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Instrumentation & Control
System Design Criteria

MASTER

Test Cell ETS-1
NNRDC

VOLUME 3

CRITERIA TECHNICAL DATA SHEETS (EQUIPMENT)

COPY 38 OF 150

Aerojet-General[®] CORPORATION

A SUBSIDIARY OF THE GENERAL TIRE & RUBBER COMPANY
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TECHNICAL DATA SHEET 2.1
MASTER CALIBRATION CONTROL UNIT

1.0 INTRODUCTION

* The Master Calibration Control Unit will operate under an initiating or stepping command signal of the Lead Instrumentation Engineer (LIE), and will apply signals sequentially to the control calibration busses. These signals will be equivalent to 0, 25, 50, 75, and 100% of full-scale range, and will initiate the Calibration Sequence Unit in the Data Acquisition System. Recorders of the Control and the Data Acquisition System are also controlled, to provide readouts of the above. Indicator lights, showing status of control (local or remote), shall be provided.

2.0 PHYSICAL REQUIREMENTS

* The unit will consist of a module designed for standard rack mounting, containing a rugged telephone-type stepping switch, timer, and time-delay relays. The stepping switch will advance through the calibration ranges specified above, and the timer will adjust the dwell on each step to permit stabilization of Control and Data Acquisition circuitry. Connector boards shall be included to provide flexibility in calibration sequencing. The unit shall be rack mounted in the Control Center, readily accessible to the Facilities and Test Stand control operating personnel, and under the immediate control of the LIE.

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1.0 INTRODUCTION

This document contains Technical Data Sheets to accompany the design criteria for the Instrumentation and Control System for the National Nuclear Rocket Development Test Cell ETS-1, and is related to the efforts being conducted under Task Item 4.0 of Contract SNP-1.

The Technical Data Sheets represent preliminary technical descriptions of the major "Black Boxes" in the Instrumentation and Control System. Their primary purpose is to form a basis for preparing the technical section of the procurement specifications, and they do not provide complete, or final, coverage of all engineering requirements. They are subject to revisions, additions, or deletions, as dictated by new requirements which may result from detailed design.

These sheets are based on the accumulated knowledge and experience of system and facility engineers representing NERVA Operations; Astronuclear Laboratories of Westinghouse Electric Corporation; Edgerton, Germeshausen, and Grier, Inc.; Los Alamos Scientific Laboratory; and Aetron Division of Aerojet.

The five volumes of this criteria (of which this is Volume III) are identified as follows:

- Volume I - Criteria
- Volume II - Criteria Drawings
- Volume III - Criteria Technical Data Sheets (Equipment)
- Volume IV - Engine Control System Criteria;
 Data Acquisition List;
 Facility Instrumentation and Control Channel List
- Volume V - Rough-Order of Magnitude Costs

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TECHNICAL DATA SHEET 2.1
MASTER CALIBRATION CONTROL UNIT

1.0 INTRODUCTION

The Master Calibration Control Unit will operate under an initiating or stepping command signal of the Lead Control Engineer (LCE), and will apply, signals sequentially to the control calibration busses. These signals will be equivalent to 0-10-25-50-75% of full-scale range, and will initiate the Calibration Sequence Unit in the Data Acquisition System. Recorders of the Control and the Data Acquisition System are also controlled, to provide readouts of the above. Indicator lights, showing status of control (local or remote), shall be provided.

2.0 PHYSICAL REQUIREMENTS

The unit will consist of a module designed for standard rack mounting, containing a rugged telephone-type stepping switch, timer, and time-delay relays. The stepping switch will advance through the calibration ranges specified above, and the timer will adjust the dwell on each step to permit stabilization of Control and Data Acquisition circuitry. Connector boards shall be included to provide flexibility in calibration sequencing. The unit shall be rack mounted in the Control Center, readily accessible to the Facilities and Test Stand control operating personnel, and under the immediate control of the LCE.

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TECHNICAL DATA SHEET 2.2
MASTER CHECKOUT CONTROL UNIT

1.0 INTRODUCTION

The Master Checkout Control Unit will operate in conjunction with the Master Calibration Control Unit, selecting the step at 75% of full-scale, and transmitting the channel signals to the comparators in the Control and Data Acquisition Systems. It will contain a memory system for storage of GO/NO-GO limits for each Control channel to be checked, and suitable circuitry to feed this information into the control comparator for readout of out-of-tolerance conditions. The memory for the Data Acquisition System will be an integral component.

2.0 PHYSICAL REQUIREMENTS

The unit will consist of a module designed for standard rack mounting, and containing a solid-state memory capable of storing GO/NO-GO information for the control channels to be checked. Location of the unit shall be below the Master Calibration Control Unit in the Control Center. Local and remote control status indicator lamps shall be included.

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TECHNICAL DATA SHEET 2.3
TEST DIRECTOR CONSOLE

1.0 INTRODUCTION

The Test Director Console shall consist of the necessary controls, displays, and monitors for use of the Test Director and the Assistant Test Director.

2.0 DETAILED REQUIREMENTS

This Console shall provide two operator positions, including the following functions:

2.1 TEST DIRECTOR POSITION

- (a) Reactor Period Meter - The period meter at the Test Director Position shall be a slave unit operating in parallel with the period meter on the Reactor Monitoring Panel (see TDS No. 3.1.2).
- (b) Duct Temperature - The unit shall provide for reading of maximum duct temperatures.
- (c) Major-System Status Reporting Modules - shall be rear-projection indicators: see Appendix 1.1, paragraph 11.4 of the Design Criteria.
- (d) Six-Channel Strip-Chart Recorder (REAL-TIME TREND ANALYSIS) - shall record typical parameters, such as duct and shield flow and temperatures, pump-discharge pressure, turbopump speed, log-power neutron level, period, etc. These parameters will be changed as required by the specific test conditions. (see TDS No. 3.1.4.)
- * (e) ~~Dual 8 in. TV Monitors - Each monitor will have a multi-channel selector panel. (see TDS No. 4.13.)~~
- (f) Communication, Public Address, Etc. - The Test Director Position shall be equipped with a Communications Panel, as described in TDS No. 4.21.

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2.2 ASSISTANT TEST DIRECTOR POSITION

- (a) Subsystem Status Reporting Modules - There shall be approximately 50 of these units employed in the console.
- (b) Count Clock Controls
- (c) Communication, Public Address, etc. - (see TDS No. 4.21.)

2.3 DESIGN CONSIDERATIONS

The Human Engineering Design Considerations for the console must comply with those shown in Appendix 1.1 of the Design Criteria.

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TECHNICAL DATA SHEET 2.4
PORTABLE TEST EQUIPMENT

1.0 INTRODUCTION

The portable test equipment shall consist of such equipment which will be suitable for checkout, maintenance, and calibration of the ETS-1 Complex, I & C System, where existing test equipment and light indicators may be inadequate.

2.0 DETAILED REQUIREMENTS

The portable test equipment shall consist of the following equipment:

- (a) Oscilloscope - conforming to specifications given in TDS No. 5.2.12.
- (b) Vacuum Tube Voltmeter (VTVM) - This unit shall conform to specifications given in TDS No. 5.2.11.
- (c) Volt-Ohmmeter (VOM) - shall conform to the following specifications:
 - (1) Ranges
 - dc volts: 0-2.5-10-50-250-1000-5000 at 20,000 ohms/volt.
 - ac volts: 0-3-10-50-250-1000-5000 at 5000 ohms/volt.
 - db: -20 to +11, +21, +35, +49, +61, +75, "0" db at 1 milliwatt on 6000-ohm line.
 - dc/ μ a: 0-100 at 250 millivolts.
 - dc-milliamps: 0-10-100-1000 at 250 millivolts.
 - dc-amps: 0-10 at 250 millivolts.
 - ohms: 0-1000-10,000.
 - megohms: 0-1-100.
 - volts ac output: 0-3-10-50-250-100 at 5000 ohms/volt.

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- (2) Frequency Response - shall be 5-500,000 cps.
- (3) The Triplett, Model 630-PL, meets the above requirements, and is mentioned as a standard of quality only.
- (d) DC Voltmeter - This unit shall have a movement of the D'Arsonval type, with an accuracy of $\pm 1/2\%$ of full scale, and shall have a range of 150-300-600 v, and a sensitivity of 1000 ohm/volt.

Simpson, Model 9 dc, meets the above requirements, and is mentioned as a standard of quality only.
- (e) AC Ammeter - This unit shall have a movement of the iron-vane type, with an accuracy of $\pm 1\%$ of full scale, and shall have a range of 50 amp.

Simpson, Model 10 AC, meets the above requirements, and is mentioned as a standard of quality only.
- (f) DC Ammeter - This unit shall have a movement of the D'Arsonval type with an accuracy of $\pm 1/2\%$ of full scale, and shall have a range of 10-25-50 amp.

Simpson, Model 9 DC, meets the above requirements, and is mentioned as a standard of quality only.
- (g) Megohmmeter - The Megohmmeter shall conform to specifications given TDS No. 5.3.2.
- (h) Audio Oscillator - The Audio Oscillator shall conform to specifications given in TDS No. 5.2.13.
- (i) Universal Counter - The Universal Counter shall conform to the specifications given in TDS No. 5.2.10.
- (j) Impedance Bridge - This unit shall provide for dc and ac impedance measurements covering 7 decades of inductance, capacitance, resistance and conductance, and 3 decades of capacitor dissipation factor (D) and storage factor (q), to 4-place readings; accuracy to 0.1% complete with line operated ac and dc generator-detector units.

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Model 291, Universal Impedance Bridge, ESI, meets the above requirements, and is mentioned as a standard of quality only.

(k) Potentiometers

- (1) Measuring Ranges - shall be from 0 to 16.1 mv, readable to ± 0.001 mv; and from 0 to 80.5 mv, readable to ± 0.005 mv.
- (2) Reference Junction Compensator Ranges - shall be, from 0 to 1.1 mv, adjustable to ± 0.001 mv; and from 0 to 5.5 mv, adjustable to ± 0.005 mv.
- (3) Limit of Error - shall be as listed:

<u>Measuring Range</u>	<u>Compensator Range</u>	<u>Limit of Error</u>
0 to 16.1 mv	0 to 1.1 mv	0.01 mv
0 to 16.1 mv	0 to 5.5 mv	0.02 mv
0 to 80.5 mv	0 to 1.1 or 0 to 5.5 mv	0.05 mv

- (4) Galvanometer Balancing Sensitivity - The unit shall have balancing sensitivity of ± 0.002 mv in circuits, with external resistance up to 15 ohms.
- (5) Rubicon Model 2745, Minneapolis-Honeywell, meets the above requirements, and is mentioned as a standard of quality only.

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TECHNICAL DATA SHEET 2.5
SAFETY CONSOLE

1.0 INTRODUCTION

The Safety Console shall contain the necessary controls and displays to maintain a safe working area for all personnel during test operations periods, plus the controls and displays for use during certain emergency conditions.

2.0 GENERAL REQUIREMENTS

The Safety Console shall contain several panels (i.e., sections of normal control and display area), each associated with one of the following functions of the Safety System:

- (a) Fire Protection - This panel shall contain controls and displays necessary for operation of the Test Stand Area deluge systems, monitors of the test-site area automatic sprinkler systems, and heat rate-of-rise detector systems.
*
- (b) Combustible Gas, Oxygen and Carbon-Monoxide Analyzers - This panel shall contain displays necessary to monitor the combustible gas detector, oxygen, and carbon-monoxide analyzer systems.
- (c) Radiation - This panel shall contain displays necessary for monitoring radiological conditions (direct radiation and airborne activity) at specific locations throughout the test site.
*
- (d) Area Warning and Control - This panel shall contain controls and displays necessary to control personnel and vehicular traffic flow throughout the test site (doors, gates, lock-and-key system, etc.) plus controls and displays for the visual and aural warning systems.
*
- (e) Television, Communications, and Public Address - These three panels shall contain necessary controls and displays for each of the above subsystems. Space shall be allotted for each panel, in accordance with requirements of suppliers of each equipment type.

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Human engineering design considerations for the console must comply with those shown in Appendix 1.1 of the Design Criteria.

Nominal dimensions of Consoles shall be: 48 in. wide, 36 in. deep, and 44 in. high.

3.0 DETAILED REQUIREMENTS

The following controls and displays shall be located on the Safety System panels of the console:

3.1 FIRE PROTECTION PANEL

- (a) Controls - One switch shall be used to control each remote shutoff valve of the Test Stand, Pipe Chase, and Duct Vault deluge systems. Additional switches shall be used to remotely control other fire-fighting systems (fog, foam, CO₂, and water), if remote control of such systems is required during test periods.
- (b) Indicators - Water-supply pressure indicators shall be included for each master header of the three Test Stand Area deluge systems. Adequate pressure (165 psig) will be assured in the system at all times if valves are properly positioned, hence the indicators may be Fail-Safe indicator-lamp displays. Rear-projection indicators (see Appendix 1.1, paragraph 10.4) shall be used.

A Fail-Safe indication shall display: (1) presence or absence of normal line pressure, and (2) whether or not all control valves are in correct positions. A Safe condition shall be indicated by line identification in white letters in a circular green background. A flashing red background (two lamps) shall be used to indicate low water pressure or improperly positioned valves; the nature of the fault shall be displayed.

*

One (or more) rear-projection indicators shall be used to indicate the operation (i.e., deluge) of any of the automatic sprinkler systems within the test site. The indicator shall display the area involved in white letters centered in a flashing red background. Up to 10 areas may be connected to a single indicator module; two lamps shall be paralleled for the flashing-red indication as a protection against lamp failures.

- (c) Alarms - An alarm gong with a reset switch shall be included as a part of the console to supplement the flashing-red visual alarms of the fire-protection system.

3.2 COMBUSTIBLE GAS AND OXYGEN ANALYZER PANEL

- (a) Indicators - One (or more) rear-projection indicators shall be used to indicate safe or unsafe conditions, as determined by the combustible gas detector system, and by the oxygen analyzer system. White letters on a flashing-red background shall be used to display location of an unsafe area. ~~(i.e., detector station number) for the combustible gas system, and a red background for unsafe oxygen (less than 16%) area.~~

Meters associated with the two gas detector systems shall be located on the panel. ~~a multi-position switch shall be used to select the detector channels for quantitative readouts.~~

- (b) Controls - Reset controls associated with the gas detection systems shall be included as a part of this panel.
- (c) Alarms - An alarm horn, with reset switch, shall be included as a part of the console to supplement the flashing-red visual alarms of the combustible gas detection system.

3.3 RADIATION MONITOR PANEL

- (a) Indicators - Rear-projection indicators shall be used to report the status of as many as 25 radiation detector stations in the ETS-1 area. (See Section ~~2.2.7.5 and 2.2.7.6~~, and Drawing ICC-145 ~~and 195~~ of the Design Criteria.) ~~Station numbers shall be shown in white characters.~~ Radiation levels shall be indicated by background light colors as follows:

- (1) GREEN - area is safe
- (2) AMBER - area is unsafe for personnel, but radiation level is within the range predicted for the type of test involved.
- (3) FLASHING MAGENTA - area is unsafe, and radiation level is in excess of the level predicted for the type of test involved.

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* Channel readouts for detectors shall be accomplished by use of meters or recorders, or both.

- (b) Controls - Controls shall be located within the console for adjustment of the indicator light change-over points.
- (c) Alarms - An alarm chime shall be included as a part of the console to indicate unsafe radiation levels. Circuitry shall be so arranged that the alarm chime shall operate in both the AMBER and FLASHING-MAGENTA conditions, excepting that it shall be possible to Lock-Out when in the AMBER condition by switch, providing the Safety lock-and-key system is in a SAFE condition (that is, that all personnel have been cleared from all unsafe areas).

3.4 AREA WARNING AND CONTROL PANEL

- (a) Controls - A multi-position selector switch shall be used to control the operation of each visual warning light in the area. (See Section 2.2.7.4, Appendix 2.5, and Dwg ICC-037 of the Design Criteria.)

A two-position (ON-OFF) switch shall be used to control each of the aural warning sirens in the area.

A two-position (ON-OFF) switch shall be used to open or close each of the electrically operated doors or gates in the area.

- (b) Indicators - All indicators shall be located on the Area Control Map of the Safety System Graphic Display.
- (c) Alarms - None.

3.5 LOCK-AND-KEY CONTROL SYSTEM PANEL

An interlock system shall be included as part of the Safety Console. Circuitry shall be designed in a GO/NO-GO series configuration. A number of points throughout the ETS-1 Complex will be locked, by Safety System key, when a responsible safety individual has determined that the area is clear of all personnel. All test-site

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safety-keys will have to be inserted into an appropriate key-switch located in the console to complete an electrical circuit, which shall be used to: (1) light a Ready-Light on the Safety Console when all keys are properly in place, and (2) to electrically disable certain test functions (e.g., ARM and FIRE switches) whenever one or more keys are out of place. The differing nature of successive tests will require frequent variations in the lock and key system. A selector switch or patchboard system shall be located within the Safety Console to control these variations; the system shall be contained within a locked compartment, and the locking key shall be a part of the Safety Lock-and-Key System.

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TECHNICAL DATA SHEET 2.5.1
SAFETY SYSTEM GRAPHIC DISPLAY PANEL

1.0 INTRODUCTION

The Safety System Graphic Display Panel shall consist of two maps, each displaying the ETS-1, ETS-2 Complex area. Each map shall be approximately 72 in. wide and 36 in. high. One map shall be used to display the qualitative status of the combustible and toxic gas detectors and the radiation detectors, located in the ETS-1, ETS-2 area. The second map shall be used to display the status of doors, gates, signal lights, and other control devices used to control personnel and vehicular traffic throughout the area. The Graphic Display is intended as an extension of the Safety Console, and shall contain partial duplicate displays of information presented on the Safety Console, which must be viewed by other operating personnel in addition to the Lead Safety Engineer.

2.0 DETAILED REQUIREMENTS

The two area maps, located one above the other, shall be prepared on translucent plates. The areas connected by the tunnel shall be shown to scale, except that the buildings shall be somewhat larger than scale to permit non-ambiguous presentation of status data. Remote roadblocks, camera sites, etc., shall be displayed on the borders of the maps, not necessarily to scale. Area or building identification shall be made by graphic means wherever possible (shape and relative location); areas or locations shown on the borders shall be positively identified (i. e., Camera Pad #3). Identical maps are not a requirement; optimum presentation of information is to be given primary consideration.

The status or condition of each area shall be indicated by lamp and jewel assemblies located behind the translucent map. Appropriate light guards shall be used to limit illumination to the area involved. Common electrical circuitry shall be used to control the indicators on the Safety Console and the Graphic Display maps.

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2. 1 COMBUSTIBLE GAS AND RADIATION MAP

The following back-lighting colors shall be utilized to indicate the status of combustible gas and of radiation detectors:

- GREEN - (1) Safe gas conditions
(2) Safe radiation conditions
- AMBER - Radiation level unsafe for personnel, but level is within the range predicted for the type of test involved.
- FLASHING MAGENTA - Radiation level is unsafe for personnel, and in excess of the predicted level for the type of test involved.
- FLASHING RED - Unsafe combustible gas condition.

2. 2 AREA WARNING AND CONTROL MAP

The following back-lighting colors shall be utilized to indicate the status of area visual and aural warning signals, and the position of doors, gates, roadblocks, etc. (See Section 2. 2. 7. 4, Appendix 2. 5, and Dwg. ICC-037 of the Design Criteria.)

- GREEN - (1) Area lights are Green
(2) Doors, gates, etc. , are open
- AMBER - Area lights are Amber
- RED - (1) Area lights are Red
(2) Doors, gates, etc. , are closed
- FLASHING RED - Area lights are Flashing-Red
- FLASHING MAGENTA - Area lights are Flashing-Magenta (i. e. , radiation danger area).

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TECHNICAL DATA SHEET 2. 5. 2
COMBUSTIBLE GAS ANALYZER

1. 0 INTRODUCTION

The Combustible Gas Analyzer is an instrument for detecting and measuring combustible gases and vapors, and will be used to operate warning devices and/or activate automatic control circuits. Its principle purpose will be to protect life and property in the ETS-1 operation.

2. 0 DETAILED REQUIREMENTS

The instrument shall be calibrated for hydrogen. Operation will be dependent on a balanced electrical bridge with an electrically heated filament of platinum as one arm of a Wheatstone Bridge circuit. When a test sample passes over this hot filament, any combustible gases or vapors present shall burn catalytically at its surface, raising the filament temperature, and increasing its electrical resistance. The resulting unbalanced bridge will develop an output voltage proportional to the concentration of combustibles in the sample.

- (a) Recording - The output signal shall be used to operate a recording potentiometer and a direct reading meter at the Safety Console.
- (b) Calibration Stability - The filaments shall be interchangeable. The containment of the filament shall compensate for normal variations in pressure, temperature, and humidity of the sample. The filament shall be insensitive to sample flow variation of $\pm 15\%$.
- (c) High-Temperature Operation - Remote-head analyzers in locations exposed to weather must withstand ambient temperatures over a range of 20 to 140°F.
- (d) High Radiation Field - Remote-head analyzers in exposed locations must withstand high radiation levels (up to approx. 10^6 R/hr), on the direction and distance from the Test Stand.

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- (e) Failure Warning - Visual and audible warnings are to be given for the following failures:
 - (1) Filament failure
 - (2) Flow failure
 - (3) Pump failure
 - (4) Open circuit in any relay coil
 - (5) Failure of bridge power supply
 - (6) Failure of electrical circuit pair.
- (f) Monitor Unit - One monitor unit for each station shall be supplied and shall include: an indicating meter calibrated to 20% of the lower explosive limit; a meter to continuously indicate bridge voltage; the bridge dc power supply; relays, alarm contacts, and calibration resistors; receptacle for optional plug-in warning unit; terminals for record potentiometer; alarm, warning, trouble, and pilot lights; pushbuttons for horn output and alarm reset.
- (g) Control Unit - The control unit for the remote head shall be provided with a locking door, to prevent tampering.
- (h) Remote Heads - The remote head shall be an explosion-proof assembly. It shall consist of a detector cell, high temperature air-purge, and solenoid valve. It shall transmit an electrical signal to the control and monitor units for reading and recording.
- (i) Station Selector - The function of the station selector unit is to scan the various sample stations according to a pre-selected, timed sequence. The sequence may be interrupted to permit sampling of any desired station for a continuous period of time. Panel lights shall indicate which station is being sampled at any given time. The station selector tray will contain solenoid valves; a program timer with fail-safe circuits; and annunciator, pilot, and trouble lights. Sample time per station shall be 30 sec maximum.

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TECHNICAL DATA SHEET 2.5.3
OXYGEN ANALYZER SYSTEM

1.0 INTRODUCTION

The Oxygen Analyzer System will consist of a group of instruments to be used for measuring the oxygen content (by volume) of an atmosphere. The Analyzer shall be arranged to operate warning devices, or to activate automatic control circuits. Principle uses in the ETS-1 Operation will be to protect personnel who are re-entering a burning or room previously inerted, and to monitor flare stack piping to determine presence or absence of oxygen prior to exhausting gases - hydrogen.

2.0 DETAILED REQUIREMENTS

The Analyzer shall be calibrated for oxygen content (by volume) over a range between 0 and 25%. ~~Operation will be dependent upon a depolarization cell that will contain carbon and zinc electrodes, and be filled with oxylite electrolyte. The cell will be polarized by hydrogen ions generated by the cell itself. This action will be counteracted by the flow of oxygen, which will depolarize the cell and change the terminal voltage with the amount of oxygen.~~

- (a) Recording - The output signals shall be capable of operating a recording potentiometer, a local or remote meter, or both. The remote meter shall be located in the Safety Console.
- (b) Calibration Stability - Readout accuracy of $\pm 1\%$ oxygen shall be maintained throughout the system. Line-trap assemblies for collecting condensed water or acid products, or both, shall be provided wherever applicable.
- (c) High Temperature Operation - Remote-Head Analyzers in locations exposed to weather must withstand ambient temperatures over a range of 20° to 140° F.
- (d) High Radiation Field - Remote-Head Analyzers in exposed locations shall withstand high radiation levels (up to approx. 10^6 R/hr), depending upon the direction and distance from the Test Stand.

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- (e) **Failure Warning** - Visual and audible warnings are to be given for the following failures:
- (1) Depolarization cell failure
 - (2) Flow failure
 - (3) Pump failure
 - (4) Open circuit in any relay coil
 - (5) Failure of any power supply
 - (6) Failure of electrical circuit pair.
- (f) **Control Unit** - The control unit for the remote-head shall be provided with a locking door to prevent tampering.
- (g) **Remote Heads** - The remote-head shall be an explosion-proof assembly. It shall consist of a detector cell, high temperature air-purge, and solenoid valve. It shall transmit an electrical signal to the control and monitor units for reading and recording.
- (h) **Station Selector** - The function of the station selector unit shall be to scan the various sample-stations according to a pre-selected, timed sequence. The sequence may be interrupted, to permit sampling of any desired station for a continuous period of time. Panel lights shall indicate which station is being sampled at any given time. The station selector tray will contain solenoid valves, a program timer with fail-safe circuits, and annunciator, pilot, and trouble lights. Sample time per station shall be 30 sec maximum.
- (i) **Monitor Unit** - One monitor unit for each station shall be supplied and shall include: an indicating meter calibrated for 0 to 25% oxygen (5% at approximately mid-scale); alarm indicators to show power supply, detector, electronics, or relay failure; terminals for recording instruments; and remote alarm circuitry, which shall be adjustable over the range of 0 to 25% oxygen.

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TECHNICAL DATA SHEET 2.5.4
RADIATION MONITORING SYSTEM

1.0 INTRODUCTION

The Radiation Monitoring System will be a group of instruments used to measure radiation levels and airborne activity at selected locations throughout the ETS-1 area. In addition to continuous monitoring of low background areas, the system shall provide the information necessary to assist in protection of personnel who are re-entering areas which previously exhibited hazardous radiation environments. A primary requirement of the system involves accurate measurements (in the low mr/hr range) in areas which have decreased from radiation levels in very high R/h ranges. Removal of sampling heads in high radiation areas may not be feasible prior to operation; therefore temporary shielding of the heads will be utilized to provide instrument protection during these periods.

2.0 GENERAL REQUIREMENTS

- * Radiation monitoring equipment shall be designed to operate accurately, especially in the low and fractional mr/hr range (i.e., the "Safe" range), and detectors in potentially higher radiation areas shall be capable of operation over several decade ranges.

3.0 DETAILED REQUIREMENTS

- * The Radiation Monitoring System shall consist of the following:
 - * (1) Area Radiation Monitoring System (gamma)
 - * (2) Continuous Airborne Particulate Monitors (beta-gamma)
 - (3) Deleted
 - (4) Continuous Radioactive Gas Monitors (beta-gamma)
 - ** (5) Neutron Detectors
- (a) Detector Locations - Detector locations for above-ground and below-ground monitoring points are shown on Dwg. ICC-145,
- *

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and are discussed in Sections 2.2.7.6 of the Design Criteria. Final location and quantity of detectors (including additional detectors not specifically discussed in the above references) shall be subject to approval of NERVA Operations.

- * (b) Radiation Measurement Equipment - Radiation measurement equipment is discussed in Section 2.2.7.6. The equipment used in this system shall be field-proven, and suitable for the Safety System requirements and the environments of the NERVA Program. Rugged, long-life equipment, capable of unattended stable operation for prolonged periods, is required. ~~The high radiation levels in the test stand area will necessitate the use of two (or more) types of instruments to cover the radiation levels involved.~~
- * (c) ~~Output Signals - The output signals of each type of equipment shall operate a recording potentiometer, a local meter, and a remote meter at the Safety Console. Two alarm signals shall be provided to actuate the Green-Amber-Magenta rear projection indicators as described for the Safety Console (TDS 2.5.1). The two alarm levels shall be independently adjustable over the full range of each equipment type.~~

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TECHNICAL DATA SHEET 2.5.5
CARBON MONOXIDE ANALYZING EQUIPMENT

1.0

INTRODUCTION

Carbon monoxide (CO) can and does produce serious physical effects when personnel breathe in an atmosphere containing 100 ppm of CO. Because CO has no odor or color, it is imperative that adequate and reliable CO detection equipment be installed at ETS-1.

2.0

DETAILED REQUIREMENTS

The multi-point CO analyzer will draw air samples continuously from sensing stations through lines to a centrally located analyzing cabinet. The sample will pass through a detector cell consisting of a series of thermocouples imbedded in a catalyst. CO will cause a temperature change in the catalyst which will be detected by the thermocouples. Local visual and audible alarms plus a local oxygen generator, will be pre-set, to actuate when pre-determined levels are present.

Calibration of the analyzer will be accomplished by the use of gas containing a known percentage of CO.

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TECHNICAL DATA SHEET 4.1
FACILITIES DISPLAY PANEL AND CONTROL PANEL BOARD

1.0 INTRODUCTION

The purpose of the Facilities Display Panel and Control Panel Board is to graphically display the major facilities vessels, equipment, and connecting pipe lines; and to provide a control panel to operate valves and equipment from an isolated control center. This display panel will serve as a simplified flow schematic for training personnel, maintaining continuous vigilance of cryogenic vessels, valves, and equipment, and will supply general information during checkouts, countdowns, and program tests. The control panel board will contain all the valve switches, valve position indicating lights, pressure, temperature, flow, and level indicators and recorders; alarm lights, and controllers, that are required to monitor and control liquids and equipment in a safe manner before, during, and after an engine test.

2.0 PHYSICAL REQUIREMENTS

2.1 GENERAL

The Facilities Display Panel and Control Panel Board is one of a number of panels and consoles located in the Control Center. This board will be approximately 8 ft high and 16 ft long. The display panel will be approximately 4 ft high and 16 ft long, covering the upper portion of the panel board. The control panel will be a sloping area, located directly below the picture graphic display, and designed to allow operating personnel to reach all controls and read the meters, indicators, recorders, and alarm name plates from a sitting position.

2.2 DISPLAY PANEL

The Display Panel (see Dwg ICC-100) shall be of a material practical for mounting display lights, digital indicators, electrical meters, and other medium weight instruments. The color shall match that of other panels and consoles. Vessel and equipment symbols need not be to scale. Symbol shapes shall be reasonably symbolic, limiting details and sizing as required to include indicators, meters, and spacing for a neat and practical display. Symbol graphics and lines shall be adhesive-backed pressure-sensitive Mylar plastic (equivalent) material. Symbols and lines shall be different colors to represent various cryogenic liquids, gases, water, steam, propane, and air. Vessels and lines carrying the same material shall be the same color. Symbols for facility equipment, i. e., steam generators, deflector duct, etc., shall be of colors other than those used for liquids and gases.

2.3 CONTROL PANEL

Material used for the sloping control panel shall be easily machinable, and of sufficient strength to mount instruments weighing up to 35 lb, and protruding 24 in. behind the panel, without bending the panel or using extra supports. Finish shall be consistent with other panels and consoles located in the control center. Panels shall be mounted on a rack or frame for support and sized to conform with good instrumentation installation practice, to decrease the need for special material cutting, and rebuilding of standard instruments.

Momentary-contact electrical switches shall not be used for activating the RSV valves furnished with Open-Close valve-position-indicating switches. Indicating lamps shall have sufficient intensity for easy visibility from 30 feet and still not create excess glare to disturb operators sitting directly before a bank of lamps.

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All switches and controls shall be within reach of an operator in a sitting position. All meters, indicators, recorders, and controllers shall be located to be easily readable from a sitting position.

The area below the sloped panel shall be recessed to allow knee room for a man sitting in contact with the lower edge of the sloping panel.

