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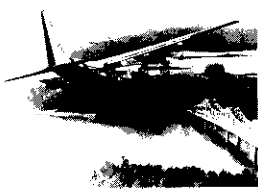

COVER: An early Brazilian Hercules on a test flight over Lake Lanier in north Georgia, USA.

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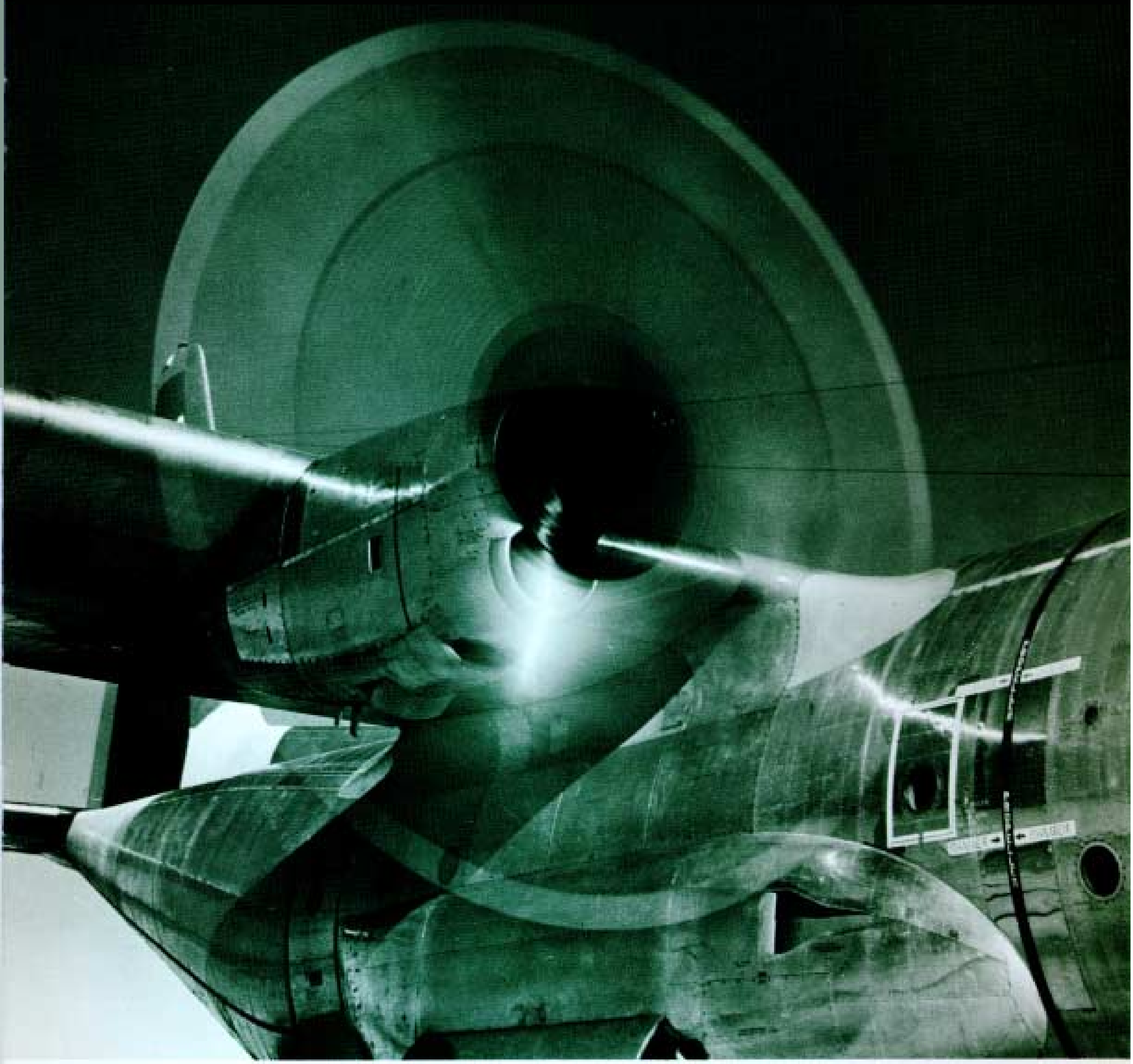
TURBINE TEMPEMTURE TROUBLESHOOTING

by AL BARRETT, *Chief Flight Engineer*

You don't have to be an expert to be able to successfully troubleshoot a turbo-prop engine. In fact, it is easy to do if you have four engines running at one time.



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One problem we arc seeing quite a bit these days is eroded thermocouples. When one or more of these turbine inlet temperature pickup units fail, we end up with incorrect turbine inlet temperature (TIT) readings in the cockpit, and incorrect temperature input to the temperature datum (TD) control system. Worse yet, we may also have excessive temperatures at the turbine itself.

Let's look at the following engine readings:

Engine No.	1	2	3	4
Torque (in-lbs)	15,000	15,000	16,500	15,000
TIT	1.010%	1.010 C	1,010 C	1,010 C
Fuel Flow (lbs/hr)	1,100	1,100	1,300	1,100

With the above readings and the TD system selected to AUTO, and with properly rigged engines; it is obvious the No. 3 engine TD valve is passing more fuel than is normally required for 1010°C TIT. If we retard the No. 3 throttle until the torque and fuel flow are even with No. 1, No. 2, and No. 4 engines, we find that No. 3 indicates approximately 988 C TIT. How ***can this be?*** Examine the chart, "INDICATED VS ACTUAL TIT · ALLISON T56-A-15/501-D22A."

