check-out still revealed no obvious problems, we decided to let our FCF pilot fly with a checklist to aid in maintenance. The pilot performed many maneuvers, but reported no subsequent CAS failures. Then, on final approach as soon as the gear was extended, CAS dropped off. The pilot then went around, and took the aircraft back out for some more experimentation. With the gear retracted, CAS would never fail. With the gear extended and CAS off line, he was only able to reset CAS with pitch ratio in emergency.

After the aircraft was in the shop, the PTC (pitch trim controller) was swapped and the gear handle logic was checked out. No further problems have been reported to date.

The second CAS problem proved a little less obvious. On aircraft 78-564, the pilot reported that he was "slammed" into the canopy on a right roll because of an apparent uncommanded degree of roll or an increase in stick authority. Again, the aircraft FLTS checked good. All LRUs were removed and sent to AIS, where the rate gyro package checked out bad.

On the subsequent FCF, the pilot reported no sign of increased stick authority or uncommanded inputs. However, it was noted that at high angles of attack this particular aircraft has a tendency to roll to the right at a much higher rate than normal. The rig checks (ground and in-flight) indicate that the rigging is good. The aircraft has been released and has subsequently flown with no further flight control problems.

F-15 RADAR FIRE CONTROL SYSTEM
Thomas E. Folkner
36 TFW, Bitburg AB, Germany

The new radar and central computer OFPs (operational flight programs) were finally in place this month so that incorporation of the update TCTO could commence. The normal procedure here is to load two aircraft and fly them before loading the rest of the fleet. This lets us determine if there is a problem with the new tape that would affect combat capabilities of the aircraft. The only problem that appeared was an apparent inability to lock on in the new slewable supersearch scan pattern. The radar would lock on with no problem in the normal (old) pattern, but only intermittently and after long delays when "nodded" to its upper and lower positions in the new pattern.

A query to St. Louis provided an answer to our problem. Both the pilot and I had overlooked the scan centers for these modes. The pilot was placing the targets in the area above the combining glass and below the canopy bow, while the actual scan volume is above the canopy bow, centered at +34°. The lower scan volume is centered at -19°, which results in most of the scan volume being obscured by the nose of the aircraft. The elevation scan limits are approximately 20° about those centers; and to asssure lockon after slewing up or down, the pilot needs to be sure the target is within the scan pattern limits.

Once we understood this, the system worked with no faults and permission was given to load the rest of the aircraft. Over 20 aircraft have been loaded so far with no problems. ■

F-15 UHF/VHF COMMUNICATIONS
Donald J. Brooks
18 TFW, Kadena AB, Japan

One of our aircraft has had a history of intermittently weak reception and transmission on the No. 1 radio. Technicians here were of the opinion that during the modification for TCTO 1F-15-857, several wires were run improperly. After operational checks of the system, it was determined that the radio worked correctly with the upper antenna selected but that reception was weak and garbled in the lower position.

Technicians assured me that the antenna and cable "ohmed good" with a meter so the "antenna and coax were correctly installed." However, this check only tests for continuity between LRUs, not for transmission losses. The lower No. 1 antenna was removed, and we found that the coax cable had been spliced by separating the shield and inner conductor and crimping the ends together. This would be satisfactory for a DC voltage, but it just doesn't work for RF energy. At this point, several demonstrations of power loss were made (holding a small neon light near the antenna), but our technicians already had the message

F-15 AVIONICS INTERMEDIATE SHOP
Larry P. Baugher
116 TFW, Dobbins AFB, Georgia

Our AIS was located in an "Agile Aerie" (portable) building located 105 feet from a "hush house." This did not present a problem at first, because the hush house was not being used much. However, they recently started running engines several hours a day, and we started to notice unusual problems with our stations.

We began to have numerous wiring problems, transistors vibrated out of plug-in sockets, circuit boards were coming loose, etc. (The vibration was so bad that the clock on the wall literally did a dance when they ran engines in afterburner!) Looking in the facilities manual, we were able to find no minimum distance figures between AIS and engine test facilities. However, the book did say that compressors, air handlers, and other vibration-generating equipment should be shock-mounted so as not to transmit vibrations into the building. From this, it was obvious that we were experiencing vibrations from these engine runs far beyond any acceptable limits.

We contacted facilities specialists in St. Louis and got the opinion that an AIS located in an Agile Aerie should be no closer than 2500 feet from a hush house! They also recommended that no engines be run until all AIS stations and equipment could be moved, to prevent further damage. New F-15 bases should give consideration to our experience when locating AIS-type test facilities.

F-15 Overload Warning System

Q ***We are experiencing occasional overloads in the mass items (MIT), with most overloads ranging from 9.1 to 10.2 G and 101 to 113 percent. We believe the MIT overloads are valid. Most of the MIT overloads are the only ones listed in the OWS matrix – there are no accompanying overloads in any other area. For example, last week we had an aircraft with 9.9 G, 110 percent, severity code 2. All other areas were severity code zero.***

We have been asked how there could be a severity code of two on the MIT, and not have at least a code one on the wings. Should not wing overloads accompany MIT overloads?

A The mass items are limited at 9.0 G for a severity code of 1.0. Aircraft loading is the only factor that will impact mass items. However, a fuselage overload may also exist under certain conditions. MIT overloads do not relate to wing overloads because other factors impact the wing computational algorithms.

This might be a good time to present some additional information on certain characteristics of OWS operation and the resulting data displayed on the VSD (vertical situation display). Two areas of confusion on the VSD seem to be the ACC (acceleration) column and the OVL (percent design limit load or warning ratio) column.

The numbers in the ACC column indicate the G loading experienced by the aircraft at the warning ratio number displayed in the OVL column. The G loading and/or warning ratio are based on combinations of variables such as mach number, altitude, gross weight, aircraft configuration, profile parameters, attitude rate inputs, aerodynamic effects, etc. As the variables change, the resulting VSD output data could also change. For instance, at 10,000 feet altitude, a specific aircraft configuration, gross weight, mach, etc., will provide a certain G load or warning ratio. At a different altitude, the same other conditions would result in a different G load or warning ratio. This is the basic principle behind an overload warning system.

As an example, the wing is designed for 7.33 G at a mach number of 1.05, an altitude of 20,000 feet, with an aircraft weight of 37,400 pounds. If load factor or weight is reduced or the mach number or altitude change, wing load will be less than the design value of 100 percent. Also, a lateral stick input will reduce the allowable load factor. Conversely, if the mach number and/or altitude change but the weight stays at 37,400 pounds, the load factor could be raised above 7.33 G before 100 percent wing load would be achieved. In fact, in some mach/altitude/weight combinations, the allowable load factor could be greater than 9.0 before 100 percent wing design limit load is reached. This same basic principle is used for all components of the aircraft except the mass items, as noted above.

The prime function of the F-15 OWS is to allow the pilot to maneuver his aircraft at its maximum operational capability without subjecting it to structural damage. To determine OWS operational integrity, primary emphasis should be placed on the severity codes and the warning ratios of the OVL column. Information there will provide sufficient data to determine maintenance actions or specific inspections required.

(Dale Cattoor
Technical Specialist – Avionics Group)

F-15 Radar LRU Operating Temperatures

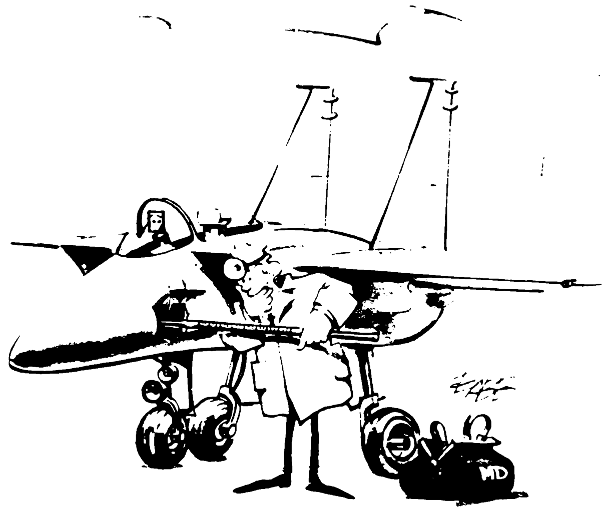
Deficiency analysis personnel here are interested in trying to correlate what seems to be improved radar system operation following the replacement of secondary heat exchangers. Is there any data to substantiate their opinions? Also, can you provide the optimum operating temperatures for the head-up display unit and the central computer?

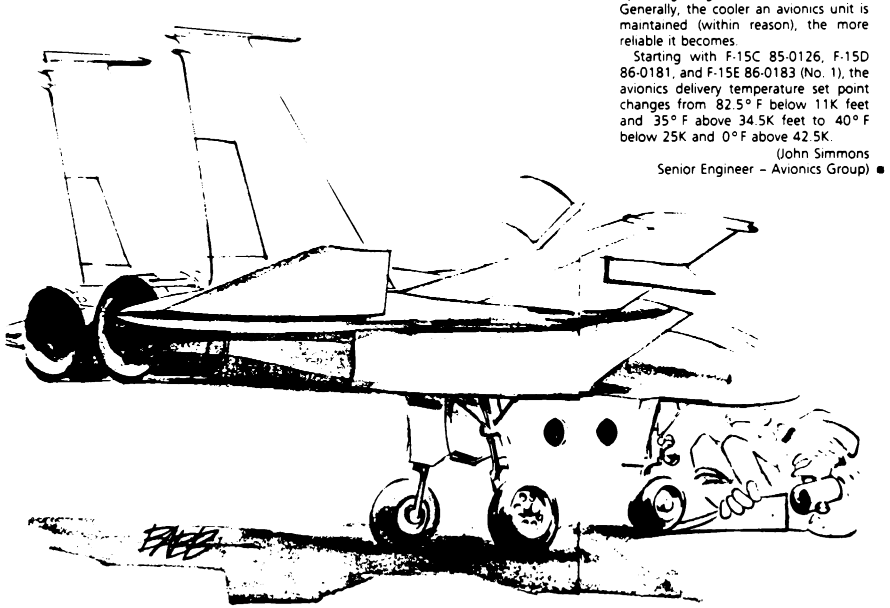
There is no data available relating only to improved radar system operation following replacement of the secondary heat exchanger. However, replacing a defective exchanger would certainly improve radar system reliability along with all other avionics systems, since the exchanger supplies cooling air to all avionics units requiring it.

There has never been an optimum operating temperature established for these units since they are designed to operate over the full military temperature range in accordance with MIL-E-5400, para 3.2.5. The CC requires cooling air but the HUD unit does not. The critical area for units requiring cooling air is the ability of the ECS to maintain the proper flow rate/temperature within the various operating ranges of the avionics units. Generally, the cooler an avionics unit is maintained (within reason), the more reliable it becomes.

Starting with F-15C 85-0126, F-15D 86-0181, and F-15E 86-0183 (No. 1), the avionics delivery temperature set point changes from 82.5° F below 11K feet and 35° F above 34.5K feet to 40° F below 25K and 0° F above 42.5K.

(John Simmons
Senior Engineer – Avionics Group) ■





F-15 Inertial Navigation Set

Q ***An Air Guard squadron is scheduled to transition into the F-15 shortly, and the OPS and maintenance people are devouring every piece of F-15 literature they can lay hands upon. In one of the MCAIR "EAGLE TALKS" (DIGEST reprints) that has been provided to the squadron for planning purposes, there was an article about the INS (Inertial Navigation Set), in which the following statement was made "...IMU (Inertial Measurement Unit) alignment requires the aircraft to be parked in a relatively level area during the alignment period..."***

The words "relatively level area" bother the ANG technicians. As they point out, everything is "relative," and they would like to see some specific numbers for use when they get into the full-time Eagle flying business. They ask what is the maximum amount of "pitch" (fore-and-aft slope or grade) permissible in the parking area where aircraft INS alignment is conducted.

A A very good question, and one which reminds us that we always need to be as specific as possible when discussing design and operational details of fighter aircraft. Words or statements that seem perfectly clear to a sender may not always be so to a receiver. Therefore, our Avionics Integration & Mission Systems Department (Ralph E. Herndon, Unit Chief, Electronics, and Carmon D. Thiems, Lead Engineer, Electronics) has provided the numbers requested. Actually, the basic data was generated several years ago, but in the context of a "roll" (side-to-side slope or grade) aspect. However, the roll and pitch allowable ground slope figures are the same, so we are able to give you even more information than asked for! In the data below, the maximum permissible degrees "off-level" (height differential) between the main landing gear wheels for roll also apply between the main landing gear wheels and nose landing gear wheels for pitch.

The original situation developed back in 1981, when a problem was identified wherein the INS IMU would not align when the unit had an initial roll of two degrees or more. As a result of this problem, MCAIR and the unit vendor (Litton Systems, Inc.) determined the limits of operation which could be expected. The allowable initial roll/pitch is related to the time the IMU remains in the coarse level mode.

With early versions of the IMU (683420-23 and -24), the time in the coarse level mode was temperature-related. At low temperatures, these units had a short coarse level profile and would not align if rolled or pitched above approximately three degrees. If the unit was hot, alignment could be accomplished with roll or pitch up to approximately ten degrees. The three degree roll translates to a 5.7 inch maximum permissible off-level (height differential) between the main gear wheels. The three degree pitch translates to an 11.1 inch maximum permissible off-level between the main gear and the nose gear.

With the 683420-25 IMU, which was modified to provide rapid align mode, the coarse level mode was a fixed time and independent of temperature. This version will not align with an initial roll or pitch of approximately four degrees or more. The four degree roll translates to a 7.4 inch maximum permissible off-level between the main gear wheels. The four degree pitch translates to a 14.8 inch permissible off-level between the main gear and nose gear.

In conclusion, it should be noted that the originally reported alignment problem at two degrees of roll could not be duplicated in our tests with any of the IMU versions. However, MCAIR did verify the condition at three degrees of roll – a condition verified in analysis by Litton.

By GLYN BOWEN
Senior Engineer – Avionics Group

Note: This Air National Guard unit will be receiving A and B versions of the F-15, transferred from an active Air Force squadron. The USAF INS depot has been upgrading the INS from the 683420-23 and -24 IMU to the 683420-25 in a program which is currently about 80% complete. Although there are still some -23 and -24 units in the field, it is most likely that the -25 will be installed by the time this ANG unit receives its aircraft, thus reflecting the four degree roll and pitch figures discussed above.

The F-15E, which is scheduled to begin arriving in the field in early-1988, contains an entirely new and different inertial navigation set. The INS in the E model contains a fully automatic Ring Laser Gyro (RLG) system. The RLG is a rate-integrating gyro which does not use a "spinning mass" like the conventional gyroscopes contained in the IMU in earlier Eagles, and is less susceptible to the off-level conditions of earlier Eagles, and is less susceptible to the off-level conditions analyzed in this article. RLG system specification is for operation with a 10 degree off-level (pitch 37.3 inches and roll 19 inches).

The F-15E RLG INS has also been designed for installation into the F-15A/B/C/D aircraft, simply by unbolting and removing the 683420 unit and battery and bolting in the RLG INS and battery. The NCI display will be a little different during align, but otherwise the RLG INS will operate the same as the 683420. USAF has initiated a plan to accomplish this backfit. Details on the RLG INS will be provided in a future article in the DIGEST. ■

METS - Evolved for Air Force use with the F-15E avionics intermediate shop from earlier McDonnell Douglas EETS development for the Marine Corps. Lighter in weight, a smaller cube, and more reliable than the replaced stations, METS will join the USAF in 1988.

- 1980's Technology
  - Microprocessors
  - Bubble Memory
  - Interactive Plasma Display
  - Modular Calibration Standards
- Short Test Times
- Smaller/Lighter Weight
  - Each Unit 20.5" x 14" x 22.5", 152 lb Max
- Higher Reliability
- Ease of Operation and Maintenance

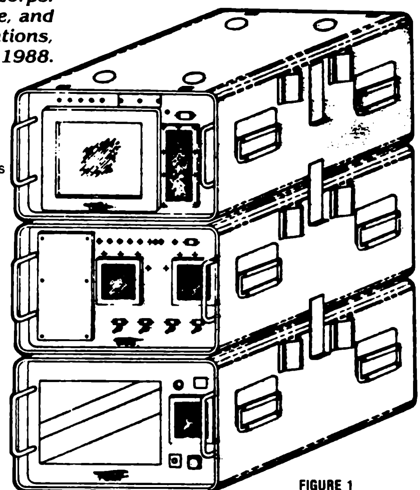


FIGURE 1
F-15E MOBILE ELECTRONIC TEST SET (METS)

F-15E Supportability Leaps Ahead with METS

By WILSON D. YATES III/*Lead Engineer, Reliability*

The Mobile Electronic Test Set (METS) is a revolutionary new approach to F-15 avionics intermediate shop (AIS) automatic test equipment. In a typical F-15 wing there are three sets of automated test equipment and two sets of manual test equipment. Each of these two types of equipment contains three stations. Two of the new man-portable METS will replace three automated F-15 Computer Test Stations and two manual F15 CNI Test Stations at more than triple the hardware reliability of existing AIS test stations. This is accomplished by a combination of utilizing state-of-the-art technology and incorporating a change in testing philosophy.

The F-15 AIS Today

Existing AIS test stations were designed to utilize primarily "parametric" testing. This type of testing philosophy was originally required because the line replaceable units (LRU), which were to be tested, had been designed with very limited or no built-in-test (BIT) capability. Many initial F-15 LRUs were of the 1950s and early 1960s technology and contained virtually no BIT. Newly developed LRUs had some limited BIT capabilities, but at this early stage of development, BIT was still an emerging technology. The F-15 AIS test stations needed to test these LRUs evolved from later 1960's technology, and at the time they were developed were advanced state-of-the art test stations. The internal architecture of the test station was designed based upon the testability requirements of the LRUs it would be supporting.

With "parametric" testing, appropriate signals are applied systematically and measurements are made at many points throughout the unit under test (UUT). These measurements are individually evaluated to determine if out of tolerance conditions exist. Normally, each step in the testing sequence is dependent upon the previous steps. In this manner, malfunctions can be isolated to specific small groups of parts on a circuit card. This type of testing is very precise, but slow, with several hours required to fault isolate being commonplace.

The "parametric" testing philosophy ignores any self-test capability the UUT might have. For this reason, the test station must provide all the stimuli required for testing each UUT, and the testing must start at the beginning and proceed end-to-end. This approach might be compared to a doctor who automatically schedules an expensive, thorough series of lab tests for each patient without asking the patient what's wrong or where does it hurt.

After fault isolation, the test station notifies the operator of the malfunction and directs him/her to change a suspected faulty circuit card. The testing sequence must then be repeated to ensure that the repair was successful. UUT repair at the intermediate maintenance level is normally limited to removal and replacement of circuit cards, which are then sent to the depot facility for repair.

LRU Advances

LRU technology has dramatically changed since the development and fielding of the first F-15 aircraft. Testability of each succeeding generation LRU has increased. LRUs are now compartmentalized with functionally isolated circuitry. BIT has been greatly improved, both from a reliability and a capability standpoint. Because of the advances in LRU testability, the intermediate level testing philosophy has been shifted from one dependent on primarily "parametric" to one of primarily "functional."

The internal AIS test station architecture, however, has prevented significant advances in AIS testing capabilities. The advent of the microprocessor and evolution of small, inexpensive peripheral devices, such as rigid disk drives, have been heralded as the major advances needed to produce a leap forward in testing capabilities.

METS Technology

The METS is a new, man-portable "test station" which takes advantage of the new technologies (Figure 1). New internal architecture now allows multiprocessing which means the METS can perform several testing sequences at the same time. Also, with the advances in the testability of LRUs, the METS testing philosophy is different from the equipment it replaces.

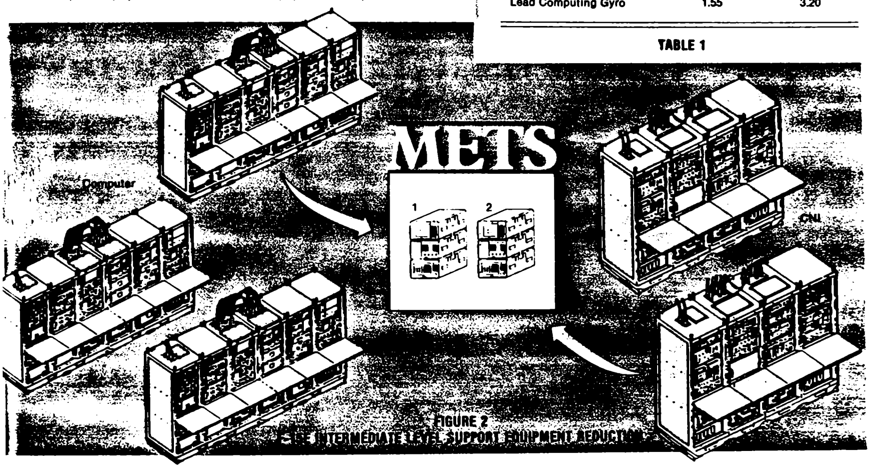


FIGURE 2
F-15E INTERMEDIATE LEVEL SUPPORT EQUIPMENT REDUCTION

The extensive BIT capability of each UUT is utilized by METS to assist in the fault isolation. A "functional" testing philosophy is used which greatly reduces fault isolation times in comparison to existing AIS test stations utilizing the "parametric" testing philosophy. With "functional" testing, several input stimuli for a total UUT function are applied simultaneously. The resulting output is monitored by functionally equivalent aircraft circuits located in the METS. If the output is correct, the total circuitry between the input and output is considered as functioning properly.

Fewer measurements are necessary, thereby speeding up test and fault isolation times. Table 1 provides a comparison of the testing times between METS and AIS for selected UUTs. After repairs are complete, a retest of the affected circuitry is required to ensure success of the repair action. As before, the defective circuit cards are sent to the depot facility for repair.

METS – Mobile and Compact

METS is much smaller than conventional test stations. Figure 2 shows a physical comparison of METS to the equipment it replaces. This directly impacts mobility. A complete wing METS system to support 26 F-15E LRUs can be packed onto one standard mobility pallet, with room left over. There are many benefits from this downsizing of the support equipment. There is less teardown, packaging, and setup time for deployment, thus the METS will be ready to test UUTs in much less time than the equipment it replaces. In addition, there is less need for spares and support equipment for METS itself. An F-15E AIS with the current METS will require two less C-141B loads than an equivalent F-15C/D conventional Wing AIS which can require from 6 to 8 aircraft. A direct increase in F-15 supportability is the result.

UUT	METS Test Times (Hours)	AIS Test Times (Hours)
Engine Monitor Display	1.10	4.30
Flight Control Computer	2.15	7.80
Intercom Set Control Panel	1.30	5.80
Lead Computing Gyro	1.55	3.20

TABLE 1

AIS Of The Future

METS will reduce the support equipment required for the F-15 community. In early 1988, when this equipment is fielded, a revolution in intermediate level support equipment will have begun. Sometime in the future, a complete AIS may be mobilized and transported on a single C-141B, with room to spare. ■

"Small and two-man portable, the METS contrasts sharply with AIS stations, which must be moved by forklift. Furthermore, METS is five times more reliable, processes broken systems six times faster, and doesn't require stringent environmental controls. As a result, better support is provided by more mobile equipment."

—BGen FRANK S. GOODELL, USAF, Air Force Magazine, October 1987

product support digest

VOLUME 32 NUMBER 2 1985

Cover photographs: (front) Before the F/A-18 can be put in this spectacular position, it needs to "get off the ground," as discussed on page 6. Picture by MCAIR photographer Bob Williams. (back) Sgt Jacquelyn Banks, storage and issue specialist, at work in supply warehouse of 32nd TFS, Camp New Amsterdam, The Netherlands. USAF photo by SSgt Clyde Bird; courtesy of "THE INTERCEPTOR" base newspaper.

PAUL T. HOMSHER/Vice President, Product Support Division; HERMAN J. CORREALE/Director, Product Support Operations; THOMAS L. PLEIN/Director, Product Services.

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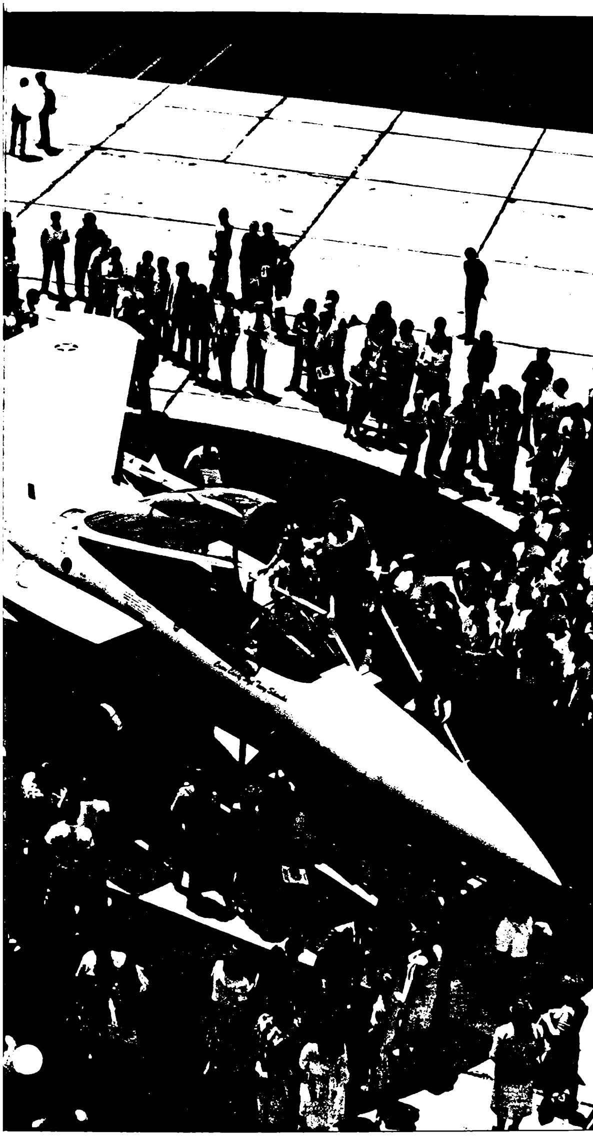


MSIP EAGLE
"our part of the bargain"

The F-15 Eagle has proven to be the finest air superiority fighter aircraft ever built. It was designed in the 1960's, first flew in mid-1972, and became operational in late 1974. In U.S. Air Force service through August of this year, it had accumulated almost one million one hundred thousand flight hours and a loss rate of 3.6 (aircraft per 100,000 flight hours). The Eagle is, by these numbers, the safest fighter ever flown by the Air Force. It is undefeated in actual aerial combat, by a fifty-eight to zero margin. An Eagle can operate with loads aboard that add up to more than its own (unloaded) weight. It has accomplished every task and successfully carried every tank, store, or load assigned by the mission planners. What more could be asked of this airplane? According to the military/industrial team responsible for the weapon system, more. . . much more.

Exactly how much more was demonstrated for 2,000 guests assembled in the MCAIR Flight Test hangar in St. Louis on 20 June 1985 for the unveiling of F-15 aircraft serial number 84-001, a "D" model and the first to be produced in the Multi-Stage Improvement Program. "MSIP" is the latest phase in a continuing plan to keep the Eagle ahead of whatever threats may evolve in the future.

"If you do not think about the future, you cannot have one." Sanford N. McDonnell, Chairman and Chief Executive Officer of McDonnell Douglas Corporation, used this quotation by John Galsworthy, English novelist and playwright, to open his remarks at the largest rollout ceremony ever staged by

Sanford N. McDonnell

General Robert D. Russ

LtGen Thomas H. McMullen

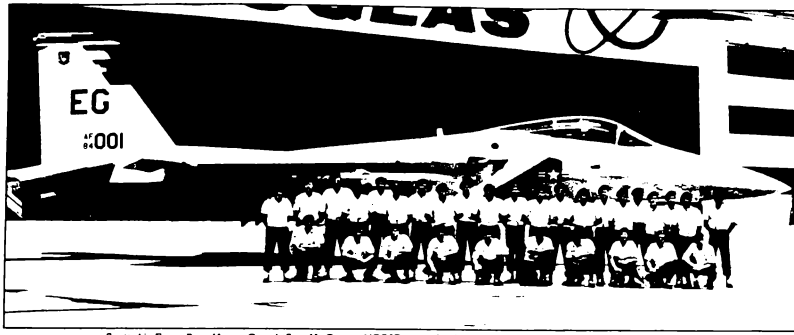
the corporation. In taking his listeners back more than sixteen years ago, Mr. McDonnell noted that "the Eagle has always had a future because the U.S. Air Force and McDonnell Douglas team has always had the future in mind." Many of the people in his audience, which included representatives of government, military, and industrial organizations, had been participants in the F-15 program from the very beginning. They were reminded of the remarkable history behind the Free World's top fighter and were provided a glance into the future, in the form of the F-15C/D MSIP and the F-15E dual role fighter (which is scheduled for first flight in December 1986).

"Thinking about the future" was the overall theme of the rollout ceremonies. And the Air Force, because of MSIP, can look ahead to the 1990's and beyond with assurance that it has an air superiority fighter aircraft with greatly enhanced combat capabilities. After being introduced to the audience by Don Malvern, MCAIR president and master of ceremonies, Air Force Lieutenant General Thomas H. McMullen, Aeronautical Systems Division commander, remarked that "General MacArthur once characterized the common element in all military failures as being 'too late' — that is, 'too late' in recognizing a developing threat and 'too late' in doing something about it. The F-15 developed under MSIP is a calculated step forward to ensure that the 'too late' trapdoor doesn't get sprung in the tactical arena. MSIP will add the precious gift of increased capability and survivability for the F-15 as we move into the 1990's. It will allow us to compete more effectively if we are called upon to fight."

On hand to accept the MSIP Eagle on behalf of the Tactical Air Command was its new commander, General Robert D. Russ. From its inception, General Russ has been a major participant in the program to improve the F-15 in carefully planned multiple stages. From past positions in the Air Force, he watched the program grow, nurtured it in the Pentagon, and justified its cost to various committees and conferences on Capitol Hill. In accepting the aircraft, the general noted that he had now come "full circle" with the program and emphasized his pride in being part of a team effort — a team of military turning out quality pilots and a team of civilians turning out quality aircraft. In conclusion, he put a challenge to the men and women of MCAIR to "hold up their end of the defense bargain" by continuing to provide the Air Force with quality products.

After the general's remarks, the hangar doors were raised to reveal the real star of the show and guest of honor — the first production MSIP Eagle. Parked quietly on the flight ramp and resting on a large blue and white armed forces rondel carpet, USAF 84-001 looked externally just like its predecessors and contemporaries. However, MSIP advanced internal systems now provide USAF pilots greatly enhanced ability to manage air battles without any increase in cockpit workload. Many manufacturers, including Pratt & Whitney, Hughes, IBM Federal Systems Division, Dynamic Controls, Magnavox, Tracor, Northrop, Loral,

Air Force Band of Mid-America (Major Roger Sebby, Commander) from Scott AFB, Illinois entertained at F-15 MSIP rollout ceremony.



Scott Air Force Base Honor Guard (Sgt. H. Carter, NCOIC) posted colors to open ceremony staged at MCAIR, St. Louis.

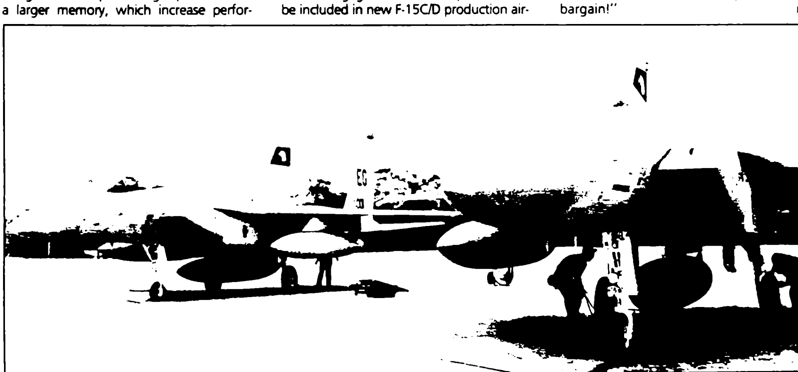
and Sperry Corporation, have been senior members of the MSIP team with major responsibilities for these internal improvements.

A programmable armament control system includes a five-inch color TV screen surrounded by buttons with which to select and arm various weapons. This new system will accommodate advanced versions of the AIM-7M, AIM-9M, and the new AIM-120 AMRAAM (advanced medium range air-to-missile). The screen can also be used to display command and control information from the Joint Tactical Information Distribution System (JTIDS). A new central computer stores four times more information, processes data three times faster, and is 20 percent more reliable than the old computer. The APG-70 radar has greater data processing capabilities and a larger memory, which increase performance and improve reliability. New F100-220 turbofan engines incorporate a number of modifications which will also improve reliability and performance.

Air superiority and rapid deployment capabilities have been basic characteristics of the F-15 since its inception. MSIP Eagles build upon these capabilities and add staged improvements designed to maintain superiority over increasingly sophisticated threat aircraft such as the Mig-29 Fulcrum, Su-27 Flanker, and Mig-31 Foxhound, as well as newly developing cruise missiles and low earth orbiting satellites. Conformal fuel tanks (with tangential air-to-ground weapons carriage) now add a new dimension for utilization of the Eagle in long range rapid deployment missions, thus creating tactical advantages to complement its short-range weapons and agility in close-in engagements. MSIP capabilities will be included in new F-15C/D production aircraft over the next three fiscal years, will be selectively retrofitted into earlier model F-15A/B and F-15C/D's, and will become the foundation for the next generation of Eagles — the F-15E dual role fighter.

Initial MSIP aircraft are being assigned to the 60th Tactical Fighter Squadron of the 33rd Tactical Fighter Wing at Eglin AFB, Florida. After the "Fighting Crows" are fully equipped, the wing's two other squadrons, the 58th and 59th, will be assigned MSIP Eagles. Upon arrival of the first two new F-15's at Eglin, Colonel George J. Foster, commander of the 33rd TFW, remarked that "the improvements incorporated in these aircraft have ensured that the Eagle will remain the most capable all-weather air superiority fighter in the world for many years to come."

Agreed. For all of us at MCAIR, that was our intention — "our part of the bargain!" ■


F-15's 84-001 and 84-002, first two MSIP Eagles, are chocked after arrival at Eglin AFB, Florida, "ready for business." (Photo by Ken Moyer, Dynalectron.)

F-15 Electrical Generator Malfunction

Q ***The left IDG (integrated drive generator) on one of our F-15s has been dropping off the line when the right engine is shut down. This has occurred both during taxi and inflight, and recently has changed from an intermittent condition to a hard failure. Maintenance has repaired damaged wiring on the CSD (constant speed drive) speed sensing line and receptacle, tightened the B1 terminal on the left line contactor, and checked all wiring between the GCU (generator control unit) and left IDG for opens and shorts. We verified by using a Megger meter that all wiring is correct from current transformer to GCU - wire to wire as well as to ground. No problems can be found, and we have exhausted all of our technical procedures. Can you give us some ideas?***

A From the information available, it is possible that the discrepancy is being caused by an over-voltage condition or by a problem in the current differential protection circuit. Since the IDG is dropping off the line very quickly, Engineeering suggests looking at the latter possibility first. Jumper small u and small p on the aircraft wire bundle side of the connector to the GCU. Install a switch in the jumper to permit bringing the protection circuit in and out of the system during engine operation. If the system operates normally with the circuit jumpered out, your problem is isolated to that area, and it will be a matter of tracking down the bad wiring. Since the system operation is marginal when your problem occurs, use of the jumper is safe and this check will have no adverse impact. Make sure that the jumper wires are insulated when installed.

By DALE CATTOOR
Technical Specialist – Avionics Group

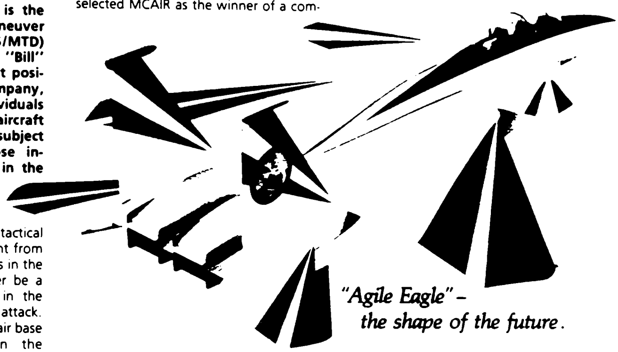
Note: The squadron performed the jumper procedure recommended, with results as predicted by MCAIR Engineering. With both engines running and the protection circuit jumpered out, system operation was normal. As soon as the protection circuit was switched back in, the left IDG immediately dropped off the line. The problem was then traced to somewhere in wires X25C22, X26C22, X27C22, and X28C22 between Bay 15 and the GCU. After a replacement wire bundle was installed, an operational check was performed with both engines running and everything possible turned on.

The right generator was shut off the line approximately 50 times, and the left generator immediately took over the load as advertised. With both engines running, the right generator was shut off and the left generator turned off and reset 25 times, again with successful results. Finally, with both engines running and both generators on line, the right engine was shut down three times. Each time, the left generator did the job properly. The "ultimate" test occurred shortly thereafter, with an operational check flight. The aircraft returned Code One!

This fault isolation procedure resolved a perplexing problem for the F-15 squadron, saved considerable maintenance manhours, and got a valuable airplane back in commission in much less time than originally feared. Special thanks were expressed by the squadron and our company reps in the field to the St. Louis engineers responsible for the procedure – Al Feldman, Unit Chief, Design, and Ed Sandoval, Technical Specialist, Engineering Laboratories. Their idea is a great one to keep in mind for the next time you find yourself with an electrical generator problem that seems to defy resolution.

F-15 STOL and MANEUVER Technology Demonstrator Program

Lieutenant Colonel Richard A. Borowski (AFWAL/FIMX), from the Aeronautical Systems Division at Wright-Patterson AFB, Ohio, is the U.S. Air Force F-15 STOL/Maneuver Technology Demonstrator (S/MTD) Program Manager. William H. "Bill" Brinks occupies the equivalent position at McDonnell Aircraft Company, St. Louis. Recently, both individuals talked briefly about the aircraft ("Agile Eagle") which is the subject of that program, and whose innovative shape is presented in the photo shown at right.



"Agile Eagle" – the shape of the future.

COLONEL BOROWSKI

The environment of the future tactical air battlefield will be very different from that experienced by U.S. air forces in the past. The air base will no longer be a "sanctuary," and any air base in the theater will be subject to intense attack. The most vulnerable aspect of an air base is its runways. Experience in the Falklands, Pakistan, and other recent battlefields has proven that runways can be closed by enemy action and that reopening them can be difficult. It is probable that the development of improved runway repair techniques will be matched by the development of more effective anti-airfield munitions – a standoff situation at best. In future conflicts, a determined attacker will be able to overcome defenses sufficiently to deliver effective ordnance against an attractive target.

The U.S. Air Force recognizes the above situation and is investing in systems to support operations from air bases that have been attacked. These systems include runway repair techniques, mobile aircraft arresting equipment, ski jumps (inclined takeoff structures), and aircraft that require less runway for takeoff and landing. It is this latter system which forms the basis for the USAF-MCAIR project known as the F-15 STOL/Maneuver Technology Demonstrator Program.

"STOL" – short takeoff and landing – aircraft are not new. However, the design characteristics necessary for effective short takeoff and landing capabilities have been considered generally incompatible with superior up-and-away maneuvering performance. While current STOL aircraft are quite good at what they do, next generation fighters will require optimization at both ends of the performance spectrum. S/MTD is planned to get us moving strongly toward that goal. Using an existing air superiority vehicle, the F-15 Eagle, as the baseline fighter, this program intends to break the current incompatibility relationships by development technology that contributes equally to up-and-away performance and short takeoff and landing performance.

BILL BRINKS

In October 1984, the United States Air Force (Aeronautical Systems Division), selected MCAIR as the winner of a competition to design, develop, and demonstrate advanced technologies related to providing improved maneuvering and short takeoff/landing capabilities for current and future high performance fighter aircraft. Among the key technologies to be investigated in the program are –

- Two-dimensional thrust vectoring/reversing exhaust nozzles
- Fully integrated flight/propulsion control system
- Improved landing gear for rough/soft field operation
- Advanced pilot/vehicle interface (cockpit)

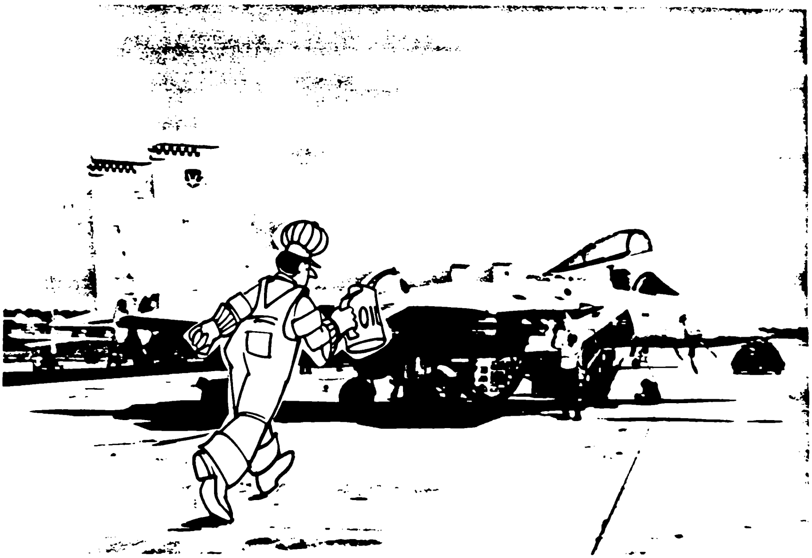
A basic aircraft design requirement of the program is development of a capability to take off with 6,000 pounds of payload and to land with a ground roll (including dispersion tolerances) of 1,500 feet or less under adverse conditions (such as at night in wet and gusty weather). In addition, a contractor initiative is to assure that aircraft performance in up-and-away flight will be equal to or better than the unmodified F-15 (baseline aircraft). Also, we intend to provide design options for derivatives and future fighter aircraft.

Selection of the F-15 for the program was natural because of the record this model has accumulated thus far – fourteen years of operational service; over 1,000 delivered; more than 1.2 million flight hours by U.S. and foreign operators; best flight safety record of any USAF fighter; and design proven in training, operational, and combat environments. The first two-place Eagle built by MCAIR, F-15 aircraft serial number 71-290, has been selected for modification into the S/MTD aircraft. It was one of our first R&D birds, made its initial flight in July 1983, and currently has logged over 2,200 flight hours. Shop modifications of the aircraft are underway now, and first flight is scheduled for March 1988. Five initial checkout flights are planned in the St. Louis area, after which the aircrft will be ferried to Edwards Air Force Base, California, for approximately 95 additional flights.

I am pleased to report that the program is on schedule, and proceeding satisfactorily through the design and development phases. All major milestones have been met to date, including the preliminary and critical design reviews relating to systems design and analysis and Pratt & Whitney (our major subcontractor) engine development. The support of subcontractors and suppliers who have joined with us on the program has been outstanding.

Because of the widespread interest in this advanced technology program and its critical importance to future fighter weapon systems, we plan to keep you posted on our progress through periodic articles in the DIGEST, as the project develops. ■

Time Well Spent...



F-15 AMAD OIL SERVICING

By FRANK H. BRUEY/*Senior Engineer-Product Service Technical Support Group*

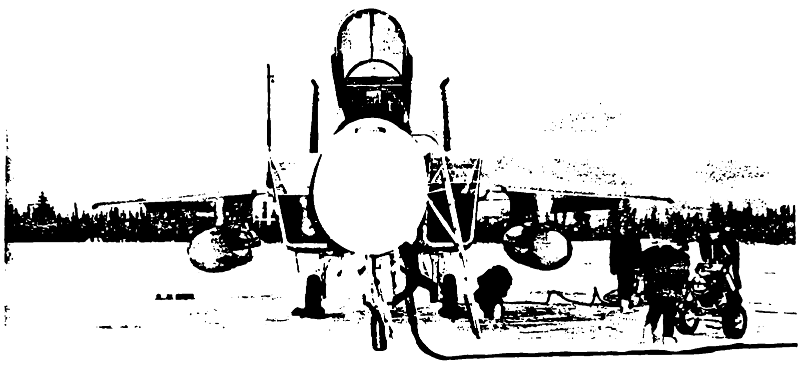
The F-15 AMAD (Aircraft Mounted Accessory Drive) is a vital component in the Eagle and has been the subject of several discussions in past issues of the Digest. This time, I want to take a look at "servicing" aspects of this system, and offer you a few tips on reducing problems caused by insufficient maintenance attention to this expensive piece of aircraft equipment. A little review of proper AMAD servicing procedures, including some warnings, cautions, and special notes of interest, can pay off in improved operating life and better MMH/FH numbers.

Servicing, by definition, means preparations to make fit for use, adjust, repair, and maintain. This article will examine "preparation of the AMAD to make it fit for use," and more specifically AMAD "oil servicing." Adjustment, repair, and maintenance of the AMAD are all much easier if proper oil servicing procedures are followed. Before we get into details, let's take a general look at the basic design of the AMAD oil system, which will underscore the importance of careful attention to proper servicing procedures.

The F-15 AMAD contains a gear train that transfers Central Gear Box (CGB) rotational power to the engines and accessories (hydraulic pumps and integrated drive generator) during engine start and limited duty mode, and transfers engine rotational power to those same accessories during engine run. The AMAD gear box has an integral, highly compartmentized, "wet sump" lubrication system with many passages and other features that restrict free movement of oil during static conditions. Functional features of the oil system include a reservoir and sump that accommodates thermal expansion and contraction, a quantity sight gage, fill and drain facilities, standpipe, and G factor and inverted flight provisions. Oil capacity of the right AMAD is 6.8 pints; the left contains 7.4 pints. Despite all of these built-in design features, the system is susceptible to human error, and that's where this article comes in.

When properly used as a surface coating between moving parts, oil permits smooth, efficient, and wear-free operation of these parts. Too little lubricating oil causes restriction of moving parts, excessive friction, and a build-up of heat that deteriorates the lubricating qualities of the oil itself, resulting in premature wear and/or more serious damage. Too much oil produces excessive churning, impaired lubricating qualities, and a rapid build-up of heat, resulting in undue stress on the moving parts which can cause failure and breakage. Proper oil servicing means not too much and not too little.

Official AMAD servicing procedures in the F-15 technical manuals are



Cold weather conditions like those pictured above can complicate oil servicing procedures. If ambient temperatures drop below zero, use a portable pre-heater to avoid prolonged servicing.

thorough and accurate. However, each step in those procedures must be followed to assure proper operation; any deviation or shortcuts will cause problems or malfunctions. Improper servicing (either under or over filling) has caused too many AMAD failures, as well as about 25% of the failures of the Constant Speed Drives returned to Depot. Some of the things people often fail to take into consideration prior to AMAD oil servicing are position and attitude of the aircraft (uphill, downhill, sideways across an incline); and temperature (both ambient and of the AMAD itself). All of these things have a critical effect upon oil servicing, and all are covered in the T.O.

The manual discusses three AMAD gearbox oil servicing procedures —

(1) Initial Servicing — Performed on a newly installed AMAD, or one which may have been drained of oil.

(2) Oil Servicing Check — Performed after AMAD operation.

(3) Routine Oil Servicing — Performed on an in-use AMAD that does not meet the requirements for an Oil Servicing Check.

Before starting any of these procedures, check the attitude of the aircraft. For proper oil servicing, the aircraft should be parked level ("level" is defined in AFM 86-8 as an 0.5 to 1.5% grade on aprons, hardstands, and pads). If local terrain does not permit this, the aircraft should be headed uphill with the wings level, so that servicing according to the sight gage indications will not result in an over-filled condition.

If ambient temperature is 0°F or below, you can avoid prolonged oil servicing by pre-heating the AMAD bay, AMAD, tank, and pump reservoir unit prior to servicing. Thermal expansion/contraction of the oil in the AMAD itself can have an effect upon the sight gage readings; when the AMAD is hot and the oil level shows near the middle of the gage, additional oil servicing may be required after cooldown.

There are several other key servicing details in the T.O. that bear repeating -

• If it becomes necessary to drain oil from the AMAD during any of the servicing procedures, remember that the gearbox is pressurized during operation and depressing the overflow drain valve button may release a sudden spray of pressurized oil. Be careful that the overflow drain hose is not pointed at you or anyone else.

For proper servicing, three external AMAD components are important - (top) filler valve with dust cover installed; (center) overflow drain valve; (bottom) AMAD sight gage. Note that location of overflow drain valve above sight gage can affect gage readings.

• During the Initial Servicing procedure, the engine dry motoring cycle must be maintained for at least 90 seconds after oil has been serviced, to assure that all components and compartments have been adequately supplied with oil and that any voids within the AMAD have been eliminated.

• Because the overflow drain valve is located above the sight gage, the oil level within the AMAD may be above the top of the sight gage. This condition is satisfactory so long as no oil flows from the overflow drain valve when the button is depressed.

• Keep the overflow drain valve button depressed during servicing and until all draining stops. This assures correct sight gage indication and prevents AMAD damage from overservicing. When servicing is completed, make sure the button returns to the extended position.

• Last but not least, always make sure that the oil servicing unit contains only MIL-L-7808 engine oil, and that the supply tank sight gage indicates a minimum of four quarts of oil.

Let me conclude by reminding you that *servicing* of any piece of equipment is undoubtedly the most important aspect of maintenance. The time you devote to proper oil servicing of the AMAD saves much more time that will not have to be spent by someone else in repair or overhaul of a damaged unit. ■

keep eagle engines where they belong, with...

expandable, quick release
ENGINE MOUNT PINS

By JOHN M. KILLORAN Jr./*Unit Chief, Design;* and JOHN A. MEYER/*Senior Engineer, Design*

The only tool required is a 5/8 inch socket wrench to rotate the locking cam.

You do not need a bigger hammer, brute force, strong words, or sweat to remove or install the engine mount pins in the F-15 — just one socket and some awareness of the engineering design behind the ABC5722 and ABC5723 Quick Release Expandable Engine Mount Pins. These pins are designed to save you turnaround time and temper, but if you treat them as if they were old fashioned, close-tolerance bolts in tight fitting bushings, you are defeating our best design efforts.

Trouble reports on these pins have been generated periodically, almost since program inception. They are mainly nuisance problems which focus on "improper" operation of the pin (failure to latch or unlatch, loss of locking capability, etc.), with two reports of pins which failed on inflight aircraft. In every incident investigated, the "improper" operation was traced to pin damage from ground handling abuse, or failure as a result of improper installation. Obviously, there is some misunderstanding as to how these pins are designed to work. With this background of field experience, we think it's worth a closer look at the design behind the F-15 engine mount pins and an explanation of how well they will work if handled properly.

One of the primary reasons for the rapid turnaround times achievable when changing F-15 engines is the use of "expandable, quick-release" pins in the engine mounting system There are two of these unique pins used with each engine, on the engine forward upper mount and on the lower side link attach point. They not only facilitate engine removal/installation, but simplify general engine maintenance compared to other mounting methods. In some earlier systems, it is necessary to drive close tolerance bolts in and out of tight fitting bushings — a time-consuming job that often produces extra maintenance because of high bolt/bushing mortality rates.

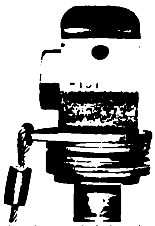
Unfortunately, some engine maintenance people are bringing along outmoded procedures and attitudes when they begin to work on Eagle engines. These procedures are causing hardware and operational problems which are completely unnecessary with F-15 engine mount pins. Unlike their predecessors, F-15 quick-release pins are designed to be installed and removed *without* using force.

As noted earlier, the only tool required with these pins is a 5/8 inch socket wrench, which is used to rotate a hex-shaped cam device which expands or contracts a series of internal rings and bushings to create a locking or loosening effect. These pins weigh only a few ounces and are worth their weight in gold to engine mount security and F-15 maintainability. When properly installed, these quick-release pins will resist loosening or backing out of the mounting hole during all engine/aircraft operating conditions. When properly handled, the pins should remain serviceable through many engine replacements; but because of their unique nature, improper or brute-force handling can only cause problems.

You can follow our discussion of design and operating details by referring to the photographs of typical F-15 engine mount pins at right. The heart of the pin is its center shaft, threaded on one end and attached to a cam mechanism on the other. This shaft is surrounded by an alternating series of ramp rings and split-expansion bushings. This entire assembly is held together by a bullet-shaped cap nut which is permanently pinned in place on the threaded end of the center shaft. The cam mechanism contains a spring latching arrangement to secure the cam when the pin is installed in the engine mount.

To expand the pin (tighten it in the mount), the cam is rotated clockwise, causing the center shaft to retract. As it retracts, the cap nut compresses the

Typical expandable, quick-release engine mount pin installation on F-15 F100 engine.



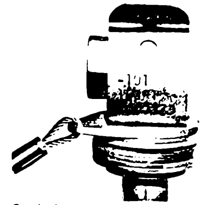
Cam latch spring in unlocked condition; pin not visible in latching spring hole.

split expansion bushings between the cap nut and thrust washer, causing them to expand as they ride up on the ramp rings. At the same time, the split lock ring rides up on the end ramp ring and expands beyond the diameter of the hole in the engine mount. The pin has now expanded to make an interference-fit joint with the engine clevis and the airframe link. Under this condition it takes 600 to 800 pounds of axial force to move the pin. In addition, the split lock ring now exceeds the clevis diameter and thus acts as an added safety feature to prevent the pin from backing out. When the pin is fully expanded in the bore, the belleville springs (wave washers) allow further cam rotation so the cam latching pin can engage the hole in the locking spring.

To contract the pin (loosen it in the mount), the process is reversed. The thumb is used to push the locking spring back to disengage the latch pin. With the lock spring back, the cam is rotated counterclockwise until it stops (about 1/2 turn). This reverses the pin expansion process described above, and once again makes the pin/clevis joint a loose fit. To assure a loose pin fit during engine removal/installation it is important that the pin be *completely contracted*. If completely contracted, and you still encounter pin binding (pin does not slide into or out of the clevis link easily), don't start banging on the pin! Rather, adjust the appropriate roller on the engine installation rail to better align the engine clevis with the airframe link.

Job Guides 1F-15A-2-71JG-01-1 (A/B models) and 1F-15C-2-71JG-01-1 (C/D models) contain complete instructions for using quick release expandable engine mount pins. Because of the uniqueness of these pins here are a few important points for you to remember —

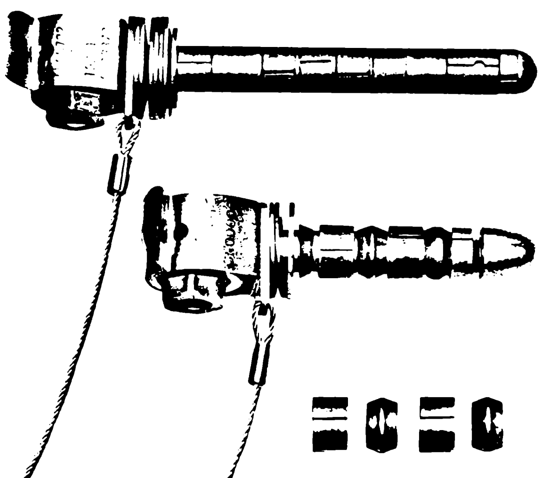
- Never use force or strike the pins.
- Make sure the pin wrenching cam is fully rotated counterclockwise to assure that the pin is "relaxed" before inserting or removing.
- Release the latching spring fully before rotating the cam counterclockwise. Use finger pressure only to release the cam latch. If necessary, rotate the cam slightly clockwise to relieve side loads between the latching springhole and the locking pin.



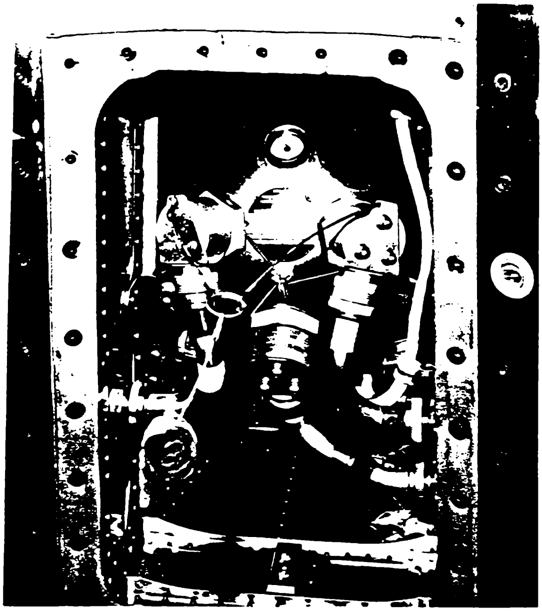
Cam latch spring in locked condition; pin visible in latching spring hole.

- Adjust appropriate engine rail rollers as required to relieve pin binding; do not use force or strike the pin.
- Fully insert the pin. Assure that the thrust washer is bottomed out and the end cap nut and lock ring are protruding.

Finally it would be a good idea to make a quick visual inspection of the completed installation each time an engine is installed, just to make sure that everything is flightworthy. ■



ABC-5722 Pin is used at engine lower side link attach point. ABC-5723 Pin, used in engine forward upper mount, has been disassembled to show parts and method of operation as described in text. Threaded center shaft is visible in disassembly; and two each ramp rings and split expansion bushings have been removed from shaft and displayed below.



F-15 OVERHEAT & FIRE PROTECTION SYSTEM

By JOHN A. MEYER/*Senior Design Engineer*

Safety and survivability have played important parts in the F-15 design since inception of the aircraft. To be most effective, safety features should be incorporated in an aircraft as early as possible in the design stage, and this was done with the F-15 fire protection system. An analysis of potential fire hazard areas of the airplane indicated that both engine compartments and the interconnected AMAD/JFS compartments should be designated as "fire zones," and a simple but effective overheat and fire protection system was designed for these areas. This article explains how the system works and provides some maintenance tips on how to keep it as trouble-free as its vital mission requires.

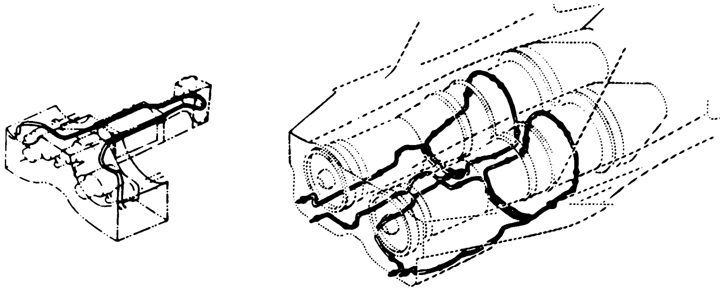
A "fire zone" on an aircraft is so designated when it contains the three elements necessary to start or sustain fire - air, a "combustible" (oil or fuel), and a possible means of ignition (such as failed electrical components or malfunctioning engines). Every effort was made during design to keep these areas as free as possible from combustibles, and where fuel lines pass through the engine bays, they are fabricated of titanium and covered with self-sealing material. Ignition sources such as hydraulic pumps and generators, and all components not interfacing with the engines, have been separated from the engine compartments. The compartments are isolated from the rest of the aircraft by highly fire-resistant titanium walls (designed to withstand a 2000°F fire for ten minutes). Tight fitting structural seams and metal seals are used at all pass-throughs. Compartment ventilation prevents a build-up of combustibles. In addition to these design features, the fire zones are provided with overheat and fire sensors and are protected by an on-board fire extinguisher. Louvers and doors are located in convenient positions for ground fire extinguisher access.

DETECTION SYSTEM

Overheat and fire detection coverage is provided by an electronic detection system designed to detect fires that can raise AMAD/JFS and engine compartment temperatures above safe limits for structural integrity. In the area of the engine bleed air lines, a hot air leak sensitive system will detect local leaks which could damage aircraft structure. The pilot thus has time to shut down systems which may be causing overheat or fire problems before the aircraft sustains disabling damage.

The fire detection system consists of sensing elements, interconnecting wires, three control boxes with a "transient signal" suppressor, an aircraft-mounted ground maintenance test panel, and a cockpit control panel. The sensing elements are thin tubes that are routed throughout the fire zones. Except for the bleed air elements, they are composed of an outer tube which protects two electrical wires that are separated by ceramic insulation. A constant low voltage current is applied to these sensor circuits and if the temperature of any bay exceeds a preset value, the ceramic insulation changes electrical characteristics, the electrical resistance in the loop decreases, and the resulting increase in electrical current is detected by the controller monitoring circuit. According to the temperature level sensed, a flashing or steady red light then illuminates on the cockpit fire warning panel, indicating an overheat or fire condition in the left/right engine bay or AMAD/JFS compartment. A warning is also heard in the pilot's headset. Depressing the lighted switch "arms" the fire extinguisher and shuts off fuel flow to the affected (engine) compartment. At this point, the pilot may "test" the system or he may discharge the extinguisher immediately. Placing the panel-mounted lever switch in the DISCHARGE position automatically deploys the extinguishing agent into the proper compartment.

To save weight, a single fire extinguisher bottle is used to service all ▶



FIRE DETECTION ELEMENT ROUTING IN JFS/AMAD BAY (LEFT) AND ENGINE BAYS (RIGHT)

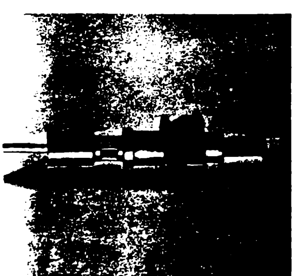
three fire zones. Because of this, the detector system must indicate the location of the fire and provide a means of directing the extinguishing agent to the affected compartment. This is done by using a pyrotechnic charge to rupture a disk on the container that leads to an appropriate discharge line and the agent is thus routed directly into the proper compartment. Bromotrifluoromethane ($CBrF_3$), commonly called Halon 1301, is used as the extinguishing agent because it is non-toxic, non-corrosive, and a very efficient fire fighting compound. When discharged, the agent circulates throughout the compartment to reach any fire source, and then is sent overboard by the normal ventilation system. Because Halon 1301 is a gas which evaporates, no compartment clean-up is required after use.

MAINTENANCE TIPS

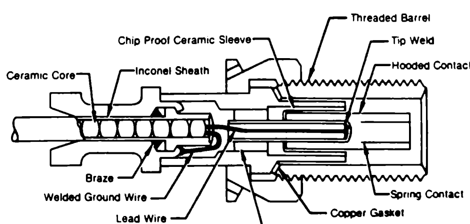
The F-15 is a very "survivable" airplane. The use of fire suppressant foam in the fuel tanks, identification and isolation of fire zones, early fire detection capability, and a responsive fire extinguishing system help make it that way. Care and attention to detail when maintaining and servicing fire protection components will keep it that way. Job guide T.O.s 1F-15A (and C) - 2-26JG-10-1 provide complete step-by-step maintenance information for the fire detection/protection systems in the engine and JFS/AMAD bays, but there are several points worth emphasizing.

There is a system operational check switch located on the cockpit fire warning panel. This is a dual-mode switch, normally spring-loaded to OFF, but with DISCHARGE and TEST positions. Selecting the TEST position illuminates all fire warning lights on the panel if the system is "dispatchable." Before any subsystem compartment warning light fails to illuminate on test, there must be a failure of both sensor loops in the affected compartment. This feature can lead to a problem when the cockpit TEST switch is used in place of the BIT checkout panel in Door 6L for system maintenance. It can happen that the system has been functioning for some time with one failed loop, but the cockpit light will still illuminate upon cockpit TEST switch activation. Eventually, the bad loop will be discovered during scheduled 100-hour BIT check, but in the meantime, subsystem failure could be imminent. There is an effort in progress to increase the BIT check frequency to basic postflight (end of day); meanwhile, it would be prudent practice to BIT check the system frequently.

During manufacture of the fire detection sensing elements, the ceramic insulation is crimped, so that when assembled it will break into "beads" and thus permit sufficient flexibility for routing the element tubes through the fire zones. The tubes are sealed to exclude moisture, but a crush washer is required to seal element-to-element or element-to-wire connections. The Inconel metal tubing, while quite strong for its diameter, must be handled carefully during removal or installation. Dents and kinks are to be



TYPICAL ELEMENT CONNECTOR



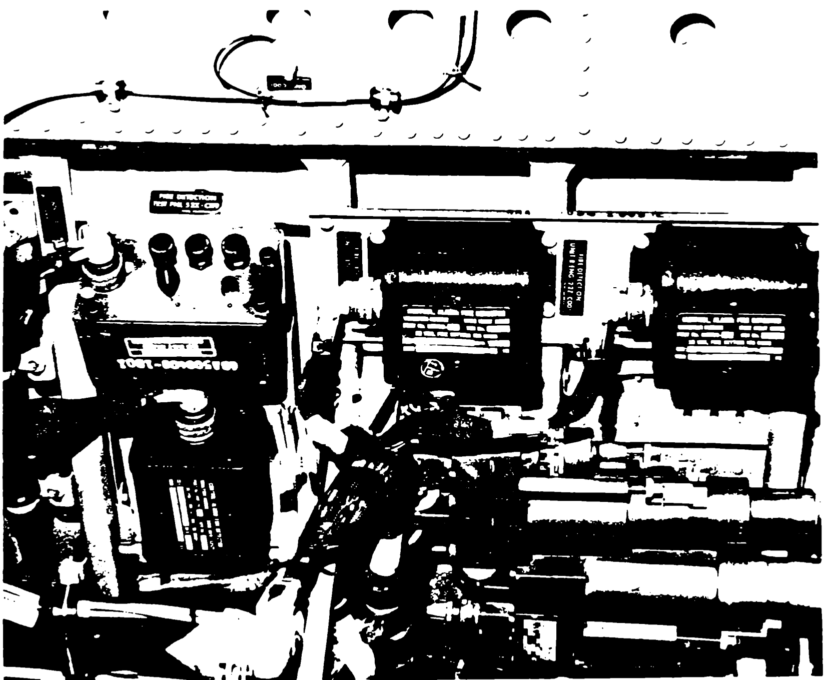
avoided, but if they occur should not be straightened. If a section of tubing is crushed so that tube diameter is decreased by more than 10 percent, the damaged section must be replaced.

