A Computerized Aircraft Battery Servicing Facility

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The NASA Dryden Flight Research Facility at Edwards, California, operates a fleet of research aircraft which use a variety of nickel-cadmium storage batteries. These batteries range in capacity from 3 to 40 Ah with numbers of cells ranging from 10 to 22. All employ flooded cells with pressure relief vent caps and are manufactured by the Marathon Battery Co. of Waco, Texas.

To meet the stringent safety requirements of research flight operations, batteries are serviced every 30 to 60 days. To handle the volume of servicing with limited manpower, Dryden developed the computerized Battery Servicing Laboratory in the 1970s. This presentation describes the latest upgrade to this facility which has been renamed the Aerospace Energy Systems Laboratory (AESL).

Battery Assignments by Aircraft

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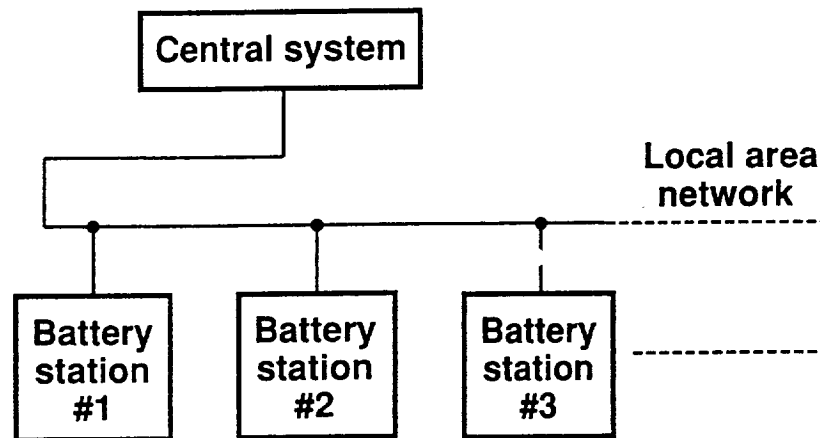| Aircraft	Model number	Part number	Amp-hr rating	Batteries/ project	# ship sets
B-747	CA-54-1	28002-001	5	4	2
C-140	CA-5H-20	24535-19	30	4	2
F-16	DA-81755	30192-03C	10	6	3
F-18	ARC-14M220-19	31310-001	10	14	7
F-18	ARC-40SP100-19	F18-C-113	40	16	2
F-104	MA-300H	18241-001	3	12	6
F-111	MA-7 MA-8	24540-007 27797-001	10 24	2 3	2 3
PA-30	ARC-10H120-21 CA-24A	10H120-21 27312-001	10 24	2 2	2 2
T-38	MA-500H	23729-01	5	4	4
X-Wing	SP-176	30134-001	17	8	4
X-29	ARC-3H120-21 CA-9-20 CA-121	31463-001 28974-01C 19150-01C	3 24 12	9 5 6	3 5 6

The AESL is a distributed digital system consisting of a central system and battery servicing stations connected by a high-speed serial data bus. The entire system is located in two adjoining rooms; the bus length is approximately 100 ft.

Each battery station contains a digital processor, data acquisition, floppy diskette data storage, and operator interfaces. The operator initiates a servicing task; thereafter the battery station monitors the progress of the task and terminates it at the appropriate time.

The central system provides data archives, manages the data bus, and provides a timeshare interface for multiple users. The system also hosts software production tools for the battery stations and the central system.

AESL Overview

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          ┌──────────────────┐
          │  Central system  │
          └──────────────────┘
                    │                    Local area
        ┌───────────┘                     network
        │
  ──────┼──────────────●──────────────●────────- - - - - - - - -
        │              │              │
  ┌───────────┐  ┌───────────┐  ┌───────────┐
  │  Battery  │  │  Battery  │  │  Battery  │    - - - - - - -
  │  station  │  │  station  │  │  station  │
  │    #1     │  │    #2     │  │    #3     │
  └───────────┘  └───────────┘  └───────────┘
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Station 3 (Front View)

The battery station benches are 34-in. wide modular wooden structures which can be moved through a standard doorway with a pallet mover. The following components are mounted to the bench:

Charger – analzyer   Placed on top of the bench

Status and control panel   Mounted beneath top of bench

Primary power panel   Mounted behind bench (near top)

Barcode reader gun   Holster at right side of work surface

Temperature probes   Connected at rear of work surface

Left Connector panel   Mounted under left side of work surface
   Terminal connector
   Printer connector
   Load bank control connector

Right connector panel   Mounted under right side of work surface
   Battery cable connector
   Monitor plate connector