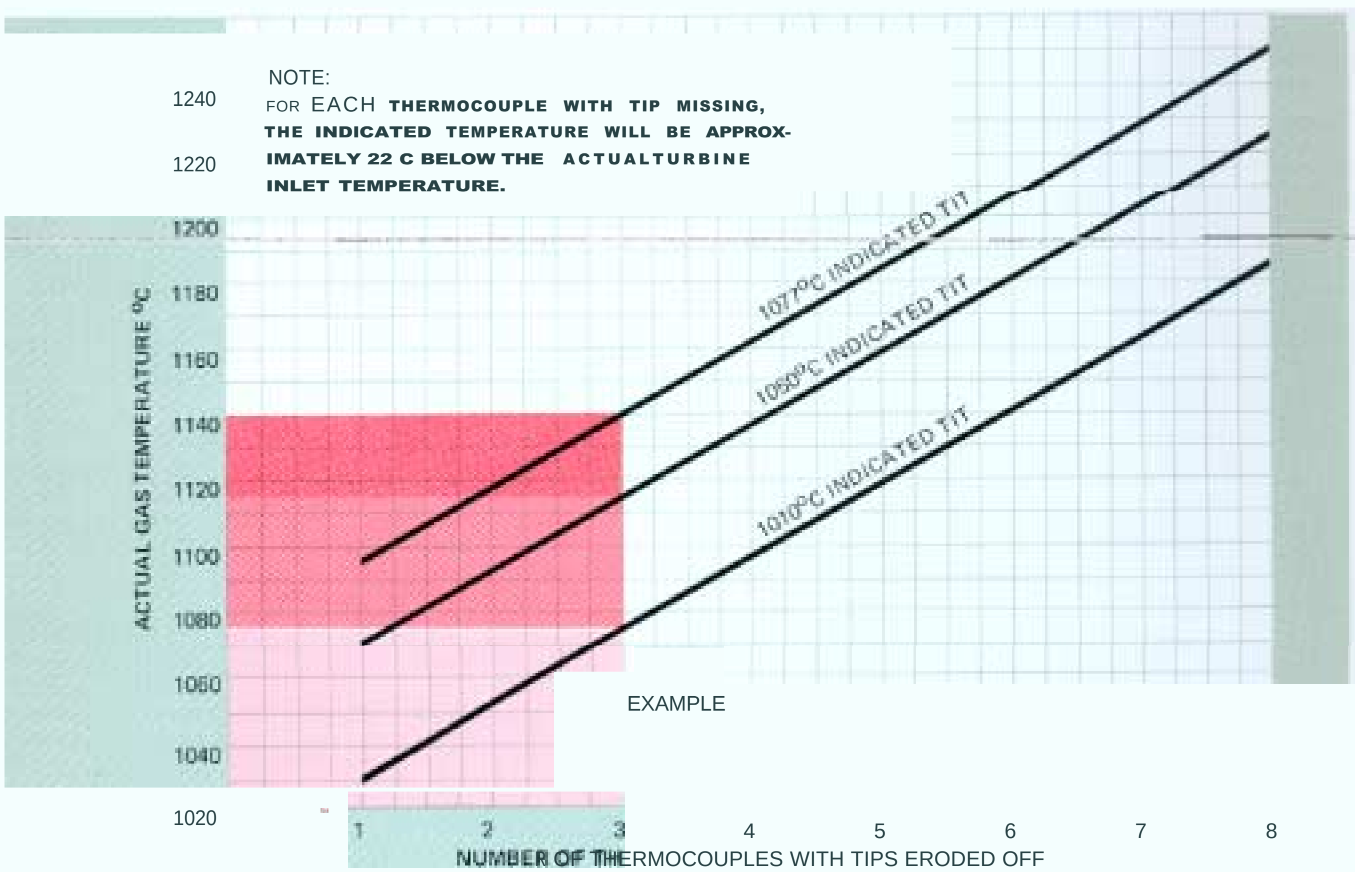
The "INDICATED VS ACTUAL TIT" chart might point to the cause of the problem we have with No. 3 engine. Well, how? This chart does not have fuel flow or torque references, but we in the cockpit do. Assuming good indicating systems, torque and fuel flow are proportional. Therefore, in the case of No. 3 engine, if we have 1,300 lbs per hour of fuel flow and 16,500 inch-pounds of torque the extra heat has got to be somewhere; and it is, right in the turbine area.

Let's try something else with this set of four engines. Switch them all to NULL and set the throttles to 1,000 lbs fuel flow.

Engine No.	1	2	3	4
Torque (in-lbs)	10,000	10,000	10,000	10,000
TIT	900 C	900 C	856 C	900 C
Fuel Flow (lbs/hr)	1,000	1,000	1,000	1,000

This set of figures indicates that two thermocouples failed to operate correctly (22 C per thermocouple).

We can see now, how over a period of time, turbine damage could result from TIT being well above takeoff



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limits, although we don't see it indicated in the cockpit.

With all the engines set to NULL, the throttles may not be perfectly aligned, because of differences in each fuel control, nor will the engine readings line up as neatly as they do in the example.

Things to remember:

1. If torque and fuel flow are higher on one engine than on the other engines, the TIT is probably higher also, even though we do not see it so indicated on the cockpit TIT gage.

2. With all engines in AUTO, the throttles should be approximately aligned when the same TIT is indicated.

3. If torque and fuel flow are high on one engine in AUTO with throttles aligned and equal TIT's, use the torque and fuel flow readings of the other engines to set power on the high reading engine.

4. When you see differences between engines, write it up, This may prevent serious turbine damage at alater date.

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StarTips

TURNBUCKLE TOOLS

The handiest and simplest set of tools we know of for adjusting turnbuckles consists of three items. A handle of wire to hold both cable terminals, a wrench of wire to turn the barrel and a guard for the wire ends when the tools are not in use.

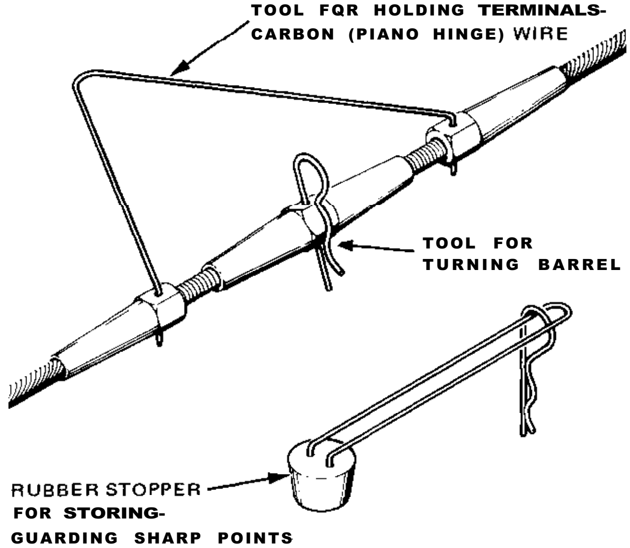
The holding tool starts as a piece of solid steel wire with a diameter that will fit snugly into the holes in the largest cable terminals. Material similar to the hinge pin wire for the Hercules wing leading edge is suitable. The length should be about 16 inches. Hard wire can damage ordinary wire cutters. Such wire can be notched on a grinder and broken. Finish grinding the ends to a taper approximately 3/8" long suitable for inserting into the smaller terminal holes. This one tool is good for both sizes.

With the wire cut to length make the easy bend in the center first, around a piece of 1/4 inch rod. The wire will spring out to the desired bend radius. The included angle should be about 75.

With the ends even, both of the 90 bends can be made at the same time. Clamp the ends down in a vise about one inch and pull the handle section toward you, hammering the wire gently near the vise to get the degree of bend you need. Don't make bend radius too small or wire may break. The purpose of these bends is to limit the penetration of the wire ends through the holes, which is not critical. It is important that the bent ends be parallel.

A wrench for turning the barrel of the turnbuckle can be made from the same steel wire; or a manufactured pin can be found at most hardware stores at a reasonable cost.

The illustration shows the holder and wrench in place for adjusting a turnbuckle.