Some element failures have occurred in the AMAD compartment as a result of improper installation technique. The elements terminate in a coupling which has an extended backshell that is intended to provide protection to the tube-connector weld joint. If the element tube is pulled sideways against this backshell extension and then held there by one of the installation clamps, the tube may chafe through and cause degraded system operation. To prevent this, make sure the tube comes straight out of the connector backshell for a half-inch before bending it to fit in the installation clamps. Upon completion of the installation, especially if adjustments were required to get the tubing to fit in the clamps, check to make sure the tube has not been pulled up against the backshell.

Broken and damaged wiring on the outboard side of the AMAD compartment, at the electrical interface, has also been creating some problems. Although it may be hard to see because of the tight installation, this problem is caused by a portion of the "parent" wire bundle being pulled up against the branch wire where it exits from the interface connector. Vibration then causes chafing and produces excessive loads on the branch wire, which in turn causes the protective sheath around the wire to break and eventually pull out of the connector. To prevent this problem, be sure that during installation there is at least a half-inch clearance between the branch wire and the parent bundle. This may require some adjustment of the wire bundle, but it was designed to provide at least this much clearance.

One other problem continues to occur, involving the loss of what are called "hooded contacts." These contacts are hollow cylinders with internal fingers that act as grippers. They are simply pushed over the small pin that is in every connector and serve to convert a pin type to a receptacle type connector where required. Occasionally, the hooded contact is pulled out and lost. It may also hang onto the mating pin as it is pulled apart and subsequently become misplaced. If the connection is reassembled without this contact, it will cause a system malfunction, rejection of the element, and considerable extra maintenance time. Be careful when removing fire detector elements and watch for loose or misplaced pieces.

Editor's Note: This article has emphasized maintenance aspects of the F-15 fire/overheat protection system, and as such provides a good background for reviewing again an article on the same system published in DIGEST Issue 5/80. "F-15 Engine Fire - No Foul Systems in the Eagle" discusses the pilot's side of the picture, including the DASH ONE engine fire emergency procedure. ■

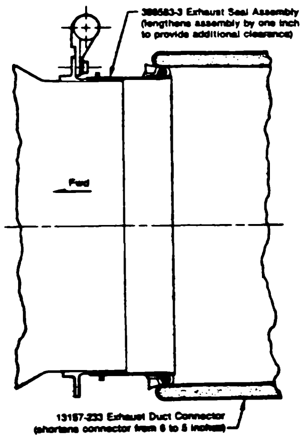


Photograph on page 7 shows fire extinguishing (Halon 1301) container in door 111 area. BIT check panel and fire and overheat detection controllers in door 6L are shown above.

How to Increase F-15 JFS Life

JOE HAYS/*Senior Engineer* - "Home Office" *Technical Support Group*

TCTO 1F-15-637 provides for a change to the F-15 jet fuel starter (JFS) and the JFS exhaust duct to prevent buckling damage resulting from thermal expansion of the ducts. Production effectivity for this change was F-15C 79-0073/F-15D 80-0054 and up, with retrofit effectivity for all F-15 aircraft except early flight test models. Completion of the retrofit program is scheduled for late June of this year.



384238-4-1 JFS (After TCTO 1F-15-637)
JFS/JFS Exhaust Duct Interface

The TCTO lengthens the JFS plenum exhaust seal assembly by one inch; replaces the JFS exhaust bolt circle special short head bolts with standard MS 21279-10 bolts; decreases the length of the JFS exhaust duct connector slip section by one inch; eliminates the top center clip which retains the seal assembly to the JFS plenum; and shortens the attach bolt by one grip length. The JFS part number is changed from 3842838-3-1 to 384238-4-1. (Modification of the JFS itself is accomplished by TCTO 2JA3-50-503.)

During JFS maintenance operations, there have been some recent cases of a JFS that has been modified by TCTO 1F-15-637 being replaced in an aircraft by a JFS that has not yet been modified. This not only causes problems with the aircraft records, but several operational discrepancies can occur. A short exhaust duct can be paired with a short JFS seal; a long exhaust duct connector can be used with an extended (long) JFS seal; the exhaust duct connector clamp can be installed in the wrong location; and the JFS exhaust ducts can be improperly seated in the JFS louvers. These discrepancies can result in excessive JFS compartment temperatures which will reduce life of the JFS.

The post-TCTO appearance of the JFS/JFS exhaust duct interface is shown at left.

Joe B. Hays has been a frequent and valued contributor of technical articles to this magazine since retiring in 1964 (as Senior Chief Aviation Structural Mechanic) after a twenty-year career in the U.S. Navy. Now, after twenty-one years with McDonnell, Joe is again retiring, and this brief article on F-15 jet fuel starters will be his last by-line appearance in the DIGEST. All of his articles reflected the knowledge and experience gained during 41 years of military and contractor service. He sailed aboard the baby flat-top USS SITKOH BAY in WW II, was an aircraft systems training instructor (both in the Navy and with MCAIR), company field service representative, and HOME OFFICE systems specialist. We will miss Joe's expertise in aircraft hydraulics, flight controls, and power plant maintenance, and wish him well in his "third career." ■

Servicing an Eagle's CGB

BY JOHN KILLORAN/*F-15 Secondary Power System Subsystem Manager*

Recently, several field reports have mentioned that some confusion exists among maintainers concerning central gearbox (CGB) servicing on the F-15 Eagle. Proper oil level is vital to the operation of both the jet fuel starter (JFS) and CGB, since both components share a common oil sump. Historically overservicing of the JFS/CGB lubrication system has been and still is the primary problem. Overservicing can cause the JFS/CGB to be severely damaged, thus necessitating the replacement of both components. Also, oil migration contributes to this problem because it creates a need for more frequent servicing and, therefore, more of an opportunity to overservice the CGB.

The best way to assure proper servicing of the JFS/CGB is to understand how the lubrication system is designed to function. So first, let's review Figure 1, a schematic presentation of the JFS/CGB. The oil reservoir is internal to the CGB and located at the top of the unit. It is important to note that the sight glass "only" indicates the oil level in the reservoir, not in the sump. For an accurate oil level in the sump, one must depress and hold the overfill drain button until all oil stops flowing from the drain port during the servicing procedure. For the lubrication system to function properly, both the reservoir and sump must be serviced correctly.

When the CGB is serviced, lubrication oil enters the reservoir through the oil fill servicing port and begins filling the reservoir. When the reservoir has approximately 1700cc of oil in it, oil will be at the top of the standpipe which connects the reservoir to the sump. Oil will then spill over the standpipe and splash fill the sump. Once the oil level in the sump reaches the sump overfill drain port, oil will flow out the drain port only if the overfill drain button is depressed. The essential ingredient in ensuring that the JFS/CGB are properly and fully serviced is to depress and hold the drain button until the oil flow stops completely.

Because of the path the oil must follow inside the CGB, a time lag will be experienced between the time oil enters the reservoir and when it finally finds its way to the sump drain. Also, one pump of the handle on the ground servicing oil cart provides about one-half to one pint of oil to the CGB. So it is quite possible during normal servicing that an extra one-half to one pint of oil can be added to the unit. It takes a relatively long period time to drain a pint of oil from the overboard drain port; especially if you are the one holding the drain button and it's cold, late, and you're tired. Obviously, the temptation is to say, "Nuts! Good enough!" and move on. WRONG! The JFS/CGB lubrication system holds less than five pints of oil when fully serviced. Remember, just one extra pint and your lubrication system is grossly overserviced. Excessive oil, plain and simple, is detrimental to system operation. So the bottom line is that the only way to ensure a properly serviced system is to "hold the button until all oil stops flowing." (See Editor's Note at the end.)

Oil migration also plays a role in this overservicing phenomenon. Simply stated, migration is what happens when the oil in the reservoir finds its way into the CGB sump while it is sitting static. This occurs because there are several possible internal leak paths which can develop as a gearbox accumulates operational hours. The net result is that the reservoir (sight glass) shows an "add" oil condition, but the oil is actually all still there, only now it is in the sump.

The most important aspect of maintaining a system which requires lubrication is proper servicing. A thorough understanding of how the JFS/CGB lubrication system functions will certainly prevent overservicing.

The temptation (once again) is to just top off the reservoir to bring the sight glass level up to the proper level without holding in the button. WRONG again! Overservicing would be the end result, so let's take a look at the oil migration illustration in Figure 2.

Whenever migration is severe enough that the oil level drops below the "add oil" mark in 48 hours, a entry should be made in the aircraft forms to monitor the system for oil migration. A component which experiences chronic migration (continuously drops below the add oil level in a 48 hour period) should be removed and returned to the depot for overhaul as soon as practical.

Operating a JFS/CGB which is overserviced will cause excessive churning of the lubrication oil, thus impairing the lubricating qualities of the oil which will lead to rapid build-up of heat and result in the failure of both the JFS and CGB. By the time the problem is recognized (brown gearbox, excessive smoke), both the JFS/CGB have sustained serious damage which usually costs between $20,000 and $50,000 to repair. It really does pay to

Just one extra pint and your lubrication system is grossly overserviced. Excessive oil is detrimental to system operation.

make sure you understand how the servicing system is designed to operate. Figure 2 provides sketches of a properly and improperly serviced lubrication system and of a system which is experiencing oil migration.

Here are some general tips and recommendations on CGB overservicing:

• A CGB can be serviced hot or cold as long as the servicing procedures outlined in the technical order are followed.

• NEVER add oil without continually holding the sump overfill button in the depressed position. Always continue depressing the drain button until all oil stops flowing out the overfill port. This is the key to ensure that the CGB is properly serviced.

• When servicing, pump slowly and even wait a few seconds between pumps when the sight glass is full. Remember, just one pump of the servicing cart handle adds one-half to one pint of oil to the CGB. Adding oil slowly will minimize excess oil servicing and minimize time required to hold the overfill drain button.

• Once the oil level has been determined to be within the black band (whether it be after flight or during servicing), then, after an extended non-operational period (48 hours) if an "add" oil indication exists, the system should be serviced again. First check the system for a leak. If none exists, monitor the JFS/CGB for possible oil migration associated problems.

One last thought – a properly serviced oil system ensures there is a proper lubrication (surface) coating between all moving parts, thus permitting a smooth, efficient, and wear-free operation of all moving parts. Proper oil servicing means doing it by the book.

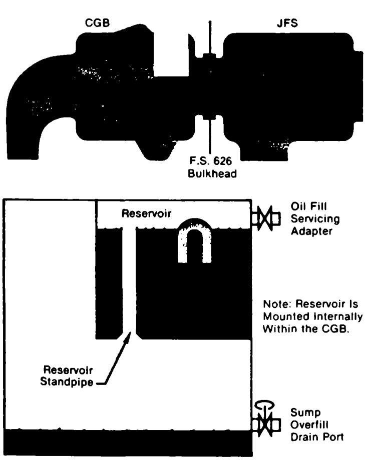


FIGURE 1. JFS/CGB CROSS SECTION

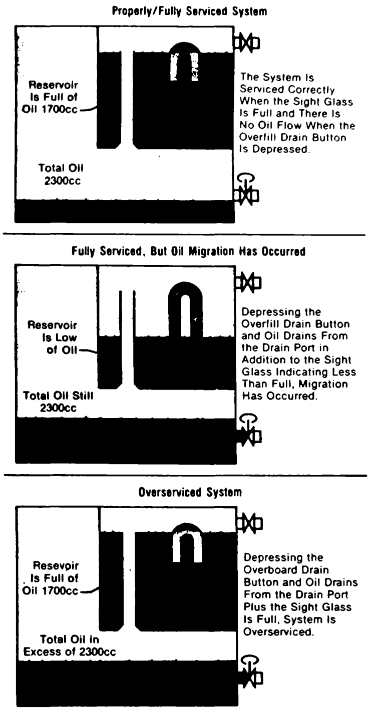


FIGURE 2. SYSTEM SERVICING

EDITOR'S NOTE: In the last issue of the Product Support DIGEST (Vol. 34, No. 3, 1987), we discussed how "Working Groups" of the 405th TTW (Tactical Training Wing) at Luke AFB, Arizona solved several maintenance problems through some innovative ideas. These resolutions to maintenance problems ultimately improved the overall reliability of their Eagles. One of the items discussed in the article relates to this subject. The group designed and locally manufactured a "clip" to hold the overfill drain button in the depressed position whenever the CGB required servicing. This not only ensured that the unit was correctly serviced, but also reduced a safety hazard when servicing the unit within 30 minutes after engine shutdown because the overfill drain button was normally too hot to touch.

Since this tool is locally manufactured it cannot be included in your maintenance manuals, but usage of the tool could be covered in a local MOI (maintenance operating instruction) for your AMU (aircraft maintenance unit).

If you have not seen a copy of the last issue, contact your MCAIR Field Service Engineer for a copy of the article. ■

F-15 ECS Effects Upon Engine Operation

Q ***One of our aircraft landed with the left ram air inlet scoop of the primary heat exchanger jammed closed. We pried the door open and found the 68A830927-2005 outboard Teflon guide melted and displaced. The primary heat exchanger was also leaking. We think the Teflon guide jammed the door and that air from the heat exchanger partially melted the parts.***

Our concern is that, in this particular situation, if the ram air check valve was bad, the hot air from the leaking heat exchanger would enter the front of the engine via the plenum. Would this bleed air adversely affect the engine?

A Turbine engines are extremely sensitive to conditions at the compressor inlet. At any given throttle position, thrust varies with air density – the density being inversely proportional to air temperature and directly proportional to air pressure. The outside air temperature and the temperature rise due to ram air determine the inlet temperature which, together with altitude and airspeed (ram pressure) at which the engine is operating, will affect the amount of thrust the engine will be able to produce.

On a cold day, the engine will develop more thrust than on a hot day. Fuel controls are designed to compensate automatically for varying compressor inlet temperatures and inlet pressures in flight to maintain the percentage of rated thrust the pilot calls for when he adjusts the throttle. On a hot day, the high pressure compressor (N2) RPM on a dual compressor engine for any given thrust condition will be higher than on a standard day. On a good day, RPM for the same thrust condition will be lower than on a standard day. This change in speed with varying compressor inlet temperatures (which, in turn, varies with the ambient air temperature) is known as "speed bias temperature vs RPM." Although this is a normal characteristic of dual compressor engines, the amount of bias desired is a built-in feature of the fuel control on military engines.

If hot bleed air from a leaking heat exchanger was able to reach the engine via a bad ram air check valve and plenum, the engine fuel control would simply reschedule fuel flow to the corresponding inlet air temperature increase, with no adverse effect upon the engine.

By CARL MILLER
Engineer – Field Service

F-15 ECS Cabin Airflow

Q ***ECP 1610 incorporates a new high pressure water separator (HPWS) environmental control system configuration in the Eagle. Aircraft affected are F-15C S/N 368 and F-15D S/N 61 and up, and all F-15Es. There was a brief description of the new configuration in a recent issue of the DIGEST (No. 1/87, page 6), and we understand that detailed data should become available soon. However, we would appreciate a little more information now on the "cabin airflow priority reverse" feature of the new system.***

A This new feature reduces the cabin airflow schedule when an avionics cooling airflow shortage is detected. When avionics cooling airflow falls to 90% of the scheduled flow requirements, the cabin airflow is reduced as required to keep the avionics airflow from falling below the 90% value. The cabin cooling and pressurization system will continue to operate in this manner until the cabin flow reaches a preset low limit. Any additional cooling shortages will result in avionics airflow reduction below the 90% level and a probable ECS light illumination.

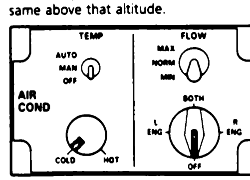
High ambient temperatures and humidity increase the likelihood for activation of the priority reverse feature. The cabin airflow control switch is disabled when cabin airflow is in the priority reverse mode of operation. The resulting notable difference in cabin cooling schedules may not be too well understood or received by aircrews.

By CARL MILLER
Engineer – Field Service

INCREASED ECS CAPACITY – HIGH PRESSURE WATER SEPARATOR SYSTEM (ECP 1610)

The avionics cooling capacity of the F-15 environmental control system (ECS) has been increased to permit installation of new electronics equipment. The low-pressure water separator system is replaced with a high pressure system to deliver dry air at lower temperatures, boosting avionics capacity by approximately 18 kilowatts. The pilot's indication of this change is the addition of a cabin airflow selector switch which provides for selection of one of three airflow settings.

An airflow priority reversal system automatically diverts cooling air from the cabin to the avionics system if avionics airflow drops to approximately 90% of the needed volume. However, cabin airflow will not fall below predetermined limits – 13 pounds per minute in the F-15C and 20 pounds per minute in the F-15D. These ECS changes deliver avionics cooling air at 40°F from sea level to 25,000 feet, dropping at a linear rate to 0°F at 42,500 feet and remaining the same above that altitude.



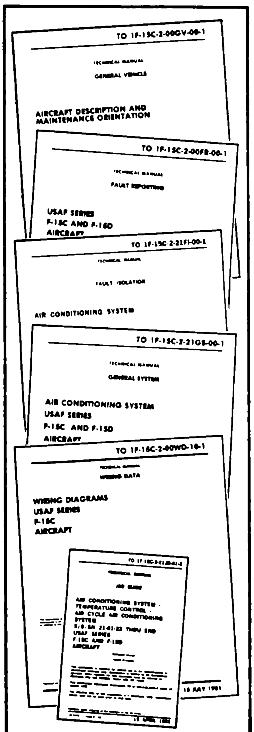
"How goes it?"...

A Status Report on the NEW F-15 MAINTENANCE MANUALS

By WILLIAM A. WARD/*Section Manager, Technical Data*

In Issue 3/81 of the DIGEST, we gave you a preview of the U.S. Air Force's new F-15 Technical Order system — highlighting the benefits and giving a general idea of what to expect when the time came to implement "MIL-M-83495" (Organizational Maintenance Manual Set). On 1 January 1982, the USAF officially began the changeover, and on 18 June declared the transition complete — after that date, the old-style DASH TWO maintenance publications could no longer be used. In the opinion of those who researched and established the new system, this was a milestone in the history of the Eagle, and MIL-M-83495 is destined to have an enormous impact upon the USAF/F-15 operating environment.

When the new system hit the field, the following MCAIR technical data specialists visited F-15 bases to help ensure a smooth transition and complete understanding of the new publications — Charles Chandler, Harry Eggleston, Jim Hallowell, Leon Haralson, Rob Koeneman, Paul Luebbers, Edgar Sanchez, Pete Urbanski, Andy Ward, Gary Waaso, Barry Witmer, and John Williamson. This article, by one of those specialists, reviews the phasing from the old to the new manuals, recounts some user reactions, and addresses some of the questions raised during the transition period.



Initial reaction by military personnel to the new manuals appears to be overwhelmingly positive. During our recent introductory trips around the F-15 world with MIL-M-83495 pubs in hand, we found an encouraging willingness on the part of Eagle Keepers everywhere to meet the system much more than half-way! What they were being asked to do was certainly no small matter — a complete changeover from one technical data system to another, from a system many of them had worked with for years to one that looked good "on paper" but had yet to be proven in the field. Everything about the MIL-M-83495 books was different — different numbers, different formats, even some different sizes. If approached negatively, this major change in USAF maintenance philosophy had all the earmarks of "big trouble" across the board — for MMH/FH, mission readiness rates, and especially for relationships between the ops and maintenance sides of the house. None of this happened; implementation of the "Job Guide" approach to Eagle maintenance has been smooth; and we as the contractor responsible couldn't be more pleased at the way things turned out. It has been a big and cooperative job effort between contractor and customer, and some interesting things occurred along the way.

Upon learning the system, each person seems to have acquired a favorite feature and the overall winner seems to be the improved numbering method. The System/Subsystem/Subject Number (S/S/SN) allows quick access to any data, and is perhaps the feature that best reflects the logical, common-sense approach to aircraft maintenance provided by the new manuals.

Another favorite is the Job Guide "Input Conditions" page. This allows the technician to select all the equipment, supplies, and data needed to complete the assigned task before leaving the shop. It also provides manpower recommendations and safety precautions to be taken while performing the specified maintenance activity. Other elements praised by those introduced to the new system are the improved access to the Illustrated Parts Breakdown manuals and the handy size of the Job Guide manuals with their improved illustrations.

The most consistent comment heard was that the new Fault Reporting (FR) pilot debriefing manual promises to be the biggest maintenance manhour saver of all. This new debriefing procedure is a radical departure from previous methods and requires adjustment on the part of pilots and maintenance personnel alike. Both parties now need to spend a few extra minutes in debriefing, but the benefits should far outweigh any inconvenience. More aircraft will be made available for flights because the time spent troubleshooting and the demands made on the supply system will be reduced.

Conscientious completion of AFTO Form 241 (noting any system failure indications such as caution lights, BIT lights, and fault indicator latches) prior to debriefing, will enable the session to proceed more smoothly and quickly. To ensure that the maintenance debriefer is "getting the whole story," the pilot must not only report the cockpit indications but also any fault indications found on the avionics status panel in the nose wheel well. The pilot may also need to have the crew chief open quick-release access panels for additional indications. These extra efforts add valuable information and are tremendous timesavers in the debriefing and fault isolation process.

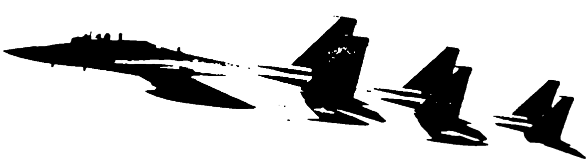
The FR manual should be used as a "shopping list or menu," and responding to the statements or questions with a "YES" or "TRUE" will provide enough data to develop a fault code and ultimately direct the technician to the correct fault isolation procedure. Once the fault code is developed, the pilot writes up any squawks (as indicated in the FR manual) and can add supplemental information at his discretion. This relieves the pilot of the burden of over-detailing problems and trying to indicate which component is defective. Proper use of the FR manual means that it will do the work for you!

It is essential that the pilots and debriefers become thoroughly familiar with the FR manual. Knowing how to use the manual means fewer problems with it and a quicker and more reliable finish to your debriefing session. One final suggestion to pilots and debriefers — for the benefit of the maintenance technicians, when the FR manual identifies a squawk as a normal indication, please trust the manual and don't write up the squawk. A squawk written up in spite of the "Normal Indication" flag will mean hours spent looking for a problem that doesn't exist and may even end in replacement of a perfectly good component.

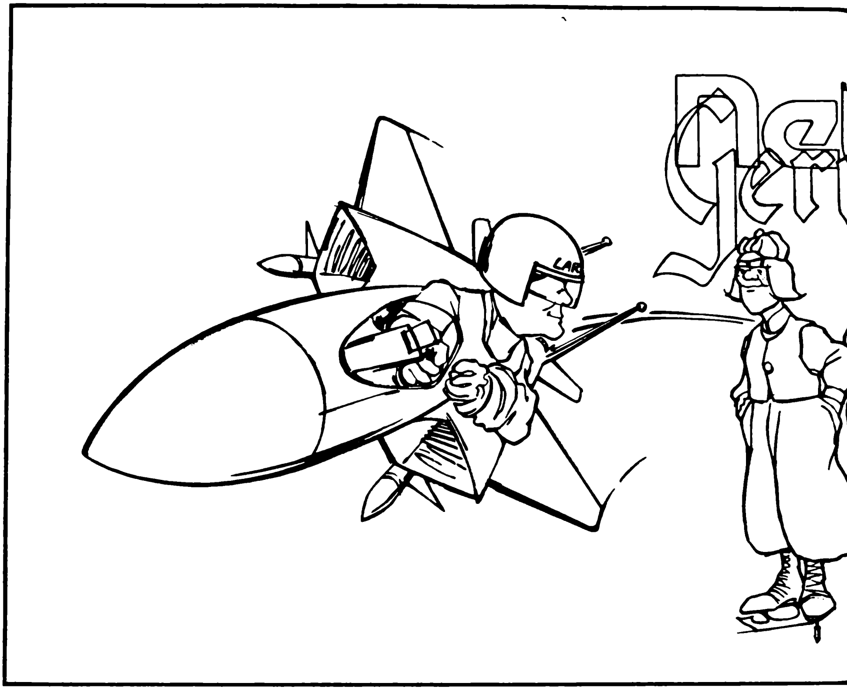
The primary area for concern resulting from the implementation of the new T.O. system relates to the large number of "little" books. The adjustment to this can be made a lot easier with a little ingenuity on the part of the maintenance squadrons. Since most references are to the ground handling and servicing Job Guide manuals (Aircraft System Numbers 05 through 12), they should be made readily available at the aircraft. Several methods have been proposed, including carrying the manuals in a roving van or placing them in a metal box mounted to strategically-placed crew chief stands. If these basic manuals are made available, the problem of carrying many little books to the job is greatly diminished because most specific maintenance tasks will require only one specific Job Guide.

The cooperative effort of the USAF and MCAIR to ensure that the transfer of the new T.O. system went as smooth as possible is evidenced by the adjustments made by all parties. For example, in order to facilitate any changes made to the technical manuals during the conversion, Publication Change Requests (PCRs) were handled via teletype exchange or telephone conferences. Corrections could then be immediately incorporated, distributed to all concerned bases, and "business as usual" could resume.

And so, the tough job of transitioning from the old to the new system has passed and so too have most of the initial problems. The enormous tasks of printing, distributing, training, and familiarization are behind us all now and the full advantages of the new T.O. specification can be realized. Please let us hear from you if any new problems come to light. ■



F-15 "Threagle." Holloman AFB, New Mexico appears to have come up with an extremely long range air superiority fighter, if you could believe there is such a thing as a one-cockpit, three-wing, six-tail Eagle! In truth, it was some exceptional formation flying by three pilots of 49th Tactical Fighter Wing, captured in this exceptional photograph by Douglas photographer Harry Gann back in 1978.



ON THE ROAD (AGAIN)

By PAT HENRY/*Director of Flight Operations, MCAIR*

(reprinted from USAF FLYING SAFETY magazine, December, 1982)

McDonnell Aircraft Company is "taking the show on the road!" Well, not exactly the whole company, just a few of the F-15 pilots.

A few years ago, company pilots routinely traveled to military organizations that flew the F-4 for the purpose of providing insight and information from the perspective of a company test pilot. Now we have begun a new series of visits, this time for the F-15.

Our purpose in conducting these briefings is twofold: To provide squadron pilots with in-depth information on the airplane and its systems, and to gain feedback from the wing level on the strong or weak points of the aircraft.

The briefings currently cover eight general subject areas that cover 16 specific topics plus a condensed briefing that lasts about 45 minutes and touches very briefly on all the topics. Before making a presentation at a wing, we will be in touch with the Safety and Ops officers. The staff safety officers may be interested in accompanying us during the individual briefings in order to see the material first hand, judge reception, and hear the feedback. We plan on at least a two- or three-day visit at each F-15 wing, if required, and will be presenting information at two (or more) sessions a day. We will be happy to cover all the information we have formally prepared; if another topic is of concern, just let us know, and we'll gather as much information as we can. We want to be flexible and responsive to the needs of the entire F-15 community.

Introduction/Safety

The introduction reviews some basic design goals of combat survivability and takes a brief look at safety records.

OFF THE ROAD (AWHILE)

By GLEN LARSON/*Senior Experimental Test Pilot*

True to Mr. Henry's word, as indicated across the page, MCAIR has been "on the road" for the past year, with a series of F-15 briefings directed specifically at Eagle pilots. In this case, "MCAIR" means me in that I presented all the briefings. I have appreciated the opportunity to become the "voice of the Eagle," so to speak; and am proud to have been assigned to carry on a long tradition at McDonnell Aircraft Company. Nobody has been around here long enough to remember whether a "contractor pilot briefing team" went out in 1945 with the company's first fighter, the FH-1 (I wasn't even born then!), but for many years it has been standard policy for our flight test organization to share what we know about our airplanes with the customer. Somebody from St. Louis is almost always "on the road (again);" and now that I am "off the road (for a while)," I'd like to tell you a little about my year-long adventure with the F-15 road show . . .

This program differed somewhat from previous ones in that my intent was not so much to focus on specific issues, as to provide insight into some of the engineering and development that has gone into the F-15 since its inception in 1965. I structured my briefings in "segments" (the eight subjects and 16 topics noted by Pat in his article) to allow each individual unit to request specific presentations according to their particular needs and interests. As it turned out, each unit requested all eight subject areas, which indicated that the contractor and the customer look at the Eagle pretty much the same way.

The best part of the trips was renewing old acquaintances and making new friends in the vast F-15 community (if I could have flown on the same airline, I'd have enough mileage credit to go around the world twice — free!). And ▶

OFF THE ROAD (AWHILE) (CONT'D)

without exception, the hospitality I experienced at each base was superb — interest in my material was high; questions asked were relevant and penetrating; and the pride we here at MCAIR have in building the F-15 was just as evident out there with you who are flying it. Here's how things went, command by command, with some examples of the types of questions I encountered at each location.

My tour of TAC actually started *outside* TAC, at the USAF Safety Center at Norton AFB, California. Since one of my primary goals was to help improve an already exceptional safety record, it seemed appropriate to visit first with the USAF safety experts and discuss the overall program.

The next stop was at HQ/TAC Safety and DO offices to explain our goals; and the inaugural show was then presented at Langley AFB in November 1982 to the 1st TFW and 48th FIS. This was followed by trips to Eglin, Nellis, Luke, and Holloman for discussions with the people at the 33rd, 57th, 405th, and 49th Wings.

One of the most interesting parts of each trip was the exchange of information, and I learned a great deal about problem areas in the field. Some of the subjects brought up were: muting of the UHF by the voice warning system; secondary power system; canopy; and OWS anomalies. These problems and others you brought up have been passed on to our engineering staff and where possible, solutions will be forthcoming.

Also, I have been able to work directly with several individual pilots. Major Dave Perron from Langley has given us some great information on INS and OWS problems, as well as some weapons problems. Major Dave Greschke of HQ/TAC, Captains Paco Geisler from Nellis and Neil Kacena from Luke, and I spent many hours discussing stall and spin characteristics of the airplane. Hopefully, some revisions to Section 6 of the DASH ONE will result.

Alaska in March was outstanding! Most of the snow was gone, except for some huge mounds left over from snow clearing operations. The 43rd TFS at Elmendorf ("Top Cover for America") play for real since they frequently look the "opposition" in the eye during Air Defense scrambles, not to mention the excitement of short runways made icy slick by the long Alaskan winters. Fulfilling night flying requirements when sunset is at 2200 must be agonizing!

Incidentally, it was here in AAC that I was first struck by the incredible variety of climatic, geographic, and situational challenges faced by the Eagle and its pilots. Most USAF assignments are at one location for one to three years, so "global" operational complexities only come across when one makes a rapid around-the-world tour as I did — in Alaska the harsh climate; typhoons and immense flight distances in PACAF; rains, fog, and exceptionally congested airspaces in USAFE; the mixture of all of these conditions and more resulting from F-15 basing at TAC sites all around CONUS. All of this must create mind-boggling "management" problems.

Many of the questions and comments at Elmendorf were similar to those in TAC, but one was unusual — Captain Phil Skains had noted an apparent discrepancy in the flight manual takeoff performance chart with regard to max abort speeds. It appears that the chart is "backwards," i.e., abort speeds for heavyweight airplanes are higher than for lightweight airplanes! Guess what? The chart is right. (The last issue of the DIGEST contains an excellent discussion of this pecular phenomenon and explains why the chart is correct.)

My Pacific tour started with a visit to HQ/PACAF in Hawaii, where I talked with the PACAF staff and then spent half a day on the beach. What a great way to start a briefing tour, even though the beach bit may not have been what my boss had in mind when he sent me out there! The next stop was HQ/5th AF at Yokota for a staff briefing

ON THE ROAD (AGAIN) (CONT'D)

Engines/Performance/JFS

Engines have always been a high interest item, and this presentation explains how the top speed of the airplane is affected by engine trim levels, ambient temperature, and aircraft configuration. Included in this presentation is a brief look at engine trim in terms of past, present, and future trim levels. The JFS is presented in a brief review of airstart envelopes. Fuel leaks are discussed in terms of where they happen, the causes, and pilot actions.

High AOA

High angle of attack is a subject of continuing interest. Here we cover the biggest contributor to loss of control and how to recognize the signs of impending control loss. We also explain the autoroll; and as an extension of autorolls, the roll coupling phenomena, which is especially relevant to "jink out" maneuvers.

G-Loads/OWS

G-loads, especially over-gs, have plagued fighter aircraft for years, and the F-15 is no different. In this presentation, we take a look at how g loads affect the aircraft and how we integrated the OWS (overload warning system) to open the g limits to 9.0 gs symmetrical.

Flight Controls

The flight control system isn't really a deep, dark mystery; and in this briefing, we go back and explain some basic design goals and how they were implemented, along with a discussion of malfunctions. Also included is a section on c.g. position and how it affects turn performance.

Maneuvering Performance

One question we are asked constantly is: "What is the AOA for an optimum turn?" This briefing answers that question in terms of maximum and optimum turn performance and also explains the best acceleration profile.

Landing Gear

Landing gear problems have been with the F-15 for some time, and a final change has been implemented that eliminates all single point failures and adds some extra features to warn of any gear not being extended. The pulser brake system is currently entering service, and this new system is explained from a pilot's viewpoint. Late rotating airplanes are still a problem, so a review of the causes, solutions, and pilot techniques for slow or late rotating aircraft is provided.

New Programs

Several new programs are coming down the pike, and this final presentation covers the latest information on the MSIP (Multi-Stage Improvement Program) effort, the Dual Role Fighter (F-15E), and yet to be approved design studies such as new engines, electronic flight controls, integrated flight and fire control, drag chute, and several other items.

and a mandatory tour of the local electronic emporium. My final stop in the Far East was with the 18th TFW at Kadena, where Colonel "Mac" MacFarlane of "Streak Eagle" fame is Vice Commander. The term "cross-country" takes on entirely new meaning at Kadena since they routinely travel vast distances on deployments to such places as Australia. They also logged a non-stop marathon to Eglin in Florida for their very successful William Tell competition last year. (Conformal tanks anyone?)

Questions and comments here were again similar to TAC and AAC, but they have had some special problems with the vertical tail structure. This one has our full attention and will be resolved in the near future. Captain Rick Carrier had some good questions on the "dual gradient" stick force design. On paper, it would appear that a design which requires 3 3/4 pounds/g up to 3 g's and a change to 2 pounds/g above 3 g's would cause problems. In fact, the reverse is true. Early testing indicated that stick forces at higher g levels were unacceptably high, and a design change was needed to get the forces down to a reasonable level. In daily operations, the pilot won't even notice the difference in stick force levels. (Got to go a long way back to get this one, but an article in Issue 4/1973 of the DIGEST has an excellent analysis of the engineering and simulation work which went into resolution of stick force per g and other flight control system complications.)

Europe in June. Fantastic! First stop was Ramstein/Sembach to visit with the HQ/USAFE and 17th AF staffs, then back to Frankfurt for a flight to Amsterdam and a short drive to Soesterburg. Four days with the "Wolfhounds" of the 32nd TFS were delightful. Again, similar problems were brought up here, and Leiutenant Colonel Mike Francisco asked some good questions about the OWS. (The latest in a series of DIGEST discussions on the overload warning system is presented on page 14 of this issue. The article addresses several points relating to OWS parameters and interfaces that were the subject of questions during my briefings, and is worthwhile reading.)

The next leg of the trip took me back to Frankfurt for a drive down the Mosel River to Bitburg for sessions with the 36th TFW. Comments again were similar to other bases, but Captain Stub Henderson had some good questions about INS align times — can they be reduced? The answer is yes and no. No, the current system can't really get much better than the rapid align feature; and yes, a new INS can be made to align somewhat faster (The last issue of the DIGEST had the first of a two-part series of good articles on INS characteristics and CND problems. the next issue will offer some cockpit INS alignment tips and a preview of some new ideas in inertial navigation systems.)

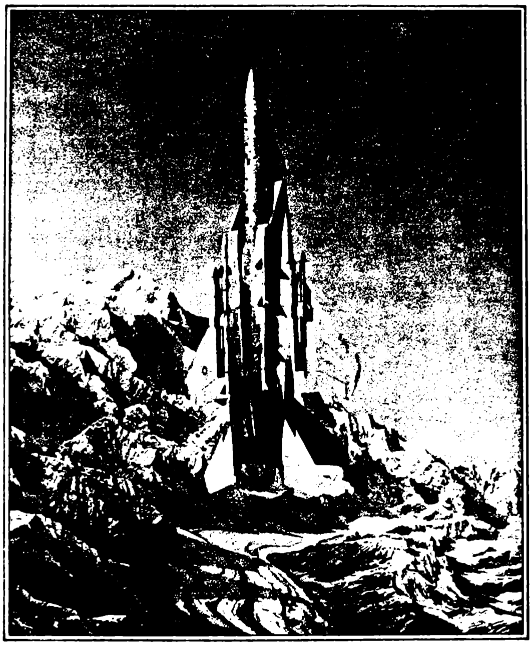
Now that our first F-15 world tour is completed and this article published, I can sit back and relax — but just for a while. Because of the success of the program, we are planning on continuing this type of presentation, with changes and updates as appropriate. And as a follow-up to this program, a special pilot-oriented Product Support document will be coming out soon.

Our company aircrews and technical specialists have been writing articles about the F-15 for publication in the DIGEST for more than ten years, but many of the past issues of the magazine are no longer available. If you are fairly new to the Eagle, you probably aren't aware of just how extensive a storehouse of ops-type knowledge has been accumulated through these articles, so we're putting together reprint collections of them all. Several volumes of "EAGLE TALK" (P.S. 1257) are to be published. Volume I is in work now and will be composed of general interest articles arranged in chronological order — sort of a pilot's history of the F-15 from first flight up to the present. Volume II (and subsequent volumes) will contain the more technically-oriented article reprints, arranged in subject order, such as flight controls, engines, systems, avionics, etc.

As for myself, I plan to follow up this summary DIGEST article with several detailed ones, based upon those areas in my briefings that seemed to be of the most interest to you — turn and acceleration performance, out of control and spins, landing gear, etc. Also, with the assistance of our engineering people, I plan to include answers to many of the questions you all threw at me, so make sure to reserve your copy of the next few DIGESTS.

If your unit would like one of our pilots to visit and present a briefing on a specific subject, please let us know. In the meantime, remember that we also encourage individual pilots to call, write, or stop by St. Louis to discuss problems or offer suggestions for the F-15 program. You can call us at (314) 232-3456, write us at Department 290, or stop by our office in Building 42 on the MCAIR flight ramp. Our door is always open, and I'd personally welcome the opportunity to return your super hospitality of the past year! ■

ANGLE OF ATTACK a



Of the many questions about the F-15, a few seem to be asked repeatedly, and one of the most frequent is -

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"What are the angle of attack guidelines for turn performance, acceleration, cruise, and endurance?"

This article, in addition to developing AOA guidelines, provides a pilot's perspective on turn performance. It is the result of several months' effort and was a part of the briefings recently given to F-15 pilots worldwide. Like the F-15 itself, this discussion is the result of a team effort and my special thanks and appreciation are offered to several individuals. Dave Thompson, Chief Technology Engineer, was a special source of technical advice and guidance; and without the help and engineering expertise of Clarence Mongold, F-15 Aerodynamics Branch Chief, Carl Miller, Lead Technology Engineer, and Drew Niemeyer, Technology Engineer, this article could never have been written.

Ever since aircraft were first used in air-to-air combat, pilots have been concerned with how to get maximum turn performance out of their machines. Aerodynamicists have developed equations that explain the turning performance of any aircraft; but until recently, few guidelines existed to aid the pilot. Early fighters had control systems and aerodynamic characteristics that provided a wide variety of clues for turning performance. Lumped together, they provided what was often called the "feel" of the aircraft; and with that, the pilot could maneuver his fighter very effectively. With the advent of hydraulic (irreversible) controls and artificial feel systems, these guidelines became unusable; and other guidelines such as airspeed or angle of attack were used. Before moving on to specific guidelines for the F-15, we need to review some basic theory.

AN ENGINEERING PERSPECTIVE

Angle of attack is used by the Navy as a landing aid because unlike airspeed, the AOA value for final approach remains constant, regardless of gross weight or altitude. AOA is also used as a reference for turn performance. Angle of attack is simply the angle between the chord line of the wing and the free stream airflow, which is usually presented to the pilot in actual degrees, as in the F-18, or in non-dimensional units, as in the F-15 or F-4. For the F-15, an approximation of the actual angle of attack in degrees can be obtained by subtracting ten from the indicator reading. (For example, at 40 cockpit units, the wing is at approximately 30° AOA.) "Corner" velocity, which is the minimum speed at which the aircraft can reach (but not sustain) the maximum allowable g load, and "on speed" turns are also common references.

Let's review F-4 "on speed" turns for a moment. The "on speed" reference, or 19.2 units for the original F-4, developed as a landing aid for the Navy, happened to work out as a reasonable reference for maximum performance turns in ACM. It is often assumed by F-4 pilots that the 19.2 unit reference is at maximum coefficient of lift (C_L) - not true, it actually occurs just below the peak in the C_L curve, as shown in Figure 1. This is a good reference for ACM because above 19.2 units, induced drag is so high that the rate of energy loss is unacceptable; and more importantly, the handling

By GLEN LARSON/*Senior Experimental Test Pilot*

id TURN PERFORMANCE

qualities degrade markedly. Unpleasant characteristics such as nose rise, nose slice, and departure/spins can develop rather quickly at higher angles of attack.

What about the slatted F-4's? How come 23-24 units are used instead of 19.2 units? The basic reason is that the slats keep the airflow attached to the wing at higher AOA's, improving the high AOA handling qualities of the airplane. The addition of slats to the wing extends the lift curve, as shown in Figure 1, allowing the aircraft to fly to higher AOA's.

What are the limiting factors for turn performance? The turn equations shown below have only two variables: g's and true airspeed.

$$\text{Turn Radius} = \frac{V^2}{11.3\sqrt{n^2-1}} \text{ feet}$$

$$\text{Turn Rate} = \frac{1092\sqrt{n^2-1}}{V} \text{ °/sec}$$

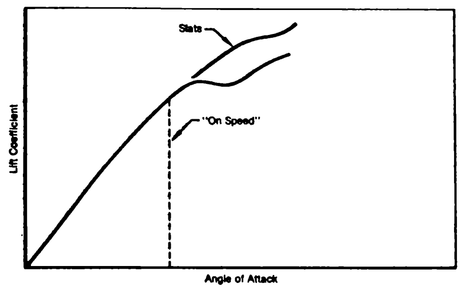
Where V = True Airspeed in Knots
n = Load Factor or G's

The physical limits that apply to these equations are: structural limits, aerodynamic limits, and thrust (power) limits. Let's examine these three limits and how they apply to the equations.

- Structural Limits - In order to get the radius as small as possible and the rate as high as possible, it's necessary to operate at the highest possible g level at the lowest possible true airspeed. The g limit is determined by the aircraft structure, and the g capability of the aircraft is determined by the aerodynamics of the aircraft. At high speeds, loads on the aircraft structure are the limiting factors; while at low speeds, aerodynamics limit the g level attainable.

- Aerodynamic Limits - This can be thought of as a lift limit, control surface deflection limit, or a handling qualities limit, depending on the type of aircraft. In the F-15, the effective aerodynamic limit occurs at full aft stick. Large lateral asymmetries (one wing heavy) in any aircraft can cause some unpleasant handling qualities at high AOA's which will force the pilot to operate the aircraft at a lower AOA, thus limiting the g capability. Whatever the effective aerodynamic limit is caused by (handling qualities, maximum lift, or weight asymmetry), it has the effect of limiting the g's the aircraft can pull, which lowers turn performance.

FIGURE 1 - F-4 LIFT COEFFICIENT VARIATION WITH ANGLE OF ATTACK



Up to this point, we've been discussing instantaneous turn performance. For sustained or optimum turn performance, the third limit (thrust) becomes a major consideration.

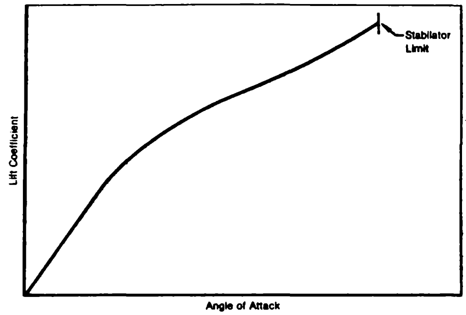
- Thrust Limits - This one isn't quite as straightforward since energy-maneuverability (E-M) must now be considered. E-M considerations become important since maneuvering flight is a dynamic situation. E-M can be broadly defined as the "total energy" of the aircraft at a given point in time, and is made up of a combination of kinetic energy (speed) and potential energy (altitude). The excess thrust available (thrust minus drag) can be thought of as the ability to change total energy, resulting in a gain in speed or altitude if thrust exceeds drag. E-M concepts are usually presented in the form of a graph known as a V (velocity) and H (altitude) diagram, with contours of constant P_s, or specific excess power. P_s is a number that quantifies aircraft capability to change energy at a given flight condition and is usually expressed in terms of feet per second. When the V-H diagrams for different aircraft are calculated for the same g level, a pilot can tell quantitatively how much advantage (or disadvantage) he has relative to an adversary. Referring back to the turn equations, it becomes apparent that the more g's the aircraft can sustain at a given speed, the better the turn performance. In E-M terms, this means that the higher g levels attainable at $P_s = 0$, the better the turn performance.

As a review, here's a specific example: A B-52 at 520 knots true airspeed and 5 g's would have exactly the same turn rate and radius as an F-15 at the same conditions. Obviously, the B-52 couldn't get to 5 g's (structural limits), would quickly reach $C_{L_{max}}$ and stall (aerodynamic limits), and couldn't sustain 5 g's (thrust limits). The F-15, however, will easily sustain 5 g's without exceeding structural or aerodynamic limits. These concepts are excellent for understanding relative turn performance, but don't provide any readily available guidelines.

A PILOT'S PERSPECTIVE

Now that theory is out of the way, let's explore some practical applica- ▶

FIGURE 2 - F-15 LIFT COEFFICIENT VARIATION WITH ANGLE OF ATTACK

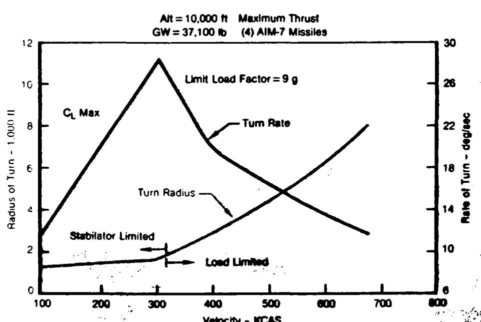


ons. For purposes of this discussion, ıere are really only two kinds of turns ɔ be concerned with: *maximum* and 'hat is sometimes known as *optimum* ɹrns. A "maximum" turn is defined as ıe best rate and radius possible 'ithout regard to energy loss. Defining n "optimum" turn is not quite as easy ecause pilots have used that term to escribe a turn that was actually a susıined turn. A "sustained" turn is one ıat is performed at a single set of conitions that results in a specific *sustain-ɗ* g level. The exact combination of OA and speed will vary, depending pon gross weight and altitude. Rather ıan develop exact AOA's for each combination of conditions, we will determine a range of AOA's that encompass most sustained turn conditions but since some energy will be gained or lost, this range does not represent an optimum.

Maximum Performance Turns

Intuitively, a maximum performance turn would be at the point where the wing is producing maximum lift or C_{Lmax}. The F-15 is somewhat unusual in that it won't reach C_{Lmax} in a sustained turn because it is prevented from reaching that point by available stabilator authority, which limits lift, as shown in the lift curve in Figure 2. This is an intentional design feature of the F-15 which keeps the loads on the tail structure at a manageable level, and which also has the added benefit of preventing the aircraft from reaching very high AOA's where unpleasant handling qualities can develop. This implies that the F-15 wing cannot be stalled; and in a gradual 1 g deceleration, it really doesn't stall. The aircraft ends up in a full aft stick, high sink rate condition that resembles a stall (wing rock, buffet, etc.), but it isn't truly stalled (i.e., above C_{Lmax}). In an abrupt turn, the AOA will overshoot the value for a steady C_L, but will return to a steady value of C_{Lmax}.

FIGURE 3 - F-15C TURN PERFORMANCE



Guidelines for maximum performance turns can be determined from Figure 3, which is a plot of turn rate and radius without regard for energy loss. Two general conclusions can be drawn:

- These turn rates generally cannot be sustained; therefore, it's better to operate above 300 KCAS in order to be able to use the maximum available turn rate. As the speed decreases, turn rate increases until reaching a maximum at 300 KCAS; thereafter, the turn rate decreases as speed decreases.
- Since the wing C_{Lmax} can't be reached, the best guideline is to simply pull to the stick stop (full aft stick) or the g limit, whichever occurs first. For a 9 g airplane (symmetrical), the crossover speed is 305 KCAS. Above 305, stop pulling when you hear the OWS tones; below 305, pull to the aft stick stop. (For a non-OWS equipped aircraft, the crossover speed for 7.33 g's is 275 KCAS.) This speed, 305 KCAS, is the corner velocity of the F-15.

Incidentally, there is a modification to the control augmentation system that significantly increases the instantaneous pitch rate at low speeds. This change (which has been tested by the USAF at Edwards AFB) is in the proposal stage for retrofit, and is included in the Dual Role Fighter proposal.

A word of caution for non-OWS equipped aircraft: The classic academic definition of corner velocity is the lowest speed at which the aircraft can reach its structural limits. This implies that you can snatch the stick full aft and not exceed the structural limits; however, any time you are rolling the aircraft or are at high gross weights, the g limits are lower, so be careful. In any event, the OWS is smart enough to allow for these factors. Also, observe the asymmetric load limits and stay below 30 units AOA if the imbalance exceeds allowable limits.

Sustained Turn Performance

The most significant limit on sustained level turn performance is thrust minus drag, or Specific Excess Power. Energy-Maneuverability considerations, discussed earlier, become important since we are dealing with dynamic maneuvering flight.

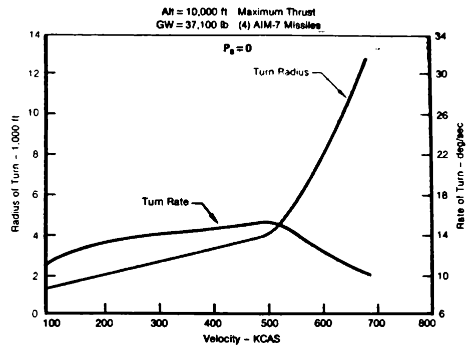
The chart in Figure 4 is similar to Figure 3, but with one significant difference: it is for sustained performance or $P_S=0$. This chart defines turn performance for a specific set of conditions (altitude, weight, and thrust). Generally speaking, a pilot wants the best rate possible without losing energy. Therefore, the area around 500 KCAS is best for this type of turn since the rate is maximized. The radius isn't a significant consideration since you are trying to turn as quickly as possible and still sustain energy. Unfortunately, this chart doesn't provide enough information to develop AOA guidelines.

Figure 5 is a pilot-oriented chart designed to more clearly explain optimum turn performance; it may appear slightly confusing initially, but with some explanation, should become quite clear. The chart is designed to be pilot-usable. The vertical axis is the g level read in cockpit, and the horizontal axis is angle of attack in units. The lines fanning out from the origin are airspeeds read on the A/S indicator and plotted across the airspeed lines are lines of $P_S=0$ for mil and max power.

From Figure 4, we determined that 500 KCAS is the speed for max sustained turn rate for the given conditions. If that's true, then the $P_S=0$ line for max power should reach almost 9 g's just above 500 KCAS on Figure 5, which it does. The effect of thrust on turn performance is clearly illustrated by the difference in sustained g between mil power and max power; in this case, a 3 g advantage in max power. The speed at which a given g level can be sustained can be thought of as an "ultimate" or "sustained" corner velocity. This is in contrast to classic corner velocity mentioned earlier where the aircraft can reach the maximum structural limits, but cannot sustain that g level. In fact, the "classic" corner velocity of the aircraft can be determined from this chart. The upper right hand corner represents the lowest speed (305 KCAS) that the aircraft can reach, but not sustain 9 g's.

By referring to the AOA scale, the exact AOA for a given speed and power combination can be determined for sustained turns. For example, at 405 KCAS, you can sustain 6 1/2 g's at 19 units in max power or 5 g's at 16 units in mil power. The best sustained turn points for a 37,100 pound aircraft are at 500 KCAS, 13 units at mil power for 5.8 g's and 507 KCAS, 16 units at max power for 8 g's. It is possible to draw lines of $P_S=0$ for an adversary aircraft on this chart and get an instant comparison to your own.

FIGURE 4 - F-15C TURN PERFORMANCE

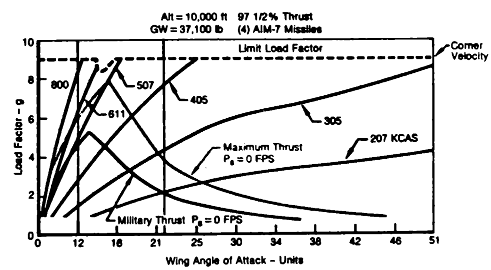


It's difficult for a pilot to remember precise values of AOA for all the combinations of speed and power settings. To make things easier, a range of AOA's that encompass most sustained turns can be determined by defining a range of airspeeds generally flown in air combat. You can, of course, pick your own speed ranges; but for the general case, 300 to 600 KCAS is reasonable. The range of AOA's that correspond to this speed range is 12-22 units. This is a fairly wide range and, with experience, you may want to shade it one way or the other, depending on the tactical situation. This range of AOA's will not give true sustained turn performance, but is a good "rule of thumb" guideline that will result in some energy gain or loss. For example, mil power at 22 units and 350 KCAS results in a loss of energy; and max power at 12 units and 450 KCAS will result in a gain.

Another guideline for sustained turns is the beginning of aerodynamic buffet. Since there are no lights, tones, bells, or whistles to tell the pilot when he is in the range of 12-22 units, the beginning of light buffet can be used as an approximate guideline to determine when you're in the 12-22 unit range. Table 1 is a summary of the AOA's at which various aerodynamic buffet levels begin. The distinction between light and moderate buffet is somewhat subjective, but the point at which light buffet begins is usually apparent.

Figures 4 and 5 are for 10,000 ft MSL; but since energy maneuverability is

FIGURE 5 - F-15C TURN PERFORMANCE



▶

TABLE 1 - BUFFET ONSET POINTS

Mach Number	AOA for Light Buffet	AOA for Moderate Buffet
.4	18 Units	22 Units
.5	18 Units	22 Units
.6	18 Units	22 Units
.7	18 Units	22 Units
.8	17 Units	20 Units
.9	14 Units	16 Units

FIGURE 6 - F-15C TURN PERFORMANCE

Alt = 20,000 ft 97 1/2% Thrust
GW = 37,100 lb (4) AIM-7 Missiles

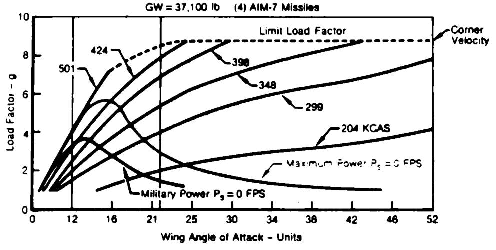
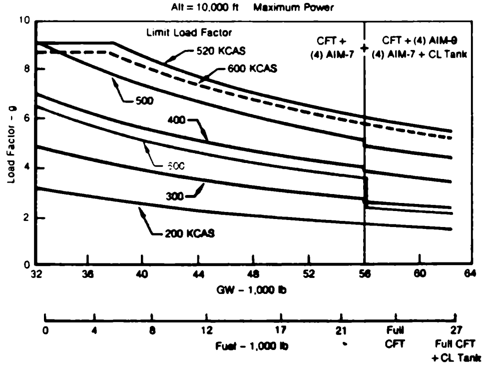


FIGURE 7 - F-15C SUSTAINED G CAPABILITY

Alt = 10,000 ft Maximum Power



dependent on altitude, what happens to this 12-22 unit reference at higher altitudes? Figure 6 is identical to Figure 5 but is at 20,000 ft. As expected, for a given power setting, the g capability is reduced. You can't sustain 8 g's, but can sustain 6 g's in max power. The range of 12-22 units, as shown on Figure 6, remains valid as a guideline at 20,000 feet, or for that matter, any altitude. The g's that the aircraft will sustain will be different. The point at which the aircraft will sustain the most g's at 20,000 ft in max power is at 424 KCAS, 16½ units AOA, resulting in 6.3 g's; and for mil power, 13½ units AOA, resulting in 4.4 g's at 424 KCAS.

The effects of weight are similar to the effects of altitude. The guideline of 12-22 units AOA still applies, but the g level that the aircraft can sustain will change. Figure 7 for max power and Figure 8 for mil power, show how sustained g will drop as weight increases. The vertical axis is the load factor or g level the aircraft will sustain, and the horizontal axis is gross weight; and for clarity, an additional scale shows fuel on board. To use the charts, enter with the gross weight (or fuel on board) and go up to the speed you are interested in and then across to read the sustained g level. If a diagram similar to Figure 5 were developed for a high gross weight, the AOA would still fall in the 12 to 22 unit range.

Since you may enter combat at speeds other than corner or sustained corner velocities, other lines on the charts illustrate the sustained g level possible for a given speed and weight combination. For example, a CFT-equipped aircraft weighing 52,000 pounds (17,000 fuel), in max power at 400 KCAS, can sustain 4½ g's, and at 40,000 pounds (7,900 fuel), 5½ g's. In any case, the guideline of 12-22 units still applies. The configuration of the aircraft has little effect on sustained turn performance; however, weight has a dramatic effect. The charts are for a CFT equipped aircraft, but apply to other configurations as well. Simply calculate the gross weight for your configuration and use that value rather than fuel on board to determine the sustained g.

Acceleration

What's the best technique for accelerating the F-15? The answer depends on what you are trying to accomplish, because the F-15 is somewhat unique with respect to acceleration characteristics. Aircraft accelerate best when the total drag on the aircraft is at a minimum. This usually occurs for most fighters at the point where the wing isn't generating lift, which happens when the flight path is near ballistic and the g load is approaching zero. However, with the F-15, minimum drag does not occur at zero lift. The reason for this is its sophisticated wing camber design, in which the F-15 wing can be thought of as having a leading edge flap that is permanently extended to meet a design requirement to sustain high g's at high altitudes.

Precise values of AOA can be determined for use as a guideline to accelerate at minimum drag: below 1.2 Mach, 8 units, and above 1.2 Mach, 9 units, results in minimum drag. In the range of .4 to 1.0 Mach, 8 units AOA will be at 1 g or slightly less; but at higher Mach numbers and lower altitudes, 9 units AOA results in a 2 to 3 g turn. Rather than attempt to fly precise values of AOA, a more reasonable method is to pick a range of AOA which will result in a slightly longer time to reach a given speed or energy level, but allows the pilot to initially set the AOA in a range and then pay attention to the target. The range of 5-10 units represents a reasonable compromise.

One final point: the F-15, like other aircraft, will accelerate downhill using the added acceleration from gravity. However, because of the wing design, the F-15 gains less from pushing over during an acceleration than do most fighters, so don't spend a lot of time going downhill. Depending on the tactical situation, level off or climb back to Eagle country!

Cruise and Holding

To wrap all this up, guidelines can be developed for best cruise and best loiter. Since the AOA reference for best cruise or loiter is nearly constant for all altitudes and weights, it can be used in place of airspeed. For max range cruise, the numbers work out such that 12 units gives the best range; and for holding, 14 units gives the minimum fuel flow for max endurance.

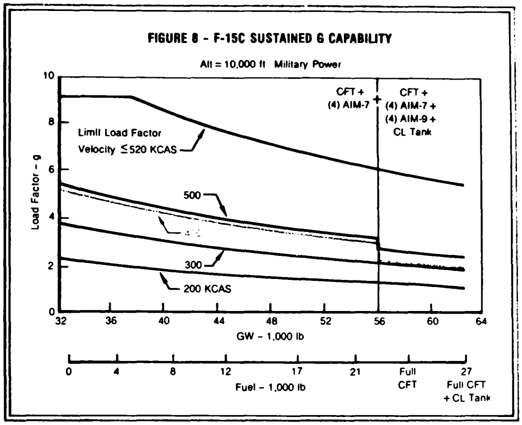


FIGURE 8 - F-15C SUSTAINED G CAPABILITY

In summary, you might want to tape the following information to your kneeboard for quick reference during those moments of doubt... Sustained turn performance is generally in the range of 12-22 units AOA; and maximum performance turn guidelines are the stick stop or g limits (whichever occurs first). For acceleration at minimum drag, use 8 units below 1.2 Mach, 9 units above. Best cruise is at 12 units and best endurance is at 14. While these guidelines are unique to the F-15, similar charts can be developed for any aircraft and associated guidelines determined.

F-15 "ON THE ROAD" Briefing-Status Report

You have just finished reading the first installment of a promise I made to many F-15 pilots during my initial round of Eagle briefings last year. This article on turn performance is based upon presentations of that subject during the briefings; and articles on out-of-control/spins, conformal fuel tanks, engines, and other topics will follow (if I can find time between trips to do the writing). Our goal is to publish one article in each issue of the DIGEST, until we have made available in "hard-copy" form all of the data provided in our personal visits to operational units. Also, Volume II of "EAGLE TALK" is in work and should be available later this year.

The second round of F-15 briefings (or "Road Shows," as they have come to be known) was kicked off at McChord AFB, Washington earlier this year. This series of presentations contains extensive new material as well as revisions and updates of some of the old standbys, such as engines and out-of-control/spins. New information is included on the brakes/anti-skid system, hot brakes, CFTs, and the JFS. New engine performance data has been added to the turn performance segment. The discussion on ballast has been condensed and the section on OWS is now more relevant to the operational world. Incidentally, a new dimension was added to the program when I began flying with the units during my visits. This has proven beneficial to both TAC and MCAIR as it is helping keep us up-to-date on F-15 operations and should lead to better aircraft - now and in the future.


GLEN.G. LARSON

Glen Larson has been a test pilot with McDonnell Aircraft Company since 1979. In addition to briefing F-15 units worldwide, he flies the F-15 Eagle and F/A-18 Hornet in test programs such as the F-15 DRF and F/A-18 follow-on testing.

Glen has been flying fighters since 1971 and has logged over 2800 hours in military and contractor flight operations. He flew 220 combat missions in the F-4 in Southeast Asia with the 8th Tactical Fighter Wing and still flies Phantoms with the Missouri Air National Guard.

His academic background includes a BS in Aeronautical Engineering from the University of Wyoming and a Master's degree in Business from the University of Utah. He is a member of the American Institute of Aeronautics and Astronautics and the Society of Experimental Test Pilots.

Looking back over what has been an exceptionally busy year of almost constant travel, I can't recall a period in my life which has been more personally challenging and rewarding. And I look forward to the prospect of seeing many of you again this year to continue our discussions about Eagles.

Our schedule for "Road Show II" is totally flexible. We will be happy to respond to requests from F-15 units anywhere in the world for the entire series of briefings (allow two days) or for any specific subject. In the meantime, if you have any questions, give us a call at (314) 232-3456; and if you're in St. Louis, be sure to stop by and say "hello." ■

STALLS, SPINS, an

Angle between aircraft and contrails in this photograph taken during Category I spin test program several years ago dramatically illustrates high angle of attack capabilities of F-15.

An article of the length and detail of this one and which addresses such a complex subject requires a great deal of assistance from the engineering community. Special thanks are due to several individuals who were key contributors to what you are about to read. Jack Krings, currently Director of Marketing for Navy and Marine programs in Washington, D.C., flew the original F-15 spin tests and deserves special credit for his pioneering effort in the program. Dave Thompson, Director of Program Engineering for the F-15E; and Clarence Mongold, Branch Chief, F-15 Aerodynamics, were of invaluable assistance. Extra recognition goes to Pat Wider, Lead Engineer, F-15 Aerodynamics, who patiently reviewed multiple rough drafts for engineering accuracy. These gentlemen made this article possible; and they, along with the rest of the MCAIR team, have produced the finest flying fighter in the world.

Aircraft loss of control and spins have been with us since shortly after the Wright brothers' flight at Kitty Hawk and by 1916, spins had become fairly common events. For a while, they were used as defensive maneuvers in air combat, but as such were of limited value; an attacker simply waited for his target to recover and then resumed the attack. Aircraft design theory evolved to more modern designs and for the first time, pilots encountered the flat spin which proved difficult to stop. Aircraft with weight concentrated in the fuselage (such as the century-series fighter) will flat spin, and also exhibit some exciting gyrations during spin entries.

Spins should not be feared - understood and respected, yes, but not feared. Our purpose here is to impart some general understanding of loss-of-control and spins and, specifically, how the F-15 behaves during high-angle-of-attack flight. The F-15 has successfully demonstrated numerous spins and spin recoveries. The spin characteristics are well known; and with sufficient altitude, the recovery procedures are reliable - there aren't any deep dark secrets or hidden surprises.

Spins in any aircraft share some common characteristics. For example, spin entries at high speeds will be more violent and spins entered at high gross weights tend to be higher-energy spins from which it takes longer to recover. Also, the character of a spin entered at 40,000 feet doesn't differ significantly from one entered at 20,000 feet. Current generation aircraft such as the F-15 have design features that make it difficult to spin. If you do manage to enter a spin, other design features make recovery easier.

