

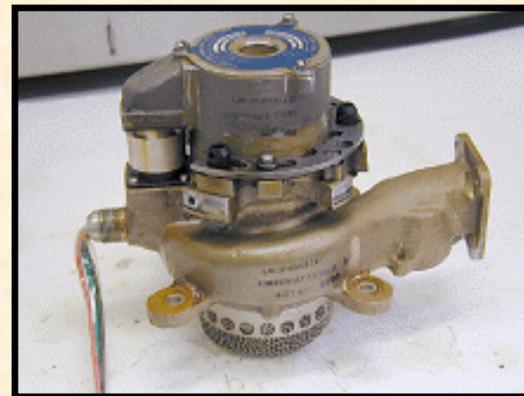
Fuel Pump Condition Monitor Developed for C-141 Aircraft

ORNL Developed An ESA-based Instrument For Monitoring The Condition Of C-141 Fuel Booster Pumps



C-141 Starlifter

- Each C-141 has 20 fuel booster pumps (5 fuel tanks per wing, 2 pumps per tank)
- Fuel pumps are centrifugal and driven by 3-phase electric motors
- ESA prototype diagnoses problems on both main and auxiliary fuel pumps

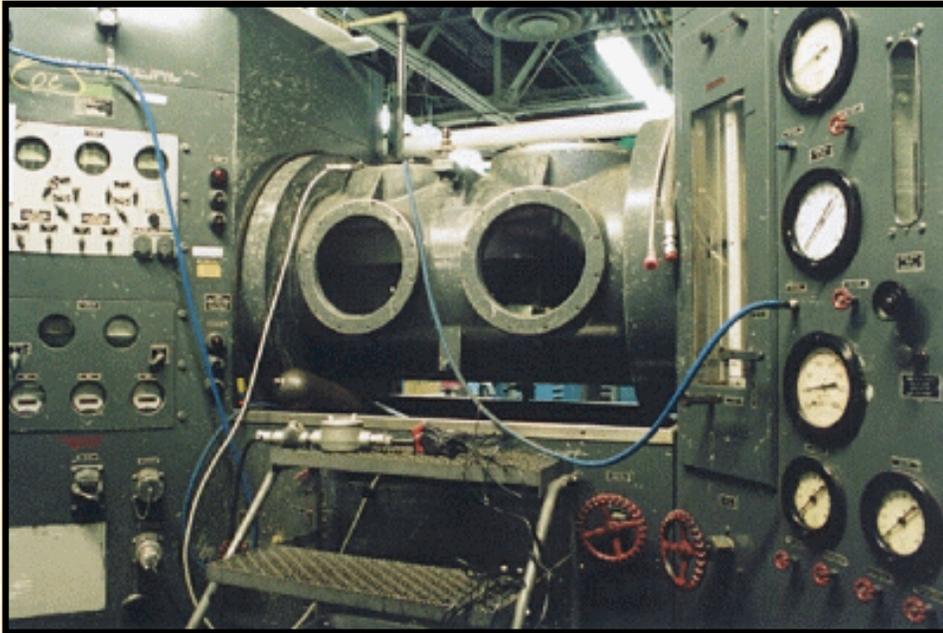


Main Fuel Pump

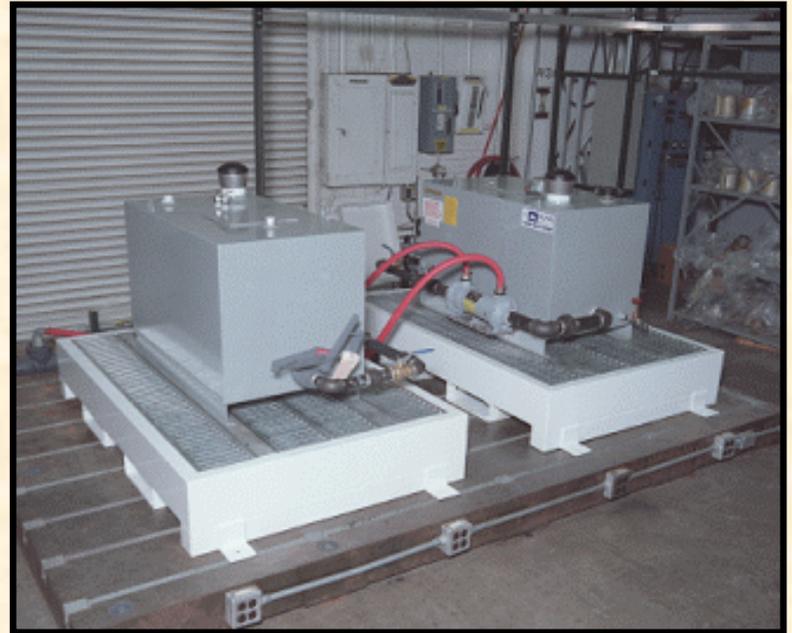


Prototype Unit

Fuel Pumps Were Tested At Two Test Facilities



***Oklahoma City Air Logistics Center
(OC-ALC) Fuel Pump Test Facility***



***Oak Ridge National Laboratory Fuel
Pump Test Facility***

Fuel Pumps Were Also Tested On Four C-141 Aircraft At Wright-Patterson Air Force Base



