VOL. 2, NO. 2, APRIL-JUNE 1975

service news

A SERVICE PUBLICATION OF LOCKHEED-GEORGIA COMPANY, A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

A SERVICE PUBLICATION OF
LOCKHEED-GEORGIA COMPANY
A DIVISION OF
LOCKHEED AIRCRAFT CORPORATION

Editor
Jay V. Roy

Associate Editors
James W. Buttram
James A. Loftin

Art Direction & Production
Anne G. Anderson

COVER: The Hercules is playing a vital role in oil exploration and development of the Alaska North Slope. It is the air truck of the Arctic · the only vehicle which can deliver the materials undamaged where they are needed, when they are needed, and on a reliable year-round basis.

Published by Lockheed-Georgia Company, a Division of Lockheed Aircraft Corporation. Information contained in this issue is considered by Lockheed-Georgia Company to be accurate and authoritative; it should not be assumed, however, that this material has received approval from any governmental agency or military service unless it is specifically noted. This publication is for planning and information purposes only, and it is not to be construed as authority for making changes on aircraft or equipment, or as superseding any established operational or maintenance procedures or policies. The following marks are registered and owned by Lockheed Aircraft Corporation "", "Lockheed", "Hercules", and "JetStar". Written permission must be obtained from Lockheed-Georgia Company before republishmg any material in this periodical. Address all communications to Editor, Service News, Department 64-22, Zone 278, Lockheed-Georgia Company, Marietta, Georgia, 30063.

Vol. 2, No. 2, April -June 1975

CONTENTS

PRODUCT SUPPORT

Director	T. J. Cleland

CUSTOMER SERVICE DIVISION

Manager	D. L. Braund
Field Service & Inventory Mgmt	A. H. McCrum
JetStar Support & Customer Training	J. L. Thurmond
Spares Stores & Shipping	A. R. Love

CUSTOMER SUPPLY DIVISION

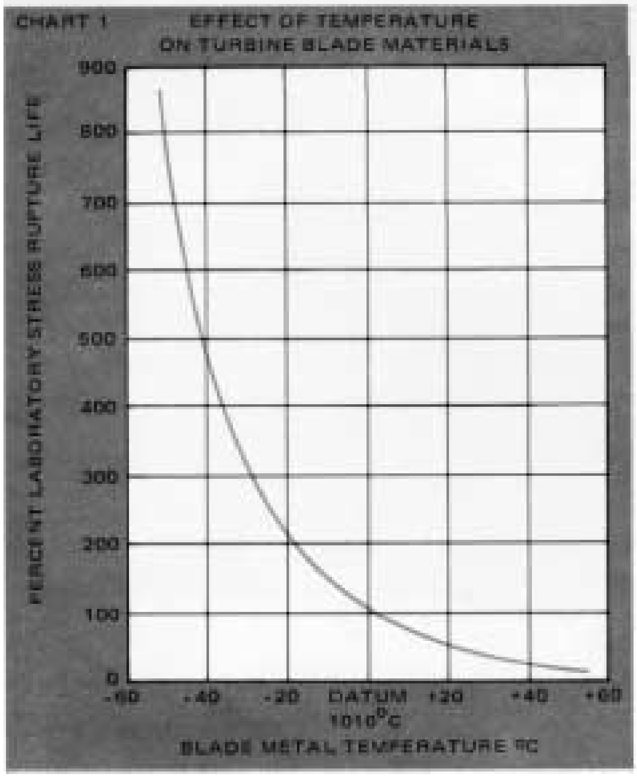
Manager	M. M. Hodnett, Jr.
Supply Procurement	R. C. Weihe
Supply System & Inventory Control	C. K. Allen
Supply Sales & Contracts	H. T. Nissley
Supply Technical Support	H. L. Burnette

STARTING FOR A LONGER ENGINE LIFE

THE MOST EXPENSIVE entry in the ledger of aircraft operating costs is for the power plant. It makes good sense for any operator to provide good preventive maintenance for his engines. With the Allison T-56, as with any engine, good preventive maintenance begins with good operating procedures. The best place to begin is at the start- the engine start, that is.

It is during the engine start cycle that we have a good chance to lengthen or shorten engine life. It has to do with something called stress rupture life. Stress rupture life, stated simply, means every piece of metal has a memory – subject it to overtemperature and it will remember the incident. Repeat the cycle often enough and the material will fail. This is a rough way of saying the stress rupture life has been exceeded. Stress rupture life is dramatically affected by metal temperature. Does this mean that after one hot start the turbine is ready to shed its blades? No. Does it mean that after one start of 90 seconds duration with the TIT hovering around the start limit for the complete cycle the turbine is ready to shed its blades? No, again. But it does mean that the effects of the poor starts are accumulative. Remember, the turbine has a memory. A look at chart 1 shows how an excursion from the selected datum point (temperature) affects turbine blade life.

Previous Page Table of Contents Next Page



Does this mean the engine was ready to fail? Not necessarily, but it had deteriorated to the point that a blade failure was a probability. So what can we do? Quite a lot. For a start, we can follow good operating practices as set down in the approved operating manuals.

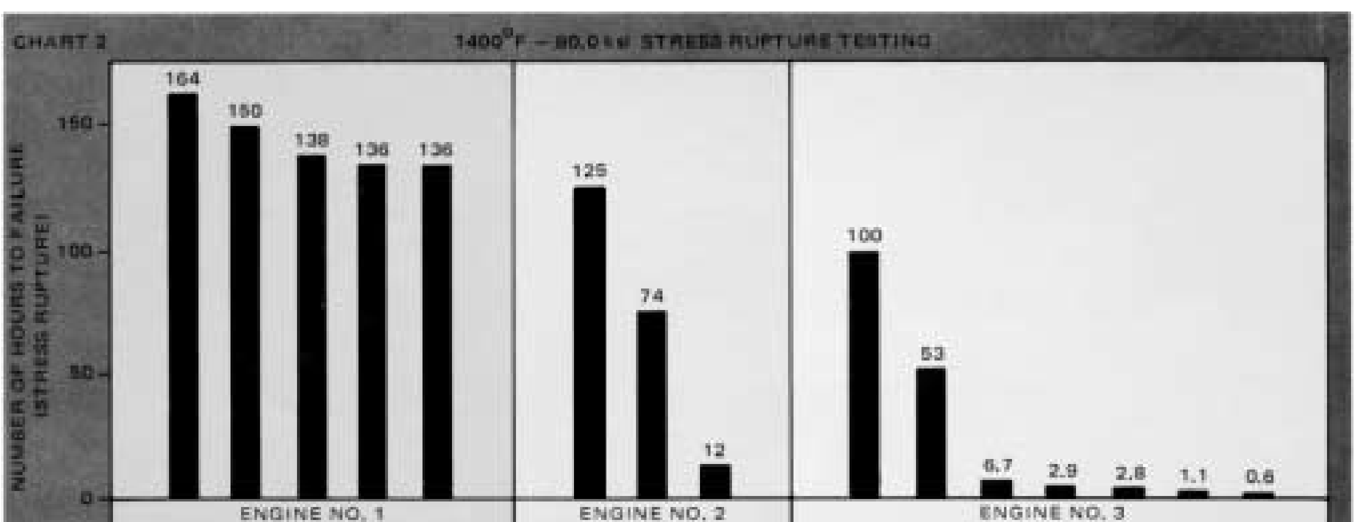
The T56 engine is an easy engine to start when the proper equipment is used and correct procedures are followed. Some ground starting problems have been encountered during line operation; and, in the majority of cases, the trouble has been in the area of procedures rather than component malfunctions. In this article, we will review and expand certain steps in ground starting procedures.

First, a look at Engine Gas Temperature and Turbine Inlet Temperature (TIT). (We can't read EGT in the cockpit, only TIT; but there is a direct correlation). Chart 3 shows first stage vane temperature for various TIT's during start. During a start, cooling air flow to the turbine is at a minimum. The longer it takes the engine to come on speed, the greater the chance of decrease in stress rupture life of the turbine.

Chart 3 shows that considerable emphasis should be placed on engine acceleration time, especially for the RPM range (0 to 30%) wherein the engine does not produce enough torque to sustain speed. Minimum gas temperature for the scheduled fuel flow will vary inversely with the engine acceleration rate; in other words, slow acceleration results in high gas temperature and fast acceleration results in low gas temperature. Minimum time to accelerate to low speed ground idle RPM is limited by the pressure setting of the starter control valve. The prime consideration, however, is the maximum time, which depends on the starter air source energy level.

Now for a brief review of some of the factors of engine starting:

Chart 2 shows a comparison of lab tests on turbine blades from three different engines. The actual numbers for the tests aren't too important, but the results are interesting. As expected, the blades from the practically new engine had the best test results – 136 hours or better before failure. The high-time engine blades didn't do too badly; in fact, pretty good. The engine still had a lot of life in it. But look at the 660 hour engine – very poor test results. Its turbine blades failed very early in the test, indicating they had reached their stress rupture point; a good suspect in this case is poor start system performance (slow acceleration, exceeding maximum start time, etc.).



Lab tests on three engines. Engine No. 1 had 200 operating hours; No. 2 had 8,000 operating hours; No. 3 almost 700 operating hours. The worst and best results are shown. Stress rupture tests were conducted on 0.100 inch diameter bars made from 2nd stage turbine blades.

Previous Page Table of Contents Next Page

TIT SHOULD BE LESS THAN 200°C

Starts on a hot engine tend to be mildly explosive. This abrupt light off causes an instantaneous rise in combustion chamber pressure which can cause compressor stall or surge. This can slow engine acceleration, cause RPM stagnation, and result in overtemperature. If this occurs, immediate shutdown is necessary to prevent turbine damage. This, of course, causes an undesirable delay before another start can be attempted.

AIRCRAFT BOOST PUMPS "ON" FOR STARTING

While the T56 engine will start on gravity fuel feed, a positive head (pressure) of fuel at the engine-driven pump inlet will assist in ground starting. If possible, aircraft boost pumps should be "ON" to assure a positive head of pressure to the engine-driven pumps. This will preclude pump cavitation or entrapped air disrupting the fuel nozzle spray pattern during start.

