REVISED 1 JUNE 1962

T/D/SNA--1672 (Vol. 1)

Instrumentation & Control System Design Criteria

Test Cell ETS-1
NNRDC

VOLUME 1
CRITERIA

MASTER

COPY 170 OF 183

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TABLE OF CONTENTS

Volume I, Criteria

<u>Section</u>		<u>Figure</u>	<u>Page</u>
1.0	GENERAL		I, 1.1-1
1.1	INTRODUCTION		-1
	Model of ETS-1 Test Stand	I, 1.1-1	
	Model of ETS-1 Test Stand	-2	
	Model of ETS-1 Test Stand	-3	
	Model of ETS-1 Test Stand	-4	
	General Plan ETS-1 Complex	-5	
	Artist's Conception, Control Room	-6	
1.2	SCOPE		I, 1.2-1
1.2.1	Criteria Contents		-1
1.2.2	Task Description		-2
1.2.3	Integration with ETS-2		-4
	Integration of ETS-1 with ETS-2 (Drawing)		-8
1.3	IMPLEMENTATION AND SUPPORT REQUIREMENTS		I, 1.3-1
1.3.1	Equipment Specifications		-1
1.3.2	Drawings		-2
1.3.3	Quality Assurance		-9
1.3.4	Final Acceptance Testing		-13
1.3.5	Operation and Maintenance Manuals		-16
1.3.6	Spares		-18
1.3.7	Human Engineering Design		-21
	Parts List	I, 1.3-1	
	Parts Tabulation	-2	
	Parts Tabulation	-3	
	Spare Parts List	-4	
1.3.8	Equipment Bays and Terminations		-22
1.4	CONTRACTOR FURNISHED EQUIPMENT		I, 1.4-1
1.5	CONTRACTOR DESIGN		I, 1.5-1

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Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A-1

Date 1 June 1962

Par. Contents

<u>Section</u>		<u>Table</u>	<u>Page</u>
<u>2.0</u>	<u>INSTRUMENTATION AND CONTROL</u> <u>SYSTEM, ETS-1 COMPLEX</u>		I, 2.1-1
2.1	SCOPE		-1
2.1.1	Purpose		-1
2.1.2	Function		-1
2.1.3	I & C System Equipment Interfaces		-2
2.2	EQUIPMENT AND OPERATIONS CONCEPTS		I, 2.2-1
2.2.1	Type of Tests		-1
2.2.2	Usage Factors		-3
2.2.3	Summary Description of ETS-1 Complex		-4
2.2.3.1	General Areas		-4
2.2.3.2	General Area Breakdown		-4
2.2.3.3	General Description of Specific Items		-6
2.2.4	Organization and Procedures for Engine Testing		-18
2.2.5	Checkout and Calibration		-26
2.2.5.1	Scope		-26
2.2.5.2	Definitions		-26
2.2.5.3	Basic System Checkout Philosophy, ETS-1		-28
2.2.5.4	Operational Calibration Philosophy, ETS-1		-32
2.2.5.5	Transducer/System Calibration		-34
2.2.5.6	Laboratory Setup		-38
2.2.6	Reliability		-41
2.2.7	Safety		-52
2.2.8	Nuclear Effects Test Capability System (NETCS)		-59
2.3	GENERAL CRITERIA FOR SUBSYSTEMS		I, 2.3-1
2.3.1	Power		-3
2.3.2	Standardization		-5
2.3.3	Approach to Circuit and Equipment Design		-5
2.3.4	Environmental Factors		-11
2.3.5	Standard Signal Levels		-12

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A-1

Date 1 June 1962

Par. Contents

Section		Table	Page
2.3.6	General Equipment Stability		-13
** 2.3.7	Signal Conditioning Equipment		-15
	ETS-1 Signal Conditioning		
	Equipment for all Systems	I, 2.3-1	
2.4	CONTROL CENTER CONTROL AND		
	DISPLAY REQUIREMENTS		I, 2.4-1
2.4.1	Consoles		-1
2.4.2	Graphic Display Panels		-19
3.0	REMOTE ENGINE CONTROL SYSTEM		I, 3.1-1
3.1	SCOPE		-1
3.1.1	Purpose		-1
3.1.2	Function		-1
3.2	I & C SYSTEM CONSIDERATIONS		I, 3.2-1
3.2.1	Basic Concepts and Operations		
	Philosophy		-1
* 3.2.2	Interface Considerations		-5
3.3	SYSTEM REQUIREMENTS		I, 3.3-1
3.3.1	General Requirements		-1
* 3.3.2	Remote Engine Control System		
	Equipment		-4
3.3.3	Test Stand Control Equipment		-5
* 3.3.4	Test Stand Malfunction Control		-7
3.3.5	General Test Stand Requirements		-9
3.4	GENERAL SUBSYSTEM CRITERIA		I, 3.4-1
3.4.1	Instrumentation		-1
3.4.2	Television		-2
3.4.3	Communications		-3
3.4.4	Timing		-3
3.4.5	Electrical Power		-3
3.5	SYSTEM CRITERIA		I, 3.5-1
* 3.5.1	Engine Ground Test Master		
	Programmer Controlling Equipment		-1
3.5.2	Test Stand Control System		-7
3.5.3	Test Stand Malfunction Control		
	Equipment		-20
3.5.4	Display Equipment		-22
3.5.5	Equipment Integration		-23

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A-1

Date 1 June 1962

Par. Contents

<u>Section</u>		<u>Table</u>	<u>Page</u>
<u>4.0</u>	<u>FACILITY OPERATION AND CONTROLS</u>		
	<u>SYSTEMS</u>		
4.1	SCOPE		I, 4.1-1
4.1.1	Purpose		-1
4.1.2	Function		-1
4.1.3	Existing Facilities		-2
4.2	I & C SYSTEM CONSIDERATIONS		I, 4.2-1
4.2.1	Facilities Control		-1
4.2.2	Facilities Support		-2
4.2.3	Test Stand Support Equipment		
	Controls		-2
4.2.4	Transmission (Cable and Patching)		-3
4.2.5	Interface Areas		-3
4.3	SYSTEM REQUIREMENTS		I, 4.3-1
4.3.1	Facilities Control		-1
4.3.2	Facilities Support Systems		-5
4.3.2.1	Communications		-5
4.3.2.2	Closed Circuit TV		-6
4.3.2.3	Timing		-7
4.3.2.4	Electrical Power		-8
4.3.3	Test-Stand Support-Equipment		
	Control System		-9
4.3.4	Transmission (Cable and Patching)		-12
4.4	GENERAL SUBSYSTEM CRITERIA		I, 4.4-1
4.4.1	Instrumentation and Control		-1
4.4.2	Closed Circuit TV		-2
4.4.3	Timing		-4
4.4.4	Communications		-6
4.4.5	Electrical Power		-8
4.5	SYSTEM CRITERIA		I, 4.5-1
4.5.1	Facilities Control		-1
4.5.1.1	Hydrogen		-1
4.5.1.2	Oxygen		-4
4.5.1.3	Helium		-6
4.5.1.4	Nitrogen		-7
4.5.1.5	Propane		-9
4.5.1.6	Reactor Cooling Gas		-11
4.5.1.7	Steam Generators		-12

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A-1
Date 1 June 1962
Par. Contents

Section		Table	Page
4.5.1.8	Hydrogen Gas Flares	I, 4.5-13	
4.5.1.9	Vacuum		-15
4.5.1.10	High-Pressure Gas		-16
4.5.1.11	Process Water System		-17
4.5.1.12	LH ₂ Engine Run Tank System		-19
4.5.2	Facilities Support Systems		-20
4.5.2.1	Communications		-20
4.5.2.2	Closed Circuit TV System		
	Criteria		-28
4.5.2.3	Timing System		-43
4.5.2.4	Electrical Power		-52
4.5.3	Test Stand Support Equipment		
	Control Systems		-55
4.5.4	Transmission (Cable and Patching)		-62
	Cable Details	I, 4.5-1	
5.0	<u>DATA ACQUISITION SYSTEM (ELECTRONIC)</u>		I, 5.1-1
5.1	<u>SCOPE</u>		-1
5.1.1	Purpose		-1
5.1.2	Function		-1
5.2	<u>SYSTEM REQUIREMENTS AND CONSTRAINTS</u>		I, 5.2-1
5.2.1	Data-Measurement Requirements		-1
5.2.2	Operational Requirements		-7
5.2.3	Recording Capabilities		-13
5.2.4	Data Reduction Capabilities		-15
5.2.5	Design Requirements		-19
*	Measurement Summary for ETS-1		
	Data Acquisition List	I, 5.2-1	
*	Data Acquisition List		
	Measurement Summary	-2	
*	Measurement System Accuracies	-3	
*	Relative Time Relationship of		
	Checkout and Calibration	-4	
5.3	<u>CONCEPT OF OVERALL SYSTEM</u>		I, 5.3-1
5.3.1	General		-1
5.3.2	Inputs		-2
5.3.3	Recording		-2

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A-1

Date 1 June 1962

Par. Contents

Section		Table	Page
5.3.4	Analog and Digital Systems		I, 5.3-3
5.3.5	Functional System Diagram		-4
5.3.6	System Integration		-4
5.4	SIGNAL CONDITIONING SUBSYSTEMS		I, 5.4-1
5.4.1	Strain Gage Subsystem		-2
5.4.2	Resistance Temperature Subsystem		-8
5.4.3	Full Bridge Resistance Temperature Subsystem		-12
5.4.4	Flow Measuring Subsystem		-14
5.4.5	Speed Measuring Subsystem		-16
5.4.6	Thermocouple Subsystem		-17
5.4.7	Pressure Potentiometer Subsystem		-21
5.4.8	Position Potentiometer Subsystem		-24
5.4.9	Linear Variable Differential Transformer Subsystem		-26
* 5.4.10	Vibration and Acoustic Subsystem		-28
* 5.4.11	Proportional Voltage Subsystem		-30
5.5	DIGITAL SUBSYSTEM		I, 5.5-1
5.5.1	Development of Digital Subsystem		-1
5.5.2	Preliminary Design		-8
5.6	ANALOG RECORDING SUBSYSTEM		I, 5.6-1
5.6.1	Requirements		-1
5.6.2	Preliminary Design		-1
5.6.3	Recorders		-2
5.6.4	Wide Band Amplifiers		-4
5.6.5	Control and Patching		-4
5.7	EVENTS RECORDING SUBSYSTEM		I, 5.7-1
5.7.1	Subsystem Isolation		-1
5.7.2	Signal Conditioning		-1
5.7.3	Recording		-2
5.8	PRELIMINARY DATA REDUCTION		I, 5.8-1
5.8.1	Proposed System		-1
5.8.2	Capabilities		-2
5.8.3	System Checkout and Calibration		-4
5.8.4	Operational Check System		-4
5.9	FINAL DATA REDUCTION		I, 5.9-1
5.9.1	General		-1
5.9.2	Scope of Computations		-1

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A-1

Date 1 June 1962

Par. Contents

<u>Section</u>		<u>Table</u>	<u>Page</u>
5.9.3	Final Data Output		I, 5.9-2
5.9.4	Channel Records		-2
5.9.5	Standard Channel Ranges		-2
5.10	SYSTEM OPERATION		I, 5.10-1
5.10.1	Checkout		-1
5.10.2	Calibration		-1
5.10.3	Run Modes		-2
5.10.4	Personnel Required		-4
6.0	<u>DATA ACQUISITION SYSTEM (PHOTOGRAPHIC)</u>		I, 6.1-1
6.1	PURPOSE AND FUNCTIONS		-1
6.2	I & C SYSTEM CONSIDERATIONS		I, 6.2-1
6.2.1	Engineering Sequential Photography		-1
6.2.2	Data Analysis Photography		-1
6.2.3	Documentary Photography		-1
6.3	SYSTEM REQUIREMENTS		I, 6.3-1
6.3.1	Pre- and Post-Test Coverage Requirements		-1
6.3.2	Test Firing Coverage Requirements		-1
6.3.3	Permanent Station and Control Center Requirements		-3
6.3.4	Timing Requirements		-4
6.3.5	Film Radiation Tolerance Requirements		-4
6.3.6	Controls		-5
6.3.7	Engine Test Requirements		-6
6.4	SUBSYSTEM CRITERIA		I, 6.4-1
6.4.1	Introduction		-1
6.4.2	Camera Station Design Criteria		-1
6.4.3	Detail Photographic Plan		-4

PAGE BLANK

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A-1

Date 1 June 1962

Par. Contents

<u>Section</u>		<u>Page</u>
<u>1</u>	<u>GENERAL</u>	
1.0	GLOSSARY AND DEFINITIONS	
1.0	INTRODUCTION	I, App 1.0, 1.0-1
2.0	GLOSSARY AND DEFINITIONS	2.0-1
2.1	Organization	2.1-1
2.2	Area	2.2-1
2.3	Test Complex	2.3-1
2.4	Test Personnel	2.4-1
2.5	Engine	2.5-1
2.6	Reactor	2.6-1
2.7	Computer Definitions	2.7-1
2.8	General Terms	2.8-1
1.1	HUMAN ENGINEERING DESIGN	
1.0	INTRODUCTION	1.1, 1.0-1
2.0	AMBIENT ENVIRONMENT	2.0-1
3.0	WORKSPACE CRITERIA	3.0-1
4.0	GENERAL EQUIPMENT CRITERIA	4.0-1
4.1	Panel Layout and Design	4.0-1
4.2	Controls	4.0-3
4.3	Specific Control Criteria	4.0-5
4.4	General	4.0-13
4.5	Design for Maintainability	4.0-21
4.6	Accessibility	4.0-21
4.7	Aperture Openings	4.0-23
4.8	Interposition of Units	4.0-25
4.9	Design for Fabrication and Operation	4.0-25
4.10	Fasteners	4.0-26
4.11	Mounting of Units	4.0-27
4.12	Casters and Levelling Pads	4.0-28
4.13	Input Connectors	4.0-28
4.14	Name Plates	4.0-28
4.15	Equipment Finish	4.0-28
5.0	CONTROL CENTER	5.0-1
6.0	INTERIORS	6.0-1
7.0	CONSOLES AND EQUIPMENT RACKS	7.0-1
8.0	PANELS, DISPLAYS, AND CONTROLS	8.0-1
9.0	GRAPHICS (Console Panel, Control, and Display Identification)	9.0-1

<u>Section</u>		<u>Page</u>
10.0	CONTROL ROOM DISPLAY BOARDS	10.0-1
11.0	NERVA CONTROL AND DISPLAY SPECIFICATIONS	11.0-1
<u>2</u>	<u>I & C CRITERIA</u>	
2.1	Count Schedule	
2.2	Automatic Checkout and Calibration Equipment, ETS-1	
2.3	Reliability of the Digital Data Acquisition System	
2.4	Illustrations of Reliability Analysis of I & C System	
2.5	Area Warning	
2.6	Radiation Measuring Equipment	
<u>3</u>	<u>REMOTE ENGINE CONTROL SYSTEM</u>	
3.1	Engine Data Display	
3.2	Test Stand Data Display	
<u>4</u>	<u>FACILITY OPERATIONS AND CONTROL SYSTEMS</u>	
4.1	Facilities Systems (General Index on pp. App. 4.1-1 through -3)	
4.2	ETS-1 Instrumentation and Control Interface Areas	
4.3	Facilities Control Locations	
4.4	Public Address and Interphone Considerations	
4.5	Proposed ETS-1 Facility Modifications	
4.6	Facilities Control Valves	
<u>5</u>	<u>DATA ACQUISITION SYSTEM</u>	
5.1	Considerations of Handling Channel Information	
* 5.2	Measurement Summary for ETS-1 I & C System	
5.3	Data Processing Computation	
5.4	Error Evaluation	
5.5	Computer Operations	
5.6	Comparison of Binary Coded Decimal and Straight Binary Systems	
5.7	Support Facility Requirements	
5.8	Measurement Accuracy Goals	
** 5.9	Temperature Measurement	
** 5.10	Determination of Digital Data Volume and Resulting Tape Format

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.0

1.0

GENERAL

1.1

INTRODUCTION

This document contains 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 on Contract SNP-1.

**

Test Cell ETS-1 is described in the photographs of the test facility model Figures 1.1-1 through -4, in the ETS-1 Complex Area Designation Plan, Figure 1.1-5, and in an artist's conception of the Control Center of the Control Point Building, Figure 1.1-6.

This criteria is 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. A report of Ralph M. Parsons Co. this job No. 1877-1, June 16, 1961, entitled "National Nuclear Rocket Development Facility" (Secret-RD), and with NASA-Lewis Code Number of 61,275, was also utilized in the preparation of this document.

*

The four volumes of this criteria 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

MODEL OF ENGINE TEST STAND (ETS-1)

Figure 1.1-1

MODEL OF ENGINE TEST STAND (ETS-1)

Figure 1.1-2

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par.

MODEL OF ENGINE TEST STAND (ETS-1)

Figure 1.1-3

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par.

MODEL OF ENGINE TEST STAND (ETS-1)

Figure 1.1-4

1. EXAMPLE DWG. NO. CODE

AREA 400 ETS-1 COMPLEX

SPECIFIC AREA (LAST 2 DIGITS OF AREA NO. PER TABLE)

3332-P3

AETRON DIVISION OF AGC DRAWING NO.

PIPING SHEET NO.

PIPING

2. EXAMPLE EQUIPMENT, ITEM, & VESSEL NO. CODE

COMPLETE VESSEL NO.

V-3206

VESEL DESIGNATION

ITEM NO.

SPECIFIC AREA (LAST 2 DIGITS OF AREA NO. PER TABLE)

AREA NO.	
3307	DISTRIBUTION PIPING - PROCESS
3310	CONTROL POINT BLDG.
3312	ACCESS TUNNEL
3320	UTILITY EQUIPMENT BLDG.
3324	DIESEL GENERATOR BLDG.
3325	ELECTRICAL SUB-STATION
3327	TRUCK UNLOADING STATION
3328	LIQUID OXYGEN
3330	FILL STATION
3332	HI-PRESS. GAS STORAGE
3334	PROPANE
3336	LIQUID NITROGEN
3338	LIQUID HYDROGEN
3340	TEST CELL BLDG.
3350	TEST STAND
(NOT SHOWN ON DWG. BUT INCLUDED FOR REF.)	
3300	INDEX SHEETS, ETC.
3301	SITING (GEN'L. LAYOUT, PLOT PLANS)
3302	ROADS
3303	RAILROADS
3304	GRADING
3305	FLOW DIAGRAMS
3306	DISTRIBUTION PIPING - WATER
3308	ELECTRICAL & INSTRUMENTATION DISTR'N.

ETS - 1 COMPLEX
AREA DESIGNATION PLAN

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par.

Figure 1.1-6
ARTIST'S CONCEPTION
CONTROL CENTER
CONTROL POINT BUILDING

1.2

SCOPE

1.2.1

Criteria Contents

This document establishes design concepts, criteria, and preliminary design for the Remote Engine Control System, the Facilities Operations and Controls Systems, and the Data Acquisition System for the NNRDC Test Cell ETS-1. Included are drawings necessary to depict system and subsystem concepts and preliminary design; not included however, are hardware fabrication drawings, which are tasks of detailed design, and represent the point of departure between criteria and preliminary design, and detailed design. In addition, the integration of these systems into the complete facility is analyzed with respect to overall facility missions, objectives, and system interfaces.

It is the aim by inclusion of the above listed items, to produce a comprehensive document which can be used by subcontractors as the basis for detailed engineering design, which therefore can be accomplished quickly and accurately with only a minimum of external technical direction. Scheduling time can be held to a minimum, since the criteria document will enable rapid preparation of procurement specifications. Costly revision to contractors' designs, because of inadequate information, will be minimized, since the Criteria Document will serve as the basis for the final design, and more accurate budgeting will be possible since ROM equipment costs are included.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 1.2.2

1.2.2

Task Description

This criteria is prepared to establish operational requirements, system concepts, preliminary block-diagrams, subsystem identification, system and subsystem criteria, and rough order-of-magnitude (ROM) system and subsystem costs. It is composed of five major sections, which will be discussed in the following paragraphs.

A. GENERAL

The purpose, scope, and system support requirements for the Instrumentation and control system is established in the general section (1.0) of this document, and the overall concept and objective of the task is detailed in this section. The requirements for supporting tasks such as: quality assurance, operation and maintenance manuals, final acceptance testing, drawings, spares, and human engineering, will be defined. The efforts required to attain these supporting tasks have been clearly emphasized because these tasks, properly prepared and used, are essential to provide a reliable and operable testing facility.

B. SYSTEMS

The systems integration effort involves the analysis and consideration of subsystem interface problems, the establishment of overall facility system criteria, and specific requirements for the Operations Center, with its consoles, displays, controls, computers, programmers, etc.

The systems test operations concept is explained by detailing the philosophy and functions of the operation, and the prime line of authority in the test. Since an important part of systems consideration is reliability, procedures and concepts for obtaining a reliability program are established.

C. REMOTE ENGINE CONTROL SYSTEM

The remote engine-control system criteria is sufficiently detailed to establish its integration into the I & C System, along with its operational requirements, system concepts, subsystem

criteria, system criteria, and Rough-Order-of-Magnitude (ROM) costs of its equipment. The remote engine-control elements, control loops, safety and malfunction loops necessary for engine testing, and appropriate visual displays of the operational engine parameters constitute the equipment included in this system.

D. FACILITY OPERATIONS AND CONTROL SYSTEMS

The facility operations and control system criteria is sufficiently detailed to establish its integration into the I & C system, operational requirements, system concepts, subsystem criteria, system criteria, and ROM costs of its equipment. The facility operations and controls systems include controls and instrumentation for local and remote handling of gaseous nitrogen, hydrogen, and helium; liquid hydrogen, oxygen, nitrogen, and propane; and steam, vacuum, and water. Equipment for facility checkout, communication, television, and electrical power form the nucleus of the operations systems. The test stand support equipment controls are also included; these constitute control for operation of the engine radiation compartment shields, the plug shield, and the deflection duct door; for installation of the engine in the test stand; and for replacement of the deflection duct in case of burnout.

E. DATA ACQUISITION SYSTEM

The data acquisition system criteria is sufficiently detailed to establish its integration into the I & C system, operational requirements, system concepts, subsystem criteria, system criteria, and ROM costs of its equipment.

The data-acquisition system is assumed to include all diagnostic measurements extending from the individual facility and engine transducer outputs through data presentation, reduction, and analysis. Temperatures, pressures, flow rates, radiation, vibration thrusts, liquid levels, valve and actuator positions, and rotational speeds are parameters that are considered. Consideration is also given to data conversion, displays recording, and parameters that are to be displayed and/or recorded. Data quick-look on-site requirements and criteria, and the photographic requirements are established.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	1.2.3

1.2.3

Integration with ETS-2

Test Stand ETS-1 is closely associated with Test Stand ETS-2 since they are both part of the same Complex in which certain buildings, equipment, and services are coordinated and shared. For this reason the ETS-2 Complex will be based on, and be compatible with, that criteria previously established for the ETS-1 Complex.

In general, the facility identified as the ETS-1 Complex will be added to, or expanded, in certain areas to provide an integrated ETS-1 and ETS-2 Complex. See Figures ICC-196, 206 and 207 for overall illustrations of the integrated facility.

Controls Systems will lead directly from the Test Stands and the farm area to separate Control Centers in the Control Point Building on a no-share basis; portions of the Data Acquisition System will be shared and switched between ETS-1 and ETS-2. The data Acquisition Systems of ETS-1 and ETS-2 will both be serviced by the multiplexing, amplifying, and Analog-to-Digital equipment in the Forward Control Room together with recording and any other data handling equipment in the Control Point Building. Controls for the two Test Stands must go straight through to separate Control Centers, rather than being switched to one common Control Center. This is for the purpose of maintaining safe and reliable operation, and to economically provide both for simultaneous setup of the Stands (to meet schedules or rate of testing) and for sufficiently diversified test setup requirements.

In providing two separate Control Centers (as shown on Dwg. ICC-204), little (if any) duplication is involved since very few items are common to both facilities. Most Facilities items are separate; all Engine items are separate; most Safety items are separate; most TV, Timing, and Photographic distribution and controls are separate, etc. Therefore, combining the separate operations into one common control center would not result in savings of either space or money. In fact, safe and reliable operation would be jeopardized, and a significant loss in schedule and operational time

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.2.3

and money would result from the unnecessary interference introduced by a combined Control Center, thus negating the advantages of two widely spaced Test Stands.

1.2.3.1

Control Point Building

Initially, the Control Point Building will be modified slightly to accommodate the estimated equipment installation, and to provide operational separation between the Control Center Rooms provided for ETS-1 and ETS-2. The proposed equipment and control center layouts are shown on Drawing ICC-204.

The estimated equipment requirement necessitates the utilization of the electronic maintenance room for equipment installation.

If detailed design indicates that estimated equipment space allocation is inadequate and would affect operational separation or compromise provisions for space equipment bays, then a proposed recommendation for modifying the Control Point Building and revised equipment layout is shown on Drawing ICC-207. The Ready Room and Control Office space would also be duplicated in this extension. The arrangement shown in Drawing 207 would clear the Electronic Maintenance Shop for its original intended use, provide separate Recording and Terminal Room extensions, and in general, would provide better operational and maintenance capability.

All other instrumentation and control equipment required at the Control Point Building, but not directly in the Control Center, will be located in the Recorder Room.

Those functions located in the Control Center will appear in the control consoles and on vertical display boards. Vertical displays will include such items as graphic display panels and TV monitors. Items displayed on vertical graphic display boards will be limited to those that must be observed by two or more operators. This readily assimilated type of display is employed to cut down the reaction time of operators, thus providing a safer more reliable operation.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	1.2.3.2

1.2.3.2

Tunnel

The section of tunnel extending from the Control Point Building to the Y will be shared. Maximum separation will be provided between control and data-acquisition cabling, and each of these two main divisions will be further separated into such groupings as low-level, high-level, pulsed-circuit, etc. In the future, a new extension of the tunnel from the knockout existing at the Y will be provided to ETS-2 (see Figure ICC-202). The section of tunnel at the FCR will require modifications similar to those suggested in the referenced figure.

1.2.3.3

Forward Control Room

The Forward Control Room will be shared rather than duplicated. However, sharing will require modification to the existing cable-carrying capacity in the adjacent tunnel-flow-crossover and room-entry, as described above and as shown in Dwg. ICC-202 and 206.

The addition of ETS-2 requires that serious consideration shall be given to locating the Data-Acquisition System equipment in such a manner that the maximum sharing of this most expensive equipment may be realized.

The Control Point Building is too distant from the test stands to serve as a satisfactory location for the initial Data-Acquisition signal conditioning equipment, because of the difficulties introduced by the long run of low level signals and the expense of the extra cable transmissions involved.

If Test Stand ETS-1 were being built without consideration of a future Test Stand ETS-2, then allowance for sharing of the Data-Acquisition equipment would not be required, and a large portion of it could be located in the Test Cell Building, with the remainder in the Control Point Building, and no equipment in the Forward Control Room. However, the addition of ETS-2 makes it advantageous to relocate Data Acquisition instrumentation equipment from the ETS-1 Test Cell Building to the Forward Control Room, where it can be directly shared with ETS-2 (see Dwg. ICC-202). Substantial long term saving over two identical systems is realized, since only one system must be serviced, maintained, and provisioned with spares.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.2.3.4

1.2.3.4

Test Cell Area

With regards to the Test Cell Building and the Equipment Building at the Test Stand site, ETS-2 will require new, but similar, provisions to those required, for ETS-1, since the functions performed at those widely separated locations are similar, but separate, for each Test Stand. The Test Cell Building for ETS-2 shall be oriented as shown in Dwg. ICC-196, and equipment in the Test Cell Room shall be located as shown in Dwg. ICC-203.

Local controls and indications will be provided in protected locations at the Test Stand for maintenance and test purposes. Any and all such controls that might result in dangerous or potentially unsafe conditions will be in series with remote controls at the Control Center, in such manner that the Lead Facilities Control Engineer at the Control Point must give his permission to create a controlled unsafe condition in the Test Stand, and conversely, so that the local mechanic can prohibit the Control Point from making the condition unsafe while he is working in or near the area.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A
Date 1 June 1962
Par.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3

1.3 IMPLEMENTATION AND SUPPORT REQUIREMENTS

1.3.1 Equipment Specifications

Maximum practicable use, commensurate with design requirements, shall be made of MIL approved parts or equipment. Commercial items may be used in lieu of MIL parts if they are not available, or if delivery would be seriously affected by qualification test time. The equipment should be standardized as much as possible, and the variety of parts (types, sizes, etc.) shall be held to a minimum, compatible with system requirements. This requirement shall also apply to proprietary, commercial, or off-the-shelf items, for which suppliers must be approved under the provisions of the quality-control program.

The equipment shall be in accordance with provisions of the Quality Assurance Program, as detailed in Section 1.3.3.

1.3.2Drawings1.3.2.1Definition

I & C Project Drawings are defined to be those developed for or used in conjunction with, or to illustrate the design of, components and assemblies of the I & C systems, and are those which will be prepared by the prime-contractor, or the prime subcontractor.

Instrumentation and Control drawings shall be of 3 basic types:

Reference Drawings - Reference drawings include basic system block diagrams, vicinity plans, orientation plans, legend sheets, etc., and are prepared for overall systems orientation and checkout purposes.

Fabrication Drawings - Fabrication drawings delineate information required for shop fabrication and assembly of I & C System parts and assemblies. Details required for field installation shall not be shown on shop fabrication drawings.

Installation or Construction Drawings - Installation drawings delineate a sufficient amount of detail to permit the appropriate subcontractors to properly install and fabricate the I & C System and components with the absolute minimum of field engineering determinations. Shop details or assembly information shall not be shown on installation drawings.

1.3.2.2General

- * Drawings shall comply with the following Military Drawing Standards, except as modified by these criteria:

MIL-STD-1 - General Drawing Practice

MIL-STD-2 - Engineering Drawings, Sizes and Formats

- * ~~MIL-STD-7 - Types and Definitions of Engineering Drawings~~

MIL-STD-8 - Dimensioning and Tolerancing

MIL-STD-9 - Screw Thread Conventions and Methods of Specifying

MIL-STD-10 - Surface Roughness, Waviness and Lay

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.3.2.2

- MIL-STD-12 - Abbreviations for Use on Drawings
- * ~~MIL-STD-14 - Architectural Symbols~~
- MIL-STD-15 - Electrical and Electronic Symbols
- MIL-STD-16 - Electrical and Electronic Reference Designations
- * ~~MIL-STD-17 - Mechanical Symbols~~
- * ~~MIL-STD-18 - Structural Symbols~~
- MIL-STD-19 - Welding Symbols
- MIL-STD-20 - Welding Terms and Definitions
- MIL-STD-24 - Revision of Drawings
- MIL-STD-28 - Drawing Titles, Approved Method for Assignment of
- MIL-STD-30 - Associated Lists (Data List, Index List, and List of Material)
- MIL-STD-31 - Numbering and Coding of Engineering Drawings, Associated Lists and Documents
- * ~~MIL-STD-103 - Abbreviations (For Electrical and Electronic Use)~~
- MIL-STD-106 - Mathematical Symbols
- * ~~MIL-STD-129 - Marking for Shipment and Storage~~
- * ~~MIL-D-70327 - Drawings, Specifications, and Associated Lists~~

Exceptions to the above may be made, with the approval of NOO, where commercially accepted drawings or equipment manuals are already available, as in the case of equipment considered to be standard, off-the-shelf, catalog items.

Where safety codes or trade standards are applicable, they should be referenced on the drawings.

The format of all drawings shall comply with MIL-STD-2 - Engineering Drawings, Sizes and Formats, in accordance with the sample furnished by NERVA Operations Office, and on a paper in conformance with Fed Spec UU-P-561, Type III.

All drawings shall be prepared on Military "F" size drawing sheets zoned in accordance with MIL-STD-2.

A symbol or legend sheet shall be included with all drawing packages defining symbols which are not Military or trade accepted. Source of all symbol references shall be noted.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.3.2.2

Sufficient detail shall be shown in order that the appropriate subcontractors can properly fabricate and install the I & C System. It is not necessary to delineate beyond the point which should be required by any competent contractor or subcontractor to install or fabricate. Excessive delineation shall be omitted. No shading shall be used.

1.3.2.2.1

*

Prior to preparation of drawings, I & C System Design Subcontractors shall submit to NOO, for approval, copies of the Drafting Room manuals to which it is proposed that the subcontractor's subsequent drawings shall comply.

* 1.3.2.2.2

Drawings shall specify MIL-STD reference code identification designations to be metal stamped or metal tagged near, or adjacent to all components requiring wiring or piping connections. These reference designations shall be the same as those referenced on the applicable schematics, flow sheets, and diagrams.

All drawings will be reduced to 11" x 17". Lettering shall be in strict accordance with MIL-STD-1, Section 5.5. Drawings must be legible after reduction. All linework shall be on the front side of the drawings.

1.3.2.3

Drawing Numbering

The NERVA Operations Office will assign a block of numbers to the Design Activity for use on the I & C System Drawings. Part numbering of hardware shall be in accordance with AGC DRM.

Multi-sheet drawings shall be avoided wherever possible.

1.3.2.4

Drawing Submittal

All drawings shall be submitted to a representative of NERVA Operations for approval signature prior to final release.

Ten sets of all final released drawings, reduced to 11" x 17", bound and indexed, shall be submitted to the NERVA Operations Office. Two cloth reproducibles and two 105-mm microfilm negatives shall be submitted to the NERVA Operations Office.

Preliminary submittals of prints or reproducibles shall be furnished the NERVA Operations Office for review upon request.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	1.3.2.5

1.3.2.5 Changes to Drawings

After release, all revisions to drawings will be accomplished by engineering authorization using an engineering order form, in accordance with the sample format to be furnished by NERVA Operations Office.

- * Revisions to the drawings which in any way effect the general layout, installation, or function must be formally reviewed, approved, and distributed in the same manner as the original submittal (see 1.3.2.4), before the drawing can be changed.

1.3.2.6 Parts Tabulation Sheets

The parts-tabulation sheets are a basic engineering and procurement reference used to list parts required for equipment, subsystems, or systems. They are to be generated in a series of entries; an entry being made on the Parts Tabulation Sheet as soon as sufficient information is available to procure any specific item. As detail design progresses, the parts-tabulation sheets will become more and more complete. When the design is complete, the Parts Tabulation Sheets will be a complete list of material (down to the screws, wire, etc.) necessary to complete the work. Items are to be listed chronologically as they become known; not by parts, or the subassemblies and assemblies into which parts go, like a parts list which cannot be completed until the detail design is finished and thus is not normally available until late in the program.

The parts tabulation serves two basic functions:

- (a) It is a current engineering and procurement reference sheet of parts sufficiently well identified to permit their procurement
- (b) It is a current revised estimate of the total anticipated costs of materials.

The activity responsible for the design will prepare parts-tabulation sheets in accordance with the format shown on

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3.2.6

Figures 1.3-1 and 1.3-2. A NERVA Operations representative will approve items as they are added to the parts-tabulation sheets, and will authorize immediate procurement as appropriate.

The parts-tabulation sheets will be submitted bi-monthly to the NERVA Operations Office for information purposes.

The activity responsible for the Parts Tabulation Sheets shall observe the following rules in their preparation:

- (a) Items will be added and consecutively listed at the time they can be adequately specified for procurement
- (b) Item numbers will never be changed or re-assigned
- (c) Deletions, changes, etc., are made by explanatory notes. A line is to be drawn through a deleted item (the item should remain legible even after it has been so deleted).

1.3.2.7

Parts List

The Parts List is a listing of all parts and subassemblies that go into the major or final assemblies. The listing is prepared in outline form with the parts or subassemblies indented and listed below the assembly or subassembly into which they go. See Figure 1.3-3.

This Parts List does not replace the parts list shown on the drawing.

The Parts List will carry the same number as the Top Assembly Drawing.

The Parts List is to be prepared on 11" x 17" sample format, furnished by NERVA Operations Office; see Figure 1.3-3.

Submittal to the NERVA Operations Office shall be the same as required for drawings; see Paragraphs 1.3.2.4 and 1.3.2.5.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3.2.8

1.3.2.8

Fabrication Drawing Requirements

Next assembly or assemblies shall be noted on all subassembly detail and diagram drawings. The applicable installation drawing shall be noted on all major assembly drawings (complete for installation).

Multi-detail drawings are acceptable provided that the sheet is divided by heavy lines separating each detail. No line or dimension of any detail may be closer than 2" to any other detail. Each detail shall have the appropriate title and identifying number appearing directly below it. Details and dimensions shall be spaced in such a manner as to avoid overcrowding.

Lists of materials are to be on all fabrication drawings. Each separable part shall be assigned an item number (finding number). The item number will appear on the face of the drawing in 1/2" diameter balloon leader-lined to the applicable item. The leader line shall be omitted on multi-detail drawings.

Material list and part identification to be in accordance with MIL-STD-2, and in accordance with sample format furnished by NERVA Operations Office.

All linear dimensions are to be given in inches. Tolerances shall be specified, where necessary, to ensure proper field installation of I & C System components and assemblies.

The titling of all fabrication drawings shall be in accordance with the following example:

Typical for all
fabrication
drawings

ETS-1 COMPLEX
I & C SYSTEM FABRICATION

Specific title
per
MIL-STD-28

PANEL, SWITCH - SAFETY CONSOLE

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3.2.9

1.3.2.9

Installation Drawing Requirements

Applicable reference drawings shall be listed by number and title in the lower left hand of each installation drawing.

All physical dimensions are to be given in feet and inches. Tolerances shall be specified, where necessary, to ensure proper field installation of I & C System components and assemblies.

Drawings shall specify the physical identification of all routing devices, cable trays, conduits, etc.

The titling of all installation plans shall be in accordance with the following example:

Typical for all installation plans	{	ETS-1 COMPLEX I & C SYSTEM INSTALLATION
Specific area	{	TEST STAND MECH. EQUIP. ROOM
Specific func- tion or type of work pre- sented on the drawings	{	CABLE TRAY PLAN

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3.3

1.3.3 Quality Assurance

1.3.3.1 Purpose

To specify the required Quality Control and its scope, to be employed for the fabrication and installation of all equipment, and to establish a standardized classification that will define a minimum quality control requirement for the contractual items.

1.3.3.2 Applicable Documents

The following standards, specifications, and publications are referenced as supporting documents, upon which this criteria was based:

Marshall Space Flight Center, Quality Engineering Bulletin, QEB-Nr. 2.

QC Activity Classification, Procedure 1-3b, Level III, Aerojet-General Corp.

DOD Supply and Logistics Military Spec. 105B, Sampling Procedures and Tables for Inspection by Attributes.

Spec. MIL-W-9411 (USAF), General Specification for Aeronautical Weapons Systems.

Spec. MIL-Q-9858, Military Specification for Quality Control Requirements.

USAF Spec. Bulletin Nr. 515, Control of Nonconforming Supplies.

1.3.3.3 Procedures

1.3.3.3.1 Classes of Equipment

Following are the classes of equipment considered:

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3.3.3.1

All equipment fabricated and assembled for use by and in the experimental test program at Aerojet-General's subcontractor or any customer facility;

Any equipment fabricated and assembled for delivery and use by the customer or his designated representative.

1.3.3.3.2

Program Activities in Detail

The following activities shall be conducted:

An effective quality control system shall be initiated which will assure that adequate control of quality is maintained throughout all phases of contract performance.

Procedures shall be written for control of the QC system encompassing the total range of actions of the quality control program.

An effective and adequate program shall be established for the maintenance and control of all inspection tools and test equipment, including production tools and equipment having a direct bearing on the quality of the equipment produced. This program shall also encompass any fabrication tooling used as a medium of acceptance inspection.

The Quality Control program shall ensure through design specification review that design specifications contain requirements for determining and controlling quality of all items procured or produced for either the experimental test program or for delivery to the customer or his designated representative. Special process specifications shall be reviewed on processes not covered by existing applicable specifications with emphasis placed on processes which would affect product quality.

The Quality Control program shall exercise review authority on all procurement documents to assure that all necessary reliability and quality requirements are contained therein. All suppliers shall satisfy conditions as called for in the listed QEB-Nr 2, Paragraphs 2.4.2, a and b, or equivalent.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3.3.3.2

In procurement of standard and commercial parts or equipment, maximum practicable use, commensurate with design requirements, shall be made of military standard parts and commercial parts that are in common use or readily available. The variety of types and sizes of parts shall be held to a minimum compatible with system requirements. This requirement shall also apply to proprietary, commercial, or off-the-shelf items, for which suppliers must be approved under the provisions of the Quality Control program.

The system shall provide for control of changes to drawings, specifications, test procedures, and procurement documents, and shall assure that all changes are incorporated into all documents mentioned and in addition, incorporated into production planning and inspection planning and instructions. For articles of supplier design, the control shall assure notification of the buyer (contractor) by the supplier of the proposed change and approval of the change by the contractor. A system of maintaining and documenting all changes shall be established.

Concerning control of nonconforming parts or equipment; the system shall establish a policy for the control, review, and disposition of nonconforming materials:

- (a) Nonconforming materials or equipment, as classified under the first paragraph of Section 1.3.3.3.1 of this document shall be reviewed and disposed of by action of Engineering Review. This review shall be conducted by a qualified representative of the Project engineering staff and a qualified representative of the Project Reliability and Quality Assurance Department.
- (b) Nonconforming materials or equipment, as classified under the second paragraph of Section 1.3.3.3.1 of this document shall be reviewed and disposed of by action of Material Review. This review shall be conducted by a board composed of the customer or his authorized representative, a representative of the Project engineering staff, and a representative of the Project Reliability and Quality Assurance Department. See the listed USAF Bulletin Nr 515, Control of Nonconforming Supplies.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 1.3.3.3.2

- (c) Nonconforming materials which fail to conform to acceptance criteria and cannot be satisfactorily disposed of by Engineering Review or Material Review will be handled in accordance with the provisions of the contract concerning acceptances, waivers, changes, deviations, etc., which require formal contract authorization. Provisions shall be made to remove all nonconforming material from the fabrication or assembly area, and a bonded area shall be provided for storage until disposition is completed.

1.3.3.3.3

Inspection and Test Procedures

Inspection instructions shall be prepared for the acceptance of all incoming materials; specific inspection instructions shall be prepared where the primary concern is with safety and performance; and integrated inspection planning shall be required for all shop orders used for fabrication or assembly. Complete inspection procedures shall be provided for all tests performed. All acceptance criteria must be clearly defined, and procedures for incorporation of drawing, specification, etc., changes shall be clearly defined.

Complete records of all tests, engineering or experimental shall be maintained throughout the life of the program.

Procedures and control of acceptance sampling shall be established for all phases of the program.

A procedure shall be established to initiate immediate corrective action and preventive measures of deficiencies found in fabricated articles, assemblies, or tests, and a follow-up program established to assure that recommendations are being followed.

1.3.3.3.4

Additions to, and amplification of, this document shall be made as the needs or requirements of the program demand.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3.4

1.3.4 Final Acceptance Testing

1.3.4.1 Purpose

Final acceptance testing of the Instrumentation and Control System for Test Cell ETS-1 shall be conducted at the Nevada Test Site, with the purpose of demonstrating a complete and successful operational sequence before witnessing SNPO representatives (or their designated authorized representatives) and NERVA Operations Office representatives.

1.3.4.2 Final Acceptance Test Procedure

The Final Acceptance Test Procedure shall be prepared by the contractor who furnishes the major portion of the I & C System equipment, and under the direction of NERVA Operations Office and subject to approval by SNPO representatives. These procedures are to be completed and approved four weeks before the scheduled test day.

The acceptance test procedure shall be made up of checkout, readiness, test-run, shutdown, and safety demonstration procedures. These procedures will be a part of, and will be tied together by, the requirements set forth in Paragraph 1.3.4.2.3, Test Sequence.

1.3.4.2.1 Checkout Procedures

Checkout procedures shall be prepared as part of the Final-Acceptance Test Procedure. Each subsystem shall have a checkout procedure for set-up, calibration, and checkout of the equipment in that subsystem. Each procedure shall be a self-supporting document prepared in a step-by-step format. Since this procedure will be the supporting document for checking out the equipment prior to the nuclear test runs, therefore it will be used not only as part of the acceptance test, but also as a permanent document for the checkout of the subsystem and system prior to tests.

1.3.4.2.2 Readiness Procedure

A Readiness Procedure shall be prepared as a part of the Final Acceptance Test Procedure. The Readiness Procedure

shall describe the steps necessary to check various points of the system for satisfactory performance leading to firing of the nuclear engine as described in the Test Operation, Phase 2, of Appendix 2.1. The procedure shall be a self-supporting document prepared in a step-by-step format. Since the Readiness Procedure will be the reference document for the readiness sequence of the nuclear test runs, therefore it will be used not only as a part of the acceptance test, but also as a permanent document in support of the nuclear test runs.

1.3.4.2.3

Test Run Procedure

A Test Run Procedure shall be prepared as a part of the Final Acceptance Test Procedure. The Test Run Procedure shall describe the operation of the test run, and shall follow the sequence described in the Count Schedule, Phase 3, of Appendix 2.1. The procedure shall be a self-supporting document prepared in a step-by-step format. Since the Test Run Procedure will be the reference document for the running phase of the nuclear test runs, therefore it will be used not only as a part of the acceptance test, but also as a permanent document in support of the nuclear test runs.

1.3.4.2.4

Shutdown Procedure

A Shutdown Procedure shall be prepared as a part of the Final Acceptance Test Procedure. The Shutdown Procedure shall demonstrate the steps necessary for both a controlled and a Scram shutdown. The Controlled Shutdown procedure will follow the sequence described in Test Operation, Phase 4, of Appendix 2.1. The procedure shall be a self-supporting document prepared in a step-by-step format. Since the Shutdown Procedure will be the reference document for shutdowns for nuclear test runs, therefore, it will be used not only as a part of the acceptance test but also as a permanent document in support of the nuclear test runs.

1.3.4.2.5

Safety Demonstration Procedure

A Safety Demonstration Procedure shall be prepared as a part of the Final Acceptance Test Procedure. The Safety

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962
Par. 1.3.4.2.5

Demonstration Procedure shall demonstrate the various safety devices and methods used in initiated Scram actions. The procedure shall include various simulated conditions that will present failures and catastrophic indications leading to Scram functions. All alarms, displays, and other warning devices are to be demonstrated for acceptable operation.

1.3.4.3

Test Sequence

The demonstration of the Instrumentation and Control System shall be organized in the Final Acceptance Test Procedure in a sequential manner. It shall require, first, that all sub-systems shall be demonstrated by use of the checkout procedure. After each subsystem has been acceptably tested, the countdown will begin, in which a simulated nuclear engine shall be used, with programmed conditions and actions. As the countdown progresses, various simulated actions will test the system's safety features, reliability, adaptability, and operational capability. At some designated time during the simulated nuclear engine test run, a Scram shutdown shall be demonstrated. At the completion of the simulated run, controlled shutdown procedures shall be demonstrated. This shall include a demonstration of the monitoring and control instruments used for removal of the engine and area radiation detection.

1.3.4.4

Test Assignments and Responsibilities

The prime subcontractor shall provide personnel for the acceptance test demonstration. During the system test demonstration, the personnel assigned to the various stations shall function in the same manner as they would in an actual engine firing test. These personnel shall include the Test Director, Chief Test Engineer, Chief Safety Engineer, etc., as described in the Count Schedule document in Appendix 2.1. During the course of countdown, these test people will be assigned to their respective positions to control and react to predetermined contingencies, which will have to be planned to demonstrate the various Scram features of the system. The system test procedures, therefore, will require provisions for consideration, first, of proving the technical capabilities of the equipment, and secondly, demonstrating human factors and ease of operation.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3.5

1.3.5 Operation & Maintenance Manuals

1.3.5.1 Purpose

The purpose of the manuals shall be to provide sufficient information for the technicians to perform pre-operational functions, such as calibration, operate the equipment, and maintain it in the proper operating condition.

1.3.5.2 Contents

The contents shall include, but not necessarily be limited to, the following: operational instructions, checkout procedures, maintenance instructions, troubleshooting instructions, wiring diagrams, schematics, parts lists, and lists of recommended spares.

1.3.5.3 Organization of Manuals

The manuals furnished with each of the individual equipment modules shall be grouped together according to their use in the subsystems. That is, each subsystem will have an Operation and Maintenance Manual (or Manuals) made up of individual commercial instruction books plus other information as necessary and appropriate, to provide continuity and system considerations. Manuals shall include subsystem descriptions explaining the overall operation, and shall also include the checkout procedure to be used in the acceptance testing.

1.3.5.4 Quantity Required

Ten complete sets of the Operation and Maintenance Manuals shall be provided, and with the following distribution:

Nevada Test Site Library	- 2 sets
Nevada Test Site ETS-1 Control Center	- 3 sets
NERVA Operations Office	- 5 sets

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3.5.5

1.3.5.5 Manual Covers

Hard cover expandable bindings shall be used. The cover should be entitled "Operation and Maintenance Manual", with suitable subtitles. Cover layouts shall be subject to approval by NERVA Operations.

1.3.5.6 Three sample manuals shall be submitted to NERVA Operations for approval 60 days before final submittal of the complete set. The sample manuals shall include a master table of contents for the entire set and one complete subsystem description. The subject manuals will be reviewed by NERVA Operations and returned with approval or comments within 15 days after receipt of same. The final submittal of the manuals will be subject to review and approval by NERVA Operations within a 30 day period.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3.6

1.3.6 Spares

1.3.6.1 Purpose

The purpose of this section is to prescribe the procedures governing the selection and furnishing of spare parts for support of the NNRDC ETS-1 Instrumentation and Control System.

1.3.6.2 Scope

This Section (1.3-6) of the Criteria Document will be incorporated into contracts for all articles of equipment for the Instrumentation and Control System. The procedures written herein shall be used for selection of all parts, assemblies, and components required as spares to insure operational status.

1.3.6.3 Documentation - Spare Parts List

Parts, assemblies, and components required as spares to insure operational status shall be itemized on the Spare Parts List. Each supplier or vendor will be required to furnish a recommended spares list. The spares list will be reviewed and approved under the direction of NERVA Project personnel.

The Spare Parts List shall be prepared in accordance with the form shown in Figure 1.3-4. A vellum of the form will be furnished to each supplier or vendor. Reproducible lists of the recommended spares shall be made from the supplied vellum. The supplier or vendor shall fill in the applicable columns as follows:

- (a) Item Number - Each item in the Spares List shall be assigned an item number in sequence beginning with 1.
- (b) Part Location Code No. - This column will not be filled in by the vendor, but by NERVA Project personnel. Its use is for identifying the building, the rack, or other means of identifying the parts' physical location in the complex.
- (c) Reference Symbol Nos. - Electrical and electronics components bearing reference designations (such as R-1, C-10, X-5, etc.) shall be arranged in alpha-numerical sequence.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3.6.3

This column shall contain all reference and designation shown on the schematic drawings. If several parts are identical (say R-1, R-2, and R-5 have the same value) they will all be listed under the same Item Number.

- (d) Part No. - This column shall contain the manufacturer's drawing number, including dash numbers assigned to each part in accordance with contract drawing specification.
- (e) Part Description - Enter name (noun) and modifier assigned to each part in accordance with contract drawing specifications.
- (f) Tolerance - When the component, assembly, etc. has a designated tolerance it shall be indicated in this column.
- (g) Quantity - The total quantity of the part shall be indicated in this column.
- (h) Recommended Manufacturer - The recommended manufacturer of the part or equipment will be indicated in this column.
- (i) Manufacturer Part No. - The manufacturer's part number shall be indicated in this column.
- (j) Manufacturer Code No. - The code number to be inserted in this column shall identify the manufacturer of the line item, corresponding to the name of the manufacturer indicated in (h), Recommended Manufacturer. Codes to be used in this column shall be those in Federal Cataloguing Code Books H4-1 and H4-2, except that if no such code is listed therein for the manufacturer, a line shall be drawn through the space.
- (k) Federal Stock No. - If the part has a Federal Stock No., the number shall be indicated in this column.
- (l) Unit Price - This column shall contain the actual unit price.
- (m) Total Price - This column shall contain the actual total price.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3.6.4

1.3.6.4 Submittal

The recommended spares list shall be submitted to NERVA Operations 30 days before the scheduled delivery of the articles of equipment to the site.

1.3.6.5 Revisions

All revisions to the spares list shall be submitted in the same format and manner as the original lists.

1.3.6.6 Approval

The submitted recommended spares list will be reviewed for approval within 10 days after submittal to NERVA Operations. All revisions or changes will be recommended during this period.

1.3.6.7 Spare Parts Procurement

On approval of the recommended spares, the procurement of the spares shall be initiated by NERVA Operations.

1.3.6.8 Operational Spares

Operational Spares for 6 months operation shall be supplied with the equipment initially ordered for the Test Cell ETS-1.

1.3.6.9 Packaging and Preservation

The spare parts shall be packaged to the best commercial standards for shipping and storage. The method of packaging will be subject to approval by NERVA Operations.

1.3.6.10 Shipping Instructions

Shipping instructions and F. O. B. points will be furnished with the issuance of the spare parts order.

1.3.6.11 Quality Control

The spare parts shall abide by the provisions of the Quality Assurance Program detailed in Section 1.3.3.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3.7

1.3.7

Human Engineering Design

This section is intended to aid the designer in making optimum decisions wherever human factors are involved in man-machine systems and to provide continuity of design in equipment and environment.

Appendix 1.1 includes general recommendations for the design of ambient environment, workspace criteria, equipment criteria, and several specific design recommendations for the Control Point Building, test cell, fill station areas, and equipment hardware. The subject matter is presented in the following order: ambient environment, workspace criteria, equipment criteria, specific design recommendations.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	1.3.8

1.3.8

Equipment Bays and Terminations

When two or more racks of equipment are interconnected and form a system, subsystem, or a part thereof, they shall be mounted in rack bays (two or more racks permanently bolted or welded together). All equipment in a system or subsystem shall be completely wired together at the Manufacturer's facility. The only wiring allowed at the site will be wiring between major equipment bays, or for the purpose of tying systems together. Equipment so tied together shall be completely checked out and tested as a system at the Manufacturer's facilities.

For example, the Digital Data System shall be supplied in one control console and two equipment bays, one of which will include the digital recorders, formatting, and system control, while the other bay will contain the computing equipment. The Digital System Control Console will be placed between the two equipment bays, and the console will contain the computer control and digital system control. The complete system shall be completely checked out at the Manufacturer's facilities and be supplied (in the manner explained above) to the site for installation.

Each termination and patch rack bay shall be constructed and wired as a unit at the Manufacturer's facility. The In and the Out termination blocks and patch panel shall be so wired that only external wiring to the bays will be necessary in the field installation.

Terminal receptacle in the enclosures shall be of a type equivalent to Kulka Electric Corp. modified 600 series with two horizontal Klip Tites; the screw type termination shall be avoided wherever possible. An AMP preinsulated Faston, or equivalent, shall be used to match the Klip Tites and signal wire size.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par.

PARTS TABULATION SHEET FORMAT

PARTS TABULATION		TITLE		ISSUE NO		DATE		(DESIGN ACTIVITY NAME)					
DRAWING NO				ENGR									
SHEET		OF		APPROVED									
QTY	DESCRIPTION	MODEL NUMBER SPECIFICATION NO FIRST USED ON	NOTE †	P O R NO DATE	VENDOR	P O NO DATE	DATE REQ'D	VENDOR DATE	DATE REC'D	EST COST	ACTUAL COST	APPROVAL	
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													

3/4" MARGIN

● INDICATES ADDITIONS OR REVISIONS TO EQUIPMENT LIST SINCE LAST ISSUE ONLY
† SEE SHEET 1 FOR RELATED NOTES

DISTRIBUTION

Figure 1.3-2

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par.

PARTS LIST FORMAT

PARTS LIST		TITLE		ISSUE NO	DATE	(DESIGN ACTIVITY NAME)
DRAWING NO	SHEET NO			ENGR		
				APPROVED		
NO.	NO. REQUIRED THIS ASSEMBLY	DESCRIPTION	TOTAL NO REQ'D	DRAWING NO PART NO. SPEC. NO	VENDOR/MANUFACTURER	REMARKS
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						

3/4" MARGIN

NOTES
1 * SEE REMARKS COLUMN FOR SHEET & ITEM NO. OF INSERTION. INSERTION IS TO FOLLOW ITEM MARKED *
2 DESCRIPTION CALLOUTS ARE IDENTIFIED BY SHEET NO & ITEM NO, EXAMPLE 4-16 * SHEET 4, ITEM 16

DISTRIBUTION

Figure 1.3-3

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.4

1.4 CONTRACTOR FURNISHED EQUIPMENT

1.4.1 General

The Digital, Timing, RF Communications, and TV Systems shall be furnished only by vendors who have satisfactorily built and delivered similar systems of equivalent accuracy and complexity, which have been in use for a period of one year without major modifications.

These systems must be obtained from contractors who manufacture at least 50% of the items comprising the particular system they propose to supply. This applies to the I & C system contractor, as well as to his sub-contractors.

All major equipment supplied by the I & C System contractor, or his sub-contractors, shall have NOO approval prior to procurement. Any item not manufactured by a sub-contractor and furnished under this contract shall be listed with the manufacturer's name, model number, and technical specifications. No substitutions for items on this list should be made after award of contract, unless specific approval is granted by NOO.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	1.5

1.5

CONTRACTOR DESIGNS

The Contractor shall submit, for approval, complete subsystem and system schematic diagrams, block diagrams, and flow diagrams prior to detail design based on these criteria.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.0

2.0 INSTRUMENTATION & CONTROL SYSTEM, ETS-1 COMPLEX

2.1 SCOPE

* These criteria are the presentation of that information which represents the basis for detailed equipment design, personnel organization, and logistics support for the ETS-1 Instrumentation * Control System. The instrumentation and control equipment at ETS-1 Complex comprises those remote engine and reactor controls which are not a part of the engine or reactor integral controls, all facility controls, all instrumentation (including television, photographic, timing, and communications systems), and the ETS-1 safety-system display and controls.

** Space is provided in an advantageous location in consoles and racks for housing the equipment of the engine and reactor control systems in such manner that these controls may be changed as required during the developmental stage.

2.1.1 Purpose

* The purpose of the ETS-1 Facility is to provide a capability for the safe conduct of full-scale, full-power testing of nuclear-rocket engines, which will include a fission reactor, liquid and gaseous hydrogen feed systems and the associated engine structure, nozzle and drum controls. During the series of tests to be conducted at ETS-1 complex performance data will be accumulated on the propulsion-reactor system design, and limited engine reliability data will be obtained. From this data, design improvements will be defined and validated in later tests. Engine checkout procedures, as well as related facilities, will be validated.