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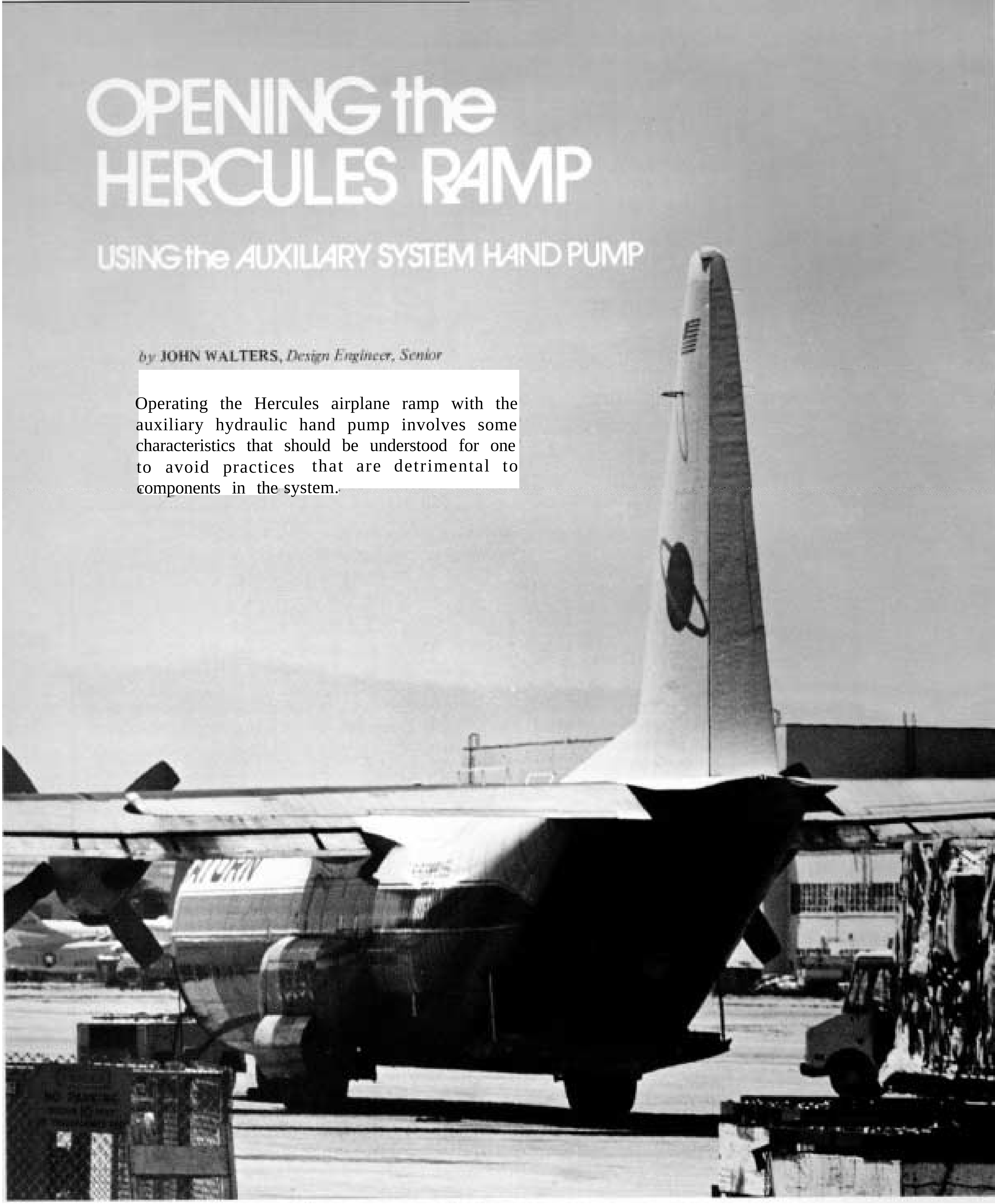
OPENING the HERCULES RAMP

USING the AUXILIARY SYSTEM HAND PUMP

by **JOHN WALTERS**, *Design Engineer, Senior*

Operating the Hercules airplane ramp with the auxiliary hydraulic hand pump involves some characteristics that should be understood for one to avoid practices that are detrimental to components in the system.



The rate at which a ramp can be hand pumped to the open position depends on several factors, including the ramp manifold valve manufacturer. There are three currently approved manufacturers and each one's valve has its own characteristics. The peculiar characteristics of the new Sterer valve has raised a question in the minds of some personnel as to what is normal. A short explanation of the events that transpire when the ramp is hand pumped to the open position will help us better understand what is normal during this operational mode.

The ramp selector valve module – one of three selector valves contained within the ramp manifold valve assembly – is a pilot operated valve assembly. This pilot operated valve is comprised of a main spool and sleeve valve plus two solenoid operated ball/poppet pilot valves.

The spool and sleeve valve has four ports, i.e., pressure, return, ramp down, and ramp up. It has three positions. In neutral, all ports are blocked. In a second position pressure is ported to ramp down, and ramp up is ported to return. In a third position pressure is ported to ramp up, and ramp down is ported to return.

The pilot valves are two position valves. In one position incoming pressure is ported to one end of the spool and return is blocked. In the other position incoming pressure is blocked, and one end of the spool is ported to return.

The force required to shift the main spool is more than a solenoid can develop. Therefore, the solenoids are used to actuate the pilot valves, which in turn port system pressure to the ends of the main spool. This pressure is used to shift the spool to the selected position. With the valve deenergized (switch in neutral position) system pressure is ported through one pilot valve to one end of the spool and equal system pressure is ported through the second pilot valve to the opposite end of the spool. With the same amount of pressure – whether one psi or 3000 psi – acting on both ends of the spool, the spool is balanced at the neutral position.

When RAMP DOWN is selected, one pilot valve is actuated as its solenoid is energized, and the other pilot valve remains as is (solenoid deenergized). The actuated pilot valve dumps pressure from one end of the spool, thus allowing the pressure on the opposite end of the spool to push it to the RAMP DOWN position.

Approximately 50 psi is required to generate sufficient force to shift the spool; if the pressure is less than 50 psi the spool will remain in (or near) neutral regardless of switch position. Shifting of the main spool opens the system pressure port to the ramp down port, and simultaneously opens the ramp up port to the return port.

If either the ramp control switch or manual control handle is positioned to one of the actuation modes (while 3000 psi is available from the electric motor driven auxiliary hydraulic pump) all manufacturer's valves will react the same. Pressure will be dumped from one end of the spool due to the actuation of one pilot valve, and the 3000 psi acting on the opposite end will shift the spool. This will port 3000 psi to one end of the ram-; actuating cylinders, and open the opposite end to return.