BLADE ANGLE/THROTTLE POSITION

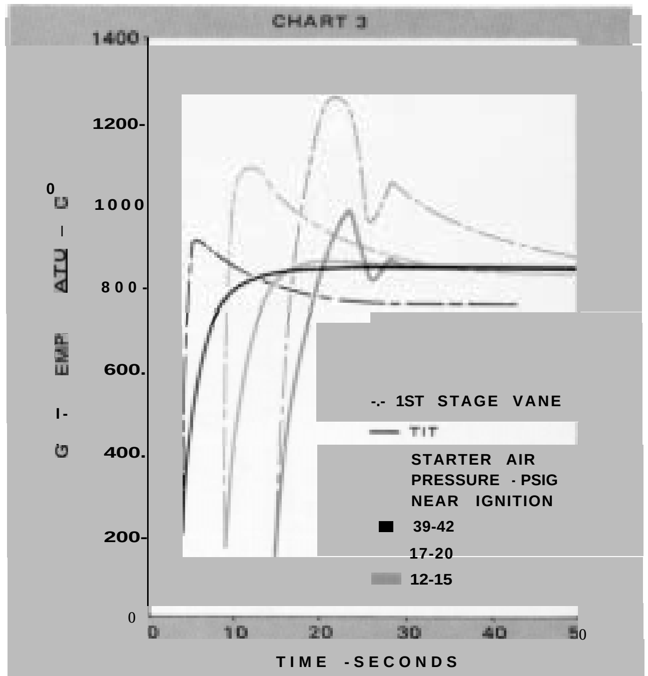
It is a design characteristic of the gas turbine engine that the starter must supply starting torque up to light off and continue to assist the turbine up to starter cut-out speed to get a good start in the minimum time. Any propeller blade angle other than minimum torque (start) will be working against the starter. Indeed, if the blade angle is sufficiently high, RPM stagnation can occur. The point of least torque is the start position of the throttle. If it is necessary to change the prop blade angle prior to starting, position the throttle to start and hold the condition lever in the AIR START position.

AIR PRESSURE FOR STARTING

In accomplishing a stable start from prop rotation to low speed ground idle, the air pressure should be 25 PSIG or higher from IO-16% engine RPM. The pressure is read on the flight deck gauge. If the presssure is less than 22 PSIG, discontinue the start. The GTC output should be checked in accordance with the latest Lockheed documents. Once an engine is started use engine bleed air as a source to start the other engines.

ACCERLERATION TIME

The engine should accelerate to low speed ground idle RPM in one minute. If the engine is not on speed in one minute, the start should normally be discontinued. The exception is under high temperature/high altitude conditions (high density altitude). A start time of seventy seconds is permitted under these conditions. In the event of high density altitude starts, engine acceleration must still be smooth and at a constant rate with no overtemping.



EFFECT OF VARYING STARTER AIR PRESSURE
ON ENGINE GAS TEMPERATURE
ALLISON 501-D22, D22A, T56-A-15LFE ENGINE
ABIENT AIR TEMPERATURE = 94°F

OTHER ENGINE INDICATIONS

We would refer you to the applicable operating manuals and Technical Orders at this point for the use of fuel enrichment, normal sequence of events and their indications, and emergency procedures to be followed during engine start. We caution that TIT should be closely monitored throughout the start. THIS IS THE MOST IMPORTANT GAUGE DURING START.

Since the start cycle, once set in motion, is automatic, there is little we can do except watch and stop it if everything isn't right. We can lay down some guide lines concerning good and poor starts. The following should be written up for corrective action:

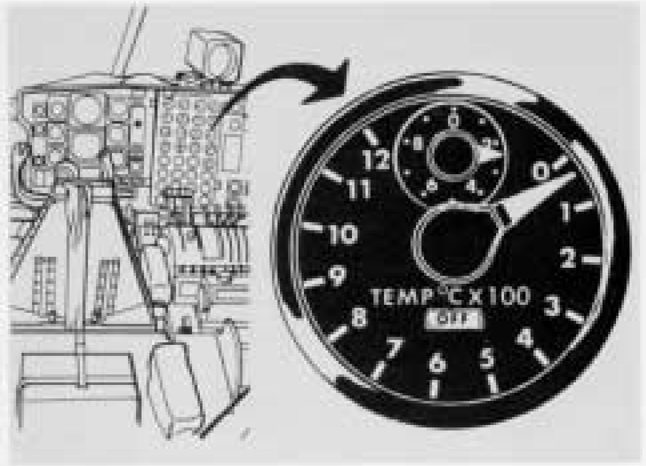
- Rapid, constant rate of increase in TIT to a slight overtemperature, then staying at the limit for the rest of the start,

- Slow acceleration rate to low speed ground idle RPM. This is based on the time from prop rotation to low speed ground idle exceeding the allowed time as discussed above.

Using the same approach, the following is associated with a good start:

- A rapid initial rise in TIT but a noticeable decrease in the rate of increasing TIT as the engine continues to

Previous Page Table of Contents Next Page



accelerate. The TIT and the RPM should increase smoothly. The TIT should peak in the range from 720°C to 83O C. But don't be misled – even low TIT associated with poor acceleration can be detrimental. Peak start attempts of less then 720°C are generally too cold and do not provide sufficient turbine developed horsepower to assist the GTC in accelerating the engine to on-speed within the start time limits.

THE START SHOULD BE DISCONTINUED IF:

- Starting bleed air manifold pressure is less than 22 PSIG with the engine accelerating between 10-16% RPM. (Pressure read on flight deck gauge.)
- Engine fails to light off by 35% RPM or maximum starter motoring RPM, whichever occurs first.
- Engine speed stagnates or begins to decay. (See definition of a stalled start accompanying this article.)
- There is no oil pressure indication at 35% RPM for either the reduction gear or the power unit.
- TIT exceeds 850°C (excluding the peak occurring at approximately 94%).
- Compressor surge occurs (indicated by backfiring through the compressor).
- Acceleration time from start of rotation to low speed ground idle exceeds 60 seconds, except during extreme ambient conditions, (high altitude, high temperature), start time may be increased to 70 seconds.

So, what have we said? Simply this: engine life can be extended by using good operating procedures, especially during start. Be aware of available air pressure. Don't start an engine with too high residual TIT. Closely monitor engine indications. Know what the engine is telling you about its condition. And a word to flight crews. If the mission permits, throttle back. Any decrease in cruise TIT is reflected in longer engine life.

POINTERS FOR FLIGHT CREWS **(Based on -15, -22A engines)**

- Engine failure rate is increased by operating engines at high turbine inlet temperatures. A 50°C increase in TIT causes an 88.5% reduction in stress rupture life of turbine blade materials while a decrease of 50°C would increase stress rupture life by approximately 800% (ex.; 1010°C to 1060°, or 1010 C to 96O C).
- Sulfidation effects on turbine components increase significantly above 98O C. An increase in TIT from 980°C to 1010°C results in the sulfidation effect being increased by a factor of 2. Sulfidation is the accelerated oxidation of metals in the presence of sulphate ions -call it "Hot Corrosion." Major sources of engine sulphate residue are jet fuel, engine and aircraft cleaning solutions, and sulphur dioxide in the air.
- Aircraft fatigue is increased at increased cruise speeds even though flight duration is decreased. Another good reason to reduce TIT at cruise.
- Based on a 2000 mile leg, reducing TIT from 101 O°C to 932 C increases block time only about 10% (6 min/hr.) while resulting in fuel savings of approximately 8%.

DEFINITION OF A STALLED START:

Sequence of events on a stalled start ***is the same as for a*** normal start until beginning of a stall which can be recognized by slower than normal acceleration in the 36% - 50% rpm range. At ***this*** time TIT will be ***at or close to the*** start limiting temperature of 83O C and fuel flow can be seen decreasing progressively as the trim system performs ***a*** take operation to keep TIT from exceeding 83O C. RPM ***will*** usually stagnate during ***this*** take operation, and when the trim system has taken fuel to ***its full*** capability, temperature ***may*** rise rapidly to full scale and RPM will start decaying. Move the condition lever ***to*** GROUND STOP immediately before the temperature rises to prevent serious engine damage. If RPM has not reached starter drop-out speed, it may be left engaged to continue air flow through the engine after the condition lever has been placed in GROUND STOP. However, allowable engaged time limit for the starter must be observed. Time involved for stagnation and fuel cut-back to occur is of sufficient length to allow an alert pilot to recognize an ensuing ***stall*** and to abort ***the*** start before the ***stall progresses to the*** point of overtemperature.

Previous Page Table of Contents Next Page

THE EXTERNAL SCAVENGE OIL FILTER

With the appearance of the External Scavenge Oil Filter have come reports of oil venting and pre-mature "popping" of the differential pressure indicator button. Before we jump to the conclusion that the filter is at fault, let's discuss the filter kit installation and some of the things to watch for.

Technical Order 2J-T56-627 covers the kit installation for the military while Allison Bulletin CED 72-1058 and Service Letter CSL-1504 cover the installation for the commercial operators. These documents detail procedures for field installation on in-service engines. The engine oil system schematic shows the location of the filter in the system.

The external scavenge oil filter kit improves the service life of the engine by removing carbon particles and other foreign material from the engine oil which could damage the contact surfaces of highly loaded bearings, gears, and seals. Sludge formation is reduced throughout the engine, oil cooler, and tanks. Restriction of the engine oil jets is significantly reduced. The possibility of cross-contamination in the event of power section or gear box failure is minimized. Further, debris from such failures is kept out of the QEC (Quick Engine Change) oil system components.

The pressure pumps incorporate 104 micron filters. The external scavenge oil filter adds 20 micron filtration to the system. This means very small particles will be filtered from the oil. The filter element is likely to clog quickly when installed in a "dirty" oil system. Integral with the filter assembly is a differential pressure indicator to alert maintenance personnel when an element change is necessary.

The differential pressure indicator "pops" at a difference in pressure across the filter of 20 +/- 3 PSI at oil temperatures above 120 F. (The indicator is blocked out at oil temperatures below 80 F. for starting.) A filter by-pass valve opens at 65+/-5 PSI.

One problem experienced with the external scavenge oil filter is popping of the filter button shortly after installation of the kit. As mentioned above, if the filter is installed in a "dirty" oil system the element will need to be replaced early. The element should be replaced as soon as the need is indicated.

If the filter is installed on an engine where the QEC scavenge oil system back pressure exceeds the allowed 30 PSI before installing the filter, then the addition of the filter could result in problems as the element begins to clog. To minimize this problem, the QEC scavenge back pressure should be checked following installation of the external scavenge filter kit. Refer to T.O. 2J-T56-26 or -46 or applicable commercial documents for instructions. The usual corrective action to reduce the back pressure is to clean/replace such components as the fuel heater and oil cooler.