2.1.2 Function

In order to fulfill the purpose of full-scale, full-power nuclear rocket-engine static testing, the facility must provide the functions of propellant storage and transfer, remote engine operation, extensive data-acquisition, and remote handling facilities and storage. The facility must be capable of rapid reuse without constituting a radiation hazard to test-stand personnel, and must be flexible enough to accept a variety of physical engine configurations. The instrumentation provided will measure both engine and facility mechanical hydrodynamic, thermal, and nuclear radiation parameters.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.1.3

2.1.3

I & C System Equipment Interfaces

The purpose of this section of the Criteria is to present a logical functional breakdown of the equipment which will constitute the ETS-1 Instrumentation & Control System, defined as the Remote Engine Control, Facility Control, and Data Systems (Sections 3.0, 4.0, 5.0, and 6.0 of this document). The groupings of this paragraph establish subsystems which can generally be handled later as separate design and installation packages, to be described by a set of specifications and drawings. Further, the interfaces between these subsystems are outlined, so that subsequent systems engineering design efforts will recognize:

The requirements placed upon the sub-system by all other subsystems.

The demands of the sub-system made upon all other sub-systems.

As a simple example, the photographic subsystem imposes certain demands for various types of timing codes upon the timing sub-system, for camera operating power and bunker lighting upon the primary power subsystem, for bunker shielding upon the facilities subsystem, etc. On the other hand, the engine subsystem, flow-controls subsystem, and safety subsystems establish photographic coverage requirements which can only be met by providing specific types of film, camera speeds, resolution, camera locations, etc.

Dwg. ICC-101 shows the functional equipment groupings (sub-systems) which form the I & C system of ETS-1 complex. The primary interfaces are shown by the interconnecting lines. In addition, the NERVA nuclear-rocket engine and the facility (defined to be that equipment, process fluids systems, distributed power, etc., which are described presently in the Test Cell "D" detailed A & E Design Criteria prepared by AETRON for the AEC) are shown in the dotted boxes. The subsystems are covered in the following sections:

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.1.3

Subsystem	I and C Criteria Sections
Services and Support	2
Safety	2.2.7
Nuclear Effects Test Capability	2.2.8
Remote Engine Control	3
Facility Operations and Controls	4
Facility Controls (Support)	4.3.3, 4.5.3
Facility Controls (Flow)	4.3.1, 4.4.1, 4.5.1
Communications	4.2.2.1, 4.3.2.1, 4.4.4, 4.5.2.1
Timing	3.4.5, 4.3.2.3, 4.4.3, 4.5.2.3
Electrical Power	2.3.1, 3.4.6, 4.3.2.4, 4.3.4, 4.4.5, 4.5.2.4
TV	3.4.3, 4.3.2.2, 4.4.2, 4.5.2.2
Data Acquisition	5
Data Electronic	5
Photographic	6

In order to clarify the systems engineering relationship between the subsystems listed above, these definitions are applicable:

- (a) Engine - The flight propulsion unit, including the reactor, engine-mounted power, and thrust-vector control actuators; the nozzle, pressure shell, and support structure, (including gimbal, if any); engine-mounted transducers, flight cabling, and electrical equipment; such lines and valving as must be a part of the flyable engine; remote master engine programmer and engine GSE supporting the flight engine.
- (b) Remote Engine Control System - All engine-control equipment and visual display instrumentation not a part of the engine or later vehicle-mounted engine thrust level and thrust-vector control subsystems. Includes controls for certain facility flow-control valves used for propellant coolant and purge gases which are fed to the engine; manual override and "scram" controls. Considerable circuitry and signal conditioning equipment are shared with the landline data subsystem (see below).
- (c) Facility - Test-stand support structure; equipment shelter; fluid storage and run piping, ducting, flumes, and valving not part of (a), (b) above. Generally, all of the test complex already described in the A & E Test Cell "D" plans prepared by AETRON for the AEC.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.1.3

- (d) Facilities Support - Remote handling equipment, air conditioning, lighting controls. Other controls and displays not covered elsewhere in subparagraphs (a) - (n).
- (e) Flow Control - Controls and displays for facility process fluid transfer and use which are not part of (a), (b) above. Generally these are the remote controls for operating the process fluid subsystems in (c) above.
- (f) TV - Television cameras, transmission links, monitors, kinescopic recorders and TV controls (zoom, pan, tilt, on-off).
- (g) Timing - Generation and distribution of various timing signals.
- (h) Communications - Hardwire intercom, public address, and such RF communications links as are required to support scheduled ETS-1 test operations.
- (i) * Electrical Power - Instrumentation and Control system power distribution from the present 4160-v, 3- ϕ , 60 $\sim$, 3-wire-instrument bus, together with all diesel power generation and distribution. Does not include special purpose power supplies provided with the landline data system.
- (j) Neutronics - Nuclear radiation detection equipment used primarily for monitoring reactor power level and providing safety system input data. Does not include detectors or the dosimetry equipment used for specific nuclear effects test capability experiments [see (n) below] .
- (k) Landline Data - Signal conditioning, transmission, encoding, recording, etc. of test data. Does not include transducers (considered a part of the engine or facility). Certain data system transmission elements are shared with the remote engine control and flow control subsystems. The latter subsystems include signal conditioners, amplifiers, etc. of identical design to those also used in the data system.
- (l) Photography - Film cameras, film, lighting, shielding, periscopes, and associated camera controls.

**Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC**

Revision A

Date 1 June 1962

Par. 2.1.3

- (m) Safety - Safety display and control system including console, area-access indicators, radiation-level monitors, combustible gas detectors, personnel showers, evacuation alarms.
- (n) Nuclear Effects Test Capability - Mounting provisions, power, dosimetry for monitoring behavior of materials, typical air-borne hardware, etc., exposed to reactor-generated radiation field.
- (o) Patch Facilities - The contractor shall provide termination-patch facilities in which the patch system will be internally wired to both ETS-1 and ETS-2 terminations as a complete package, thus requiring no further field wiring other than the tying-down of ETS-1 and ETS-2 transmission lines.
- (p) Note that the consoles, control, and displays are considered part of the appropriate I & C subsystem.

**

2.2

EQUIPMENT AND OPERATION CONCEPTS

2.2.1Type of Tests

The ETS-1 Test Complex must be capable of supporting preparatory checkout, countdown-controlled testing, post-test securing activity and special tests. Typical of such tests are these:

(a) Test Complex Checkout and Calibration

- (1) Determine flow, heat-transfer characteristics of the LH_2 , LN_2 , LO_2 , propane and water systems (required orifice simulators at engine interface, special dump lines, etc.).
- (2) Series of engine-control system and facility-control system dynamic response tests in manual, programed, and automatic modes (requires an engine simulator).
- (3) Electrical and instrumentation system grounding and electro-interference surveys.
- (4) Data-acquisition system end-to-end accuracy tests, using voltage calibration system inputs.
- (5) Demonstration of facility and engine controls under simulated Scram command.
- (6) Test of emergency fluid dump and vent systems; test of emergency fire-fighting equipment.
- (7) Radiation-shield emplacement and removal and steam ejector system evaluation.
- (8) Duct cooling and structural cooling-system checkout.
- (9) Demonstration of remote engine-mating to the test cell, with mechanical and electrical umbilical checks; remote locomotive operation, duct removal. Remote restoration of test cell to pre-test configuration.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.2.1

- (10) Facility power system checkout, including switchover to emergency or secondary power supplies. May require load banks, dummy loads.
- (11) Checkout of TV, photo, and communications in conjunction with simulated maximum power run ("dry run").
- (12) Simulated radiation release accident evacuation, decontamination exercise.
- (13) Simulated equipment failure (engine or facility) and demonstration of proper corrective action.

(b) Engine Tests

- (1) Neutronics system calibration run subcritical operation for flux patterns and detector calibration.
- (2) Low power run (possibly with GH_2 cooling) including pre-irradiation of transducers; possibly duplicate power, temperature profiles at small fraction of full-scale values.
- (3) Power run at 40% checkout of fallout detectors, determination of possible core hot spots and drum binding.
- (4) Step, sinusoidal engine-control-drum actuation to evaluate dynamic response.
- (5) Full-power LH_2 run - various durations, various startup and shutdown cycles leading to optimum rapid power changes.
- (6) Thrust-vector-control system tests (possible sinusoidal gimbaling). Requires dynamic programmer.
- (7) Special purpose tests to evaluate nuclear effects on future airborne hardware, or to verify facility or engine system changes.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.2

2.2.2

Usage Factors

*

These criteria are based on accomplishing engine tests at both on the GTX (ground test-experimental) engine and E (experimental) engines. The ETS-1 facility will be required to support frequent full-power runs in addition to preparatory tests. Preparatory testing will include "zero" power, fractional power, and certain special startup and shutdown profile tests. See classified detailed schedules for further information on the planned usage factors for the ETS-1 facility.

2.2.3 Summary Description of ETS-1 Complex

2.2.3.1 General Areas

In a broad sense, the ETS-1 Complex will be composed of the following general areas as shown in Drawing ICC-190:

- (a) Test Cell Area
- (b) Storage Farm Area
- (c) Forward Control Area
- (d) Power Substation Area
- (e) Control Point Area
- (f) Tunnel

2.2.3.2 General Areas Breakdown

The aforementioned general areas can be broken down as follows:

- (a) Test Cell Area

 Test Stand

 Superstructure

 Foundation (Substructure)

 Shadow Shield

 Test Stand Building

 Test Cell Building

 Side Shields

 Plug Shield (Duct Cover)

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.2.3.2

Duct Vault and Flame Deflector Duct

Railroad Spur

LO₂ and LH₂ Gas Generator Run Tanks

(b) Storage-Farm Area

Hydrogen System

Oxygen System

Helium System

Nitrogen System

Propane System

Cold Gas System

Steam-Generator System

Hydrogen-Gas Flare System

Vacuum System

High-Pressure Gas System

Process-Water System

LH₂ Engine Run-Tank System

(c) Forward-Control Area

Forward-Control Room

Upper-Level Fill Station

Truck Weighing Scale

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 2.2.3.2

(d) Power-Substation Area

Substation

Diesel-Generator Building (I & C Power)

(e) Control-Point Area

Control-Point Building

Utility-Equipment Building

(f) Tunnel

(g) Hydraulic System

(h) Air System

(i) Pump Station

(j) Road

(k) Fluid-Handling System

2.2.3.3 General Description of Specific Items

(a) Test Cell Area

(1) Test Stand

The Test Stand will consist of: a superstructure for supporting the reactor engine, reactor-engine feed system, and run tank; and the foundation for supporting the superstructure and housing the flame-deflector duct and steam generators.

a Superstructure

The all-aluminum superstructure will be approximately 33-ft square and 120-ft high. Aluminum construction is required because of the radioactive environment. Power-driven roll-up doors will be

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.2.3.3

provided on each of the open sides of the superstructure near the base as weather protection for the engine assembly. A water-filled aluminum radiation shield will be mounted between the reactor-engine assembly and the run vessel. Access to the upper levels of the superstructure will be gained by way of stairs and an elevator. An insulated aluminum run tank, which will be pressurized to 50 psig operating pressure, will be installed in the superstructure above the engine assembly location to provide LH_2 for engine test runs. This tank will have a capacity of 70,000 gallons. Since some long-duration test runs will require more than 70,000 gallons, provision has been made for transferring LH_2 from the spherical 250,000-gal Dewar to the superstructure run tank during a test run to provide a continuous flow of LH_2 . GH_2 burnoff flares will be provided at the top of the superstructure for disposal purposes.

b Foundation (Substructure)

The foundation, in addition to supporting the superstructure, will house the deflector duct vault and steam generators.

c Shadow Shield

A reinforced concrete wall 3-ft thick and 30-ft high at the base of the superstructure, will act as a shadow shield between the reactor-engine assembly and the remainder of the complex.

(2) Test Stand Building

The underground Test-Stand Building will be located at the base of the test stand with approximately 3000 sq ft of floor space. The structure will be of reinforced concrete and be fully air-conditioned. Since all space in this building will be occupied by test-stand power equipment, elevator motors and starter equipment, etc., no space will be available

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.3.3

for Instrumentation and Control equipment. The tunnel will terminate in this Test Stand Building.

(3) Test Cell Building

*

The underground Test-Cell Building will be located approximately 85 ft from the Test Stand for the purpose of housing forward electronic signal conditioning equipment, transmission-cable termination and battery room. The Test-Cell Room (Electronics Room) will provide space for 68 instrumentation racks as shown in Dwg. ICC-203, and is available for Instrumentation and Control equipment. However, the Mechanical and Electrical Equipment Room in the Test-Cell Building will be full occupied by electrical and air-conditioning equipment, and no space will be available in that room. The tunnel will pass through this room. A Terminal Room will be available in each of two tunnel openings, one for termination of the cables from the test stand, and one from the Forward Control Room and/or the Control Point Building. The Battery Room will house 28-volt batteries which will be floated across the 28-volt dc power supply rectifier, providing control power. This building will be of reinforced concrete and is fully air-conditioned.

(d) Side Shields

Two semi-cylindrical side shields, one on either side of the test stand, will be provided for the purpose of containing the greater majority of the radiation during and immediately following a test run. These shields will be of aluminum construction filled with de-mineralized water for shielding and cooling, and will be mounted on remotely controlled railroad carts. A sealed cell will be formed around the engine assembly when the carts and shields are in the run position.

(5) Plug Shield (Duct Cover)

A remotely controlled aluminum-plug shield, mounted on railroad track will provide for closing off the hot radioactive duct inclosure directly below the engine. This

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.2.3.3

shielding, along with that of the duct vault shield door, which will close the lower end of the exhaust duct vault, will allow for earlier personnel access to the test stand, and area following a test run.

(6) Duct Vault and Flame Deflector Duct

Directly below the engine assembly, and part of the test-stand foundation, will be the duct vault, housing the flame-deflector duct, which will divert the hot unburned hydrogen gas away from the test-stand foundation. The deflector duct will be close-coupled to the engine assembly to provide a discharge system, and will be a dry-type one-pass water-cooled flame deflector. Ignition of the propellant gas will be accomplished at the discharge end of the deflector duct rather than at the nozzle of the engine. A steam ejector purge system located in the test-stand foundation will be provided to remove all air from the deflector duct at the start of the test run and all unburned hydrogen gas at the end of the test run. The deflector duct will be remotely controlled, thus permitting easy removal, replacement, repair, and decontamination. Water cooling of this duct will be accomplished by a single-pass demineralized water flow of approximately 40,000 gallons per minute. The discharge water will be drained off and away from the test stand in an open drainage ditch.

*

(7) Railroad Spur

A railroad spur will be provided, extending from the existing MAD Building to the test stand, for the purpose of transporting the cold reactor-engine assembly to the test stand and the hot reactor-engine assembly from the test stand back to the MAD Building, for remote-handling disassembly, inspection, and evaluation. The locomotive will be remotely controlled via RF link from the MAD Building up to the point where it will be brought to a stop and plugged in automatically to the hardline controls extending to the Control-Point Building. Final positioning of the engine assembly to the test stand will be remotely accomplished from the Control Center in the Control-Point Building. This aforementioned final positioning and mating of the engine assembly

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2:2:3:3

to the test stand will be accomplished by the independent motion of a unit mounted on the railroad flat-car. All electrical, hydraulic and pneumatic connections to the test stand will be accomplished during this remotely controlled mating process.

(8) Oxygen and Hydrogen Gas Generator Run Tanks

A 550-gallon 1200-psig LO₂ gas tank and a 4400-gallon 1200-psig LH₂ gas tank were originally mounted near the test stand to serve as run tanks for the hot-gas generator. The LH₂ tank will now be used for cooling the reactor as needed.

(b) Storage and Farm Areas

(1) Hydrogen System

a Liquid Hydrogen

A 250,000-gallon spherical aluminum low heat-leak Dewar will be provided with pressurization capabilities up to 100-psig for propellant storage and auxiliary run tank purposes. Normal run pressures used in this tank will be approximately 50 psig. Shielding will be provided around the lower portion of this Dewar to permit access to the LH₂ manifolds prior to, and at some time after, a reactor-engine test run.

An insulated aluminum run tank of 70,000-gallon capacity will be installed in the test-stand superstructure. This run tank will generally be pressurized to 50-psig operating pressure.

b Gaseous Hydrogen

GH₂ will be stored in one or more of six 3600-psig vessels and will be used for the pressurization of the LH₂ Dewar, as well as for purging the hydrogen systems before and after the test runs and cooling

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.2.3.3

the reactor after the test run. Total storage capacity of the six vessels will be approximately 3,000,000 SCF.

(2) Oxygen System

The LO_2 storage vessel will be a 20,000-gallon 200-psig Dewar, and will be used to fill the LO_2 gas-generator run-tank near the test stand.

(3) Helium System

A gaseous helium system will be provided for purging of the hydrogen system at those times when the low temperature of the hydrogen system would cause freezing out of the gaseous nitrogen. GHe will be stored in one or more of the six 3600-psig storage vessels.

(4) Nitrogen System

A nitrogen system will be provided for purging, pressurization of LO_2 and propane, and cooling of the reactor after a test run.

a Liquid Nitrogen

Nitrogen is stored in the liquid state, for convenience, in a 28,000-gal. Dewar.

b Gaseous Nitrogen

Gaseous nitrogen will be stored in one or more of the 3600-psig storage vessels. All six of these vessels will be approximately 5-ft in diameter by 80-ft in length.

(5) Propane System

A 15,000-gallon 400-psig storage tank will be provided for propane, which will be used as the fuel for the steam generators and the hydrogen-burnoff flares.

(6) Flare System

The flare system will provide for a disposal of hydrogen gas resulting from boiloff from storage and run tanks. The flares, burning propane, will be remotely ignited from the control areas.

(7) Steam Generator System

A steam-generator system operating on propane and LO_2 will consist of two steam generators and will be provided to remove all air from the deflector duct, thus pulling a partial vacuum to simulate high-altitude starting, and to remove all unburned hydrogen gas at the end of the run.

(8) Hydrogen Gas Flare System

Hydrogen-gas flare burnoff systems maintained by propane flares are provided for the safe disposal of hydrogen gas in the top of the test-stand superstructure, in the storage and farm area, and near the base surface of the test stand at the exhaust of the deflector duct.

(9) Vacuum System

Two vacuum pumps will be provided for evacuating vessels and lines prior to purging and filling. One pump will be located in the storage area; the other in the Test-Stand Building.

(10) High-Pressure Gas System

A storage facility will be provided for gaseous hydrogen, helium, and nitrogen at pressures of 3600 psig. These systems will be used to pressurize the liquid Dewars, to purge the various systems before and after test runs, and to cool the reactor after a test run. Storage capacity will be approximately 3,000,000 SCF. There will be six storage vessels, each approximately 5-ft-dia. by 80-ft long.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.3.3

(11) Process Water System

A 150,000-gal. water-storage tank will be provided to supply normal utility and fire-fighting water. A 2,500,000-gal. storage tank will be provided for demineralized water which will be used for cooling and shielding in the test-cell shields, deflector duct cooling, steam generator and deluge. A 42-in. header, approximately 8,000-ft long, will be fed by this tank. The de-mineralizing equipment will be located in the Utility Equipment Building in the Control Point area.

(12) LH_2 Engine Run Tank System

A 70,000-gallon LH_2 engine run tank is located in the test stand superstructure, directly above the reactor-engine assembly. This tank is normally pressurized by gaseous hydrogen to approximately 50 psig.

(c) Forward Control Area

(1) Forward Control Room

*

The Forward Control Room will be located in an underground reinforced concrete building at the side of the tunnel, midway between the Test Stand and the Control Point Building. This building will be located below the Compressor Building. The Forward Control Room will have space for approximately 72 instrumentation racks available for instrumentation and control use. Layout of these racks is shown on Dwg. ICC-202. Immediately adjacent to the Forward Control Room will be an Electronic Repair Room, the total area of which will be available for I & C use. The Mechanical and Electrical Equipment room, adjacent to the Forward Control Room, will not be available for I & C use since all the space is committed. Air conditioning and entrance to the tunnel is provided in this building.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.2.3.3

(2) Upper Level Fill Station

The Upper-Level Fill Station will consist of the air and high-pressure gas compressor rooms, and a mechanical and electrical-equipment room.

(d) Power Substation Area

(1) Substation

Commercial power at 69 kv, 3 phase, 60 cycle, will be provided to the substation where the voltage will be reduced by a 2500-kva transformer to 4160 volts for distribution throughout the test complex. Distribution at 4160 volts is made to separate utility and instrumentation control buses.

(2) Diesel Generator Building

* Three 150-kva, 4160-volt, 3-phase, 60-cycle 0.8-power factor, diesel generators will be connected to the I & C 4160-volt supply buses for Instrumentation and Control power during test runs and other critical periods.

(e) Control Point Area

(1) Control Point Building

* The Control Point Building will be an underground, reinforced concrete structure provided to house control-center personnel, remote-control equipment, and recording equipment. This building will be located relatively close (approximately 1,000 ft) to the test stand to facilitate the transmission of signals, while providing adequate blast and radiation protection for personnel during a test run. The two main rooms of this building will be the Recording Room and the Control Center. Capacity of the Recording Room will be approximately 110 instrumentation racks (see Dwg. ICC-204.) A subfloor space of 3-ft depth will be provided under both of these rooms to facilitate flexibility in the arrangement of equipment and to provide run-way for inter-connecting cables. A Terminal Room will be provided immediately adjacent to the Recording Room for the termination

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.3.3

cables coming from the forward areas. Immediately adjacent to the Recording Room will be an Electronic-Maintenance Shop which will be available for I & C use. The Control operations will be located in the Control Center. These will comprise, in part, a Test-Director's console; control consoles for instrumentation, facility, remote engine-reactor; safety subsystems; and the graphic display boards and other displays such as TV monitors, etc. This building will be completely air-conditioned, and shielded access to the structure will be provided. The tunnel will terminate just beyond this building.

(2) Utility Equipment Building

The Utility Equipment Building will be located above-ground, near the Control Point Building. This building will house the various utility equipments not requiring manning during a test run; it will not be occupied by personnel during a test run.

(g) Tunnel

A reinforced concrete tunnel, approximately 1000-ft long, 8-ft high, and 8-ft wide, will extend from the Control-Point Building to the Test-Stand Building. It will have lateral drifts connected to the air-intake structure, and will provide a passageway for wire transmission, air-conditioning ducts and cableways, and personnel. It will have entrances to, or exits from, the upper-level fill station, the forward-control room, the high-pressure gas-bottle farm, the LH_2 storage area, and the test-cell building. A parking area for vehicles will be located at the tunnel portal in the Control-Point area.

(h) Hydraulic System

* (deleted)

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	2.2.3.3

(i) Air System

A series of air compressors and tanks will be installed in the Compressor Building to provide 225-psig plant air to the entire ETS-1 Complex.

(j) Pump Station

A reinforced concrete structure will be located near the unloading station to house all gas compressors. This building will be above grade, ventilated, and connected to the tunnel.

(k) Road

A 24-ft wide paved access road, approximately 5,000-ft long, will be provided from the existing road "H" to the ETS-1 Test Stand.

(l) Fluid Handling Systems

(1) Filling of Storage Vessels

LH₂ will be transferred through the fill station from the hauling trailers to the storage Dewars by pressurization of the trailer tank. All cryogenic transfer lines will be vacuum jacketed. GH₂ will be supplied to the gas-storage bottles by vaporization of LH₂ from the trailers at the fill station. GH₂ will be transferred to the gas-storage bottles by taking the boil-off from the LH₂ Dewar through the high-pressure compressors to the storage bottles. Transfer of GN₂ from the supply trailer to the storage bottles will be accomplished with a trailer vaporizer and a booster compressor. Helium transfer will be accomplished in the same manner as will the gaseous nitrogen.

(2) Filling of Run Tanks

Transfer of all cryogenic liquids to the test-stand area will be accomplished by pressurization. LH₂ will be fed to the superstructure run tank by pressurizing the 250,000-gal. Storage Dewar. LO₂ will be transferred from the Storage Dewar to the hot-gas generator run tank by pressurization.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	2.2.3.3

(m) Weighing Station

Weigh scales are provided at the Weighing Station for the purpose of weighing the LH_2 and any other cryogenic fluid in the delivery trailer before and after unloading.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	2.2.4

2.2.4

Organization and Procedures for Engine Testing

The mission of the ETS-1 complex will involve derivation of useful information regarding the performance of engines during test runs. The total national investment in a given test engine will be large in terms of time, materials, manpower, and money. Irregularities in the performance of men or equipment at the time of testing could easily jeopardize or destroy the technical significance of an engine run, and could also compromise personnel safety. It is therefore of vital importance that every reasonable effort be made to insure integrity of the test program through suitable equipment, training, personnel, organization, and procedures.

In order to promote understanding of organization and procedures at the time of testing, it is necessary to describe the count schedule. The entire engine-test operations period will be subdivided into four intervals, as illustrated on Drawing No. ICC-154.

The count schedule, as shown in Appendix 2.1, will be initiated a day or two prior to the test run. The count will commence only after all required equipment has been installed and checked out as completely as possible, short of actual engine run conditions and environment. In addition, all activities necessary to program or set up individual systems to support the ensuing tests will have been accomplished. The entire checkout phase will then basically represent a process of re-checking only. The checkout phase should only identify recent equipment malfunctions or errors in equipment setup and calibration. The four count phases will be discussed later in more detail.

The following paragraphs delineate the approach to the organization and procedures to be followed in subsequent planning of the ETS-1 Complex and in all major test operations.

2.2.4.1

Test Organization

The test organization will be that specific group which will conduct test activities from the initiation of count to the end of a test operation. The basic concept in this organization is that

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.2.4.1

the overall responsibility for the safe and effective conduct of test operations will reside in one individual, the Test Director. He personally, or through delegation, will direct all activities throughout the count. Drawing No. ICC-155 depicts his organization. It may be noted from this drawing that the Chief Test Engineer and five Lead System Engineers will occupy the Control Center along with the Test Director and his assistant during the final phases of checkout and the subsequent phases of readiness, test run, and shutdown. These six engineers will follow specific step-by-step procedures, as issued by the Test Director (or his Assistant), in order to suitably conduct and monitor test operations.

The Lead Engineers will each be responsible for the activities of their respective operating teams. The vertical team organization shown on Drawing No. ICC-155 illustrates the immediate operating and monitoring support groups occupying other positions in the Control-Point Building (CP), as well as the remaining portions of the checkout team, whose duties usually cease when the forward areas are cleared and all operations are conducted from the CP.

(a) General Conduct of Count

In the early stages of the countdown, the entire organization shown on Drawing No. ICC-155 will be involved. During the preliminary portion of the checkout phase, each of the six Lead Engineers will direct the checkout of all hardware within his functional area of responsibility. This takes the form of step-by-step procedures and check list activities involving visual inspection, electrical checks, and mechanical checks. During this phase, personnel will be dispatched to numerous areas to insure proper positioning of certain manually operated devices, to visually inspect previously setup system consoles, and to proceed with any necessary re-calibration and late readiness procedures (e.g., film loading, etc.). As the countdown proceeds, check lists will be completed and certified in accordance with detailed procedures.

During the final portion of the checkout phase, final tests will be run on the more complex and/or less reliable or less stable equipment for proper operation. The last personnel will complete their task in the forward area. The last manual safety locks will be

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.2.4.1

opened and the forward area will be formally cleared of personnel. At this juncture there will be a high degree of assurance that all equipment forward of the CP is in proper order for the ensuing tests. The final checkout will continue from the CP with the primary operating team at their consoles in the Control Center and the supporting operators and monitors at their consoles or stations in other CP areas. The remaining members of the several checkout teams will stand by without further responsibilities.

The Test Director will then be able to receive reports from each Lead Engineer regarding individual functional readiness as well as final reports from other test site activities concerning such items as weather, air sampling aircraft, etc. Using this information, the Test Director will then be able to make decisions regarding continuation, hold, or aborting of the test.

After the test run phase, the shutdown phase will commence with the entire CP team still at their stations to accomplish suitable shutdown and securing of facilities.

(b) Count Instructions and Supporting Documents

For each reactor or engine test, a series of documents will be issued. These fall into four general categories:

Checkout Procedures
Readiness Procedures
Test Run Procedures
Shutdown Procedures

For a given test, these documents will represent an integration of standard procedures (e.g., facilities and support system operations), as well as special instructions and requirements pertaining to the particular tests to be run. The count schedule will be a step-by-step document wherein individual Lead Engineers and Support Operators are instructed to perform specific functions. The entire concept of the system and capabilities of the ETS-1 Complex must be based on the premise that step-by-step instructions are issued for the conduct of test operations. This implies that any actions or interpretations of performance which occur too quickly for such a sequence of operation need to be automatically programmed, controlled, sequenced, or handled in some other suitable fashion.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 2.2.4.2

2.2.4.2

Operating Team Job Descriptions

The following sections define the major duties, responsibilities, and authority of the individuals comprising the operating team during the Test Operations Period.

(a) Test Director (TD)

- (1) Verify that all prerequisite tests, calibrations, and equipment setups are complete.
- (2) As required, review test preparations and readiness with SNPO representative and with NTS management personnel. Obtain approval to run scheduled test.
- (3) Review data available on present and predicted weather, conflict with other NTS test operations, etc., which may affect conduct of the test.
- (4) Verify that all required personnel are at stations and that non-essential personnel have left.
- (5) Announce (personally, or through the Assistant Test Director) revisions of existing test procedures, all probable holds, etc.
- (6) Direct and monitor the conduct of the countdown, test run, and post-test run securing activity. (Lead Systems Engineers will report routine accomplishment of a countdown step, or minor difficulties to the Assistant Test Director.)
- (7) Direct emergency operations as required.

(b) Assistant Test Director (ATD)

- (1) Responsible for the final preparation, and then the execution, of the detailed step-by-step count schedule.
- (2) Report directly to, and work in association with, the Test Director; in this capacity can assume the Test Director's functions whenever such responsibility is so delegated by the Test Director.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.2.4.2

- (3) Direct the progress of the test by announcing (reading) each step of the count schedule at the designated time.
- (4) Maintain the check lists and logs based on status reports received from Lead Systems Engineers.
- (c) Lead System Engineers (General Responsibilities)
 - (1) Supervise all personnel in their subsystem functional areas during precountdown, checkout, readiness, test run, and shutdown phases.
 - (2) Operate console controls and monitor displays during test runs in accordance with count schedule requirements.
 - (3) Report accomplishment of all count schedule steps to Assistant Test Director.
 - (4) Report developing delays, equipment failure, and other problems to the Test Director.
 - (5) Carry out directions of the Test Director or his designate.
 - (6) Maintain check lists and logs with entries as required during the countdown. (The "log" during critical phases will consist of VOICE recordings.).
 - (7) Approve (sign) procedures or check lists on his subsystem as the work is completed.
- (d) Lead Safety Engineer (LSE)
 - (1) Responsible for all safety functions at ETS-1. This includes control of personnel safety (steel helmets, radiation detectors, etc.).
 - (2) Report directly to Test Director.
 - (3) Control safety lock-out key system.
 - (4) Monitor weather conditions continuously prior to test run and record data on vertical display.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 2.2.4.2

- (5) Monitor and control area safety by aerial and ground survey (helicopter, jeeps, TV, Etc.).
 - (6) Control area safety by system of traffic signals, gates, lights, sirens, and other signaling devices.
 - (7) Monitor radiation levels during pre-test run, test run, and post-test run operations.
 - (8) Monitor conduct of test operation to verify that safety requirements are met.
 - (9) Supervise emergency procedures whenever appropriate (fire-fighting, personnel injury, routine or non-routine de-contamination, etc.).
- (e) Chief Test Engineer (CTE)
- (1) Responsible for remote engine operation, which includes operation of critical facility items directly associated with engine operation.
 - (2) Report directly to Test Director.
 - (3) Direct the necessary checkouts required to assure subsequent safe engine operation.
 - (4) Monitor and/or control critical engine parameters throughout a test run; can directly initiate either a controlled shutdown or Scram as required.
- (f) Lead Reactor Engineer (LRE)
- (1) Responsible for monitoring reactor operation.
 - (2) Report directly to the Test Director. During the engine test-run, he will monitor the operation of the reactor and assist the Chief Test Engineer.
 - (3) Direct the necessary checkouts required to assure safe and correct reactor operation.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.4.2

- (4) Determine proper operation of the reactor by means of console displays; if safe limits are exceeded, can request a controlled shutdown or Scram of the Chief Test Engineer - reactor control panel does not have either control.

(g) Lead Facilities Engineer (LFE)

- (1) Responsible for remote operation of those portions of the facility-systems which are electrical, mechanical, hydraulic, and pneumatic in nature. (Purely electronic facility subsystems - - TV, timing, etc. - - will be under the direction of the Lead Instrumentation Engineer.)
- (2) Report directly to the Test Director. During the engine test-run, he will assist and work in association with the Chief Test Engineer.
- (3) Direct the fill, transfer, and storage activities of the "tank-farm" over the several-day period prior to the test operation.

*

- (4) Direct the necessary checkouts required to assure proper remote control operation of the facilities systems from the Control Point Building.
- (5) Monitor and/or control the various elements of the facilities systems during the test run and post-test run period. Specifically, this will include, but not be limited to: remote positioning of the engine, shields, J-box, etc.; monitor and/or control of all facilities power subsystems; and monitor and/or control of the liquid or gas systems which are not controlled by the Chief Test Engineer during the test run and post-test run phases of the count schedule.

(h) Lead Instrumentation Engineer (LIE)

- (1) Responsible for operation of the Data-Acquisition System, plus the TV, timing, photo, communications, and display subsystems.
- (2) Report directly to the Test Director.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.4.2

- (3) Direct the necessary checkouts required to assure continuous remote operation of the aforementioned systems and subsystems during the test run and post-test run phases of the count schedule.
- *
 - (4) Monitor and/or direct (including manual override, if necessary) the functions of the Data Acquisition system whenever data is being recorded.
 - (5) Monitor the various real-time displays in the Control Center and initiate pre-planned corrective action in the event of erroneous displays.
- *
 - (6) Monitor and/or direct the operation of the TV, timing, photo, and communications subsystems and will initiate corrective action in the event of a malfunction.
- (i) Lead Controls Engineer (LCE)
 - (1) Responsible for the integration and coordination of the test-site controls systems.
 - (2) Report directly to the Test Director.
 - (3) Direct the preparation (patching, rewiring, and preliminary checkout) of both the local and remote-control systems, which will vary in scope and purpose, according to the type of test involved.
 - (4) Monitor the checkout activities of all systems to ascertain that all remote-control circuitry is functioning as planned, and will stand by to initiate such corrective action as may be necessary in the event of a malfunction.
 - (5) Monitor the overall operation of the Control Center during tests runs and will act in an advisory capacity to the Test Director and Chief Test Engineer in the event of failure of any portion of the control systems.
 - (6) Monitor and report any abnormalities in the various electrical power systems, as well as the special hydraulic or pneumatic sources used within the Controls System.

2.2.5 Checkout and Calibration

2.2.5.1 Scope

Checkout and test of all systems and subsystems considered to be an integral part of the ETS-1 Complex (this excludes MAD Building and E-MAD Building) will be considered in these criteria.

Those portions of checkout and test equipment that will ultimately be furnished at the launch site as Ground Support Equipment (GSE) will not be considered in these criteria either in their initial (breadboard), intermediate (prototype), or final (deliverable) form. However, cabling and space at the ETS-1 Complex to support this type of GSE will be covered by the criteria.

Examples of deliverable checkout and test equipment (GSE) not covered by these criteria include:

- Engine simulator used to checkout the Engine Master Programmer
- Engine checkout and test console
- Telemetry checkout and test station
- Checkout and test GSE used at the factory
- Checkout and test GSE used at the MAD and E-MAD Buildings at NTS
- Checkout and test GSE used at the Missile Assembly Building at launch locations.
- Calibration Laboratory (specific)

As part of the facilities-test equipment, there will be a requirement for equipment capable of dynamic simulation of the closed-loop system represented by the pipe line and valves feeding the engine.

Dynamic simulation capabilities will also be required, representing the closed-loops containing engine and reactor, neutronic system, and heat transfer (thermocouple) systems.

2.2.5.2 Definitions

- (a) Calibration is defined as the comparison and recording of response of a device, to a known stimulus supplied by a reference standard, to define performance of the device in terms of standards traceable to NBS.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.5.2

- * (b) A calibrator is a generator capable of supplying a standardized signal for calibration purposes.
- * (c) Operational Calibration - The operational procedure portions of the calibration process, during which standardized electrical or physical stimuli are supplied to systems or subsystems to establish responses for use in reduction of data. (See Drawing ICC-172). Operational calibrations are generally performed before and after a test run, as follows:
 - (1) Pre-Pre Firing Calibration - The operational calibration of data acquisition and control channels performed sufficiently in advance of a test to permit the accomplishment of corrective measures indicated by inspection of the calibration record.
 - (2) Pre-Firing Calibration - The operational calibration of data acquisition and control channels performed immediately (approximately 25 minutes) prior to a test, after which no further adjustments are permitted. Data reduction is normally based upon the pre-firing calibration record.
 - (3) Post Firing Calibration - The operational calibration of data acquisition and control channels following a test run, for the purpose of assessing performance of measuring systems, to permit compensation during data reduction for intervening drifts.
- * (d) Maintenance - Maintenance is the function of systematized adjustment and repair of the constituent instruments of a system in order that performance within calibration limits may be accomplished.
- * (e) Checkout is defined as a procedure for verifying performance of a system, subsystem, or component, to a predetermined standard. Includes, but is not limited to, visual inspections, electrical checks, and checks of zero suppression and span.
- * (f) Operational Checkout - Operational checkouts are generally performed before and after a test run, as follows:
 - (1) Pre-Pre Checkout - This is defined as an interval, extending from days to hours, in advance of the test run. (Refer to Drawing ICC-172).

- (2) Pre-Checkout - The checkout interval preceding the test run by approximately one hour.
- (3) Post Firing Checkout - The checkout interval following the test run.

2.2.5.3

Basic System Checkout Philosophy, ETS-1

- (a) The ETS-1 Complex must include an integral checkout system suitably integrated with the calibration system to provide indications as to whether the I & C, elements, system, and subsystems will operate within predetermined tolerances in accordance with requirements of the impending test run. Checkout will be on a single-point basis (preferably 75% of full scale value).

Checkout will be on a local or remote control basis from the Test-Cell Room or Control-Point Building. Refer to Drawings ICC-162, 163, 165, & 167. Provisions will be made for local checkout which will enable locking-out of the "remote" mode, thus inhibiting interruption during local checkout.

Systems of relatively high stability will be checked out within the pre-pre checkout interval; time allocated to checkout of each channel will be in accordance with stabilization time requirements of the channel.

- (b) Checkout will extend from sensor points as close to the primary pickup as possible, through and including the cabling, signal conditioning, recorders, and/or indicators. It will include such indications as are required, for example, in indicating accuracy of indexing at the engine and stand interfaces.
- (c) Automatic checkout will be provided as far as is economically possible, with initiation by a master control at the main checkout point.

The automatic checkout system must be designed for flexibility of setup, that is, it must be possible to rearrange check sequences by means of simple patch boards or the equivalent.

Completion of each checkout operation will result in stepping of the equipment to the next checkout position.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.5.3

Checkout of systems, subsystems, and components subject to drift must be allocated a time interval as closely preceding the test run as is practicable (pre-checkout time).

As much provision will be made, as is reasonably possible, for manual spot or random checkout of points in the complex before final checkout.

- (d) For the purpose of minimizing overall checkout time, checkout functions will operate in parallel as far as is economically practical, subject to limitations of the data-processing, display, and recording equipment.

Normal real-time display of the checkout status will be on a GO/NO-GO basis by means of red (NO-GO) and green (GO) lamps at the checkout panel. Automatic printout of out-of-tolerance values will be provided, together with channel identification.

*
*

~~Indication of a NO-GO condition during pre-pre checkout can stop the checkout at this point; operation of an override switch, at the discretion of the Test Director, will permit continuation of checkout.~~

Adequate backup of the checkout information will be provided by concurrent recording of the checkout and checkout command status by signals forwarded to the Data-Recording System.

Checkout provisions shall permit verification of system channel integrity, and existence of system conditions unique and critical to the specific system in sufficient detail to permit detection and isolation of critical system components from transducers to end-recording or indicating instruments.

- (e) When dictated by operational and cost consideration, checkout facilities may be common to several systems.

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System-checkout facilities shall be combined with operational calibration facilities.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.5.3

The checkout-facility must be buffered from and interlocked with, the ETS-1 Control System to prevent any checkout operation from interfering with a control function and compromising the requirements of safety to personnel and equipment.

- (f) The impracticability of automatic checkout of many components (remotely-operated valves, etc.) under "dry" and service conditions in the pre-pre checkout is realized. Such checkout may range from visual inspection of such devices, including nameplate data, to actual manipulation, with circuit setups (i.e., valving), appropriately arranged for isolation of the subsystem or unit to be checked out. At this time, it is not possible to specify the time programming required for the above, but a reasonable scheduling is considered a future requirement.

As indicated in the above paragraph, the pre-pre checkout by local manual control on an extended-time basis, of certain components (valves, etc.) will be more practical than applying full automatic means, and such checkouts would be best accomplished by setting up valve-control switching combinations at the facilities control panel, in accordance with a master check-off list.

- (g) The Pre-Checkout is an automatic quick scan and printout of out-of-tolerance values of 75% of full-scale points of the Data-Acquisition and those Control channels that can be checked at the time of approximately one hour preceding the test run. This operation will be accomplished by remote control from the Control Point Building. Items of sufficiently high stability checked out during pre-pre checkout will not be rechecked during this interval if physical conditions preclude checkout at this time.

*

- (h) Checkout of Typical Systems

- (1) Strain-gage system checkout (visual and electrical):

Check each channel for:

Proper transducer range

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.2.5.3

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Leakage resistance

All conductors to shield.

Shield to ground (Without excitation or power supply ground).

Check for response to the application of a single-shunt calibration resistor value.

Check for amplifier gain.

Check for proper folding error filter.

(2) Thermocouple system checkout (visual and electrical).

Verify system continuity.

*

~~Measure reference junction temperature (well or bath temperature).~~

(3) Flow & Speed System Checkout

Verify serial number of flowmeter and freedom of rotation of turbine rotor during and following installations.

Check channel integrity (continuity).

*

Check resistance to ground.

Check N_t pickup, output during pump rotation.

(4) RTB System Checkout

Verify range and serial number of transducers.

Check channel continuity.

*

Check leakage resistance to ground.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.5.3

(5) Liquid Level Transmitter (Capacitive).

Substitute capacitor arms in bridge to simulate calibration levels. (Refer to Drawing ICC-105.)

NOTE: Point sensors may be given a gross check between firings, by checking for operation of all sensor relays under empty and full-tank conditions. An alternative would be to substitute capacitors for each point sensor to simulate "wet" and "dry" conditions, and to verify operation of the associated relay.

(6) Thrust

Operate calibrating jacks to obtain indications on load cells and calibration cells. Check output from each cell. (Part of pre-pre checkout).

2.2.5.4 Operational Calibration Philosophy, ETS-1

- (a) The requirement here is that the ETS-1 facility shall include means for calibrating all channels transmitting test and operational data to their designated display or recording points, with all components in place. Refer to Block Diagrams ICC-162, 163, 165, and 167.

Calibration methods shall conform as far as possible to the basic methods of signal pickup employed in the ETS-1 system involved.

While desirable, end-to-end calibration is presently considered impractical over most of the ETS-1 systems. Calibrators are to be connected as closely to the "front end" as possible consistent with time and cost allotted for the calibrating process.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.5.4

- (b) Automatic calibration shall be specified; the time allocated to automatic calibration shall be a minimum consistent with required accuracy of calibration, not to exceed one minute. The Data Acquisition System calls for channel maximum signal inputs to occur at 75% of transducer full range, the general calibration technique (special cases will be handled according to their particular requirements) for ETS-1 will appropriately consist of sequentially applying calibrating input signals of levels corresponding to 0, 25%, 50%, 75% and 100% of full scale to the channels, each percentage signal being applied simultaneously to all sensor channels undergoing calibration. During the dwell on each step, all channels shall be scanned and the outputs recorded.

Calibration outputs and stimuli shall be of appropriate magnitude to meet the standardized input ranges outlined by the Data-Acquisition criteria. For example, at calibration the amplified output signal from a given pressure transducer should be within the -5 to +5-volt range required by the above.

- (c) The Calibration Facility must be buffered from, and interlocked with, the ETS-1 Control Facility to prevent any calibration operation from interfering with a control function and compromising the requirements of safety to personnel and equipment.
- (d) Calibration data must be recorded in a form such that it may be inserted into the test data processing system to provide automatic correction for errors and non-linearities in the various calibrated sensors, within the dynamic ranges of the latter. It is the intent here to permit maximum interchangeability of data recorders.
- (e) Calibration will be on a local or remote basis, i.e., from the Test Cell Building or Control Point Building, as indicated in ICC-162, 163, 165, and 175.

Local calibration is intended to provide step-by-step manual calibration of selected groups of channels, with indication back to the remote control point that these channels are under local calibration. The local calibration system must provide isolation of such channels to prevent interference with activity on other channels.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 2.2.5.4

Remote (automatic) calibration will be by the Automatic Calibration Control unit located in the Control Point Building. This unit is described in Appendix 2.2. Functionally, on initiation of a START Signal, the unit will apply percentage calibration signals sequentially to all channels to be calibrated, at the same time switching in the recording system. Refer to Drawing ICC-166.

(f) Pre-Pre Firing Calibration. (T-10 hours approximately)

During this interval, there will be step-by-step calibration on an extended time basis, locally or by remote control. The philosophy here is that any subsystem or component indicating incapability of acceptable calibration may be removed or repaired without holding up the impending test run.

(g) Pre-Firing Calibration

This is a high-speed, fully automatic calibration by the Automatic Calibration Control unit located in the Control Point Building. Calibration data for all percentage steps and all channels will be recorded on magnetic tape for subsequent test computation and reduction. The interval will start at approximately T minus 30 minutes (see ICC-172), and the sequence will be as shown on ICC-166.

(h) Post-Firing Calibration

This calibration will follow the same procedure as the Pre-Firing Calibration. The objective is to obtain correction data in the event of drift and sensitivity change in the system during test. Post-firing calibration will start as soon after conclusion of the test period as practical in view of cool-down transients. The approximate interval is shown in ICC-172.

2.2.5.5

Transducer/System Calibration

- (a) As indicated previously, calibration is the introduction of a test signal to determine the transfer function of a system from physical variable through recorded or displayed data. Parameters of interest are gain, zero, and linearity. In an ideal system, calibration should be necessary only when a transducer or other

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 2.2.5.5

component is changed. In practical systems, with less than ideal stability, some form of calibration is necessary. Required frequency of calibration is determined by the stability of the system. From an accuracy standpoint, the best calibration would be the application of known physical stimulus to a transducer "in place". Operating considerations usually prevent this; the next best course is to calibrate "in place" as much as possible of the system, excluding the transducer, and depend on vendor or user laboratory calibration of the transducer.

(b) Design Criteria

The specific design of calibration equipment should be based in part upon principles mentioned in the following paragraphs.

The equipment clearly must provide necessary resolution and stability to meet the accuracy requirements placed on the various types of channels. The equipment must be sufficiently flexible in its design and operating adjustment characteristics so that certain critical channels may be maintained in a suitable manner to provide maximum achievable accuracy from the associated transducer.

A sufficiently large number of channels are involved that the stability of calibration circuitry (and signal conditioning) is of extreme significance. Suitable stability should be provided in order that the majority of channels will remain within acceptable error limits without adjustment for a period of 30 days.

From a standpoint of spares, cost, and simplification of operation and maintenance, it is desirable to design the signal conditioning and calibration equipment for all types of sensors in such manner that a minimum number of different elements are required.

(c) Speed of Calibration

In order to make best use of the calibration capability, it is desirable to provide calibration immediately prior to the test run on those channels most subject to drift, as well as on those channels requiring maximum accuracy. Control of the calibration system should be such that a full calibration cycle can be run in a period of 10 to 15 seconds, and the systems outlined in previous paragraphs are intended to provide the above.

(d) Selective Calibration

Calibration equipment should be designed such that any one channel may be individually calibrated at will. In addition, the system should be so arranged as to allow selective calibration (or inhibition from calibration) of groups of channels associated with individual functions or systems. Examples are selective calibration of channels associated with Coolant Water System, LH₂ System, duct instrumentation, Neutronics System, etc.

Through this arrangement, all necessary calibrations may be accomplished when desired, while inhibiting calibration when channels are needed for continuous monitoring of closed-loop system use.

This selectivity allows more effective use of maintenance personnel by permitting operation of entire functional systems while others may be undergoing calibration and checkout.

(e) Calibration Methods

In the case of active transducers such as thermocouples, voltage substitution calibration is used.

For passive transducers such as strain-gage bridges, there are several possible calibration methods, which may be divided into two categories. One is to vary artificially the electrical value of one or more of the passive elements constituting the transducer. Shunt resistance calibration of strain gages is an example of this, and may be applied as indicated in Diagram ICC-163. Another method is to substitute a voltage equivalent to that which the transducer would generate. The source of the voltage could be either the excitation supply or a separate supply. An example of the former is the Ayrton shunt-voltage substitution method for RTT bridge measurements as shown in ICC-163. Each method of calibration of passive transducers involves certain assumptions, and has both advantages and limitations.

Voltage substitution calibration is the substitution for the transducer output of a voltage equivalent to the raw transducer output over the span of physical variables to be measured. The calibration voltage must define the end points of the electrical span of the actual transducer used. Calibration must in addition, define

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.5.5

points within the electrical span in order to determine system nonlinearity. The end points of span of a channel are called Zero Information and Full-Scale Information, and are spoken of as Zero and Full Scale for short. Zero of a channel does not necessarily mean zero value of stimulus, but can be, for example, 600°R or 20 psia; it is the lower limit of the channel span. Likewise, electrical zero of a channel does not necessarily mean zero volts, but is the transducer output corresponding to lower limit of channel span. It is apparent that the electrical span of a channel can be unipolar or bipolar; for example, in the case of a thermocouple this depends on reference temperature.

The voltage calibration must provide zero calibration either positive or negative with respect to nominal zero.

*** Zero suppression is applied as a series voltage of adequate stability to meet measurement accuracy requirements over the period of one week after voltage calibration. The zero suppression voltage must be sufficiently stable to need no adjustment for 30 days to remain within the dynamic range of the system.

* An Omni-span voltage calibration system for use in calibrating proportional voltage, and meeting the above requirements, is described in ICC-185.

Referring to ICC-185, Common $\pm 10\text{-v}$ Ref, -10 v Ref, and 0 to $\pm 10\text{-v}$ stepped calibration supplies are used for all channels. By proper choice of R_1 , R_2 , R_3 , and R_4 , and one jumper, calibration can cover any electrical span in the range from -10-v to $\pm 10\text{-v}$. For example, to calibrate a 7.5-v span with Zero information at -2.5-v and Full Scale information at $\pm 5\text{-v}$, R_3 is connected to -10-v Ref and

$$\frac{R_4}{R_3 + R_4} = 1/4, \text{ thus } E_2 = -2.5 \text{ v}$$

$$\frac{R_2}{R_1 + R_2} = 3/4, \text{ thus } E_1 = 0 \text{ to } \pm 7.5 \text{ v in 10 equal steps.}$$

$$E_1 \quad E_2 = -2.5 \text{ to } \pm 5 \text{ v in 10 equal steps}$$

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A
Date 1 June 1962
Par. 2.2.5.5

(f) Strain-Gage Bridge Transducers

For this type of transducer, resistive calibration will be used. Fixed resistors are shunted across one or more arms of the bridge to unbalance the bridge in amounts equivalent to the unbalance caused by a known physical stimulus. Since bridge resistances and sensitivities may vary, either the shunt-calibration resistors must be individually chosen, or the transducers must be standardized to use standard calibration resistors. Shunt calibration has the advantage that it is essentially unaffected by excitation voltage inaccuracies; however, it has the disadvantage of requiring that the physical stimulus be known within the accuracy required of the calibration. Zero pressure, for instance, may be achieved by bleeding the sensor environment to atmosphere. If a strain-gage pressure transducer is under pressure, a shunt calibration causes a shift in output, the magnitude of which must be individually calculated, based on the pressure. Voltage substitution does not require that the physical stimulus be known at the time of calibration and so is usable with pressurized transducers. The relationship between the excitation voltage and the calibration must be known within the required calibration tolerance.

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The shunt-resistor system more closely approaches true end-to-end calibration.

2.2.5.6

Laboratory Setup

- (a) A calibration laboratory, not covered by these criteria, will be required for periodic calibration of certain types of transducers. It is desirable that maximum utilization be made of laboratory capabilities to simplify and hence reduce the time necessary for the installation of a given transducer and associated signal conditioning and calibration equipment into the instrumentation system.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.5.6

To a large degree, the design concepts of signal conditioning and calibration will influence the division of total calibration and set-up activity between laboratory personnel and field installation personnel.

- (b) A central instrument calibration and maintenance facility, should be specifically equipped and staffed to carry the following responsibilities:

Maintenance of secondary standards.

Certification and liaison with NBS primary standards.

Maintenance of calibration records as required.

Calibration of ETS sensors.

Establishment of routine of calibrations, suitable to requirements of devices involved.

Retention, calibration, and repair of "roving" GSE instruments utilized in trouble-shooting checkout systems.

- (c) Secondary standards and suitable measuring equipment shall be maintained for at least the following types of instrumentations:

	Temperature	Voltage (dc thru RF)
*	Pressure	Current
	Flow	Frequency
*	Force	Gain
	Resistance	Radiation level
	Pulse analysis	

- (d) The central instrument calibration facility, shall employ a minimum number of different types of secondary standards, commensurate with the variations of types of sensors to be calibrated.

Secondary-standard accuracies must be commensurate with the tolerances of the devices being calibrated.

Secondary standards shall be referenced to the National Bureau of Standards, with checking intervals in accordance with drift characteristics and handling of the secondaries.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.2.5.6

- (e) ICC-186 is a simplified block diagram showing the relation of transducers to operational and laboratory calibration facilities. This is a proved system, with emphasis on standardization as an off-line responsibility of the calibration laboratory.

2.2.6

Reliability

The ultimate goal of these criteria is to assure that the test facilities will be available when required for critical nuclear rocket engine tests. System availability is a function of reliability and maintainability.

- (a) Reliability, in over-simplified terms, is the chance that a product will work; A more precise definition would be: "Reliability is the probability of performing without failure a specified function under given conditions for a specified period of time".

Electronic equipments have, in many cases, times-to-failure which are exponentially distributed. When this is the case, a convenient expression for reliability is given by:

$$R = e^{-\lambda t} \quad (1)$$

Where R = Reliability of the system

t = Operating time

λ = Failure rate of the system

The failure rate is constant when times to failure are exponentially distributed and is equal to the reciprocal of the mean time between failures of the system. The equation presupposes that failures occur only at random, i.e., the equipment is not subject to wear-out failures for the operating time, t.

- (b) "Maintainability", says the DOD, "is a quality of the combined features and characteristics of equipment design which permits or enhances the accomplishment of maintenance by personnel of average skills, under the natural environmental conditions in which it will operate." Or in other words, maintainability is the ease with which an equipment can be kept operable.
- (c) To show the relationship between reliability, maintainability, and availability it is necessary to consider the possible maintenance actions at ETS-1. Maintenance can be classified as scheduled or non-scheduled. Scheduled or preventive maintenance is performed at regular intervals (between test runs) to keep the equipment in proper operating condition.

- (d) Non-scheduled maintenance is performed when the system develops a malfunction during use, and therefore its frequency is governed by component mean time between failures. The average number of non-scheduled maintenance actions (replacement, repair, etc.) would be:

$$t/m_1 \quad (2)$$

where

m_1 = mean-time between failures

t = system operating hours

The average number of maintenance actions for n components in series is given by:

$$\frac{t}{m_1} + \frac{t}{m_2} + \frac{t}{m_3} + \dots + \frac{t}{m_i} = \sum_{i=1}^{i=n} \frac{t}{m_i} \quad (3)$$

Systems with redundancies incorporated into them can almost always be reduced to a series configuration by probability techniques, so the above equation is completely general.

If the time required to replace or repair the i^{th} component is T_i , then the total time consumed for non-scheduled maintenance, M , would be:

$$M = \frac{t}{m_1} T_1 + \frac{t}{m_2} T_2 + \frac{t}{m_3} T_3 + \dots + \frac{t}{m_n} T_n = \sum_{i=1}^{i=n} \frac{t}{m_i} T_i \quad (4)$$

M is also the system down time if we consider down time to be the time when the system is actually needed for tests but is not available. The time between test runs is not considered as down time.

- (e) The system utilization factor, μ , can be defined as the fraction of the time when the services of the system are required and are available. μ is given by:

$$\mu = \frac{t}{M + t} \quad (5)$$

- (f) For M to approach zero, the component mean-time-to-failures, m_i , must be increased, and the maintenance times, T_i , must be decreased. Or, in other words, for μ to be near one, the system must possess reliability and maintainability. Reliability and maintainability are characteristics that must be designed and built into a system; neither can be achieved after the system has reached the field.
- (g) The purpose of this section of the design criteria is to outline procedures necessary to assure that a high degree of reliability and maintainability is attained in the ETS-1 I & C Systems. It should be emphasized that the points presented will not be sufficient in themselves to attain high reliability, since reliability problems that will develop in the various stages of the program cannot possibly be foreseen at this time. It is for this reason that the program in its entirety should be monitored by a capable reliability staff.

2.2.6.1

Design and Development Phase

The design phase of this work covered by these criteria is the most critical from the reliability viewpoint; the increment of reliability per dollar cost is at a maximum. If a hazard to reliability is designed into the system, neither Quality Control procedures, testing, nor any other means (short of redesign) can correct the situation at this point. The following paragraphs point out some of the more important procedures to be implemented in the design phase to attain a high degree of reliability.

2.2.6.1.1

Circuit Selection

The circuit selection for the ETS-1 instrumentation and controls systems will be reliability oriented. The following practices shall be followed:

- (a) Redundancy will be incorporated into the design as required. Cost and reliability of the individual components and switching devices (if needed for redundant operation) are to be prime considerations in reaching a decision concerning redundancy. For example, if two redundant components of reliability R are used in place of one to perform a function and no switching device is

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.6.1.1

needed, the reliability of the function is increased by an amount $R - R^2$. The gain in reliability would have to be weighed against the cost of the component to make a decision for or against redundancy.