All switches and controls shall be those primarily required to transfer cryogenic materials, to start equipment, and to place all facilities in an operating and standby condition in the countdown procedure at the same time, prior to the final test countdown. The primary responsibility of the operator immediately before testing, at test, and immediately after test, is to monitor and operate valves and equipment in case of emergency, and then only on the instructions from chief operators. A tabulation of the items required on the facilities display panel and control panel is shown in the following list:

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3.0 FACILITIES DISPLAY PANEL AND CONTROL PANEL

Equipment Number	Function	Switches Lights	Indicators Controllers Recorders
50-RSV-285	GHe block from He purge to Run TK V-5001	1 2	
50-P1-75A	GH ₂ sub-header reduced pressure		1
50-RSV-201	GH ₂ sub-header block for cooling gas to engine	1 2	
38-RSV-271	GN ₂ sub-header block to FS-3801 molecular seal	1 2	
50-PC-249	GN ₂ pressure control to H. P. LO ₂ storage Dewar V-5003		X 1
50-P1-70A	GN ₂ sub-header pressure to H. P. LO ₂ storage Dewar V-5003		1
34-RSV-329	V-3401 propane storage block to steam-generator header 2-LP-4"BD	1 2	
34-RSV-330	GN ₂ pressurization of propane tank header V-3401	1 2	
34-L1-11A	V-3401 propane storage tank liquid level		1
34-P1-118A	V-3401 propane storage tank pressure		1
34-RSV-331	V-3401 propane storage tank vent to atmosphere	1 2	
30-P1-96A	Plant air pressure		1
50-P1-191A	GN ₂ reduced header pressure to cooling gas		1
50-P1-193A	GN ₂ bypass line pressure		1
50-P1-192	GN ₂ header pressure after atomizers		1
50-P1-103A	GH ₂ cooling gas line pressure		1
50-P1-194	LH ₂ line 2-LN ₂ -4"BS pressure		1
50-P1-195A	LH ₂ line 2-LN ₂ -4"BS cont. flow pressure		1
50-P1-196A	LH ₂ bypass cont. flow pressure		1
50-T1-191A	GN ₂ reduced header gas temperature to cooling gas		1
50-T1-53	GN ₂ header gas temperature after atomizers		1
50-T1-33	GH ₂ cooling gas line temperature		1
50-T1-55	LH ₂ line 2-LN ₂ -4"BS temperature		1

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Equipment Number	Function	Switches	Lights	Indicators	Controllers	Recorders
50-FRC-50	GN ₂ FRC with output to set point FRC-51 and FC-52				1	X
50-FRC-51	GN ₂ bypass FRC with set point cont. from FRC-51				1	X
50-FC-53	LH ₂ flow control-set point from 50-FRC-51			X	1	
50-FC-52	LH ₂ flow cont. -set point from 50-FRC-50			X	1	
50-RSV-338	GN ₂ main header block to atmosphere	1	2			
50-RSV-134	Main GN ₂ cooling gas header block to engine	1	2			
50-RSV-334	GN ₂ block in GN ₂ line 31-GN ₂ -3"AS to atomizer	1	2			
50-RSV-320	LH ₂ block from LH ₂ trans. line to cooling gas	1	2			
50-RSV-222	GN ₂ block in line 9-GN ₂ -8"FS for system expansion	1	2			
50-RSV-221	GN ₂ block in GN ₂ header for radiation shield sealing	1	2			
50-RSV-309	Process water 14 in. sub-header block to steam generator	1	2			
50-RSV-328	Process water 4 in. sub-header block def. duct vault cool	1	2			
50-RSV-303	Process water 10 in. sub-header block to top shield	1	2			
50-RSV-305	Process water 10 in. sub-header block to S1 shield	1	2			
50-RSV-305	Process water 10 in. sub-header block to bottom shield	1	2			
50-RSV-304	Process water 10 in. sub-header block to S2 shield	1	2			
50-P1-168A	Process water 42 in. main header pressure				1	
50-T1-47	Process water 42 in. main header temperature				1	
50-RSV-298	Process water 36-in. def. duct sub-header block	1	2			
50-RSV-296	Process water 4-in. def. duct sub-header block	1	2			
50-RSV-297	Process water 12-in. def. duct sub-header block	1	2

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Equipment Number	Function	Switches	Lights	Indicators	Controllers	Recorders
50-FC-32	Process water flow controller for 50-FCV-32			X	1	
50-FC-31	Process water flow controller for 50-FCV-30			X	1	
50-FC-30	Deflector duct flow control (50-FCV-32)			X	1	
	LH Dewar hydraulic pump fluid pressure				1	
30-PdA-32	Line filter D/P GN ₂ to solenoid valve box		1			
30-PdA-59	Line filter D/P GN ₂ to propane storage		1			
28-PdA-33	Line filter D/P GN ₂ to Dewar pressure		1			
32-PdA-34	Line filter D/P GN ₂ to solenoid valve boxes		1			
32-PdA-67	Line filter D/P GN ₂ to LN ₂ Dewar pressure		1			
38-PdA-36	Line filter D/P GN ₂ to molecular seal FS-3801		1			
38-PdA-37	Line filter D/P GN ₂ to LN ₂ storage Dewar		1			
38-PdA-39	Line filter D/P GN ₂ to instr. gas to solenoid box		1			
50-PdA-40	Line filter D/P GN ₂ to H. P. LO ₂ pressure V-5003		1			
50-PdA-75	Line filter D/P GN ₂ to header pipe 30 GN ₂ -6"FS		1			
50-PdA-41	Line filter D/P GN ₂ to shield seal and def. duct		1			
50-PdA-42	Line filter D/P GN ₂ to pressure LH ₂ run tank V-5001		1			
50-PdA-43	Line filter D/P GN ₂ to pressure H. P. LH ₂ tank V-5002		1			
50-PdA-46	Line filter D/P GN ₂ instr. gas to solenoid box		1			
30-PA-17	Solenoid valve box pressurization		1			
32-PA-25	Solenoid valve box pressurization		1			
32-PA-24	Solenoid valve box pressurization		1			
32-PA-23	Solenoid valve box pressurization		1			
38-PA-19	Solenoid valve box pressurization		1			
50-PA-20	Solenoid valve box pressurization		1			
50-PA-26	Solenoid valve box pressurization		1			
32-T1-01	V-3201 bottle storage gas temperature				1	
32-T1-02	V-3202 bottle storage gas temperature				1	
32-T1-03	V-3203 bottle storage gas temperature				1	
32-T1-04	V-3204 bottle storage gas temperature				1	
32-T1-05	V-3205 bottle storage gas temperature				1	
32-T1-06	V-3206 bottle storage gas temperature				1	
32-P1-01A	V-3201 bottle storage gas pressure				1

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Equipment Number	Function	Switches	Lights	Indicators	Controllers	Recorders
32-P1-04A	V-3202 bottle storage gas pressure			1		
32-P1-07A	V-3203 bottle storage gas pressure			1		
32-P1-10A	V-3204 bottle storage gas pressure			1		
32-P1-12A	V-3205 bottle storage gas pressure			1		
32-P1-16A	V-3206 bottle storage gas pressure			1		
32-RSV-03	V-3201 (1) 2nd vent valve	1	2			
32-RSV-05	V-3201 (2) 2nd line block valve	1	2			
32-RSV-02	V-3201 (3) 1st block bypass valve	1	2			
32-RSV-01	V-3201 (4) 1st block valve	1	2			
32-RSV-207	V-3201 (5) 1st vent valve	1	2			
32-RSV-08	V-3202 (1) 2nd vent valve	1	2			
32-RSV-10	V-3202 (2) 2nd line block valve	1	2			
32-RSV-07	V-3202 (3) 1st block bypass valve	1	2			
32-RSV-06	V-3202 (4) 1st block valve	1	2			
32-RSV-208	V-3202 (5) 1st vent valve	1	2			
32-RSV-13	V-3203 (1) 2nd vent valve	1	2			
32-RSV-15	V-3203 (2) 2nd line block valve	1	2			
32-RSV-12	V-3203 (3) 1st block bypass valve	1	2			
32-RSV-11	V-3203 (4) 1st block valve	1	2			
32-RSV-209	V-3203 (5) 1st vent valve	1	2			
32-RSV-18	V-3204 (1) 2nd vent valve	1	2			
32-RSV-20	V-3204 (2) 2nd line block valve	1	2			
32-RSV-17	V-3204 (3) 1st block bypass valve	1	2			
32-RSV-16	V-3204 (4) 1st block valve	1	2			
32-RSV-210	V-3204 (5) 1st vent valve	1	2			
32-RSV-23	V-3205 (1) 2nd vent valve	1	2			
32-RSV-25	V-3205 (2) 2nd line block valve	1	2			
32-RSV-22	V-3205 (3) 1st block bypass valve	1	2			
32-RSV-21	V-3205 (4) 1st block valve	1	2			
32-RSV-211	V-3205 (5) 1st vent valve	1	2			
32-RSV-28	V-3206 (1) 2nd vent valve	1	2			
32-RSV-30	V-3206 (2) 2nd line block valve	1	2			
32-RSV-27	V-3206 (3) 1st block bypass valve	1	2			
32-RSV-26	V-3206 (4) 1st block valve	1	2			
32-RSV-212	V-3206 (5) 1st vent valve	1	2			
-Fl _T -	Propane flow rate indicator totalizer			2		T
-Fl _T -	Oxygen flow rate indicator totalizer			2		T
-Fl _T -	Demineralized water flow rate totalizer			2		T

Equipment Number	Function	Switches	Lights	Indicators	Controllers	Recorders
-FlT-	Output product totalizer			2		T
-Pl -	Demineralized water manifold pressure			2		
-Pl -	Liquid propane manifold pressure			2		
-Pl -	Liquid oxygen manifold pressure			2		
-F/FC-	Ratio controller set point				2	
-Pl -	Steam generator cooling water pressure			1		
-AL -	No-ignition on start-up alarm light		2			
-AL -	Steam generator flame out alarm		2			
-AL -	Propane to oxygen ratio less than 0.275		2			
-AL -	Steam generator cooling water flow switch		2			
-AL -	Steam generator over pressure alarm		2			
-AL -	Steam generator over temperature alarm		2			
-RSV-	GN ₂ - Off-On valves (14 total)	6	12			
-RSV-	Propane - Off-On valves (4 total)	4	8			
-CV -	Propane control valves (6 total)					6
-RSV-	LO ₂ - Off-On valves (6 total)	6	12			
-CV -	LO ₂ - Control valves (6 total)					6
-RSV-	Water - Off-On valves (4 total)	4	8			
-CV -	Water control valves (6 total)					6

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TECHNICAL DATA SHEET 4.2
FACILITIES CONSOLE

1.0 INTRODUCTION

The purpose of the facilities console is to monitor and control those operational functions of the facilities which are required during final countdown, test, and immediately after test. The operators at this console may be requested to maintain control of cryogenic liquid transfer, purge, gas flow, vessel pressurization, steam generators, cooling gas, deflector duct water flow and temperature; radiation shield cooling water and temperature; and moving radiation shields, and locomotives.

2.0 PHYSICAL REQUIREMENTS

The facilities console shall be made up of a number of panels sized to accommodate the required functions, located directly in front of facilities picture graphic and control panel boards, with operators facing the picture graphic panel. The shape shall be in keeping with other consoles located in the Control Center. The color and finish shall be the same as specified for other consoles within the Control Center.

The installation of the equipment and instruments shall adhere to good standard practice and be of high quality craftsmanship.

All controls, switches, indicators and meters, shall be within working distance of the operator, while he is in a sitting position.

Provision shall be made, on the console, for a multichannel recorder. This recorder shall be capable of being patched into the appropriate recorder channels for a given test.

** Make provision for 2 8-in. TV monitors and camera controls on the Facilities Console Panel. Viewing station and camera controls shall be selected by an oral request to the Master TV Control Console.

A tabulation of the items required on the Facilities Console Panel follows:

3.0 FACILITIES CONSOLE PANEL REQUIREMENTS

Equipment Number	Function	Switches	Lights	Indicators	Controllers	Recorders
50-RSV-126	C. G. LO ₂ block valve from H. P. LO ₂ V-5003	1	2			
50-RSV-125	Cold-gas return line block valve to LH ₂ storage	1	2			
50-RSV-111	Cold-gas LH ₂ block valve from H. P. LH ₂ V-5002	1	2			
38-RSV-257	V-3801 LH ₂ storage Dewar block valve to atmosphere	1	2			
38-PlC-179	V-3801 LH ₂ storage Dewar pressure controller to vent					
38-L1-02	V-3801 LH ₂ Dewar liquid level				X	1
38-Pl-68A	V-3801 LH ₂ Dewar pressure			1		
38-RSV-87	V-3801 LH ₂ Dewar GH ₂ pressurization	1	2			
50-RSV-253	GH ₂ pressure header block valve to vent header	1	2			
50-RSV-109	V-5002 H. P. LH ₂ block valve to vent header	1	2			
28-RSV-69	V-2801 LO ₂ storage Dewar vent to atmosphere	1	2			
28-RSV-68	V-2801 LO ₂ storage Dewar GN ₂ pressurization	1	2			
28-Pl-49A	V-2801 LO ₂ storage Dewar pressure indicator					1
28-L1-01	V-2801 LO ₂ storage Dewar liquid level indicator					1
50-RSV-335	2nd LO ₂ block valve to steam generator	1	2			
50-RSV-73	H. P. LO ₂ transfer valve to gas generator	1	2			
50-RSV-71	V-5003 H. P. LO ₂ run tank vent valve	1	2			
50-RSV-70	V-5003 H. P. LO ₂ run tank GN ₂ pressurization	1	2			
50-Pl-52A	V-5003 H. P. LO ₂ run tank pressure					1
50-RSV-283	GH ₂ sub-header block to pressurize run tank V-5001	1	2			
50-RSV-286	GH ₂ sub-header block to H. P. LH ₂ run tank V-5002	1	2			
50-PC-251	GH ₂ line 15-GH ₂ -6" F. pressure control				X	1
50-RSV-322	He purge block to GH ₂ header for engine cooling	1	2			
50-RSV-324	GN ₂ valve between GN ₂ header 30-GN ₂ -6" FS & 15-GH ₂ -6" FC	1	2			
	Test stand instr. hydraulic pump starter	3	6

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Equipment Number	Function	Switches	Lights	Indicators	Controllers	Recorders
	Test stand instrument hydraulic fluid pressure			1		
38-RSV-83	LH transfer valve from V-3801 LH ₂ storage Dewar to engine run tank	1	2			
38-RSV-256	Block valve between cold gas return and vent header	1	2			
** -F1 _T -	Propane flow rate indicator totalizer			2		T
-F1 _T -	Oxygen flow rate indicator totalizer			2		T
-F1 _T -	Demineralized water flow rate totalizer			2		T
-F1 _T -	Output product totalizer			2		T
-P1 -	Demineralized water manifold pressure			2		
-P1 -	Liquid propane manifold pressure			2		
-P1 -	Liquid oxygen manifold pressure			2		
-F/FC-	Ratio controller set point				2	
-P1 -	Steam generator cooling water pressure			1		
-AL -	No-ignition on start-up alarm light		2			
-AL -	Steam generator flame out alarm		2			
-AL -	Propane to oxygen ratio less than 0.275		2			
-AL -	Steam generator cooling water flow switch		2			
-AL -	Steam generator over pressure alarm		2			
-AL -	Steam generator over temperature alarm		2			
-RSV -	GN ₂ - Off-On valves (14 total)	6	12			
-RSV -	Propane - Off-On valves (4 total)	4	8			
-CV -	Propane control valves (6 total)					6
-RSV -	LO ₂ - Off-On valves (6 total)	6	12			
-CV -	LO ₂ - Control valves (6 total)					6
-RSV -	Water - Off-On valves (4 total)	4	8			
-CV -	Water control valves (6 total)					6

** NOTE: See TDS 4.10 for Radiation Shields, Deflector Duct, and Train Controls.

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TECHNICAL DATA SHEET 4.3
ISOLATION CIRCUITRY EQUIPMENT
(See TDS 3.6)

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TECHNICAL DATA SHEET 4.4
DISPLAY CIRCUITRY EQUIPMENT

1.0 INTRODUCTION

Amplifiers shall be used in a data system for preamplification of millivolt-level transducer signals. The amplifiers shall possess high common-mode rejection ratios at input and output, high linearity, and high stability of zero and gain voltage transfer. Amplifiers shall be supplied as modular inserts for mounting bins, which are permanently mounted into standard racks.

2.0 DETAILED PERFORMANCE

The performance of amplifiers, as measured in a normally installed fashion in a rack-mounted bin, shall be met under any conditions of specified power supply variation and environment. Amplifiers shall be capable of ± 10 v output with various full-scale inputs applied. All performance specifications shall be based on a full output span of 10 v, where this span may be taken at any point within the ± 10 v output capability. It shall be specifically noted that in the following paragraphs, percent of full scale or of design span is intended to mean percent of a 10 v output span.

2.1 GAIN

Amplifiers shall be provided with a front panel step-gain switch, as well as an internal adjustment (not accessible from, or through, front panel), for vernier gain trim.

2.1.1 Fixed Steps

The step-gain switch shall have selected gain steps of 100, 250, 500, and 1000.

2.1.2 Special Fixed Gains

Provision shall be made for establishment of any fixed gain between 100 and 1000, by installation of a precision resistive divider, mounted as a plug-in assembly.

2.1.3 Vernier Gain

A vernier-gain adjustment shall be provided, for use with fixed-gain steps and with special fixed gains, and shall possess an adjustment span of approximately $\pm 1.0\%$ for full adjustment travel of any applicable nominal gain.

2.1.4 Gain Accuracy

With the vernier gain control centered, fixed-step gain accuracy shall be $\pm 1.0\%$. The vernier-gain adjustment shall provide capability for adjusting gain to an accuracy of $\pm 0.1\%$.

2.1.5 Gain Stability

Gain stability shall be $\pm 0.1\%$ for 1000 operating hours or 90 days (whichever is less), under any condition of gain adjustment (fixed, special fixed, vernier).

2.2 ZERO TRANSFER

Amplifier output shall be nominally 0 v for 0 v input. An internal zero-offset adjustment (not adjustable from, or through front panel) may be provided, if deemed necessary.

2.3 ZERO OFFSET

Zero offset at any gain position or zero offset resulting from a change in gain, shall be greater than $\pm 0.1\%$ of design span. Internal adjustment for this condition is allowable.

2.4 ZERO STABILITY

Zero offset shall remain stable to $\pm 0.1\%$ of design span for a period of 1000 operating hours, or 90 days (whichever is less).

2.5 LINEARITY

Linearity error between input and output shall not exceed $\pm 0.1\%$ of design span, when calculated as terminal linearity.

2.6 BANDWIDTH

The following bandwidth specifications shall be met with any local resistance of 10,000 ohms, or greater, in parallel with any

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capacitance of 1 mf or less, stated as percent of output peak voltage as a function bandwidth:

$\pm 0.2\%$ dc - 10 cps

$\pm 3\%$ dc - 40 cps

2.7 RISE TIME

Output shall respond to 99.9% of a step-input change in no more than 20 ms.

2.8 NOISE

Noise shall be measured at the amplifier output terminals and shall be construed to mean noise emanating from all sources. This specification shall be met with source impedances up to, and including, 500 ohms and for any gain between 100 and 1000. Allowable output noise will be 20-mv peak-to-peak, measured over a bandwidth of dc to 10 kc.

2.9 SIGNAL CONFIGURATION

Amplifier input and output are to be differential. The input, amplifier chassis, and output are to be mutually independent, from an impedance standpoint, to the degree necessary to meet the common-mode rejection specifications.

2.10 OVERLOAD RECOVERY

* The amplifier shall incur no damage when a ± 10.0 v signal from a source impedance of 25 ohms (or greater) is applied to the input. Amplifier recovery shall be complete within 500 ms after removal of overload signal.

2.11 COMMON MODE REJECTION (INPUT)

The amplifier shall meet the following specification with up to 500 ohms resistive unbalance in the input circuit. If an input guard shield is used, tests for this performance parameter will

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be made with the guard shield attached to the common-mode source. The amplifier shall sustain maximum common-mode voltages of ± 100 v for test purposes. Maximum expected common-mode voltage under operating conditions shall be ± 3 v, peak-to-peak. The common-mode rejection shall be:

dc to 60 cps	120 db minimum
dc to 3 kcs	80 db minimum

2.12 COMMON MODE REJECTION (OUT)

The allowable differential output signal shall be produced by application of output common-mode voltage through connection of a source between amplifier chassis and an output lead. Common-mode voltage for test purposes shall be ± 100 v. Output common-mode rejection shall be 80 db, or greater, over bandwidths to dc from 1.0 kc under any condition of amplifier gain, source unbalance, and allowable input voltage.

2.13 OUTPUT CAPABILITIES

The amplifier shall be capable of ± 10 v output dc or ac peak. The intended design span is 10 v. The effective output impedance of the amplifier shall be low enough that the output voltage shall not change by more than 1.0%, with an amplifier resistive load change of no-load to 10,000 ohms, with any output voltage between -10 and +19 v.

2.14 INPUT IMPEDANCE

The input impedance shall be 1,000,000 ohms minimum, for any allowable input signal of any gain between 100 and 1000.

2.15 SIGNAL SOURCE IMPEDANCE

Performance specifications shall be met with source impedance between 0 and 500 ohms, except as otherwise noted. Source impedances up to 1000 ohms shall not result in amplifier instability or severe degradation of performance.

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2.16 INPUT OUTPUT SENSE

Input and output connections shall be labeled or identified to insure that a positive signal on the stated input lead will produce a positive signal on the stated output lead.

2.17 ENVIRONMENT

2.17.1 Temperature

Amplifiers shall meet all specifications when mounted in a bin of a standard equipment rack, filled with similar operating amplifiers, for room ambient temperatures between 65°F and 90°F. Maximum ambient temperature change shall be 10°F/hr. Use of rack blowers will be undesirable.

2.17.2 Altitude

Amplifiers shall meet performance specifications at elevations between sea level and 8000 feet.

2.17.3 Humidity

Amplifiers shall meet performance specifications between 0 and 90% relative humidity.

2.17.4 Mechanical

Amplifiers shall be designed to withstand normal handling and commercial transportation.

2.18 POWER SUPPLY REQUIREMENTS

Main amplifier power shall be from 115 v $\pm 10\%$, 60 cps, ± 0.2 cps. ~~In the event that electro-mechanical choppers are used, all choppers in a large bank of amplifiers shall be synchronized.~~ It is acceptable that individual choppers, or groups of choppers, shall operate at slightly different frequencies, if existing power supply designs result in this mode of operation, and if individual amplifier performance is not degraded. All primary power entering mounting bins must be adequately fused at the bin.

2.19 PHYSICAL

The front panels of amplifiers and front visible portions of bins shall be painted with light gray baked enamel, conforming to finish specifications. Amplifier front panel lettering is to be black.

2.19.1 Amplifier Bins

Amplifier bins shall be provided for standard 19-inch rack mounting, with Electronic Industries Association (EIA) standard hole spacing. If connectors are used between the bin and external power or signal wiring, mating connectors and guides are to be supplied.

2.19.2 Amplifier Modules

Amplifier modules shall be fully interchangeable, electrically and mechanically. The only front panel control shall be for selection of fixed-gain steps. Amplifiers shall not contain independent power supply switches.

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TECHNICAL DATA SHEET 4.5
CONTROLLERS

- See TDS 4.5.1 Controllers for LH₂ Storage Dewar and
Run Tank Pressurization
- 4.5.2 Controllers for Hydrogen Gas Cooling Flow
System Control
- 4.5.3 Controllers for Cold Nitrogen Gas System
- 4.5.4 Controllers for Duct Water Flow

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TECHNICAL DATA SHEET 4.5.1
CONTROLLERS FOR LH₂ STORAGE DEWAR AND RUN TANK
PRESSURIZATION

1.0 INTRODUCTION

The LH₂ Storage Dewar and Run Tank pressurization controllers will be nearly identical. The following discussion will apply to both controllers, unless specified.

2.0 DETAILED PERFORMANCE

2.1 CONTROLLED ITEMS

* The following valves will be electro-pneumatically operated.

LH₂ Storage Dewar, pressurization valve 38-PCV-248, and vent valve 38-PCV-179.

Run Tank pressurization valve 50-PCV-165, and vent valve 50-PCV-180.

2.2 VALVE POSITION SIGNAL

* The signal required by the electro-pneumatic valve shall be from 1 to 5 ma dc for zero to full stroke. Input impedance shall be less than 3000 ohms

2.3 MODES OF CONTROL

The controllers shall provide adjustable proportional band, rate, and reset.

Sufficient mathematical analysis and/or analog computer analysis shall be performed to insure that the proper range of adjustments will be available for stable system operation, maximum speed of response, and maximum accuracy system.

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2.4 SET POINT

- The set point adjustment will be an external control. The set point signal to the controller shall be compatible with the requirements of the controller. Maximum indicated pressure will be the working pressure of the tank.
- *

2.5 MANUAL VALVE POSITIONING

- Provision shall be made, by a switch not on the controller, to manually set the valves. The signal to the controller for valve positions shall be compatible with the controller.
- *

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TECHNICAL DATA SHEET 4.5.2
CONTROLLERS FOR HYDROGEN GAS COOLING FLOW SYSTEM CONTROL

1.0 INTRODUCTION

- * The valve, 50-PCV-251, shall be electro-pneumatically operated.

2.0 DETAILED PERFORMANCE

VALVE POSITION SIGNAL

- * The signal required by the electro-pneumatic valve shall be from 1 to 5 ma dc for zero to full stroke. Input impedance shall be less than ohms.

MODES OF CONTROL

The controller shall have an adjustable proportional band, rate, and reset. Sufficient mathematical analysis and/or analog computer analysis shall be performed to insure that the proper range of adjustments will be available for stable system operation, maximum speed of response, and maximum accuracy.

CONTROLLED VARIABLE SIGNAL

The controlled variable input signal will be 0 to 10 v dc.

SET POINT

- * The set point adjustment will be an external control. The set point signal to the controller shall be compatible with the requirements of the controller.

MANUAL VALVE POSITIONING

- * Provision shall be made, by a switch not on the controller, to manually set the valve. The signal to the controller for the valve position shall be compatible with the controller.

TECHNICAL DATA SHEET 4.5.3
CONTROLLERS FOR COLD NITROGEN GAS SYSTEM

1.0 INTRODUCTION

This system will require two controllers or sets of controllers to control the two sets of valves used to cover the flow range of the gas system.

1.1 FIELD ITEMS

The controllers will work with the following field items:

<u>High Range System</u>	<u>Low Range System</u>
50-FCV-52	50-FCV-53
50-FCV-50	50-FCV-51
50-FT-52	50-FT-53
50-FT-50	50-FT-51

2.0 DETAILED PERFORMANCE

2.1 VALVE POSITION SIGNAL

The valves will require a 1 to 5 ma signal for zero to full stroke. The controller must be capable of working into a maximum impedance of 3000 ohms.

2.2 MODES OF CONTROL

The controller shall provide for an adjustable proportional band, and an adjustable reset.

2.3 CONTROLLED VARIABLE SIGNAL

All inputs will vary from 0 to 10 v for the variable range of zero to full scale.

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2.4 SET POINT

- * The set point adjustment for gas flow rate will be an external control. The ratio set point will be on the controller.

2.5 MANUAL VALVE POSITIONING

- * Provision shall be made, by a switch not on the controller, to manually set the valves. The signal to the controller for the valve position shall be compatible with the controller.

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TECHNICAL DATA SHEET 4.5.4
CONTROLLERS FOR DUCT WATER FLOW

1.0 INTRODUCTION

The controllers shall form a single flow control system to cover a range of 1000 to 1.

1.1 CONTROL ITEMS

50-FC-30 controls 50-FCV-30
50-FC-31 controls 50-FSV-31
50-FC-32 controls 50-FCV-32

2.0 DETAILED PERFORMANCE

2.1 CONTROLLED VARIABLE SIGNAL

The input signal to each controller shall be from 0 to 10 v. The signals will represent the square of the flow. The transducers and ranges shall be:

50-FT-30	0-500 gpm
50-FT-31	0-5000 gpm
50-FT-32	0-50,000 gpm

2.2 VALVE POSITION SIGNAL

* The valves will require a 28 v dc signal to increase flow; a 28 v dc signal, on a separate line, to reduce flow; and no signal on either line to maintain steady flow.

2.3 SET POINT

Each controller shall have a set point. The set point adjustment will be an external control, and the signal to the controller will vary from 0 to 10 volts for zero to full stroke.

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2.4 MODES OF CONTROL

The controller shall provide an adjustable proportional band, a rate reset, and "dead band." It shall be possible to slow the response of the controller to prevent water hammer.

2.5 MANUAL VALVE POSITIONING

Provision shall be made, by a switch not in the controller, to manually set the valve. Manual control of the valve shall be by the use of a three-position switch.

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TECHNICAL DATA SHEET 4.6
RESISTANCE TEMPERATURE TRANSDUCERS (RTB)

1.0 INTRODUCTION

The sensing element shall be made of a platinum alloy, designed as a precision resistance element used for temperature measurement. It shall be fully supported and mounted in ceramic insulation, protected by a stainless steel tube.

2.0 DETAILED PERFORMANCE

2.1 OPERATIONAL RATINGS

Each RTB shall meet the following operational requirements:

2.1.1 Range

-435[°]F to +500[°]F at 4000 psi working pressure.

2.1.2 Sensitivity

Sensitivity difference between any 2 probes with the same range shall not exceed ±0.1%.

2.1.3 Repeatability

* Repeatability of any point shall be better than ±0.1%.

2.1.4 Response Time

Response time shall be 0.2 sec for 63.3% response to a temperature step from ambient air (77[°]F) to water flowing at 3 fps.

2.1.5 Vibration Rating

Vibration rating shall be 60 g (peak) at 0.5 in. in the spectrum from 10 to 2000 cps.

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2.1.6 Flow Rating

Flow rating shall be 80 fps of water at a specific gravity of 1.0

2.1.7 Temperature Resistance Relationship

Temperature resistance relationship shall follow the same curve within 0.1%.

2.2 INSULATION RESISTANCE

Insulation resistance shall be 100 megohms at 10 v dc between element and enclosure

2.3 MATERIALS

The materials used in the probe exposed to the working fluid shall be Types 303 and/or 304 stainless steel, platinum alloy, Teflon, and ceramic. Items for use in the test stand shall be designed with the use of radiation resistant materials. If the platinum element or ceramic mounting is not compatible with the working fluid, necessary protection shall be provided. If this causes any deviation from the requirements, the deviation shall be stated on test report forms furnished as specified

2.4 BURST PRESSURE

Burst pressure for all units shall be greater than 6000 psi

2.5 ELECTRICAL REQUIREMENTS

2.5.1 Connections

The resistive element shall be terminated in a connector to mate with AN3106E-14S-5S. Each end of the element shall be wired to 2 pins with parallel platinum wires. Mating connections shall be supplied with each transducer. Wiring shall be:

Pins A & B wired to one end of the element
Pins C & D wired to the opposite end of the element, and
Pin E reserved for shield and not connected to the shield

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2.5.2 Self-Heating Effect

In still liquid nitrogen, an IR power of 0.2 w shall cause a temperature rise of not more than 2° F.

2.5.3 Element Resistance

Element resistance shall be suitable for the temperature range specified.

2.6 TESTS

Test equipment and qualification testing shall be as specified.

2.6.1 Quality Assurance Tests

Quality assurance tests shall include tests for:

Vibration, element resistance, temperature - resistance relationship, sensitivity, repeatability, and calibration.

Each probe shall be calibrated at the following temperatures;
* -422.9, -320.4, -297.4, +32.0, +212.0, +500.0° F.

Accuracy of calibration shall be 0.1° F. Reproducible copies of calibration data and certified dimensional outlines shall be provided.

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TECHNICAL DATA SHEET 4.7
GAUGE AND DIFFERENTIAL PRESSURE TRANSDUCERS
(Differential transducer used for water flow measurement)

1.0 INTRODUCTION

Requirements for design, manufacture, testing, and packaging for radiation-resistant strain gauge differential and gauge pressure transducers are defined below. Differential pressure transducers will be used for water-flow measurement.

2.0 PHYSICAL REQUIREMENTS

Materials and processes shall be of highest quality and functionally suited to the application.

Transducers having the same range are to be interchangeable in installations.

All parts exposed to pressure media shall resist corrosion from the process fluid.

Differential pressure transducers shall operate as specified, with the process fluid on both high and low pressure taps. Gauge pressure transducers shall operate as specified with demineralized water on the pressure tap, and with reference pressure to atmosphere that has 95 % relative humidity. Organic materials shall not be used in construction of transducers. The transducer shall be used outdoors and shall be capable of withstanding a direct spray of demineralized water.

The transducer shall withstand a total integrated dose of 2.5×10^7 neutron/sq cm plus 2.5×10^8 rads, gamma.

Pressure tap (or taps) shall be MS33656, 1/4 in. fitting. Weight and size shall be kept to a minimum, consistent with requirements.

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3.0 ELECTRICAL REQUIREMENTS

3.1 CONNECTIONS

Electric connections shall be Bendix 10-72614-55 with a mating Bendix 10-72-72614-55 connector supplied with each transducer.

Input excitation power shall be wired to pin A positive and pin D negative. With pressure on the high-pressure port positive with respect to the low-pressure port, the output shall be positive on pin B, and negative on pin C. Pin E shall be reserved for a shield and shall not be grounded, but shall have the capability of being grounded. Terminals for keying in a shunt-type calibrating resistor shall be B and C.

3.2 BRIDGE

The electrical elements shall form a four-arm resistance bridge with two elements coupled to the pressure sensing element. Four active arms shall be used.

The electrical resistance of the pressure-sensitive bridge input shall be 350 ohms $\pm 5\%$ at 70°F and shall not change more than $\pm 15\%$ with a variation in transducer temperature between 75 to 250°F.

The transducer shall function between limits of 0° to 300°F. Specifications apply between temperature limits as noted. The coefficient of thermal sensitivity shall be less than 0.01% full scale/°F between limits of 75 to 300°F.

All electrical connections of the transducer shall be spot welded.

Transducer excitation shall be dc.

- * Error, including hysteresis and non-linearity, shall be within 0.5% of full scale.

Transducer output for both gauge and differential pressure units shall shift less than 0.02% full scale/[°]F with rated 10 v excitation, zero applied pressure, and between limits of 75 to 300[°]F.

Insulation resistance between any electric terminal and transducer case shall be at least 1000 megohms, measured at 100 v.

Mechanical natural frequency of the pressure-sensitive portion of any transducer shall be above 2500 cps, for all ranges.

3.3 TRANSDUCER OUTPUT

- * Gauge pressure transducer output shall be 3.0 mv/v, 0.015 mv/v for full range. Differential pressure transducer output shall be 3.0 mv/v normal. Appropriate resistors are required to provide calibrated points at 0, 25, 50, 75, and 100%.

3.4 TRANSDUCER RANGES

Gauge pressure transducers shall be available in the following ranges:

0 to 5	0 to 250
0 to 10	0 to 500
0 to 25	0 to 1000
0 to 50	0 to 2500
0 to 100	0 to 4000 psig

Differential pressure transducers shall be available in the following ranges:

0 to 5	0 to 100
0 to 10	0 to 250
0 to 25	0 to 500
0 to 50	0 to 1000 psid

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Transducers for gauge and differential pressures shall withstand overloads, depending upon the range as listed below:

<u>Operating Range</u> <u>psig or psid</u>	<u>Overload</u>
0 to 5	50
0 to 10	100
0 to 25	250
0 to 50	500
0 to 100	1000
0 to 250	5000
0 to 500	5000
0 to 1000	5000
0 to 1500	5000
0 to 2500	5000
0 to 4000	5000

Applied overload pressures shall cause less than 1% zero shift with pressure applied 3 min, with no leakage.

Differential pressure transducers shall have taps labeled Hi and Lo, and shall produce unidirectional output.

The pressure applied to both sides of a differential pressure transducer between 0 and 80% of maximum line pressure, shall not cause an output variation of more than 0.5% of full-scale reading, when operated at rated differential range.

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4.0 ENVIRONMENT

The transducer shall withstand sinusoidal vibrations of 1/8-in. double amplitude from 5 to 30 cps and 20 g rms from 25 to 2000 cps, and shall withstand transportation by common carrier.

Output variation, as a function of vibration, shall be less than 0.5% full scale per g.

The transducer shall withstand 95% relative humidity at 200°F for 1 hr with output change not to exceed the temperature sensitivity rating.

5.0 QUALITY ASSURANCE

The vendor shall supply a complete list of equipment used, and procedures followed in his quality assurance testing, and shall perform qualification tests in the following manner:

Qualification testing shall be performed using equipment compatible with the requirements of tests.

Two copies of all quality assurance data shall be provided for each transducer, and shall include diagrams of test setups.

Quality assurance testing shall be performed at a time mutually agreeable to vendor and user, on each model of transducer ordered, preceding shipment of any transducer. Tests shall be witnessed at the discretion of the user.

