Lockheed

VOL. 19, NO. 2, APRIL-JUNE 1992

service news

A Service Publication of Lockheed Aeronautical Systems Company

HERCULES 2000

Lockheed service news

A SERVICE PUBLICATION OF LOCKHEED AERONAUTICAL SYSTEMS COMPANY

Editor
Charles I. Gale

Art Director
Cathy E. Howard

Vol. 19, No. 2, April-June 1992

Photographic Support: John Rossino

Covers: Our front cover shows the 2000th Hercules aircraft during a test flight. The ground shots on the back cover offer some additional views of the historic aircraft shortly before it was delivered to the Kentucky Air National Guard on May 15, 1992.

Service News is published by Lockheed Aeronautical Systems Company, a unit of Lockheed Corporation. Information contained in this issue is considered by Lockheed 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 Corporation: " ", " Lockheed ", "Hercules," and "JetStar." Written permission must be obtained from Lockheed Aeronautical Systems Company before republishing any material in this periodical. Address all communications to Editor, *Service News*, Department 66-34, Zone 0308, Lockheed Aeronautical Systems Company, Marietta, Georgia 30063. Copyright 1992 Lockheed Corporation.

Ship 2000! The Line Breeds True

Few who witnessed the inaugural flights of the early C-l 30A Hercules aircraft in the spring of 1955 could ever have imagined it. The very first airplane to roll off the assembly line is still in service and earning its keep 37 Years later. Most would have been even more incredulous had they been told that the production line turning out the gleaming new turboprops would also still be earning its keep nearly four decades later. And in championship style! In May of this Year, the Lockheed production facility in Marietta, Georgia, proudly delivered its 2000th Hercules. It is appropriate that the new owner should be the Kentucky Air National Guard. Today's Hercules, an updated and much improved version of the original, is a thoroughbred in every sense of the word.

There is nothing in the history of aviation that even remotely matches the record of the Hercules aircraft. Long the mainstay of both military and commercial airlift around the world, the Hercules has been in continuous production for more than a third of the time since the Wright brothers taught the world how to fly.

It was, as some have said, a case of the right airplane at the right time. But in the aerospace business there is no more unforgiving challenge than the test of time. A record of achievement like that of the Herk takes a lot more than luck; it has to be earned. It took a unique combination of engineering excellence, designed-in versatility, and uncompromising quality to transform yesterday's high-tech concepts into today's most capable airlifter. It is no coincidence that the same combination of qualities that opened the doors to yesterday's achievement are also pointing the way to tomorrow's success.

An early C-130A tries its wings over Marietta.

PRODUCT SUPPORT LOCKHEED AERONAUTICAL SYSTEMS COMPANY

J. L. GAFFNEY – DIRECTOR

FIELD SUPPORT	SUPPLY SUPPORT	TECHNICAL PUBLICATIONS	RM&S DESIGN	CUSTOMER TRAINING
J. D. Adams	J. L. Bailey	A. G. Hunt	H. D. Hall	S. S. Clark

Fuel Quantities Update

by **W. G. Moses,** *Aircraft Structures Engineer, Senior*
LASC Aeromechanics Department

Recent studies conducted by the U.S. Air Force and Lockheed have shown that the fuel capacity values given for the Hercules aircraft in much of the authorized documentation need to be updated. Operational Supplement T.O. lC-130B-IS-263 already reflects some of these changes as they apply to USAF airplanes.

The tables that accompany this article offer a broader selection of data and include the correct capacities for all tanks installed in the more prevalent configurations of the airplane. Note that the values shown in the tables for external tanks are for the Lear Siegler PN 305JOOl units, the type currently being installed in new production Hercules aircraft. Other kinds of external tanks will have different unusable and usable fuel volumes and weights.

The new fuel volumes apply to aircraft Lockheed serial number LAC 4542 and up, and to earlier airplanes which have had their outer wings replaced with either FY '73 (LAC 4542) or FY '84 (LAC 4992)-type outer wings. Modifications to improve the outer wing structure and update the fuel system have contributed to the changes in fuel capacities of the main tanks. The changes amount to a reduction of approximately 3.5% in the capacities of these tanks. The fuel quantity indicating system is not directly involved. Careful checking has determined that its accuracy is well within the limits required by thespecification. Further studies to establish the overall effects of the fuel quantity changes on the airframe are in progress.

Establishing the New **Values**

The Lockheed tests to establish current total fuel capacities were conducted on two new Hercules airplanes on initial fueling after rollout. These aircraft were selected as typical baseline airplanes, and were not equipped with either refueling pods or explosion-suppressant foam. The total capacities in volume and weight obtained from these studies are shown in Table 1. No attempt was made to confirm or revise the unusable fuel volumes in these tests. The tables thus show the existing unusable fuel volumes, which have been retained, and the resulting usable fuel volumes. JP-4 and JP-5 under standard-day conditions were used as the bases for the weight calculations.

Table 2 shows fuei capacities for non-USAF Hercules aircraft equipped with refueling pods but no foam. Table 3 contains the volumes and weights for USAF aircraft equipped with foam. For these USAF aircraft, the total fuel figure should be understood to mean the total capacity minus the fuel that is displaced by the dry foam. Table 4 shows the corresponding values for USAF C-130 airplanes equipped with refueling pods. The effects of foam on tank capacities were determined by Warner Robins Air Logistics Center.