Controller assembly   Mounted on lower shelf
   Cardcage
   Floppy diskette drive
   Current leakage box
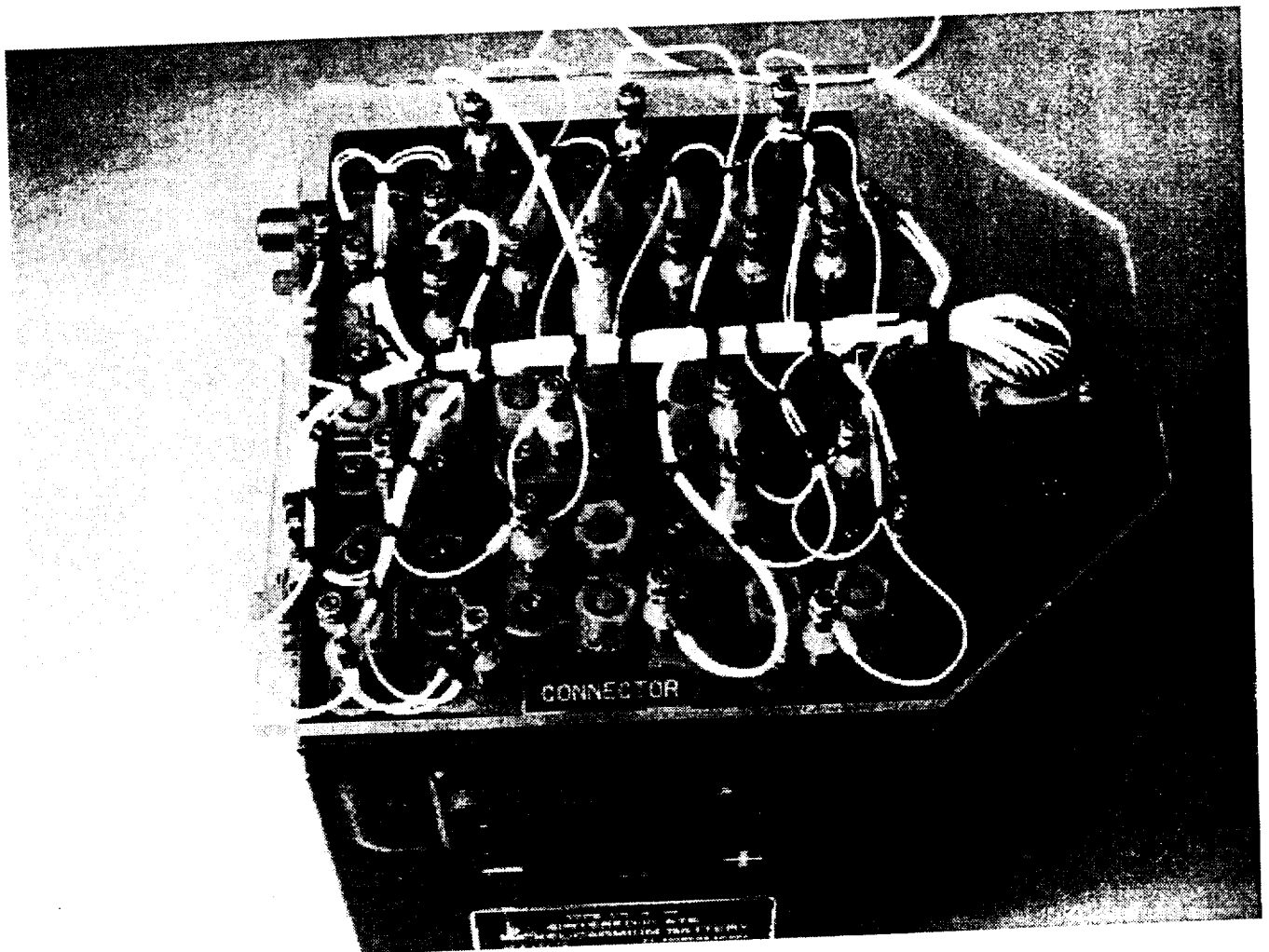   Accessory power box
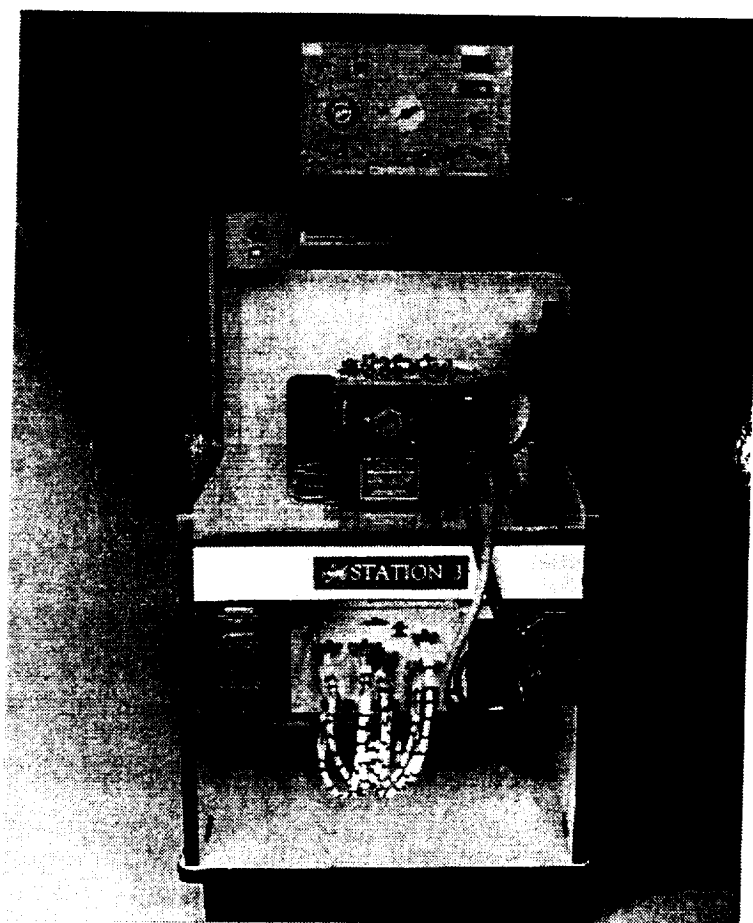
Monitor Plate Attached to CA-9-20