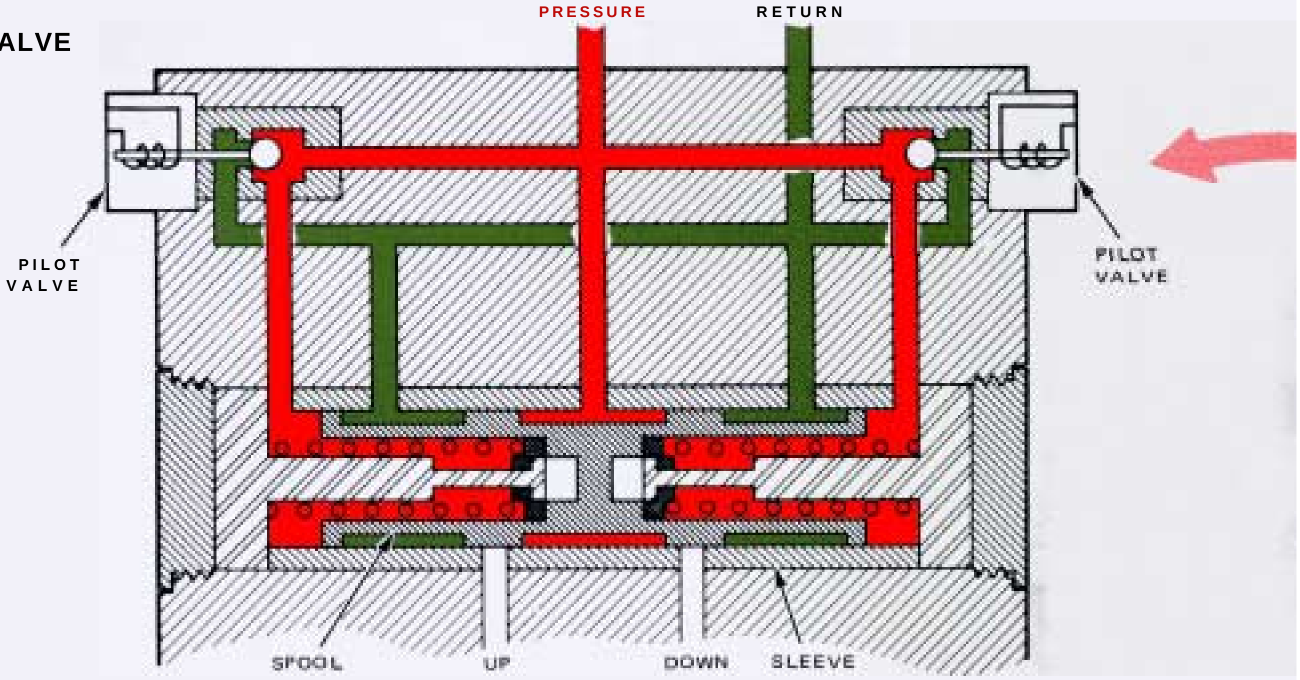
When the hand pump is used to supply power in lieu of the electric pump the differences between the various vendor's valves becomes more apparent. Several more variables become involved, which makes each vendor's valve exhibit somewhat different characteristics, depending on the design. When RAMP DOWN is manually selected (position 2 on control dial), and the hand pump is used, the rate at which the hand pump is cycled determines whether a minimum of 50 psi is maintained through the pilot valve and to the main spool, thus keeping the spool in the selected position. Centering springs will return the spool to neutral if this pressure level is not maintained. Since system leakage is continuously bleeding fluid from the pressure line, the operator must pump at a rate such that system leakage can be replenished and, additionally, a minimum of 50 psi can be maintained at the valve.

If the valve spool is positioned to RAMP DOWN and 50 psi is maintained, the weight of the ramp will cause the actuators to extend. The ramp extension rate is controlled, not by pressure applied to the ramp down (head) side of the actuator, but rather by the rate at which return fluid can be forced from the rod end of the actuators. This rate is limited by the two-way, 2 GPM flow regulator installed in the ramp up line. As this ramp extension occurs, the suction at the head end of the actuator would create a vacuum and stop the ramp except for the low cracking pressure check valve that connects the ramp down and auxiliary return lines.

The "free-falling" ramp cannot suck fluid through the hand pump; therefore, another path had to be provided for the head end of the actuator to suck fluid from the reservoir. The aforementioned check valve, set to open at 1.5 psi, allows fluid to flow from the reservoir into the ramp down line when a negative pressure occurs at the head end of the actuators.

On aircraft prior to the installation of this check valve, approximately 700 hand pump cycles were required to pump the ramp down. This was due to the fact that all fluid going to the head end of the cylinders had to come through the hand pump. Since the hand pump only delivers 0.70 cubic inches per cycle, this operation was very time consuming.

RAMP SELECTOR VALVE MODULE



With this design change, the hand pump is needed only to maintain enough pressure to keep the valve spool in the ramp down position. The weight of the ramp serves as the force to extend the actuators. The check valve allows the required make-up fluid to fill the vacuum, created at the head end of the actuators, to come from the reservoir. The operation now requires less than 150 hand pump cycles.

The ability to maintain 50 psi on the small quantity of fluid that is necessary to position the valve spool is dependent on the system's leakage rate, and the rate at which the hand pump is operated. In a system with tight clearances and with rapid hand pump operation, the pressure at the valve spool will remain high, and the ramp will extend at a constant rate. Even after the operator is no longer hand pumping, the ramp will continue to extend until the pressure trapped at the end of the valve spool decays below 50 psi.

There are two correct ways to stop ramp extension at any desired point.

1. In using the electrical ramp control switch you can release it to neutral when the ramp reaches the desired level.

2. Without electricity, you can move the manual ramp control dial to position 3 when the ramp reaches the desired level.

Either of the above accomplishes exactly the same result which is to cause the solenoid plunger to reseat the pilot valve ball, allowing equalization of system pressure at the ends of the spool valve. Springs center the spool, trapping fluid on both sides of the ramp actuating piston.

Control for starting and stopping the ramp down operation is achieved by actuation of either the electrical or manual control; the hand pump is provided to supply power and not for use as the primary means for controlling.

Converseiy, if the system leakage rate is high, and the hand pump is cycled slowly, the ramp may stop when the operator stops pumping. This is because the fluid is leaking from the pressure to return side of the system's valves faster than the hand pump is replenishing, and 50 psi is not being maintained at the valve spool. Remember, the valve spool returns to neutral regardless of the switch or manual handle position when the pressure drops below 50 psi.

It **is** important to remember that if you wish to stop the ramp at some intermediate position, do it with the valve control (electrical switch or manual control) --- don't attempt to control the stopping positron during a ramp extension by ceasing to hand pump.

This explanation only provides information relative to characteristics that should normally be expected during manual operation of the ramp. Operation to ADS, ground, or loading dock level --- these being the normal cases --- shall be in strict accordance with the instructions on the decal attached to the ramp valve.