Unusable Fuel - Two Standards

The tables show two sets of unusable fuel volumes for airplanes without foam. Both are in current use. The differences between them arise from differences in the way the numbers have been derived. The first set of values are those employed by the USAF. These volumes for unusable fuel are the same as originally used for C-130B and C-130E models. The usable fuel volumes for airplanes with foam in the tanks apply only to USAF Hercules aircraft.

The other set of figures show the unusable fuel volumes that have been certified by the FAA for civil models of the Hercules. These values are also used for military models, except for those operated under USAF technical orders. The resulting usable fuel volumes are thus applicable to most non-USAF Hercules aircraft.

Reviewing the Structural-Limit Fuel Weights

It should be noted that the full-fuel weights shown in the tables for JP-4 (6.5 pounds per gallon) continue to define structural-limit fuel weights for aircraft with hard struts. Similarly, the full-fuel weights shown for JP-5 (6.8 pounds per gallon) are the structural-limit fuel weights for aircraft equipped with soft struts. Since the main tank volumes are reduced, it might be supposed that a fuel with higher density could be used to produce the same allowable fuel weights as previously employed. Unfortunately, this is not the case.

The purpose of the new outer wing designs was to offer enhanced fatigue resistance in critical areas and incorporate improvements to the fuel system. Although the changes resulted in a better outer wing, some weight was added in the process. Design requirements result in a total weight limit for the outer wing which is the sum of the structural, system, and fuel weights. The decrease in fuel capacity, in effect, compensates for the increased weight of the empty wing. Substituting a fuel with a higher density to offset the reduced volume would therefore not be appropriate and, if used, could lead to restrictions for ground operation of the airplane.

TABLE 1.

FUEL CAPACITIES -HERCULES AIRCRAFT WITHOUT REFUELING PODS, NO FOAM

IN U.S. GALLONS

TANK	TOTAL	UNUSABLE		USABLE	
		USAF	OTHER	USAF	OTHER
1	1300	10	12	1290	1288
2	1200	10	14	1190	1186
3	1200	10	14	1190	1186
4	1300	10	12	1290	1288
TOTAL MAIN	**5000**	**40**	**52**	**4960**	**4948**
LEFT AUX	910	0	9	910	901
RIGHT AUX	910	0	9	910	901
INTERNAL	**6820**	**40**	**70**	**6780**	**6750**
LEFT EXT	1400	40	21	1360	1379
RIGHT EXT	1400	40	21	1360	1379
TOTAL	**9620**	**120**	**112**	**9500**	**9508**

IN POUNDS (Fuel weights based on 6.5 lbs. per gallon for JP-4; 6.8 lbs. per gallon for JP-5.)

TANK	TOTALS		UNUSABLE				USABLE			
			USAF		OTHER		USAF		OTHER	
	JP-4	JP-5	JP-4	JP-5	JP-4	JP-5	JP-4	JP-5	JP-4	JP-5
1	8450	8840	65	68	78	82	8385	8772	8372	8758
2	7800	8160	65	68	91	95	7735	8092	7709	8065
3	7800	8160	65	68	91	95	7735	8092	7709	8065
4	8450	8840	65	68	78	82	8385	8772	8372	8758
MAIN	**32,500**	**34,000**	**260**	**272**	**338**	**354**	**32,240**	**33,728**	**32,162**	**33,646**
L AUX	5915	6188	0	0	59	61	5915	6188	5856	6127
R AUX	5915	6188	0	0	59	61	5915	6188	5856	6127
INTERNAL	**44,330**	**46,376**	**260**	**272**	**456**	**476**	**44,070**	**46,104**	**43,874**	**45,900**
L EXT	9100	9520	260	272	137	143	8840	9248	8963	9377
R EXT	9100	9520	260	272	137	143	8840	9248	8963	9377
TOTAL	**62,530**	**65,416**	**780**	**816**	**730**	**762**	**61,750**	**64,600**	**61,800**	**64,654**

Previous Page Table of Contents Next Page

TABLE 2.

FUEL CAPACITIES -HERCULES AIRCRAFT WITH REFUELING PODS, NO FOAM

IN U.S. GALLONS

TANK	TOTAL	UNUSABLE		USABLE	
		USAF	OTHER	USAF	OTHER
1	1075	10	12	1065	1063
2	1200	10	14	1190	1186
3	1200	10	14	1190	1186
4	1075	10	12	1065	1063
TOTAL MAIN	**4550**	**40**	**52**	**4510**	**4498**
LEFT AUX	910	0	9	910	901
RIGHT AUX	910	0	9	910	901
INTERNAL	**6370**	**40**	**70**	**6330**	**6300**
LEFT EXT	1400	40	21	1360	1379
RIGHT EXT	1400	40	21	1360	1379
TOTAL	**9170**	**120**	**112**	**9050**	**9058**

IN POUNDS (Fuel weights based on 6.5 lbs. per gallon for JP-4; 6.8 lbs. per gallon for JP-5.)