Previous Page Table of Contents Next Page

THE EXTERNAL SCAVENGE OIL FILTER ILLUSTRATED IN FIGURES 1 AND 2, IS LOCATED BETWEEN THE SCAVENGE PUMP OUTLETS AND THE FUEL HEATER

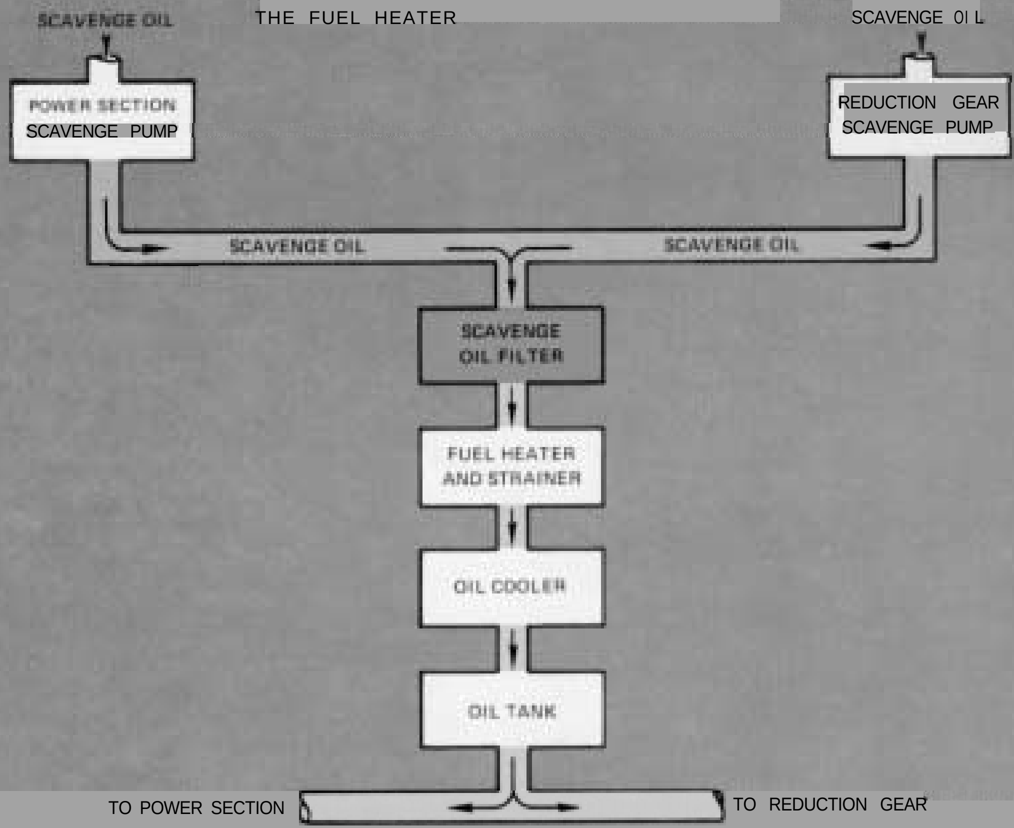


FIGURE 1

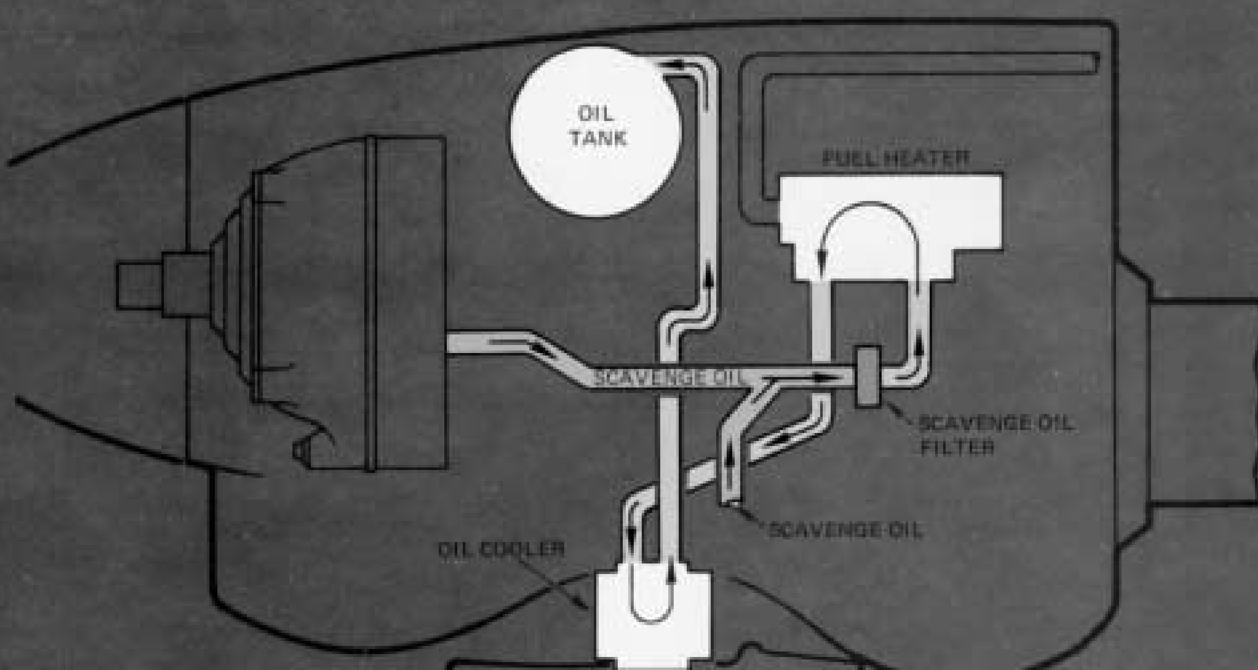


FIGURE 2

Previous Page Table of Contents Next Page

FIGURE 3. (above) A differential pressure (clogged filter) indicator is integral to the filter assembly. FIGURE 4. (right) It is difficult to install the element upside down – remember the tang end goes up. Sometimes stamped with the word "top".

Another factor which can contribute to high back pressure and associated problems is incorrect installation of the filter element. It should be installed with the element tangs "UP." Someelements are stamped on the tang end with the word "TOP." Mis-installation results in a higher than normal filter differential pressure and button "popping" The oil system hoses should be checked to see if they were kinked during installation. Any of these problems can cause oil venting from the overboard drain during flight. Replacement of the filter element and/or checking and correcting the QEC back pressure should correct the problem. If venting continues, consideration should be given to possible inefficiency of the main scavenge oil pump.

The following checks should be performed:

1. Make an operational leakage check after a filter assembly or filter element has been replaced.

2. If oil venting from the overboard drain is experienced and high scavenge oil back pressure is suspected, measure the back pressure in accordance with approved procedures.

3. If the differential button indicator "pops":

   a. Reset it with a definite feel of bottoming out. This should prevent a premature indication of filter accumulation.

   b. If the indicator is again actuated after a ground run, replace the element. If this does not correct the condition, remove the filter assembly for a functional check and repair of the indicator.

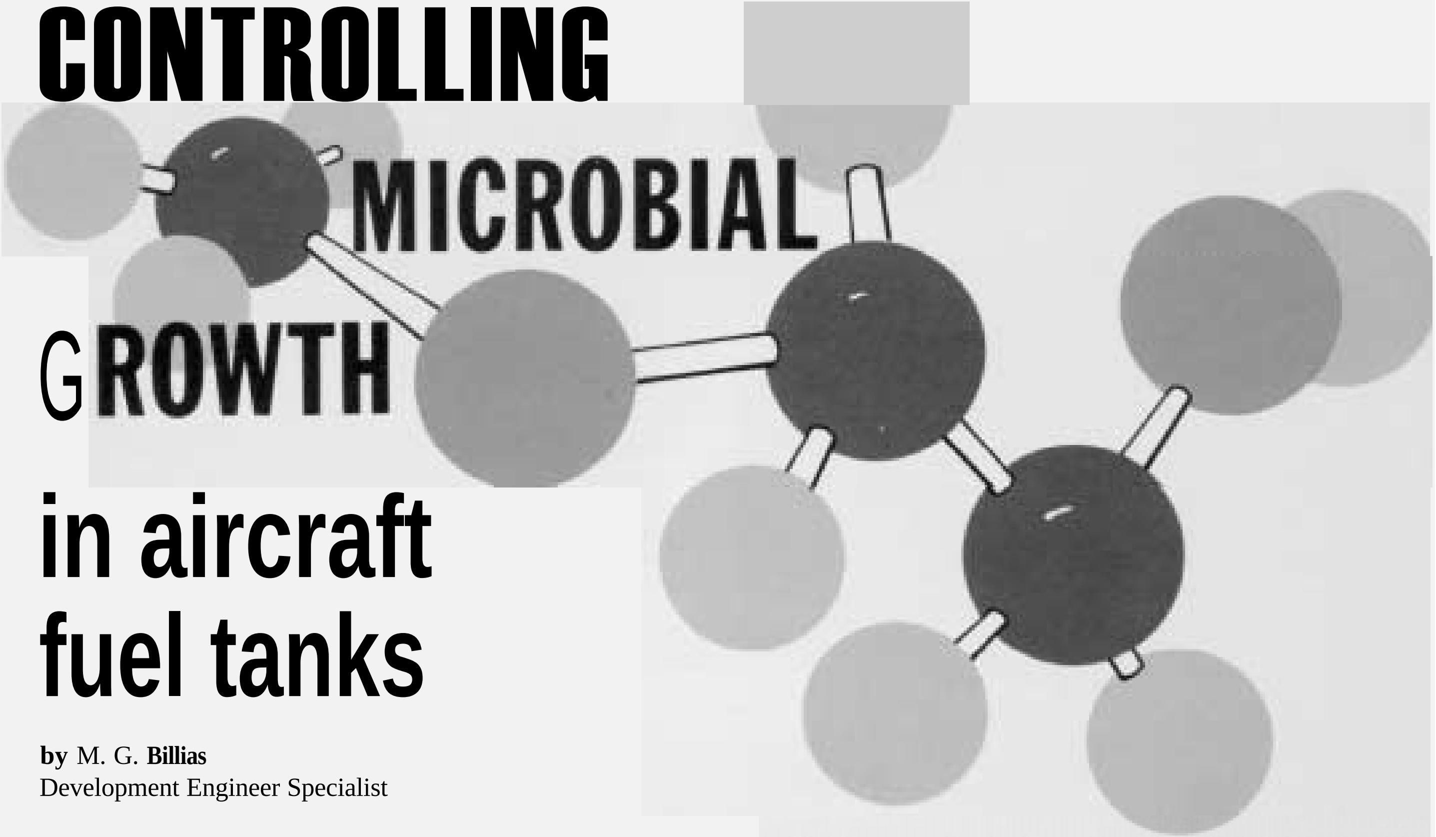
4. With initial installation of the filter assembly on in-service engines, it is recommended that filter elements be replaced after 25 hours of engine operation whether or not the indicator is actuated. If the indicator is actuated prior to 25 hours of engine operation, replace the element.

If the external scavenge oil filter kit is installed on an engine/QEC which has been properly maintained and the element is replaced when required, the filter will accomplish its intended purpose of keeping the oil system clean, prolonging bearing surface life.

FIGURE 5. When resetting the indicator button make sure it is well seated – but don't use excessive force.