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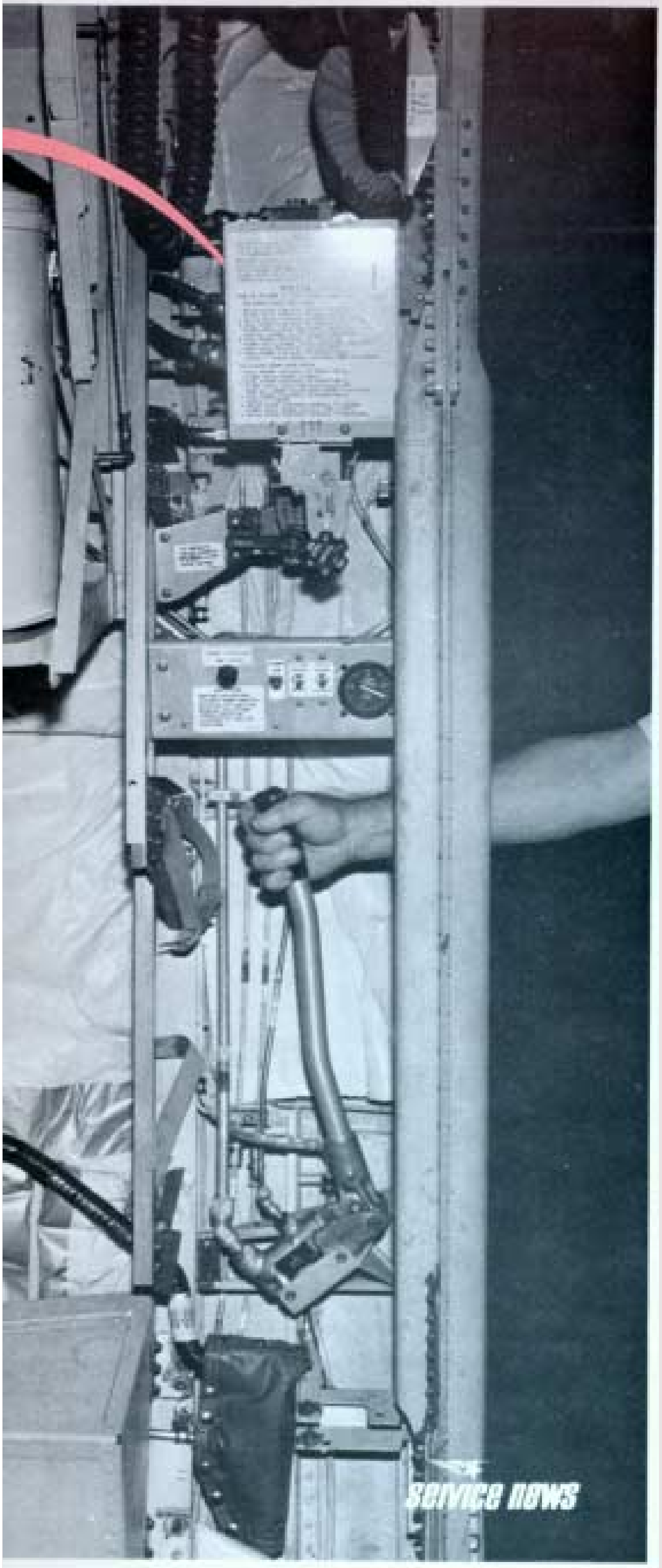

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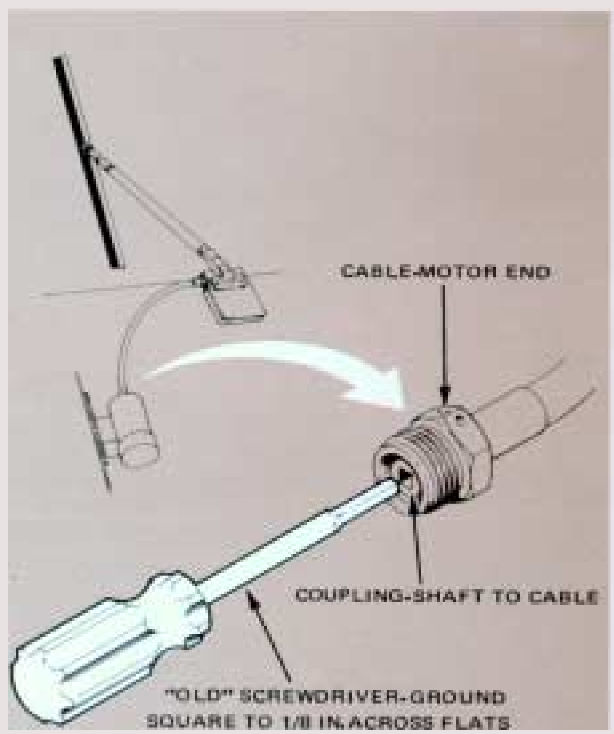
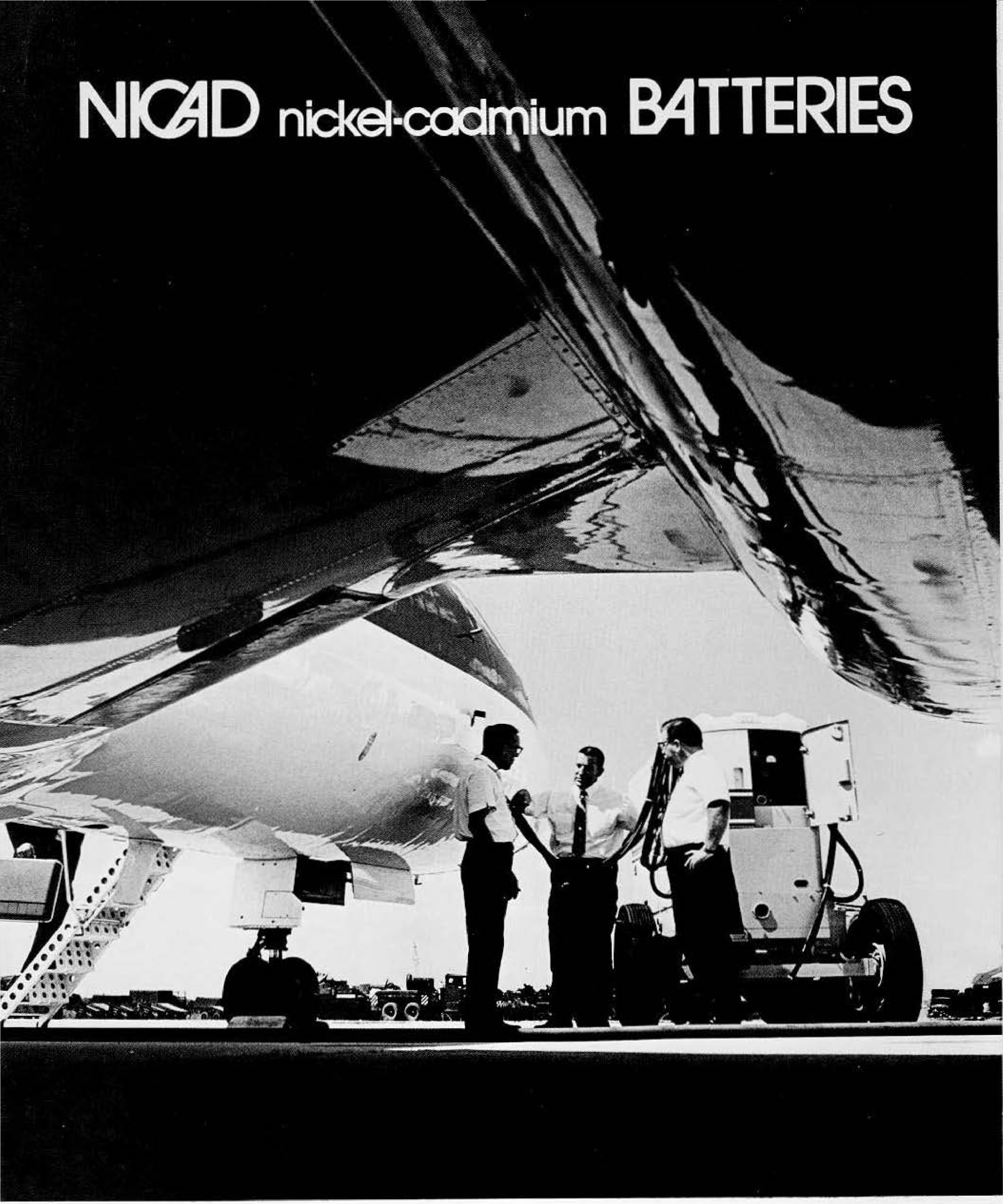
WINDSHIELD WIPER ALIGNMENT TOOL