TANK	TOTALS		UNUSABLE				USABLE			
			USAF		OTHER		USAF		OTHER	
	JP - 4	JP - 5	JP - 4	JP - 5	JP - 4	JP - 5	JP - 4	JP - 5	JP - 4	JP - 5
1	6988	7310	65	68	78	82	6923	7242	6910	7228
2	7800	8160	65	68	91	95	7735	8092	7709	8065
3	7800	8160	65	68	91	95	7735	8092	7709	8065
4	6988	7310	65	68	78	82	6923	7242	6910	7228
MAIN	**29,576**	**30,940**	**260**	**272**	**338**	**354**	**29,316**	**30,668**	**29,238**	**30,586**
L AUX	5915	6188	0	0	59	61	5915	6188	5856	6127
R AUX	5915	6188	0	0	59	61	5915	6188	5856	6127
INTERNAL	**41,406**	**43,316**	**260**	**272**	**456**	**476**	**41,146**	**43,044**	**40,950**	**42,840**
L EXT	9100	9520	260	272	137	143	8840	9248	8963	9377
R EXT	9100	9520	260	272	137	143	8840	9248	8963	9377
TOTAL	**59,606**	**62,356**	**780**	**816**	**730**	**762**	**58,826**	**61,540**	**58,876**	**61594**

TABLE 3.

FUEL CAPACITIES -USAF C-130 AIRCRAFT WITHOUT REFUELING PODS, WITH FOAM

IN U.S. GALLONS

TANK	TOTAL	UNUSABLE	FOAM RETENTION	USABLE
1	1267	10	33	1224
2	1170	10	30	1130
3	1170	10	30	1130
4	1267	10	33	1224
TOTAL MAIN	**4874**	**40**	**126**	**4708**
LEFT AUX	887	0	23	864
RIGHT AUX	887	0	23	864
INTERNAL	**6648**	**40**	**172**	**6436**
LEFT EXT	1365	40	35	1290
RIGHT EXT	1365	40	35	1290
TOTAL	9378	120	242	9016

IN POUNDS (Fuel weights based on 6.5 lbs. per gallon for JP-4; 6.8 lbs. per gallon for JP-5.)

TANK	TOTAL		UNUSABLE		FOAM RETENTION		USABLE	
	JP - 4	JP - 5	JP - 4	JP - 5	JP - 4	JP - 5	JP - 4	JP - 5
1	8235	8615	65	68	214	224	7956	8323
2	7605	7956	65	68	195	204	7345	7684
3	7605	7956	65	68	195	204	7345	7684
4	8235	8615	65	68	214	224	7956	8323
MAIN	**31,680**	**33,142**	**260**	**272**	**818**	**856**	**30,602**	**32,014**
L AUX	5765	6031	0	0	149	156	5616	5875
R AUX	5765	6031	0	0	149	156	5616	5875
INTERNAL	**43,210**	**45,204**	**260**	**272**	**1116**	**1168**	**41,834**	**43,764**
L EXT	8872	9282	260	272	227	238	8385	8772
R EXT	8872	9282	260	272	227	238	8385	8772
TOTAL	**60,954**	**63,768**	**780**	**816**	**1570**	**1644**	**58,604**	**61,308**

TABLE 4.

FUEL CAPACITIES-USAF C-l 30 AIRCRAFT WITH REFUELING PODS AND FOAM

IN U.S. GALLONS

TANK	TOTAL	UNUSABLE	FOAM RETENTION	USABLE
1	1048	10	27	1011
2	1170	10	30	1130
3	1170	10	30	1130
4	1048	10	27	1011
TOTAL MAIN	**4436**	**40**	**114**	**4282**
LEFT AUX	887	0	23	864
RIGHT AUX	887	0	23	864
INTERNAL	**6210**	**40**	**160**	**6010**
LEFT EXT	1365	40	35	1290
RIGHT EXT	1365	40	35	1290
TOTAL	**8940**	**120**	**230**	**8590**

IN POUNDS (Fuel weights based on 6.5 lbs. per gallon for JP-4; 6.8 lbs. per gallon for JP-5.)

TANK	TOTAL		UNUSABLE		FOAM RETENTION		USABLE	
	JP - 4	JP - 4	JP - 4	JP - 5	JP - 4	JP - 5	JP - 4	JP - 5
1	6812	7126	65	68	175	183	6572	6875
2	7605	7956	65	68	195	204	7345	7684
3	7605	7956	65	68	195	204	7345	7684
4	6812	7126	65	68	175	183	6572	6875
MAIN	**28,834**	**30,164**	**260**	**272**	**740**	**774**	**27,834**	**29,118**
L AUX	5765	6031	0	0	149	156	5616	5875
R AUX	5765	6031	0	0	149	156	5616	5875
INTERNAL	**40,364**	**42,226**	**260**	**272**	**1038**	**1086**	**39,066**	**40,868**
L EXT	8872	9282	260	272	227	238	8385	8772
R EXT	8872	9282	260	272	227	238	8385	8772
TOTAL	**58,108**	**60,790**	**780**	**816**	**1492**	**1562**	**55,836**	**58,412**

A New, Multi-Purpose, INSTRUMENTATION TEST SET

by **William C. Turbyfield,** *Electronics Engineer, Senior Electronic Support Equipment Engineering Department*

The functionality and mobility requirements demanded by today's military and commercial aviation communities have created unique problems with regard to test equipment. The equipment used to test aircraft components must be versatile, easily transportable, and reliable. At the same time, it must also be able to meet the broad spectrum of accuracy and capability standards set by maintenance organizations.