The F-15 flight control system is designed to provide comfortable, predictable response throughout the flight envelope; and the aerodynamics provide honest, straightforward handling characteristics. Directional stability remains positive at any angle of attack normally attainable in flight, which makes entering spins difficult. In addition, the control system has features that prevent inadvertent pro-spin inputs at high angles of attack. As a result, it isn't necessary (as it was with other systems) to "fly with your feet" when at high AOA. The F-15 system lets the pilot do what comes naturally - fly with the stick. Nothing magic about it. The mechanical flight controls simply blend rudder and aileron together to provide coordinated flight using very little rudder at low angles of attack, but rudder almost exclusively at high AOAs.

Rudder rolls are really uncoordinated maneuvers. Some aileron is needed during a rudder roll; but in the heat of battle, it's tricky to use just the right amount of aileron. Using too much aileron can result in adverse yaw which can lead to a departure. Your flight control system blends the proper amount of aileron and rudder for relatively coordinated flight during all flight conditions. The system doesn't eliminate aerodynamic phenomena such as adverse yaw or the dihedral effect (roll due to yaw); it uses the dihedral effect to your advantage and keeps adverse yaw under control.

To help understand the complex world of high-AOA flight, we need to establish some definitions for a common frame of reference; review the causes of departures/spins and autorolls; as well as briefly explore aerodynamic, kinematic, and inertial coupling.

DEFINITIONS

Exactly where a stall occurs in a modern high-performance aircraft is difficult to determine. In some older

By GLEN LARSON/*Senior Experimental Test Pilot*

AUTOROLLS

fighters, a stall is an exciting event. The AOA gets high enough that as the wing quits producing lift, directional stability breaks down and yaw rates can develop rather quickly. As a result AOA limits are often imposed in an attempt to prevent departures or spins. These are artificial limits, since high AOA isn't the source of the problem. The real cause is the breakdown in directional stability, which makes the aircraft susceptible to developing a yaw rate. However, a stall in an F-15 is a "non-event." It's not possible to exceed the point of maximum lift (i.e., the "classic" stall) even with full aft stick. A stall is characterized by moderate wing-rock and buffet and a high sink-rate. Accelerated stalls behave much the same way, assuming a symmetrically-loaded airplane. The most important thing is that total directional stability remains positive.

Departure and out-of-control aren't as easily defined. As an aircraft progresses from controlled flight to a spin, several events occur. For the purposes of this discussion, we will use operationally-related definitions of out-of-control and departure. Simply put, out-of-control is the point at which the aircraft no longer responds in pitch, roll, or yaw to pilot inputs. With this definition, it's possible to be out of control for some time before actually departing since we define departure as the point where the aircraft flight path changes drastically from the expected. In case there is any doubt; if the yaw-rate tone is steadily beeping, the aircraft has departed.

Causes of out-of-control or departure can be the result of a combination of circumstances. Traditionally, a spin is encountered after increasing AOA to the point that directional stability is weak enough that a yaw rate develops. As AOA increases, the aircraft will stop responding since the controls will lose effectiveness. If directional stability is weak, a yaw rate will develop and the aircraft will seem to have a mind of its own. At this point, you are not necessarily in a spin. You *have* departed controlled flight since the aircraft is doing something you didn't command, but it hasn't necessarily entered a spin. Generally speaking, neutralizing the controls at this point will allow the aircraft to fly itself out. This phase of flight between a departure and a spin can be very brief, depending on the dynamics of the maneuver. The gyrations the aircraft goes through in this phase can be mild or eye-watering, depending on speed or energy level at departure.

The first of two spin modes encountered by the F-15 is the oscillatory mode which, as the name implies, exhibits large variations in pitch, roll, and yaw. You can expect to see ±30° pitch oscillations, some bank oscillations, and yaw-rate hesitation with intermittent spikes as high as 100°/second. The good news is that this mode is generally recoverable with neutral controls, but may take some time and altitude to recover.

The second spin mode is the flat spin, also referred to as a "smooth" spin. A flat spin has very little oscillation in any axis and the yaw rates will be fairly steady (generally higher than in the oscillatory mode - somewhere in the neighborhood of 66° to 130° per second). These high yaw rates can result in "eyeballs out" g-loads of 1 to 4 g's, which is uncomfortable to say the least. During the spin test program, at least three-dozen flat spins were performed, all of which recovered with full anti-spin aileron and stabilator. It's not necessary to first be in an oscillatory spin to develop a flat spin; under certain circumstances, the aircraft will go directly into a flat spin. Inverted spins were also tested and found to recover with neutral controls.

DEPARTURES AND SPINS

The contributors to spins and out-of-control conditions can be divided into major and minor categories. A significant contributor can be flight control inputs, even though the flight control system is designed to control adverse yaw or other inputs that can induce yaw rates at high AOAs. During the spin test program, it was necessary to "trick" the control system in order to enter a spin. It's also possible to trick the system during ACM and apply pro-spin controls inadvertently. If, for example, in a hard or "break" turn, the aircraft rolls out on its own (perhaps due to weight asymmetry or something else), the natural reaction is to unload and counter the roll with opposite stick. If the stick is near neutral when applying aileron opposite the roll, the result will be yaw away from the stick input and is in the same direction as the yaw that was present with the initial uncommanded roll. This combination is pro-spin. Don't misunderstand this discussion as meaning that you're going to instantly spin out of a hard turn. That's not true, but pay attention to what the airplane is telling you. Any uncommanded motion is cause for neutralizing the controls and taking a few seconds to see what's going on.

During the spin test program, the "trick" used to enter a spin was to pull into high AOA, develop some sideslip and yaw rate with rudder, then suddenly move the stick to neutral and apply full opposite lateral stick while AOA was still high. This action, in effect, bypassed the aileron washout feature and the technique was successful in getting into a spin about 50% of the time. Power settings and longitudinal c.g. position have relatively minor effects on departures and spin recoveries. The flight conditions, altitude, and Mach number were also players, but of relatively small consequence.

AOA, on the other hand, does have some importance. Generally, as AOA increases, directional stability decreases; but as long as the dihedral effect remains strong, there's no problem. In the range of 30-35 units, the static directional stability has gone to zero or less, but the dihedral effect is very strong. Static directional stability and dihedral effect make up the total directional stability of the aircraft. In the 40-45 unit area, the dihedral effect contribution to stability is reduced but still positive; and since the static directional stability has gone negative, total directional stability is weakest. It's difficult to quantify this reduction in stability in pilot terms, but the important thing is that the total directional stability is still positive; whereas in earlier century-series fighters, total directional stability went to zero or negative at high AOA. Any time directional stability is reduced, the airplane ►

is more subject to developing sideslip and yaw rate. The source of this yaw rate can be pilot input, inertial coupling, or anything that causes the nose to move sideways.

Aircraft configuration also has some effect on departure resistance. When the aircraft is flown with centerline tank only, the total directional stability is slightly reduced, resulting in lower departure resistance. When loaded with wing tanks, the directional stability is essentially the same as a clean airplane, but the longitudinal (pitch) stability is slightly reduced. The biggest contribution that the airplane makes to loss of control at high AOA is in lateral c.g. or lateral weight imbalance.

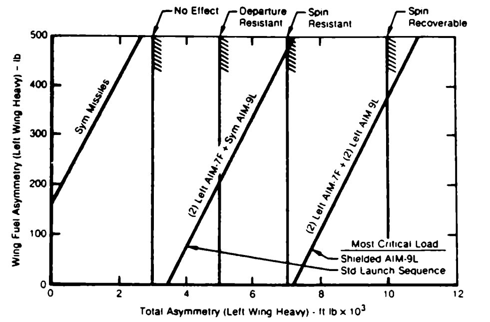
LATERAL ASYMMETRY

The airplane will probably always be out-of-balance laterally to some degree; therefore, limits need to be established because the flight characteristics can change dramatically as a function of asymmetry. The aerodynamic characteristics of asymmetric external loads have little effect on the departure resistance of the F-15; weight is the big factor. Incidentally, this lateral c.g. shift affects *all* aircraft. Since fighters carry wing tanks and bombs/missiles on the wing, they are subject to the effects of a lateral c.g. shift caused by weight asymmetry. I suspect that many F-4 stall/spin accidents may have been due to a large weight imbalance, either fuel or wing stores. (Experience in Southeast Asia with the F-4 bears this out. Large weight differences between left and right bomb loads were not uncommon.)

The Category II test program determined that operational loadings of up to 10,000 foot-pounds were acceptable, although the handling qualities at high AOA were somewhat degraded. The limit of 5,000 foot-pounds was recommended for training in order to avoid degraded handling qualities. Testing has shown that with an asymmetric load of 5,000 foot-pounds, the aircraft is still very departure resistant. Above 10,000 foot-pounds, departure susceptibility increases to the point that fully-developed spins can be generated in as little as 3 to 4 seconds with only full-aft stick.

Since 5,000 foot-pounds may not mean much to you, let's put it in terms of equivalent loadings. The rolling moment in foot-pounds is calculated by multiplying the distance from the centerline to where the weight is located times the weight. If the external load is balanced, 650 pounds of internal wing-fuel imbalance equals 5,000 foot-pounds (650 pounds times the 7.7 foot distance from centerline equals 5,000 foot-pounds). With two

FIGURE 1 - LATERAL ASYMMETRY DUE TO WING FUEL AND MISSILES



AIM-7s on one side, only 200 pounds of internal wing-fuel imbalance is needed to add up to 5,000 foot-pounds. In any case, below 30 units AOA, the aircraft will generally not depart at any level of asymmetry. That's where the 30-unit Dash One limit comes from when the internal wing fuel imbalance exceeds 600 pounds (200 pounds for imbalanced missile loads).

Figure 1 is a graphic representation of the preceding discussion. The horizontal axis is total asymmetry in thousands of foot-pounds; the vertical axis is internal wing fuel imbalance, left wing heavy. The divisions defining the points of departure, resistance, spin resistance, etc., are based partly on test data and partly on analytical data. Configurations up to one full external wing tank were evaluated up to 30 units for stalls and departure susceptibility.

The departure characteristics of a symmetrically loaded airplane are relatively straightforward. There's adequate warning in terms of buffet and wing-rock; but for an asymmetric load, these warnings may be reduced, and the first indication of departure may be the departure warning tone. If you don't back off (reduce AOA) at the first warning tone, the next event could be a fully developed spin - especially with a large asymmetry.

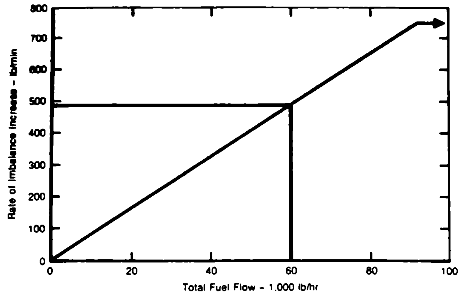
Just because you begin an ACM engagement with balanced internal wing fuel doesn't mean you can't get into trouble. Figure 2 shows how quickly an imbalance can develop if one of the wing fuel transfer pumps fails. Total fuel flow in thousands-of-pounds per hour is on the horizontal axis, and rate of wing fuel imbalance in pounds per minute is shown on the vertical axis. For example at a fuel flow of 30,000 pounds per hour per engine, the imbalance will increase at a rate of 480 pounds per minute, which means that after a two-minute engagement in burner, the imbalance will be 960 pounds (equating to nearly 7,400 foot-pounds of asymmetry). Asymmetry can ruin your whole day by quickly putting you in a high-rate flat spin, which will require a great deal of altitude to recover.

RECOVERY PROCEDURES

The recovery procedures in the Dash One were developed to cover all out-of-control/spin events in a logical and rational manner. At the first sign of an out-of-control condition (the airplane quits responding correctly to your inputs), neutralize the controls and let the basic stability of the airplane straighten things out. If the aircraft fails to recover, it may be in an autoroll or a spin; the next step is rudder opposite the roll direction which is the best recovery from an autoroll (more on autorolls later). It really doesn't matter if you misidentify a rolling departure as an autoroll since the rudder is the appropriate control to reduce sideslip and yaw rate (assuming you use the correct rudder). Rudders alone have little effect on getting in or out of spins. A word of caution here: *don't use aileron opposite the roll in an autoroll or rudder roll.* That's one of the quickest ways to enter a spin!

During any out-of-control event, listen for the departure warning tone as it's designed to give you specific warnings. It first comes on at 30°/second yaw rate. Except for autorolls, it was

FIGURE 2 - RATE OF WING FUEL IMBALANCE (ONE WING TRANSFER PUMP INOPERATIVE)



found during testing that the airplane would always self-recover if the pilot neutralized the controls at yaw rates of 30°/second. Above 60°/second, the "beep" rate of the tone reaches a maximum and positive pilot action (anti-spin controls) will probably be required to recover. The control augmentation system (CAS) is shut down at 42°/second yaw rate to prevent pro-spin CAS inputs and the spin-recovery mode is engaged at 60°/second, allowing full aileron/stabilator deflection regardless of fore and aft stick position. If the beep rate has reached a maximum, you're probably approaching (or are in) a fully-developed spin. The last step in the procedure - lateral stick full in direction of yaw - requires a bit of thought. Spend a few seconds determining which way you are spinning before putting in any aileron. (In fact, any time the departure warning tone is on, be very careful with aileron - especially with the stick near neutral longitudinally.)

The best way to recover from a spin is to decide which way you're spinning, put the aileron in the correct direction (the wrong way accelerates the yaw rate), and *wait*. It can take up to 10 seconds (and two turns) before any change in yaw rate is noticeable. Be patient, you may not be able to detect any change in yaw rate until just before recovery. The exact time-to-recover depends on several variables. If the yaw rate hasn't exceeded 60°/second, you need to have the stick centered fore and aft or you won't get full aileron deflection and recovery will take longer. Large weight asymmetry will lengthen the recovery time, as will cycling the recovery controls in and out. Finally, if you're still spinning at 10,000-feet AGL, get ready to eject because there probably isn't enough altitude left to recover.

During the recovery phase of a flat spin, the aircraft will remain in a fairly flat attitude until the yaw rate stops. The nose will then drop, sometimes past 90°, to a slightly inverted position. At this point, it's much like the recovery from a tail slide. The airplane will do a couple of rolls while regaining flying speed. These are rolls due to sideslip, *not* autorolls.

AUTOROLLS

The autoroll is a special case and is one of the most misunderstood phenomena in the F-15. The autoroll is not unique to the F-15; other aircraft, such as the F-111, autoroll very easily. An autoroll can be stopped with very little energy or altitude loss; but before discussing recovery, let's review the causes of autorolls. The technical reasons are a little deep, but an autoroll can consistently be entered from a specific set of flight conditions and control inputs:

- Airspeed in the 200-300 KCAS range
- 20-30 units AOA
- Roll and yaw initiated with a rudder input
- Relaxing of aft stick to induce coupling

The aerodynamics of all this are complex. The first principle is the dihedral effect which causes the initial roll due to yaw; then easing of aft stick inertially couples pitch and roll to produce a yaw acceleration. During an autoroll, the airspeed is well above the stall speed and the AOA is held in the 20-30 unit range through inertial pitch coupling. The roll rate will be pretty fast, approximately 150°/second, and the flight path will be ballistic.

During the entry to the autoroll, inertial coupling will appear to the pilot as an increase in the roll rate as the stick is eased forward. Although the primary motion apparent to the pilot is roll, there is a yaw rate present (around 30°/second). The yaw rate warning tone may be on or off during the autoroll. The CAS aileron rudder interconnect gets in the act during the entry phase because it works as a function of AOA and roll rate and applies rudder to coordinate the roll. This rudder deflection is in the direction to get into an autoroll, but fades in a few seconds and *will not* keep the aircraft in an autoroll. If friction in the rudder cables is high, the rudders will tend to stay slightly deflected in the direction of the roll and that *will* tend to keep the autoroll going. An aircraft with little or no rudder friction or rudder displacement from whatever cause will not stay in an autoroll. In any event, it's easy to recover.

The best way to recover from an autoroll is to apply *rudder* opposite the roll. Technically speaking, the rudder is being applied to eliminate the sideslip, however, it's easier for the pilot to determine roll direction, so referencing recovery procedures to roll direction makes more sense. As soon as the roll stops, neutralize the rudder and be ready to come in with a little aft stick to counter the "nose tuck" that follows. This nose tuck is very mild and is caused by inertial coupling.

Other recovery techniques do exist, but are of academic interest only. For example, doing nothing at all will work. An autoroll will eventually stop, depending on rudder cable friction. Time and altitude loss may be excessive, therefore this technique is not recommended. Moving the stick fore or aft may possibly work through coupling, but isn't recommended since it doesn't directly affect the yaw rate and can lead to extreme AOAs. Aileron applied *with* the roll (an unnatural tendency) will break the autoroll phenomenon, but the transition from an autoroll to an aileron roll is impossible to detect. Aileron against the roll (normal reaction) is *definitely not recommended* since it is a pro-spin control and it is possible to get into a spin in as little as three or four seconds. There is plenty of warning from the departure tone and aircraft motion that things are going from bad to worse.

Aircraft configuration has no effect on getting in or out of autorolls. Weight asymmetry doesn't affect autoroll entry or recovery, but does make it easier ▶

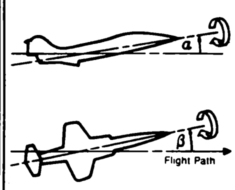
to spin out of an autoroll if the wrong recovery technique is used. Warnings are somewhat reduced so your best indication that things are getting worse is the departure warning tone.

COUPLING

Several times I've referred to aerodynamic and inertial coupling, both of which are complex phenomena. The good news is that coupling can be reduced to some fairly simple concepts. The term "coupling" simply refers to the response of the aircraft about one axis due to a disturbance about another. An example of uncoupled aircraft motion is the response of the aircraft to the stabilator. Pulling aft on the stick in straight and level flight causes a collective motion of the stabilator, resulting in a nose-up motion. The pilot has commanded a pitch motion, and only a pitch motion has resulted. An example of a coupled aircraft motion is the combination of roll and yaw that results from rudder deflection. The pilot has commanded a yaw with rudder and the aircraft also rolls. This particular type of aerodynamic coupling is the dihedral effect.

"Kinematic" coupling occurs if an aircraft is rolled rapidly about the longitudinal axis, as shown in Figure 3. What was AOA (α) becomes sideslip (β), triggering roll due to yaw. Aircraft don't roll purely about their longitudinal axis, so the results are mixed with inertial coupling. To understand inertial coupling, imagine an aircraft represented by a system of weights, as shown in Figure 4. The fuselage is represented by large masses near the nose and tail, the wing by smaller masses near the wing tips. If the aircraft is rolled rapidly about the flight path (velocity vector), the masses in the fuselage will overpower the

FIGURE 3 - KINEMATIC COUPLING



smaller wing masses and will pull the nose and tail away from the flight path. This is an example of roll coupling into pitch and is dominant at high speeds, and is the reason many fighters are prohibited from continuous 360° rolls. (A more in-depth explanation of this whole subject is presented in an article titled "Whifferdills, Divergences, and Other Roll Coupling Phenomena" by MCAIR project test pilot Larry Walker in DIGEST Issue 6/1979.)

There are some important things to understand about coupling:

- Aerodynamic, kinematic, and inertial coupling never operate independently.
- It's very difficult for a pilot to judge what degree or type of coupling is present.
- It's possible to get away with a coupling-prone maneuver several times; but on the next one, you could break the airplane.

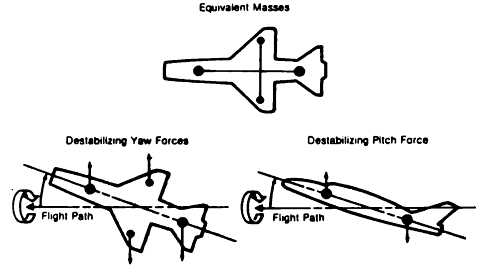
Every airplane in the world is subject to coupling to some degree, and several examples of coupling were encountered during the F-15 spin test program. Other than entering from an autoroll, they were successful in generating a spin with a clean configuration aircraft only 50% of the time. Occasionally, instead of spinning, the aircraft was inadvertently inertially coupled into a maneuver that saw g-excursions of up to +9 g's.

Another maneuver subject to coupling is a negative g "guns jink-out" (rapidly moving the stick forward and to the right or left corner). You're walking on the ragged edge with this maneuver and if the aircraft couples up, it'll water your eyes. At high speeds, structural damage is a very real possibility and at lower speeds, out-of-control may result. These things won't happen every time, so be careful and remember that the stick doesn't have to be against the forward stop to trigger coupling.

A third and probably the most significant example of coupling is the spin itself. Without inertial coupling, the F-15 couldn't spin. As in the autoroll, simultaneous yaw and roll rates inertially couple with the pitch axis, preventing a reduction in AOA. Reducing the yaw rate with recovery controls lessens the magnitude of the coupling, allowing the nose to drop.

The world of departures, spins, autorolls, and coupling is a complex one. However, total understanding of the dynamics of it all isn't necessary; an awareness of the causes (conditions/configuration) is desirable, but the most important point of this discussion is to pay attention to your airplane. It will "talk" to you and by its response (or lack of response), tell you how it feels about what's going on. The Eagle is the most stable and forgiving fighter ever built; but it can change character rapidly and become downright unpleasant if you don't pay attention to what it is telling you!

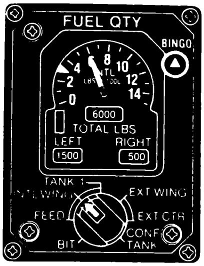
FIGURE 4 - INERTIAL COUPLING



Please note: My article "Angle of Attack and Turn Performance" in the last issue of the DIGEST contained two inadvertent errors. The first one is relatively minor - the text referring to Figure 7 equates a gross weight of 52,000 pounds to 17,000 pounds of fuel, which should actually be 19,000 pounds of fuel. The second error is a little more interesting. Figure 6 and the other similar figures were originally calculated for full thrust or 102% thrust engines, and the text indicating that the aircraft will sustain 6.3 g's at 20,000 ft was based on the original charts. Later, to make the charts more relevant, they were redone to the 97½% thrust level, but not all the text got changed. (Murphy strikes again!) The correct numbers can be read from the charts and the sustained g-point at Max power is 16 units and 5.6 g's, and at Mil power, 12 units and 3.5 g's. ■

WING-FUEL IMBALANCE

By GLEN LARSON/*Senior Experimental Test Pilot*



A large wing-fuel imbalance can ruin your whole day by making it easier to get into a high yaw rate flat spin due to degraded high-AOA handling characteristics. The causes of these imbalances can be traced to sources such as the fuel/oil heat exchanger, a failed transfer pump, indicator malfunctions, and others.

The malfunction that will cause an imbalance to develop the fastest is a failed wing transfer pump. The rate at which an imbalance will develop is dependent on total fuel flow. (A rough guideline is one-half your total fuel flow.) For example, on a cross-country, total fuel flow is in the 5500 pounds per hour range, and an imbalance caused by a failed transfer pump will develop at the rate of 2750 pounds per hour or 46 pounds per minute. In ACM, where 60,000 pounds per hour isn't unusual, the rate is 500 pounds per minute. The rate will also be affected by a failure of one of the three electrical phases that power each pump. The failure of one phase is, in effect, a partial pump failure and may result in asymmetrics of 400 to 500 pounds.

A transfer pump failure can be insidious. If you have external tanks, they will transfer to any internal tank that will accept fuel; therefore, it's impossible to detect a failed wing transfer pump by reference to the fuel gauge until the externals are dry. An imbalance that becomes apparent during ground operations may be normal and the result of something other than a transfer pump failure. For example, if the aircraft isn't reasonably wings-level during refueling, one internal wing tank may not fill completely. An internal wing-fuel imbalance on the ground is not necessarily a valid indication of a transfer system problem.

The heat exchanger can cause a wing-fuel imbalance due to a failed thermal bypass valve. This valve is designed to control the fuel recirculation to the wings as a function of temperature. It's designed to begin opening at a fuel temperature of 185°F and is fully open at 200°F. These valves do not require any power source, and the predominant failure mode is loss of calibration resulting in incorrect temperature scheduling. The result is that the valve on one side isn't opening

If you find yourself in an airplane with a large fuel asymmetry, stay below 30-units AOA and you won't have any problems. Testing has shown that the aircraft is departure resistant at any level of asymmetry as long as you stay below 30 units.

and closing at the correct time, which will cause an imbalance. If one valve was fully open and the other closed, the imbalance would develop at a rate of 30 pounds per minute; however, the actual rates are somewhat less since it's unusual for one valve to be failed fully open while the other remains closed. Since the functioning of these valves is dependent on fuel temperature, imbalances will tend to develop at low total fuel flows since that is where fuel temperatures will tend to be higher. Presently, the only way to fix a failed thermal valve is to remove the heat exchanger.

Another source of imbalances can be malfunctioning level control valves. A problem with these valves will usually become apparent at low power settings (low transfer rates), and the rate of asymmetry development is relatively slow. All aircraft have been modified with what are known as "snap action" level control pilot valves. These allow the feed tank fuel level to decrease (about 150 pounds) before "snapping" open to refill the tanks. This has the effect of ensuring that both wing transfer pumps will transfer fuel to the feed tanks by creating adequate volume in the feed tanks to accept fuel.

One of the often overlooked sources of asymmetry is the fuel gauging system. At times, due to intermittent grounding and loose wires or grounding between the inner and outer probes in the tank, a sudden asymmetry may appear to develop. Normally, this would appear during acceleration, deceleration, or heavy maneuvering. In any case, troubleshooting for any asymmetry problem should begin with the fuel gauging system.

The fuel system should maintain an imbalance of no more than 200 pounds, if operating correctly. The wing transfer pumps have "trimmer" valves installed to match output pressures at transfer flow rates. Current "Dash One" procedures allow an asymmetry of up to 600 pounds with a balanced external load; however, if the asymmetry consistently exceeds 200 pounds inflight, write it up since there is a problem somewhere in the system.

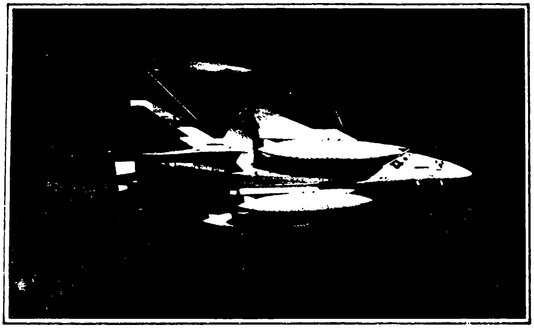
If you find yourself in an airplane with a large fuel asymmetry, stay below 30-units AOA and you won't have any problems. Testing has shown that the aircraft is departure resistant at any level of asymmetry as long as you stay below 30 units.

Clear, concise write-ups are essential to getting a fuel imbalance problem solved. Maintenance needs to know exactly when the imbalance appeared and how quickly it developed. If time and workload permit, a chronological record of the fuel readings will help trace the problem, and a short discussion of your flight conditions prior to noting the imbalance will also be helpful. All of this information will help maintenance get your Eagle fully mission capable as soon as possible. ■

As was the case in my previous DIGEST articles, the two discussions you have just read could not have been developed without the assistance of the MCAIR engineering community. Jim Pousson, Lead Design Engineer, and Walt Beck, Design Specialist, supplied invaluable technical expertise on the F-15 fuel system. Bill Bath, Lead Engineer in the Systems Safety group, is due special recognition for his technical and operational advice in the flight safety aspects of fuel system problems.

FUEL LEAKS

By GLEN LARSON/*Senior Experimental Test Pilot*



Fuel leaks in the F-15 are infrequent, but the potential for losing your entire fuel load in just a few minutes does exist. (In fact, not long ago an F-15 flamed out approximately 20 minutes after takeoff because of a massive fuel leak.) While the magnitude of a leak can range from very minor to severe, it usually can be controlled by following checklist procedures. Before getting into causes and corrective actions however, we need to review the basic layout of the fuel system.

Figure 1 is a simplified sketch of the F-15 fuel system. The left side represents the feed tanks and the components on the right side of the diagram lead to the engines, which are just downstream of the fuel flow transmitters. The various components located in the feed tanks aren't of much interest since a leak in that area isn't a threat to your fuel supply. The plumbing, external to the tanks and located in the heat exchanger and engine bays, is the main area of concern. Figure 2 is a photograph of the plumbing from the heat exchanger and airframe mounted shut-off valve to just before the fuel flow transmitter. (Because these components are located in an area that is difficult to photograph, we assembled the various parts on the hangar floor so you could clearly see what the components actually look like.)

The fittings highlighted on Figures 1 and 2 are Wiggins couplings that connect the fuel/oil heat exchanger and the airframe mounted fuel shut-off valves to the plumbing. These couplings are very reliable, but if incorrectly reassembled during maintenance, leaks can result. Your primary indication of a leak is a rapid, unexplained decrease in fuel quantity. Although a better indicator would be fuel streaming from the fuselage, it won't always be visible from the cockpit, and your wingman (if you have one) may not be able to see the fuel vapor at night or in heavy weather. As usual, there's a "gotcha" –failures within the indicator or quantity measuring system may indicate a fuel quantity decrease without actual fuel loss. In most cases, your wingman will be able to confirm the actual presence of a leak; but, single ship, at night, in the weather, you can't tell if it's real or not. Your best bet is to head for the nearest suitable base.

The flight manual contains two emergency procedures to control fuel loss. Which one you use depends on where the fuel is being lost. If it's coming from the wing dump masts, then the procedure for UNCOMMANDED FUEL VENTING (pages 3-22 and 23 in TO 1F-15A-1) is the one to use. This procedure will stop the loss of fuel through the plumbing to the wing masts, which are actually vent (both sides) as well as dump masts (right side only). Fuel loss from both sides indicates a fuel system pressurization or transfer malfunction, and the loss rate will be less than the maximum fuel dump rate of about 900 pounds per minute. This procedure will usually stop fuel loss through the vent/dump masts, whatever the cause, including failure of the dump system to stop when you turn the switch off. Remember that your feed tank fuel (about 2700 pounds) will never be lost through the wing vent/dump masts, even if the dump system can't be shut down for some reason, since fuel in the feed tanks can't be dumped. Fuel loss through the vent/dump masts is at a low enough rate that you should have enough time to sort things out and get to the nearest base or tanker.

Potential for massive fuel loss exists in the plumbing to the engine bays. The fuel lines from the feed tanks to the engines are capable of sustaining flow rates of over 100,000 pounds per hour, which can deplete your entire internal fuel load, including feed tanks, in about eight minutes. Fortunately, loss rates of that magnitude are rare and, while exact rates are difficult to predict, will generally not exceed 20,000 pounds per hour except for a catastrophic failure.

The most likely source of a massive leak in the plumbing is the Wiggins fittings and the loss rate depends on how loose the fitting becomes. Little maintenance is required in these areas except for the fuel/oil heat exchangers, which are often changed as a result of internal wing-fuel imbalances. Some other causes of an imbalance could be a failed wing transfer pump or other components within the fuel system, which are discussed briefly in my accompanying article. Removing and reinstalling the heat exchanger is difficult; if one of the Wiggins fittings is incorrectly reassembled, a massive, uncontrollable leak can result.

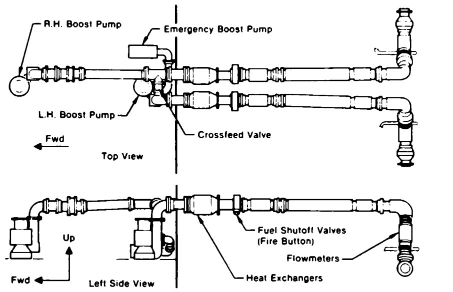
The flight manual procedures for IN-FLIGHT FUEL LEAK (page 3-23 in TO 1F-15A-1) recommends *increasing* airspeed to maximize your range. Don't confuse this situation with the traditional concept of slowing down to maximum endurance speed to conserve fuel. The idea here is not fuel conservation - the fuel is running out the bottom of the airplane anyway so you might as well use it to get to the nearest airfield. *And remember the warning which tells you not to use afterburner to get home.* Lighting the afterburner will almost certainly ignite any fuel leaking from the fuselage.

The most difficult part of the procedure is deciding exactly which side of the aircraft is the source of the fuel loss. Referring to Figure 1, if fuel is being lost downstream in the engine plumbing, for example, then the associated fuel flow indicator would show a higher than normal fuel flow. Since the fuel flow transmitters are located downstream of the heat exchangers and because of the relatively high pressure in the lines, the fuel flow indicators won't be much help if the leak is upstream of the transmitters - the readings will be normal.

Engine operation will probably be normal as well. A leak will fill the various cavities in the engine and airframe mounted accessory drive (AMAD) bays, and fuel will vent from panel areas all over the bottom of the airplane. Your wingman may be able to make an educated guess as to which side seems to be leaking so you can shut that engine down with the FIRE button. Keep an eye on the fuel gauge. If the fuel loss rate decreases, great - you picked the correct engine. If not, reset the FIRE button and restart the engine and shut down the other engine with its FIRE button. Remember, even if you get the leak stopped, fuel will continue to run out the bottom of the airplane until all the cavities in the engine and AMAD bays have run dry.

If the fuel loss cannot be stopped by shutting the engine down with the FIRE buttons, it wasn't your day because the most likely source is the fitting upstream of the fuel/oil heat exchanger and airframe mounted shut-off valve. A leak from this fitting will deplete your entire fuel supply since it won't stop when the associated feed tank runs dry. The fuel crossfeed valve in the feed tanks will open and allow the other feed tank to supply its fuel to the open coupling. Testing has determined that the maximum loss rate from the Wiggins coupling upstream of the airframe mounted shut-off valve is approximately 350 pounds per minute. You can't stop this leak, but the remaining steps of the INFLIGHT FUEL LEAK procedure will help reduce the loss rate. Selecting STOP TRANS(FER) may save some fuel from being lost overboard, and resetting the FIRE button and starting the engine will allow you to head to the nearest suitable field as fast as possible without using afterburner.

FIGURE 1 - LEAK AREAS



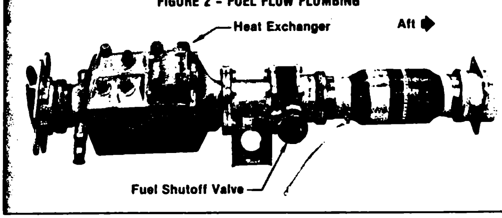
Finally, get the emergency generator on-line, confirm emergency boost pump pressure, and place both main generator switches OFF, like in the last portion of the UNCOMMANDED FUEL VENTING procedure. This stops the transfer pumps and turns off the main boost pumps. The emergency boost pump can't pump as much fuel as both main boost pumps, which should reduce the loss rate to about 250 pounds per minute if the leak is in the fitting upstream of the heat exchanger.

It is very important to closely monitor the feed tanks. With the generators off, fuel will gravity-transfer into the feed tanks, but not fast enough to keep up with engine demand plus loss rate. To refill the feed tanks, simply turn the generators on and select NORMAL TRANSFER; and it's a good idea to turn the main generators back on for landing.

Maintenance procedures have been revised to help ensure the heat exchanger Wiggins coupling is properly installed each time the heat exchanger is replaced; and starting with F-15C production number 335 and F-15D number 55, the wing fuel recirculation system will utilize the electrically controlled solenoid valves instead of the current failure-prone passive valve. Fleetwide retrofit is awaiting approval.

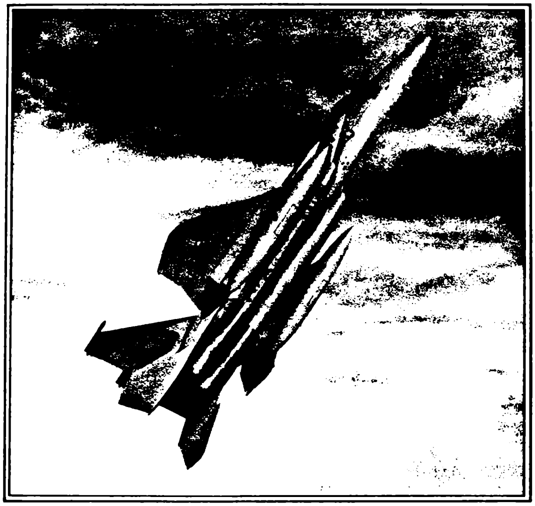
In the meantime, keep an eye on the fuel gauge; if it begins to decrease rapidly, follow checklist procedures and head for the nearest airfield. ■

FIGURE 2 - FUEL FLOW PLUMBING



CENTER OF GRAVITY

By GLEN LARSON/*Senior Experimental Test Pilot*



Aircraft center of gravity concepts, handling qualities, and ballast considerations would appear to be relatively simple subjects to discuss. In reality, and as I found after deciding to look into these aspects of F-15 operations, they are not simple and writing this article was possible only with the contributions of several members of the MCAIR engineering team. My appreciation is expressed to Dan Knewitz, Section Chief, and Bob Hahn, Lead Engineer Weights for cg data. Clarence Mongold, Branch Chief, and Bill Nelson, Section Chief Technology, provided aerodynamic data. Bill Hollingsworth, Lead Engineer Technology, did the performance comparisons. Special thanks go to Bill Crawford, Technical Specialist F-15 Guidance and Control, and Bill Bath, Lead Engineer Systems Safety, for their careful review of multiple drafts of this article for accuracy.

The position of the center of gravity (cg) has a dramatic effect on the way an aircraft behaves in flight. Aft movement, for example, usually produces the most challenging flight characteristics and to retain reasonable handling qualities, ballast is needed to keep the cg within predetermined limits. Ideally, no ballast would be required, but with the wide variety of bombs, missiles, and fuel tanks carried on fighters today, ballast is inevitable. Usually, the combination of external stores and internal fuel that produces the most aft cg determines ballast requirements. During testing, an aircraft is flown with different center of gravity positions and aft limit is established in terms of handling qualities.

The following article is an introduction to the technical aspects of center of gravity management. It includes a discussion of the changes in aircraft response as cg changes and a review of cg travel in the F-15 with some performance comparisons.

ENGINEERING PERSPECTIVE

The general relationship between the cg and aerodynamic center (ac) is shown in Figure 1. The closer together the two points are located, the less stable the aircraft will be in the pitch axis; however, these points are not constant, fixed reference points. The aerodynamic center will move as a function of AOA and Mach number. For example, high Mach numbers tend to move the ac aft and high AOAs can move it either way. Burning and dumping of fuel or weapons release will move cg fore or aft, depending on the specific aircraft design. (For instance, cg in the F-4 normally moves forward with fuel consumption; however, if fuel is dumped immediately after takeoff, cg will move aft and if not managed properly, can change aircraft stability from positive to negative.)

The cg position influences the static stability of an aircraft, as well as dynamic response. There can also be a lateral shift of cg, but we will limit this discussion to fore and aft cg changes. (For a discussion of large lateral weight imbalances, see my article in DIGEST issue 3/1984 "Stalls, Spins, and Autorolls.") Longitudinal stability of an aircraft is expressed in terms of four reference points: stick-free neutral point, stick-fixed neutral point, stick-free maneuver point, and stick-fixed maneuver point.

Stick-fixed stability is indicated by stick movement, whereas stick-free stability is indicated by the force the pilot applies to the stick. For example, the stick-fixed neutral point is the cg position where changes in stabilator deflection approach zero for an incremental speed change; and the stick-free neutral point is the cg position where stick forces do not change when speed changes. Stick-fixed and stick-free maneuver points are defined similarly except that the variable is normal acceleration (g's) instead of speed. In any case, unaugmented, irreversible hydraulic control systems with a simple spring-feel system have the same stick-fixed and stick-free neutral points. For the purposes of this general discussion, we can consider the neutral point and aerodynamic center as essentially the same point.

PILOT PERSPECTIVE

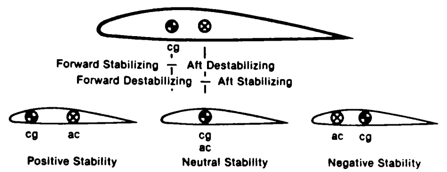
Precise definition of these points is not of much concern to the operational pilot. What is relevant is that the aircraft does not immediately become uncontrollable if cg is aft of the neutral point. However, the aircraft will be hard to control and tasks such as gun tracking will be very difficult to perform.

As cg moves aft, static stability decreases. When cg reaches the neutral point, control forces (without some type of flight control augmentation such as the F-15 CAS or the F-4 stability augmentation system) essentially go to zero. Strictly speaking, the difference between cg position and neutral point is the static margin. For example, imagine an aircraft stabilized and trimmed for one-g flight at 300 knots. If cg is at neutral point and the aircraft is slowed to 250 knots, there will be no change in stick position or force. Without augmentation, a neutrally stable aircraft will be difficult to trim. A longitudinal stick pulse will result in the aircraft not returning to the trimmed condition, and close attention is necessary to control the aircraft.

When cg is aft of the neutral point, the aircraft becomes unstable; and if changed from a given trim condition in flight, will require forward stick pressure when slowed and aft pressure when accelerated, just the opposite of what is normally experienced. Further aft movement results in the cg and maneuver point becoming coincident. The difference between the maneuver point and the cg position is the maneuver margin. If these points are coincident, an aircraft can theoretically be stabilized at a constant g and speed with no change in stick force or position. The aircraft will be very difficult to trim, control forces will be very light, and there will be a tendency to over-control. Also, there will be little need to change trim as speed changes, which is actually a desirable characteristic for tasks such as ground attack. However, without flight control augmentation, an excessively high workload is created, especially for instrument flight.

Although the discussion has centered on aft movement of the cg, there is a forward limit as well, which is usually

FIGURE 1 - AIRCRAFT STABILITY RELATIONSHIPS



the result of structural loads or nose wheel liftoff requirements rather than handling quality problems. Moving the cg well forward will make the aircraft very easy to trim. Stick forces will be relatively high and the aircraft will have a "heavy" feel. Moving the cg aft to a mid-range location reduces control forces and does not make trimming more difficult.

A positive static margin allows a pilot to fly aircraft without artificial control augmentation. For example, the F-15 can be safely flown and landed using the mechanical system alone, and although the F-18 has a four-channel digital flight control system, it can be flown through a mechanical backup system in the event of complete electrical failure since both aircraft have positive static margins. All current operational aircraft have a positive static margin except the F-16, which has essentially neutral stability. An aircraft with neutral stability requires high levels of concentration and flight control augmentation is necessary to reduce workload.

(Future aircraft may have large negative static margins, such as those being tested in the X-29, since there are significant improvements possible in performance. Spectacular gains in turn performance, as well as reductions in aerodynamic drag, result from a large negative static margin.)

F-15 CENTER OF GRAVITY

The discussion so far has been directed toward aircraft with unaugmented control systems. The F-15 basic mechanical flight control system contains devices such as the pitch trim compensator (PTC) and pitch roll changer assembly (PRCA) that are designed to provide neutral speed stability (no trim change with speed changes) and change the gearing between the stick and stabilator to keep stick forces nearly constant throughout the flight envelope. The control augmentation system (CAS) contains

FIGURE 2 - BALLAST LOCATIONS (F-15C)

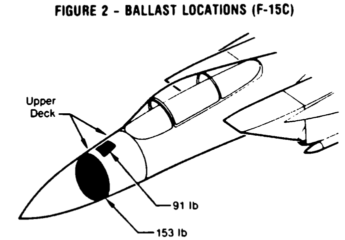
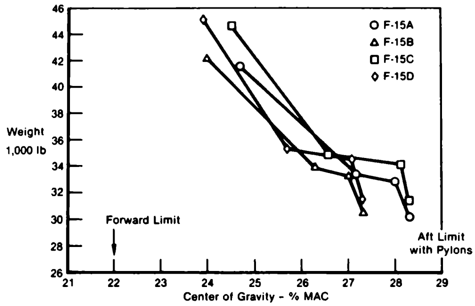


FIGURE 3 - CENTER OF GRAVITY TRAVEL



the devices necessary to damp undesirable motion in the various axes, as well as authority to move flight control surfaces in response to pilot inputs. These systems work together to fine-tune the aircraft to provide constant, predictable aircraft response by compensating for cg or ac movements as much as possible.

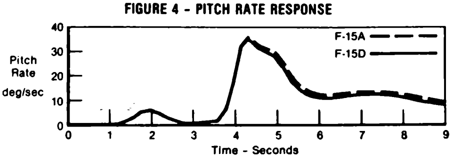
The majority of the ballast in the F-15 is carried on the bulkhead just aft of the radar antenna bulkhead. Figure 2 shows location and approximate amount of ballast in certain C models. The A model carries 270 to 290 pounds, the B model 0 to 38 pounds, and the D model carries zero ballast. MSIP aircraft will carry 0 to 39 pounds in C models. These ballast amounts are pre-TCTO 818 (Modification of ICS Ballast Adjustments) and vary according to individual aircraft differences.

With some minor exceptions, cg in the F-15 moves aft as the aircraft gets lighter. Figure 3 is a greatly simplified cg movement chart, which does not include external tanks or weapons release. *It is intended to generally illustrate the cg movement due to fuel consumption in various models of the F-15 and should not be used to determine the cg of a specific aircraft.* The vertical axis is the gross weight of the aircraft, and the horizontal axis is a percent of mean aerodynamic chord (MAC). The MAC is an imaginary line drawn between the leading and trailing edges of the wing, near midspan.

Distances along this line are expressed as a percentage, with leading edge as zero and trailing edge as 100%. Each line on the chart illustrates cg movement for each model of the F-15. At first glance, it appears that the C model enjoys a cg that is farther aft than other models. That is true only when all aircraft are compared at the same gross weight. However, if two models such as a C model and an A model were to take off together and begin an ACM engagement soon after entering the area, the C would actually have a cg up to ½% ahead of the cg in the A. (For example, an A model at 39,000 pounds has a cg at 25.5%, but a C at the same point in the mission would weigh about 42,000 pounds and have a cg position of 25%.)

The forward cg limit for the F-15 is established by various structural loads and nose wheel liftoff speeds. However, the aft limit is not as easily defined. The neutral point for an F-15 moves as a function of external stores. For example, neutral point for a clean F-15 is at 32.5% MAC, but addition of conformal fuel tanks moves it to 31.0% MAC. The aircraft has been safely flown and landed in a three-tank and eight-missile configuration with cg at 30% MAC or a .5% static margin. Testing has shown that the CAS can handle a negative margin as large as 1%; however, the current aft limit of 29% MAC for most store loadings was established during USAF testing to determine handling qualities for close formation and air refueling. During flight tests, the cg was varied from 24.5% to 30% MAC. In several instances with the CAS off, a low frequency pitch oscillation developed caused by the pitch trim compensator (PTC). The g on the aircraft typically changed by plus or minus .5 over a period of 7 to 10 seconds because the PTC response to pilot inputs was out of phase, which resulted in a mild pitch oscillation. Although easily compensated for by the pilot, it was deemed unacceptable for high gain tasks such as air refueling and close formation. Consensus of pilot opinion was that a cg aft of 29% would result in marginal flying qualities for air refueling with pitch CAS off.

FIGURE 4 - PITCH RATE RESPONSE



HANDLING QUALITIES

Handling qualities are determined during the development phase of an aircraft. A subjective pilot evaluation determines if the aircraft has level I, II, or III handling qualities as spelled out in MIL-F-8785(ASG). Level I is defined as being completely acceptable for all mission elements with a reasonable pilot workload. At level II, the mission can still be accomplished but pilot workload is higher; and at level III, the aircraft can be controlled but pilot workload is excessive and mission effectiveness is impaired. The F-15 in the air-to-air configuration has level I handling qualities throughout its flight envelope with CAS on and, in small parts of the envelope, handling qualities degrade to level II with CAS off. (Handling qualities of the F-4, by comparison, do not remain at level II throughout its flight envelope - most notably at low altitude and high speed.)

For the F-15, the loading requiring maximum ballast was: 1100 pounds internal fuel, two empty external wing tanks, centerline pylon, four AIM-7F missiles, 20mm ammunition fired (cases retained), and a 50-percentile physical profile pilot. The amount of ballast for this loading was based on results obtained during handling quality tests.

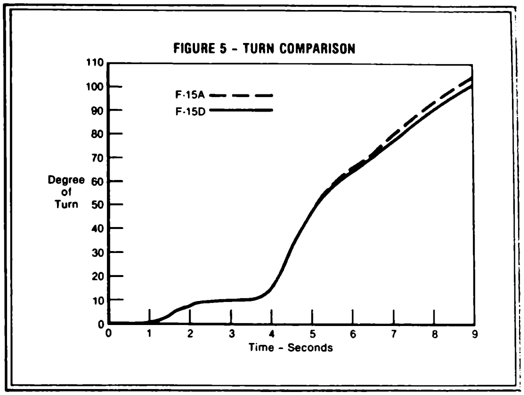


FIGURE 5 - TURN COMPARISON

Loading four AIM-9 missiles, an empty centerline tank, downloading the four AIM-7 missiles, or adding internal fuel moved cg forward, which resulted in a more stable static margin. For example, increasing internal fuel to 3700 pounds moved the cg forward 1.5% of the location with 1100 pounds of fuel in C/D models and approximately 1.0% in A and B models.

PERFORMANCE EFFECTS

To illustrate the effect of cg position on turn performance, let's compare an A model with a D model at the same point in a mission: 50% internal fuel, four AIM-7s, and full 20mm ammo for each aircraft. In this configuration, cg position of the A will be at 26.1% and at 25.0% for the D. (The configuration for both aircraft must be the same; the fact that tanks or AIM-9s are not included doesn't make much difference.) In order to allow simulation of rapid full-aft stick without exceeding aircraft load limits, 220 KCAS at 10,000 feet MSL was used as a starting point.

These conditions were used in a six-degree-of-freedom simulation, the results of which are shown in Figures 4 and 5. The aircraft were assumed to be straight and level at time zero. A roll to approximately 90° of bank was completed in two seconds and full aft stick was applied. Pitch rates peaked at approximately 35° per second for both aircraft in about four seconds. Six seconds into the run, two seconds after full aft stick, pitch rates were 12° per second for the A and 11° per second for the D, as shown in Figure 4. Plots of actual degrees of turn against time are shown in Figure 5. After eight seconds of running time, the A will complete 4° more turn than the D, which is essentially the same as a 4° nose position advantage in six seconds. The same comparison with both aircraft at the same weight results in smaller performance differences.

BALLAST MANAGEMENT

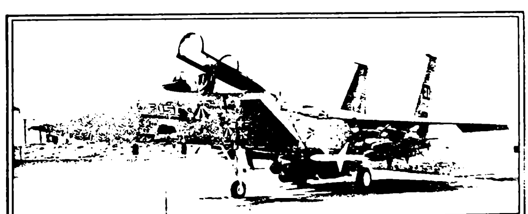
Prior to TCTO 818, no ballast was removed from the aircraft when the internal countermeasures set (ICS) was installed in the equipment bay aft of the cockpit. This TCTO is intended to eliminate the performance penalty caused by carrying approximately 200 pounds of unneeded ballast with ICS installed. When ICS is installed, ballast must be removed, which keeps the cg in the range it would be in without ICS.

A word of caution about nose strut servicing is in order at this point. Moving weight around in the aircraft changes the load on the nose gear and it is *very important* that the strut always be correctly serviced. An F-15 unit experienced loss of nose gear steering during taxi after TCTO 818 was incorporated. Initially, it was thought that removing ballast for the ICS installation caused the nose to be "light," resulting in loss of steering during taxi. The problem was eventually traced to over-serviced nose struts which extended the strut far enough to engage nose wheel centering cams during taxi. The result; no steering. To properly service the strut, the full T.O. procedure must be followed since correct strut dimensions with full fuel does not indicate correct servicing.

TCTO 818 is an excellent form of ballast management since it allows maintenance to manage ballast for the configuration of the aircraft. However, to operate at cg's near the neutral point, major and perhaps unreasonable changes would be needed. For example, an electronic fly-by-wire system would allow the F-15 to operate at or near the neutral point. That sounds good, but the gains may not offset the cost. The CAS-off refueling problem, discussed earlier, can be minimized by installing a pitch damper not associated with the CAS or by simply installing a device to allow the pilot to disable the PTC. Either or both of these options would minimize the pitch oscillation encountered during CAS-off refueling, but these options have not been fully evaluated to determine their effectiveness. An "active" cg control system would keep the cg as far aft as possible by controlling internal fuel transfer; however, a system of this type would add weight and complexity and be of limited value.

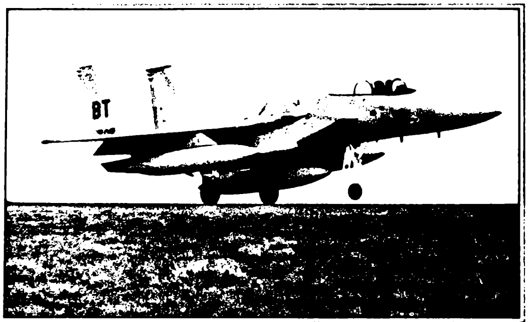
Ballast in one form or another will be carried in fighter aircraft for a long time. A great deal of time and energy is expended during the design and development process to keep the need for ballast at a minimum. However, the final decision on handling qualities, and therefore aft cg limits, rests with the pilots who evaluate aircraft during the development phase.

As you can see, cg position and its effect on the aircraft is a complex subject. There are no clear-cut answers, but TCTO 818 is a major step in the direction of tailoring ballast to configuration and ensuring that performance losses are minimized. ■



LANDING and R

By GLEN LARSON/*Senior Experimental Test Pilot*



In the tactical aviation world, the majority of a pilot's time and attention is concentrated on fighter tactics, which is only appropriate. However, the phase of flight from touchdown to clearing the runway is also important, often overlooked, and not clearly understood. Knowledge of the most effective braking techniques for any situation which might be encountered should be an integral part of your Eagle "bag of tricks." Mr. Ray Ehle, Senior Design Engineer and our recognized expert on F-15 braking systems, deserves credit for making this article possible through contribution of his technical expertise. Mr. Bill Bath, Systems Safety Unit Chief, is due special appreciation for his patient and careful review of multiple drafts for accuracy. Thanks to the efforts of these gentlemen and other members of the MCAIR team, all of your landings and rollouts should be routine events.

Your F-15 mission has been a long one – multiple ACT engagements interspersed with several refuelings, and to top it off the weather at the home drome isn't all that great. A weather approach, perfect landing, and now it's time to relax. Hold it – you still gotta get that 33,000 pound jet, rolling at 120 knots, stopped!

The laws of physics that describe how airplanes stop aren't really deep, dark, or mysterious. In fact, they are fairly exact and straightforward – it's the application of these laws that's sometimes tricky. Before developing pilot procedures for landing and rollout, we need to review some basic concepts of braking and how the anti-skid system fits into the picture. The objective is to (safely) maximize the drag on the aircraft during landing and maintain directional control at the same time. There are only two sources of drag during the landing roll: that produced by the rules of aerodynamics and what you get from the wheel brakes.

AERODYNAMIC BRAKING

Aerodynamic braking is quite straightforward – the amount of drag force varies directly as a function of airspeed and wing angle of attack. The higher the speed and the higher the angle of attack, the more drag produced. Most Eagle drivers use aerodynamic drag to one degree or another by holding the nose up during rollout. This means of slowing is relatively effective during the high speed portion, and there's nothing to wear out.

The amount of drag produced by holding the nose up can vary, depending on pilot technique; if the nose-high attitude is less than about 10° some drag is lost, and at 15° the tails will contact the runway. Holding the nose up at about 12 to 13° is a comfortable attitude that produces reasonable aerobraking without scraping the tails. This angle is not AOA, it is the angle between the ⁻w⁻ symbol and the horizon line on the HUD.

Aerodynamic braking (as well as aerodynamic directional control), decreases as speed decreases; and before losing stabilator authority at around 70 KCAS, it's a good idea to lower the nose to the runway. Flaps position or speed brake position doesn't seem to add much drag, but because every little bit helps, speed brake out and flaps down is what we recommend. (A word of caution: when the flaps are up, stabilator effectiveness is increased and you can easily drag the tails.) There is a point around 70 knots where aerodynamic braking with the flaps up is no longer effective; and although the nose is between 12 and 13° pitch attitude, the aircraft will not slow down. The aircraft is in equilibrium, therefore, it's possible to go off the end of the runway with the nose still in the air! Eventually, you *have* to get on the brakes.

WHEEL BRAKING

As usual in the world of physics as applied to fighter aircraft, nothing operates independently and everything is related to some degree. Drag produced by the wheel brakes is really made up of three components – weight on the wheels; available friction coefficient; and slip rato. The drag available from these components varies as a function of several major variables – aircraft weight, speed, aerodynamic lift, runway condition (wet or dry), runway surface, and tire wear.

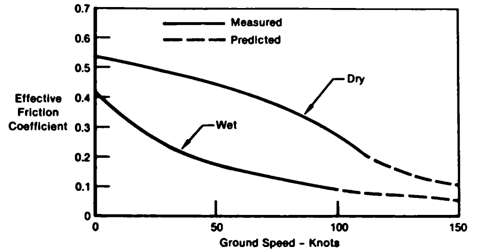
Friction coefficient is used to express how much of the weight on a wheel can be converted into drag. For example, if the friction coefficient is .8, then 80 pounds of drag can be produced for every 100 pounds of weight on the wheel. A value of 1.0 is theoretically perfect, and 0 describes a frictionless environment. On a dry runway, the friction coefficient stays fairly constant regardless of speed; but in reality, braking effectiveness is less at high speed because weight on the main gear is less due to the aerodynamic lift being generated by the wing at high speeds. Runway surface also impacts how much brake drag can be produced. A grooved and brushed concrete surface will allow the tire to get a good "grip" during braking and keeps water from interfering. A smooth, oily surface will have a much lower drag capability. Add a little water, and it's like glare ice! Tire tread also has some effect on producing drag. Smooth tires actually produce more drag on dry runways; but on wet runways, they "hydroplane" easier and don't produce as much drag. Be sure to follow T.O. guidance for tread wear limits, especially on a wet runway.

On wet runways, friction coefficient decreases a great deal with increasing speed. One reason is *hydroplaning,* a phenomenon which is always present to some degree on any wet surface. Hydroplaning is best described as the tire "floating" on a thin film of water. Under extreme conditions of standing water and high speeds, the tire is lifted completely off the runway surface. Since friction coefficient, by definition, implies that the tire must be in contact with the runway, little or no drag force can be generated through friction. As a guideline, you can expect to experience total hydroplaning in the F-15 at a ground speed roughly equal to the expression $9 \times \sqrt{T.P.}$ (where T.P. is tire pressure), or 149 knots for the F-15.

Don't interpret this as meaning that you can't have problems at speeds below 149 knots. There are other kinds of hydroplaning such as viscous (sometimes referred to as reverted rubber) hydroplaning, which can reduce friction coefficient at much lower speeds. The concept is similar to classic hydroplaning, except that the lifting mechanism is steam generated by heat from a skidding tire. The speed at which you can expect to encounter this is very hard to precisely define. Generally speaking, it will be at a speed equal to around $7 \times \sqrt{T.P.}$, or approximately 116 knots. Be careful, however. Once viscous hydroplaning starts, you may stay in it for awhile. Incidentally, viscous hydroplaning leaves distinctive skid marks. Instead of long black streaks, there will be long streaks of spotless runway surface, a phenomenon explained by the "steam cleaning" action between the tire and the runway.

Figure 1 ties all of the above discussions together. This chart is based on actual test data up to approximately 100 knots; beyond that point, it is predicted data. The curve for a dry runway clearly shows the reduction in effective friction coefficient at high speeds. Even more impressive is the reduction in effective friction coefficient on wet runways at high speeds. From this chart, it's obvious that there isn't much friction coefficient to convert weight to drag at high speed, especially on a wet runway. The anti-skid system does a pretty good job of maximizing whatever friction is available, but remember that under some conditions there isn't much available.

Figure 1 - Friction Coefficient
Tire Pressure 275 (Weight-on-Gear)



ANTI-SKID

Earlier generation anti-skid systems used a variety of concepts to prevent skids. Some simply controlled wheel speed, while others controlled optimum deceleration rates. The Mark III anti-skid system used in the F-15 (also in the F-4, F-18, and space shuttle) is designed to maximize braking effectiveness by maintaining an optimum "slip ratio." A wheel must rotate at some speed less than the free-rolling speed in order to produce any kind of drag. The tire is actually skidding to some degree, and the amount of skid is called the slip ratio. Analysis shows that the F-15 gets its best braking effectiveness at a slip ratio of approximately .2 to .3.

Figure 2 shows how braking effectiveness changes as a function of slip ratio. It's important to note that the vertical axis represents maximizing whatever friction coefficient is available, which, in some cases, may be very low. The upper curve, showing how drag force goes down as a skid is approached, explains why the aircraft seems to accelerate as it enters a skid. There really isn't any acceleration causing a speed increase. Instead, the *rate of deceleration decreases,* giving an illusion of acceleration. At high speeds on a wet runway, there isn't much friction coefficient available; so even though the anti-skid is working, little deceleration will be apparent.

The Mark III system contains several interesting features in addition to preventing skids. Touchdown protection prevents hydraulic pressure from reaching the brakes for five seconds after the proximity switches tell the system that the aircraft has touched down. This ensures that the brakes will not be locked at touchdown. In order to provide braking immediately after landing, a wheel spin-up override feature allows normal braking as soon as the wheel speeds up to 50 knots or greater and the ARI is defeated at the same time to enhance lateral control for crosswind landings. Crossover protection compares the speeds of both wheels and reduces pressure to both brakes if one wheel speed is 50% less than the other wheel. In order to ensure that braking is available at taxi speeds, the anti-skid is cut out below 15 knots.

DIRECTIONAL CONTROL

A related and equally important concept is cornering force. Cornering force is what keeps the airplane traveling in the desired direction (main gear contribution) and steers it (nose gear contribution). The lower curve in Figure 2 shows how the force changes with the ▶

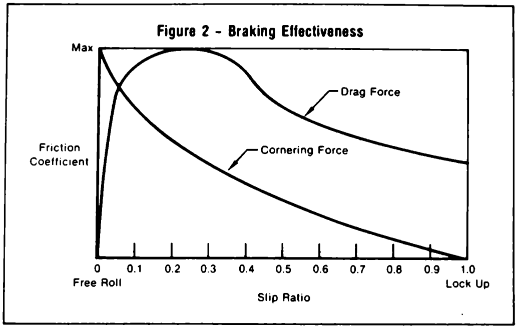


Figure 2 - Braking Effectiveness

slip ratio. In full skid, there is no cornering force available on the main gear. Directional control is poor; braking effectiveness is at a minimum; and to make matters worse, it's hard on tires. Once the aerodynamic power of the rudders is no longer effective, you're in trouble – no directional control and little braking effectiveness.

NORMAL PROCEDURES

With all of the innovative technology just discussed, the pilot still has the most important role to play when it comes to "stopping the Eagle." To quote from an article written in 1965 by McDonnell Test Pilot, Don Stuck: *"Above all, remember that the most important facet of your landing occurs before the aircraft is even on the ground – the final approach."* Those words, written for early F-4B operations, are every bit as true today. It is very important to fly a proper, on-speed approach. The energy that must be dissipated after landing is simple kinetic energy given by the equation:

$$K.E. = 1/2\, mv^2 \quad \text{where} \quad m = \text{mass},\; v = \text{velocity}$$

Every extra knot of speed on final approach increases kinetic energy as the *square* of velocity. Every extra pound adds energy in a 1 to 1 ratio, but also requires extra speed, hence a double whammy. That's where the guidance "don't land heavy or fast" came from. This isn't meant to imply that you should fly or land slower than the flight manual dictates. It simply means that you will have a lot of excess energy to deal with if you land faster or heavier than necessary.The amount of runway used during landing roll depends not only on runway condition, but how much energy you land with and how far down the runway you touch down.

Once on the runway, kinetic energy must be dissipated through aerobraking or wheel braking. Aerobraking is generally the best choice initially since it minimizes brake wear and tear. After lowering the nose, get on the brakes with smooth, steady pedal pressure. The system is designed to operate with a full 3,000 psi of hydraulic pressure at the control valve. Full pedal deflection, carefully applied, provides the best wheel braking. Remember, at high speed little deceleration from the brakes will be appparent, especially on a wet runway. It's not a good idea to use differential braking for directional control since this results in longer landing rolls. Besides, the full-time nose gear steering does a better job of steering.

Once your speed is under control, go ahead and clear the runway at a taxiway before the end of the runway (local procedures permitting). It's pretty scary to discover little or no braking at 100 knots with 2,000 feet remaining. Get slowed down early and keep as many options available as possible!

MINIMUM RUN LANDINGS

The technique for minimum run landings depends entirely on the runway condition. For dry runways, fly an on-speed approach, lower the nose immediately after touchdown, and apply full anti-skid braking. On a wet runway, you *must* use aerobraking initially. Attempting to use wheel brakes immediately after touchdown on a wet runway will result in landing distance more than double that possible if you aerobrake first. In both cases, be sure to plan your approach to land at the proper distance down the runway.

COMPLICATIONS

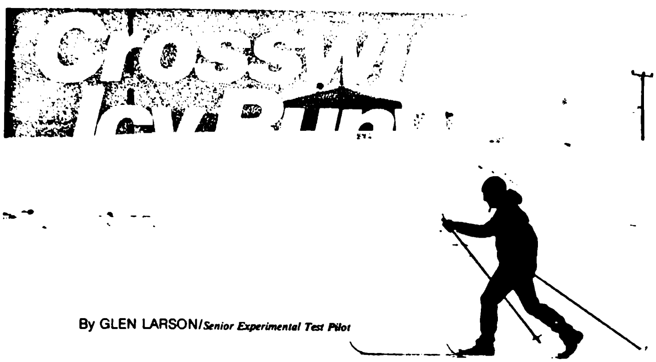
Aerobraking always works, but wheel brakes do occasionally fail. Remember, you have five mechanical ways to stop an F-15: normal anti-skid braking; pulser brakes; non anti-skid brakes; emergency brakes; and the hook. (And further remember that the pulser brakes work either automatically as a backup to normal anti-skid or upon pilot activation of the PULSER switch on the miscellaneous control panel.) If you are absolutely convinced that the brakes have failed, I recommend putting the hook down before doing anything else. It's retractable and a reasonably reliable device. If you're still convinced that the brakes aren't working, try the pulser switch.