Previous Page Table of Contents Next Page

CONTROLLING MICROBIAL GROWTH in aircraft fuel tanks



by M. G. **Billias**
Development Engineer Specialist

Fuel tank corrosion and contamination by microorganisms has been reported many times over the past fifteen years. Although solutions have been found to prevent or control many of the problems, the magnitude of the problems varies depending on environment, operating conditions, and action taken concerning the problems. Further, some operators are not aware of the potential hazards of using fuels contaminated with microorganisms. For this reason, it was thought timely to provide a brief history of the “bug problem” and the corrective action taken by the airframe manufacturers, fuel suppliers, and the military; and the preventive action that can be taken by the customer to safeguard against costly and time-consuming repairs.

THE CAUSE – How it Happened

Microorganisms (often referred to as bugs) are found almost everywhere on this planet – land, water, and in the air. Certain materials are foods, or nutrients, for these microorganisms, and hydrocarbon fuels fall into this category (see Figures 1 and 2). This fact has been known for many years; however, it had never caused a severe problem until the advent of the jet engines and the jet fuels. The reason is that even though fuels are nutrient for the bugs, they cannot live in the fuel alone; they require high humidity and/or water in order to live and propagate. Reciprocating engines use highly refined high-octane aviation fuel (avgas). The weight (or specific gravity) of avgas is significantly lighter than water permitting easy separation of water and fuel; thus, there is less entrained water with avgas than with jet fuels. Secondly, the solubility of water in avgas is significantly less than in jet fuel; thus, there is less dissolved water in avgas. Thirdly and most importantly, avgas, in order to obtain its high octane rating, contains an organic lead compound (tetraethyl lead) which is toxic to microorganisms. Jet engines burn a variety of fuels, including kerosene, Jet A-l, and all the JP series (JP 1-JP 5) each containing a broad mixture of hydrocarbons.

The jet engine, having no pistons or cylinders, has no need for high octane fuels. The main concern is heat content per unit weight or per unit volume. The early jet fuels contained no additives that were biocidal to microorganisms. Up to a few years ago (late 1950’s, early 1960’s), little effort was made to keep jet fuel free of

FIGURE 1. Microbial growth — this is a magnification of microbial growth in the water layer of a fuel tank.

water. In some storage tanks the fuel was floated on a layer of water. Some of these "water bottoms" were grossly contaminated with minerals, rust, salt, and bugs. The ability of the jet fuel to keep the entrapped water suspended is enhanced by the presence of surface active agents (surfactants) left in the fuel by the refinery. Hence, the water and all the other contaminants combine to provide an excellent environment for the prolific growth of microorganisms.

THE EFFECT – **Damages Resulting**

All of a sudden a huge problem hit the jet aircraft industry. Prolific microbial growth in aircraft fuel tanks clogged fuel filters and pumps, sometimes resulting in fuel starvation and engine flameouts. The bugs attached themselves to tank structure and in many cases consumed or otherwise degraded the organic tank coating (Buna-N), degraded the chemical finish of the metal, and caused severe corrosion damage to the aircraft structure (see figures 2, 3, and 4). In many cases, wing skins were corroded beyond repair and had to be replaced. The entire industry was affected – commercial airlines, the military, foreign operators, and virtually all users of jet aircraft. The magnitude and severity of the problem demanded immediate investigation and corrective action.

ACTION - To Solve **the Problem**

The USAF undertook to coordinate the effort for the military services. All affected organizations were invited to participate in the corrective action. The problems were defined; the causes were described to the degree they were known; and corrective action was outlined. The action taken, in general, was as follows:

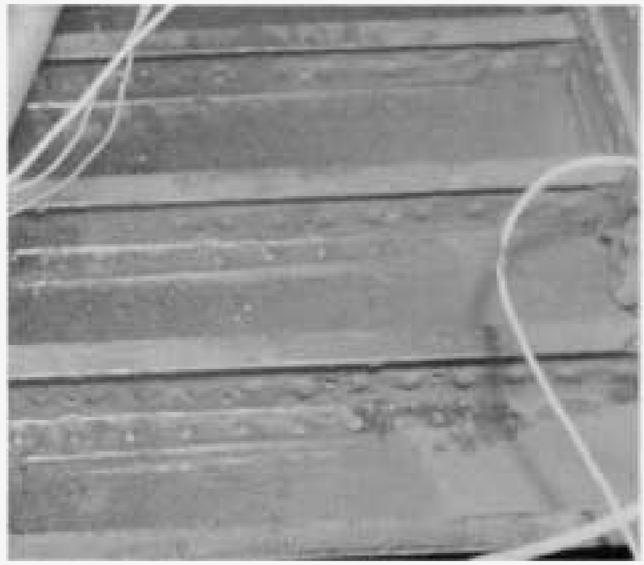


FIGURE 2. A C-130 fuel tank showing the bug growth (black mat) attached to the tank bottom. Tank coated with Buna-N (MI L-C-4383) which is nutrient to the bugs.

- The aircraft users (USAF, USN, commercial airlines, etc.) were charged with the responsibility of cleaning up their fuel storage and handling facilities and equipment in order to maintain clean, dry fuel for their aircraft.

- The USAF was charged with the responsibility of revising the jet fuel specification, requiring more stringent quality control.

- The oil companies were charged with the responsibility of developing a biocidal additive for the turbine fuels and to deliver clean, dry fuel.

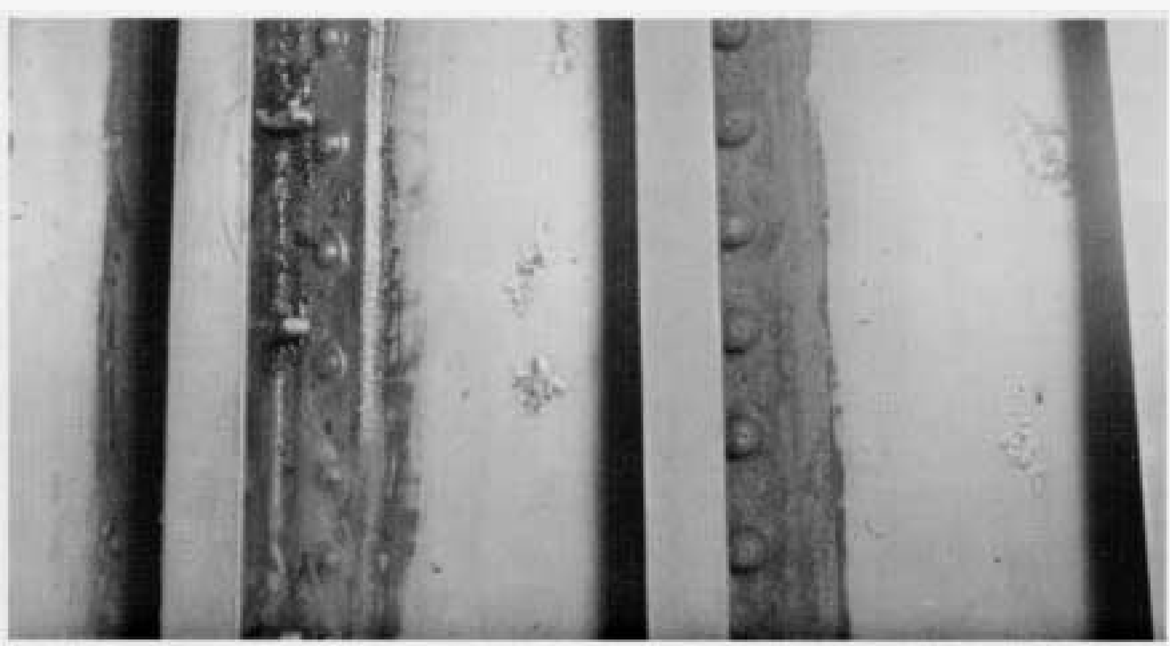


FIGURE 3. C-130 fuel tank after removal of the Buna-N shows the corrosion blisters and pockets.

- The aircraft manufacturers were charged with the responsibility of developing better chemical and organic finishes for aircraft fuel tanks to resist the new corrosive environment.

- The Army Bacteriological Laboratories were to assist the oil companies and the aircraft manufacturers by identifying the type of microorganisms being encountered in fuel tanks.

RESULTS OF EFFORTS

All aspects of this massive effort were successful! All objectives were accomplished to the degree feasible and practical. This, of course, required a considerable length of time. It was not possible to renovate or replace equipment and facilities "overnight."

- Efforts were started immediately to clean up fuel storage and fuel handling equipment; to eliminate "water bottoms"in storage tanks; and to provide clean fuel, free of entrained water and other contaminants.

- The fuel specification MIL-F-5644 was revised to tighten the quality requirements.

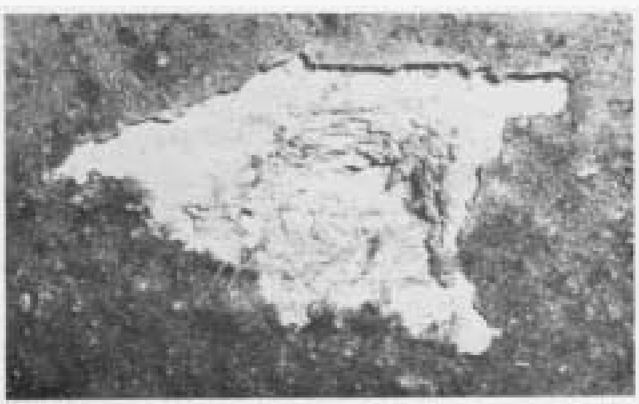
- The recently developed anti-icing additive PFA 55MB proved to be biocidal and was adopted for use by the USAF (see Figure 5). Later the USN incorporated the MIL-I-27686 anti-icing additive into its fuel.

- The airframe manufacturers, after intensive testing, developed an excellent fuel tank coating (MIL-C-27725) which is extremely resistant to contaminated fluid environments. The Buna-N coating which was previously used proved to be a nutrient to microorganisms and was discontinued.

- A new chemical finish, sulfuric acid anodize with a dichromate seal, proved to have greatly improved corrosion resistance over previously used chemical finishes and, under a controlled thickness of the anodic coating of 0.0003 to 0.0005 inches, did not degrade the fatigue life of the metal.