Quality assurance test procedure outlines shall be originated by the vendor, and submitted to the user for acceptance, prior to testing.

Quality assurance tests shall include all acceptance tests listed in this specification, and tests for natural frequency, overload capability, line-pressure sensitivity, impact, vibration, and relative humidity.

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Failure to pass all transducer quality assurance tests shall preclude all transducers of the model tested from acceptance.

6.0

ACCEPTANCE TESTS

Prior to shipment, each transducer must pass tests for the conditions listed.

Materials of construction
Differential transducer performance with liquid
Gauge transducer performance with liquid
Pressure tap type and size
Electrical connector
Mating connector
Excitation polarity
Output polarity
Shield pin
Input resistance
Output resistance
Operating temperature limits
Thermal sensitivity.

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- * TECHNICAL DATA SHEET 4.8
LIQUID HYDROGEN LEVEL PROBES: TAG NUMBERS 38-LT-02, 50-LT-09,
and 50-LT-10

- * 1.0 LH₂ STORAGE TANK PROBE 38-LT-02

The liquid hydrogen level probe shall determine the level of liquid hydrogen in tanks by measuring the difference in dielectric constants between gaseous hydrogen and liquid hydrogen. The probe shall maintain continuous level measurement from the low point of the probe (not necessarily the low point of the tank) to full tank position (not the top point of the probe). The unit shall also include point sensors to provide indication of discrete level points as checks against the continuous level gage, and to provide a calibration of the continuous level gage.

1.1 COMPENSATION

The unit shall include compensators, as required, to determine and correct for changes in gas density and in the liquid conditions due to pressure and temperature variations.

1.2 STRENGTH

The probe shall be a self-supporting unit with its own strength and rigidity built in.

1.3 CONSTRUCTION

The probe shall be capable of installation through flanged nozzles or manholes on the tank, and shall be constructed on an inner probe electrode and a concentric outer probe sleeve. The outer probe sleeve shall be the second electrode, insulated from the inner electrode. Capacitance measurement shall be between the two electrodes.

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The tank wall shall not be a part of the electrical circuit, and can be considered grounded. A series of holes in the outer sleeve shall allow free passage of liquid and gas throughout the length of the probe. The top point of the sleeve shall not act as a gas trap. The probe shall not be contoured to compensate for vessel shape. Readings shall be in distance from the bottom of the tank or probe.

1.4 PROBE SLEEVES

A probe sleeve shall be provided at the bottom of the tanks to hold the bottom of the probe in position. The probe sleeve will be a 2-1/2 in. Schedule 80S pipe flare, and will accept approximately 3 in. of probe guide. The centerline of the probe sleeve shall be the same as the entrance nozzle.

1.5 ELECTRONIC UNITS

A complete bridge circuit, oscillator, amplifier, and indicator unit shall be supplied as a part of the continuous level sensor system. The unit shall provide all necessary signals and signal conditioning, bridge networks, calibration adjustments, and indicators. The unit shall include a suitable means of transmitting the level signal to a remote location.

1.6 TANK CONDITIONS

Tank conditions shall be:

Pressure, 100 psig and vacuum purge

Temperature, +70°F to -423°F

Tank Material, aluminum inner vessel, carbon steel outer vessel.

The distance from the bottom of the mating flange to the top of the probe sleeve will be 41 ft. It is anticipated that this distance will shrink in excess of 1 in. during cooldown.

The probe shall be supplied in sections, lowered into the nozzle, and be capable of connection without the need of a special crane.

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1.7 OUTER VESSEL

The probe wires shall be brought through the outer vessel through a suitable flange, to be furnished as a part of the probe. The wires shall pass through a suitable connector and a mating water-proof cable connector shall be supplied. The wires between flanges shall be supplied, with wire lengths of 8 feet. Means shall be provided and/or specified to connect the wires to the inner flange connection.

1.8 POINT SENSORS

The point sensors shall consist of a pair of flat plates or rings, mounted parallel to the static liquid surface, and placed at the tank level locations of 100, 75, 50, 25, and 10%. Liquid between the plates shall cause a change in capacitance large enough to be detected in an "ON-OFF" manner.

1.9 POINT SENSOR ELECTRONIC UNIT

Each point sensor shall be provided with a suitable network, bi-stable circuit, and relay to provide an "ON-OFF" circuit. The relay shall provide a DPDT contact arrangement. A single oscillator shall be used to supply all point sensors and the continuous gage.

1.10 POWER

- * The available power, 60 cps, single phase power, will vary between 120 v and 100 v. Voltage regulation shall be provided in the electronic circuits, as required.

1.11 PACKAGING

All electronic units for one probe system shall be mounted in a suitable box for wall mounting in a controlled atmosphere room, with suitable connectors and/or terminal strips. Mating connectors shall be supplied for all connectors used.

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1.12 TEMPERATURE PROBE

The temperature probe shall include a resistance temperature transducer near the lowest point, to sense the liquid temperature. This unit shall be in accordance with the Resistance Temperature Transducer Specification, except for appropriate connections.

2.0 HIGH PRESSURE LH_2 RUN TANK PROBE 50-LT-9

** The probe shall be constructed in 2 sections; the lower section must be capable of entering the vessel through a manhole, and the top support and cable must enter through a 3-in. 900-lb RTJ nozzle (ASA B16.5). The mating flange shall be a part of this probe. The 2 sections shall be mated after they are in the vessel. Probe sleeve will be as described in par. 1.4 above.

2.1 WIRING

All electrical connections shall enter through the flange. A connector and a mating waterproof cable connector shall be provided and the entire assembly shall be waterproof.

2.2 TANK CONDITIONS

Tank conditions shall be:

Pressure zero to 1200 psig
Temperature 70 to -423° F

Probe length from face of vessel flange to top of probe sleeve is 12 ft 7 in. and, nozzle length from top of nozzle to inside of tank is 38 in. Nozzle and probe sleeve are on the same centerlines.

2.3 POINT SENSORS

Same conditions as in paragraph 1.8 above.

2.4 POINT SENSOR ELECTRONIC UNIT

Same conditions as in paragraph 1.9 above.

2.5 POWER

Same conditions as in paragraph 1.10 above.

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2.6 PACKAGING

Same conditions as in paragraph 1.11 above.

2.7 CABLE LENGTHS

Cable lengths, from probe to electronics, will be approximately 250 feet.

2.8 TEMPERATURE TRANSDUCERS

A temperature transducer shall be provided as specified in TDS 4.6, and located at 10% of "full" level as part of each level-probe system. Remote temperature indication shall be included in the liquid-level remote indicating unit. Temperature transducer shall be tagged 50-TT-36.

2.9 ACCURACY

Accuracy of continuous level probe shall be 1% of full scale. Accuracy of the point sensor shall be ± 0.25 inch.

2.10 RESPONSE

Response of continuous level probe shall be at a rate of 2 in./sec with an accuracy of $\pm 5\%$ of full-scale level of tank. Response of point sensors shall be 20 millisecc

3.0 RUN TANK PROBE 50-LT-10

The probe shall be supported from an 8-in., 150 lb RTJ flange made of aluminum which will be bolted to a companion nozzle on the inner vessel. The flange cannot be lowered through the 8-in. nozzle on the outer tank, but must be brought in through a manhole and carried to the inner vessel nozzle. The flange assembly should not have a length in excess of 3 feet. The flange and flange ring shall be supplied as a part of the unit.

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3.1 WIRING

The necessary wires shall enter through the flange. The header on connector must withstand a pressure of 113 psia inside the tank (the probe side) and zero psia (vacuum) on the other side.

3.2 TANK CONDITIONS

Pressure, vacuum to 50 psig
Temperature, $+70^{\circ}\text{F}$ to -423°F
Tank material, aluminum

The distance from the top of the inner vessel nozzle (bottom of the mating flange to the top of the probe sleeve) is 34 ft, 3 in. It is anticipated that this distance will shrink in excess of 1 in. during cooldown. Probe shall be supplied in sections of a length which can be handled at top of the 150-foot tower, lowered into the nozzle, and connected without the need of a special crane. The "full" level is 5 ft 0 in. below the face of the inner vessel flange. The top of the probe sleeve will be at a 9.9% linear level of "full" level.

3.3 OUTER VESSEL

The wires shall be brought through the outer vessel through an 8-in. 150-lb O-Ring type blind flange of aluminum (ASA B16.5), which shall be supplied. The connector must stand a pressure of zero psia (vacuum) on the cable side and atmospheric on the connector side. The wires, of 8 feet length between flanges, shall be supplied. Means shall be provided to connect the wires to the inner flange connection.

3.4 RADIATION

The probe will operate in a radiation environment, with dose rates of

$$\begin{array}{l} 4 \times 10^4 \text{ Rads per hour of gamma} \\ 3 \times 10^9 \text{ n/cm}^2/\text{sec neutrons} \end{array}$$

Total integrated dose during the life of the unit will exceed 4×10^5 Rads gamma. The unit must be designed for this lifetime.

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3.5 POINT SENSOR ELECTRONIC UNIT

Same conditions as in paragraph 2.4 above.

3.6 POWER

Same conditions as in paragraph 2.5 above.

3.7 PACKAGING

Same conditions as in paragraph 2.6 above.

3.8 CABLE LENGTHS

Same conditions as in paragraph 2.7 above.

3.9 TEMPERATURE RESPONSE

Same conditions as in paragraph 2.8 above, except that temperature transducer shall be tagged 50-TT-32.

3.10 ACCURACY

Same conditions as in paragraph 2.9 above.

3.11 RESPONSE

Same conditions as in paragraph 2.10 above.

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TECHNICAL DATA SHEET 4.9
DUCT AND SHIELD MONITORS

1.0 INTRODUCTION

The duct and shield monitors are to scan a number of analog signals and provide alarms when any signals exceed preset limits.

2.0 DETAILED PERFORMANCE

2.1 INPUT LEVELS

Inputs shall be dc mv level signals from thermocouples and transducers.

2.2 OUTPUT SIGNALS

GO, Caution, NO-GO signals, as contact closures, occur on individual lines for each of the areas given.

2.3 SET POINTS

Provide 15 levels of Caution setpoint and 15 levels of NO-GO setpoint. These levels should be programable to all channels.

2.4 SAMPLING RATE

Each channel shall be sampled a minimum of 2 times each second. Scanning shall be continuous on any channel, regardless of condition indicated.

2.5 DUCT SECTIONS 1 THROUGH 9

2.5.1 Input, Each Section

*	Temp. T.C., chromel-alumel	-	10 channels
	Flow		2 channels
	Pressure		4 channels

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2.5.2 Output, Each Section

GO, Caution, NO-GO

2.5.3 Duct Steam System

* Temp. T.C., chromel-alumel 2 channels
 Pressure 6 channels
 Output - GO, Caution, NO-GO

2.5.4 Duct Miscellaneous

Vibration 3 channels
Water level (on-off) 1 channel
Output - GO, Caution, NO-GO

2.5.5 Shield S1 and S2 (Quantities Each Unit)

* Temp. T.C., chromel-alumel 10 channels
 Pressure 4 channels
 Output - GO, Caution, NO-GO

2.5.6 Shields, Top and Bottom

* Temp. T.C., chromel-alumel 10 channels
 Pressure 4 channels
 Output - GO, Caution, NO-GO

2.5.7 Malfunction Channel Indicator

* The malfunction channel indicator shall provide a gross indication on the Facilities Display Board, and an indication on the Facilities Control Panel Board of the channel number that is off-normal.

2.5.8 Malfunction Channel Readout Selector

* The malfunction channel readout selector shall provide a means of selecting a digital readout of any channel to permit monitoring of any off-normal channel, or other channel.

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TECHNICAL DATA SHEET 4.10
DUCT, SHIELD AND TRAIN CONTROLS

1.0 INTRODUCTION

The duct, shield, and train controls shall consist of panels containing all components necessary to operate and monitor control functions pertaining to the Test Stand Support Equipment.

2.0 DETAILED REQUIREMENTS

Panel components such as switches, pilot lights, and indicators shall be grouped on control panels to provide ease of operation and monitoring. Control and monitoring functions shall be clearly identified on all control panels.

Items required for each panel are listed in the following tabulations:

SHIELD CONTROL PANEL REQUIREMENTS

<u>System</u>	<u>Item</u>	<u>Switches</u>	<u>Lights</u>	<u>Meters</u>
North side radiation shield	Cart-drive control	5	2	
	Position indication		5	4
	Local-remote indication		2	
	Latch mechanism control	2	5	
	Cable control	2	2	
	Molten-metal seal control	3	4	1
	Bellow-seal control	1	1	
	Water remote shutoff valve (RSV)	2	2	
South side radiation shield	Cart-drive control	5	2	
	Position indication		5

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<u>System</u>	<u>Item</u>	<u>Switches</u>	<u>Lights</u>	<u>Meters</u>
South side radiation shield (cont.)	Local-remote indication		2	
	Cable control	2	2	
	Molten-metal seal control	3	4	1
Duct cover shield	Cart-drive control	3	2	
	Position indications		3	1
	Cable control	2	2	
	Track-switch control	1	2	
Deflector pit door shield	Door-drive control	3	4	
	Emergency override	1		
	Local-remote indication		2	
Top and bottom shields	Bellow seal	2	4	
	Top shield water RSV	2	2	
	Bottom shield water RSV	2	2	

DUCT CONTROL PANEL REQUIREMENTS

<u>System</u>	<u>Item</u>	<u>Switches</u>	<u>Lights</u>	<u>Meters</u>
Deflector duct	Duct-seal bellows control	2	2	
	Molten-metal seal control	2	2	1
	Local-remote control	1	2	
	Position indication		1	1
	Hydraulic pump control	2	1	
	Vertical jacks	3	4	1
	Water-line clamp control	8	16	
	Steam-line clamp control	6	8	
	Side jacks (trunnions) control	4	16	4
	Connector control	2	2	
	Cooling-water control	2	1

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TRAIN CONTROL PANEL REQUIREMENTS

<u>System</u>	<u>Item</u>	<u>Switches</u>	<u>Lights</u>	<u>Meters</u>
	R. F. release switch	1	1	
	Position indicators		6	
*	Cart-coupler control	2	1	
	Engine jig-drives control	4	4	1
	Cart elevation control	2	2	1
	Locking clamp control	2	2

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TECHNICAL DATA SHEET 4.11
POWER SUPPLIES

See TDS 4.11.1 10-volt Power Supply

* 4.11.2 30 -volt Power Supply

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TECHNICAL DATA SHEET 4.11.1

10-VOLT POWER SUPPLY

1.0 INTRODUCTION

The 10-v power supplies shall be entirely of solid-state design. Construction shall be rugged and of industrial quality.

2.0 DETAILED PERFORMANCE

2.1 REMOTE SENSING

Remote sensing shall be provided on the power supplies.

2.2 OUTPUT TEST JACKS

Output test jacks shall be provided on the front panel.

2.3 DUTY CYCLE

The power supplies shall be designed for continuous duty.

2.4 LIFE

The power supplies shall be designed for a minimum life of 10,000 operation hr.

2.5 OPERATING TEMPERATURE

The power supplies shall be designed to operate over an ambient temperature range from 10°C to 50°C.

2.6 ELECTRICAL REQUIREMENTS

2.6.1 dc Voltage Output

The voltage output from the power supplies shall be from 0 to 10 v dc, continuously adjustable between 0 and 10 v, with a resolution of 0.001 from 0 to 10 v with the specified control.

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2.6.2 Output Amperes

The voltage output of the power supplies shall be available at output currents from 0.001 to 10 amp.

2.6.3 Power Input

The power supplies shall be designed to operate from a power source of 117 vac, $\pm 10\%$, 60 cps, single phase.

2.6.4 Internal Impedance

The internal impedance of the power supplies shall be less than 0.01 ohms from dc to 1 kc.

2.6.5 Floating Output

The output of the power supplies shall be isolated from the chassis and cabinet ground.

3.0 PERFORMANCE REQUIREMENTS

Unless otherwise noted, the following performance specifications shall be met by the power supplies over the entire output ranges as specified.

3.1 REGULATION FOR LOAD CHANGES

The power supplies shall regulate the voltage output for the load changes listed below:

<u>Load Change</u>	<u>Regulation</u>
No load to full load	± 50 mv
20% full load step change	± 1.0 mv

3.2 REGULATION FOR LINE CHANGES

The power supplies shall regulate the voltage and output for ac voltage changes of $\pm 10\%$ to within $\pm 10\%$, ± 1.0 mv.

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3.3 COMBINED LOAD AND LINE CHANGES

The power supplies shall regulate the voltage output for combined 20% load step change and $\pm 10\%$ line change to within ± 2 mv.

3.4 RIPPLE

The ripple component of the output voltage from the power supplies shall be less than 0.5 mv rms.

3.5 MAXIMUM EXCURSION

* The power supplies shall limit maximum excursions caused by transients to 10% of full range; this shall also apply during power turn-on and power turn-off.

3.6 STABILITY

The output voltage of the power supplies shall be maintained to within ± 1.0 mv for a 24-hour operating period, after a maximum 30-min warm-up period.

3.7 TEMPERATURE COEFFICIENT

The output voltage of the power supplies shall be maintained within $\pm 0.03\%/^{\circ}\text{C}$ change in temperature, within the operating temperature range specified.

3.8 SHORT CIRCUIT PROTECTION

The power supplies shall be designed to withstand a direct short across the output for an indefinite period without damage. The voltage output shall return to normal upon removal of the short.

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TECHNICAL DATA SHEET 4.11.2
30 - VOLT POWER SUPPLY

1.0 INTRODUCTION

* The 30 -v power supply shall employ vacuum tube design. Construction shall be rugged and of industrial quality.

2.0 DETAILED PERFORMANCE

2.1 REMOTE SENSING

Remote sensing shall be provided on the power supplies.

2.2 OUTPUT TEST JACKS

Output test jacks shall be provided on the front panel.

2.3 DUTY CYCLE

The power supplies shall be designed for continuous duty.

2.4 LIFE

The power supplies shall be designed for a minimum life of 10,000 operating hr.

2.5 OPERATING TEMPERATURE

The power supplies shall be designed to operate over an ambient temperature range from 10° C to 50° C.

3.0 ELECTRICAL REQUIREMENTS

3.1 VOLTAGE OUTPUT

* The voltage output from the power supplies shall be continuously adjustable between 0 and 30 v, with the manual control, and shall be available at output currents from 0.001 to 0.600 amp.

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3.2 POWER INPUT

* The power supplies shall be designed to operate from a power source of 117v ac to ± 10%, 60 cps, single phase.

3.3 INTERNAL IMPEDANCE

The internal impedance of the power supplies shall be less than 0.6 ohms from d-c to 100 cps.

3.4 FLOATING OUTPUT

The output of the power supplies shall be isolated from the chassis and cabinet ground.

4.0 PERFORMANCE REQUIREMENTS

4.1 REGULATION FOR LOAD CHANGES

The power supplies shall regulate the voltage output for these load changes:

<u>Load Change</u>	<u>Regulation</u>
No load to full load	<u>±</u> 0.025%
20% full load step change	<u>±</u> 0.025%

4.2 REGULATION FOR LINE CHANGES

The power supplies shall regulate the voltage output for a-c line voltage changes of ± 10% to within ± 0.025%.

4.3 COMBINED LOAD AND LINE CHANGES

The power supplies shall regulate the voltage output for combined 20% full load step change and ± 10% line change, ± 0.05%.

4.4 RIPPLE

The ripple component of the output voltage from the power supplies shall be less than 2 mv rms.

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4.5 MAXIMUM EXCURSION

The power supplies shall limit maximum excursions caused by transients to 0.03% of full range; this shall also apply during power turn-on and power turn-off.

*

4.6 STABILITY

The output voltage of the power supplies shall be maintained to within ± 100 mv for a 24-hour operating period, after a maximum of 30-min warm-up period.

4.7 TEMPERATURE COEFFICIENT

The output voltage of the power supplies shall be maintained within $\pm 0.01\%/^{\circ}\text{C}$ change in temperature, within the specified operating temperature range.

4.8 SHORT CIRCUIT PROTECTION

The power supplies shall be designed to withstand a direct short across the output for an indefinite period without damage. The voltage output shall return to normal upon removal of the short.

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TECHNICAL DATA SHEET 4.12
TIMING SYSTEM

1.0 INTRODUCTION

A timing system shall be used at the NERVA test facility to provide a time reference for the correlation of events and a precision time standard for the evaluation of acquired data.

2.0 DETAILED REQUIREMENTS

2.1 OSCILLATOR

The external oscillator (timing standard) shall adhere to the following requirements:

It shall be a 100-kc, temperature controlled crystal, with a frequency stability of 1 part in 10,000,000.

It shall contain provisions to permit visual comparison of oscillator frequency against WWV transmission, provide suitable manual adjustments to enable its use in conjunction with a standby oscillator. Malfunction indicators shall be supplied in either visual or audible types.

2.2 ACCUMULATOR

The accumulator shall meet the following requirements:

It shall incorporate binary coded decimal (BCD) decade counting, arranged to facilitate both BCD and decade decimal readout. Count shall be achieved in BCD from a 1-kc input to a total of 10^5 sec.

It shall read in straight seconds and recycle automatically at the end of each 24-hr period.

2.3 TIME-CODE GENERATOR

The time-code generator shall consist of a pulse-rate divider, mixers, line amplifiers, and necessary power supplies. Frequency stability shall be 3×10^{-8} -sec per day; accuracy shall be better than 1 sec/mo.

*

2.3.1 Power Required

115 v ac $\pm$ 10%, 50-400 cps, 1 amp

2.3.2 Formats

Five formats shall be provided, consisting of the following:

- (1) A BCD 6-decade format
- (2) Twenty-four pulses defining time of day in straight seconds and tenths
- (3) Width-modulated code
- (4) Frame lengths of 0.1, 1.0, 10, 100, and 1,000 sec
- (5) Code-scan rates of 250, 25, 2.5, 0.25, and .025 pps.

Modulated carrier frequencies shall be 10 kc and 1 kc for the 250 and 25-pps scan rate formats. (See ICC-151)

2.3.3 Auxiliary Pulses

Auxiliary pulses shall be provided by the generator for correlation with other equipment, e.g., auxiliary generator, data reduction center, etc.

2.3.4 Output Voltage Levels and External Loads

The serial code dc level shift shall not exceed 0-12 v dc. The maximum external load shall be 100 ohms, unbalanced to ground. Source impedance shall be 100 ohms.

The serial code carrier shall have an output of 15 v, peak-to-peak. The maximum external load shall not exceed 600 ohms, unbalanced to ground. The output shall be adjustable with a screw driver control in the chassis.

Output of the parallel code shall be 11 v for the binary "0", and 0 v for binary "1". The maximum external load shall not exceed 10,000 ohms, unbalanced to ground.

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2.3.5 Controls

Separate digital controls shall be provided for resetting the time of day, and day of year, and shall be interlocked to eliminate accidental stopping of the accumulator.

2.3.6 External Shorts

The time-code generator shall not be damaged by momentary shorts occurring at any of the outputs.

2.3.7 Design

Circuit design shall employ only solid-state circuits; the chassis construction shall include provisions for easy installation on commercial chassis slides.

2.4 THE RELAY DRIVER

The relay driver requirements shall include:

2.4.1 Input Requirements

The relay driver input shall consist of at least 7 separate channels. A d-c level shift from 0 to $+3 \text{ v} \pm 0.5 \text{ v}$ shall close the output relay. The maximum input rate shall be 100 pps for each channel. Input resistance shall be 10,000 ohms.

2.4.2 Output Requirements

In the relay driver, one single-pole relay closure shall be provided for each of the 7 input channels.

Relay contacts shall be a mercury-wetted type, and shall be rated as: 500 v, max; 0.5 amp. max; and 250 va, max.

The 28 v dc supply, used to provide the 28 v output via the relay contacts, shall be rated at 3.0 amp. The delay of the output signal, relative to input signal, shall not exceed 4 ms.

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2.4.3 Power Requirements

The relay driver power requirements shall consist of 105 to 125 v;
60 $\pm$ 3 cps; 75 w, max.

2.4.4 Temperature Requirements

The relay driver shall operate within an ambient temperature range
of -20°C to +55°C without adverse effects.

2.4.5 Design

The relay driver shall contain solid-state "T" series Germanium
transistor plug-in circuits, mercury-wetted contact relays, and
solid-state semiconductor power supplies.

All components of the relay driver shall be mounted on one section
of a three-section chassis assembly. The remaining space on the
chassis shall be available for two additional relay drivers when
necessary.

2.5 LINE DRIVER REQUIREMENTS

Each of 12 independent channels shall have a high-impedance input
and a balanced low impedance output.

2.5.1 Input Signals

Line-driver input signals shall be applied through a single multi-
pin connector. Frequency range of the input a-c signals shall be
100 to 20,000 cps and impedance shall be greater than 10,000 ohms.

Front panel adjustments shall accommodate input signals from 0.25
to 50 v rms.

2.5.2 Output

Line-driver output shall be applied through 12 separate output con-
nectors, to provide flexibility in signal routing. Each channel shall
be a 2-wire output from a center-tapped transformer.

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Capability for monitoring peak neon current shall be provided by a front panel-mounted meter.

Provisions shall be included to enable any input signal to be fed through any, or all, of the output channels. The amplifier shall allow 1, 2, or 3 input signals to be patched to an arbitrary combination of output channels.

2.6.2 Power Requirements

The neon-distribution amplifier power requirements shall be 105 to 125 v, 60 cps $\pm$ 3 cps, 0.5 amp. The unit shall be capable of effective operation within an ambient temperature range of -20°C to $+55^{\circ}\text{C}$ (-4°F to 131°F).

2.6.3 Design Requirements

Design requirements shall include: solid-state "T" series germanium transistor plug-in circuits, and solid state semi-conductor power supplies, which shall be provided for reliability and ease of maintenance. All components shall be mounted on one section of a three-section chassis assembly, to allow the addition of a supplementary neon distribution amplifier within the single chassis, if required.

Two-wire shielded cabling shall be provided for timing distribution to neon lamp positions.

Cameras may be located up to 5500 ft from the neon-distribution amplifier when using pulse rates up to 100 pps, and up to 500 ft at a pulse rate of 1000 pps. When distances exceed the foregoing, or when higher pulse rates are required, supplementary neon drivers shall be employed as repeater amplifiers in the cables.

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TECHNICAL DATA SHEET 4.13
CLOSED CIRCUIT TV SYSTEM EQUIPMENT REQUIREMENTS

1.0 INTRODUCTION

The closed circuit TV system, as detailed in the following requirements, shall be implemented to provide a visual indication within the Control Center, and/or Forward Control Room, of activities on the Test Stand and within the complex area. Areas will be monitored for personnel safety, equipment handling, and firing observation.

2.0 DETAILED PERFORMANCE

The system shall produce a minimum of 600 lines of horizontal resolution at a standard scanning rate of 525 lines, 2:1 interlace, 60 fields, 30 frames per second; a uniform flat picture field; and 9 distinguishable shades of gray, an incident illumination of 20 foot-lamberts, using an f/1.5 lens on an EIA test pattern.

The system shall employ synchronization in full accordance with EIA standards. Non-linearity, as measured by EIA standards, shall be less than 2% in the vertical and horizontal dimensions.

The system shall incorporate an automatic target control circuit and operate within 0.10 sec over a scene illumination range of 2000:1.

A white peak clipper circuit shall be incorporated to enable viewing detail in high-brightness portions of the scene.

The above performance characteristics shall not be affected by ac line voltage changes between 95 and 130 v. The use of external voltage regulator transformers shall be held to a minimum.

2.1 RELIABILITY

Continued high performance shall be assured by these factors:

Each system shall be cycle-tested for a minimum of 100 hr, prior to shipment.

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Vidicon tubes shall be radiation-resistant when intended for use in areas of high radiation levels (see Dwg ICC-038).

All circuits shall be operated from an electronically regulated dc voltage power supply. Regulation shall be held to 1% maximum between 95 to 130 vac.

The SYNC generator shall include crystal control with binary dividers, and may use a stable 60 cps line source.

The video circuitry shall employ variable aperture correction, a separate high peaker circuit, a clamp keyed to the horizontal scanning rate, and a bandwidth of 10 mc.

The system shall also incorporate an automatic target regulator and focus coil current regulation of 1% maximum between 95 to 130 vac.

The camera shall employ an automatic electronic vidicon sweep failure protection circuit.

All exterior surfaces of the cameras and/or housings shall be painted with corrosion resistant white enamel to protect internal elements from adverse effects of prolonged exposure to typical Nevada desert environment.

All circuitry in the camera and camera control unit must be contained in plug-in modular subassemblies.

2.2

OPERATING PARAMETERS

Operating parameters of the camera shall be in accordance with these specification procedures:

Vibration - MIL-E5272B, Procedure 1

Shock - MIL-E-5272B, Procedure 2

Acoustical Noise - 185 db above $0.0002 \text{ dynes/cm}^2$, design objective, certified 150 db.

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Explosion Proof - MIL-E-5272B, certified.

To assure compliance with the above requirements, the vidicon shall be securely clamped in position by a vibration-proof mechanical assembly. Explosion-proof housings or environmental housings (as considered necessary) shall completely enclose the camera and associated lenses to offer protection against flying debris, corrosive atmosphere (wind, dust, and rain), and other adverse environmental conditions.

2.3 ACCESSORIES

2.3.1 Monitors

The monitor shall contain an aluminized picture tube covered by a Polaroid filter. The video amplifier bandwidth shall be 10 mc and shall be capable of at least 600 lines of horizontal resolution. The monitor shall contain an electronically regulated power supply and shall provide 2 input video terminals, with a switch for either high impedance or terminated video input.

2.3.2 Lenses

Remotely controlled lens turrets with varying focal-length lenses shall be provided. The lenses shall be completely enclosed by the explosion-proof housing. Focal lengths of all lenses shall range from 1/2 to 12 in., and shall have ratings from f 2.5 to f 3.8. Zoom lenses shall be substituted for fixed-focal-length lenses as indicated in Dwg ICC-038. The lenses shall be radiation resistant (non-browning), as required.

2.3.3 Video Switchers

Each video switcher shall have provisions for selecting any one of 8 input signals and 1 output. All unused incoming video circuits may be terminated into a 75 ohm load within the switcher. The signal presented to the monitor shall receive its termination at the monitor.

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2.3.4 Pan and Tilt Unit

The weatherproof camera pan and tilt mount shall be a remotely controlled unit, and shall comply with MIL-Spec E-5272C for explosion-proof equipment.

2.3.5 Control Panel - Accessory

The camera accessory control shall permit remote control of any, or all, of the following accessories: lens turret and optical focus, pan and tilt, and zoom adjustments.

2.3.6 Radiation-Resistant Television Camera

The special radiation-resistant camera shall be assembled so that those components adversely affected by radiation will be kept outside of the radiation field. The camera proper shall contain the lens, focus and deflection coil, vidicon tube, and electronic circuitry, as necessary. The remaining electrical components shall be placed in an amplifier unit up to 15 ft away from the more destructive radiation field.

2.3.7 Junction Boxes

The junction boxes shall provide suitable outlets for the camera control cable, the accessory control cable, and communication equipment.

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TECHNICAL DATA SHEET 4.14
DC RECTIFIER

See TDS 4.14.1 — Regulated 28-volt, 100-amp, dc Power Supply

See TDS 4.14.2 — Regulated 28-volt, 400-amp, dc Power Supply

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TECHNICAL DATA SHEET 4. 14. 1
REGULATED 28-VOLT, 100 AMP, DC POWER SUPPLY

1. 0 INTRODUCTION

The power supply shall furnish a regulated output voltage adjustable between 22 and 32 v.

2. 0 DETAILED PERFORMANCE

2. 1 INPUT AND OUTPUT

It shall have an ac input of $440 \text{ v} \pm 10\%$, 3 phase, 60 cps; and a dc output, rated at 28 v 100 amp continuous rating with $\pm 10\%$ variation in input voltage, and shall be smoothly adjustable from 22 to 32 v, No-Load to Full-Load, with $\pm 10\%$ variation in input voltage.

2. 2 DYNAMIC REGULATION AND RIPPLE

It shall have dynamic regulation of $\pm 0.5 \text{ v}$ from No-Load to Full-Load over an input range of 400 to 490 v, with a ripple of less than 1 mv rms (of output voltage setting) at any load or any line condition ($\pm 10\%$ variation).

2. 3 RESPONSE

It shall have a response of 50 microseconds to within the regulating range, upon sudden application or removal of full load at any line voltage, with a maximum output voltage variation of $\pm 0.5 \text{ v}$.

2. 4 AMBIENT RANGE

It shall operate within a temperature range of -20 to 55°C .

2. 5 RECTIFIERS AND POWER TRANSFORMER

The power supply shall incorporate hermetically sealed silicon diodes connected in a bridge circuit, and a two-winding isolating type, power transformer, with Class B insulation.

2.6 CONTROL SYSTEM

It shall include magnetic amplifier control with static components; and On-Off control by ac magnetic contactor with Start-Stop push button on front panel, and provision for remote control and indicating light; and shall have provision for dc output remote indicating light.

2.7 WARM-UP TIME

No warm-up time shall be required; output voltage shall stabilize within $\pm 1.0\%$ of output setting with no overshoot.

3.0 DESIGN3.1 METERS

The power supply shall include 4-1/2 in. rectangular dc voltmeters and dc ammeters, using D'Arsonval movements with 2% accuracy. Provision shall be made for remote metering.

3.2 CONTROLS

Meters, voltage adjustment control, start-stop button, and any other required controls shall be mounted externally for visibility and accessibility.

3.3 COOLING

Unit shall have forced air cooling.

3.4 REMOTE SENSING

Provision shall be made for remote sensing only.

3.5 PROTECTION AND SAFETY

Thermal overload protection (automatic reset type) shall be provided for sustained overload. There shall be magnetic overload protection for excessive surge loads, and instant action protection against fan failure. Automatic nickel cadmium battery charging and adjustable

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current limiting protection shall be provided. The output circuit shall be completely insulated from the input. The unit shall have an Underwriter's Label.

3.6

CABINET

The unit shall have a stationary, sturdily constructed cabinet, and equipment shall be accessible from the front for inspection and servicing.

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TECHNICAL DATA SHEET 4. 14. 2
REGULATED 28-VOLT, 400 AMP, DC POWER SUPPLY

1. 0 INTRODUCTION

The power supply shall furnish a regulated output voltage adjustable between 26 and 36 v.