Individual pieces of single-function equipment designed to check specific components may have been acceptable in the past, but the realities of today's aerospace maintenance environment are dictating new levels of applicability and performance. There is a real need for a single, lightweight package that will combine multiple testing capabilities.

At Lockheed Aeronautical Systems Company, we are meeting this challenge by building a unique, new generation of test equipment. One outstanding product that has resulted from this effort is the portable, practical, and highly reliable PN ES125051-1 Instrumentation Test Set.

This test set is a versatile and powerful unit designed to test aircraft instrumentation components at organizational, field, and depot levels. It is housed in a rugged, transportable case that offers true portability. This allows easy transfer of the unit to the particular repair shop where it is required. When teamed with the PN ES125052-( ) Interface Kit that contains the adapters and cables appropriate to the instrumentation being checked, the test set is capable of functionally testing an impressive variety of indicators and associated transmitters .

To be considered truly mobile and multifunctional, test equipment must be easy to set up and require a minimum of documentation to operate and maintain. The Instrumentation Test Set establishes standards of performance in this category. All circuitry for simulating instrument parameters and measuring transmitter outputs are contained in the test set itself. Instructions to the operator, pull-down and pop-up menus, and on-line help are displayed on the built-in flat-panel graphics display.

Operator input is provided through use of the test set's numeric key pad. Depending on the unit under test, selected values of simulated parameters are presented on the display in an easy-to-read format, as are the measured values of transmitter outputs.

The software routines necessary to adapt the unit for the particular instrumentation systems to be checked are loaded into the tester by the use of external cartridges. These cartridges and the cable assemblies required for interfacing with the capabilities that will be tested are contained in separate kits. This allows each user to configure the test set for his particular needs.

The PN ES125052-1 Interface Kit, which allows testing of Hercules aircraft instrumentation components, is available now. However, provision has been made to expand the test set to accommodate new instrumentation as required. Other interface kits for different aircraft will become available as needed to meet customer requirements. This will greatly increase the tester's value over time.

In addition to being easy to use and expandable, the test set also offers outstanding dependability. Included among its features are built-in self-test and calibration procedures that ensurehigh reliability. Simulated signals from the test set are looped back to monitor circuitry, permitting an internal test of the equipment's operation and accuracy. This type of self-testing capability gives the user additional assurance that the equipment is functioning properly and providing accurate results.

When used with the appropriate interface kit, the Instrumentation Test Set provides the means to test the following components and systems:

Transmitters for pressure systems (oil, hydraulic, and fuel) may also be connected to the test set and checked if an additional dead-weight tester (not supplied with the test set) is provided.

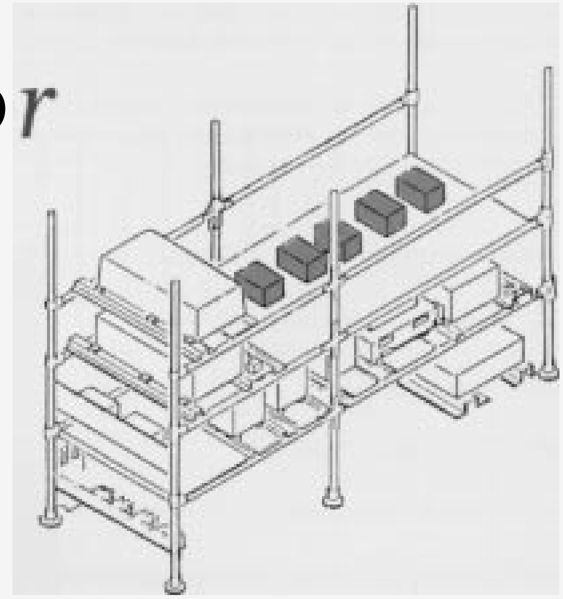
- Aileron trim tab position indicators
- Elevator trim tab position indicators
- Fuel flow indicators
- Fuel flow power supplies
- Fuel pressure indicators
- Fuel quantity indicators
- Hydraulic pressure indicators
- Landing gear position indicators
- Oil cooler position indicators
- Oil pressure indicators
- Oil quantity indicators
- Oil quantity transmitters
- Rudder trim tab indicators
- Tachometer generators
- Tachometer indicators
- Temperature indicators
- Torquemeter indicators
- Turbine inlet temp. indicators
- Wing flap position indicators

For further information concerning the PN ES125051-1 Instrumentation Test Set, and for ordering information, please contact:

Customer Supply Business Management Department 65-11,
Lockheed-LASC, Marietta, GA 30063-0577

Telephone: 404-494-4214; Fax 404-494-7657
Telex 804263 LOC CUSTOMER SUPPL

A New Generator Control Unit for the Hercules



by Larry Arnold, *Staff Engineer*
C-130/L-100 *Electrical Design Group*

The electrical power system of the Hercules airlifter has recently been updated to provide the aircraft with a system that will offer greater reliability, easier maintenance, and supply higher-quality power to the using subsystems. Beginning with Lockheed serial number LAC 5271, the 40/50 KVA generators installed on the engines and the APU are controlled and monitored by new, PN 697856-l generator control units (GCUs).

The modifications to the electrical system required to incorporate the new equipment were designed to have the least possible impact on the overall aircraft electrical system installation. None of the changes affect the generators or any of the associated wiring in the wings and nacelles.

The GCUs are installed on the second shelf of the underfloor electrical control and supply rack. The new units replace the voltage regulators, generator control/ protective panels, and frequency-sensitive (underfrequency) relays.