ORNL Delivered 2 Each Prototype C-141 Fuel Boost Pump Condition Monitor Systems



Test Setup Screen

The screenshot displays the 'C-141 Fuel Pump Condition Monitor' software interface, version 6.21. The window title is 'C141FuelPump_MainVI(ver 6.21).vi'. The interface includes a menu bar (File, Edit, Operate, Tools, Browse, Window, Help) and a toolbar with icons for Run, Stop, and Pause. The main title is 'C-141 Fuel Pump Condition Monitor' with 'ver 6.21' below it. A subtitle 'Electrical Signature Analysis' is displayed, along with 'Developed by the Oak Ridge National Laboratory'. The interface has five tabs: 'SYSTEM INFO', 'TEST SETUP' (selected), 'ACQUIRE DATA', 'ANALYZE DATA', and 'TREND DATA'. A yellow banner reads 'COMPLETE STEPS 1 - 4, THEN PRESS "ACQUIRE DATA" TAB'. The 'TEST SETUP' tab is divided into four sections: (Step 1) - Start Software, (Step 2) - Turn on SCE*, (Step 3) - Connect Probes, and (Step 4) - Enter Test Information. (Step 1) includes a 'Press Run Button Above' instruction and a button icon. (Step 2) shows 'Check Battery Voltage' with two meters: 'SCE* Battery (+ Volts)' at 7.05 and 'SCE* Battery (- Volts)' at -7.01, both marked 'OK'. A note states '* SCE = Signal Conditioning Electronics'. (Step 3) instructs to see 'Current Probe Instructions' in the 'SYSTEM INFO' folder. (Step 4) includes 'Pump Serial Number' with 'Known' and 'Unknown' radio buttons, three dropdown menus for 'Auxiliary', 'WPAFB (Aircraft)', and '8. E2, Aux, Secondary', and 'Fuel Transfer Deadhead' with radio buttons. Below these is a text field for 'ENTER 5 DIGIT TAIL NO.' containing '50249'. A 'Data Storage Folder' field contains 'C:\FuelPumpData'. A red 'NOTE' box states: 'The ESA-Based Pump Bearing Condition Indicator Requires Pump Testing To Be Performed At Zero Flow (Deadheaded)'. The Windows taskbar at the bottom shows the Start button, several application icons, and the system tray with the time '2:13 PM'.

Data Acquisition Screen

C-141 Fuel Pump Condition Monitor
ver 6.21

Electrical Signature Analysis
Developed by the Oak Ridge National Laboratory

SYSTEM INFO | TEST SETUP | **ACQUIRE DATA** | ANALYZE DATA | TREND DATA

Updating "Preview" Data Screen

(Step 5) - Preview Data

PHASE CURRENT SIGNALS

Amps (RMS)

Time

CURRENT IS STABLE

T1 Phase Current (A)	8.09	NORMAL
T2 Phase Current (A)	8.16	NORMAL
T3 Phase Current (A)	8.09	NORMAL
Neutral Current (A)	0.48	NORMAL
Unbalance (%)	0.60	NORMAL

(Step 6) - Acquire Data

PRESS TO ACQUIRE DATA

The Preview Data Screen Will Be Momentarily Disabled

T1 Current (A) STABLE

T2 Current (A) STABLE

T3 Current (A) STABLE

N Current (A)

Time (seconds)

(Step 7) - Save Data

PRESS TO SAVE DATA

TO TEST ADDITIONAL FUEL PUMPS, REPEAT STEPS 3 - 7

Windows taskbar: Start, Eudora, Microsoft Pow..., LabVIEW, C141FuelPu..., 2:27 PM

Data Analysis Summary Screen

C-141 Fuel Pump Condition Monitor
ver 6.21

Electrical Signature Analysis
Developed by the Oak Ridge National Laboratory

SYSTEM INFO | TEST SETUP | ACQUIRE DATA | **ANALYZE DATA** | TREND DATA

Start Software
Press Run Button Above

PRESS TO ANALYZE A STORED DATA FILE
[Data File Read]
C:\FuelPumpData\
C141_A_-----_WP_50249_2A5_DHEAD_04100
3_52022.FPD
[Month] 4 [Day] 10 [Year] 2003
[Hour] 14 [Min] 27 [Sec] 2
[Pump Type] Aux
[Serial No.] n/a n/a
[Test Location] WPAFB (Aircraft)
[Aircraft Tail Number] 50249
[Position] LW, E2, Aux, Sec
[Flow Rate (pph)] 0
[Pressure (psi)] Unknown

PRESS TO STORE THE ESA RESULTS

Ready to Read Data File

SUMMARY | ESA 1 | ESA 2 | ESA 3 | ESA 4 | ESA 5 | ESA 6

SUMMARY OF C-141 FUEL PUMP ESA RESULTS

PUMP CONDITION PARAMETERS	More Info
(Data Stability)	OK ESA 1
(SCE Battery)	OK ESA 2
(RMS Current Level)	OK ESA 1
(Current Unbalance)	OK ESA 2
(Neutral Current)	OK ESA 1
(Bearing Condition Indicator)	OK ESA 3 See Note Below
(Motor Speed Detected)	OK ESA 4
(Motor Condition Indicator)	OK ESA 5

OTHER PUMP ESA RESULTS

OTHER PUMP ESA RESULTS	More Info
Motor Speed Harmonic Spectrum	ESA 6

Note: The ESA-Based Pump Bearing Condition Indicator Requires Pump Testing To Be Performed At Zero Flow.