- (b) Where redundant components are used in the design, failure-detecting devices should be employed if possible. This will permit the replacement of key components at the time of failure. As the time of replacement becomes smaller the mean-time-between-failure of the system becomes larger.
- (c) Proven circuits with the accent on simplicity shall be used whenever possible. Use MIL source recommended circuits where feasible. Uncomplicated circuits are essential to good maintainability.
- (d) Circuit selection will be based on the limits of the allowable output rather than just the mean output. Also, allowances must be made for system power source variations.
- (e) The educated use of derating and safety margins shall be an integral part of the design. Derating could possibly furnish the increase in mean-time-to-failure necessary to meet the reliability requirements of the systems in many cases.

2.2.6.1.2

Component Part Selection

Several considerations are important in the selection of component parts for circuit application. These include:

- (a) In the selection of parts, the hazard to reliability due to environment shall be considered. ETS-1 systems will be subjected to radiation in varying degrees. The sparse data available concerning effects of radiation on components must be evaluated carefully in trying to select components relatively immune to radiation. Also, expected variations in temperature, sand, dust, etc., are to be considered in the part selection. Where possible, extreme environmental conditions will be reduced by shielding.
- (b) Proven parts with long histories of satisfactory operation shall be used whenever possible. If and when the use of newer or more exotic parts or assemblies becomes necessary, the part

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Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 2.2.6.1.2

or assembly should be evaluated carefully. Vendor and source data of the new part or assembly should be used in the evaluation.

- (c) A concentrated effort shall be made to standardize parts wherever possible. Standardization of parts results in a minimum amount of special training of design personnel in application of the parts. Also standardization will provide savings through quantity purchases, standard tooling, testing, and spares provisioning.
- (d) Parts must be purchased from vendors with histories of producing reliable parts. To be considered, a vendor should have reliability test data available on his parts. Vendors who have not recognized the need for reliability test data usually have not recognized the necessity for quality control either.
- (e) Part information exchange programs, such as IDEP, will be utilized. Frequently, through use of these programs, costly testing of components can be avoided.

2.2.6.1.3

Procurement Specifications

An effort will be directed toward controlling reliability through procurement specification monitoring. The procurement specifications shall be written in a manner consistent with the following:

- (a) Environmental conditions must be complete, correct, and specific. Special mention must be made of the radiation environment (see par. 2.3.5) to which components and systems will be exposed.
- (b) Operations requirements, rather than just nominal values, will be specified on components and assemblies to prevent degradation of reliability.
- (c) The reliability requirements must be complete and specific. The requirements will include mean-time-to-failure expectations, testing to be accomplished, and sampling plans to be used. Tests shall be specified in a manner consistent with obtaining the required reliability at a suitable confidence level.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A
Date 1 June 1962
Par. 2.2.6.1.3

- (d) Adequate Burn-In time should be specified. Burn-In will eliminate the initially defective parts so that the true inherent failure rate of the part is realized in operation.

2.2.6.1.4 Early Prediction and Analysis

Early in the design phase, an extensive reliability analysis of the systems shall be accomplished. The analysis shall include in particular the following:

- (a) A malfunction prediction analysis will be conducted. This analysis will detect modes-of-failure inherent in the design. The chain of events leading to a failure mode shall be described in detail. Reliability techniques such as redundancy, derating, and the use of alternate components, should be used to minimize failures.
- (b) Reliability block diagrams of each major system and subsystem shall be developed.
- (c) Mathematical reliability models of each major system and subsystem shall be formulated.
- (d) Reliability goals shall be established for the three major systems based on a thorough reliability versus cost analysis. The optimum mean-times-to-failure for a system are a function of design costs, development cost, installation costs, operation and maintenance costs, cost of tests to be performed with the equipment, and the criticality of the tests to be performed with the equipment. The latter of these is probably the most important in the case of ETS-1 Instrumentation & Controls Systems because the tests are connected in a very tangible way with our nation's defense.
- (e) Apportionment of reliability to each major subsystem will be accomplished. The apportionment will be on the basis of the relative complexity of the subsystems. Where mean-times-to-failure are not available, careful estimates shall be made. Make appropriate recommendations to reduce failure rates of the subsystems which are beyond their apportioned failure rate, or make trade-offs between subsystems so that the overall reliability goal will be met. In those cases where the Reliability goals approach 1.0 (as in scram), no trade-offs will be permitted; redundancy will be used if necessary.

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Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.2.6.1.4

- (f) A breadboard testing and analysis program may be necessary when the design is in the developmental phase. The testing and analysis shall include the check of all critical parameters to verify that they are within predetermined performance limits. The breadboard testing will detect areas where excessive stresses are applied to individual components and thereby degrading the reliability of the circuit.
- (g) Reliability growth curves shall be developed. The object of this function will be to monitor the growth in reliability throughout the design phase.

2.2.6.1.5

Design Reviews

Design reviews will be conducted as needed throughout the design phase of the program.

Prior to release of the design to fabrication and the procurement organization, a final design review will be conducted, to permit design changes at relatively low cost and with minimum difficulty and delay. The reviewing group will:

Consider previous recommendations for changes in the design, and determine whether the changes truly fulfilled the purpose for which they were intended.

Consider system interactions. Frequently, when a part is exposed to varying conditions separately, it will not fail, but when exposed to these conditions simultaneously, it does fail.

Review the maintainability of the system. Circuits or subsystems which are known to have the highest failure rates should be the most accessible. Color coding will be used.

Consider suitability of the design for manufacture. If possible, the design should be consistent with existing fabrication techniques to avoid costly delay.

Consider whether the design has adequate safety margins. In particular, the radiation environment should be well provided for.

Ascertain that the design will meet the reliability goals. A comprehensive reliability analysis will help provide this assurance.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.6.1.6

2.2.6.1.6

Prototype Testing

A prototype test will be performed if deemed necessary. The prototype test, if performed, will be statistically designed to obtain maximum data at minimum cost. All possible required functions of the equipment should be checked in this test to verify that the requirements can be met. The conditions for failure in the test should be more severe than those expected in operation, but should not be severe enough to force unrealistic modes of failure.

The prototype test will determine the significant modes of failure, if any, in the system, and will also expose some of the minor troubles. The design group will take action to alleviate the significant modes of failure. The minor troubles will provide a basis for some of the acceptance tests needed in the subsequent fabrication of the system.

2.2.6.1.7

Final Design Phase Reliability Analysis and Prediction

Prior to release of the design for fabrication, a complete reliability analysis will be performed. The previous analysis was based on, at best, rough estimates of failure rates. At this stage of the program the design will be firm and sufficient information should be available to make relatively good estimates of failure rates of the various components.

The estimated failure rates will be combined in a method consistent with the reliability configuration of the system to determine if the preassigned reliability goals will be met. If required, recommendations will be made for design changes to meet the established reliability goals. Also, at this time it should be verified that all replaceable components are readily accessible, to provide ease of maintenance.

*

2.2.6.2

Fabrication Phase

Reliability must be controlled in fabrication if the inherent and potential reliability in the design is to be achieved. Maintaining the reliability inherent in the design requires that the many variations in manufacturing, packaging, shipping, etc., be controlled, as indicated in (a) through (f) following:

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 2.2.6.2

(a) Quality Control

The most important safeguard to reliability in production is an effective and complete quality control program. The quality control program for the Instrumentation & Controls Systems forms Section 1.3.3 of these criteria.

(b) Environmental and Life Testing

In addition to acceptance tests, fabrication tests, and screening tests which will be monitored by the quality control function of the program, life, accelerated life and environmental testing will be a part of this program to the extent required. It is expected that a radiation environmental test, in particular, will be required for some subsystems. These tests will be statistically designed to obtain maximum information at minimum cost.

The test data resulting from such tests will be subjected to statistical and engineering analysis. Summaries of the analysis and appropriate recommendations will be given to the design group and then fed into the data storage system.

(c) Failure Reporting and Analysis

The failure data from production acceptance and screening tests will be evaluated frequently to determine if any significant modes of failure are present in the design. If significant modes of failure are found, a thorough failure analysis will be conducted to determine the origin of the failures and possible methods of correction.

(d) Updating Reliability Analysis and Prediction

The reliability analysis and prediction will be kept current in the fabrication phase. More failure rate data may be available and minor changes in the design may have been made so as to alter the expected reliability of the system.

(e) Materials Handling

In order to prevent degradation to reliability and quality by handling in fabrication, complete fabrication procedures and controls will be implemented in the manufacture of various systems.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.2.6.2

(f) Packing and Shipping

Adequate packing and shipping procedures will be implemented to avoid any degradation to the reliability of the subsystems in transit.

2.2.6.3 Spares

Adequate spares provisions will be developed. The quality of replacements should be at least that of the original part. In developing spare quantities, consideration should be given to component mean-time-to-failure, component mean wear-out life, and the replacement of marginal parts in routine maintenance.

2.2.6.4 System Maintenance

Adequate and orderly information will be contained in the Operation and Maintenance Manuals to insure that the inherent reliability of the system is realized in operation. Provisions will be included for the following:

- (a) Regularly scheduled preventative maintenance to perform such tasks as cleaning and lubricating components. Also, failed redundant parts, that are not replaced at time of failure, should be replaced or repaired at regular intervals. The latter is very important but is often neglected.

To illustrate, suppose that a system consists of two redundant components of failure rate, λ . If the exponential failure law holds, and if the system is allowed to operate until both parts fail, the mean-time-between-failures of such a system is $3/2\lambda$. On the other hand, if failed parts are inspected and replaced every T hours, the mean time between failures of the system M is given by:

$$M = \frac{\frac{3}{2\lambda} - e^{-\lambda T} \left(\frac{2}{\lambda} - \frac{e^{-\lambda T}}{2\lambda} \right)}{1 - e^{-\lambda T} \left(2 - e^{-\lambda T} \right)} \quad (6)$$

As T approaches zero, the mean time between failures of the system approaches infinity. For a practical example assume that $\lambda = .0005$ failures/hour and $T = 2000$ hours. The mean-time-

between-failures of the system, if not subject to regular inspection, would be 3000 hours. The mean-time-between-failures of the system, if subject to inspection, would be 4100 hours.

- (b) Regular overhaul of some of the complex subsystems may be necessary. The frequency of overhaul will be determined from the mean-time-between-failures of the subsystem. If the exponential failure law holds, the probability of an equipment surviving, $P(s)$, until the next overhaul, is given by:

$$P(s) = e^{-\frac{T}{M}} \quad (7)$$

Where T = time between overhauls

M = mean-time-between-failures of the subsystem.

The time between overhauls should be governed by the cost and time of overhauls and emergency maintenance.

2.2.6.5

Reliability Synthesis

At the time of preparation of this document, the design configurations of the various I & C systems and subsystems are not sufficiently well defined to subject them to any detailed reliability analysis. However, a few of the I & C subsystems, chosen at random, are discussed briefly from a reliability viewpoint, in the following Appendices:

Appendix 2.3 - Discussion on Reliability of the Digital Data Acquisition System.

Appendix 2.4 - Illustrations on Reliability Analysis of Instrumentation & Control Systems.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.7

2.2.7

SAFETY SYSTEM

Adequate provisions shall be made to prevent personnel exposure to unsafe levels of radiation resulting from planned test operations or from accidents resulting in release of radioactive material. Likewise, adequate provisions shall be made for industrial (non-radiological) safety. These safety provisions are to be made by incorporating appropriate safety features in the facility and in the instrumentation and control design, and by preparation of appropriate operational procedures. Design considerations shall be given to provisions for minimizing the periods of time during which personnel access to the Test Stand shall be restricted due to radioactive contamination.

The overall responsibility for safety of test operations resides in the Test Director. Section 2.2.4.1 outlines the manner in which the Test Director will delegate responsibilities for the safe and effective conduct of test operations. Section 2.2.4.2.(d) outlines the responsibilities which are normally delegated to the Lead Safety Engineer.

Safety shall be considered in five basic areas: (1) Fire Protection (see par. 2.2.7.1); (2) Industrial Hygiene (see par. 2.2.7.2); (3) Industrial Safety (see par. 2.2.7.3); (4) Area Surveillance and Warning Systems (see par. 2.2.7.4); and (5) Radiation Safety (see par. 2.2.7.5).

2.2.7.1

Fire Protection

Standard fire protection systems have been provided for the ETS-1 Test Site in the initial construction contracts. These systems include: a deluge system for the Test Stand, an automatic sprinkler system in each applicable area, fire hydrants, etc. Local and remote controls shall be provided for the Test-Stand deluge system, and a local and remote alarm system shall be provided for the automatic sprinkler systems.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.7.1

The remote control and alarm systems shall be integrated into the Safety Console at the Control Center. These items will be used during operational periods by the Lead Safety Engineer in conjunction with other monitoring devices (e.g., water-supply pressure indicators, television, communications, etc.) in the event that a fire does occur in spite of existing preventive measures. The design of the remote control and alarm system shall take into account the fact that normal electrical power in a fire area may be interrupted during an emergency, and therefore electrical power for the fire-fighting system shall be provided from the line-side of main-service-breakers.

Special fog nozzles, foam, or CO₂ protection systems shall be considered for areas requiring special treatment or where high-rate water application is undesirable and/or dangerous.

2.2.7.2

Industrial Hygiene

* The Industrial Hygiene Program will cover the thermo-environment, noise, and toxic air contaminants sampling and analyzing. The majority of metering and sampling will be accomplished by an array of fixed type instrumentation.

* A multi-point carbon monoxide system will be provided for ETS-1, which will have a standard scale range of 0 to 1500 ppm (0-0.15% by volume). The alarm signal horn, pilot lights, reset switches, and other control units shall be located on the Safety Console in the Control Center. Sampling heads shall be located in machinery rooms, and in tunnel sections and other like spaces occupied by personnel, as shown in Dwg.

** ICC-189 (optimum position to be determined by field survey).

** A multi-point Oxygen Analyzing System will be provided for ETS-1 as part of the Industrial Hygiene Program; this system will also function as a part of the Industrial Safety Program. Location of stations in this system is shown on Dwg. ICC-198 (optimum position to be determined by field survey).

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.7.2

2.2.7.3

Industrial Safety

* The Industrial Safety program will provide for combustible gas detection-analysis and control, plus standard safety measures, such as positive physical guarding of potentially dangerous machinery and electrical systems, and control of other physical hazards.

** An array of fixed instrumentation will be used to determine various environmental conditions. A combustible gas analyzer shall be furnished, having the capability of being programmed to sample on a minimum of 10 various stations. The combustible gas detectors shall be monitored by displays on the Safety Console and on the Safety System Graphic Display Panel in the Control Center (see Section 2.4.2.2) during engine tests and other operational periods. An alarm system which shall operate in the forward working areas shall be made a part of this detection system. The alarm system shall both warn personnel in the area, and activate any blowers, fans, vents, etc. which are incorporated in the facility to purge areas of trapped combustible gases. See Dwg. ICC-197 for combustible gas analyzer detection stations (optimum position to be determined by field survey).

** A multi-point oxygen analyzing system will be provided for ETS-1 as a part of the Industrial Safety Program. This system will provide a warning should the concentration of oxygen reach a level creating a combustible atmosphere, or in certain areas, if the oxygen reduces to the point to endanger life. Locations of stations in the Oxygen Analysing System are shown on Dwg. ICC-188 (optimum position to be determined by field survey.)

2.2.7.4

Area Surveillance and Warning System

- (a) An area access and egress control and monitor system shall be furnished to control the movement of personnel throughout the ETS-1 Complex. This control shall be effected by:
 - (1) Green-amber-red-flashing Red and Magenta (Radiation danger) light systems, and an aural

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.7.4

warning system throughout the area. These signals are detailed in Appendix 2.5, and are shown in block diagram form on Dwg ICC-037.

- (2) Gate or road-block traffic controls on roadways connecting to the ETS-1 Complex.
- (3) Lock and key door control systems within the ETS-1 Complex proper. These systems shall be provided for hazardous areas such as tunnel exits into the Test Stand area, camera and TV stations, etc.

- (b) The control of the above systems will be located on the Safety Console or Safety Graphic Display in the Control Center. The displays which will indicate the status of each area will be located on the Safety System Graphic Display (see Section 2.4.2.2).

* 2.2.7.5 (Deleted)

** 2.2.7.6 Radiation Monitoring System

Reliable radiation monitoring and measurements are a necessity for effective radiation safety operation, and several types of radiological hazards are generated during operation of a nuclear reactor system. These hazards include both direct radiation, and radioactive contamination of the air (particulates and gaseous). Standard personnel exposure limits are established by a National Committee on Radiation Protection (NCRP), and administered as Federal Regulations by the AEC. Thus, accurate collection of data by instrumentation must be accomplished for control of personnel movement within potentially radioactively contaminated areas and radiation areas to maintain exposures of personnel below established limits.

** 2.2.7.6.1 Fixed Radiation Monitoring Equipment

The fixed radiation monitoring system shall include the equipment required to monitor the radiation levels in areas occupied by personnel, both during testing and after shutdown. This system shall include

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.2.7.6.1

means for monitoring the concentration of radioactive gases and radioactive gases and radioactive particulates, which contaminate the air to which personnel may be exposed.

The fixed radiation monitoring system will be supplemented by such radiological equipment as portable survey meters, dosimeters, hand and foot counters, portal monitors, and other equipment normally used for radiological safety, which are not considered a part of these Criteria.

The fixed radiation monitoring system equipment shall include: area radiation monitors, mobile radioactive airborne particulate monitors, mobile radioactive gas monitors, and neutron monitors.

Each of the Radiation Monitor Stations shall provide local, audible, and visual alarm. Each of the area radiation monitorings shall also provide local indication of radiation level and remote alarm, and shall record in the Control Point Building.

Each mobile radioactive airborne particulate monitor and each mobile radioactive gas monitor shall also provide a local and remote recording of the concentration of radioactivity in the air, in addition to remote alarm and recording, which shall be made in the Control Point Building, and they shall be sensitive to beta-gamma radiation. The particulate monitors shall be provided with moving filter paper.

The Neutron Monitor shall provide both local and remote alarm, and remote recording in the Control Point Building, and shall monitor the neutron flux levels external to the reactor, during shutdown and power operation. Provisions shall be made for additional power outlets and adequate cable lengths for all individual detectors, to provide flexibility in monitoring locations.

The radiation monitoring equipment shall be installed at the following locations, as shown on Drawing ICC-145A. (Optimum position to be determined by field survey.) In this listing,

A = area
P = particulate
G = gaseous
N = Neutron

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.7.6.1

- 1 - Area Radiation Monitors (U-Underground)
 - A/U - South Tunnel entrance
 - A2U - Control Point Building
 - A3 - Utility Equipment Building
 - A4U - At turn inside tunnel
 - A5 - Upper Level Fill Station
 - A6U - Forward Control Room
 - A7 - Entrance to tunnel near LH₂ Dewar
 - A8U - Tunnel near Test Cell Building
 - A9U - Test Cell Building
 - A10U - Test Stand Building
 - A11 - To right of shadow shield (facing shield)
 - A12 - To left of shadow shield (facing shield)
 - A13 - Engine level at rear of test stand
 - A14 - Engine level at rear of test stand
 - A15 - Near bottom of access ladder in vicinity of flame deflector area.
- 2 - Mobile Radioactive Airborne Particulate Monitor
 - P1U - Control Point Building
 - P2U - Tunnel near Forward Control Room
 - P3U - Test Cell Building
 - P4U - Test Stand Building
- 3 - Mobile Radioactive Gas Monitor
 - G1U - Control Point Building
 - G2U - Tunnel near Forward Control Room
 - G3U - Test Cell Building
 - G4U - Test Stand Building
- 4 - Neutron Monitor
 - N1 - Engine level at side of test stand
 - N2 - Engine level at side of test stand

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.7.7

2.2.7.7

Meteorological Instrumentation

A continuous survey of Test-Site weather conditions will be required starting several days prior to each test operation. Existing NTS facilities will be used to furnish the majority of the information required; wind and cloud conditions will be of primary interest due to possible fallout problems. This information will be used to determine safe/unsafe operating conditions.

~~Local instrumentation will be required to supplement the
aforementioned data. Conventional wind speed and wind direction,
temperature, and barometric instruments shall be furnished.
The readout instruments shall be located adjacent to the
Safety System Graphic Display at the Control Center.~~

**

Local instrumentation shall be monitored at the ETS-1 site to supplement the aforementioned data from NTS as additional precautionary measures for prevention of radioactivity introduction into the air ventilating system. Conventional wind velocity, wind direction, temperature, humidity, and barometric instruments shall be furnished. The readout and recording instruments shall be located adjacent to the Safety Graphic display in the Control Center, and the meteorological instruments shall be mounted on a 100-ft tower located above the Forward Control Room, at an optimum position, to be field located between ETS-1 and 2. This location shall be subjected to site examination, further evaluation, and possible relocation for improved application.

2.2.7.8

Central Particulate Gas & Ventilating Air Balance System

**

Criteria for operational concepts and design for this system will be provided later, at the conclusion of a study now in progress. The study will, in part, compare the effectiveness of the air balance system against the mobile-particulate and gas-monitor system.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.8

2.2.8

Nuclear Effects Test Capability System (NETCS)

- (a) It will be desirable and economically advantageous to the overall National Nuclear Test Program for the ETS-1 facility to have the capability of conducting nuclear effects tests in conjunction with engine/reactor power test runs. Such a test capability requires that the test site shall have certain fixed facilities (cable, power, space, etc.). Certain other types of facilities (control panels, recording equipment, etc.) will be peculiar to the items brought in for test, and therefore cannot be considered a part of the Test-Site facilities.
- (b) This section provides only for the transmission cables, patching, some power supplies, empty recorder and equipment racks, an unequipped control console, and an additional underground power vault. Not provided for are the signal conditioning, amplifying, recording, and control equipment which will differ for the various tests and will be supplied by others. Said equipment will be mounted in the space provided, using the transmission and patching facilities provided. Radiation measurement and monitoring shall be accomplished by isolation units operating from the external neutronic detector equipment which is part of the Remote Engine Control System. The radiation level shall be transmitted and displayed in the unequipped control console. The display equipment shall also provide a separate output capable of driving a high input impedance (500,000 ohm or greater) recorder. A limited amount of additional equipment can be installed, providing the equipment types used for the aforementioned systems is applicable and available.
- (c) It is expected that most test articles will be typical airborne hardware items. For example, they may be flight controls, electrical and hydraulic or pneumatic equipment, guidance equipment, missile electrical power sources (batteries, solar cells, etc.), transducers, and telemetry equipment. To measure the effects of the reactor neutron and gamma flux on this equipment will require the following facility or user support:

*

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.8

- (1) Electrical power (commercial utility, dc, and 400 cps).
- (2) Available data channels in excess of, and separate from, those required for safe, reliable engine/reactor and facility instrumentation.
- * (3) Available control channels in excess of, and separate from, those required for safe, reliable engine/reactor and facility control.

2.2.8.1

General

Separate space, transmission cables, patching, power equipment, empty equipment racks, and control console shall be provided at the Test, Stand, Test-Cell Building, Forward Control Room, and Control-Point Building to assist in the implementation of NETC tests. Adequate electrical isolation must be provided between NETC equipment and the engine/reactor test equipment. Separate space allocation will be required at all four locations. A layout of basic NETC requirements is shown in the Block Diagram, Dwg. ICC-102.

2.2.8.2

Test Stand

* Approximately 1500 additional and separate data and test signal transmission lines shall be provided at the Test Stand terminals running from the Test Cell Room for nuclear effects instrumentation. The NETC 1500 signal lines shall include 450 C/A thermocouple wires, 450 shielded 6-conductor 16-ga. cables, and 600 16-ga shielded pairs. A minimum of 500 additional and separate transmission lines, 16-ga. shielded pairs shall be provided for various required NETC test controls. The 1500 signal lines and the 500 control lines shall be routed separately from all other engine/reactor data and control channels.

** Routing space is not available in the cable trays in the tunnel. These cables will have to be routed externally to the tunnel or in the center ceiling space of the tunnel, thus making it necessary that the lights be moved to the tunnel wall.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.2.8.2

Radiation monitoring equipment will be required at the Test Stand to determine neutron and gamma-flux densities. This information shall be used in conjunction with NETC data to determine the final test analysis. Approximately 150 transmission lines for radiation information shall be provided. These channels are included as part of the 1500 signal lines mentioned above.

2.2.8.3

Test Cell Building

*

NETC signal transmission lines, as described above, shall be routed to terminals in the Test Cell Building where patch facilities and space only will be provided for patching, signal conditioning amplifiers, bridge circuits, excitation voltage sources, etc. (These electronic items are not provided as a part of the ETS-1 I & C NETC system.) Signal transmission lines from the Test Cell Building to the Forward Control Room shall be shielded pairs of 16-ga. cable.

Separate power supplies from those used in engine/reactor tests in the Test Cell Building and Test Stand shall be provided. A well regulated 28-v, dc, 200-amp capacity and a 120/208-v, ac, 400-cps, 5-Kw capacity motor-generator set and required panel boards shall be provided and housed in an additional, separate building immediately adjacent to the Test-Cell Building. These units shall be supplied from a 4160-volt utility bus (thus not disturbing the I & C bus) feeder through appropriate transformers, air switches, fuses, and motor control center. Service outlets shall provide power for all NETC Test-Stand and Test-Cell Building equipment. Drawing ICC-006 shows typical power provisions at the Test Stand and Test Cell Building.

2.2.8.4

Forward Control Room

Patching facilities will be provided in the Forward Control Room for NETC signal channels. Provisions for patching any

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.8.4

* or all 1500 channels of shielded pair 16-ga cable, either direct to the Control Point Building, or through user supplied multiplexers to the Control Point Building, shall be made available.

2.2.8.5

Control Point Building

An area in the Recording Room in the Control Point Building shall be provided for 5 unequipped racks and a partially unequipped control console. NETC signal channels shall be routed to the empty racks. Patching facilities shall be provided at the Test Cell and Forward Control Room locations. The 500 control transmission lines at the Test Stand shall be routed through the patch facility in the Test Cell Room to the NETC partially unequipped control console and terminated on terminal boards. These channels shall be used to control various electrical conditions in electrical or electronic units, actuators, solenoids, on-off conditions, cyclic rates, etc.

The existing power facilities at the Control Point Building shall be used through separate circuit breakers to supply the NETC control console and recorder rack requirements.

2.2.8.6

Environmental Instrumentation (Not Furnished)

* Apart from tests on actual equipment subjected to radiation fields, instrumentation transmission cable only for environment measurement in the space between the engine and side-shields shall be provided. These channels will be concerned with the following environments:

Temperature	Dose rate
Humidity	Integrated dosage
Gas flow due to seal leaks	Pressures

Dose-rate and integrated dose-rate measurements shall include neutron and gamma levels. The six basic measurements listed above shall be expanded to several types of each measurement. Sensors used shall be distributed throughout the area to determine environmental gradients. A minimum of 75 basic channels

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.8.6

shall be required as a part of the ETS-1 NETC system for the environmental instrumentation. One additional transmission line for each basic transmission line shall be provided in the interest of reliability. A total of 150 transmission lines shall thus be provided as part of the 1500 data and signal lines.

*

2.2.8.7

NETC System Utilities

Mounting provisions in the annular area between the side-shields and engine shall be required for approximately 30 types of electrical and mechanical apparatus during any one test. Multiple-contact electrical connectors, pneumatic, hydraulic, and cryogenic connectors, fittings, and associated piping shall be required. Separate cable trays for control and data channel cabling shall be utilized from the Test Stand to the Control Point Building.

2.2.8.8

Nuclear Effects Testing Techniques

- (a) Two distinct types of equipment tests will be conducted in the nuclear environment: passive and active.

Passive tests require a minimum of instrumentation and control inasmuch as the unit under test is placed in the environment in a non-operating condition. Subsequent tests are conducted on the unit to determine the effects of high-level radiation on the individual components and the unit as a whole.

Active testing requires a more sophisticated instrumentation and control system for each test item, since a bulk of the test information derived must be acquired during the relatively short period of the engine run. The latter class of test requires that the unit under test be instrumented for input and output signal levels, various voltage and current levels distributed throughout the equipment, temperatures in all sections or areas shielded by each other, and induced electrical effects on various components as caused by neutron or gamma-flux intensities.

- (b) In addition to the irradiation measurements and electrical tests, mechanical equipment will be instrumented for the following typical characteristics:

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2.8.8

Thermal expansion
Thermal conductivity
Pressure
Fluid and gaseous temperatures
Actuating measurements (position indicators, etc.)
Dynamic and static stresses
Velocities
Displacements (linear and rotary)

- (c) A study of the requirements of 5 typical packages which would be tested on an active basis has indicated that each package requires a minimum of 40 measurements. Thus, if 15 of the 30 aforementioned types of electrical and mechanical apparatus are tested on an active basis, better than 600 of the 1500 data and signal transmission circuits will be required for measurement purposes. The remainder will be used for environmental instrumentation, test signal transmission, other data transmission, and spares.

2.2.9

Location of Personnel During Test Operations

The radiation levels during full-power engine tests, when consideration is allowed for the maximum credible accident case, may be too high to allow human occupancy of all areas forward of the Forward Control Room. Consequently, all operational concepts are based on limiting occupancy to the Forward Control Room, or other areas further removed from the Test Stand, during these periods.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	2.3

2.3

GENERAL CRITERIA FOR SUBSYSTEMS

The I & C System comprises dozens of subsystems which in turn are composed of hundreds of chassis and allied equipment. Many designers will be needed to accomplish the task of system realization in order to meet existing schedules.

The following sections define criteria and salient elements of design which should be followed in the design or specifications of all equipment for the I & C System.

These criteria have been prepared to direct design and specification activities based upon these optimization factors:

- Suitable performance (including ease of operation)
- Suitable reliability
- Maximum simplicity
- Minimum overall maintenance effort
- Minimum quantity of spare parts
- Minimum variety of circuits
- Minimum down-time
- Lowest cost consistent with other primary factors

The following systems priorities and responsibilities are established:

(a) Systems Priorities

1st Priority - Control used just prior to, and during, test. (Malfunction here may cause possible destruction of engine, damage to facilities, and endanger human life, therefore, shutdown is initiated resulting in loss of entire test from that point forward.)

2nd Priority - Control Display (Malfunction here may, but not necessarily, cause shutdown and loss of entire test.)

3rd Priority - Data Acquisition (Malfunction here does not result in shutdown, because of precautions indicated below, but will result in loss of data to some degree.)

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	2.3

(b) Systems Responsibilities

Isolation - In accordance with the priority established above, all Data Acquisition shall be isolated from Controls. (Open or short circuits in data-acquisition will not be reflected into the control being instrumented through the isolation circuit.)

Isolation shall be the responsibility of the Control Subsystem involved. This is not meant to imply that the circuitry will in fact be designed by the Control group, but it must be reviewed and approved by the control group involved.

Standardization - Standardization of control and data-acquisition circuitry will be accomplished through coordination by the NERVA Systems Group of the remote engine-control subsystem, the facilities-control subsystem and the data-acquisition subsystem. Standardized circuits will be approved and circulated by the NERVA Systems Group.

Separation - Control cabling, patches, terminations, etc., will be separated from Data Acquisition for ease in maintenance and operation, and for maintaining a tight control on reliability in accordance with the aforementioned established priority. Critical control and control-display terminations and patches will be maintained under lock and key.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.3.1

2.3.1

Power

Several types of primary power shall be available within the complex. Within the limits of practicality, all equipment shall be designed or selected to operate from these sources. Additional power supplies shall be specified only in those cases where performance or economics so dictate.

Listed below are summary characteristics of major site power systems. Refer to detailed specifications in Appendix 4 for additional information on performance.

2.3.1.1

60-cps Line (Commercial-Utility) and Diesel (I & C) Power

Line power (Commercial Utility) will be available as necessary, in all buildings and outside areas. The general power (utility, or non-I & C) and lighting requirements are connected to the utility bus. This commercial-utility power shall be utilized for both utility and I & C purposes during the non-test periods (prior to T-4hr, and after T+8 hr. approx.).

*

During testing or other critical periods, the tie-breaker which connects the utility bus to the 2 I & C busses, shall be opened, and the busses will be supplied by the three diesel generators having 1% regulation, 0.8-pf and 450-kw total capacity.

*

The only motors connected to the I & C busses will be those for one 5-hp ventilation fan for the Control Point Building, and one 25-hp humidity and ventilation fan for the racks in the same building, and these will both be connected to one bus. Since these motors will be isolated in only one bus, they will therefore not introduce pips or transients into the I & C system, which will be isolated in the other I & C bus.

2.3.1.2

400-cps Instrument Power

Instrument power at 400 CPS shall be available for use with variable reluctance devices, synchros, magnetic amplifiers, instrument choppers, etc. Two motor-generator sets shall be located in the Fill-Station Building to supply the power. Since the motors will operate synchronously with the 60-cycle power line, the M-G output frequency is directly related to power-line frequency. The second M-G set is to provide standby power. The M-G sets shall have the following rating:

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.3.1.2

<u>Voltage (rms)</u>	<u>Phase</u>	<u>Wire</u>	<u>Frequency</u>	<u>Harmonic Distortion</u>	<u>Capacity</u>
120/208 $\pm$ 10%	3	4	400 $\pm$ 0.7 cps	1%	5 kw

2.3.1.3

DC Power

DC power supplies shall be located in the Test Cell and in the Control Point Buildings. These supplies are for operating such devices as relays, contactors, solenoids, indicator lamps, timing systems, etc. It is also expected that some electronic equipment will be run from these supplies. Each unit shall be protected against overload, and be backed up by batteries with an automatic rectifier disconnect in case of dc power or ac supply failure. Pertinent characteristics are listed below.

<u>Location</u>	<u>Voltage</u>	<u>Max. Current</u>	<u>Battery Amp hr</u>
Test Cell	28 $\pm$ 1 v	400 amp	200
Control Point	28 $\pm$ 1 v	400 amp	100

The negative side only of each supply shall be interconnected and grounded at one point. It is mandatory that the design of 28-v circuitry includes handling power with pairs of wires in which equal and opposite currents flow. No additional grounds shall be established in racks, terminal boxes, etc. All pairs shall be kept together and shall be twisted to minimize magnetic field transients during switching periods.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	2.3.2

2.3.2

Standardization

(a) Circuit Standardization

Several hundred channels of ON-OFF type indication and control functions will be required in the ETS-1 Complex. These channels will normally be associated with the operation and status indication of valves, motors, power supplies, and instrumentation equipment. In many cases both local control (nearest controlled object) and remote control (farthest from controlled object) will be required with various schemes of local and remote crossover and lockout.

Since the majority of all such circuit requirements may be met by a few basic and flexible circuits, a high degree of standardization may be achieved. Significant savings will therefore be possible through reduced design requirements, fewer types of circuits to maintain, and fewer spares to stock.

Drawings ICC-031 through -035 illustrate standard circuits for various ON-OFF control and indication functions. These will be used unless performance degradation or severe cost increases are involved.

(b) Physical Hardware Standardization

From the standpoint of appearance, minimum spares requirement and ease of maintenance, it is important to establish a high degree of uniformity in the physical hardware which will comprise the I & C System. This applies to terminal boxes, wire and cable (inter-rack and transmission), console foundations, equipment racks, and panel hardware on consoles and equipment chassis. From the overall logistics standpoint, it is also extremely desirable to minimize the total number of different electronic components (resistors, capacitors, transistors, etc.) which must be stocked locally to support maintenance efforts.

2.3.3

Approach to Circuit and Equipment Design

In all instances where equipment must be designed specifically for the I & C System, several basic principles and concepts should be complied with, to realize adequate levels of performance, reliability, and maintainability.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.3.3.1

2.3.3.1

Simplicity

Equipment design should be aimed toward realization of performance requirements with the fewest number of component parts.

2.3.3.2

Selection of Components

Electronic components should be selected from those available items possessing a stable history of manufacture and field performance. Preferred types listed herein are to be used where possible. Special or long-lead-time items should generally be avoided if short-lead-time alternates would serve as well.

2.3.3.3

Derating

Suitable derating of components is a prerequisite of reliability. Deratings primarily apply to situations which involve component heating or potential dielectric breakdowns. Power and voltage are therefore the prime factors to be considered. As a guide line, voltage and power deratings in the range of 2 to 5 times should be employed with respect to component vendor ratings at the worst possible combinations of temperature, input voltage, circuit operation, etc. Although such conservatism reflects increases in initial component costs, the investment is more than justified in system reliability and consequent relative freedom from maintenance.

2.3.3.4

Equipment Mounting

Equipment should be designed to fit in standard 19-in. equipment racks except as may be otherwise dictated in console areas. Equipment racks will accept standard slide hardware.

2.3.3.5

Maintainability

Since most I & C System equipment should be available for continuous use, it is a prime requisite that circuits and packaging be so designed as to minimize time required to locate and correct a malfunction. Such malfunctions may be classified as minor (impairing accuracy) or major (loss of data or control). In either case, the primary task is to correct the fault and restore equipment to normal operation as quickly as possible.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A	
Date	1 June 1962
Par.	2.3.3.5

Suitable test points should be provided to assess circuit operation and to locate faults. Modular replacement of individual parts, circuits, or in some cases, entire chassis, represent the most effective technique for minimization of down time for repairs.

Strong consideration will be given to mounting equipment on extension slides if rapid chassis access is deemed important.

Chassis-mounted components and circuit elements will be identified in such a way as to enhance correlation between hardware and schematic diagrams and parts lists.

2.3.3.6

Manual Adjustments and Programming

Several thousand manual adjustments associated with electronic equipment will be required to adequately set up the I & C System in a given configuration. These will typically consist of trims on power supplies, bridge-balance potentiometers, amplifier step-gain selection and vernier trim, patchboard programming, etc. These adjustments are provided primarily for purposes of flexibility in order that a wide variety of system configurations may easily be achieved to support changing test requirements. In addition, adjustments are needed in some cases to compensate for slight analog circuit changes due to component parameter variation, changes in loading, etc.

The manner in which adjustments are handled from both the procedural and design standpoints vitally affects the integrity of any system as complex and extensive as that of the ETS-1 I & C System.

The degree of accessibility of a given adjustment should be directly related to the expected frequency of use. But it is also of importance to mechanically locate and/or protect critical adjustments from inadvertent or irresponsible use. The underlying principle of the mechanical design of adjustments is to minimize the time necessary to accomplish a given adjustment, while also minimizing the probability of human error in overall system operation.

For stepwise or discrete setup and adjustments (rotary switches, patchboard, etc.) visual inspections can adequately determine or confirm desired settings. Continuous-type adjustments in many

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.3.3.6

cases may not be set or checked by visual reference alone. In such cases, locking devices should be provided to discourage inadvertent or unnecessary control use. The complexity of the lock should be related to the criticality of the adjustment and the capability to determine maladjustment. Such techniques as lock-wired acorn nuts over control shafts represent acceptable techniques to suitably protect against inadvertent adjustment, while still maintaining relatively quick access when necessary.

Local operating techniques controlling lock-wire procedures or inspection stickers should be developed to allow visual determination of critical adjustment changes.

2.3.3.7

Fail-Safe

Circuits and equipment shall be designed so that upon loss of power on malfunction of other equipment, when wiring the circuit or control functions, will tend toward a fail-safe condition. Depending upon the function, the action may be in the direction of hold capability, next reduced capability, auto-to-manual, and calibrate-to-run.

2.3.3.8

Grounding

Adequate concepts and basic ground rules for grounding are important in these criteria for ETS-1 and -2, especially since so many different systems and equipment subcontractors are involved, and since interrelated control and measurement signal levels are of necessity varied, and the amplitudes and resolution requirements range from extremely large to minute.

The following concept and basic ground rules, to be used during detailed design will insure that subsequent integration of Systems and Subsystems into the I & C System will insure optimum performance, and will assure mutual compatibility by providing uniform and adequate grounding measures.

The basic rule is the requirement for, and the correct use of, three basic ground network-systems:

(a) Power Ground System

This system is required for power voltage stabilization, equipment protection, and personnel safety.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.3.3.8

(b) Equipment Ground System

This system is required primarily for safety reasons to protect personnel and equipment from fault voltages and currents and, partially, to provide shielding from stray electrical fields.

(c) Instrumentation Ground System

This system is required to provide noise suppression in the instrumentation systems.

2.3.3.8.1 Power Ground System

(a) 60-Cycle ac Power Ground

The 60-cycle ac ETS-1 power ground bus and earthing network will be supplied as an integral part of the facility buildings, as indicated in Bid Package 292-61-40, which is referenced in Section 4.1.3. All 60 cycle ac power distributions or outlets, either internal or external, to contractor or subcontractor furnished equipment shall be properly referenced to the power ground, to assist in the assurance of a complete and adequate overall ground system network.

(b) 28 v dc Power

The 28 v dc power ground shall be referenced and connected to the existing power ground at the output of each 28 v dc power supply.

(c) 400-Cycle ac Power Ground

All 400-cycle power distributions and outlets, either internal or external, to contractor or subcontractor furnished equipment shall be referenced and connected to the power ground. This power ground reference shall be in turn connected to the existing ETS-1 power ground.

(d) System

The completion of all above defined power grounds shall result in an open-ended network with no ground loops.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.3.3.8.2

2.3.3.8.2

Equipment Ground

The equipment ground, although electrically associated with and connected to the 60-cycle ac power ground at many points, is important to the I & C System to aid in noise suppression and to provide equipment and personnel protection.

All I & C System equipment installed in ETS-1 shall include all-metal enclosures with an equipment ground for each, for reference and connection to the existing ETS-1 power ground. The use of equipment cases or relay-rack enclosures, and other metal structures, shall be awarded for either signal or control transmission or conduction paths to minimize the effect of fault ground currents on system operation.

2.3.3.8.3

Instrumentation Ground System

The instrumentation ground concept of providing a separate isolated grounding network for the exclusive use of the I & C measurement systems is extremely important to the ultimate performance of the complete measurement systems.

The instrumentation ground-bus network shall be connected to the facility earthing network at one point only, and as close to the 60-cycle ac power ground earthing point as is practical. See Bid Package 292-61-40 (ref. Section 4.13, these criteria) for information on existing instrumentation ground bus and connection to the existing earthing network. The existing instrumentation ground bus and its termination shall be investigated for its adequacy, during the development of the I & C System design.

Each measurement module, equipment unit, subsystem, and system which performs measurement functions shall include provision for a distinct instrumentation ground, isolated and independent of all other grounds, and capable of satisfactory (no ground loops, etc.) termination to a ground reference point or node. All grounded measurements (such as grounded thermocouples) shall incorporate isolation (such as provided by differential four-terminal amplifiers) to isolate the transducer grounds from the measurement systems instrumentation ground, which will be connected to the reference node.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.3.3.8.3

Shields shall be carried through on separate pins or terminals, and shall be isolated from ground by at least 1000 megohms, except at the ground point. Shields for transducer cables on other input signal cables shall be grounded as close as possible to the transducer or other signal source, and shall be floated or ungrounded in all other parts of the System or Subsystem input.

The System design shall include a means of opening the grounds as required by the various subsystem checkout operations.

Signals shall be isolated from the measurement system by at least 1000 megohms, and shall be referenced to ground only at the output of the appropriate isolating device. For each System, Subsystem, or equivalent group, the single reference point or node shall be designed so that all signals brought to this ground point will include appropriate terminals mounted upon (but insulated from by a value of 1000 megohms), the ground reference node for terminating the high side of the signal.

This scheme will insure a minimum length of unshielded signal pairs, and will place all signal returns with the high side, thus reducing loop area. Each reference node shall be isolated from ground, except that each shall be connected separately to the single point which is common to the power ground.

2.3.4

Environmental Factors

The following environmental characteristics should be taken into account when designing or specifying I & C equipment:

Temperature

Inside buildings	50° - 100° F room ambient
Outside	20° - 130° F

Relative Humidity

Inside buildings	2% - 60%
Outside	2% - 100%

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.3.4

Sand and Dust Severity

Inside Buildings	Low to moderate
Outside	High

Shock and Vibration

Inside Buildings
Essentially none on rack-mounted equipment.

Radiation

The nuclear radiation levels to which the I & C equipment will be exposed at various locations are indicated on Dwg. ICC-176, -177, and -178.

2.3.5

Standard Signal Levels

The I & C System will contain in the order of 2500 separate wire pairs conveying voltage analog signals. These will be representative of numerous physical variables (e.g., pressure, temperature, force) as well as voltages derived from servo system and controller operation (e.g., programming and error voltages).

In order to minimize the variety of equipment and procedures required to handle these signals, it is important to standardize levels to the maximum degree possible consistent with performance and cost.

The analog signals of interest may generally be divided into three categories:

Low level	less than 100-Mv span (10, 20, 30, 40, 50, 100 Mv)
Intermediate level	100-Mv to less than 5-v span
High level	5-v and greater span

In discussing voltage analog signals, it is imperative to use uniform definitions of the terms Zero and Full-Scale, both with reference to the physical variable under measurement, as well as with respect to the voltage analog. The specification of any given measurement channel involves the establishment of the specific range of measurement to be made. Ranges are chosen to

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A	
Date	1 June 1962
Par.	2.3.5

encompass the values of the variable over which information is desired. The lower limit of the dynamic range is the Zero of information, while the highest value is the Full-Scale. For example, if a tank is to be instrumented to measure pressures expected to be close to 800 psi, a channel might be set up to measure from 750 to 850 psi. Pressures outside of this range would not be measurable on such a channel. In this case, 750 psi would be the Zero Information and 850 psi, the Full-scale Information. These terms also refer to the voltage analogs associated with the electrical part of the channel. Through proper signal conditioning, the above measurement may readily be transformed into a voltage analog of 0 to 50 volts as the pressure changes from 750 to 850 psi. The Zero Information is thus 0 volts and Full-scale Information is 50 volts.

The following table represents the standard analog voltage signal levels to be used in the I & C System, as far as practical:

<u>Zero</u>	<u>Full Scale</u>	
0 Mv	10 Mv	
0 Mv	20 Mv	
0 Mv	30 Mv	Amplifier and low-level multiplexer inputs
0 Mv	40 Mv	
0 Mv	50 Mv	
0 Mv	100 Mv	
0 v	5 v	High-level multiplexer inputs
-5 v	+5 v	Error signals meter inputs
-0 v	5 v	Standard low-frequency data transmission meter inputs

These levels have been chosen on the basis of compatibility with current types of transducers and associated analog-transmission and data-handling hardware.

2.3.6

General Equipment Stability

The quantity of personnel required to maintain the I & C System in operational readiness is strongly related to the stability of the analog portions of the system. Although any one adjustment may be neither difficult to make nor apparently time consuming, the

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.3.6

total quantity of adjustable functions is so great that unless suitable levels of equipment stability are provided, the task of calibration and adjustment becomes totally unmanageable.

There will not be a great deal of working space in the buildings once racks have been installed, a fact which establishes a maximum number of people and test equipment that can occupy the space at any one time.

The need for adjustments in analog circuits is related to desired accuracy of adjustment and the stability of the various elements comprising the circuitry. Instability generally shows up as variation in the Zero and Full-Scale of information in voltage-analog circuits. Power supplies outputs also tend to change with time.

In order to keep periodic maintenance to a reasonable level, equipment shall be designed or selected which will have sufficient overall operating stability to remain within acceptable operating limits for a period of at least 30 days. In order to meet such criteria, it is recognized that design, materials, and equipment will be more expensive than needed for less severe requirements; however, the dollar costs of the original investment will be quickly repaid by the strong reduction in maintenance personnel needed.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A1

Date 1 June 1962

Par.

2.3.7 Signal Conditioning Equipment

** Table 2.3-1, following, presents a listing of the different types of signal conditioning required for the various measurements in the Remote Engine Control, Facilities Control, and Data Acquisition Systems. The list does not include any DC amplifier requirements, but should be interpreted to include power supplies (individual or common) and all check-out and calibration equipment. The quantities listed under "Contingency Requirements" are considered necessary for System back-ups or program contingencies, and must be installed for the initial I & C System check-out.

**Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC**

Revision A 1

Date 1 June 1962

Par.

TABLE 2.3-1

ETS-1 SIGNAL CONDITIONING REQUIREMENTS FOR ALL SYSTEMS

Number of Signal Conditioners						Type	
R.E.C. ₃		F.C. ₃		D.A. ₃		Measurement	Transducer or Input
List (1)	Contingency Requirements(2)	List (1)	Contingency Requirements(2)	List (1)	Contingency Requirements(2)		
4	2	144	10	29	3	Pressure, Flow (ΔP)	Standard four-arm bridge
-		6	3	42	10	Vibration, Level(ΔP)	Type strain gage, 350 ohm bridge resistance
		9				Thrust, Weight	(0-30 mv output)
-	-	-	-	299	15	Strain	Strain gage, 120-1000 ohms with bridge-completion network
16	2	-	-	168	11	Temperature	Tungsten/Tungsten-26% Rhenium
					24	"	Copper/Constantan
8	2	133	11	378	17	"	Chromel/Alumel
15	2	19	2	80	7	"	Resistance Temperature Thermometer (Platinum element)
7	1	2	1	75	15	Pressure, Flow (ΔP)	Potentiometer 500-10,000 ohms
		1				Level (ΔP)	
15	2	-	-	30	8	Position	Potentiometer 500-10,000 ohms
		15	-				Linear variable differential Transformer
1	-	3	-	3	1	Flow	Turbine Flowmeter (0 - 600 cps)
1	-	-		1	1	Speed	Variable Reluctance (0-20 kc)
	-	2	-	7	2	Vibration, Sound	Self generating 0-1000 mv
21	2	37	8	17	10	Proportional voltage	0 - 5 Volts
2	-	-	-	-	-	Gas analysis	Mass Spectrometer
15	2	-	-	39	4	Neutronics	Ion Chamber

TOTALS	106	15	371	35	1168	128	
LIST TOTAL							1656
CONTINGENCY REQUIREMENTS TOTAL							175
							SUMMARY TOTAL 1831

NOTES: 1. Requirement as defined in Data Acquisition Measurement List and Facility I & C Channel List

2. Recommended operational spares

3. R.E.C.-Remote Engine Control System
F.C.-Facility Control System
D.A.-Data Acquisition System Only

2.4

CONTROL CENTER CONTROL AND DISPLAY REQUIREMENTS

The Control Center control and display design shall be predicated on a concept of providing only the necessary equipment to support the checkout, readiness, test run, and shutdown phases of engine tests. Peripheral equipment required to support the control and display systems shall, in general, be located externally of the Control Center proper. All data recording equipment used for "quick-look" evaluation of engine runs shall also be located externally; only those recorders which are required for operational purposes (e.g., trend analysis) shall be located in the Control Center.

The concept of a minimum of control and display equipment is in keeping with the concept of a minimum number of operator personnel in the Control Center during operations. The expected number of operators in the area during engine tests ranges from a minimum of eight to a maximum of twelve; job descriptions are listed in Section 2.2.4 of this document. Technical observers of test operations will be isolated from the Control Center by viewing windows to minimize noise and like distractions. The Control Center layout is shown on Drawings ICC-134 and ICC-135, and discussed in Appendix 1.1, Section 4.0.

All controls shall be logically located on a series of consoles which shall, in turn, be located within the Control Center in such a manner as to provide optimum visual coverage of the area as dictated by the job requirements of each operator. The display equipment shall be located on consoles, and on vertical graphic-display panels. In general, the parameters presented on the graphic-display panels shall be limited to the parameters which are of interest to two or more console operators. Additional displays may be added which are of interest to the technical observers, providing such displays do not seriously detract from the primary purpose of the panels: providing functional information to the Test Director and the console operators.

2.4.1

Consoles

Six console groups shall be provided as indicated below. The specific requirements of each console are outlined in other

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.4.1

sections of the document; the general requirements are discussed in the listed paragraphs:

- par. 2.4.1.1 - Test Directors Console
- par. 2.4.1.2 - Safety Console
- par. 2.4.1.3 - Test Operations Console
- par. 2.4.1.4 - Facilities Console
- par. 2.4.1.5 - Lead Instrumentation Engineer's (LIE) Console
- par. 2.4.1.6 - Lead Control Engineer's (LCE) Console

2.4.1.1

Test Director's Console

The Test Director's console shall contain the necessary controls, displays, and monitors for the Test Director and the Asst. Test Director. In keeping with the philosophy of minimum direct control by these operators, this console shall contain a minimum number of operational controls. The controls, displays, etc., for the Test Director's console shall include the following functions:

(a) Test Director's Position

Reactor period meter

Duct temperature (maximum reading)

*Major-system status reporting modules (approx. 10)

6-channel strip-chart recorder (real-time trend analysis)

*~~Dual 8-in. TV monitor (each with multi-channel selector panel)~~
Communication, P.A., etc.

*Shared with Asst. Test Director's position

(b) Assistant Test Director's Position

*(Shares * items on Test Director's position)

Subsystem status reporting modules (approx. 50)

Count clock controls

Communication, PA, etc.

2.4.1.2

Safety Console

The Safety Console shall contain the necessary system controls to maintain a safe working area for all personnel, plus controls

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.4.1.2

* for use during emergency situations. The controls, alarms, displays, and recorders for this console shall include:

Area access and egress control system (lights, sirens, door, gates, lock-out key system, etc.)

Emergency control systems (fire-fighting, deluge, etc.)

Radiation monitoring system

Combustible gas monitoring system

Communications, etc.

** Carbon monoxide monitoring system

Oxygen analyzer system

2.4.1.3 Test Operations Console

The Test Operations console shall contain the necessary equipment for controlling the engine, the reactor, and certain critical test stand functions. The controls, displays, and monitors for this console are listed in Appendices 3.1 and 3.2. Function and equipment items are listed for the engine, reactor, and test stand panels. The reactor panel will be operated by the Lead Reactor Engineer, and the engine panel by the Chief Test Engineer. The test-stand panel which includes those critical test-stand items not a part of the engine, will be operated by the Chief Test Engineer or his assistant, if the number and nature of these controls is such that they cannot be safely handled by one operator.

**

A large percentage of the functions associated with the Test Operations Console will be automatically controlled by the Ground Master Engine Programmer. Thus, the duties of these operators will be primarily a monitoring function. The direct controls on the engine panel will be the Arm, Fire, Shutdown, and Scram switches, and trim controls associated with the turbopump and reactor. The engine and reactor panels require an array of meters and lights, in addition to the operational monitoring information presented on two 6-channel strip-chart recorders. The test stand panel will require a number of controls and switches for control and refill pressurization and feed functions

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.4.1.3

* of the LH_2 run tank, plus the GH_2 actuation supply, cooldown, and purge systems. These control systems will be augmented by visual displays on the test stand panel and on the engine-reactor graphic display panel.

2.4.1.4

Facilities Console

The Facilities Console shall contain the necessary equipment for properly operating the various Facilities Control Systems (process fluids and steam generator) as described in Section 5.5.1 of this document, and the Test-stand Support-equipment Control System (duct, shields, train, etc.), as described in Section 4.3.3.

(a) Facilities Control Panel (process fluids)

* The controls and displays for the Facilities Control Systems will be located in the Control Center. The division of functions between the Control Center and the forward areas is shown in Appendix 4.3. In the Control Center, the controls and displays shall be again divided, according to function and time of use, between the Lead Facilities Engineer's console and the process-fluids graphic display panel with its associated operator's console. The controls which are to be located on the graphic-display console shall be limited to functions which are normally preset to either an "ON" or "OFF" condition during the latter stages of the countdown, and only then if the likelihood of further critical adjustment during the run or critical cooldown periods is essentially nil.

The operators will remain at the consoles during the engine run to perform emergency shutdown procedures if necessary. All functions which are directly associated with the engine run will be controlled by the Lead Facilities Engineer at his console. The controls and displays which are to be located on these consoles are those which relate to the pressurization and transfer of the hydrogen, oxygen, nitrogen, propane, cooling gas, and run-tank systems. The appropriate functions are listed, together with the number of controls and displays, in Appendix 4.

(b) Test Stand Support Equipment Panel (Duct, shield, train, etc.)

The Test-stand support Equipment includes the duct, shields, protective doors, and the transport train. Local controls for operation of these items will be provided for use whenever the

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par. 2.4.1.4	

test-stand area is radiation safe. Remote control, from the Test-stand Support-equipment Panel at the Control Center, will permit operation during unsafe periods.

The Test-stand Support-equipment Panel shall be subdivided into the two basic functions of positioning and operation. The positioning function shall include all necessary controls and displays for moving the support items to and from the storage and operating positions of each item. Control of the transport train will be accomplished via a radio link (located at the Mad or E-Mad Buildings). R.F. control will be interrupted at a position adjacent to the Test Stand by means of a disabling interlock. Subsequent control of the engine cart for mating of the nuclear engine to the test-stand will be accomplished with controls on the panel at the Control Center via an interlock connector at the test stand. The block diagrams of these positioning functions are shown on Drawing ICC-008 (4 sheets), and discussed in Section 4.3.3. The controls and displays for the panel are listed in Appendix 4.

2.4.1.5

Lead Instrumentation Engineer's Console (LIE Console)

*

*

The controls and displays on this shall be those which are necessary to monitor and control the operation of the Data-Acquisition, Display, Timing, Photo, and Communications Systems. In general, these systems will be self-sustaining by various means, such as automatic transfer from one tape machine to another (Data System), by automatic Fail-Safe transfer on a master and slave basis (Timing), or by programmed ON-OFF techniques (Photo). Thus, the functions associated with the Instrumentation (LIE) Console will be primarily the monitoring of pre-planned system operations, plus manual override controls for use in the event of a malfunction.

Whenever practical and applicable, the functions controlled and displayed on the LIE Console shall only be the Master controls and displays for each of the six sub-systems involved.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.4.1.5

(a) Data Acquisition Control Panel

A relatively large number of recorders are involved in the Data-Acquisition System, and the system is further operationally complicated by the fact that a number of the recorders will hold only enough paper or tape for a fraction of the total anticipated test interval. Automatic sequencing of Turn-On and Turn-Off shall be mandatory requirements for all normal test operations and for recorder-to-recorder transfers. However, a number of manual operations also exist. Basically, each recorder (or group of recorders) shall be controllable from a Data-Acquisition Control Panel, not a part of this console. Controls on this console will be limited to those necessary to insure proper operation under the following circumstances:

**

- (1) Manual-override - used in the event of a failure of the automatic sequencer.
- (2) ~~"Panic" - used in the event of an engine or reactor emergency, to insure the acquisition of a maximum amount of data for subsequent study.~~
- (3) Calibrate - used to command system calibrations as required.