Looking aft at the shelf from right to left, the GCUs are designated No. 1, No. 2, APU, No. 3, and No. 4. The aircraft wiring has been changed to route all the signal and control lines to the generator control units instead of the ensemble of equipment- voltage regulator, generator control panel, and frequency-sensitive relay-that each GCU replaces.

The overhead control panel in the flight station has also been modified. The control switch for each generator is changed from a four-position rotary to a two-position rotary switch. The new positions are ON and OFF/BESET.

Automatic Configuration

The GCUs are designed to provide the control and monitoring of the 40/50 KVA generators installed on the engines and APU, and to operate automatically with either the Bendix or the Leland (GE) generator. Each GCU provides the following functions:

- Voltage regulation
- Undervoltage monitoring
- Overvoltage monitoring
- Underfrequency monitoring
- Overfrequency monitoring
- Differential fault protection
- Generator contactor control
- Status lights

The voltage regulation is designed to provide high-quality electric power that meets the steady-state and voltage transient requirements of MIL-STD-704D. The GCU monitors the permanent magnet generator (PMG) input from the main generator to determine the type of regulation to provide. If the PMG voltage is 30 VDC, the generator is Bendix and the regulator for the Bendix generator control field is selected. If the PMG voltage is 108 VAC, the generator is a Leland and the regulator for this type generator control field is selected.

This selection is done automatically and requires no action on the part of the aircraft operator's maintenance personnel. With this feature, it is possible to operate an aircraft with a mix of generator types without having to match the generators to a particular voltage regulator.

Previous Page Table of Contents Next Page

System Monitoring

Each GCU also provides system monitoring of the generator output and controls the contactor which ties the generator to the aircraft loads. If any of the monitored parameters are outside the design limits, the generator contactor will be deenergized and the GEN OUT light illuminated. In some cases, the generator will also be deenergized. System monitoring includes:

1. UNDERVOLTAGE – If voltage drops to 95 VAC or below for more than 4 seconds, the line contactor will open, the generator will deenergize, and the GEN OUT light will illuminate. The generator can be reset by placing the control switch to OFF/RESET and then back to ON.

2. OVERVOLTAGE – When voltage exceeds an inverse time curve of 5 volt-seconds above 130 VAC, up to a maximum of 190 VAC, the line contactor will open, the generator will deenergized, and the GEN OUT light will illuminate. The generator can be reset by placing the control switch to OFF/RESET and then back to ON.

3. UNDERFREQUENCY – If the frequency drops below 365 Hertz, the line contactor will open and the GEN OUT light will illuminate. When frequency rises above 375 Hertz, the line contactor will close and the light will go out.

4. OVERFREQUENCY – If the frequency exceeds 440 Hertz, the line contactor will open and the GEN OUT light will illuminate. When the frequency drops to 430 Hertz, the contactor closes and the warning light will go out.

5. DIFFERENTIAL FAULT – If the difference between the current at the generator terminals and the current at the contactor terminals exceeds 35 amps, indicating a feeder fault, the line contactor will open, the generator will deenergize, and the GEN OUT light will illuminate. The GCU cannot be reset after detecting a differential fault until all power sources are removed from the GCU.

BIT Capability

The GCU has built-in-test (BIT) capability which is used to verify that the monitoring circuits are performing properly. The BIT is initiated with a pushbutton switch on the front of the unit. This test can be done at any time that power is on the aircraft, whether the generators are on or not. When the button is pushed, four LED indicators on the front of the GCU will illuminate for approximately 10 seconds and then go out if the GCU passes all of the internal tests. If a test fails, one or more of the LEDs will remain illuminated to indicate that nature of the failure. An LED "truth table" on the front ofthe GCU indicates to the maintenance technician which module to replace.

The four LED indicators are used to indicate the nature of a system failure during BIT and normal operation. If the GCU trips during normal use, the LEDs will illuminate in a pattern to indicate what caused the system trip. The operator should look at the GCU LED indicators before attempting to reset the system.

Normal checkout procedures, as well as troubleshooting, will be much simpler with the new GCU. Preflight checkout will take a fraction of the time previously needed and require only one person.

The BIT will help to isolate a problem by displaying information that shows the operator the type of failure involved. Troubleshooting is also simplified by the fact that there are fewer line replaceable units (LRUs) in the system. Substitution is also a practical approach for trouble analysis, since all GCUs are identical and interchangeable.

The new generator control units are designed to be highly reliable and easy to maintain. The MTBF for the units is expected to exceed 20,000 hours. This will significantly reduce the maintenance requirements for this portion of the aircraft electrical system, and lower the overall cost of operating the Hercules.

Flight Characteristics and Performance:

Simulated Engine-Out Control Speeds

by M. A. DeCastro Jr., *Senior Engineer*
Product and System Safety Engineering Department

Which of the following situations will produce the highest minimum speeds at which the aircraft can be controlled ?

- No. 1 engine failed, propeller feathered.
- No. 1 engine failed, propeller windmilling.
- No. 1 engine simulated out, throttle at flight idle.

Under certain conditions, the engine-out simulation will require higher speeds to maintain directional control than either of the other situations. Since simulated engine-out approaches and landings are an almost daily occurrence, it is important for Hercules flight crews to be thoroughly familiar with this characteristic and what can be done to prevent potential problems in the traffic pattern.