The pulser system is specifically designed to prevent blown tires; it "pulses" whatever pressure you apply to the brakes at a frequency that allows the tire to spin up and roll roughly two-thirds of the time instead of skidding full time. This ratio allows some braking action and retains directional control at the same time. If you don't have the pulser, or it doesn't work, non anti-skid braking is next. Be careful! It is nearly impossible to detect a skid, and it only takes a few seconds to blow a tire. If you're still not getting any braking, go to the emergency brakes.

In my opinion, the emergency system is misnamed; it should actually be called an "alternate" brake/steering system. The emergency system has gotten a bad reputation; and to become more comfortable with it, I recommend exercising the system frequently. During taxi, pull the handle and get used to the feel of the system. If the brakes "grab" when you pull the handle, there's excessive friction in the cables and the system needs maintenance. Loss of steering when you pull the handle means that the hydraulic shuttle valve is sticking. Hitting the paddle switch will cut out the normal system and allow the emergency steering system to do its job.

If all of your braking efforts have been to no avail and you are still sailing merrily (more or less) down a rapidly diminishing runway, prepare to take the cable. The hook is already down, and your attention should now be devoted to getting your direction of travel pointed straight down the runway. If you've begun to drift off the runway, don't try to get back on the centerline. Trying for the centerline is actually aiming for the other side and will compound your problem. Accept an off-center cable engagement; the system can handle it.

As noted in the beginning of this article, stopping the Eagle is usually a routine event. During landing and rollout, the name of the game is to stay ahead of your airplane and keep as many options available as possible. Fly the approach correctly . . . touch down at the proper point . . . use aerobraking/wheel brakes as appropriate . . . be ready to go to back-up systems. For those rare occasions when "routine" suddenly turns into "spectacular," I hope this discussion will have given you some ideas with which to handle the situation. ■



By GLEN LARSON/*Senior Experimental Test Pilot*

Navy JOC John Peterson does some cross-country skiing, not on a far off slope in the mountains of Iceland, but right on the NATO Base at Keflavik, home of the 57th Fighter Interceptor Squadron and their F-15 Eagles. Peterson, base assistant public affairs officer, helps make the point established in the article below. Ice, snow, and wind may be just part of the sport for a skier, but these harsher elements of nature add severe complications for fighter pilots attempting to land fighter airplanes at places like Keflavik. (Photograph by JO1 Howard W. Watters, Editor of THE WHITE FALCON, base newspaper.)

Combinations of icy runways, crosswinds, low ceilings, snow, and darkness can generate pucker factors that are right off the scale! However, it's an unfortunate fact that the pilot has little control over these adversities, and the best he can do is minimize their effects upon his approach and landing. Since instrument and night flying advice is not the purpose here, let's limit our discussion to crosswinds and low RCR's (runway condition readings).

Crosswinds, up to the recommended limit of 30 knots, aren't a major problem in the F-15. There is plenty of directional control available from the rudders and nose gear steering, and the flight control system is designed to minimize directional control problems. The ARI, which normally coordinates the rudders and ailerons in flight, is cut out when the wheels spin up to 50 knots on touchdown. Without this lockout feature, applying aileron to keep the upwind wing from rising in a crosswind situation would also deflect the rudders upwind. This would add to any weathercock tendency and the net result would be exciting (*?*@!) to say the least. Incidentally, the ARI will cut back in when the wheel speed drops below 50 knots during the landing rollout. The 50-knot signal is supplied by the anti-skid system. If this system is off, ARI will be cut out any time the gear is down.

The key to an uneventful crosswind landing is to establish a wings-level crab with your flight path straight down the runway. The velocity vector may be unusable since it could be at the limits of the HUD field of view. Hold the crab through touchdown and gently raise the nose for aerobraking. If the crosswind is more than 25 knots, an aerobraking attitude of more than 10° may be uncomfortable since the upwind wing will produce a great deal more lift than the downwind wing; and nearly full stick may be needed to keep the wings level. In any case, if it gets too uncomfortable, or you begin to drift toward the side, lower the nose to the runway, and use the nosewheel steering as necessary.

Extremely low RCR's present their own problems. The aerodynamic controls such as rudders, etc., will do a fine job of keeping you going straight. . .up to a point. Once below about 100 knots, they lose their effectiveness; and you have to depend on the tires to keep you straight. Unfortunately, the maximum available tire cornering force is quite low, which means that steering effectiveness from the nosewheel and the stabilizing effect from the main gear are greatly reduced. The possible extreme result – little or no directional control, ground loops, etc. Add in high idle thrust due to low temperatures, poor braking effectiveness, and things can get exciting real quick! By now, the best choices should be obvious – divert or take an approach end cable! If no cable is available, and the entire runway is a sheet of ice – *divert!* If diverting isn't a viable alternative, be prepared to shut down an engine after touchdown and lower the hook for the departure-end cable. If you miss the cable, be prepared to roll off the end since the landing roll can exceed seven to ten thousand feet in extreme cases. It's better to roll into the overrun at 20 knots under control then go off the side at 80 knots out of control.

Combine crosswinds with very low RCR's and the *only* choice is to take a cable – approach end is your best option or a mid-field at least. Hold the crab through touchdown and use aerodynamic controls to keep your direction of travel straight down the runway. Accept a crab angle during rollout and cable engagement. If you drift to one side, don't worry about getting back to the center. Get things under control and stabilize the aircraft direction of travel straight down the runway before trying to correct your runway position. An off-center, crabbed engagement won't hurt anything. Finally, don't be any heavier than absolutely necessary, and don't fly a fast final.

Flying jet fighters is great fun – most of the time. However, crosswinds and icy runways can be a tough combination in any aircraft anywhere in the world. The key to safe operations under difficult conditions is to fly smart! Avoid heavy weights and fast landings, use cables, and think well ahead of your aircraft! ■

F-15 OWS REVISITED*

By JIM HAKANSON *Lead Engineer, Technology* & MARK RINEHART *Senior Engineer, Systems Safety*

VERIFYING OWS OPERATION

The overload warning system provides a display on the HUD of current and maximum allowable G's. If the current G versus maximum allowable G display is not present on the HUD, then OWS is ***not*** operational (see TO 1F-15A-1, pages 1-65 and 5-8). If OWS is inoperative, the HUD will revert to the non-OWS display (only the current G will be displayed and this number will contain a decimal point). Since this is the pilot's only automatic cue of whether or not OWS is operating, the HUD should be monitored frequently during maneuvering. When OWS is inoperative, the tones and voice warning will be deactivated; therefore, the pilot will have no warning of an impending or actual over-G.

The VSD ground-initiated BIT checks the accuracy of the lateral stick and total fuel inputs to the central computer (CC), but it does not check OWS operation. Therefore as noted above, the pilot must monitor the HUD to verify OWS operation.

COMPONENT MALFUNCTIONS

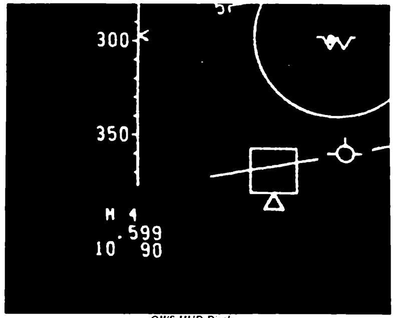
Failure of systems which supply data to OWS can cause OWS to malfunction. Since these systems are also of prime importance for flight, a failure would be apparent to the pilot (for example, CAS drop-off, ADC BIT, fuel quantity malfunction, current G's unreasonable). If the pilot detects a malfunction in one of these systems, he should consider OWS inoperative and observe the flight manual non-OWS G limits, even though the HUD G window may still indicate that OWS is operating.

Certain failures can result in a continuous "over-G" voice warning. Logic was therefore incorporated to shut down OWS after 30 seconds of accumulated voice warning. Thus the pilot should be aware that if the voice warning comes on for 30 seconds and then stops, it is not because the system has corrected itself. Checking the HUD in this situation will verify OWS shutdown, and the non-OWS G limits must be observed.

TEMPORARY ERRORS

OWS Operation at Power-Up

When the CC is turned off at the end of a mission, it stores the last fuel quantity in its memory.



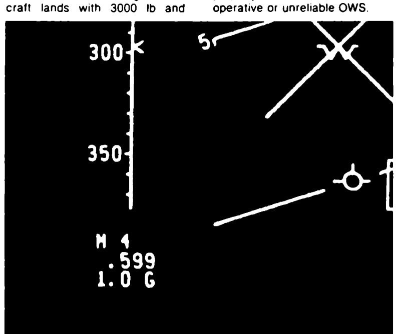
OWS HUD Display

When the CC is powered up after ground refueling, it does not instantaneously reinitialize to the new total fuel weight. Instead, it begins at the shutdown fuel weight and adds fuel at a rate of 40 lb/sec until it gets to the total fuel weight as currently displayed on the fuel quantity gage.

The purpose for this logic is to minimize the effects of fuel slosh during the computations for maximum allowable G. Depending on the amount of fuel at shutdown and the number of external tanks being carried, this incremental fuel addition can take up to 10 minutes. A typical time, however, is six minutes assuming the aircraft lands with 3000 lb and refuels to full internal tanks plus the centerline tank. During this time, OWS will indicate operational (via the HUD), but will be inaccurate.

ACP Configuration Setting

The correct external fuel tank and armament configuration must be entered on the armament control panel (ACP) for proper OWS operation (see TO 1F-15A-1, page 5-8). OWS must determine how many external tanks are being carried and where they are installed in order to calculate the fuel location properly. Failure to set up the ACP properly will result in an inoperative or unreliable OWS.



Non-OWS HUD Display

For example, if a full external fuel load is being carried but all tanks are not entered on the ACP, OWS will shut down when it computes more external fuel than is possible with the external tank configuration recognized by OWS. OWS will become operative again when the total fuel depletes to an amount that agrees with the internal capacity plus the number of external tanks reflected by the ACP.

LIMITATIONS (WITH FULL-UP OWS)

Store Over-G

Individual store G limits are not programmed in OWS; therefore, OWS will not warn of a potential store over-G.

Prohibited Maneuvers

Logic is not programmed in the CC to compute maximum allowable G's for prohibited maneuvers; therefore, OWS cannot provide over-G warning during these maneuvers.

High G Onset Rates

At low altitudes and high airspeeds, rapid stick inputs (full aft stick in less than 1/2 second) can cause very high G onset rates. OWS will work as designed, but the high G onset rate can cause a serious over-G before the pilot can react to the OWS warning.

The potential for structural overload from abrupt stick inputs increases as gross weight increases because at higher gross weights, less G is required to overload the airframe. During low altitude/high speed flight, large, abrupt stick inputs must be avoided.

THE BOTTOM LINE

The overload warning system has proven to be a very reliable aid to the pilot in deriving maximum maneuvering performance from his F-15 Eagle. It does not compensate for or restrict pilot action, nor does it relieve the pilot of his responsibility to be familiar with the DASH ONE limits. The pilot can verify that OWS is operational by observing that –

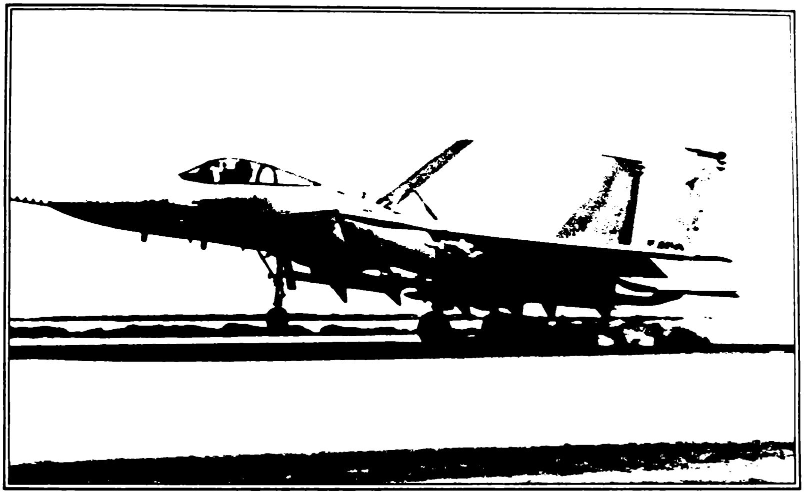
- Allowable G's are displayed on the HUD and current G's are of reasonable value;
- The ACP displays the actual airplane configuration;
- The systems supplying information to OWS are up (no CAS lights, no ADC BIT light, reasonable fuel quantity indications). ■

**This article is an "update" to several previously published discussions on the F-15 overload warning system, all of which have been reprinted in MCAIR booklet P.S. 1321. Ask your rep on base or write us directly for a copy. A three-part color video tape on OWS [CVT F-15( )-11K00-1] is also available through normal USAF channels.*

F-15 BRAKE SYSTEM

HOT BRAKES

By GLEN LARSON/*Senior Experimental Test Pilot*



Overheated brakes and tires are not part of normal training operations – they usually result from aborted takeoffs or heavy-weight landings, neither of which are daily events. "Hot brake" definitions could easily be established in terms of measured temperature of the aircraft brake discs after landing, but since the Eagle does not have a temperature indicator installed, some more general guidelines need to be developed. With the able assistance of Glen Kirkland, Section Chief, Design; Ray Ehle, Senior Design Engineer; and Steve Meyer, Systems Safety Engineer, this article has a go at the task. Incidentally, what you are about to read is a follow-on to my article in the last DIGEST on F-15 landing and rollout characteristics (i.e., overheated brakes can result from less than desirable landing/rollout situations).

First of all, it is important to understand that "all" brakes – in the family station wagon, a Greyhound bus, an F-15 air superiority fighter – heat up to some degree. That's how they work – by converting *kinetic* energy into *thermal* energy. The point at which brakes become overheated is a function of their heat-absorbing capacity. That simple statement takes us into the not-so-simple area of materials technology.

The brakes in your Eagle are made of advanced carbon material. This material has several advantages over steel, one of which is its ability to absorb large amounts of energy without overheating. Carbon brakes can tolerate operating temperatures of nearly 4000°F, while conventional steel brakes can't go much above 1200°F. This tremendous increase in temperature capability has led to some misunderstanding about when F-15 brakes are really overheated. The "overheat" limits for the F-15 are established by the limits of the wheel and axle materials, and to better understand the situation let's look back at the baseline design criteria for this airplane.

The original stopping performance specifications for the Eagle were based upon steel brakes and required the following performance –

- 45 "normal" stops – equivalent to braking at 133 knots (1.1 times the stall speed) and 35,000 pounds gross weight for the A/B model; or 138 knots and 38,600 pounds for the C/D;

  or
- 5 "overload energy" stops – equivalent to braking at 137 knots (1.0 times stall speed) and 45,000 pounds for the A/B; or 143 knots and 47,000 pounds for the C/D;

  or
- 1 "rejected takeoff" (high speed abort) at 151 knots (stall speed) and 53,000 pounds for the A/B; or 165 knots and 68,000 pounds for the C/D.

The carbon brakes currently installed on the aircraft exceed these requirements, including the high speed abort. However, the energy level of a high speed abort is so high that even carbon brakes are good for only one stop and the brakes will be dangerously hot. The brakes can be considered to be overheated at the point at which the fuse plugs melt, releasing pressure in the tire, which will have built up to 600 psi. The fuse plugs are designed to release the pressure in the tire before temperatures in the tire or wheel flange reach the point where the materials are weakened enough that they may fail explosively. There is, however, a large safety margin built in since the tires and rims are capable of withstanding 1190 psi pressure.

While overheated brakes are easy to define, the question remains – when do F-15 brakes begin to get hot? The answer to that question lies in determining how much energy has been put into the brakes during landing. That energy is "kinetic" energy, which is equal to one-half the mass times velocity (ground speed, in this case) squared, or

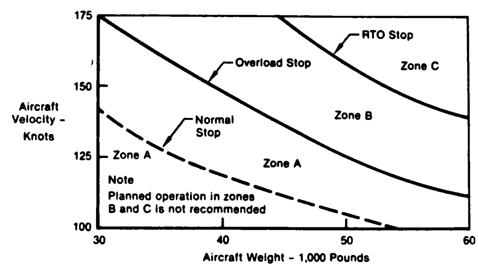
$$K.E. = 1/2\ mv^2$$

The pilot has two primary ways to get rid of that energy – aerodynamic braking and wheel brakes. (Since braking techniques were discussed in detail in my last article, we'll concentrate now on just the energy absorbed by the brakes.) Because the temperature the brakes eventually reach depends entirely upon the energy they must absorb, the two primary variables involved are the aircraft speed and gross weight when the brakes are applied. For example, good aerobraking before applying the wheel brakes will reduce the energy put into the brakes significantly. The pilot is the only one who really knows how fast he was going and how much the aircraft weighed when he applied the brakes.

Traditional indications of hot brakes – smoking or glowing brake discs – are not reliable indicators for the F-15. It is a characteristic of carbon brakes that they can "glow" visibly and not present any danger! Smoking brakes are usually caused by contamination of the brakes by oil or hydraulic fluid, and in fact, hot brakes will smoke very little because any contaminant will have been vaporized by the intensely hot brake discs.

Since you as the pilot are the key to determining if the brakes are hot, figures 1 and 2 are designed to help you in that determination for the A/B or the C/D model F-15's.

FIGURE 1 - F-15A/B BRAKE OPERATION

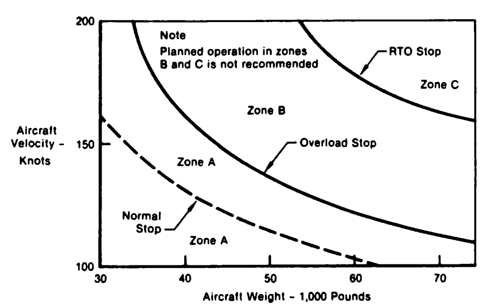


"Velocity" on the vertical axes is ground speed at which the brakes are applied, and the curved lines represent the specifications discussed earlier and assume full stop landings. The dotted line labeled "Normal Stop" is where the aircraft is operated routinely. "Zone A" is defined as the general area where routine operations are carried out, and no danger to equipment or personnel should exist. To keep the energy levels in the brakes reasonable, a one and one-half hour cool-down period is suggested between events. The line labeled "Overload Stop" represents the dividing line between normal and overload stops (defined earlier). "Zone B" can be defined as the area where the brakes will get hot and where repeated operation is not recommended. As the conditions approach "Zone C," the brakes will become hot, fuse plugs may blow, and fires could result. Caution should be exercised, and a minimum two-hour cool-down period is required between events.

The "RTO Stop" (rejected takeoff stop), or high speed abort line represents the point at which you will have extremely hot brakes. Routine operation in Zone C is definitely not recommended, and you can expect to damage wheel, brake, and tire assemblies. The possibility of personnel injury also exists. You should encounter Zone C only during high-speed, heavy-weight aborted takeoffs.

The differences in gross weights and braking capabilities between the A/B and C/D Eagles are obvious in the two

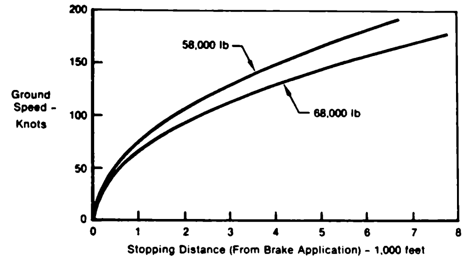
FIGURE 2 - F-15C/D BRAKE OPERATION



figures. It's nearly impossible to heat up the C/D brakes during normal training operations. With a two-pylon and centerline tank configuration, there isn't enough energy available to get hot brakes during normal landings. However, add CFT's, three tanks, and an extensive taxi, and it's another story – an abort at 170 knots and 68,000 pounds puts you in Zone C. Not only are you going to heat things up, but getting stopped in the remaining runway may be difficult.

Few Eagle drivers routinely operate their airplanes at high gross weights, but the advent of conformal fuel tanks will change that. Not only will hot brakes be a potential problem, but stopping distances will become critical. Figure 3 shows how much runway it will take to stop at max gross weights on a dry runway from the point of brake application. Using the previous example of 170 knots and 68,000 pounds gross weight, it will take about 7,500 feet to stop. Pilot reaction time will eat up another 1,000 feet, and pretty soon the runway isn't long enough, and to complicate things, the brakes will be extremely hot. A high speed abort at high gross weights is a potentially dangerous situation. Since experience with CFT's and three tanks is limited, get into the books and know the numbers before you start to roll!

FIGURE 3 - F-15C/D STOPPING DISTANCE
(Dry Runway, Maximum Anti-Skid)



Other variables can also heat up the tire and wheel assembly, creating additional problems. Malfunctions such as dragging brakes will add heat, as will long taxi distances because of added braking requirements and higher tire temperatures due to tire sidewall flexure. In fact, rolling to the end of the runway and a long taxi distance adds more heat to the system than an early turn-off and a direct taxi route. Don't interpret this as meaning that maximum anti-skid braking for an early turn-off is better than controlled aero braking. In general, hard braking or easy braking at speeds under 90 knots will create about the same brake temperature. Below 90 knots, zero drag is replaced with engine idle thrust. The point here is to avoid taxiing long distances where possible, and don't taxi around trying to cool the brakes. Remember, the brake discs reach their maximum temperature immediately when the wheel stops rolling, and the structure and wheel and tire assembly reach maximum temperature about 15 to 30 minutes after the wheel stops since it takes a while to conduct the heat from the brake discs.

In summary, F-15 brakes based on carbon technology present significant advances in energy absorption capabilities, and we can no longer depend on visual clues to evaluate hot brake situations. You as the pilot are the key element in the process, and need to be aware of airplane speed and weight when the brakes are applied. Routine operations in Zone A will not produce hot brakes. When speed and weight are high enough to get into Zone B, the brakes can be considered hot, but not necessarily dangerous. In Zone C, things are extremely hot, and extra caution is definitely in order. ■

F-15 PERFORMANCE

FLYING CONFOI

By GLEN LARSON/*Senior Experimental Test Pilot*

Flight characteristics of any fighter aircraft always generate a lot of discussion among aircrews, and the F-15 is no exception. Today, several squadrons worldwide are flying F-15C/D aircraft configured with "conformal fuel tanks" (CFTs). Any time there is a major change to an aircraft configuration (and the addition of a 32-foot, 1200-pound conformal fuel tank under each wing root is unquestionably a major change), pilots are going to have a lot of questions. The intent of this article is to provide some answers through flight performance comparison data and figures for aircraft equipped with a centerline tank or with CFTs. (Incidentally, even if you are not flying C or D aircraft with conformal tanks right now, you probably know that the F-15E "dual role fighter" on our production line today also has them, so there is quite likely a "CFT Eagle" in your future and your close attention to this article is encouraged!)

After getting into some of the finer aspects of this subject, I realized the facts were not as simple as they first appeared, and writing this article was made possible only with contributions of several members of the MCAIR engineering team. My appreciation is expressed to Jim Agnew and Bill Nelson, Section Chiefs Technology; Drew Niemeyer, Senior Engineer Technology; and Bob Anderson, Chief Technology Engineer, for providing the aerodynamic data and performance analyses presented herein.

One of my earliest presentations in this lengthy series on flight characteristics of the F-15 discussed angle of attack and turn performance. While the data presented in that article back in 1984 touched upon the effects expected from the addition of conformal fuel tanks to the airplane, my emphasis then was on the basic Eagles most of you were flying at the time. Today there is a "new kid on the block" – CFTs are one of the most recent additions to production F-15s – and it's time for a detailed look at what's in store for the Eagle driver whose next assignment may be to a CFT-equipped F-15 squadron.

You may also have heard these fuel tanks referred to as "fastpacks" or pallets, but by any name, they mean significant expansion of capabilities for

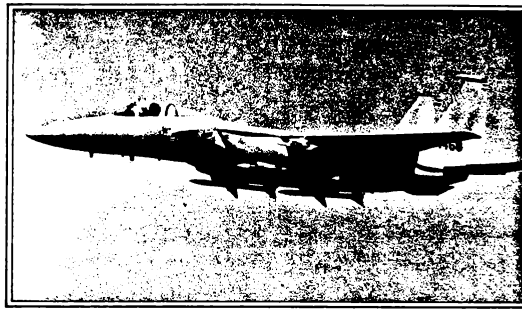
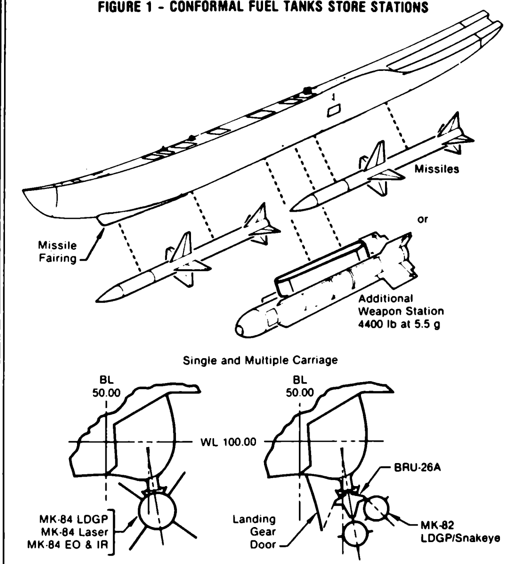


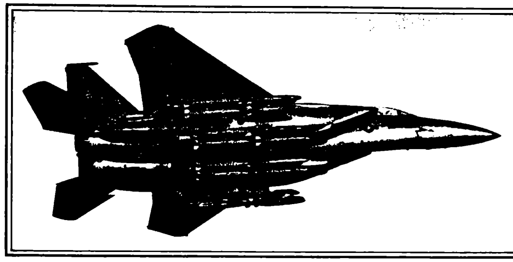
FIGURE 1 - CONFORMAL FUEL TANKS STORE STATIONS



AL FUEL TANKS

the airplane. The addition of nearly 10,000 pounds of fuel in CFTs increases combat radius dramatically, and provides unit commanders with unprecedented flexibility in combat tactics and strategy.

As you might expect, all these good things aren't free without charge; some compromises are necessary. Speed and turn performance are affected, and since these are two topics of great interest to all Eagle drivers, we will examine exactly what effect CFTs have on F-15 top speed and on both instantaneous and sustained turn performance. But first, a little background about these strange looking objects that are appearing on more and more of our Eagles these days.



HISTORY

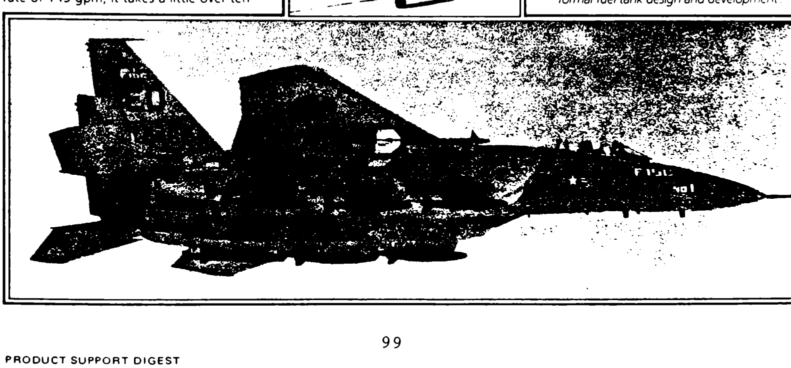
Conformal fuel tanks originated as a MCAIR advanced design concept shortly after the original F-15 contract was awarded and well before first flight of the airplane in 1972.

The CFT prototype program was initiated and funded by the company as one of the ways to take advantage of the Eagle's inherent versatility and growth potential. The tanks are "wet" (no bladders) and are made of conventional aluminum skin, frame, and stringer construction. Each tank is divided into three compartments, with electric transfer pumps in the aft and center compartments. The CFT fuel system is connected to the aircraft manifold through a single quick-disconnect probe. The aircraft fuel system permits transfer, refuel, normal defuel, and dumping of CFT fuel. (At a rate of 145 gpm, it takes a little over ten minutes to dump a full CFT fuel load.)

F-15B S/N 71-291 (a pre-production two-seater) was modified to carry the CFTs; and the first prototype tank set was flown on 27 July 1974. This prototype set was used on a transatlantic flight in August 1974 – a nonstop, unrefueled, 2,650 nautical mile trip from Loring AFB, Maine, to RAF Bentwaters, England.* Seven more transatlantic flights and one transpacific flight were subsequently flown. In mid-1978, the Government of Israel placed an order for CFTs. The first set, delivered in June of 1980, was used for heavyweight testing and certification for 68,000 pounds gross weight operations.

Go-ahead was received in June 1982 from the US Air Force for initial production of the -2 CFTs. The F-15 multi-stage improvement program (MSIP) provided several major updates and changes to the aircraft, particularly a programmable armament control system (PACS). This weapon system update also required ▶

**If you have a copy of "EAGLE TALK" (Volume I), there are two interesting articles therein, reprinted from the 1974 DIGEST and titled "Fast Pack to Farnborough," on the early engineering and flight test history of conformal fuel tank design and development.*



changes to the CFT air-to-surface weapons configuration interface, and the original contract was amended to immediately begin production of the -3 CFTs. This configuration included air-to-surface weapon interfaces for both MSIP and non-MSIP aircraft.

Today, F-15C/Ds currently assigned to the 57th FIS at Keflavik, Iceland; 1st TFW at Langley AFB, Virginia; 18th TFW at Kadena AB, Japan; and the flight test centers at Eglin AFB, Florida and Edwards AFB, California are presently flying -2 or -3 CFTs. All F-15Es will be equipped with the latest version, the -4 with tangential weapons carriage, slated to go into production in the near future.

WEAPON CARRIAGE CAPABILITIES

CFTs are designed with both air-to-air and air-to-surface stations, as shown in figure 1. This gives the aircraft equipped with PACS five air-to-surface stations, all capable of various single and multiple store loadings. During the AFC (advanced fighter capability) demonstration program in 1982, a test aircraft equipped with CFTs was loaded with five BRU-26A bomb racks and twenty-two MK-82 bombs. Although (refer to the top photograph on previous page) this was certainly an impressive load, the aircraft suffered from the effects of a 198 drag index (127 after bombs dropped), contributed primarily by the BRU-26A bomb racks.

Therefore, the best load for an air-to-surface mission with current production CFTs has been determined as the MK-84 family of bombs utilizing direct pylon carriage. With a maximum load of five bombs, the drag index is greatly decreased to 63 (42 after bombs dropped). These drag indexes include four AIM-9s. In comparison, the drag index of a four AIM-7/four AIM-9 configuration is 33, and adding a centerline tank increases the total to 58.

TANGENTIAL CARRIAGE

The name of the game during the comparative evaluation for the F-15E Dual Role Fighter (DRF) was range and payload. The operational analysis people favored twelve MK-82s; but as you can guess, this weapon load was far from optimum (drag index of 116). In order to reduce the drag (thus increasing range), MCAIR funded the "tangential" bomb carriage test on the CFTs. This method of carrying various bomb configurations greatly reduces the amount of drag associated with current CFT multiple and single carriage.

In a program that took only six weeks from go-ahead to first flight with bombs, the tangential carriage concept was evaluated. Arrangement of the bombs and the dramatic decrease in frontal area (refer to the bottom photographs on previous page), plus additional external fuel which can be carried provides a 28% range improvement for a MK-82 bomb load. Remember, the name of the game is combat radius and/or time on station. CFTs aren't suited for ACM missions 20 miles from the field but are ideal for deep interdiction or long range CAP/escort missions.

Now that I have provided you a peek into the improved capabilities of the next generation of CFTs, let's get back to what is at hand – a discussion concerning the basic, non-tangential carriage CFTs, commonly referred to as -2 and -3 versions.

AIRCRAFT PERFORMANCE

How do conventional CFTs affect the capabilities of the F-15? The best way to answer that question is in terms of speed and turn performance.

Speed

In level flight, the total subsonic drag of a CFT-equipped airplane is significantly less than one carrying a centerline external tank. Above 1.0 Mach, the drag of the CFTs is somewhat more than that from the centerline tank. In any case, drag from two CFTs is much less than that produced by two or three external tanks.

Figure 2 shows the top speed attainable in level flight at 10,000 feet MSL with 97.7% thrust engines. The first configuration (pylons and one AIM-9) is one typically employed in training; the second is a full up air-to-air load. For comparison, top speeds were calculated for these configurations with a centerline tank and with CFTs. As you can see, in a training configuration an aircraft with CFTs will reach 615 KCAS, and with only the centerline, 626 KCAS in full afterburner. (Incidentally, these speeds should be representative of the real world since they were determined by calculating what the speed would be at an acceleration rate of one knot/second. That level

FIGURE 2 - F-15C MAXIMUM SPEED
Maximum Velocity at Acceleration Rate of 1 kt/sec
Altitude = 10,000 ft 97.7% Engines Standard Day

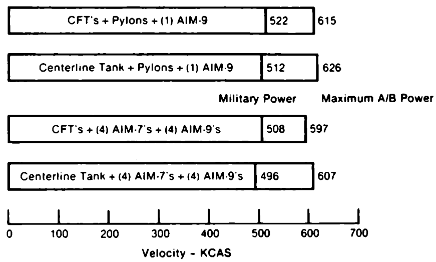
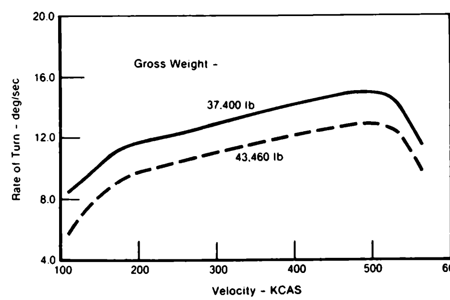


FIGURE 3 - F-15C TURN PERFORMANCE
Alt = 10,000 ft P_S = 0 FPS Maximum Power



of acceleration was chosen since it will seem to most pilots that the aircraft is no longer accelerating at that point.) In mil power, you can expect to see 522 knots with CFTs onboard, and because of slightly more drag, 512 knots with the centerline tank alone.

Speed by itself doesn't tell the whole story; the time required to reach these speeds is also critical. In max power at 10,000 ft, it takes 19 seconds to go from 300 to 500 knots when configured with CFTs, pylons, and one AIM-9 at 50% fuel weight. Dropping the CFTs and adding the centerline tank results in 17 seconds at 50% fuel weight. If however, we look at the CFT configuration at the same weight as the centerline tank loading, we would see a time of 16 seconds. Since aircraft acceleration is highly dependent on weight, the basic difference is due to the additional weight in fuel and structure for the CFTs. In mil power, the time is about 56 seconds for both the CFT and centerline tank configurations.

Altitude also has some effect. For example, in max power at 20,000 feet you can expect to see 553 knots with CFTs, two pylons, and an AIM-9, or 569 knots if you drop the CFTs and put on a centerline tank. In mil power, both are about 445 knots. Times to accelerate in max power from 300 to 500 knots at 20,000 ft with 50% fuel weight are 26 seconds for a centerline tank, 30 seconds for the CFTs.

All these numbers demonstrate that conformal fuel tanks will not materially change speed and acceleration characteristics when compared with a centerline tank equipped F-15. And remember, the centerline only carries 3,965 pounds of fuel, whereas the two CFTs carry a total of 9,630 pounds.

Turn Performance

Configuration differences have essentially no effect on instantaneous turn rates. It is only the change in gross weight or load limits (stores remaining on board) that actually affect instantaneous turn rates. However, sustained turn performance will be affected by both gross weight and configuration differences.

Figure 3 is a comparison of sustained turn rates for low and high airplane gross weights at various airspeeds. The solid line shows a 37,400 pound aircraft (a fairly low gross weight) with four AIM-7 missiles onboard. Its maximum sustained turn rate is about 15 degrees per second at 500 knots. The dashed line is for a gross weight of 43,460 pounds also with four AIM-7s onboard (loading really doesn't matter a great deal at this speed; the weight is more significant). The best sustained turn rate drops to approximately 13 degrees per second, but it still occurs at 500 knots.

Since sustained turn rate is a function of how many g's the aircraft can withstand, we need a chart that shows how

FIGURE 4 - F-15C W/O CFTs SUSTAINED G CAPABILITY
Alt = 10,000 ft Maximum Power

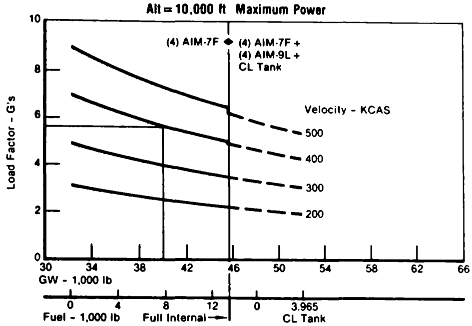


FIGURE 5 - F-15C + CFT SUSTAINED G CAPABILITY
Alt = 10,000 ft Maximum Power

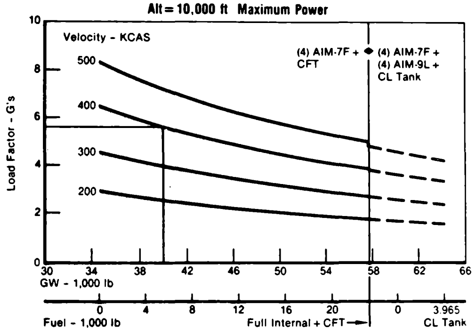
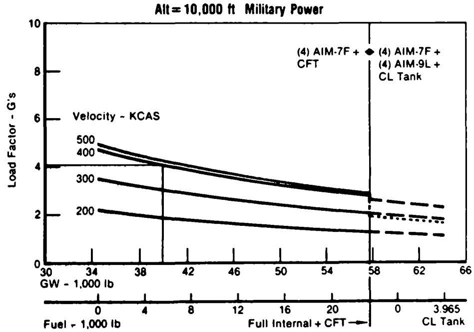


FIGURE 6 - F-15C + CFT SUSTAINED G CAPABILITY
Alt = 10,000 ft Military Power



sustained g changes with weight and speed. Figure 4 relates load factors (or g levels) to aircraft gross weights and amount of fuel on board. The constant airspeed curves, from 200 to 500 KCAS, represent sustained g levels at various gross weights. A specific example is shown on the chart: an F-15 at 40,000 pounds gross weight and 400 KCAS will sustain 5.5 g's at 10,000 ft.

The most important point concerning figure 4 is the significant decrease in sustained g capability with an increase in aircraft gross weight. Additional weight and drag reduce sustained g capability, especially at higher speeds. The step change in the g sustainable on the 500 KCAS line when changing configuration is caused by the added drag of the AIM-9 missiles and centerline tank. Below approximately 300 KCAS, the drag of these configuration changes has little effect on sustained turn performance; above 300 KCAS, the effects become more and more significant. This is why it helps to jettison the external tanks – lower weight means higher sustained g's and less drag means higher speeds with better acceleration.

Figure 5 is identical to figure 4 except that the configuration includes CFTs. At 40,000 pounds gross weight, the aircraft still sustains 5.5 g's at 400 KCAS but the fuel onboard is 5400 pounds, compared to the fuel onboard in figure 4 of 7800 pounds.

Figure 6 is included for comparison with figure 5. The two charts are identical except that the values in figure 6 are calculated at mil power. As expected, the sustained g level at 40,000 pounds gross weight and 400 KCAS drops to 4 g's from the 5.5 g's sustained with max power. Higher altitudes have a similar effect. At 20,000 feet, the sustained g at 40,000 pounds will be 4 g's at 400 KCAS in max power and 3 g's in mil power.

Another interesting point on this chart is that the 500 KCAS sustained g capability is about the same level as the 400 KCAS. This is explained by the fact that at 500 KCAS, most of the available thrust is required for level flight, leaving very little for sustained turns. Sustained turn performance is highly dependent on weight; therefore, at the high fuel weights possible with CFTs, sustained g capability will be significantly lower than for a basic F-15.

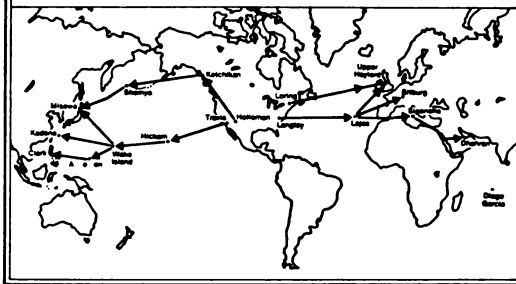
HANDLING QUALITIES

Handling qualities of a CFT-equipped airplane are not noticeably different from those of a clean airplane. The major effect is, again, the added weight. Because of the higher weights and inertia, the airplane may be perceived as being slightly less responsive. At high angles of attack, the only noticeable difference is a slightly higher angle at full aft stick. This results from a reduction in the basic nose-down pitching moment of the aircraft due to the CFTs.

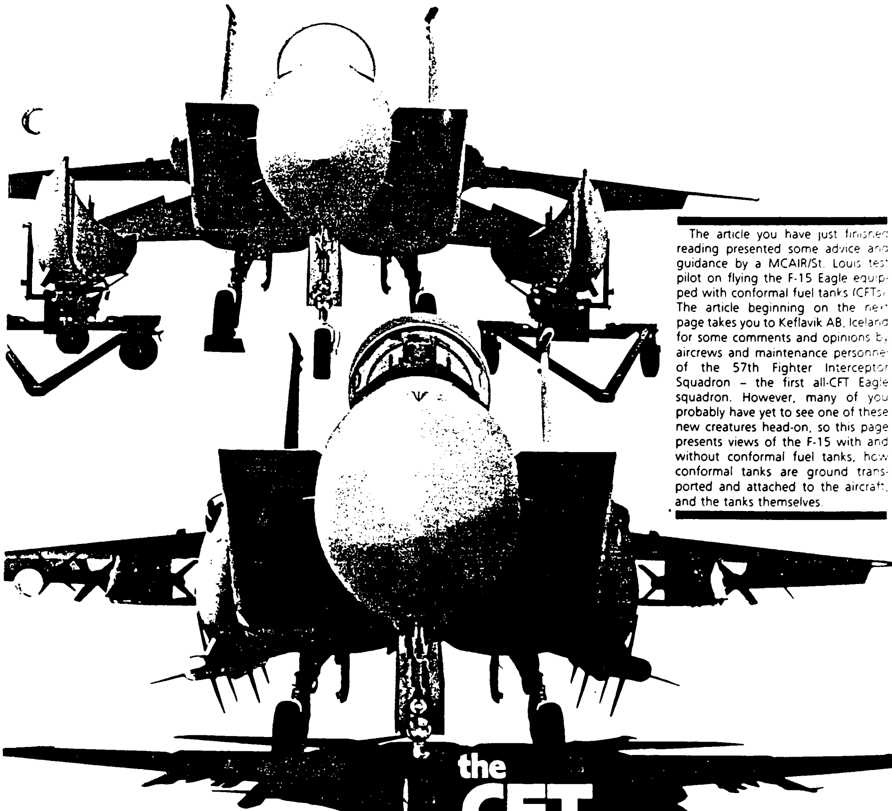
Additional ballast isn't required when CFTs are added, and fuel asymmetry shouldn't be a problem. The CFTs are designed to never exceed 500 pounds imbalance during normal system operation, and they will feed before the internal wing tanks to minimize any imbalance possibility.

In summary, the price which must be paid for conformal fuel tanks in terms of performance is relatively small when compared with the tremendous increase in range they provide. Figure 7 shows the deployment capability of the CFT-equipped F-15 aircraft, which is unequaled in the world today. CFTs full of fuel are not appropriate for daily training flights to a restricted area or MOA 50 or 60 miles off the end of the runway. They're definitely a hindrance if you're trying to shoot the dart or fight DACT right after takeoff. But if you've got to go to war tomorrow – without tankers – then they're indispensable. You need CFTs to provide prolonged air cover for ground forces, AWACS protection, or airfield defense. ■

FIGURE 7 - F-15C WORLD DEPLOYMENT WITHOUT TANKERS

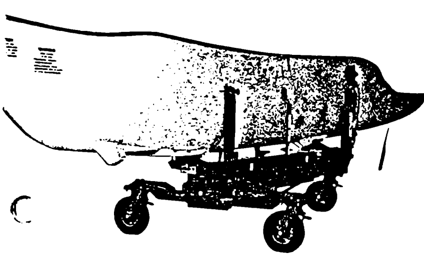


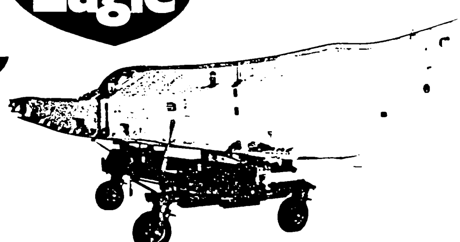
McDONNELL DOUGLAS F-15 EAGLE



The article you have just finished reading presented some advice and guidance by a MCAIR/St. Louis test pilot on flying the F-15 Eagle equipped with conformal fuel tanks (CFTs). The article beginning on the next page takes you to Keflavik AB, Iceland for some comments and opinions by aircrews and maintenance personnel of the 57th Fighter Interceptor Squadron – the first all-CFT Eagle squadron. However, many of you probably have yet to see one of these new creatures head-on, so this page presents views of the F-15 with and without conformal fuel tanks, how conformal tanks are ground transported and attached to the aircraft, and the tanks themselves.

the CFT Eagle





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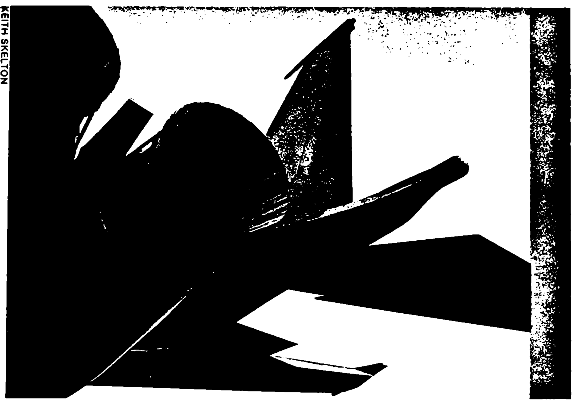
the EAGLE's Aileron/Rudder interconnect system

By DALE CATTOOR/*Technical Specialist - Avionics Group*



KEITH SKELTON

Ever since the first Eagle took to the air, on 27 July 1972, discussions continually center around the flight control wizardry of the F-15 Eagle. In past issues of the DIGEST are several articles presenting different aspects of the system: its purpose and mechanization in the flight control system; ways to check it during pre-flight; and how the system functions in flight. In this article, we continue our discussions, once again, with the directional control system.

I'm going to assume that you're somewhat familiar with the F-15 flight control system. In this article we are going into more detail concerning what the rudder control system, and particularly the ARI system, is designed to do. All rudder pedal inputs go through the Aileron Rudder Interconnect (ARI) unit, a part of the Control Stick Boost/Pitch Compensator. The ARI combines rudder pedal signals with functions of roll and pitch, providing turn coordination over the range of pitch and roll maneuvers. Rudder linkage malfunctions downstream from the ARI can adversely affect the ability of the rudder control surface to function properly.

Several questions from aircrews have surfaced: What are the corrective actions for ARI rudder interconnect cable failure modes? What are the results of such failures on aircraft handling qualities?

After discussions with Dave Thompson, F-15 Director of Engineering, our company's test pilots, and engineers in our Engineering Technology Division, here's their advice on various characteristics of the ARI system.

AIRCRAFT ROLLING MANEUVERS - At positive AOA (nose up), aircraft rolling maneuvers commanded by the pilot result in adverse yawing motion - left yaw when attempting a right roll and vice versa. This phenomenon (which is characteristic of conventional aircraft), causes roll hesitation at moderate AOA and roll reversals at high AOA. Incorporation of the ARI system corrected the adverse yaw characteristics of the F-15 and provided acceptable roll performance (feet-on-the-floor) throughout the maneuvering flight envelope of the aircraft. Roll maneuvers at negative AOA (nose down) result in the opposite effect - proverse yaw and excessive roll rate. This problem was also corrected by the ARI mechanization.

ARI OPERATION - The ARI works in conjunction with the PRCA (pitch and roll channel assembly) to provide acceptable roll performance over the useful AOA range. This is possible even though there are no AOA inputs to either the PRCA or the ARI because the PRCA pitch output position (which is basically the same as stabilator deflection) is also a reasonable approximation of AOA.

The PRCA sends this (pseudo) AOA information to the ARI by way of the interconnect cable, which in turn drives a yaw ratio changer inside the ARI box. Yaw ratio is the ARI gain, which varies as a function of PRCA pitch output. Roll coordination is accomplished by driving the rudders in the direction of the lateral stick when AOA is positive and in the opposite direction when AOA is negative.

This is quite a sophisticated function in that the amount of rudder deflection per inch of lateral stick increases with aft stick displacement. At large aft stick inputs (positive AOA), the ARI gain is - 15 degrees of rudder per inch of lateral stick (right stick gives right rudder). At large forward stick inputs (negative AOA), the ARI gain is + 7.5 degrees per inch (right stick gives left rudder). Near neutral stick (small AOA), the ARI gain is near zero and lateral stick movement results in little or no rudder deflection.

The ARI system can deflect the rudders to their extreme of travel (30 degrees left or right, which equals 16.5 inches deflection at the rudder lower closure rib) whether yaw CAS is on or off. Rudder deflection via the rudder pedals is + 15 degrees (8.25 inches) yaw CAS off; + 30 degrees yaw CAS on. Total rudder available is + 30 degrees, and actual rudder displacement within these limits will be the result of rudder pedal displacement, ARI, and yaw CAS all adding (or subtracting) their demands.

INTERCONNECT FAILURE MODES AND EFFECTS - Aircraft handling qualities can be affected by various interconnect failure modes which can cause the ARI function to be mis-scheduled:

- If the cable jams in a position that corresponds to full forward stick, aircraft roll response at low and positive AOA would be very sluggish since stick deflection would produce rudder which would oppose the commanded roll. (For example, right stick deflection would yield left rudder.) At negative AOA, the response would be near normal.
- A jammed cable in the direction that corresponds to aft stick deflection would have the opposite effect - aircraft roll

response at low and negative AOA would be too sensitive because proverse yaw would be generated by the ARI, which would aid roll rate. (Roll sensitivity would be further increased in this situation if the aircraft were carrying three full external tanks, or if the yaw CAS were off.) At high positive AOA, the response would be near normal since large rudder motion in the direction of the lateral stick is the desired result.

• Breaking or disconnecting of the ARI interconnect would most likely result in the ARI gain moving to the – 15 degree per inch value, which would cause increased roll sensitivity at low and positive AOA. (Although maintenance records show that jammed interconnect cables have occurred, there has never been a report of an actual broken cable.)

PILOT CORRECTIVE ACTIONS – It is be treated in the same way as any apparent roll control malfunction.

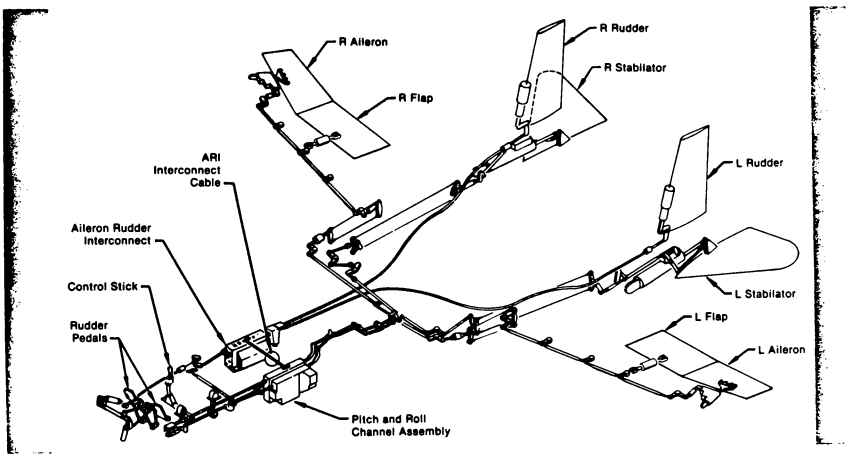
If the aircraft is difficult to control, select emergency position of the roll ratio switch. This action immediately defeats all of the ratio changing and boost functions in the ARI and roll portions of the PRCA. Do not disengage CAS because it is helping to control the aircraft. If CAS is off when the control problem occurs, it is even more imperative to select roll ratio emergency. Maneuvering at AOA above 30 CPU should be avoided with roll ratio in emergency. The same is true if pitch ratio is in emergency since that also deactivates the ARI.

If the yaw rate warning tone is on, the aircraft is definitely in a departure situation and roll ratio emergency should NOT be selected. With roll ratio in emergency, roll control authority will be significantly satisfactory operation of the ARI system during normal checks of the flight control system before taxi. It is important that the pilot visually confirm actual flight control surface positions during these checks:

• With the stick in the full aft position, full right lateral stick should produce full right rudder.

• While holding the stick full right, slowly move the stick full forward Near the neutral fore and aft stick position, the rudders should return to neutral and then deflect full left as the stick approaches full forward.

All deflections would reverse if these checks are made with left stick. "Full rudder deflection" in these checks is the same position that should be observed with stick neutral and full rudder pedal displacement with yaw CAS on. ■



important to remember that there are two distinctly different classes of problems that can result in lateral control difficulties:

• The aircraft departs controlled flight at high AOA. This can occur with a perfectly normal flight control system, and pilot corrective action is described in the "Out-Of-Control Recovery" procedures of the DASH ONE.

• The aircraft experiences a flight control system malfunction. Corrective action is described in the "Flight Control System Malfunction" procedures of the DASH ONE, and amplified here.

If the malfunction occurs in the ARI, it will be evident to the pilot as abnormal lateral control of the aircraft and should reduced and may degrade spin recovery. The warning tone comes on as an interrupted 900 Hz tone at 30 degrees/second yaw rate. The interrupt rate increases with increasing yaw rate and reaches a steady 10 Hz interrupt rate at 60 degrees/second and above.

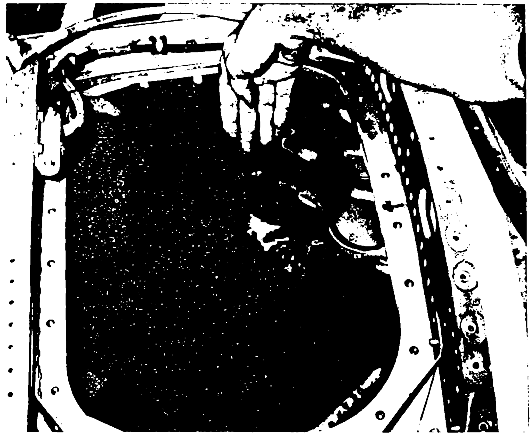
Pitch, roll, and yaw CAS are programmed to disengage at approximately 42 degrees/second. This is normal and is intended to prevent the CAS from introducing control surface movements that could detract from the pilot's ability to recover the aircraft from a spin. After recovery from a departure/spin situation, all CAS should be reset by the pilot.

BEFORE TAXI FLIGHT CONTROL CHECKS – It is very easy to determine

Editor's Note: See the Product Support DIGEST reprint collection PS 951 ("F-15 Flight Control System"), which discusses the ARI both as an integral part of the directional control system and as a related system; or see DIGEST reprints PS 1257 ("Eagle Talk," Volumes I and II). PS 951 articles are included in "Eagle Talk" Vol. I; Vol. II contains a reprint of "F-15 Preflight Control Checks," which discusses additional steps beyond those in the DASH ONE to verify operation of the ARI system. MCAIR reps on base have, or can get, extra copies of any of these reprints.

Electricity can do things for you . . . or it can do things to you. In the form of "current," electricity flowing through conductor cables is harnessed and obedient — switch on the light in your room and you are seeing the immediate result of current electricity. An actual and controlled movement of electrical energy has occurred through the wires and into the bulb — your light goes on. In the form of "static," electricity is completely unharnessed and disobedient — on a cold, dry winter day, walk across the carpet in your room, put your hand on the metal doorknob, and you will most likely feel the immediate result of static electricity. A faint blue spark, zaaap, ouch! Build up a big enough collection (charge) of these disobedient electrons, and your "lights" may well go out!

It is not our purpose here to "explain" electricity (especially since we really don't understand it all that well ourselves), except to say that it is, in the words of Webster, "a fundamental entity of nature." Suffice for us to say that it exists, and in the "harnessed" form of current, electricity is vital to operation and maintenance of fighter airplanes like the Phantom, Eagle, Harrier, and Hornet. Current electricity helps our aircraft do all sorts of wonderful things. In the unharnessed form of static, electricity can cause them (and you) to do all sorts of decidely unwonderful things. Therefore, to help promote the former and prevent the latter, it is our purpose here to discuss



Static Electricity... UNWANTED WONDER!

Two recent events prompted us to decide that a DIGEST article on the natural phenomenon of "static electricity" might be worthwhile —

• Event No. 1 — An F-15 returned from flight with a pilot report of uncontrolled fuel venting. During troubleshooting, it was discovered that six to eight inches of the fire suppression foam was burned in the top of No. 1 fuel cell (photograph above was taken looking into this cell and shows condition of foam). In more than 600,000 flight hours, this was the first reported incident of such a fire in the Eagle, and naturally generated great interest. Facts uncovered during the ensuing investigation indicate that the fire was not caused by a failure in the fuel tank pressurization system or in any electrical component in the tank. It was concluded that the most probable cause was static electricity discharge in the vicinity of the four vent lines located in the forward portion of tank 1. The fire was successfully contained by the suppression foam in the tank, damage was minor, and there was no apparent impairment of fuel system operation. Customary anti-static additives were not being used in the JP-4 fuel supply at this aircraft's home base at the time of the incident.

The static electricity accumulation was most likely a product of abnormal fuel and/or vapor flow through the vent system tubes, as a result of a failure in the feed tank level control system. Several fuel lines in tank 1 showed unusually high resistance across some couplings, with questionable static grounding into tank 1. The polyurethane foam in this tank, though a known contributor to static charge generation, did protect the aircraft as it was designed to do, by preventing fire propagation and the build-up of explosive over-pressures. Anti-static additives are now being used in the jet fuel supplied at this base; and careful checks are now being made to ensure correct electrical bonding paths after fuel system maintenance.

• Event No. 2 — A message arrived in St. Louis from one of our field service engineers. His message stated that the squadron he was supporting questioned the need to "static ground" their aircraft during maintenance. He went on to say that he had given them some basic reasons for doing so, but they wanted documentation, justification, etc. They wanted to know how much static electricity could be built up in an aircraft and what it took to get a discharge. After consultation with the MCAIR Electrical Engineering Department, here were the words passed back to the field by our Home Office technical specialist.

"MIL-E-6051D requires aircraft grounding jacks to be installed to allow static grounding of the aircraft during servicing. Under certain conditions (for example, very dry, snappy cold, high windy weather, while hanging external tanks or ordnance, refueling with a high refueling rate, or adding anything to the aircraft that will increase its electrical capacitance), difference of ▶

50,000 volts or more, structure to ground, can exist. Operations in high humidity/warm weather conditions will normally not produce charges this high, but there is always a possibility that a sufficient difference may exist to shock personnel as they install ladders or touch the aircraft. Not enough of the charge will be dissipated through the rubber tires. Even if the charge can be dissipated, for example, by taxiing over a wet runway, the potential can be reintroduced through fuel flow into the aircraft, hanging of ordnance, LOX servicing, etc."

"We do not want to spell doom if static grounding is not provided. It is possible to go for a long time and never encounter a shock hazard to personnel or aircraft. However, it is a specification requirement as well as a commonsense, precautionary procedure, and we can see no operational or maintenance considerations to justify otherwise."

These two events, one involving an inflight incident probably resulting from static electricity and one indicating a probable lack of knowledge concerning static electricity, tell us that perhaps the "documentation and justification" requested by that squadron would be worth offering to the rest of our readers.

DOCUMENTATION

Military Specification MIL-E-6051D (Systems Electromagnetic Compatibility Requirements) outlines ". . . overall requirements for control of electromagnetic environment, including . . . static electricity, bonding, and grounding." This is an Air Force specification, also applicable to other US services.

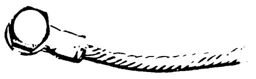
This specification requires that grounding jacks shall be installed on the (aircraft) system in sufficient quantity to permit connection of grounding wires for fueling, weapons handling, and other servicing operations. Servicing and maintenance equipment that can cause electrical shock, or sparks in areas prone to explosion or fire hazards, shall be provided with a permanently attached grounding wire suitable for connection to an earth ground rod. Static dischargers shall be installed on the aircraft. System designs shall include provisions for protection of personnel from R-F (radio frequency), electromagnetic, electrostatic, and shock hazards. System designs shall also include provisions for protection of ordnance from any form of electromagnetic or electrostatic energy. The compatibility testing required by this specification can involve literally hundreds of equipment relationships and conditions, and produce "criticality" category ratings ranging from annoyance to loss of vehicle or life.

MIL-E-6051D is a general contractual "design" specification, but there are numerous military manuals and reports relating to working level considerations of static electricity, its hazards, and its prevention. For example, AFR 127-101 (Ground Accident Prevention Handbook) and TO-00-25-172 (Ground Servicing of Aircraft and Static Grounding/Bonding) contain flight line and maintenance shop rules to follow. AFAPL-TR-78-56 (Static Electricity Hazards in Aircraft Fuel Systems) is a 200-page USAF technical report describing results of extensive contracted studies on the subject. Every document concerning static electricity (including the one you are reading now) comes to the same simple and basic conclusion — this is nothing to play games with!

In routine aircraft operation and maintenance, static sparking can ruin your whole day!

The point we wish to imbed in your mind here is that, without careful and conscientious attitudes on the part of maintenance people, all of these specification requirements, technical reports, and magazine articles are just so many words — and the word has not yet been written that can prevent a tiny blue spark of static from jumping a poorly bonded fuel system gap into a tank full of jet fuel. Static electricity is variable and unpredictable; spark energies can vary greatly according to the manner in which they are generated and the medium into which they flow — what may be insufficient to set anything off one time may ignite a catastrophe the next. Again, the technical documentation tells you all this, but you must be a believer. Leaving a fuel nozzle ground wire unconnected during refueling, failing to maintain designed-in bonding paths during aircraft systems maintenance; neglecting to static ground yourself where the maintenance manual warns to do so — just three examples of a "failure to believe" that could hurt both you and the airplane.

So, the "documentation" the



squadron asked our Rep for is there, and it's clear. How about "justification"? Facts and figures have been accumulating on airplanes ever since the Wright Brothers, and they are just as clear — static electricity is not going to go away. It is a phenomenon that's been around since the beginning of time and in all likelihood will be around until the end of time. It can affect the accuracy and reliability of controls and instrumentation. It is a constant source of danger to both equipment and personnel, particularly when generated near fuel or flammable vapors. In order to enjoy a long and happy life around fighter airplanes, static electricity is obviously something we must learn to live with, respect, and counter.

JUSTIFICATION

What is static electricity and how is it created? In reviewing data to prepare this article, it became clear to us that static electricity, while a fascinating topic, is a not very well understood phenomenon. Scientifically speaking, there is still a great deal of mystery concerning exactly why and how it forms; why its occurrence can be so variable; and why its severity can be so inconsistent. Here is one possible definition of it —

"A negative or positive charge of electricity that an insulated object accumulates, which creates a spark when that object comes near another object to which it may transmit its charge or from which it may receive a charge."

The static spark itself can be defined as "a luminous disruptive electrical discharge of very short duration." Disruptive indeed, for it is the occurrence of that "spark," as minute as it might be, that brings on all the subsequent problems. We really don't have to agree upon a definition for static electricity, or fully understand all the scientific properties and complexities behind it, but we had all better believe that that little blue spark is for real! In routine aircraft operations and maintenance, static sparking can ruin your whole day; understanding the phenomenon is not really important, controlling it is!

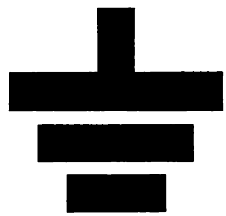
Around an aircraft, static electricity can be created in many different ways:

- By fuel, other petroleum products, and low conductivity consumables flowing through aircraft tubing, hoses, pumps, etc.
- By the flow of air containing dust particles, snow, ice crystals, etc., over an aircraft surface (aircraft can be parked, taxiing, or flying).
- By liquids dropping through space.
- By ionized contaminants (rust, mill scale, water, air) in petroleum products. (Contaminants become ionized during inactive settling in storage tanks and drums, fuel cells, etc.)
- By ionized contaminants suspended in fuel vapors.
- By atmospheric inductive coupling (lightning storms).
- By the contact and separation of two unlike substances.
- By almost any sort of motion of people or material.
- By personal clothing made from rayon, wool, silk, nylon, 100% synthetic materials, and certain plastics.

Electrostatic discharges, resulting from static electricity build-up, have been highly suspected as the cause of numerous fires and explosions involving fuel trucks, bulk tanks, and other fuel handling equipment, both in the military and civilian sectors. Also, over the past few years, several aircraft have been destroyed or damaged by fuel system fires caused by electrostatic discharges within the fuel tanks.

Because turbine fuels (jet fuels) are poor conductors of electricity but good generators of static electricity, their movement through pumps, plumbing, and particularly filtration equipment, causes generation of electrostatic charges. Also, tests have demonstrated that reticulated (open pore) urethane foam provides a surface for charge generation and retention with movement of fuel through the foam. Spark energy (charge transfer) measurements made with an oscilloscope at a fuel inlet have shown that blue polyether foam is more electrostatically active than red polyester. Blue foam energy discharges are 10 to 100 times greater than red foam discharges.*

If fuels contain a high electrostatic charge, sparks or "corona discharge" (a luminous discharge due to ionization of the air surrounding a conductor, around which exists a voltage gradient exceeding a certain critical value) may occur. If these discharges have sufficient energy to be "incendive" (capable of igniting a flammable fuel/air mixture), an explosion or fire can result. Electrostatic discharges are short-lived, but it doesn't take much energy from the charge to cause a problem. Laboratory tests have shown the electrical energy required to light a one watt light bulb for one thousandth of a second is sufficient to ignite a fuel vapor mixture at normal temperature. If prevailing weather conditions are cold and dry, electrostatic build-up and the chance of ignition are increased significantly. A startling fact not too well known is that during refueling



operations, measured electrostatic charges exceeding 50,000 volts have been developed. In addition, during aircraft servicing, especially during over-the-wing refueling, fuel has been noted to glow and crackle. If this ever occurs while servicing your aircraft, suspend all operations immediately until the phenomenon is no longer evident.