*

~~The status of each recorder shall be displayed on the console by means of Running/Ready/Out-of-Service status lamp modules. Further, controls shall be included to switch back-up recorders to operational status as required.~~

*

Status modules shall be included on the panel to display the status of critical sub-system equipment (e.g., digitizers, multiplexer groups, programmer, etc.). The total number of peripheral equipment items in the data system will preclude the use of status displays for each individual item; therefore monitoring and status reporting of these units will be done by the local operators.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962
Par. 2.4.1.5

(b) Display Control Panel

The reliability requirements for each display in the Control Center will be extremely high inasmuch as critical decisions will often have to be made on the basis of the information portrayed. In the instances where redundancy is required to meet the necessary reliability, a combination of man and/or machine judgments will be necessary to determine whether the operating or the standby display system should be used at any given time. The Display Control panel shall be furnished with the necessary switching capability to allow the operator to choose between the two (or more) display systems as necessary.

(c) Timing Control Panel

The Controls and Displays on this panel shall include monitoring and control circuitry to maintain proper outputs of the timing system. The panel shall include:

- (1) ~~Time-code displays~~
- (2) Manual selection of primary or secondary time-code generator
- (3) Manual selection of primary or secondary master oscillator.

(d) Photo Control Panel

The Photo Control Panel shall include the following control and display equipment:

- (1) Each camera group shall include: "Start-Stop" control switch via automatic camera sequence programmer, "Start-Stop" control via manual switch, and "Remote-Local-Off" switch.
- (2) Each camera shall include: "Automatic-Manual" selector switch, "Start-Stop" manual switch, "Dump Speed" manual switch, "Remote-Local-On" switch, "Running/Ready/Out-of-Service" status module, and "Remaining Run-Time" indicator.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.4.1.5

- * (e) T. V. Control Panel
(deleted)
- (f) Communications Control Panel

The communications panel of the Instrumentation Console shall have the ability to monitor all communications shannels as an aid in trouble-shooting, etc. Further, the panel shall contain a selector switch and tape-recorder control arrangement which will permit the operator to select any communication channel and record data as desired.

2.4.1.6

Lead Control Engineer's Console (LCE Console)

The equipment located on the LCE Console shall be those which are necessary to monitor the various actuation power sources for the control systems (115-v ac, 24-v dc, hydraulic, pneumatic, etc.). In addition, this console shall also contain monitoring voltage and frequency meters for the test site primary power systems (60 cps, 400 cps and 24-v dc). No requirements for controls are anticipated on this panel, with the possible exception of switches to be used in selecting alternate actuation power sources in the event of a source failure.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.4.2

2.4.2 Graphic Display Panels

Three graphic display systems shall be provided: Engine-Reactor, Safety, and Facilities. The specific requirements of each display is outlined in other sections of this document; the general requirements are discussed in the following paragraphs.

2.4.2.1 Engine-Reactor Graphic Display

The Engine-Reactor Graphic Display is shown on Drawing ICC-141. A combination of digital, analog, and light displays are used to show the status of critical engine-reactor parameters which are required by two or more control-center operators. The display will also portray overall engine operating characteristics to the technical observers.

The digital displays shall depict two distinct parameters. First, the quantitative representation of each function shall be shown (in engineering units) via alpha-numeric characters which can be read at distances of at least 40 ft. Second, the qualitative representation of each function shall be shown via multi-colored backgrounds. Typically, a black background (no light) with white numerals will indicate a normal condition, an amber background will indicate a marginal condition, and a red or flashing red background will indicate a dangerous condition. Additional details of the digital displays are discussed in Section 2.4.2.4.

The analog displays shall be large industrial type indicating meters with ribbons (or large pointers) to indicate the position of the reactor control drums, and shall be in a single row to form a bar graph presentation. This portion of the display is not expected to provide sufficient resolution for reactor-control purposes; however, the gross position of the drums will be displayed with sufficient accuracy for the needs of all other operators in the control center.

Light displays shall be used to display valve positions (open or closed) in addition to the Black-Amber-Red status lights previously discussed.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A	
Date	1 June 1962
Par.	2.4.2.2

2.4.2.2

Safety System Graphic Display

The Safety System Graphic Display shall consist of two semi-identical area maps. One map will display the status of all doors, gates, etc., which are used to control the movement of personnel throughout the area. The second will display Safe-Unsafe areas on the basis of radiation or combustible gas danger conditions.

(a) Area Control Map

The area control map will be a graphical depiction of the ETS-1 and ETS-2 sites, and will include all roadblocks associated with the area. The areas which are connected by the tunnel shall be shown to approximate scale, except that the buildings shall be somewhat larger than scale to permit a more detailed presentation of their status. Remote roadblocks, camera sites, etc., will be displayed on the borders of the map, but not necessarily to scale. The information on the map will be presented by means of red-amber-green light modules which will be controlled in conjunction with the door-gate, siren-light and lock-out key systems.

* (b) Radiation-Gamma/Air Voc. - O^2 - Combustible Gas - CO Map

* The Radiation-Gamma/Air Voc. - O^2 - Combustible Gas - CO map shall show the area in approximately the same manner as described for the Area Control map. (Nominal up or down scaling of area dimensions is permissible if necessary to provide information in greater detail.) The information furnished by this display shall be the Magenta-Red-Amber-Green qualitative status of each of the area safety detectors; quantitative indications are to be displayed on the Safety Console only. This display panel will permit the Lead Safety Engineer and Test Director to determine gross area safety conditions at a glance, and will also provide the Safety Engineer a guide for his use in selecting the proper switch/meter monitoring combination whenever console quantitative information is required regarding a non-predicted status light change.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.4.2.3

2.4.2.3

Facilities Graphic Display

The Facilities Graphic Display panel shall be a multi-colored depiction of the facilities process fluid systems in schematic form. The panel will be approximately 5-ft high and 16-ft long, and is shown in preliminary form on ICC-100. The status of all elements of the systems which are used during the latter portions of the countdown, the engine-run, and the cooldown phases of the operation will be depicted by means of digital or analog indicators, or by light displays. Digital and analog indicators shall be used to display the status of critical temperature, pressure, flow, level, and proportional valve position measurements throughout the facility. The open or closed positions of solenoid operated valves will be shown by two-color light displays.

A console group is to be located immediately below the Facilities Graphic Display panel. This console group will be a continuation of the Lead Facilities Engineer's console, and will contain the controls and displays for preset functions as discussed in Section 2.4.1.4 (a).

2.4.2.4

Digital Display System

The digital displays on the graphic panels shall be the visual read-out portion of commercial digital voltmeters. A maximum of three variable digits shall be displayed; if, as an example, five digits are required to display the function in normal engineering units, the last two digits shall be fixed "0's." The digital voltmeters shall be of the design which displays information by means of continuous updating techniques. Specifically, transition from a reading of 120 to a reading of 121 shall appear as 120 rather than a cycling of all three digits while the unit "hunts" for the proper number. (Units which require from 1/4 to 1 second to resolve input level changes are not suitable for this application.)

- (a) Two basic factors must be considered in the final design of the digital display system in order to adequately present the information in "engineering units:"

Is the transducer or amplifier output signal a linear or non-linear representation of each function involved?

Will a high degree of accuracy be required over the total or a limited range of transducer or amplifier output signal range?

If the signal is basically linear (e.g., strain-gauge pressure transducer) it will only be necessary to scale the input signal to the digital voltmeter by an appropriate factor, and insert the decimal point (if required) at the proper position.

Limited range linearization can be considered only if the function is predictable, and if a significant departure from some given point would be considered such a gross error that exact quantitative readouts would be relatively meaningless. A temperature readout of -100°F from the LH_2 storage system could be considered as a typical example: A $\pm 50^{\circ}$ error in the readout at this point would not be particularly significant; the flashing-red background of the display would be far more indicative of the status of the system. An accurate readout over the range of -400 to -430°F should suffice for this particular readout, and therefore, simple scaling techniques which would provide accuracy over a small calibrated range can be considered for this and other similar examples.

Linearization over the total output signal range of a transducer or amplifier can be accomplished by a number of existing techniques in both the analog and digital domains. Digital techniques should be considered for reasons of simplicity, flexibility, and economy. Ultra-linear characteristics are normally designed into the typical digital voltmeter through the use of a number of identical precision comparator resistors in each decade. If the resistors of the most significant decade are changed to non-identical values, the device would automatically become non-linear. Thus, if resistors are properly chosen, non-linearity curves can be achieved which are approximately equal and opposite to those of the transducer or amplifier output. This technique, when accompanied by appropriate scaling, can result in reasonable accuracy over the total range of the signal, with a higher order of accuracy at selected points.

- (b) Smoothing circuitry shall be added to the input of the digital voltmeters in instances where the frequency response or noise characteristics of the signal source(s) would otherwise result in changes exceeding the rate of human assimilation.

Two rate-of-change conditions exist which must be considered. The first assumes the typical condition wherein a change from near-zero to near-full scale occurs very rapidly. In this case, only the first one or two variable digits are necessary to portray the gross reading; the latter digits will be a blur, and therefore naturally assumed to be zeros.

The second rate-of-change condition which normally exists involves a quasi-state signal which may be fluctuating over a fraction of the full scale value. The fluctuation may represent random noise, 60-cycle pickup, or a low-frequency oscillation of the function being displayed. Noise or 60-cycle pickup must be eliminated by suitable filtering techniques. Low-frequency oscillation represents meaningful information, inasmuch as it may indicate a condition that will worsen if not corrected. In this state, the first two digits of the display should be more or less stable, with the latter digit indicating the rate and magnitude of the fluctuation. Thus, the frequency-response characteristics of the smoothing circuitry must take into account the rate which the function (including transducer) is physically and electrically capable of changing, as well as the rates which can be assimilated by the operator. Time constants of 1/10 to 2 seconds (for zero to full-scale ranging) represent the response times which will be applicable in the majority of instances.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.0

3.0

REMOTE ENGINE CONTROL SYSTEM

3.1

SCOPE

* This section will establish the design criteria for the system necessary for remotely controlling the operation of the engine control system and the test stand control equipment which directly affects engine operation. The equipment described in this section is a part of the facility, and not a part of the engine.

* Criteria for Engine Controls, including the ground-test master programmer, (which are integral parts of the Engine System) is contained in Volume IV, Section 1.0, "Engine Control System Criteria."

Engine checkout equipment defined as GSE (such as the engine checkout console and the engine simulator console), is excluded from the scope of this criteria.

3.1.1

Purpose

* The primary purpose of this system is to provide the controls necessary for remotely operating, through the Engine Control System, a liquid-hydrogen pump-fed nuclear rocket engine in a safe and reliable manner over a variety of scheduled and unscheduled test conditions, and to provide a flexibility of control so that an economy of operation can be effected.

3.1.2

Function

* The function of the system is to provide instrumentation and control for remote operation of the Engine Control System and those test stand facilities which directly affect engine operation. Appropriate displays will be provided in the Control Center for rapid assimilation and evaluation of the engine operation, which will be presented in the form of digital printout, analog recording, indicator lights, and meters.

* Controls will be available for start, shutdown, and manual control of the engine during its operation; however, all operations performed by the engine will be controlled through the ground-test master programmer.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.1.2

* A further function of the remote engine-control system is to provide an automatic engine shutdown initiation in the event of a test stand maloperation which is not detected by the Engine Control System.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 3.2

3.2 I & C SYSTEM CONSIDERATIONS

3.2.1 Basic Concepts and Operations Philosophy

3.2.1.1 General Considerations

The operation of the remote engine-control system is based on the philosophy existing for R & D testing of liquid rocket engines. However, for the purposes of engine development, it is considered that the operating characteristics of the reactor may not have been fully established prior to initiating the engine tests. Therefore, although automatic programming is a prime requisite for engine development testing, manual control is provided.

The basic operating principle necessitates that all remote engine controls be integrated with the ground-test master programmer. Dwg. 1CC-036 depicts the block diagram of the engine-control system. The remote engine-control system shall be capable of initiating the engine starting and shutdown cycles through the ground-test master programmer; additionally, remote controls shall be provided for manual control of certain engine parameters. Although these manual controls are available for all engine operations, they are primarily intended to provide flexibility during initial reactor testing operations. It is not expected that the manual control will be used during periods of rapid transients, or when complex control operations on several parameters are required. These manual controls cannot compromise engine safety because of control limiting and shutdown circuits provided in the programmer and in the malfunction equipment of the remote engine-control system.

The location of the ground-test master programmer cannot be established until economic and operational feasibility studies are undertaken and completed. For the purposes of this criteria the location of the programmer will be the Test Cell Building.

The programmer will incorporate provisions to detect engine maloperation and will have the capability of instituting a shutdown cycle. As part of the remote engine-control system,

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 3.2.1.1

malfunction control equipment will be able to initiate an engine shutdown through the ground test programmer. The malfunction control unit will analyze pertinent test stand operating parameters and if the limits are exceeded, will initiate a programmer shutdown regardless of the mode of operation (manual or automatic) at the time of malfunction.

The engine may be shut down in one of two methods:

- (a) Controlled Shutdown - this will follow a programmed power reduction schedule and will be initiated when the engine can be shut down, as in a normal end-of-test shutdown. Provisions for obtaining full-power operations from the reduced level will be possible.
- (b) Scram Shutdown - this will be accomplished by simultaneous, immediate rotation of all control drums to the full-in position accompanied by accomplishment of the required cooldown and purging schedule, and will be initiated when: the integrity of the test stand is jeopardized, personnel safety is concerned, or indications are that the reactor may destroy itself.

Limits will be set into the malfunction control equipment, where possible, so that a controlled shutdown will be initiated before Scram conditions are reached. Reliability will be a paramount consideration in circuitry design.

3.2.1.2 Specific Considerations

- (a) In the control center, all remote controls for the engine master programmer operation and related test stand functions will be contained in the test-operations console.

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Pertinent displays will be provided both on the test-operations console and on graphic displays located in the control center, and in the remote recording area of the Control-Point Building.

Manual controls for the engine and the test stand facilities are provided on the various panels of the test-operations console.

- (b) Simulators will be utilized in checkout of the remote engine control and to insure proper functioning prior to initiating an engine test.
- (c) All controls from the Test Operations Console will, in general, be transmitted through appropriate transmission cabling into the Test Cell Building and will there be distributed through a patching network to the control areas. The patching network will be designed with the intent of standardizing the distribution, reducing electrical trouble spots, and increasing network reliability for R & D testing. The patch distribution equipment will be designed to prevent accidental disruption of the patch cabling.
- (d) All control wiring will, where possible, be a pair of twisted wires. One wire will be installed from the power source to the component to be energized or de-energized, and a return wire twisted around the first wire will be grounded at the power source (which is the same as the power supply ground). This method is used because the electrical pulses generated during energization and de-energization are nullified. Single-wire systems grounded at the point of operation may cause electrical pulses to be generated during component energization and de-energization, thus causing spurious signals in critical control circuits which may indeed cause premature test termination.
- (e) The order of priority assigned to the control, display, and data-acquisition circuitry follows:

Controls - These circuits have the highest priority with respect to reliability. Therefore, all displays and data-acquisition channels monitoring the control circuits will be isolated to prevent their failure from affecting the remote engine control.

Displays - Displays are required to evaluate the performance of the engine during its operation. The data-acquisition channels monitoring the same displays will be isolated to prevent any failures in the data-acquisition system from affecting the display capability.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.2.1.2(e)

Data Acquisition - These circuits have the lowest priority and must be isolated, so that their failure will not influence the remote engine controls and the visual displays. Those parameters required for data acquisition only need not be isolated.

(f) Typical equipment in the Remote Engine Control System will include

(1) Transmission cabling, except for those cables which are part of closed-loop engine controls.

(2) Signal conditioning equipment.

** (3) Meters and other visual displays.

(4) Isolation equipment.

(5) Control and display equipment for control of necessary test stand and facility functions.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.2.2

3.2.2 Interface Considerations

- * Interface areas affecting the Remote Engine Control System are those involved with the Facility Control System (see par. 3.2.2.1), the Engine Control System (see par. 3.2.2.2), and the Data Acquisition System (see par. 3.2.2.3), as illustrated in Dwg. ICC-208.

3.2.2.1 Facility Control System Interface Areas

- * The Facility Control System interfaces with the Remote Engine Control System at the controls which directly supply the engine with process fluids. Controls are required in the Remote Engine Control System for checkout, purging, and testing operations.

- * ~~Controls in the interface areas must be locked out of the facilities console during testing operations, since direct control is required from the test operations console.~~

The following are the Facility Control System interface areas:

- (a) LH₂ feed, from run tank to engine
- * (b) GH₂ Engine Actuation System
- * (c) ~~Cooling gas system~~
- * (d) ~~High-pressure LH₂ run tank~~

3.2.2.2 Engine Control Interface Areas

- (a) The Remote Engine-Control System will interface with the Engine Control System at the ground-test master programmer. The ground-test master programmer provides the means for operating the engine, while the Remote Engine-Control System initiates, monitors, and may manually control certain engine parameters through the programmer during test operations. Specifically the number and type of connecting receptacles and wires must be defined.
- * (b) Pre-firing checkout of the engine will be conducted through the ground-test master programmer by an engine checkout console

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	3.2.2.2(b)

and an engine simulator, which are considered GSE equipment. Although the design criteria for this equipment is not established in this document, interfaces between the ground test master programmer, the checkout equipment, and the remote control system are apparent.

- (c) Checkout of the test stand control equipment, excluding the engine, is primarily the responsibility of the Facility Control System; however, those facility items directly affecting engine operation will be controlled from the test-operations console.

*

3.2.2.3

Data-Acquisition Interface Areas

The Remote Engine Control System interfaces with the Data-Acquisition System at the isolation equipment between the Data-Acquisition equipment and the Remote Engine Control System. The isolation equipment will be furnished as a part of the Remote Engine Control System.

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Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.3

3.3 SYSTEM REQUIREMENTS

All controls and related displays necessary for control of the Engine Control System will be contained in the Remote Engine-Control System. The ground-test master programmer (part of the Engine Control System) and required test stand functions will be controlled from the test-operations console located in the Control Center.

3.3.1 General Requirements

General requirements for the remote engine-control system are specified in the Parsons Report of 16 June 1961, titled "National Nuclear Rocket Development Facility," Vol. 3, par. 11.3.2 (see Section 1.1, this volume), as follows:

- (a) It must be reliable,
- (b) It must be capable of operating over long transmission circuits,
- (c) It must be stable and insensitive to line voltage variations, acoustics, temperature, and radiation disturbances,
- (d) Vital control circuits must be protected against power failure,
- (e) Monitors must be easily readable,
- (f) The console array must be arranged to permit efficient and safe operation of test hardware,
- (g) It must afford ready check and verification of control circuit status,
- (h) It must be easily serviced, and
- (i) It must permit ready modification to accommodate test program variations,

3.3.1.1 Test Program Requirements

- * (a) The Remote Engine-Control System will be capable of controlling the Engine Control System for the tests outlined in Dwg. ICC-074.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.3.1.1

- * In addition to, or as a preliminary part of, the tests outlined, the Remote Control System must be capable of operating the Engine Control System for such evaluation procedures as:

Low-level tests in which reactor power is below that level which requires coolant.

Low-level tests during which the reactor power is programmed to the point of LH₂ flow initiation, in a prototype power-time manner, then Scrammed.

Low-level tests during which gaseous coolant may be used.

- * ~~Engine operation requiring an auxiliary supply of gaseous hydrogen for turbopump operation.~~

- * (b) ~~This system will establish the I & C Design Criteria to achieve the above requirements; however,~~ These criteria do not include any requirements for performing the following types of tests:

Utilization of a gas generator for turbopump operation,

Turbopump development tests whereby the pump discharge flow is returned to the storage tank, or

High-pressure LH₂ feed directly to the reactor from a tank bypassing the turbopump

3.3.1.2

Test Operations Console

- * The operation of the Engine Control System will be remotely conducted from the test-operations console. Controls and displays will be available in this console for initiating the starting and shutdown cycles through the ground-test master programmer in addition to manual control of the engine. Also available will be controls to operate those test stand facilities directly affecting engine operation.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.3.1.2

As illustrated in Dwg. ICC-003, this console will consist of three panels, the engine-control panel, reactor-monitoring panel, and test-stand control panel.

The operations to be conducted from these panels are as follows:

Engine Control Panel - All operations required to operate the engine through the ground-test master programmer including manual control of pertinent engine parameters will be controlled from this panel.

Reactor Monitoring Panel - Displays pertinent to reactor operating will be monitored from this panel.

Test Stand Control Panel - All test stand facilities directly affecting engine operation will be controlled from the panel.

In addition, two multichannel strip-chart recorders will be located on the test-operations console for real-time display of pertinent engine parameters.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	3, 3, 2

3. 3. 2

Remote Engine Control System Equipment

The Remote Engine-Control System equipment shall consist of displays and controls necessary for monitoring the engine during test, and for necessary controlling of the engine. The controls shall work through the ground-test master programmer, and will be located on the test-operations console.

* ~~Provisions will be made for controls to accomplish Engine startup, including reactor startup, and adjustment of necessary engine parameters during test.~~

Controlled shutdown and Scram switches will be on the test-operations console.

* Displays analog or digital form. Provisions will also be made for visual display of pertinent valve positions.

* Provisions will be made for use of external neutronics as back-up for engine contained neutronics. This equipment will be used for monitoring only, and will not be incorporated into the malfunction-control unit or Engine Control System.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.3.3

3.3.3 Test Stand Control Equipment

*

The test-stand control equipment of the Remote Engine Control System shall consist of controls and displays necessary for operation of the test-stand functions directly related to engine control. These controls will be located on the test stand panel of the test-operations console. ~~Similar controls may be required on the facilities console. Primary responsibility, during testing operations, of any duplicated controls must be in the remote engine control system; therefore the circuitry will be arranged to lock-out operations from the facility console.~~

3.3.3.1 Controls and displays are required to provide the following test stand services to the engine:

(a) LH₂ supply to the engine, which includes the following systems:

Run Tank Refill - LH₂ transfer from the storage tank to the run tank, since the run tank has only sufficient capacity for 9 minutes of operation, and the maximum duration required for specific tests is 20 minutes.

Run Tank Pressurization System - Control of the run-tank pressurization is a requirement for engine operation so that a regulated flow rate can be delivered to the engine.

Run-Tank Venting System - Control of the run-tank venting is a requirement to prevent over-pressurization of the run tank.

LH₂ Feed from Run Tank to Engine - Control of the circuit between the tank outlet and the engine inlet is required to insure that an adequate flow of liquid hydrogen is available to the engine at the specified pressure required.

(b) Engine GH₂ Actuation Supply

Controls are required for initially charging the engine actuation gas bottles to a specified pressure or directly supplying gas at regulated pressure to the engine actuation system in the event that actuation gas bottles are not furnished with the engine.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.3.3.1

(c) Cooling-Gas System

* ~~Controlled shutdown coolant supply - Controls are required at engine shutdown to cool the reactor with a programmed flow of gaseous hydrogen and cold gaseous nitrogen.~~

~~Emergency LH₂ Coolant Supply - Controls are required to supply LH₂ coolant for reactor cooling, in event of Scram at the full-power level.~~

(d) Purging

Controls are required to purge the various systems of the engine and the test stand systems directly connected to the engine.

It is required that air be purged from the line prior to introducing the hydrogen, and that the hydrogen be purged from the lines prior to maintenance or repair work on, or removal of, the engine.

Controls will be required for the purging of the following:

- (1) Line between the tank-outlet valve and the engine-inlet shutoff valve,
- (2) Line from engine-inlet valve through the engine thrust-chamber exit and turbine-exhaust duct,
- (3) Cooling-gas system, and
- (4) Engine actuation supply.

(e) Gaseous Hydrogen Supply for Initial Engine Tests

* ~~Controls are required for initial low power engine tests for supplying gaseous hydrogen in place of liquid hydrogen. The gaseous hydrogen must be supplied at a specified pressure from a high pressure source.~~

Controls must also be available, if required, to provide a source of gaseous hydrogen for the turbopump drive fluid.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.3.4.

3.3.4 Test Stand Malfunction Control Equipment

The malfunction-control equipment can initiate an automatic shutdown in the event of pertinent test stand maloperation. Information will be inserted into the malfunction-control equipment, and when predetermined limits are exceeded, a shutdown signal will be presented to the ground-test master programmer, which will shut down the engine. A basic requirement of the malfunction control unit is the prevention of spurious shutdowns. Accordingly, the number of shutdown circuits shall be held to a minimum, and programming of appropriate shutdown limits is required.

3.3.4.1 Provisions will be made for 2 shutdown modes:

Controlled Shutdown - when initiated, either manually or automatically, shall reduce reactivity and adjust related power transfer functions to lower levels as in a normal end-of-test shutdown. Provisions for re-obtaining full-power operations from the lower levels will be incorporated.

Scram - when initiated, either manually or automatically, all control drums will simultaneously rotate full-in. Scram will be "fail-safe"; it will function on loss of all power. Generally the limits for a controlled shutdown will be less than those for a Scram shutdown.

3.3.4.2 A controlled shutdown shall be initiated automatically under the following conditions by the malfunction-control equipment:

LH₂ flow is reduced below required level, but not to lower level which initiates Scram.

LH₂ run-tank level is reduced to amount which is just sufficient for normal shutdown.

Other facility functions whose relationship to safe engine operation is not now established and will require further analysis.

3.3.4.3 A Scram shall be initiated automatically under the following conditions:

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.3.4.3

- (a) When LH_2 flow is reduced below required level.
- (b) When other facility functions whose relationship to safe engine operation is not now established and require further analysis.

3.3.5General Test Stand Requirements

All hydraulically operated controls shall have a response rate of less than 45° phase shift at a frequency of 1.0 cps.

All pneumatically operated shutoff valves will be designed for "fail safe" operation. This will generally require the valve to close in the event of failure of power on the valve-actuation system.

Systems where the "fail safe" feature may result in over-pressurization should be protected by means of a mechanical relief valve.

Where possible, all wiring for control and indication purposes will be composed of a pair of twisted wires, thus eliminating electrical pulses associated with energization and de-energization activities.

Polarized and non-polarized circuitry shall be employed as required:

Polarized circuitry will generally be utilized for valve open and closed indications.

Non-polarized circuitry will generally be utilized for relay and solenoid operation.

All control circuitry shall be grounded at the power supply. No control circuit floating grounds are permissible due to possible interference with instrumentation circuitry.

Control wiring transmission shall be separated from instrumentation transmission to minimize possible electrical pulses generated in control circuitry from affecting the Data-Acquisition System.

Malfunction-control wiring shall be isolated from all other wiring to prevent inadvertent operation of the Scram or normal shutdown circuits from spurious signals generated in other circuits.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	3.3.5

All control wiring must be locked in cabinets and racks and routed in such a manner as to prevent accidental circuit disruption.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.4

3.4

GENERAL SUBSYSTEM CRITERIA

In the Instrumentation and Control System, several supporting subsystems will implement the Remote Engine Control System equipment. These subsystems will be organized as follows:

Instrumentation Subsystem - for the sensing and transmission of pertinent data (see par. 3.4.1).

Television Subsystem - for visual monitoring of pertinent areas (see par. 3.4.2).

Communication Subsystem - for necessary conversing among test personnel (see par. 3.4.3).

Electrical Power Subsystem - for powering the remote engine-control system and related subsystems (see par. 3.4.4).

Timing - for recording the time relationship of independent engine parameters (see par. 3.4.5).

3.4.1

Instrumentation

The instrumentation requirements for the remote engine-control system includes the signal conditioning and transmission to the display units of pertinent engine parameters.

Sensing units (pickups) will be furnished with the engine. For the transmission of display information and control functions in the Remote Engine-Control System, the following will specifically apply:

- (a) All instrumentation will be patched in the Control-Point Building for use in the Remote Engine-Control and Data-Acquisition Systems.
- (b) Isolation circuits, having one input and one or more outputs, will be used where necessary. A malfunction in any one of the outputs will have no effect on the input device or any remaining outputs. Specifically, isolation circuits will be used where:

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A	
Date	1 June 1962
Par.	3.4.1

- (1) Control circuits, including malfunction control, are monitored by display and/or data acquisition units,
- * (2) Displays are monitored by the Data Acquisition System, or
- (3) Any other case where isolation is necessary, as in the case where two displays monitor a single sensor.
- * (c) ~~All signal conditioning and isolation functions will be accomplished in the Test Cell Building.~~
- (d) Wire or cable transmission will be used exclusively.
- (e) Transmission cabling will have proper impedance match at both the patch and display unit.
- (f) Standard circuits will be used throughout.
- (g) All checkout, signal conditioning, and calibration equipment in the Remote Engine Control System shall be identical to corresponding equipment of the Data-Acquisition System, wherever possible. This equipment shall be provided with means for control of physical access independently of the Data-Acquisition System equipment. Means must also be provided for independent calibration control, or for calibration simultaneously with the Data-Acquisition System.
- (h) Provisions shall be made for 200 channels of patchable instrumentation for engine control and display.
- (i) Detailed requirements for individual controls and displays are delineated in Appendices 3.1 and 3.2.

A control and reporting block diagram is shown in Dwg ICC-147.

3.4.2

Television

For the remote engine-control system, the basic requirement for television is to provide, for the Chief Test Engineer, visual display of the engine area and supporting facilities.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.4.2

The Chief Test Engineer should have a minimum of two simultaneous displays which are considered necessary:

A closeup view of the circular shields plus the exhaust jet.

A wide angle, panoramic view of the circular shields, run tank, exhaust duct, and surrounding area.

3.4.3

Communications

Suitable communications means shall be provided so that the Chief Test Engineer can converse directly with the Test Director, personnel in the remote strip-chart recorder area, personnel in the forward control room, personnel in the Test Cell Building, and personnel in the test stand at the various levels.

The communication set of the Lead Reactor Engineer will be in parallel with the set of the Chief Test Engineer, except that the Chief Test Engineer will have means to override the Lead Reactor Engineer.

3.4.4

Timing

Time shall be displayed digitally on the test-operations console and the graphic display.

Timing marks shall be recorded on all pertinent recordings so that correlations can be made between recordings.

3.4.5

Electrical Power

Electrical power necessary for operation of the remote engine-control system shall be supplied from the facility power system.

Backup power (for use in the event of electrical power failure) must be available, sufficient for at least 20 minutes operation at maximum power consumption. See paragraph 4.5.2.4(b).

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Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.5

3.5 SYSTEM CRITERIA

* All equipment in the Remote Engine Control System is divided into the following groups:

* Engine Ground-Test Master Programmer Control Equipment - for remotely controlling the Engine Control System. (See par. 3.5.1.)

* Test-Stand Control Equipment - for operation of necessary test stand facilities (see par. 3.5.2).

* Test Stand Malfunction-Control Equipment - for initiating a shutdown in event of a Test Stand Malfunction (see par. 3.5.3).

** Display Equipment - for display of parameters not furnished as a part of the Engine Control System (see par. 3.5.4).

3.5.1 Engine Ground Test Master Programmer Controlling Equipment

* This equipment contains all the controls and displays necessary for remote operation of the Engine Control System.

* The Engine Ground Test Master Programmer Controlling Equipment may be grouped into two types of equipment:

* (a) Ground Test Master Programmer Controlling Equipment

(b) Reactor Monitoring Equipment

* For detailed list of controls and indicators required, see Appendix 3.1.

3.5.1.1 Ground Test Master Programmer Controlling Equipment

* This equipment will consist of all controls and monitors, as shown in Dwg. ICC-061, which are necessary for:

* (a) ~~Checkout of the Programmer Controlling Equipment - This includes all switches, controls, displays, transmissions, patching, etc., required for engine, including reactor, operation to the point of connection to the master programmer.~~

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	3.5 1 1

- * (b) Operation of the Ground Test Master Programmer - This includes the following switches and lights located on the engine control panel of the Test Operations Console:
- Arm - This switch when operated shall check through the ground-test master programmer, the malfunction control, and the complete engine safety circuits for correct positioning of limit, and pressure switches, etc. A "ready" light will indicate proper circuitry.
- Fire - This switch when operated will initiate the program preset into the ground-test master programmer. A "fire" light will indicate that the ground-test master programmer has received the proper signal.
- Shutdown - This switch when operated during an engine test shall initiate a controlled shutdown in the ground-test master programmer.
- Scram - This switch when operated during an engine test shall cause an immediate simultaneous rotation of all control drums to the full-in position accompanied by the scheduled cooldown and purging procedure. The shutdown schedule will be determined by the Ground Test Master Programmer.
- * Reset - This switch will be operated after shutdown to reset any lock-in circuits.
- * Refire - Operated after a controlled shutdown initiation and during low level power phase will bring power level demand to the operating level before the controlled shutdown.
- Malfunction Lights - One of two lights will indicate a normal shutdown cycle malfunction condition and the other will indicate a Scram shutdown condition. In addition, lights will be incorporated to indicate the cause of a shutdown.
- (c) Manual Controls - These include:
- (1) Turbo Pump Control (Chamber pressure control)
- A control shall be incorporated on the engine control panel which will allow for manual adjustment of the chamber-

pressure reference input for the turbopump control. This control will track chamber-pressure reference so that minimum perturbations will be introduced if manual control is initiated.

Thrust-chamber pressure reference/Manual-position error meter - A meter shall indicate the difference between the thrust-chamber pressure reference and the position required by the manual thrust-chamber reference control.

A manual/automatic switch and indicator will be provided for initiation of manual control of the turbopump. This switch will be interlocked to prevent changeover from manual to automatic when the error meter signal is above zero.

(2) Chamber Temperature Control (Drum Position Control)

Manual control of thrust-chamber temperature reference will be provided. The control shall track the thrust-chamber temperature reference during automatic operation for minimum perturbations on switch-over.

Temperature Control Error Meter - A meter shall indicate the difference between the Thrust Chamber Temperature Reference and the position of the Thrust Chamber Temperature Reference Manual Control.

A manual/automatic switch and indicator will be provided for initiation of manual control of chamber temperature reference. This switch will be interlocked to prevent changeover from manual to automatic when the error meter signal is above zero.

(3) Drum Position Control

Drums may be controlled by the programmer or by a "ganged" drum manual control. In addition, any one drum may be selected for manual control while the remainder are controlled by the programmer. This requires the following controls, switches, and indicating lights:

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.5.1.1

Individual drum control switch for selecting any one drum for manual control.

Ganged drum control switch for selecting all drums for manual control.

Automatic switch for controlling all drums automatically. This switch will be interlocked to prevent changeover from manual to automatic when the error meter signal is above zero.

Drum manual control for manual controlling of all drums or any individual drum. In the automatic mode this controller will track the drum position reference.

Drum position Error Meter - One meter, through a 12-position selector switch, will indicate the difference between actual drum position and the position of the individual reference control of the selected drum.

(d) Displays - These include:

Reactor Neutron Log Power - with associated range selector switch to select from three ranges, source, intermediate and power. Lights to indicate range displayed.

Reactor Period - Logarithmic Presentation must include 1 millisecond through infinity to -1 second.

*

Reactor Neutron Power Level - Neutron power level is displayed on a linear scale over the range of source to 1.5 rated power.

Chamber pressure
Chamber temperature
Turbopump speed
Core-inlet temperature
Turbine control valve position
Core-inlet pressure
Cooldown valve position

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.5.1.2

3.5.1.2 ~~Reactor Monitoring Equipment~~

- ~~*~~ ~~All controls related to engine checkout (except for checkout of the remote engine control system) will be contained in Ground Support Equipment.~~
- ~~*~~ ~~The controllers for valves associated with engine and line purging will be locked out during testing.~~
- ~~*~~ ~~A block diagram showing the programmer controlling equipment is shown in Dwg ICG-061.~~

3.5.1.2.1 Reactor Monitoring Equipment

- ~~*~~ (a) The Reactor Monitoring Equipment shall consist of the following displays located on the reactor-monitoring panel of the test-operations console:
- ~~*~~ Control drum position indication, 12 individual displays.

Reactor neutron log power - with associated range selector switch to select from three ranges, source, intermediate and power. Lights to indicate range displayed.

- ~~*~~ Reactor period - Logarithmic presentation must include 1 millisecond through infinity to -1 millisecond. ~~Meter must have accurate display in range of 100 seconds through infinity to 100 sec.~~

Reactor core temperature - From the engine instrumentation patch, five thermocouple outputs will be furnished to the reactor panel. A switch will select one of these for display.

Reactor neutron power level - Neutron power level will be displayed on a linear scale over the range of source to 1.5 rated power,

External period - One meter and associated electronic circuitry shall be manually switched among the external neutron detectors at appropriate times.

External neutron power level - The same switch as above, shall also switch one external flux meter and electronic circuitry among the same external neutron detectors (see Dwg ICC-106). The two outputs of this switch shall be isolated in

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	3.5.1.2.1

such manner that a malfunction in period circuitry shall not effect power level circuitry and vice versa.

(b) ~~Checkout of the Reactor Monitoring Equipment - This includes all switches, displays, transmission and patching required for reactor monitoring to the point of connection to the Master Programmer.~~

*

(c) A block diagram of the reactor monitoring equipment is contained in Dwg ICC-106.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.5.2

3.5.2 Test-Stand Control Equipment

Controls will be provided on the test operations console to operate the test facilities directly concerned with engine operation. These controls will be designed in such a manner to give safe reliable operation.

The test stand control equipment will operate the following:

LH₂ feed from run-tank to engine (see par. 3.5.2.1).

Engine GH₂ actuation supply (see par. 3.5.2.2).

* Emergency Coolant (see par. 3.5.2.3.2).

Purging (see par. 3.5.2.4).

* GH₂ feed for engine checkout tests (see par. 3.5.2.5).

To determine the interrelation between the test stand control requirements and the engine, refer to Dwg ICC-028, the mechanical flow diagram.

The test-stand display and panel requirements, as defined by the following subsystem requirements, are found in Appendix 3.2.

3.5.2.1 LH₂ Feed from Run Tank to Engine

This equipment includes all controls and displays required to supply liquid hydrogen in a safe manner at a regulated pressure and flow rate to the NERVA engine.

For engine operation, the Feed equipment is subdivided into the following categories:

LH₂ run-tank refill (par. 3.5.2.1.1).

Run-tank pressurization (par. 3.5.2.1.2).

Run-tank venting (par. 3.5.2.1.3).

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 3.5.2.1

Engine-LH₂ supply (par. 3.5.2.1.4).

3.5.2.1.1

LH₂ Run-Tank Refill

(a) Discussion

The LH₂ used during an engine test will be stored directly above the engine in a run tank which will be filled from a storage tank located in the tank farm. For short duration tests not exceeding 540 seconds, the 70,000-gallon run tank will have adequate capacity. For tests of longer duration, transfer from the storage tank to the run tank is required while the test is in progress. Calculations have indicated that adequate refill capability is available, so that tests of 1140 seconds can be achieved. Refilling will be controlled from a liquid level sensing device.

The liquid-level indicator will be a capacitance probe which will put out an analog voltage as a function of liquid level. The output voltage from the liquid level indicator will be conditioned to allow the following to occur:

- (1) Initiate refilling when predetermined level is reached
- (2) Discontinue filling if tank has refilled to upper maximum limit
- (3) Signal a normal shutdown to occur if the level reaches a lower minimum level.

The bleed-temperature transducer upstream of Valve 50-RSV129 shall control Valve 50-RSV130 to assure that liquid is the transfer line.

Override controls for the Transfer Valve 50-RSV-129 will be provided at the test-operations console and at the transfer valve.

Lights on the facilities console and at the valves will indicate its operation. Manual control will also be provided for the Bleed Valve 50-RSV-130 from the test-operations console, with lights on the console and at the valve indicating its operation.

The relays to be used will be selected for maximum reliability without too much regard for size and weight.

The displays required for this operation will consist of:

- (1) Valve operation lights (4 ea)
- (2) Bleed temperature (analog display)
- (3) Liquid level (analog display)

(b) Refill Procedure

The following is the procedure for refilling the LH₂ run tank for tests in which the 70,000-gallon initial capacity is insufficient:

- (1) Open Remote Shutoff Valves 38-RSV-83 and 50-RSV-252, thus allowing an open line from the storage tank to the refill valve.
- (2) Pressurize the storage tank to 100 psig.
- (3) Operate the Bleed Valve 50-RSV-130. This allows a flow of hydrogen from the storage tank through the supply line to the flare stack. Monitor the bleed temperature and when the temperature has indicated LH₂ conditions, manually close the bleed valve, to insure that LH₂ is available at the control valve for the refilling operation.
- (4) After the test is initiated, the control circuit will be energized and Refill Valve 50-RSV-129 will operate when a predetermined level is reached. The refill flow conditions will be such that the tank level should continue to drop, but at such a reduced rate that operation for the required time period will be possible.
- (5) In the event that the tank level increases, the refill valve will close and then reopen at the lower level.
- (6) In the event that the tank level reaches a predetermined lower limit, a controlled shutdown will be initiated.

- (c) A typical electrical schematic of the LH₂ run tank refill system is shown in Dwg ICC-062.

3.5.2.1.2 Run Tank Pressurization

- (a) Discussion

For engine operation, pressurization of the run tank must be supplied from the facility pressurization system.

To accomplish this, high-pressure gaseous hydrogen at 2210 psig will be regulated to approximately 50 psig through a remotely operated Control Valve, 50-PC-165. Gas at the regulated pressure will flow through remotely operated Shutoff Valve 50-RSV-186 and enter the run tank.

The Remote Shutoff Valve 50-RSV-186 is an ON-OFF valve with a fail-safe feature to allow for closing in the event of electrical power failure or loss of pneumatic gas supply.

The remotely operated control valve is actuated by hydraulic pressure which is supplied through an electrical servo system. The set-point signal to the servo system is applied from the test-operation console in the control center, and a control signal is fed into the servo system from the tank-pressure transducer.

The controls will operate if the tank pressure is lower than the setpoint signal into the servo system. A switch will be available in the test-stand area as a safety to prevent inadvertent pressurization of the system.

- (b) A typical electrical schematic for LH₂ run-tank pressurization is shown in Dwg ICC-063.

3.5.2.1.3 Run Tank Venting

- (a) Discussion

Venting of the LH₂ run tank is required to prevent over pressurization.

The gas in the tank will vent to the flare stack through the remotely operated Control Valve 50-PCV-180. This valve will be actuated by hydraulic pressure which will be supplied through an electrical servo system. The set-point signal to the servo system will be applied from the test-operations console in the Control Center, and a control signal will be fed into the servo system from the tank pressure transducer.

The controls will operate and vent if the tank pressure is higher than the set-point signal into the servo system.

An override switch will be located in the Control Room for rapid venting of the fuel tank.

- (b) A typical electrical schematic for LH₂ run-tank venting is shown in Dwg ICC-064.

3.5.2.1.4

Engine LH₂ Supply

- (a) Discussion

Liquid hydrogen will be forced from the run tank under a pressure of approximately 50 psig through a remotely operated shutoff valve through a flowmeter system, and through the engine-test stand disconnect fitting, into the engine.

In the event that both the tank outlet shutoff valve and the engine inlet valve are closed, the pressure rise in the deadheaded system (due to heat leak into the liquid hydrogen) will not exceed the relief-valve setting (Valve X-2). Simultaneously with the closure of the tank outlet, Valve 50-RSV-132 (Valve No. X-1) will be opened to prevent a buildup of this pressure. However, if the valve is not desired to be opened, override provisions will be incorporated to keep it closed.

Provisions will be incorporated to de-energize the Tank Outlet Valve 50-RSV-132 simultaneously with a Scram shutdown condition.

Provisions will be incorporated for monitoring pressure, temperature, and flow rates in the line between the tank outlet and engine inlet.

Local override of the tank outlet safety valve (50-RSV-132) and vent valve (X-1) will be provided from the test stand area.

Lights energized from limit switches positioned on the two shut-off valves will be transmitted to the local override switch locations and to the test-operations console for visual indication of valve operation.

- (b) A typical electrical schematic of the LH_2 flow from the run tank to the engine is shown in Dwg ICC-065.

3.5.2.2

Engine GH_2 Actuation Supply

Provisions will be provided to supply gaseous hydrogen to the engine for charging of the actuation gas bottles or directly supplying gas for engine actuations.

This mechanical flow system is not currently available and must be supplied as a facility addition (see Figure ICC-028 for mechanical flow schematic).

- (a) Discussion

The controls for the engine pneumatic-gas actuation supply will provide a continuously regulated gas flow. Mechanical provisions are provided against over-pressurization by means of venting through a relief valve (X-5) and remotely operated controls are available for remotely venting the pneumatic fluid through Valve X-4.

The regulated pressure being supplied to the actuation system will be monitored by a pressure transducer. This signal will be supplied to the data acquisition system and will also be used for real time display.

- (b) Operating Procedure

The following operations are required to supply a regulated pneumatic actuation gas supply to the NERVA engine.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.5.2.2

- (1) Open GH_2 Supply Line Valve 50-RSV-201. A light operated from a limit switch attached to the valve will indicate proper operation.
 - (2) Open GH_2 Pneumatic Line Valve X-3. A light operated from a limit switch attached to the valve will indicate proper operation.
 - (3) Set pressure on potentiometer on test-operations console in the Control Center to the electrical controller of the servo system. A control signal will be fed into the controller from the pressure transducer.
 - (4) To vent the pressure from the actuation system, operate Valve X-6.
- (c) A typical electrical schematic for engine GH_2 actuation supply is shown in Dwg ICC-066.

3.5.2.3 Cooling-Gas System

3.5.2.3.1 Shutdown Procedures

* deleted

- (a) Controlled Shutdown Coolant Supply

* deleted

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	3.5.2.3.1

(b) Emergency LH₂ Coolant Supply

* deleted

3.5.2.3.2 Emergency Coolant Supply

Controls must be provided for pressurizing the high-pressure LH₂ tank, No. V5002, to the desired pressure required.

Additionally, controls must be provided to insure that LH₂ will be available to the engine by including a bleed valve and temperature indication immediately upstream of the engine interface. Although the sequencing of the emergency coolant will be a function of the master ground test programmer, redundant manual controls shall be available to initiate emergency coolant flow.

3.5.2.3.3 Interlocking Controls

* deleted

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.5.2.3.4

3.5.2.3.4 Engine Cooldown

* Deleted

3.5.2.3.5 A typical schematic for the pressurization and supplying of the emergency coolant to the engine is shown in Dwg. ICC-104.

3.5.2.4 Purging

* Purging of the LH_2 lines is required to eliminate air prior to charging with hydrogen, and eliminating hydrogen prior to proceeding with inspection or disassembly operations.

The following will be purged:

Line between tank outlet shutoff valve and engine inlet valve.

* Line from engine inlet valve to engine thrust chamber exit.

Cooling-gas system.

Engine actuation supply.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.5.2.4.1

3.5.2.4.1

Purge line between run tank outlet shutoff valve and engine inlet valve.

(a) Purging Air from Line

From the facilities console, evacuate the vacuum system through Valve 50-RSV-143 to the following valves:

50-RSV-133
50-RSV-108
50-RSV-138

After the vacuum system has been evacuated, operation of Valve 50-RSV-133 will remove air from the flow system between the Tank Outlet Shutoff Valve 50-RSV-132 and the Engine Inlet Valve (TSOV).

Open Helium Purge Valve 50-RSV-142 for a predetermined length of time, and purge the system through the vacuum pump and then close Valve 50-RSV-143.

Open Valve X-1 for predetermined length of time, then close. Close Valve 50-RSV-142.

(b) Purging Hydrogen from Line

Open Valve X-1; then open Valve 50-RSV-142, and purge GHe through system for predetermined length of time. Close Valve 50-RSV-142 and open Valve 50-RSV-108. Allow GHe to flow through system for predetermined length of time, then close Valves X-1 and 50-RSV-108. Repeat above procedure two times.

Purge indication should be obtainable from the flow meter and pressure transducer.

(c) A typical electrical schematic for purging between the run tank outlet and engine inlet is shown in Dwg ICC-068.

3.5.2.4.2

Purge Line from Engine Inlet Valve to Engine Thrust Chamber Exit

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 3.5.2.4.2

(a) Purging Air or Gaseous Hydrogen

Prior to initiating this operation, secure the side shields and evacuate the engine area by means of the steam ejector. These operations will be provided from the facility console.

After completing the operations required in paragraph 3.5.2.4.1.(a) or 3.5.2.4.1.(b), open Valve 50-RSV-142 and open engine tank shutoff valve. Allow gaseous helium to purge through the engine. Alternately operate the turbopump control valve (TPCV) and the turbopump bypass valve for predetermined length of time. Cycle approximately five times.

Purge indications should be obtainable from the flow meter and pressure transducer.

(b) A typical electrical schematic for purging between the run tank shutoff valve through the engine is shown on Dwg ICC-069

3.5.2.4.3 Purge of Cooling Gas System

(a) It is assumed that as a function of the facility checkout the cooling-gas system will have been purged to the following points:

(1) Valve 50-RSV-134 in Line 30 GN-6" FS

(2) Check Valve 50-CHV-681 in Line 15 GH-6" FC

(b) Checkout Procedure

Open Valve 50-RSV-134 and flow GN_2 through the engine for predetermined length of time; then close Valve 50-RSV-134. Open Valve 50-RSV-322 and set Controller 50-PC-251 to flow 10 psig gaseous helium through engine for predetermined time period; then close Valve 50-RSV-322 and reset Controller 50-PC-251 to zero.

Repeat the purge requirements specified in paragraph 3.5.2.4.2.

(c) A typical electrical schematic for purging the cooling-gas system is shown in Dwg ICC-070.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 3.5.2.4.4

3.5.2.4.4

Purge Engine Actuation Supply

Purging Air or Gaseous Hydrogen

The procedure to be followed will be to evacuate the actuation supply while operating the engine controls, then refill with gaseous helium from the 10-psig supply. This procedure will be repeated twice.

- (a) Operate these valves: 50-RSV-322, X-3, X-6

Set controller on Valve X-4 for 10 psig.

This will allow gaseous helium to purge out through Valve X-6 to flare stack. After a predetermined length of time, close Valve X-6 and Valve 50-RSV-322.

From the facilities console evacuate the vacuum line to these valves: 50-RSV-138, 50-RSV-143, X-7.

- (b) After evacuation, open Valve X-7 and evacuate the actuation supply line while manually operating the engine controls.
- (c) Close Valve X-7, open Valve 50-RSV-322, and pressurize the pneumatic system with gaseous helium to 10 psig. Operate all engine controls in the actuation supply line.
- (d) Close Valve 50-RSV-322, open Valve X-7, and evacuate the actuation supply line while manually operating the engine controls.
- (e) Close Valve X-7, open Valve 50-RSV-322, and pressurize the actuation supply line with gaseous helium to 10 psig. Operate all engine controls in the actuation supply line.

Close Valve 50-RSV-322, open Valve X-7, and evacuate the actuation supply line while manually operating the engine controls.

Close Valve X-7, open Valve 50-RSV-322, and pressurize the actuation supply line with gaseous helium to 10 psig. Operate all engine controls in the actuation supply line.

- (f) Close these valves: 50-RSV-322, X-3, X-4.
- (g) A typical electrical schematic to purge the engine actuation supply is shown on Dwg ICC-071.

3.5.2.5

Gaseous Hydrogen Feed for Engine Checkout Tests

Engine checkout tests utilizing gaseous hydrogen may be required prior to initiating the liquid hydrogen tests. Two methods are available to supply the gaseous hydrogen to the engine:

Through the propellant-tank pressurization system

Through the cold-gas cooldown system.

If GH_2 flow pressure to the engine is less than 50 psig, the path for introducing the gaseous hydrogen into the engine can be through the run-tank pressurization and vent system.

The control system for this has been discussed in paragraphs 3.5.2.1.2 and 3.5.2.1.3.

If pressures higher than 50 psig are required, the gaseous hydrogen section of the cold gas cooldown system can be utilized. The same basic control system, as defined for paragraph 3.5.2.3, will be adequate.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	3.5.3

3.5.3

Test Stand Malfunction Control Equipment

*

The Malfunction Control Equipment shall include all equipment necessary to determine the necessity of, and initiate action for, automatic shutdown of the engine should a facility malfunction (procedural or equipment) occur.

As illustrated in Dwg ICC-029, inputs to the malfunction-control equipment are received from the test-stand control equipment. These inputs will be compared with previously set limits, and if any limit is exceeded, a shutdown signal will be initiated.

The malfunction-control equipment will be electrical; inputs to this equipment will be single-ended electrical voltages, and the internal limit functions will be readily adjustable. Limits will be adjusted in such manner that a controlled shutdown is initiated before Scram conditions are developed.

The malfunction-control equipment shall have a positive electrical voltage as a normal output, and the shutdown mode shall be a no-voltage output. Thus, this equipment must be energized before the engine can be fired remotely; and also, should power to the malfunction-control equipment later fail, the reactor will be Scrammed.

*

The Scram actuator (or relay) and controlled-shutdown actuator (or relay) are independent. As illustrated in Dwg. ICC-029, the controlled shutdown actuator will initiate a shutdown, if these events occur:

If LH_2 flow is reduced below a predetermined limit

If the LH_2 level in the run tank drops to that amount which is just sufficient for normal shutdown

If other parameters, which may be incorporated, occur

The Scram actuator will initiate a Scram (full instantaneous insertion of all control rods) if these events occur:

If LH_2 flow ceases (or approaches zero)

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	3.5.3

If other parameters, which may be incorporated, occur

Both the automatic Scram actuator and the automatic controlled shutdown actuator will be backed up by manual switches located on the Test-Operations Console.

Because Scram and controlled shutdowns are automatic in action, no displays are provided. However, all input parameters to the unit will be displayed in the Control Center. In addition, on the Engine-Control Panel, lights will indicate the cause of shutdown in the event the malfunction-control equipment actuates a shutdown.

*

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	3.5.4

3.5.4

Display Equipment

In the remote engine-control system, displays will be provided in such manner that the Chief Test Engineer and the Lead Reactor Engineer can rapidly assimilate and evaluate the engine and reactor operations. For detailed requirements see Appendix 3.1 and 3.2.

Four major types of displays will be provided:

Graphic - a large display which contains pertinent engine and reactor parameters in digital and/or analog form.

Strip Chart Recorders - two direct writing, 6-channel recorders, having 3-speed operation will be located on the test-operations console.

Console meters and lights will be provided to monitor active system parameters.

Remote strip chart recorders, not located on the test-operations console, will be provided in the remote recording area of the Control-Point Building. These will be direct inking, multi channel, recorders operating at the relatively slow speeds of 5 mm or 1/4" per second.

In addition to the foregoing, oscillographic recorders will be provided for quick looks at transient or short-duration parameters after engine shutdown and before information from the data-acquisition system is available. A total of 3 oscillographic recorders of 36 channels each are required.

*

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	1 June 1962
Par.	3.5.5

3.5.5 Equipment Integration

* All equipment listed in paragraphs 3.5.1 through 3.5.4 must be integrated into a complex having interfaces with facility systems, the Data Acquisition System, and the Engine Control System.

The basic control and instrumentation for the remote engine control system will be in accordance with Dwg ICC-003.

Appendices 3.1 and 3.2 tabulate the engine and test-stand display and console-panel requirements.

3.5.5.1 Equipment Location

The major equipment items for remote engine control and instrumentation are located as shown below:

	<u>Item</u>	<u>Bldg.</u>	<u>Area</u>
	Test-operations console	Control Point	Control Center
	Graphic display	Control Point	Control Center
	Remote recorders	Control Point	Recording Room
	Inter-console patching Unit	Control Point	Terminal Room
*	Control and display transmission equipment (including Patch)	Test Cell	Electronics Room
	Malfunction-control equipment	Test Cell	Electronics Room
	Isolation-circuitry equipment	C. P. Bldg.	Recording Room
	Signal-conditioning equipment	C. P. Bldg.	Recording Room
	Test-stand panel	Test Stand	-

* To facilitate control changeover between the facilities and the Test-Operations Console, a patch system will be located in the Control-Point Terminal Room.

3.5.5.2 Interrelationship Between ICC Drawings

Drawings ICC-072 and -108 show the overall diagrams of the Remote-Engine Control System and provide for the operation of the components shown in the engine test stand mechanical flow schematic, Dwg ICC-028.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 3.5.5.2

The circuits shown in Drawings ICC-072 and -108 are a consolidation of the circuits shown in Dwgs ICC-029, -061 through -071, -104 and -106. The latter drawings illustrate the circuits that comprise the various subsystems. The overall drawing is presented to show the interrelationship between the subsystems since the same circuit may be required for several of the subsystem drawings.

3.5.5.3 General Circuitry Criteria

- (a) The circuitry shown in Dwgs ICC-072 and -108 shows the general schematic of the required controls and instrumentation. During the detailed design phase, these drawings must be re-evaluated in terms of latest requirements and interface considerations with facility controls. A two-wire non-polarized or polarized control transmission system (as applicable) will be employed. A twisted pair of electrical wires will be used for the operation of each control item.

Typical examples of the above circuitry requirements are shown in Dwgs ICC-032 through -035.

- (b) Each control circuit will have its own ground return to the power source. This will prevent ground-loop problems in the instrumentation circuitry.
- (c) All relays locked in the circuit through its ON contact will be unlocked from reset switches from the Test-Operations Console.
- (d) All relays and solenoid valves will be provided with diodes to prevent voltage surges during de-energization; these will be located in areas where the radiation level will be of magnitude that will not affect its operation.
- (e) Control of valves required for test operations will be through a relay contact. The controlling switch, supplied with electrical power from the Control-Point Building, will operate a relay in the Test-Cell Building. Electrical power supplied at the Control-Point Building will operate the solenoid valve through the relay-contact closure.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.5.5.3

- * (f) Circuits required for control will have a minimum of termination
 - (g) Circuits required for engine operational display will be isolated from the control circuits to prevent a failure in the display circuit from affecting the ability to control.
 - (h) Circuits required for data acquisition will be isolated from the control and display circuits to prevent a failure in the data-acquisition circuit from affecting the control and display circuits.
 - (i) The electronic controls for the hydraulic actuators will be located in the Test-Cell Building to minimize the radiation effect on these controls.
 - * (j) ~~The system will be designed so that test-stand control circuits operated from the Facilities Console will be disabled when operated from the Test-Operations Console.~~
 - (k) A panel will be provided on the test stand so that the test crew can open the electrical circuits to the control valves to prevent inadvertent operation from the Control Point Building.
- Polarized circuitry will generally be utilized for valve open and closed indications
- Non-polarized circuitry will generally be utilized for relay and solenoid operation.
- (l) Control wiring transmission shall be separated from instrumentation transmission to minimize electrical pulses generated in control circuitry from affecting the data-acquisition system.
 - (m) Scram-system wiring shall be isolated from all other wiring to prevent inadvertent operation of the Scram circuits from spurious signals generated in other circuits.
 - (n) All electrical circuits, the shorting of which would jeopardize engine safety, must be fused.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	3.5.5.4

3.5.5.4 Remote Engine Control System Patch Equipment

For remote engine control, two patching units are required:

* A patch unit will be located in the Terminal Room of the Control-Point Building so that control functions can be transferred from one console to the other as desired.