This photo shows the monitor plate design used with the CA-9-20 battery. This is a 20-cell, 24-Ah battery used on the X-29A forward-swept wing aircraft to supply power to onboard instrumentation. The plate is made of Lucite with spring loaded plunger pins to provide contacts to all the busbars. The connector is standard for all monitor plates so that only a single interconnect cable is required at each battery bench.

Electrical connections are provided for up to 30 cell voltages, total battery volts, and the battery case leakage test circuit. While not electrically part of the monitor plate, the hot vapor sensor is installed in a hole drilled in the center of the monitor plate.
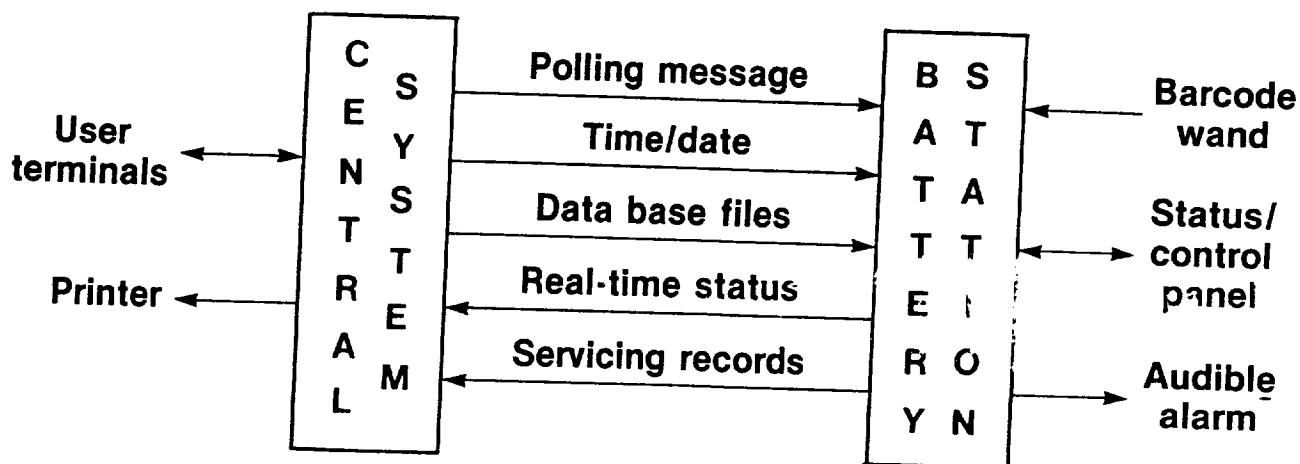

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The operator initiates a servicing task by positioning the case temperature probes, attaching the monitor plate and power cable, installing the hot vapor sensor, selecting the task, and reading the barcode tag on the side of the battery. The database files necessary to support the servicing of this battery are automatically transferred from the central system and an open circuit data file is created. The operator then configures the charger – analyzer and initiates the run phase of the task; a start of run file is created.

While the task is running, numerous parameters are analyzed automatically, and data files are created at timed intervals during the run. If desired, the task may be monitored at the battery station using the status and control panel, or may be monitored by the central system multiuser interface using real-time status transferred on the data bus.

When programmed conditions are met, an end of run data file is created, the charger – analyzer is shut off, and the operator is notified by the audible alarm on the battery station. All data files are stored locally on floppy diskett: and are also sent to the central system archives as servicing records.

AESL Functional Overview

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Each battery station has an intelligent A/D subsystem consisting of a Datel ST701-A2 microcomputer board and a companion ST742 expander board. This provides a total of 48 channels using a multiplexer feeding a single ± 10 V, 12 bit, 20 μs converter. A programmable-gain amplifier at the input to the converter provides gains up to 128X.

Dryden developed software for the Z80 processor on the ST701 board provides several input algorithms. For the reflex charger pulse waveform, the channels are scanned rapidly in succession and 32 past values for each channel are saved in a 32-frame buffer. These equally spaced samples permit pulse shape analysis, plateau averaging, and pulse period computation. For the constant current mode (typically full wave rectified 60 Hz), each channel in turn is allocated a window 1/60-sec. wide. During the window, as many samples as possible are taken in a burst which is then averaged. Ampere-hour integration is also performed by the ST701 using a 64-bit integral and a 64-bit counter tallying the number of iterations.