Improvements in aircraft capabilities and servicing techniques have also increased electrostatic buildup problems. For example, fuel system capacities have been increased to extend aircraft range, and single-point refueling has been developed to decrease turnaround time. Since both of these improvements involve more fuel passing through more system plumbing, there is also more potential for electrostatic buildup. And now that JP-4 and JP-8 fuels contain an anti-static additive, you may think it is unnecessary to statically ground your aircraft. Not so — these additives are very valuable in that they increase the electrical conductivity of the fuel and thus improve charge relaxation time, but the only way the decreased charge can be fully bled off is by the bonding path to ground.

**USAF Technical Report AFAPL-TR-78-56*

Up to this point we've confined ourselves to the generation of static electricity as it relates to jet fuels; however, fuel movement is not the only source of electrostatic buildup within an airplane. It can also be present (and is just as dangerous) when hanging ordnance or servicing an aircraft with other consumables such as oil, hydraulic fluid, liquid oxygen, and/or water/alcohol mixtures. With the exception of hand operated hydraulic and oil servicing carts, all other aircraft servicing equipment must be grounded prior to making servicing connection.

SIMPLIFICATION

By now you may have come to the same inescapable conclusion we have - that static electricity is everywhere. Its generation is inevitable and complete elimination is impossible. It is especially dangerous in that it cannot be seen until it occurs and its potential hazards are not commonly understood. Even so, as infamous and complex as static electricity is, it can be effectively controlled by just two simple measures - bonding and grounding. While there is considerable debate on the "nature" of static electricity and why it occurs, there is complete agreement on how to control and minimize it. "Bonding" keeps the electrical charges moving (prevents them from accumulating in a structure or system to the energy development point where they can spark or ignite); "grounding" carries them away to a safe place (earth) for disposition . . . without using you or the airplane as a dangerous "middleman."

Bonding

Bonding eliminates the differential in electrical charge which may exist, or be generated between two objects. Bonding is accomplished by connecting the two objects with bonding wire, soldered connections, bolting, or clamping. Before being joined together, metal parts at the connecting point must be free of all protective coatings such as tape, paints, lacquers, and oxidized finishes, since these substances insulate the connecting points. Particular attention must be paid to anodized aluminum parts as anodizing affords a high electrical resistance and must be removed prior to the installation of bonding wire.

During fuel system maintenance, good bonding practice requires that conductivity checks with use of an ohmmeter be made of reassembled plumbing to ensure that electrical conductivity to ground exists. Although bonding allows the charge between two electrically charged objects to equalize, the objects themselves may ▶

still be highly charged with respect to other objects or ground. In order to dissipate this charge, electrical continuity to ground is necessary.

Grounding

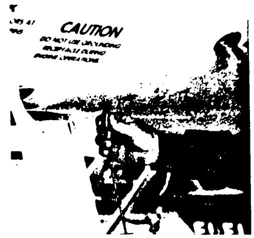
The earth is a constant source of electrical potential. By providing an electrical path between an aircraft and this source, all bonded aircraft components are brought to the same ground potential, thus "relaxing" the electrostatic charge. Grounding is the most practical way to control static electricity since, through a low resistance wire path, all components can then be brought to the same ground potential.

Another significant reason for grounding your aircraft is to provide lightning protection. There have been several cases where lightning has hit parked aircraft which were electrically grounded. The grounding connection provided a conductive path for the electrical energy to travel without creating sparks and arcing, thus preventing extensive damage to the aircraft.

As mentioned previously, electrostatic build-up and an ignition hazard are more likely in cold, dry weather than during warm, humid conditions. Aircraft surfaces coated with a film of moisture make good conductors and aid in drawing off static charges. Since there is not much one can do to control outdoor weather conditions, it is even more important to statically ground an aircraft, *indoors or outdoors,* in cold dry weather.

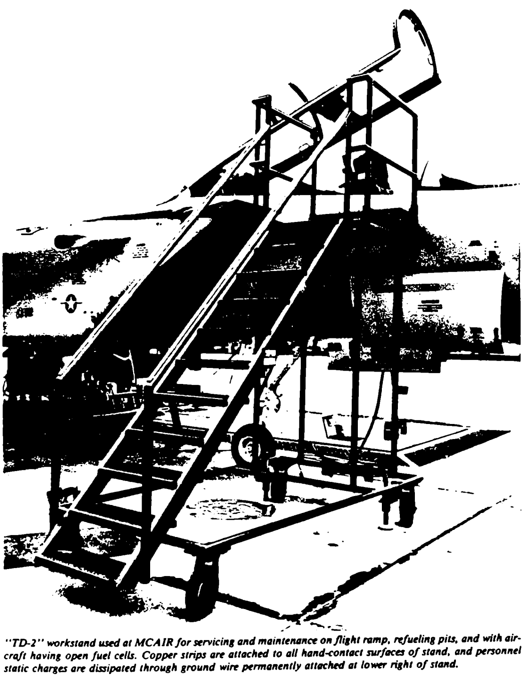
At long last, how might we sum up everything presented to this point? Perhaps in two ways -

• Aircraft bonding and grounding do not *eliminate* the static electricity hazard. However, they greatly reduce the hazard by providing paths for opposite charges to recombine without a spark . . . and all the bad things that can happen begin with a spark.



First commandment of maintenance safety – Thou shalt ground thy aircraft.

• NOT bonding or grounding your aircraft does not automatically guarantee an accident - you could go for a long time and not encounter an electrostatic hazard. You "could," but the odds are you won't.

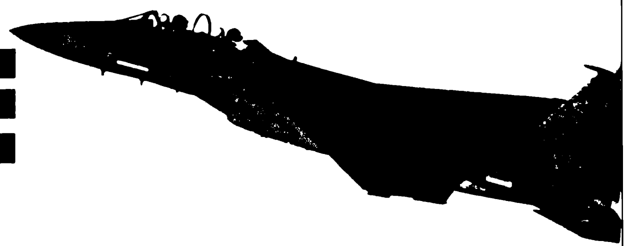


"TD-2" workstand used at MCAIR for servicing and maintenance on flight ramp, refueling pits, and with aircraft having open fuel cells. Copper strips are attached to all hand-contact surfaces of stand, and personnel static charges are dissipated through ground wire permanently attached at lower right of stand.

Explosion and fire are the two things jet fighter pilots least like to encounter in flight; and those two hazards are hardly more tolerable on the ramp or in the maintenance shop. Static electricity is a recognized cause of aircraft explosions and fires, so on behalf of pilots and ground personnel everywhere, let's "S..O..S - "Stamp Out Static!"

This discussion has concentrated on the "big" picture with respect to static electricity and its effects upon aircraft and personnel. However, we would like to end this article by reminding you that the DIGEST has also examined the "little" picture. Back in Issue 2/79, the equipment electrostatic caution label illustrated below was used as the title of an article concerning the effects of static electricity on transistors, resistors, integrated circuits, and other small electronic devices. Now, as then, the thought we would like to leave you with is that almost everything about a fighter aircraft is in some way "electrostatic sensitive" - equipment, systems, components, bits & pieces, even the people who fly and maintain it. Come to think of it, perhaps every new airplane should leave the factory enclosed in a huge antistatic polyethylene bag and marked . . .

F-15E Rollout



If you have seen one of the thousands of photographs taken of the MCAIR F-15 Eagle since it first began flying nearly fifteen years ago, the F-15E "dual role fighter" version pictured here during one of its first test flights doesn't appear much different. However, appearances are very deceiving. While all of the 850 F-15A/B/C/D Eagles delivered to U.S. and allied air forces thus far have been exceptionally capable and important to defense of the free world, the "DRF" is in a class by itself. There is simply no other way to describe it – and we think that is what each of the guest speakers had in mind with their remarks at the official unveiling of this latest model in the Eagle series.

Introduced with pomp and circumstance on the 18th of December 1986, the F-15E dual role (air-to-air/air-to-ground) Eagle made its first public appearance "half-and-half." It won't ever fly that way of course, but this one-time configuration offered a vivid display of its dual-role capability. From the right side, guests at the rollout ceremony saw the newest Eagle displayed with the AIM-7 radar and AIM-9 infrared missiles of the air superiority configuration that has been the primary F-15 capability since inception of the design. Viewed from the left, the display aircraft carried armament and equipment (including conformal fuel tank) of the long-range interdiction configuration that makes this design brand new and the most formidable weapon system of its time.

Eagle serial number 86-183, the first of 392 F-15E's scheduled for delivery to the United States Air Force, was officially introduced before a gathering of more than 1700 MDC employees and invited guests assembled in MCAIR hangar building 42. The Scott Air Force Base honor guard, color guard, and Military Airlift Command band (under the direction of SSgt Tony Chapman) provided a colorful and impressive accompaniment for the opening ceremonies. The audience included officials from the Department of Defense and Department of the Air Force; congressmen from the State of Missouri; military personnel from HQ/USAF, Tactical Air Command, Air Force Systems Command, Military Airlift Command, and the St. Louis Naval Plant Representative Office; and aerospace industry officials of the McDonnell Douglas, Martin Marietta, Hughes, and Pratt & Whitney corporations, plus supplier and vendor representatives.

Sanford N. McDonnell

Sanford N. McDonnell, Chairman and Chief Executive Officer of McDonnell Douglas, was the official spokesman for MDC. In introducing the newest version of the Eagle, he recalled the performance and safety accomplishments of earlier versions. "The F-15 has an air-to-air combat record of 62 wins and no losses. Its reliability is higher than Air Force standards. It has the finest safety record of any Air Force fighter in history. The Eagle has brought pilots safely back home and landed with major pieces of structure missing – a nose, wing tips, half the tail, and once after an entire right wing was sheared off in a midair collision."

The F-15E DRF will provide aircrews with even more safety features, plus protection from the ground-based threats they can expect to encounter in the interdiction role. In this vital area of aircraft and crew survivability, Mr. McDonnell noted that "the most modern electronic systems and sensors will enable this newest Eagle to carry pilots safely through darkness, poor weather, and hostile territory. Its cockpit is the most advanced in existence and the best suited to the needs of aircrews of today and tomorrow."

The MDC chairman promised his audience, and the free world, that the vital partnership between our corporate team and the United States Air Force would continue. "Together, we have developed several of the world's best fighters – the F-101 Voodoo, F-4 Phantom II, and the Eagle A/B/C/D series. Together, we are determined to prepare for the future, with such new programs as the F-15E dual role fighter; and through support of government efforts at streamlining the procurement system, improving guidelines for contractors and customers, and increasing competition."

Mr. McDonnell concluded his remarks by emphasizing that "MDC has products which we want to be the core of our nation's military strategy. That is, we want to be the designers and builders of products of such high quality that no enemy of our country will ever think it possible that they can gain from an attack on the United States or its allies. The F-15 Eagle is such a product."

The Honorable Edward C. Aldridge, Jr.,

Edward C. Aldridge, Jr.

General Robert D. Russ

LtGen William Thurman

Secretary of the Air Force, was the first guest speaker, representing the entire Air Force. The rollout ceremony that had brought so many visitors to St. Louis this bright December day was, in his words, "a landmark event in the modernization of our tactical air forces. Our tactical air force commanders have identified the need for an aircraft capable of theater air defense and air field attack. It must have the range and payload to perform in the vast reaches of the Pacific and Southwest Asia theaters, as well as in Europe. It must perform deep interdiction, and find and attack fixed and mobile targets at night and under the weather. The F-15E dual role fighter answers that need.

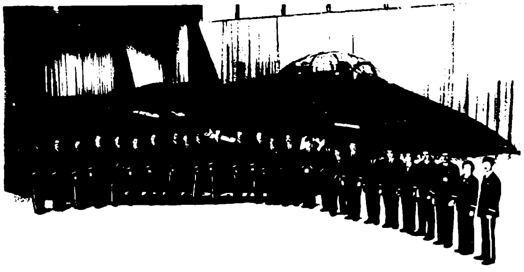
"This program is the latest chapter in a real success story, a story of collaboration between the Air Force and the aerospace industry to meet national security requirements in the most cost-effective way. The F-15E will make a true contribution to aerospace power for peace, and we all very much hope that its deterrent value will be successful throughout its lifetime."

General Robert D. Russ, Commander of the Tactical Air Command, spoke on behalf of the worldwide tactical air forces, and as an individual who had participated in the actual development process for the F-15E during earlier duty as USAF Deputy Chief of Staff for Research, Development, and Acquisition. "When the F-15 made its maiden flight some 15 years ago, it immediately gave the United States the upper hand in air-to-air combat. Its maneuverability, avionics, and thrust-to-weight ratio combined to make it the very best air superiority fighter in the world. Our day-to-day training and actual air-to-air combat statistics continue to demonstrate its quality. Even with current state of the art airframe, engines, and avionics, the Eagle has one of the highest available-to-fly rates of modern times, and it has become the safest fighter we have ever had in our history."

The general noted the great pride felt throughout the Tactical Air Command at acceptance of "yet another very fine McDonnell Douglas aircraft. The F-15E is indeed on the leading edge of technology" with navigation systems, radar capabilities, ordnance load capacities, and other features of the new weapon system guaranteeing it "a great future in the tactical air forces."

Final speaker at the rollout ceremony was LtGen William E. Thurman, Commander of the Aeronautical Systems Division of the Air Force Systems Command. ASD is the primary and immediate customer for aerospace industry products, and is responsible for providing weapon systems such as the F-15E to the operational and support commands. After acknowledging the distinguished lineage of the F-15 fighter aircraft series, the general turned his attention to the people and organizations involved in the program. "An aircraft is more than just a piece of machinery – it is also the sweat and the hope and the commitment of an army of contractor engineers, factory workers, industrial planners, supporters, and managers. It includes all the suppliers and subcontractors. It includes the members of our Systems Program Office, which is the buying activity for the Air Force. A fighter aircraft couldn't do what it does without the inputs of people from Tactical Air Command, to get the cockpit layout right and the performance right. The Air Force Logistics Command, Air Training Command, and the Plant Representative Office personnel are all vital to making a program such as the F-15E successful."

General Thurman's concluding remarks were particularly appropriate for the Christmas period in which the Eagle rollout ceremony occurred; and had added relevance for the senior employees in the audience who had often heard the late James S. McDonnell, founder of our company, present the same point of view. In expressing his personal appreciation to the personnel in the program, the general said, "You have all made a significant contribution toward an objective that we are especially aware of at this time of year – peace on earth. General John Vessey, former chairman of the Joint Chiefs of Staff, said it well – 'We can be weak and hope for peace or we can be strong and be sure of it.' As builders of the F-15E, you are giving us the strength that will ensure the peace for years to come. Thank you very much." ■



USAF Military Airlift Command Band (SSgt Tony Chapman director)

FLY SAFE!

USAF F-15 IMPROVEMENT PROGRAMS

F-15 EAGLE

By PETER J. VONMINDEN/*Manager, F-15 Support Programs*
and
DAVID E. NOTHSTINE/*Chief Program Engineer, F-15*

In the conclusion to his article on the Eagle in FLYING magazine, Lieutenant Colonel Durocher noted that "channelized (pilot) attention cost us in 1981." While an airplane manufacturer has no direct influence upon that particular aspect of military flight operations (except to design and plan cockpit configurations to minimize the probability), MCAIR considers every other aspect of F-15 activity to be part of its prime responsibility to the customer.

The F-15 began its U.S. Air Force career in 1972. Now, approximately 11 years later, more than 680 Eagles are in the USAF tactical inventory and the airplane is considered the world's top air superiority fighter. Because its service life is programmed until well into the next century, MCAIR is continuously preparing modifications to improve capability and reliability of the Eagle. Here is a synopsis of several ongoing programs designed to enhance the safety and effectiveness of the aircraft.

FACT FINDING VISITS

Last year, MCAIR representatives from the F-15 program office, engineering, and product support visited every USAF Eagle base in the United States and overseas. The intent of our visits was to discuss day-to-day problems that operations and maintenance personnel may have been experiencing with the airplane. Although our time on each base was brief, we found every stop to be beneficial and enlightening, both from our standpoint and the Air Force's. Because we know that in some instances our visits caused disruptions of work schedules, we'd like to take this opportunity both to apologize and to express our appreciation for the excellent reception we got at all locations. We noted an exceptionally fine ▶

"...We love the F-15 – It does an excellent job for us, but we want it to be even better!"

Colonel Ronald N. Hoelzer, (then) DCM, 18th TFW, Kadena AB, Japan in remarks opening F-15 Field Support Conference, May 1982.

attitude and real enthusiasm for the F-15, by both officer and enlisted personnel, as well as in-depth knowledge. When given an opportunity to describe problems or suggest improvements, both Eagle Drivers and Eagle Keepers offered excellent ideas which we brought back to St. Louis for consideration.

Technical questions and suggestions from the field applied to almost every area of F-15 engineering, operations, and maintenance; therefore, it took some time back here for everybody concerned to absorb and respond to all the detailed points. However, we eventually succeeded in compiling all the inputs and all the responses into a "letter report" addressed to F-15 command headquarters (AFLC, TAC, PACAF, USAFE, AAC); Air Logistics Centers and Aeronautical Systems Division; Wing-level operations and maintenance commanders; and all F-15 MCAIR Field Service Engineers. It was a 37-page letter covering structures, landing gear, armament, secondary power, ECS, fuel system, crew station, avionics, controls, hydraulics, electrical, propulsion, ground support equipment, AIS/TITE, and even a couple "miscellaneous" items that we couldn't include anywhere else! This was our first total F-15 "fact finding" expedition, and the letter report was our best effort at responding to all of your concerns. Since we obviously couldn't include everything discussed during our base visits in this DIGEST article, what follows is a representative sampling of topics; if you don't find a response to your specific question as posed during our visit to your base, please see your commander or the local MCAIR Rep – they've got the whole nine yards . . . or the whole 37 pages!

STRUCTURES/VERTICAL TAIL GROUP

Based on F-15 Signal Data Recorder (SDR) data received from the field for the 1980/81 time period, MCAIR engineering has developed a new fatigue spectrum. This new spectrum has been used for an analysis from which several improvement changes for the vertical tail group have evolved. More recent SDR data has just been received and is being evaluated to update our analysis.

Production changes already being incorporated include larger fasteners for tip pod attachment, thickened forward box skin at the upper end, stronger honeycomb in the forward box and torque box, and improved sealing and draining provisions for the tip area.

ECP 1701 has been approved to retrofit 3/16 inch diameter flush head fasteners in the 2 and 6 inch support fittings with protruding head fasteners (TCTO 1F-15-855). These new fasteners have a better torquing capability to provide greater joint strength and tightness to minimize water intrusion.

ECP 1597, a production and retrofit change, has been submitted to provide through fasteners for the 2 and 6 inch tip pod support fittings and replacement of the upper portion of the forward box with titanium structure.

CREW STATION

(Joseph Gregurech/Unit Chief)

When Jet Fuel Starter (JFS) in-flight starting capability was incorporated in the F-15, the circuitry which required the pilot to cycle the engine master switch prior to re-engaging the JFS was removed. This was done to minimize pilot actions and the possibility of procedural errors during an emergency situation. Currently this circuitry change presents a potential problem, brought about because the main engine start switch is activated by the same fingerlifts that must be raised to retard the throttles to cutoff. Investigations have shown that this switch is frequently unintentionally "made" when the throttles are moved full aft.

As long as there is electrical power on the aircraft, the engine start circuit will remain energized with engine rear compressor speed (N_2) below starter cutoff speed (50% N_2). This means that as soon as the JFS is started, it will automatically engage that engine without any further pilot action because the start circuitry is already activated. This presents no problem under normal circumstances because the JFS is either not operating (normal shut down), or engine N_2 is above 50% (JFS inflight start Acceptance Test Procedure).

However, the one time this situation cannot be tolerated is the one time it is most likely to occur – when an inflight dual engine stagnation takes place. In this situation, it is very probable that one or the other of the engine start circuits will be inadvertently energized, resulting in a failed decoupler shear section and making a JFS restart of the engine impossible. In addition, this condition would be very difficult to diagnose from the cockpit as there is no positive feedback to tell the pilot why the engine is not accelerating, even though all other indications say that it should be.

To correct this potential problem, a proposal has been made to add a fingerlift "stop" between the IDLE and OFF throttle positions to prevent inadvertent actuation of the engine start switch. The F-15 lighting mock-up throttle quadrant was modified to include the proposed fingerlift stop. The System Application Panel (SAP) reviewed the mock-up installation in July of 1981 and recommended that the design be adopted. ECP 1496-0 was submitted to the SPO in November 1981, and technically approved in December 1981. TCTO 1F-15-831 go-ahead is expected in early 1983, and full retrofit is proposed. The first production delivery will not be until early 1984, and retrofit will continue into 1985. Therefore, operators must continue to be aware of the current condition and use caution when retarding the throttles to cutoff.

HYDRAULIC ACTUATORS

(Paul T. Gentle/Unit Chief)

There have been numerous instances of hydraulic switching valves failing to switch. This occurs primarily during single-engine taxi and results in loss of either aileron or rudder function. Failure of the valve to switch is caused by a leaking relief valve, which the switching valve interprets as a system leak. Relief valve leakage is caused by severe wearing of the poppet where it contacts the seat. This wear appears to be caused by excessive cycling, but why the valve cycles excessively has not been determined. The fix to this problem is to change the relief valve to a "spool and sleeve" configuration which is less subject to wear from cycling. The supplier has been authorized to proceed with redesign of the valve but, because of tests required before production begins, it will be June 1984 before the new switching valves appear in service on production aircraft.

Leaking and damaged splines are

causing many rudder actuator removals. Endurance tests at MCAIR have shown a new seal material, phosphonitrilic fluorelastomer (PNF), to be superior to presently used Buna N material for holding shape and elasticity after long exposure to high temperature. A Class II change has been initiated to change all static seals and seals under cap strips in both the rudder and stabilator actuators to the PNF compound. Actuators with new seals should be in service in the third or fourth quarter of 1983.

Damaged rudder actuator drive splines and rudder drive fittings have been causing removals for some time. Tests at MCAIR of a new drive fitting made of Inconel X have shown a large improvement in the life of both the splines on the drive shaft and in the life of the fitting. This new fitting is interchangeable with the present titanium fitting, has an interference fit with the splines on the drive shaft, a 5/16 inch crossbolt, and an added vertical "pinch" bolt to prevent relative motion across the split in the fitting. These new fittings are now available as spares and will appear on new aircraft about June 1983.

ARMAMENT
(Larry C. Scott/Unit Chief)

Field experience with the LAU-114A/A AIM-9 Sidewinder launcher on the F-15 indicates poor reliability of the 60K-W008 head slaving relay. The wing pylon-mounted launcher is located in a high vibration environment. The relay, currently rigid mounted to a bracket inside the launcher, is sensitive to the environment and is failing prematurely. The classical failure mode of this relay is breakage of the glass beads around the solder joint "J" hooks which allows either movement of the hook(s) and intermittent relay operation, or moisture intrusion around the breakage area of the hooks.

Various relay mounting configurations have been vibration tested to evaluate a more acceptable means of supporting the relay. Removing the relay from the mounting bracket and folding it back to lie secured with a wrapping of silicone tape to the main-branch of the launcher wire bundle proved to be the most effective configuration. This "soft mounting" reduces relay sensitivity to the vibration environment, and by allowing the relay/wiring to move as a unit, reduces the strain on the "J" hooks. This configuration has been further improved by the addition of rigid potting around the relay "J" hook and wire solder joints.

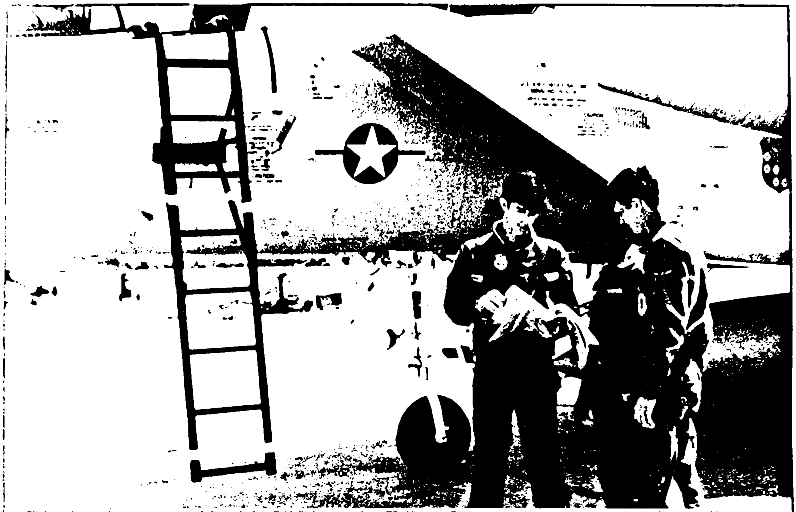
This change is in production, beginning with launcher S/N BG43-2276 which is scheduled for delivery in March 1983. The simplicity of this change lends itself to field rework of launchers already delivered. This will be covered in Warner Robins Air Logistics Center Change 5 of Launcher TO 11L1-2-14-2 which is not presently scheduled. In the mean time, see your local MCAIR Rep as he has all the information needed for immediate implementation of this change.

ENVIRONMENTAL CONTROL
(Milton A. Freiert/Unit Chief)

The ejector shutoff valve, which controls the flow of engine bleed air to the primary and secondary heat exchanger ejectors, has been experiencing relatively high failure rates, resulting in supply shortages in the field. This has prompted an extensive investigation into causes of failure, with resultant interim changes being made to the valve and further recommendations to the Air Force for a long term solution to the problem.

The valve is a sleeve type, normally (spring loaded) closed, and electrically energized-open. The primary causes for removal from the aircraft are defective solenoid coils and mechanical failures which prevent the valve from opening or closing. Teardown examination and analyses of several valves have revealed failure modes, many of which have subsequently been addressed by changes being implemented by the valve supplier effective in future production units. However, it is not expected that these improvements will provide the degree of reliability desired, particularly in the primary heat exchanger ejector application. In fact, MCAIR believes that the environment

Air-to-air configured F-15A of 32nd TFS takes off from Soesterberg AB, the Netherlands, for training mission in 1980. The "Wolfhounds" and several other units now fly C/D model aircraft containing many production improvements over original Eagles. However, extensive retrofit programs on A/B models assure that these older aircraft contain latest combat capabilities.



Flight and ground crew review aircraft forms before F-15 flight at Langley AFB, Virginia. Eagle improvement programs are vital to both pilots and line personnel since contractor modifications to the airplane usually affect both groups in varying degrees. Significant inputs were made by many pilots and maintenance specialists during recent "fact finding" visits by MCAIR to F-15 bases.

is severe enough that a sleeve type valve could not tolerate it even with extensive redesign; therefore, a recommendation was made to the Air Force in October 1982 that MCAIR be authorized to submit a proposal for replacing the sleeve-type valve with a new butterfly type valve which would be much more tolerant of such an environment. Authorization to proceed is presently pending.

FUEL SYSTEM

(Roger H. Speth/Unit Chief)

One high maintenance item on the F-15 is the Fuel/Oil Heat Exchanger. It is both a difficult and time consuming unit to replace. The usual mode of failure is a shift in the thermal by-pass valve opening/closing temperature, causing premature by-pass flow to one or both wings of the aircraft and resulting in wing fuel asymmetry. Improvements in the reliability of the thermal element that drives the valve have been made in the past; however, their impact is still uncertain and further improvements to the present design (such as a thermal element cartridge that can be replaced with the heat exchanger remaining in the aircraft) require substantial time for development and qualification and would result in changes to other aircraft systems and tube routing.

The MCAIR fuel group has developed and tested an alternative Hot Fuel Recirculation system with a number of advantages over the present system. The proposed system removes the thermal element and shutoff valve from the heat exchanger and incorporates a solenoid-operated valve in each of the recirculation lines. The valves are controlled by temperature switches mounted in the boss for the Engine Electronic Control (EEC) by-pass flow on each engine feedline. The switches sense engine inlet fuel temperature, and when either switch senses fuel temperature above its set point, both recirculation valves open, thus maintaining equal fuel to the wings and balanced fuel loading. Control logic will also open both valves when the Secondary Power System is placed in limited duty. All parts of the system are F-15 qualified design and are located for easy access when replacement or repair is necessary. The system was installed on F-15A S/N 71-288 in August 1982 and has been successfully tested both on the ground and in flight. The F-15 SPO has granted authority to MCAIR to submit a proposal for this improvement change.

SECONDARY POWER

(John M. Killoran, Jr./Unit Chief)

Although field data indicates that the overall Jet Fuel Starter performance is meeting specification requirements of 2000 starts, turbine wheel burning has been, and continues to be, a major contributor to F-15 Secondary Power System maintenance workload and downtime. Investigations have led to the conclusion that performing JFS starts with low energy levels in the hydraulic start accumulators is the primary cause for turbine wheel burning. Even though the JFS will start with low accumulators, the wheel blade tips sustain pitting and erosion damage to some degree. This begins an irreversible, unstoppable process which eventually results in wheel destruction. The number of starts this process takes before final burn-up is a function of accumulator servicing level after the initial blade tip damage is incurred.

After extensive investigations into possible solutions to this problem, MCAIR has determined that the most practical approach is to provide additional energy for JFS starting. This will result in a system which requires servicing much less frequently than the current system, is much more tolerant of servicing, and will also permit simplification of the current servicing chart to a single line graph. ECP-1563 is being prepared to add additional nitrogen bottles to the hydraulic accumulators and to install a hydraulic pressure intensifier in the circuit to bring the accumulator working pressure up to 3500 psi.

These changes are expected to solve the JFS turbine wheel burn problem; however, the first production delivery is still over two years away so we must continue to stress the importance of accumulator servicing in accordance with the maintenance manuals. Periodic reviewing of the special ten minute servicing film (#CVT-F15( )-01340-1) created as a result of this problem is also worthwhile. MCAIR is currently preparing another film which explains how the secondary power system and the hydraulic start system works. This film should be available for distribution early in 1983 and will provide additional insight into the JFS wheel burning phenomenon.

LANDING GEAR/BRAKES

(Glen D. Kirkland/Unit Chief)

Recently procured by the Defense Electronic Supply Center (DESC), new weight-on-wheels (WOW) and landing gear proximity switches have been introduced to the F-15 fleet. These new switches look the same as the old ones but tests have shown that they are vastly improved. The specifications for both switches have been revised to increase testing for electro-magnetic interference (EMI) resistance.

Improvements to the brake system have been made in the area of anti-skid "off" braking. A "pulser" system has been added as a primary back-up for anti-skid. Aircraft relay logic has been added to provide automatic changeover from anti-skid to pulser when the skid system detects a fault. One-way restrictors have also been added to the normal and emergency brake lines to improve manual control of the brakes. These changes have been incorporated in F-15C 80-0002 and 80-0039 and up; also F-15D 80-0058 and up. Full retrofit of the pulser system is to be accomplished by TCTO 1F-15-763 (Improved Braking System) with kit delivery beginning in January 1983. This TCTO is to be worked concurrent with TCTO 1F-15-791 (Landing Gear Control and Indication Circuit Improvement). Further information on these changes can be found on page 28 of this issue.

FUTURE PROGRAMS

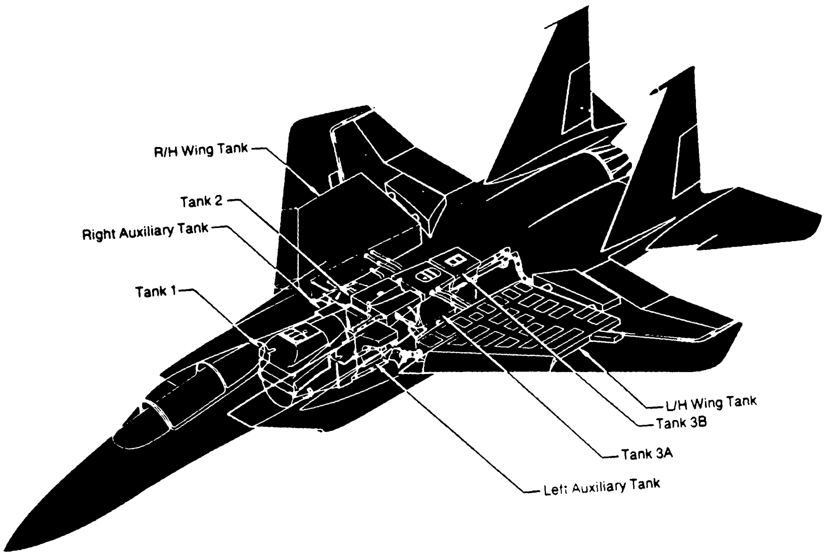
Efforts are currently underway, via the "Multi-Stage Improvement Program" (MSIP), to enhance F-15 capabilities over those that exist today. As we heard from many people during our base visits, the Eagle is doing an excellent job, but everybody wants to see it even better. That is the whole purpose of MSIP.

Beginning in June 1983, conformal fuel tanks will be delivered to the USAF. The tanks will provide the F-15 with an increased fuel capability with little drag penalty. In addition, the tanks will also provide two additional weapons stations for future air-to-ground use. Also in early 1983, the BRU-26A/A multiple ejector rack will enter the fleet. This rack is an improvement to the MER-200 rack which was demonstrated on the F-15 during CAT II testing in the early 70's.

Development is underway for the F-15 to carry the Advanced Medium Range Air-to-Air Missile (AMRAAM) with a multi-shot capability. In addition, a new programmable armament control set plus a larger, high-speed computer is in development. With these additions, the F-15 will have the enhanced software to employ many configurations of air-to-ground armament while retaining air superiority capability. Electronic warfare equipment will also receive an upgrading in

(Continued on Page 27)

Conformal fuel tanks now scheduled for delivery to USAF in June 1983, have received extensive evaluation and demonstration. Photograph above shows F-15B S/N 71-291 in 1974 during one of first test flights with tanks installed. Eagle improvement programs are continuous, and this particular airplane has been the "test bed" for many of them. It is flying today as the first F-15 converted to the "DRF" (Dual Role Fighter) configuration (see page 1).

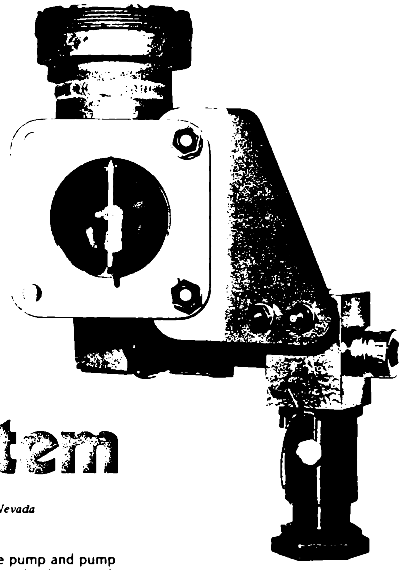

R/H Wing Tank
Tank 2
Right Auxiliary Tank
Tank 1
L/H Wing Tank
Tank 3B
Tank 3A
Left Auxiliary Tank

"For a turbojet engine to operate at peak efficiency, there can be no doubt whatsoever regarding the soundness of its fuel supply system; its components must be installed correctly."

A Check Valve "STICK-UP"...

F-15 Fuel System

By PHIL ROYER/ *Field Service Engineer, Nellis AFB, Nevada*



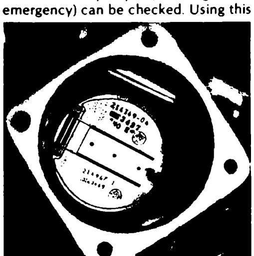
68A581311-1001 elbow assembly as it is installed on 214352-4 manifold. Note that check valve stop is in vertical position when elbow is correctly attached to manifold.

Recently we here in the Fuel Shop at Nellis AFB, learned the wisdom of the above statement the hard way. Although our problem turned out to be self-inflicted, we did come out ahead in the long run by finding a sure way to check the integrity of the internal fuel supply of the Eagle. I'd like to pass on the knowledge we gained from this incident because it could prove helpful when troubleshooting the F-15 fuel system, and at the same time you might avoid "shooting yourself in the foot" as we did.

The problem started following replacement of an emergency boost pump and a 3A fuel cell. Naturally, when replacing the cell all components within it were removed. After completion of the job and while functionally checking out the fuel supply system, we found that with the emergency boost pump operating, the BOOST SYSTEM MALFUNCTION light on the master caution light panel illuminated.

During troubleshooting, with a direct reading gage tied in at the emergency boost pump pressure switch connection (located beneath door 66), we found the emergency boost pump had a pressure output of only four psi. That scant amount of pressure was not enough to close the emergency boost pump pressure switch, let alone feed a thirsty jet engine. When checks of the voltage supply to the pump and pump electrical phasing proved to be normal, the solution to our problem appeared to be quite simple – the fuel system had a bad boost pump. But it wasn't that simple and it wasn't a bad pump. Here's how we proved it.

A direct reading gage was tied into the engine electronic cooling control flexible fuel line. (This is the one with the quick disconnect, and it's located in doors 85 L&R.) With the gage tied into the system, and with the switches on panel 48L, the output of any of the three boost pumps (left, right, or emergency) can be checked. Using this hook-up, we confirmed that the emergency pump did in fact have an output of only four psi. However, our big surprise was the output of the main boost pumps, which read between 12-1/2 and 13 psig. (This incidentally, was enough pressure to illuminate the test lights on panel 48, indicating "normal" boost pressure since pressure above 11 (±) 1 psig will illuminate the test lights. Thus in our particular case, these usually helpful test lights only helped to confuse and cloud the issue.) With this additional information in hand, it was quite evident that somewhere in one of the feed tanks there was a very large "hole" (internal leak).



A correctly installed 214967-1 suction by-pass check valve as it appears looking down into the 214352-4 boost pump manifold. Note that valve is installed beneath check valve stop (circle).

Because the 3A cell was just installed and it is the easiest one to open up, we decided to look there first. A visual, internal inspection revealed nothing out of the ordinary. In a further attempt to locate our leak, the system was pressurized using air pressure. This proved futile, so our next effort was to hook up a refuel truck to the defuel receptacle of the aircraft. Maintaining a constant 20 psi, we were successful in locating the leak, and quite surprised to learn that it was an open, left hand, boost pump canister discharge (flapper type) check valve. This is where we had "shot ourselves in the foot" (our self-inflicted problem), and here is how it happened.

When the left boost pump was removed, the elbow containing the check valve was also removed (for what at the time was thought to be ease of maintenance). Now there is nothing wrong in trying to ease maintenance, but our whole problem stemmed from the fact that removal of the elbow is not called out in the Job Guide we were following (for removal of the 3A fuel cell). Consequently, we missed the caution note in the relevant Job Guide (covering left boost pump canister removal/installation) to assure that the check valve is in the down (closed) position when the elbow is reinstalled in the pump.

The logic behind this caution is that a check valve *stop* is contained within the elbow to prevent the valve from opening overcenter and possibly remaining in that position. If the valve is in this overcenter position (as it was in our case) when the elbow is connected to the boost pump, the pump attempts to pressurize the feed line but fuel is escaping (by-passing) back into the cell via the open check valve. Operating under this "run-around" condition, the emergency pump can only maintain about four psi and the main pumps their 12-1/2 and 13 psi.

Boost pump with 214352-1 manifold and 68A581311-1001 elbow attached. The 214967-1 suction by-pass check valve contained in the manifold is not spring loaded to the closed position; therefore, if elbow is removed, reinstallation must be made with pump and manifold in position shown. Otherwise, valve can hang up on elbow valve stop.

After finding and correcting our problem (removing the elbow and closing the check valve) and swallowing a bit of our pride, we again hooked up the refueling truck to the defuel receptacle to confirm that the system was no longer leaking. However there was a "creep" on the refuel truck fuel totalizer. Looking at the schematic we found that this was caused by fuel flowing into the wings via the thermo by-pass valves located on the fuel/oil heat exchangers. To stop this flow we disconnected the two return lines from the thermo by-pass valves and capped them off (there is one connected on each side of the tank). With the lines capped off, the refuel truck totalizer will indicate "dead head" (not creep). With these two lines not capped off, even though the system is tight, there will be approximately 1/4 gallon of fuel per minute passing through each of the thermo by-pass valves of the fuel/oil heat exchangers. (This fuel is feeding into the wing tanks, then gravity feeding into the feed tank.) This slow flow could possibly confuse your troubleshooting, plus create a fire hazard if the cell was opened.

If you suspect an internal leak in the fuel supply system of your Eagle, we urge you to use what we now call the "Nellis Check" to prove or disprove your suspicion. It's a proven check that we learned the hard way. ■

a short safety lesson on popped...

Fuel System Circuit Breakers

Experience is a great teacher. Unfortunately, her teaching methods are often very expensive and accompanied by loud noises and bright lights, but that seems to be the only way she can really get our attention. Her teaching technique seems to be to offer first, a lesson; then, a moral; and last, guidance for the future. A real-life example follows.

A few months ago, a very large and many-motored aircraft went up in smoke and flames while innocently sitting on the ramp. Ms. Experience certainly got everyone's attention with that one, for there was an awful lot of noise and bright lights and it was exceptionally expensive —

• Lesson — Resetting popped circuit breakers when those breakers control electrical system circuits involving an aircraft fuel system. The subject breaker popped because of a short circuit in the system; an explosive potential (fuel vapors) existed in the fuel tank; resetting the breaker during maintenance produced an ignition source (spark). Arithmetically, the lesson might look like this: Ignition Source (short circuit spark) + Explosive Potential (fuel vapor) = Lost Airplane.

• Moral — When brought together in a situation like this, sparks and fuel vapors will only do what comes naturally; i.e., produce bright lights, loud noises, and great expense.

• Guidance for the Future — We shouldn't let this happen anymore.

The best way to describe the experience would be to quote from the USAF message analyzing the accident. . .

"Recently an aircraft was destroyed by fire while parked on the ramp. This mishap contains some important lessons that could be of value to others. During the mishap investigation, the board detected a common maintenance and flight crew procedure which could produce a hazardous situation. This situation must be brought to the attention of all who are associated with the operation or repair of electrical components that are within the fuel cells on any aircraft.

"When a short circuit associated with an electrical component exists, the circuit breaker will open (pop) when circuit is energized. If the fault is in the tank/fuel cell, reenergizing the circuit by resetting breaker can produce an ignition source, which may be either high temperature or arcing. When conditions inside a fuel cell are present for ignition

of fuel vapors, only an ignition source is needed to cause an explosion.

"Any individual who resets circuit breakers must ensure that an explosive condition is not present. This may be accomplished by ensuring that fuel in any tank or bladder covers the electrical component."

Shortly after the incident described, the Air Force released DASH ONE Safety Supplements on the F/RF-4 series aircraft which provided aircrew procedures for electrical fuel transfer pump malfunctions. Again, a quote from the safety supplement.

"There have been isolated incidents where circuit breakers for the No. 4 and 6 electrical fuel transfer pumps have popped in flight due to faulty electrical connectors located in the fuel tanks. Although evidence thus far is inconclusive, there is a possibility that arcing at these connectors could be a fire hazard. Therefore, until testing has been completed to determine the seriousness of this problem and the appropriate modification of the connectors and/or pumps, a procedure for electrical transfer pump malfunction has been developed."

The remainder of the safety supplement enumerates the aircrew procedures but the most important one relates to circuit breakers E-3, F-3, G-3, E-4, F-4, G-4 (fuel transfer pumps) on No. 2 panel. Step 1 reads — *"Circuit breakers if popped — DO NOT RESET."*

"When conditions inside a fuel cell are present for ignition of fuel vapors, only an ignition source is needed to cause an explosion."

Just as the Air Force took stock of its overall procedures as a result of its own experience, MCAIR fuel system engineering design personnel reviewed our own local maintenance practices. While company shop and test facilities were found to be following acceptable troubleshooting procedures, there was no formal guidance in the matter. Written safety procedures were therefore developed for in-plant use in the event of a popped breaker or suspected short in the electrical circuits inside fuel tanks, as follows —

1. Remove electrical power from aircraft.
2. Refuel aircraft fully. (Ensures that electrical components in tanks or bladders are covered with fuel and eliminates possibility of fuel "vapors.")
3. Using a multimeter set to R × 100 scale and appropriate system schematic, check for short to ground on power pin of system components served by popped circuit breaker (Multimeter must be on R × 100 scale to ensure low current draw.)

3A. If short exists, defuel aircraft and replace defective component or repair wiring.

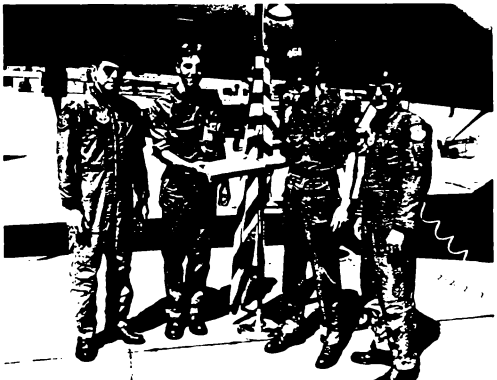
3B. If no short exists, reset circuit breaker and retest.

Our shop and flight maintenance groups are following the above procedures on all of our aircraft, and we would recommend their application in the field also. In modern day aircraft, circuit breakers are the "life savers" of their respective electrical circuits, and when one has popped, it's a normal reaction to immediately reset it. However, think twice before resetting one that is connected to the fuel system when power is on the aircraft — a fuel system circuit breaker which has popped during maintenance presents a potentially dangerous and explosive situation. Too fast a reaction could ruin your whole day and your aircraft. ■

Eagle Crew Chief "Change of Command"

Military "change of command" ceremonies are normally held when unit, base, or other top leaders move on and pass responsibilities into the hands of their successors. However, a most unusual "change of command" ceremony was held at Luke AFB recently when Staff Sergeant Robert E. Morrison passed the title of crew chief, the aircraft logbook, and the responsibility for F-15A 73-098 on to Senior Airman Kevin Augustine. This ceremony marked the end of SSgt Morrison's tenure as a crew chief with the 461st Aircraft Maintenance Unit as he is now assigned as an instructor with the 527th TTW.

During his three-year stint as crew chief for this F-15, the expertise and dedication displayed by SSgt Morrison was recognized by 405th TTW commander Colonel Daniel Sherlock who selected 73-098 to be his assigned aircraft and to be painted with the wing colors. Chosen because of overall appearance, dependability, and least amount of preventive maintenance required, SSgt Morrison's F-15 was also selected frequently as a static display for open houses at other bases and made the 405th TTW "high flyer" (most hours flown) list several times.



405th TTW commander Col Daniel Sherlock and 461st TFTS instructor pilot LtCol Mike Farra (far left and right) observe as SrA Kevin Augustine receives the logbook for F-15A 73-098 from SSgt Robert Morrison (photograph by A1C Brian Friday).

Contractor Case Study...

F-15 Fuel Tank Foam Degradation

By JOHN M. KILLORAN/*Unit Chief, Design* and JAMES H. POUSSON/*Lead Engineer, Design*

Several issues ago, we published an article titled "F-15 Engine Fuel Contamination - a contractor case study," in which the author presented a technical discussion to a depth not usually attempted in this magazine. There was considerable interest and positive reaction to this approach to analysis of a current problem in the field of mutual interest to both contractor and customer. Some of our military readers complimented the author for his careful examination of important but often obscure aspects of a typical contractor engineering investigation into a customer problem; and as a result felt they had better insight into various causes for F-15 engine anomalies possibly resulting from fuel contamination. These same readers suggested that we consider continuing this approach for other "problem topics."

We appreciate this level of interest, and are pleased to respond with the following article on F-15 fuel tank foam. This is a particularly logical "problem topic" since the foam, used as fire and explosion suppressant filler material in the F-15 fuel tanks, was analyzed in the earlier article to be one of the possible contributors to fuel contamination. Thus our second "contractor case study" is actually a continuation of a sort of the first, although the two were not concurrent MCAIR engineering efforts.

RED POLYESTER WING FOAM AFTER HYDROLYSIS

Two outside blocks of foam in upper row have discolored due to hydrolysis, but not yet crumbled. Lower row shows remains of foam blocks that have crumbled, with particles distributed through the fuel system.

Reticulated polyurethane foam, a proprietary product of the Scott Paper Company, has been used in aircraft fuel systems since 1966 to suppress explosive overpressures caused by fuel tank fires. This material is a fully reticulated, flexible polyurethane foam composed of a skelital network of tiny, lightweight, interconnecting strands which act as a three-dimensional fire screen to prevent fuel tank explosions. It defeats the flame front caused by an explosion by removing energy from the combustion process by absorbing heat. It also tends to quench the explosion by mechanical interference. The smaller the foam pore size, the more effective the material becomes and the less thickness is required to stop a flame front. Another benefit of the foam is to attenuate fuel slosh.

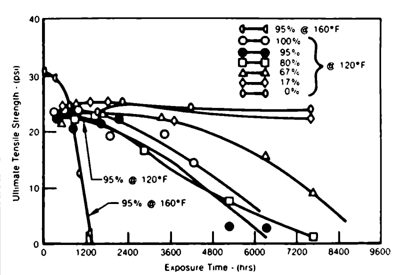
When used in aircraft fuel systems, the foam possesses two undesirable characteristics. It displaces and absorbs fuel, thus reducing the usable fuel quantity while adding its own weight to the total weight of the aircraft. It will eventually degrade in a hot and humid environment, requiring costly replacement.

POLYURETHANE FOAMS

There are two kinds of polyurethane foam (polyester and polyether) manufactured under Military Specification Mil-B-83054B. Both are provided in coarse and fine pore sizes. There are five "types" of foam material and each is color coded to identify type and pore size. Physical properties and characteristics of the materials, as listed in Mil-B-83054B, are presented in Table I.

During 1967-68, the U.S. Air Force began installing Type I (orange) polyester foam in a fully packed configuration in tactical aircraft fuel tanks. Installation resulted in a reduction of usable fuel of approximately 5%; and it was also found that useful life of the foam was only two to three years in the hot, humid environment in Southeast Asia. Foam deterioration resulted from a process called hydrolysis (decomposition of the material by reaction with water). Higher temperatures accelerate this process. Hydrolysis causes a change in material structure, which results in weakening of its polymer network (cross-linkage) and an eventual breakup into particles. The foam becomes friable and easily breaks into small "dogbone" and "Y" shaped particles usually larger than 400 microns in size. Figure 1 shows the effect of water and elevated temperature on foam life. Obviously, water is required for

FIGURE 1 - EFFECTS OF RELATIVE HUMIDITY ON POLYESTER POLYURETHANE FOAM



hydrolysis to occur, but elevated temperatures greatly accelerate the process. While both physical and chemical changes occur, the most consistent and obvious change is loss of tensile strength. Foam installed in aircraft fuel systems will usually turn to a dark brown color as it deteriorates, although some foam has been found to be bad without a significant change in color.

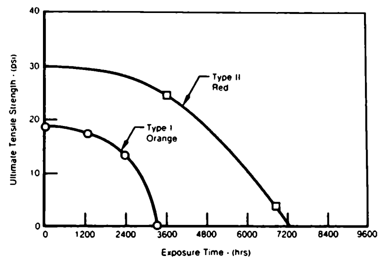
Providing more cross-linkage can improve hydrolytic stability of the foam. A urea group was added to Type II (yellow) and Type III (red) polyester foams to increase cross-linkage, producing an improved resistance to hydrolysis as shown in Figure 2. The Type III red foam was developed into a smaller pore size (25 pores per inch) to permit coring and voiding (versus fully packed) configurations. This reduces the amount of foam required and thus the amount of fuel displaced and absorbed. However, even with an increase in hydrolytic stability, the life of polyester type foams in fuel tanks is still substantially less than that of the airframe of USAF aircraft, thus requiring frequent and costly replacement.

Therefore, in 1974, the USAF in conjunction with Scott Paper Company, initiated development of a longer life foam. As noted above, an ester type urethane has good physical properties but is poor in hydrolytic stability. Ether type urethanes have excellent hydrolytic stability but exhibit excessive swell and loss of tensile strength when placed in hydrocarbon fuels. Scott was able to modify a polyether urethane to reduce swell and strength loss to acceptable levels while retaining its good hydrolytic stability. The chemistry of the ether based urethane does not contain any ester linkages and has a beneficial complexity of cross-linkages. Comparative testing showed polyether urethane to have five to ten times longer life than polyester urethane (Figure 3).

Tests were also performed to determine the effects of fuel additives on foam life, since JP fuels contain a variety of additives to improve performance. It was found that in normal concentrations there were no adverse effects upon foam life. When subjected to concentrations 50 to 100 times above normal, the foam deteriorated and exhibited many of the same characteristics as hydrolysis – turning a very dark brown and crumbling. It also showed a higher acid content and more embrittlement.

Both the USAF and USN funded studies to develop methods for determining the life of installed

FIGURE 2 - HYDROLYTIC STABILITY TEST AT 120°F/95% RH
(Showing Effect of Additional Urea)



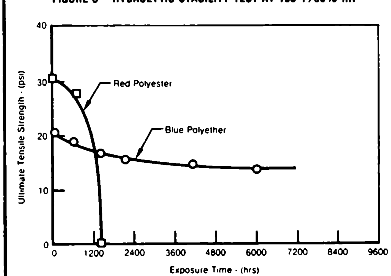
foam. No consistent, "easy-to-use" method resulted, and the study concluded that the standard pull test is the only reliable indicator of foam condition. Unfortunately, the rate of strength loss is dependent on somewhat uncontrollable variables (additive concentrations, humidity, temperature), so that precise inspection interval recommendations cannot be made. Foam strength could be unchanged or reduced to zero between inspections, depending upon the environment to which the foam is exposed. Under conditions of high temperature/humidity, the foam can experience some deterioration in a few weeks. In addition, the tear strength of the ether based (blue) foam is substantially less than that of the polyester (red and yellow) foams. Therefore, the pull test is not a recommended procedure for the blue foam, since even a new piece tears easily after wetting with fuel.

F-15 EXPERIENCE

The F-15 Air Vehicle Specification listed a requirement for an explosion suppression system in the aircraft internal tankage. MCAIR selected Type III (red) polyester polyurethane foam to satisfy this requirement since it accommodated the foam voiding technique newly developed by the company. Tank 1 was 50% voided; tanks 2 and 3A had foam only in their ullage spaces; tank 3B was 34% voided; and the wing tanks were 80% voided.

The expected service life of this foam was a minimum of five to seven years and possibly longer since the F-15 vent system was closed and would therefore minimize atmospheric effects upon the foam. Also, since the vent boxes were packed with foam and open to the atmosphere, it was believed that this foam would be the first to show deterioration and could be used to determine the remaining life of the internal foam.

FIGURE 3 - HYDROLYTIC STABILITY TEST AT 160°F/95% RH



Late in the F-15 development program, it became evident that tank 1 foam was collapsing and scrambling in "g" reversal maneuvers. Early USAF experience showed the foam scrambling in tank 1 to be a maintenance headache, but in 1978 the problem was solved by changing tank 1 foam to a Type II (yellow) polyester in a fully packed configuration. Type II was chosen because of its lower density, larger pore, and lower fuel retention characteristics.

MCAIR became aware of the longer life polyether polyurethane foam in 1975 and determined it should be used in the F-15 wing. Following qualification of Type V (light blue) foam, it was placed in production F-15C/D models beginning with S/N 79-0059 and scheduled for retrofit on an attrition basis. This change would give the "hard to replace" wing foam a life expectancy at least equal to that of the airframe. Warner Robins Air Logistic Center (WRALC), the designated repair depot for the F-15, was to prepare for wing foam replacement with Type V foam, based upon the five to seven year expected life span of the Type III foam. Polyether Types IV or V foams were not used in replacing fuselage foam since change-out of deteriorated fuselage foam is relatively easy and it was believed that the stronger polyester foam was needed to overcome the scramble problem.

Late in 1980, WRALC reported finding severely deteriorated wing foam in F-15A S/N 76-0021, an aircraft with only four years service life, two of which were at the Center in hangar storage. The vent box foam was in excellent condition. Before storage, its fuel tanks had been purged with Phillips Soltrol 220, and following discovery of the deteriorated wing foam, a substantial amount of water was found in the purging fluid. F-15A 76-0073 was also placed in storage at the same time, and examined at the same time; no deteriorated foam or water-contaminated purging fluid were found.

In late 1981 and early 1982, Holloman AFB began to experience augmentor light problems resulting from augmentor wash filters clogged with deteriorated foam particles. Substantial amounts (as much as two gallons) of foam particles were found in the feed tanks of some aircraft. Wing foam was deteriorating much earlier than expected in these aircraft, some of which had as little as three years service. While there was much speculation and contradictory evidence for cause a primary contributor was determined to be the practice of refueling aircraft several hours after flight, which allowed the foam to be unwetted with fuel and heated by the sun for substantial periods of time. It should be noted that a damaged aircraft at Luke AFB had its tanks purged and was then placed in storage for one year completely void of fuel. Foam in this aircraft was found to be in excellent condition. However, there was no evidence of water in the tanks and the aircraft had been stored in a shelter.

In 1982, aircraft at Luke also began to show signs of deteriorating wing foam, mostly in the center section of the wing. As at Holloman, these aircraft had good wing vent box foam and little or no deteriorated fuselage foam. While Luke and Holloman are situated in the same very dry, hot climate, the foam failures at these two bases were very similar to the ones at Warner Robins (where the foam had been subjected to a fluid containing substantial amounts of water). Examination of deteriorated wing foam by Scott Paper Company confirmed that hydrolysis had occurred in all of these cases.

A small piece (approximately 2×2×3 inches) of Type II (yellow) foam from tank 1 of a Holloman aircraft was found to tear easily. Tests of this weakened sample by Scott suggested some of the characteristics of foam that had failed after exposure to high concentrations of fuel additives. Because the actual presence of additives could not be confirmed in this analysis and the remainder of the tank 1 foam was unaffected. This is considered at this time as an isolated and unexplained occurrence.

Foam deterioration in both wing and fuselage tanks is becoming evident in the ten-year old aircraft bailed to MCAIR and NASA, and in some of the older aircraft at Langley AFB. No other bases, including those in hot, humid regions such as Eglin and Kadena, have reported problems.

PROBLEM RESOLUTION

WRALC has been replacing wing foam as part of routine depot TCTO incorporation since September 1982. As a result of the accelerated deterioration of foam at Holloman AFB, a second line was initiated at Warner Robins to handle foam replacement only. This effort was called "Foam Express," and was in operation from June 1983 until October of this year. Foam replacement is now being done on an "as required" basis as part of the routine Speedline operation at WRALC.

There are several conclusions to be drawn from our experiences with F-15 fuel tank foam degradation over the past few years. Water is the primary cause of the problem, through the process of hydrolysis. Water must be present for hydrolysis to occur, and although the process may occur at any normal ambient temperature, it is greatly accelerated at high (above 100°F) temperatures. Ambient humidity conditions alone are not sufficient to cause rapid hydrolysis, as evidenced by the absence of vent box foam problems. Partially filled tanks ("unwetted" foam) permit a higher temperature environment which accelerates hydrolysis. Fuselage tank foam is relatively unaffected because these tanks are in a cooler environment and spend less time unwetted. Water is being routinely introduced into the aircraft at some locations. This could be from the fuel itself or through the vent system during descents in flight. The "closed" vent system retains this moisture, and if then combined with high ambient temperatures, early hydrolytic degradation of the foam can occur.

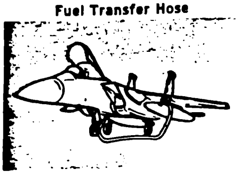
MCAIR has several recommendations to offer units in the field which would assist in resolving the problems which have been experienced with deteriorated fuel tank foam. First, take all reasonable precautions to minimize the amount of water in the tanks. Second, aircraft on the ground should spend as little time as possible in an unrefueled or partially fueled state. Finally, when aircraft are going into extended storage, check very carefully to assure that no water is in the tanks. ■

TABLE I
COMPARISON OF PHYSICAL PROPERTIES AND CHARACTERISTICS
(FROM MIL-B-83054B)

	Coarse Pore Types*			Fine Pore Types*	
Property	**Type I**	**Type II**	**Type IV***	**Type III**	**Type V**
Polyol Type	Polyester	Polyester	Polyether	Polyester	Polyether
Color	Orange	Yellow	Dark Blue	Red	Light Blue
Density Range (lb/ft^3)	1.70-2.00	1.20-1.45	1.20-1.45	1.20-1.45	1.20-1.45
Porosity, Pore Size (PPI)	7-15	8-18	8-18	20-30	20-30
Air Pressure Drop (inches of water)	0.190-0.285	0.140-0.230	0.14-0.230	0.250-0.330	0.250-0.330
Tensile Strength (PSI) Minimum	15	15	10	15	15
Tensile Strength at 200% Elongation (PSI) Minimum	10	10	—	10	—
Ultimate Elongation (%) Minimum	220	220	100	220	100
Tear Resistance (lb per inch) Minimum	5	5	3	5	3
Constant Deflection Compression Set (%) Maximum	30	35	30	35	30
Compression Load Deflection at					
25% Deflection (PSI) Minimum	0.40	0.30	0.35	0.35	0.35
65% Deflection (PSI) Minimum	0.60	0.50	0.60	0.50	0.60
Fuel Displacement (Maximum Volume %)	3.0	2.5	2.5	2.5	2.5
Fuel Retention (Maximum Volume %)	2.5	2.5	2.5	4.5	4.5
Flammability (inches/minute) Maximum	10	15	15	15	15
Extractable Materials (Weight %) Maximum	3.0	3.0	3.0	3.0	3.0
Low Temperature Flexibility (−55°F)	No cracking or breaking of strands				
Entrained Solid Contamination (milligrams/ft^3) Maximum	11.0	11.0	11.0	11.0	11.0
Steam Autoclave Exposure (% Tensile Loss) Maximum					
Type I, II, III 5 hrs at 250°F	40	40	—	40	—
Type IV and V 10 hrs at 250°F	—	—	30	—	30

*Sequence of Types (I, II, IV, III, V) provides easier comparison of Ester and Ether types.

F-15 Overwing Fuel Transfer Hose



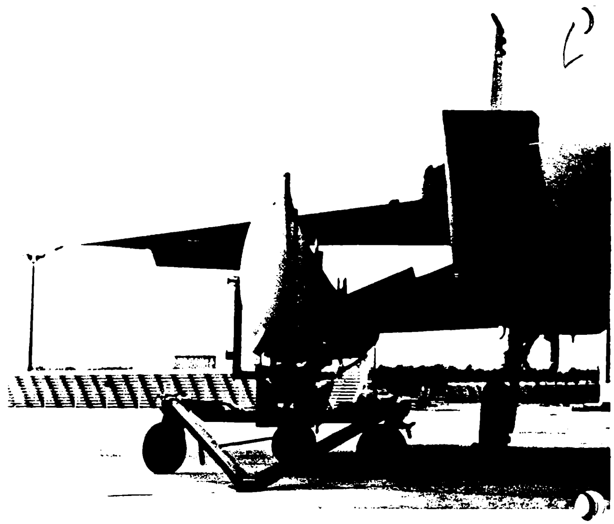
Uploading of the external fuel tanks onto the F-15 aircraft requires that the external tanks be leak and transfer checked after installation at the Organizational level. To perform these checks, approximately 2,000 pounds of fuel must be loaded into each tank to be tested.

In order to prevent having a defuel truck remove 2,000 pounds of fuel from the aircraft and a refuel truck add 2,000 pounds of fuel to the external tanks, a means of transferring the fuel directly from the aircraft to the external tank is required. A transfer hose to accomplish this task was first fabricated and used at Holloman AFB in 1979. One end of the hose is made up of a single-point nozzle which connects to the aircraft defuel receptacle and the other end is a standard overwing nozzle which is inserted into the external tank fill receptacle.

Several other F-15 bases also locally fabricated this hose with the drawings provided by Holloman AFB and they were pleased with its operation. In March 1979, Holloman AFB submitted a suggestion to MCAIR recommending the use of this hose. MCAIR concurred and submitted the hose to the USAF under AGERD 3758. A hose manufactured and demonstrated at MCAIR was officially approved by the USAF in October 1984. Availability of this hose to the customer has been classed as local manufacture. Use of this hose is shown in T.O. 1F-15A/C-2-05JG-00-2, work package 05-00-24. The hose is listed in T.O. 1F-15A/C-2-00GV-00-1, Table 25, as Tool Number 68D290053-1001

Back in 1974 when the F-15 Eagle became operational, MCAIR design engineers conceived the idea of "conformal fuel tanks" (CFTs). Equipped with these low-drag fuselage-mounted tanks, the F-15 air superiority fighter would have additional capabilities and a high degree of mission flexibility. The aircraft could be quickly converted for various missions and tasks without compromising its basic air superiority role or causing loss of armament stations because of external fuel tanks.