* The second patch is required for engine instrumentation, and will be located in the Test Cell Building.

3.5.5.4.1 Patching Advantages

The advantages of this method are:

Better space utilization in Test-Cell Building. See Dwg ICC-092 for typical layout.

All input and output cables are permanently terminated.

Failure of relay base or wiring in relay module can be repaired in the shop. A spare module can be installed in the patch system.

Complete flexibility allows new programs to be prepatched on spare boards or minor changes can be made in existing boards without necessitating any rewiring of the unit.

The sequence of operation can be easily checked out.

Unit construction of components permits rapid trouble-shooting and repair. The interchangeable feature permits repair of a damaged component and reduces down-time to a minimum.

3.5.5.4.2 Description of Components

The following components are required:

A rack consisting of a 24-in. x 24-in. x 80-in. standard Unistrut bay with dual terminal strips located at the top or bottom,

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 3.5.5.4.2

front or back, of the bay, or both, as required. See Dwg ICC-093 for typical layout.

Four to eight plug-in relay modules. These modules have 10 each plug-in D.P.D.T. relays with connector on back of modules for replacement capability of complete unit. See Dwg ICC-095 for typical layout.

A 1632-amp patchboard, recessed 5 in., with locking door to protect patching. See Dwg ICC-096 for typical layout.

A timer module providing 10 transistorized plug-in timers. Time outputs are S.P.D.T., 5-amp contact. Helipots on front of module allow ranging of timers. See Dwg ICC-086 for typical layout.

Harnesses necessary to connect cables, relays, and timers to the 1632-amp patchboard. The relay harness consists of a 156-pin connector that mates with the relay module, and, on the other end, uses taper pins to connect to the amp board. The timer-module harness is identical to the relay harness. Additional harnesses are required to connect console inputs, outputs to Test Stand, and test-stand panel, and use fanning strips terminated to terminal strips and taper pins at the patchboard. See Dwg ICC-094 for typical layout.

3.5.5.4.3

Operation of Sequence Control Bay

All functions such as inputs, outputs, relay and timer coils, and contacts, etc., show up on the face of the patchboard. These are identified as shown on Dwg ICC-084.

The inputs can now be connected by patch direct to an output, a relay or timer, and/or interlock with the other functions as necessary. Switch traces may be connected directly to the Control Room as voltage traces or through shunts as current traces. Micro indication may be patched directly to Control Point Building indicating lights.

Dwg ICC-085 shows typical circuitry with the patched portion indicated by identification letters and numbers as appear on the front of the board.

4.0 FACILITY OPERATIONS AND CONTROL SYSTEMS

4.1 SCOPE

The Facilities System, as described in Section 2 of these criteria, comprises all the necessary functions required in support of the engine tests which are not an integral part of the Engine-Control System. This section covers specifically the instrumentation and controls required to operate the Facilities System.

4.1.1 Purpose

The Facilities Instrumentation and Control System consists of such items as transducers, cables, relays, switches, indicators, controllers, and consoles that are required to perform both local and remote operations of support functions for engine test. In addition, this system includes electrical power, communications, television, and timing, which are required to operate and correlate the many facets of the overall operation.

4.1.2 Function

The Facilities Control System shall provide local and/or remote control of motors, pumps, valves, and all items not directly a concern of the engine, or data recording. It shall include indicators, local and/or remote, to permit operators to judge the results of operator actions, and to permit proper sequencing and timing by the operator and/or automatic equipment. It shall provide information to all operating personnel to permit safe decisions, where facility items are concerned.

The system shall include necessary means of communications to attain and coordinate facilities support and safety, and to act as a supporting activity to the engine test operations and data gathering systems.

The system shall also include consideration of and means of calibration and checkout of all items associated with the system.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A	
Date	1 June 1962
Par.	4.1.2

Included in the supporting functions are 28 V dc, 120/208-V 60-cycle and 400 cycle, and 480 V 3 Ø 60-cycle power.

4.1.3

Existing Facilities

Throughout this section reference is made to "existing facilities." Flow-diagram sketches are included in the drawing section of the criteria. Appendix 4.2 describes interfaces with "existing" equipment, or equipment not yet contracted for. It must be noted that all such statements and drawings are given here as reference only and are not meant to be the working drawings and "final" reference where "existing" facilities are concerned. The various drawing packages and specifications, together with all of the addenda for Test Cell D, prepared by AETRON for the AEC, are the only authoritative source for this information. These "packages" are as follows based upon numbers as used with Bid Invitations, of which these packages were a part:

292-61-39	Plant Road "K" and Water Line "G"
292-61-40	Building and Utilities
292-61-41	Liquid Hydrogen Dewar
292-61-42	High Pressure Gas Vessels
292-61-73	Railroad Extension
292-62-14	Test Stand and Process Systems
292-62-15	Miscellaneous Process Vessels
292-62-30	Radiation Shields
292-62-32	Steam Generator
- - -	Facilities Instrumentation and Control
- - -	Exhaust System
292-62-45	Fire Protection System

If needed for reference, copies of the listed packages may be seen at the NERVA Controls office.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.2

4.2

I & C SYSTEM CONSIDERATIONS

The design of all systems shall be predicated on safety operational personnel and equipment, simplicity of operation, reliability of equipment, flexibility and ease of monitoring and display.

4.2.1

Facilities Control

~~The design of the control system shall be such that the number of valves requiring control from two locations such as the Control Point Building and the Forward Control Room shall be held to a minimum.~~

Manual operation of locally controlled operators shall be used where feasible. The unloading of cryogenic liquids and gases shall be made by manual operations with local controls. The process vessels, transfer pipes, high-pressure headers, pumps, steam generators, cold-gas systems, and gas flares shall be operated from the Control Point Building.

All remotely operated shut-off valves (RSV) shall be provided with remote indicators for full-open and full-closed. Hand operated valves shall not be provided with indicators.

All transducers, valve actuators, etc. located along pipe lines shall be of weather-proof construction only. Purging shall be used on boxes and motors in areas requiring explosion proof fixtures.

Equipment located in underground rooms shall not be required to be explosion proof. Interlocks shall be kept to a minimum to improve the reliability of the control systems and to minimize checkout and maintenance, when their presence does not compromise personnel or equipment safety.

4.2.2 Facilities Support

4.2.2.1 Communications (see par. 4.3.2.1)

The basic concept of the communications system is to provide the NERVA Test Facility with the necessary interphone, public address, dial telephone, direct line, and RF communication equipment for two-way conversations between test-site personnel. The concept includes provisions for conference calls, safety announcements and warnings, paging, and direct line availability to extended areas.

4.2.2.2 Closed Circuit Television (see par. 4.3.2.2)

The basic concept of closed TV in facilities support is that of providing visual assistance in the operation of the overall facilities. Since all of the Facility Support equipment is handled by remote control, observation by means of the TV system shall be substituted for human vision. TV cameras shall be installed in large enough numbers, and in the most advantageous locations, to present an adequate picture of all critical functions of facility support before, and during, the engine test. The television system shall be sufficiently versatile to permit cameras and monitors to be brought to bear on any specific activity, equipment, or area, on command. Cameras shall have pan and tilt capability, and lenses of varying focal lengths shall be utilized as necessary.

4.2.2.3 Timing (see par. 4.3.2.3)

The requirement for Timing in conjunction with facilities support is based on the need for providing a common time base for the correlation of events, and for the synchronization of all time calibrated instrumentation. The timing standard employed will facilitate the reduction of any data obtained.

4.2.3 Test Stand Support Equipment Controls

The basic concept for the test-stand support equipment controls is to enable the operation of support equipment from a remote

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 4.2.3

location away from danger of radioactivity to man. Instrumentation shall be such that the operation of test-stand support equipment can be accurately monitored at all times.

4.2.4

Transmission (Cable and Patching)

The instrumentation ground shall be a single-point system. This ground point shall be located in the terminal room of the Control Point Building and shall be extended by cable to the terminal room of the Test Cell Building. Cables having different functions shall be routed in such a manner as to minimize cross talk or interference. Control cables, communication cables, ac cables, high frequency cables, etc. shall be kept distinct and separate from analog-signal cables. Analog, power, and control cables shall be run in separate cable trays, conduits, and ducts. When terminating in boxes, cables shall terminate in separate boxes. All cable routing in rooms with false floors shall be in a direct, but neat, manner. The design of systems shall be such as to minimize the number of terminations or breakout points on a wire, when this does not interfere with other requirements.

Patch panels shall be incorporated to allow flexibility in the Instrumentation and Control System.

4.2.5

Interface Areas

The field equipment, in general, and as discussed and described in these criteria, is designed, specified, and "existing." This section of the criteria establishes the requirements for the completion of the facility. The exact interfaces where electrical connections for each item are located, are given in Appendix 4.2. It is necessary to provide cables from these locations to the control-indicator panels. In a few cases, which are indicated in this section, it is necessary to provide transducers or field mounted items.

Control panels shall be provided in necessary locations, with racks and consoles.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 4.2.5

Necessary signal conditioning equipment and amplifiers shall be provided as required to drive indicators and recorders on the control panels.

A communications system suitable for operations and checkout shall be designed, implemented, and installed.

A public-address system is existing. It shall be modified to fit the operations.

A closed circuit television system shall be provided and installed.

A timing system, coordinated with the other systems, shall be provided and installed.

Power requirements shall be met by design, purchase, and installation of necessary equipment.

Cables, terminal boxes, and patching facilities shall be provided and installed for signal transmission.

Details concerning the aforementioned are presented in the following sections.

4.3 **SYSTEM REQUIREMENTS**4.3.1 **Facilities Control**

The Facilities Instrumentation and Control System shall provide the capability of performing the following functions:

(a) **Hydrogen Systems**

- (1) Truck unloading of LH_2 to storage dewar
- (2) Pressurization of LH_2 storage dewar from high-pressure GH header.
- (3) Transfer of LH_2 from storage dewar high-pressure run tank
- (4) Transfer of GH_2 from storage dewar to high-pressure gas storage
- (5) Pressurization of GH_2 header from high-pressure gas storage
- (6) Pressurization of high-pressure LH_2 Run Tank

(b) **Oxygen System**

- (1) Truck unloading of LO_2 to storage dewar
- (2) Pressurization of LO_2 storage dewar from high pressure GN header.
- (3) Transfer of LO_2 from storage dewar to steam generator and high-pressure LO_2 run tank.
- (4) Pressurization of high-pressure LO_2 run tank

(c) **Helium Systems**

- (1) Truck unloading of helium to high-pressure gas storage
- (2) Pressurization of helium gas header from high-pressure gas storage

- (3) Purge fill-station transfer lines, compressors, truck unload lines, from helium header
- (4) Purge the LH_2 storage dewar from the helium header
- (5) Purge LH_2 and GH_2 transfer lines from the helium header
- (6) Purge the engine-run tank and associated lines from the helium header
- (d) Nitrogen Systems
 - (1) Truck unloading of LN_2 to storage dewar
 - (2) Pressurization of LN_2 storage dewar from high-pressure GN_2 header
 - (3) Pressurization of GN_2 header from high-pressure gas storage
- (e) Propane Systems
 - (1) Truck unloading of liquid propane to storage tank
 - (2) Pressurization of storage tank from high-pressure GN_2 header
 - (3) Transfer of propane from storage tank to steam generator
 - (4) Transfer of propane from storage to flare system
- (f) Gas Cooling Systems
 - (1) Supply hydrogen gas from GH_2 header to engine for cool-down
 - (2) Supply nitrogen gas from GN_2 and LN_2 headers to engine for cooldown
- (g) Steam Generator System

Transfer steam from steam generators to duct eductor

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 4.3.1

(h) Hydrogen Gas Flare System

- (1) Burn vented hydrogen gas from LH_2 storage area by flare stack
- (2) Burn vented hydrogen gas from test-stand area by flare stack
- (3) Burn hydrogen gas from duct by flare

(i) Vacuum System

- (1) Provide vacuum purge of LH_2 storage dewar, associated transfer lines, high-pressure hydrogen header lines, and provide pump-down of LH_2 dewar vacuum jacket
- (2) Provide pump-down of the vacuum jacket of transfer lines and valves by means of a portable vacuum pump
- (3) Provide vacuum purge of engine-run tank, transfer lines and headers, and provide pump-down of engine run-tank vacuum jacket.

(j) High Pressure Gas System

- (1) Transfer gases to storage, and transfer from one storage bottle to another
- (2) Transfer gases from storage to headers for use throughout the facility

(k) Process Water System

- (1) Demineralize water from utility water main and transfer to storage tank
- (2) Operate sprinkler and deluge systems throughout the facility
- (3) Transfer water from header to test stand shields for cooling
- (4) Transfer water from header to duct for cooling

- (1) LH_2 Engine Run Tank System
 - (1) Transfer LH_2 from storage dewar to engine run tank
 - (2) Pressurization engine run tank from high-pressure GH_2 header.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	4.3.2

4.3.2 Facilities Support Systems

4.3.2.1 Communications

The communication requirements of the NERVA facility may be divided into three categories. Listed in the order of usage, these categories are: support of installations and checkout; personnel safety; and support of countdown, engine-run operation, and maintenance assembly and disassembly (MAD & E-MAD).

(a) Support of Installations and Checkout

*

An interphone and public-address system shall be provided to support the multitude of rack-to-rack and rack-to-console installations. Interphone stations shall be provided in sufficient quantity to avoid awkwardness and to allow simultaneous checkout of two or more operational systems. Personal or "outside" calls shall be restricted to dial telephone lines, but dial telephone lines shall also be used for additional communication support.

(b) Personnel Safety

In the interest of safety, NERVA communications shall be capable of extending to all areas. Integration of systems shall be provided to ensure maximum flexibility and utility for the safety director.

(c) Support of Countdown, Engine Run, & MAD

*

The communications provided for a systematic operation shall contain an independent interphone system supplemented with a local and remote P. A. system. The system or combined systems shall be capable of pre-arranged communications from point-to-point in any desired combination of stations. The system shall also be capable of providing conference calls. Interphone stations shall be provided in sufficient quantity to facilitate the most congested operational or checkout areas. An RF system

for linking the Safety Director to an observation helicopter shall be provided and designed to tie into the P. A. or interphone lines at the Safety Director's or Test Director's discretion. Dial telephone lines shall be used for additional support and shall be distributed to all areas. Personal or "outside" calls shall be restricted to the dial telephone lines.

4.3.2.2

Closed Circuit TV

4.3.2.2.1

General

The basic requirement for closed circuit TV systems is to provide visual indication, within the Control Center, of activities in the test stand area and immediate surroundings. Prior to actual tests, the equipment will be used to monitor the general areas and to ensure the evacuation of all personnel from potentially hazardous areas.

During preparations for firing, the television equipment will be used to assist in the remote handling of equipment used at the test stand.

During engine test, the TV system will provide a visual display of the engine area and all supporting equipment. The TV system will be employed as a supporting medium in the installation of the duct, the installation of the engine, closure of the shields, and monitoring of such equipment as the flare stacks during firing. Cameras will be situated throughout the area in order to provide a comprehensive coverage of each phase of equipment installation, and the test firing. In addition to observing the I & C System equipment installation and engine testing, the entire area within the confines of the ETS-1 complex will be monitored for personnel safety.

4.3.2.2.2

Equipment

The visual display will be obtained through the use of a system which will include cameras with lenses of varying focal lengths, remote camera controls, monitors, video switches, and the necessary supporting hardware. All elements of the system will be integrated by means of appropriate cables.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 4.3.2.2.2

Accessories will be added to the system to enhance the over-all system versatility: variable focal length lenses will provide for varying image size or angle of coverage; pan and tilt units will free the camera from a single fixed target and allow for a wide scanning range; switching units working with a group of cameras on a single monitor will provide for quick transfer of visual information from one target to another; patching panels will be provided not only to facilitate installation of cabling, but also to ensure adequate facilities for future expansion.

Junction boxes will be provided at all fixed installations in order that most of the camera control cable can be routed underground.

4.3.2.2.3

Equipment Requirements

The cameras to be supplied for use in the NERVA program will be suitable for operation under highly radioactive conditions (see table, ICC-038). Special cameras will be provided for use in areas of extreme radiation where the conventional environmental cameras would fail. In addition to radioactivity, the equipment at each camera site will be operative under conditions of shock, vibration, heat, and possible explosion. (In isolated instances cameras will be subjected to water environments.)

4.3.2.3

Timing

Timing shall be implemented in the facility for the purpose of providing a means for correlating all data acquired during a test firing. The system shall also provide a precision time standard for real-time displays of time during all phases of a firing test.

The timing system, described in detail in later sections, shall consist essentially of an assembly of components which will provide a series of pulses synchronized with an accurate time standard, divided into required frequencies, and shaped to present a variety of time codes on recording instruments, and, simultaneously, time presentations on various clock displays. Basically this equipment shall consist of oscillators, frequency dividers, clocks, accumulator, generators, and code comparators.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	4.3.2.3

Accessory equipment shall include camera lamp-driver amplifiers, and relay drivers for use with strip-chart and oscillograph recorders. (See Section 4.5.2.3 and appropriate Technical Data Sheet for detailed description.)

4.3.2.4

Electrical Power

* The electrical system shall be capable of supplying suitable power to fulfill the power requirements of all the systems involved. All power and control equipment, wire, and conduit required for instrumentation and control, including 120-volt 1 $\emptyset$ 60 cycle; 120/208-volt 3- $\emptyset$ 400 cycle; and 28-volt dc, shall be furnished and connected with suitable transformation to the Instrument and Control 4160-volt system.

The three existing diesel generators (150-kw, 4160-volt, 0.8-pf) shall be capable of sustaining the Instrument and Control system.

** The I & C load shall be divided as shown on Dwg. ICC-006B, Sheet 1, in such manner that two generators will be connected to the instrumentation load, and one generator to the motor loads. This will isolate the large motor load, which could cause transients and modulation in the Instrumentation System.

These generators, and the Instrument and Control System, shall be isolated from the Utility System during the test period.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.3.3

4.3.3

Test-Stand Support-Equipment Control System

The basic requirement for the Test Stand Support Equipment Control System is to provide control and instrumentation for the operation of the following equipment:

- (a) Radiation shields (top, bottom, and sides) (see par. 4.3.3.1)
- (b) Duct-cover shield (see par. 4.3.3.2)
- (c) Deflector-pit door shield (see par. 4.3.3.3)
- (d) Weather doors (see par. 4.3.3.4)
- (e) Deflection duct (see par. 4.3.3.5)
- (f) Engine-transport train interlock (see par. 4.3.3.6)
- (g) Engine-loading and unloading equipment (see par. 4.3.3.7)

4.3.3.1 Radiation Shields (top, bottom, and sides)

Controls included for the radiation shields shall be those for operating the drives of two semi-circular side shields. The two side shields run on tracks, and in closed position, will form a circular shield around the nuclear engine, at which time hydraulic locking mechanisms shall be actuated. These side-shield locks will provide a positive locking force which will hold the two side shields together against forces produced by bellow seals. The seal bellows interiors shall be pressurized with nitrogen which system will be part of the control system.

A heater-control system shall provide for Molten-metal seals between top and side shields as well as between bottom and side shields.

Controls and displays (position, temperature, and pressure indicators and TV) shall be located in the Control Center at the Control-Point Bldg.

Controls for operating the radiation shields from the test-stand location shall consist of a hand-held control box with extension control cable.

This cable shall be plugged in to a receptacle in the test-stand control panel, so that operation of the radiation shields can be readily observed by the operator. Provision shall be made within the circuitry of the control-cable connector so that actuation from the Control-Point Bldg. will be disabled when the connector is inserted in the receptacle.

4.3.3.2 Duct Cover Shield

The Duct-Cover Shield will serve as a plug shield over the deflection duct opening to protect people working on the Test Stand against any harmful radiation from the deflection duct. It will be similar to the side radiation shields, running on tracks, and shall be controlled and monitored from the Control Point Bldg. Override control shall enable operation from an area where the operator can observe the shield. A hand-held control box with extension cable shall be plugged in to the test-stand control panel for this purpose.

4.3.3.3 Deflector-Pit Door Shield

The deflector-pit door shield will serve the same purpose as the duct-cover shield. It will run on tracks and shall be controlled and monitored from two locations, the Control-Point Building, and a location in the immediate vicinity of the deflector pit.

4.3.3.4 Weather Doors

The weather doors are to protect people working on the test stand from the effects of adverse weather conditions. As they are to be used under non-hazardous radiation conditions, the controls shall be located in an immediate proximity to the weather doors.

4.3.3.5 Deflection Duct

A TV monitor, controls, and position displays for the transfer, jacking and positioning of the duct shall be located in the Control Center at the Control Point. Override control shall permit

transfer, jacking, and positioning operations to be controlled from an area where the operator can observe the deflection duct. A hand-held control box with extension cable shall be plugged into the test-stand control panel to satisfy this condition.

4.3.3.6

Engine Transport Train Interlock

An interlock at the Test Stand shall provide for the control of the Engine-Transfer Train to the Control-Point Building, from which point it can be precisely positioned into place for loading and unloading of the nuclear engine. While loading or unloading an engine, the R. F. controls of the train, which are initiated at the MAD Building, shall be interrupted. An override control at the Control Point Building Control Room shall return the capability of R. F. control to the MAD Building. Phone communication between Control Point and MAD Building shall be used to relay the information that MAD Building again has control of the train. Positioning and alignment of the train will be monitored by means of TV.

4.3.3.7

Engine Loading and Unloading Equipment

When engine-transport train has been positioned in place at the Test Stand, the engine will be lifted up to the thrust plate by an elevator mechanism on the engine cart. This operation will be remotely controlled from the Control Point Building. Although guide pins will be provided for alignment of the engine, monitoring shall be provided at the Control Point Building by means of TV. Fastening of the engine to the thrust plate shall be accomplished by means of remote controls located in the Control Center at the Control Point Building.

4.3.4

Transmission (Cable and Patching)

(a) Cabling

All cabling required to make a complete and operable system, as based on requirements noted elsewhere in the criteria, shall be furnished. The typical routing of cables is shown on Drawings ICC-052 and -107. Detailed cable requirements are noted but not limited to those shown in the Technical Data Sheet 4.19.

(b) Patching

In order to provide the maximum flexibility for obtaining and recording test data and for ease of modifying control circuits, provision shall be made to patch the instrumentation and data-acquisition systems and the majority of the control systems as shown on Dwg ICC-107. Instrumentation and some control functions require pre-programming arrangements, and the "AMP" Patch-type panel shall be used. For control functions requiring infrequent changing, the Vector-patch-type panel shall be used. The arrangement of patching modules shall be based on an overall system study to provide the optimum usage of the panel boards consistent with the ease of operation. The actual size and number of patch panels shall depend upon the system requirements. Consideration shall be given for future growth ~~at the Forward Control and Control Point Buildings.~~ Detailed patch-panel requirements are shown in Technical Data Sheet 4.20.

*

4.4

GENERAL SUBSYSTEM CRITERIA

4.4.1

Instrumentation and Control

A number of standard circuits are shown in Drawings ICC-031 through -035. They shall be used whenever and wherever applicable and feasible, for facility control purposes. These circuits provide a balanced line pair for each signal, with both sides of the line switched.

Solenoid pilot valves for the ON-OFF valves shall be wired to two terminals each for two-wire control. Meter start-stop, shield controls, duct moving controls, all shall be provided with control relay boxes which shall be designed to work with these circuits.

In order to make the design of the facility control items uniform, it is necessary to use the standard circuits.

4.4.2

Closed-Circuit TV

The closed-circuit TV systems will be utilized to assist in the task of engine testing by providing visual information to personnel directly concerned with the test. The utilization of the systems will be broken down into the following 3 categories during countdown: Safety, Remote Equipment Handling, and Firing Observations.

(a) Safety

The Lead Safety Engineer will monitor all hazardous areas for personnel safety (i. e., either unsafe conditions at sites or the presence of unauthorized personnel in potentially hazardous areas). He will also utilize the TV system as a visual monitoring aid in the event of emergency operations, such as fire-fighting, etc.

(b) Remote Equipment Handling

The Lead Facilities Engineer will utilize TV monitors to assist him in his task of handling and installing the engine and associated test equipment. Cameras will be switched to monitors in order of task accomplishment, i. e., after the duct has been installed and the cameras monitoring this task are no longer needed, other cameras will be switched onto the monitors for surveillance of the next task of equipment handling (see Table, Dwg. ICC-038).

(c) Engine Firing Observation

After all equipment has been installed and made ready for firing, the cameras specifically assigned to the Chief Test Engineer and the Lead Reactor Engineer will be adjusted for the surveillance of the areas with which they are concerned. Cameras not required by these two engineers will be left for use by either the Lead Safety Engineer or the Lead Facilities Engineer.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 4.4.2

(d) Usage of Equipment

Use of the equipment will be assigned to the users in reverse order, i. e. , Firing Observation monitoring to Equipment Handling, and finally to the Safety Monitoring task.

Usage of the TV equipment is indicated in the Table, Dwg. ICC-038 and Paragraph 4.5.2.2.4, according to intent.

4.4.3

Timing

The timing system shall be incorporated in the ETS-1 facility to provide a reference time source which will be used as a basis for all engine tests and supporting activities. The timing system shall be used to provide time information in actual time of day, display of count-time, timing signals for various recorders, and synchronizing pulses for other data acquiring media.

(a) Clocks

Clocks shall be provided to indicate the time of day, to present the status of the count-down, and to provide range time for recording purposes.

(1) Count Clocks

The count clocks shall present time in both hours, minutes, and seconds, and in seconds only. During activities prior to test firing, the count clocks shall serve as count-down display devices, indicating time counting backwards preceded by a minus (-) sign. During count-up, i.e., immediately after initiation of test firing, the display shall be shown as time counting forward, with a plus (+) sign preceding the display.

(2) Range Time Clock

The output of the range time clock shall be used for imprinting elapsed time on strip chart records, thus providing a distinct relation between time and event.

(b) Timing Signals

- (1) Coded time pulses shall be transmitted to all recorders (strip chart, oscillograph and magnetic tape), indicating time of day in seconds. Time of day coded signals shall be transmitted to the data-acquisition section for use in various recording media.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 4.4.3

- (2) A number of pulses in varying frequencies shall be transmitted to the flow-calibration and turbine-speed instrumentation.
- (3) Coded pulses shall be transmitted to the photographic cameras where the code will be imprinted on the film simultaneously with the recording of the events.
- (4) Video tape recorders or vidicon tube recorders shall utilize timing codes for event correlation if the TV system will employ such recorders.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.4.4

4.4.4

Communications

NERVA communication facilities shall consist of five subsystems; interphone, public address, dial telephone, direct line, and radio frequency. The following general criteria apply to each subsystem.

(a) Interphone Subsystem

* The interphone subsystem shall consist of common trunk lines connecting strategically located interphone stations throughout the test complex. Several trunklines shall be reserved for general and area paging, calling, and conference setups, and for emergency P.A. Operators or any personnel using the system shall be able to confer with another station over a trunkline selected by the caller. The station called shall be paged over one of the designated interphone area paging trunks, or over the universal, all-areas, paging trunk. The operator shall be able to set aside his headset by switching to a small speaker on his station panel.

(b) Public Address Subsystems

* The public-address subsystem shall consist of an overall or universal paging system with power amplifiers, and with the capability of paging interphone stations, which shall be accomplished by a system of speakers located throughout the test complex in a manner beneficial to all interphone stations. The interphone headset shall serve as a public-address microphone.

* The universal paging system shall incorporate high-power audio amplifiers for driving all wall and ceiling mounted speakers located throughout the test complex. The system shall incorporate relay controls for paging originating at the Test Director's

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.4.4

console, Safety Director's consoles, and in the Control Office. No area at the test complex proper shall be beyond the audible range of the universal paging system.

(c) Dial Telephone System (Bell System)

Dial telephones shall be installed at each test console and in each room in all buildings in the Test Site. These telephones shall be used for outside calls and additional communications support. Dial telephone lines shall tie into the NTS dial-telephone switchboard.

(d) Direct Line Telephone (Bell System)

* Direct telephone lines (non-dial) shall be provided for usage between the Control Point and remote buildings. These lines shall service the LIE Console, the Test Director's Console, the LSE Console at the Control-Point Building.

(e) Radio Frequency Subsystems

VHF or UHF communications shall be provided for a link between the observation helicopter and the Safety Director. Equipment for this purpose shall consist of a radio-frequency transmitter and receiver, and their associated antennas. Receiver sensitivity and transmitter power shall be at a level considerably greater than required to provide satisfactory communications.

VHF "Walkie-Talkie" sets of the small fasten-to-belt or contained-in-helmet variety shall be provided as additional communications supports, serving as supplements to the interphone system in areas such as the test stand superstructure and remote areas. At least four channels shall be provided at the Control Point with transmitting and receiving equipment located at the consoles and high antennas located above the Control-Point Building.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.4.5

4.4.5 Electrical Power

4.4.5.1 General

The following four basic voltages are available for the I & C power systems:

- (a) 120/208-volt, 3-phase, 60-cycle regulated
- (b) 120/208-volt, 3-phase, 400-cycle regulated
- (c) 28 volt-dc regulated
- (d) 480-volt, 3-phase, 60-cycle regulated for loads 1/2 hp and larger.

*

The I & C 120/208-v, 60-cycle distribution panels are existing, as noted on Dwg. ICC-006, which also designates distribution panels, motor-control centers, etc., in accordance with the abbreviations used herein.

4.4.5.2 Control Point Building 3310

- (a) Distribution panels P10A, B, C, D, E, F, G, H, and J 120/208-v, 60-cycle with 30-amp single-pole breakers are existing in the Recording Room. Distribution panels P10K, L, and M, 120/208-v, 60-cycle, with 30 and 50 amp, 1-phase breakers are existing in the Control Room. Rack and console-regulated 120-v, 60-cycle power shall be supplied from these panels.
- (b) A 100-amp, 28-volt rectifier and 100-amp-hr battery shall be installed in the Utility Equipment Building, 3320, and a new dc panel, DC 10A, with 1-pole breakers in the Control Point Building, 3310. The dc power requirements, primarily for data acquisition, pilot valves, and relay control shall be supplied from this panel.
- (c) The 28-v rectifier shall be connected to the existing 480-v motor-control center (MCC-20I).

*

4.4.5.3 Forward Control Room Building, 3330

- (a) Distribution panels P30C, D, and E, 120/208-v, 60-cycle, with 30-amp single-pole breakers, are existing in the Control Room. Rack and console-regulated 120-v, 60-cycle power is to be supplied from these panels.
- (b) A 28-v, dc panel, DC30A, with 15-amp, 1-pole breaker is existing in the Forward Control Room, and is supplied and wired to the location of a new dc panel DC40A in the Test Cell Building, 3340. The dc power, which is primarily required for pilot valve and relay control, shall be supplied from this panel.
- (c) Two 5-kw, 120/208-v, 3-phase, 400-cycle, motor-generator sets operating in parallel shall be installed in the Fill Station Building, 3330; and new 400-cycle panels, 400 P10A in the Control Point Building, 3310; and 400 P40A in the Test Cell Building, 3340. The engine and reactor 400-cycle requirements shall be supplied from these panels. Shielded 2/c sensing leads shall be installed to each 400-cycle panel. The 120-v 400-cycle feeder shall be routed in conduit through the tunnels as far from the cable trays as possible.

4.4.5.4 Test Cell Building, 3340

- (a) Distribution panels P40C, D, E, and F with 20-amp single-pole breakers are existing in the Electronics Room. Rack 120-v 60-cycle regulated power is to be supplied from these panels.
- (b) A 400-amp 28-v rectifier and 200-amp-hr battery shall be installed in the Mechanical and Electrical Equipment and Battery Rooms. A new dc panel, DC40A, with 1-pole breaker in the Electronics Room shall supply the dc power requirements, primarily for valves, relays, instrumentation, and control.
- (c) Install a new 45-kva 4160-480-v 3-phase transformer and primary switch and motor control center, MCC-40I, in the Mechanical and Electrical Room to supply power to the 28-v rectifier.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.4.5.5

4.4.5.5 Test Stand Equipment Room, 3350

- (a) There is no 28-v dc or 120-v, 400-cycle power source available in this area. All requirements shall be supplied from panels in the Test Cell Building, 3340.
- (b) The 480-v 3-phase power, MCC-50I, ~~for the steam generators and for 2 100-hp pumps,~~ is existing.

4.4.5.6 Facility Electrical Measurement Requirements

In order to have a record of the system electrical characteristics, provision shall be made to record the following in the Control Point Building, 3320: The recorder may be a multipen device with two-speed drive. Normally the recorder will be used on slow speed during the checkout period, and on high speed during the actual test.

4160-v I & C bus voltage
4160-v I & C bus frequency
28-v dc rectifier voltage output, 2 required
400-cycle M-G set voltage output, 2 required
400-cycle M-G set frequency output, 2 required.

4.5

SYSTEMS CRITERIA

Construction contracts have been let, by AETRON Division of Aerojet, for many parts of the test facilities and associated controls. Data concerning those parts of the facilities on which design has been completed or contracts have been let, will be identified by presenting relevant information in the present tense. Data concerning the additional work required to complete engineering design, and on which contracts based on these criteria be let, is presented in the future tense.

4.5.1Facilities Controls4.5.1.1

Hydrogen

- (a) Hydrogen is received as a liquid, and is used in both liquid and gaseous states for heat transfer and aftercooling in testing nuclear reactor engines. Gases from LH_2 in the LH_2 Storage Dewar V-3801 are passed through high-pressure compressors, stored in 3600-psig bottles, and used to pressurize LH_2 vessels and for reactor-engine aftercooling.

The Test Facility hydrogen system includes: the LH_2 truck unloading station; low-pressure (100-psig) 250,000 gal Storage Dewar, V-3801; LH_2 high-pressure (1200-psig) 4400 gal run tank, V-5002; one or more of the six 3600-psig storage bottles, V-3201, 2, 3, 4, 5, 6; the 70,000-gal 50-psig engine run tank, V-5001; and piping headers for transfer of liquid and gaseous hydrogen and vent gases. The vacuum pumps (par. 4.5.1.9) and flare stacks (par. 4.5.1.8) support the hydrogen system.

- (b) Instruments and controls for evacuating, purging, and transferring LH_2 from the truck at the unloading station to the Storage Dewar V-3801 are field located and include Boxes 27-VCB-1 and 38-VP-1.

Controls and measurements required for safely operating and controlling the hydrogen systems shall be operated and indicated in the Control Center. These operating functions shall

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.1.1

include, but not be limited to, the following: transfer of LH_2 between LH_2 storage dewar, V-3801, and engine-run tank, V-5001; helium purging of the transfer lines between V-3801 and V-5001; operation of vent valves from all vessels and headers containing liquid or gaseous hydrogen; after-cooling gas system; hydrogen compressor and 3600-psig bottle; LH_2 run tank, V-5002; gas generator; and turbopump.

- (c) Truck unloading of liquid hydrogen and transfer to the storage dewar is a local operation. The facilities are designed to accomplish all of the operations necessary and include block valves, purge valves, regulators, and pressure gages. No additional facilities control items are needed to complete the operating system, the flow diagram of which is shown in Drawing ICC-022.
- (d) Pressurization of the storage dewar is a preparation for transfer of liquid hydrogen to the test stand, as shown in the flow diagram, Drawing ICC-021. This operation will be carried out only from the Control Center. Complete all circuits necessary to carry out the pressurization. The controller system required is shown in Drawing ICC-009, and the controller specifications are given in TDS 4.5.1. The controller set point shall be on the facilities-control panel board. The point from which cables must be continued will be found in paragraph 4.2.5.
- (e) Transfer of liquid hydrogen to the engine-run tank (not to be interpreted to include the purge operations, which are covered in other paragraphs) shall be carried out from the Control Center. This flow system is shown in Drawing ICC-027. Provide the necessary switches and lights on the control panels. The point from which cables must be continued will be found in par. 4.2.5.
- (f) Hydrogen gas is obtained by vaporization of the liquid from the storage dewar, as shown in the flow diagram, Drawing ICC-022. It is compressed and stored for use through a control system for the compressors, vaporizer, and storage bottle farm, which

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Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.1.1

* is provided as a part of the facilities. The necessary switches and lights shall be provided on the Facilities Control Panel to complete this function.

(g) Hydrogen gas from the storage bottles is made available throughout the facility for various uses. The valves necessary to accomplish this are a part of the bottle farm and header system, as shown in the flow diagram, Drawing ICC-025. Switches and lights shall be provided on panels in the Control Center. The terminals for all of the items, including pressure measurements, temperature measurements, and alarms are available in terminal boxes or racks in the Control Center. See par. 4.2.5.

*

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.1.2

4.5.1.2

Oxygen

- (a) Oxygen is received, stored, transferred, and used in the liquid state. Liquid oxygen (LO_2) is burned with propane, and water is added at the steam generator to produce large quantities of steam to operate the deflector duct steam ejector. Liquid oxygen and hydrogen are used in the gas generator to operate the turbopump at the engine-test stand.

*

The test-facility oxygen system includes; the LO_2 truck unloading station; low-pressure 22,000 gal LO_2 storage dewar, V-2801; high-pressure 550-gal run tank, V-5003; and pipe transfer headers to the steam and gas generators. Liquid-oxygen boil-off shall be vented to the atmosphere, and gaseous nitrogen at the proper reduced pressure from the 3600-psig GN_2 header shall be used to pressurize LO_2 vessels and purging transfer pipes.

- (b) Instruments and controls for evacuating, purging, and transferring liquid oxygen from the truck at the unloading station to the LO_2 storage dewar, V-2801, are located on the vessel and furnished by the vessel fabricator.

Controls and measurements required for safely pressurizing LO_2 vessels, transferring LO_2 between the storage vessel and the high-pressure LO_2 run tank, and controlling the LO_2 flow to the steam and gas generators, and to the safety vent valves to atmosphere with indicated variables, shall be operated at the Control Center.

*

- (c) Truck unloading of LO_2 and transfer to the storage dewar is a local operation. The facilities are designed to accomplish all of the operations necessary and include block valves, purge valves, regulators, and pressure gages. Provide Series switches and lights to operate the valves from the Facilities Control Panel. See Drawings ICC-017 and -019.
- (d) Pressurization of the storage dewar is a preparation for transfer of LO_2 to the test-stand area. It is accomplished by opening a valve which allows nitrogen gas to flow into the tank through a

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 4.5.1.2

pre-set regulator, and by closing other lines and vents. All of the items necessary to accomplish the pressurization shall be on the facilities-control panel board. The point from which the cables must be continued will be found in par. 4.2.5.

- (e) Transfer of LO_2 to the steam generator requires control of remote shut-off valves, which controls will appear on the facilities-control panel board in the Control Center. The point from which the cables must be continued will be found in par. 4.2.5.

4.5.1.3

Helium

- (a) Helium is received in a gaseous state (GHe) and is used primarily as a purging and pressurizing gas in the hydrogen and nitrogen systems.

The test-facility helium system includes; the helium-truck unloading station; the high-pressure gas compressor; one or more of the 3600-psig storage bottles, V-3201, 2, 3, 4, 5, 6; GHe pipe headers, and vents to atmosphere. Instruments and controls for the operation of the helium system shall be located on the facilities-control panel board, or exist as local controls.

- (b) Truck unloading of GHe and transfer to high-pressure storage bottles is a local operation. The facilities were designed to accomplish all the operations necessary, and include block valves, purge valves, regulators, pressure gages, and high-pressure pump controls. The necessary series switches and lights shall be provided to operate the valves from the Facilities Control Panel.
- (c) Pressurization of the GHe header is from the 3600-psig storage bottle.
- (d) Transfer of GHe for purging LH₂ storage dewar, LH₂ engine-run tank, and LH₂ transfer pipes, requires control of remote shut-off valves. These valve operators and pressure gages shall appear on the facilities-control panel board. The point from which the cables must be continued will be found in Appendix 4.2.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.1.4

4.5.1.4

Nitrogen

- (a) Nitrogen is used in a gaseous state in considerable quantities over extended periods of time as reactor-test-engine after-cooling heat-transfer gas. It is also used throughout the test facility for instrumentation and valve-actuator power, for purging, and for pressurizing gas for the oxygen system.

*

Nitrogen may be received at the test facilities in either the liquid or gaseous state; it is received in the liquid state (LN_2) at the truck unloading area and is transferred to the 28,000-gal LN_2 Storage Dewar, V-3601; and is received in the gaseous state (GN_2) at the truck unloading station, where it is passed through the high pressure compressor and stored in one or more of the 3600-psig storage bottles, V-3201, 2, 3, 4, 5, 6.

- (b) The test-facilities nitrogen system includes: an LH_2 truck unloading station, a GN_2 truck unloading station, a 28,000-gal LN_2 storage dewar, V-3601; one or more storage bottles, V-3201, 2, 3, 4, 5, 6; a test-engine cooling-gas system; GN_2 purging, pressurizing, and high-pressure headers with necessary reduced gas pressure headers.
- (c) Truck unloading of LN_2 and transfer to the storage dewar is a local operation. The facilities were designed to accomplish all of the operations necessary and include block valves, purge valves, regulators, and pressure gages. The necessary series switches and lights shall be provided to operate the valves from the Control Panel. See Drawing ICC-023 for the flow diagram.

*

Pressurization of the LN_2 storage dewar is a preparation for transfer of the liquid to the test stand, which is shown by the flow diagram, Drawing ICC-023. Pressurization is accomplished by opening a valve to allow gaseous nitrogen from a pre-set regulator to enter the tank. The necessary lights, switches and meter indicators must be provided on the facilities-control panel board. The point from which cables must be continued will be found in Appendix 4.2.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	4.5.1.4

- (d) Truck unloading of GN_2 and transfer to high-pressure bottle storage is a local operation. The facilities were designed to accomplish all of the operations necessary and include valves, regulators and gages. Series switches and lights will be provided to operate the valves from the Facilities Control Panel. See Drawing ICC-025 for the flow diagram. The operation of the compressors and the high-pressure bottle valves will also be controlled from the Facilities Control Panel.

Pressurization of the GN_2 header is accomplished from the Control Center on the facilities-control panel board. Header-pressure and bottle-pressure indications, and header-block-valve lights shall also appear on this panel. The point from which cables must be continued will be found in Appendix 4.2.

- (e) Controls and measure measurements required to safely operate the nitrogen system and to control the use of liquid and gaseous nitrogen, as used for purging, pressurizing, and heat transfer after cooling gas, shall be located in the Control Center on the facilities-control panel board

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.1.5

4.5.1.5

Propane

- (a) Propane is received at the Test Facility by transport truck, transferred from the truck unloading station to the 15,000-gal 400-psig propane storage tank, V-3401. Propane is transferred through the vaporizer, VR-3401, and is used as a gas for burning hydrogen gases. Propane is transferred in the liquid state to the steam generator, where it is burned with oxygen with water added, to produce large quantities of steam for the steam ejector in the deflector duct.

The propane system includes the truck unloading station; the 15,000 gal propane storage tank, V-3401; the propane vaporizer, VR-3401; and pipe headers to the steam generator, to the test stand flare, FS-5001, to the gas generator flare, FS-5003, to the LH₂ storage flare, FS-3801, and to the deflector tube burner, FS-5002.

- (b) All hydrogen flares shall be start-stop controlled from the Control Center facilities-control panel board. A flameout check is made on the test-stand by ejecting small amounts of acetylene gas from the storage bottle mounted on the test stand. The resulting black smoke will be visually checked with a TV camera monitored from the Control Center.

*

- (c) Truck unloading of liquid propane and transfer to the storage tank is a local operation. The facilities are designed to accomplish all of the operations necessary and include valves, regulators, and pressure gages. Series switches and lights will be provided to operate the valves from the Facilities Control Panel. See Drawing ICC-024 for the flow diagram.

*

- (d) Pressurization of the propane tank is a preparation for transfer to the steam generator, and is done by admitting nitrogen gas from a preset regulator to the tank, as shown on Drawing ICC-024. This operation will be carried out only from the Control Center, where it will be necessary to provide, on the facilities-control panel board, all the necessary switches, lights, and indicators to pressurize the tank. The point from which cables must be continued will be found in Appendix 4.2.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 4.5.1.5

- (e) Transfer of liquid propane to the steam generator involves several valves. Provide the necessary control from the Facilities Control Panel Board in the Control Center. The point from which the cables must be continued will be found in Appendix 4.2.

Transfer of propane to the flare system involves only locally operated valves. Propane vaporization in the storage tank will cause sufficient pressure to feed gaseous propane to the flares. The regulators are manually adjustable; no additional facilities-control items are needed to complete the operating system. See Drawing ICC-024 for the flow diagram.

4.5.1.6

Reactor Cooling Gas

- (a) Cooling gas is derived from LN_2 , and is used to cool the reactor after an engine test. Cooled GN_2 is generated by the ejection of liquid and gaseous nitrogen into atomizers.
- (b) Hydrogen gas to cool the reactor is available, as shown on the flow diagram, Drawing ICC-015. See Drawing ICC-077 for the proportional-control system, which utilizes a sonic orifice with upstream pressure control to achieve mass-flow control. Provide the necessary controls including controller set point on the facilities console, and provide a controller (for specifications of this controller, see TDS 4.5.2), which shall be placed in a rack in the Control Point Building.
- (c) Cooled nitrogen gas is provided for engine cooldown, as shown in the flow diagram, Drawing ICC-015, and Drawing ICC-014, the control system. Provide all items necessary to complete the system. Controls, including controller set points, shall be on the facilities-control panel board; the controllers (see TDS 4.5.3 for specifications) shall be mounted in a rack in the Control Point Building. The programmer is a device for pulsing the flow near the end of the cooling period. Flow must be above a certain minimum to achieve turbulent flow conditions for proper heat transfer; but since the flow rate is greater than necessary to carry away the heat, conservation of nitrogen is accomplished by turning the flow on and off, with cycle periods determined by reactor temperature rise rate and heat capacity. For this purpose, provide a programmer or cycle timer that will be sufficiently flexible to adjust on-and-off time separately over large ranges (from 1 second to 1 minute); valve response will be several seconds.

4.5.1.7

Steam Generators

A minimum of two steam generators will be installed for the purpose of generating large quantities of steam over relatively short periods of time to operate the steam ejector in the deflector duct. The manufacturer of the steam generator shall furnish the primary sensors, and the controlling, indicating, and rationing devices for safe and efficient operation of these steam generators.

The percentage settings shall be established, and ratio controls shall be set by the manufacturer for the most efficient operation of the steam generator. All start-stop controls, valve actuators for purging and control of valves, temperature, flow, and pressure indicators required to maintain safe operating control shall be located on the facilities-control panel board.

4.5.1.8

Hydrogen Gas Flare

- (a) Hydrogen-gas flares are used to burn hydrogen boil-off excess and purged flammable gases produced in the Test Facilities. Hydrogen-gas flares are located at the test stand, FS-5001; at the gas generator, FS-5003; and at the LH₂ storage, FS-3801.

Combustion of the hydrogen gases at these flares is maintained by electrically ignited propane burners. These propane burners shall be operated at all times that liquid or gaseous hydrogen is stored at the Test Facilities.

All controls, valve actuators, and indicating instruments for the safe operation and burning of hydrogen gases shall be operated from the facilities control-panel board.

- (b) The LH₂ storage-area flare flow system is shown in Drawing ICC-079. The ignition system is a complete unit specified in the facilities design, requiring a 28-volt signal to start the Light-Off sequence and to provide a Fire-Out contact closure. The details must be obtained from the vendor when the information becomes available. Provide the control of the stack from the Forward Control Room. The acetylene gas is to provide a puff of smoke visible on a TV screen as a visual means of determining that the flare is lighted. The solenoid valve shall have a timer control to provide a changeable cycle of 10 seconds acetylene ON, and 50 seconds acetylene OFF. See Appendix 4.2 for the location of termination for cable continuation.
- (c) The control system for the test-stand flare for burning hydrogen boil-off is identical to the LH₂ storage-area flare control system; control shall be from the Control Center. See Drawing ICC-080 for the flow diagram.
- (d) The control system for the gas-generator flare is identical to the LH₂ storage area flare, but it is anticipated that the system will not be used. Provide all necessary operating cables to the Control Point Building. No control panel shall be supplied.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	4.5.1.8

- (e) The deflector-tube flare-control system is similar to the LH_2 storage-area flare-control system except that there is no purge nitrogen and no acetylene. Provide all necessary control from the Control Center, as shown in the flow diagram, Drawing ICC-082. See Appendix 4.2 for the location from which cables must be run.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 4.5.1.9

4.5.1.9

Vacuum

The vacuum system consists of two vacuum pumps and headers distributed throughout the Test Facilities. One two-stage vacuum pump, VP-3801, is used to evacuate the LH₂ storage dewar, V-3801, the 3600-psig storage bottles, and their associated transfer pipe lines. The second vacuum pump, VP-5001, is used for evacuation of the engine run tank, V-5001, the high-pressure LH₂ storage tank, V-5002, and their associated pipe lines.

The vacuum-pump start-stop switches and valve actuators, as used to evacuate the storage dewars, run tanks, storage bottles, associated headers, and pressure gages, are located in the field. No additional facilities systems are needed to complete the operating system.

Valves, lights, and pressure indicator required to evacuate the engine run tank prior to filling shall be operated from the Facilities Control Panel Board. The point from which cables must be continued will be found in Appendix 4.2.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	4.5.1.10

4.5.1.10

High-Pressure Gas

- (a) The high-pressure gas system is used for storage of hydrogen, helium, and nitrogen gases in six 3600-psig storage bottles; gases are distributed in high-pressure headers with a number of pressure reducing stations. Associated with the high-pressure gas system is one low-pressure compressor with a 300-psig output pressure, and two diaphragm-operated high-pressure pumps with 300-psig input pressure and 3600-psig output pressure.

High pressure hydrogen, helium, and nitrogen gases are required for purging, pressurizing, and cooling, and shall be controlled from the facilities-control panel board.

- (b) The control for transfer of gases to storage and transfer from one storage bottle to another is from the Control Center. All of the necessary items are a part of the facilities design. No additional items are required to complete the system, as shown in the basic flow diagram, Drawing ICC-025.

*

- (c) The control for the pressurization of the headers has been covered in the paragraphs 4.5.1.1 (g), 4.5.1.3 (c), and 4.5.1.4 (d); these functions are controlled from the Control Center. The valves associated with fill only are not to be a part of this system, and are covered as a part of paragraph 4.5.1.10 (b) above. Those valves that are used for both full and header pressurization will be controlled from the Control Center.

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Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.1.11

4.5.1.11

Process Water System

- (a) Demineralized process water is treated at the rate of 150 gpm, and is stored in a 2,500,000-gal tank located 8000 ft from the Test Facilities with a 400-ft head. This water is used for making steam, duct cooling, radiation shielding, and for sprinkler and deluge systems.

Controls for the demineralized water plant are locally operated and are presently a part of the existing facilities.

Valve operators for discharge of process water to the steam generator, the duct-cooling shield, and the test-cell radiation shield shall be operated from the Facilities Console. Valve operators for the emergency sprinkler and deluge systems located at the cryogenic tank storage test cell, and deflector duct vault areas, shall be operated from the Safety Console.

- (b) The demineralizer and the transfer of water to the storage tank are local controls, and are located mainly in the Utility Equipment Building. All of the items required are a part of the facilities design. No additional items are required to complete the system.
- (c) The deluge system will be designed to a specification to be provided; exact details of controls and alarms shall be obtained from the contractor's drawings. In general, all remote control and alarm connections will be made to alarm panels in the Control Center and the Test Cell Building; and each separate deluge area will have a deluge ON switch, a deluge ON light and deluge OFF switch to override a deluge ON condition. All local controls and alarms will be a part of the facility.
- (d) Shield cooling is accomplished from the Control Center; see Drawing ICC-083 for the flow diagram. The flow diagram and instrumentation of the shields must be obtained from the design package drawings. Provide all necessary control and monitoring in the Control Center. The water-flow shutoff valve to each shield is a dual-pressure regulator valve to provide two flow rates. Each valve requires a three-position control, HIGH, LOW, and OFF.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 4.5.1.11

- (e) The duct-cooling water flow is shown in Drawing ICC-082, and its control system is shown in Drawing ICC-010. Provide all items required to complete the system. Control shall be from the Control Center. See TDS 4.5.4 for the controller specifications. Set points shall be on the Facilities Console, and the controllers shall be in a rack.

4.5.1.12

LH₂ Engine Run Tank System

The 70,000-gal LH₂ engine-run tank, V-5001, is located in the test stand above the engine, and is used for holding and discharging LH₂ at controlled rates during engine testing.

The transfer of LH₂ to the run tank shall be controlled from the Test Stand Panel in the Control Center, as shown in the flow diagram, Drawing ICC-027. Provide all controls necessary to transfer the liquid. See Appendix 4.2 for the terminals from which cables must be run.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.2

4.5.2 Facilities Support Systems

4.5.2.1 Communications

* The interphone subsystem shall provide the capability of connecting a single station to any other station in the entire test complex. This shall be provided by using a common trunk system (31 trunks) routed to self-operated interphone stations located in each building. The P.A. System shall be utilized for "calling" the interphone stations (Ref. 4.5.2.1.7), which shall be distributed in substantial quantity to provide maximum utility. Each shall contain a headset, two headset jacks, a trunk-selector switch, a small isolation amplifier, and a speaker and power supply. To provide an alleviation of ear fatigue and the ability to listen or be paged a short distance from a station, a small amplifier - speaker unit shall be made available. This unit shall plug into the headset outlet, or in most cases, can be part of the communications panel. The interphone system shall have design features to allow conference calls with open microphones for at least 30 parties, and shall be capable of doing everything that can be done on the usual telephone patch system, but without the inconvenience of a central office and special communication personnel.

4.5.2.1.1 Interphone Mechanics

- * The interphone system shall utilize headsets of the Western Electric type with a minimum cord length of 6 ft.
- * Modular construction shall be employed in the design of communication panels and amplifiers, and all "standard" units shall be wired internally the same.

4.5.2.1.2 Interphone Utility

- * Approximately 200 interphone stations shall be employed throughout the interphone subsystem; by areas these are:

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.2.1.2

<u>Area</u>	<u>Stations</u>
Control Point Building	
Recording Room	24
Terminal Room	6
Control Center	8 (Ref. 4.5.2.1.4)
	10
Control Office	2
Ready Room	2
Office No. 1	2
Office No. 2	2
Tank farm	6
Fill station	5
Forward Control Room	16
Unloading platform	3
Test Cell Building	36
Test stand	25
Photo cameras	5 (1 at each photo station)
T.V. cameras	10 (1 at each photo station)
Utility Equipment Building	4

These interphone stations shall be serviced by a minimum of 31 active trunklines, assigned as follows:

<u>Trunklines</u>	<u>Assignment</u>
5	Public address
6	Test cell area
2	Tank farm
3	T.V. cameras
3	Photo cameras
12	General assignments (all areas)

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.2.1.2

Interphone stations in the test-stand area shall be constructed of materials compatible with the environmental requirements outlined in the radiation charts on Dwgs. ICC-176, -177, and -178. Stations shall be distributed in sufficient quantity so that personnel in all rooms, in each building, and at all levels of the Test Stand shall be within a reasonable working distance from their stations.

Special communication panels at the consoles shall include indicator lamps to determine the position of the sub-system disconnect push-button switches. Lamp ON shall indicate that the circuit is connected.

4.5.2.1.3 Interphone Quality

The interphone system shall incorporate design features which will minimize cross-talk, distortion, and ground loops. All lines shall be properly terminated and long lines shall be bridged where necessary. All trunk lines shall be transformer coupled and balanced to ground or common. Weatherproof construction shall be used in equipment installed in open areas. The signal attenuation shall be held to a maximum of 6 decibels with 30 parties on a single trunk line.

4.5.2.1.4 Special Features

- * The Test Director, LSE, and the Lead Engineers for Reactor, Engine, Facilities, and Instrumentation shall be equipped with special communication facilities at their consoles. These special panels shall consist of a trunk selector switch, R.F. channel selector switch, R.F. communication set transmit and receive switch, a universal PA selector switch, a dial or direct line selector switch, and an instrument selector switch. The instrument selector switch shall give the operator the opportunity to select between a mike and speaker combination and a headset. The mike and speaker combination shall be comprised of a small speaker mounted in the panel and a small amplifier for driving this speaker. It shall also include a high-output microphone with push-to-talk switch and preamplifier. The push-to-talk circuit shall include a control line for muting the speaker.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.2.1.4

Each sub-system line into the special console communication panels shall be connected to the interphone trunk selector switch common contacts through an appropriate isolation amplifier. Following each isolation amplifier shall be a push-button line disconnect switch. The interphone trunk selector switch common line shall also include a disconnect switch. A block diagram of the special console communication panel is shown in Dwg. ICC-142.

The Safety Director's special communication panel shall include a universal PA override switch. This switch shall enable the Safety Director to have exclusive use of the universal PA system in the event of an emergency.

4.5.2.1.5 Design Features

* Isolation amplifiers and local PA amplifiers shall be transistorized where possible. Printed circuit cards shall be employed to facilitate system servicing. Communication panels shall utilize modular construction and spares shall be provided in the interest of rapid servicing. A sidetone shall be provided in the headset receiver so that any operator may have the ability to listen and talk simultaneously. The sidetone shall be sufficiently suppressed so that conversations may be carried on at a comfortable level.

4.5.2.1.6 Interphone Power Supply

115-v ac 60-cps primary power shall be brought up to each communication panel. Each communication panel shall incorporate a transformer rectifier type supply for supplying dc to isolation amplifiers, relays, and local PA amplifiers. The interphone power supply shall incorporate "fail-safe" features, such as battery switchover in case of primary power failure.

4.5.2.1.7 P.A. System

The PA System, consisting of Local-Area, Universal, and Emergency PA, shall employ high-power audio amplifiers capable of driving all of the test-complex wall-mounted, ceiling-mounted, and outdoor speakers, which shall be equipped with "L" or "T" pads mounted at an accessible height. PA speakers which have been

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.2.1.7

previously installed shall be tied into the system as shown in Dwg. ICC-054. Line transformers shall be utilized for forward areas. Outdoor speakers shall be weather proofed and constructed of materials compatible with the environmental requirements outlined in the Radiation Charts on Dwg. ICC-176, -177, and -178.