2. 0 DETAILED PERFORMANCE

2. 1 INPUT AND OUTPUT

The power supply shall have an ac input of 440 v $\pm 10\%$, 3 phase, 60 cps; and a dc output of 28 v, 400 amp continuous rating with $\pm 10\%$ variation in input voltage, and shall be smoothly adjustable from 26 to 36 v, No-Load to Full-Load, with $\pm 10\%$ variation in input voltage.

2. 2 DYNAMIC REGULATION AND RIPPLE

It shall have dynamic regulation of ± 1.0 v from No-Load to Full-Load over an input range of 400 to 490 v, with a ripple of less than 3 mv rms (of output voltage setting) at any load or any line condition ($\pm 10\%$ variation).

2. 3 RESPONSE

It shall have a response of 200 microseconds to within the regulating range, upon sudden application or removal of full load at any line voltage, with a maximum output voltage variation of ± 0.5 v.

2. 4 AMBIENT RANGE

It shall operate within a temperature range of -20 to 55°C.

2. 5 RECTIFIERS AND POWER TRANSFORMER

The power supply shall incorporate hermetically-sealed silicon diodes connected in a bridge circuit, and a two-winding isolating type power transformer, with Class B insulation.

2.6 CONTROL SYSTEM

It shall include magnetic amplifier control with static components; and On-Off control by ac magnetic contactor with Start-Stop push button on front panel, and provision for remote control and indicating light; and shall have provision for dc output remote indicating light.

2.7 WARM-UP TIME

No warm-up time shall be required; output voltage shall stabilize within $\pm 1.0\%$ of output setting with no overshoot.

3.0 DESIGN

3.1 METERS

The power supply shall include 4-1/2 in. rectangular dc voltmeter and dc ammeters, using D'Arsonval movements with 2% accuracy. Provision shall be made for remote metering.

3.2 CONTROLS

Meters, voltage adjustment control, start-stop button, and any other required controls shall be mounted externally for visibility and accessibility.

3.3 COOLING

Unit shall have forced air cooling.

3.4 REMOTE SENSING

Provision shall be made for remote sensing only.

3.5 PROTECTION AND SAFETY

Thermal overload protection (automatic reset type) shall be provided for sustained overload. There shall be magnetic overload protection

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for excessive surge loads, and instant action protection against fan failure. Automatic nickel cadmium battery charging and adjustable current limiting protection shall be provided. The output circuit shall be completely insulated from the input. The unit shall have an Underwriter's Label.

3.6

CABINET

The unit shall have a stationary, sturdily constructed cabinet, and equipment shall be accessible from the front for inspection and servicing.

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TECHNICAL DATA SHEET 4.15
REGULATED 400-CYCLE POWER SUPPLY REQUIREMENTS

1.0 INTRODUCTION

The 400-cycle regulated power supply consists of 2 motor generator sets and control cabinets.

2.0 DETAILED PERFORMANCE

2.1 INPUT AND OUTPUT

The power supply shall have an ac input of 440 v $\pm$ 10%, 3 phase, 60 cps; with a motor power factor of unity at rated load, unity to 0.9 from Half-Load to Full-Load, and a unit efficiency of at least 70%. It shall have an output of two 120/208 v, 400 cps, 3 phase, 4 wire, 5 kw continuous duty, with 50°C rise at power factors from unity to 0.8 lagging.

2.2 PARALLEL OPERATION

Units shall be designed for parallel operation, and synchronizing equipment with indicating lights shall be provided. A plugging switch shall be installed on Unit No. 2 to permit restarting for synchronization if first attempts fail, but for use only after the motor has stopped. Unit No. 2 is for standby operation.

2.3 VOLTAGE STABILITY

The output voltage shall be stabilized within 1 min after start-up, and will remain within a $\pm$ 1/2% regulation band at any constant load within the unit rating, and over an ambient temperature range of 0 to 125°F.

2.4 TRANSIENT VOLTAGES

Output voltage shall not deviate by more than $\pm$ 25% from the pre-set value in event of sudden application or removal of rated kw at rated power factor. Recovery to within the regulated band shall be complete in 0.2 sec.

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2.5 HARMONIC CONTENT

The total rms harmonic content, line-to-line, or line-to-neutral shall not exceed 1.0% without use of filters.

2.6 PHASE VOLTAGE BALANCE

With 1/3 rated current on one phase and no load on the other two, maximum deviation of any phase voltage from the average of the three-phase voltages shall not exceed 4%.

2.7 MODULATION

Voltage and frequency modulation shall not exceed 0.25%.

2.8 SHORT CIRCUIT CAPABILITY

The units shall be capable of delivering 300% of rated current, to a short circuit, until the output circuit breaker opens.

2.9 RELIABILITY AND MAINTENANCE

No adjustments, servicing, or maintenance shall be required for periods of less than 5000-hr. The units shall have a Mean-Time-Before-Failure statistical reliability of at least 5000 hr under rated load conditions.

2.10 RADIO NOISE SUPPRESSION

The units shall be certified to meet all requirements of MIL-I-6181 and MIL-I-26600 with radiated noise measurements taken at distances of 6 ft.

3.0 DESIGN

3.1 CONTROL AND INSTRUMENTS

The units shall provide:

- (a) Magnetic motor starter, across-the-line, with two thermal overload and undervoltage protectors, Start-Stop pushbutton station, and indicating light units shall be rated by NEMA Standard IC-1.

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- (b) Fused control circuit transformer with 110-v secondary, to power all applicable control devices.
- (c) Output circuit breaker, industrial type, providing thermal overload, reverse current, and short circuit protection, and including a load indicating light.
- (d) Output voltage adjustment, screwdriver type with locknut, allowing $\pm 10\%$ range of adjustment.
- (e) Output ammeter and voltmeter, 3-1/2 in. rectangular, 2% accuracy, calibrated for 400 cps, and selector switches to permit reading individual line-to-line voltages and line currents. Provision shall be made for remote metering.
- (f) Out-of-Step Relay, to protect the unit from being pulled out of step by loading conditions; if this should occur, the relay shall immediately drop the motor off the line by de-energizing the motor-starter contactor.
- (g) A synchronizing panel with indicating lights.
- (h) Remote sensing in the units, with a three-position remote sensing selector switch. The remote sensing leads to 400 cps panels shall be shielded.

3. 2 MOTOR GENERATOR SETS

Both motor and generator shall be brushless, 1200 rpm, synchronous, revolving field and in full conformance with NEMA Standard MG1. Motor, generator, and exciter shall be combined on a single common shaft, 2-bearing assembly; the completed shaft assembly shall be statically and dynamically balanced. Windings shall be impervious to oil, solvents, moisture, mild acids, and alkalies.

3. 3 EXCITER-REGULATORS

Each exciter regulator shall provide:

- (a) Effective isolation of the generator output from transient changes in the input supply voltage.

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- (b) Completely static voltage regulators with no tubes or vibrating contacts, and fully stabilized against long term drift, as well as against ambient temperature variations from 0 to 125°F.
- (c) Completely automatic initial voltage build-up not requiring the use of manual switches or relays.
- (d) Rotating ac type exciters, brushless and delivering their output to a shaft-mounted, 3-phase, full-wave silicon rectifier assembly.

3.4

CONTROL CABINETS

Each motor generator and all control equipment shall be integrally mounted in a floor-standing, dead-front NEMA-1 enclosure. Removable panels shall provide convenient access to all internal components. The operator's control panel shall be hinged, and permit observation of meters and operation of all manual controls from a normal standing position. Each functional circuit, such as the voltage regulator, shall be mounted on an individual panel or chassis with input and output terminals or connecting plug and receptacle provided. All hardware shall be cadmium plated and iridited. Shakeproof fastening devices shall be utilized throughout.

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TECHNICAL DATA SHEET 4.16
DISTRIBUTION PANELBOARD

1.0 INTRODUCTION

Panelboards shall be furnished for distribution of 28 vdc and 120/208 v 400 cps power to fulfill instrumentation requirements.

2.0 DETAILED PERFORMANCE

2.1 28 VOLTS DC

Panel DC 10 A in the Control Point Building 3310 shall be Type NAB with single-pole breakers of suitable rating.

Panel DC 40 A in the Test Cell Building 3340 shall be Type NAB with single-pole breakers of suitable rating.

Spare breakers (25% of total number) shall be provided in each surface mounted panel.

2.2 120/208 V, 400 CYCLE

Panel 400 P 10 A in the Control Point Building 3310 shall be Type NAB with single-pole breaker of suitable rating.

Panel 400 P 40 A in the Test Cell Building 3340 shall be Type NAB with single pole breaker of suitable rating.

Spare breakers (25% of total number) shall be provided in each surface mounted panel.

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TECHNICAL DATA SHEET 4.17
28-VOLT FLOATING BATTERY

1.0 INTRODUCTION

28-volt dc, 22-cell, nickel cadmium alkaline storage batteries shall be furnished to provide back-up protection for the dc rectifier systems.

2.0 DETAILED PERFORMANCE

2.1 AMPERE-HOUR CAPACITY

Batteries shall have an ampere-hour capacity at 8-hr rate, to 1.14 v per cell, of 100 amp-hr minimum for the Control Point Building, and 200 amp-hr for the Test Cell Building.

2.2 DISCHARGE CAPACITY

They shall be capable of delivering the following minimum current for 20 min to not less than 24 v (or 1.14 v/cell), when discharged at 77°F:

100 amp-hr batteries, 90 amps
200 amp-hr batteries, 180 amps

2.3 SERVICE

The batteries shall be floated on the 28 v cutout of a dc rectifier, which will also maintain the charge.

2.4 AMBIENT

They shall operate in the temperature range of 0 to 55°C.

3.0 DESIGN

3.1 RACK

They shall be mounted on 2-step racks, complete with hardwood trays.

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3.2

ACCESSORIES

Standard accessories shall include intercell, intertray, and end-terminal connectors; hydrometer electrolyte level test tube, wall card, and instruction book.

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TECHNICAL DATA SHEET 4.18
TERMINAL BOX

1.0 INTRODUCTION

This section covers a standard terminal box to be used throughout the facility for termination of cables as shown in Drawing ICC-150. By modification, use as a relay box with terminals, shall be possible.

2.0 DETAILED REQUIREMENTS

2.1 ENCLOSURE

The enclosure shall be a standard product.

2.2 TERMINALS

Each enclosure shall have 384 numbered terminals.

2.3 LOCKS

The enclosure latch shall include a key lock to prevent unauthorized changes.

2.4 GROUND BUS

The enclosure shall have a ground bus, top and bottom.

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TECHNICAL DATA SHEET 4.19
INSTRUMENTATION AND CONTROL CABLES

1.0 INTRODUCTION

Instrumentation and control cables are to be used as transmission and distribution lines, for industrial application.

2.0 TECHNICAL REQUIREMENTS

2.1 CODE AND SPECIFICATIONS CONFORMANCE

All materials and tests shall conform to applicable sections of latest issues and revisions of the following Specifications and Standards:

Insulated Power and Cable Engineering Association (IPCEA).

International Municipal Signal Association (IMSA).

Federal Spec. L-P-590, Plastic Compounds, Molding and Extrusion, Polyethylene.

Mil. Spec. MIL-C-17c, Cables, Radio Frequency Coaxial, Dual Coaxial, Twin Conductor and Twin Lead.

Mil. Spec. MIL-W-76A, Wire and Cable, Hookup, Electrical, Insulated, Type HF

ASTM D 470, Methods of Testing Rubber and Thermoplastic Insulated Wire and Cable.

Rural Electrification Administration (REA) Section PE-23.

2.2 IDENTIFICATION

All cable reels shall be clearly marked or tagged in an indestructible manner, with designation number, a brief description of the cable contained on the reel, the length, and the code number.

2.3 REELS

Reels shall be of suitable design to protect the cable in handling and rolling. The cable shall have both ends exposed to allow testing without unreeling. Cable ends shall be secured to prevent unreeling and sealed to prevent entrance of moisture.

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2.4 INSTALLATION CONDITIONS

The cable will be installed in open trays, in conduit, through underground tunnels, trenches and structures.

Ambient temperatures will range from -65 to $+165^{\circ}\text{F}$. All materials shall be suitable for service at 221°F .

2.5 WIRE

Wire used shall be AWG No. 16 consisting of 19 strands of No. 29 tinned-copper wire or AWG No. 18, consisting of 16 strands of No. 29 tinned-copper wire. Wire shall comply with Federal Specification MIL-W-76A.

2.5.1 Wire Lay

There shall be one continuous length of wire to each reel. (Splicing will not be accepted.)

Multiple tinned-copper conductor cable wire shall be twisted prior to shielding to a nominal wire lay in accordance with the following formula:

$$5 \text{ DN}$$

where

D = wire diameter (over the insulation)

N = number of conductors.

2.5.2 Insulation

Insulation shall be 0.020-in. wall thickness (minimum) stabilized polyethylene, conforming to Federal Specification L-P-590.

2.5.3 Sheath

Sheath shall be nylon, 0.004-in. wall thickness (over polyethylene).

2.5.4 Capacitance

Capacitance between conductor and shield (with other conductors connected to shield) shall be less than 50 mmf/ft except single conductor cable.

2.6 SHIELDING

2.6.1 Component Cable Shielding

Shields of single and multiconductor cable shall consist of continuous, tight fitting, closely wound, tinned-copper wires. Shield wires shall be spirally wrapped, without gaps or voids, providing a minimum 90% coverage, with a reverse lay drain wire of 4 or more tinned-copper strands over the shield. Shield and drain wires shall be No. 34 AWG.

2.6.2 Overall Cable Shielding

The overall cable shielding shall consist of a continuous spirally wound, .005 in. thick tinned-copper tape, free from burrs. Overlap shall be at least 15% of tape width, and enough to prevent cable cutting when the cable is flexed through a radius of 8 times the cable diameter.

- (a) Cable Jacket - The cable jacket shall be of tight-fitting polyethylene, with a minimum wall thickness of 0.028 in. on No. 16 to 22 AWG cables, and 0.042 in. on No. 10 AWG cables. The cable jacket shall not impregnate the shielding material.
- (b) Fillers (If Required) - Fillers, if required, shall be of stabilized polyethylene.
- (c) Insulation Resistance - Insulation resistance on completed cables shall have these minimum values:
 - (1) Between conductors of shielded cable: 50,000 megohms / 1000 ft.
 - (2) Between each conductor and its shield, with all other conductors electrically connected to the shield: 20,000 megohms / 1000 ft.
 - (3) Between jacketed cable shields - 100 megohms / 1000 ft.
 - (4) Between shield of each jacketed cable and overall cable shield - 100 megohms / 1000 ft.

2.7

CABLE TYPES

The instrumentation and control cables listed below are typical, but do not designate limitations, of preferred types and nomenclatures.

<u>Type No.</u>	
1/C	37 strand, AWG No. 16, not shielded
1/C	19 strand, AWG No. 16, not shielded
S 2/C	16 strand, twisted AWG No. 18, with shield and jacket overall
S 2/C	19 strand, twisted AWG No. 16, with shield and jacket overall
S 4/C	19 strand, twisted AWG No. 16, with shield and jacket overall
S 6/C	19 strand, twisted AWG No. 16, with shield and jacket overall
S12/S2/C AWG No. 16	24 conductors, No. 16 AWG. Consists of 12 shielded and jacketed 2-conductor cables with a shield and jacket overall.
S12/S4/C AWG No. 16	48 conductors, No. 16 AWG. Consists of 12 shielded and jacketed 4-conductor cables with a shield and jacket overall.
S12/S6/C AWG No. 16	72 conductors, No. 16 AWG. Consists of 12 shielded and jacketed 6-conductor cables, with a shield and jacket overall.
S100/C AWG No. 16	100 conductors, No. 16 AWG. Consists of 50 twisted pairs, with a shield and jacket overall.

Note: Those cables to be used in nuclear radiation areas must be given special consideration with regard to radiation damage and life expectancy. Expected radiation levels may be ascertained from Nuclear Radiation Level Charts, Drawings ICC-176, -177, and -178.

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COLOR CODE, WIRE, AND CABLE LAY

COLOR SEQUENCE FOR INSTRUMENTATION AND CONTROL CABLES

Conductor Number	Base Color	First Tracer	Second Tracer	Conductor Number	Base Color	First Tracer	Second Tracer
* 1	Black			51	White	Black	Orange
2	White			52	Red	Orange	Black
3	Red			53	Green	Red	Blue
4	Green			54	Orange	Black	Blue
5	Orange			55	Blue	Black	Orange
6	Blue			56	Black	Orange	Green
7	White	Black		57	White	Orange	Green
8	Red	Black		58	Red	Orange	Green
9	Green	Black		59	Green	Black	Blue
10	Orange	Black		60	Orange	Green	Blue
11	Blue	Black		61	Blue	Green	Orange
12	Black	White		62	Black	Red	Blue
13	Red	White		63	White	Orange	Blue
14	Green	White		64	Red	Black	Blue
15	Blue	White		65	Green	Orange	Blue
16	Black	Red		66	Orange	White	Red
17	White	Red		67	Blue	White	Red
18	Orange	Red		68	Black	Green	Blue
19	Blue	Red		69	White	Green	Blue
20	Red	Green		70	Red	Green	Blue
21	Orange	Green		71	Green	White	Red
22	Black	White	Red	72	Orange	Red	Black
23	White	Black	Red	73	Blue	Red	Black
24	Red	Black	White	74	Black	Orange	Blue
25	Green	Black	White	75	Red	Orange	Blue
26	Orange	Black	White	76	Green	Red	Black
27	Blue	Black	White	77	Orange	White	Green
28	Black	Red	Green	78	Blue	White	Green
29	White	Red	Green	79	Red	White	Orange
30	Red	Black	Green	80	Green	White	Orange
31	Green	Black	Orange	81	Blue	Black	Green
32	Orange	Black	Green	82	Orange	White	
33	Blue	White	Orange	83	Green	Red	
34	Black	White	Orange	84	Black	Green	
35	White	Red	Orange	85	White	Green	
36	Orange	White	Blue	86	Blue	Green	
37	White	Red	Blue	87	Black	Orange	
38	Black	White	Green	88	White	Orange	
39	White	Black	Green	89	Red	Orange	
40	Red	White	Green	90	Green	Orange	
41	Green	White	Blue	91	Blue	Orange	
42	Orange	Red	Green	92	Black	Blue	
43	Blue	Red	Green	93	White	Blue	
44	Black	White	Blue	94	Red	Blue	
45	White	Black	Blue	95	Green	Blue	
46	Red	White	Blue	96	Orange	Blue	
47	Green	Orange	Red	97	Yellow		
48	Orange	Red	Blue	98	Yellow	Black	
49	Blue	Red	Orange	99	Yellow	White	
50	Black	Orange	Red	100	Yellow	Red	

* First color for all units of construction, excepting that conductor of S1/C (shielded and jacketed one-conductor cable) shall be coded white.

2.9

CABLING

Wire lay of shielded and jacketed multiconductor cables shall follow the specified color sequence, starting with No. 1, BLACK for each cable, except that single conductor S1/C cable shall be coded white.

Wire lay of multiconductor cable shall follow the color sequence specified, starting with No. 1, BLACK, on the inside of the assembly.

Cable lay of cabled, shielded, and jacketed cables shall follow the color sequence, starting with No. 1, BLACK jacketed cable, inside the assembly.

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TECHNICAL DATA SHEET 4.20
PATCHING SYSTEMS DETAILED REQUIREMENTS

1.0 INTRODUCTION

Patching panelboards shall be either the non-programed vector type or the programed amp patch type as noted on Dwg ICC-107. Panels shall be arranged for recess mounting in racks, and provision shall be made for securing all control patching.

2.0 DETAILED REQUIREMENTS

2.1 VECTOR TYPE PATCHBOARDS

The vector patchboards shall provide a simple method of making multiple connections, single conductor patching, where "pre-programing" is not required. Units shall be made up in as many blocks of 100 receptacles (arranged end-to-end or top-to-bottom) as may be required.

Terminals shall be on 0.265-in. centers, with 0.094 ± 0.002 in. hole diameters. Terminals shall be beryllium copper, 0.002 in. silver plated, with 0.00003-in. gold flash, complete with 2 holes for soldering.

Each panel shall be approximately 3.25 x 0.875 in. Insulation shall be epoxy-paper laminate, off-white color, 0.093 in. thick.

In the identification printing, which shall appear on both front and back, horizontal rows shall be lettered, starting with "A" at the top; while vertical columns shall be numbered starting with "1" on the left, as viewed from the plug side.

Minimum rating between adjacent contacts shall be 1000 rms v, ac or dc, at sea level. A minimum of 20% spare vector modules shall be provided, prewired to terminal strips for future growth. The face of the board shall be color coded to distinguish between cables, relay coils, relay contacts, etc. Patching cords shall be provided as required; and for each type of cord used, 25% spare cords shall be provided.

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2.2

AMP TYPE PATCHBOARD

The programed patchboards shall be amp shielded patch type. The size, number, and location of the patchboards shall be determined by the system requirements, except that the size shall be no greater than AMP type P-1041 or one panel.

The patchboard shall consist of a fixed section, held rigidly in the rack, and a removable section with a suitable positive inserting mechanism. The panel shall be constructed of individual nylon cells mounted on 0.375-in. centers, completely surrounded by interlocking metal bars, thus providing a metal barrier around each patchboard contact spring.

The leakage resistance of the nylon cells to ground shall be a minimum of 10^{12} ohms, and the contact resistance shall be a maximum of 0.002 ohms. The panel shall have a voltage rating of 1500 v dc and 1200 rms between adjacent contacts, and to ground, at sea level.

The board shall be molded diallyl-phthalate with gold plated spring located contacts. The face of the board shall be color coded to distinguish between cables, relay contacts, relay coils, types of data, etc.

A minimum of 10% spare terminals shall be provided, prewired to terminal strips for future growth. Three removable sections for each stationary section shall be provided.

Patching cords and plugs of suitable type shall be provided as required. Where shielded wires are used, the patchboard and plugs shall provide a continuous shield. For each size and type used, 100% spare patching cords shall be provided.

2.3

TERMINATIONS AND INTERCONNECTIONS

Terminations of transmission cables shall be made on terminal strips in the rack. All terminals of the patchboard shall be wired to the rack terminal board. The required rack interconnections shall be made with internal rack connections. Patchcords between racks shall not be employed.

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TECHNICAL DATA SHEET 4.21
STANDARD COMMUNICATION PANELS

1.0 INTRODUCTION

The interphone subsystem communication panels shall provide a means of signalling and pre-arranging network communications from area to area.

2.0 DETAILED REQUIREMENTS

2.1 MECHANICAL CHARACTERISTICS

2.1.1 Panel Contents

Communication panels shall be rack mounted and large enough to include:

- * Headset
- Trunk selector switch (32 positions)
- * Speaker/Headset Switch
- Headset jacks (3)
- 3-in. speaker
- Push-to-talk switch
- Power fuse
- Power On-Off switch
- Power "On" lamp

2.1.2 Chassis Contents

Communication panels shall be attached to a chassis. The chassis shall accommodate the following items:

- * Transformer and rectifier power supply
- 52-pin connector
- Transistorized isolation amplifiers (2)

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2.2 ELECTRICAL CHARACTERISTICS

2.2.1 Transformer and Rectifier Power Supply

The transformer and rectifier power supply shall consist of a 60 cps transformer and semi-conductor diodes in a full-wave bridge configuration. Voltage output shall be from 12 to 24 v dc, depending on the type of transistors used in the power system. Output ripple shall be held to 1% of the output supply voltage. Current capacity shall be 500 ma.

* 2.2.2 (deleted)

2.2.3 Connectors

Miniature ribbon-type connectors shall be used. Connectors shall be lock and press-to-unlock type.

2.2.4 Isolation Amplifiers

The headset jack and speaker shall be supplied from the same isolation amplifier. Isolation amplifiers shall present a high impedance to line transformer or repeat coil primaries during both transmission and reception (approximately 100,000 ohms).

* The amplifier design shall include provisions for side-tone suppression, via phase cancellation methods. Amplifiers shall contain two inputs: one for the microphone, and one for the receiver, with a common ground to accommodate a three-wire headset or handset. Provisions for increasing or decreasing amplifier gain shall be incorporated. The gain control shall affect the level of the headset earphone or the speaker and be accessible from the front of the panel through a spring-loaded adjustment door and shall be continuous. Solid-state circuitry shall be used for amplification stages.

* 2.2.5 (deleted)

* 2.2.6 (deleted)

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interphone trunk line signal levels. Speaker muting during paging at a communications panel location shall be accomplished by relay control of amplifier supply voltage. The relay shall be operated by the handset cradle switch.

Solid-state circuitry shall be used for amplification stages.

2.2.6

Relays

The page or muting relay operating voltage shall be consistent with the supply voltage used for the amplifier electronics. Hold-in current requirements shall not exceed 100 ma. The buzzer relay shall be a sensitive relay requiring not more than 1 ma of operating current. The sensitive relay voltage shall be supplied from the communications panel supply voltage.

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TECHNICAL DATA SHEET 4.22
SWITCH PANELS

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TECHNICAL DATA SHEET 4.22A
"WEATHERPROOF" COMMUNICATION PANELS

1.0 INTRODUCTION

The interphone subsystem communication panels shall provide a means of signaling and pre-arranging network communications from area to area.

2.0 DETAILED REQUIREMENTS

2.1 MECHANICAL CHARACTERISTICS

2.1.1 Enclosure

** Enclosure shall be weather-proof, made of materials conducive to low radiation retention and suitable for column or wall mounting with hubs for rigid conduit

2.1.2 Panel Contents

Communication panels shall be rack mounted and large enough to include

Headset
Trunk selector switch (32 positions)
Speaker/Headset Switch
Headset jacks (3)
3-in. speaker
Push-to-talk switch
Power fuse
Power On-Off switch
Power "On" lamp

2.1.3 Chassis Contents

Communication panels shall be attached to a chassis. The chassis shall accommodate the following items

Transformer and rectifier power supply
52-pin connector
Transistorized isolation amplifiers (2)

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2.2 ELECTRICAL CHARACTERISTICS

2.2.1 Transformer and Rectifier Power Supply

The transformer and rectifier power supply shall consist of a 60 cps transformer and semi-conductor diodes in a full-wave bridge configuration. Voltage output shall be from 12 to 24 v dc, depending on the type of transistors used in the power system. Output ripple shall be held to 1% of the output supply voltage. Current capacity shall be 500 ma.

2.2.2 Connectors

Miniature ribbon-type connectors shall be used. Connectors shall be lock and press-to-unlock type.

2.2.3 Isolation Amplifiers

The headset jack and speaker shall be supplied from the same isolation amplifier. Isolation amplifiers shall present a high impedance to line transformer or repeat coil primaries during both transmission and reception (approximately 100,000 ohms).

The amplifier design shall include provisions for side-tone suppression, via phase cancellation methods. Amplifiers shall contain two inputs: one for the microphone, and one for the receiver, with a common ground to accommodate a three-wire headset or handset. Provisions for increasing or decreasing amplifier gain shall be incorporated. The gain control shall affect the level of the headset earphone or the speaker, and be accessible from the front of the panel through a spring-loaded adjustment door and shall be continuous. Solid-state circuitry shall be used for amplification stages.

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TECHNICAL DATA SHEET 4.23
SPECIAL COMMUNICATION PANELS

1.0 INTRODUCTION

* The interphone subsystem special communication panels will be primarily for use at the Key Test Consoles. They will provide facilities similar to the communication panels. Complete flexibility in patching the various subsystems will be provided, along with the incorporation of talk/listen instrument selection, i.e., switching from headsets to a sensitive microphone and speaker.

2.0 DETAILED REQUIREMENTS

2.1 MECHANICAL CHARACTERISTICS

2.1.1 Panel Contents

Special communication panels shall be rack mounted in consoles, and panels shall be large enough to include:

- ** Headset
- Headset jack
- Trunk selector switch
- Subsystems disconnect switches (push-button)
- Lamps
- RF transmit or receive switch
- RF channel selector switch
- Instrument selector switch
- Mike switch selector (Push-to-Talk or "On")
- * General P.A. selector switch
- Dial or direct-line selector switch
- * General P.A. override switch (LSE console only)
- Power on-off switch
- Fuse

2.1.2 Chassis Contents

Special communication panels shall be attached to a chassis. The chassis shall accommodate the following items:

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Isolation amplifiers
Buffer amplifiers
Microphone pre-amplifier
Speaker amplifier
Control relays
Transformer and rectifier power supply
52-Pin Connector

2.2 ELECTRICAL CHARACTERISTICS

2.2.1 Transformer and Rectifier Power Supply

The transformer and rectifier power supply shall consist of a 60-cps transformer and semi-conductor diodes in a full-wave bridge configuration. Voltage output shall be from 12 to 24 v dc, depending on the type of transistors used in the power system. Output ripple shall be held to 1% of the output supply voltage. Current capacity shall be approximately 500 ma.

2.2.2 Isolation Amplifiers

The headset jack shall be supplied from separate isolation amplifiers. Isolation amplifiers shall present a high impedance to line transformer or repeat coil primaries during both transmission and reception (approximately 100,000 ohms).

The amplifier design shall include provisions for side-tone suppression, via phase cancellation methods. Amplifiers shall contain two inputs: one for the microphone, and one for the receiver, with a common ground to accommodate a three-wire headset or handset. Provisions for increasing or decreasing amplifier gain shall be incorporated. The gain control shall be accessible from the rear of the panel only, and shall be set in steps with a switch. Solid-state circuitry shall be used for amplification stages.

Isolation amplifiers for audio into, and from, the RF transmitters and receivers, shall be of a design similar to amplifiers previously described, but need not incorporate side-tone suppression. Dial and direct-line instruments shall incorporate similar transmission and receiver elements for isolation amplifier standardization.

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2.2.3 Buffer Amplifiers

Special communication panels shall contain buffer amplifiers to isolate low impedance microphone lines to the P. A. amplifier control center from the interphone trunk lines. Buffer amplifiers shall provide high impedance inputs (100,000 ohms) and low-impedance outputs (500-600 ohms). Solid-state circuitry shall be used for amplification stages.

2.2.4 Microphone Preamplifiers

A preamplifier shall be provided for a sensitive, low-level microphone. The input impedance shall be high, with switching facilities to accommodate either high- or low-impedance microphones. A 200 to 100,000 ohm step-up microphone transformer shall be included in the preamplifier to facilitate the HI-Z LO-Z switching. Preamplifier output impedance shall be high to facilitate direct connection to the headset isolation amplifier output through a control relay and instrument selector switch. Solid-state circuitry shall be used. Sufficient gain shall be provided to bring the microphone level up to the interphone trunk level requirements. Two gain controls shall be provided: one on the front panel, and a master gain set control on the chassis.

2.2.5 Speaker Amplifier

A speaker amplifier shall be incorporated to bring the interphone trunk line level and other subsystem levels up to the required power output to drive a 3-in. speaker. The amplifier shall have a high-impedance input and have sufficient gain and power output to drive the speaker to approximately 0.5 w audio output through a small output transformer. Amplifier stages shall use solid-state circuitry. The amplifier shall be disabled by lifting the supply voltage by a relay and a Press-to-Talk switch - the latter being incorporated on the microphone. Two gain or volume controls shall be provided: one on the front panel, and a master gain set control on the chassis.

2.2.6 Control Relays

A relay shall be provided on the chassis, in a separate shielded compartment or enclosure, to select between a headset or sensitive

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microphone and speaker. Relays shall be hermetically sealed and shall operate from the supply voltage. Current requirements shall be below 25 ma/relay. Relay control shall be provided for Press-to-Talk operation of the RF communication set.

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TECHNICAL DATA SHEET 4.24
RADIO FREQUENCY TRANSCEIVERS

1.0 INTRODUCTION

The radio frequency transceivers shall provide two-way communications from the Control Point Area to remotely located "walkie-talkies" and to a similar transceiver in a helicopter.

2.0 DETAILED REQUIREMENTS

2.1 MECHANICAL CHARACTERISTICS

Radio frequency transceivers shall be rack mounted, and shall include all the controls and indicating devices necessary for tuning on the front panel. The chassis shall include transmitter and receiving components, and chassis-mounted coaxial connectors at the rear. The rear of the chassis shall also mount the power connector and a control connector, the latter including audio output from the receiver and audio input to the transmitter. The front panel shall have a microphone input connector and a headphone jack, suitable for a headset, Western Electric, or equivalent.

2.2 ELECTRICAL CHARACTERISTICS

Output and input impedance shall be 50 ohms nominal.

Frequency range shall be mc to mc in 1-mc steps.

Power output shall be consistent with security requirements.

Microphone input shall be carbon, and compatible with Western Electric, or equivalent headset.

Receiver sensitivity shall be 1 microvolt for 10 db of quieting (VHF), and 2 microvolts for 10 db of quieting (UHF).

Receiver noise figure shall be 3 db maximum (VHF), and 6 db maximum (UHF).

Receiver overall bandwidth shall be 50 kc between half power points.

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Receiver tuning shall be crystal controlled - 5 channels.

Transmitter oscillator tuning shall be crystal controlled - 5 channels.

Transmitter output tuning shall be Pi network.

Spurious responses shall be contained, in the second harmonic, from 60 db down, and in all others, from 80 db down.

Modulation and detection shall be amplitude modulation.

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TECHNICAL DATA SHEET 4.25
TAPE RECORDERS

1.0 INTRODUCTION

Two tape recorders shall be provided for recording inter-phone network and other communications during the countdown phase of NERVA operations. They shall be located in the recording room, and coupled to a communication panel.

2.0 DETAILED REQUIREMENTS

2.1 MECHANICAL CHARACTERISTICS

They shall be rack mounted, have a speed of 7-1/2 ips, a tape width of 1/4 in., with 1/4 track record and playback heads, and standard 7 in. RMA reels.

Controls shall include those sufficient for record, playback, forward, fast forward, rewind, clutch stop and release, record gain (4 channels), and playback gain (4 channels).

Receptacles shall be provided for 4 separate inputs for recording; 2 separate outputs for playback, with switching to any two simultaneous channels; and 2 tape monitor outputs with switching.

Indicators shall include volume unit meters (2 switchable), and index counter.

2.2 ELECTRICAL CHARACTERISTICS

Frequency response shall be ± 4 db, 50-15,000 cps.