CURRENT STATUS

The above sounds like a great "story book" success story, and indeed it was. It was an excellent example of how an industry-wide problem can be identified and solved when all affected industries and organizations cooperate. Before it is concluded that the bug and corrosion problems are all past history, let me assure you that they are not. In the United States the problem, generally, is under control. The USAF and USN use the biocidal anti-icing additive in their jet fuel. They have cleaned up their fuel storage facilities, and they use the clean fuel with additive in all their foreign bases. Thus, the U.S. military have essentially eliminated this problem. For economic reasons, the commercial airlines in the U.S. have chosen not to use the biocidal anti-icing additive. All have cleaned up their fuel storage and fuel handling facilities. Some, in order to "control" the bug growth to some degree, utilize a biocidal flush of aircraft fuel tanks and fuel systems at every "letter check" (each 1,000 flight hours). During this maintenance period, a fuel tank is filled with fuel containing a biocide and is allowed to soak for a few hours. The fuel is then transferred through the fuel lines into each tank and allowed to remain for a specified length of time to kill (hopefully) all microorganisms. At the end of the maintenance period, the fuel is consumed in the engines. The success of such a process depends on many factors, including cleanliness of fuel used, environment of operations, and usage of the aircraft. According to some airlines, this process is an economical way to control the bug problem; others say the process is almost useless. Other operators, unfortunately, are doing little or nothing to ensure clean, dry fuel free of microorganisms.



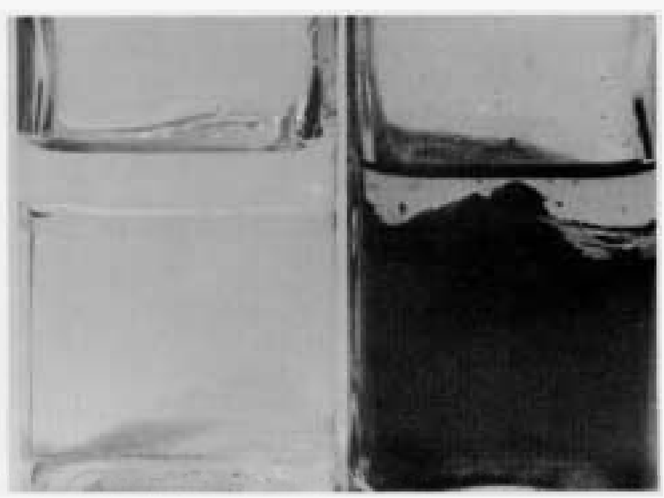


FIGURE 4. (above) A close-up of exfoliation corrosion this corrosion can penetrate the entire thickness of the skin plank.
FIGURE 5. (right) The PFA 55MB can keep your fuel free of microorganisms when properly used.

Previous Page Table of Contents Next Page

RECOMMENDATIONS

It has been verified by the USAF, the RAF and many other organizations that the proper use of a biocidal additive in the fuel will eliminate the microbial growth and the resulting corrosion

It is strongly recommended that only fuel with a biocidal additive be used in aircraft fuel tanks. The military specification MIL-T-5624 requires the MIL-I-27686 anti-icing inhibitor in JP4 and JP5. The chart at the right lists the various NATO fuels, with and without the additive, and the U.S. equivalent fuels.

The MIL-I-27686 anti-icing inhibitor is not the only inhibitor that can be used to control the microbial growth. Another additive called ***Biobor JF*** was developed and successfully tested. This additive contains a boron ester, and although it has no anti-icing properties, it is biocidal to microorganisms at a minimum concentration of 250 ppm (parts per million). For the recommended concentration of 270 ppm, the volume percent additive necessary is 0.02%; whereas, the MIL-I-27686 additive is used at a volume percent of 0.1 to 0.25%. Biobor JF has been tested and approved for continuous use on the Lockheed JetStar and for intermittent or noncontinuous use on the C-l 30. Only MIL-I-27686 anti-icing additive is approved for continuous use in the C-130 engines. Biobor JF may be used in the fuel as a biocidal flush at every "letter check" as described earlier. The concentration of Biobor JF in fuel shall not exceed 270 PPM which is equivalent to 20 PPM elemental boron. This restriction is imposed by the engine manufacturer.

The following companies have been granted licenses by Phillips Petroleum Company to manufacture and sell the biocidal anti-icing additive throughout the world. The additive is identified as PFA55MB or as MIL-27686.

Australia	Imperial Chemical Industries of Australia and New Zealand, Ltd.
The Netherlands	Shell Internationala Research Maatschappij
France	Societe des Usiness Chirniques Ugine Kuhlmann
Germany	Badische Anlin - & Soda-Fabrik AG
Italy	Societa Industriale Catanesa S.p.A.
Japan	Mitsui & Co., Ltd. Showa Denko K.K.

NATO Fuels	U.S. Equivalents	MI L-I-27686 Anti-Icing Additive
F-30	Jet A	No
F-34	Kerosene, Jet A-l	Yes
F-35	Kerosene, Jet A-l	No
F-40	JP 4 (MI L-T-5624)	Yes
F-42	JP 5 (MI L-T-5624)	Yes
F-44	JP 5	No
F-45	JP 4	No

Houston Chemical Company, Houston, Texas is also licensed to sell the anti-icing additive and in addition sells metering devices for incorporating the additive while refueling. The Houston Chemical Company name for the additive is "Prist."

In addition to the use of a biocidal additive in the fuel, if corrosion is to be minimized, it is also necessary to:

1. Keep fuel tanks as free of water as possible. This can be accomplished by keeping clean, water-free fuel storage tanks and using a "final filter" in the fuel line that will absorb dispersed water prior to delivering the fuel to the airplane.

2. Drain the accumulated water from aircraft fuel tanks daily using the condensate drains.

3. Inspect the integral fuel tanks on a periodic basis and maintain the integral fuel tank protective coating system. The presence and accumulation of microorganisms should be removed by cleaning, flushing, and sterilizing the tank. The use of contaminated fuel should be stopped; otherwise, little will have been accomplished by the cleaning process. Older tanks, coated with Buna-N, may still be holding up well and functioning properly if clean, non-contaminated fuel has been used. If fuel contaminated with microorganisms has been used for prolonged periods, the Buna-N coating may be so degraded that repair or replacement of the coating on the lower surfaces may be necessary.

Previous Page Table of Contents Next Page

another Lockheed Hercules first . . .

Locating Leaks in auxiliary fuel tanks by color

by: D. J. Lipscomb,
Material & Processes Engineer, Senior

With some exceptions, Hercules airplanes have two auxiliary fuel tanks in the center wing section. Each tank consists of three flexible bladder cells made of synthetic rubber. They are located in cavities between the inboard engines and the fuselage, and between the wing front and rear beams.

COLOR COATING ADVANTAGES

On Airplanes, Serial Number LAC 4461 and up, each bladder cell is coated on all exterior surfaces, except the top, with a colored, fuel soluble compound. The purpose of the coating is to aid in leak detection and location. It can distinctly color any leaking fuel from the auxiliary tanks sufficiently for you to ascertain which individual cell is leaking; and, at the same time, it will provide a permanent visible trace of the fuel path on the cell exterior. This locates the point of leak origin. The color coating can make leak detection and repair of bladder cells possible without removing the cell from its cavity.

The leak detection coating material can be applied to any Hercules bladder cell at an appropriate time when they are removed, Application instructions appear later in this article.

CELLS INSTALLED

The bladder cells are secured to the center wing structure by cord lacing and rigid fasteners in combination. They are supported at the sides by attaching bolts around the interconnecting holes and plumbing support fittings. The cell bottoms rest on backing boards above the lower wing surface internal stringers except in an area below the center bladder cell. Here a sump extends downwards to an access door in the lower skin of the wing. The auxiliary tank booster pump and condensate drain valve are mounted on this door. Removal of the door provides the only access to the interconnecting cells.

Openings in the side walls of the center bladder cell interconnect this cell with the cell on each side through a corresponding hole. The walls of the connecting cells are secured together, as well as to the bulkhead around the openings, with bolts and nut rings.

CAVITY DRAINS

Each auxiliary tank cavity is provided with an inboard and an outboard set of drain holes, which are located in the lower surface skin panels. The inboard drains (located at approximately wing station 72) consist of open holes that allow any condensate or leaking fuel to be collected in a trough. This trough is fitted with a line that is routed to the lower surface of the respective main landing gear wheel well fairing. This drainage system is permanently open.

The outboard drain valves on early Hercules (through 4299), that have not been modified, consist of 14 manual drain valves located at approximately wing station 174. On Hercules of recent production and those having center wings modified to the new configuration, the outboard drains (located at the same wing station 174) consist of 14 holes which are permanently open. These holes allow drainage into a trough that is fitted with a single manual drain valve. (See Photograph on Page 15). If any fuel, colored or clear, is observed at the inboard drains or can be drained from any of the manual drain valves, a leak from an auxiliary tank or plumbing is-indicated.

INSPECTION

Inspection of Bladder Cells is covered in your Maintenance Manuals. The leak detection coating on the cells does not eliminate the requirements expressed in current manuals. However, this coating will enable you to more efficiently perform any task related to inspection for leaks.

We point out that, whenever possible, bladder cells should be inspected without removing them from the airplane. This inspection should be very thorough and complete to prevent the unnecessary disassembling and removal of the cell. Locate and confirm true sources of all leaks before beginning repairs. Certain repairs can be accomplished on installed tanks. Try to complete all repairs with one tank entry.

Take all precautions directed in the sections of your handbooks related to tank entry and to safety in fuel handling.