Crystal microphones shall be available and equipped with press-to-talk switches and quick-disconnect cable connectors; but the system shall also be compatible with headset microphone usage. PA speaker and microphone locations are as shown in Dwg. ICC-054. Controls shall include provisions to page the entire test complex from any interphone station (Universal PA) or to page individual local areas (Local -Area PA). The system design shall also provide that emergency announcements will override the Universal and Local-Area PA by the use of a voice actuated relay (Emergency PA).

Five of the 31 interphone trunklines will be tied in the PA System for the purpose of "calling" interphone stations throughout the test complex or local areas and also for emergency announcements.

The interphone PA trunks shall be:

<u>Trunks</u>	<u>Description</u>
1	Control Point Area Power Substation Area
1	Forward Control Area Storage Farm Area
1	Test Cell Area
1	All areas (Universal PA)
1	Emergency PA - all areas (Overrides Universal and Local Area PA)

4.5.2.1.8 PA Subsystem (Universal)

(Combined as part of 4.5.2.1.7)

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.2.1.9

4.5.2.1.9

Radio Frequency Subsystem

*

A VHF or UHF (depending on channel availability) transmitter and receiver shall be installed at the LSE console for establishing communications between himself and an observation helicopter. Two similar units shall be installed at the instrumentation console and engine control console. Each of the three console R.F. communication sets shall service two or three console positions in the following manner:

Communication Set 1 – Test Director, LSE, and Chief
Test Engineer

Communication Set 2 – Reactor Control and Engine Control

Communication Set 3 – Facilities and Instrumentation Consoles

Since five channels with identical frequencies are provided, all lead console positions may switch back and forth to any desired net. A fourth and similar unit shall be installed in the observation helicopter. Transmitters shall be crystal controlled with at least five selectable XTAL frequencies spaced approximately 100 kc apart. Transmitters shall have provisions for press-to-talk operation. Receiver channels shall be crystal controlled and shall employ overload protection at the antenna input. Separate receiving and transmitting antennas shall be used and located at the Control Point Building, but separated as far as possible. Antennas shall be erected at a height sufficient to preclude shadowing of signal paths, which might be caused by helicopter flights that would be low with relation to the surrounding terrain.

VHF "Walkie-Talkies" of the small milliwatt variety shall be provided for personnel working in remote and semi-remote areas where interphone outlets are impractical or difficult to reach. The small units shall be designed as compactly as practical, consistently with reliable power output and receiver sensitivity for communications up to 2 or 3 miles. Walkie-talkie units shall be designed to either hang from personnel's belts or to be contained in a helmet. A sufficient quantity of units shall be provided to support test-stand personnel, tank-farm

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 4.5.2.1.9

personnel, and remote TV and photo-camera personnel. Five discrete channel assignments with two selectable crystal frequencies per unit shall be provided. One crystal frequency in each unit shall be on the helicopter - Safety Director link. This channel may also be used for inter-walkie-talkie communications at the discretion of the Safety Director.

The other crystal frequency shall be for the particular channel assignment of that group. Walkie-talkie units shall be divided into four groups with three active channel assignments and one spare. These units shall be made available at a centrally located checkout point. The following table shows a typical system channel assignment and unit grouping with hypothetical frequencies in the VHF band:

Communication Sets
Helicopter and Control Point

<u>Function</u>	<u>Channel</u>	<u>Transmitting Frequency</u>
SD/Helicopter	1	150.0
TV	2	151.0
Photo	3	152.0
Test Stand and Tank Farm	4	153.0
Spare	5	154.0

Walkie - Talkies

<u>Function</u>	<u>Channel</u>	<u>Group</u>	<u>Transmitting Frequency</u>	<u>Quantity</u>
SD/Helicopter	1	-	150.0	All Units
TV	2	A	151.0	10
Photo	3	B	152.0	10
Test Stand and Tank Farm	4	C	153.0	25
Spare	5	D	154.0	5

A block diagram of the R.F. system is shown on Drawing ICC-056.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.2.1.10

4.5.2.1.10 Direct Line Subsystem

*

A direct line telephone service shall be supplied between the Control Point Building and E-MAD and MAD buildings. Connection at the Control Point Building shall be to the LSE, Test Director, and Engine Control Consoles. At least four direct lines shall be provided, two lines for each remote building.

4.5.2.1.11 Dial Telephone Subsystem

Dial telephones shall be provided at the Test Consoles, all offices, and in rooms at each building in the Test Site, including the equipment at the Test Stand. Dial telephones shall be equipped with "hold" buttons on each instrument at the consoles and offices. Lines shall connect to an automatic exchange at the test site. The automatic exchange shall then connect to the NTS dial telephone trunks. A layout of instrument locations of the direct line and dial telephone subsystems is shown in Drawing ICC-055.

4.5.2.1.12 Communication Recording

Two tape outputs shall be provided on one of the recording room communication panels. These outputs shall be connected to its individual trunk selector switch of the panel. The tape trunk selector switches shall be separate from those provided for normal communication purposes.

Two 1/4-in. dual-track tape recorders shall be provided at or near the above mentioned communication panel. It shall be possible to record two critical nets simultaneously.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	4.5.2.2

4.5.2.2 Closed Circuit Television System Criteria

4.5.2.2.1 General Requirements

(a) Scope

The scope of this section is to present adequate criteria for equipment specification and design of the complete closed circuit television system to be used at ETS-1. These requirements are based on the configuration of the engine test stand, and the locations of storage facilities, equipment, and control stations as presently defined. Included in these criteria are the number and locations of camera stations; number of cameras required; function of each station and camera; required camera accessory equipment, including specifications for pan and tilt units, turret mounts, and lenses; control units; switching provisions; control consoles; and types and locations of monitoring and recording equipment. Consideration is given to the environmental conditions expected, and to the necessity for special equipment to protect the television system from damage due to these conditions. Support requirements for operator and technicians are defined. Definition of interfaces with other subsystems is also included. Descriptions of design criteria and techniques are given for provision of compatibility with television coverage at ETS-2.

(b) Purpose

The purpose of the closed circuit television system is to provide visual indications at a remote point of equipment status or operations, and to observe and record data as a supplement to the primary data-acquisition system.

(c) Functions

The subsystem must perform these basic functions:

- (1) Maintain constant surveillance of the entire test complex before, during, and after engine tests so that adequate personnel safety measures can be maintained.
- (2) Provide visual displays of the engine area during engine connect and disconnect operations, pre-run tests and post-run operations. The television coverage will include adequate equipment to observe the remote handling of all engine-area equipment, the alignment and connection of the engine to the thrust mount, operations of the engine side shields, deflection-duct vault door, and plug shield.
- (3) Provide visual coverage of remotely controlled duct removal and re-installation as may be required.

4.5.2.2.2 Interfaces with Other Subsystems

- (a) An inter-tie with the basic timing system is required so that range timing may be recorded simultaneously with the event coverage on TV kinescope recorders.
- (b) Communications via the intercom system will be required to pass commands and responses between the consoles of the Safety Engineer, the Facilities Engineer, and the Chief Test Operator and the console of the Television System Operator. Provisions for patching any communications net into the audio-recording track of the TV on kinescope are required.
- (c) Power requirements for the television subsystem are:

115-v ac, 60-cps, 1Ø regulated - approximately 20 kva

28-v dc, regulated - approximately 1 kw

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	4.5.2.2.3

4.5.2.2.3 Subsystems Requirements

(a) Nuclear Environment Protection

Because of the high nuclear environment that will exist at many locations in the area, special care must be given to the design and selection of cameras, lenses, pan and tilt units, and mounting facilities. Because of the low resistance to nuclear radiation (both neutron and gamma) of semi-conductor devices, vacuum tube equipment is specified for all high radiation environments. The radiation levels expected in the vicinity of each camera station are given in the table on Dwg. ICC-038.

(b) Thermal and Blast Protection

Temperature requirements in the vicinity of those camera stations monitoring the engine test stand, duct area, and gas generator (optional) are not yet known. Cameras located in these areas must be as fully insulated against the thermal ambient as possible. In addition, blast protection must be provided in these areas.

(c) Reliability

Cameras and associated equipment may be required to operate for extended periods of time in locations inaccessible to personnel. Sufficient reliability shall be provided in such equipment to assure that no appreciable picture deterioration will occur during these extended times. Environmental parameters, including shock, vibration, acoustical noise, and thermal specifications are given in Section 4.5.2.2.5 of these criteria for each camera location. Radiation levels are indicated in Dwg. ICC-038.

(d) Compatibility and Expansion

In the selection and design of control and distribution

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A	
Date	1 June 1962
Par.	4.5.2.2.3

equipment, consideration shall be given to the requirement for the ultimate expansion of the television system to include ETS-1 and ETS-2. Camera station locations planned shall be subject to change after site evaluation.

4.5.2.2.4 Selection of Camera Positions

The proper location of camera positions for the closed-circuit TV system comprises a critical factor in the successful operation of the NERVA engine test. The criteria guiding the final selection of camera positions shall include the following considerations:

(1) Optimum Visual Coverage

The primary objective of the entire TV system is to provide good visual operation of the equipment and activities involved in the engine test so that remote control may be achieved in complete safety.

(2) Line of Sight and Distance from Subject

Camera positions shall be selected to provide an unobstructed line of sight to the subject under surveillance. Cameras shall be located at such distances from the subject matter that good viewing angles will be maintained, eliminating the need for lenses of either extremely long or extremely short focal lengths with the resultant loss of normal perspective.

- (3) A total of 21 camera stations utilizing 17 cameras shall provide the necessary coverage. These stations are to be located as indicated in Dwg. ICC-030 and as described
- * in par. 4.5.2.2.5. Stations 1 through 7, 9 through 14, 17 through 19, and 21 will be permanent installations with respect to camera assemblies and pan and tilt units, except as noted on Dwg. ICC-038. The remaining stations shall be used as required to provide the desired coverage for a given operation phase. Each station shall consist of a permanently installed junction box which contains all

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	4. 5. 2. 2. 4

necessary connectors for patching power, control, and video circuits between the camera and the switching equipment at the Control Point. All camera stations shall be connected to the control point switching equipment by means of permanent underground cables. Exposed cable runs between camera stations and the actual camera location shall be kept to a minimum.

4. 5. 2. 2. 5 Camera Stations, Environmental Conditions, and Special Requirements

(a) Camera Station 1

Purpose: Observation of duct-vault shield-door operation, engine connect and disconnect operations, side-shield installation and removal, engine alignment, and general view of pad area.

Environmental Conditions: Ambient temperature range will be 25 to 130°F for non-engine operating conditions. Maximum temperature during engine run must be determined. Acoustic noise may be as high as 160 db, referenced to 0.0002 dynes/cm². Protection against moisture condensation on the lens and housing during operation of the steam ejection equipment shall be required.

Special Requirements: The vidicon and yoke assembly shall be mounted in an explosion and heat proof enclosure. Pan and tilt unit shall be similarly protected. The remainder of the camera assembly shall be mounted inside the concrete pier as shown in Dwg. ICC-143.

(b) Camera Station 2

Purpose: Observation of duct-vault shield-door operation, steam ejector operation, engine connect and disconnect operations, side-shield installation and removal, engine alignment, and general view of pad area.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	4.5.2.2.5

Environmental Conditions: Same as Camera 1.

Special Requirements: Same as Camera 1.

(c) Camera Station 3

Purpose: Observation of exhaust area during engine run and general area surveillance.

Environmental Conditions: Ambient temperature range will be 25 to 130°F for non-engine operating conditions. Maximum temperature during engine run must be determined. Protection against sand, dust, and wind is required.

Special Requirements: The entire camera assembly shall be mounted in an explosion and heat proof enclosure. Pan and tilt unit shall be similarly protected.

(d) Camera Station 4

Purpose: Observation of engine connect-disconnect operations, side-shield installation and removal, engine alignment, duct-cover installation, area surveillance, and general viewing of pad area.

Environmental Conditions: Ambient temperature range will be 25 to 130°F for non-engine operating conditions. Maximum temperature during engine run must be determined. Acoustic noise levels may be as high as 180 db referenced to 0.0002 dynes/cm². Protection against sand, dust, and wind is required.

Special Requirements: Same as Camera 1.

(e) Camera Station 5

Purpose: Observation of engine connect-disconnect operations, side-shield installation and removal, engine

alignment, duct-cover installation and removal, area surveillance, general viewing of pad area, and downstream viewing of engine exhaust.

Environmental Conditions: Same as Camera 4.

Special Requirements: Same as Camera 1.

(f) Camera Station 6

Purpose: Observation of rear area of test stand plus general surveillance of transmission area.

Environmental Conditions: Ambient temperature range will be 25 to 130°F. Protection against sand, dust, and wind is required.

Special Requirements: Complete camera assembly shall be enclosed in a weatherproof housing. Pan and tilt unit shall be similarly protected.

(g) Camera Station 7

Purpose: General area surveillance of fill-station area, gas-storage area, transmission area, and power sub-station area.

Environmental Conditions: Same as Camera 6.

Special Requirements: Same as Camera 6.

(h) Camera Station 8

Purpose: General viewing of LH₂ Dewar, flare stack, and gas-storage area, plus area surveillance.

Environmental Conditions: Same as Camera 6.

Special Requirements: Same as Camera 6.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	4.5.2.2.5

(i) Camera Station 9

Purpose: Observation of remote removal and installation of flame deflector duct.

Environmental Conditions: This equipment shall be operated only during periods of duct removal and installation. Temperature ambients must be determined. Relative humidity may reach 100%.

Special Requirements: Illumination of the scene to be observed shall be required. A minimum of 2 foot candles of incident light on the face of the vidicon is required and the use of a high-sensitivity radiation-resistant vidicon is required.

(j) Camera Station 10

Purpose: Same as Camera 9.

Environmental Conditions: Same as Camera 9.

Special Requirements: Same as Camera 9.

(k) Camera Station 11

Purpose: Same as Camera 9.

Environmental Conditions: Same as Camera 9.

Special Requirements: Same as Camera 9.

(l) Camera Station 12

Purpose: Observation of engine connect-disconnect operations, side-shield installation and removal, and area surveillance of rear pad area.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 4.5.2.2.5

Environmental Conditions: Ambient temperature range will be 25 to 130°F for non-engine operation conditions. Maximum temperature during engine run must be determined. Acoustic noise levels may be as high as 150 db, referenced to 0.0002 dynes/cm². Protection against sand, dust and wind is required.

Special Requirements: Vidicon and yoke assembly shall be mounted in an explosion and heat proof enclosure. Pan and tilt unit shall be similarly protected. Remainder of camera assembly shall be mounted in a concrete enclosure on the rear of the main shield wall so that the maximum distance to the vidicon and yoke assembly will not exceed 15 feet under any extremes of vidicon and yoke travel.

(m) Camera Station 13

Purpose: Observation of LH₂ and LO₂ run tanks, rear of test stand, gas-generator and run-Dewar flares, main Dewar, and general surveillance of NW and SW quadrants of the test area.

Environmental Conditions: Ambient temperature range will be 25 to 130°F for non-engine operating conditions. Maximum temperature during engine run must be determined. Acoustic noise levels may be as high as 160 db referenced to 0.0002 dynes/cm². Protection against sand, dust and wind is required.

Special Requirements: Same as Camera 1.

(n) Camera Station 14

Purpose: Same as Camera 13.

Environmental Conditions: Same as Camera 13.

Special Requirements: Same as Camera 13.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.2.2.5

(o) Camera Station 15

Purpose: General observation of gas storage area or loading area as required.

Environmental Conditions: Ambient temperature range will be 25° to 130°F. Protection against sand, dust and wind is required. When used, complete camera assembly shall be enclosed in a weather-proof housing. Pan and tilt shall be similarly protected.

Special Requirements: None

(p) Camera Station 16

Purpose: Same as Camera 15.

Environmental Conditions: Same as Camera 15.

* Special Requirements: Same as Camera 15.

(q) Camera Station 17

Purpose: Observation of activities in Forward Control Room for display at Control Center as required.

Environmental Conditions: No extreme environments expected.

Special Requirements: None

(r) Camera Station 18

* Purpose: Observation of activities in Test-Stand Building for display at Control Center as required.

Environmental Conditions: No extreme environments expected.

Special Requirements: None

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	4.5.2.2.5

(s) Camera Station 19

* Purpose: Observation of activities or equipment in
Test Cell Building as required.

Environmental Conditions: No extreme environments
expected.

Special Requirements: None

(t) Camera Station 20

Purpose: General viewing of LH_2 Dewar, flare stack,
and gas-storage area, plus area surveillance.

Environmental Conditions: Ambient temperature range
will be 25 to 130°F. Protection against sand, dust,
and wind is required.

Special Requirements: Complete camera assembly
shall be enclosed in a weatherproof housing. Pan and
tilt unit shall be similarly protected.

(u) Camera Station 21

Purpose: Test set-up for operation and maintenance of
camera equipment. This station is intended to be used
in such a manner that a camera may be patched into the
regular control and monitor system for maintenance,
adjustment, and equipment evaluation.

Environmental Conditions: Not applicable.

Special Requirements: Not applicable.

4.5.2.2.6 Control System

Refer to Dwg. ICC-144, Control System block diagram.
Of the 21 camera stations in this system, 8 may be

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.2.2.6

activated at any given time. The selection of the camera station, the appropriate camera-control unit, accessory modules, and control panel shall be performed at the Control Point patch-panel. Accessory modules shall be installed to permit the use of various types each of pan and tilt heads and camera lens assemblies.

** One remote camera accessory control will be located on the Facilities and Safety consoles, respectively. These controls will be switchable at the Master TV Console to any camera location.

The camera-station cables, camera-control unit and accessory module input and output terminations, and the control-panel cables shall be permanently terminated on multipin connectors. Patch cables shall be provided to interconnect the camera station to the appropriate control unit and accessory module output, and the control panel to the selected camera control unit and accessory module input.

4.5.2.2.7 Video Distribution

Picture monitors in the indicated quantities and types shall be provided at the following locations (see Drawing ICC-005):

	8 each	21-in.	Main Control Room
	8 each	8-in.	Television Control Console
*	2 each	8-in.	Facilities Console
*	2 each	8-in.	Test Director's Console
	1 each	21-in.	Forward Control Room
	2 each	as furnished	Kinescope Recorders

The distribution of video signals shall conform with Dwg. ICC-005, Block Diagram, Closed Circuit TV.

* Remote switching shall be provided for the TV monitors on the Master TV Control Console.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.2.2.7

* ~~Room monitors. The command switches shall be located respectively at the two consoles, Console and in the Forward Control Room.~~ Video inputs to the control room 21-in. monitors shall be patched at Patch-Panel 2, located near the television control console. Selection of the eight video signals to be distributed through the area shall be made at Patch Panel 1, located adjacent to the camera-control-unit bank.

* A video waveform monitor shall be provided for the selective viewing of the incoming video signal.

Two Kinescope recorders shall be provided for selective recording of composite video signals.

4.5.2.2.8 Cabling

(a) Camera, and Pan/Tilt Control Cabling

Cabling extending from cameras to junction boxes shall be installed under ground (in the tunnel where feasible).

* Between the terminal boxes in the Test Cell Building and the Forward Control Room, and the TV patch panels in the Control Center, the cabling shall be installed in raceways within the tunnel.

Camera-control cabling in the Forward Control Room shall be fixed within the terminal boxes and then routed under-floor to the racks containing the camera-control panels.

* Camera-control cabling in the Control Center shall plug-in at the patch panel, and shall be routed under-floor to the racks containing the control panels by means of cable trays.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.2.2.8

(b) Coax Cable (Video)

- * Coaxial cables shall be used for video signal transmission between the camera controls and the monitors.

4.5.2.2.9 System Synchronization

- * Synchronization for the television system shall be provided in accordance with the most recent synchronization (sync) standards of the Electronics Industry Association (EIA). Individual EIA standard sync generators shall be provided to supply sync, blanking, vertical drive, and horizontal drive pulses to each camera monitor chain.
- * Each sync generator shall have the capability of being either crystal controlled or synchronized with a stable 60-cps source, such as the power-line frequency.

4.5.2.2.10 Control Console

- * The design of the control panels on the master TV control console shall be compatible with the various types of cameras and equipment used in the system. The panels will provide control for at least the following functions: pan, tilt, pan and tilt speed, zoom in and out, lens focus, and aperture control. As previously noted, provision shall be made for video waveform monitoring.

Remote controls and indicators for the operation of kinescope recorders shall be located at the television control console.

Operation of the control console will require three operators who shall be skilled television technicians. Two of these operators shall be seated at the console, and primarily engaged in manipulation of the various controls and monitoring of the picture and waveform

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	4.5.2.2.10

signals. The third operator shall be available for local operation of the kinescope recorder and general operational maintenance of the equipment, including camera control units, patch-boards, and distribution amplifiers.

4.5.2.3 Timing System

The timing system is to be employed as part of the Facilities Support System, and shall provide a time reference for the correlation of all events, and a precision time standard for evaluation of data.

4.5.2.3.1 General Requirement

The timing system shall provide serial and parallel time codes to strip-chart recorders, oscillographs, magnetic-tape recorders, and motion-picture cameras. Timing pulses shall be provided for the count clocks; in addition, the time code generator shall provide synchronization pulses to the Data Handling, Recording, Reduction, and Analysis Section; and auxiliary timing signals shall be provided for use by sequencers and automatic checkout equipment.

4.5.2.3.2 System Criteria

(a) General

All time displays and time codes shall be derived from a single central line oscillator. Although the timing system shall be referenced to local time, the system design shall be such that, with the addition of equipment at a later date, the local accumulator may be accurately set with radio-time references to local time, Z time, or any other desirable basic time reference. Provision shall also be made for synchronizing and setting the ETS-1 accumulator to NNRDC Central Range Time when, and if, such a central facility becomes available.

(b) Accumulator

An accumulator shall be provided which will accumulate time from the master oscillator, and form the basis for all time signals within the system. Suitable provisions shall be made for easily setting the accumulator in conjunction with external time indications. The accumulator will read in straight seconds and will automatically recycle at the end of each twenty-four-hour period at midnight. The logical design of the accumulator will incorporate binary coded decimal (BCD) decade counting, so arranged as to facilitate both BCD and decade decimal readout.

(c) Time-Code Generator

The time-code generator derives time intelligence from the accumulator. Its purpose is to provide a number of serial and parallel time code outputs suitable for recording in all forms of data records. The timing system shall consist of two identical time-code generators, and one common comparator to facilitate interconnection between the generators and to serve as a distribution center for the various time-control and power signals (see Dwg. ICC-098). One time-code generator will normally be used as the operating unit, while the other will serve as a standby unit; however, either generator must be capable of normal operation if the other unit is either inoperative, or operating inefficiently. Audible and visual warning shall be provided to warn of a failure in the operating generator. The system shall be so designed that the operation will be manually transferred to the standby unit without noticeable interruption of timing signals in the event of failure in the operating unit.

Each time code generator shall generate 1 pulse per second (pps) which shall be time-synchronized to within plus or minus 5 microseconds of the 1 pps of the other generator. An output signal from the operating generator shall be used to synchronize the standby unit.

Each Time-Code Generator shall be designed so that there is no signal feedback or interaction between outputs. The wave-shape of the output signal shall be essentially the same at all points from No-Load to Maximum-Load.

(d) Time Codes

The following criteria shall govern the selection of serial time codes:

(1) Codes should be so designed as to require minimum bandwidths for transmission and recording. This implies a minimum number of pulses per frame and maximum utilization of the total time frame for writing coded time.

(2) A sufficient quantity of codes shall be provided to adequately handle serial time entry for strip-recorder speeds from 1-in. /hr to 100-in. /sec. The quantity of codes necessary shall also be based on the premise that the reading of serial codes shall not require resolving pulses or space widths less than 4 times the recording trace widths, and, in addition, that all full time codes may be found on any strip recorder within ± 15 inches of any given instant on the record.

(3) Time codes shall be designed for purely binary operation. Either two levels of recording or On-Off modulation must be usable.

(4) Codes shall be so designed as to require the minimum amount of training for operating and analysis personnel.

(5) All serial time codes shall have the same basic format independent of frame length.

(6) Time codes shall be so designed as to facilitate automatic reading from magnetic tapes.

(7) Time codes shall be designed to facilitate time interpolation between basic time frames. Pulses shall be uniformly distributed and shall consist of numbers useful for time interpolation.

(8) Code frame lengths shall be decade related, and shall be based on power of 10 frame periods in seconds.

(e) Auxiliary Signals

Auxiliary signals at 1 mc, 100 kc, 1 kc, 10 pps, and 1 pps shall be made available for general utilization within the I & C System.

(f) Clocks

(1) A Count clock shall be provided to form the time basis for the formal conduct of engine testing. The clock shall operate from 1 pps signals from the accumulator. The count clock will be arranged to read in hours, minutes, and seconds; and in seconds only. A total counting and display capacity will be

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.2.3.2(f)

provided in the hours decade for a full count of 99 hours, and up to a count of 86,399 in the second mode. Clock controls will be so arranged as to allow use of this equipment in a countdown mode or in a time-of-day mode. In the countdown mode, used during testing operation, time will be counted backwards from some preset value. The negative sign shall be inserted both in front of the decades of hours, and in front of the seconds display, respectively. Clock logic shall be designed to permit countdown through zero and subsequent increasing time with a positive sign preceding the hour decades and preceding the seconds-only display. Controls shall be arranged to permit stopping the clock on manual command, as well as to reset the clock to any positive or negative time value. In the time-of-day mode, the countdown time and all paralleled displays shall operate as a twenty-four-hour time-of-day indicator with automatic recycling at the time the master time clock recycles to zero. Clocks will probably be set to recycle at midnight.

(2) A Test Run clock shall be provided to present elapsed time of test. Clock information shall be displayed in hours, minutes and seconds, and shall not be halted during test "holds."

(3) A Hold clock shall be provided to indicate total hold time in hours, minutes, and seconds. This clock will be started at the beginning of a "hold," and stopped at the conclusion of the "hold." The clock shall be manually resettable so that previous hold-time display may be eliminated if desired.

(g) Displays

* Displays of both range time and count clock time will be located throughout the ETS-1 complex. All displays will be slaved to the appropriate central clocks. Displays will all read in a decade decimal fashion. Timing display shall be distributed as indicated in the following table:

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 4.5.2.3.2(h)

	<u>Control Center</u>	<u>Control Point Recording Room</u>	<u>Forward Control Room</u>	<u>Test Cell Elect. Rm.</u>	<u>Cameras</u>
Range Time (seconds, recycling every 24 hours at midnight)	X	X	X	X	
T. O. D. Clock (hours, minutes, seconds)	X				
Count Clock (hours, minutes, seconds)	X	X	X	X	
Count Clock (seconds)	X	X	X		
Hold Clock (hours, minutes, seconds)	X				
Serial Time Codes	X	X	X		X

(h) Supplementary Equipment

In addition to the foregoing, the timing system shall consist of the equipment described below, and as indicated in Block Diagram ICC-098.

(1) A relay-driver shall accept separate pulse trains or pulse-width modulated time codes from the Time-Code Generator. At least seven separate output channels shall be provided as mercury-wetted relay contact closures to control external equipment. The primary purpose of the relay-driver shall be the driving of time pens in oscillographs, strip charts, and plotting boards. Additional Relay Drivers may be added as required, by simply connecting to an output of the relay-driver attached to the Time-Code Generator.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.2.3.2

* (2) "Deleted"

- (3) A neon distribution amplifier shall accept three, or more, pulse-width-modulated signals from the Time-Code Generator, and shall provide at least 12 separate channels of output signals to drive camera neon lamps in remotely located instrumentation cameras. Inexpensive lines, such as two-shielded, or unshielded, cables may be used as transmission lines.

If more than 12 cameras require timing simultaneously, additional amplifiers shall be provided by paralleling outputs with the other unit(s).

- (4) Cables shall be provided, in lengths and numbers required, to each camera site, and shall terminate in the respective camera junction box. The other ends of the cables shall be conducted to the Control Point Center terminal room, and to the timing equipment.

(i) WWV Cabling

Cabling shall be installed from a position on the roof of the Control Point Building to the racks housing the timing equipment, providing for ready installation and hook-up of a WWV antenna and receiver, whenever it should be deemed necessary.

(j) Transmission

The transmission of all time signals from the various clocks and time-code generators shall be at a standardized voltage level and at a relatively low impedance. Transmission levels shall be chosen to simplify the design of equipment bridging the various lines for time code readout into the numerous end items.

4.5.2.3.3 Preliminary Design

(a) Block Diagram

The block diagram, Drawing ICC-098 illustrates the major equipment required in the timing system.

(b) Oscillator

The oscillator used for driving the accumulator shall possess a stability of at least one part in 10^8 per day. Two units should be provided, and provision made for manual crossover to the backup oscillator in case of malfunction.

(c) Accumulator

The accumulator shall count in decimal fashion from a 1-kc input to a total capacity of 10^5 seconds. Circuitry shall be arranged for automatic recycling at precise 24-hr intervals. Output lines (BCD) shall operate at the voltage and impedance levels which will simplify the circuitry required for scanning in order to produce the several serial time-code readouts.

(d) Time-Code Generator

The range time-code generator shall produce serial time codes with time information derived from the accumulator. This may be accomplished by scanning the BCD decades.

(1) Basic Serial Code

Based upon the criteria of paragraph 4.5.2.3.2, the required code for use is a six-decade BCD format based upon the 8-4-2-1 type. Twenty-four pulses are required to define time of day in straight seconds and tenths. The time frame consists of these 24 pulses, plus a space during the 25th interval for recognition of the basic frame. The code is binary in nature and is width-modulated to provide the necessary code intelligence. Zeros and ones are identified as $1/4$ interval and $3/4$ interval widths respectively.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.2.3.3

In order to meet the wide range of strip-recorder speeds, as well as to comply with criteria for maximum time resolution and maximum frame length, decade related codes with frame periods of 1/10 second to 1000 seconds are required. Drawing ICC-152 illustrates a typical time code as recorded on the strip chart. Table ICC-151 provided particulars of the several serial code characteristics.

(2) Forms of Time Code Recording

a Magnetic Tape

* Time codes must be recorded on magnetic tape in both analog and digital formats. Frequency modulation may be used by directing the unmodulated code to voltage controlled oscillators, or to magnetic tape recorders with FM record amplifiers.

* Time information must appear in the digital data-system tapes. BCD codes of range time, in straight seconds and of countdown time, will be recorded on the digital data tapes by the Data Acquisition System.

b Strip Chart Recorders

Time codes for all forms of strip-chart recorders will be binary level serial entry. This includes galvanometer recorders, direct writing recorders, and potentiometer recorders. Time codes will be selected with regard to recorder speed on the basis of meeting the criteria for resolution capacity and maximum time code frame lengths. Drawing ICC-153 relates suitable codes as a function of strip-recorder speeds. It is desirable that all strip recorders be arranged to automatically select the proper code at the time that a given speed is selected.

c Photographic Film

Provision shall be made for entering the selected time codes on the basis of On-Off coding on the film margin outside of the picture format. Suitable buffer amplifiers shall be provided for driving camera time-code lights when distances or pulse rates exceed the limits of the neon-drive output. These shall provide suitably high bridging impedance to the time-code transmission lines.

(3) Transmission Characteristics

All time-code signals will be transmitted at the standardized levels of -5 volts for the space, and +5 volts for the mark intervals. Source impedance at transmission shall be 100 ohms or less. The rise time (10 to 90%) shall be less than 10 microseconds.

(4) Bridging Impedance

All circuitry bridging time-code transmission lines shall have an impedance in excess of 50,000 ohms. Such circuitry shall not accept from, or return to the line, currents in excess of 120 microamperes. Equivalent shunt input capacitance shall not exceed 50 micromicrofarads. See sketch below.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	4.5.2.4

4.5.2.4

Electrical Power

The electrical installation shall comply with the National Electric Code (latest edition). All conduit shall be rigid galvanized and shall be 3/4-in minimum. The existing I & C distribution power system, as noted on Drawing ICC-006, shall be extended to supply the power requirements at locations specified elsewhere in the criteria.

**

Three diesel generators will supply the I & C System power requirements during a test run. The load will be divided in such manner that two generators will supply the instrumentation, power, and one generator will supply the large motor loads. This will isolate the Instrumentation System so that changes in the motor loads will not cause transients or modulations in the Instrumentation System. All control wiring presently terminated in the Test Cell Building and the Forward Control Room, shall be extended to consoles and racks in the Control Point Building as required.

(a) 120/208-volts, 3-phase, 60-cycle, Regulated Power

This regulated power shall be supplied to all racks, consoles, TV, Timing, PA, and communication systems as required. Fuses or circuit breakers shall be installed in all equipment to protect the wiring, where necessary as required by code.

(b) 28 Volts dc

This regulated power shall supply all solenoid valves, relays, instrumentation data acquisition, and control dc power. The dc power shall be grounded in the Control Point Building and interconnected through a common bus of adequate size, and the +28-v outputs of the rectifiers shall not be interconnected. The regulation and typical specifications are listed in TDS 4.14.1 and 4.14.2; typical specifications for the batteries are listed in TDS 4.14.2, and for the distribution panels, in TDS 4.16. The batteries shall provide backup power for the DC rectifiers. In event of failure of the 400-amp rectifier in the Test Cell Building, the nickel-cadmium battery shall provide 180-amp minimum for 20 minutes.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
------	-------------

Par.	4.5.2.4
------	---------

(c) 480-v, 3-Phase, Regulated Power

The 480-v supply power for the 28-v dc equipment in the Control Point Building shall be supplied from an existing motor-control center MCC-20I in the Utility Equipment Building.

A new 45-Kva load center and motor control center, MCC-401, shall be installed in the Test Cell Building to supply 480-v power for the 28-v dc equipment.

* A new 25-Kva, 4160 - 480-v, 3-phase transformer with secondary main circuit breaker shall be connected between the existing fused switch and the 45-Kva transformer, Feeder 25I2. This 480-v feeder shall supply power to the two 5-kw, 120/208-V, 400-cycle, 3-phase motor-generator sets.

(d) Remove 4160-v breaker control and metering provisions have been made for the remote tripping control and metering of the 4160-volt tie breaker and diesel generators. Provisions shall be made for synchronizing across the tie breaker. Wiring has been installed to the Control Point Building. An existing control and metering panel is to be installed in a rack in this building and connected to the existing wiring.

(e) 4160-Volt Diesel Generator
(Deleted)

(f) Remote Monitoring Equipment

Provision shall be made in the Control Point Building console for a light indication that each dc rectifier and 400-cycle

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 4.5.2.4

generator is operating. Provision for recording 4160-volt bus voltage and frequency output voltage of each rectifier, and the output voltage and frequency of each 400-cycle generator, shall be made on a rack in the Control Point Building.

4.5.3

Test Stand Support Equipment Control Systems

Controls shall be provided in the Control Center at the Control Point Building to operate and monitor operations of the following equipment:

- Radiation shields (top, bottom, and sides)
- Duct-cover shield
- Deflection-pit door shield
- Deflection duct
- Engine transport train interlock
- Engine loading and unloading equipment
- Track switches

In addition to the controls at the Control Point Building, controls shall be provided at local equipment positions, as shown on the block diagram, Drawing ICC-008.

4.5.3.1

Radiation Shields Control System

The Radiation Shields Control System shall consist of all displays and controls necessary to operate the radiation shields.

(a) Operating Controls

Controls for operating the radiation shields shall be located at the Control Point Building (Ref. 2.4.1, Consoles). Override controls shall enable operations to be controlled from an area where an operator can visibly observe the radiation shields. This will be possible by plugging in a hand-held control box with an extension cable to a receptacle on the Test Stand Control Panel. This shall disable actuation to be made from the Control Point Building.

The control functions shall be as follows:

- (1) Side Radiation Shields Cart Drives - The controls for each of the two Cart Drives shall include the following functions: Forward, Reverse, Forward jog, Reverse Jog, and Stop. Lockout stops shall be provided at the drive-motor starters.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.3.1

- (2) Side-Shield Locking Mechanisms - Each of the two side radiation shields will have 4 individually controlled hydraulic locking mechanisms actuated by solenoids. The control functions shall be Lock, and Retract.
- (3) N₂-Pressurization of Bellow Seals - The side-radiation-shield vacuum seals will be pressurized by a solenoid actuating valve, 50-RSV-221. Control functions shall be ON, and OFF.
- (4) "Molten Metal" Seals, Heater System - Controls shall be provided for operating two heater contactors. The modes of operation will be High Temperature, Low Temperature, and OFF.

(b) Monitoring

In addition, to permit observation of the operations of the radiation shields on a TV monitor at the Control Point Building, the following displays shall be included:

- (1) Side-Radiation-Shield Operation - Pilot lights shall indicate forward or reverse motion of the shields. A series of pilot lights shall indicate coarse position of the shields on the tracks. For final positioning of the shields, an LVDT and indicator shall be provided.
- (2) Side-Shield Locking Mechanisms - Pilot lights shall be included for the purpose of indicating whether the mechanisms are locked or retracted.
- (3) N₂-Pressurization Bellow Seals - Pilot lights shall indicate actuation of the valve solenoid. A pressure indicator shall indicate the pressure of nitrogen in the bellow seals.
- (4) "Molten Metal" Seals - Pilot lights shall be provided to indicate the operation of the heater system contractors, High Temperature, Low Temperature, and Off positions. Temperature indicators shall indicate the temperature of the molten metal.

4.5.3.2

Duct Cover Shield Control System

The Duct-Cover Shield-Control System shall consist of all displays, including a TV monitor and the controls necessary to operate the duct-cover shield. These controls and monitors shall be located in the Control Center of the Control Point Building (Ref. 2.4.1, Consoles). A hand-held control box with extension cable plugged in to a receptacle on the test stand control panel shall afford local control. The circuitry shall be such that actuation of the controls from the Control Point Building is disabled when the cable is plugged into the receptacle.

(a) Operating Controls

The controls provided for operating the duct-cover shield will be those of the Drive Cart. Control functions shall be as follows: Forward, Reverse, Forward Jog, Reverse Jog, and Stop.

A lock-out stop shall be provided at the motor starter. Limit switches shall automatically stop the Drive Cart at the extreme positions.

(b) Monitoring

Provisions for monitoring the duct-cover-shield drive cart shall consist of pilot lights indicating forward and reverse motion and stop.

4.5.3.3

Deflection Pit Door Shield Control System

The Deflection-Pit Door-Shield-Control System shall consist of all displays and controls necessary to operate the deflection-pit door shield. These controls and monitors shall be located at the Control Point Building (Ref. 2.4.1, Consoles), and on a panel near the Deflector pit. Local remote switching of the controls shall be provided.

(a) Operating Controls

The controls provided for operating the deflection-pit door shield will be those of the drive motor. The control functions will be as follows: Open, Close, Open Jog, Close Jog, and Stop.

A lockout stop shall be provided at the motor starter. Limit switches shall automatically stop the door shield at the extreme Open and Close positions.

(b) Monitoring

Pilot lights shall be used for monitoring the opening and closing of the door as well as stop.

4.5.3.4

Deflection Duct Control System

The Deflection Duct Control System shall consist of all monitors and controls necessary for installation or removal of the Deflection Duct.

(a) Operating Controls

Remote controls for deflection-duct alignment, jacking, and locking operations shall be located in the Control Center of the Control Point Building (Ref. 2.4.1, Consoles). Local control of these operations shall be made possible by the use of an extension cable with attached control box which shall be plugged in to a panel receptacle located nearby the equipment chase at the Deflector Pit. By inserting the extension cable connector in the receptacle, control from the Control Point Building shall be disabled.

The controls shall be those required to operate the following:

- (1) Duct Elevating Jacks - Controls shall be provided to start and stop a hydraulic-pump motor supplying fluid to four hydraulic jacks, and to actuate solenoid valves for raising

and lowering of the jacks. Limit switches shall be provided to automatically stop the jacks at the fully expanded or retracted positions.

- (2) Lock and Support Trunnions - Four trunnions will be provided for locking and supporting the deflection duct when in final elevated position. The controls shall afford individual operation of these trunnions for expansion or retraction. Limit switches shall automatically stop the trunnions in fully expanded or retracted position.
- (3) Water and Steam-Line Locking Clamps - Individual controls shall be provided for the operation of four water lines and two steam-line connector clamps, hydraulically operated. These controls shall actuate solenoid valves to lock or open the clamps. The extreme positions shall be protected by limit switches.
- (4) Instrumentation Connector Mechanism - This mechanism consists of a hydraulically operated plunger, with a connector plate which, when extended, will match the instrumentation connectors of the deflection duct. The controls shall actuate solenoid valves for closing or opening of the connector mechanism. Limit switches shall prevent overtravel of the plunger.
- (5) "Molten Metal" Deflector Duct Seal - Controls shall be provided for operating two heater contactors. The modes of operation shall be: High Temperature, Low Temperature, and OFF.

Pilot lights shall be provided to indicate the operation of the heater system contactors, High Temperature, Low Temperature, and OFF positions. Temperature indicators shall indicate the temperature of the molten metal.

(b) Monitoring

A TV monitor and the following displays shall be provided at the Control Point Building for the operation of the deflection duct.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.3.4

- (1) Duct Cart Position Indicator - An indicator shall be provided that will indicate the last 6 inches of the duct cart travel before it comes up to a mechanical stop which will align the duct for the elevating jacks. The position indicator is to be used to prevent the duct cart being slammed in to the mechanical stop.
- (2) Duct Elevating Jacks, Position Lights - Pilot lights shall be provided to indicate fully expanded and retracted positions. Pilot lights shall, in addition, indicate the 1/3 and 2/3 expanded positions.
- (3) Lock and Support Trunnions, Indicating Lights - Pilot lights shall be provided for each of the four trunnions to indicate fully expanded, half expanded, and retracted positions.
- (4) Locking clamps, Indicating Lights - Pilot lights shall be provided to indicate that clamps are opened or closed.
- (5) Instrumentation Connector Mechanism, Indicating Lights - Pilot lights shall be provided to indicate that the instrumentation connectors are opened or closed.

4.5.3.5

Engine Loading and Unloading Control System

The Engine Loading and Unloading Control System shall consist of all control and monitors necessary for disabling the R. F. control of the engine-transport train, and the loading and unloading operations of the engine at the test stand.

- (a) Transportation of Nuclear Engine - A series of limit switches shall be located in intervals along the track route from the MAD building to the test stand. These limit switches shall actuate pilot lights at the MAD building and at the Control Point Building for indication of the train's position and speed limits.
 - (b) Disabling Switch - The train shall come up to a mechanical stop at the test stand (monitored on TV at the MAD Building).
- * A connector on the engine cart shall mate with a connector

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.3.5

at the test stand as the train stops. A disabling switch in the Control Center shall be connected through the connector to the engine cart. By manually throwing the disabling switch closed, the Prime Mover shall be prevented from moving. Power and controls shall be provided at the Control Point Building for actuation of a disabling actuator on the Prime Mover. Energizing this relay shall disable the Receiver on the Prime Mover. Proper interlocking shall be provided to prevent any operation, as described in Paragraph 4.5.3.5.(c), from occurring until the disabling switch is thrown closed. When the operation is complete and the train is ready to move out, opening the disabling switch shall return control to the engine cart.

- (c) Nuclear Engine Loading and Unloading - The following control functions shall be accomplished from the Control Point Building when the interlock connector has been mated:

*

~~(1) Coupling and decoupling of engine cart~~

- (2) Forward, reverse, left and right motion of engine jig on
- (3) Actuation of engine-cart elevating mechanism
- (4) Actuation of locking mechanisms for fastening nuclear engine to test stand.

4.5.3.6

Track Switching Control System

The Track Switching Control System shall consist of the controls and displays necessary for the switching between the duct-cover shield tracks and the side-shield track spur.

The controls for operating the track switch shall be located in the Control Point Building (Ref. 2.4.1, Consoles). Override control shall afford capability of operating the track switch from the test stand control panel. Pilot lights shall be provided at both locations for indicating track-switch position.

4.5.3.7

Weather Doors Control System

The weather doors shall be locally controlled. The controls shall include for each of three doors, Up, Down, and Stop, and a lockout stop at the motor starter. Limit switches shall be provided to automatically stop the doors at the fully Up and Down positions. Pilot lights shall indicate the mode of operation of the doors.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5.4

4.5.4 Transmission (Cable and Patching)

4.5.4.1 Transmission Cables

The transmission cable systems shall transmit visual and data intelligence and the necessary control functions required for the task of engine testing. The signal and control-transmission cable systems include the following main categories:

Television
Interphone and public address
Photography
Engine control
Data acquisition
Test stand support
Facilities control

Cables will be installed in existing cable trays in the tunnel where possible. Cables with ac frequencies, or which are subject to switching surges, shall be separated as far as possible from the data-acquisition cables to avoid cross talk or signal interference. The common instrumentation ground shall be at the Control Point Building only. The block diagram of the cable runs is shown in ICC-052, and the cable details are shown in par. 4.5.4.3.

4.5.4.2 Patching

Patching facilities shall be incorporated to provide the maximum degree of flexibility commensurate with the testing requirements. The TV patching, as shown on ICC-005, shall be an integral part of the TV system as supplied by the contractor. The interphone and public address system selection are to be made with switches and no external patching will be required. The test-stand support control wiring will not require patching. Refer to Table 4.5-1 for list of cables that will require patching, and for the location of the patch boards.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par.

Table 4.5-1

CABLE DETAILS

Cable	Quantity	Function	Specs(1)	Patching Required
1A	3	Camera Control	12 Sh. Pr.	AT C. P.
	6	Pan Tilt	Coax.	AT C. P.
1B	7-1/2	Camera Control	12 Sh. Pr.	AT C. P.
	15	Pan Tilt	Coax.	AT C. P.
1C	1-1/2	Camera Control	12 Sh. Pr.	--
	3	Pan Tilt	Coax.	--
1D	1	Camera Control	12 Sh. Pr.	--
	1	Pan Tilt	Coax.	--
1E	1/2	Camera Control	12 Sh. Pr.	--
	1	Pan Tilt	Coax.	--
1F	6	Camera Control	12 Sh. Pr.	--
	12	Pan Tilt	Coax.	--
1G	1/2	Camera Control	12 Sh. Pr.	--
	1	Pan Tilt	Coax.	--
Interphone & Public Address				
2A	1	Trunk Lines	S/52 Pr	--
2B	1	Trunk Lines	S/5 Pr	--
Photo Cameras				
3A	1	Camera Control	100 Pr	AT C. P. & T. C.
3B	1	Camera Control	16 Pr	AT T. C.
3C	1	Camera Control	44 Pr	AT T. C.
3D	1	Camera Control	32 Pr	AT T. C.
3E	1	Camera Control	8 Pr	AT T. C.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par.

Table 4.5-1 (cont.)

<u>Cable</u>	<u>Quantity</u>	<u>Function</u>	<u>Specs (l)</u>	<u>Patching Required</u>
Engine Control				
4A	25	Systems Control	12 Sh. Pr.	AT T. C.
4B	25	Systems Control	12 Sh. Pr.	AT T. C.
4C	7	Engine Measurements	12 S/6 Cond	T. C. B.
	24	Engine Measurements	T/C	
4D	9	Engine Measurements	12 S/Pr	T. C. B. & C. P.
4E	9	Engine Measurements	12 S/Pr	F. C. R.
Data Acquisition				
5A	110	Data Acquisition	12 Sh. Pr.	AT T. C. & F. C.
5B	70	Data Acquisition	12 S/6 Cond.	AT T. C.
	546	Data Acquisition	T/C	
5C	34	Data Acquisition	12 Sh. Pr.	AT F. C. & C. P.
5D	13	Data Control	12 Sh. Pr.	--
5E	13	Data Control	12 Sh. Pr.	--
5F	1	Data Control	12 Sh. Pr.	--
5G	1	Data Acquisition	12 S/6 Cond	--
Test Stand Support				
6A	25	Control	12 Sh. Pr.	--
* 6B	--	Control	20 wires	--

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par.

Table 4.5-1 (cont.)

<u>Cable</u>	<u>Quantity</u>	<u>Function</u>	<u>Specs (1)</u>	<u>Patching Required</u>
Facility Measurements				
7A	117	Facility Measurement	T/C	
	8	Facility Measurement	12 S/6 Cond	
7B	12	Facility Measurement	12 S/6 Cond	
	16	Facility Measurement	T/C	
7C	30	Facility Measurement	12 S/Pr	C. P.
7D	30	Facility Measurement	12 S/Pr	F. C. B.
7E	38	Facility Measurement	12 S/Pr	
Facilities Control				
8A	25	Switches	12 Sh. Pr.	--
8B	17	Switches	12 Sh. Pr.	--
8C	1	Safety	12 Sh. Pr.	--
8D	10	Safety	12 Sh. Pr.	--
8E	6	Safety	12 Sh. Pr.	--
8F	4	Safety	12 Sh. Pr.	--
8G	4	Safety	12 Sh. Pr.	--
8H	2	Timing	12 Sh. Pr.	--
8I	1/2	Timing	12 Sh. Pr.	--
8J	4	Electrical Control	12 Sh. Pr.	--

(1) Where sizes shall be specified by the designer, based upon design requirements.
Note: The information presented in this table represents the best information available at this time. The cable requirements must be finalized during the design phase.

5.0

DATA ACQUISITION SYSTEM

The Data-Acquisition System at ETS-1 Complex embodies both electronic and photographic systems. The Electronic Data-Acquisition System includes all diagnostic electronic recorded measurements, from the transducer outputs, for flight, test stand, and facilities, including transmission through accessory equipment, signal conditioning, multiplexing, data handling and recording, to and including, preliminary data reduction. Photographic data acquisition includes cameras, bunkers, controls, and support requirements to provide complete time and area pictorial data records of essential ETS-1 test activities. Criteria for the electronic portion of the Data-Acquisition System is included in this Section, 5.0, of the Criteria Documents; criteria for the photographic portion is included in Section 6.0.

5.1

SCOPE

This section provides criteria for the design, fabrication, installation, and operation of the complete ETS-1 Electronic Data-Acquisition System. Although they are not considered part of this System, consideration must be given to transducers and to the final data-reduction and computation systems. Specific considerations and assumptions regarding transducers and data handling are included where appropriate as a guide to the preparation of specifications and equipment designs.

5.1.1

Purpose

The purpose of the Data-Acquisition System is to obtain and provide engine and facility test information during NERVA developmental tests accomplished at ETS-1.

5.1.2

Function

The function of the Electronic Data-Acquisition System is to provide systems and equipment to accumulate test information

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 5.1.2

during engine tests, and to provide this test information or computed results in engineering terms and in a satisfactory form for dissemination following tests. The system includes three major functional areas: Transducers and Accessory Equipment; On-Line Data Handling and Recording, and Preliminary Data Reduction and Processing; a fourth functional area, Final Data Reduction and Processing is not a part of the system, but is a factor for consideration.

5.2SYSTEM REQUIREMENTS AND CONSTRAINTS

There are many factors and considerations which must be evaluated to provide a satisfactory data-acquisition system for a developmental program of this magnitude. Consideration must not only be given to specific data input and output requirements for number and types of measurement channels, but consideration must also be given to such areas as reliability, simplicity, safety, compatibility, accuracy, ease of operation and maintenance, and the effects of the expected environment. Certain assumptions and considerations have been made with respect to ETS-2, and have been identified where appropriate; that is, in those instances where potentially large savings can be effected, or where negligible criteria effort or equipment costs are involved. Factors considered and the requirements or constraints thus determined for the ETS-1 Data-Acquisition System are detailed below.

5.2.1Data-Measurement Requirements

The ETS-1 Data-Acquisition System must provide the capacity for making the number of measurements demanded by the test program, and must have the capability of making the various types of measurements required, and to a specified accuracy.

5.2.1.1Measurement Capacity

*

For analysis of the System measurement requirements, a measurement list was prepared (see Volume IV, NERVA Data Acquisition List). To aid in the analysis, several functional performance requirements such as time resolution, bandwidth, and %-amplitude resolution are included. The measurements have been functionally categorized as to operational and data priority and specific uses. A summary listing of these measurements is given in Table 5.2-1, and a detail summary in Table 5.2-2.

The referenced Data Acquisition List is a best-estimate compilation of the data needs for support of only the foreseen

and known requirements for the first series of ETS-1 test activities. Additional capability will be required to provide for failure contingencies and for meeting requirements of the changing test program. As the test-engine and associated hardware development progresses, the requirement for data will increase, due to the appearance of unforeseen problems and difficulties which will require additional test information for their solution; however after problem solutions have been verified, the total data requirement will be reduced to the amount necessary to monitor equipment integrity.

The start of another test phase in general results in the re-initiating of some of the above development and design cycles so that data requirement peaks will repetitively appear for each phase (see Data Diagram below)

DIAGRAM OF DATA REQUIREMENTS

* Signal Conditioning Capacity as a Function of Operational Requirements for ETS-1 Data Acquisition System (does not include 558 events channels)

5.2.1.2 Measurement Capabilities

* The Data-Acquisition System must provide a satisfactory capacity in terms of number of channels, and must also provide those types of measurement systems which will be required to correctly operate in conjunction with such standard and special types of transducers, such as bridge, differential transformer, potentiometer, and various self-generating types. This system must also provide a measurement-system signal conditioning capability for transducer inputs, as indicated in the following table.

** Total signal-conditioning requirements for ETS-1, including remote engine control, facility control, and operational spares, are listed in Section 2.0.

* Quantity	Measurement	Transducer or Input
29	Pressure, Flow (ΔP)	(Standardized, 4-arm bridge type strain gage - 350 ohms bridge resistance. 0-30 mv output.)
42	Vibration Level (ΔP)	
299	Strain	Strain gage, 120 - 1000 ohms w/bridge completion network.
168	Temperature	Tungsten - tungsten 10% rhenium thermocouple
24	Temperature	Copper - constantan
378	Temperature	Chromel - Alumel thermocouple
80	Temperature	Resistance temperature thermometer (platinum element)
75	Pressure, Flow (ΔP) and Level	Swept potentiometer 500 - 10,000 ohms
30	Position	Swept potentiometer 500 - 10,000 ohms
3	Flow	Turbine flowmeter 0 - 600 cps
1	Speed	Variable reluctance 0 - 20KC
7	Vibration, Sound	Self-generating 0 - 1000 MV
17	Proportional voltage	0 - 5.0 volts
39	Neutronics	Ion chamber
<hr/>		
1,168	Total

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.2.1.3

5.2.1.3 Measurement Accuracy

The accuracy of data measurements is of major importance.

Performance of measurement systems are evaluated by the quantification of many performance variables such as amplitude resolution, time resolution, bandwidth (frequency response), linearity, reproducibility, and noise. It is difficult to properly evaluate or assign numerical values to these performance variables; this difficulty is accentuated, since they also vary in relative magnitude and therefore in importance for each of the different measurement subsystem types. Additional factors to be considered are the varied and changing performance requirements necessary to adequately support the scheduled NERVA engine tests at ETS-1 (and ETS-2).

Certain basic assumptions or statements are required to be able to specify performance requirements for ETS-1 data measurement systems:

(a) State-of-the-Art accuracy (or the maximum accuracy practically obtainable) is and will be required for a significant quantity of measurement systems of all types at ETS-1 (and ETS-2).

(b) Although it would be desirable to provide maximum accuracy for each measurement channel, the quantity (approximately 1,800) of channels required for NERVA ETS-1 (and possibly for ETS-2) dictates for economic reasons that all channels need not necessarily provide ultimate "State-of-the-Art" accuracy. That is, only sufficient accuracy to satisfactorily provide the engineering requirements need be furnished, if significant cost savings are realizable.

*

**

1,800 channels are indicated, as one discrete number of several which could be used to describe the system capacity, and represents a tabulation identifying transducer outputs. The actual digital system has 1,750 channels. Operational assignment of measurements will provide channel assignment details. The above figures do not include 600 possible ON-OFF events which are not handled as part of the measurement portion of the tape-record format.

(c) However, "State-of-the-Art" maximum accuracy capability shall be provided for each measurement type subsystem so that any measurement subsystem input (transducer), of any physical location, can be connected to a maximum-accuracy measurement subsystem without regard to the type of subsystem; with exception of one limitation, the quantity which can be so connected.

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Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.2.1.3

This limitation is not considered significant, since any program must have a quantity (cost) limitation based on a compromise of need versus dollars.

- (d) The quantity of State-of-the-Art, or maximum-accuracy systems, to be furnished shall be based on demonstrated Need and Use capability for each channel furnished.
- (e) The measurement subsystems will be furnished to operate with transducers in common usage of basic analog types (except for flow and speed). No attempts will be made to anticipate new measurement systems which might be required as a result of future transducer development.
- (f) The accuracy of a measurement system can not be any greater than the least accurate portion thereof.
- (g) Both analog and digital means of recording will be required:
 - (1) Analog - Methods such as strip chart, direct recorders, and recording oscillographs are required to display and record data which is readily and easily interpretable into engineering terms during and immediately after test operations.
 - (2) Digital - To adequately record and store data in such manner the information can be quickly and economically reduced and still provide the accuracy requirements of final data.
- (h) The digital system will be required to record the maximum accuracy (State-of-the-Art) data, therefore it should exhibit an accuracy no less than that exhibited by the highest accuracy portion of each measurement subsystem (see Table 5.2-3 and Appendix 5.4). This is estimated to be a realistic and economic approach, as a significant improvement in all of the

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Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.2.1.3

least accurate portions of each measurement subsystem would be required before the digital portion would be an accuracy limitation factor.

- * (i) Measurement Accuracy Goals, as listed in Appendix 5.8, are considered State-of-the-Art and are to be used as a reference of performance requirements for the ETS-1 measurement systems.

Measurement systems performance requirements will be detailed on a measurement subsystem basis, since each type of measurement subsystem will have different performance requirements.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 5.2.2

5.2.2 Operational Requirements

In addition to providing data measurements in the specified quantities, types, and accuracies, the Data-Acquisition System must also provide operational flexibility, which includes the following considerations of operational spares, subsystem isolation, standardization, patching, and checkout and calibration.

5.2.2.1 Operational Spares

The capacity of all measurement systems shall be sufficient to provide for peak data requirements, as well as for unexpected requirements generated by equipment failures.

5.2.2.2 Subsystem Isolation

Suitable isolation shall be provided between the Data Acquisition System and the Engine and Facilities Control Systems, so that the normal operations of patching, checkout, and calibration, will not interfere with control, display or recording functions of other systems during the countdown period.