Signal-to-noise ratio shall be 60 db minimum.

Flutter and wow shall be under 0.2%.

Playback timing accuracy shall be 0.2% or ± 3.6 sec for a 30 min recording.

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TECHNICAL DATA SHEET 4.26
ANTENNAS

1.0 INTRODUCTION

Two antennas shall be provided at the Control Point Area for reception and transmission of radio frequency signals between transceivers at the Control Point Area, walkie-talkies, and the helicopter transceiver.

2.0 DETAIL REQUIREMENTS

2.1 MECHANICAL CHARACTERISTICS

Antennas shall be quarter-wavelength ground-planes, mounted on 50 ft masts or towers. The radiating elements and ground plane radials shall be ruggedly supported in weather resistant material. Four ground plane radials shall be utilized, spaced 90° apart. A low-loss weather-proof constant-impedance coaxial connector shall be provided at the converging point of the 5 elements, and shall be mounted on a silver-plated metallic circular plate, which, in turn, shall fasten to the ground-plane elements.

2.2 ELECTRONIC CHARACTERISTICS

Feed impedance shall be 52 ohms nominal.

Pattern shall be omni-directional.

Center frequency shall be mc.

Bandwidth shall be 5 mc at half-power points.

Matching shall be done with impedance transformer.

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TECHNICAL DATA SHEET 4.27
WALKIE-TALKIES

1.0 INTRODUCTION

The "walkie-talkie" communication sets shall serve as links between remote installations and the Control Point Area. They shall have low power output and moderate sensitivity, since weight must be held to a bare minimum.

2.0 DETAILED PERFORMANCE

2.1 MECHANICAL CHARACTERISTICS

The "walkie-talkie" shall be packaged in a compact, one-piece unit and equipped with a belt-clip. Controls shall include a transmit or receive switch, receiver volume, and a 2-channel selector switch. A speaker and carbon microphone shall be mounted at opposite ends of the housing, or the speaker may be used for a microphone, whichever will result in a lighter, and more compact unit. A telescoping antenna shall be fitted at the top of the unit.

2.2 ELECTRICAL CHARACTERISTICS

Transmitter oscillator shall be crystal controlled - 2 channels.

Frequency range shall cover mc to mc.

Power output shall be of milliwatt level, consistent with security requirements.

Transmitter and receiver tuning shall be fixed, and bandwidth shall accommodate 2-channel switching.

All spurious responses shall be 60 db down, minimum.

Receiver sensitivity shall be 1 microvolt for 10 db of quieting.

Overall bandwidth of receiver shall be 100 kc between half power points.

Modulation and detection shall be amplitude modulation.

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TECHNICAL DATA SHEET 4.28
ACCESSORY SPEAKER UNITS

1.0 INTRODUCTION

An accessory speaker unit to plug into a headset jack shall be provided to give extra freedom of movement at any of the interphone stations. The unit shall contain a cord, plug, and a 3-in. speaker in a small cabinet. The cabinet shall accommodate a transistorized amplifier to drive the speaker. Such units shall be provided in limited quantity.

2.0 DETAIL REQUIREMENTS

2.1 MECHANICAL CHARACTERISTICS

The cabinet shall have a speaker grille, or perforations on the front and shall be deep enough to accommodate the amplifier electronics. A small rubber or plastic covered hook shall be provided at the top rear of the cabinet to suspend the unit at a convenient hanging point.

2.2 ELECTRICAL CHARACTERISTICS

2.2.1 Amplifier

A small utility audio amplifier shall provide enough gain and power to drive a 3 in. speaker to 0.5 w audio output. All stages shall be transistorized, and powered by a small battery pack located within the cabinet. A gain control shall be provided in one corner of the cabinet. The amplifier input impedance shall be approximately 100,000 ohms.

2.2.2 Speaker

A 3 in. speaker with a 3.5-ohm voice coil shall be provided, and mounted on the front of the cabinet.

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TECHNICAL DATA SHEET 4.30
PUBLIC ADDRESS CONTROL CENTER

1.0 INTRODUCTION

The "Universal" Public-address Control Center shall allow selection of any general area, or building, in the Test Site when paging. It shall also include facilities for Universal paging. Audio mixers shall be included for coupling inputs from several microphones.

2.0 DETAILED REQUIREMENTS

2.1 MECHANICAL CHARACTERISTICS

The public-address control center shall be housed in a dust-tight cabinet, and shall contain a chassis for mounting electronic hardware such as relays, barrier strips, resistors, transistor circuitry, line transformers and connectors.

2.2 ELECTRICAL CHARACTERISTICS

2.2.1 Amplifier Loading and Speaker Selection

The public-address power-amplifier output terminals and speaker lines from 4 major areas shall be connected to the Control Center. Selection of each area, or all areas simultaneously, shall be accomplished by relays. Proper loading to the power amplifier shall be maintained under all conditions by relay selection of resistor values equal to the various combined speaker impedances as required.

2.2.2 Amplifier Input & Output Requirements

Relay contacts shall also be utilized to route various microphone lines into a multiple-stage input mixer. Transformers shall be included for stepping up low-impedance microphone transmission lines to match high-impedance mixer inputs. Inputs to each mixer shall be shorted under "No signal" conditions. The mixer

amplifier output (low impedance) shall be coupled to the Public Address amplifier input, which is assumed to be remotely located from the Public Address Control Center. If not, high-impedance coupling may be used. Control lines shall be brought into the Public-Address Control Center for separate selection of speaker area relays and input selector relays.

2.2.3 Override Requirements

An additional control line from the Safety Director's Console shall be brought into the Public Address Control Center to disconnect all mixer inputs other than the Safety Director's own input. This shall be accomplished via a master input selector relay.

2.2.4 Noise

Extraneous noise or hum, developed as a result of adding the Public-Address Control Center to the system, shall be virtually non-existent, nor shall it degrade the signal-to-noise ratio of the Public Address amplifier more than 2 db.

2.2.5 Distortion

No distortion shall be apparent as a result of utilizing the Public Address Control Center.

2.2.6 Power

The unit shall operate from a self contained 60 cps transformer-rectifier power supply, which shall furnish well-filtered dc voltages to the electronic circuitry and relays.

2.2.7 Amplifier Circuitry

Solid-state circuitry shall be used, where applicable.

TECHNICAL DATA SHEET 4.31
ANTENNA COUPLERS OR MULTIPLEXERS

1.0 INTRODUCTION

Antenna couplers shall be provided at the Control Point Area to couple the transmitting and receiving antennas to the transceivers. The receiving coupler shall couple all receiver sections of the transceivers to the receiving antenna. The transmitting coupler shall couple all transmitter sections of the transceivers to the transmitting antenna. All coupling shall be electronic, and shall not require switching.

2.0 DETAILED PERFORMANCE

2.1 MECHANICAL CHARACTERISTICS

Duplexer or multiplexer-type couplers shall be provided, consisting of cavity resonators tuned to discrete transmitting and receiving frequencies. Coaxial connectors shall be provided for connecting to transmitters and receivers, and for interconnection between duplexers for parallel and simultaneous operation of 3 transmitters and 3 receivers. The coupler shall be rack mounted.

2.2 ELECTRICAL CHARACTERISTICS

Channel separation shall be 1 mc minimum.

Insertion loss shall be 1.5 db maximum.

Channel isolation shall be 20 db minimum.

VSWR shall be 1.3 maximum.

Channel bandwidth shall be 1.15 mc at half power points.

Channel bandwidth at VSWR of 1.3 shall be 0.5 mc

2.3 CHANNEL CENTER FREQUENCIES

** The following frequencies are representative only, and may be changed, consistent with security requirements:

Channel 1	150 mc
Channel 2	151 mc
Channel 3	152 mc
Channel 4	153 mc
Channel 5	154 mc

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TECHNICAL DATA SHEET 4.32
LH₂-RUN-TANK OUTLET SHUTOFF VALVE

1.0 INTRODUCTION

The LH₂-run-tank outlet valve will be installed at the tank outlet flange. The valve will be designated as 50 RSV-132, and must be designed for a fail-safe operation and a high-radiation environment.

2.0 DETAILED REQUIREMENTS

	Process fluid	LH ₂
	Normal inlet temperature	-423°F
	Normal inlet pressure	50 psig
	Pressure drop at normal flow	1.0 psi or less
	Nominal flow rate	75 lb/sec
	Material	Body, aluminum; seat, Kel-F; vacuum-jacketed
*	Actuator	500 psig gas actuation cylinder type
	Body size	14 in.
	Port size	14 in.
	Connections	Inlet - to mate with tank outlet flange Outlet - flanged
	Valve position on failure	Spring, actuated closed

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TECHNICAL DATA SHEET 4.33
FLOW MEASURING SYSTEM, PROPELLANT SUPPLY TO ENGINE

1.0 INTRODUCTION

A flow-measuring system shall be incorporated in the propellant-feed line between the run-tank outlet shutoff valve and the engine-inlet connection. The location of this system is shown on Dwg. 3305-M7, AETRON Division of Aerojet, as done for the AEC on Project NTS-400, and is also shown on Dwg. ICC-028 in the I & C design criteria. The flow measuring system must be designed for operation in a high radiation environment, and will contain:

Flow straightening section
Pressure transducer
Temperature transducer
Flowmeter

2.0 DETAILED REQUIREMENTS

2.1 OPERATING CONDITIONS

Fluid	LH ₂
Operating pressure	50 psig
Fluid temperature	-435 to -335°F
Flow rate	75 lb/sec

2.2 FLOW STRAIGHTENING SECTION

Line size	14 in.
Line length (minimum) (straightening vanes required)	80 in.
Line length (maximum)	140 in.
Pipe specification	150-lb nominal class rating Aluminum vacuum jacket
End connections	Flanged to 50 RSV-132 Flanged to flowmeter

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Other connections	As specified in Dwg. ICC-028
Other provisions	Temperature transducer connection
	Pressure transducer connection
Allowable pressure drop	1.0 psi or less

2.3 PRESSURE TRANSDUCER

Range 0 to 60 psig

For additional requirements see TDS 4.7.

2.4 TEMPERATURE TRANSDUCER

Operating range -435 to -335°F

For additional requirements see TDS 4.6.

(Guard-tube materials to be aluminum)

2.5 FLOWMETER REQUIREMENTS

150-lb rating, aluminum

Vacuum jacketed

Turbine type

Magnetic brake to prevent overspeeding

Connections - flanged to mate to flow straightening section

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TECHNICAL DATA SHEET 4.34
FLOW MEASURING SYSTEM, EMERGENCY COOLANT TO ENGINE

1.0 INTRODUCTION

The complete capacity of the LH₂ emergency coolant flow, if required for reactor cooling in event of the engine turbopump failure, must be available for control and diagnostic purposes. The flow measuring system will contain these components: flow straightening section, pressure transducer, temperature transducer, and flowmeter.

This system is located as shown in Line 4-LH-6" HV on Dwg. 3305-M-6, AETRON Division of Aerojet, as done for the AEC on Project NTS-400, and is also shown on Dwg. ICC-028 in the I & C design criteria.

2.0 DETAILED REQUIREMENTS

2.1 OPERATING CONDITIONS

Fluid	LH ₂
Operating pressure	1000 psig
Flow rate	Variable up to 75 lb/sec
Fluid temperature	-435 to -335°F

2.2 FLOW STRAIGHTENING SECTION

Line size	6 in.
Flanged ends	Designed to mate with existing flanges
Line	Vacuum jacketed
1500 lb nominal class rating stainless steel	
Minimum overall line	
length between flanges	80 in.

Line to contain provisions for: pressure transducer, temperature transducer, and flowmeter

2.3 PRESSURE TRANSDUCER

Range	0 to 1500 psig
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For additional requirements see TDS 4.7.

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2.4 TEMPERATURE TRANSDUCER

Operating range -435 to -335°F

For additional requirements see TDS 4.6

(Guard tube material to be aluminum)

2.5 FLOWMETER REQUIREMENTS

1500-lb rating stainless steel

Vacuum jacketed

Turbine type

Magnetic brake to prevent overspeeding

Connections - flanged into flow straightening section

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TECHNICAL DATA SHEET 5.1.1
DIGITAL DATA ACQUISITION SYSTEM

1.0 INTRODUCTION

This specification is for the digital data system for ETS-1, which system will consist of the equipment necessary to record, in the digital domain, the transducer outputs involved in a NERVA engine operation. This includes the necessary equipment to scan, digitize the sensor value, and provide time identification. The system shall have the capability of handling 200 - 4000 channels with a data rate of 40,000, 12-bit data words per second, and a recording accuracy to 0.1%. Signal conditioning equipment is not specified in this section, but is shared with the analog recording system. In addition to recording capabilities, this system shall have the capability of providing a system checkout and a preliminary data report through a preliminary data-reduction subsystem and a general-purpose computer.

2.0 DETAILED PERFORMANCE

Operational blocks of this system are identified as follows:

*	Signal Filters "Deleted"	(TDS 5.1.2)
	Signal Commutation Equipment	(TDS 5.1.3)
	Analog-to-Digital Equipment	(TDS 5.1.4)
	Digital Data Tape Recording Subsystem	(TDS 5.1.5)
	Checkout and Preliminary Data Reduction Subsystem	(TDS 5.1.6)
	General Purpose Computer	(TDS 5.1.7)

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TECHNICAL DATA SHEET 5.1.2
SIGNAL FILTERS

"Deleted"

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TECHNICAL DATA SHEET 5.1.3
SIGNAL COMMUTATION EQUIPMENT

1.0 INTRODUCTION

This specification is for a high and low-level 50-channel electronic multiplexer to produce a pulse-amplitude modulated (PAM) wave train by sequentially sampling a group of transducers. The multiplexer is to have differential inputs with several possible input voltage spans ranging from 0 + 10 millivolts to 0 + 10 volts, one of which will be selected by a switch. Commutation rate shall be 200 samples per second. Stability of zero of ± 20 microvolts, and stability of gain of 0.1%, both for 30 days, are required. With suitable external programming, the multiplexer shall be used as part of a pulse-code modulated (PCM) system.

2.0 DETAILED PERFORMANCE

2.1 INPUT CHARACTERISTICS

2.1.1 Source Impedance

0-500 ohms for millivolt ranges
0-5000 ohms for 0-10 volt range

2.1.2 Source Impedance Unbalance

0-500 ohms for millivolt ranges
0-1000 ohms for 0-10 volt range

2.1.3 Signal Level

0-10, 0-20, 0-30, 0-40, 0-50, and 0-100 millivolts;
0-5 volts; switch selectable

2.1.4 Overload

± 1 volt differential for millivolt ranges, and/or ± 10 volt common mode for millivolt ranges; ± 15 volts differential for

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0 + 10 volt range and/or ± 10 volt common mode for 0 + 10 volt range and/or OPEN INPUT on any range; provided that, no combination of the above overloads shall cause potentials in excess of the switch breakdown voltage specified.

Above overload must cause less than the following percentage of full scale change in output of any normal channel:

0.2% on 10 and 20 millivolt ranges
0.1% on 30 millivolt and higher millivolt ranges
0.05% on 5V range

The overloaded channel shall recover within one frame.

2.1.5 Common Mode Signals

Maximum common mode signals will be any combination of the following from a source impedance of less than 50 ohms. The instantaneous peak common mode voltage shall not exceed ± 9 v.

± 3 v dc for millivolt ranges
 ± 8 dc for 0 - 10 volt ranges
9 v peak-to-peak ac 0-100 cps
1.5 v peak-to-peak ac 100 cps - 3000 cps

The common mode voltage shall be defined as $\frac{e_1 + e_2}{2}$,

where: e_1 and e_2 are voltages from each input wire, respectively, to instrument common.

2.1.6 Signal Grounding

Input must be differential and capable of meeting all specifications with balanced grounded, or unbalanced grounded inputs. The maximum impedance to ground of any channel shall be 50,000 ohms for normal operation.

2.1.7 Input Impedance

500,000 ohms minimum

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2.2 OUTPUT CHARACTERISTICS

Full-scale signal - +10 volts

Zero signal - 0 volts

Output clamping - Output shall not exceed -1 v or +11 v under any conditions.

Duty cycle - 100%.

Overshoot - Less than 20% of full-scale.

Settling time less than 60 microsec to settle within the specification.

Noise - 10 microvolts rms referred to input, or 0.05% rms of full-scale, whichever is greater.

Output load - 10,000 ohms minimum resistance

Output grounding - Output shall be singled-ended with the low side not connected to chassis or frame ground. The low side of the output can be connected to the input common.

2.3 INPUT-OUTPUT RELATIONSHIP (Accuracy and Stability Requirements)

Linearity - $\pm 0.05\%$ of full-scale.

Crosstalk - less than 0.02% of full-scale for normal conditions.

Channel-to-channel offset - Initially ± 10 microvolts, subject to ± 20 microvolts per 30 days drift spec.

Input common mode rejection - 100 db for 500-ohm source impedance unbalance

Zero drift - ± 20 microvolts for 30 days, referred to input

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Gain stability - $\pm 0.1\%$ of full-scale for 30 days

Warm-up time - unit shall meet all specifications after a 1-hour warm-up.

Gain accuracy - $\pm 0.1\%$ of full-scale for all millivolt ranges; $\pm 0.1\%$ on 10 volt ranges for source impedance from 0 to 500 ohms plus an additional $\pm 0.1\%$ error for each additional 500 ohms increase in source impedance.

3.0

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Commutation Rate - Sampling rate shall be 200 samples per second per channel.

External Synchronization - Operation of commutator shall be programmable and synchronized from an external source.

Power Input - 115 volts $\pm 10\%$, 60 cps ± 0.5 cycle, properly fused.

Environment - Ground station, air conditioned room, rack mounted, 65°F to 100°F operating temperature range.

Test Points - Test points accessible from the front of the unit shall be provided to facilitate in-place trouble shooting.

Front Panel Controls - power On-Offs, power pilot lamp, power fuse, and test points (may be behind door)

Hidden Controls - Controls which require only infrequent adjustment shall be hidden from casual view to discourage tampering.

Mechanical - Unit is to mount in 19-in. relay rack with EIA standard mounting dimensions, and shall be of generally open construction to facilitate repairs. Circuit cards shall be replaceable without removing unit from rack. Front panel height shall be 10-1/2 inches.

Connectors - Mating connectors for all inputs and outputs shall be supplied. In choosing connectors, ruggedness shall be more important than small size.

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Switches - The signal switches shall be transistor electronic switches, matched initially to +10 microvolts. The switch breakdown voltage shall be at least +30 v. The switches shall be transformer driven, to isolate the switch from ground and its driving source.

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TECHNICAL DATA SHEET 5.1.4
ANALOG-TO-DIGITAL EQUIPMENT

1.0 INTRODUCTION

The analog-to-digital conversion equipment (ADC) shall provide the capability of converting the analog signal levels from the multiplexer into digital values for recording by the Digital Data Recording Subsystem.

2.0 DETAILED PERFORMANCE

2.1 OUTPUT REQUIREMENTS

The ADC shall be a 12-bit binary device capable of operating continuously at a rate of 10,000 conversions per second. Accuracy and stability shall be, for a minimum of 30 days, $\pm 0.05\%$, $\pm 1/2$ least significant bit. Output shall be compatible for direct recording by recording subsystem. If output is not directly compatible, then a format control device shall be provided. Output in the form of two 7-bits (6-bit data plus parity) shall be stored in output register for recording upon command.

2.2 INPUT REQUIREMENTS

Input to the ADC shall be from the signal commutation equipment, in the range of 0 to + 10 volts. Input resistance shall be 10 megohms. Input signal supplied from signal commutator shall be stable for 25 microsec of the conversion period.

2.3 OPERATIONAL REQUIREMENTS

Internal reference supply shall be provided to supply a stable internal reference for measurements. This supply shall be accurate and stable for 30 days within $.01\%$, ± 5 ppm per 1°C . Output and control circuit commons shall be isolated from analog input.

Full scale span and zero-offset shall be adjustable.

Parity check shall be generated within ADC for utilization by recording system.

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TECHNICAL DATA SHEET 5.1.5
DIGITAL DATA TAPE RECORDING SUBSYSTEM

1.0 INTRODUCTION

- * The digital tape recording subsystem shall provide the capability of recording all data generated by the Digital Data Acquisition System. This subsystem shall operate at a rate of 40,000, 12-bit binary data words per second. Both record and playback operations are required.

2.0 DETAILED PERFORMANCE

2.1 TYPES OF MACHINES REQUIRED

- * One type only of magnetic tape recording machine shall be used at ETS-1, and machines with record-playback capability are required; with the capability of handling mylar or cellulose acetate magnetic tape, 0.5-in. wide, 1.0 or 1.5-mil thickness on 10-1/2-in. NARTB reels.

2.2 OPERATIONAL MODES

- * Subsystem operational modes shall be: continuous record, one record/10 sec, one record/100 sec, and one record upon command. Automatic timing and control equipment shall be provided to accomplish those modes. Since long-term recording operations on the continuous mode are anticipated, it is required that the capability to automatically switch to alternate recorder be provided at end-of-reel.

2.3 INPUT SIGNAL

Input level to recording subsystem shall be the output signals from the tape format control equipment. Signal shall consist of a 7-parallel track pulse-code modulated input word.

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2.4 OPERATING SPEED AND TAPE DENSITY

- * An operating speed of 100 ips will be required. Recording density shall be 800 characters/inch.

2.5 START-STOP OPERATION

Access time of machines shall not exceed 7.5 millisec.

2.6 RELIABILITY

Machines shall include Read-Write heads. Read heads are for read operations with preliminary data subsystem and for parity check during record operation. Capability shall be provided to automatically switch to alternate recording machine after the occurrence of the 4th parity error. All tape recording machines shall be connected together through a common control unit which will select and utilize any machine at any time for recording of system operational priority data.

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TECHNICAL DATA SHEET 5.1.6
CHECKOUT AND PRELIMINARY DATA REDUCTION SUBSYSTEM

1.0 INTRODUCTION

The preliminary data subsystem will consist of sufficient equipment and techniques to accept digital magnetic tape or real-time data input, and to provide an output (value and time) in the form of digital displays, tabulations, and graphic records. In addition to processing digital magnetic tapes, this subsystem will also be required to provide limited reduction capabilities for analog magnetic tape. Additional capabilities for this subsystem are identified by Technical Data Sheet 5.1.7, General Purpose Computer.

2.0 DETAILED PERFORMANCE

The Preliminary Data Subsystem shall have the capability to perform the following output operations when given input from any digital magnetic tape recorded at ETS-1, or when operating from real-time data.

2.1 DIGITAL DISPLAY

The Digital Display Subsystem shall provide a lighted digital display of any selected channel. Display shall include channel number, event value, and event time. Numerical value of event, time, and channel number will be displayed in 10-base decimal.

*

2.2 GRAPHICAL PRESENTATION

The Graphical Presentation Subsystem shall prepare X-Y plots of any selected channel with an accuracy $\pm 0.25\%$ full-scale, referenced to the digital input value. Plots shall be provided on 11 x 17-in. graph paper, which has been preprinted or provided with a transparent overlay for time scale and amplitude value. Full-scale amplitude value shall equal 10 in.

**

This operation will function as a result of the computers providing an output two DACs, to the X-Y plotter. The plotter time scale drive shall also be computer controlled.

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This subsystem, including plotter, shall operate with time scales of 30, 75, 150, 300, 750, 1500, and 3000 seconds full scale. The maximum time required to reproduce a single channel from the summary tape shall be 2 min, where the summary tape is defined as a recording of a 750-sec run with two data point/channel/sec. The 2-min period shall include tape rewind and paper handling in such manner that the system will be capable of sustained printing operations of 30 channels/hr. Machine printing of channel number and time on graph will not be required.

2.2.1 Strip Chart

* The Strip Chart Subsystem will be required, as an extension of the graphical presentation capability, to prepare a simultaneous presentation of 24 channels of direct-writing strip-chart records of information. Information speeds will exceed the speed capabilities of the X-Y plotter; however, accuracy will be reduced to $\pm 0.5\%$ full scale, as referenced to the digital input value.

** This operation will function by utilizing the on-site computer. Output of the computer shall be through 24 DACs which will drive 24 channels of direct recording.

Chart speeds utilized shall range from 0.1 to 20 in./sec, and serial time scales shall be recorded on the charts.

The direct-writing strip-chart recording machines utilized to perform this function may be the machines provided with ETS-1 for real-time recording. Patching and control equipment shall be provided from the preliminary data reduction subsystem to these recording machines.

2.2.2 Tabulations

* The Preliminary Data Subsystem is required to prepare tabulations on paper tape of any selected channel. This presentation shall include the data value, channel number, and the time of event, in 10-base decimal units. Printing rate shall be at a minimum of 600 lines/min.

2.2.3 Analog Tape Reduction

The presentation of data from an analog magnetic tape recording shall be accomplished by playback of the tape, and by recording the information on a direct-writing strip-chart recorder or photographic

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oscillograph. For detailed analysis of an analog magnetic tape a method shall be provided of replaying a tape into a single 10 kilo-cycle analog-to-digital conversion equipment, from which a digital magnetic tape can be made for resulting digital reduction and presentation. All remote operations for analog-tape reduction shall be controlled from the Preliminary Data-Reduction Subsystem.

2.3 IMPLEMENTATION

The following equipment functions are required (but are not necessarily the only required functions) of items necessary to comply with operational requirements of this subsystem.

2.3.1 Magnetic Tape Handling Equipment

Provide equipment to playback any magnetic-tape (both analog and digital tapes) records made within the ETS-1 operations. It is desirable that the tape-playback equipment be shared with the Data-Acquisition Recording Equipment.

2.3.2 Digital Decommutator

* Provide equipment which shall accept pulse-code modulated (PCM) information input, either recorded or real-time, and decommutate this signal into selected channels for output to other devices. This function may be performed by the On-Site General Purpose Computer.

2.3.3 Digital-to-Analog Converter

* Provide 10-bit binary equipment with 24 channels to convert the PCM information into proportional analog levels for input to the X-Y plotter or oscillographic recorder. In addition to the conversion from PCM to analog for channel-event value, it is also required that time be converted from PCM to actuate the X-Y plotter time scale.

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2.3.4 X-Y Plotter

Provide a servo X-Y plotter compatible with subsystem requirements which will produce 11 x 17-in. graphs. Machine shall be actuated from the digital analog computer.

2.3.5 Digital Display

Provide a lighted digital display which shall present channel value, channel number, and event time.

2.3.6 Tabulator

- * Provide a line printer to produce tabulated data, which will be capable of operating at a rate of 600 lines/min.

2.3.7 Control Panel

- * Provide a conveniently located control panel to control all operations concerned with preliminary data reduction. This panel shall be combined with the digital data system and computer controls into a system control console.

2.3.8 Subsystem Arrangement

Arrange this subsystem so that all preliminary data reduction operations may be conveniently performed as a one-man operation. If remotely located equipment is required, provide remote-control equipment to perform all operations from the preliminary data center.

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TECHNICAL DATA SHEET 5.1.7
GENERAL PURPOSE COMPUTER

1.0 INTRODUCTION

The On-Site General Purpose Computer shall be a high-speed digital machine capable of performing the following data manipulations:

- (a) Locate and identify any required channel value during real-time operation of data system for checkout operations, calibration, and maintenance; and monitor value and time during run operations.
- (b) Locate and identify value and time for any channel sample recorded on either the summary or complete data tape.
- (c) Correct recorded values by use of system calibration data, and equations to introduce linearity, for conversion of data to engineering units.
- (d) Perform editing functions to produce correlation studies or profile data.
- (e) Perform operations to produce derived systemic parameters, major statistical iterations, and complete evaluations of components and systems.

2.0 DETAILED PERFORMANCE

2.1 OPERATIONAL REQUIREMENTS

Computer words shall use a minimum 12-bit binary parallel configuration. Minimum clock-rate shall be 2.5 megacycles. The memory unit shall be core type, with a minimum capacity of 8,000 12-bit, minimum, computer words, and shall be expandable on a modular basis. The computer shall be equipped with magnetic tape input and output capability. Normal data reductions will be

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- * performed from magnetic tapes with records having a length of 4,000 12-bit binary words. Methods and equipment of counting down to the desired record portion shall be provided.

2.2 OUTPUT REQUIREMENTS

The computer shall provide the following outputs:

- (a) Graphs and listings of physical variables as a function of time.
- (b) Graphs and listings of physical variables grouped together to provide time-slice operational profiles.
- (c) Magnetic tapes of selected and edited information in various formats for use in further computational operations, or as input to slow plotting or recording devices.
- (d) Punched cards of selected and edited information.

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TECHNICAL DATA SHEET 5.2.1
WIDE BAND DIFFERENTIAL DC AMPLIFIER

1.0 INTRODUCTION

A wide-band amplifier with common-mode rejection equal to that of narrow-band amplifiers shall be provided in the Analog and Events Recording System, with two important features: (1) The common mode rejection ratio shall increase in direct proportion to the amplifier gain, and be insensitive to line unbalance, (2) The input impedance from either input terminal to any other terminal shall be 1000 megohms minimum.

2.0 DETAILED PERFORMANCE

2.1 GAIN

Gain shall be in ten fixed steps maximum, at any value from ± 10 to ± 1000 . (Gain change shall not affect bandwidth.)

- (a) Control - Provide manual or remote control of fixed steps, with vernier interpolation between steps.
- (b) Accuracy - shall be $\pm 0.02\%$ at dc (Standard).
- (c) Linearity - shall be $\pm 0.01\%$.
- (d) Stability - shall be $\pm 0.01\%$.

2.2 BANDWIDTH

- (a) Full Scale- Full scale bandwidth shall be in ten fixed steps maximum at any value from 20 cps to 100 kc/s. Bandwidth change shall not affect gain, common-mode rejection, or drift.
- (b) Control - shall be either manual or remote.

2.3 COMMON MODE REJECTION (CMR)

CMR shall be 1000 x gain setting, dc to 150 cps.

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- (a) Voltage - Maximum voltage shall be ± 10 v peak, ac or dc.
- (b) Input Impedance - shall be, in either line, 1000 megohms minimum at dc.
- (c) Line Unbalance - shall be 0 to 1000 ohms, either line.

2.4 DRIFT

Drift shall be $\pm (10 + \frac{300}{\text{Gain Setting}})$ microvolts referred to input.

2.5 NOISE

Noise shall be $\sqrt{10^2 + (\frac{300}{\text{Gain Setting}})^2}$ microvolts.

where rms is referred to input at 100 kc/s bandwidth.

2.6 INPUT IMPEDANCE (EITHER LINE)

Input impedance for either line shall be 1000 megohms minimum at dc. (These inputs are truly differential. There is no preferred input terminal.)

2.7 SETTling TIME

Settling time shall be in full-scale step input: 20 microsec to 0.01% of final value at 100 kc/s bandwidth.

2.8 OUTPUT

Output shall be ± 10 volts ± 100 milliamperes (with an unconditionally short-circuit proof, no output fuse).

- (a) Loading - shall be 5000 μ pf in parallel, maximum, with 100 ohms at 100 kc/s bandwidth.
- (b) Impedance - shall be 10 milliohms maximum at dc inclusive of output connector, 10 ohms maximum dc to kc/s. (An external feedback connection shall be available for further reduction of output cabling, etc.)

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2.9 OVERLOAD CONDITIONS

Overload shall have a recovery time of 150 millisec.

- (a) Common Mode Voltage - shall be ± 20 volts peak maximum safe value.
value.
- (b) Differential Voltage - shall be ± 20 volts peak maximum safe value.

2.10 TEMPERATURE OPERATING RANGE

It shall operate within the range of 0 to 50°C.

NOTE: Redcor, Model 361, complies with the above requirements.

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TECHNICAL DATA SHEET 5.2.2
THIRTY-SIX CHANNEL DIRECT WRITING OSCILLOGRAPH

1.0 INTRODUCTION

The recording oscillograph shall be an electrical optical-mechanical precision recording instrument of multi-channel direct-writing type, simple to operate, self-contained, and requiring only one source of voltage. The record processing will be completely dry, no chemical being involved. The oscillograph shall be composed of plug-in units as much as possible, to facilitate replacement and interchangeability.

2.0 DETAILED PERFORMANCE

2.1 MECHANICAL

2.1.1 Shock Mount

Protect instrument from vibration and shock, and permit the oscillograph to operate as detailed, while exposed to specified operating environmental tolerances. Shock mounts shall protect instrument from damage over the range of conditions specified under Environmental Requirements, Non-Operating.

2.1.2 Magazine

Magazine shall have a minimum capacity of 200 ft., and shall be quickly detachable, and daylight-loading, containing both feed and take-up spools. There shall be an unexposed paper percentage indicator integral with the record magazine.

2.2 ELECTRICAL

2.2.1 Power Source

The power source shall be 115 volts, 60 cps, single phase, with possible variation from 105 to 125 volts.

2.2.2 Signal

The input connectors shall be 36 3-pin individual galvanometer receptacles for the active traces, comparable to Cannon XL-3-11.

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2.2.3 Receptacles

Provide receptacles for remote control circuitry, and for event numbering circuitry.

2.3 OPTICAL

2.3.1 Single Optical System

The instrument shall have a single galvanometer trace recording system. Intensity of source shall be controlled by front-mounted selector switch for high or low intensity. Active galvanometers shall be divided into two banks, with each bank centered opposite 1/2 of the total record width.

2.3.2 Trace

There shall be 36 active galvanometer slots, 18 to each bank, and 4 static reference traces, one built in at each end of each galvanometer block.

3.0 OPERATING REQUIREMENTS

3.1 GENERAL

All operating controls and indicating devices shall be grouped on one central control panel located at the front of the instrument. These controls shall be logically arranged and tersely identified.

3.2 SERVICE

It shall be possible to replace the lamp without removing the oscillograph from the operating well. The following items shall be plug-in units for simplicity in servicing: power supply, record numbering unit, transmission and drive motor assembly, galvanometers, damping resistor extensions, primary exciter lamp and lamp housing, and remote control unit.

3.3 CONTROLS AND INDICATORS

These controls and indicators shall be at the front of the oscillograph.

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- (1) Record number visual counter
- (2) Red no-record lamps
- (3) Amber record lamps
- (4) Green ready lamps
- (5) Power switch
- (6) Data number switch
- (7) Record switch
- (8) Counter manual step switch
- (9) Timer switch
- (10) Speed control

3.4 AUTOMATIC CONTROLS

The Galvanometer Block Temperature Control shall be thermostatically controlled, with standby basis when instrument is not recording.