Minimum Control Speed-Air (V_{mca})

The V_{mca} for an aircraft is the minimum speed at which the pilot can maintain control and continue straight flight. It is a precisely defined value that is determined by flight test and based on a set of constant conditions. In the case of the Hercules aircraft, the V_{mca} constants for one-engine failures are as follows:

- Maximum power on the operating engines.
- No. 1 engine inoperative and the propeller windmilling on NTS .
- Full rudder deflection, or 180 pounds pedal force.
- Five degrees bank away from the failed engine.
- Gear down.
- Flaps at 50 percent.
- Minimum flying weight.

These are the most critical conditions involved in computing minimum control speeds. The two-engine V_{MCA} for the Hercules adds No. 2 engine failed and feathered, bleed air off, and only one hydraulic system operating at 3,000 psi to this list of conditions.

It is important to keep in mind that changing any of these constants will affect the pilot's ability to control the aircraft. For example, with one engine out, if the wings are kept level instead of at the prescribed five degrees of bank, the speed at which directional control can be maintained increases by 9-12 knots. Similarly, low rudder boost instead of high boost requires an additional 13 knots above the charted V_{mca} for controllable flight. The aircraft cannot be controlled at the charted V_{mca} given in the performance manual if any of the constants are changed in a way that adversely affects controllability.

Propeller Thrust

Before we take a closer look at the effect of engine-out (or engines-out) simulations on controllability, let us briefly examine the question of propeller thrust. We seldom think in terms of thrust in connection with the Hercules because our measure of engine power and performance is normally given in inch-pounds of torque. However, it is in terms of thrust that the physical effects involved in engine-out simulations are best understood.

At takeoff power, the engine-propeller combination produces approximately 9,650 pounds of thrust per engine under static conditions, and 8,650 pounds at 100 KTAS at standard-day, sea-level conditions. A propeller produces positive thrust by accelerating the air that passes over its blades. But under some conditions, air can actually be decelerated when passing through a propeller. When this happens, the result is a negative thrust value.

Depending on the airspeed, a propeller at flight idle can produce as much as 2,000 pounds of negative thrust, as shown in Figure 1. Such negative thrust has clear implications for aircraft controllability, but simply knowing this as an abstract fact will not be very helpful. A thorough understanding of the problem is necessary if this knowledge is to be applied properly.

C-130H Minimum Engine/Propeller
Thrust vs Speed (Sea Level - Standard Day)

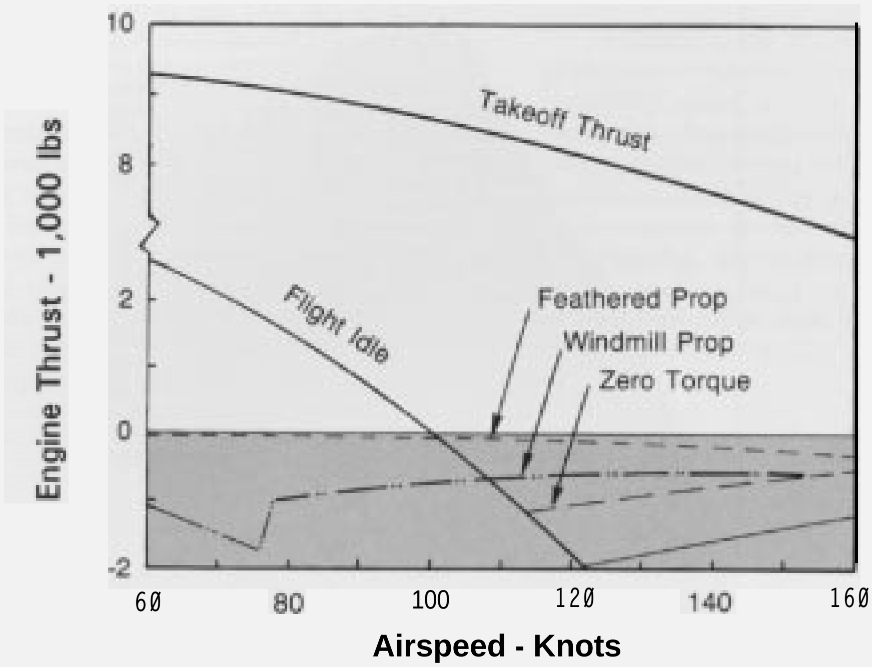


Figure 1.

The first thing we can do is convert thrust to some usable value, since we cannot measure thrust directly in the flight station. If we express thrust effects in knots of airspeed, we can then apply a correction to the already defined value of V_{mca} to derive a new minimum speed at which control is possible.

Note again that this does not change charted V_{mca} in any way. We need a corrected minimum control speed because we've changed one or more of the constants in the V_{mca} definition.

Simulated Engine(s)-Out Minimum Control Speeds

Figure 1 shows that the negative thrust effect of a propeller at flight idle begins at about 98 knots, hence the minimum touchdown speed for the aircraft in the performance manual. In cases where one engine is simulated out, the effect is such that at approximately 109 knots the pilot must begin increasing the minimum control speed as the negative thrust makes itself felt. The increase in minimum control speed reaches a maximum of 8 knots over charted V_{mca} as the negative thrust builds toward a maximum of 2,000 pounds, after which the effect decreases to an average of about 5 knots above V_{mca} (see Figure 2).