5.2.2.3 Standardization

The concept of standardization is important for operational ease, system performance, and flexibility. For these reasons, all transducers, measurement systems, equipment, modules, power supplies, etc., of the Data-Acquisition System shall be standardized as much as possible to permit interchangeability and multiple use; specifically, as listed below:

(a) Transducers

(1) Pressure

Strain gauges
Potentiometric

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 1 June 1962

Par. 5.2.2.3

(2) Thermocouples

Iron-constantan
Copper-constantan
Chromel alumel
Tungsten-rhenium

(3) Resistance temperature transducers

(4) Position potentiometers

(5) Differential transformers

(6) Flow-meters

(7) Strain gauges

(b) Power Supplies; Bridge, RTT

(c) Multiplexers

(d) Patch systems

* (e) Digital tape handlers

(f) Analog tape recorders

(g) Direct recorders

(h) Strip-chart recorders

(i) Oscillograph recorders

(j) dc differential amplifiers

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.2.2.4

5.2.2.4

Patching

* Provision must be made to conveniently and rapidly change from one arrangement or configuration of measurement types or quantities to another arrangement or configuration, to provide for optimum utilization of systems, subsystems and equipment, including operational spares and multiple function equipment. Programmable patching capabilities shall be provided within the ETS-1 Data-Acquisition System to accomplish the following:

- **
- (a) To provide for sharing with ETS-2, ETS-1 data-acquisition recording systems. (Complete termination-patch facilities shall be provided and installed, in which the patch system shall be internally wired to both ETS-1 and ETS-2 termination as a complete package, thus requiring no further field wiring, except for tying down of ETS-1 transmission lines, and providing capability for tying down of ETS-2 transmission lines.)
 - (b) To provide a fast reliable means of programming (for tests to be accomplished both at ETS-1 and ETS-2) for different test measurements both by quantity and types, as required for one test relative to another.
 - (c) To provide for rapid substitution or interchange of measurement channels and major components in the event of equipment failure.
 - (d) To provide for rapid isolation of major subsystem components and access to test points as required for operational and maintenance purposes.

5.2.2.5

Checkout and Calibration

The furnishing of equipment and systems which will provide convenient, fast, and reliable means of checking and calibrating the measurement system is important to measurement systems operational requirements. The spectrum of checkout and calibration will necessarily range from manual step-by-step manipulations and readings, through semiautomatic programing and automatic recording and readout, due to the magnitude and the great range of involved systems and related equipment.

Regardless of the specific means provided, either manual or semiautomatic, several basic rules must be considered to provide checkout and calibration with minimum operational expense, time, and manpower:

- (a) All standard or certified instruments required for checkout or calibration are to be designed and built into the system, both physically and electrically.
- (b) Adequate provision of such items as access and test points, and test equipment, shall be provided, to permit accomplishment of checkout and calibration without disassembly of installed systems, subsystems, or equipment.

5.2.2.5.1 Pre-Pre-Checkout

(a) Measurement Subsystems

Pre-pre-checkout of all measurement subsystems shall be accomplished by providing equipment control, patching, and test equipment as required to report on the correctness of each channel of each measurement system. This pre-pre-checkout shall be a precise detailed methodical test, with manual measurement and adjustment, channel-by-channel for each measurement.

(b) Analog Recording Subsystem

Pre-pre-checkout of all analog recording subsystems, including amplifiers, patching, ranging and recorders, shall be accomplished by providing control, signal generating and test equipment as required to verify correct zero, span, and channelization for all analog-recording channels.

(c) Digital Data System

Phase I - channel-by-channel check shall be made to determine that channels appear in the correct time slot, by manually calibrating each channel separately. This is a slow test, taking 8 to 16 hours.

Phase II - An all channel check shall be made for correct zero and full-scale calibration. This shall be a sequential automatic scanning of all active channels for correct calibration, having as its output a printed listing of those channels which are outside a predetermined tolerance and the actual channel output. This check could be made at a rate of 1 channel per second and would normally precede the run by several hours.

5.2.2.5.2 Pre-Checkout

* Check shall be made of one channel per multiplexer, plus all priority-one channels, for correct zero and full-scale calibration, to detect failures of major component blocks. This check will occur just prior to recorded calibration, and just before the run.

5.2.2.5.3 Calibration

* All measurement systems shall be provided with built-in calibration equipment and circuitry for calibration and checkout purposes. The calibration circuitry shall be intrinsic with the measurement systems, and shall include the transducer, wherever practical. Means shall be provided to electrically calibrate all measurement channels at 5 points, as specified in Paragraph 2.2.5.4(b). Local control (at the Test Cell Building) and remote control (from a master calibration control unit located in the Control Point Recording Room) shall be provided. Means to selectively control or inhibit specific calibration channels by types and groups shall also be provided. This selectivity will permit all necessary calibrations when desired, but during the calibration and checkout, will prevent calibration of other channels which are needed for continuous monitoring of closed-loop system use and for operation of functional systems. Calibration of all channels to be checked shall be accomplishable simultaneously; all calibration levels shall be in synchronism for all channels for all types; and the entire calibration sequence shall not exceed one minute. Table 5.2-4 provides information on the time relationship of checkout and calibration.

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Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.2.2.6

5.2.2.6

Support Requirements

The long-term accuracy, reliability, and operational efficiency of the Data Acquisition System requires the availability of calibration and repair facilities in addition to an adequate supply of spare transducers. Although not an integral part of the system, the following operational considerations apply:

(a) Calibration Facilities

All measurements reported as final data must be referenced to the National Bureau of Standards (NBS) by means of calibrations traceable to the NBS. Thus, all components of the Data-Acquisition System used as calibration references must be compared against suitable reference standards and adjusted as required to meet established performance tolerances at prescribed intervals.

(b) Maintenance Facilities

Suitable personnel, equipment, and working space must be available to perform routine preventive maintenance and to effect needed repairs of Data Acquisition equipment items (see Appendix 5.7). The highest-level working standards used in calibration activities shall be under the calibration control of the Calibration Facility.

(c) Transducers

A sufficient supply of transducers shall be available, in addition to those required during actual tests, to provide spare units for meeting operational replacement needs and to permit laboratory recalibration.

*

5.2.3Recording Capabilities

The size and complexity of the ETS-1 operation implies the generation of large amounts of highly precise data. This data originates from many single sensors which must be continuously or semi-continuously monitored for long periods of time. In addition, a large part of this data must be measured and retained in a manner which will not reduce the accuracy and confidence level of the sensor information. The data-recording capabilities must be generated from considerations of data volume, speed, and accessibility.

5.2.3.1Data Volume

In most State-of-the-Art data systems, the real volume of data generated does not impose recording problems; however, a NERVA test operation will generate approximately 40,000,000 individual measurements, which introduces severe data-recording problems.

When utilizing recording systems, two data domains are available; analog and digital. Analog recordings provide the best speed and time resolution capabilities, but digital techniques provide the best accuracy capabilities. ETS-1 shall utilize both techniques. Analog recording on analog recorders and magnetic tape shall be utilized to provide records of dynamic data for which time resolution is of primary interest. Digital magnetic tape recordings shall be utilized to record the largest bulk of system data with the recording accuracy required.

5.2.3.2Data Speed

The speed of data acquisition is intimately related to data volume, and one cannot be described without the other. The data-acquisition problem within ETS-1 is that approximately 1800 parallel channels [see 5.2.1.3(b)] will be recorded in the digital system, at a rate of 40,000 measurements per second, for periods up to 1000 seconds. The recording

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subsystem design shall be based upon its ability to comply with recording and system output requirements, with maximum reliability.

5.2.3.3

Data Accessibility

The ability to comply with the real-time data-recording requirement is only half of a data specification; the other half involves consideration of data accessibility.- the ability to reduce, analyze, and present the data. A recording facility, therefore, not only has input requirements, but also output requirements. For this reason, data-reduction (i. e., computer) facility input requirements must be carefully considered when establishing data-recording input requirements, as follows:

- (a) Any information recorded must be of sufficient accuracy to be usable in final output.
- (b) Any single item of information must be retrievable with respect to sensor identification and time of event. This requires recorded channel and time identification.
- (c) System reliability must be sufficient to warrant its ability to record any event.
- (d) The data format must be organized and arranged to provide an input which will be compatible for most computer facilities, to reduce the time, cost, and complexity of data processing operations.

5.2.4Data Reduction Capabilities

ETS-1 operations will generate large volumes of data which will be recorded primarily on magnetic tape, in both the analog and digital domains, at assumed volumes of 40,000 digital data measurements per second, and 100 channels of 10,000 cps analog information, and with an anticipated time length of 1000 seconds. Various strip-chart and oscillographic records will also be available for reduction. Data reductions of this magnitude can only be processed by a computer facility.

Prior to the establishment of criteria for data reduction, it is necessary to evaluate the operational purpose of this activity - to reconstruct a NERVA operation and make an understandable presentation. No large general-purpose computer facility is anticipated for ETS-1 now, or in the near future. Therefore, digital information recorded at ETS-1 must be transported or transmitted to the computer facility, reductions performed, presentations made, and returned to the end user - an operation normally accomplished in 7 days. With high priority, a package can be returned in 4 days. From an operational viewpoint this time delay cannot be tolerated. Immediately after a run, operational questions must be answered with respect to the attainment of test objectives. Certainly such questions require answers within 10 to 12 hours after a run.

It is possible to suggest a division of the data-reduction requirements into two groups.

- (a) Preliminary Data System - for quick-look application, and to provide immediate answers to operational questions. For rapidity, this system may provide only abridged tabulations of recorded information in engineering units.

Final Data System - to produce derived systemic parameters, major statistical iterations, and graphic presentations, for complete evaluations of components and systems.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.2.4.1

5.2.4.1 Preliminary Data Reduction System

(a) Pre-Pre Calibration Review

* The operational calibrations of all data channels made at or near the start of the countdown period, defined as pre-pre calibrations, will comprise the initial on-line data recording. The preliminary data-reduction system shall provide for reducing the information recorded at this time, which includes channel identification, pressure and force transducer range, and all calibration steps. Review of this information will confirm the operational status of all channels. The complete pre-pre calibration recording shall also be reviewed by automatic means, and shall produce a tabulation easily reducible to engineering units, in final data format, and identify those channels not meeting established standards.

(b) General Data Review

* The first operation necessary following a test will be to review approximately 200 channels over long periods of time (300-1500 seconds), looking for general trends which will aid in the identification of specific events. The system must therefore provide graphic presentations of a type and size which can be easily handled by using personnel.

* Charts must be complete with scales for signal amplitude and time. Since this review will involve the presentation of many individual data points on rather short graphs, it will be required to time-sample the original data.

(c) Detailed Data Review

In (b) above, general points of interest were identified. Detailed data review will be a continuation of the same activity and will utilize the same equipment, but with the desired output of more detailed data by increased time resolution.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.2.4.1

(d) Specific Data Review

* In operations (b) and (c) above, data is processed in decreasing units of time to specifically identify the occurrence of events. However, many events will occur during a run requiring even greater expansion of time. In this operation, time scales of 3 to 30 seconds will be utilized. Since this requirement probably exceeds the speed capability of the plotter used above, it is suggested that an oscillographic device be used. Since analog recording operations at ETS-1 will also use oscillographs in real-time, the capability will exist to utilize these devices as high-speed print-outs for the preliminary data system. Presentation accuracy of greater than $\pm 2\%$ will not be required.

(e) Precision Data Review

* In the above data reviews, trade-offs between accuracy and presentation speed were permitted, to provide a volume of data, but this compromise with system accuracy cannot be entirely permitted. A digital listing is required, to answer questions concerning specific data values such as peak excursions and maximum values. The analog graphs, used in previous listed data reviews, will not identify or correct for sensor non-linearities or system calibrations. To provide data at full-system accuracy, a digital tabulation device is required, for listing individual channel data value and time, in engineering units, on a printed form. Corrections for system calibration shall be made prior to the supplemental tabulations.

5.2.4.2

Final Data Facility

The Final-Data Facility shall have as its primary requirement the ability to report upon all parameters involved in an ETS-1 operation. Since this facility will not be at NTS, the data must be transported to the computer. The first step of this operation will be the preparation of a transportable record, of a format immediately usable by the

computer facility. It will consist of both digital and analog magnetic tapes, since primary data will not be retrieved from recorded media other than magnetic tape.

(a) Operations required of the computer shall consist of the following data manipulations:

- (1) Utilization of system calibration.
- (2) Conversion to engineering units and correction for sensor nonlinearity.
- (3) Editing functions to produce correlation studies or profile data.
- (4) Operations to produce and derive systemic parameters, major statistical iterations, and complete evaluations of components and systems.

(b) When all data manipulations have been completed, a data package shall be provided for presentation. This package shall consist of the following types of information:

- Type I - Graphs of physical variables as functions of time
- Type II - Listings of physical variables as functions of time.
- Type III - Graphs of numerous physical variables grouped together to provide time-slice operational profiles.
- Type IV - Listings of numerous physical variables grouped together to provide time-slice operational profiles.
- Type V - Magnetic tapes of selected and edited information in various formats for use in further computation or for input to plotters.

5.2.5 Design Requirements

These requirements concerning power, grounding, noise and channelization are critical to the Data-Acquisition System criteria:

5.2.5.1 Power

All equipment is to be capable of the specified performance, using the following power sources:

- (a) 120/208 Volt, 3 Phase, 60 Cycle

Amplitude regulation, plus or minus 10%.

Line voltage transients shall be kept to a minimum, however, all equipment should be capable of continuous operation while experiencing 10% transient variations in power-source voltage.

- (b) 28 Volt DC

Amplitude regulation, 22 to 32 volts, dynamic ± 0.5 volts with transient recovery within 50 microseconds.

5.2.5.2 Grounding and Noise

To provide an optimum integrated system with respect to grounding and noise, the following listed criteria is to be implemented to the maximum extent possible:

- (a) Grounding

System design shall be such as to provide a completely independent instrumentation ground system isolated from power ground, except at one point. This point or grounding plate shall also be the central grounding point for the equipment and power ground. This central ground point shall be connected to an earth ground of less than 5 ohms.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.2.5.2

*

~~Shields - All shields shall be connected together and in turn connected to the instrumentation ground, in the largest groups possible, and at one point only.~~

Signals - Both signal positive and signal return wires shall not be grounded by design. Specific grounds will be unavoidable in the case of grounded thermocouples, but all transmission, accessory circuits, conditioning, etc. shall be designed, wherever practical, as balanced ungrounded circuits.

(b) Noise

A complete evaluation and discussion of the importance of noise, its sources, and coupling means and methods of eliminations are out of the scope of this criteria. However, the following basic criteria shall be diligently followed to provide for noise elimination, or reduction to acceptable levels of noise of all types.

Separation - All systems, transmission, control, etc. which are potential noise sources, shall be designed and installed in such manner that the maximum practical physical and electrical separation shall be provided between the noise source and instrumentation wires, equipment, subsystems, and systems.

Shielding - Shielding shall be provided for all signal wires, and terminations shall be designed so that minimum lengths of wire are unshielded.

Grounding - Improper grounding of shields, excessive lengths of unshielded wire, common impedances between circuits, and multiple connections to ground of the signal and excitation wires and shields, shall be avoided.

Insulation and Isolation - Insulation, and therefore the resultant isolation of signal channels from power-input circuits, adjacent channels, and common excitation sources, shall be at extremely high levels (in the order of 10,000 megohms), to minimize spurious interacting responses.

5.2.5.3

Channelization

The concept of channelization, and the identification, routing, and grouping of the thousands of measurement channels and associated equipment involved, is exceedingly important to the Data Acquisition System design.

Not only must adequate identification be provided to satisfy the tabulation and records requirement, but specific operational identification, such as equipment module or channel functional and descriptive identification, must also be provided.

5.2.5.3.1

Functional and Descriptive Identification

Specific functional and descriptive identification will be required on all equipment, equipment controls, connectors, patch panels, etc., to provide for specific operational identification in such manner that operation of the entire system will be easy and comprehensible, requiring reference to a minimum of documents. To provide for the above operational, functional, and descriptive identification the following criteria is specified:

- (a) The identification of all equipment shall include an identification number, which identifies it as the *i*th unit of *n* total items or channels, and specific information as to its type or function. Abbreviations are permissible, but code letters only, such as A1001, are never to be used as physical markings for the identification of equipment or patch panels requiring operational use. For tabulation and record-keeping, coding only is permissible, as specified in Appendix 5.1, Consideration of Handling Channel Information. See also par. 5.2.5.3.2.
- (b) The nomenclature used shall be readily associated with the particular equipment, purpose, etc., and shall provide for identification of the following where appropriate:

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	5.2.5.3.1

- (1) Input or output
- (2) Point of origin
- (3) Point of termination
- (4) Use or purpose
- (5) Type
- (6) Title
- (7) Group or category

5.2.5.3.2

Tabulation and Records

It is imperative that simultaneously with design, a system for identification of equipment, measurement channels, transmission, etc., be established. This tabulation and records identification system can be accomplished purely on a coded basis, however since correlation must exist with the functional and descriptive identification specified in par.

5.2.5.3.1, maximum coordination of methods, names, codes, etc., shall be accomplished.

A preliminary plan or method of tabulation and records identification to aid in the operational aspect of keeping up-to-date tabulation records is provided in Appendix 5.1, Considerations of Handling Channel Information.

TABLE 5.5-1
QUANTITY OF CHANNELS AT VARIOUS SAMPLING RATES

Arrangement No.	Samples Per Second						Total Channels
	<u>200</u>	<u>100</u>	<u>50</u>	<u>40</u>	<u>20</u>	<u>10</u>	
1	200						200
2	100	100			500		700
3	100		200		500		800
4	100			250	500		850
5	50			500	500		1050
6	50		200		1000		1250
7	100			250		1000	1350
8	50			500		1000	1550
9		100		250		2000	2350
10						4000	4000

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Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A-1

Date 1 June 1962

Par.

TABLE 5.2-2

MEASUREMENT SUMMARY FOR ETS-1 DATA ACQUISITION LIST

Measurement	Measurement Location					Measurement Totals
	Engine	Reactor Only	Facility			
	Engine (Less Reactor		Conventional Facilities Only	Duct	Side Shields	
Temperature	73	549	29	117	16 * 34	802
Pressure	48	19	43	41	32	183
Strain	153	116		30		299
Flow	28	5	22	36		91
Vibration	30	12		9		51
Thrust			10			10
Weight			1			1
Position	9	36		7 *	8 *	(60) * 45
Speed	2					2
Gas Analysis			2			2
Level (Liquid)			10			10
Neutronics		54				54
Miscellaneous Analog Voltage	8	30	37			75
On/Off	33		525			558
Totals	384	821	677	233	66	2183

* These measurements do not enter the data acquisition system and are not included in totals. Signal conditioning is req'd.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.2.2.3

TABLE 5.2-3

MEASUREMENT SYSTEM ACCURACIES

System Type	Electrical Calibration	Measurement Variables			Maximum Required Digital System Accuracy See Note 1
		Amplifier	Multiplexer		
			Hi Level	Lo Level	
Bridge	See Note 2. 0.05	0.15	0.1	0.5	0.05
		-	-	-	0.07
Thermocouple	0.05	0.15	0.1	0.5	0.05
			-	-	-
Flow	(0.01 freq.)	Frequency-to-dc	0.1	-	0.05
		0.10	-	-	0.05
Speed	(0.01 freq.)	Frequency-to-dc	0.1	-	0.05
		0.10	-	-	0.05
Resistance Temperature	0.05	0.15	0.1	0.5	0.05
			-	-	0.07
Potentiometer	0.05	-	0.1	-	0.05
			-	-	-
Ludt	0.1	0.15	0.1	-	0.05
		-	-	-	0.05
Proportional Voltages	0.05	0.15	0.1	0.5	0.05
			-	-	0.025

NOTE 1. This is based on $\frac{\sigma_1}{\sigma_2} = 0.5$, where σ_1 = most accurate portion
 σ_2 = maximum required digital accuracy

See Appendix 5.4, Error Evaluation, for details.

2. For Bridge Systems calibration, consists of shunting one leg with known (0.05%) resistors.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.2.2.5.3 (ref.)

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TABLE 5.2-4

DATA ACQUISITION SYSTEM
RELATIVE TIME RELATIONSHIP OF
CHECKOUT AND CALIBRATION
(1)

Period (2)	Operation	
	Calibration	Checkout
1		Pre-Pre checkout
2	Pre-Pre Firing Calibration	Pre-Checkout
3	Pre-Firing Calibration occurs just prior to start of run (minutes), and is to be re-initi- ated if a hold occurs so that a calibration is accomplished just prior to a test	
4	Test Operation	
5	Post-Firing Calibration	
6		Post-Firing Checkout [duplication of Pre-Pre- Checkout Phase II, (see par. 5.2.2.5.1 (c)) to deter- mine channels which have malfunctioned during the test]

(1) The relative relationship shown is for the majority of the measurement systems. A minority of the systems (for example, thrust) will exhibit different time relationships, since manual input, setup, and adjustments are required. For detailed explanation and definition of the checkout and calibration periods, see Section 2.2.5.

(2) For an explanation of period with respect to time of Count see Dwg. ICC-172.

5.3CONCEPT OF OVERALL SYSTEM

The Data-Acquisition System will be developed on the concept of being required only to record test data. It shall be considered completely independent, since the conduction of the test operation will be possible without the use of the Data Acquisition System. This does not imply that satisfactory operation of the Data Acquisition system will not be necessary to have a successful operation, but that it will not be involved or required for test operations control or display. The Data-Acquisition System can also be used as secondary support for facilitating or expediting the test operations. The Facility Operation and Control Systems, combined with the Remote Engine Control System, will provide all of the display and control functions required for test operations. The primary role of the Data-Acquisition System will be to monitor and record data on measurements, functions, and events which occur as a result of test operations. One of the test-operation tasks is to provide for the operations necessary to put the Data-Acquisition System on line, and get it checked out and calibrated; in this sense the Data-Acquisition System is involved with Test Operations.

5.3.1General

Considering the Data Acquisition System as an entity, receiving transducers, parameter variations and voltages as inputs, and producing hard copy data as an output, it is evident that the overall system performance requirements may be realized through use of many different designs.

Each such design will possess varying amounts of the characteristics listed below, while each might meet the minimum specifications.

Performance

- Reliability
- Accuracy
- Flexibility
- Ease of operation
- Rapid access to usable data

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	5.3.1

Cost

Initial cost
Operating and maintenance cost
Amortization

It must be borne in mind that system performance specifications can be written which cannot be achieved with the knowledge and materials available today. It is also difficult to technically justify hard-and-fast requirements for such things as ease of operations, data reduction rate, degree of flexibility, etc. Such statements are criteria or typical acceptable values, which must be stated as a basis for preliminary design.

The purpose of the criteria is to select system principles and configurations which will generally satisfy the requirements, and then to develop a final design which will tend toward increased accuracy, capacity, speed, reliability, and utility for the minimum total investment (rather than only initial investment). The following paragraphs are based upon the foregoing premises.

The final design of the Data Acquisition System shall reflect the general arrangement of function shown on the Data Flow Block Diagram, ICC-088.

5.3.2

Inputs

All data-system inputs will be either analog voltages or electrical parametric variations of transducers. Independent of the nature of subsequent portions of the data system, standardization of signal levels and calibration capabilities must be provided as analog functions. A need therefore exists for transducer excitation, signal conditioning (zero suppression, power amplification, gain adjustment), and calibration.

5.3.3

Recording

Since the total information rate of the Data System is so great, it is economically infeasible to process the data as

tests are being run; additionally, it will probably never be necessary to reduce all data taken. In testing of this kind, many channels are instrumented, or are allotted more than normal bandwidth, on the possibility that the data would be valuable in case of certain irregularities in the course of testing. If all the test data were reduced from a 10-minute run and were suitably plotted against time on 11 x 17-inch graph paper, approximately 2,500,000 sheets would ensue. It is therefore evident that the data must be put into storage at the test site as it is taken, and that editing and processing must be done later.

The primary storage system principles shall be selected to satisfy the considerations of reliability, accuracy, ease of operation, and lowest commensurate cost.

Magnetic tape storage is required from the standpoint of capacity, storage density, and rapid data access. It also possesses a relatively low equipment and record cost per recorded data word. With suitable prerecording modulation techniques, a virtually error-free storage capability exists. Suitable reliability may readily be obtained through equipment redundancy. Magnetic tape should therefore be used as the primary data storage media for all but picture or video type information.

5.3.4

Analog and Digital Systems

Two constraints on the Data Acquisition System design arise from the facts that, while all input signals are analog in nature, still a large portion of the data reduction process is carried out through a digital computer. Many channels therefore require conversion from continuous analogs to digital representation prior to computer entry. This conversion may be accomplished at several points within the system. Since magnetic tape recorded in the analog domain contributes significant errors in the overall system, digitizing or encoding

should occur prior to recording, if the analog errors are considered too great. Magnetic-tape storage errors typically run 0.3 to 0.6% of full scale with analog recording, while digital recording is better characterized by zero error for all but perhaps a millionth of that recorded. In addition, the binary-tape circuitry associated with digital information handling and processing is far more stable and more easily checked than its analog counterpart. This reduces the level of maintenance effort.

Thus it is desirable to handle as much of the input data as practical in a digital fashion. A number of the channels required possess bandwidths in excess of the reasonable capabilities of a digital system. In general they also require less overall accuracy. This group of signals is most economically handled by analog transmission and analog recording systems.

5.3.5 Functional System Diagram

The functional parts of the above are related as diagrammatically shown on Data-Acquisition System, Dwg ICC-073, which shows a functional block diagram of the System.

5.3.6 System Integration

For the purposes of system calibration and data recording, the Facility Controls System, Remote Engine Control System, the Engine Control System, and the Data Acquisition System must be considered as an entity. The Data Acquisition System must not only record all test information, regardless of the system of origin, it must record sufficient calibration information to permit the quantitative analysis of all recorded data.

Where possible, all measuring systems shall be calibrated simultaneously, to minimize the number of calibration operations required to record all calibration information. Proper integration of all systems requires attention to system isolation and calibration control, as follows:

5.3.6.1

Electrical Isolation

It is essential that checkout and calibration operations of the Data Acquisition System shall not interfere with the normal functioning of systems for engine controls or data displays, therefore, in addition to physical separation or control of physical access, electrical circuitry must be provided to enable completely independent operation of the various subsystems. Ideally, measurement systems that are integral with the Engine Control System, the Remote Engine Control System or the Facility Controls System shall be isolated completely from the Data Acquisition system, so that likely or possible operational errors cannot interfere with either the accuracy or the proper functioning of the controls systems. Measurement systems used to provide displays only, and which are not a part of a closed-loop control system, must be isolated so that either a shorted condition or the application of potentials up to 5 volts from the applied Data Acquisition system interface, will not result in display inaccuracies exceeding 1/2%.

5.3.6.2

Calibration Control

All measurement systems are to be integrated with respect to operational calibration control. The calibration control units provided with each system shall be capable of completely independent control of the associated system, including selection of calibration steps, until the "automatic" calibration mode is selected. Selection of the "automatic" mode shall then place the system under calibration control of the master calibration control units. The calibration-step indicator lamps for each subsystem

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	5.3, 6.2

shall indicate which calibration step, if any, has been selected for the subsystem, either locally or by the master calibration control units.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	5.4

5.4

SIGNAL CONDITIONING SUBSYSTEMS

This section defines the technical requirements for the components and subsystems required for the recording of engine and facilities information, up to the patching system. It is assumed that all facilities and test stand transducers and all transducers provided with the engine and reactor are compatible with the input capabilities provided. Refer to par. 5.2.1.2 for the quantity requirements for each type of measurement.

The specific design of signal conditioning and calibration equipment shall be based upon the following principles:

- (a) The equipment shall provide necessary resolution and stability to meet the accuracy requirements established for various types of measurements. The equipment must be sufficiently flexible in its design and operating adjustment characteristics so that certain critical channels may be maintained in a suitable manner to provide maximum achievable accuracy from the associated transducer.
- (b) A sufficiently large quantity of channels are involved that the stability of signal conditioning and calibration circuitry is of extreme significance. Suitable stability should be provided in order that the vast majority of channels will remain within specified error limits without manual adjustment for at least a period of 30 days.
- (c) Each subsystem shall provide a means to calibrate "in place" as much of the system, as possible, including the transducer, depending upon the laboratory calibration of the transducer when it is not included. In general, calibration of systems using self-generating or grounded transducers cannot include the transducer element. The large number of channels involved dictates that electrical calibration of the system be used except where this is

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.4

impractical. Calibration equipment and circuitry shall provide for local calibration and remote automatic calibration, and shall be designed to allow selective step calibration of groups of channels associated with one type of measurement. In addition, the design shall allow step calibration in modular groups, and shall be arranged so that system calibration will also function as a final checkout of system integrity and stability.

- (d) Each of the following sub-sections (5.4.1 through 5.4.11) contains a functional and operational description of a subsystem with the subsystem electrical characteristics. All subsystem equipment except the narrow band amplifiers are to be located in the Test Cell Building. The amplifiers are to be located in the Forward Control Building.

5.4.1 Strain Gage Subsystem

* This section describes the system for the measurement of pressure flow, vibration, force, and strain information. The system shall be a dc-excited six-wire system with two conductors carried to the transducer exclusively for shunt-calibration purposes. Dwg ICC-040 is a functional block diagram of a typical strain-gage system. The system primary units shall be as described below.

5.4.1.1 Transducers

* The system is designed to operate with standardized 4-active-arm strain-gage-type transducers having 350-ohm bridge resistances. Standardization must be such that with 10-volts dc excitation and zero applied physical stimulus, signal outputs corresponding to calibration points as specified in Paragraph 2.2.5.4(b), will be produced by the application of the corresponding shunt resistors; transducers shall be standardized to a sensitivity of 3 millivolts per volt; and the combined effects of non-linearity, hysteresis, repeatability, and temperature shift over the range of 30 to 130°F shall not cause more than a 1% error.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.4.1.1

It is expected that all elements of the bridge will be affected alike in the radiation field, so that the accuracy of transducers mounted on or near the engine will suffer minimum degradation.

*

Since there is a possibility that some non-standardized gages in the range of 120 to 1000 ohms may be used, performance capability shall be as specified by contractor for transducers of this resistance range.

5.4.1.2

Bridge Checkout & Control Unit

This unit will perform the following functions:

- (a) Manual balance - The balance network shall be of sufficient impedance so it will not load the bridge. A push-button switch shall connect the output of the bridge to the millivoltmeter. The balance function will not be required for all bridge channels.
- (b) Bridge completion - This function will not be required for all bridge channels.
- (c) Zero off-set - Required for load cells and certain other bridge channels.
- (d) Operational check (sensitivity) - A push-button switch shall connect the 75% calibration resistor to the bridge and the bridge output to the millivoltmeter.
- (e) Insulation check - Separate push buttons shall be provided for reading conductor-to-shield and shield-to-ground resistance leakage on each channel.

5.4.1.3

Bridge Power Supplies

Individual channel power supplies shall be given primary consideration. Each power supply channel shall be isolated from adjacent channels and from ground. The supplies may be of the type which are fed directly from a 115v, 60-cycle, ac line, or of the type indicated in the block diagram below. Each channel shall be provided with a means of switching to the voltage check panel to measure the excitation to each channel.

Block Diagram-Bridge Power Supplies

Since differential amplifiers with good common mode rejection characteristics are to be used, common power supplies (several transducers paralleled on one dc output) should be investigated as another alternate approach.

The power supply system must provide dc voltages with noise and ripple in the microvolt level ($10\mu\text{v}$).

5.4.1.4

Voltage Check Panel

Voltages from each power-supply output shall be fed to the voltage check panel when the switch in a selected power supply channel is depressed. The voltmeter shall be a 0.1% digital indicating instrument, and will be used to accurately set bridge excitation, and for precise measurements in other physically adjacent systems for set-up and trouble shooting maintenance.

5.4.1.5

Megohmmeter

Separate push-button switches on the Checkout and Control Unit connect each channel to the megohmmeter to indicate conductor-to-shield and shield-to-ground leakage resistance. The meter should read up to 10^{12} ohms mid scale, and can be shared by other sub-systems as appropriate.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.4.1.6

5.4.1.6

Millivoltmeter

This meter shall perform as a null indicator and as a strain indicator. Separate push-button switches on the Checkout and Control Unit shall connect each channel to the zero center scale for observing the zero balance of the bridge; other switches shall connect each channel to the 0-30 mv scale to observe the output of the bridge with selected calibration shunt resistors applied.

5.4.1.7

Calibration Unit

This unit shall contain the precision shunt resistors and calibration relays which will provide for connecting selected resistors to individual channels. As an example, one relay will connect 75% shunt resistors to 6 channels. The calibration unit will contain the requisite number of relays to calibrate all of the channels in a Checkout and Control modular group. The calibration relays will be commanded by the step-selector relays in the Step-Selector Unit. A set of 4 resistors will be required for each channel; one each for the calibration points specified in Paragraph 2.2.5.4(b). It is anticipated that most bridges will be standardized at 350 ohm, and that one set of resistance values will apply to all of these bridges. Other sets of values will apply for non-standardized 350-ohm bridges, and for other than 350-ohm bridges.

*

5.4.1.8

Calibration Step Selector Unit

This unit will contain the calibration unit relays associated with each calibration step. These relays will be commanded by either the local calibration control unit or the remote calibration control (located in the Control Point Building) through a local-remote control on the local Calibration-Control Unit. Only one of four relays will need to be energized at a time during application of a calibration step.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.4.1.9

5.4.1.9

Calibration Control Unit

This unit shall provide for selection of a Checkout and Control modular group and any one of the calibration steps. A local-remote control switch shall be provided to prevent any action from the remote controls, and also to permit sub-system groups to be calibrated while others are in operation or process of checkout. This unit shall be so located as to permit the operator to reach the selector switches and conveniently reach the controls on every Checkout and Control module associated with it while at the same time observing the millivoltmeter.

5.4.1.10

Load Cell Subsystem

This system, to be used for measuring thrust, will be the same as any other four-arm bridge system with the following exceptions:

- (1) The load cells will be the double 4-arm bridge type.
- (2) Provisions shall be made for switching individual bridge outputs from the millivoltmeter used for null balancing to the digital voltmeter for purposes of comparison with the calibration load-cell output.
- (3) Bridge Checkout and Control modules designated for these channels shall specifically include balancing and zero off-set.

Special consideration shall be given to patching capabilities for these channels so it will be possible to record separately all load-cell outputs as individual signals and to record the sum of four signals (one from each load cell). There will, therefore, be two summed signals as well as eight separate signals.

One of the summed signals will be fed to a digital visual display, but otherwise shall be considered as a data-acquisition signal.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	5.4.1.11

5.4.1.11

Weight Subsystem

This subsystem, used to measure tank weight, will be identical to any other four-arm bridge system, and shall specifically provide for balance and zero off-set.

5.4.2 Resistance Temperature System

Critical temperature measurements using single-element transducers are to be displayed and recorded by this subsystem, as shown on Drawing ICC-163. The signal-conditioning equipment must provide for transducer excitation, bridge completion capability, calibration, and checkout. Either a constant-voltage or a constant-current system may be used, the choice to be based upon optimum performance and cost considerations as revealed by detailed design analysis. Differences in the detailed functioning of subsystem components, as related to the choice of system, are included in the following descriptions where appropriate.

5.4.2.1 Transducers

Transducers acceptable for use in the resistance-temperature subsystem may be, but will not necessarily be limited to, those which will have a single platinum element, standardized for sensitivity and reference temperature resistance for the specified measurement range. The maximum permissible excitation will be 10v dc. A duplicate set of connector pins shall be provided for each end of the sensing element to permit isolation of measurement and calibration circuits.

5.4.2.2 Power Supply

An individual electrically isolated power supply shall be provided for each resistance temperature-transducer input. Constant-voltage power supplies shall provide an output adjustable over the range of 9 to 11v dc but regulated to $\pm 0.1\%$, assuming a load impedance variation of not in excess of $\pm 4\%$. Constant current power supplies shall be regulated to maintain transducer current variations within $\pm 0.1\%$ over the usable transducer temperature range, with the output voltage at any time not to exceed 28 volts.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.4.2.3

5.4.2.3 Voltage or Current Check Panel

This unit shall measure the individual channel excitation voltage or current, as appropriate, when activated by push buttons located on the power supplies. Measurement resolution and stability shall be sufficient to permit detection of power-supply instability.

5.4.2.4 Calibration Unit

* The calibration unit will be a modular system component containing resistors and relays as required, to provide calibration steps as specified in Paragraph 2.2.5.4(b), for each channel of the subsystem. Actual circuitry of the unit will depend upon the choice to be made between constant voltage and constant current systems.

* For the constant-voltage system, the calibration unit must provide for the substitution of precision resistors for the transducer, simulating the transducer resistance at the zero reference, and at defined steps. The substitution circuitry must include a complete loop of the transmission cable to the transducer to compensate for possible variations in cable resistance.

* If the constant-current system is chosen, the calibration unit shall provide circuitry for obtaining calibration voltages by inserting precision dropping resistors in series with the transducer power supply circuit. The resistance values shall be chosen to yield calibration voltage drops corresponding to the zero reference temperature output and as specified.

Other than the provision for plug-in calibration resistors, no controls or adjustments will be required for this unit.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	1 June 1962
Par.	5.4.2.5

5.4.2.5 Calibration Step Selector Unit

%

This calibration step selector will provide the relay-control circuitry required to energize separately the defined relays in the various calibration units upon external command. No control or adjustments are required for this unit.

5.4.2.6 Calibration Control Unit

%

The calibration control unit will provide for manual selection of the defined calibration steps, or for acceptance of control signals from the master calibration control. A single switching mechanism, rotary or interlocking push-button, shall be used for the calibration step selection, with a "remote" position to enable calibration-step selection by the master calibration unit located in the control point building. The unit shall also contain individual lamps to indicate the selected calibration steps, to operate in either the manual or automatic selection mode, and shall provide for selection of check-out and control modular groups.

5.4.2.7 Millivoltmeter

A millivoltmeter, of scale suitable for reading the output signal level, shall be provided to permit readout of any one of the subsystem channels. Accuracy of readout shall be sufficient to permit checkout of the operational status of the subsystem channels.

5.4.2.8 Megohmmeter

A megohmmeter shall be provided for reading the transducer leakage to ground during system checkout. The instrument may be shared with physically adjacent systems, if operational conditions permit. The instrument must permit reading of 100-megohm leakage resistances.

5.4.2.9

Checkout and Control Unit

The checkout and control units shall provide the primary operational controls for the set-up and checkout of individual channels of the subsystem. Each unit will contain bridge-completion circuitry, bridge-balance control, a push button for leakage check, and a push button for connection of the millivoltmeter to the bridge output, sufficient for a standard number of channels.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 1 June 1962

Par. 5.4.3

5.4.3Full Bridge Resistance Temperature Subsystem.

Certain critical temperatures will be measured by resistance temperature transducers of the full-bridge type. Except for the transducer, calibration unit, and the checkout and control unit, this subsystem will be identical in every respect to the constant-voltage system as described in par. 5.4.2.2. Drawing No. ICC - 163 also applies to this subsystem. Although identical in external appearance and function, the internal circuitry of the following units is unique to this system.

5.4.3.1

Transducer

The transducers acceptable for use in this subsystem are to be constructed as a complete 4-arm bridge, standardized to produce outputs of 0 to 30 mv over the operating temperature range of the transducer, when supplied with 10-v dc excitation. It is essential that each bridge excitation connection be wired to duplicate connector pins for use in calibration and checkout.

5.4.3.2

Calibration Unit

The Ayrton shunt method of voltage substitution calibration shall be used, in which excitation voltage for the Ayrton shunt network is derived from the potential pins at the transducer. Calibration is, therefore, possible only if a transducer is present in the circuit. Calibration voltage steps shall be as previously specified (of full-scale transducer output voltage. Each calibration unit shall contain the Ayrton shunt circuits and the relay switching circuitry as required for a modular type unit capable of calibrating a standard number of channels. Relay control is to be provided by the calibration step selector. The calibration unit will require no external controls or adjustments.

*

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 5. 4. 3. 3

5. 4. 3. 3

Checkout and Control Unit

The checkout and control unit shall provide push buttons for leakage checks and for connection of the millivoltmeter to the bridge outputs, sufficient for a standard number of channels.

5.4.4 Flow Measuring Subsystem

This section describes the system for the measurement of fluid flow. The system will accept signals from turbine type flowmeters and convert the signals to a form suitable for multiplexing and for entry into the digital system. Dwg ICC-048 is a block diagram of a typical flow system. The primary system components are described below.

5.4.4.1 Transducer

Turbine-type flowmeters, of the types manufactured by the Potter Aeronautical Company or by the Waugh Engineering Company, may be used with this system; they will generate ac pulses at a frequency proportional to the volumetric flow rate. With proper sizing, the maximum expected flowmeter output frequency will be nominally 600 cps. The calibration factor, relating frequency to flow rate, will be repeatable and relatively constant over the operating range, but will be unique to individual flowmeters. Calibration in LO₂ will be required for flowmeters intended for use in cryogenic flow measurement.

5.4.4.2 Frequency-to-dc Converter

One of these frequency-to-dc converter units per channel provides dc isolation at the input, amplification, limiting, and integration functions. The dc output will be proportional to the input frequency, as required for analog display or recording of flow rate. The output level will be suitable for graphic recorders, but will require some amplification prior to the digital data system inputs.

5.4.4.3 Calibration Selector/Control Unit

This unit provides for the manual or automatic calibration of the flow system by frequency substitution. During calibration the flowmeter elements will be isolated

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	5.4.4.3

and signals from the time-base unit fed to the frequency-to-dc converter inputs. Signals from the remote calibration control will activate the calibration relays when the AUTO-MANUAL switch is in the AUTO position.

5.4.4.4 Megohmmeter

This meter will be the same as that first described in Section 5.4.1.5.

5.4.4.5 Checkout & Control Unit (One Per Channel)

This unit will perform the following functions:

- (a) Operational Check - Separate push buttons shall be provided to permit checking electrical continuity of the flow-meter pickup element and to permit control of the flow-meter spin check. Readout indications shall be provided for both of these checks.
- (b) Insulation Check - Separate push buttons shall be provided to read conductor-to-shield and shield-to-ground leakage resistance.

5.4.4.6 Use of twin-rotor mass flowmeters for use in NERVA ETS-1 tests are under consideration. If a decision is made to use this type of flowmeter, design criteria for a subsystem will be provided.

5.4.5 Speed Measuring Subsystem

This system, ICC-167, will provide for the measurement of rotational velocity and for simultaneous display and recording. The major components of the system shall be as described in the following paragraphs.

5.4.5.1 Transducers

The system will accept signals from (but will not necessarily be limited to) self-generating magnetic type sensors. Flux variations in the permanent magnet core caused by turbine-drive gear teeth passing the probe tip will induce voltage pulses in the probe coil at a frequency proportional to the rotational velocity. The transducer shall be in the order of 5 to 15 v peak-to-peak at 20 Kc.

5.4.5.2 Preset Counter

This unit will count pulses from the transducer for preset time intervals so that the count is readable in direct engineering units on an associated digital display. The counting and display recycle time will be 1 second. Time correlation between recycling time and other recording systems will be provided by pulses from the time-base system. The counter shall provide an output at a lower frequency through a frequency divider for analog recording. The purpose of this recording is to monitor the output during startup for analysis of turbine drive. The counter shall also provide outputs for in-line digital display and print-out of rotational velocity in direct engineering units. The counter shall contain an integral digital display.

5.4.5.3 Frequency-to-dc Converter

This unit will be operated in parallel with the preset counter and will convert the raw signal to a dc analog which will be directly proportional to frequency.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.4.5.4

5.4.5.4

Checkout, Calibration, and Calibration-Control Unit

This unit (one per measuring channel) shall perform the following functions:

- (a) Insulation Check - Separate pushbuttons shall be provided for reading conductor-to-shield and shield-to-ground leakage resistance.
- * (b) Calibration - Controls shall be provided to apply the calibration steps as previously specified to the preset counter and the frequency-to-dc converter.

The calibration stimulus shall be four fixed frequencies fed from the master time base system. This unit shall provide for the selection of either the manual-calibration mode or the automatic-calibration mode under the sequential control of the master calibration-control unit.

- (c) Checkout - Controls shall be provided to connect the output of the frequency-to-dc converter to the dc voltmeter which may be the same instrument used in physically adjacent systems. The built-in display in the counter will function as the operational check of that portion of the subsystems.

5.4.5.5

Megohmmeter

This unit can be the same instrument as that used in other physically adjacent systems and will be connected to each flow measuring channel by pushbuttons located on the respective control unit.

5.4.6

Thermocouple Subsystem

5.4.6.1

Transducers

It is anticipated that ISA Type-K thermocouples (Chromel-alumel) will be used for most temperature measurements in the 700 to 2000°R range. Some measurements may be made by using iron-constantan and copper-constantan thermocouples.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.4.6.1

It is anticipated that tungsten-rhenium thermocouples will be used for temperature ranges higher than 2000°R . These will be specially built for engine use and will have outputs at full scale of 35 to 40 mv. A carrier-type amplifier (magamp) may be provided with the engine package to preamplify these channels to the 1-volt range.

**

See Appendix 5.9 for a discussion of measurement of temperatures related to ground-test models of the NERVA Engine.

5.4.6.2

Reference Junctions

*

Chromel-alumel (C/A) iron-constantan (I/C), and copper-constantan (C/C) thermocouple reference junctions shall be provided in existing 25-ft deep wells, the mean temperature of which will be about 70°F . For the tungsten - tungsten rhenium thermocouples, the ambient temperature in the Test Cell Building will be used as the reference temperature. Copper conductors shall be run from the reference junction through to the signal patch.

5.4.6.3

Zero Suppression or Ranging

*

This function is not required for all channels but where required, the following concept shall be investigated (and, if determined to be satisfactory, this concept shall be given preference over a mercury cell for a bias-voltage source):

- (1) A bucking voltage of the proper value can be supplied from a third "bucking-voltage" junction that will be heated to a temperature sufficient to develop the necessary output.
- (2) Different temperature range groups of the same type of thermocouple will be grouped, so that all bucking-voltage junctions of that range group would be held at the same temperature. This temperature can easily be held constant and controlled to $\pm 1^{\circ}\text{F}$.
- (3) Display or recorded values will have a zero value until the crossover polarity point is reached. That is, zero output will be recorded or indicated as some temperature above zero

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.4.6.3

These bucking-voltage sources have the advantage of long-term stability, are virtually maintenance free, and will not be subject to replacement as will mercury cells. However, it will be necessary to maintain a fixed range for each thermocouple in a group. Each group of reference junctions shall be provided with a resistance-temperature type of sensor to measure the temperature of the junctions (in wells or at terminal point). This information shall be fed into the digital system for data reduction.

5.4.6.4

Checkout Unit

This unit will provide the controls to determine the continuity of each thermocouple with its reference junction and bucking-voltage junction. The unit shall contain an ohmmeter with the necessary controls to connect each channel to the meter, and shall have a means of indicating which channel is connected. The large number of channels involved and the time required to perform this simple check indicates a semi-automatic scheme of operation. The circuitry shall be so arranged as to permit checking any one channel at random or to step sequentially through all channels or a selected group. It is not required that advancement to the next channel be automatic because the operator must read each channel. Rather the intent shall be to reduce the number of buttons or other controls required to connect each channel to the ohmmeter. Advancing through all channels or a group of channels is probably best accomplished by a single push button.

5.4.6.5

Calibration Unit

*

This unit shall provide relays for calibration of all thermocouples by means of an Ayrton shunt, which is also contained in this unit. This method will provide a constant high-impedance load for the voltage source. The calibration-voltage source may be a separately mounted unit or contained within the Calibration Unit.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.4.6.6

5.4.6.6

Calibration Control Unit

This unit will be basically the same as that described for the Strain-Gauge system in par 5.4.1.7, and shall provide for selection of a group of channels to which calibration stimulus will be applied simultaneously, and for selection of any one of the calibration steps as specified in paragraph 2.2.5.4(b).

*

5.4.6.7

Grounding

Shield Grounding shall be so accomplished as to minimize common-mode voltage at the input to the amplifier.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.4.7

5.4.7

Pressure-Potentiometer Subsystem

The Pressure-Potentiometer Subsystem, Drawing ICC-041, will accept inputs from potentiometer-type pressure transducers, and provide standardized linear outputs at the 0 to 5 v level, including calibration steps, for recording and display. Calibration control of operation calibration will be obtained from the Master Calibration Control Unit.

5.4.7.1

Transducer

Transducers acceptable for use in the pressure-potentiometer subsystem may be (but not necessarily limited to) ungrounded, swept potentiometer types, having potentiometer total resistances in the range of 500 to 10,000 ohms, and operating with 10-v dc excitation. Each transducer shall have a tapped resistance element, with the tap at a point representing 95 $\pm$ 2% of full-scale output.

*

5.4.7.2

Power Supply

A common 10-v dc power supply will be suitable for transducer excitation, provided that system shielding and grounding is controlled to minimize common-mode voltages. Individually isolated power supplies may be used, with the choice of common or individual power supplies to be made when optimum performance and cost factors are developed. If a common power supply is chosen, requiring individual channel fusing, suitable precautions must be taken to minimize temperature drift and fuse replacement problems.

5.4.7.3

Checkout, Range and Balance Unit

The Checkout and Control Unit will provide for completion of the transducer circuit to a bridge configuration, and for all switches and controls required for the setup and checkout of each measurement channel, exclusive of calibration. Pushbutton switches shall permit connection of the megohmmeter, the output voltmeter, and initiation of an output signal for checkout purposes utilizing the nominal 75% tap on the

transducer element. Manual controls shall be provided for adjustment of zero balance and system sensitivity. Range of the balance control in terms of full-scale output shall be limited to provide increased resolution of the adjustment. The sensitivity control shall not adversely affect system linearity. A standard number of channels shall be accommodated in each unit.

5.4.7.4

Calibration Unit

*

The Calibration Unit will contain the circuitry and relays required to provide voltage calibration signals representing specified percentages of full-scale transducer output, for each individual channel. The calibration circuitry shall derive excitation from the individual bridge excitation leads. Because of the checkout capability provided through the use of the 75% transducer tap, it will not be required that the excitation of the calibration circuits be obtained from duplicate transducer connector pins. A standard number of channels shall be accommodated in each calibration unit.

5.4.7.5

Calibration Step Selector

*

This unit, which may be identical to those provided for other subsystems, contains the necessary relay logic to energize, simultaneously, all calibrator relays in the subsystem associated with a single calibration step; that is, the relays associated with the defined calibration steps. No controls or indicators will be required for this unit.

5.4.7.6

Calibration Control Unit

*

The Calibration Control Unit, identical to calibration control units of other subsystems, will provide for manual selection of calibration steps, or for acceptance of control signals from the master calibration control. A single switching mechanism, rotary or interlocking pushbutton, shall be used for the calibration-step selection, with a "remote" position to enable calibration-step selection by the Master Calibration Unit located in the

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 5.4.7.6

Control Point Building. The unit shall also contain individual lamps to indicate the selected calibration steps, to operate in either the manual or automatic selection mode, and shall provide for selection of check-out and control modular groups.

5.4.7.7

Voltmeter

A voltmeter, of scale suitable for reading the output signal level, shall be provided to permit readout of any one of the subsystem channels, upon command from the corresponding checkout, range, and balance unit pushbutton. Accuracy of readout and voltmeter input impedance shall permit checkout of the operational status of the subsystem channels. The instrument may be shared with physically adjacent systems, if operational conditions permit.

5.4.7.8

Megohmmeter

A megohmmeter shall be provided for reading the transducer leakage-to-ground during system checkout. The instrument may be shared with physically adjacent systems, if operational conditions permit. The instrument must permit reading of leakage resistances between conductors and shield, and between shield and ground, up to values of 100 megohms.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.4.8

5.4.8

Position Potentiometer Subsystem

The Position Potentiometer Subsystem, Drawing ICC-039 will accept inputs from linear-or rotary-motion potentiometers and will provide standardized, linear 0 - 5-v dc signals for analog recording and display. Calibration of the system is to be manually accomplished during the pre-checkout operational phase.

5.4.8.1

Transducer

Transducers acceptable for use in this subsystem may be (but will not necessarily be limited to) ungrounded swept potentiometer types, having maximum resistances in the range of 500 to 10,000 ohms, which will be mechanically linked to the valve or other monitored item. The transducer must be of the proper type to match the mechanical motion of interest, so that the change of resistance bears a linear relationship to the physical displacement, whether linear or angular.

**

For electrical checkout, each transducer shall have a resistance element, in which the tap shall be at a point representing 50 $\pm 2\%$ of full-scale output.

5.4.8.2

Power Supply

A common 10-v dc power supply will be suitable for transducer excitation, provided that system shielding and grounding is controlled to minimize common-mode voltages. Individually isolated power supplies may be used, with the choice of common or individual power supplies to be made on determination of optimum factors of performance and cost. If a common power supply is chosen, requiring individual channel fusing, suitable precautions must be taken to minimize temperature drift and fuse replacement problems.

5.4.8.3

Checkout, Range, and Balance Unit

*

The checkout, range, and balance unit will provide all switches and controls required for the setup and operation of each of the subsystem channels. Pushbutton switches shall permit connection, for insulation checks, of the megohmmeter, the output voltmeter, the wiper arm, and the 50% checkout tap. Manual controls shall be provided for adjustment of zero balance and system sensitivity. Adjustment of the sensitivity control shall not adversely affect system linearity.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 5.4.8.4

5.4.8.4

Megohmmeter

Access to a megohmmeter will be required to permit checking of conductor-to-shield and shield-to-ground leakage resistance. The megohmmeter may be shared with other subsystems, as operational considerations permit.

5.4.8.5

Voltmeter

A voltmeter, or scale suitable for reading the output signal level, shall be provided to permit readout of any one of the subsystem channels, upon command from the corresponding checkout, range, and balance unit pushbutton. Accuracy of readout and voltmeter input impedance shall permit checkout of the operational status of the subsystem channels. The instrument may be shared with physically adjacent systems, if operational conditions permit.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A ~

Date 1 June 1962

Par. 5.4.9

5.4.9 Linear Variable Differential Transformer Subsystem

This subsystem will provide for the measurement of linear motion on position for simultaneous recording and display. Drawing ICC-049 is a functional block diagram of a typical subsystem. The major components of the subsystem shall be as described in the following paragraphs.

5.4.9.1 Transducers

The transducers acceptable for use in this subsystem may be (but will not necessarily be limited to) linear variable differential transformers with a full-scale output of approximately 5 volts ac or greater for a stroke up to 4 inches.

5.4.9.2 Power Supply

A common power supply, 30 volts at 3 Kc, shall provide excitation for all short stroke transducers, while 10 volts at 400 cycles shall be used for long stroke (up to 4 inches) transducers.

** A technique for calibration of L.V.D.T. Systems (including the transducers) shall be investigated since physical displacement for calibration checkout is limited.

5.4.9.3 Checkout and Control Unit

This unit shall provide all switches and controls for the checkout of each channel module contained in the unit and shall contain an optimum number of channels per unit. Each module shall perform the following functions:

- (a) Output signal demodulations.
- (b) Operational check - push-button switches shall be provided to permit checking electrical continuity of the transducer primary and secondary elements. The ohmmeter for this check may be the same as provided in physically adjacent systems if operating conditions permit.
- (c) Sensitivity - a push-button switch shall permit correction of the demodulator output to the voltmeter during manual calibration.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.4.9.4

5.4.9.4

Voltmeter

This meter, a dc instrument, may be the same as that used in physically adjacent systems, and will be used to monitor the demodulator output.

5.4.9.5

Calibration Unit

System calibration stimulus will be derived from a tapped transformer fed from the excitation supply.

5.4.9.6

Calibration Step Selector and Calibration Control

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 specified calibration steps or acceptance of controls from the Master Calibration Control in the Control Point Building.

*

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.4.10

5.4.10

Vibration and Acoustic Subsystem

The Vibration and Acoustic Subsystem will accept inputs from piezo-electric type accelerometers and microphones, and will Provide output and calibration signals for recording on analog recorders in the analog recording subsystem. Data recorded by this subsystem will require special handling to produce such specialized information as power-spectral-density and audio-level contour plots, and frequency-amplitude charts. Drawing ICC-165 is a functional block diagram of a typical system.

5.4.10.1

Transducer

*

Either of two types of high-impedance piezo-electric transducers (such as, but not necessarily limited to, accelerometers and high-level microphones), or either of two types of self-generating low-impedance transducers, may be acceptable for use in this subsystem. Acceleration data will be required in the range up to 5000 cps. The sound-level frequency range of interest will extend nominally to 10 kc. Transducers are to be provided with tri-axial transmission cable.

5.4.10.2

Amplifier

A shield and line driving amplifier, one per channel, will be required to prepare the transducer signals for transmission to the Control Point Building. Each amplifier input shall be equipped with relay circuitry to permit isolation from the transducer and substitution of a calibration signal. The amplifier output shall be capable of driving coaxial transmission cable.

5.4.10.3

Calibration Unit

The Calibration Unit will include all controls and adjustments required to set up each channel of the subsystem, with the exception of calibration control. Specific controls and adjustments required will be: individual channel switches for choosing either the high- or the

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.4.10.3

low-frequency calibration signal source, a rotary switch to permit monitoring of the calibration signal level on each channel, and an individual control for the adjustment of the maximum calibration signal level supplied to each channel. Circuitry shall be provided to enable the selection of calibration signal levels corresponding to the calibration steps specified, by relay contact closure.

*

5.4.10.4

AC Voltmeter

An instrument capable of reading the RMS calibration signal voltage shall be provided. The instrument shall be activated by the rotary selector switch on the calibration unit. See TDS 5.2.11.

**

5.4.10.5

Calibration Step Selector and Calibration Control Unit

This unit will provide for the selection and indication of the calibration steps for the complete subsystem, and selection of either the manual-calibration mode, or the automatic-calibration mode under the sequential control of the Master Calibration Control Unit.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.4.11

5.4.11 Proportional-Voltage Subsystem

It will not be possible to record directly some signals that must be fed into the Data-Acquisition System. As for example, those signals which are used in a closed-loop control or for display in either Facilities Control or Engine Control.

These signals will be provided suitable isolation prior to their entry into the recording subsystems, and before entry into the Data-Acquisition Systems. The analog voltages corresponding to pressure, temperature, or other control system variables, may require conditioning, so that full-scale is represented by a standard 5-volt signal. Drawing ICC-051 presents a functional block diagram of the system.

5.4.11.1 Calibration

* Calibration shall be by substitution of standardized fixed voltages corresponding to the calibration steps specified. The subsystem calibration will require a step-selector unit and a Calibration Control Unit similar to the units described in par. 5.4.1, and shall provide calibration on a manual basis from the Test Cell Building, or shall provide it either automatically or manually from the Master Calibration Control in the Control Point Building.

5.5 DIGITAL SUBSYSTEM

The following paragraphs present the criteria design of the Digital Subsystem and the basis for the particular configuration.

5.5.1 Development of Digital Subsystem

Because of constraints on the input and output of the subsystem, a number of statements regarding configuration may immediately be made.