MCAIR, with its own funds, designed and built a prototype set of conformal tanks (originally called "Fast Packs") and conducted limited flight testing. In the summer of 1980, the U.S. Air Force and a foreign military customer jointly funded the project for more extensive testing



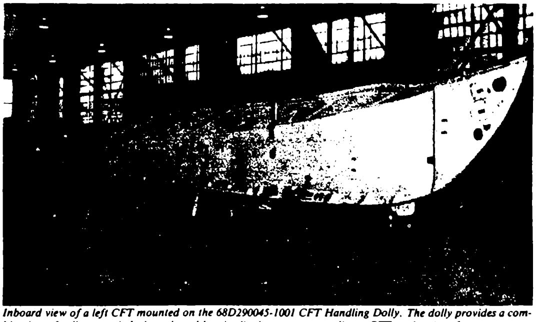
F-15C/D CONFORMAL

My initial view of F-15 conformal fuel tanks reminded me of a cross between sponsons on an outrigger canoe and the pontoons on a seaplane. However, on the Eagle, CFTs serve the purpose of neither a sponson or pontoon. Conforming to the shape of the aircraft fuselage and nestled beneath the wings, each CFT can carry approximately 750 gallons (5000 pounds) of extra fuel. This additional fuel gives the Eagle a diversity in mission capability; extended range; increased combat time; additional weapons stations; and sustained afterburner operation.

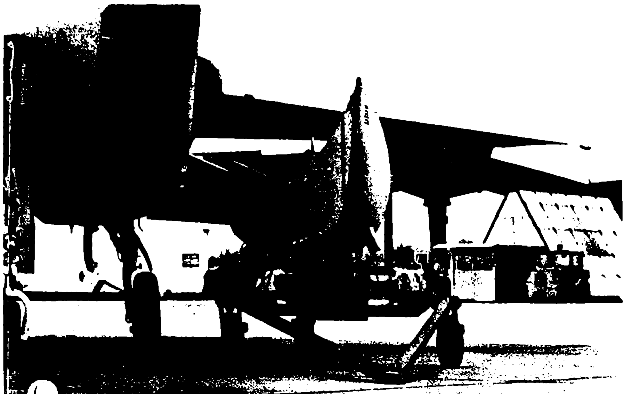
TANK DESIGN AND OPERATION

The tanks are semi-monocoque, aluminum structures using conventional skin, frame/bulkhead, and longeron build-up techniques. Each tank is approximately thirty-two and one-half feet in length, and weighs approximately one thousand pounds. A tank is divided into three fuel compartments — forward, center, and aft. The compartments are wet (no bladders) and to reduce vulnerability and increase survivability from overpressures caused by fuel tank fires, contain type V polyether, light blue reticulated foam.

The forward and center compartments are connected by flapper check valves and the center and aft compartments by a gravity interconnect valve. A transfer pump (similar to the F-15 wing transfer pump) is located in each of the center and aft compartments. An ejector pump which gets motive flow from the center



Inboard view of a left CFT mounted on the 68D290045-1001 CFT Handling Dolly. The dolly provides a combination of roll, yaw, pitch, lateral, and longitudinal movement to align a CFT to the aircraft.



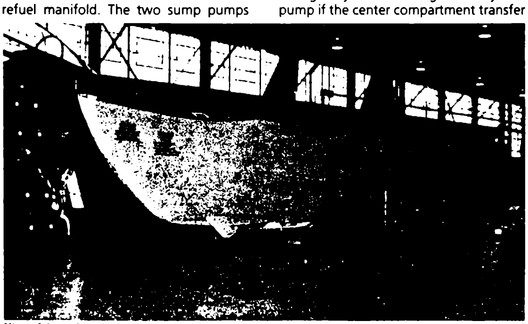
and production of the CFTs. To enhance their capabilities in the Rapid Deployment Force, the 1st Tactical Fighter Wing at Langley Air Force Base, Virginia, received CFTs in July 1983. Shortly thereafter, FOT&E (Follow-on Operational Test & Evaluation) was conducted at Langley by personnel of the 57th Tactical Weapons Wing from Nellis AFB, Nevada.

MCAIR Field Service Engineer Russell Roy has been working with CFTs since the first production set went through a test program at Edwards AFB, California. He is now assigned to the 1st TFW and has assisted the wing in initial phase-in of the tanks. The DIGEST invited Russ to describe his CFT experiences, with the aim of making the task easier when these new tanks arrive for installation on your F-15s.

FUEL TANKS

By RUSSELL E. ROY/*Field Service Engineer, Langley AFB, Virginia*

compartment transfer pump is located in the forward compartment. Normal fuel transfer into the aircraft internal tanks is accomplished by transfering fuel into a common transfer manifold to the aircraft refuel manifold. The two sump pumps are also connected by the gravity interconnect valve; if one pump fails, this valve allows the other pump to transfer all CFT fuel. Forward compartment fuel will gravity flow through the ejector pump if the center compartment transfer pump fails. The ejector pump is used to keep the center compartment full until the forward and aft compartments are empty. This aids in maintaining the aircraft center of gravity (CG).



View of the outboard side of a left CFT secured in a handling dolly. The three rubber-tired caster wheels on the dolly are provided with individual foot brakes.

During refueling operations, the CFTs will refuel through the aircraft refuel receptacle. Refueling can be accomplished with or without aircraft electrical power. However, just as with the basic aircraft, in order to lock out the CFTs during refueling, it is necessary to apply electric power and set the CFT switch on the fuel control panel (cockpit, left console) to STOP REFUEL. One fuel level control valve, a fuel level control pilot valve, and one overpressure protection shutoff valve are located in the forward and aft compartments of each CFT. During aerial refueling, if the fuel level in the CFTs is below 2280± 310 pounds, the CFT aft compartment refuel level control pilot valves are electrically energized closed by a float switch located in the center compartment. This action prevents fuel from entering the aft compartment until the fuel level increases above 2280± 310 ▶

Using the handling dolly, a five man crew moves a CFT into position for mounting to the aircraft. The dolly is raised or lowered by a hand-operated hydraulic power pack.

pounds. This weight control prevents an aft CG shift. Above 2280± 310 pounds, refueling continues until the fuel level reaches the pilot valves, which causes the shutoff valves to close. This entire operation is very similar to the fuel tank operation in the aircraft.

The CFT pressurization and vent systems are independent of the basic aircraft systems, but function similarly to, and use the same components as, those in the aircraft. Both systems are made up of climb and dive vent lines, dive vent check valves, pressure relief and vent valves, ram air inlet control, and pressure relief valves. Only ram air is used for pressurization, which enters a flush inlet on the side of the CFT and then into the ram air control valve (same as that used in the aircraft) and vent plenum. This valve regulates air pressure from 0.2 to 0.7 psig below 27,000 feet and 3.5 to 4.5 psia above 27,000 feet. Venting of this fuel tank is controlled by the pressure relief and vent valves and exhausted through the CFT vent outlet, located on the underside aft end of the CFT. This is the same pressure relief and vent valve used in the aircraft. Just as you must check each aircraft vent outlet during aircraft refueling, you must also check each CFT vent outlet during CFT refueling.

TANK INSTALLATION

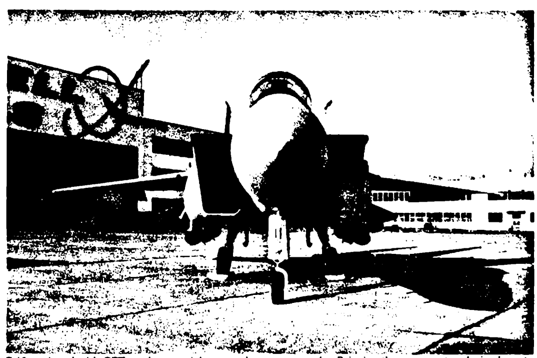
Before installing your first set of CFTs, you must be familiar with TO 1F-15C-2-05JG-00-3 (Aircraft General Maintenance) and TO 33D2-3-101-1 (Operation and Maintenance Instructions — 68D290045-1001 CFT Handling Dolly). The Job Guide contains procedures for tank installation, removal, and functional checkout. It also identifies the numbers and locations of several small doors and panels that must be removed from the aircraft to provide access for the CFT mounting points. Many of these doors are located in the area of the CFT inboard fairing. (Incidentally, it is very important to keep all loose items, such as aircraft doors, jumper bundles, launcher bolts, etc., stored in their proper place. If you don't, sooner or later these items will end up missing, just when you need them most.) TO 33D2-3-101-1 describes operation of the CFT handling dolly. In my opinion, mastering operation of the dolly and learning its handling procedures are the secrets to problem-free tank installation/removal.

Before CFT installation, the LAU-106 missile launchers must be removed from the aircraft (and retained for later installation in the CFTs). Located inside the CFT forward fairing are four special launcher attach bolts for each launcher. These bolts have a longer grip length, and must be used because of the difference in the CFT missile fairings. (Store the shorter grip-length bolts peculiar to the normal launcher-to-aircraft installation in the CFT forward fairing area.) Because of the size of some of the installation hardware, we developed a special tool box for CFT and external tank installations, which saved time from running all over the base for special size sockets or wrenches.

With each tank you'll find a box of "CFT kit parts," including CFT attach fittings, inlet louver cover plate, environmental control system exhaust duct extension, and attaching hardware. Install the CFT attach fittings on the aircraft bulkheads at F.S. 509 and F.S. 626. After these fittings are properly torqued and saftied, the remaining "kit parts" can then be installed. At this point, you are now ready to mate and install the CFTs on the aircraft. The tanks mate to the aircraft at the following points —

- CFT pin fitting at F.S. 416. Pin engages a slotted bushing on the aircraft.
- CFT pin fitting at F.S. 509. Pin engages a monoball bearing on the aircraft fuselage.
- CFT fork fitting at F.S. 626. Fitting engages an extended lower wing attach bolt.
- CFT lower forward attach fitting at F.S. 509. Fitting engages the previously installed "kit parts" fitting.
- CFT lower aft attach fitting at F.S. 626. This fitting also engages the previously installed "kit parts" fitting.

When positioning the dolly for align-



F-15 equipped with CFTs and tangential mounted armament racks. Bringing the armament racks in closer to the aircraft moldline (tangentially mounted) improved the F-15 drag characteristics considerably. This Eagle is carrying twelve MARK-82 "Snakeye" bombs.

ment with the aircraft, we found it best to approach the aircraft from the front. When the tank is properly aligned, raise it into position and install, torque, and safety the two special CFT attach bolts. Then connect the cable assemblies and the electrical bonding wires.

After lowering the handling dolly, move it clear of the aircraft and carefully inspect the entire tank installation. All access doors can then be closed. With the exception of the CFT operational check and the AWM-72 checks on the LAU-106 missile launchers, you have just installed a conformal fuel tank on your F-15!

SUPPORT EQUIPMENT

In addition to the handling dolly, there are several other AGE items required to support the CFTs, both on the flightline and in the fuel shop. When it becomes necessary to store empty CFTs, two lightweight storage stands (P/N 68D290057-1001) are used for each tank. A CFT is easily transferable from these stands to the handling dolly or vice versa. When running in-shop fuel system checks, use only the heavyweight 68D29005-1001 maintenance stand. Please remember, this is the only stand authorized for fuel system checks with CFTs off the aircraft. For in-shop CFT system component functional tests, the 68D290052-1001 test rig is used. This rig has a one-thousand gallon holding tank (dubbed the "mother tank" by fuel shop personnel) for fuel system purging fluid. For checking the CFT weapons wiring, the 68D150077-1001 armament circuitry test set is used.

The CFTs have several ground protective covers, which I classify into two groups — ON aircraft and OFF aircraft. The ON aircraft covers consist of the fuel vent plug, environmental control system exhaust cover, engine vent plug, and ram air inlet plug. The OFF aircraft covers include those just mentioned, and the ambient sense port plug and two duct covers.

After reading all this, you may come to the conclusion that the whole CFT installation process is quite complicated, but it really isn't. After becoming accustomed to the procedures, reducing your learning curve, and developing efficient techniques with the handling dolly, you'll find CFT installation to be a normal maintenance procedure. During FOT&E, we found that a five-man crew (consisting of three APG and two weapons specialists) was able to complete the entire job in three and one-half hours.

Not all F-15 units will receive these new conformal fuel tanks, but some day, many of you Eagle Keepers will be involved in CFT installation and operation. If you have any questions, feel free to talk to your local MCAIR rep or give me a call at the 1st TFW AGS (Autovon 432-3615 or 2750). ■

TROUBLESHOOTING the F-15 Fuel Vent System

By JAMES POUSSON/*Lead Engineer, Design*

The F-15 flightline photograph above was taken right after a rainstorm, and the ramp is only covered with water. However, to some frequently frustrated Eagle fuel systems maintenance specialists, it might often seem as if that liquid is JP, and widespread enough to reflect the world! If you've had such a feeling a time or two yourself, spend a few minutes with the article below – it might help "dry up" the situation.

The F-15 Eagle has a "closed" fuel pressurization and vent system. Most of the system plumbing is inside the fuel tanks for maximum survivability. However, when the fuel tanks are full, the majority of the plumbing and components are submerged and thus exposed to the problem of "nuisance" leaks when the aircraft is in a static condition.

The airplane has chronically experienced fuel venting and fuel vent leaks out the vent exits. Most of these occurrences are not serious and do not present hazards to either personnel or equipment. However, they do cause aircraft downtime and are often difficult and frustrating to troubleshoot and correct. I hope the information presented in this article will help you understand the system better and reduce both your maintenance frustrations and the time an aircraft may be out of service for problems of this type (see editor's note).

Let's start with a couple definitions which will clarify exactly what I'm going to talk about. "Fuel venting" is the term most often used to describe the situation in which fuel exits from the aircraft vent masts. However, it is helpful to differentiate between large and small fuel losses from the vent masts, so for purposes of this article, "fuel venting" will be used to describe larger fuel losses under pressure and "fuel vent leaks" to describe the drippers. "Fuel venting" involves a fault in the refuel, dump, or transfer system; "fuel vent leaks" involve faults in the vent system plumbing and/or components, and/or thermal expansion.

Circumstances under which a problem occurs are important factors in determining the cause. During troubleshooting for any vent squawk, you need to know whether the problem occurred during refueling, some time after refueling, or in flight. If possible, a detailed sequence of events and a thorough account of all conditions surrounding the venting should be recorded.

"Fuel venting" most often occurs under the following conditions – during refueling (ground or inflight); during fuel transfer (ground or inflight, external or internal); or during fuel dumping. "Fuel vent leaks" will occur only when the vent lines are submerged (tanks essentially full).

FUEL VENTING

Venting During Refueling

As fuel enters the aircraft and a tank fills, the pilot valve will close the shutoff valve and the tank ceases to take fuel. If this does not happen, the tank pressure will rise until it is relieved through the pressure relief valve, which cracks open at about 7.0 psig. As this valve opens, fuel enters the vent manifold, opens the wing vent valves, and then flows out the vent exit in either or both wings. This flow is a very heavy stream from both exits, much as it appears when command fuel dumping is selected from the right exit only. This condition may occur either on the ground or during inflight refueling, and refueling must be terminated immediately.

To troubleshoot this fault, the aircraft should be defueled and then set up for a "power on" refuel. Refueling should be done at normal pressure (approximately 50 psig deadhead), using the ground check panel. All tanks should be prechecked by using the master check switch. Any tank that does not pre-check and continues to take fuel has a failed pilot valve or a failed shutoff valve. (The only other possible cause would be a failure of the associated plumbing in the refuel and transfer system.)

Venting During Transfer

During fuel transfer (normal aircraft operation, not during refueling), the external tanks (or conformal fuel tanks if the aircraft is so equipped) transfer first. They empty directly into the refuel/transfer manifold which supplies all tanks. Next, the internal wing tanks and tank 1 simultaneously transfer into the feed tanks (2 and 3). Fuel venting can occur by the same sequence of events as described for "Venting During Refueling" except that the pressure source is from the external tanks or the transfer pumps. Troubleshooting is also the same.

If venting occurs before the externals or CFT's have completed transferring, it could result from two conditions. There is a problem in one of the internal tank fuel level control valve (LCV) assemblies (pilot valve or fuel shutoff valve), or there is a leak in the associated plumbing. If the venting stops by discontinuing external tank or CFT transfer, the problem is in tank 1 or the wings. If discontinuing external transfer does not stop the venting, the problem is in one of the feed tanks.

If venting occurs after the externals or CFT's have completed transferring, the problem is in one of the feed tank LCV assemblies and/or their refuel/transfer manifold.

Venting During Command Dumping

When the pilot commands fuel to be dumped, fuel should exit from the right side only. While a small quantity of fuel exiting from the left dump mast at the beginning of dump is normal, any steady flow from the left dump exit indicates a problem. If this occurs, the right pressure relief and vent valve (which has a check valve feature to prevent reverse flow) has failed. This permits fuel to travel to the left side and out the left vent mast. Replacing the right vent valve resolves the problem.

FUEL VENT LEAKS (DRIPPERS)

A vent box is located in each of the outboard wing sections to collect small amounts of fuel leakage in the vent system which occur during aircraft maneuvering and fuel thermal expansion. Each box has a four-gallon capacity, which equals the amount of fuel which the vent system lines would contain if the vent system were completely flooded. This fuel is pumped back into the wing tanks by an ejector pump which operates whenever the wing transfer pumps are running.

Total fuel system expansion space available is approximately 30 gallons, and will accommodate a fuel temperature rise of approximately 24°F without venting. Above a 24°F rise, the vent box will fill, and fuel will subsequently drip from the vent exit.

Fuel vent leaks are usually the result of fuel entering the vent system plumbing and causing the line pressure to exceed operating pressure of the pressure relief and vent valve. Design fuel system air pressurization level is nominally 0.9 psig after refueling. Some of this pressure may bleed off after an aircraft has been parked for some period of time; however, it is normally pressurized to some level up to 0.9 psig. An additional 0.5 psi pressure head is available from a totally flooded vent line. Any fuel temperature rise would add another increment of pressure. All of these factors come together to cause the pressure relief and vent valve to open, which permits the fuel in the vent lines to leak into the vent box and eventually overboard.

Leaking dive vent check valves, emergency pressure relief valves, and plumbing couplings (wiggins fittings, o-rings) are common sources of flooded vent lines. All of these leaks are difficult and time consuming to resolve. The troubleshooting procedure is intended to trace a leak to a particular tank. It requires making a "power on" refueling, filling one tank at a time, and waiting approximately one-half hour between tank fillings to see if a leak develops. The next step is to go into the affected tank and check the valves and plumbing. T.O procedures should be carefully followed.

Vent leaks can also occur as a result of "normal" thermal expansion, although this is not as common as the situations just described. If the bulk fuel temperature rises about 25°F, thermal expansion will cause fuel to overflow the tank 1 standpipe and flood the vent plumbing. This will again open the vent valve and permit leakage out the vent. There is no troubleshooting required, but unfortunately there is also no way to distinguish this vent leak from any other without troubleshooting. However, there are some clues to help decide if thermal expansion is the culprit. If an aircraft has been fueled with "cool" fuel and then permitted to sit out in the sun for an extended period, "normal" thermal expansion should be suspected. In this case, the vent box may be drained to relieve the immediate problem.

A leaking check valve in the vent box ejector pump will also cause leaking out the vent. This can be diagnosed by draining the vent box and visually observing the source of the fuel into the vent box.

Editor's note: The F-15 fuel system troubleshooting information you have just read was originally presented as part of an internal technical memorandum prepared for company engineering personnel on the F-15 project. Copies of this memo were sent to all MCAIR field service reps-in-charge at Eagle bases.

Although its general contents may be beyond the interest of many maintenance specialists, the memo contains a wealth of descriptive information and illustrations on specific components of the F-15 fuel pressurization and vent system. A particularly valuable section is Enclosure 4, a tabulation of failure modes of various system components – valves, regulators, pumps, plumbing, connectors, etc. Knowing how these components work and the conditions most conducive to their malfunctioning is bound to make you a better technician and a more skilled troubleshooter.

While too detailed for inclusion in the DIGEST, the complete memo can be borrowed from your MCAIR rep. Ask him for J.M. Killoran Memo 199-14674 – A discussion of fuel venting in the F-15. ■

A Very Simple Idea... *Improves the reliability of the F-15*

TSgt Byron K. Hodges installing the cap he designed on an engine feed manifold.

(U.S. Air Force photo by A1C James G. Bryan)

TSgt Byron K. Hodges, fuel system specialist, 32 TFS Camp New Amsterdam, the Netherlands, is always looking for ways to improve the reliability of the Eagle's fuel system. A seemingly never-ending painstaking problem with malfunctioning fuel flow transmitters plagued the fuel shop and appeared to be tied to the removal of engines requiring maintenance. While searching for what was causing the high failure rates, he discovered that the fuel was drained from the transmitter when the engine feed manifold was disconnected, allowing the transmitter to dry out.

Looking for a solution to the problem, TSgt Hodges designed and manufactured a cap for the engine feed manifold. This helped to retain any residual fuel in the engine feed manifold and prevented the engine fuel flow transmitter from drying out. The results: a greatly reduced number of transmitters being replaced (29 the year prior, to 9 the following year). He then submitted his idea to the USAF Suggestion Program, and received a $4,000 award.

The DIGEST asked Jim Pousson, our MCAIR engineering resident expert on the Eagle's fuel system, if he had any comments. The use of a cap on the engine feed manifold is a great idea, he said. It guards against foreign objects entering the fuel manifold and massive fuel spills if someone would inadvertently open the fuel shutoff valve by turning on the engine master switch.

Our hats off, here at MCAIR, to TSgt Hodges for a job well done. ■

F-15 Conformal Fuel Tanks

Q ***While all of our assigned aircraft are C/D models, there are some A/B model inlet duct ramps in our fleet. We have several questions relating to this situation with respect to conformal fuel tank installations. What are the consequences of not installing the 68A250300-2003 variable inlet ramp covers when conformal fuel tanks are not aboard? If the variable inlet louver is not needed when conformal fuel tanks are aboard, is it needed any time? Is an aircraft flyable without the vortex generator? Finally, can A/B model ramps be modified for use with C/D model CFTs?***

A The variable inlet bleed air louver covers are installed when conformal fuel tanks are aboard to prevent possible reverse air flow through the louver and into the inlet during high mach flight, and to prevent damage to the tank seals. Air flow through the ramp louver has slight theoretical effect upon engine performance in the supersonic range. Degradation is minimal in the subsonic range.

The aircraft is flyable without the vortex generator, but to prevent structural damage, bolts must be installed in the generator mount bolt holes. The vortex generator was installed to prevent the aft missile from going inboard during separation, therefore, missile launch is not recommended unless the generator is installed. The F-15 A/B model ramp cannot be modified to allow installation of the F-15 C/D ramp inlet louver covers.

(Norm Tupper
Engineer – APG Group)

F-15 Fuel Cell Activation

Q ***This squadron has just experienced its second fuel cell activation, and cells in two other aircraft awaiting maintenance are suspected. Service life on the first cell was five years, while the second one lasted six years against the estimated service life for F-15 fuel cells of 10 years. We have a couple general questions on the subject. What do your records show has been the average service life of cells removed for activation to date; and is there any possibility that the type of jet fuel used could have an effect upon premature cell activations?***

A The average service life for F-15 fuel cells removed for activation is six – seven years, so the ones you've had to take out are fairly typical. The self-sealing type fuel cell material ("Vitane") used in the Eagle is compatible with all jet fuels, including JP-4 and JP-5, so a change from one type to another should have no effect. There are several military and commercial aircraft that use these types of cells with all types of fuels and report no problems.

Activation of the self-sealing material normally results from two causes:

- Damage to the fuel barrier material itself. This is a nylon-type material which is brushed on the inside of the cell to prevent fuel from reaching the sealant rubber. Fuel cell activations from inside the cell itself are almost always maintenance-induced – improper handling, a dropped tool, etc.
- Leakage around a tank fitting which allows fuel to gather in the tank cavity on the outside of the cell. There is no fuel barrier material on the outside of the cell, so fuel there can penetrate the rubber sealant and activate the cell. If a fitting leaks and fuel is allowed to collect in a cavity area, thus continuously soaking the outside of the cell, cell activation can be expected imminently.

By TOM GIMBEL
Technical Specialist – APG Group

"The most sophisticated assembly can not function without simple but properly applied torque." *(Foxblack)*

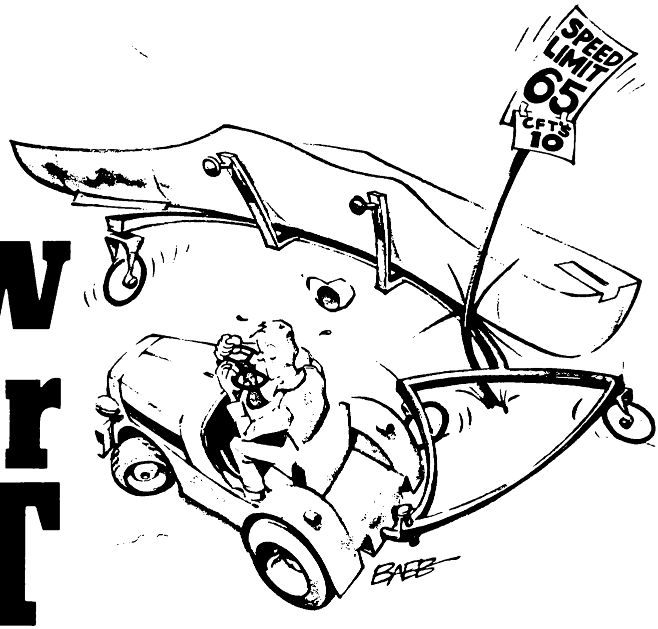
If aircraft parts could only talk, the tubing assembly pictured below would probably have said more than "ouch!" Most likely, it would have screamed bloody murder because it was literally – and unnecessarily – destroyed. Our first photograph is a "picture-perfect" example of how not to perform maintenance on aircraft hydraulic tubing installations (or anything else which requires the application of torque, for that matter). Compare the mangled results here with the situation presented in our second photograph at right which illustrates the old, common, and highly recommended procedure known as "double wrenching."

The damaged component shown here is a 2200617-1 heat duct tube assembly used in the F-15 environmental control system. When installed, it attaches to an AN 815-12D union. The aircraft was undergoing modification at Warner Robins ALC, and when technicians discovered this wrecked stub tube, they checked other Eagles on the mod line. Of fourteen inspected, they found three more tubes just as unserviceable as the one shown here! Now, the F-15 ECS is a sophisticated assembly, and it is made up of a number of parts which require simple but properly applied torque to function properly. This damage could have occurred as a result of pure overtorquing or from not using the double-wrenching technique. Either way, the result was the same. . .more time, more cost, more parts – and less availability of Eagles for mission accomplishment.

The F-15 is not our only fighter to suffer at the hands of inappropriate tool procedures. A Phantom experienced demise of a centerline fuel tank pressurization line and a time-consuming No. 2 fuel cell replacement when a technician failed to hold a B-nut with a second wrench when torquing a hot air check valve with another wrench. Still another F-4 was downed for erratic operation of the nose gear steering system – the result of a crushed roll pin which was itself the result of not using two wrenches on the feedback shaft and collect during replacement maintenance. We don't have any bad examples right now to offer on our F/A-18 Hornet or AV-8B Harrier II, but is there anybody out there who thinks it hasn't happened? Incidentally, the cost of the damaged F-15 heat tube assembly was several hundred dollars. There are lots better places for that kind of money.

When you are removing or installing tubes or shafts, use two wrenches – one on the tube or shaft, the second on the assembly to which attachment or removal is being made, as shown below. Even though much system tubing and many components used in aircraft today (B-nuts, unions, collects, etc.) are made of titanium or stainless steel, a combination of brute force and incorrect wrenching techniques can destroy them. As they (might) say in the chewing gum commercials – "double wrenching is double good." ■

Tow Tow Tow Your CFT



By MIKE CREECH/*F-15 Senior Technical Data Engineer*

Most Eagle maintenance personnel are quite familiar with towing an F-15 aircraft. However, when it comes to towing a -2 or -3 configuration conformal fuel tank (CFT) installed on a 68D290048-1001 handling dolly (32 feet long plus the length of the tow bar) for the first time, one may find it somewhat awkward and cumbersome to handle. Towing techniques for CFTs are not quite the same as those for towing an aircraft.

Now let's add in the unfamiliarity of CFT towing, plus the combination of a CFT handling dolly with an unlocked aft wheel, and look out! In all likelihood, you'll wind up with the tail end of the CFT passing the front end of the vehicle doing the towing, especially when cornering or stopping. This situation could and probably would ruin your whole day.

An explicitly detailed procedure (05-00-33) has been added to T.O. 1F-15C-2-05JG-00-3 to clarify towing procedures for single and dual towing of dollies with CFTs installed. Let's explore some of the tasks listed in this technical order.

Screw and Turnbuckle Assemblies

Two screw and turnbuckle assemblies are used to secure the CFT to the handling dolly. Check that each screw assembly is properly seated in the CFT forward and aft attach points, and the screw assembly lock is snugged down against the cradle arm.

Next, inspect the turnbuckle assembly links. The lower edge of the links must be snugged up against the CFT forward and aft lower attach fittings. If the turnbuckles will not snug down, the CFT may be sitting on the dolly incorrectly. This could have been caused by the dolly cradle roll adjustment not being locked prior to loading the CFT onto the dolly, or the turnbuckle assemblies being reversed. The shorter turnbuckle assembly attaches to the aft attach point and the longer to the forward attach point.

Roll Movement

Roll movement is provided in the dolly cradle assembly to aid in installation of the CFT onto the aircraft. To prevent shifting of the CFT during towing, lock out the roll movement of the cradle assembly. To lock the roll movement in the neutral position, insert steering bars into the forward and aft cradle arms attach points, and loosen the friction locks. Rotate the cradle arms (upward or downward) until the quick release pins lock into position, then snug the friction locks down.

Alignment Marks

Alignment marks on the tube and frame assembly provide a center of gravity (CG) reference point for the CFT and dolly. To align, slightly raise the CFT, loosen the handwheels, then reposition the CFT and dolly frame. Once aligned, tighten the handwheels, and lower the CFT.

Hydraulic Control Valve

Before transporting the CFT, slowly open the hydraulic control valve and lower the CFT/tube assembly until the tube assembly is seated in the bottom of the V-shaped plate. Leave the hydraulic control valve in the full open position.

Trailing Aft Wheel

All three dolly wheels caster, but only the aft wheel has a swivel lock. One of the most important check list items before towing is to ensure that the aft (trailing) wheel is locked out. This prevents the CFT/handling dolly from pivoting around the tow vehicle whether towing in a single or dual tow configuration (also see Dual Towing Differences). The lock will only engage with the aft wheel in the trail position. When the wheel is not properly aligned, the quick release pin will not engage the swivel lock. Using a steering bar, rotate the aft wheel until the lock engages (wheel will not swivel).

Dual Towing Differences

Dual towing of the CFTs means towing one shipset; i.e., a left-and right-hand CFT side-by-side, not two left- or two right-hand CFTs.

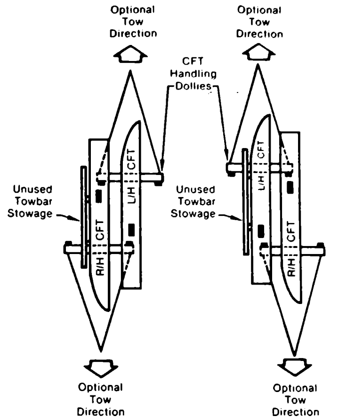
Two CFTs, when properly positioned for dual towing, are nested together so the one being towed by a vehicle is facing forward and the other (slaved dolly) is facing in the opposite direction. Dual towing towbars (shorties) are used to connect the dollies together. The unused V-shaped towbar for the slaved dolly is stored in the brackets of the dolly cradles that are not adjacent to the other dolly being towed. (See illustration Dual Towing Possibilities.)

The dual towing handling dolly configuration requires that only the rear wheel of the dolly actually being towed is to be locked out (not allowed to swivel). The rear wheel of the slaved dolly will be facing forward and must be allowed to swivel (track) with the forward facing dolly wheels.

F-15E CFT Dollies Differences

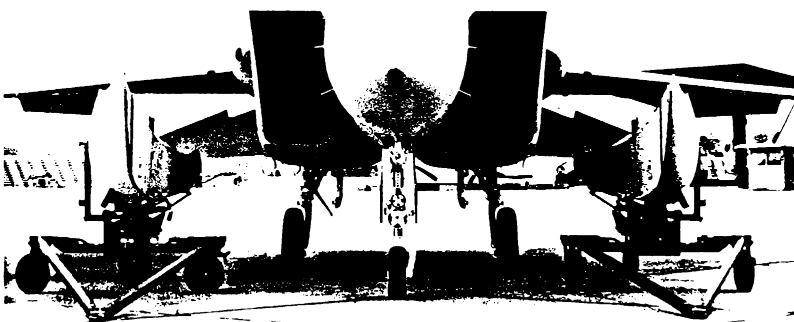
The newest addition to the Eagle family, the F-15E, will be flying with -4 configuration tangential CFTs, which will require the use of 68D290048-1005 handling dollies. The -1005 dolly can also be utilized to handle -2 and -3 configuration CFTs; however, the -1001 handling dolly cannot accommodate -4 configuration CFTs. Towing procedures for both the -1001 and -1005 dollies will be almost identical.

The keys to safe CFT towing are keep your speed below 10 MPH, lock the rear wheel of the towed dolly, and watch your turning radius. This will keep the CFT and its handling dolly behind you.



Dual Towing Possibilities

Note: Unused towbar should not be stowed on dolly brackets of CFT adjacent to the other CFT.

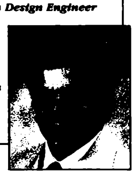


YOU TELL ME – Are these CFTs ready to be towed from beneath this beautiful Eagle? At a glance, one can see that the right-hand CFT's aft trailing wheel is not properly aligned, so it is obvious that the wheel is not locked out. Now, what about the left-hand CFT? Is the aft trailing wheel locked out, or is it just in correct position? We don't know. Would you want to take a chance and possibly damage the aircraft, CFT, or handling dolly because an unlocked aft wheel allowed the CFT to strike the aircraft, and then pass you by? So before you tow, always check that the aft wheel is actually locked out. Obviously, there is no way to tell other than to take the time and physically make that most important final check – aft wheel in proper position and the swivel lock engaged. ▪

Eagle's Hot Fuel Recirculation Improvements

By EDWARD A. DI GIROLAMO/*F-15 Fuel System Design Engineer*

Ed DiGirolamo received a BS in Aerospace Engineering from the University of Kansas. A fuel system design engineer with McDonnell Aircraft Company since 1987, he has been involved in the development/retrofit of the hot recirculation system for the F-15 Eagle. Ed has a private pilot's license and is a member of the American Institute of Aeronautics and Astronautics (AIAA).



When the word comes into the fuel shop from maintenance control that an Eagle is returning from flight with a write-up for an internal wing fuel imbalance discrepancy, prior to time compliance technical order (TCTO) 1F-15-901, one can almost see fuel specialists grimace with pain, maybe utter, "Not another one." With a fuel imbalance comes a high probability that the malfunction will be traced back to the thermal bypass valve, requiring the removal and repair of the fuel/oil heat exchanger.

Improvements to the hot fuel recirculation system (production incorporation per ECP-1723 on F-15C 85-0093, F-15D 85-0129, and F-15E 86-0183 and up, and other F-15A/B/C/Ds retrofitted per TCTO 1F-15-901) will provide a significant increase in the overall reliability and maintainability of the fuel system. This redesigned hot fuel recirculation system will make heat exchanger repair/replacement for a malfunction of this nature a thing of the past.

This article will discuss the system's original design, how it functions, its improvements, and some pointers on troubleshooting and maintenance.

System Function

The hot fuel recirculation system is designed to keep engine fuel from becoming too hot. It accomplishes this by providing extra fuel flow through the fuel oil heat exchanger whenever the fuel temperature rises above 185 ± 5°F prior to TCTO 1F-15-901, or 170°-190°F after incorporation of ECP-01723 or TCTO 1F-15-901. It is important that the fuel entering the engine is kept below 200°F to meet engine requirements.

Fuel in the F-15 is used to cool hydraulic, integrated drive generator (IDG), and airframe-mounted accessory drive (AMAD) fluids. Heat transfer from these fluids to the fuel takes place within the fuel/oil exchangers. Figure 1 shows the effects of heat transfer on engine fuel temperature. The AMAD, IDG, and hydraulic systems (power control – PC-1 and PC-2, and Utility) all contribute to the heat input level.

The temperature of fuel exiting the heat exchangers is dependent on the heat input level, the fuel flow rate, and the temperature of the fuel in the internal tanks. During ground idle (especially on a hot day) or at low power settings, the fuel flow rate through the heat exchangers may not be sufficient to keep the exiting temperature below the required 200°F. The hot fuel recirculation system is designed to allow more fuel flow through the heat exchangers by recirculating additional fuel to the internal wing tanks for cooling. With the flow rate increased, the temperature of the fuel entering the engines will be kept within acceptable levels.

Original Design

The original hot fuel recirculation system in the Eagle incorporated a thermal bypass valve to control recirculation flow. The bypass valve consisted of a temperature sensitive pellet, called a thermal element, and a plunger-type valve. As the temperature of the fuel rose, the pellet expanded, pushing on the valve plunger, which opened the valve. The amount that the valve would open (modulate) depended on how hot the fuel was within the heat exchanger (the valve started opening at a fuel temperature of 185°F and was fully open at 200°F).

Problems presently being encountered in the field usually originate in the thermal element. Fuel seeps past the seal in the element, contaminates the wax pellet, and causes the thermal element to actuate at a lower temperature level (i.e., the valve experiences loss of calibration resulting in incorrect temperature scheduling). With one valve open and the other closed, wing fuel imbalance occurs. The rate at which the fuel imbalance grows in this condition is the same as the recirculation rate and can be as high as 32 pounds of fuel per minute.

Through the years as these problems became more apparent, various design changes of the bypass valve were incorporated in an effort to improve its reliability. None of these changes significantly improved the reliability of the hot fuel recirculation system. It was decided, therefore, to redesign the system. The design philosophy was centered on creating a system that used off-the-shelf F-15 qualified components that had already demonstrated high reliability.

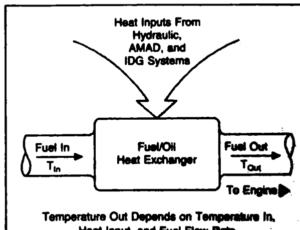


Figure 1. Factors Affecting Engine Fuel Temperature

Improved System

The redesigned system eliminates the thermal bypass valve in the fuel/oil heat exchanger. The thermal bypass valve is the high failure item in the system. This new system was extensively tested in the laboratory and proved that the system worked exceptionally well and kept fuel temperatures below the 200°F requirement. Tests were done on the hot fuel recirculation valve and temperature switch for up to 100,000 cycles to assure

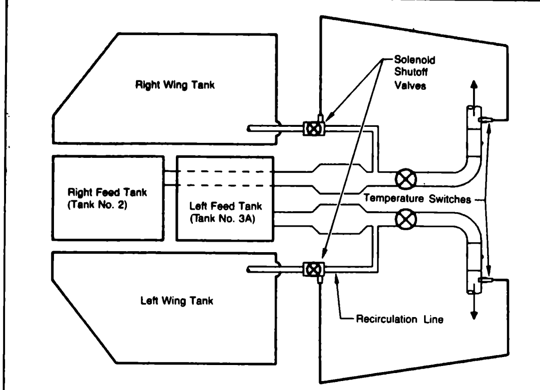


Figure 2. Hot Fuel Recirculation System

the system would be highly reliable once it was put into service. Some of the aircraft with this system installed have surpassed 500 hours with no failures – a very good indication that the system will provide the reliability expected.

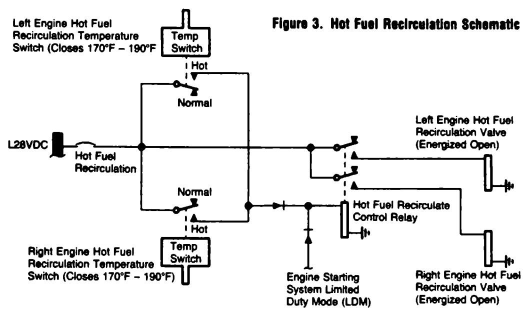
Two hot fuel recirculation valves (electrically operated solenoid), shown in Figure 2, replace the thermal mechanical bypass valves. They are located in doors 144 L/R, providing ease of accessibility.

These hot fuel recirculation valves are controlled by hot fuel temperature switches installed in the engine feed lines. These switches function in a manner similar to the "Hot Fuel" light temperature switches.

Recirculation flow is now controlled by the recirculation valves which are fully opened or closed. Whenever either temperature switch senses a hot condition, it will activate both the left and right hot fuel recirculation valves, routing fuel back to both wing internal tanks simultaneously.

Power is provided to the system by the left hand 28VDC bus, shown in Figure 3, which is available during engine operation, limited duty mode operation, and when external power is applied for system checkout or troubleshooting. When either hot fuel recirculation temperature switch senses an engine inlet fuel temperature between 170°-190°F, the switch contacts will close allowing 28VDC to energize the hot fuel recirculate control relay. With the control relay energized, 28VDC will be applied to both the left and right hot fuel recirculation valves.

Figure 3. Hot Fuel Recirculation Schematic



Whenever hot fuel is recirculated simultaneously, it will flow from both fuel/oil heat exchangers at equal flow rates back to the internal wing tanks at approximately 32 pounds per minute. This will help to ensure balanced fuel loading between the left and right internal wing tanks.

SYSTEM MAINTENANCE AFTER TCTO 1F-15-901

Troubleshooting

Don't be fooled into thinking that only one component within the system can cause a wing imbalance. One of the often overlooked sources of imbalances is the fuel gauging system. At times, due to intermittent grounding and loose wires or grounding between the inner and outer probes in the tank, a sudden imbalance may appear.

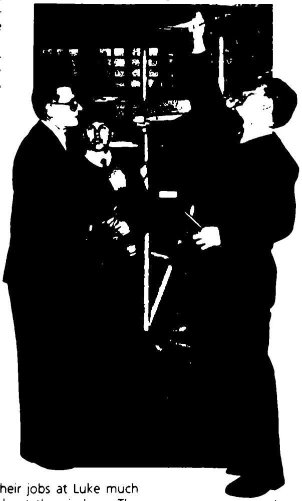
During troubleshooting of the redesigned system always check both hot fuel recirculation valves; a heavy wing does not always mean that the hot recirculation valve is stuck open. It could be the opposite valve is stuck closed, or power is not getting to both valves. The fault isolation procedure requires operation of the boost pumps and monitoring fuel quantity as this is the only way to ensure both valves are opened or closed. Also remember to make sure the aircraft is level in roll. A couple of degrees of roll, due to a low strut, low tire, or sloped ramp, can induce an apparent wing fuel imbalance. A key element in solving an imbalance problem is a clear, concise write-up from the pilot. During the debrief, ask the pilot to provide you with such details as: when the imbalance occurred, how quickly it developed, a record of fuel readings, and flight conditions prior to the imbalance developing.

In any case, troubleshooting for any imbalance should always include following the fault isolation procedures, which provide a step-by-step analysis to help identify the malfunctioning component.

In-Tank Maintenance

During in-tank maintenance in tank No. 3A, make sure if you replace the engine feed line interconnect valve that the part number (MCAIR 68-580115-103) is correct. This fuel manifold has been modified to provide a vent function that was originally incorporated in the thermal bypass valve prior to TCTO 1F-15-901. This vent function is needed to remove trapped air following maintenance on the engine feed lines. ■

TECH VISIT



Seven "Eagle Keepers" from the 405th TTW at Luke AFB, Arizona recently had a chance to ask a lot of questions about the F-15. They were the first group of military aviation maintenance specialists to visit the manufacturing facilities of McDonnell Aircraft Company in St. Louis – as part of the new TAC "Technician Visitation Program" which has been initiated under the co-sponsorship of the Tactical Air Command and MCAIR.

Luke participants in this groundbreaking visit were Captain Timothy Ryan, a maintenance officer with one year's experience on the F-15 and seven years total maintenance time; Sgt Darrell Clark, fuel systems; SSgt Richard Houchens, phase dock chief; SrAmn Pride Johnson, crew chief; TSgt Jon Mandeville, AIS shop chief; SSgt Perry Ply, weapons; and Sgt Martin Talbert, structural repair specialist.

They were able to see for themselves how their Eagles are put together; and they could get first-hand, authoritative answers to their questions . . . why was a particular system designed this way . . . exactly how are these bulkheads contructed . . . why was this or that type of fastener used . . . when is such and such a TCTO going to be in the field . . . why is EMI so critical on new aircraft? Questions they may have puzzled over for a long time, but had no opportunity to ask.

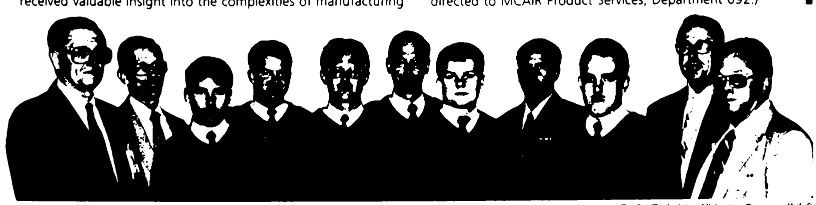
For two days last November, these seven troops had unrestricted access to contractor manufacturing facilities and personnel – to all the expertise responsible for the F-15 weapon system – and from their comments, they returned to their jobs at Luke much more familiar with and knowledgeable about the airplane. The same opportunity may be available to you, and we would welcome your participation in the program. MCAIR has agreed to make these visits available on a periodic basis to groups of military personnel numbering approximately five to seven individuals, who have specific technical responsibilities on our aircraft.

During their time in the St. Louis factory, the visiting technicians spent most of their time on Eagle-related topics and the F-15 MSIP and F-15E dual-role fighter assembly lines. However, they also got a look at Marine AV-8B Harriers and Navy F/A-18 Hornets under construction, and were able to observe typical parts fabrication and build-up procedures from a detail item through final assembled component. Each member of the group received valuable insight into the complexities of manufacturing fighter aircraft, into the way things are done that affect product maintainability and reliability, and into the realization that to the maximum extent possible, fighter aircraft are built with the user in mind.

After a brief introduction which outlined the purpose and plan for the program from the contractor's point of view, the six enlisted men and one officer in attendance were quickly immersed in a first-person look at construction of a jet fighter – from bit & piece fabrication to final flight acceptance. Their tour included stops in the composite materials production area, wire bundle assembly and manufacturing, machine shop, small parts assembly, sub-assembly, paint shop, final assembly, pre-flight, and flight test. They saw the extensive handwork that is still a part of aircraft manufacture as well as the computer controlled/robotics processes that are becoming increasingly important. Throughout the program, company specialists provided explanations and answered questions at each area visited. Later, they received orientations on the overall F-15 project and an in-depth review of the Eagle supportability program, again from experts in the subjects. There was even time for a quick trip through the MDC "Prologue Room" – a fascinating and colorful presentation of the contributions of the McDonnell and Douglas aircraft companies to aerospace history.

Most importantly, the visitation program provided an opportunity for our military guests to come face-to-face with MCAIR technical managers, engineers, and manufacturing specialists. Both contractor and customer personnel noted that the informal discussions which were constantly taking place were exceptionally beneficial to both sides – an important link in improved communications between builder and user. Future visits will be tailored as much as possible to each Eagle Keeper's area of expertise and interest.

(Information regarding participation in the TAC Technician Visitation Program should be obtained from HQ TAC/LGMF-15 at Langley AFB, Virginia. Visiting groups must provide their own transportation, meals, and lodging arrangements from local unit funds. While no plans currently exist for the establishment of similar programs for the Navy F/A-18 Hornet or Marine AV-8B Harrier II, inquiries as to their feasibility are welcomed and may be directed to MCAIR Product Services, Department 092.) ■



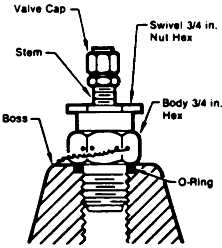
MCAIR personnel and Luke AFB guests pose for group photograph during pause in first visit of military personnel to St. Louis factory in TAC "Technician Visitation Program." (left to right) Field Service Department hosts Art Hyde and Dick Niehoff; Sgt Darrell Clark, SSgt Richard Houchens, SSgt Perry Ply, Capt Timothy Ryan, SRA Pride Johnson, TSgt Jon Mandeville, Sgt Martin Talbert; Wayne Rogers, Superintendent of Inspection; and Ernie Dickey, General Foreman, Flight Test Inspection.

High-Pressure Air Charging Valves

High-pressure air systems are used in several places on all fighter aircraft. On the MCAIR F-4 Phantom, F-15 Eagle, F/A-18 Hornet, and AV-8 Harrier, you'll find them on such components as accumulators, tail hook actuators, landing gear shock struts, pneumatic canopy actuators, pneumatic storage bottles, etc. When properly maintained and handled, these systems give little trouble and are highly reliable and safe to operate. However, as with any other part of a complex weapon system, components of high pressure air systems can cause problems when incorrectly maintained.

The MS 28889 high pressure air charging ("Schrader") valve has been a common but vital part of aircraft pneumatic systems for years. Externally, it looks much like the valve stem on an automobile tire, and the threads on both are exactly the same. However, the similarities end there. The aircraft-type air valve is composed of a body and nut assembly, swivel nut, and stem; and is designed for operating pressures up to 5000 psi. It does not have a "core" for air pressure retention. Air enters and is discharged through a drilled passage in the valve stem. This passage is opened and closed with a rotating swivel nut, and a valve cap keeps the valve clean. The typical assembly contains two "O"-rings and a teflon back-up ring.

Improper installation of the Schrader valve through over- or under-torquing can lead to valve leakage. And if treated carelessly or incorrectly, the cap, nut, and



valve itself can suddenly become a high-velocity projectile aimed at anything or anybody (such as you) that unfortunately happens to be in its way. Never turn (loosen or tighten) the swivel nut hex with valve cap installed – an instantaneous decompression can occur in the air chamber.

You can prevent valve air leakage by doing a careful and quality job of installation. Check the O-rings for nicks, cuts, or other flaws, and lubricate with MIL-L-4343 grease. To avoid O-ring damage from valve threads or sharp corners, use a threaded metal protector or a piece of plastic tubing over the valve threads. When valve is properly seated in boss, torque the body hex 100 – 110 in-lb and safety wire. Loosen the swivel nut hex to the free swivel position (using a second wrench on body hex to keep it from loosening), and then retorque swivel nut 50 – 70 in-lb. To prevent damage to valve, never loosen swivel nut more than two turns. Install valve cap finger tight.

When leakage of an installed valve through the stem or body nut is suspected, cautiously loosen (do not remove) the valve cap to allow any trapped air to escape. Then remove valve cap and verify existence of a pneumatic leak with an approved leak detector fluid. Torque swivel nut hex to 125 ±5 in-lb; then loosen to free swivel position (zero torque) without discharging system pressure. Do not allow body hex to turn during this procedure. Retorque swivel nut hex to 50 – 70 in-lb. If leak continues, replace valve assembly, being sure to totally discharge system before removing valve assembly from boss. ■

MSIP RETROFIT PHASE I – F-15C/D FY 82-83 (ECP 1614)

Certain MSIP (multi-stage improvement program) capabilities are being retrofitted into F-15C/D aircraft, and this change covers the non-recurring effort, validation/verification, and TCTO preparation. The changes described here are applicable to all F-15C/D aircraft, but another document will cover validation/verification for earlier FY (fiscal year) aircraft due to block differences.

Among the capabilities to be incorporated are a programmable armament control system; improved central computer; AIM-7M, 9M, and 120A hardware, data transfer module set; split-screen video-tape recording set; improved avionics control; non-cooperative target recognition (NCTR) capability in the radar; AIS pod; tactical information system; enhanced radar warning receiver; enhanced internal countermeasures system (F-15C); countermeasures dispenser; and the use of air-to-ground weapons on five stations.

MSIP RETROFIT PHASE II – F-15A FY 76 ASAT (ECP 1615)

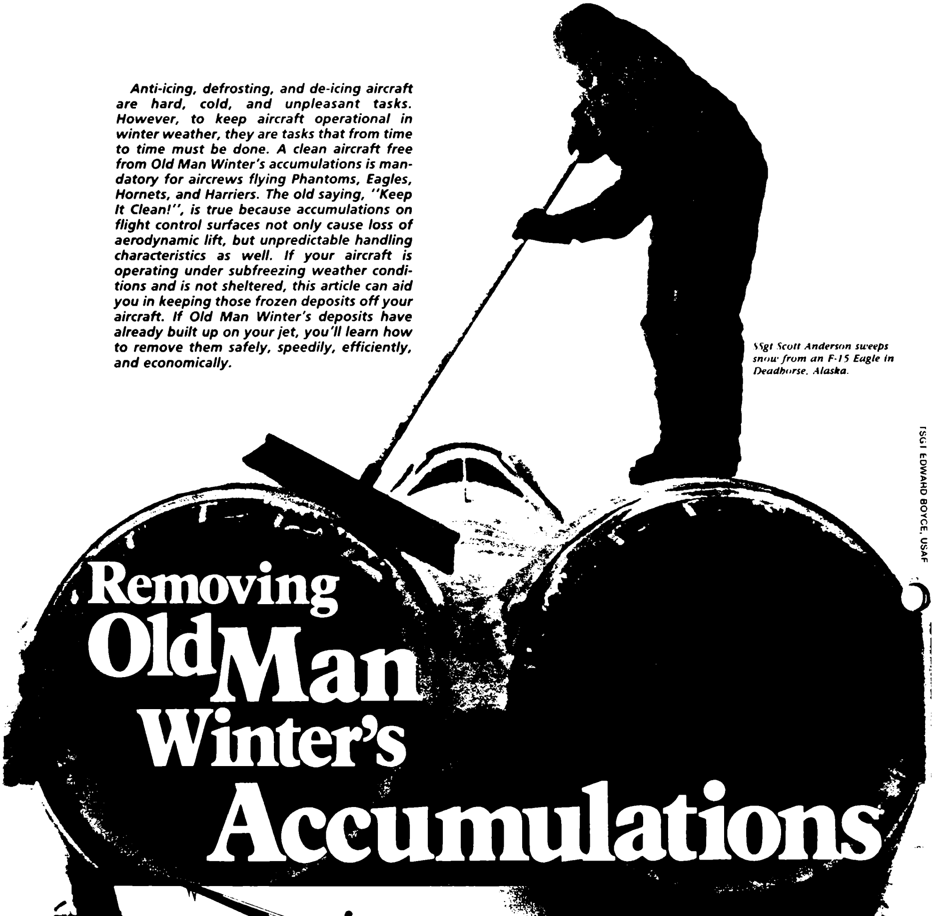
The ASAT (anti-satellite) configuration is defined as the FY 76 F-15A model aircraft. This change covers the non-recurring effort, validation/verification, and TCTO preparation for those aircraft only.

Enhancements to be incorporated include ASAT missile carriage, launch, and training capability; programmable armament control system, data transfer module set; improved central computer; programmable signal processor (PSP) radar with high pulse repetition frequency; NCTR capability; improved avionics capability; weapon system compatibility with AIM-7M, -9M, and -120A provisions and with the airborne instrumentation subsystem (AIS) pod, split-screen videotape recording set; partial JTIDS (joint tactical information distribution system) provisions; tailored MIL-STD-1760 weapon electrical interface provisions; and high-frequency communications provisions. These aircraft will also include the increased capacity environmental control system developed under ECP 1610, with minor modifications to accommodate the ASAT capability.

MSIP PRODUCTION CHANGES – FY 85 (ECP 1604)

These changes add new capabilities to F-15C/D aircraft and give pilots a new fire control system. Modifications include a new AN/APG-70 radar, improved air-to-air displays, a modified central computer operational flight program, a modified radar tactical flight program, and a new interface between the radar and central computer. To accommodate the new system, GFE software changes must be incorporated in the AN/ALR-56C radar warning receiver and AN/ALQ-135 interface control system.

Anti-icing, defrosting, and de-icing aircraft are hard, cold, and unpleasant tasks. However, to keep aircraft operational in winter weather, they are tasks that from time to time must be done. A clean aircraft free from Old Man Winter's accumulations is mandatory for aircrews flying Phantoms, Eagles, Hornets, and Harriers. The old saying, "Keep It Clean!", is true because accumulations on flight control surfaces not only cause loss of aerodynamic lift, but unpredictable handling characteristics as well. If your aircraft is operating under subfreezing weather conditions and is not sheltered, this article can aid you in keeping those frozen deposits off your aircraft. If Old Man Winter's deposits have already built up on your jet, you'll learn how to remove them safely, speedily, efficiently, and economically.



SSgt Scott Anderson sweeps snow from an F-15 Eagle in Deadhorse, Alaska.

TSGT EDWARD BOYCE, USAF

Removing Old Man Winter's Accumulations

Frost, snow, ice, and freezing rain have never been compatible with any flying machine – be it propeller- or jet-powered. If the accumulations of these natural deposits are permitted to continue and go undisturbed on the surfaces of an aircraft, they will degrade the lift characteristics of its airfoil surfaces. This is a major "safety-of-flight" hazard that results in loss of lift and increases stall speeds. Added weight of these deposits on the control surfaces can cause dangerous changes in aircraft trim. In addition, ice in the engine air intake ducts and/or an iced-up compressor can result in engine Foreign Object Damage (FOD) and degraded performance and operability. Any airplane with an accumulation of frozen slush all over its brake assemblies is not going any place. Also, every tactical aircrew member rightfully insists upon and deserves a canopy and windshield that can be seen through.

There are several methods to fight the adhesion and proliferation of frost, snow, ice, and freezing rain on an airplane's surface while it is still on the ground. Of course, the oldest, easiest, and ideal way is to maintain the aircraft's surface temperature above 32°F in a heated hangar where the elements and cold temperatures can't get to it. However, because of operational commitments, hangaring your aircraft is not always possible.

If compelled to maintain an aircraft while exposed to freezing weather, other methods must be used. These include manpower (the "Broom Brigade"); approved ground heaters; covers for wing, tail, pitot tube, tailpipe, intake duct, and canopy; plus fluid chemicals. Each method has its advantages and disadvantages. Depending upon weather conditions at the time, they can be used individually or in combination.

Never, under any circumstances, use hot water for the removal of deposits of frost, ice, or snow. Above all, do not use any type of impact to remove any deposits.

The most widely used means of fighting the freezing elements is the use of fluid chemicals. The following fluids are currently approved for use on military aircraft:

- MIL-A-8243: Anti-icing and De-icing Defrosting Fluid. This is basically a 3-to-1 mixture of etyhlene glycol and propylene glycol with corrosion inhibiting and wetting agents added.
- Federal Spec TT-I-735: Isopropyl Alcohol. This is isopropyl alcohol containing a maximum of 0.4 percent water.
- FED O-E-760: Ethyl Alcohol (Ethanol), denatured alcohol, proprietary solvents, and special industrial solvents.

Taking frost, snow, ice, and freezing rain separately, let's take a look at the best methods to prevent their adherence and removal from the surface of an aircraft, its canopy, windshield, and wheel/brake assemblies.

FROST

A coat of unheated undiluted MIL-A-8243 fluid applied to the aircraft surface will prevent frost build-up. How long this protection lasts depends entirely upon local weather conditions. If your aircraft has to make an early morning departure, a good rule of thumb to follow is to apply the fluid as an anti-icer after the last flight of the day, or as close to midnight as possible.

In areas where as much as a quarter inch of frost accumulates, it has been known that a single coat of fluid applied between 2000 and 2400 hours will keep surfaces free and clear of frost throughout the night and the aircraft can take off in the morning without further de-frosting (de-icing).

If frost has been allowed to build up on the aircraft's surfaces, it can be easily removed by spraying with either cold undiluted, or hot (not boiling) water-diluted MIL-A-8243 fluid. The table on the next page gives the recommended rate of fluid dilution. Keep in mind that de-icing fluid is very expensive. Coverage will go further, be more effective and economical, if hot diluted fluid is used.

SNOW

When snow is forecast, the best protection for your aircraft is the use of wing, tail, pitot tube, tailpipe, intake duct, and canopy covers. Anti-icing fluids should not be used when snow is predicted except in conjunction with the covers. If used by itself, the fluid will become diluted by the melting snow, forming a slushy mixture that freezes in place and is very difficult to remove. Also, slushy mixtures can seep into control surface hinges and freeze.

If your aircraft must get off the ground as quickly as possible, diluted heated and sprayed MIL-A-8243 fluid will remove thin layers of snow. The heat from the fluid and force of the spray will remove the slush as it is formed. However, removal of large quantities of snow with heated fluid is cost prohibitive.

In cases where covers are not available, the best method to prevent heavy accumulations of snow on the aircraft is by constantly brushing or sweeping it during the snowfall or by blowing heated air on aircraft surfaces in accordance with TO 35E17-6-11

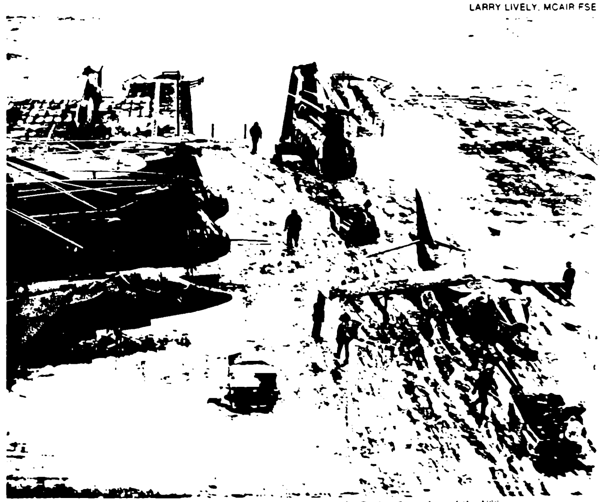
When a large accumulation of snow has been unavoidably permitted to build up, its removal can best be accomplished with the use of brushes and brooms. However, it is not unusual to find that after its removal, a thin, rough, frozen crust of ice remains underneath. This can easily and quickly be removed by using heated, undiluted MIL-A-8243 fluid.

ICE AND FREEZING RAIN

The various covers mentioned previously offer excellent protection from ice and freezing rain. However, if covers are used, it's a very good idea to apply a light coat of MIL-A-8243 fluid to the aircraft surfaces before their installation. This will prevent the covers from freezing to the aircraft's surface, making their removal a simpler task. Care should be taken to ensure that the covers are secured and closely conform to the aircraft. If rain is permitted to get between the covers and the surface of the aircraft, it will dilute the de-icing fluid, render it ineffective, and cause the covers to freeze to the aircraft.

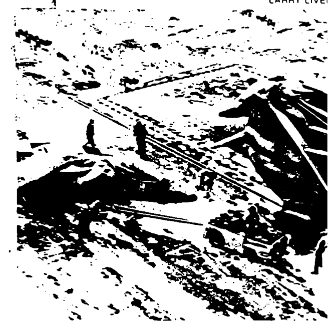
If covers are not available, sprayed undiluted MIL-A-8243 fluid will protect aircraft surfaces if applied as often as ▶

LARRY LIVELY, MCAIR FSE



AV-8B Harrier from VMA-331, conducting winter exercises in the Bering Sea, aboard the USS BELLEAU WOOD.

LARRY LIVEI



necessary during precipitation. The application of the fluid should be repeated often, if not, the amount of protection afforded by the fluid will be dependent upon the amount of freezing rain. It must be kept in mind that at some period of time the rain will dilute the fluid and then wash the surface clean.

If weather conditions get to the point where it is impossible to fight the formation of freezing rain this way, then hot diluted de-icing fluid solutions should be used. Again, mixtures should be made in accordance with those shown in the table below.

Applying hot diluted fluid for ice removal is best performed by spraying a solid stream of fluid (at a pressure as high as possible, but not over 300 psi on metal surfaces and not over 15 gallons per minute) to flood the surface and wash away loose pieces of ice. Special attention must be paid to clearing all ice from the hinges of flight control surfaces.

Spraying large amounts of de-icing fluids into operating engine inlets should be avoided because they are potential fire/explosion hazard. With the engine shutdown, care must be taken to ensure that puddles of de-icing fluid in the inlet duct area are removed prior to engine start.

Cold undiluted fluid will do the job if a hot de-icing fluid solution cannot be used and it is absolutely necessary to remove an accumulation of ice. To assure complete coverage without excessive drainage, the fluid should be sprayed on the surface at intervals approximately 15 – 20 minutes apart. Again, removal of heavy accumulations of ice using cold undiluted fluid is a very expensive and slow operation.

For Ambient Temperature of Fahrenheit Degree	Percent Fluid by Volume	Percent Water by Volume	Approximate Freezing Point of Mixture Fahrenheit Degree
30° and Above	20	80	10°
20°	30	70	0°
10°	40	60	– 15°
0°	45	55	– 25°
– 10°	50	50	– 35°
– 20°	55	45	– 45°
– 30°	60	40	– 55°

RECOMMENDED FLUID DILUTIONS FOR MIL-A-8243 FLUID-WATER SOLUTION

GROUND HEATERS

The primary intended use of approved ground heaters is for the engine air intake ducts, on the engine compressor/turbine sections, and for melting frozen slush from wheel brake assemblies. The heaters can be used, however, to help remove frozen deposits from aircraft surfaces, canopies, and windshields. But use of a heater is proportional to the accumulated amount of frost, snow, ice, or freezing rain. The larger the amount of frozen deposits, the longer it will take to melt them. In addition, once melted, the residual moisture must be dried up immediately or it will refreeze.

CANOPIES AND WINDSHIELDS

Before using any de-icing fluid on a canopy or windshield or any other unpainted (non-metal) surface, be sure to check the individual aircraft maintenance manuals. Solvents, such as de-icing fluids, can be harmful to some types of plastics. In the case of the F-15 Eagle, MIL-A-8243 fluid can be used on the canopy and windshield but their surfaces must be cleaned immediately with Federal Spec TT-I-735 Isopropyl Alcohol to remove the de-icing fluid residue.

Hot air from a ground heater can be used to melt frozen deposits off a canopy and windshield. However, do not apply heat directly to the canopy or windshield, and make absolutely sure the hot air supply is below 200°F. Overheating a canopy or windshield will bring on its ruination, such as causing the acrylic transparencies to stretch and eventually crack.