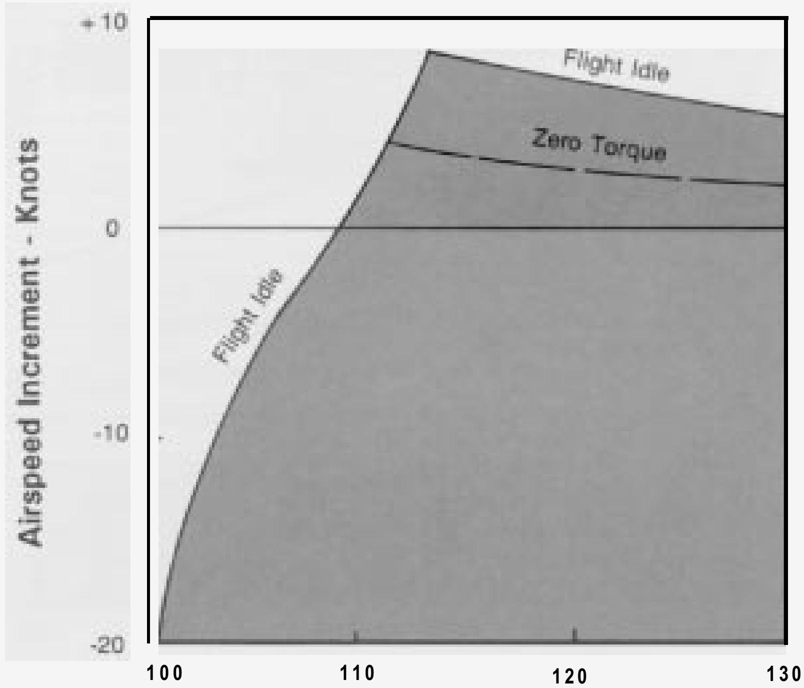
Although two-engines-out simulations do require higher V_{mca} and are more difficult to handle, their relative effect on minimum control speed is not as pronounced. Figure 3 shows that between approximately 117 and 128 knots, the thrust effect requires an increase of up to 5 knots over the charted two-engine V_{mca} Outside of this range no increase is necessary, primarily because both rudder boost systems will be operating and normal bleed air is on instead of off.

Throttle Setting

Now that we know about the worst-possible cases, let us see how the negative thrust penalty incurred in training simulations can be reduced or eliminated altogether. Variations in airspeed and propeller rigging result in a fairly wide range of acceptable torque (and therefore thrust) values for a propeller at flight idle. We can eliminate most of the effects of this variable by setting the throttle(s) on the "failed" engine(s) so that torque is zero or slightly above.

This does two things. First, it eliminates NTS activation and its accompanying yaw oscillations. Second, it reduces the negative thrust enough to decrease the airspeed penalty by at least half for one-engine-out simulations and eliminate it altogether for two-engines-out simulations. Thus, by setting the torque to zero, only 4 knots needs to be added to the charted one-engine out V_{mca} instead of 8 knots, and the need for any increase to two-engines-out V_{mca} is eliminated entirely. Figure 1,2, and 3 contain the zero-torque lines that illustrate this effect.

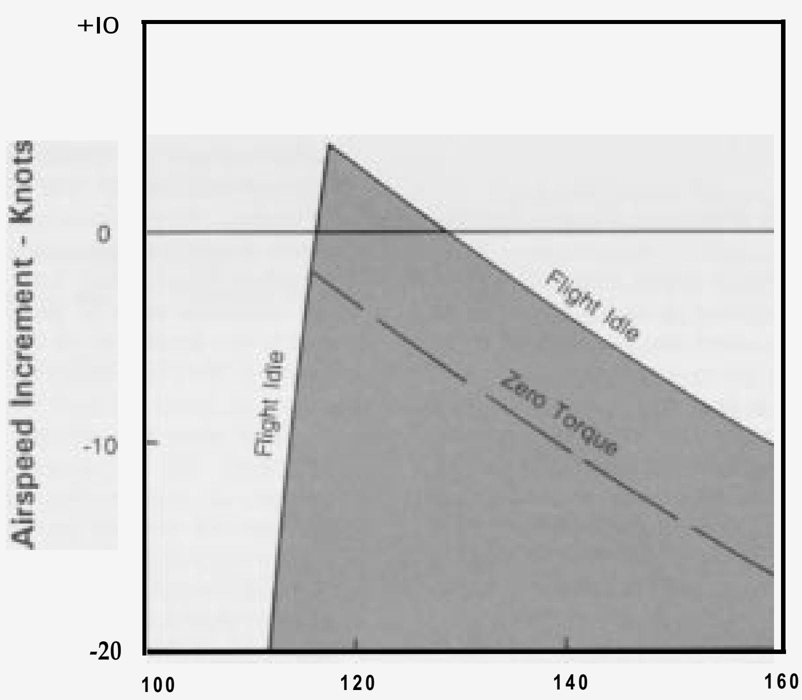
C-130 Three-Engine Air Minimum Control Speeds
Flaps 50%, 180~lb Max Pedal Force, 5-Deg Max Bank Angle



Flight Manual Minimum Control Speed - KCAS

Figure 2.