Windows Taskbar: Start | Eudora | Microsoft Pow... | LabVIEW | C141FuelPu... | acquire data e... | 2:29 PM

Data Analysis Detail Screen – Motor Diagnostics

C-141 Fuel Pump Condition Monitor
ver 6.21

Electrical Signature Analysis
Developed by the Oak Ridge National Laboratory

SYSTEM INFO | TEST SETUP | ACQUIRE DATA | **ANALYZE DATA** | TREND DATA

Start Software
Press Run Button Above

PRESS TO ANALYZE A STORED DATA FILE

[Data File Read]
C:\FuelPumpData\
C141_A_----_WP_50249_2A5_DHEAD_04100
3_52022.FPD
[Month] 4 [Day] 10 [Year] 2003
[Hour] 14 [Min] 27 [Sec] 2
[Pump Type] Aux
[Serial No.] n/a n/a
[Test Location] WPAFB (Aircraft)
[Aircraft Tail Number] 50249
[Position] LW, E2, Aux, Sec
[Flow Rate (pph)] 0
[Pressure (psi)] Unknown

PRESS TO STORE THE ESA RESULTS

Ready to Read Data File

SUMMARY | **ESA 1** | ESA 2 | ESA 3 | ESA 4 | ESA 5 | ESA 6

MOTOR DIAGNOSTIC PARAMETERS

- OK 1.343E-4 Overall Shorted Turns Magnitude
- OK 7.683E-4 Overall Static Eccentricity Magnitude (rotor bar based)
- OK 1.400E-5 Overall Dynamic Eccentricity Magnitude (rotor bar based)
- OK 1.480E-4 Overall Dynamic Eccentricity Magnitude (motor speed sideband based)
- OK 8.897E-4 Overall Rotor Winding Asymmetry Magnitude (slip-poles sideband based)
- OK 1.158E-3 Demod slip-poles peak
- OK 2.107E-4 Demod 1xM5 peak
- OK 2.533E-4 Demod 3xM5 peak
- OK 2.695E-5 Demod 5xM5 peak

[Overall Motor Condition]

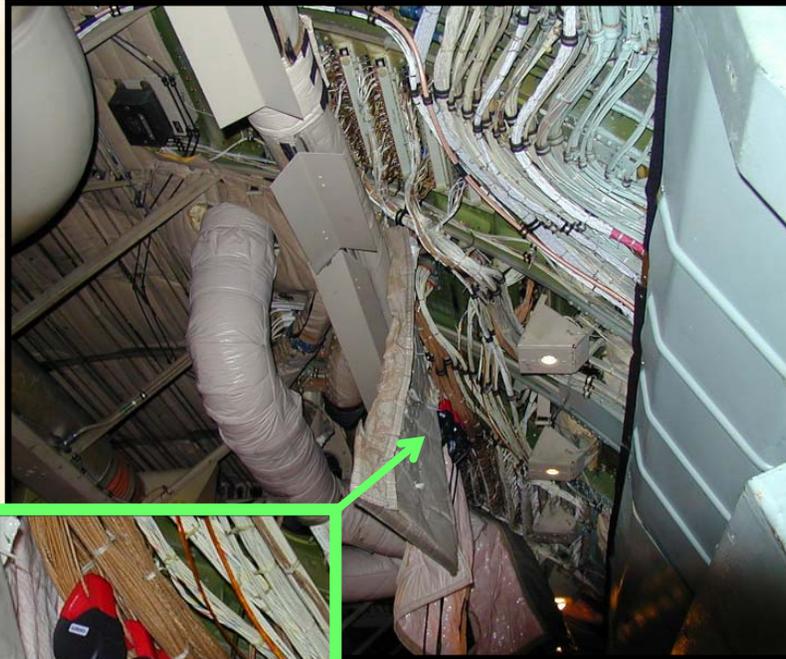
0.0 0.5 1.0 2.0
0.34

Windows taskbar: Start, Eudora, Microsoft Pow..., LabVIEW, C141FuelPu..., 2:34 PM

To Make Diagnosis on C-141 Aircraft, Fuel Pump Motor Leads Can Be Easily Accessed At Several Locations

Inside Fuselage

Under Wing



Current transformers clamp around wires, so no wires have to be cut



The system is easy to use - USAF fuel technicians on first attempt demonstrated capability to connect transformer clamps, initialize computer files and acquire data in 4 minutes per pump!

ORNL ESA Air Force Project Team Demonstrated System to Sponsors at Warner Robins AFB, GA



Lead to current transformer clamped to fuel pump power cable behind wing

C-141 aircraft

Prototype hardware packaged in metal suitcase