There shall be an unexposed paper percentage indicator.

4.0 RECORD DRIVE SYSTEM

4.1 RECORD DRIVE SPEED RANGE

The speed range of the drive system shall be as follows: at least 15 basic speeds within a range from a minimum of 0.1 ips to at least 160 ips, through a quick-change gear train, or equivalent conversion. The unit shall contain a local and a remote operated jump-speed control, with a jump-speed factor of at least 10:1.

4.2 AUTOMATIC RECORD LENGTHS

Record lengths from 1 ft to 10 ft, in 1-ft increments, shall be available from a control on the front of the panel; this control shall automatically reset.

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4.3 TIMING SYSTEMS

Full-width timing lines of either or both of 0.01 or 0.30-second intervals shall be produced on the record. Control shall be available to eliminate the 0.01-second line.

5.0 RECORD IDENTIFICATION

5.1 TRACE IDENTIFICATION

Trace identification shall be provided by a sequential light interrupting device.

5.2 NUMBERING

5.2.1 Automatic Record Numbering

A four-digit number shall be provided automatically by photographic means on the record each time the record switch is turned off. This counter is to be synchronized with an externally visible counter on front of the instrument.

5.2.2 Event Numbering

A four-digit counter, controlled from an external source, shall be provided for producing successive numbers on the record at intervals of one second.

5.2.3 Long Record Numbering

Provisions shall be provided for repeating the data number on record lengths selected by selector switch.

6.0 ENVIRONMENT REQUIREMENTS

The oscillograph, when mounted on shock mounting, shall be capable of operating and giving satisfactory records under the following ranges of environmental ambient conditions, either considered separately or in any combinations.

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- (a) Temperature - Design center temperature 72°F; ambient range 0° to 150°F, (except, 0 to 90°F for galvanometer block temperature control).
- (b) Atmospheric - Average corrosive conditions such as sea coast locations.
- (c) Inertial and Gravitational Forces - Vertically down, 10 g; vertically up, 2 g; horizontal forward and backward, 5 g; horizontally side-to-side, 5 g.
- (d) Vibratory Forces - Double amplitude of 0.03 in. in any direction through frequencies from 10 to 60 cps.
- (e) Non-Operating - The oscillograph, when mounted on its shock mount, shall be capable of withstanding, without permanent damage, shocks of 15 g in any direction.

7.0

GALVANOMETERS

The type and quantity of galvanometers to be supplied shall be specified on purchase order. The characteristics of the galvanometers shall comply to the following table:

Type 102A-40

Undamped natural frequency, cps - - - - -	40
Frequency response, flat $\pm$ 5% from zero to cps - - - -	24
DC sensitivity at 12-in. optical arm, milliamp/in. - -	0.0040
System voltage sensitivity at 12-in. optical arm, millivolt/in. - - - - -	1.5
Nominal coil resistance, ohms - - - - -	33
Required external damping resistance (3), ohms - - - -	350
Balanced maximum static deflection per G at 12-in. optical arm, in. - - - - -	0.120/Normal
Maximum safe current, milliamp - - - - -	10
Mirror size, in. - - - - -	0.020 x 0.125

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Type 102A-60

Undamped natural frequency, cps - - - - -	60
Frequency response, flat $\pm 5\%$ from zero to cps - - - -	36
DC sensitivity at 12-in. optical arm, milliamp/in. - - -	0.0070
System voltage sensitivity at 12-in. optical arm, millivolt/in. - - - - -	2.7
Nominal coil resistance, ohms - - - - -	39
Required external damping resistance (3), ohms - - - -	350
Balanced maximum static deflection per G at 12-in. optical arm, in. - - - - -	0.070/Normal
Maximum safe current, milliamp - - - - -	10
Mirror size, in. - - - - -	0.020 x 0.125

Type 102A-100

Undamped natural frequency, cps - - - - -	100
Frequency response, flat $\pm 5\%$ from zero to cps - - - -	60
DC sensitivity at 12-in. optical arm, milliamp/in. - - -	0.0098
System voltage sensitivity at 12-in. optical arm, millivolt/in. - - - - -	2.54
Nominal coil resistance, ohms - - - - -	34
Required external damping resistance (3), ohms - - - -	225
Balanced maximum static deflection per G at 12-in. optical arm, in. - - - - -	0.030/Normal
Maximum safe current, milliamp - - - - -	25
Mirror size, in. - - - - -	0.020 x 0.090

Type 102-150

Undamped natural frequency, cps - - - - -	150
Frequency response, flat $\pm 5\%$ from zero to cps - - - -	90
DC sensitivity at 12-in. optical arm, milliamp/in. - - -	0.021
System voltage sensitivity at 12-in. optical arm, millivolt/in. - - - - -	3.67
Nominal coil resistance, ohms - - - - -	30
Required external damping resistance (3), ohms - - - -	145
Balanced maximum static deflection per G at 12-in. optical arm, in. - - - - -	0.030/Normal
Maximum safe current, milliamp - - - - -	25
Mirror size, in. - - - - -	0.020 x 0.090

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Type 102-200

Undamped natural frequency, cps - - - - -	200
Frequency response, flat $\pm 5\%$ from zero to cps - - - -	120
DC sensitivity at 12-in. optical arm, milliamp/in. - - -	0.039
System voltage sensitivity at 12-in. optical arm, millivolt/in. - - - - -	4.99
Nominal coil resistance, ohms - - - - -	28
Required external damping resistance (3), ohms - - - -	100
Balanced maximum static deflection per G at 12-in. optical arm, in. - - - - -	0.030/Normal
Maximum safe current, milliamp - - - - -	50
Mirror size, in. - - - - -	0.020 x 0.12

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TECHNICAL DATA SHEET 5.2.3
STRIP CHART RECORDER

1.0 INTRODUCTION

The strip-chart recorder shall be a multiple-record instrument used for monitoring and recording high temperatures,

2.0 DETAILED PERFORMANCE

- (a) Range - The strip chart recorder shall be supplied with the following ranges:

0° to 1500°R
1000° to 2000°R
1500° to 2500°R
2000° to 3000°R
2500° to 3500°R
3000° to 4000°R
1000° to 4000°R

The range shall be easily changed through the use of a range resistor card.

- (b) Scale - 11-inch calibrated length. Large, easily read figures required.
- (c) Print Wheel Speed - Full scale travel shall be 4-1/2 seconds for 60-cycle operation.
- (d) Printing Speed - For 60-cycle operation, minimum time between closely spaced points shall be 1 second, maximum time between widely spaced points shall be 5 seconds. Intermediate spacings shall be proportional.
- (e) Calibrated Accuracy - Calibrated accuracy shall be within $\pm 3/8\%$ of scale span, or within ± 0.045 mv for spans of less than 12 mv.
- (f) Sensitivity - Sensitivity shall be 1/4% of scale span, or 0.019 mv for spans of less than 8 mv.

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- (g) Chart Speeds - Chart speeds shall be, in inches per hour: 2, 6, 10, 30, 40, and 120.
- (h) Calibration - Recorder shall be calibrated to the Tungsten-Tungsten Rhenium, or other state-of-the-art thermocouples, which provide the high-temperature measurements designated in this Technical Data Sheet.
- (i) Record Points - The recorder shall be capable of recording 2, 3, 4, 6, 8, 10, 12, 16, 20, or 24 points, with the number of points to be recorded, capable of being easily changed in a matter of seconds.

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TECHNICAL DATA SHEET 5.2.4
RECORDING OSCILLOGRAPH

1.0 INTRODUCTION

The recording oscillograph shall be an electrical-optical-mechanical precision recording instrument of multi-channel photographic type, simple to operate, self-contained and requiring only one source of voltage.

2.0 DETAILED PERFORMANCE

2.1 MECHANICAL

- (a) Dimensions - Overall dimensions, including shock-mount base assembly and record magazine, shall be a maximum of 14 in. high, 18 in. wide, and 28 in. long.
- (b) Shock Mount - shall protect instrument from vibration and shock, and permit the oscillograph to operate as detailed, while exposed to specified operating environmental tolerances. Shock mounts shall protect instrument from damage over the range of conditions specified under Par. 5.0, Environmental Tolerances, Non-Operating.
- (c) Magazine - Capacity shall be 200-ft minimum, and shall be quickly detachable, containing both feed and take-up spools. Provide indicator to show amount of unexposed paper. Indicator shall be integral with the record magazine.

2.2 ELECTRICAL

- (a) Power Source - 115 v, 60 cps, single-phase, with possible variation from 105 to 125 v.
- (b) Signal - 36 three-pin Cannon XL-3-11 (or equivalent) individual galvanometer receptacles for the active traces.
- (c) Controls - Provide receptacle for remote control circuitry.

2.3 OPTICAL

System shall be energized by a single high-intensity mercury-vapor arc lamp, or by two tungsten-filament lamps, one for each bank of

galvanometers. If tungsten-filament lamps are used, they shall have spare filaments or reserve lamps which will activate instantaneously upon the failure of either of the main recording lamps.

2.4 TRACE

There shall be 36 active galvanometer slots, 18 to each bank; and 2 static reference traces, one installed at the outside ends of the galvanometer blocks.

3.0 OPERATING CHARACTERISTICS

3.1 GENERAL

All operating controls and indicating devices shall be grouped on one central control panel located at the front of the instrument. These controls shall be logically arranged and tersely identified.

3.2 TEMPERATURE CONTROLS

- (a) Galvanometer Block Temperature Control - This control shall maintain a temperature of $100^{\circ}\text{F} \pm 5^{\circ}\text{F}$ at ambient temperatures of 0 to 90°F .
- (b) Internal Components Temperature Control Cooling - Excessive internal component shall be prevented by means of an internal air blower or blowers.
- (c) No Record Indication - This indication shall be provided to indicate failure of oscillograph to record.

3.3 RECORD DRIVE SYSTEM

- (a) Speed Range of the Record Drive - At least 16 speeds from 0.1 ips to 100 ips driven through a quick-change positive gear train by a governor controlled motor.
- (b) Jump Speed Mechanism - This mechanism shall be remotely or locally electrically operated to increase or decrease the record speed by a factor of 4 or greater.

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- (c) Automatic Record Lengths - Lengths from 12-100 inches shall be automatically obtainable by means of a calibrated dial located on the control panel.

3.4 RECORD TIMING SYSTEMS

These systems shall be provided to print full record width for timing lines recorded at 0.01 and 0.10 second intervals. Control shall be available to eliminate the 0.01 second lines.

3.5 RECORD IDENTIFICATION

- * (a) Trace Identification - Provide a sequential interruption of galvanometer traces, and the printing of a corresponding channel number.
- (b) Automatic Record Numbering - An identification number shall be photographed on the record near the beginning and the end of each run. The number shall automatically advance one unit for each new run, or shall be controlled manually. Provide for resetting of all counters. Record number shall be externally visible.

3.6 GALVANOMETERS

- (a) Case Construction - A closed case shall exclude foreign material, moisture, or contaminants. Galvanometer bodies shall be machined from solid bar stock.
- (b) Lens Construction - Lens shall be mounted permanently to prevent loss and avoid damage.
- (c) Wiring - Galvanometer shall operate with either side of the circuit at a potential as high as 250 v above ground. Galvanometer wiring shall be self-contained and insulated from the case.
- (d) Adjustment of Mirror-- Mirror adjustments shall be smooth with no tendency to stick. Adjustments shall be provided to move the spot of light laterally, and also up and down.

3.8 GALVANOMETER TYPES

Galvanometers shall be available covering all, or portions, of the following ranges:

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3.8.1 Fluid Damped Requirements

Undamped natural frequency, 0-8000 cps.

Flat frequency range ($\pm 5\%$).

DC sensitivity at 12-inch optical arm, 72 milliamps per inch, maximum.

3.8.2 Magnetically Damped Requirements

Undamped natural frequency, 0-500 cps.

Flat frequency range ($\pm 5\%$), 0-300 cps.

Undamped DC sensitivity at 12-inch optical arm, 500 microamps per inch, maximum.

4.0 ENVIRONMENTAL TOLERANCES

The oscillograph, when on shock mounting, shall be capable of operating and giving satisfactory records under the following ranges of environmental ambient conditions, either considered separately or in natural combinations.

- (a) Temperature - Design center temperature 72°F; ambient range 0 to 150°F, (except 0 to 90°F for galvanometer block temperature control).
- (b) Atmospheric - Average corrosive conditions, such as sea coast locations.
- (c) Inertial and Gravitational Forces - Vertically down, 10 g; vertically up, 2 g; horizontal forward and backward, 5 g; horizontally side-to-side, 5 g.
- (d) Vibratory Forces - Double amplitude of 0.03 inch in any direction through frequencies 10 to 60 cps.
- (e) Non-Operating - The oscillograph, when mounted on its shock mount, shall be capable of withstanding without permanent damage, from shocks of 15 g in any direction.

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STANDARD EQUIPMENT

Supply the following items with each oscillograph:

- One record magazine
- Two static reference trace galvanometers.
- Vibration isolation base assembly
- Matching connectors for galvanometer input receptacles
- Matching connectors for remote control receptacles
- Power cable complete with connectors
- One set of tools and essential spare parts
- Dust cover
- Instruction manual.

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TECHNICAL DATA SHEET 5.2.6
14-CHANNEL MAGNETIC TAPE RECORDER

1.0 INTRODUCTION

The 14-Channel Magnetic Tape Recorder shall be capable of recording simultaneously 13 frequency modulated signals and one direct signal, or 9 frequency modulated signals and 5 direct signals on a magnetic tape. The recorder shall be complete with all the required components, including tape transport, 13 channels of FM record-and-reproduce amplifiers, 1 channel of direct record-and-reproduce amplifiers (or 9 channels of FM record-and-reproduce amplifiers, and 5 channels of direct record-and-reproduce amplifiers), associated power supplies, blower and power distribution units, alignment check system, and servo speed control. These items shall be assembled in two cabinets forming an integrated combination of direct-and-FM, 14-channel magnetic tape recording systems.

The components specified herein are based on products of Ampex Corp., and are so specified as standards of quality only.

2.0 DETAILED PERFORMANCE

2.1 TAPE TRANSPORT MECHANISM

The latest proven instrumentation quality tape of the 1.5-mil thickness backing type (mylar or cellulose acetate) shall be used in adjusting, aligning, and testing of the tape system. Tape width shall be 1-in.

- (a) Tape Speed - The normal operating speeds of the tape for both recording and playback shall be 60 and 15 ips; however, the system furnished shall have the capability of operating at speeds of 60, 30, 15, 7-1/2, 3-3/4 and 1-7/8 inches per second.
- (b) Starting Time - Stable tape motion shall be achieved within 2 sec after operating the start button at any speed. Stable tape motion means that the signal-to-noise ratio of the FM channels will be below the maximum specified level.

- (c) Stopping Time - Tape motion shall cease in less than 0.8 sec after pressing the stop button. No more than 30 in. of tape shall pass through the head housing for a tape speed of 60 ips after operating the stop button.
- (d) Playback Timing Accuracy - Without servo speed control, the playback timing shall be accurate to within $\pm 0.25\%$, assuming constant power line frequency and no change in tape dimension. With servo speed control, the instantaneous timing shall be accurate to better than ± 1.0 millisecc. This shall include all effects, such as those due to flutter, skew, tape stretch, mechanical tolerances, and power-line voltage variation.
- (e) Rewind Time - The rewind time shall be a nominal 4 min for a 5000-ft NAB reel of tape.
- (f) Flutter and Wow - At a tape speed of 15 or 60 ips, the flutter and wow shall not be in excess of 0.1% peak-to-peak in the pass band from 0 to 500 cps, when using a 3000 cps tone. The meter for making flutter and wow measurements shall have an accuracy of $\pm 5\%$ or better.

2.2

HEAD ASSEMBLY

- (a) General - The head assembly shall be of the rigid type and shall contain separate record and playback heads for the 14 channels. Erase heads are not required; tank erasure will be used. The record and playback heads shall be so arranged and magnetically shielded that the cross-talk requirements are met. The head nearest the mechanism plate shall be assigned for use with the direct record channel(s).
- (b) Alignment Uniformity - Recording and playback head alignments and tape alignment relative to the heads shall be held to such tolerances that tapes played back on different machines than used for recording will reproduce within the same limits of timing accuracy and signal levels as would be obtained if played back on the machine used for recording the tape.

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- (c) Alignment Accuracy - The longitudinal distance between the gaps of any pair of heads in adjacent head stacks in the record of the play assemblies is to be held to within ± 0.0005 in. The longitudinal distance between the gaps of any pair of heads in the same head stack is to be held to less than 0.0001 in.

2.3 OPERATING CONTROLS

- (a) Local Control - Start, Record, Fast-Forward, Rewind, Stop, and Hi-Low speed selection operations shall be operated locally on the tape transport mechanism panel. Rapid shuttling of tape back and forth shall be possible without a definite waiting period between tape operating modes; however, the tape shall be stopped before going into the play mode.
- (b) Remote Control - The functions of Start, Record, and Stop shall be operable by remote control over a multi-conductor cable. In addition to remote switching operations, a pilot light at the remote control panel shall be energized when the Record control is operated.

2.4 FM CHANNELS

2.4.1 Frequency Response

When recording at 60 ips and playing back at 60 ips, the frequency response shall be flat within $\pm 1/2$ db from 0 to 10,000 cps.

When recording at 60 ips and playing back at 15 ips, the frequency response shall be flat within $\pm 1/2$ db from 0 to 2500 cps.

When recording at 15 ips and reproducing at 15 ips, the frequency response shall be flat within $\pm 1/2$ db from 0 to 2500 cps.

- (a) Transient Response - The rise time for a 50-cycle perfect square wave (10 to 90% of amplitude) shall not be greater than 50 microseconds, with no more than 15% overshoot at 60 ips.
- (b) Input-Output Polarity - A positive polarity input signal may reproduce with negative polarity output.

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- (c) 100% Modulation - Maximum recording level is defined as $\pm 40\%$ deviation of the FM carrier frequencies. Carrier frequencies are to be 54 kc for 60 ips, and proportional for lower speeds.
- (d) Signal-to-Noise Ratio - The rms noise level over the pass band from 0 to 10 kc shall be at least 50 db below the rms value of the signal at a maximum recording level at 60 ips. The rms noise level at center carrier, over the pass band from 0 to 2.5 kc, shall be at least 50 db below the rms value of the signal at a maximum recording level at 15 ips.
- (e) Harmonic Distortion - At maximum recording level and for any fundamental frequency within the pass band of 0 to 5000 cps at 60 ips, the rms total harmonic distortion shall not be greater than 1.0%. For lower speeds, the pass band shall be proportionate.
- (f) The deviation from a linear input-output characteristic shall not exceed 1.0% of the output at maximum recording level.

2.4.2 DC Stability

2.4.2.1 Record Amplifier DC Drift

- (a) AC Line Voltage Effect - The modulator frequency variation shall not exceed 0.05% of the deviation corresponding to peak signal (100% modulation) per volt change in power line voltage over the range of 119 to 121 v.
- (b) Temperature Effect - The modulator frequency change shall not exceed 0.05% of peak signal (100% modulation) per $^{\circ}\text{F}$ change in ambient temperature over the range of 40 to 120 $^{\circ}\text{F}$.

2.4.2.2 Playback Amplifier DC Drift

- (a) AC Line Voltage Effect - The dc output change shall not exceed 0.05% of peak signal (100% modulation) per volt change in power line voltage over the range of 119 to 121 v.
- (b) Temperature Effect - The dc output change shall not exceed 0.05% of peak signal (100% modulation) per $^{\circ}\text{F}$ change in ambient temperature over the range of 40 to 120 $^{\circ}\text{F}$.

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2.4.2.3 Overall DC Drift

Under conditions of constant line voltage and temperature, the dc drift shall not exceed 0.1% over any 2-min interval. The conditions for this test shall consist of warming up the equipment for 30 min., running in record operation for 30 sec before recording the data, and in playback operation for 30 sec before playback of the data. The dc drift shall have been reduced to its minimum value within a warmup period not to exceed 30 min.

2.4.3 AC Stability

The errors in ac signal level due to the effects of line voltage changes of 6 v and temperature changes of 15°F within the range of 119 to 121 v, and 40 to 120°F, respectively, shall not exceed 0.5% of the maximum signal from each cause.

2.4.4 Monitoring

The separate record and playback systems provided shall permit monitoring during the recording operation. Level variations, which may appear during monitoring, shall not occur during subsequent playback.

2.4.5 Record Input

The gain of the record amplifier shall be adjustable over a range sufficient to handle input signal levels from 0.5 to 50 v rms, to produce 100% modulation. The normal input level shall be 1 v rms sine wave for 100% modulation.

The record input circuit dc impedance shall be at least 100,000 ohms unbalanced to ground.

2.4.6 Playback Output

- (a) Voltage - The playback amplifier output voltage across a 10,000-ohm load resistor shall be adjustable from 0 to 1.2 v rms, when playing a tape recorded at 100% modulation. The normal output level shall be 1 v rms across 10,000 ohms from tapes recorded at 100% modulation.

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- (b) Impedance - The playback output circuit shall be unbalanced to ground, and the internal impedance shall not exceed 27,000 ohms. Load impedance smaller than 10,000 ohms may result in lowered signal level, but shall not result in increased distortion.

2.5 DIRECT RECORD

2.5.1 Frequency Response

The overall frequency response shall be flat within ± 3 db from 100 to 100,000 cps at 60 ips. At 15 ips, the response shall be flat within ± 3 db from 50 to 25,000 cps.

- (a) Signal-to-Noise Ratio - The overall unweighted system noise, including bias signal and amplifier noise, as measured with a vacuum tube voltmeter, shall be at least 35 db below maximum operating level when recording without pre-emphasis in the record head.
- (b) Maximum Operating Level - Maximum operating level is defined as that level which results in 2.0% total harmonic distortion with 1.0 v rms sine-wave output across a 10,000 ohm load resistor from the reproduce amplifier at 3000 cps and 60 ips.
- (c) Monitoring - The separate record and playback systems provided shall permit monitoring during the recording operation.
- (d) Record Input - The gain of the record amplifier shall be adjustable over a range sufficient to handle input signal levels from 0.15 to 50 v rms to produce maximum operating level.

The record input circuit dc impedance shall be at least 100,000 ohms unbalanced to ground.

- (e) Playback Output - The playback amplifier output voltage shall be adjustable from 0 to 4 v rms when playing a tape recorded at maximum operating level. With the output level control advanced to deliver 4.0 v across a 10,000 ohm load resistor, the total harmonic distortion shall not exceed 3.0%. The record and play electronics,

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bypassing the record and play heads, shall each be capable of handling a signal level 10 db greater than that occurring at maximum operating level, with no more than 1.0% total harmonic distortion.

2.5.2 Servo Speed Control

The servo-speed control system shall be supplied to permit re-cording and reproducing at the same or different speeds as follows:

(a) Speeds -

<u>Record, ips</u>	<u>Reproduce, ips</u>
60	60
60	15
15	15

- (b) Carriers - The speed-control track shall contain a 17-kc carrier modulated with 60 cps, and a 68-kc carrier modulated with 240 cps.
- (c) Demodulator - The playback network shall have a 17-kc demodulator.
- (d) Voice Announcements - The presence of voice announcements on the tape shall not disturb the servo-speed control system.
- (e) Synchronism - The servo-speed control system shall maintain synchronism for step changes in recorded reference frequency up to 2.0%.

2.5.3 System Cross Talk

The interferences caused by cross talk and intermodulation measured between any two channels, both direct and FM, shall be at least 50 db below the maximum recording levels.

2.5.4 Tests

The tests should be conducted under conditions simulating as closely as possible the actual operation conditions. For this reason, it is

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required that all gain controls be set at their normal operating positions, and that all input and output circuits be properly terminated. Under operating conditions, signals will be applied to all channels. Measurements of interference between channels shall be made under the conditions and using the methods given below:

All record amplifier input and playback output circuits shall be terminated in their normal operating impedances, whether or not they carry recording signals.

All record and playback gain controls shall be set to give the normal record and playback levels.

All channels shall be put in the record mode of operations.

- (a) Single-Signal Method - A 400-cps sine-wave test signal shall be recorded at an input 20 db above maximum operating level for the direct channel(s), and at 100% modulation level for the FM channels, on one channel at a time, each channel in turn being used as the recording channel, until 14 sections of tape have been recorded.

Examination for cross-talk shall be made for each section of recorded tape, observing and measuring with a vacuum tube voltmeter, on each of the 14 channels in turn. All channels shall be in the playback mode for this operation. Measured cross talk shall be at least 50 db below the maximum recording level for both direct and FM channels.

- (b) Three-Signal Method - Three harmonically unrelated and/or properly separated (frequency-wise) pure sine-wave signals, such as 500, 700, and 5000 cps, shall be recorded at normal record level on three adjacent tape tracks (3 FM channels, or 2 FM channels and an adjacent direct channel). The 50-cps tone shall not be used on the direct channel.

The operation above shall repeat 12 times, to include all three-adjacent-channel combinations, thus recording 12 sections of tape.

Examination of each recorded channel shall be made with a distortion analyzer which will reject the intentionally recorded signal, and

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measure the combined effects of cross talk, intermodulation products, and noise. The measured values shall in all cases be at least 50 db below the maximum recording level for both direct and FM channels. The term noise shall include 60 and 120 cycle hum.

- (c) Thirteen-Signal Method - A 400-cps sine-wave test signal shall be recorded at an input of 20 db above maximum operating level for the direct channels, and at 100% modulation level for the FM channel on 13 channels at a time, each channel in turn being omitted, until 14 sections of tape have been recorded.

Examination for cross talk shall be made on the omitted channel in each section of the tape, observing and measuring with a vacuum tube voltmeter. Measured cross talk level shall be at least 50 db below the maximum recording level on each channel.

2.6

FREQUENCY RESPONSE CURVES

- (a) FM Channels - The overall frequency response of each of the FM channels shall be plotted in the conventional manner from measurements taken at maximum record level and at the following frequencies. In addition, all pertinent inflections in the curves shall be defined by measured and plotted data points.

Frequency Response Points Recorded at 15 ips			Frequency Response Points Recorded at 60 ips		
0 (dc)	200	5000	0	200	5,000
2	500		2	500	7,000
10	1000		10	1000	10,000
20	1500		20	1500	15,000
50	2000		50	2000	20,000
100	3000		100	3000	

All plots shall be properly identified and accompanied with sufficient information so that the work can be duplicated within the tolerances of the recording and indicating systems used.

- (b) Direct Channel(s) - The overall frequency response of the direct channel(s) shall be plotted in the conventional manner from measurements taken at the following frequencies and designated recording speeds:

Frequency Response Points Recorded at 15 ips			Frequency Response Points Recorded at 60 ips		
20	200	10, 000	50	500	10, 000
30	500	15, 000	100	1000	20, 000
50	1000	20, 000	150	2000	30, 000
70	2000	25, 000	200	5000	50, 000
100	5000	30, 000	300		100, 000
					150, 000

In addition, all pertinent inflections in the curves shall be defined by measured and plotted data points.

Response curves for the record and reproduce amplifiers themselves shall be separately plotted from measurements taken at the same frequencies and at suitable test levels.

Sufficient data shall be taken and plotted to show frequency response of the system for recording at 60 and 15 ips, with playback at tape speeds of 60 and 15 ips.

- (c) Identification - The curves specified above shall be identified with the particular recording system to which they apply. Sufficient information concerning the methods of taking the plotted data, such as circuit connections, equipment used, test-signal levels, and procedures, shall be provided to allow the user to rerun the frequency checks in order to maintain the overall responses and equalizations at the prescribed values.

2.7 ADJUSTMENTS AND TEST JACKS

2.7.1 FM Channel Adjustments

The adjustments for the FM channels shall be accomplished by the following controls which shall be accessible from the front of the equipment:

- Carrier frequency (Record)
- Input level (Record)
- Output level (Reproduce)
- DC zero adjustment (Reproduce)

Test jacks shall be provided at the output of the record amplifier.

2.7.2 Direct Record Channel Adjustments

Adjustments for the direct-record channels shall be accomplished by the following controls, which shall be accessible from the front of the equipment:

Record level (Record)
Bias level (Record)
Playback level (Reproduce)

2.7.3 Added Provisions

As part of the tape recorder system, preferably a part of the two-bay group, a unit is to be provided which will:

2.7.3.1 Tape System Alignment

Permit rapid checking of the tape-system alignment, using external ac oscillator, ac vacuum-tube voltmeter, events-per-unit-time meter, and distortion measuring equipment. One switch is to transfer the input and output leads of all the record-and-reproduce amplifiers from their normal connections to the test equipment, as detailed below.

One 15-position rotary switch is to connect the input bus, the output bus, and the events-per-unit-time meter to the recorder inputs, recorder outputs, and record amplifier test jacks, respectively, one channel at a time. The first position on the switch shall be labeled OFF, and each successive position numbered 1 through 14.

A two-position switch is to connect the meter bus to either the input bus or the output bus, measuring the signal level to the record amplifiers or from the reproduce amplifiers, respectively.

A two-position switch is to select ac or dc measurements, connecting the dc signal and dc voltmeter, or the ac oscillator and ac vacuum tube voltmeter into the system.

A two-position switch is to select positive or negative polarity, reversing the dc signal and dc voltmeter simultaneously with an

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alternative possibility of using a three-position switch providing Positive dc, Negative dc, or ac testing.

A 1.414 v dc source shall be provided. The combined errors due to stability and regulation in the testing system shall be less than $\pm 0.2\%$.

A switch shall be provided to short circuit the input bus, and to therefore remove all signals from the inputs for drift and noise measurements.

The dc voltmeter shall be readable and accurate to better than 0.005 v at 1.414 and 0 v. A 6-in. meter with a mirror-backed scale shall be used. A pair of terminals shall be provided on the front panel to permit comparing the internal meter and dc signal to an external reference.

2.7.3.2

Voice Announcement

The unit shall provide a means of recording and reproducing voice announcements on the direct record track, multiplexed with the servo-speed control signal, and of monitoring any one of the 13 data tracks.

The voice announcement system shall be capable of reproducing signals in the frequency range of 200 cps to 5 kc, not including the loudspeaker, with a signal-to-noise ratio of 30 db.

System gain shall be sufficient so that a normal speaking voice, 15 in. from the microphone-speaker, shall be recorded and reproduced intelligibly and audibly.

A small, permanent magnet type loudspeaker shall be provided for use alternately as a microphone and as the monitor speaker. Only reasonable voice intelligibility will be required.

A microphone preamplifier and a monitor amplifier shall be provided.

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A three-position switch shall be used to record or monitor when desired, leaving the microphone-speaker out of the circuit at other times.

A recording and playback level control and a simple volume indicator shall be provided to insure proper system gain.

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TECHNICAL DATA SHEET 5.2.7
LOW-PASS FILTER ASSEMBLIES, TYPE A AND TYPE B

"Deleted"

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TECHNICAL DATA SHEET 5.2.8
PROGRAM PATCH UNIT

See TDS 4.20

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TECHNICAL DATA SHEET 5.2.10
UNIVERSAL COUNTER

1.0 INTRODUCTION

A universal counter shall be used in the Analog and Events Recording System for measuring frequency, period, time interval, phase delay, random events, and ratios.

2.0 DETAILED PERFORMANCE

2.1 GENERAL

Registration - Six decimal places, each indicated by lighted numbers

Stability - 2/1,000,000 per week

Display Time - Variable from approximately 0.1 to 10 sec, however, display shall be capable of being held indefinitely if desired.

Self Check - Automatic count of internal 100 kc and 1 mc.

2.2 FREQUENCY MEASUREMENT

Range - 10 cps to 1.2 mc

Accuracy - ± 1 count $\pm$ time base accuracy

Input Sensitivity - 0.1 v rms; adjustable; 150 v rms maximum input

Input Trigger Level - -300 v to +300 v, adjustable, either positive or negative slope

Input Impedance - Approximately 1 megohm 50 pf shunt

Gate Time - 0.001, 0.01, 0.1, 1, 10 seconds

Reads In - Kilocycles; automatic decimal point

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PERIOD MEASUREMENT

Range - 0.00001 cps to 100 kc

Accuracy - $\pm 0.3\%$ ± 1 count $\pm$ time base accuracy (one period).
 $\pm 0.03\%$ ± 1 count $\pm$ time base accuracy (10 period average) at
0.1 v rms. Accuracy increases with input voltage.

Input Requirements - 0.1 rms minimum; direct coupled

Measurement Period - 1 or 10 cycles of unknown

Standard Frequency Counted - 1, 10, and 100 cps, 1kc, 10kc, and
1 mc, external frequency

Reads In - Seconds, msec, μ sec, automatic decimal.

2.4

TIME INTERVAL MEASUREMENT

Range - 1 microsecond to 10^6 seconds

Accuracy - ± 1 count $\pm$ time base accuracy

Input Impedance - Approximately 1 megohm 50 pf shunt

Input Requirements - 0.1 v rms minimum dc or ac coupling

Start and Stop Marker Outputs - Approximately 5 μ sec duration
and + 20 v peak, for oscilloscope intensity modulation

Start and Stop Inputs - Separate or common inputs

Trigger Level - Both channels, 0 to ± 300 v, either slope

Standard Frequency Counted - 1, 10, 100 cps; 1, 10, 100 kc; 1 mc -
external

Reads In - Seconds, msec, μ sec, automatic decimal point.

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PHASE MEASUREMENT

Range - 1 cps to 20 kc, dc coupled; 50 cps to 20 kc, ac coupled.

Input Voltage - 5 to 10 v rms, pure sinusoidal signal.

Accuracy - $\pm 0.1^\circ \pm \left(\frac{360 f_p}{f_c} \right)^\circ$

Other Data Information - Displays f_1/f_2 , or $10 f_1/f_2$, as an integer, with accuracy of ± 1 . f_1 : 10 cps to 1.2 mc. f_2 : 0.00001 cps to 100 kc.

Totalize - Electrical events, periodic or random, to 999,999 at rates to 1.2 million/sec

Output Frequencies - 1, 10, 100 cps; 1 kc, 10 kc rectangular; 100 kc and 1 mc sine wave. Stability $2/10^6$ per week.

External Standard - 100 kc can be applied.