Analog Subsystem Channels

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- **30 cell voltages**

- **1 battery monitor plate voltage**

- **1 battery cable voltage**

- **1 charger–analyzer current**

- **5 temperature probes**

- **1 case leakage current**

- **1 programmable load bank voltage**

- **1 programmable load bank current**

- **1 programmable load bank temperature probe**

Temperature Probes

Each battery bench has five temperature probes to monitor the battery being serviced. Four are mounted on stainless-steel shoes which slide beneath the bottom of the battery case. Installed in a Lucite holder, the fifth probe slips into a hole in the monitor plate to detect hot vapors.

The sensors used are miniature 50-ohm nickel foil elements biased with 2.4 mA. The calibration curve is embodied in a second-order polynomial which gives good accuracy over the 70-170 °F range.

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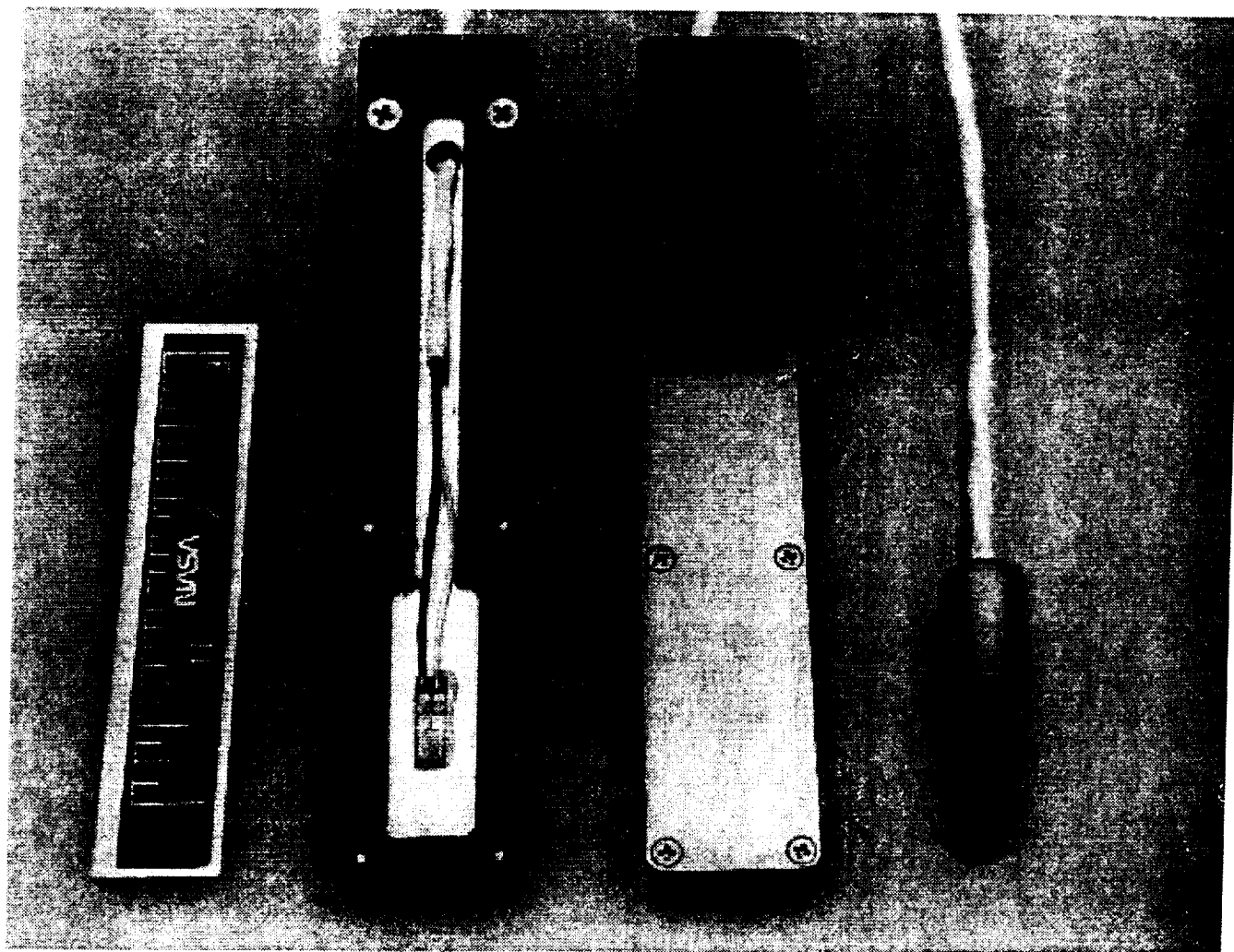
Servicing Procedure

Battery servicing in the Dryden AESL consists of the following:

1. Incoming inspection
2. Return capacity test
3. Cell equalization (zero volts per cell)
4. Cleaning (teardown if required)
5. Charge No. 1 (main and top)
6. Capacity test
7. Charge No. 2 (main and top)
8. Electrolyte level check
9. Load test
10. Charge No. 3 (main and top)
11. Check busbars torqued per spec
12. Quality assurance inspection