HEALTH AND SAFETY HAZARDS

Certain health and safety precautions must be observed during the handling and use of the consumables, and de-icing fluids are no exception.

MIL-A-8243 — These glycols are mildly toxic, therefore avoid contact with the skin and eyes. When applying fluid or fluid mixtures, protective clothing and adequate eye protection must be worn.

- Keep this fluid away from all sparks, fire, and oxidizing agents. The fluid flash point is above 200°F, but caution should be used when spraying it around heaters or engine exhausts.
- Do not apply fluid to aircraft surfaces when Liquid Oxygen (LOX) containers are in the vicinity of your aircraft. Contact of the fluid with LOX, a powerful oxidizing agent, may result in a fire or explosion. Prior to LOX servicing, remove any residual fluid from around LOX filler and overflow outlets.
- Avoid excessive use of fluid around aircraft cabin heaters and/or ventilator air intake ducts. This is essential in order to avoid toxic fumes from entering the cabin or cockpit while taxiing to takeoff.
- During spray or brush applications of fluids, keep your back to the windward side.
- Do not apply fluids by spray method unless all personnel are clear of the spray area.
- Exercise extreme caution when using glycol-water solutions in and around silver (or silver-coated) direct current (DC) electrical/electronic circuitry, components such as bare or poorly insulated wiring, switches, circuit breakers, etc. Glycol-water solutions coming in contact with the above can cause short circuits, rapid oxidation, and fire.

FED O-E-760 and Federal Spec TT-I-735 — These alcohols have an irritating effect on the eyes, throat, nasal passages and mucous membranes. Avoid excessive breathing of the vapors and use the fluids only in well ventilated areas.

- These kinds of alcohols are poisonous and should not be taken internally. ■

This article does not tell it all. If your aircraft is assigned in an environment that is subjected to the harshness of freezing weather, we highly recommend that you read NAVAIR 01-1A-520 if you are in the Navy or Marine Corps, or TO 42C-1-2 if you are in the Air Force. These technical manuals will provide you with some effective techniques to keep Old Man Winter's frost, snow, ice, and freezing rain off your aircraft.

By DAN ORCHOWSKI
Retired Staff Editor
Product Support DIGEST

F-15 SPARE PARTS REQUISITIONS

By DAVE POWELL/*Senior Field Logistics Representative, Warner Robins ALC, Georgia*

For the specialists in the first photograph above to accomplish their jobs, so that the specialist in the third photograph can accomplish his job, there must first be a great many other specialists accomplishing jobs of the types shown in the second photograph (and on our outside back cover). A roundabout way of saying that "supply is a vital part of the picture." This article discusses ways by which logistics and maintenance personnel can keep that picture bright and clear through closer attention to the processing of spare parts.

Several years ago, I wrote an article which discussed some of the then current problems in the F-15 weapon system supply system. Many of the problems then are still problems now, and the seriousness of the situation justifies another look at it, again from the point of view of F-15 System Management at the Warner Robins Air Logistics Center.

Back then, the USAF Inspector General's office had also just published some advice on the situation, and several paragraphs from the IG article were quoted, one of which is repeated here because the truth of it is so important it bears repeating (often).

> *"Supply provides the resources Maintenance depends on. Therefore, the better everyone understands the interaction between maintenance and supply, the more effective the entire maintenance organization will be. With more knowledge of supply procedures, we can expect to see less finger-pointing, more cooperation, and more people getting down to the business of maintaining aircraft."*

Being on the "supply" side of the picture here at Robins ALC, but working closely with MCAIR Field Service Engineers and the "maintenance" side; it is clear to me that the two organizations are absolutely inter-dependent. Maintenance people need not become logistics experts, but an understanding of the basics of supply operations will help insure that "the right part is in the right place at the right time . . ." (logistics responsibilities) " . . . in the hands of the right people to do the right job" (maintenance responsibilities). Because everybody's ultimate report card, whether assigned to the maintenance or the supply organization, is the aircraft FMC (full mission capable) rate, it makes good sense (and is self-preserving) to work together closely. And because many of you indicated the advice offered in my last article was worthwhile, here is a little more, along that same line of maintenance/logistic interface.

UNDERSTANDING THE SYSTEM

Of the more than 241,000 total parts required for a complete F-15 weapon system, only 90,000 or so are stock-listed with good National Stock Numbers (NSN). And even when good NSN's are established, it does not always mean that material is readily available at the "wholesale" (depot or storage site) or "retail" (squadron/base level supply) location — a point I will expand upon a little later. The balance of these non-stock listed items (some 150,000) can create an enormous identification and requisitioning problem for an operating activity. Before these raw numbers overwhelm you, please note that I said non-stock listed items "can" create problems; they do not *have* to . if there is sufficient understanding of the concepts behind the F-15/USAF supply system.

AFM 67-1 is the USAF supply "bible." Everybody who works with airplanes has a "need to know", and everything you need to know is spelled out somewhere in 67-1 and the manuals prepared in accordance with its requirements, such as the Dash Four IPBs (Illustrated Parts Breakdowns). An understanding of the SMR (Source/Maintenance/Recoverability) codes in the -4 handbooks will help the requisitioner determine the different steps that must be taken to satisfy a requirement for a non-stock listed item — one coded other than PA (Procurable-Stocked) having no NSN. More effort, research, and actions are required by the requisitioner to order these items, but the proper guidance is available if you

know how to interpret the manuals.

With respect to SMR coding, without knowing what the system is telling you in detail, there is just no way to understand why every single item required and ordered by maintenance personnel is not always "on the shelf," ready for issue immediately as needed. While it is beyond the scope of my intentions with this article to discuss SMR coding in detail, the coding breakdown tabulation itself (from USAF T.O. 00-25-195) is presented to show in general how supply management decisions have been reached for any combination of spare parts situations. In the original planning for assignment of specific item codes, several factors were considered, including maintenance capabilities, the predicted maintenance action itself, base facilities and capabilities, and the economics (cost) of each situation. It is important to remember that SMR codes have also been assigned to bulk items (nuts, bolts, screws, washers, etc.,), with assignment reflecting the lowest level of maintenance authorized to remove the item.

One of the points I stressed back in 1980 was the importance on the part of the requisitioner (the person who "needs" the part) to research the requirement. Just "dumping" a requirement into the supply system is a guarantee of trouble, of non-delivery. If other individuals in the pipeline have to second-guess or spend non-productive time researching your requirement because you spent too little time providing sketchy (or "no") technical data, your order can end up being rejected or cancelled for lack of good, correct information. And you may not even know it, especially if follow-up action is equally ineffective — you will be waiting for supply to fill an order on which no positive action is in process. This self-induced deficiency of the system can be eliminated through better research at the squadron level before requirements are passed to the base supply organization, and through better research there before an off-base requisition is passed to the managing agency.

". . . Because everybody's ultimate report card, whether assigned to maintenance or supply, is the aircraft FMC rate, it makes good sense to work together closely."

If you say that there is not enough time to properly research or to follow up on lower priority items because of heavy work loads created by MICAP requirements, I certainly understand and sympathize; but also have to say that it will be you who has to suffer the most and wait the longest for that spare part. If your only action after submitting a poorly researched requisition is to register an eventual complaint for non-receipt of material, you and the supply system are on a collision course! Guess who will receive the most damage from such an encounter?

The maintenance specialist usually identifies the required part in the Dash Four IPB series or the Dash Three Structural Repair series manuals. Don't be shy about passing these T.O. references along to the next person in the processing cycle; too much information is always better than not enough when the part you need is just one of a quarter-million! And when identification or source of supply problems cannot be overcome at squadron or base level, then assistance should be requested from the F-15 System Program Manager (SPM) division here at Warner Robins ALC. In October 1982, the SPM division assumed the engineering responsibility for the weapon system; engineering and technical personnel are assigned to the organization here for resolving problems beyond your local capabilities.

USING THE CLUES

Let's turn now to the point made earlier concerning NSN's (National Stock Numbers) — even when a good NSN exists for ordering material, that material may or may not be available in stock at the base or depot supply levels. Part of this situation stems from the decentralization of various managing agencies for spare parts, which has added to requisitioning problems of supply/logistic support personnel. Knowledge of the interactions among the Air Logistics Centers (ALC), Defense Logistics Agency (DLA), which provide the military services with depot-level supply support, and the General Services Administration (GSA), would be helpful in understanding some of these NSN problems. Each of the ALC, DLA, and GSA organizations has a customer support unit which can be contacted for assistance on any given requisition loaded into the supply system. These units can provide current status of requisitions, asset availability information and the item manager or technician's name and telephone number if a technical problem needs addressing.

The NSN is a "structured" number, whose elements contain and provide key information which help the requisitioner quickly identify the agency responsible ▶

1560-01-056-4842FX

- MMAC (F-15 aircraft)
- NIIN
- NCB (United States, after 30 September 1974)
- FSC (airborne structural component)

for managing the required item. There are thirteen "positions" (spaces) in a National Stock Number —

XXXX — FSC (Federal Supply Class Code): A four-digit number which groups similar items into "classes." Examples are 1650 — aircraft hydraulics; 5305 — screws; 5310 — nuts and washers; 5841 — airborne radar equipment. (All FSC numbers are listed in AFM 67-1, Volume I, Part II.)

XX — NCB (National Codification Bureau/NATO Code): A two-digit number which designates the NATO country which catalogued the item. United States code numbers are "00" (for stock numbers assigned before 30 September 1974) and "01" (after).

XXXXXXX — NIIN (National Item Identification Number): A seven-digit number assigned by the cataloguing agency of DLA — the Defense Logistics Service Center (DLSC) at Battle Creek, Michigan. Numbers are non-significant in themselves and are assigned in straight numerical sequence during the cataloguing process.

In addition to the standard 13-digit number, the United States Air Force adds a two-position alphabetic code series to the end of the NSN. Used to identify specific equipment or aircraft models, this is known as the MMAC (material management aggregation code). Examples are FX — F-15 aircraft; BF — F-4 aircraft; PT — Pratt and Whitney jet engines and components. An example of a typical USAF NSN is presented above (in visual presentations and catalog system publications, a dash is inserted between segments of the number) —

Recognizing and identifying the correct managing agency saves time and assures that the proper managing agent is contacted during any follow-up effort. AFM 67-1 contains charts which correlate the FSC and the material required with the responsible inventory manager and the appropriate DLA supply center and serviceable supply site. The four-digit FSC and the two-letter MMAC are the two most readily used elements for identification of managing agency effort. For example, FSC "1560" and MMAC "FX" identifies immediately to the researcher that the subject of interest is an airborne structural component for the F-15 and managed here at Warner Robins ALC. Similarly, the correct managing agencies within DLA for hardware items can be just as quickly tracked down. For example, FSC 5305 screws, 5306 bolts, and 5310 nuts and washers are managed at Defense Industrial Supply Center (S9I); FSC 5930 switches, 5935 electrical connectors, and 5945 relays are managed at Defense Electronic Supply Center (S9E).

". . . If your only action after submitting a poorly researched requisition is to register an eventual complaint for non-receipt of material, you and the supply system are on a collision course!"

STOCKS ON HAND

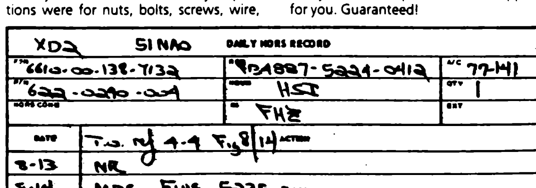
It appears to me that some locations still do not do a good job of identifying and obtaining sufficient stocks of stock listed hardware items. Some sample statistics will illustrate my point.

We sampled a few items over a typical six-month period some time ago. During that time, we found four hardware items that accounted for nearly twenty-seven thousand F-15 MICAP hours — a collar (FSC 5320), a coupling (FSC 4730), and two screws (FSC 5305). These parts ranged in price from 61 cents to 18 dollars, but I can assure you that the MICAP time cost a little more than the (non-stocked) parts themselves! Random sampling of requisitions from any given base during that same period showed that approximately 20 — 22% of their daily requisitions were for nuts, bolts, screws, wire, packing, etc. I'm pleased to note that much improvement has been made in this area over the past year. Currently, the DLA-managed hardware items are only contributing approximately 15% of the total MICAP hours against the F-15 fleet. It is imperative that we maintain this downward trend; what with all the planning, projections, computer listings, and hard work by many people in different organizations, there is no reason that these nickel and dime hardware items should be allowed to degrade the overall F-15 program.

Now let's take a brief look at another type of situation — items that are SMR coded other than "P" (procurable) having no NSN. Items source coded "MF" (manufacture — field level) or "AF" (assemble — field level) often create the biggest problem when a requisitioner tries to obtain a needed spare. I do not understand why some bases have never attempted to get proper stock on hand of raw materials for the local manufacture of "MF" coded items or other consumables called out in the maintenance books to support the weapon system.

Items of this type require a totally different approach to obtain. In some cases, the -3 and -4 series T.O.s will identify all bits and pieces or raw materials needed for manufacture or assembly, but in many cases this data is not provided. In-depth research must then be accomplished, records and documentation must be screened, and in some cases drawings must be obtained to identify raw materials. If drawings are necessary, the operating activity should request them through their local engineering data unit, which will in turn order directly from MCAIR on an open Warner Robins BOA (Basic Ordering Agreement) contract.

My conclusions from all this? The same ones arrived at in my article of four years ago — *more research and better follow-up on spares requisitions entered into the supply system are absolute musts.** You can help yourself by doing more "homework." It's like going to school — do your homework well and it will produce better grades. Do your parts research well, track your requirements in a timely manner, and the bottlenecks that others always seem to experience will disappear for you. Guaranteed! ■



WRALC tracks daily status of parts with form shown above.

Protecting our aircraft against Old Man Winter's accumulations is of vital importance. But first and foremost is how we field service engineers, maintainers, and aircrews protect ourselves. If we ignore the rules or don't use good common sense in protecting ourselves when physically facing bitter temperatures, who's going to protect our aircraft? It's our personal responsibility to be prepared to meet the winter elements on their terms. Here are some lessons I've learned out of necessity during assignments in those cold, harsh environments.

TSGT EDWARD BOYCE USAF

Protecting Against Old Man Winter's Harshness

By BOBBY MOORE/
Technical Specialist – Field Service
TAC HQS, Langley AFB, Virginia

TSGT EDWARD BOYCE, USAF

Eagle crewchiefs are preparing to marshal their aircraft out of the chocks 250 miles from the Arctic Circle in Deadhorse, Alaska.

In maintaining and operating high performance aircraft, cold weather, not the aircraft, becomes your biggest challenge to overcome. Therefore, when the temperature is well below freezing, your first priority is not that splendid fighting machine you maintain, but maintaining yourself so you can do your job to get that Phantom, Eagle, Hornet, or Harrier ready to fly.

Whether the temperature is −65° or +10°, your aircraft may not make it to the runway if you haven't taken the time to dress properly or if you're snowblind or half-frozen.

Bulky clothing, such as gloves and parkas, interfere with your ability to repair a system. The easiest jobs, such as a system checkout, servicing, or changing a tire, become challenging – if not nearly impossible. You still must be able to reach through those small bulkhead openings to install a component or repair a wire bundle. You'll find yourself spending twice as much time making those routine inspections and repairs. A driving wind and snow only complicate the situation.

FROSTBITE

Several years ago on a base in the land to our North, a young technician was troubleshooting a system on an F-4 Phantom which was essential to the mission. Not only was it snowing, but the wind chill factor had been in the minus double digits for several days. In his eagerness to repair the aircraft, he took off his gloves and other protective gear with the thought, "This will only take me a couple of minutes." He didn't realize that the wind chill factor was –65°, and he didn't know that his flesh would freeze within about a minute. Old Man Winter's harshness quickly took its toll on his hands and fingers before he could repair the Phantom. Not only was the aircraft not repaired, but the technician was also out of commission, not to mention the painful frostbite to his fingers and hands.

Frigid temperatures alone can cause frostbite, hypothermia, and even death. Almost any chill factor will chill you to the bone, but to make matters worse, any exposed body parts, such as your face and hands, will be frostbitten much quicker. The average time for bare skin to begin freezing varies with the temperature/wind conditions (see chart).

For safety's sake, WATCH for frostbite! Whether working or playing in frigid weather, use the "buddy" system whenever possible and occasionally check your partner's face and exposed skin for the gray or white evidence of frostbitten skin. Have your partner do the same for you. If you remotely suspect frostbite, get medical attention as soon as possible.

Take frequent breaks to rest, properly secure your clothing, and warm up exposed flesh for good blood circulation. Exhaustion causes deep breathing that results in a greater possibility of frigid air being inhaled into the throat and lungs. This can quickly cause throat frostbite. As wind speed increases, the freezing time of exposed flesh rapidly decreases.

The most important rule to remember when working on aircraft in subfreezing weather is to "protect yourself and know the warning signs." I've met several people throughout my travels who thought that frostbite could not happen to them. They unknowingly overlooked the warning signs until it was too late.

The first indication of frostbite is the feeling of pins and needles, followed by a prickly feeling, and then numbness, which can range to a complete loss of feeling.

TSGT EDWARD BOYCE, USAF

An F-15 pilot discusses aircraft readiness with a maintenance technician in the hostile cold weather environment of Deadhorse, Alaska.

CLOTHING

The most important weapon against frostbite is wearing proper clothing and protective devices, such as a face mask. Wearing warm clothing that fits well and doesn't restrict your movements is essential when working around aircraft.

Always wear at least two pairs of socks, but don't put on a third pair if it makes your footgear too tight. This could stop blood circulation, thus making your feet more susceptible to frostbite. Use only winter issued footgear when the temperature is hovering around or below the freezing mark.

Wear thermal underwear beneath your normal clothing and a parka with a hood, or an overcoat and pile cap, for your outermost layer against the elements. Protect your face, ears, and hands from the wind and snow by wearing a mask, ear muffs, and gloves. Wearing sunglasses will protect your eyes from the bright glare of the sun's reflection off a blanket of snow.

For maximum warmth, wear clean clothing and gloves. Dirt and grease make fabrics stiff and cause them to lose their insulating qualities. Stiffly starched and pressed fatigues look great, but excessive starch closes the pores in the material and acts like a conductor of cold temperatures.

Remember that your heavy boots, parka, and gloves make you clumsy. You'll have trouble with normally simple tasks, such as holding tools and small parts. To make the problem worse, goggles and earmuffs impair your vision and hearing. Merely accepting the fact that these extra layers of clothes and various protective items will impair your agility and efficiency is winning half the battle. Patience!

VARIOUS OTHER PRECAUTIONS

Walking and working on an icy flight ramp or an aircraft wing are especially hazardous. Climbing icy steps can also be tricky. Watch out for icy patches and other spots that freeze quickly, such as painted areas.

A special warning when working around cold soaked aircraft: don't touch cold metal surfaces or tools with your bare hands. Even if your hands feel dry, they still may freeze and possibly stick to the cold metal surfaces. Keep your tools ▶

covered and clear of blowing snow which could later freeze to your touch.

If you get fuel on your bare hands, evaporation of the fluid may cause instant frostbite. Remember, de-icing fluid is toxic and can be harmful if you breathe in the fumes or get the fluid in your eyes or on your skin. (For a discussion of safety practices while using de-icing fluids, see the preceding article, "Removing Old Man Winter's Accumulations.")

Stay alert around aircraft with engines running. You're working under serious handicaps, so you just can't afford to get careless. Your gloves, goggles, or tools can easily be ingested into the engines.

Danger at the rear of the aircraft is even greater on icy ramps because jet blast can loosen chunks of ice and hurl them at great velocities. Loose ice also may be ingested into the engine intakes.

An additional danger exists in front of aircraft parked on icy ramps. Aircraft can move unexpectedly with much less engine power than on dry ramps.

AIRCRAFT PROBLEMS

Air and hydraulic fluid leaks are amplified as the temperature plummets. Hydraulic cylinders and actuators may leak fluid because O-rings, seals, and gaskets are less pliable and become deformed at lower temperatures. In addition, ice crystals in hydraulic fluid may cut seal materials. Air leaks develop as seals and line connections contract at different rates.

Mechanical and hydraulic controls become sluggish in cold weather. Using unauthorized lubricants that seemed to work properly in warm weather will stiffen up as the temperature drops and cause bearings to require added force to move.

Moisture condensation causes water to accumulate in fuel tanks, especially in tanks that are not kept filled. If the water freezes, it may clog filters, fuel lines, and valves.

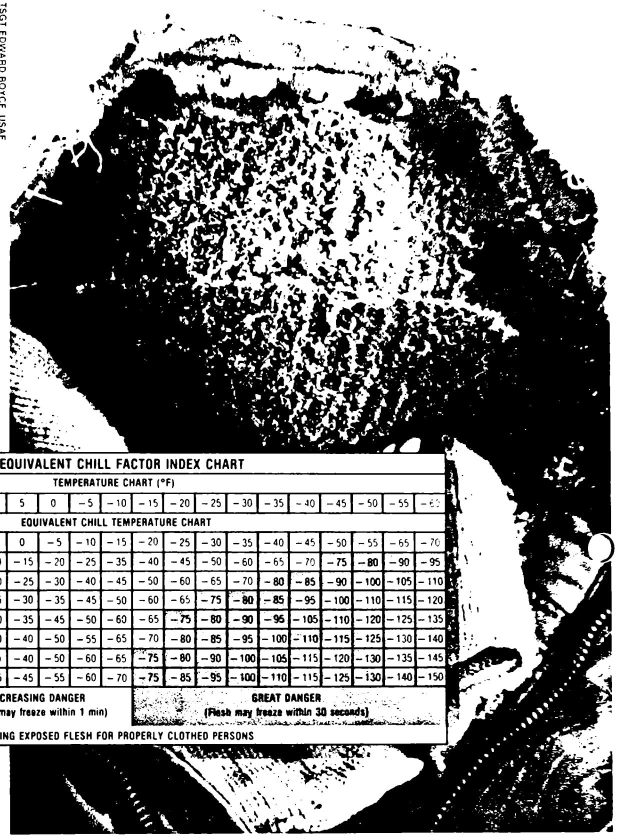
GENERAL RECOMMENDATIONS

You can avoid most aircraft problems and personal survival problems during frigid temperatures by following some simple, basic rules:

- Be aware of current weather conditions and keep updated on immediate- and long-range weather forecasts, then dress accordingly.
- When making frequent trips from the outside cold to an inside warm area, be sure to remove outer clothing upon entering the warmer area. Put them back on just prior to going back outside to brave the cold weather. This helps prevent perspiring in warmer areas with too much clothing on, and later going back out into the cold wearing damp clothing.
- Keep your feet dry, and use proper footwear.

Finally, realize that everyone else will also be functioning under the same handicaps as you. But perhaps their reactions will be slower and their responses may try your patience. So, the key to survival: patience and common sense in all that you do. And with the proper precautions, both you and your airplane will be around when the flowers bloom again. ■

TSGT EDWARD BOYCE, USAF



EQUIVALENT CHILL FACTOR INDEX CHART

WINDSPEED KNOTS	WINDSPEED MPH	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-60
KNOTS	MPH	TEMPERATURE CHART (°F)																				
CALM	CALM	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-60
		EQUIVALENT CHILL TEMPERATURE CHART																				
3 - 6	5	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-65	-70
7 - 10	10	30	20	15	10	5	0	-10	-15	-20	-25	-35	-40	-45	-50	-60	-65	-70	-75	-80	-90	-95
11 - 15	15	25	15	10	0	5	-10	-20	-25	-30	-40	-45	-50	-60	-65	-70	-80	-85	-90	-100	-105	-110
16 - 19	20	20	10	5	0	-10	-15	-25	-30	-35	-45	-50	-60	-65	-75	-80	-85	-95	-100	-110	-115	-120
20 - 23	25	15	10	0	-5	-15	-20	-30	-35	-45	-50	-60	-65	-75	-80	-90	-95	-105	-110	-120	-125	-135
24 - 28	30	10	5	0	-10	-20	-25	-30	-40	-50	-55	-65	-70	-80	-85	-95	-100	-110	-115	-125	-130	-140
29 - 32	35	10	5	-5	-10	-20	-30	-35	-40	-50	-60	-65	-75	-80	-90	-100	-105	-115	-120	-130	-135	-145
33 - 36	40	10	0	-5	-15	-20	-30	-35	-45	-55	-60	-70	-75	-85	-95	-100	-110	-115	-125	-130	-140	-150
WINDS ABOVE 40 HAVE LITTLE ADDITIONAL EFFECT		LITTLE DANGER					INCREASING DANGER (Flesh may freeze within 1 min)						GREAT DANGER (Flesh may freeze within 30 seconds)									
		DANGER OF FREEZING EXPOSED FLESH FOR PROPERLY CLOTHED PERSONS																				

CRAMPED QUARTERS IN THE GEAR WELLS

Pretend that you are an F-15 "nose landing gear!"

If you can convince yourself of that, the view in the photo here is what you would see as you were about to be catapulted up into the nose gear wheel well, just after the Eagle pilot has selected Gear Up. Pretty tight fit and not much room for you in that hole, is there? Same thing with the real NLG, and there have been some recent problems associated with that situation.

For instance, an Eagle driver tried to drop the gear once, twice, and only on the third try did all gear indicate down and locked. During the taxi run, he was informed that there appeared to be some wires hanging loose from the nose gear area. Post-flight check revealed extensive wiring damage in the well, several cable clamps were bent and torn loose, and there was a dent in the antenna cover on the gear door. There was also evidence of wiring rubbing on the outside lower portion of the nose gear strut. All in all,

a mess, but one that fortunately did not cause any serious problems on this RTB. Let's look at what happened.

While space, or rather the lack of it, is critical in all three landing gear wheel wells, there *is* a place for everything, but everything must be in its place! On this flight, the nose gear strut had caught on wiring that had not been securely clamped in place some time previously. Maintenance looked in the wheel wells of some other aircraft on the line, and found the potential for more problems of this type — loose, improperly mounted, or wrong size clamps; and incorrect routing of wiring in the area in question. Unlike you, the nose gear does not have eyes; it's going to slam up into the well regardless of what may be in the way — your job is to make sure nothing is in the way! Since this problem can occur anywhere along the line, from initial manufacture through in-service repair and maintenance, we are taking a close look at the situation here at the plant; we suggest you do the same out there. Eagles have three wheels — landing with less is not a pilot's idea of a fun time. ■

F-15 Hydraulic System

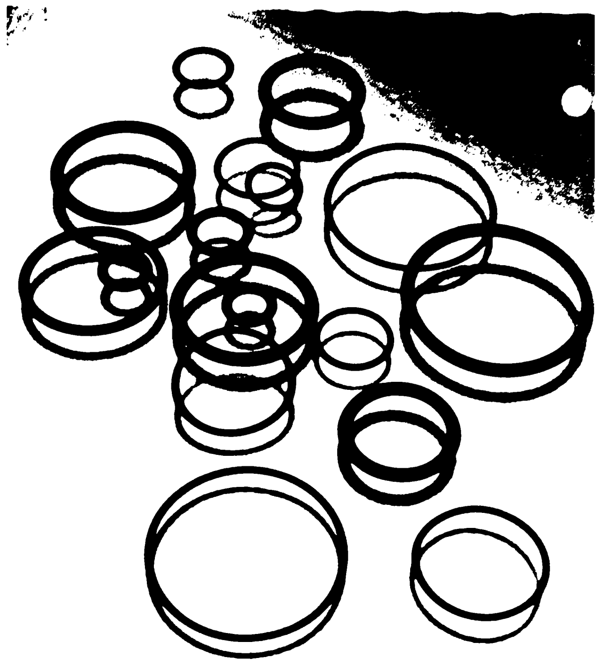
Q ***This wing maintains a continuous educational process to minimize air in the aircraft hydraulic system. They naturally look to the MCAIR rep for advice and guidance, but something is puzzling all of us here. Is it true that air can be introduced into the hydraulic system by manual movement of the speedbrake or horizontal stabilators? Perhaps this could occur if air is sucked past the seals, but if this is so, why don't we see a hydraulic leak? Also, I have heard that a negative pressure exists in the system after shutdown. True or false?***

A There used to be a return air sensing valve in the speedbrake system which could induce air into the hydraulic system when the brake was manually moved. This valve has since been removed from all aircraft.

Today, air is only introducible into the system by servicing or by system maintenance. Air is normally compressed into the hydraulic fluid, where it is known as "air in solution." When a speedbrake or other surface is manually moved, it causes a negative pressure in the actuator/lines, which allows the air that is already in the fluid to come "out of solution" and cause bubbles or air pockets. "New" air has not been introduced in this situation, even though you may be seeing bubbles in the sight glass on the hydraulic mule. Air levels in the system of up to 20%, measurable on the manometer, are acceptable.

Finally, a negative pressure does not exist in the system after shutdown. A positive pressure exists until the pressure is bled off, then the system should be at ambient.

By TOM GIMBEL



Tidbits on the F-15's Hydraulic System

By TOM ABBOTT/*F-15 Hyrdaulic Lead Design Engineer*

First of all, I would like to clarify why the return pressure sensing (RPS) valves were removed from the F-15's hydraulic system, and I would also like to discuss a previous statement made concerning negative pressure in the hydraulic reservoir after shutdown. In the DIGEST, Vol. 34, No. 3, 1987, the Product Support Technical Support Group answered a question on this particular subject. This information was contained in the article, "Home Office – Notes From Our Technical Support Group."

In addition to my discussions on the whats, whys, and therefores behind the RPS valves, I will continue with some additional thoughts on how to more effectively maintain your Eagle's hydraulic system.

Why the Removal of RPS Function

The speed brake selector valve, along with other utility system selector valves, had a return pressure sensing feature commonly called RPS. Whenever the return pressure fell to 23 ± 8.5 psi, the return device would shut off the valve and isolate that particular subsystem if the failure was downstream of the valve. Also, all the valves with the RPS function had an external button that, when manually activated, disarmed the RPS function completely.

After the aircraft were in service for a short time, it was decided to remove the RPS function from the selector valves. The RPS valves associated with the speed brake and horizontal stabilator were blamed for air being introduced into the hydraulic system whenever the speedbrake or horizontal stabilators were moved manually. In reality, the RPS device was too sensitive for the normal air content levels in the system.

It was found that during start-up and ground maintenance operations, after the system had been at rest, the air which had been dissolved into the hydraulic fluid during system operation came out of solution and formed bubbles. These bubbles had to be compressed before the RPS device could be armed. Because of the low internal leakage (allowable) rate through the RPS valve, it took considerable time to compress the free air (acceptable amount) in the subsystem and build up sufficient pressure to arm the RPS valve. Depending upon the amount of free air in the subsystem, it would take considerable time before the subsystem RPS function would operate.

Every hydraulic start-up gave the impression that there was a gross leak or failure in the system. Because of so many false indications, the RPS feature was removed. This was accomplished in two stages. First, a collar was placed under the RPS disarming button to hold it in the full out position, thus disarming the RPS feature. Second, the RPS device was completely removed from all the selector valves.

System Negative Pressure

This is an area that I need to expand upon, as to how a negative (less than atmospheric) pressure exists within the hydraulic system immediately after shutdown.

The question was asked: Can a negative pressure exist in the hydraulic system after shutdown? The answer: Yes, due to the bootstrap feature of the reservoir. When the 3000 psi input to the reservoir is interrupted (engines or external hydraulic source shut off) and the system starts cooling down, the reservoir piston will not fully follow the oil volume change due to seal friction. This causes a slight negative pressure of approximately 2 psi that eventually dissipates as the system remains at rest.

How Much Air Is Too Much?

Air in hydraulic systems is an age-old problem. Both people and aircraft have circulatory systems. While they carry different fluids for several different purposes, they both are subject to serious problems when "air" is allowed to enter their system. The human body's blood stream and the airplane's hydraulic system are similar – more than an acceptable amount of air and both are in serious trouble. Getting air out of aircraft hydraulic systems, and keeping it out, is an old and unfortunately recurring problem. While problems caused by air are often troublesome to prove, effective removal of air from a hydraulic system is vitally important to safe and successful aircraft operations.

Air is normally compressed into the hydraulic fluid, where it is known as "air in solution." When a speedbrake or other high flow rate surface is manually moved, it causes cavitation in the actuators and lines, which allows the air that is already in the fluid to come out of solution causing bubbles or air pockets. New air has not been introduced in this situation, even though you may be seeing bubbles in the sight glass on the hydraulic mule. Air levels in the system of up to 20%, measurable on the manometer, are acceptable.

The key to maintaining an acceptable air level in your hydraulic system is knowing how to properly use your external hydraulic cart. Carts have two primary methods of operation: OPEN LOOP and CLOSED LOOP.

In the OPEN LOOP configuration, the return fluid from the aircraft is directed to the reservoir in the hydraulic mule. OPEN LOOP is the most effective way to bleed air from your hydraulic system. During this operation, all the aircraft fluid is routed through the cart reservoir where the air can come out of solution and be separated. Remember, when you are operating in the open loop mode, the reservoir must be refilled and the reservoir level sensing (RLS) circuit reset upon completion of the maintenance action.

However, in the CLOSED LOOP operation, the external hydraulic cart uses the aircraft reservoir. Fluid is routed from the aircraft suction line directly to the external hydraulic cart pump and from the pump to the aircraft pressure connection. The effect of closed loop bleeding is that it will distribute large air pockets into smaller bubbles.

The F-15's hydraulic system cannot self-bleed, so don't let anyone talk you into thinking air is not a problem. Don't you ever believe it! Excessive amounts of air in a system can play havoc with it, especially when a bubble of air finds its way into a pump suction line. One bubble of air can immediately render a system ineffective – in other words the system pressure goes to zero. It is very important to know how to properly use your external hydraulic cart effectively.

For more in-depth information on this subject, contact your Field Service Engineer (FSE) and ask him for a copy of PS 979 "An age old problem. . . Air In Hydraulic Systems." If there is not a FSE at your base, contact the DIGEST in writing (see inside front cover), and we will be glad to forward a copy of the PS report to you.

Bootstrap Hydraulic Reservoirs

Each hydraulic system – PC-1, PC-2, and Utility – contains a reservoir which provides hydraulic fluid for differential volumetric displacement of actuating cylinders, thermal expansion and contraction of fluid, hydraulic line expansion, and seal deflection due to pressure and fluid leakage. The reservoir also has a feature that shuts off portions of the system in the event external leaks occur. Recently, field reports have mentioned problems associated with this particular end item.

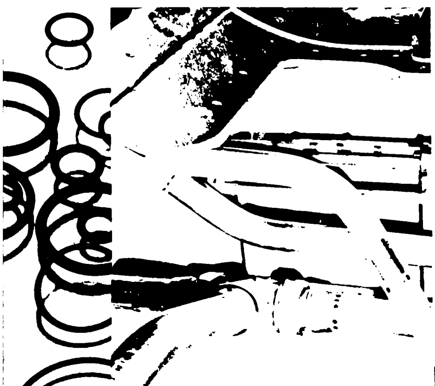
Incorrect servicing seems to be the primary reason for malfunctions associated with this component. If, in servicing a reservoir, the hydraulic fluid flow rate is too fast and the pressure too high, over-pressurization and reservoir damage will result. The servicing information in the technical orders is adequate and not difficult to follow. Merely complying with the procedures will resolve servicing problems.

Titanium Fittings

When installing a titanium line onto a "T" fitting, there are some important things to keep in mind. When a "T" fitting appears misaligned, loosen both ends of all tubes connected to that "T". This may also require loosening support clamps to allow for adjustment in the bracket slot. Always tighten each tube end fitting hand-tight, as this will provide the best way to align the lines ▶

and fitting. Next, go around to each fitting and partially tighten it, and continue this process until full torque is achieved.

During installation of a tube connected to a bulkhead fitting, you should always loosen the bulkhead fitting jam nut to allow the fitting to "float" in the bulkhead hole. Loosen the support clamps to allow for adjustment in the bracket slot, when required. First, tighten the tube end fitting hand-tight, moving bulkhead fitting around for the best fit. Then, torque support clamp bolts and bulkhead fitting jam nut. Next, torque the tube and fitting.



Remember, "double wrenching" is a must to prevent damage to associated lines and fittings. There's nothing more discouraging than to crimp a line which you just installed because you didn't take the time to use two wrenches to complete the installation.

Seal (O-Ring) Usage

Usage of the wrong size seal, diameter, or cross-section dimension should never, repeat never, be allowed to occur on any hydraulic component or fitting. A standard rule of thumb should always be that there be no deviations from the aircraft manufacture designated part number – in other words use only what is specified in your technical manuals. The slightest change in seal sizes can ruin your day – especially if the pilot has to declare an IFE (in-flight emergency) because of a hydraulic system failure.

Never, under any circumstances, use seals that are not packaged. Always make it a point to verify the part number and cure date. Beware of suitable substitute seals from supply unless technical data authorizes their usage.

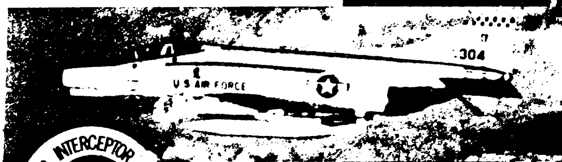
Seals are designed to function with certain types of fluids. Their material characteristics in a thermal environment are some of the factors which dictate engineers' selection. Use only designated seals called out in the technical orders. This will ensure you are getting the correct size and type needed to prevent leakage from the component.

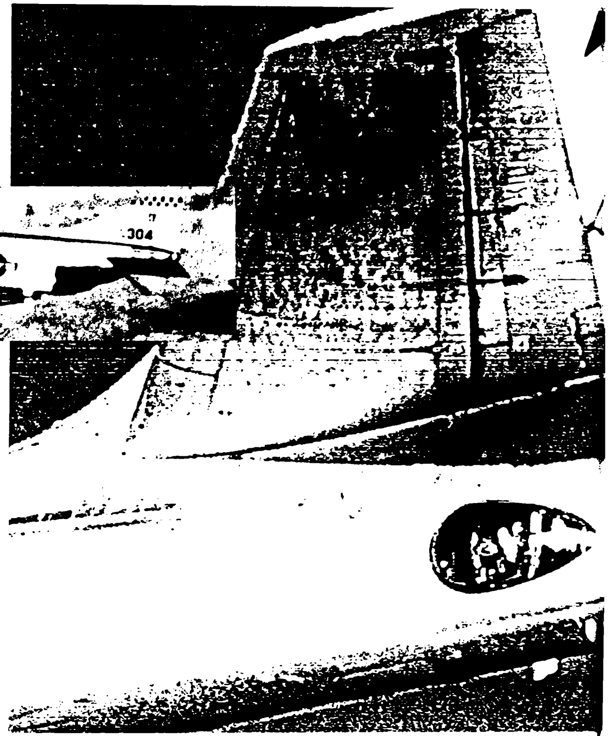
Conclusion

Hopefully these general tidbits of information on the F-15's hydraulic system will help you keep your Eagle flying. I would like to leave you with one final thought: An aircraft without properly functioning hydraulic systems can get a pilot in serious trouble. So the next time you're repairing, servicing, or functional checking your hydraulic system, "do it by the book." ■

DAVE MARTIN

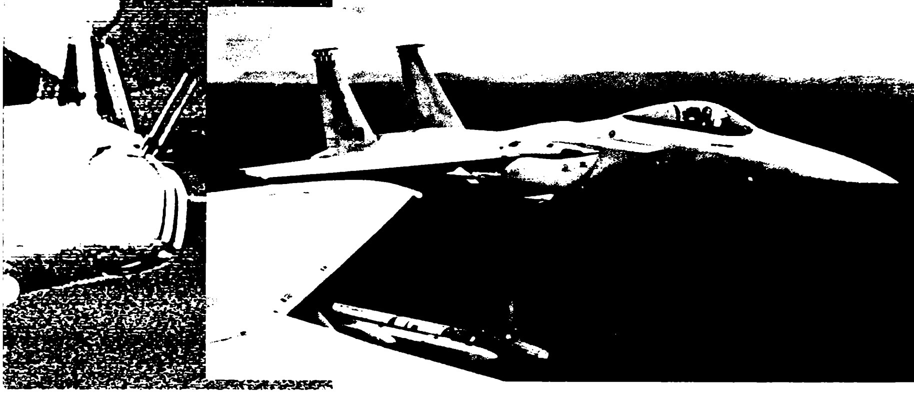
"If We Didn't Get Them, They Didn't Come Our Way."





The 57th Fighter Interceptor Squadron has been stationed at Keflavik International Airport in Iceland since 1954. They began to fly the McDonnell F-4 Phantom in 1973, and in November of 1985 converted to the MCAIR F-15C/D Eagle equipped with conformal fuel tanks (CFTs). "Bear Hunting" is exceptionally good in this part of the world, and CFTs are making it even better. Here is a first-hand report by the people who are accomplishing...

Conformal Fuel Tank F-15 Operation in Iceland



COLONEL ROBERT G. JENKINS
Commander
Air Forces Iceland

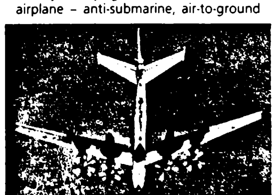
The "Iceland Defense Force" (IDF) was created in 1951 when the United States and Iceland signed a defense agreement. However, U.S. forces first arrived on this island nation strategically located in the North Atlantic halfway between New York and Moscow in July of 1941. In addition to their direct defense role, American military personnel constructed the Keflavik airport as a refueling point for aircraft deliveries and cargo flights to our European allies.

After the conclusion of WW II, all troops were withdrawn from Iceland but in 1946 a special agreement permitted continued use of Keflavik airport for flights in support of occupation forces in Europe. In 1949, Iceland became a charter member of NATO (North Atlantic Treaty Organization), and in 1951 the IDF was established. As a NATO member, Iceland has provided an effective base for anti-submarine warfare patrol aircraft and communication facilities, for search and rescue operations, and for stationing air defense forces which include AWACS, ground-based radars, and a fighter-interceptor squadron.

Last year, we more than doubled our previous year's level of activity . . . or more correctly I should say that the Russians more than doubled their previous year's level of activity, since what we do up here is in direct response to what they do out there!

When I use the word "activity," I'm referring primarily to the entrance into Icelandic air space of the Soviet TU-95 bomber series of aircraft with the NATO code name of "Bear;" our identification and surveillance of them; and our subsequent escort of them out of our zone of responsibility. We get activity almost every day of the week out of the Russians, and the trend each year has been for more rather than less.

They are flying several versions of this airplane - anti-submarine, air-to-ground stand-off missile carrier, and reconnaissance/electronic intelligence gathering types. We've had them all come through here, on their way into the North Atlantic, or completing a training run against the Norwegian coast or the U.K., or heading on over to the North American coast for practice with their long range missile carriers.



A quick-reaction alert is maintained at Keflavik at all times with two F-15s. The AWACS is also on the same alert, as is the tanker. Most of our intercepts are accomplished after coming off the ground, but sometimes during CAP. It's a combination of these capabilities - ground and airborne - that has produced the results. The motto up here is - "If we didn't get them, they didn't come our way," and there are releasable intelligence figures to prove it. In 1985, there were 170 intercepts and last year was about the same.

The feeling here at Keflavik is that we are really on the leading edge of air defense operations around the world. First, because we are closest to the Russians, and second, because we intercept more Russian aircraft than the rest of the Air Force put together. With just 20 fighters. Sometimes we have two intercepts running simultaneously; it's not at all unusual to have a couple sets of Bears airborne in our area. And in my opinion, we couldn't do what needs to be done here without the F-15 Eagle jet.

As you know, the F-4 series (first the C and then the E) was used here for more than 12 years, until late 1985. I flew the Phantom myself for years, loved every minute of it, but what we are doing with the Eagle in Iceland just could not be done by the F-4, or any other airplane. You have to think about Iceland - where it is, what it is - in order to understand ▶

the capability the F-15 provides for the mission up here.

This island sits out in the middle of the North Atlantic, smack dab in the middle of some of the harshest weather in the world. It's not always harsh, but it can turn that way almost instantaneously. The closest alternate place to land is Scotland – over 700 miles away. That simple statement has some quite profound implications if you're a fighter pilot; it dictates a lot of things, and is a necessary part of everybody's thinking. The extra on-station time possible with the F-15 and its capability for going to a distant alternate as circumstances may require, make a tremendous difference in operational planning – not only in the active mission but in the training mission as well.

With the F-4 for example, with three bags of fuel, you could take off from here on an intercept mission, go out about 200 miles to the edge of the MADIZ (military air defense identification zone), and have about 15 minutes of playing time before coming home or calling up a tanker. If an alternate was needed, you had to refuel almost by the time you got airborne. With the F-15, with conformal tanks, there is an hour forty-five of orbit or CAP available to wait out there for whatever may be coming in. And for training missions, weather does not down the Eagle very often. We have been able to lower weather minimums way below what had to be maintained for the Phantom because we always know exactly how much fuel is aboard – there is plenty of time/fuel for good training sorties, come back to Keflavik for a low approach, and divert to Scotland if the weather has suddenly closed Iceland.

What with everything I'm saying about the Eagle versus the Phantom, don't underestimate the F-4. It can carry the same basic ordnance as the F-15, and particularly with the slatted wing, it's still a top air-to-air machine. And tough as hell – I remember Phantoms being practically shot to pieces in Vietnam and still bringing people home safely. So what I'm talking about now is pure technology and state-of-the-art capability. In my opinion, there are two basic areas in which the Eagle shows to great advantage in this tactical environment. We've already talked about one of them – its on-station time capability – and the other is avionics. Especially the pulse-doppler radar.

Up here we have two ways to detect and track incoming unidentified aircraft. Ground radar sites are at both ends of the island, and we use the E-3A for airborne surveillance. Every once in a while, something will happen to our AWACS. Not often, but occasionally, and we'll have to put the F-15s out there on combat air patrol by themselves to find the Bear. They don't have a problem. That's not to say the Eagle is a mini-AWACS, but its radar is very good and a great advantage to us.

You mix the technology of the F-15 with the skills of our aircrews and the result is an unbeatable combination. Without a doubt, the most experienced pilot group in any one squadron in the Air Force today is assigned here. The average pilot in our squadron is a senior captain with 1200 – 1500 hours of fighter time – most if not all in Eagles. Every one of these guys falls under the Air Force definition of "experienced" with respect to previous tours. The environment here and the risk factors are such that we need highly qualified aircrews. Certainly, we do training missions, but we do not fly in a quote training unquote atmosphere. In Iceland, things are about as real as they can get.

The 57th Fighter Interceptor Squadron activated as a fighter training unit in January 1941 at Hamilton Field, California. Their first aircraft were P-39 Airacobras and P-40 Warhawks. After a short tour to Alaska, the unit returned to Hamilton, transitioned to the P-51 Mustang, and continued training new fighter pilots until deactivation in April 1944.

Reactivated in 1953 in Maine with F-89 Scorpions, the squadron moved to Iceland in November 1954 (as the only fighter unit assigned to the Military Air Transport Command), converted to the F-102 Delta Dagger in 1962, and in the ensuing 11 years made more than one thousand intercepts of Soviet military aircraft. By now a part of ADC (Air Defense Command), the Black Knights picked up the F-4C Phantom II in 1973 and greatly increased their mission capabilities. Four years later, they upgraded to the F-4E, and in July 1985 began conversion to the McDonnell F-15 Eagle. In their time with the Phantoms, the 57th FIS flew 151 consecutive months without a Class A mishap, intercepted more than 1200 Soviet intruders, and received numerous awards (including the Hughes and Baker trophies) for excellence in operations and maintenance.

The mission of the squadron is to be prepared at all times to intercept, identify, escort, and if required, destroy unauthorized intruders that penetrate sovereign airspace surrounding Iceland. This requires tactical planning and training for fighter operations required by the Commander of Iceland Defense Forces in fulfillment of USCINCLANT (United States Commander in Chief Atlantic) directives. The 57th FIS is assigned directly to Air Forces Iceland (AFI), the joint air component command of IDF and is a subordinate unit of First Air Force and Tactical Air Command at Langley Air Force Base, Virginia.

F-15 pilots and maintenance personnel are on alert 24 hours a day to provide immediate response. Aircraft can be airborne within minutes of a "scramble" order to intercept and identify unknown aircraft. The squadron has a secondary mission during peacetime to photograph intercepted Soviet bloc aircraft in support of continuing intelligence requirements. The Black Knights are in constant training to keep personnel and equipment at peak efficiency – demonstrated by an average of more than 100 Soviet intercepts each year.

At the present time, the 57th FIS is the only USAF squadron flying all F-15s equipped with conformal fuel tanks as the standard operating configuration. Tanks are not downloaded for any mission, but a CFT fueling "lockout" procedure is used when a complete fuel load may not be desired – during sortie surges and special exercises for example, and only when local weather conditions indicate full fuel reserves will not be required.

LIEUTENANT COLONEL LEIF R. DUNN
Commander
57th Fighter Interceptor Squadron

I took command of the squadron here in February of 1986, and the job has proven to be a lot more interesting than with a standard state-side FIS. While we are getting fairly well into Eagle flying now, there is still something new every day that reminds all of us that this is a pretty special situation. We are operating as an Air Force tenant at a Navy base located on a remote island nation subject to some of the wildest weather imaginable. And those are just a few of the differences!

Our supply is basically by military air and sea lifts with lateral support lines five to six thousand miles long. If we run out of parts – F-15 parts, typewriter ribbons, cans of paint – we can't run down to the air logistics center, the K-Mart, or Ace Hardware. If it isn't on the island, we either do without or sit at the end of a mighty long supply chain. There is no Federal Express to Keflavik – Icelandair or standard military airlift gets our MICAPS in and out – and such a logistic stream is always more demanding on the planning process, and often frustrating. But when something works right, it really feels good; and most things are working pretty well today – especially for an organization still undergoing the effects of conversion from one aircraft to another.

We have been producing steady increases in our maintenance capability. Our program is maturing slowly. Deferred discrepancies have been going down; cannibalization rates are coming down slightly – though it's important to note that our "cann" rates are still higher then we'd like, which really reflects the long logistic tail up here. Our scheduling effectiveness has been going up; MC rates are climbing slowly but surely; NMCM and NMCS rates are coming down.

Something else to consider when looking at the numbers hung up so far by the Eagle in the 57th FIS is "sortie duration." Our average sortie is about 80% longer than one in a standard TFS. An average mission up here lasts about 1.9 hours – state-side is about 1.26 for a TFS, 1.5 for a FIS. So we fly fewer sorties but many more hours than most comparable units. And time in the air is what burns up turbines, what burns up avionics.

Our average active air mission is almost five hours – at night, in weather, daytime, you name it. During a recent combat sortie surge exercise, we had a guy log a 3.3 unrefueled. That's worth saying twice – 3.3 hours unrefueled! Those are things that do not normally happen and are out of the ordinary for your standard fighter unit to do. Our longest active air mission to date is over six hours. That's a long time in the air, considering an average tactical deployment mission – CONUS to Europe – is about 9½ hours. Several times a week, we make four, five, six hour trips to work in the MADIZ – military air defense identification zone – defined for Icelandic military aircraft operations. Those missions will take the Eagle out to an operating radius of 500 miles or so. That's exceptionally demanding on both aircrews and airplanes, and is unique to activities in this small branch of the Air Force.

The "Black Knights" are the only unit that routinely flies the air-to-air mission with CFTs (conformal fuel tanks). These tanks make a significant difference in both the capability and performance of the F-15. The capability improvement is why we've got tanks. They provide lots more low-drag onboard gas – aerodynamically speaking, it's basically internal fuel.

All of our Eagles are equipped with CFTs, and we always fly that way because our nearest alternate is over 700 miles away. We need that gas on board in order to get any kind of productive training missions accomplished. We take off with all this fuel, accomplish the mission, and recover with almost as much gas as I would take off with at Eglin! We'll get back to the fix with around 10,000 pounds of fuel on board and that allows us to shoot the approach, take a look at the weather, decide to come directly on in with all that gas or stay in the pattern, burn down a bit more, and then land. We don't like to land with over about 8,500 pounds on board, especially when the weather is poor and the runway is less than optimum, which it often times is.

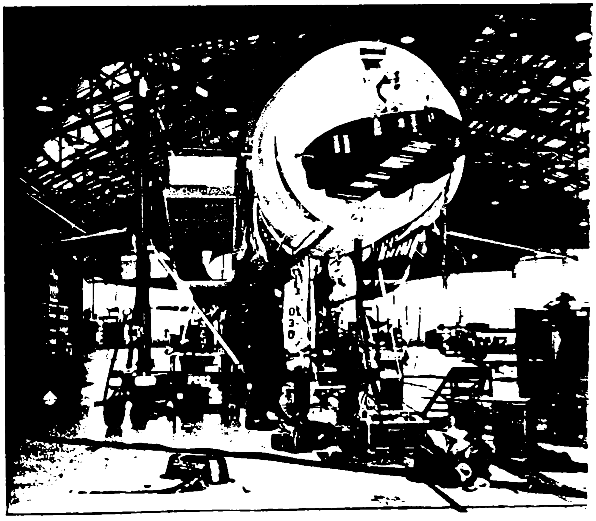
The weather here is probably no worse than at Bitburg or Soesterberg or any of the continental bases in terms of ceiling and visibility, but what we get here are the combined effects – wind, rain, snow, ice, reduced ceiling and viz – and all those things are synergistic. You wind up very often in flying conditions that any one of which wouldn't be uncomfortable, but the combination makes it tough. Up here, flying is done in a region where you want everything going for you that's possible.

You want lots of gas to get someplace if you need to go there; you want the hook to work; you want the cables up; you want the runway swept; you want the urea down; you want the GCA up; and you want the ILS working. Percentages are not that high to begin with, and every additional decimal point helps. If there is to be a failure in any system, you want the whole thing up front – and that's one of the pluses for the Eagle; it's such a good systems airplane and most everything on board works all of the time.

We have very few hard avionics failures. Something goes out on occasion, but it usually doesn't happen all at once. It degrades gradually, and when it does start to die on you, there is the redundancy of the flight control systems, the hydraulics and everything else to take up the slack. All of these good things let us operate with no alternate, with 800 miles of water on all four sides, and still feel as though we are in a fairly safe environment. Remember, there is no place to land except right here. When you come back with less than 8,000 pounds of gas, you've got two options – you can either land here or hit a tanker. Other than that, there is no place to go.

The threat up here for the 57th FIS is presently a bomber and air-launched cruise missile threat. That may change and we may be relocated, but for the time being we have a defense mission and a basic air sovereignty mission, and both are very amenable to the F-15 configuration currently assigned to us. We are happy with the performance of the CFT-equipped jet in those respects, and it is well suited to the missions here.

Any time you add to the basic weight of an airplane, you are going to suffer a corresponding loss in performance somewhere. CFTs add about 2,500 pounds of structural weight to the Eagle, shift the CG around a bit, and increase starting fuel weight by close to five tons. Naturally the cost shows in initial maneuvering performance. The benefit comes in a tremendous increase in capability in terms of range/payload – how far we can go and what we can do when we get there. That's why CFTs were originally bought, that's how we're ▶



using them, and we are getting magnificent utility out of them in that respect.

Pilots who come to this configuration of the F-15 find the initial difference in terms of maneuvering performance to be striking. I know I have. It is not the plain "A" model by any stretch of the imagination. It is not a clean A; in fact, it's not a clean anything – it's a much more rough handling airplane, much more sensitive than the clean A model. The biggest difference right off the bat is when you have 22, 23,000 pounds internal and an operational overload warning system – the transonic allowable G is very low. We keep very good tabs on our Level I OWS activations, to make sure the guys are aware that when you get into a transonic thumbprint with a heavy jet, it can be over-G'd in a heartbeat. We are very careful of that.

The payoff comes very quickly – as soon as the gas burns down, gross weight is reduced and you've got performance similar to a non-tanked C or D model. It's just a matter of how much the airplane weighs at any given time; initially, the difference is striking, but CFT Eagles overall perform about like any other F-15. Low speed handling characteristics, available G, thrust-to-weight, are all far superior to the F-4. And of course, the weapons systems are way above anything else flying. If nothing else, we could just go 350 miles away, wait for the other guy to run out of gas, and then shoot him in the tail. My only point is that with a jet that can get as heavy as this one, unless a pilot sits down and thinks about it, tries to anticipate it, he can get surprised. And up here, the fewer surprises the better!

MAJOR RONALD R. DUFRESNE
(former) Chief of Training
57th Fighter Interceptor Squadron

What makes flying the F-15 in the 57th so unique is that the squadron has a wartime and a peacetime mission. While most fighter squadrons spend their time in controlled training for their wartime mission, this unit must manage its wartime training around its relentless peacetime air sovereignty mission over Iceland. Couple this with Iceland's dynamic operating environment and the myriad of other defense activities here at the Naval Air Station, and you've got a real challenging and interesting assignment.

Being part of the cadre to convert the unit from F-4s to F-15s was a real privilege. Strategically speaking, equipping the 57th FIS with the F-15C with conformal fuel tanks has made a quantum improvement in the overall US/NATO defense commitment to Iceland and the Greenland/Iceland/United Kingdom (GIUK) gap. I think the CFT/F-15 is the perfect weapons system for this unit's peacetime and wartime missions.

A lot of Eagle drivers may scoff at hanging CFTs on the F-15, but I don't know of a pilot in this unit who hasn't come around to recognizing how much they add to the jet's capabilities – especially here in Iceland. Sure, every guy wishes all he did was fly clean A-models, day, VFR, two v two, VID required – but that's not reality. And true, the CFTs reduce Eagle performance by a few degrees per second or by a few Gs, but a good pilot doesn't employ the airplane such that he depends on those few extra degrees or Gs – if he does he needs to sit down with his squadron Weapons Officer for a little chat about tactics.

Up here, the weather can change in a heartbeat and your nearest alternate is over 700 miles away. I don't know of any other fighter squadron in the Air Force that must gear all of its operations to such a simple fact. The CFTs allow us to get reasonable day-to-day training, yet provide sufficient fuel reserves to deal with Iceland's weather – a major limiting factor. What the CFTs add to the Eagle's capabilities are what's important – especially to us in the 57th FIS.

First, as I've already alluded, is the added endurance. Because we can carry more gas, we get to fly longer and more often than would otherwise be possible up here in Iceland. And as a Training Officer I can say that there is no substitute for flying training – not a simulator, not ground school. The fact is that 57th F-15 pilots are getting twice the flying training that its F-4 pilots were getting – and that's because of the CFTs. 57th FIS pilots are better trained today than they've ever been – and that's a fact, Ivan!

Second, CFTs have added significantly to our ability to conduct our peacetime air sovereignty mission. It used to be that Soviet TU-95 Bears would come meandering around the Icelandic MADIZ, to be greeted by three-tanked Phantoms who could stay with them so long as there was a tanker near by. Now, CFT Eagles meet them, with the gas to keep an eye (and weapons) on the situation as long as Ivan wants (feels safe) to hang around. Personally, during the many intercepts I've been on, I detect a wise sense of respect from the Bear drivers towards the presence of the 57th's F-15s.

Finally, CFTs have added immeasurably towards the execution of our wartime mission. The added endurance they provide equates to added station time in maintaining air superiority CAPs over Iceland – a real force multiplier! I believe the Soviet Icelandic planners have their work cut out for them.

In my opinion, equipping the 57th FIS with the F-15 configured with conformal fuel tanks was a super decision. I'm proud to serve in this outstanding and vital unit. If anyone ever had any doubts about how vital the 57th's mission is, they should read Tom Clancy's books! The Black Knights of the 57th FIS are ready and able – in peace or in war – to provide air superiority in the GIUK gap.

"We're sleeping in the barn after having gone out in the afternoon and hacked a couple Bears. The horn goes off in the middle of the night, so the two of us take off into the weather, and after awhile we're night air-refueling out over the Norwegian Sea in the middle of nowhere. A little later we pass the AWACS on its way home because it's been working all night. There goes our 'big picture,' but we know from intelligence that there is traffic out there somewhere, so with plenty of gas onboard we set up our CAP.

"We know where to look generally, but that's all the guidance there is. So we try to locate our own Bears in autonomous long range search. After a little while, sure enough. . . hit! Let's see what we've got here. Looks good. Hold it and go see what it is. Drive up and check it out. He's all blacked out, but it's a hack – another Bear that won't get an unaccompanied tour of Iceland!

"There is still fuel to spare, so after he leaves our zone, we pick up the CAP again. About three hours later, there comes another hit on the radar. What have we here? Go check it out – another Bear! Turns out it was the same one; he had gone way out of the Icelandic MADIZ, and came back in from another direction. So our four-Bear day turns out to be two, plus one twice. Eagles on Bears – not a bad way to make a peacetime living in a peacetime Air Force!

(Major Dufresne)

MAJOR RALPH G. AGUIRRE
(former) Assistant Director of Operations
57th Fighter Interceptor Squadron

(Everybody knows me as "Slick" so please don't put my real first name in the article!) I've been flying the F-15 since 1976 and have around 1700 hours in it now. This is the first place I've been where they've used conformal fuel tanks as the standard configuration, but I've gotten so used to the feel of the airplane with CFTs that I never think about them anymore. Except to be glad they're there! But yes, an Eagle with those bulbous appendages not only looks different, it flies different – in part of the regime.

It is necessary to maintain a "heavyweight" fuel awareness not necessary at other places because we are taking off with 24,000 pounds gross fuel weight, every time and all the time. Abort speed with airplanes weighing as much as ours do is pretty low, so when the runways are wet and icy that possibility has to be firmly in your mind. Another aspect is that if you have a problem after getting airborne, you're not going to be able to land right away unless you accept landing very heavy and take the cable.

One night, I took off single ship into an 800 foot ceiling to chase down an element that had left fifteen minutes before, so I was by myself when I got a bleed air light shortly after takeoff. This is the kind of emergency that says get back on the ground ASAP because you have no idea what that bleed air may be doing inside your airplane. However, it was close to 20 minutes before enough fuel had dumped to get me down to a weight comfortable for landing on a wet, slushy runway. So on CFT takeoffs, you always need to be cognizant of weight, and on landings, you would like to have 8,000 pounds of fuel or less.

Then, when you hit the work area – and ours are fairly close, like 50 miles or so – with any other Eagle jet you are good to go for ACT, you're ready to fight even with fuel in the centerline. Not so with CFTs. When we hit the area, there is probably still 3,000 pounds of fuel in each CFT, and we don't fight until it gets below 1,500 in each. We need to do something else for awhile to reduce the weight, so we practice intercepts on the first few passes – typically supersonic intercepts, and we get good training out of it.

There are some other things to watch for that are CFT related. For instance, you've got to check the balance in them because the F-15 doesn't like an imbalance there any more than it does out on the wings. Another example is the heavyweight flying characteristics. One of my first flights here was to try doing some roll slides on a guy, and as I was just rolling up with about 3 Gs on the departure to put my nose on him I was getting the low rate beeper on the OWS. So sure, it's a heavy jet at first and it doesn't fight the same at first. Once the CFTs are empty, it's almost like a vanilla F-15. And without all that fuel, we wouldn't be able to do our job here in Iceland as well. We'd be on the way back to base, or hitting a tanker, or not even out there in the first place. With empty tanks, the airplane doesn't want to accelerate supersonic as well as other Eagles, but as far as turning performance and nose rate go, they seem to be fairly full up for the C model once the tanks are empty. I've certainly got no complaints.

If we didn't have CFTs, we'd be flying around in a three-bag configuration which would limit us in many ways. We couldn't do ACT at all or BFM with those things on our airplanes. So much of what we do is driven by our alert commitment and the tactical situation here. When Soviet activity increases, we may not be flying just the two alert birds; we might have to take four of the training lines and turn them into alert birds and put them out on Bears too. You have to have your fleet configured the way it's going to be employed, which is to chase down Soviet airplanes.

To me, an Eagle is an Eagle is an Eagle. All the models you've manufactured have been great! It's the only jet I want to fly. I've had some catastrophic things happen and it's still brought me home. Once an engine compressor section blew up about 100 miles out over the Atlantic – knocked holes in the top and bottom of the airplane and took out a lot of the hydraulics. It was doing uncommanded aileron rolls and stuff, but that Eagle got me back. I guess I've had three-fourths of the emergencies in Chapter 3, but have landed them all with no sweat. ———

"It's a moonless night and we're in the murk. We drive right up next to him, and can barely see his outline. During the intercept, he's all blacked out, but he knows we're there – he's got a radar warning receiver just like we do. Once we start getting up close of course, he turns the anti-collision beacons on 'cause he's afraid we'll hit him! This close, we feel the vibration of his counter-rotating props.

"During the day, it's really neat too. We fly right next to the Bear because part of our job is taking pictures of them. An F-4 is better as a camera platform because the WSO can take the snapshots while the other guy just flies the airplane. But anyway, sometimes the Russians are not too cooperative with our intelligence-gathering efforts. They'll abruptly start a turn, and you have to drop the camera and grab the stick to get back in position, pick up the camera again – and all the time they're doing the same thing to you. Guys in the blisters on the back of the Bear are waving and taking pictures right back! They are just as interested in us as we are in them, and they must have a really great collection of Eagle photos.

"I haven't done things like this since Vietnam. Like the other day, I was scrambled at 2330, got on four Bears, landed at 0445, had some coffee while the jet was turned, and flew again until 0800. I mean I was out all night long. Great fun, and I really dread the day they make me quit flying Eagles!"

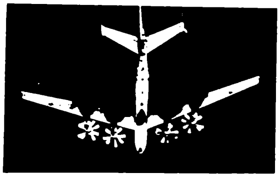
(Major Aguirre)

CAPTAIN ROBERT R. RUDOLPH
(former) 'B' Flight Commander
57th Fighter Interceptor Squadron

Our primary mission up here of course, is intercepting Soviet Bear bombers up by the Arctic Circle. For that mission, the Eagles have been just superb. The configuration we fly is two CFTs with two AIM-7 missiles. No external tanks. That gives us plenty of gas to scramble out of here, afterburner takeoffs, climb to a medium flight level, cruise out to our stop point which may be 300 – 400 miles away, set up a CAP and stay on station for quite some time in the maximum endurance mode, and then recover. You get a lot of cockpit time during scrambles up here. The F-15 has a lot of endurance advantages over the F-4s that were here before.