C-130 Two-Engine Air Minimum Control Speeds
Flaps 50%, 5-Deg Max Bank Angle



Flight Manual Minimum Control Speed - KCAS

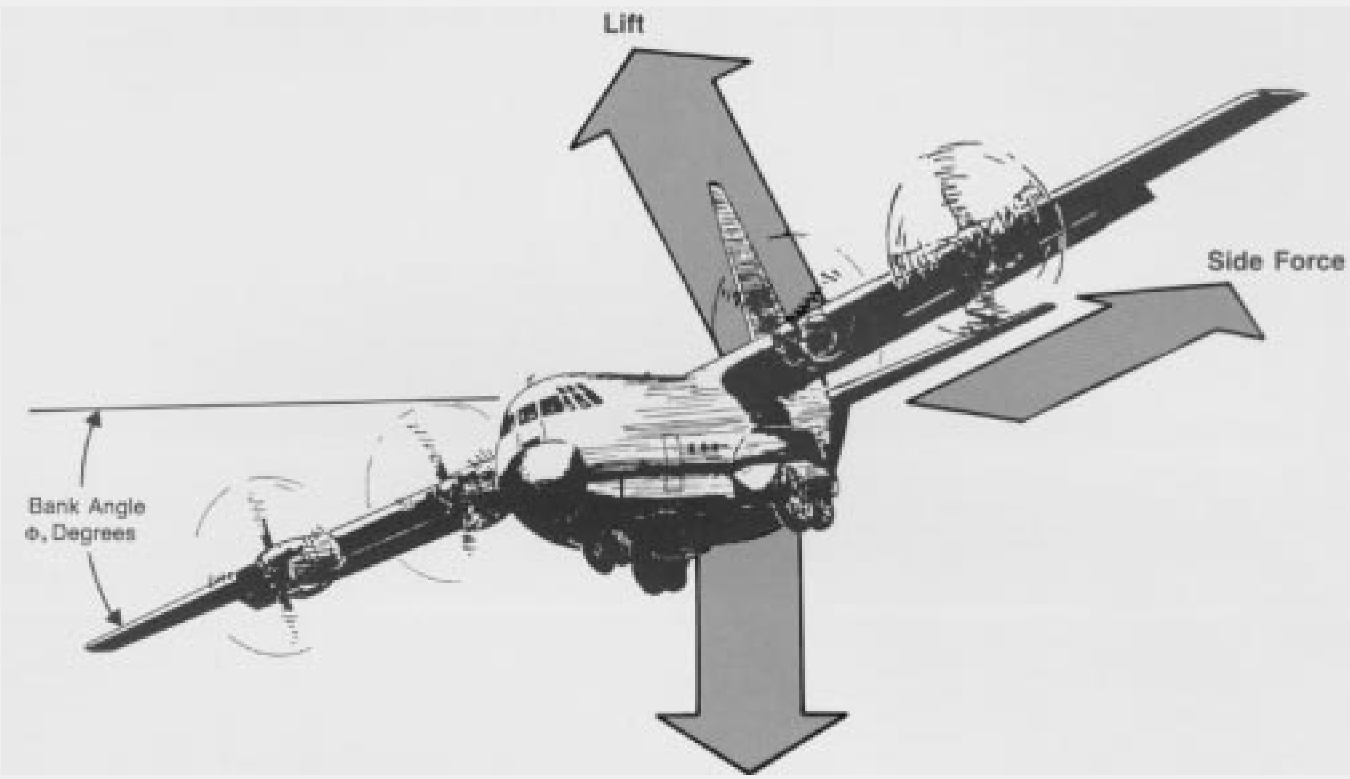
Figure 3.

Other Considerations

Recent worldwide Hercules mishap investigations have shown that too few operators fully understand the performance characteristics of the Hercules aircraft. Crews are flying into critical situations at altitudes and speeds which make recovery virtually impossible.

Improper control inputs during asymmetric thrust situations can cause *immediate loss of control*. If yaw is increased rapidly to very high sideslip angles, the result will be a drastic loss of airspeed and a rapid roll toward the thrust-deficient wing. Recovery to balanced flight with coordinated controls and symmetric power must begin immediately and may require as much as 5,000 feet of altitude. Regaining directional control is imperative; it may require nothing more than reducing power on the opposite symmetrical engine to something less than takeoff power, provided the pilot recognizes and makes proper allowance for the reduction in climb performance.

Maintaining the minimum speeds prescribed in the performance manual only ensures that the aircraft can be controlled under a very specific set of operational conditions. Prevention-that is, always maintaining an adequate speed margin during maneuvering-is the real key to controlling the aircraft. Published minimum control speeds do not afford additional margins for maneuvering, nor do they guarantee protection from further upsets if the given conditions change. Prompt, precise pilot action must occur immediately to avoid a departure from controlled flight in such cases.



Weight

Recommendations for Flight Crews

- Make sure you fully understand the aircraft's characteristics and know how to apply your knowledge in flight. Simply knowing the performance definitions is not enough.
- Understand and respect the effects that any divergence from the defined parameters may have on performance characteristics.
- Use zero torque settings for all engine-out simulations.
- *Always* know both the charted V_{mca} and the actual minimum control speeds in all situations.
- Maintain sufficient control margins during low-speed flight.

Lockheed
Aeronautical Systems Company
Customer Training Systems Department
Lockheed – LASC
Marietta, GA 30063

2001, 2002, 2003, 2004,...