Case leakage is monitored continuously during servicing.
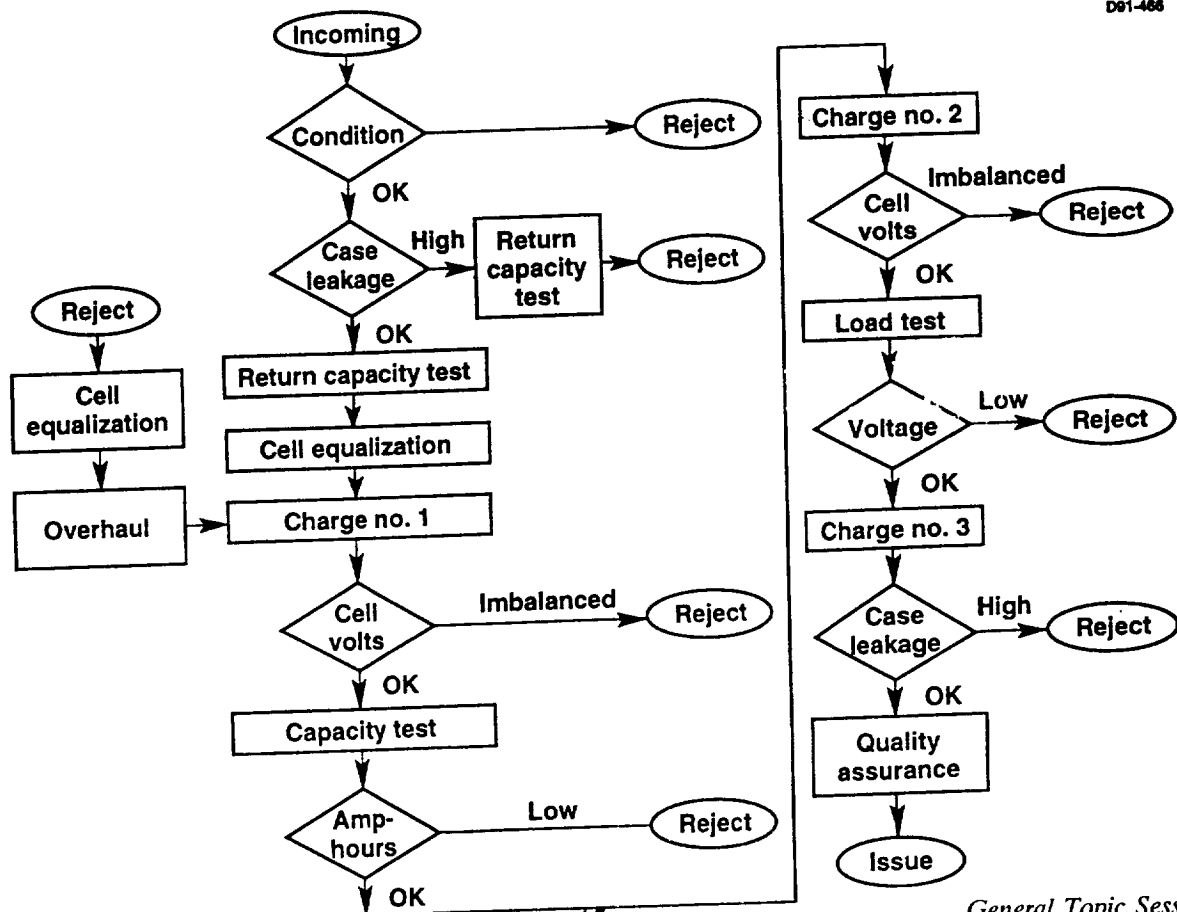
Pushbuttons Panel

The pushbuttons matrix on the Status and Control Panel provides the operator with means to set up, control, and monitor the battery servicing task in progress. The top row of pushbuttons allows the operator to select the task to be performed: open circuit, return capacity, charge 1 main, charge 1 top, capacity test, charge 2 main, charge 2 top, 2 minute load, 3 minute load, variable load, charge 3 main, and charge 3 top.

The second row of pushbuttons allows the operator to control the progress of the task. The equipment power button turns on the 220 v AC power to the charger – analyzer. The run mode button signals the software that the charger – analyzer setup is complete and shutdown tests can be run. The hold mode button signals the software to suspend shutdown tests temporarily. The stop mode button removes power from the charger – analyzer. The write file button allows the operator to create additional data files. The read file button is an indicator only.