We always fly in pairs, so add the endurance factor and the two APG-63s, and things just can't get much better than that! Two Eagle radars both looking at the same piece of sky, include GCI and an AWACS, and it's a very capable team, both day and night and in the weather. Not much gets by us.

There certainly could be times when I'd rather have a different Eagle fuel tank ▶



configuration, but not up here and not as the opposition here exists today. We have a rather benign threat as far as maneuvering capability is concerned, and all that extra gas and on-station time is very important.

I also flew the F-15 at Langley, but in an entirely different mission situation – there it was against similar-performing airplanes and in a counterair type mission. Lots of gas was not as important as maneuvering potential, so it was better to have the extra fuel available in jettisonable tanks.

MAJOR ALLEN B. DECKER
Chief of Maintenance
57th Fighter Interceptor Squadron

This is my third F-15 unit and my ninth year of association with the Eagle jet. This mission, this F-15 configuration, and this place present by far the greatest challenges I've experienced thus far in my Air Force career. The mission is absolutely fantastic. Nowhere else in the Air Force can the "alert hype" be felt as often as here. There is often plenty of alert traffic on weekends or in the "wee hours" of the morning. And that means as much to us in maintenance as it does to the ops people.

The adrenaline really flows when our alert lines launch, and especially if additional alert lines must be generated from within our resources or off the daily flying schedule. When the "hype" is over, however, the maintenance phase curve and scheduled maintenance plan are often fractured and we have to pick up the pieces and get back on track. It's often a tough price to pay in terms of work hours, non-mission capable time, and nerves, but the "mission" sets the pace and everything and everybody follows in step.

Our F-15s with conformal fuel tanks also present a tremendous challenge. The 57th FIS has more CFT experience than any other Air Force unit, and that's a source of pride even though we spend a lot of time working with them. The original idea was to just put them up and leave them up, but there are many times we have to remove them to facilitate other maintenance or for repair action on the tanks themselves. There have been a few problems with fuel leaks, fire ducts, and skin cracks, and we've been asked to test some CFT parts to solve some of these problems. We enjoy the opportunity to identify areas for improvement; and as our experience with the system grows we find that the main thing CFTs require is to understand them. Maintenance needs to adjust and adapt to the challenge they present, because there's no doubt that they are a valuable asset to us and worth the effort. Iceland has the perfect mission for an aircraft configured this way, and the F-15 is the perfect aircraft for the mission.

There's no single way to describe working on the F-15 in Iceland. I've been stationed at Bitburg and have been to Bodo, Norway and Aalborg, Denmark with the Eagle, but this is like nowhere else! The combination of wind, wind, and more wind, blowing snow, snow pellets (a big difference when they hit you upside the head), cold, long days, short days, lots of light and no light at all, make this a difficult place to work on aircraft – any aircraft.

With the arrival of the F-15, NATO has provided for hardened shelters, which give some relief from the elements. However, just the simple tasks of towing aircraft, AGE, or CFTs, or just plain walking from one place to another are often burdensome and can sometimes present equipment-damaging or life-threatening situations. Within twenty-four hours of arrival at Keflavik, everybody learns to be weather-wise and cautious. Happily, there is a big surge in facility improvements that will alleviate aircraft maintenance problems up here.

Iceland is a "remote" tour for maintenance personnel, so we come under MPC (military personnel center) at Randolph rather then being directly under TAC. Therefore, selections for assignment are based upon eligibility for overseas tours and the result is that we don't necessarily get a large number of F-15 experienced people. Incoming maintenance personnel are often highly experienced on other aircraft, but their actual time on Eagles is usually low or non-existent. They are also frequently unfamiliar with TAC maintenance or supply concepts. Couple all this with the fact that Iceland is a one-year (soon to be 18 month) unaccompanied tour means that there is a continuously ongoing maintenance training program. People up here have to learn F-15 maintenance by doing it for the first time in the weather, in the dark. That's not easy, and people who complete a tour in Iceland are ready for anything their future may have to offer.

We certainly get productive work from all of our maintenance personnel, but in a fuel systems troubleshooting situation for example, someone with two to four years as an F-15 specialist would have a head start because they've already seen a certain problem many times. They would know pretty quickly whether it's an old, repetitive problem or something brand new. In our case, maintenance specialists often have to go to the troubleshooting tree and work the T.O. word-for-word from the beginning. Nothing wrong with that, of course, but it does take time, and skews into the "maintenance indicators." In light of emphasis upon those indicators, our relative experience level is high on the list of recurring problems we need to solve.

All in all, I'd have to sum up my exposure to maintaining the F-15 in Iceland with "it's been a real experience!" I've learned more about the Eagle, cold-weather maintenance procedures, maintenance people, and myself than at any other time or place in my career. ■

[illegible] Alternate

It isn't just the 57th Fighter Interceptor Squadron pilots and their Eagles who are affected by the weather in Iceland. Civilian flights also face the possibility of heading for an alternate landing field. For example, last December, MCAIR field service engineer Tom Cline was being transferred from Elmendorf AFB in Alaska to Keflavik, in what might have been termed a "frying pan to the fire" move except that the analogy is totally inappropriate to the climates at both places. While his commercial flight had departed late from the States, it was now back on schedule, and the weapon systems specialist was ready for his official introduction to Iceland. In more ways than one.

As the aircraft arrived over Keflavik International Airport that morning, so did a sudden snowstorm. After circling the area for two hours, the flight was diverted to Scotland, and Tom didn't make it back to Iceland until late that evening. That's the same potential situation faced by every "Black Knight" pilot when taking off in an F-15 for a sortie from Keflavik. Scotland 752 miles away may suddenly and necessarily become the nearest alternate landing field.

Once back in Iceland, Tom said he didn't really mind the diversion – he'd never visited Scotland before. And, in the words of his new boss at Keflavik, field service engineer-in-charge Lonny Duchien, it had been "a truly fantastic day."

SUPPORT EQUIPMENT

(GLYN BOWEN/*Engineer*)

Equipment Maintenance Manuals

There are numerous pieces of general AGE GSE for which no specific maintenance manuals are provided. We often receive inquiries from the field regarding periodic inspection, lubrication, proof loading, and maintenance instructions for these items. One of the most common requests is for data on hoisting equipment.

USAF T.O. 36-1-58 (General Requirements for Repair, Maintenance, and Testing of Lifting Devices) contains information of the type requested. In general, on hoists not covered by specific maintenance manuals, MCAIR Ground Support Engineering recommends that they be proof tested every six months and inspected before each use. Proof load data on individual items can be provided upon request to the Home Office.

AIR INDUCTION SYSTEM

(JOE HAYS/*Senior Engineer*)

Don't Get Stuffed in F-15 Door 10L

The F-15 has very large first ramps which move to the full down position when the engines are started. Normally, the right engine is started first, and the right first ramp moves to the full down position. The left engine is then started, and if the left first ramp does not move down for some reason, the pilot usually shuts down the left engine with the finger lift and throttle full off. The ground crew then checks the air inlet controller (AIC) circuit breaker in door 10L. All the elements - both human and mechanical - for an accident are now present, as discussed below.

The left engine run relay is energized by a holding circuit even with the engine shut down by the throttle. As soon as the mechanic pushes the AIC circuit breaker in, the first ramp moves rapidly to the full down position. With hydraulic power supplied from the right utility pump and electrical power from the right generator, the ramp hits and forces door 10L closed with the mechanic's head and arm still inside the door! Injury is almost inevitable.

Could this accident have been prevented? Certainly. If the pilot had placed the left engine master switch "off," the engine run relay would de-energize and the ramp would not move down when the circuit breaker is reset; or the pilot could place the left inlet ramp to "emergency" position and the ramp won't move down.

Airplane mechanics remember - if the right engine is running, DO NOT open door 10L and push the air inlet control circuit breaker in UNLESS it has been verified with the pilot that the left engine master switch is "off," or the left inlet ramp switch is in "emergency." We know of several instances where a mechanic was caught in this situation - don't you be the next.

Cargo Care is Critical

While the material for our presentation on dielectric heat transfer fluids was being researched and evaluated, an article bearing the above title appeared in the May 1985 issue of APPROACH magazine (U.S. Naval Safety Center). The article identified the Navy's *"ten most hazardous materials reported in 1984"* and expanded upon an incident involving cargo aboard a transport aircraft. A liquid substance identified during the incident as "coolanol" leaked from a pallet containing a fill and bleed unit. One flight attendant and a passenger lost consciousness from the fumes, eyes were irritated, and several people experienced nausea, headaches, and weakness. Subsequent to the incident, a Safety Center inquiry into the chemical properties of "coolanol" indicated the substance to be "a silicated ester — a powerful anesthetic." While the article used the term "coolanol," the liquid was not specifically identified as either Coolanol 25R (Monsanto) or Flo-Cool 180 (Chevron).

Since the unfortunate and potentially catastrophic results of this cargo aircraft incident did not seem to square with product information our own research had obtained, we solicited the opinions of Monsanto Company, St. Louis-based manufacturer of the brand of heat transfer liquids known by the registered trademark name "Coolanol." We were naturally concerned because Coolanol 25R is one of the two cooling fluids approved for use in the radar systems of the MCAIR Eagle and Hornet.

According to Monsanto chemists and product engineers, a study of their own files and a computer search of medical and toxicology literature turned up no information that would associate any silicate ester with "powerful anesthetic" properties. They noted that people in product manufacturing, product testing, and aircraft maintenance have been exposed to Coolanol fluids for over 25 years without experiencing inhalation problems. The predominant medical problem associated with these fluids has been dermatitis of the hands due to extraction of protective fats and oils from the skin by repeated or prolonged contact. Contact with paint thinners and strong detergents could produce similar results. Wearing protective gloves would prevent this potential problem.

After responding to our inquiry, Monsanto contacted the Naval Safety Center for more information on the incident in question. The incident summary noted that the fill and bleed unit contained improper parts and had been stored open to the atmosphere in a hot and humid climate for at least two weeks prior to the incident. Navy investigators speculated that the silicate esters decomposed under these conditions to form 2-ethylbutanol in sufficient concentration to explain the irritation and central nervous system effects reported. Chemical analysis by the Navy did show the presence in the fluid of 0.2% 2-ethylbutanol, an alcohol used in fluid manufacture (and a by-product of coolant moisture contamination and high voltage exposure) which can produce moderate inhalation effects, including central nervous system depression at high concentrations. However, at 0.2% (a volume of approximately one teaspoon of the liquid alcohol in the 3/4 gallon fill and bleed unit), effects such as those noted on the occupants of the aircraft could not have been produced.

In an attempt to duplicate the conditions of the incident as speculated, Monsanto engineers "dosed" Coolanol 25R fluid with ten times the amount of 2-ethylbutanol found in the fluid samples taken from the Navy aircraft. At eleven thousand feet in an unpressurized aircraft cabin (the Navy aircraft was pressurized), controlled simulated spills of the dosed fluid produced no ill effects or discomfort to those present. Based on this experiment, Monsanto concluded that while a heat transfer fluid may have spilled during the flight reported in APPROACH, it could not have caused the irritation, nausea, headaches, and weakness reported. In order to produce these effects (which occurred within 10 minutes after takeoff), the offending chemical either had to be present in very large quantity or had to be very volatile — far more volatile than any chemical associated with dielectric heat transfer fluids. From the incident record, it is not clear if the possibility of such a chemical being aboard the aircraft in another container was addressed during the investigation.

While the material that caused the personnel problems aboard the Navy transport may have been heat transfer fluid or some other unknown chemical, the eight recommendations the author (Commander David L. Gracie, Chief of the Air Operations Branch at the Naval Safety Center) makes as a result of the incident are good ones, especially the one concerning liquids being only in original and unopened containers. We suggest you read his article for the other seven.

Our own conclusions from the entire incident and situation? Common sense (that old fashioned quality nobody can do very well without) says to treat heat transfer fluids like any other chemical compound — with care and respect. They must be stored in closed containers to prevent moisture pickup and possible loss of product quality. As received from the manufacturer and when stored in closed containers, they will not present vapor inhalation problems during storage, transport, or actual use conditions in properly operated electronic equipment. Which is to conclude that, like the APPROACH article says, "cargo care *is* critical," whatever the cargo. ∎

ESCAPE SYSTEMS Maintenance

SMDC LINES

By [illegible]

BILL KALIST

Since an ejection seat does not have a redundant system, aircrews must depend upon technicians to repair and install system components correctly the first time.

Editor's note: After considerable in-depth research on ejection seat maintenance for the Eagle, Hornet, and Harrier, we found that a discussion of this nature was not as simple as first thought. After looking into all aspects of seat maintenance, it was decided that the most critical part of the ejection system should be the focal point of our discussion – how to properly inspect, replace, and install SMDC lines. Writing this article was made possible only with contributions of several members of the MCAIR team. Appreciation is expressed to Dick Chinnery, F/A-18 Unit Chief Design; Steve Herberholt, F-15 Design Engineer; John Pietroburgo, AV-8B Lead Design Engineer; Mike Creech, F-15 Senior Technical Data Engineer, and Ed Reynolds, MCAIR Site Manager at Beaufort MCAS, SC. Our thanks to them for their patience and careful review of multiple drafts of this article for accuracy.

Ejection system technology in the F-15 Eagle, F/A-18 Hornet, and the AV-8B Harrier II represents the latest advances in performance, reliability, and maintainability. As with any new type of technology, technicians must learn to do things differently, while being constantly aware of proper maintenance practices and procedures.

According to several field reports from MCAIR's field service engineers, improper maintenance practices and procedures have resulted in damage to shielded mild detonating cord (SMDC) lines and booster tips. A damaged SMDC line or booster tip can cause degraded system performance or even a total malfunction of the escape system when it is desperately needed by the aircrew.

Before we get into a discussion about maintenance on SMDC assemblies, let's look at what the SMDC actually does during the escape sequence so that you will have an appreciation of how important SMDC is to the overall operation of the escape system.

SMDC OPERATION

An SMDC assembly (Figure 1) consists of a mild detonating cord surrounded by a plastic extrusion that supports this assembly within a stainless steel tube. Permanently attached to each end of the SMDC assembly is a booster tip with a threaded fitting for attachment. The escape system network is comprised of numerous preshaped segments of SMDC, which are interconnected with in-line, elbow, and "T" connectors for transfer of SMDC ignition and pyrotechnic time delay/non-delay devices.

When the ejection system is initiated (by pulling an ejection control connected to an initiator), the initiator immediately produces a pulse of hot gas pressure, which will trigger (fire) the gas-to-SMDC initiator. The initiator converts the hot gas stimulus to a detonating stimulus causing the component's booster tip to fragment.

The fragmented metal particles from the donor booster tip will in turn cause an immediate detonation of the acceptor booster tip on the adjoining SMDC line. Once the detonation explosive stimulus has propagated into the SMDC, it passes through a network of SMDC transmission lines until it has actuated all of the components required during the escape sequence.

Because the SMDC explosive stimulus travels at approximately 6,000 meters or 20,000 feet per second, the escape sequence is almost instantaneous. In today's escape systems, SMDC provides the vital link for proper operation of the escape system. Maintenance practices can and will ensure that the system will work as advertised.

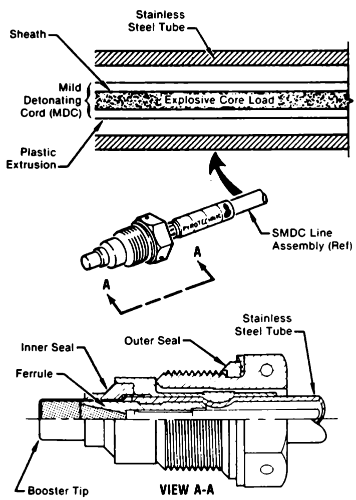
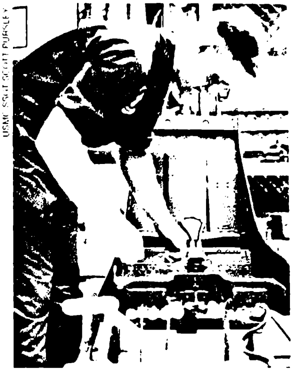


FIGURE 1. BOOSTER TIP FITTING AND SMDC LINE CROSS SECTION



USMC SGT SCOTT PURSLEY

Cpl Jim Cooke from VMFA-251, Beaufort MCAS, SC Seat Shop is completing a required calendar inspection on a Martin Baker SJU-5A ejection seat removed from an F/A-18. Not only has Cpl Cooke meticulously inspected the seat, but all other vital Hornet ejection components associated with the ejection system as well. Cpl Cook knows that when he completes all tasks by the book that if a pilot encounters an emergency situation during his mission the seat will work.

EJECTION SYSTEM MAINTENANCE TIPS

Care, handling, and maintenance techniques prior, during, and after installation of SMDC lines are critical tasks that must be performed with no margin of error. During installation or removal of an escape system component, do not take shortcuts, such as improper line positioning, clamping, or routing. A bent or dented SMDC line or booster tip may have a severe detrimental effect on the escape system operation.

SMDC lines should not be dropped, bumped, jarred, or allowed to come in contact with moisture, organic solvents, or acids. Also, lines handled incorrectly may affect the ability of the escape system to initiate.

BOOSTER TIP DAMAGE

Prior to SMDC line installation, check the booster tips for evidence of damage. No damage, however slight, is allowed on the booster tips or skirted ferrule. Damage to a booster tip requires replacement of the SMDC line if:

- Damage, such as cracks, splits, dents, scratches, or corrosion is evident;
- Foreign objects, lubricant, or paint contamination cannot be easily wiped off;
- Any radical movement of skirted ferrule occurs when slight hand pressure is applied, or the ferrule is loose or swivels, and
- The booster tip shows any evidence of being out of round or cocked.

A detonating cord inspection gage set (Figure 2) can be utilized to determine if the booster tip is beyond acceptable limits. This inspection will determine if the booster tip exceeds minimum or maximum length, or concentric alignment tolerances. The booster tip must not exceed concentric tolerance, if the booster tip exceeds the allowable tolerance, the inspection tool bar will not rotate around the booster tip.

Lastly, always check the booster tip seals for damage. If any seals are damaged replace them in accordance with the seal replacement section in your maintenance manual.

INSTALLATION TECHNIQUES

In certain areas installation of SMDC lines is no easy task, but a little preventive action on your part will ensure the line is installed correctly and without any damage. Prior to the installation routing of a line, make sure protector caps are on the booster tips. Protective covers should be left on until you are ready to connect the line (except for tip inspection). Routing of the line should be done by the most direct route, consistent with your maintenance manuals. To minimize the possibility of damage, continually guard against ▶

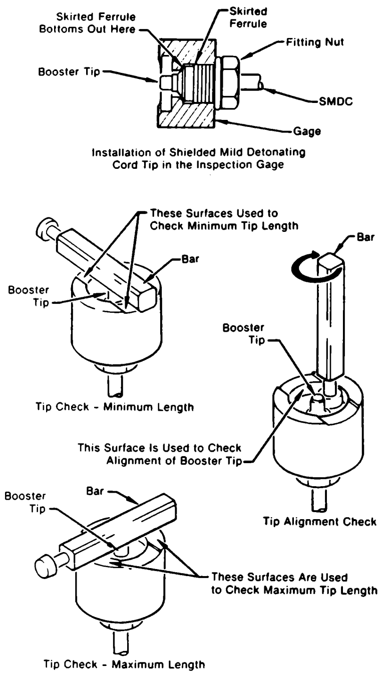


FIGURE 2. SMDC BOOSTER TIP INSPECTION

the line being dragged, scraped, or gouged while routing the line through the aircraft structure.

Prior to discussing the connecting or disconnecting of a SMDC booster tip, let's look at potential problems which can also contribute to a deficient system. Field reports have identified that booster tips can be bent as far as they will go and still seat in the pyrotechnic component mating port. This type of damage is caused by allowing the SMDC line to be rotated sideways before the ferrule sleeve clears the threaded portion of the mating port. If the escape system is actuated with a damaged booster tip installed, the booster tip will probably detonate, but propagation to the next booster tip in the escape sequence may not occur. Recent laboratory testing of damaged booster tips indicate:

- In-line booster tip will allow propagation and detonation of the SMDC components; and
- End-to-side or side-to-end booster tip propagation is very marginal at best.

Presence of foreign objects on or near the booster tip can also inhibit the successful propagation to the next booster tip. With that in mind, and the line in the appropriate position, remove the protector cap. Inspect the booster tip and fitting for any signs of contamination, then check the booster tip alignment with an inspection gage set. Remove the mating component protective cap and inspect for damage, foreign objects, lubricant or paint, then insert the booster tip into the correct pyrotechnic component mating port.

All pyrotechnic components should remain capped prior to booster tip installation and during idle periods to preclude accidental introduction of foreign objects (FOs). FO, damaged booster tips, and/or dinged, nicked, or crimped lines are your greatest concern during installation of ejection seat components. Inattention will result in a catastrophic failure of an ejection system. Never leave any component uncapped even on the cleanest work bench, as a small insect can crawl inside a fitting and hide there. A small insect, such as a spider, could possibly stop the propagation to the next booster tip.

Using care, hold the booster tip in close alignment with the mating port centerline until the booster tip assembly is fully seated. Using finger pressure only, thread the end fitting into the pyrotechnic mating port at least four complete turns. Occasionally, booster tip and mating port alignment cannot be achieved.

Structural and fabrication tolerances may necessitate:

- Loosening the pyrotechnic component, along with the adjacent SMDC assemblies and clamps until proper alignment and clearances can be obtained; and
- The flexing (not bending) of SMDC lines, which is permissible, to obtain the correct alignment.

A minimum amount of flexing may be done by opening or closing existing bends only. If a bend requiring alignment is within four inches of the SMDC booster tip, flexing must not exceed five degrees. Alignment of other established bends must not exceed ten degrees. SMDC lines can be flexed only, NOT bent, to provide clearance for alignment, as bending may fracture the explosive cord resulting in damage within the SMDC line.

Foreign objects, damaged booster tips, and/or dinged, nicked, or crimped lines are your greatest concern during installation of ejection system components. Inattention will result in a catastrophic failure of an ejection system.

Once the SMDC line is properly installed, check for sufficient clearance between the line and any moveable installations such as cables or bellcranks. Then torque booster tip fitting nuts per your maintenance manual. Do not apply excessive torque to the booster tip fitting nuts, as this may result in deformation, flattening, or wrench cutting of the nut. More important, overtorquing will lead to hidden damage—ruptured booster tips or swollen ferrules which make removal difficult, if not impossible. Improper torquing could prevent stimulus transfer.

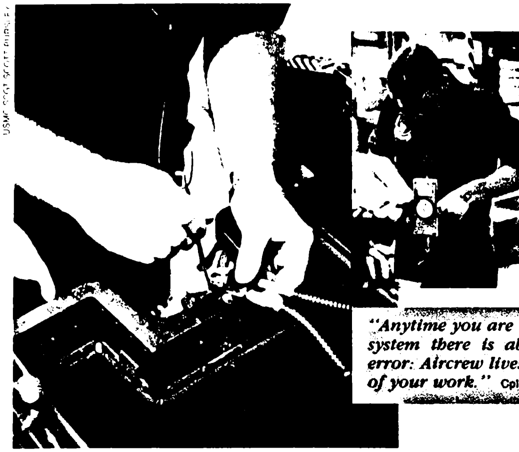
CLAMPING

After torquing the booster tip fitting nuts, the line must also be properly supported using clamps to prevent SMDC damage. Clamping is as important as the installation of the SMDC assembly itself. Correct clamp spacing must be maintained between SMDC components, structure, and any other operating mechanism to prevent damage associated with vibration, thermal changes, or structural deflections.

To maintain the proper clearances between any supported section of SMDC line and structure, the use of washers or spacers under the clamps is acceptable. To ensure proper support of SMDC lines: nine inches is permitted between clamps on a line; 11 inches is permissible between a clamp and pyrotechnic component; or 13 inches between any two components. Always refer to your maintenance manual for the clearances that must be maintained between lines, structure, wire bundles, and any operating mechanism.

BONDING

A maintenance requirement often overlooked during buildup and installation of an ejection system - but just as important as any other maintenance accomplished - is "bonding" of SMDC components. Bonding is the key to eliminating a differential static electrical charge between the aircraft structure and ejection system devices. Maintenance manual procedures must be followed



Cpl Jim Cooke is checking the release tension on the ejection seat control handle on a Martin Baker SJU-5A ejection seat to ensure it is within the required pull tension.

"Anytime you are working on an ejection system there is absolutely no room for error: Aircrew lives depend on the quality of your work." **Cpl Jim Cooke**

explicitly to ensure that a common path (bond) between components is accomplished. This will allow static electrical charges to be equalized, thus preventing a buildup of static electricity between SMDC components.

Static electricity, a fundamental entity of nature, can cause all sorts of decidedly "unwonderful" things around ejection system components. Because it is unseen, it is often forgotten about, and it is this complacency about static electricity that can cause an inadvertent firing of an escape system component or system. For a more in-depth discussion of static electricity, once you have finished this article, we recommend you read the Product Support DIGEST, Volume 29, No. 3, 1982, "Static Electricity. . . Unwanted Wonder."

INSPECTION

Once the installation is completed, inspect all lines and fittings for unacceptable visible damage, such as corrosion, cracks, discoloration, flatness, incorrect bends, kinks, splits, swelling, or wrinkles. Smooth dents or slight depressions in the SMDC lines are permissible if they do not exceed maximum limits. There must be no dents or depressions within two inches of the ferrule at either end of the SMDC assembly. Smooth dents or depressions, beyond two inches of the ferrule must not exceed 20 percent of the outside diameter or exceed one inch in length. For other specific tolerances, which apply to the aircraft you are maintaining, refer to your maintenance manual. ■

CONCLUSION

For maintenance technicians responsible for maintaining an escape system, "safety" must always be foremost in mind – not only for the maintenance personnel working on the escape systems, but for the aircrews flying the aircraft as well. Each technician knows an escape system in any fighter aircraft is totally dependent upon their gentle hands; it's not only what the individual does, but how the task is performed that ensures the crew can eject from their crippled plane. As we all know, a malfunction of an escape system caused by careless hands and/or inattention to procedures in maintenance manuals leaves the aircrew with no alternatives. With the urgency of the situation, the crew has no time to turn back or divert to another base. Their destiny is "sealed" in your hands.

You Stow it WHERE?

By DICK KIERTZNER/*Senior Field Service Engineer*

F/A-18 Hornet fighter aircraft never have enough room to stash personal items when going across country. So this calls for a little ingenuity to try to find space for items other than a few bare essentials.

Someone suggests maybe there's enough space behind the seat, and, yup, the space is just large enough to squeeze in the old shaving kit and other little necessities and knickknacks for the trip. There's a little space underneath, too!

Now that everything is neatly tucked away and you have completed your walkaround, you are ready to strap in. Once strapped in, you realize the seat is too high and you hit the seat down adjust switch. Unknown to you the downward movement of the seat forces

the shaving kit against some SMDC lines, bending them out of their normal alignment. The seat is still not low enough so you hit the seat down adjust switch again, thinking nothing about how the seat shuddered slightly but continued downward to the position you selected. Unbeknownst to you, the downward pressure exerted against the SMDC lines caused extensive internal damage to an SMDC component, which could prevent a successful ejection.

Fortunately an ejection seat failure as described above has never happened that we're aware of. But it could. Recently several field reports have mentioned that using the area behind and under the seat as storage areas has occurred in the fleet. Now that you have these "words of wisdom," make sure that neither you nor anyone else is stowing ANYTHING behind or beneath any seat. Who knows, maybe tomorrow you will be flying the aircraft that yesterday carried a shaving kit and knickknacks behind and under ■

LOX CONVERTERS:
Critical, Delicate

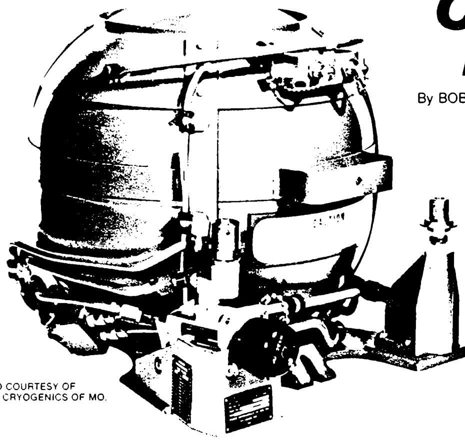


PHOTO COURTESY OF ESSEX CRYOGENICS OF MO.

By BOBBY MOORE/*Technical Specialist - Field Service, Hq. TAC, Langley AFB, Va.*

"It cannot be overemphasized that LOX converters must be handled with care. . . . Treat them as loaded weapons."

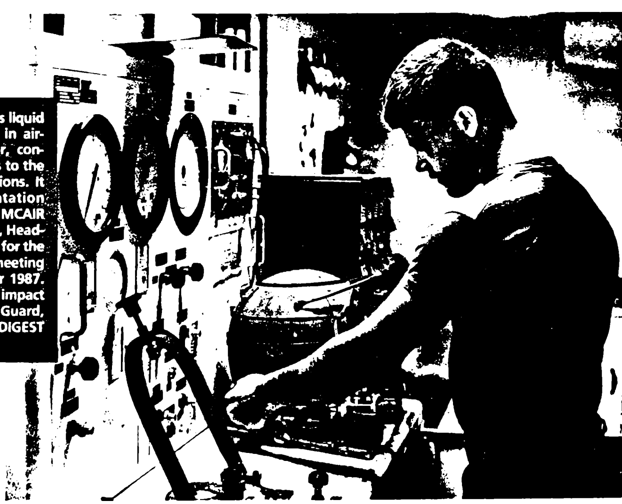
Oxygen is what permits the operation of high performance jet aircraft at extremely high altitudes and in a variety of mission situations. This oxygen is stored as a liquid on the aircraft and is converted to a gaseous state for use by the aircrew. The oxygen is stored and converted to a gas through use of a LOX converter.

Mishaps that have occurred with the converters usually are in the form of an explosion, both on and off the airplane, but also with the aircrew not getting proper oxygen flow.

Several questions have been asked searching for short-term solutions to these problems. Long-term solutions have been sought through conferences involving the major commands (MAJCOM) and the system program managers (SPM).

In discussing this problem some short-term solutions are presented. The phenomenon of LOX stratification, as compared to LOX converter venting, also bears on the handling and use of the LOX converter and must be understood to achieve an accident-free environment.

Editor's note: This article defines liquid oxygen (LOX), how it is used in aircraft, the use of the converter, converter explosions, and solutions to the problem of converter malfunctions. It is derived from a presentation prepared by Bobby Moore, MCAIR Field Service Technical Specialist, Headquarters, TAC, Langley AFB, Va. for the Air National Guard Council meeting held in St. Louis on 22 October 1987. Since converter problems also impact aircraft users other than the Air Guard, the broader audience of the DIGEST deserves to be reached.



LCPL DENNIS PARKER USMC

CPL Buster Moser, USMC, MCAS Beaufort, SC, prepares a 10 liter converter for test and check-out.

LIQUID OXYGEN (LOX)

Liquid oxygen is a clear, slightly greenish liquid which changes from a liquid to a gas (boils) at a pressure of one atmosphere (14.7 PSIG) and at -297° Fahrenheit. At higher pressures it will remain in a liquid state at warmer temperatures. When kept in a liquid state it can be stored in a much smaller space. However, to be useful, the LOX must be converted into a gaseous state at a pressure and temperature suitable for operating aircrew demand regulators.

LOX CONVERTER

The LOX converter is a device used to store liquid oxygen and to convert it into a gas. It is a double-walled spherical shaped container, in sizes of five liters and larger. The space between the walls is filled with a lightweight volcanic glass called perlite, an effective insulator. Air in the wall space is pumped out to create a vacuum of 10-6 TORR which is held between the walls of the container to provide a very high level of insulation.

The container has a series of tubes and valves that limit pressure build-up and provide relief in the event of overpressure. There are usually quick disconnects that provide for easy installation and removal of the converter from the aircraft. When the container is fully serviced and the service hose has been disconnected, the pressure build-up circuit is activated. Liquid from the container flows into the service line and "boils off" (warms up) to generate a gaseous oxygen pressure in the system. This pressure passes through the pressure closing valve and into the service valve, then to the top of the liquid in the container. This gas creates a head pressure on the top of the liquid that forces more liquid from the container into the lines to "boil off," thus increasing the gaseous oxygen pressure until the required system pressure is achieved. The normal relief valve then relieves the gaseous oxygen pressure to maintain it within the desired operating range.

LOX CONVERTER PROBLEMS

In 1984, an unexplained explosion of a LOX converter occurred while installed in an F-4. This caused a good deal of concern among maintenance managers. The converter had been serviced and installed about an hour before the explosion. What at first seemed to be an isolated incident turned out to be not so unusual after all when research revealed that several mishaps similar to this had occurred over the past several years. It was discovered that within TAC two similar incidents involving an F-15 and an F-111 had occurred. The F-15 converter had exploded outside the aircraft. The F-111 converter was installed in the aircraft when it exploded and the aircraft sustained some structural damage. Both converters had been serviced within two hours before the explosions occurred.

Some important questions:

Are the majority of our LOX converters reaching the end of their service life? ***We don't think so.***

Can the vacuum container seal be broken without being apparent? ***No.***

Could it explode if the seal is broken? ***Probably not.***

If the converter relief valve is jammed or blocked, can the converter build up enough pressure to explode? ***Maybe.***

Can the relief valve be checked for jams before servicing? ***Yes, but jamming can occur during servicing.***

The same type of LOX converter is used in most of our high performance jet aircraft. Answers to these converter problems were needed in a hurry. Although we had aircraft damage from these explosions, no one had been hurt yet. It was determined that the explosions that occurred in the TAC aircraft were caused by:

1. Ice and/or metal particles prevented the pressure controlling valve from closing when operating pressure was reached. This left the converter in a continual build-up mode with a rapid gas pressure increase as more and more LOX was converted into a gas.
2. Moisture froze in the converter relief valve and prevented it from opening.

During recent testing, under these simulated conditions, the converter exploded after the pressure reached about 1700 PSI. The explosive energy blew the top and sides off a 3/8 inch steel bunker. It has finally been concluded that the problem of ice in the converters was the result of moisture being inadvertently induced during LOX servicing.

As the LOX in the converter begins to convert from a liquid to a gaseous state, the pressure can increase to as high as 12,000 PSI if not relieved. If a damaged converter (with vacuum lost) also has a malfunctioning relief valve, the converter bottle can become a potential bomb with over six tons per square inch of pressure. It cannot be overemphasized that LOX converters must be handled with care – they are critical, delicate vacuum containers.

As mentioned earlier, the vacuum between the walls of the container provides a very high level of insulation. Frost may indicate that this vacuum has been lost. Except for minor frosting around the servicing/vent valve immediately after servicing, the bottle should not frost up. If a bottle does frost up, especially at the top, or it is much colder to the touch than the air temperature, then the vacuum may have been lost and the bottle should be emptied and returned to the depot for repair.

Care must also be used to prevent moisture (most likely rain) from inadvertently entering the relief or service valves and freezing because later the valves may not relieve any excessive pressure build-up.

STRATIFICATION AND VENTING

Due to an early misconception of the phenomenon of LOX stratification, an arbitrary two hour stabilization requirement after each LOX converter servicing was established. Additionally, it was decided that a vent cap would be installed immediately after servicing to prevent the LOX converter from building up pressure and to allow stabilization to occur. A better understanding of the need to vent the converter immediately after servicing has developed and has little to do with stabilization. An immediate five-minute venting period for the converter after servicing is more than adequate time to expel any moisture build-up within the service valve. Any longer venting period is a waste of LOX and delays the beginning of the build-up cycle.

If a fully serviced converter is placed in the build-up cycle and left undisturbed, the head pressure will build up to the operating pressure and stabilize at that pressure. Now that the LOX is pressurized and if its temperature increases slightly, it will remain in a liquid state. The only heat reaching the liquid now is that radiating across the vacuum space. The bulk of the LOX in the center of the converter is somewhat colder than the surface layer. Therefore, convection thermal currents are generated throughout the liquid which causes it to be thermetically stratified.

If the LOX converter is intentionally vented with a vent cap immediately after servicing, the build-up cycle is delayed. The pressure build-up will begin only when the converter is placed in a non-vented condition. After the converter has completed the build-up cycle and the liquid is agitated, as would be the case with an aircraft taxiing or taking off, the warmer layer will mix with the colder layer and the overall LOX temperature will decrease. As a result, some of the gas will revert into a liquid, decreasing the head gaseous oxygen pressure. A sudden drop in pressure will generate a momentary pause in the oxygen flow to the aircrew member's regulator.

To overcome this stratification phenomenon entirely, a LOX converter should be serviced and set undisturbed in build-up for a long period of time. It can ►

LCPL DENNIS PARKER USMC

CPL Moser makes minor adjustments to the converter before release for servicing.

require as much as 12 hours for LOX in a container to reach a stabilized uniform temperature throughout. Obviously, such a lengthy stabilization period is impractical when dealing with aircraft flying schedules and exercises. However, if time permits, LOX converters should be given as much time as practical to stabilize after servicing and before installation of the converter in the aircraft, or taxiing and taking off. This is to minimize as much as possible the gaseous oxygen pressure drop when the LOX is agitated during converter movement.

SYSTEM PURGE

Hot purging is a procedure designed to flow hot air through the converter to drive out moisture and particles in the converter and valves. However, recurring hot purges must be accomplished at frequent intervals in order to be assured that converters are kept free of moisture and particles that can cause relief and service valves to malfunction.

We are all faced with the complications of complying with LOX converter purge requirements. Each aircraft model has a slightly different set of requirements, but if followed, all will achieve basically the same satisfactory results.

A LOX converter conference was held at the Oklahoma City Air Logistics Center during May 1984 to discuss these problems. It was decided that each aircraft model would have its own hot purge requirement interval instead of one general purge requirement interval for all aircraft as it had been in the past. All of the MAJCOM and SPM representatives unanimously agreed that individual purge intervals should be established that would not impair the mission responsibilities of the MAJCOM and to preclude imposing any undue limiting factors on one aircraft that were not applicable to other aircraft.

A one-time hot purge requirement was levied on all TAC F-4 units in order to be assured our LOX converters were again serviceable. During this special purging requirement, it was learned that hot purge units were in short supply and some of those were inadequate to do the job. It was suspected that many of the converters had not been adequately purged for several years.

New hot purge units have been procured by OOALC and are being issued.

Our specific problem with converter purging is that we do not have a standardized method of tracking the purging due dates of converters. During the 1987 System Safety Group conference, a decision was made by OCALC that the maintenance servicing technical data be changed to include a requirement to attach an inspection sticker to the converters. The sticker is to be similar to the type in use by the US Navy. It is a simple sticker that indicates the day, month, and year the next hot purge of the converter is due.

Unfortunately, LOX converter problems won't go away by themselves. During this past year another five-liter converter exploded. The converter had been sitting empty for a month. It was serviced without being hot purged first. Shortly after servicing, it exploded while still in the LOX servicing area. Fortunately, again no one was injured.

Exercise extreme caution when handling LOX converters. Treat them as loaded weapons. Never, repeat never, service in an open uncovered area during rain or when excessive moisture is in the air. The bottom line is to follow all technical order precautions and procedures when handling LOX, LOX servicing equipment, and LOX converters. ■

Remember: LOX Means Safety and Caution Must Be Exercised at All Times

USAFE Safety Achievement Award

Teamwork by the engine maintenance crew saved an F-15 and hush house. Recipients of the USAFE Safety Achievement Award (left to right) are SSgt Michael T. Herron, A1C Todd D. Anhert, SSgt Thomas W. Lee, Sgt Randy Brown, TSgt James H. Dixson, and A1C Mark Coplen.

Quick reaction by six technicians of the 32 TFS, Camp New Amsterdam, The Netherlands, prevented the loss of a valuable F-15 and hush house. This crew was in the hush house, preparing to dynamically test an F-100 engine installed in an Eagle. Their task was to troubleshoot the engine and determine what was causing it to surge.

Upon the initial engine start attempt, when the engine failed to light-off, the start was immediately aborted. During the aborted start, fuel collected in the tailpipe of the engine and suddenly ignited.

When the ground crew saw smoke coming from the tailpipe area, they advised the engine run technician in the cockpit of the potentially serious situation. Emergency procedures for fire on start were initiated. However, motoring the engine didn't produce enough air flow to blow out the fire in the tailpipe.

While the engine run technician secured the engine and Jet Fuel Starter, the ground crew doused the fire with a Halon extinguisher. Although nauseated by the fumes, they put out the fire before the fire department arrived.

As a result of their quick thinking and actions, damage was limited to a small heat crack in the tailpipe of the F-100 engine. ■

– Courtesy USAFE AIR SCOOP

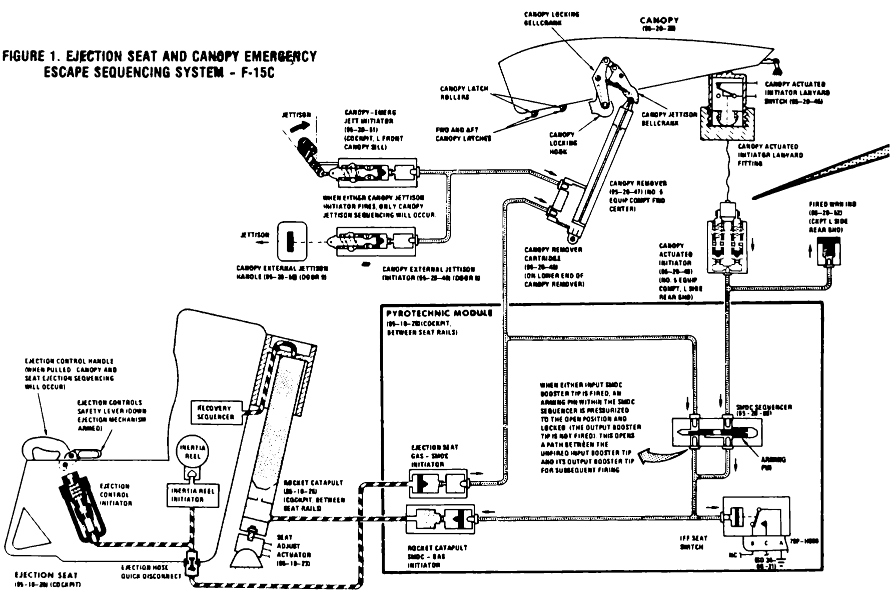
The Eagle's Ejection System

By MIKE CREECH/*F-15 Senior Technical Data Engineer*
and
AL CARY/*Senior Field Service Engineer, Soesterberg AB, Netherlands*

What if the accident investigation board's report read: "F-15 pilot could not eject because the cockpit safety pin in the canopy actuated initiator was not removed, and even if the safety pin had been removed, improper attaching hardware used to attach the canopy actuated initiator lanyard switch to the canopy would have prevented a successful ejection. . . accident resulted in pilot fatality."

Fortunately, an accident of this nature has never happened, but it could. Why? Because there have been several occurrences of pilots "unknowingly" flying their Eagles with the cockpit safety pin installed in the canopy actuated initiator and/or improper attaching hardware (pin, bushings, washers, and collar) installed in the canopy actuated initiator lanyard switch. So, to all you pilots and maintainers out there, listen up and pass this message along.

FIGURE 1. EJECTION SEAT AND CANOPY EMERGENCY ESCAPE SEQUENCING SYSTEM - F-15C



Before any pilot climbs into the cockpit, he should make sure that not only the ejection seat safety pin assembly has been removed, but the cockpit safety pins are removed from the internal canopy jettison handle and canopy actuated initiator, as well.

Everyone climbing into the cockpit readily sees the ejection seat safety pin assembly and its "REMOVE BEFORE FLIGHT" streamer lying across the ejection seat cushion. Unfortunately, removal of this safety pin assembly is not enough.

The cockpit safety pin has to be removed from the canopy actuated initiator in order for the ejection seat sequencing system to complete a full cycle. Trying to eject with this safety pin installed is impossible. With the cockpit safety pin installed, pulling the ejection control handle merely positions the arming pin within the SMDC sequencer; in other words, the ejection sequence would terminate at that point. (See Figure 1.)

With the safety pin removed, the ejection seat sequence would be: ejection control handle pulled; repositioning of the SMDC sequencer arming pin; canopy jettisoned; firing of the canopy actuated initiator ; ignition of the rocket catapult, and ejection of the ejection seat.

Always, before climbing into the cockpit, look rearward for any evidence of a "REMOVE BEFORE FLIGHT" streamer dangling from the canopy actuated initiator (see Figure 2). If installed, have the crew chief remove it. On two-seater aircraft, it cannot be seen by just looking rearward, so have the rear seater make sure the cockpit safety pin is removed. On the F-15A and F-15C the canopy actuated initiator is located on fuselage station No. 377 back in No. 5 equipment compartment next to the canopy actuator. On F-15B, F-15D, and F-15E models the canopy actuated initiator is located just aft of fuselage station No. 377 in the canopy actuator well next to the canopy actuator.

Using the Correct Attaching Hardware

An aircrew, during their walk-around checks on an F-15D, were inspecting required pre-cockpit entry items when it was discovered that the canopy actuated initiator lanyard switch was disconnected from the canopy and dangling by its two electrical leads. On the two-seater B, D, and E model aircraft the area where the canopy actuated initiator and associated components are mounted is difficult to see, thus unfortunately often overlooked. Aircrews and maintainers must take time to check not only this area, but any area that is not out in the open.

A point of interest, the canopy actuated initiator lanyard switch is a key element in an ejection sequence. It activates the canopy actuated initiator (as long as the cockpit safety pin is removed) when the canopy is jettisoned. This will allow the ejection seat sequencing system to complete a full cycle.

It appears that sometime in the past the lanyard switch (see Figure 2) was fastened to the canopy with the wrong attaching hardware, which eventually fell out. After checking two additional F-15Ds, it was discovered that incorrect attaching hardware had also been used to attach the lanyard switch to the canopy on one of these aircraft as well. (It was felt that both rebuilt canopies were received with the wrong attaching hardware.) As a result, an interim urgent action TCTO 1F-15-1044 was issued by the Air Force requiring a thorough inspection of the attaching hardware on all F-15B/Ds. ■

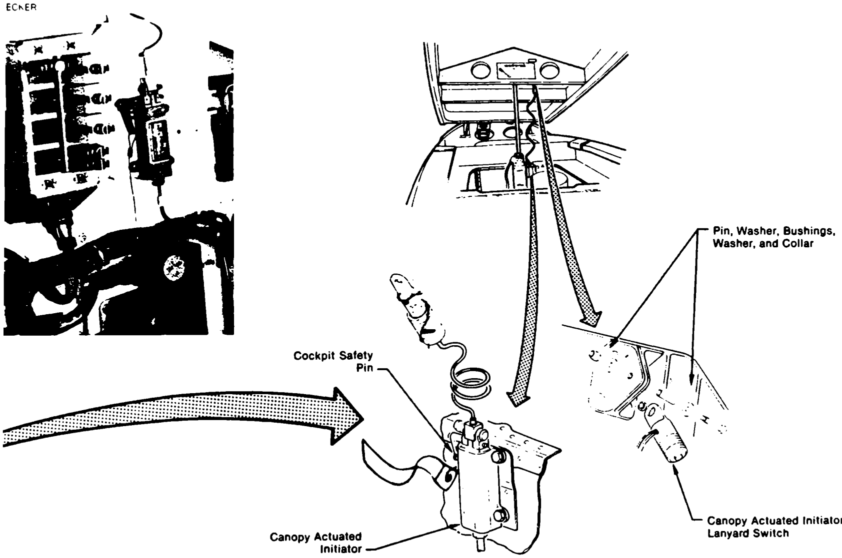


FIGURE 2. EMERGENCY ESCAPE SYSTEM COMPONENTS

Observations

Major Allan Reed (standing) and Lt Col Larry (Scoop) Cooper of the USAF 6510 Test Wing peer into the nearly completed F-15E No. 2 cockpit while touring the MCAIR final assembly area.

The United States Air Force at Edwards AFB, California received the first F-15E Eagle – No. 1, 86-0183, on 1 March 1987, followed by F-15E No. 2, 86-0184, on 12 August 1987. Since then, aircrews from the 6510th Test Wing have been conducting an extensive flight test program to develop and evaluate the flight characteristics, avionics, and weapons systems of this state-of-the-art dual role (air-to-air/air-to-ground) F-15E – the latest addition to the Eagle family.

From the Front Seat:

"I immediately got the impression that there's a lot of potential just waiting to be unleashed... It gives the crew a flexibility that's unique, which the USAF doesn't have in any other fighter aircraft." *Major Allan Reed*

about the F-15E Eagle

From the Back Seat:

"The F-15E will provide aircrews with a tremendous amount of flexibility... Its flexible and complex systems must be sophisticated and simple; a simple system is a very sophisticated system." *Lt Col Larry (Scoop) Cooper*

At Edwards AFB, California there's a new Eagle – the F-15E. Outwardly – compared to its famous F-15 predecessors – it appears to have only a darker shade of gray paint. But underneath the cosmetics is a very different airplane.

It is so different – considered to be in a class by itself – that throughout the flight test program USAF aircrews are coming to MCAIR's facilities for in-depth simulator training on the latest refinements to the newest Eagle's systems. The simulator allows flight test crews to work out switchology and display procedures, plus save valuable flight test time, not to mention the safety factor.

Aircrews are able to familiarize themselves with changes in cockpit layout and displays, and gain much needed proficiency in both crew coordination and techniques. This type of training provides USAF flight test aircrews with the additional skills needed to properly evaluate the F-15E's systems.

Aircrew teams presently flying the new Eagle are: pilots, Lt Col Steve Stowe, Commander of the Combined Test Force (CTF), Major Allan Reed, and Major Charles Precourt; and Weapon Systems Officers (WSOs), Lt Col Larry (Scoop) Cooper, Deputy CTF Director, Major Tom Toltzien, Major Jim Heald, and Capt Dave Walker. MCAIR aircrews which are also part of the Combined Test Force team: pilots, Gary Jennings, F-15 Project Pilot; Fred Madenwald, Experimental Test Pilot; and WSO, John York.

Major Reed and Lt Col Cooper were in St. Louis recently for some on-going simulator training. They granted an interview to the DIGEST and toured the assembly area, where they gained insight into how the newest Eagles are manufactured.

Because of their extensive backgrounds (Major Reed, F-111 deep interdiction, and Lt Col Cooper, F-4 and F-111 operational, training, and test and evaluation roles), they are eminently qualified to comment on the F-15E with a high degree of perception. The DIGEST would like to share with you some of their conversations:

AIRCRAFT POTENTIAL

First and foremost, the role of the F-15E is to fulfill a mission role of deep strike interdiction. The Air Force is seeing the need for what it calls a "dual capable" airplane which, in NATO and European terms, means an airplane that can perform both mission roles. In terms of capability across the tactical spectrum, the F-15E is expected to have the potential to do it all.

Major Reed, on flight test:

"The initial phase of the test program is where, for the first time, the actual potential of the an airplane is realized. Just sitting in the cockpit of F-15E No. 1, I immediately got the impression that there's a lot of potential just waiting to be unleashed. So my job as a member of a flight test aircrew is to go out there and fly the airplane to determine its performance and handling characteristics, and evaluate the integration of the avionic and weapon systems.

"Probably in a lot of ways we seem to be the bad guys because we're out there finding things that aren't quite right, as well as what is working as designed. That's our job, but in the end, both the MCAIR and USAF teams win. We're flying the plane to evaluate and rate its systems – some of which may be marginal or unacceptable. The low altitude warning system, for example, initially kept giving false altitude warnings.

"Once the problems were identified in flight test, MCAIR engineering implemented refinements to improve system performance. Upon completion of this intensive flight test program, the F-15E will better be able to perform its long-range, all-weather mission, plus complement the F-111."

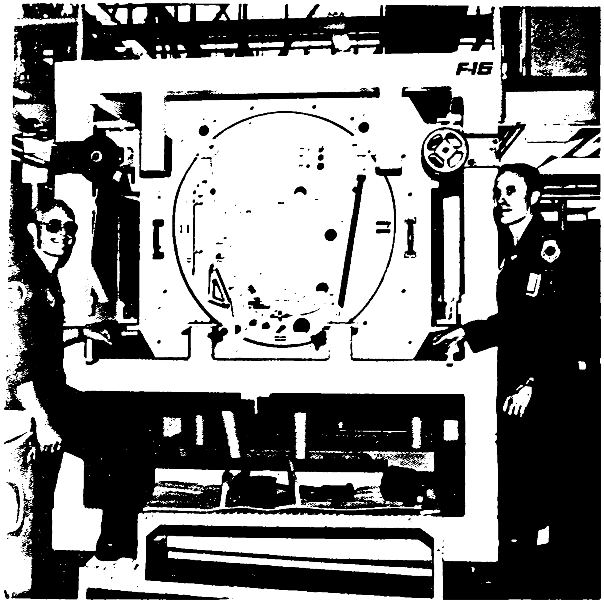
AIRCREW COORDINATION

The Eagle was initially designed for growing room, so when the newest addition to the Eagle family arrived with a back seat, reserved for the WSO, aircrews began to ask an all-important question: What about aircrew coordination, particularly handing off duties between the front and back seat? Both Major Reed and Lt Col Cooper provide insight as to how they feel about aircrew coordination in general, including the F-15E.

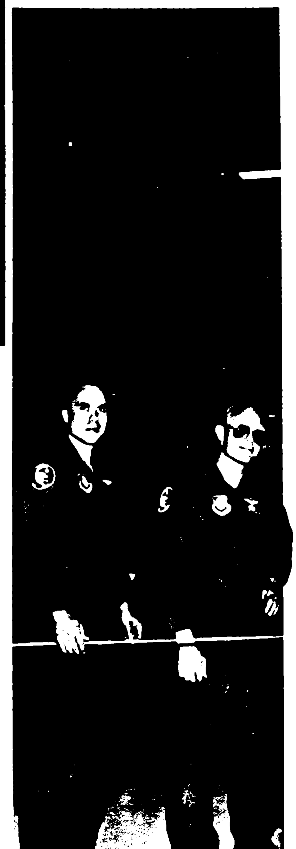
Major Reed, on aircrew workload:

"The F-15E is a very mission-dependent, two-seat airplane. When a deep interdiction mission requires a low-level, in-the-weather ingress, ducking under the weather using the FLIR, targeting pod, etc., in the middle of bad guy country, the key element for a successful mission is crew coordination. Several established crew coordination standards also apply to the F-15E. But, state-of-the-art avionic systems have created some unique crew coordination differences, such as the ability of either crew member to take control of any sensor in the airplane. I'm not saying that's bad. I think that's good. It gives the crew a flexibility that's unique, which the USAF doesn't have in any other fighter aircraft.

"This uniqueness introduces a new crew coordination matrix, which has not been encountered in other fighter air- ▶



Lt Col Cooper (left) and Major Reed are standing in front of the assembly jig supporting F-15E No. 3 cockpit. This aircraft will be going to Eglin Air Force Base, Florida for weapons separation and Tactical Electronic Warfare Systems (TEWS) flight testing.



craft. Crew coordination problems and interaction between the pilot and WSO can best be developed within the training arena by using simulators. They're fantastic training tools, which afford aircrews the opportunity to work as a team to resolve whatever crew coordination differences may arise."

Lt Col Cooper, on the cockpit environment being user-friendly:

"Compared to some of the other aircraft I've flown, I think the F-15E is user-friendly – once you've been in the simulator or cockpit long enough to figure out the logic behind it. First, it just overwhelms you. The initial reaction of most of the pilots and WSOs is that they will be awed by all the system interfaces, symbology on the HUD, digital display menus, and how to employ them effectively.

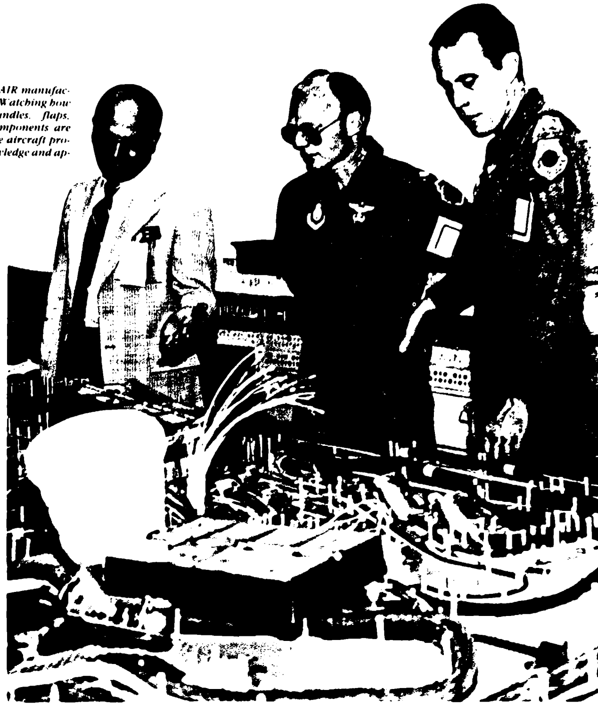
"The best way to get up to speed on all the systems is through simulation, which provides aircrews the ability to work as a team with the systems in normal, degraded, and emergency modes. Simulators are the key for aircrews to maximize their skills, plus experience a wide range of flight and system phenomenons. Once aircrews get their coordination techniques down and start working as a team, they'll no longer be awed by the state-of-the-art avionic systems incorporated into the F-15E.

"Once a crew understands the logic within the cockpit environment, it becomes user-friendly. User-friendliness of the integrated avionic and weapon systems is one of many areas we will evaluate as the flight test program continues, and we'll make recommendations so that it becomes more user-friendly as we see that it needs to be done."

Lt Col Cooper, on well integrated cockpit:

"In order to have a well integrated airplane, the cockpit environment must be very disciplined and well regulated. A total team effort with the ability to work independently and hand off tasks is necessary because frequently, in the tactical environment, high workloads shift radically from seat to seat. Aircrews must force themselves into a disciplined structure, so that during an actual engagement everything is controlled right up into the shot. In a combat environment there is no other way.

"The F-15E will provide aircrews with a



Both crewmembers toured the MCAIR manufacturing area where F-15s are built. Watching how components, such as wire bundles, flaps, bulkheads, and various other components are manufactured and installed in the aircraft provided this crew with a greater knowledge and appreciation of the Eagles they fly.

tremendous amount of flexibility. But flexibility can breed complexity. Cockpit complexity, coupled with complex targets in a tactical environment, is very non-forgiving of people who are busy. There are things outside the canopy that are going to keep you a lot busier.

"Through an extensive flight test program the USAF and MCAIR are flight testing the logic and architecture of the computer software programs. This ensures the flexibility designed into the system will allow each task to default to reasonable logical streams of task performance, thus keeping the airplane on-line with the mission.

"These flexible and complex systems must be sophisticated and simple; a simple system is a very sophisticated system and the basic F-15 is that way. You get in, pull the JFS handle and start the engines. Radar comes up with a couple of switches and you're ready. Put your numbers in the INS and taxi. That same basic philosophy must hold true for all the systems, particularly the weapons delivery system.

"For aircrews in combat, a weapons system must be sophisticated enough to allow them, both front and back, to be headup, keep themselves out of the rocks, see the enemy SAMS and defeat bogeys. To do that, the menus on the digital displays and HUD information must be logical. Logical means a system that is intuitive and easy, enabling the crew to train around them and develop habit patterns that will not crumble under combat."

CAPABILITY AND RANGE

The capability and range of the F-15E are not only important to the crews who fly it, but for the commanders who will utilize the airplane in a mission role of deep strike/deep interdiction. Here are the crew's thoughts on how they think the F-15E will complement the F-111 and the USAF's mission.

Major Reed, on versatility:

"The F-15E will be able to do everything that an F-111 can do, precision bombing and navigation, but much more accurately. Aircrews will find the workload a lot lower than it is for similar mission-type aircraft. The bottom line is it's going to be a safer airplane because of the reliability and dependability of the systems.

"Once the aircraft is in operational squadrons, it will be a tremendously versatile battlefield tool for a NATO planner, or Tactical Air Force (TAF) commander. They will have the ability to stuff the aircraft into a shelter, load it up with conventional weapons, and launch. Comeback, load up for air-to-air in long-range combat air patrol (CAP) and, if the need arises for the basic air superiority mission, download the Lantrin pods and give us wall-to-wall missiles. It is a tremendous asset for the USAF to have this kind of flexibility built into the F-15E."

Lt Col Cooper, on capability and range:

"The Air Force now has a dual capable aircraft which, in NATO's terms, means an aircraft that can perform both conventional and nuclear strike roles, with the added capability of delivering precision-guided munitions while retaining all of its air superiority munitions. So, in the terms of capability across the tactical spectrum, the "E" is going to be able to do it all.

"It will be a very powerful tool for NATO and the tactical air forces because the airplane has the ability to be configured to ferry to a forward staging area, drop external tanks, spot load munitions, and fly a combat mission quickly. If the USAF is called upon to meet a threat anywhere in the world, this aircraft will provide us with a lot of power to do so."

The F-15 Eagle is the safest fighter in the USAF history, and this latest addition to the Eagle family will increase the ability of the aircraft to survive in an increasingly hostile environment. Improved survivability through hardening efforts of the structure, redundant systems plus the addition of electronic protection will ensure this aircraft can meet the threat. ■

By MARK FLORETTA
Staff Editor, Product Support DIGEST

digest

VOLUME 35 NUMBER 3 1988

Front and back covers: To make safe flying happen for VFA-106 at Cecil Field, Florida, pilots such as LCdr Jim Stone, Assistant Operations Officer, and maintenance personnel such as Plane Captain AN Kimberly Phelps and Line Division Chief CW04 John Gilbert, observe the Gladiators' motto of SA + SA = P.A. Photos by Lt Mary Roots, USN, Public Affairs Officer at Cecil Field, dramatize the confidence of operations and intensity of maintenance at VFA-106. Combined with magnificant flying machines, the results of the motto were celebrated on 5 May 1988 when the VFA-106 became the first squadron to achieve 50,000 accident-free (no Class A accidents) hours flying the F/A-18 Hornets. Picture story covering the event starts on page 2.

MCAIR Product Support Division Executive Management: DENNIS BEHM/Vice President, Product Support Division; HERMAN J. CORREALE/Director, Support Technology Development; PHILIP E. MACY/Director, Customer Services; and THOMAS L. PLEIN/Director, Product & Process Improvement.

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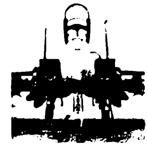
RESTRICTION NOTICES

Staff Sgt Jimmy Ray, 1st F-15E Crew Chief at Luke AFB, in conversation with Major Terry Branson and Major Ron Heydon.

Major Terry Branson, Instructor Pilot, Inspecting No. 86-186 prior to flight.



F-15E ARRIVES AT LUKE

On 14 November 1974, the first F-15 for the Tactical Air Command was delivered at Luke AFB, Arizona. The principal speaker at the ceremony commemorating the arrival of the first Eagle was then-President Gerald R. Ford. At a similar ceremony almost 14 years later and at the same base, the newest member of the Eagle family, the F-15E "Strike Eagle," was welcomed to the Tactical Air Command. This event was held on 18 July 1988 and Gen Robert D. Russ, Tactical Air Command Commander, officially accepted delivery of the aircraft.

The 461st Tactical Fighter Training Squadron (TFTS) of the 405th Tactical Training Wing (TTW) is the first TAC squadron to have the new Eagle aircraft. The first TAC F-15E, tail number 86-186, was on static display for the ceremony as well as tail number 86-187, which arrived at Luke on the 17th and just in time to participate in the ceremony.

Jim Spehr, MCAIR Vice President and General Manager of the F-15 program, represented McDonnell Douglas at the ceremony and stated that the activation of the F-15E with the 461st TFTS was one of the most important milestones in the program. Addressing his remarks to the members of the 461st "Deadly Jesters," Spehr stated, "Today's ceremony is the culmination of years of hard work and dedication by many people within the US Air Force and the aerospace industry. It's gratifying for all of us to see the product of that hard work put into service."

Gen Robert D. Russ, Commander, Tactical Air Command, US Air Force, officially accepted delivery of the F-15E from Spehr and McDonnell Douglas. Gen Russ described the F-15E as the top priority program within the tactical air force. He continued, "I can say I've never seen the tactical forces as ready, as capable, and as dedicated as they are today."

The general then compared the capability of the new F-15E with the B-17 of World War II, stating that the B-17 had a payload of ten 500-pound bombs. He said, "Today, the F15E fighter, not a bomber, can not only carry more bombs – 12 versus 10 – but can carry them 40% farther than the B-17. The B-17 was expected to fly twice a week. The rest of the time it was down for maintenance. During war, we expect to fly the F-15E around three times a day.

"The navigation system on the F-15E has ten times the reliability and three times the accuracy of the current F-15 system. The radar has four times the speed, five times the memory, and 25 times better resolution than our next best system."

The general directed his concluding remarks to the men and women of the 461st squadron and the 405th wing. He said, "Today, these men and women are some of the most dedicated, most capable, and most professional operators and maintainers in the armed forces. We are looking forward to great things from you as we activate the first F-15E squadron."

As more "Strike Eagles" arrive at Luke AFB, the 461st will be joined by the 550th TFTS "Silver Eagles" in the training mission. For the foreseeable future, Luke AFB will provide all maintenance and crew training for the nearly 400 F-15E aircraft that the USAF plans to procure. ■

By WHIT WALLACH
Staff Editor, Product Support DIGEST

Gen Robert D. Russ, Commander, Tactical Air Command, officially accepting delivery of the F-15E.

James L. Spehr, Vice President and General Manager, F-15, McDonnell Aircraft Company, and Lt General Peter T. Kempf, Commander, 12th Air Force, arrive at the ceremony.

not for public release

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