A special tool, made from an old screwdriver, can eliminate that game of chance when replacing a windshield wiper motor on the Hercules. Usually when a windshield wiper is removed the cable between the motor and the converter will be pulled out of the coupling at the converter. The cable must be aligned with the converter coupling, pushed back into the coupling, and then the wiper must be positioned to coincide with the motor position PARK prior to reconnecting the motor. This small coupling in a confined area is a little difficult to manage with fingers alone.

The square hole in the adapter is a nominal one-eighth inch square. The shank of the most common screwdriver is more than adequate for grinding to fit snugly into the adapter. The square shaped section should extend about one inch

Place the motor coupling on the tool and then on the cable end fitting. Then, turn and push on the tool to align and insert cable in converter coupling. Finally, rotate tool to position wiper blade to the PARK position and, with the motor in PARK, reconnect the cable at the motor.




NICAD nickel-cadmium BATTERIES

DON'T leave "well enough" alone!

Many of the facts needed for the successful maintenance of nicad (nickel-cadmium) batteries have been established only in the last couple of years. There are some characteristics of the "wet" nicad battery that can't be fully explained but we definitely know what is necessary to keep these batteries doing an excellent job for an indefinite service life.

There have been very few serious problems with nicad batteries. However, the potential seriousness of the problems warrants everyone's attention. The danger lies in a condition that can evolve, over a period of time, into a hazard called THERMAL RUNAWAY. If you turn the charging current off in time the thermal runaway subsides. If the process is not detected and stopped, a small explosion of defective cells is likely, or the extremely hot temperature may burn holes in the battery. We will not attempt to place responsibility for any previous problems. We do want to profit from previous investigations and research.

NICADS ARE DIFFERENT

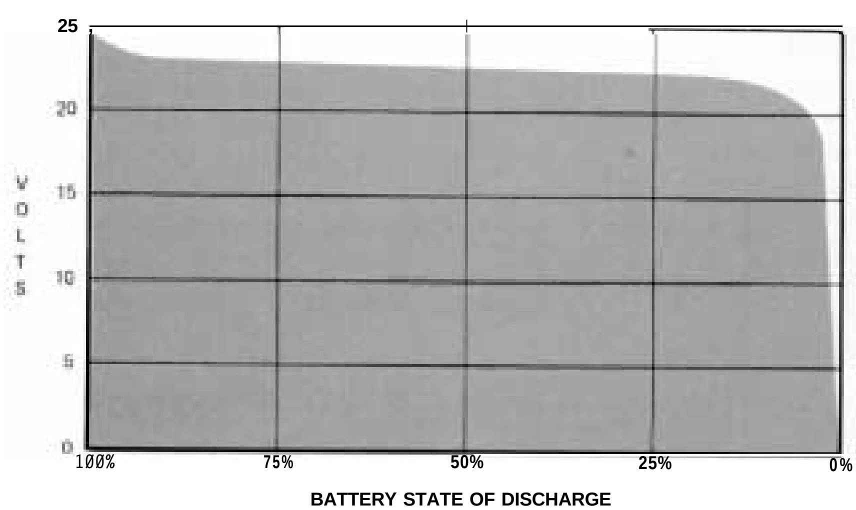
When first introduced to aircraft service the nicad battery compared so favorably with the lead-acid type that periodic maintenance didn't seem as important as before.

Maintenance people experienced with lead-acid batteries could get a false impression of the condition of a nicad battery when checking voltage and specific gravity. Both of these remain practically constant in the nicad battery through almost 90 percent of its cycle.

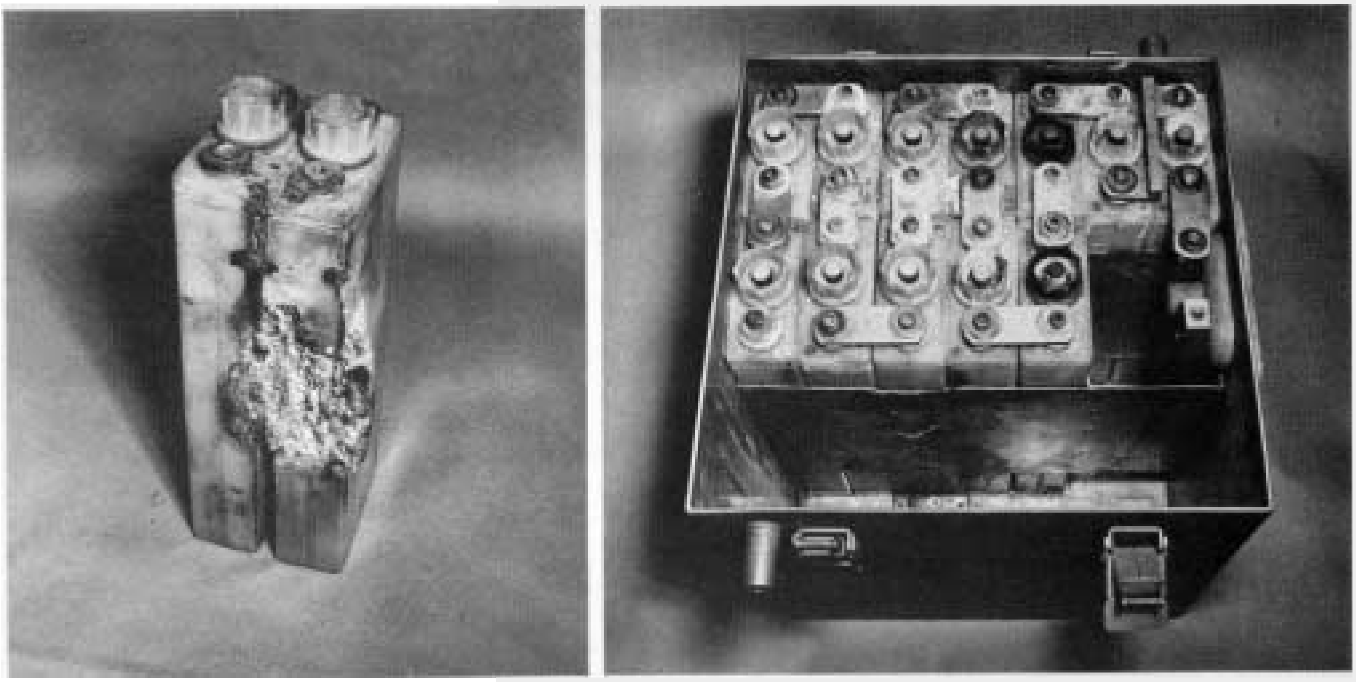
If voltage readings are good and specific gravity is within limits, what could be wrong? Answer: The battery could be about 85% discharged and one or more cells could be ready for thermal runaway, under certain conditions.