The botttom row of pushbuttons is used to control the display unit.
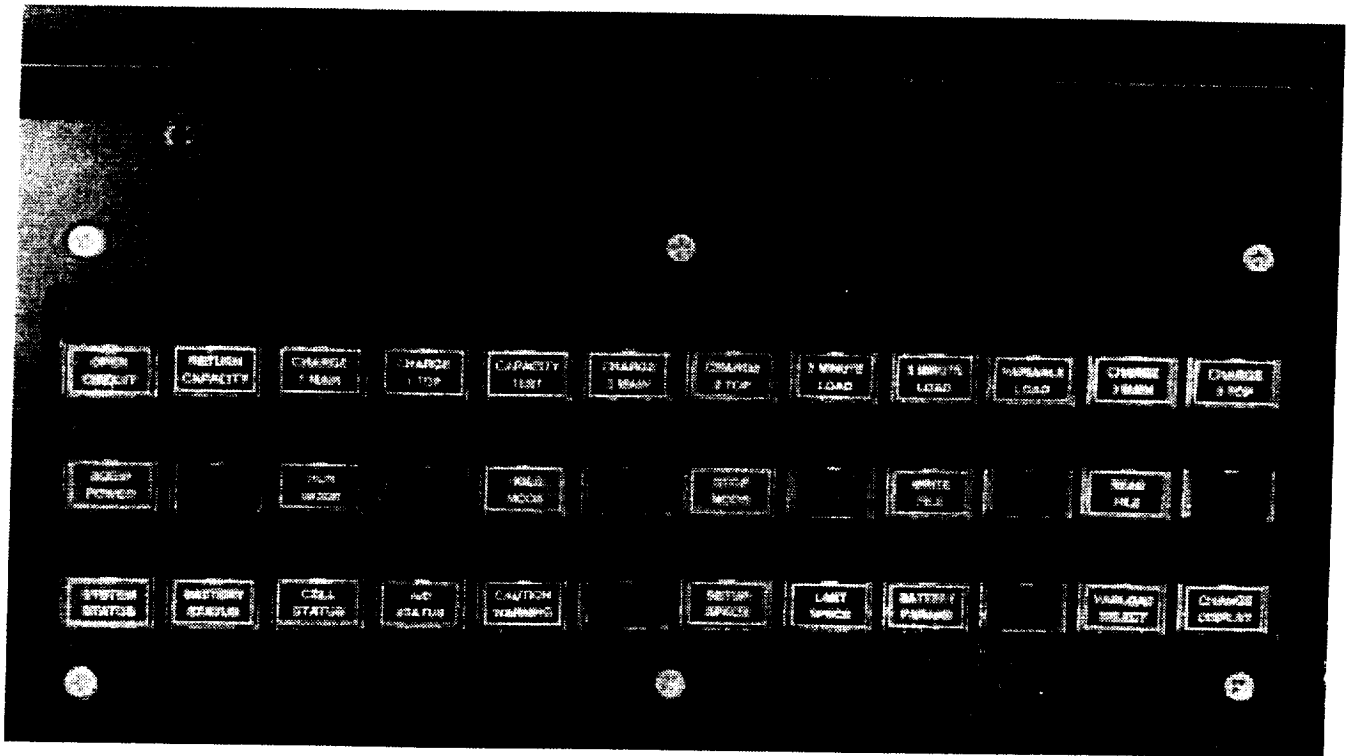
The battery station controller software monitors the progress of each servicing task and terminates the task when the appropriate conditions are sensed. There are three abnormal conditions which always cause immediate shutdown: hot vapor sensed at the top of the battery, high case temperature sensed at the bottom of the battery, or excessive case leakage current.

During reflex charge, normal shutdown occurs when the pulse rate slows to one per second or when the desired amp-hrs is reached. During constant current charge, normal shutdown occurs when the desired amp-hrs is reached or when the maximum battery voltage is reached. Abnormal shutdown conditions include rapid cell voltage drop indicating thermal runaway, or excessively high cell voltage.

During capacity tests, normal shutdown occurs when the lowest cell voltage drops below 1.00 V.

During load tests, the normal shutdown is based on elapsed time. An abnormal shutdown would occur if a lower limit were reached for either a low cell voltage or a low total battery volts.

Shutdown Criteria

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- **General**

  - **Hot vapor sensor (top of battery)**

  - **High case temperature**

  - **Excessive case leakage current**

- **Charging tasks**

  - **Minimum pulse rate (reflex charger)**

  - **Cell voltage drop (thermal runaway)**

  - **Maximum ampere-hours**

  - **Maximum cell voltage (typ. 1.80 V)**

- **Capacity tests**

  - **Minimum cell voltage (typ. 1.00 V)**

- **Load tests**

  - **Elapsed time**

  - **Minimum cell/battery voltage**

Central System Console

The AESL central system consists of an Intel System 310 CPU, an auxiliary chassis containing hard disk drives, a Wyse Model 60 terminal, and a Dataproducts M200 printer.