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TECHNICAL DATA SHEET 5.2.11
VACUUM TUBE VOLTMETER

1.0 INTRODUCTION

A high accuracy audio range vacuum-tube voltmeter shall be required in the Analog and Events Recording System.

2.0 DETAILED PERFORMANCE

- (a) Voltage Range - 1.0 mv to 300 v full scale. 12 ranges.
- (b) Frequency Range - 10 cps to 4 mc.
- (c) Accuracy - $\pm 1\%$ 50 cps to 500 kc; $\pm 2\%$ 20 cps to 1 mc.
- (d) Input Impedance - 10 megohms shunted by 15 pf on ranges 1 to 300 v; 25 pf on ranges 0.001 to 0.32.

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TECHNICAL DATA SHEET 5.2.12
OSCILLOSCOPE

1.0 INTRODUCTION

The oscilloscope used in the Analog and Events Recording System shall be used to measure complex voltages, stress, strain, pressure, flow, displacement, and other phenomena through proper transducers.

2.0 DETAILED PERFORMANCE

2.1 SWEEP

- (a) Sweep Range - The sweep range shall have 15 calibrated sweeps, accurate to within $\pm 5\%$, in a 1-2-5-10, sequence, 5 μ sec/cm to 200 millisecc/cm. A vernier shall permit continuous adjustment of sweep time between calibrated steps, and shall extend the 200 millisecc/cm step to at least 0.5 sec/cm.
- (b) Sweep Expand - The times-5 sweep expansion may be used on all ranges and will expand the fastest sweep to 1 sec/cm. Expansion will be about the center of the cathode-ray tube and expanded sweep accuracy will be $\pm 10\%$.
- (c) Synchronization - Will be automatic from 50 cps to 250 kc; internally from vertical deflection signals which cause 0.5 cm or more deflection; externally from 2.5 volts peak-to-peak; or from line voltage. Use of level control will extend synchronization, range to 10 cps.
- (d) Trigger Point - shall be automatic. Manual control shall be capable of overriding the automatic permitting the trigger point to be set between -10 and +10 v. When the manual knob is turned fully counterclockwise to "AUTO," automatic operation shall be restored.

2.2 VERTICAL AMPLIFIERS

- (a) Bandwidth - Dc coupled; dc to 200 kc. Ac coupled: 2 cps to 200 kc. Bandwidth shall be independent of the calibrated sensitivity setting.
- (b) Sensitivity - shall be 10 millivolts/cm to 100 v/cm in 4 calibrated steps accurate within $\pm 5\%$, 10 mv/cm, 100 mv/cm, 1 v/cm, and 10 v/cm. Vernier shall permit continuous adjustment of sensitivity between steps, and extend 10 v/cm step to at least 100 v/cm.
- (c) Internal Calibrator - Calibrating signal shall be automatically connected to the vertical amplifier for standardizing of gain with an accuracy of $\pm 2\%$.
- (d) Input Impedance - shall be 1 megohm, with approximately 50 pf shunt capacitance.
- (e) Phase Shift - Vertical and horizontal amplifiers shall have the same phase characteristics within $\pm 2^\circ$ to 100 kc when verniers are fully clockwise.
- (f) Balanced Input - Both amplifiers shall have a balanced input when set on the 10 mv/cm range, with an input impedance of 2 megohms shunted by approximately 25 pf. Common signal rejection shall be at 40 db. Common signal must not exceed ± 3 v peak.

2.3 HORIZONTAL AMPLIFIER

- (a) Bandwidth - Dc coupled: dc to 200 kc. Ac coupled: 2 cps to 200 kc. Bandwidth shall be independent of calibrated sensitivity setting.
- (b) Sensitivity - shall be 0.1 v/cm to 100 v/cm in 3 calibrated steps (accurate within $\pm 5\%$): 0.1, 1, and 10 v/cm. Vernier shall permit continuous adjustment of sensitivity between the steps and shall extend the 10 v/cm steps to at least 100 v/cm.
- (c) Input Impedance - shall be 1 megohm, nominal, shunted by approximately 100 pf.
- (d) Phase Shift - Horizontal and vertical amplifiers shall have same phase characteristics within $\pm 2^\circ$ to 100 kc.

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TECHNICAL DATA SHEET 5.2.13
AUDIO OSCILLATOR

1.0 INTRODUCTION

An audio oscillator shall be required for the Analog and Events Recording System

2.0 DETAILED PERFORMANCE

- (a) Frequency Range - 1 cps to 100 kc (5 bands).
- (b) Calibration Accuracy - $\pm 2\%$.
- (c) Output to 600 ohms - 160 mw 10 volts.
- (d) Load - 600 ohms
- (e) Maximum Distortion - 0.5% above 5 cps.
- (f) Maximum Hum & Distortion - 0.1%.

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TECHNICAL DATA SHEET 5.3.1
DC POWER SUPPLY (STRAIN GAGE)

1.0 INTRODUCTION

The power supply shall furnish a regulated output voltage of 9 to 15 v, dc.

2.0 DETAILED PERFORMANCE

- (a) Output Voltage Regulation - There shall be no more than 0.1% change in voltage output with a 2.0% change in connected load resistance, and a simultaneous 10% change in ac line voltage.
- (b) Output Voltage Setting - Individual power supply output voltage shall be continuously adjustable from 9 to 15 v, and shall be capable of being set to 10 v within 0.1% by use of a separate voltage check panel with a 120 to 1000 ohm, $\pm 2\%$, load connected to the output terminals.
- (c) Ripple - Individual power supply output ripple voltage appearing across the output terminals shall be less than 0.5 millivolt peak-to-peak with power supply terminated in a 120 to 1000 ohm load.
- (d) Aging of Components - Output voltage shall change less than 0.1% due to the aging of components over a period of 1000 hours of continuous operation
- (e) Service - Power supply shall be capable of 10,000 hours of continuous service without deterioration of any components.
- (f) Temperature - Output voltage change shall be less than 0.1% with temperature change from 0°C to +45°C.
- (g) Insulation Resistance - Shall be 10,000 megohms minimum from either output lead to case ground, and to 120 v ac input lines.
- (h) Polarity of Power - Proper operation shall not be dependent on polarity of 120 v, 60 cps power source.
- (i) Input Power - Input power to power supply will be 120 v ac ($\pm 10\%$), 60 cps, single phase.

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TECHNICAL DATA SHEET 5.3.2
MEGOHMMETER

1.0 INTRODUCTION

The megohmmeter will be used to measure the isolation of ungrounded strain-gage bridges and connecting cable from external ground, and to measure the isolation resistance between ungrounded cable pairs.

2.0 DETAILED PERFORMANCE

2.1 RANGE AND ACCURACY

The Megohmmeter shall have a single range at 50,000 megohms full scale, with an accuracy of $\pm 3\%$ of the reading at center scale values, and at least $\pm 10\%$ of full scale at all other values.

2.2 INDICATOR

A 5-inch meter shall be provided for readout, and shall be logarithmically calibrated from zero to 50,000 megohms. Center of scale shall be 1000 megohms. A calibration mark shall be provided on the meter face to facilitate adjustment of the test voltages.

2.3 TEST VOLTAGE AND CALIBRATION

Test voltage shall be 10 v dc, supplied from an internal electronic power source. An internal calibration resistor shall be provided to verify the test voltage setting.

2.4 ALIGNMENT CONTROLS

Controls shall be provided for the following functions:

- (a) Infinity Adjustment - To adjust the gain of the vacuum-tube voltmeter with megohmmeter input circuit open.

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- (b) Test Voltage Adjust - To adjust the test voltage to the proper value when the megohmmeter input circuit is shunted by the calibration resistor.
- (c) Calibration - To insert the calibration resistor into the circuit.
- (d) On-Off Switch - To turn on the prime power to the megohmmeter. A Power On indicator light shall also be provided.

2.5 INPUT

- (a) Signal Input - Signal input shall be terminated in a 3-pin receptacle on the rear of the instrument. This shall be a Cannon XLR type (or approved equal) with the following termination sequence: Pin one, positive signal; pin 2, negative signal, pin 3, chassis ground. Mating plug shall be provided.
- (b) Power Input - Prime ac power shall be terminated in a rear-mounted receptacle, Amphenol No. 61-M10 (or approved equal). Mating plug shall be provided.

2.6 PROTECTION

A short circuit applied to the measuring terminals shall in no way damage the instrument.

3.0 OPERATING CONDITIONS

3.1 EXTERNAL POWER

AC power will be provided from external sources, and will be 115 v, +10%, 60 cps, single phase.

3.2 ENVIRONMENT

- (a) Operating - The instrument will be operated in a controlled temperature environment between 65 and 85°F, and in a relative humidity of 50%.
- (b) Storage - Equipment will be stored for periods up to 90 days in an environment of 50 to 90°F, in a relative humidity of 95% maximum.

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TECHNICAL DATA SHEET 5.3.3
VOLTAGE CHECK PANEL

1.0 INTRODUCTION

A DC Digital Voltmeter is required to check bridge excitation and the signal output of certain channels. The voltmeter shall be capable of a repeatability of $\pm 0.02\%$ over a period of 5000 hours of continuous use under all normal operating conditions.

2.0 DETAILED PERFORMANCE

Range.- shall be ± 0.0001 to 0999 v dc with automatic ranging, polarity indication, and decimal-point indication.

Indication - shall be of 4 digits, plus decimal point and polarity.

Isolation - The input shall be isolated from ground.

Input Impedance - shall be 100 megohms dc to 10 v; 11 megohms dc to 999 v.

Accuracy - The absolute accuracy shall be $\pm 0.01\%$ and one digit.

Note: Electro Instruments Inc., Model 800 series. will meet the above requirements.

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TECHNICAL DATA SHEET 5. 3. 4
STRAIN-GAGE CALIBRATION UNIT

1. 0 INTRODUCTION

The Calibration Unit (Ref. I & C Criteria Volume I, Par. 5.4.1.7) shall provide the precision resistors and relays for the shunt calibration of strain-gage type transducers to determine the bridge output as a function of resistance change.

2. 0 DETAILED PERFORMANCE

- (a) Construction - The unit shall accommodate the precision plug-in resistor units, the plug-in relays, the input and output connectors, and the relay control from the step selector. Each unit should accommodate approximately 60 channels, or multiples of the number of channels in a Checkout and Control Unit.
- (b) Circuitry - The unit shall provide, for each channel, the relay switching of any one of four precision resistors into a shunt calibration circuit upon command from the Calibration Step Selector unit. The circuit for one channel shall be approximately as shown in Figure 1.
- (c) Resistors - Exact values shall be chosen so as to produce bridge outputs corresponding to transducer stimuli of 25, 50, 75, and 100% of full scale; within 0.1%. The resistance values shall change less than 0.1% due to aging over a period of 1000 hr of continuous operation.
- (d) Relays - The relays shall operate from a 28 v, dc source, and shall close reliably at coil voltages as low as 15 v, dc, and shall not release until the coil voltage falls below 13 v, dc. Relay contact resistance, which would add to the calibration resistor value, shall be a negligible portion of the total.

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TECHNICAL DATA SHEET 5.3.5
CALIBRATION STEP SELECTOR UNIT

1.0 INTRODUCTION

The Calibration Step Selector Unit will provide for a subsystem, the relay circuitry required to permit energizing of relays in the associated Calibration Units from a local power source, under control of signals from the Calibration Control Unit.

2.0 DETAILED PERFORMANCE

- (a) Construction - The unit shall be constructed to be usable in all subsystems requiring intermediate slave-circuit control as a result of the large number of relays required. Input connections shall be provided for the Calibration Control Unit and for the local 28 v, dc relay power supply. Output connections are required for the Calibration Units.
- (b) Circuitry - Relay circuitry shall be provided as required to actuate all relays in the Calibration Units associated with each calibration step (viz. 0, 25, 50, 75, and 100% steps) from signals supplied by the Calibration Control Unit. The control logic shall be such to minimize relay power supply load transients. The circuit for one calibration step shall be approximately as shown in Figure 1.

Figure 1

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TECHNICAL DATA SHEET 5.3.4
STRAIN-GAGE CALIBRATION UNIT

1.0 INTRODUCTION

The Calibration Unit (Ref. I & C Criteria Volume I, Par. 5.4.1.7) shall provide the precision resistors and relays for the shunt calibration of strain-gage type transducers to determine the bridge output as a function of resistance change.

2.0 DETAILED PERFORMANCE

- (a) Construction - The unit shall accommodate the precision plug-in resistor units, the plug-in relays, the input and output connectors, and the relay control from the step selector. Each unit should accommodate approximately 60 channels, or multiples of the number of channels in a Checkout and Control Unit.
- (b) Circuitry - The unit shall provide, for each channel, the relay switching of any one of four precision resistors into a shunt calibration circuit upon command from the Calibration Step Selector unit. The circuit for one channel shall be approximately as shown in Figure 1.
- (c) Resistors - Exact values shall be chosen so as to produce bridge outputs corresponding to transducer stimuli of 25, 50, 75, and 100% of full scale; within $\pm 0.1\%$. The resistance values shall change less than 0.1% due to aging over a period of 1000 hr of continuous operation.
- * (d) Relays - The relays shall operate from a 28 v, dc source, and shall close reliably at coil voltages as low as 15 v, dc, and shall not release until the coil voltage falls below 13 v, dc. Relay contact resistance, which would add to the calibration resistor value, shall be a negligible portion of the total.

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TECHNICAL DATA SHEET 5.3.6
CALIBRATION CONTROL UNIT

1.0 INTRODUCTION

The Calibration Control Unit will provide, for a subsystem, local capability for calibration step selection, transfer of calibration step selection to the Master Calibration Control Unit, visual indication of the selected calibration step, and provision for inhibition of calibration on a modular group basis.

2.0 DETAILED PERFORMANCE

- (a) Construction - The unit shall be constructed to provide local calibration control for a subsystem. Except for the number of modular groups controlled by the unit, the same basic design shall be usable in all subsystems requiring a calibration control unit. Input connections shall be provided for the 28 v, dc relay supply, and the Master Calibration Control Unit, and output connections shall be provided to either the Calibration Step Selector or the Calibration Unit(s).
- (b) Circuitry and Controls - Individual switches shall be provided to enable selection of each modular group of subsystem channels for calibration, as required for the operational Calibrate Inhibit function. A single rotary switch, or interlocking pushbuttons, shall be used for manual selection of the 0, 25, 50, 75, and 100% calibration steps, or an "auto" position which will place calibration step selection under control of the Master Calibration Unit or Units. The output of the unit shall be a positive polarity 28 v, dc signal on one of the set of terminals designated 0, 25, 50, 75, and 100%, with a common terminal for the negative return. A set of indicator lamps shall operate in either the manual or automatic mode, to designate the activated calibration step.
- (c) Power Supply - The unit shall operate on 28 v, dc.

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TECHNICAL DATA SHEET 5.3.7
STRAIN-GAGE INDICATOR (MILLIVOLTMETER)

1.0 INTRODUCTION

The strain-gage output indicator shall be a high-accuracy, self-balancing potentiometer voltmeter. In response to an output voltage, a servo system will drive the scale pointer to the appropriate millivolt position on a calibrated scale.

2.0 DETAILED PERFORMANCE

- (a) Isolation - The input circuit shall be isolated from ground.
- (b) Accuracy - Absolute accuracy of the voltmeter shall be $\pm 0.25\%$ of full scale of the range selected.
- (c) Scales - will be (1) 150 to 0 to 150 microvolts divided into 150 even divisions with a heavy line indicating every 5 divisions, and (2) 0 to 30 millivolts divided into 150 even divisions with a heavy line indicating every 5 divisions.
- (d) Range Selection - The range shall be changeable from normal 1.5 to 0 to 1.5 millivolts range to the 0 to 30 millivolts range by an internal 24-volt relay which shall be remotely operated.
- (e) Impedance - The input impedance of the indicator measuring circuit shall be greater than 100,000 ohms or either range. The source impedance will be 350 ohms.
- (f) Termination - Provide two terminal strips in back of instruments. One for 24 v, dc scale change relay, and one for signal input.

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TECHNICAL DATA SHEET 5.3.8
STRAIN-GAGE CHECKOUT AND CONTROL UNIT

1.0 INTRODUCTION

The Checkout and Control Units shall provide all the switches and controls required to set up and operate the subsystem, including the circuitry for bridge completion, zero off-set, and integration of the other subsystem components, exclusive of calibration control.

2.0 DETAILED PERFORMANCE

- (a) Construction - Each unit shall be constructed to accommodate, for each channel: bridge completion circuitry (as required), null balance control (as required) for setting zero bridge output, zero off-set (as required), pushbuttons for the megohmmeter and output tests, and appropriate connectors for transducer input, calibration-unit input, power-supply input, output to the millivoltmeter, and the signal-output leads.
- (b) Circuitry - Each unit shall incorporate the major circuitry included in the unit functions to complete the bridge, balance the bridge, and to produce the calibration signals based upon inputs from the Calibration Unit.
- (c) Bridge Completion - The bridge completion circuitry shall be of plug-in configuration, matched to the specific transducer resistance. It shall be possible to interchange calibration plug-in units of the same resistance without introduction of a measurement error in excess of $\pm 0.1\%$.
- (d) Balance - The balance network shall be capable of balancing the bridge to within 10% of zero output, and shall produce a negligible loading effect on the transducers when balancing a transducer which is approximately 5% unbalanced.
- (e) Zero Off-set - Will provide for off-setting approximately 50% of transducer output by means of a self-contained stable voltage source.

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TECHNICAL DATA SHEET 5.3.9.1
RESISTANCE TEMPERATURE CALIBRATION UNIT
(ONE-ARM, CONSTANT VOLTAGE)

1.0 INTRODUCTION

The Calibration Unit shall provide for the substitution of precision resistors to provide 0, 10, 25, 50, and 75% simulated bridge output for specified temperature ranges.

2.0 DETAILED PERFORMANCE

- (a) Construction - Each unit shall be constructed to accommodate the precision plug-in calibration resistors, relays, and input and output cable connectors. Each unit shall accommodate approximately 60 channels, or multiples of the number of channels in a Checkout and Control Unit.
- (b) Circuitry - For each channel, the unit shall provide for the relay switching of any one of four precision resistors into a resistance substitution calibration circuit upon external command from the Calibration Step Selector.
- (c) Calibration Resistors - The calibration resistance values, when applied to appropriate bridge terminals in the Checkout and Control unit, shall produce bridge outputs corresponding to transducer temperatures of 0, 10, 25, 50, and 75% of full-scale temperature ranges within $\pm 0.1\%$. The calibration resistance values shall change less than 0.1% due to aging over a period of 1000 hr of continuous operation, or due to changes in relay contact resistances with temperature. The values shall also be chosen to minimize the effects of line resistances expected between the calibration unit and the checkout and control unit. The plug-in calibration resistors shall be clearly identified as to range, in agreement with the standard temperature ranges chosen for the transducers.
- (d) Relays - The relays for the selection of the calibration resistors shall be operated by signals from the Calibration Step Selector Unit. The relays shall operate reliably at coil voltages as low as 15 v, dc, and shall not release until the coil voltage falls below 13 v, dc.

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TECHNICAL DATA SHEET 5.3.9.2
RESISTANCE TEMPERATURE CALIBRATION UNIT
(ONE-ARM, CONSTANT CURRENT)

1.0 . INTRODUCTION

- * The Calibration Unit shall provide the the substitution of precision resistors to provide 0, 25, 50, 75, and 100% simulated bridge output for specified temperature ranges.

2.0 DETAILED PERFORMANCE

- (a) Construction - Each unit shall be constructed to accommodate the precision plug-in calibration resistors, relays, and input and output cable connectors. Each unit shall accommodate approximately 60 channels, or multiples of the number of channels in a Checkout and Control Unit.
- (b) Circuitry - The unit shall connect by relay switching any one of four precision resistors to each channel upon external command from the Calibration Step Selector.
- (c) Calibration Resistors - The calibration resistance values, measured at the unit output terminals, shall correspond to the transducer resistances at 0, 25, 50, 75, and 100% of full-scale temperature, within $\pm 0.1\%$. The calibration resistance values shall change less than 0.1% due to aging over a period of 1000 hr of continuous operation, or due to changes in relay contact resistances with temperature. The plug-in calibration resistors shall be clearly identified as to range, in agreement with the standard temperature ranges chosen for the transducers.
- * (d) Relays - The relays for the selection of the calibration resistors shall be operated by signals from the Calibration Step Selector Unit. The relays shall operate reliably at coil voltages as low as 15 v, dc, and shall not release until the coil voltage falls below 13 v, dc.

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TECHNICAL DATA SHEET 5.3.10
RESISTANCE TEMPERATURE CALIBRATION UNIT (FOUR-ARM)

1.0 INTRODUCTION

- * The Calibration Unit shall provide for the substitution of precision voltages, derived from the transducer excitation terminals, equal to 0, 25, 50, 75, and 100% of full-scale bridge output for specified temperature ranges.

2.0 DETAILED PERFORMANCE

- (a) Construction - Each unit shall be constructed to accommodate the precision plug-in voltage dividers, relays, and input and output cable connectors in multiples of 6 channels. Each unit shall accommodate approximately 60 channels, or multiples of the number of channels in a Checkout and Control Unit.
- (b) Circuitry - Each unit shall be supplied input voltages derived from the duplicate excitation terminals of each 4-arm transducer. Upon external command from the Calibration Step Selector, the unit shall provide calibration voltages representing 0, 10, 25, 50, and 75% of full-scale transducer output, within $\pm 0.1\%$, by the use of relay-switched Ayrton-shunt voltage divider circuits.
- (c) Voltage Dividers - The plug-in voltage divider for each channel shall consist of the necessary precision resistors in an Ayrton-shunt-type voltage divider configuration to provide calibration
* voltages equal to 0, 25, 50, 75, and 100% of the full-scale transducer output, within $\pm 0.1\%$. The plug-in units shall be clearly identified as to range, in agreement with the standard temperature ranges chosen for the transducers.
- (d) Relays - The relays for the selection of the calibration voltage steps shall be operated by signals from the Calibration Step Selector unit. The relays shall operate reliably at coil voltages as low as 15 v, dc, and shall not release until the coil voltage falls below 13 v, dc.

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TECHNICAL DATA SHEET 5.3.11.1
RESISTANCE TEMPERATURE CHECKOUT AND CONTROL UNIT (ONE-
ARM, CONSTANT VOLTAGE)

1.0 INTRODUCTION

The Checkout and Control Units will provide all of the switches and controls required to set up and operate the subsystem, including the circuitry for bridge completion and integration of the other subsystem components, exclusive of calibration control.

2.0 DETAILED PERFORMANCE

- (a) Construction - Each unit shall be constructed to accommodate, for each channel, plug-in bridge completion circuitry, a relay for switching between operate and calibrate modes, balance control for setting of zero range point, pushbuttons for the megohmmeter and output tests, and appropriate connectors for transducer input, calibration unit input, power supply input, output to the millivoltmeter, and the signal output leads.
- (b) Circuitry - The major circuitry included in the unit functions to complete the bridge and to produce the calibration signals will be based upon inputs from the Calibration Unit.

The bridge completion circuitry shall be of plug-in configuration, matched to the specific standard temperature ranges chosen for the transducers. The values of the precision fixed resistors shall be such that the full-scale output of 30 mv will be achieved with 10-volt excitation without exceeding the limitations imposed by the self-heating effect. It shall be possible to interchange plug-in units of the same range without introduction of a measurement error in excess of $\pm 0.05\%$.

The circuitry must function together with the Calibration Unit to produce calibration signals upon command from the Calibration Control Unit.

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In the Calibrate mode, the precision resistors in the Calibration Unit, when keyed in by appropriate relay contact closures, must substitute resistance values for the transducer equivalent to the standardized transducer resistance values at zero range point, and at 10, 25, 50, and 75% of full-scale temperature. The calibration circuit must be completed through the duplicate transducer connector pins and through the transmission cable loop, to simulate as nearly as possible the actual signal transmission circuit used during system operation and to prevent calibration unless the transducer is in place. Calibration signal accuracy shall be essentially independent of Calibration Unit location.

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TECHNICAL DATA SHEET 5.3.11.2
RESISTANCE TEMPERATURE CHECKOUT AND CONTROL
UNIT (ONE-ARM, CONSTANT CURRENT)

1.0 INTRODUCTION

The Checkout and Control Units will provide all of the switches and controls required to set up and operate the subsystem, including the circuitry for transducer excitation and integration of other subsystem components, exclusive of calibration control.

2.0 DETAILED PERFORMANCE

- (a) Construction - Each unit shall be constructed to accommodate, for each channel, the relay switching for providing the choice of Operate or Calibrate modes, zero suppression control, push-buttons for the megohmmeter and output tests, and appropriate connectors for transducer input, power supply input, output to the millivoltmeter and megohmmeter, and the signal output leads.
- (b) Circuitry - The excitation and signal output circuits shall use separate transducer connector pins. Relay switching shall select either the voltage drop across the transducer output pins or across the series-connected calibration resistor as an output signal. Energizing of the calibration mode relay shall be accomplished by the Calibration Unit. The calibration signal shall be obtained from the resistors of the Calibration Unit upon command of the Calibration Control Unit.

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TECHNICAL DATA SHEET 5.3.12

RESISTANCE TEMPERATURE CHECKOUT AND CONTROL UNIT (FOUR-ARM)

1.0 INTRODUCTION

The Checkout and Control Units will provide all of the switches and controls required to set up and operate the subsystem, including the circuitry for transducer excitation and integration of other subsystem components, exclusive of calibration control.

2.0 DETAILED PERFORMANCE

- (a) Construction - Each unit shall be constructed to accommodate, for each channel, the relay switching for providing the choice of operate or calibrate modes, pushbuttons for the megohmmeter and output tests, and appropriate connectors for transducer input, power supply input, output to the millivoltmeter and megohmmeter, and the signal output leads.
- (b) Circuitry - The duplicate transducer excitation connector pins shall be used to provide the voltage source for the Ayrton-shunt type voltage dividers in the Calibration Unit, so that calibration is possible only if the transducer is installed. Energizing of the calibration mode relay shall be accomplished by the Calibration Unit.

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TECHNICAL DATA SHEET 5.3.13
FLOWMETER (TURBINE) CHECKOUT AND CONTROL UNIT

1.0 INTRODUCTION

The Flowmeter Checkout and Control Unit shall provide for continuity testing of the flowmeter pickup element, and for conductor-to-shield and shield-to-ground leakage tests.

2.0 DETAILED REQUIREMENTS

The interconnecting cable between a flowmeter transducer and the signal conditioning equipment is typically a twisted-pair shielded cable. Provisions shall be made on the Flowmeter Checkout and Control Unit to terminate the three conductors of each of the cables in the flow measurement system.

Pushbutton test switches and measurement circuits shall be incorporated on the unit to provide the following functions:

- (a) To check the continuity of the flowmeter pickup elements; for which the measurement shall be made by means of a self-contained low-current, single-scale (0 to 2000 ohms), ohmmeter. A separate pushbutton shall be incorporated for the purposes of zero-setting the ohmmeter.
- (b) To check the conductor-to-shield (one only) and the shield-to-ground insulation resistance of the cable; for which the measurement shall be made by means of an external megohmmeter -- the typical resistance will be in the order of 10^3 megohms.

TECHNICAL DATA SHEET 5.3.14
FREQUENCY-TO-DC CONVERTER

1.0 INTRODUCTION

The Frequency-to-DC converter will consist of a rack-mounting assembly, converter module (eight converter modules per rack) with integral power supply.

2.0 DETAILED PERFORMANCE

2.1 OPERATION

- (a) Input Impedance - Input impedance shall be greater than 100,000 ohms at all frequencies up to, and including, 25,000 cps, un-grounded.
- (b) Cross Talk or Intermodulation - Cross talk or intermodulation between any 2 channels shall be less than 0.01% of interfering channel signal level.
- (c) Frequency Ranges - Frequency ranges shall be 5 cps to 10,000 cps in 7 over-lapping ranges (refer to Figure 1).

<u>Range</u>	<u>Minimum Frequency</u>	<u>Full Scale Adjustment</u>	
		<u>From</u>	<u>To</u>
1	5 cps	50 cps	100 cps
2	5 cps	100 cps	200 cps
3	5 cps	200 cps	400 cps
4	5 cps	400 cps	800 cps
5	5 cps	800 cps	1600 cps
6	5 cps	1600 cps	3200 cps
7	5 cps	3200 cps	10,000 cps

- (d) Range Selection - Range selection shall be by means of front panel mounting switch or by plug-in units.

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NOTE: Ranges shown are nominal. Sufficient overlap shall be provided so that full-scale (5 v, dc) can be obtained for any frequency from 50 to 10,000 cps.

2.2 DC OUTPUT

- (a) Output Voltage - Output voltage unit shall produce a floating, ungrounded output of 0 to 5 v which shall be directly proportional to input frequency, but independent of input voltage. Full-scale input frequency for each range setting shall produce 5 v output when terminated in 1000 ohms.
- (b) Full Scale Adjust - A full-scale adjustment on the front panel shall permit smooth and continuous adjustment of the output over the specified range to an accuracy of $\pm 0.1\%$ when measured with an external precision voltmeter.
- (c) Stability - Full-scale output shall be stable to within $\pm 0.25\%$ of set value for any 24-hour period following a warmup period of not less than 30 minutes.
- (d) Linearity - Calibration curve connecting zero output and all points, including full-scale, shall not deviate in excess of 0.1% of full-scale from the straight line connecting zero and full-scale.
- (e) Noise Level - Narrow-band noise (defined as any extraneous signal in the output, including ripple, which bears no relationship to the desired signal within band of dc to 200 cps) shall be less than 5 millivolts peak-to-peak under the following conditions:
 - (1) Output terminated in any impedance above 1000 ohms.
 - (2) Any applied frequency up to value which produces rated output of 5 volts.
- (f) Output Filter - Provide an output smoothing filter with appropriate time constants selected by range switch to give optimum output ripple factor.

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- (g) Input Signal Amplitude - Unit shall perform as specified with input signal amplitudes varying from 5 millivolts to 100 volts. Unit shall not be sensitive to wave form.
- (h) Output Impedance - Output impedance of frequency-to-DC converter shall not exceed 200 ohms.

2.3 CABLE CAPACITANCE

Shielded cables connecting converter to its load and to a transducer may introduce a maximum shunt capacitance of approximately 0.05 microfarads across converter input and output. This capacitive loading shall not adversely affect system performance.

- (a) Signal Input and Output Cables Connectors - Three terminal input connectors for 6-S2/c cables shall be provided on the rear of rack mounting assembly. Three terminal output connectors for 12-S2/c cables shall also be provided on rear of rack mounting assembly.
- (b) Grounds - All signal inputs and outputs shall be isolated from converter chassis ground. Grounding of one side of any output line shall not result in degradation of recorded data. Provide terminal or lug to permit grounding of chassis.

2.4 POWER SUPPLY

Power-supply portion of unit shall provide all necessary operational power.

2.5 OPERATING CONDITIONS

- (a) Temperature - Room in which the equipment will be housed will have an ambient temperature range between 50 and 100°F.
- (b) Relative Humidity - Room in which the equipment will be housed will have relative humidity controlled to less than 60%.
- (c) Electrical Disturbances - Electrical disturbances which may be expected to affect output signal are:

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- (1) Induction effects (60 cycle) on instrumentation low-level input signal cables.
- (2) Relay coil induction and/or contact arcing or sparking, in 28 v, dc control system lines parallel to signal cables.
- (3) AC power line transients due to High-Frequency Spike and line bounce (not attenuated by electronic line regulator).
- (d) Provisions for Overcoming External Electrical Disturbances - All low-level input signal conductors in instrumentation system will be provided with continuous electrostatic shielding, except by junctions such as terminal blocks and necessary switching and patching units.
- (e) Power - Power to be utilized will be nominal 120 volt, 60 cps, regulated to $\pm 1\%$ (against line changes of $\pm 10\%$).

2.6 STORAGE CONDITIONS

No damage, including corrosion, shall result from extended storage of unit in environment in which temperature may vary from 30 to 120°F, and relative humidity may range up to 95%. Units will be assembled into instrument racks.

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	ZERO OUTPUT	FIXED CALIBRATION FREQUENCIES	* FULL-SCALE OUTPUT	
			MINIMUM FREQUENCY	MAXIMUM FREQUENCY
RANGE 1	5 CPS	50 CPS	50 CPS	100 CPS
RANGE 2	5 CPS	100 CPS	100 CPS	200 CPS
RANGE 3	5 CPS	200 CPS	200 CPS	400 CPS
RANGE 4	5 CPS	400 CPS	400 CPS	800 CPS
RANGE 5	5 CPS	800 CPS	800 CPS	1600 CPS
RANGE 6	5 CPS	1600 CPS	1600 CPS	3200 CPS
RANGE 7	5 CPS	3200 CPS	3200 CPS	10,000 CPS

* THE FREQUENCY FOR FULL-SCALE OUTPUT SHALL BE CONTINUOUSLY SELECTABLE BETWEEN THE MINIMUM FULL-SCALE OUTPUT FREQUENCY AND THE MAXIMUM FULL-SCALE OUTPUT FREQUENCY FOR EACH RANGE.

FREQUENCY VS OUTPUT
CHARACTERISTICS
FOR FREQUENCY-TO-DC CONVERTER

FIGURE 1

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TECHNICAL DATA SHEET 5.3.15
FLOWMETER CALIBRATION SELECTOR AND CONTROL UNIT

1.0 INTRODUCTION

The Flowmeter Calibration Unit shall provide for the manual or automatic calibration of the flow system by means of frequency substitution techniques. During calibration, the flowmeter elements are to be isolated from the circuit, and the signals from a stabilized time base unit then coupled to the Frequency-to-Dc Converter input. Signals from a master calibration control unit shall activate calibration relays when the AUTO-MANUAL switch on the Flowmeter Calibration Unit is in the AUTO position.

2.0 DETAILED REQUIREMENTS

(a) Relays and Switches

A group of relays and switches shall be incorporated to accomplish the following functions:

Interrupt the incoming signal line (from the flowmeter) whenever a calibration signal of any type is commanded.

Connect one of the four calibration signals to the outgoing signal line (to the Frequency-to-Dc Converter) whenever one of four calibration signals are commanded.