CLUES FROM THE AUXILIARY TANK CAVITY DRAIN SYSTEM

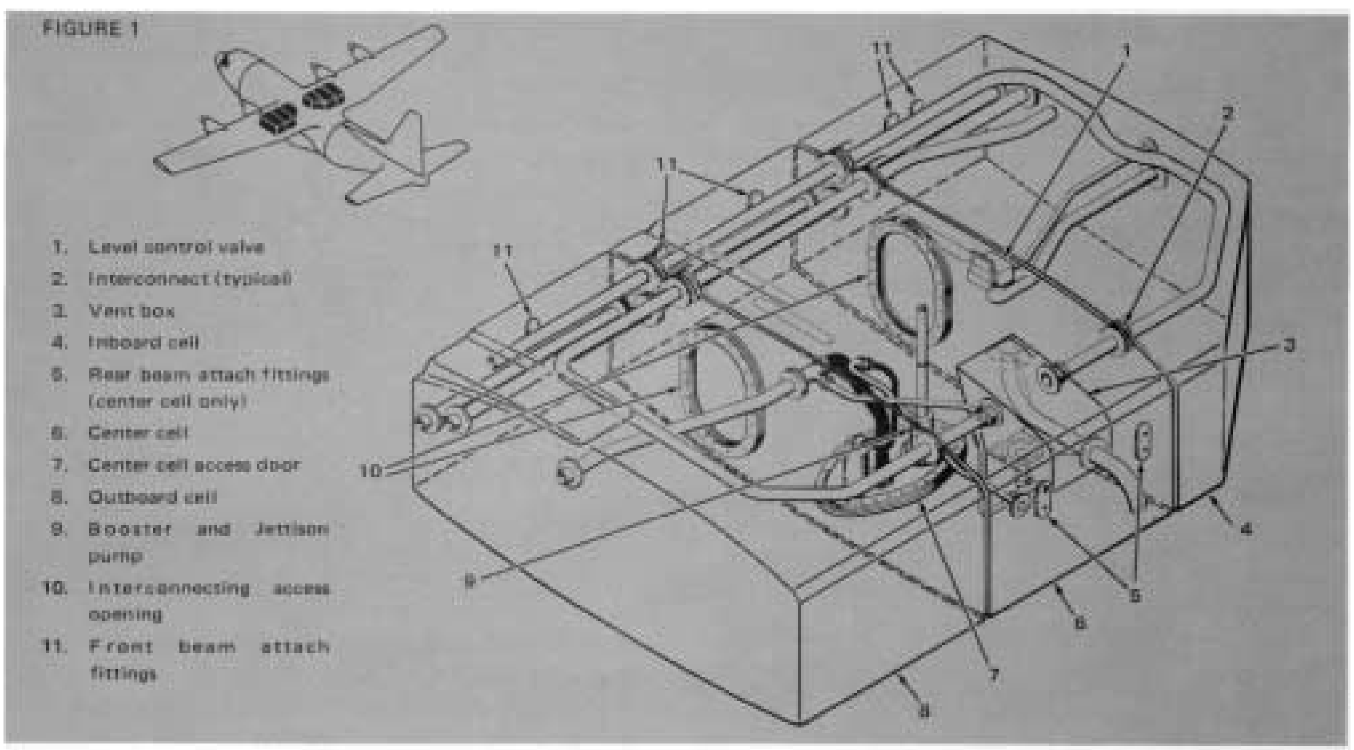
As stated previously, if any fuel, colored or clear, is observed at the drain outlets, an auxiliary tank or plumbing leak is indicated. When the bladder cells have leak detection coating, the color of the leaking fuel will usually identify the cell that requires more attention.

The TEMPORARY attachment of a plastic bag on the end of the inboard drain line may allow more meaningful leak detection by collecting sufficient colored fuel to determine which auxiliary tank bladder cell is leaking. The presence of clear fuel from cavities with coated cells is usually indicative of an interconnecting fitting leak or a cell leak which has existed for a long time and has washed away the colored coating. This latter condition will, in most instances, be revealed by small traces of colored deposits around the end of the drain line.

Current production Hercules and those with new center wings have a single manual condensate drain valve at Wing Station 174 near outboard wall of aux tank cavity.

CAUTION

ALL CONTAINERS USED FOR FUEL LEAKAGE COLLECTION MUST BE REMOVED PRIOR TO FLIGHT.



INSPECTION AND LEAK DETECTION OF INSTALLED CELLS

INTERIOR SURFACES

Follow instructions in your Hercules Maintenance Manual to gain access to the suspected cell and to inspect the cell interior for the leak source. Look carefully for pin holes, abrasions, and cracks in the cell wall, as well as for loose interconnect fittings and for foreign material trapped between fitting connections. If the leak source cannot be found from inside the cell, inspect the cavity and cell exterior surfaces as outlined herein and in your Maintenance Manual. Exercise care to prevent residual fuel from contacting the exterior of the cells in order to avoid a false indication of leakage.

WARNING

DURING INSPECTION OF THE AUXILIARY TANKS AND DURING LEAK DETECTION ACTIVITIES DO NOT PERFORM ANY OPERATIONS ON THE AIRPLANE OR ANY WORK IN THE IMMEDIATE AREA OF THE AIRCRAFT WHICH COULD CAUSE A FIRE OR EXPLOSION HAZARD. COORDINATE SIGNALS BETWEEN THE MAN INSIDE AND THE MAN OUTSIDE THE TANK. VENTILATE THE TANK CONTINUOUSLY.

CELL EXTERIOR SURFACE INSPECTION INSIDE CAVITY

Rely on your Hercules Manuals for details on gaining access to the cavity and inspecting the cells. Briefly, the procedure is as follows:

Access beneath the center cell is gained by collapsing the cell upwards and crawling into the cavity through the lower wing surface access opening. Access to the bolts securing the cells to the front beam is gained by removing access doors in the lower surface of the wing leading edge, inboard of each inboard engine nacelle. Access to fasteners and fittings retaining the center cell to the rear beam is gained by removing (life raft) access doors on the wing upper surface aft of the rear beam at approximately wing stations 110 and 130. See Figure 1 on Page 15.

Access to either of the other two adjacent cavities (below the inboard or the outboard cells) is gained by separating the cell from the center cell at the manhole access opening on the side of the center cell. Crawl into the adjacent cavity beneath the suspected cell through the side manhole access opening. Untie lacing cords at each lower corner of the cell being inspected (four places). Collapse cell upwards as required for access.

CAUTION

MAKE SURE THE TEMPERATURE OF THE CELL AND CAVITY IS ABOVE 45 F BEFORE COLLAPSING THE CELL FOR ENTRANCE ACCESS. AFTER DEPUDDLING AND PURGING OPERATIONS ARE COMPLETE, WARM AIR (NOT EXCEEDING 120 F) FROM AN APPROVED EXPLOSION PROOF HEATER MAY BE USED FOR WARMING THE CELLS.

WARNING

THE FAN OF ANY HEATER USED IN FUEL TANK MAINTENANCE IS TO BE IN OPERATION BEFORE DUCTS OR HOSES ARE DIRECTED INTO CAVITIES OR TANKS. THE FAN IS TO REMAIN IN CONTINUOUS OPERATION UNTIL THE DUCTS OR HOSES HAVE BEEN REMOVED FROM THE AIRPLANE.

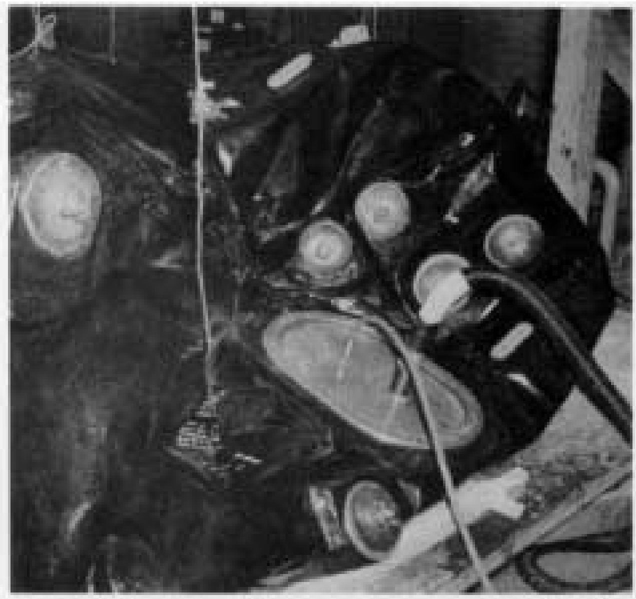
Lift the bottom of the center cell and examine the cavity for fuel puddles, which may be traced to fuel stains on the outside of the cells, indicating leak exit points.

On Airplanes (Lockheed serial numbers, including 4461 up) having bladder cells with leak detection coating, carefully inspect exterior surfaces on bottom and sides of the suspected cell as high as accessible for black streaks. Give particular attention to cell surfaces beneath all interconnect fittings. Leaking fuel dissolves the colored leak detection coating on the cell exterior exposing the natural black color of the cells. These fuel runs will appear as black streaks.

Trace black streaks to the point of origin. Minute holes in the cell wall may require confirmation as true leak sources by applying soap solution at the suspected defect on one side of the cell and then blowing high velocity air on the opposite side of the cell wall. Bubbles in the soap solution will confirm the presence of a hole. Keep air nozzle at least one inch away from the cell wall to prevent damaging the cell.

If the true source of all leaks cannot be determined during inspection of the installed cell, the cell will have to be removed from the airplane. Refer to the appropriate section of your Maintenance Manual for instructions on removal, inspection and leak detection of uninstalled cells. Data is provided in the instructions to enable you to evaluate the damage and determine what repairs are to be made. In some cases a cell must be replaced.

Previous Page Table of Contents Next Page



Rubber gaskets on plates cover openings, including bolt holes, to make bladder cells air tight. Cords suspended above work platform position bladder cell for inflation. A manhole cover provides connections for a manometer and air pressure. The cell below is inflated at 1/2 psi.

INSPECTION AND LEAK DETECTION OF UNINSTALLED CELLS

NOTE:

When a cell is removed from the airplane for any reason, it should be inspected for the conditions listed in your manual and all defects corrected prior to reinstallation.

On airplanes having bladder cells with leak detection coating, inspect exterior surfaces on bottom and sides of the cell again for black streaks. Minute holes in the cell wall may require confirmation as true leaks by using soap solution and air pressure as previously mentioned in this article.

If the leak source is not found in the steps above, the suspected cell should be tested by the “chemical” method using phenolphthalein crystals in a water-alcohol solution and ammonium hydroxide. Your Hercules Maintenance Manuals and/or T.O. l-l-3, Section XIII, Page 13-39, give details on conducting this test.

LEAK DETECTION COATING APPLICATION

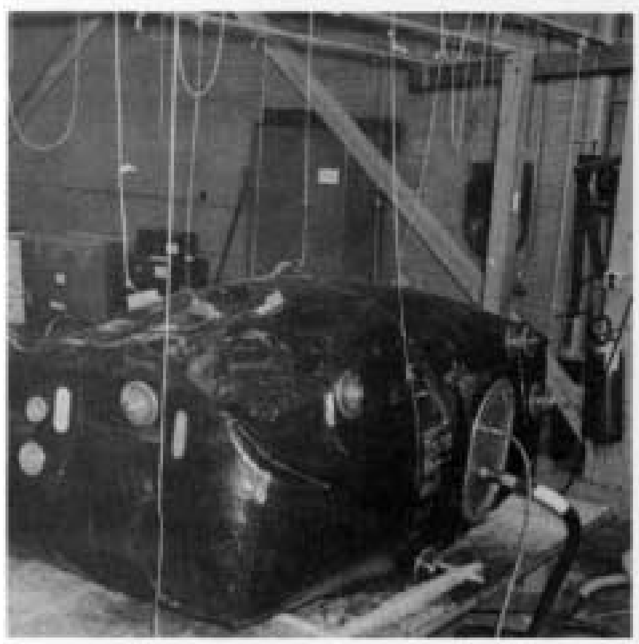
Following a leak test is a good time to apply the leak detection coating to cells not previously coated, or to touch up cells that have coating missing from a single area larger than one square foot. Inflating the cell (pressurizing to l/2 PSI) is necessary to accomplish either of these tasks.

Apply the leak detection coating to the cell after all inspection and repair procedures have been completed. The color and material for the leak detection coating are to be as shown in the following chart.