The CPU chassis contains a 80286/80287 processor board, 5 Megabytes of RAM, two communications boards providing 12 RS-232 ports, and piggyback modules for the BITBUS interface and the clock – calendar. Also installed in this chassis are a 5.25-in. floppy diskette drive, and a 0.25-in. streaming tape drive.
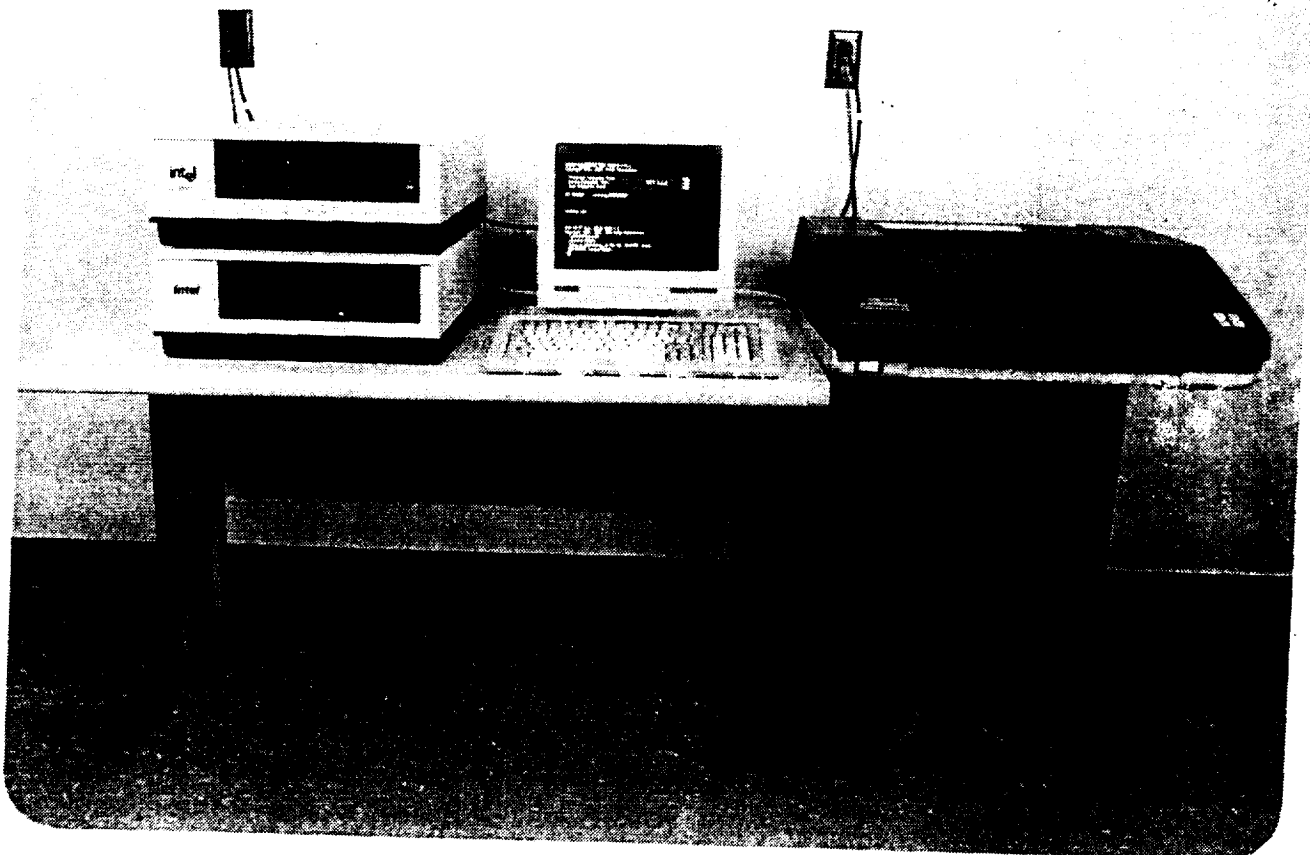
The auxiliary chassis contains two large hard disk drives plus power supplies. One of the drives contains the data archives and can store 65,500 data files (several years worth). The other is the system drive containing all the software production tools.

The Wyse terminal is used for software production and for the maintenance of the specification files controlling battery servicing operations. The printer is used to dump the nightly log of the automatic archives maintenance operations.

Central System Console

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The AESL central system provides data archives, several resident software jobs which provide automatic operations, and a variety of utility programs.

The data archives contain specification files regulating battery servicing operations, data files created during battery servicing, technician's logs for each battery, indexes providing rapid access to data records, and cross-indexes relating battery types, cell types, and applications.

Resident jobs running within the central system provide bus polling, download of specification files, upload of data files, purging the floppy diskettes at the battery stations, and maintaining indexes within the archives. In addition, if the operator inserts a tape cartridge, the archives are backed up to the tape automatically.

Utility programs are provided to review data files, update logs, assess operations schedule, and print the inspector's summary report.

Central System Features

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- **On-line records storage**
    - **Large archives for battery servicing data files**
    - **Battery servicing operations logs**
    - **Cross indexes for battery types, cell types, and applications**

- **Automatic operations**
    - **Data bus polling**
    - **Specification files download to stations**
    - **Data files upload to central**
    - **Purging temporary storage media at battery stations**
    - **Updating indexes of data files when required**
    - **Tape backup of archives when requested by operator**

- **User utilities**
    - **Servicing data files access**
    - **Operations logs access–update**
    - **Operations scheduling**
   - **Inspector's summary printout**

Battery Simulator

NASA Dryden has developed a NiCd battery simulator which has proven useful in checking out battery station hardware and software. It generates 30 individual cell voltages, total battery voltage, and the discretes logic specifying number of cells. In addition, it simulates the signal from the shunt which monitors charger – analyzer current.

The 30 cell switches on the left side of the panel have three positions: center is normal (1.40 V), up is high (1.90 V), and down is low (0.90 V). The knob at lower center of the panel allows total battery voltage to be set, while the five switches above it determine the number of cells.

The controls for the current shunt simulation are on the right side of the panel. It can simulate the pulsed waveform of the reflex charger or the steady-state signal of constant current charging. In addition, it can simulate discharge currents for capacity tests and load tests.