The four calibration signals shall be independently controlled by four relays; control of the relays shall be possible by a panel mounted rotary switch (MANUAL), or by remote signals (+28 v, dc) from a master calibration control unit (AUTO). A separate switch shall be included to select the AUTO or the MANUAL mode of operation.

(b) Terminal Strips

Terminal strips shall be located on the rear of the units for the following signals:

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Calibration control unit command inputs: 0, 10, 25, 50, and 75% and +28 v, dc.

Four calibration input signals from a separate source.

Signal input.

Signal output.

Power input: 28 v, dc (+ and -)

(c) Indicator Lamps

Indicator lamps shall be located on the front panel to indicate the particular calibration signal being commanded. Spark arresting diodes shall be wired across each relay coil.

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TECHNICAL DATA SHEET 5.3.16
PRESET COUNTER

1.0 INTRODUCTION

A high-speed frequency counter shall be required for the Speed Measuring System for remote indication of speed in rpm.

2.0 DETAILED PERFORMANCE

2.1 OPERATING FUNCTIONS (N = number of cycles, and may range from 1 to 199,999)

- (a) The instrument shall measure a period as a function of a preset count (N) and over a preset time interval. Function displayed will represent true period XN .
- (b) Event-per-Unit Time $\times N$ - will measure any frequency from 10 cps to 200 kc.
- (c) Input/N - will count batches of N cycles.
- (d) Delay - will deliver output pulse $10 N\mu$ sec after input signal.
- (e) Trigger - will generate output pulses separated $10 N\mu$ seconds.
- (f) Counting Interval - selectable: .00001 to 1.99999 sec in 10μ sec steps.
- (g) Sensitivity - shall be 0.1 v rms for all functions (sensitivity may be decreased continuously to 100 v rms with sensitivity control).
- (h) Input Impedance - shall be 100,000 ohms, ac-coupled.
- (i) Count Capacity - shall be five digits.
- (j) Accuracy - shall be $\pm$ one count $\pm$ oscillator accuracy.

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- (k) Oscillator Stability - shall be five parts in 10^7 per day from 15 to 35°C (60 to 90°F). An oven-heated crystal shall be used to obtain this stability.
- (l) External Time Base - Any frequency up to 100 kc may be substituted for the internal oscillator frequency by coupling the external signal to a rear panel jack. Input sensitivity for a sine wave shall be 3 v rms into 2 k.
- (m) Display Time - shall be continuously adjustable from 0.1 to 10 sec, and will hold display until manual reset, if desired.
- (n) Output Pulse - Pulses generated by TRIG and DELAY functions will be positive pulses, 15 v high, 4 to 6 N sec wide, with a rise time of 0.5 N sec or better. Output is to be ac-coupled with 1 K source impedance.
- (o) Coded Output - Counter will generate a 1-2-4-8 binary code representing the count indication.
- (p) Self-Test Facility - will test digital dividers, counters, count indicators, and control circuitry for correct operation.

NOTE: Beckman Model 5311 will meet the above requirements, and is mentioned as a standard of quality.

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TECHNICAL DATA SHEET 5.3.17
SPEED CHECKOUT, CALIBRATION AND CONTROL UNIT

1.0 INTRODUCTION

The Speed Checkout Unit shall provide circuits and controls to checkout and calibrate the Speed Measurement Systems.

2.0 DETAILED REQUIREMENTS

(a) This unit shall perform the following functions:

(1) Insulation check: Separate pushbuttons shall be provided for reading conductor-to-shield and shield-to-ground resistance. The readout shall be made by means of a separately supplied megohmmeter -- typical resistance will be in the order of 10^3 megohms.

* (2) Calibration: Controls shall be provided to apply 0, 25, 50, 75 and 100% calibration steps to a preset counter and a frequency-to-dc converter which are a part of the system. Application of calibration signals shall be accomplished through a group of relays; the relay operation shall be controlled by means of a front panel rotary selector switch (MANUAL), and by means of external signals from a master calibration control unit (AUTO).

(3) Test: Controls shall be provided to apply test signals from an external audio frequency generator for purpose of interpolation between the four fixed calibration frequencies, as required for general system checks and trouble-shooting.

(4) Checkout: Controls shall be provided to connect the output of the system frequency-to-dc converter to an external precision dc voltmeter.

(b) Indicator lamps shall be located on the front panel to indicate the particular calibration signal (fixed percentage steps) being commanded.

(c) Spark arresting diodes shall be wired across each relay coil.

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TECHNICAL DATA SHEET 5.3.18
THERMOCOUPLE CALIBRATION UNIT (FOUR-ARM)

1.0 INTRODUCTION

* The Calibration Unit shall provide for the substitution of precision voltages, derived from an Ayrton-shunt voltage divider, equal to 0, 25, 50, 75, and 100% of full-scale thermocouple output for specified temperature ranges.

2.0 DETAILED PERFORMANCE

- (a) Construction - Each unit shall be constructed to accommodate the precision plug-in voltage dividers, relays, and input and output cable connectors. Each unit shall accommodate approximately 60 channels or multiples of the number of channels in a Checkout Unit.
- * (b) Circuitry - Input voltages shall be derived from a separate or integral source. Upon external command from the calibration step selector, the unit shall provide calibration voltages representing 0, 25, 50, 75, and 100% of full-scale thermocouple output for specified ranges within $\pm 0.1\%$ by the use of relay-switched Ayrton-shunt voltage divider circuits.
- * (c) Voltage Dividers - The plug-in voltage divider for each channel shall consist of the necessary precision resistors in an Ayrton-shunt type voltage divider configuration to provide calibration voltages equal to 0, 25, 50, 75, and 100% of the full scale thermocouple output for specified ranges within $\pm 0.1\%$. The plug-in units shall be clearly identified as to range, in agreement with the standard thermocouple ranges chosen.
- (d) Relays - The relays for the selection of the calibration voltage steps shall be operated by signals from the calibration step selector unit. The relays shall operate reliably at coil voltages as low as 15 v dc, and shall not release until the coil voltage falls below 13 v dc.

TECHNICAL DATA SHEET 5.3.19
THERMOCOUPLE CHECKOUT UNIT

1.0 INTRODUCTION

The Thermocouple Check-Out Unit shall provide the switching and indication to semi-automatically check the continuity of thermocouple channels. Continuity shall be checked at a point in the measuring circuit so as to include the reference junction and the bucking voltage junction. The circuit shall be approximately as shown in the simplified diagram, Figure 1.

2.0 DETAILED PERFORMANCE

- (a) Channel Capacity - The checkout unit shall have a total capacity of 900 two-wire lines.
- (b) Channel Indications - There shall be in-line digital indication of the channel under test.
- (c) Continuity Indication - A meter shall be provided to indicate the continuity of the measuring circuit under test. This check will also provide a rough-order qualitative indication of the condition of the thermocouple junction.
- (d) Controls - will include channel group selection, step advance, and provisions to select any individual channel.

FIGURE 1

TECHNICAL DATA SHEET 5.3.20
POWER SUPPLY, 2-15 V, 5 AMP, 1% REGULATED

1.0 INTRODUCTION

This device will be utilized to provide excitation for pressure and position potentiometer transducers. Output voltage will be adjustable between 2 and 15 v dc, with a full load output of 5 amperes.

2.0 DETAILED REQUIREMENTS

- (a) Input Voltage Range - This shall be 105 to 125 v; single phase, 60 cycle, ac, $\pm 5\%$.
- (b) Output Voltage Range - The output voltage range shall be continuously adjustable from 2 to 15 v dc.
- (c) Output Current - The output current shall be 0 to 5 amperes.
- (d) Regulation - Regulation shall not exceed the values specified below.
 - (1) Static Regulation - This shall be $\pm 0.5\%$ variation of output voltage with 85% load for input voltage variation from 105 to 125 v ac, 60 cycles.
 - (2) Dynamic Regulation - This shall be $\pm 0.5\%$ output voltage change from a steady-state with 85% load for step-line input voltage changes to 10 v within the range of 105 to 125 v ac, 60 cycles.
 - (3) Output Voltage Regulation - Output voltage shall not exceed $\pm 2\%$ of steady-state voltage for ac voltage input from OFF to 125 v ON in one step with 50% load.
- (e) Load - Loads shall be as indicated below.
 - (1) Static Load - Static loads shall be $\pm 0.2\%$ output voltage variation for load variation from No-Load to Full-Load and from Full-Load to No-Load with nominal input line voltage.

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- (2) Dynamic Load - Dynamic load shall be $\pm 0.2\%$ output voltage change for 20% load-step change within the 0 to 5 amp load range, and with nominal input line voltage.
- (f) Transient Response - Instantaneous voltage changes shall not exceed 2% of steady-state voltage, and the response time for 63% recovery from maximum excursion shall not exceed 2 milliseconds.
- (g) Ripple - Ripple shall not exceed 5 millivolts peak-to-peak.
- (h) Ambient Temperature Range - The dc supply shall maintain accuracy within required tolerances under ambient temperature range of 60 to 95°F.
- (i) Circuit - This shall be completely transistorized, and shall contain no tubes.

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TECHNICAL DATA SHEET 5.3.21
POWER SUPPLY (STRAIN GAGE)

1.0 INTRODUCTION

This device will be utilized to provide excitation for strain-gage measurement systems and resistance-temperature systems. Output voltage is nominally 10 v dc, however, supply level shall be adjustable from 9 to 15 v dc. Application of this supply will normally be with 350-ohm bridge transducers, however, application with 150 to 1000-ohm transducers will also be required.

2.0 DETAILED REQUIREMENTS

- (a) Output Voltage Regulation - There shall be no more than 0.1% change in voltage output with a 2.0% change in connected load resistance. The load resistance will actually be 350 ohms $\pm$ 7.0 ohms.
- (b) Ripple - The individual power supply output ripple voltage appearing across the output terminals shall be less than 1 millivolt peak-to-peak, with power supply terminated in a 350-ohm load.
- (c) Total Noise - The ac component appearing between the output terminals of a balanced 350-ohm bridge, excited by a unit dc power supply operated at rated conditions, shall not exceed 5 microbolts peak when one leg of the bridge is shunted to produce an output of 30 millivolts dc $\pm$ 30 microvolts. This measurement shall be made to show true power supply noise, giving due consideration to the amplitude and phase of the inherent test equipment noise in relation to the noise contribution of the test items.
- (d) Regulation - The regulation shall be better than $\pm$ 0.1% with line voltage variations into the regulator from 95 to 130 v.
- (e) Response - The regulator shall have a time constant of less than 0.1 millisecond, and shall be capable of smoothing line bumps of 10%

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TECHNICAL DATA SHEET 5.3.22

POSITION POTENTIOMETER RANGE, BALANCE AND CHECKOUT UNIT

1.0 INTRODUCTION

A Range Balance and Checkout Unit (Ref. I & C Criteria, Volume I, Par. 5.4.8.3) will be required for the position potentiometer measurement subsystem to provide completion of the transducer circuit to a bridge configuration, and with control or switches as required for ranging, balancing, and checkout.

2.0 DETAILED REQUIREMENTS

- (a) Construction - It shall be built as a modular unit for installation in a standard 19-in. equipment bay, and be designed and packaged to provide for easy maintenance and repair as well as high component density. Each unit shall provide complete range, balance, and checkout capability.
- (b) Circuitry - shall provide, for each channel:
 - (1) Zero Balance potentiometer to provide balance or bias range adjustment.
 - (2) Range Adjust potentiometer to provide for range or span adjustment.
 - (3) Sensitivity push button to connect the transducer output signal to an external meter to measure position potentiometer output voltage.
 - (4) Leakage resistance push button, one each, for signal wires-to-shield and shield-to-ground to provide measurement, by external megohmmeter, of insulation resistance.

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TECHNICAL DATA SHEET 5.3.23
PRESSURE POTENTIOMETER CALIBRATION UNIT

1.0 INTRODUCTION

This device will be utilized with the pressure potentiometer transducer subsystem to accomplish calibration of this transducer subsystem.

2.0 DETAILED DESCRIPTION

- (a) Function - This device shall contain the circuitry and relays required to provide voltage calibration step signals representing 0, 25, 50, 75, and 100% of full-scale transducer output. The calibration unit shall derive excitation power from the individual bridge excitation leads. The 75% calibration point shall be derived from the 75% transducer tap; all other points shall be derived from a divider network.
- (b) Control - Control for the calibration unit shall be compatible with, and provided by, the Pressure Potentiometer Calibration Step Selector Unit. See TDS 5.3.5 for details.

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TECHNICAL DATA SHEET 5.3.24
PRESSURE POTENTIOMETER RANGE, BALANCE AND CHECKOUT

1.0 INTRODUCTION

This device will be utilized in the pressure potentiometer subsystem. It will accept input from potentiometer-type pressure transducers, and will provide standardized linear outputs at a level of 0 to 5 v dc, including calibration steps for recording and display. The functions of range, balance, and checkout are required.

2.0 DETAILED DESCRIPTION

- (a) Input - Input shall be from a pressure potentiometer which operates from 10 v dc excitation, and with a resistance range from 500 to 10,000 ohms. Each transducer will be tapped at $75 \pm 2\%$ of the full-scale resistance range.
- (b) Output - Output range shall be manually adjustable to provide a standardized output of 5 v dc.
- (c) Zero Balance - Manual control shall be provided to adjust zero.
- (d) Checkout - Pushbutton switches shall be provided to permit connection of megohmmeter and output voltmeter, and initiation of an output signal for checkout purposes, utilizing the 75% tap of the transducer.
- (e) Control Action - Use of sensitivity control shall not adversely affect system linearity.

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TECHNICAL DATA SHEET 5.3.25
AC POWER SUPPLY

1.0 INTRODUCTION

This device will be utilized to provide excitation for linear variable differential transformer transducers. It will provide an output of 3 kc at 30 v ac rms.

2.0 DETAILED REQUIREMENTS

- (a) Power Supply Input - Shall be 115 to 125 v, single phase, 60 cycle, ac, $\pm 5\%$.
- (b) Power Supply Output - Shall be 3000 cps, $\pm 1\%$; 30 v ac rms, $\pm 1\%$; with a minimum rated load of 30 w.

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TECHNICAL DATA SHEET 5.3.26

LINEAR VARIABLE DIFFERENTIAL TRANSFORMER CALIBRATION UNIT

1.0 INTRODUCTION

The Linear Variable Differential Transformer Calibration Unit will be a tapped transformer providing simulated stimulus, previously determined to correspond to the output of a Linear Variable Differential Transformer Transducer.

2.0 DETAILED REQUIREMENTS

- (a) Transformer Taps - The transformer secondary side shall have taps enabling the selection of calibration signal levels corresponding to 0, 25, 50, 75, and 100% of full-scale amplitude by relay contact closures.
- (b) Excitation - The transformers primary side shall receive its input from a regulated excitation supply (30 kc, 30 v ac).
- (c) Output - The output from the Calibration Unit shall be demodulated before reaching the end instrument.

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TECHNICAL DATA SHEET 5.3.27
LINEAR VARIABLE DIFFERENTIAL TRANSFORMER CALIBRATION
STEP SELECTOR AND CONTROL UNIT

1.0 INTRODUCTION

This unit will contain all of the relay logic and controls to simultaneously calibrate all channels in the subsystem selection of any one of the 0, 25, 50, 75 or 100% calibration steps or acceptance of controls from the Master Calibration Unit in the Control Point Building.

2.0 DETAILED REQUIREMENTS

This unit will provide for the selection and indication of the calibration steps, and selection of either the manual, or the automatic calibration mode under the sequential control of the Master Calibration Unit.

- (a) Signal Levels - Circuitry shall be provided to enable the selection of calibration signal levels corresponding to 0, 25, 50, 75 and 100% of full-scale amplitude by energization of relays. This will be accomplished by the use of a rotary switch.
- (b) Input Power - Input power for operating relays and light indicators in the Calibration Step Selector and Control Unit shall be 24 v dc.

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TECHNICAL DATA SHEET 5.3.28
LINEAR VARIABLE DIFFERENTIAL TRANSFORMER (LVDT)
CHECKOUT AND CONTROL UNIT

1.0 INTRODUCTION

The LVDT Checkout and Control Unit will provide the controls and circuitry required to check out the LVDT Subsystem, and to convert the ac input signal to dc for recording.

2.0 DETAILED REQUIREMENTS

- (a) Construction - Each unit shall be constructed to accommodate, for each channel, a demodulator; push buttons for the megohmmeter continuity check and output tests; connectors for the transducer-excitation and output, calibration-input power-supply input, output to the voltmeter and the demodulated output to the recording system; and relays to disconnect the power supply during continuity tests.
- (b) Circuitry - The demodulator-amplitude output shall be directly proportional to the amplitude of the ac input, with provisions for phase and amplitude balance

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TECHNICAL DATA SHEET 5.3.29
ACCELEROMETER AMPLIFIER

1.0 INTRODUCTION

The Accelerometer Amplifier will be a shield and line driving amplifier (one per channel) for conditioning accelerometer and high-level microphone signals for transmission to the Control Point Building.

2.0 DETAILED REQUIREMENTS

The amplifier shall accept input from a tri-axial transmission cable. The amplifier output shall be capable of driving co-axial transmission cable.

2.1 OPERATIONAL PERFORMANCE

- (a) Gain Ranges (Voltage With 1000 $\mu\mu$ FD Source Capacity) - These shall be 2.4 to 9.0 for low range, and 9.0 to 34 for high range.
- (b) Gain Stability - This shall be $\pm 5\%$ under specified environments.
- (c) Amplitude Linearity - This shall be 2%.
- (d) Frequency Response - Frequency response shall be $\pm 5\%$, 20 cps to 10,000 cps; and $\pm 10\%$, 15 cps to 10,000 cps. These response figures apply to a 10,000 ohm load or greater at room temperature or above.
- (e) Overload Recovery Time - This shall be 30 ms with 7 v step of 0.5 sec duration or longer.
- (f) Vibration Sensitivity Referred to Input - This shall be 0.05 $\mu\mu$ coulombs/g maximum.
- (g) Input Impedance - The input impedance shall be approximately 200,000 ohms.
- (h) Output Source Impedance - This shall be 150 ohms.
- (i) Maximum Output Level - This shall be 1.766 v rms at 0.18 ma (5 v peak-to-peak).

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- (j) Residual Noise - The residual noise shall be $2\mu\mu$ coulombs pk (primarily $1/f$ noise peaking at 5 cps) referred to input.
- (k) Cable Length - This shall be 300 ft maximum (input source capacitance, including cable and transducer, not to exceed 10,000 mmfd).
- (l) Total Harmonic Distortion and Non-Linearity - This shall be 2% maximum under all environmental extremes.
- (m) Bias - Signal output bias shall be available.
- (n) Power - The power shall be ± 28.5 v dc $\pm 9\%$. A built-in voltage regulator shall allow complete stability when power voltage is varied $\pm 9\%$ from 28.5 v dc.

2.2 ENVIRONMENTAL CONDITIONS

- (a) Temperature (Operating) - It shall operate in the temperature of -40° to $+185^{\circ}$ F.
- (b) Temperature (Non-Operating) - It shall not be affected in a non-operating temperature range of -65° to $+250^{\circ}$ F.
- (c) Shock - It shall withstand shock of 100 g for 6 ms saw tooth, or 50 g for 11 rms half sine pulse.
- (d) Vibration - It shall withstand vibratory forces of 0.06 DA, from 5 to 55 cps, and 20 g from 55 cps to 2 kc.

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TECHNICAL DATA SHEET 5.3.30
ACCELEROMETER CALIBRATION STEP SELECTOR AND CALIBRATION
CONTROL UNIT

1.0 INTRODUCTION

The Accelerometer Calibration Step Selector and Calibration Control Unit will provide for the selection and indication of calibration steps for the complete subsystem, and selection of either a manual calibration mode, or an automatic calibration mode under the sequential control of the Master Calibration Control Unit.

2.0 DETAILED REQUIREMENTS

- (a) Calibration Step Selector - Circuitry shall be provided to enable the selection of calibration signal levels corresponding to 0, 25, 50, 75 and 100% of full-scale amplitude by relay contact closures.
- (b) Automatic-Manual Switch - This switch will provide for the selection of manual or automatic calibration modes. The automatic calibration mode will be under the sequential control of the Master Calibration Control Unit.
- (c) Input Power - Input power for operating relays and light indicators shall be 28 v dc.
- (d) Relays - The relays shall operate reliably at coil voltages as low as 15 v dc, and shall not release until the coil voltage falls below 13 v dc.

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TECHNICAL DATA SHEET 5.3.31
NARROW BAND DIFFERENTIAL DC AMPLIFIER

1.0 INTRODUCTION

The DC amplifier will be a low level, narrow band differential amplifier to be used in signal conditioning subsystems.

2.0 DETAILED PERFORMANCE

2.1 OPERATIONAL PERFORMANCE

- (a) Gain - shall be in fixed steps of 50, 100, 250, and 500, with a gain setting accuracy of 1%. A potentiometer with locking knob shall be provided for interpolation between steps.
- (b) Zero Adjust - A 20-turn potentiometer will provide a range of $\pm 1\%$ of full-scale with a resolution of $\pm 0.01\%$.
- (c) Signal Configuration - The input will be isolated from the output and both will be isolated from the amplifier chassis. The resistance between any two of these three elements will be 10^9 ohms, minimum. Two channels of amplification in any one module will be referenced to a common ground.
- (d) Input Impedance - shall be 1 megohm, minimum. Input impedance shall be constant under all combinations of gain setting and source impedance over the operating range of the instrument.
- (e) Output Impedance - shall be 300 ohms, maximum, at dc, and less than 2500 ohms at f_{co} (25 cps).
- (f) Output Capability - under conditions of 2 ma into an external load of 2500 ohms, the amplifier shall be able to be shorted indefinitely without damage.
- (g) Maximum Common Mode Voltage - shall be ± 250 volts dc or peak ac.
- (h) Signal Source Impedance - All operational and measurement performance specifications shall apply with a source impedance of 1000 ohms or less.

- (i) Overload Recovery and Protection - The amplifier shall recover within 500 ms to specified performance upon removal of a ± 10 volt overload signal. The maximum input overload voltage rating shall be ± 10 volts. Output saturation voltage shall not exceed 2.5 times full-scale output and will not fall below 1.1 times full-scale output.

2.2

MEASUREMENT PERFORMANCE

- (a) Amplitude Linearity - shall be $\pm 0.025\%$ of full-scale (terminal). Bipolar gain difference (i. e., deviation from + full-scale to - full-scale) shall be $\pm 0.5\%$ maximum.
- (b) Frequency Linearity - shall be $\pm 1\%$ from dc to 10 cps; less than 3 db attenuation at 20 cps; and 12 db per octave limiting slope above 25 cps.
- (c) Zero and Gain Stability - shall both be $\pm 0.05\%$ of full-scale for a 40-hour period at $25^{\circ}\text{C} \pm 10^{\circ}\text{C}$, and $\pm 0.1\%$ of full-scale for a 40-hour period at $25^{\circ}\text{C} \pm 25^{\circ}\text{C}$.
- (d) Maximum Combined Zero and Gain Stability - shall be $\pm 0.1\%$ of full scale for a 40-hour period at $25^{\circ}\text{C} \pm 10^{\circ}\text{C}$ and $\pm 0.25\%$ of full-scale for a 40-hour period at $25^{\circ}\text{C} \pm 25^{\circ}\text{C}$.

The above values will be the worst possible case, in which the gain and zero stability will be additive, and will represent the largest region of uncertainty for the amplifier through the operating environmental range.

- (e) Combined Rise and Settling Time - shall be 25 milliseconds to within $\pm 0.1\%$ of full-scale.
- (f) Common Mode Rejection - shall be 50,000,000 to 1 at dc and 2,000,000 to 1 at 60 cps with a 1000-ohm unbalanced line. These specifications shall include degradation due to rack and rack input connectors, representing the worst operating conditions for measurement.
- (g) Noise - The combined noise from all sources within the amplifier (including crosstalk), as seen at the output terminals under the worst signal and source conditions (1000 ohms, $\pm$ full-scale), shall be $\pm 0.05\%$ of full-scale.

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2.3 ENVIRONMENTAL PERFORMANCE

- (a) Temperature - All specifications except those pertaining to stability apply over an operating range of 0° to 50°C , with a temperature rate of change not exceeding $\pm 10^{\circ}\text{C/hr}$.
- (b) Pressure - The unit shall operate satisfactorily in pressure equivalents from sea level to an altitude of 8000 feet.
- (c) Moisture - The unit shall operate satisfactorily in 90% relative humidity.

NOTE: Neff Instrument Corporation, Model 104 will meet the above requirements, and is mentioned as a standard of quality only.

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TECHNICAL DATA SHEET 5.3.32
ACCELEROMETER CALIBRATION UNIT

1.0 INTRODUCTION

The Accelerometer Calibration, Checkout, and Control Unit will include all controls and adjustments required for calibration of each channel of the subsystem by insertion of simulated electrical signals, previously determined to correspond to given accelerations at the transducer.

2.0 DETAILED REQUIREMENTS

- (a) Frequency Calibration - Individual calibration range switches shall permit selection of either high or low-frequency calibration on each channel. Frequency inputs will be 100, 1000, 2000, 3000, 5000, and 10,000 cps.
- (b) Signal Levels - Individual control for each channel shall be provided to enable the selection of calibration signal levels corresponding to 0, 25, 50, 75, and 100% of full-scale amplitude by relay contact closures. This will be accomplished by the use of a rotary switch (located on the Step Selector and Control Unit) routing the signal through proper resistor networks for the desired signal levels.
- (c) Channel Selector - A rotary switch (Channel Selector Switch) shall permit the calibration signals to be monitored on a rms voltmeter.

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TECHNICAL DATA SHEET 5.4
LEAD INSTRUMENTATION ENGINEER (LIE) CONSOLE

1.0 INTRODUCTION

The LIE Console will provide the Lead Instrumentation Engineer with status indications and overall control of Instrumentation Systems as detailed below. His role will consist of overall cognizance of the systems rather than detailed operation, and he shall perform detailed operations only to override automatic sequencing and control devices. All equipment controlled will be located externally to the Control Center, except for the displays and graphic recorders.

2.0 DETAILED REQUIREMENTS

Controls for the following systems will appear on the LIE Console in the Control Center.

2.1 DATA ACQUISITION SYSTEM

(a) Measurement Subsystem

* Calibration Status

(b) Digital Data System

* ~~Run Mode Select~~

 Status of Recording

(c) Analog Data System

 Recorders On-Off

 Status Confirm

(d) Communications with Supporting Data System Operators

2.2 REAL TIME DATA PRESENTATION

(a) Displays

 Manual Select of Display System to be Used

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(b) Graphic Recorders

Status Indication

Manual Master Override

(Manual Master Override shall command all recorders to high or low chart speed for recording transient conditions, etc.)

2.3 TIMING SYSTEM

Manual Transfer to Alternate Time Code Generator

(Time displays are part of wall mounted display.)

2.4 PHOTOGRAPHIC SYSTEM

(a) Camera Groups

Start-Stop and Sequence Control

Status Summary Indicator

(b) Individual Cameras

Override Manual Controls

Remaining Running Time Indication

2.5 ~~TV SYSTEM~~

~~(For each camera chain not specifically controlled from another console pan, tilt, focus, etc., controls.)~~

2.5 COMMUNICATIONS SYSTEM

Control of Tape Recording of Selected Nets

Selector to Monitor any Communications Channel

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TECHNICAL DATA SHEET 6.1
PHOTOGRAPHIC SYSTEM

1.0 INTRODUCTION

The photographic system shall be furnished for the purpose of providing permanent visual and audio-visual records of all activities incurred in the test firings at the ETS-1 test stand. Some of the equipment shall also, at a later date, be capable of monitoring test stand ETS-2. Photographic coverage shall be provided in both black-and-white, and color films, at various framing rates, and from different view-points and distances. All analytical coverage shall incorporate timing codes, to assist in correlation with other data.

2.0 DETAILED REQUIREMENTS

2.1 16mm CAMERAS

2.1.1 Medium Frame Rate, High Film Capacity

These cameras shall contain the following features:

- (a) Variable frame rate, from 24 frames-per-second (fps) to approximately 120 fps.
- (b) 1200-ft film magazines, for daylight installation on camera.
- (c) Variable shutter, providing apertures from 0° up to approximately 200° , with a suitable indicator.
- (d) Intermittent movement-and-pin film registration for precise film positioning. The intermittent movement may be replaced by another type of movement, if lens resolution is not degraded by substitution.
- (e) Automatic cut-out switch, to stop film drive if take-up is not functioning properly.
- (f) Readily visible footage and frame counters.

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- (g) Capability of focus through lens. This may be accomplished either by camera body rack-over or by prismatic reflex viewfinder. If the rack-over principle is selected, the camera must not be capable of operation while in the focusing position.
- (h) Timing adapter, consisting of neon lamps and capable of utilizing 100 and 1000 pps time codes.
- (i) Camera body exterior shall be painted white, with an exterior enamel.
- (j) Power requirement shall be 115 v ac or 60 cycle.

2.1.2 Low Frame Rate, High Film Capacity

These cameras operating at 24 fps, shall contain all of the features of the foregoing type, with the exception of the low-speed synchronous drive motor which is required on this model.

2.1.3 Low Frame Rate, High Film Capacity, Sound

These cameras (Auricon Super-1200 type is mentioned as a standard of quality) shall include:

- (a) Filming rate (24-fps) obtained through use of a synchronous motor.
- (b) A variable-aperture shutter, from 0° to approximately 170°.
- (c) 1200-ft film magazine.
- (d) Either body-rack-over or optical reflex focusing. (Camera shall not function in the focusing position if body rack-over is used.)
- (e) Self-blimped body.
- (f) Recording galvanometer of either Variable-Area or Variable-Density type. (The Variable-Area type is preferable to the latter, because of its superior ability to prevent shutter noise and cross-talk distortion.)
- (g) Buckle-trip switch to stop camera when film take-up is not functioning properly.

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- (h) Exterior of camera shall be in white enamel.
- (i) Power requirement shall be 115 v AC, 50 or 60 cycle.

2.1.4 High Frame Rate, High Film Capacity

These cameras (Photo-Sonics 1-b type is mentioned as a standard of quality) shall include:

- (a) Framing rate - 1200 fps (or, slower framing rate with identical effective shutter speed).
- * (b) 1200-ft film magazine.
- (c) Rotary prism compensating for continuous motion of film. A disc shutter shall be used in conjunction with the prism to provide even image exposure.
- (d) Variable shutter, from 9 to 72⁰.
- (e) Boresight focus capability.
- (f) Neon timing lights for use with 1000-pps timing signal.
- (g) Power requirements shall be 115 v ac.

2.2 35mm CAMERA, LOW FILM RATE, HIGH FILM CAPACITY

* "Deleted"

2.3 70mm CAMERA, LOW FILM RATE, HIGH FILM CAPACITY

* "Deleted"

2.4 LENS REQUIREMENTS

2.4.1 Characteristics

A number of lenses shall be furnished to match the camera types selected. Lenses shall be of good photo-instrumentation quality, consistent with the best state of the art.

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- (a) Each lens shall be capable of at least 40 lines/mm of resolution, averaged over the total field.
- (b) Lenses shall be free of discernible color fringes.
- (c) All air-to-glass surfaces shall be treated with a hard, low-light transmission coating similar to that called out in Government Specification JAN-F-675.
- (d) Aperture designations shall be in f stops.
- (e) All exterior surfaces of lens barrels, except those which come into contact with camera body, shall be painted with a highly reflective white paint or enamel.

2.4.2 Focal Lengths and Quantities

The following table indicates the focal lengths of lenses, quantities, types of camera mounts to be used, and distribution according to camera station:

<u>Camera Station</u>	<u>Film Format</u>	<u>Lens</u>	<u>Lens Focal Length</u>	<u>No. Req'd</u>
1B	16mm	C-Mount	75mm	4
2B	16mm	C-Mount	40mm	4

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*	Camera Station	Film Format	Lens		No. Req'd
				Focal Length	
	2B	16mm	C-Mount	35mm	2
	2B	16mm	Photo-Sonics Mount	50mm	1
*	2B	16mm	C-Mount	25mm	3
*	2B	70mm	Hulcher Mount	250mm	1
	3B	16mm	Photo-Sonics Mount	17mm	1
	3B	16mm	C-Mount	40mm	3
*	3B	16mm	C-Mount	17mm	3
*	3B	70mm	Hulcher Mount	250mm	1
*	4-TR	16mm	C-Mount	35mm	1
*	4-TR	35mm	C-Mount	100mm	1
*	5L	16mm	C-Mount	12.7mm	1
*	5L	35mm	C-Mount	25mm	1
	6B	16mm	Photo-Sonics Mount	35mm	2

2.4.3 Lens Accessories

- (a) Polarizing filters shall be provided for each lens. These must be optically flat and neutral grey in color, and must not degrade the optical characteristics of the lenses.
- (b) Retaining rings for the foregoing filters, along with lens shades shall be provided for each lens. These rings shall be so constructed that a rotation of the filter to at least 90° will be possible.
- (c) Lens cases shall be provided for each lens.

2.5 SOUND EQUIPMENT

2.5.1 Amplifier

The amplifiers furnished with the sound cameras shall adhere to the following requirements:

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- (a) It shall contain noise reduction circuits to match the sound galvanometer used in the camera.
- (b) It shall contain battery power for its own use, and for powering the sound-track lamp in the camera.
- (c) Meters shall be provided to enable exact control of sound level being recorded. One meter shall be used for indicating battery conditions, and level of brightness of the sound-track exposure lamp. The other meter shall serve as a visual volume-indicator.
- (d) A multi-position control shall be provided for adjustment of voice tone.
- (e) Batteries used within the amplifier shall be standardized portable-radio type.

2.5.2

Kinescope Recorder

The Kinescope recording system shall be furnished as a complete system for the purpose of producing standard 24-frame-per-second motion picture film from any incoming TV camera presentation.

The recorder shall adhere to the following requirements:

- (a) The TV section shall be capable of presenting a scanning rate of 525 lines, 2:1 interlace, 60 fields, 30 frames per second.
- (b) An electronic shutter shall control tube brightness, and blank out the tube at the end of each exposure.
- (c) The 35mm recording camera shall incorporate an intermittent movement, and a cut-off switch for shutting off the camera motor should the film fail to transport.
- (d) The system shall contain a sound recording system for implementing sound-on-film.
- (e) Power requirements - 115 v ac, 60 cps, 20 amps.