CELL LOCATION	COATING COLOR	APPROVED PRODUCTS*
Inboard	Red	PR 1009
Center	Blue	PR 1007
Outboard	Green	PR 1008

* Products Research and Chemical Corporation, 2919 Empire Avenue, Burbank, California 91504

Solvents used in the fuel leak detection coating have extremely low flash points, approximately O F, and should never be used near an open flame or other ignition source. Mix, apply, and cure the coating using only explosion proof equipment and tools.



Previous Page Table of Contents Next Page

A center cell, bottom up, is receiving a brush coat of blue leak detection compound. White stenciled specifications show through the coating.

Ingredients contained in the fuel leak detection coating are irritating and toxic; and should be kept away from skin, eyes, and mouth. When applying this coating on installed cells, personnel should wear protective clothing and air supplied respirators. Provide adequate ventilation and exhaust to prevent the concentration of toxic and flammable vapors.

Approximately two quarts of each color fuel leak detection coating are required per airplane. This amounts to one quart per cell, or one and one half gallons total.

APPLICATION OF LEAK DETECTION COATING TO UNINSTALLED CELLS -

NOTE:

If coating is applied following leak test, start with step (C).

(a) Install cover plates over all openings. Tighten the bolts to between 70 and 80 inch-pounds. Rubber seals are on covers for the openings, including the manhole covers. If air and manometer fittings are not in the cover plates available to you, you can fabricate such connections to fit one of the cover plates. T. 0. l-l-3 Section XIII page 13-40 Figure 13-42 gives details of a suitable plate with fittings.

(b) Inflate the cell with air to a pressure of 0.5 PSI maximum.

(c) Clean all exterior cell surfaces, except the top, by wiping with lint-free cloths moistened with Specification TT-N-95 or Specification P-D-680 solvent. Use liquid soap and hot water (not to exceed 120 F) to clean exceptionally dirty cells. Remove all soap residue with clear water and thoroughly dry the cell.

(d) Mix the applicable leak detection coating thoroughly before each application. Keep the coating in a closed airtight container when not in use. Do not use coating that appears too thick or thin or possesses any abnormal characteristics. If too thick, the coating will not go on smoothly. Do not thin coating.

CAUTION

THE LEAK DETECTION COATING CONTAINS FLAMMABLE SOLVENTS. USE ONLY IN AREAS WITH ADEQUATE VENTILATION AND EXPLOSION PROOF EQUIPMENT.

(e) The coating is applied by brush. Two uniform cross coats are required on all cell exterior rubber surfaces except the top. Air dry for fifteen minutes between coats and for 2 hours after the final coat.

(f) Dust all coated cell surfaces with Specification MIL-C-5024 talc, or soapstone, to prevent sticking when the cell is folded.

(g) Remove equipment and cover plates from the cell.

(h) Install or store cell as applicable per instructions in the Maintenance Manual.

Material	Suggested Source	Specification and Federal Stock Numbers
Phenolphthalein Powder, Reagent Grade	Local Chemical Supply	No Applicable Spec. 681 O-223-761 2
Ethyl Alcohol, Denatured	Local Solvent SUPPLY	MI L-A-6091 681 o-250-6808
Ammonium Hydroxide, Reagent Grade	Local Chemical Supply or F.H. Ross Company Atlanta, Ga.	O-A-451 68 1 O-222-9643
Liquid Soap	Local Chemical or Lathanot LA L Allied Chem. Corp. Morristown, N. J.	No Applicable Spec. 7930-664-0301
Talc, Soapstone	Local Rubber Goods Supply or Andrew Brown Company Marietta, Ga.	MI L-C-6024 No Applicable FSN
Solvent, Stoddard	Local Solvent Supply	P-D-680 Type I
Thinner, Aliphatic Naptha	Local Solvent Supply	TT-N-95A Type I I

Previous Page Table of Contents Next Page

If you were not familiar with the Lockheed developed fuel leak detection coating for fuel cells, we hope this article has introduced you properly to its use and advantages. Presently, this aid to troubleshooting fuel leaks is a Lockheed Hercules exclusive.

Hercules Maintenance Manuals are being updated to cover this leak detection system. An additional source for more details on fuel cells is T.O. l-l-3 which is a U. S. Military Technical Order covering the broad subject of aircraft tanks, as the title implies. The Title is: "Preparation, Inspection and Repair of Aircraft Fuel, Oil and Water Alcohol Cell and Integral Tanks".

service news

LOCKHEED AIRCRAFT SERIAL NUMBERS

In our articles we often reference Lockheed airplane serial numbers for the Hercules and JetStar when the subject is about particular items on some production models and the information does not have general application. These serial numbers are preceded by the letters LAC. Many of you are aware of these numbers.

When the airplanes become operational they are assigned other numbers to identify them individually and with their respective organizations. The U. S. Military organizations have their own systems. The U. S. Federal Aviation Administration assigns license numbers which appear conspicuously on the aircraft to identify them as private or commercial aircraft, etc.

The only relationship between our LAC serial number and your operational aircraft number is by cross reference in your records. If there should be a similarity between the numbers, it may only be coincidental, so serial number application of our magazine article should be verified before incorporation.

service news

StarTips

HERCULES PROPELLER VALVE HOUSING INSTALLATION

by: Ross Holdernan, Jr.,
Engineering Specialist – Hercules

When installing a propeller valve housing cover in the flight idle position be sure the input lever is in full reverse before adjusting the anti-backlash screw on the split gears in the cover assembly. Access to the screw is through the valve housing cover access plate opening. If unable to reach the adjusting screw through this opening with a straight, flat screwdriver, the input lever should be adjusted using the micro adjusting rings. (Reference Hamilton Standard, Propeller P5059 Manual for adjustment location). Failure to comply with this procedure could result in inability to retard the throttle below flight idle.

Previous Page Table of Contents Next Page

JetStar II

Previous Page Table of Contents Next Page

The lights are back on in the JetStar assembly building, After months of planning, engineering, and testing, JetStar II is in production. Deliveries will start in 1976.

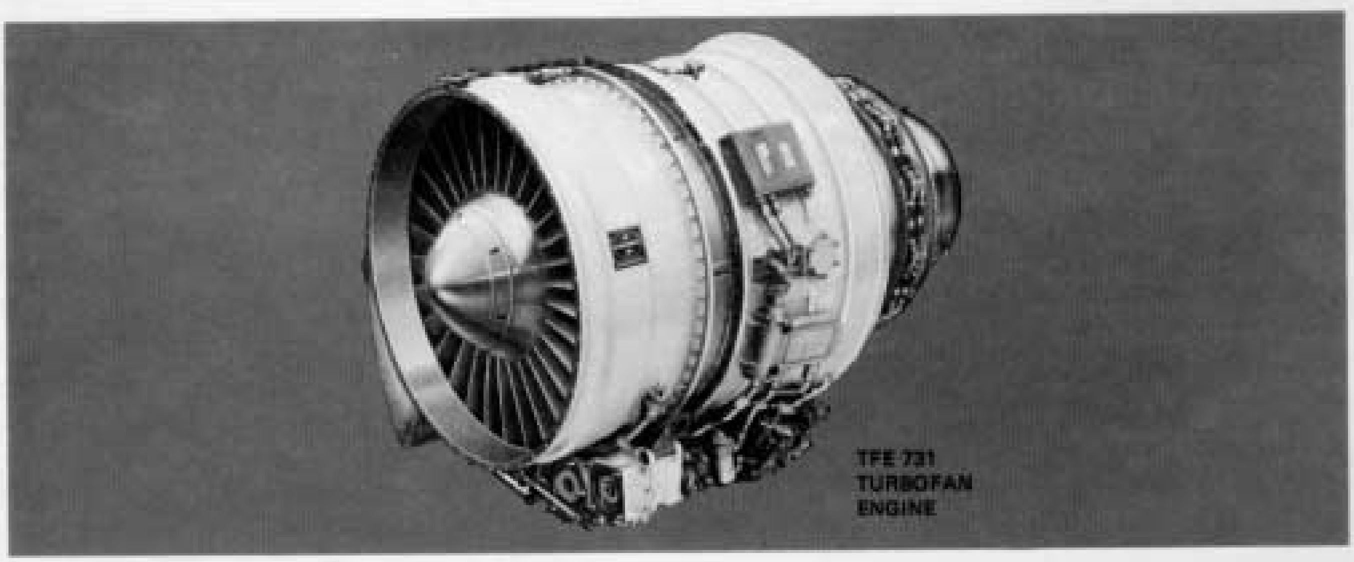
The JetStar II will make a solid contribution toward the efficient use of aircraft fuel supplies – up to 39 percent less fuel consumption than its Dash 8 predecessor, regarded as one of the world's finest business jet aircraft. Even though the JetStar II fuel load is the same as the Dash 8, it will travel almost 1,000 miles further without refueling. It will make a 500 nautical mile trip on 485 gallons; a 2400 nautical mile (non-stop) trip on 2270 gallons.

Designed for an NBAA VFR range of 2770 nautical miles and an IFR range of 2,400 nautical miles, preliminary flight tests indicate the JetStar II may do even better. Coast to coast, San Francisco to Honolulu, Denver to Paris with only one fuel stop – at speeds up to 564 miles per hour.

With the JetStar II, airport requirements are as much as 22% better than for the Dash 8. On a standard day, 10 passengers plus IFR fuel for a 1,000 nautical mile trip requires only 3,950 feet; 1,500 nautical miles only 4,600 feet.

In addition to fuel economy, the JetStar II will be a good neighbor the world over. Improvements have been made in reducing noise levels and eliminating visible smoke emission. The Garrett AiResearch Turbofan engine is. quieter, cleaner, more economical, and has good takeoff and climb performance.

The basic JetStar structure has been proven over thousands of flight hours and millions of air miles. Now fatigue and corrosion resistance have been improved by a factor of 5 or more by a change in aluminum alloys. Wing tank planks and landing gear are just two vital areas where service life has been greatly extended.



Systems have been improved. Air conditioning and pressurization are accomplished by two full-time, independent systems, either one capable of maintaining normal system operation. An advanced technology three-wheel air cycle control unit provides more efficient and effective air conditioning at low engine speeds and for on-the-ground operation with the APU.

PHOTOGRAPHS ON FACING PAGE: The JetStar Building (upper left) is humming again. Juge Jaeger, Chief Engineer - Special Projects; Jack McCrea, JetStar Project Engineer: and Bill Bullock, JetStar Project Director (upper right) examine the first JetStar II Part. Jaeger, McCrea and Bullock look over the JetStar I I model in the JetStar Project Engineering section (bottom of page).

New light weight plug-in relays and solid-state components highlight changes in the electrical system. Improved switching permits more flexible use of the AC inverter power.