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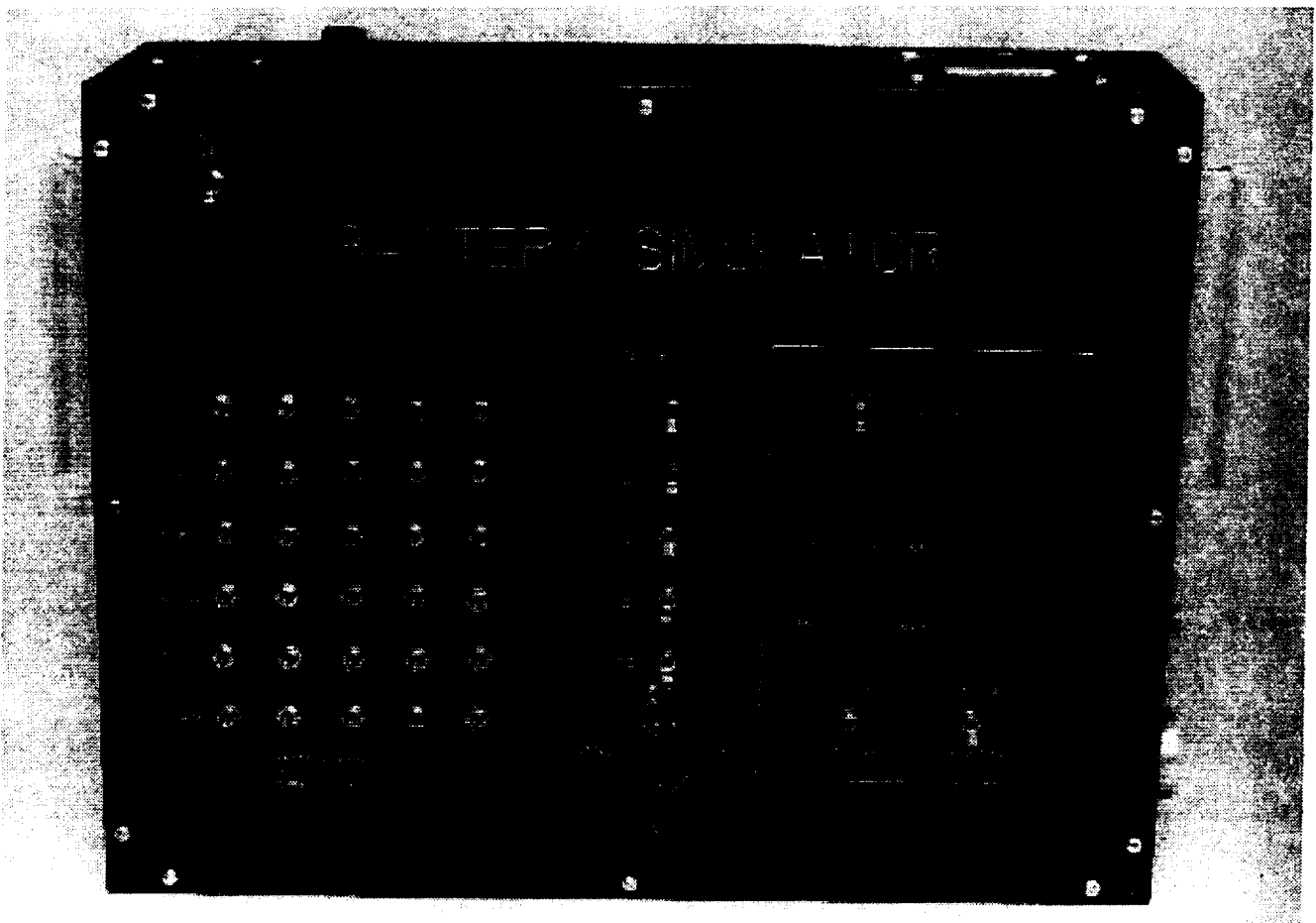
The history of the Dryden AESL project covers several years because only limited manpower was allocated for the effort. Fewer than ten people have been involved on a part-time basis and the priority of the effort has always been low.

The first three milestones in the timeline coincide with the publication of NASA technical memorandums describing progress to date. Design of the production battery stations was a lengthy process because of the complete redesign of the bench structure. Integrated testing of the first three production stations proved that the data bus hardware and software protocols were robust and heavy traffic could be accommodated.

The facility renovation has delayed moving in the new equipment and beginning shakedown testing with contractor operations personnel. It is anticipated that the AESL will be certified by the end of 1991 and that a full complement of 10 stations will be in service by September 1992.

A final report coauthored by Richard Glover and William Kelly will be published in early 1992. Additional information on the AESL can be obtained from William Kelly at (805) 258-3365.

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Project Timeline

May 1988 – Requirements and design approach finalized

July 1989 – Prototype system operational (single station)

Nov 1989 – Data bus protocols finalized

June 1990 – Production station design complete

Mar 1991 – Integrated testing using three production stations

Sept 1991 – Facility renovation complete

Oct 1991 – Begin shakedown production testing with four stations

Dec 1991 – Certify facility for production battery servicing

Sept 1992 – Complete phasing in remaining six production stations