When do the nicad batteries need attention? When the appearance of the battery shows signs of spewing electrolyte, overheating, distortion of cells, burned connections – you know it needs to go to the shop for a cleanup, an inspection, and a deep cycle. You can determine the cause of the unusual appearance by following nicad battery tests given in your maintenance manuals.

Even when the battery looks good and seems to be functioning well it still must go to the shop for scheduled periodic maintenance. This includes deep cycling to maintain balanced cells. JetStar maintenance and inspection schedules specify complete servicing when the batteries have 100 hours operating time or 200 engine starts (counting all four engines on each occasion).



TYPICAL DISCHARGE VOLTAGE CURVE UNDER MODERATE LOAD



The photo at right shows what can happen when a nicad battery is allowed to deteriorate to a condition conducive to thermal runaway. Cells were removed to reveal a hole burned through a stainless steel divider. The photo at left shows cells with walls destroyed by a thermal runaway. Leaking electrolyte acted corrosively and acted as a conductor directly to the battery case.

THERMAL RUNAWAY simply identifies a process inside the cell that generates excessive heat which in turn aggravates the condition, increasing the rate of heat generation. The key word in describing conditions that cause thermal runaway is "unbalance". Additional details about the processes are interesting and can be found in the reference publications listed.

Briefly, one or more cells in a battery may not become as fully charged as the others during flight operations. Thus, they are unbalanced. Their charge remains lower than the other cells. When the normal cells become fully charged, their higher voltage terminates the charging phase before the unbalanced cells recover their charge. During discharge the unbalanced cells "bottom out" in capacity and can even start charging in reverse polarity. A higher rate of recharging current plus a little higher temperature generates extra heat in the unbalanced cells. If the battery is already hot, a thermal runaway is likely and a small explosion is possible, caused by vaporization of the electrolyte.

A nicad battery is not subject to thermal runaway while it is discharging, although it will be damaged by a direct short.

Hydrogen and oxygen gases liberated by electrolysis of the water are highly explosive and can be easily ignited. During normal cycling, generation of these gases is at a minimum. At high temperatures, low specific gravity, and/or when the cell is about 100% charged, electrolysis or conversion of water to gases is more prevalent. Forced ventilation through the battery compartment is important for the removal of the explosive hydrogen-oxygen gases that are given off by electrolysis of water in the cells.

IF A THERMAL RUNAWAY BECOMES IMMINENT it can be abated only by disconnecting the battery from the source of power. To remove power, turn off the battery switch. If your JetStar has the battery isolation system, either or both batteries can be isolated to allow time for cooling. Also, the charging voltage to either battery can be checked separately when it is switched on again. It must be 28 to 28.5 volts to fully charge the 24 volt batteries.

TEMPERATURE MONITORING SYSTEMS

As we have pointed out, it is characteristic of the nicad battery to give little or no warning when it is in a hazardous condition. There are patterns you should routinely look for when monitoring voltage and amperage during use of the battery. Take note of no-load voltage before engine start, initial voltage drop and subsequent buildup during starter operation, and recovery time after engines are started. You can analyze these readings to determine performance and to evaluate the general condition of the battery, but there is one bit of information these readings do not give you. They do not indicate temperature.

Since high temperature is a contributing factor as well as a

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sure indication of danger, the flight crew needs to be warned when the battery temperature becomes critical.

This is where the Temperature Monitoring, or Battery Condition, system comes into play. Excessively hot temperature can be both cause and result of a bad situation; therefore, you need to know when the battery is in danger of overheating. The damaging effects of excessively hot temperature accumulate and shorten the life of the battery; more serious is the effect on an unbalanced cell that is already overheating. Thermal runaway is more likely as temperature becomes excessively hot.

In the United States, the Federal Aviation Agency requires that Temperature Monitoring, or Battery Condition systems be installed on all airplanes equipped with nicad batteries.

FAA Airworthiness Directive 72-19-4, with Amendment 29-1598, gave a deadline of October 1, 1973 for this to be accomplished. The simplest of these systems gives a warning and temperature reading when the battery temperature becomes excessively hot.

One or more sensors are attached to the side of the battery case, to a connector strap, or between two individual cells, depending on the design of the system. Some systems are elaborate, monitoring individual cell voltages as well as temperature. When a cell voltage is either too high or too low, an amber light flashes. Depending on sensor locations, warning lights come on at temperatures ranging from 120 F through 1 50 F A JetStar Operators Maintenance Report (OMR A31, 15 June, 1973) describes three of the systems suitable for JetStars.

As with any other monitoring device, it must be functioning correctly so you can rely on the information it relays to you. One caution in its maintenance is to remove all power from the JetStar during component installation or removal. The circuit breaker for "BAT TEMP IND" should be pulled.

Temperature monitoring does not diminish the importance of complete scheduled maintenance.

SERVICING

The chemical nature of these two types of batteries is so different that separate shops are recommended when practical. Separate bench facilities are a must, and they should be in separate servicing rooms at opposite ends of the service area. Separate, complete sets of tools should be provided and marked to identify them with the type of battery on which they are to be used. Even fumes from one battery can contaminate the other type battery.

Emergency measures for electrolyte spills for one type are worse than useless when used for the other type. The only emergency measure they have in common is the use of cool clean water to wash away and dilute spilled electrolyte.

A very mild acid solution, which is chemically opposite from the nicad's alkaline (base) electrolyte, is used to neutralize a spill from a nicad battery. Conversely, a mild alkaline solution is used to neutralize spilled electrolyte from an acid type battery.

In an emergency - would you be sure to grab the right solution for the type of spill? Assuring the right choice is one of the reasons for separate work areas for the different batteries.

Servicing either nicdd or lead-acid type batteries requires a lot of caution to avoid hazards that could result in chemical or physical burns to personnel or result in damage to equipment. Maintenance and service manuals should be studied by those responsible for the batteries. Detailed instructions and cautions are too numerous for us to mention each one in the space we have. A detail omitted in servicing can leave other efforts useless.