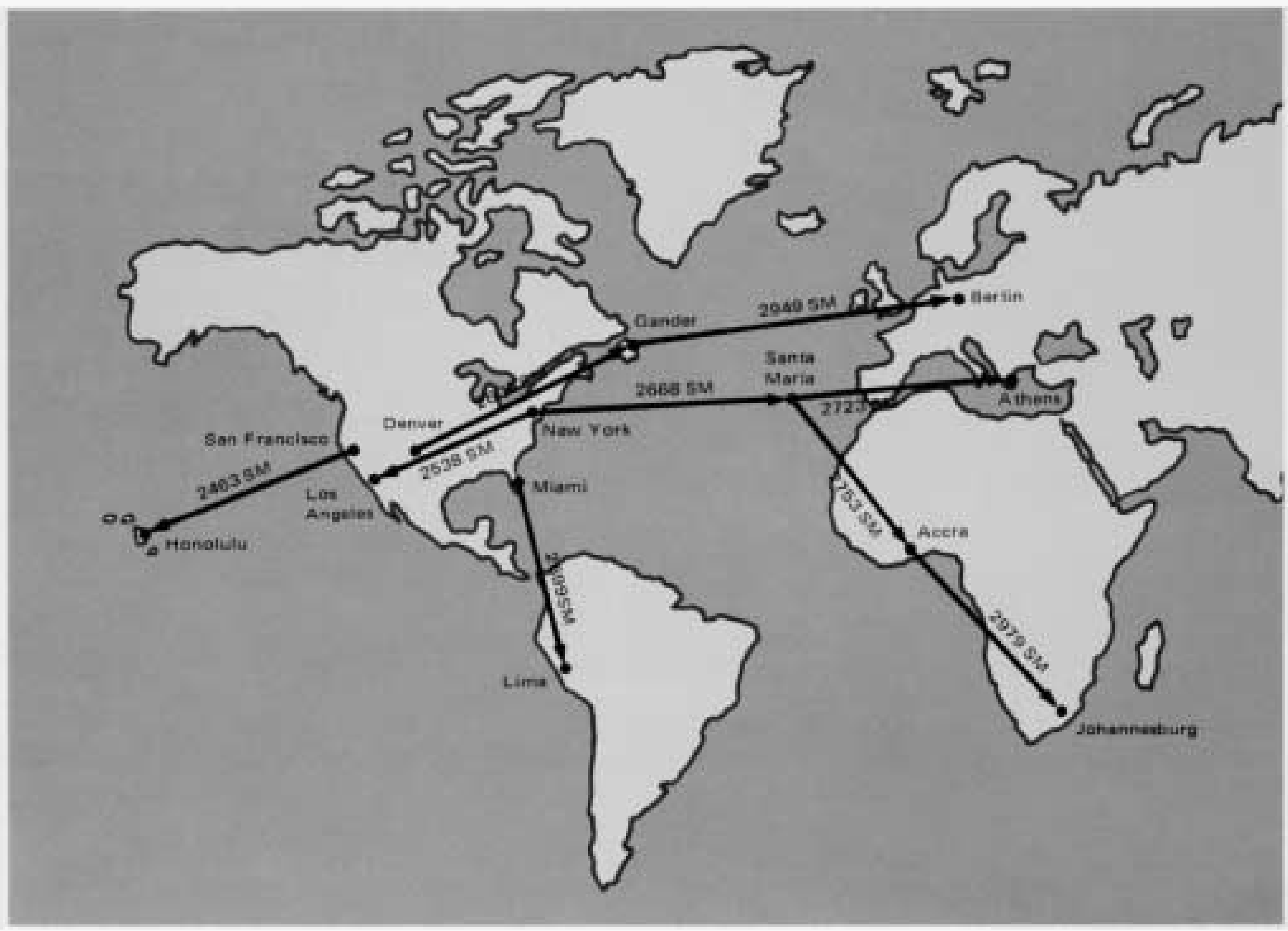
A complete fuel load can be on-loaded through the single point refueling system or over-the-wing. Fuel management is still simple and straight forward. Redesigned external tanks give better CG control with no attention from the pilot.

We have retained the much preferred JetStar size: walk-around conference size cabin with comfort for 10 passengers plus baggage; easy hangaring/parking; easy access and servicing. And of course we still have four-engine over water safety.

The new JetStar II offers more than economy, range, and comfort. It offers proven technology. It offers an airplane supported world wide. Its principle features, some of which are exclusive to JetStar II, are:

- Four fanjet engines
- Thrust reversers
- Fully modulated anti-skid braking
- Auxiliary power/air conditioning (optional)
- Single point refueling
- Complete anti-ice/de-ice systems
- Unrestricted, effective speed brake
- Dual wheels on all landing gears.

The JetStar has always been ahead of its class. Now the JetStar II is alone in its class.



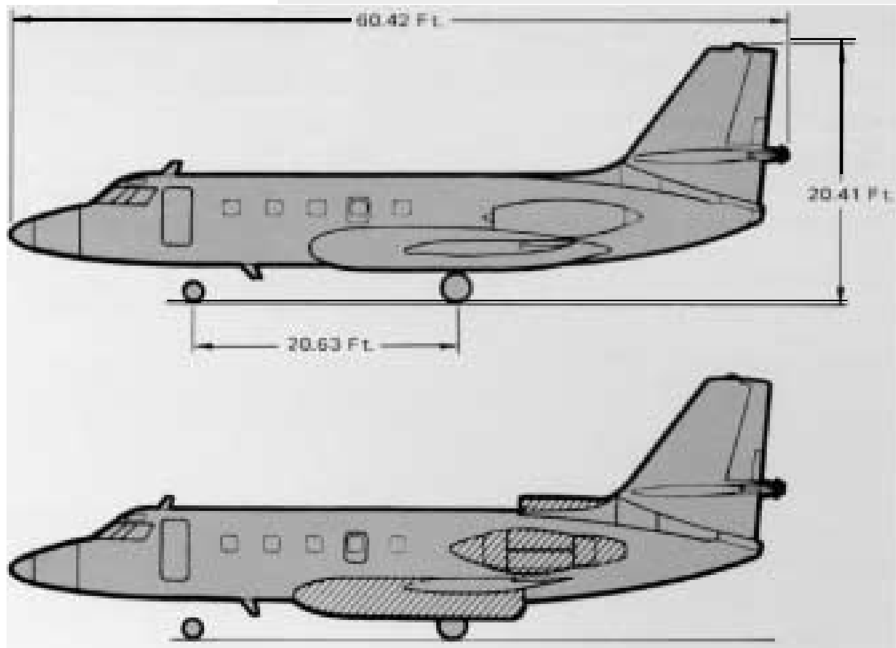
Previous Page Table of Contents Next Page

Dash 8

Maximum Weight = 42,500 Lbs.
10 Passengers, 2 Crew

JetStar II

Maximum Weight = 44,000 Lbs
10 Passengers, 2 Crew



General Arrangement

These drawings illustrate the external differences between the **JetStar II** and Dash 8. Overall dimensions, length, height, and wingspan, remain the same. The three most prominent differences are: larger nacelles, redesigned auxiliary fuel tanks and addition of a dorsal fin scoop.

FIRST Flight of Modified JetStar

by: Glenn M. Gray, *Lockheed Test Pilot*

Glenn is an ATR with ratings in JetStar, C-130 (L-382), helicopter, C-141, C-S and others. Flying since he was 16, he served in the U.S. Navy, part of the time as a Primary Instructor at Pensacola. He has flown Engineering Tests on the JetStar, C-130, C-141, C-5 and Hummingbird projects.

Your first impression is that it's sleeker, more powerful. The new turbofans and lowered external tanks definitely give the JetStar a different look. I had done my homework on the capabilities of the modified JetStar, but there is still a twinge of excitement and wonder about a first flight.

The modified JetStar doesn't have all the panel changes the JetStar II will have – but it does have the engine instrument changes. Primary for setting Power is Nl (fan) RPM in place of EPR. Preflight has changed only to include the new switches. Engine start is similar to the old start procedure. Added is the fuel control computer and fuel enrichment. The engines stabilize at idle very quickly and are extremely quiet.

Taxiing, except for the subdued engines, is about the same. The only difference is slightly higher idle thrust which is to be expected.

Interstage turbine temperature (ITT) and Nl RPM are used to set takeoff power. Acceleration is brisk and quiet. Rotation and climb out are pure JetStar, but I had to take a second look at the fuel flow gages to believe my eyes – 1600 pounds per hour per engine for all that power takes some of the bite out of the fuel crunch.

The JetStar II will have the fine handling qualities of all JetStars. New is the rudder bias system – added to compensate for the increased asymmetrical thrust of the higher thrust turbofans. Reduction of power or loss of an engine permits bleed air pressure from its opposite counterpart to displace the rudder. You can have almost maximum continuous thrust on an outboard engine with the opposite engine at idle and the only pilot effort required to maintain straight and level flight is a small amount of aileron.

Everyone who watched the first flight was impressed with the quietness. My major impression was the greatly reduced fuel flow rates. The JetStar II will be a real fuel miser with transcontinental range eastbound or westbound.

Previous Page Table of Contents Next Page

CUSTOMER SERVICE DIVISION
LOCKHEED-GEORGIA COMPANY
A DIVISION OF LOCKHEED AIRCRAFT CORPORATION
MARIETTA, GEORGIA, 30063

You get more out of a Lockheed Airlifter.

The C-130 Hercules can carry 45,000 lbs. of oversized cargo

The C-141 StarLifter can carry 72,000 lbs. of cargo across oceans

The C-5A Galaxy can carry 220,000 lbs. of anything from giant Chinook helicopters to 5 ton M 60 tanks

At Lockheed-Georgia, we have the only airlift production line in the U.S. There we build our airlifters to do what other planes can't.

Just look at the C-130 Hercules. It doesn't need ground-handling equipment to load or unload from its rear doors at truck-bed height. A rear ramp can be lowered so completely assembled trucks and bulldozers can be driven right off to work.

This timeless machine is the toughest, most proven airlifter in the world. That's one thing 37 nations agree on.

Then there's the C-141 StarLifter.

Five-ton trucks and other large vehicles can be driven on and off through its rear cargo doors. And palletized cargo has been unloaded in less than 10 minutes.

To give the C-141 even more capability, the U. S. Air Force is planning to stretch the fuselage and add in-flight refueling.

And of course, the C-5A Galaxy. No other plane being developed or redesigned can match it, in capability or mission flexibility.

For one thing, the C-5A can carry cargo impossible for other planes.

The C-5A also saves precious time in the air. It can be refueled in flight. Airdrop when you can't land.

The Lockheed Airlifters. They're the backbone of the Military Airlift Command. They're built by the company who knows more about building airlifters than anyone.

Lockheed
Lockheed Aircraft Corporation