DEEP CYCLING A MUST

DEEP CYCLE is the method used to bring all the cells in a nicad battery to the same level of charge. When completed, this level is at 100% capacity and the battery is ready for service. Actually, the only time that you can be positive that the charge in each cell is equal to the others is when all of the cells are completely discharged. This is the starting point necessary to bring each cell to 100% charge at the same time as all of the other cells.

Here is a very brief description of a deep cycle. At the intervals specified in your maintenance handbook the batteries are to be inspected, cleaned and prepared for deep cycling. Each battery is discharged for approximately two hours through a load of approximately 17 amperes. When the current appears to cease flowing, and with the load still connected, shorting straps are applied across the terminals of each cell. The overall load can now be removed. The battery is to sit 12 hours with the shorting straps on the individual cells.

After this time period the voltage across the battery terminals should total less than 2.4 volts. For practical purposes a potential below 2.4 volts indicates a completely discharged nicad battery. The battery is now ready for a constant-current charging. This method of charging is the best to restore the cells to a balanced, 100% charged condition. The voltage across individual cells is checked at intervals near the end of the charge to see that they are balanced. If any cell fails to rise to or above 1.6 volts, it should be replaced. After replacing a cell the battery must be completely cycled again.

The electrolyte level is to be checked and adjusted as necessary about two hours after completion of the charge.

It should be pointed out that the level of the (fluid) electrolyte in the discharged cells would be very low and perhaps impossible to check. A fully charged cell will have more fluid. Like magic, the level will rise in a nicad cell as it is charging. Only after a cell is fully charged can you determine if water or electrolyte should be added. If the level is low, the specific gravity will probably be a little high. If the specific gravity is too low, the cell should be replaced with a healthy one.

We feel justified in repeating the necessity for deep cycling the nicad battery at all the times specified in your maintenance manuals. Deep cycling is a time consuming, step-by-step routine that requires attention to details; and at the same time, it can seem so unnecessary. You can't be sure until you try it. Also, it is one of the essentials in extending the life of a nicad battery indefinitely.

CORROSION is not the least of our problems with batteries in general, including nicad batteries. The KOH (potassium hydroxide) electrolyte is corrosive to copper and aluminum as well as other metals. Avoid removing any nickel plating or other protective coating on parts in the battery case. Clean the battery at specific intervals removing any accumulation of the white powdery KOH that will sometime escape the cells.

Electrolyte or water should never be added while the battery is installed in the airplane. It is important that a cell be fully charged when electrolyte level is adjusted.

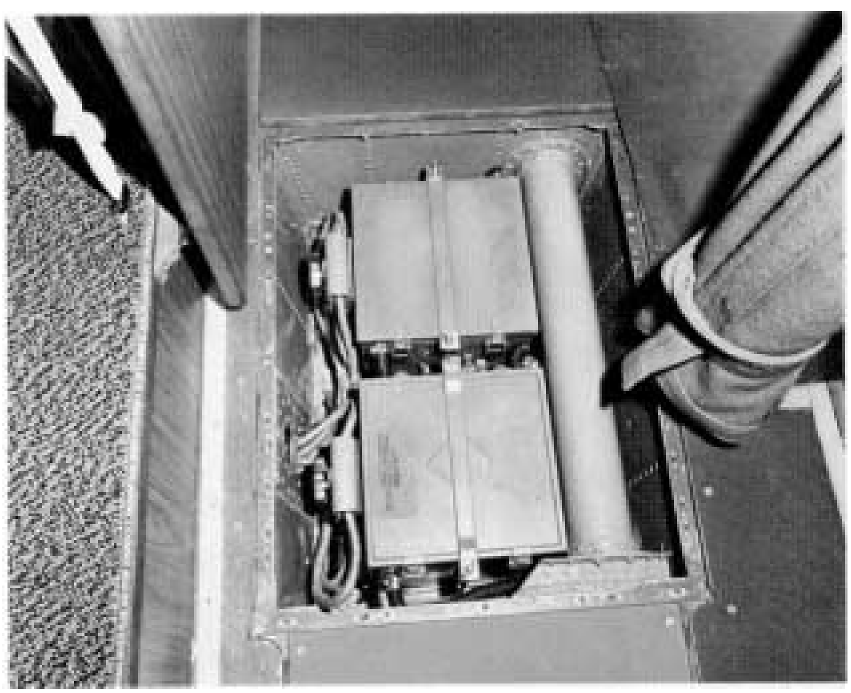
Previous neglect of a nicad battery is not always apparent. In fact, when it is apparent the presence of a serious hazard is probable. Thorough scheduled maintenance is part payment for the sustained performance of the nicad.

JETSTAR BATTERIES

Battery engine starts are routine in JetStar operations and nicad (nickel-cadmium) batteries were a logical choice to do this job, mainly because of their ability to supply full rated power continuously through about 90% of their charge. Their low internal resistance helps make this possible. The same low internal resistance allows faster recovery between flights. Normally, less heat is generated in the charge-discharge cycles compared to the lead-acid type battery, and the nicad is not as susceptible to low ambient temperature problems.

Four starter-generators supply the JetStar's basic 28-volt DC electrical system. The two nicad batteries are rated at a nominal 24 volts, or 26 volts. Battery selection is at the option of the operator.

The nicad batteries supply the JetStar with current for the essential needs as well as to start the engines. The two batteries must be identical in every respect to function together in the system. Continuous full power output during engine starts and then a fast recharge are necessary in a variety of climatic temperatures.



This battery compartment is a custom installation under the floor near the cabin entrance. However, in the production configuration the JetStar batteries are located under the floor of the baggage compartment

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"Servicing of the Batteries" is Section 12.5 in your JetStar Handbook of Operating and Maintenance Instructions (HOMI). This covers the subject. The U.S. Government publication T.O. 8D2-3-1 is a comprehensive Technical Manual on Aircraft Nickel Cadmium Storage Batteries.

The "Personality of Nickel-Cadmium Batteries" is covered in an early JetStar Operators Maintenance Report; OMR Number Al, 15 December 1970. Other OMRs related to JetStar batteries are:

Battery Condition System HOMI Section 24	OMR A-31 15 June 1973
Electrical, Parallel Start Troubleshooting HOMI Section 80	OMR A-43 15 June 1974
Battery Temperature Indicators HOMI Section 24	OMR A-45 15 August 1974

The manufacturer of your batteries probably publishes an instruction manual on his product and would likely supply a copy on request.

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CUSTOMER SERVICE DIVISION
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MARIETTA. GEORGIA, 30063

The NEW JetStar II

Efficient new Garrett turbofan engines give the JetStar II longer range, such as coast-to-coast nonstop, or San Francisco to Honolulu. Cabin space is roomy enough to hold a conference, stand up and walk around, or stretch out and relax. It will be a good neighbor, too – quiet and smokeless – to meet FAR 36 regulations.

A decision on production go-ahead is planned for near year end with deliveries to begin in 1976.

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