5.5.1.1 Principle of Time Division Multiplying

Since the need for magnetic tape recording has been established, it is necessary to consider how a large quantity of relatively narrow bandwidth data channels may be manipulated to economically feed recorders characterized by relatively few channels of great bandwidth. The principles of multiplexing apply. These involve the maintenance of channel information integrity by time or frequency domain separation from other channels. Clearly a wider bandwidth is required for transmission and storage elements.

Multiplexing represents techniques whereby one wide-band information channel can transmit many narrow band channels, while maintaining the integrity of information in each. This is accomplished by separation of channels in the frequency domain (Frequency Division Multiplexing) or by separation of channel samples in the time domain (Time Division Multiplexing). It may be noted that digital representation of an analog variable is implicitly a sampled data process. The latter multiplexing technique directly applies to the case at hand. Channels are thus connected individually to the remainder of the system, one at a time, in a suitable sequence. The terms multiplexer and commutator will be used to describe devices capable of such operations.

5.5.1.2

Implications of the IBM 7090 Computer

- (a) Since the IBM 7090 has been selected as the computer to perform final data reduction and analysis, additional constraints are placed upon the digital subsystem. Several computer characteristics are significant:
- (1) Data is most economically read into the computer from magnetic tape.
 - (2) The tape and reel detailed geometry must conform to IBM standards.
 - (3) The recording format must conform to IBM standards.
 - (4) During data read in, the process is limited only by the input word rate.
 - (5) The computer operates internally in straight binary code.
 - (6) The computer operates with 36-bit words. It cannot be economically loaded unless data words can readily be assembled in memory by taking characters off the input tape in parallel.
 - (7) The computer may be more economically operated if no data words are split between two or more computer words.
 - (8) The computer is limited to 32,000 computer word-memory storage (36-bits each).
 - (9) The memory must also contain program instructions and channel-calibration data.
 - (10) The computer cannot be economically operated if individual input records involve more data words than there is memory space available.

* Groups of words between spaces (end of record gaps) where the transport can start and stop.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.5.1.2

- (b) The above considerations then form the following criteria (taken in the same order as in (a) above) for the data to be loaded into the computer:
- (1) Magnetic tape input will be used to load data.
 - (2) IBM compatible reels and tape will be used.
 - (3) IBM track geometry, record-gap standards, file-gap standards, and reel load point and end of tape standards will be used.
 - (4) Maximum standard packing density (800 bits/inch) and maximum transport speed (112.5 ips) shall be used to achieve maximum input character rate of 90,000 characters per second.
 - (5) Straight binary coding shall be used for recording data value to eliminate the program steps and extra tape required to transform binary-coded decimal (BCD) to straight binary (SB). Time and record identification shall be recorded as BCD.
 - (6) Data words will be formatted into adjacent parallel input characters.
 - (7) Data must be organized on tape to permit an integral number of data words to make up one computer word. Ten, eleven, or twelve-bit Straight Binary data words written as two characters will meet this requirement.
 - (8)-(9)-(10) The tape must be gapped and contain no more than about 15,000 computer words per record.

5.5.1.3

Formatting for Original Digital Tape Storage

- (a) Paragraph 5.5.1.2 has identified the characteristics of computer input magnetic tape, based upon optimum use of computer time. The technique or process to be used to write tape in this format must also be considered.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.5.1.3

It has been previously stated that some form of digital recording will be used in the original tape storage. In addition, the original format must be suitable for preliminary-data reduction subsystem at the ETS-1 Complex. Finally, it is considered highly desirable that there shall exist the capability of producing 7090 computer tapes at the Test Site, so that minimum time delay will ensue in transmitting data tapes to various interested parties in different parts of the country.

(b) Original tape-record characteristics may be defined under the following headings:

*

- (1) Code - straight binary (SB) or binary coded decimal (BCD)
- (2) Recording technique (NRZ1, etc.)
- (3) Word arrangement (serial or parallel)
- (4) Packing density
- (5) Hub and tape geometry
- (6) Recording level (Saturating, Non-Saturating)
- (7) Track geometry
- (8) Parity (locations, type)
- (9) Gross data arrangement (gapped - ungapped)

(c) One particular set of choices within the characteristics above results in 7090 compatible tape at optimum conditions for computer entry. Two possibilities exist:

- (1) Record originally in 7090 format
- (2) Record in some other format and prepare 7090 format tapes on additional equipment.

- (d) The packing density required (800 bits/in.) is a recently added IBM standard. The IBM 7090 computer at Aerojet-General (Azusa and LRP), Westinghouse Astronuclear Laboratories (Pittsburgh), and at Los Alamos Scientific Laboratory, will be equipped with this input-output standard.
- (e) Pre-recording format equipment costs less than equipment required for tape translation, which amounts to a small-scale digital computer. If serial recording is employed in the original tape, rather complex clocking and synchronization equipment must be included. Cost considerations strongly favor original formatting for the 7090.

The only logical reasons for employing an off-line format changing tape translation process are:

- (1) If acceptable levels of reliability cannot reasonably be otherwise achieved
 - (2) If overall costs (original, operating, amortization) are lower
 - (3) If the same equipment needed for tape translation is also required for preliminary-data reduction.
- (f) Reliability is affected by any additional equipment complexity or demands over and above other potential formatting circuitry and the relatively advanced bit-packing density.

The formatting circuitry required to write original tapes in 7090 format is no more complex than for any other form of parallel data entry. Operating speeds are moderate compared to current logic circuit capabilities. Although more circuitry is required than would be the case for serial entry PCM, the fractional increase in overall system complexity is considered small.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.5.1.3

(g) Requirements to produce preliminary data at the site are firm. Within a few hours after an engine test, data should begin to be available to allow rough estimates of test success, etc. Subsequent sections dealing with preliminary data reduction will consider the need for a computer to assist in this process.

* (h) Costs will be markedly reduced, while overall performance requirements can reasonably be met, if the Digital Data Subsystem writes original storage magnetic tapes in IBM 7090 computer format.

(i) To comply with operational requirements which specify the permanent identification of all data, it is required that the first information recorded on a tape be Test Number, Reel Number, and Operation Date. This information shall be entered at the first of each tape, but is not required for each record. It is required that range time (time-of-day) in seconds, and count time (operating procedure time) in seconds, be retrievable from the tape. Range time shall be obtained from the Master Time Generator in seconds starting from midnight. Count time, in seconds, shall be controlled by the Test Operations Group, working from the operational procedure. Count-down time shall be recorded as a minus value and countup time shall be recorded as a plus value. Range time shall be recorded at the beginning of each record. Test number, reel number, date, range time, count time, shall all be recorded in the BCD mode.

*

5.4.1.4

Editing

Editing, as applied to records involving large quantities of data, means the preparation of new records containing only selected information. Selection generally involves choosing some fraction of the total information available in selected channels over desired time intervals.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	5.5.1.4

Two basic editing principles are applicable: editing in real-time during data acquisition, and post-test editing. It must also be recognized that a great deal of editing is required prior to completion of the data-reduction process. Real-time editing is relatively simple and inexpensive, but is limited in flexibility. It must be pre-programmed. Post-test editing to select a few channels over a given time interval for graphical presentation is also relatively simple and inexpensive. Post-test processes to prepare edited tapes for 7090 computer entry are complex and expensive, with the exception of selection of certain entire records. The degree of complexity is related to the number of data words to be read from a given piece of original tape and the number of words to be written per record into a 7090 tape.

Ultimate 7090 tape record length is determined by the memory capacity of the translation equipment. The only reason for considering editing prior to 7090 entry is to reduce overall costs. A subtle point bears significantly on this problem. If a flexible editing capability is employed prior to 7090-data entry, the organization of information in the records will be subject to constant changes. This intrinsically requires that the 7090 be re-programmed for each particular editing program. It is felt that this would impose a severe burden on the data reduction organization and could easily become unmanageable. Editing within the 7090 with a fixed input-data organization format involves programming, but of a substantially simpler nature since the basic memory location of each original channel sample remains constant.

All points considered, post-test editing prior to 7090 entry should not be contemplated. All necessary editing may be handled by the 7090 at a read-in rate equal to the rate at which data was originally acquired.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.5.2

5.5.2

Preliminary Design

A preliminary design of the Digital Subsystem is outlined in the following paragraphs. It is based upon the present estimate of input channel quantities, sampling rates, and the premise that the system should write optimal 7090 computer format tape. The design is also intended to reflect adequacy in the areas of cost, performance, flexibility, reliability, and ease of operation. Dwg ICC-087, Digital Data Subsystem, establishes the functional block areas of data manipulation.

5.5.2.1

Multiplexing

**

Multiplexers will be supplied in groups of 50 channels each, which is representative of a good balance between the economics of large channel groups sharing certain common circuitry, and the increase in reliability and performance features (especially in cross-talk) as fewer channels per unit are considered. Both low-level and high-level multiplexers will be used, and it is desirable to have them completely interchangeable. The output of each unit will be single ended, and will be normalized for zero and span. All units will have differential inputs with high common-mode rejection ratios.

Multiplexing shall be provided for a total of 1,750 channels with the following sampling distribution: 50 channels, 200 samples per second (s/s); 100 channels, 100 s/s; 100 channels, 50 s/s; 1,500 channels, 10 s/s.

Two methods of multiplexer control may be considered. The most desirable is a programmable sampling control which will permit the selection of any sampling speed for any channel. If this method is adopted, programs will be prepared on removable patch panels (thus providing various sampling programs in storage), and required sampling speeds will be 200, 100, 50, and 10 s/s. Another possible method of control is a commutation technique, which is described below and is shown on Dwg. ICC-091. No attempt will be made in the criteria to select the better of the two methods, since this will depend upon vendor's standard techniques and upon the program funding.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.5.2.1

**

If the commutation technique is adopted, all multiplexers will operate at the same basic clock rate of 10,000 total s/s, or subrates thereof. Clocking of the A, B, C, and D word-group units will be so phased as to allow sequential readout of the analog-to-digital (A-D) converters. Commutators, which will be used to sequentially connect prime multiplexers to the A-D converters, will be high level and single ended, and will operate at a rate of 200 channels per second, with the ability of being programmed to commutate 1, 2, 4, or 20 prime multiplexers.

5.5.2.2

Analog-Digital Conversion

Two methods of digitalization may be used, either the use of one high-speed Analog-to-Digital Converter (ADC) to perform all conversions; or to utilize 4 ADC's each of which will operate at one-fourth the total data speeds, with sampling and interlacing of the individual outputs. Since the latter method is more involved, it will be discussed within this criteria. However, either technique is suitable and the final method selected will depend upon vendor recommendation and proposal evaluation.

The primary requirement for the ADC block is that the unit shall operate at 40,000 conversions per second. Output mode will be 12-bit straight binary data words. Adjustable guard bands will be provided for zero and full-scale, and each will represent approximately 5% of full-scale.

The technique involving the use of 4 ADCs may be adopted to enhance reliability, on the basis that failure of an ADC would cause the loss of only 1/4 of the total data words, and also on the basis that higher speed units are less reliable due to the advanced internal clock rate. It is also questionable whether suitable accuracy and stability could be obtained at a 40-kc word rate within the allowable procurement schedule.

Each ADC will perform 10,000 conversions per second, and timing will be staggered to allow sequential assembly of words. All units will be of the successive approximation type, operating from individual reference voltage sources for greater reliability.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.5.2.2

Input circuitry will be high impedance, with sample and hold features, and single ended inputs will be used. Lateral parity check will be generated within the ADC and carried through recording.

In addition to the requirement of sampling analog information, there will also be a need for entry of direct digital information, which will consist of 600 events represented by switch closures with volt outputs of 28 v dc. Events will be assembled into 6-bit words, plus one parity; stored in a word assembly register; and dumped as a group of 100 characters once per Record.

5.5.2.3

Formatting

**

The main controller will accept data words from the transmission line. These words will be read into tape as two 7-bit parallel characters at a rate of 90,000 characters per second.

The initial system will utilize tape records having a length of 9,000 7-bit binary words with a repetition rate of 10 per second. Provision shall be made for later expansion of Record length to to 18,000 7-bit binary words at the reduced record rate of 5 per second, with possibility of addition of a sample speed of 5 s/s per channel, and a redistribution of channel sampling speeds. This capability is important with respect to future utilization of the ETS-1 data system, and shall be specifically discussed within the proposal of any bidder for this work.

Tape format per record shall be composed in the order listed below:

Range time	8	characters (BCD)
Identification	4	characters (BCD)
Count time	6	characters (BCD)
Direct digital	100	characters (Binary)
Data	8000	characters (Binary)
Gap	600	characters
Unassigned	282	characters
Total	<u>9000</u>

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.5.2.3

** This unit will write longitudinal parity at the completion of each record. File markers will not be used.

Word assembly will be performed by sequentially sampling the outputs of the ADC to construct a tape having a total capability of 90,000 characters per second. Time in seconds (BCD) will be recorded for range time, test identification, and count time, at the beginning of each record.

Each new tape placed on a recording machine shall first have the following information entered upon it:

The test number, (4 characters BCD)
Test date (6 characters BCD)
Run number (2 characters BCD)
Reel number (2 characters BCD)
Any necessary instructions added by typewriter.

5.5.2.4 Transmission

** Multiplexing equipment and ADCs will be located in the Forward Control Room, while the recording equipment will be located in the Control Point Building. Transmission distance is approximately 600 feet. Data transmission and receiving equipment shall be provided by system fabrication, but transmission cable will be provided by others, although system fabrication shall specify cable.

Data transmission may be either serial or parallel. Final decision shall be based upon vendor recommendations and proposal evaluation.

5.5.2.5 Recording

** All recorders will provide for IBM standard reel and tape geometry, track geometry, start-stop capability, and recording principles (NRZ 1-saturating). The data tape handlers will operate at 112.5 ips, and the data word rate, using 800-bit/inch packing, will be 90,000 characters per second.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.5.2.5

Three recorders will be provided, of which two will operate in alternating sequence to provide continuous recording. Automatic crossover between these recorders will be accomplished prior to tape runout, or when required because of parity error detection, which would indicate possible record-playback equipment malfunction. The third recorder will act as backup.

Controls will be provided to permit operation of the recorder facility at various scan rates. The recording equipment will either operate at a continuous rate, or at 1-second recordings with selected delays between recordings of 5, 10, 50, 100, 500, 1000 seconds. When operating at the "continuous" rate, 247 seconds of recording time will be provided by 2,400 feet of tape on each reel.

For operational check of recording quality, a method shall be provided for reading recorded range time from each Record and this time shall be displayed on the Digital-Control Console next to the range-time display. Variation between the readings will indicate recording failure.

Gapping will be accomplished by buffer-storage during the time necessary to produce a Record gap at constant tape speed.

5.5.2.6

Summary of Capabilities

** (a) Quantity of Input Channels

By modular addition of 50-channel multiplexers, the system shall be able to accommodate from 200 to 4,000 channels, using for this effort, only plug-in equipment additions and patch or pin programming of subcommutators. The initial system shall be 1,750 channels which shall be distributed as follows:

50 channels, 200 s/s
100 channels, 100 s/s
100 channels, 50 s/s
1,500 channels, 10 s/s.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.5.2.6

(b) Total System Word Rate

The total word rate of the system will be constrained, if possible, to a constant 40,000, 12-bit Binary, data words/second, using a system design to permit initial operation at a reduced rate of 20,000 data words/second. Operation at this reduced rate will require a reduced tape system speed, input word rate, and channel distribution; however, system timing shall be fabricated to permit such reduction.

(c) Preliminary Data Reduction

On-site reduction shall be provided by a general-purpose computer, which shall accept data at full data rate, either from input data lines or as playback from tape handler, and shall perform the following functions:

- (1) Review of each channel for tolerance limits during checkout
- (2) Decommutation and correction of data at a minimum rate of 4,800 corrections per second, for calibration, linearization, and conversion to engineering units. Output shall be magnetic tape, high-speed line printer, and strip chart recorders, carried through DACs.
- (3) Preparation of copy and summary tapes.

(d) Accuracy

The accuracy of the system will be determined by the analog circuitry and the analog-to-digital resolution level, which shall be one part in 4,096. Multiplexers, amplifiers, and A-D converters are available to achieve the required system accuracies with both low- and high-level input signals. Input filters to the digital system shall be provided to prevent errors due to high-frequency components in input signals.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.5.2.6

(e) Operational Flexibility

Through use of the described system, a wide degree of operational flexibility may be achieved. Prior to an engine test run, data scans may be taken periodically as desired for system checkout and calibration. During run conditions, full system capacity may be used with continuous coverage capability. After a run, during cooldown, reduced capabilities may be utilized.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A	
Date	1 June 1962
Par.	5.6

5.6

ANALOG RECORDING SUBSYSTEM

An analog subsystem shall be provided for data having a bandwidth too great to be efficiently handled by the digital system and to provide continuous analog and backup recording. Included will be purely dynamic signals, ac only, and dynamic signals with dc level measurement which will extend over a frequency spectrum of dc to 100 kilocycles, with a greatest-interest spectrum of dc to 10 kc.

*

5.6.1

Requirements

The Analog-Recording Subsystem must provide:

- (a) The means to record non-critical quasi-static and transient data in such a form to make the data immediately available after a test.
- (b) The means to record critical transient or high-frequency data in a form capable of post-test review and final data reduction and analysis.
- (c) The means, patching, amplifiers, etc., required to accomplish (a) and (b) above, and also to provide the analog-recording capability required for preliminary data reduction of the digital recorded data (see par. 5.8 - Preliminary Data Reduction).
- (d) A recorder-operation master-controller (stop-start) control system to control all analog recorders automatically (by command) by remote control to support system checkout and calibration, and by manual local control to support measurement subsystems checkout. Recorder status lights for Run (green), Ready or Standby (Amber), Out of Service (red), shall be included.

5.6.2

Preliminary Design

The analog recording subsystem shall consist of field-proven multi-channel analog recorders.

Choice of particular recording methods or types of recording equipment shall be based on these considerations: original cost, operation complexity, flexibility, recording form, and ease and ability to reduce and/or analyze the recorded data.

5.6.3

Based on the requirements of par. 5.6.2 above, the subsystem will provide two basic types of recorders (narrow and wide-band) to cover the wide spectrum of recorder requirements.

(a) Narrow Band Recorders

Three each, 8-channel direct-recording oscillographs shall be furnished to record non-critical low-frequency (dc to 100 cps) parameters, such as valve timing, slope determinations for time rise, and valve actuation time correlation and programming.

Two each, X-Y recorders shall be furnished to produce low-frequency (0 to 1 cps) amplitude versus time plots for preliminary data reduction of digitally recorded data and other support requirements.

Three each, photographic galvanometer 36-channel oscillographs shall be furnished to record high-frequency transients up to 1000 cps. They will provide for excellent time correlation between channels, millisecond time resolution with adequate accuracy, and fast access to final data.

(b) Wide-Band Recorders

Analog FM Tape recorders-reproducers (14-channel) shall be used to record wide-band data which cannot be recorded on the digital subsystem or the narrow-band analog recorders.

They will provide wide-frequency response, to 20 kc, and will have the capability of reproducing the signal

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.6.3

for analysis, plus the capability of time compression or expansion. Direct analog electronics can be employed for recording higher frequencies, above 20 kc, and where dc-level information is not required. Voice annotation and timing shall be provided to aid in data analysis and to provide automatic tape search capability during playback.

The recorders shall be 14-track types using 1-inch tape, with characteristics compatible with Ampex Type 100 C tape recorder-reproducer. Six 14-channel record decks with one set of 14 play-back amplifier demodulators shall be furnished for playback review and recording. The recorders shall also provide the electronics and tape-transport requirement to play back, at reduced standard speeds, for re-recording, analyzing, or digitizing on the digital system.

- (1) Timing and Search Control - A serial time code shall be recorded on one track of each recorder to provide time correlation. A time-code reader and a tape-search control unit shall be provided for on-site preliminary data review.
- (2) Calibration and Checkout - To provide fast convenient checkout or calibration of the tape recorder reproducers, a Calibration and Checkout Unit shall be furnished which shall:

Be patchable through the record patching system to provide calibration input signals, both ac and dc.

Provide for integrating signal generating and measurement instrument, vacuum-tube voltmeter, audio oscillator, dc-calibration source, etc. with the input-output calibration circuitry.

Be able to check-out, from the Calibration-Unit, one 14-channel tape recorder-reproducer, for both direct and FM electronics, without requiring re-patching or setup changes.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5. 6. 4

5. 6. 4

Wide-Band Amplifiers

Wide-band differential amplifiers shall be provided with input and output program patchable from the record patch. They will provide isolation for redundant recording and impedance matching during both recording and preliminary data-reduction operations.

A total of 56 amplifiers, including operational spares, shall be provided.

5. 6. 5

Control and Patching

5. 6. 5. 1

A recorder operation (stop-start) control system shall provide:

- (a) Local control for each type of recorder in groups (e. g. , direct-writing oscillographs, galvanometer oscillographs, and magnetic-tape recorders).
- (b) A recorder-operation master controller providing remote control of all recorders in groups, as in (a) above, and also including timing relays, etc. , which will provide the control to support automatic checkout and calibration for the complete Data-Acquisition System.
- (c) Remote control for the recorder-operation master controller Start-Stop control at the Data Acquisition Panel on the Instrumentation Console plus Recorder Run (green), Ready (amber), and Out-of-Service (red) monitor lights for each type of recorder group.

*

5. 6. 5. 2

Record Patch

A programmable Recorder Patch System shall be furnished to provide a flexible reliable means of interconnection between input signals and the various recorders. Inputs to the Recorder Patch System shall be outputs from the signal-patch system and timing system, and outputs from the Recorder Patch System shall be inputs to the various recorders, amplifiers, or check-out equipment.

5.8**PRELIMINARY DATA REDUCTION**

Equipment shall be provided within the Control Point Building to permit a limited amount of data reduction immediately after engine tests, or at such other times as may be desired. The actual reduction process shall consist of manually scaling values from graphic recordings and interpretation of numerical listings. The Preliminary Data Reduction Facility will also be required to process data for system checkout.

A number of critical channels will be recorded on paper-strip type devices at the time of the test. These records (see Appendix 3.5.2) will be immediately available for use. Additional equipment shall be provided to allow post-test generation of a limited quantity of graphical and tabular presentations from any channel originally recorded on tape.

Equipment and procedures required to perform post-test data reduction from magnetic tape are closely parallel to the equipment and procedures required to perform data-system checkout. Much of the equipment shall therefore be time-shared between checkout operations and preliminary data reduction operations, but when consideration is given to proposed testing schedules, it is apparent that simultaneous use of this equipment for checkout and data reduction is not required.

5.8.1Proposed System of Preliminary Data Reduction Subsystems

Drawing ICC-146 depicts the equipment required for preparing graphical and tabular data from magnetic-tape playback. In order to make the diagram functionally complete, portions of the Data-Acquisition and Data-Checkout Systems are included.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A	
Date	1 June 1962
Par.	5.8.2

5.8.2

Capabilities

The equipment of Dwg ICC-089 may be used for a variety of local data reduction functions.

5.8.2.1

Preliminary Data Subsystem

- (a) The Preliminary Data Subsystem shall have the capability of performing (when feasible, through use of the on-site general-purpose computer) the following operations when used as input together with any digital magnetic tape recorded at ETS-1, or when operating from real-time data:

*

(1) Digital Display

These subsystems shall provide lighted digital displays of any selected channel. Display shall include channel number, event value, and event time. Both range and count time shall be displayed. All numerical displays shall be 10-base decimal. During operations, Range time shall be retrieved from the tape by use of read-heads, and displayed for a system operation monitor.

*

(2) Plots

Graphic presentations shall be prepared on 11 x 17-in. X-Y plotters representing one or more channels as a function of time. Only one channel may be plotted at a given time, but multiple plots may be made on one sheet.

Input data shall be from the digital magnetic tapes. Time base for plots shall be selectable for these time intervals: 3, 7.5, 15, 30, 75, 150, 300, 750, and 1500 seconds. The complete magnetic tape shall be used for plots over intervals up to 30 seconds, and may be presented on strip-chart recorders, when resolution requirements exceed the capability of the 11 x 17-in. X-Y plotter. Summary tapes prepared by the on-site computer will be used for

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.8.2.1

* intervals greater than 30 seconds. Traces may be produced from the complete tape at the real-time acquisition rate, while traces may be generated at about 10 times real-acquisition rates from the summary tapes.

* For increased accuracy, channel-zero and full scale calibrations shall be used to set up each channel to coincide with 0 and 100% displacements on the plotter. Accuracy of reproducing data will be about 0.5% from calibration input to linear representation of percent of full scale.

* Conversion to engineering units (as well as correction for systematic non-linearity) will be accomplished with overlays, specially printed graph paper, or manually by reference to tabulated values of the variable as a function of percentage full-scale.

5.8.2.2 Strip Records

- (a) Galvanometer oscillographs or direct writing records may be driven directly from the analog magnetic tape palyback. Serial entry time code from the original recording will be used. Data interpretation will be manual, using suitable scales and conversion data.
- ** (b) Direct writing records shall be used for reproducing data from the digital tapes. Capability shall be provided for 24 channels to be recorded simultaneously, together with an appropriate serial entry time code. Direct writing pen recorders are used for re-playing data from the digital tapes solely because short-time intervals are involved and maximum sampling rates are needed.
- * (c) In both (a) and (b) above, the speed with which the computer corrects and reproduces graphical data will be accomplished at the original rate of acquisition.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.8.2.3

5.8.2.3 Tabulations

The numerical line printer of the Data Checkout System may be used for data reduction.

**

Tabulation of data on the digital tape shall be provided, along with time, at rates up to 600 lines per minute. The readout will be 10-base decimal.

5.8.2.4 Tape Operations

The preliminary data systems shall be capable of handling, shuttling, reducing, and duplicating all types of magnetic-tape records, both digital and analog. For digital tapes this duplication shall not use a large memory, but shall rather de-skew and re-clock data from the tape being read, and write this regenerated data. Editing by whole records shall be provided.

5.8.3 System Checkout and Calibration

*

Part of the Preliminary System requirements shall be that it shall operate with the checkout and calibration functions of the complete data system. Prior to an operation, system checkout and calibration shall occur, and the Preliminary-Data System will be required to monitor, check, and report upon these operation. Drawing ICC-109 illustrates this operation. In addition, the System will be required to compare digital input values during checkout, with selectable preset limits and print-out any out-of-tolerance channels. The operation of this function shall be independent of the tape recording system. The system shall be capable of displaying and printing out the sensor value of any channel along with time.

5.8.4 Operational Check System

The preliminary data system will be required to operate during real time, and to perform certain operational checks. The computer will be required to display any channel selectable

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.8.4

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during a run. Range time shall be retrieved from the tape by use of a read head, and displayed with the range time from the Master-Time Generator. Any difference between the two times shall indicate a system error. Parity check shall also be performed from the read head, and any parity errors shall be displayed. If four successive parity errors occur, an automatic shift to a standby recorder shall occur.

5.9

FINAL DATA REDUCTION

5.9.1General

Duplicates of raw data tapes will be sent to an off-site computer facility for final data reduction. An IBM 7090 computer and associated auxiliary equipment will be used to prepare the data package outlined in par. 5.2.4.2, which contains graphical, tabular, and magnetic-tape data output.

*

~~The majority of data reduction will be accomplished with the summary-data tape, while the complete data tape will be used only for short-time intervals, where its greater sampling rate is needed.~~

Raw-data tapes, will feed the 7090 directly, not through an auxiliary small computer (such as the 1401). Auxiliary equipment will be used for 7090 output functions.

A block diagram depicting the final data-reduction process is shown in Drawing ICC-148.

5.9.2Scope of Computations

In the first 7090 pass, raw data will be sorted into desired sequences, corrected for systemic errors, and linearized and scaled to engineering units. Correction for systemic errors will be done, using two coefficients computed from system calibration data to normalize zero- and full-scale information. Linearization and scaling will be done by a power series with up to six coefficients operating on normalized data in machine units to give engineering units.

In second and subsequent passes (different computer functions which may or may not use intermediate tapes and separate programs) of the 7090, calculations using

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	5.9.2

variables in engineering units will be accomplished, including preparation of tapes for tabulating and plotting data. Heat transfer, pump evaluation, etc. are examples of computations done at this stage.

5.9.3

Final Data Output

5.9.3.1

Graphical Data

Most graphical data output will concern physical variables, such as functions of time. Another graphical form will cover time-slice profiles, for example, a core temperature profile at a given instant of time.

For the volume of graphical data required, it appears that a plotting device which will operate more rapidly than a mechanical plotter will be required. It is suggested that the Final Data Reduction Facility, when designated, shall consider the use of a cathode-ray tube plotter (Stromberg Carlson 4020 as an example) to handle the graphical output load. Such a powerful device would have a small utilization factor on this project, but might be shared with other projects.

5.9.4

Channel Records

Information which will enable the IBM 7090 computer to find the desired measurement raw data, and to also find the proper data-associated scaling coefficients, will come from the Channel Records System on-site. This record system will be by electric accounting machines, and the necessary information can be transferred via a box or two of punched cards. To minimize human error, no manual transcription of channel records should occur. An IBM 1410 computer at the Computer Facility will be able to translate the card records into information tapes for the 7090.

5.9.5

Standard Channel Ranges

The standardization of channel ranges will permit more economical handling of scaling coefficient. A set of up to six coefficients can be designated by one channel range type number, and referenced in that way, rather than providing a complete separate set of coefficients for each channel.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	5.10

5.10

SYSTEM OPERATION

To adequately support the varied operations required of the Data Acquisition System, several modes of operation will be necessary, such as checkout, calibration, and various run modes. The different modes of operation are detailed below and graphically presented in Drawing ICC-172, Data Acquisition System - Master Operation Sequence.

5.10.1

Checkout

It will be required that the Data Acquisition System not only measure and record data during actual test firings, but must also be capable of supporting and aiding in the checkout and setup of other systems, such as Engine Control and the Remote Engine Control System, during the time leading up to and during countdown.

Pre-pre-checkout and pre-checkout operations for the Data-Acquisition System are considered as off-line operations, that is, except for specific channels, sub-systems, or systems which will be undergoing checkout when not required to be operational, the Data-Acquisition System will be operational and on-line, beginning with the start of countdown. This will provide the ability to record or obtain the data required to support checkout operations of other systems when required. During this period, both manual and automatic recorder record and calibration control is required. This record and calibration control is required locally at the equipment in the Test Cell Building, and at the Master Calibration and Recorder Control and Programmer units in the Control Point Recorder Room.

5.10.2

Calibration

Calibration of the Data-Acquisition System shall be automatic (push-button initiation of a pre-programmed automatic sequence) or manual step-by-step initiation,

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.10.2

for all channels or by groups of channels, and for recording on either specific preselected recorders or all recorders, as pre-programed by controls on the recorder control Local and Master Control Units. The calibration must be able to be recorded on the digital and analog systems simultaneously, or independently, dependent upon operational factors. The final pre-firing calibrations will be used for scaling and corrections during subsequent data reduction.

An automatic check conducted during the pre-pre-firing calibration will sequentially perform a checkout during the 75% calibration point. During actual calibration, a portion or all of the Data-Acquisition Measurement Systems undergoing calibration, will be disabled. For this reason, careful control of the initiation of calibration will be required.

5.10.3

Run Modes

Due to the different requirements and different characteristics of the digital and analog recording subsystems, different independent and simultaneous run modes will be required for each subsystem.

5.10.3.1

Digital Subsystem

The entire Digital Recording System, exclusive of tape handlers, will run continuously, requiring that timing should be continuously supplied by the I & C Timing System.

~~The complete Digital Tape Recording subsystem will only be required to run at full speed during the test run phase (that is, intermittent operation, as for example, once each second, will not be required except for check-out or calibration prior to testing). Automatic and manual control from the Recorder Operation Master-Controller and manual local recorder control will be possible.~~

*

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	5.10.3.1

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~~The Summary Digital Tape Recording Subsystem will be programmable for intermittent operation with selectable periods from 0.5 sec through 100 sec, and one record per control command with both manual and automatic control from the Recorder Operation Master Controller and manual local control.~~

Standby recorders will automatically transfer to an on-line condition in the event of end-of-reel or parity-error conditions. Transfer shall also be possible by manual local control as well as by remote control from the Instrumentation Console.

5.10.3.2

Analog Recording Subsystem

The analog recorders will be controlled by local manual controls at the recorders, and by automatic and manual controls on the Recorder Operation Master Controller Unit located in the Control Point Recording Room. Remote control of the recorders by groups, and status monitoring, will also be provided at the Data Acquisition panel on the Instrumentation Console. The recorders will run at different speeds depending on band-width requirements, as manually preset on each recorder; however, during a given run, only one speed will be used. Calibration of the measurements recorded on the analog recorders will be primarily accomplished during the pre-pre-firing calibration as part of the pre-checkout. It will be possible to record the pre-firing calibration on the analog recorders simultaneously with the digital system dependent upon operational requirements. The analog recorders shall be programmed to operate during the entire test for channels on which continuous coverage is required to record unexpected transients. For channels which require information during portions of the run only, as perhaps for vibration or acoustic data, recording could be programmed for only part of the test.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	5.10.4

5.10.4

Personnel Required

To adequately support the preparation for a test and the actual testing, the following estimated numbers and types of personnel are required, assuming that the system has been "sold" and is in operating condition.

Lead Instrumentation Engineer
Data Measurements Engineer
Digital Recorder Operators (2)
Analog Recorder Operators (3)
Instrument Technician (3)

6.0DATA ACQUISITION SYSTEM (PHOTOGRAPHIC)

In addition to the Electronic Data Acquisition System (see Section 5.0) which provides for the electronic recording of data, the photographic portion of the Data Acquisition System is required to provide complete area pictorial records of essential ETS-1 test activities.

**

Six camera stations will be required. Of the 6, 4 will be located in protective bunkers; 1 on a steel tower, approximately 5000' NNW from ETS-1; and 1 will be mounted on the locomotive cab. Each bunker-type camera station will contain 2 to 11 cameras with a periscope or mirror for each camera.

All cameras can be controlled from the Photo Control Panel, which will be located in the Lead Instrumentation Console at the Control Center. In addition, local controls will be provided on each camera.

Two bunkers will contain special high-speed (1000 fps) cameras which can be controlled by activation signals from the Engine Control System, denoting engine malfunction.

6.1PURPOSE AND FUNCTIONS

*

The purpose of the photographic instrumentation system associated with the coverage of static tests at ETS-1 will be the collection of graphical information which will provide a permanent record and history of the events for later technical analysis, and for other non-technical purposes.

The functions of the photographic system at ETS-1 are:

to record visual data of equipment under manual and remote control

to provide adequate camera and film shielding

to accept and record auxiliary timing information, and

to provide satisfactory stable camera mounts.

6.2

I & C SYSTEM CONSIDERATIONS

Testing the NERVA engine at ETS-1 will require visual records of engine and facility equipment performance. In addition, activity of test site personnel will be photographed. For the purpose of this criteria, the photographic coverage will be divided into three types:

6.2.1

Engineering Sequential Photography

Engineering sequential films will be made for the purpose of recording evaluation, and study of an event. The film will include timing information, and will be of sufficient size so that a frame-by-frame study or a projected image may be viewed. To aid in evaluation, they will usually involve either compression or expansion of time, in other words, the event when viewed will appear to occur faster or slower than actually happened. Included in the engineering sequential films will be the kinescope recordings, which will be permanent photographic movies made from television monitors. By including the control-room voice net on the kinescope film taken of an engine-test firing or disassembly operation, these film records will provide a permanent record, which will include visual displays of occurrences during events, synchronized with voice commands.

6.2.2

Data Analysis Photography

The purpose of data films will be for reduction of linear and/or density information from which information can be obtained. They will provide information about the conduct of tests or experiments with regard to the excursion of movement, size, velocity, and direction of objects that may require location and identification. They may be used to analyze any phase of the engine assembly, operation, test firing, shutdown, or disassembly. To provide time correlation, capability will be required to record timing on the film.

*

6.2.3

Documentary Photography

Documentary photography will involve the use of motion-picture coverage of any events and occurrences at the test site that will require the collection of graphical information for non-technical applications.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 6.3

6.3 SYSTEM REQUIREMENTS

6.3.1 Pre- and Post-Test Coverage Requirements

- * No specialized equipment or installations will be required to meet the needs of documentary photography or technical photography not associated with engine test firings. Standard frame-rate, and variable-speed cameras shall be furnished, which include the associated equipment of power supplies, mounts, lenses, etc. The photographic requirements for ETS-1 are as follows, and as indicated on Drawing ICC-042.

6.3.1.1 Engineering Sequential

- * 16-mm black-and-white, slow and medium frame-rate coverage, of any events requiring study.

6.3.1.2 Data Analysis

- * 16-mm black-and-white, high frame-rate coverage, of events requiring post-test analysis.

6.3.1.3 Documentary

- (a) 16-mm color with sound, standard frame-rate coverage, of all events of interest.
- * (b) Deleted.

6.3.2 Test Firing Coverage Requirements

- * The photographic coverage of the actual nuclear rocket engine static tests shall be in accordance with Drawing ICC-042, sheets 1, 2, 3, and 4, and shall include:

6.3.2.1 Engineering Sequential

- * (a) Camera Station 1B (4 cameras) - 16-mm black-and-white medium frame-rate coverage of the lower portion of the test stand containing the reactor, to provide coverage during the full-power run. See Dwg. ICC-042, sheet 2.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 6.3.2.1

- * (b) Camera Station 2B (4 cameras) - 16-mm black-and-white medium frame-rate coverage of the entire test stand and exhaust tube, to provide coverage during the entire full-power run. See Dwg. ICC-042, sheet 2.
- * (c) Camera Station 2B (3 cameras) - 16-mm black-and-white, very-slow frame-rate coverage of the entire test stand including the shields in their open position, to provide coverage intermittently during the preparations, and during the entire full power run. See Dwg. ICC-042, sheet 2.
- * (d) Camera Station 3B (3 cameras) - 16-mm black-and-white, very-slow frame-rate coverage of the entire test stand, storage area, and exhaust area, to provide coverage intermittently during the preparations and during the entire full-power run. See Dwg. ICC-042, sheet 2.
- * (e) Deleted.
- * (f) Camera Station 5L (1 camera) - 16-mm black-and-white, slow-frame-rate coverage of the immediate area of the mating operations. Coverage shall be provided only during the mating operations. See Dwg. ICC-042, sheet 2.

6.3.2.2 Data Analysis

- * (a) Camera Station 6B (2 cameras) - 16-mm black-and-white, high-speed coverage of the lower portion of the test stand and the exhaust duct, to provide coverage only during the rise to full power. See Dwg. ICC-042, sheet 3.
- * (b) Camera Station 2B (1 camera) - 16-mm black-and-white, high-speed coverage of the immediate test-stand area, to provide standby coverage in event of an engine malfunction or other mishap. See Dwg. ICC-042, sheet 3.
- * (c) Camera Station 3B (1 camera) - 16-mm black-and-white, high-speed coverage of the entire test stand, storage area, and exhaust tube, to be used for standby coverage in the event of an engine malfunction or other mishap. See Dwg. ICC-042, sheet 3.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 6.3.2.3

6.3.2.3 Documentary

- * (a) Camera Station 2B (2 cameras) - 16-mm color motion pictures at normal frame rates showing the test stand and exhaust areas, to show some of the preliminary operations and the entire power run. See Dwg. ICC-042, sheet 4.
- * (b) Camera Station 3B (3 cameras) - 16-mm color motion pictures, at normal frame rates and with sound, showing the entire test-stand area and side-shield operations, to provide coverage from start of preparations through full-power run. See Dwg. ICC-042, sheet 4.
- * (c) Deleted.
- * (d) Camera Station 5L (1 camera) - 16-mm color motion pictures, at normal frame rates, showing the mating of the reactor to the test-stand configuration, to provide coverage for the entire mating operation. See Dwg. ICC-042, sheet 4.
- * (e) Deleted.
- * (f) Deleted.

6.3.3 Permanent Station and Control Center Requirements

6.3.3.1 The photographic instrumentation system associated with the actual test firing must be capable of operation in extreme environmental conditions of intense gamma radiation fields, high noise and vibration levels, and across dry, high-temperature desert landscape often involving high winds and dust.

6.3.3.2 The interior of the camera stations, either by their location from the reactor or by adequate shielding techniques, must provide environments throughout the entire test run and shutdown period in which normal photographic films may be kept without undue fogging or other changes due to gamma radiation that would render them unusable for their intended application. Design of the camera stations must also allow for quick access to the cameras by film recovery personnel, so that a minimum amount of time will be spent in a possible radioactive environment after the test. The camera stations must also incorporate design features which will protect and permit the satisfactory operation of the precision cameras, lenses, and control gear in the normal desert

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 6.3.3.2

environment. In addition, the design should withstand falling debris and pieces that may occur as a result of an engine failure or malfunction.

6.3.3.3

*

Because of the intense radiation fields, the photographic instrumentation system must be a remotely operated system that will be capable of being programmed during the test by one or more operators. It shall be designed in accordance with the block diagram in Drawing ICC-173. The sequential photo coverage (Dwg. ICC-042 sheet 2) shall be accomplished by wiring "sequencing" cameras in their respective groups in such a manner that only one camera will operate at any one time except for the slight overlap when one camera is ending its run, and another is accelerating.

6.3.4

Timing Requirements

All cameras providing the technical photographic coverage will have a timing code placed on the film for correlation of the photographic records with other events occurring, or records made during the test. The timing codes shall be imaged on the outer edge of each film record as it moves through the camera by means of a pulsed marker unit, and shall display local time of day. Time code will be provided from the I & C System Central Time-Code Generator by means of neon distribution amplifiers, thus assuring the necessary correlation.

6.3.5

Film Radiation Tolerance Requirements

The total dose of gamma radiation received on the film at any station must not be more than that which will produce:

6.3.5.1

Black-and-White Films

Background density above 1.0.

6.3.5.2

Color Negative Films

- (a) Background density of the three layers above an increase of 0.3.
- (b) A reduction of the slope of the three layers to 0.8 of normal slope.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	6.3.5.2

- (c) A change in the color balance no greater than a 0.20 density in red, green, or blue direction.

6.3.5.3 Color Reversal Films

- (a) Reduction of D-max, 20%.
- (b) A reduction of the slope of the three layers to 0.8 of normal slope.
- (c) A change in the color balance no greater than a 0.10 density in red, green, or blue direction.

6.3.6 Controls

- 6.3.6.1 During engine test runs, all camera stations shall be made operative by remote control (refer to Dwg ICC-173), from a Photo Control Panel at the Control Center. In addition to the remote control of the cameras, local switching capability shall be provided to enable the use of any camera, on any site, by technicians wishing to check film run, etc. Sequencing equipment shall enable sequential cameras to run for accumulated time as indicated on Drawing ICC-042, sheet 2.
- *

6.3.6.2 Photo Control Panel (Instrumentation Console)

The Photo Control Panel shall include the following control and display equipment:

For each camera group, it shall include:

- (1) Start-Stop control switch via automatic camera sequence program.
- * (2) Start-Stop speed-jump control via manual switch.
- (3) Remote-Local-Off switch.

For each camera, it shall include:

- (1) Automatic-Manual selector switch.
- (2) Start-Stop manual switch.
- (3) Local-Remote-Off switch.
- (4) Running-Ready-Out-of-Service lights.
- (5) Remaining Run-Time indicator.

6.3.7 Engine Test Requirements

During the progress of the engine test run, the photographic engineer will manipulate the camera controls to start and stop cameras according to a pre-planned schedule. The engineer, who should be experienced in fundamentals of nuclear-engine operation, must make decisions regarding the coverage as the run progresses. He must be cognizant at all times of running times remaining in all cameras, and of the progress of the run as heard on the control-room net. It will be his responsibility to insure the adequate collection of photographic data and film records.

As soon after the test as radiation levels are sufficiently low to permit access to the stations, the film will be recovered. Film magazines and film loads will be carried in magazine cases to prevent direct contamination of the film magazine and possible confiscation by Radiation Safety Personnel.

6.4 SUBSYSTEM CRITERIA

6.4.1 Introduction

To effectively provide photographic coverage, the following plan is proposed. The plan gives detailed information about camera station locations, camera station design, types of cameras, camera running times, and fields of view for the photographic instrumentation required during the engine test firing. The plan briefly describes the equipment needed to fulfill the requirements for photography of any event or operation other than the engine itself.

6.4.2 Camera Station Design Criteria

Photography of events that occur at times other than during engine test firings which produce a radioactive environment will be covered from non-fixed stations. Cameras and equipment will be used at any location suitable for the camera crew to best obtain the desired results. These cameras will all be capable of being manually operated by cameramen on the scene.

During engine-test firings, fixed camera stations will be used. The camera station locations are shown in Drawing ICC-042; locations which were based on radiation considerations, view of test stand, existing terrain features, atmospheric thermal refraction considerations, and possible coverage of Engine Test Stand No. 2 (ETS-2). The locations selected shall be subjected to site examination, further evaluation, and possible relocation for improved application.

For photography in high gamma-radiation field, extensive precautions must be taken in the design of the stations to effectively shield the camera film, a necessary precaution since gamma radiation produces density on film similar to that produced by light. For Stations 1B, 2B, 3B, and 6B (as shown in Drawing ICC-042) bunker-type stations will be constructed, beneath the level of the existing terrain. Station 3B will be built above the level of the ground, but will have earth moved up to it. A cross section of a typical bunker to be installed is shown in Drawing ICC-046.

The following is a brief description of each station:

(a) Station 1B

- (1) Location - 800-ft NE of ETS-1
- (2) Type - Bunker with periscopes or mirrors
- (3) Radiation

Expect 500r for 20-min. run

Should plan for as high as 1500r for engine destruction tests and ETS-2 coverage
- (4) Shielding - 6-in. lead, 6-in. borax + earth.
- (5) Capability - Will look at ETS-1 or ETS-2 as required. Cameras and periscopes will rotate 90° to view either test stand.
- (6) Number of Cameras - Four.

(b) Station 2B

- (1) Location - 900-ft west of ETS-1.
- (2) Type - Bunker with periscope or mirrors.
- (3) Radiation

Expect 350r for 20-min. run

Could go as high as 1000r for engine destruction tests
- (4) Shielding - 6-in. lead, 6-in. borax + earth.
- (5) Capability - Will look at ETS-1 only, with a 45° view.
- (6) Number of Cameras - Eleven.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 6.4.2

(c) Station 3B

- (1) Location - 2000-ft NNE of ETS-1.
- (2) Type - Raised bunker with mirrors or periscopes.
- (3) Radiation - Expect about 50r, but should plan for 100r on engine destruction runs and ETS-2 coverage. Station may expect fallout from test.
- (4) Shielding - 4-in. lead + earth.
- (5) Capability - Will look at ETS-1 or ETS-2 as required. Cameras and mirrors will have to be rotated about 10°.
- (6) Number of Cameras - Eight.

(d) ~~Station 4TR~~ (DELETED)

- ~~(1) Location - About 5000-ft NNW of ETS-1.~~
- ~~(2) Type - Steel tower, 40-ft high on concrete base.~~
- ~~(3) Radiation - May get 1 to 3r, and some fallout from test.~~
- ~~(4) Shielding - None.~~
- ~~(5) Capability - Will look at ETS-1. Cameras can easily be removed and used at another location.~~
- ~~(6) Number of Cameras - Two.~~

(e) Station 5L

- (1) Location - On locomotive cab.
- (2) Type - Small housing for cameras and control gear.
- (3) Radiation - None to perhaps several r.
- (4) Shielding - None.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 6.4.2

(5) Capability - Will view mating operating from close in - locomotive will then be withdrawn from area and films recovered before run.

(6) Number of Cameras - Two.

(f) Station 6B

(1) Location - 300-ft NNW of ETS-1.

(2) Type - Underground bunker with periscopes.

(3) Radiation

Expect 5000r for 20 minute run.

May go as high as 10,000r on destruction tests.

(4) Shielding - 6-in. borax, 8-in. lead + several feet of earth.

(5) Capability - Will view deflection tube and exhaust during startup with high frame/rate coverage.

(6) Number of Cameras - Two.

* (g) Lenses required for each camera are listed by Station in Volume III, TDS 6.1.

6.4.3 Detail Photographic Plan

6.4.3.1 Pre- and Post-Test Plan

Coverage of events other than the engine-test firings will provide fields of view, running times, film type, etc. as required by the particular task at hand. Sufficient equipment, cameras, and a wide assortment of lenses will be made available to cover any required task. Drawing ICC-042, sheets 1, 2, 3, and 4 show the cameras required. A film viewer, providing an enlarged projected image of individual frames, which can be sequenced frame-by-frame at either slow or fast rates, shall be provided for analysis of sequential and data for analysis films.

6.4.3.2 Test Firing Plan

Coverage of the engine-test firings from the fixed stations is summarized on Drawing ICC-042, sheet 1.

*

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 1.0

APPENDIX 2.1

COUNT SCHEDULE

1.0

GENERAL

The following schedule is preliminary and indicates the important items to be considered in the count. Refer to Drawing ICC-154 which depicts the four phases and time scales of the test operations period.

It is assumed for the purposes of this count schedule that:

The initial facility installation checkout has been completed.

All checkouts required in the MAD Building have been completed.

The engine has been installed on the test stand.

AEC Operations notified, and the test plans coordinated with AEC and contractors.

Two types of count schedules must be developed for engine operation: cold engine on stand, and hot engine on stand.

1.1

PERSONNEL

The count will be conducted at the direction of the Test Director by the Assistant Test Director.

The Test Director (TD) will have at his disposal graphic and visual displays of important critical operating parameters, and will be in direct communication during the count with the following personnel:

Assistant Test Director	(ATD)
Chief Test Engineer	(CTE)
Lead Reactor Engineer	(LRE)
Lead Facilities Engineer	(LFE)
Lead Safety Engineer	(LSE)
Lead Instrumentation Engineer	(LIE)
Lead Controls Engineer	(LCE)

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 1.1

The above named personnel will be in communication with their subordinates in the remote recording areas.

1.2

TIME PERIODS

The time periods involved in the count will be:

<u>Phase</u>	<u>Time Start</u>	<u>Finish</u>
1. Checkout	T - 24 hrs	T - 2 hrs
2. Readiness	T - 2 hrs	T - 0
3. Test Run	T - 0	Test completion (TC)
4. Shut Down	Test completion	T + 30 hrs

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 1.3

1.3 MAJOR TASKS OF COUNT SCHEDULE

The count schedule will in general list the major tasks to be accomplished. The major tasks will be broken down on individual checklists which must be completed and signed off by the Lead Engineer or his subordinate.

1.3.1 Phase 1 - Checkout of Count Schedule

T - 24 hr to T - 2 hr

<u>Initiation Time</u>	<u>Responsi- bility</u>	<u>Task</u>	<u>Completion Time</u>	<u>Signoff</u>
T-24 hr	LSE	a. Obtains weather information for next 48 hours	T-23 hr	
		b. Checks all radiation safety monitoring stations	T-22 hr	
		c. Checks all GH ₂ leak detectors	T-21 hr	
		d. Checks water-deluge system	T-20 hr	
	LIE	Initiates pre-pre-checkout of Data Acquisition and Displays in the Control Center	T-20 hr	
	LFE	Checks capacity of all systems	T-12 hr	
		(1) LH ₂ storage		
		(2) LO ₂ storage		
		(3) Propane storage		
		(4) Duct cooling water supply		
		(5) Electrical power-generation equipment		
		(a) Start 400 cycle MG set		
		(b) Start 28 v dc rectifiers		
		(c) Start Control Point		
		Bldg. ventilating fans		
		(6) GH ₂ supply		
		(7) GN ₂ supply		
		(8) GH _e supply		
		(9) Air conditioning systems

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 1.3.1

<u>Initiation Time</u>	<u>Responsi- bility</u>	<u>Task</u>	<u>Completion Time</u>	<u>Signoff</u>
T-16 hr	CTE & CE	Sets engine program in Ground Test Master Programmer	T-10 hr	
T-12 hr	LSE	a. Activates all radiation monitoring stations	T-11 hr 30 min	
		b. Obtains weather information for next 36 hrs	T-11 hr	
T-12 hr	LFE	a. Checks hydrogen gas flare systems	T-11 hr	
		b. Checks vacuum in LH ₂ run tank and all vacuum-jacketed lines	T-11 hr	
		c. Checks all valves to insure proper position	T-10 hr	
T-10 hr	LSE	a. Places test area in amber condition		
		b. Clears all areas of unauthorized personnel and closes area	T-7 hr	
	CTE	Checks out engine from GSE checkout console	T-7 hr	
	LIE	a. Obtains engine checkout data	T-7 hr	
		b. Obtains pre-pre-firing calibration of Data Acquisi- tion & Displays in the Control Center	T-3 hr	
T-7 hr	LFE	a. Moves side shields around engine and seals.	T-6 hr	
		b. Water-fills side shields		
T-6 hr	LFE	a. Checks operation of exhaust duct steam generation system	T-5 hr	
		b. Starts two 100-hp steam- generator water pumps	T-5 hr 45 min

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 1.3.1

<u>Initiation Time</u>	<u>Responsi- bility</u>	<u>Task</u>	<u>Completion Time</u>	<u>Signoff</u>
	LIE	a. Obtains data on steam generation system checkout	T-5 hr	
		b. Loads all cameras	T-5 hr	
T-5 hr	LSE	a. Clears test stand area	T-2 hr	
		b. Removes control-drum safety locks	30 min	
	CTE	Checks remote engine controls	T-2 hr	
T-4 hr	LFE	a. Checks exhaust duct cooling water system	T-3 hr 30 min	
		b. Purges facility system up to engine interface	T-3 hr 30 min	
		c. Checks availability of electrical power		
		d. Starts diesel generators and synchronize on line	T-3 hr 50 min	
	CTE	Purges all engine systems	T-3 hr 30 min	
T-4 hr	LIE	Initiates Pre-Checkout of Data Acquisition and Displays in the Control Center	T-3 hr	
T-3 hr	CTE	a. Check normal reactor shutdown circuit with the simulator simulating reactor critical at low power		
		b. Check remote scram circuits with control drums simulated at *% open		
		c. Check fixed power scram with power setting simulated at * watts, and period at * seconds		

* To be added at time of test, as required for individual test run.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 1.3.1

<u>Initiation Time</u>	<u>Responsi- bility</u>	<u>Task</u>	<u>Completion Time</u>	<u>Signoff</u>
		d. Check floating power scram with power setting simulated at * watts		
		e. Check period scram utilizing simulator.	T-2 hr	

* To be added at time of test, as required for individual test run.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.3.2

1.3.2

Phase 2 - Readiness of Count Schedule

T - 2 hr to T - 0 hr

<u>Initiation Time</u>	<u>Responsi- bility</u>	<u>Task</u>	<u>Completion Time</u>	<u>Signoff</u>
T-2 hr	LFE	Turns on GH ₂ flare system	T-1 hr	
T-1 hr 55 min	CTE	Open LH ₂ run tank outlet shutoff valve		
	LFE	a. Services LH ₂ run tank	T-1 hr	
		b. Services emergency coolant tank	T-1 hr	
T-40 min	LSE	a. Checks weather	T-35 min	
		b. Clears personnel from test area into CP building	T-30 min	
		c. Places ETS-1 in red condition		
		d. Checks with aircraft to insure area clearance	T-30 min	
	LFE	Opens tie 4160-v breaker	--	
T-25 min	LIE	Initiates pre-firing cali- bration of Data Acquisition and Displays in the Control Center	T-20 min	
T-20 min	CTE	Pressurizes engine GH ₂ actuation system	T-15 min	
	LFE	Pressurizes LH ₂ storage system up to LH ₂ run tank refill valve	T-15 min	
* T-15 min	CTE	a. Tops and pressurizes LH ₂ run tank	T-10 min	
		b. Bleed LH ₂ up to refill valve	T-10 min	
		c. Monitors temperature on recorder	T-10 min	
		d. Pressurizes emergency coolant tank	T-10 min	

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3.2

<u>Initiation Time</u>	<u>Responsi- bility</u>	<u>Task</u>	<u>Completion Time</u>	<u>Signoff</u>
	LFE	a. Initiates engine compartment and duct GN ₂ purge b. Turns on duct flare systems		
	LIE	Starts communications recording system		
T-2 min	LFE	Starts up duct water cooling system	T-1 min	
T-1 min	CTE	Energizes arm Sw and observes ready light		
T-30 sec	LFE	Activates exhaust duct steam ejection system		
T-5 sec	LIE	Starts photo coverage		
T-0	CTE	Closes fire switch.		

1.3.3

Phase 3 - Test Run of Count Schedule

T - 0 Through Test Duration

<u>Initiation Time</u>	<u>Responsi- bility</u>	<u>Task</u>	<u>Completion Time</u>	<u>Signoff</u>
Any Time During Test	CTE	Monitors engine operation	T + TC	
	LRE	Monitors reactor operation		
	LFE	Monitors exhaust duct operation		
	LSE	Monitors radiation levels		
	LIE	Monitors instrumentation operation		
	CTE	a. Manually controls turbopump speed b. Manually controls control drums as required c. Initiates shutdown if test conditions warrant		
	TD	Requests shutdown if test conditions warrant		
T + 1 min	LFE	Reduces steam ejection system flow rate to minimum value		
TC - 1 min	LFE	Increases steam ejection system to nominal value	TC - 30 sec	
T + TC	Program- mer or CTE	a. Initiates programmed shutdown b. Initiates cooldown program	T + 25 hr	

Date 1 June 1962

Par. 1.3.4

**Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC**

1.3.4Phase 4 - Shut-down Phase of Count Schedule

TC to T + 30 hr

<u>Initiation Time</u>	<u>Responsi- bility</u>	<u>Task</u>	<u>Completion Time</u>	<u>Signoff</u>
TC + 1 min	CTE	a. Vents LH ₂ run tank	TC + 5 min	
		b. Closes storage tank outlet shutoff valve	TC + 5 min	
		c. Opens LH ₂ feed line vent valve	TC + 5 min	
	LFE	a. Decreases steam ejection system to minimum value b. Decreases duct coolant water to minimum value		
TC + 5 min	LFE	Shuts off steam ejection system and pumps	TC + 15 min	
TC + 15 min	LIE	Initiates post-firing calibration of Data Acquisition System	TC + 18 min	
T + 20 min	LSE	Determines radiation limits and is responsible for allowing personnel into test area	T + 30 hr	
T + 8 hr	LFE	Synchronize I & C bus to utility bus across tie breaker and shut-down diesel generator	T + 8 hr 10 min	
	LIE	Initiates post-firing checkout of Data Acquisition System	T + 1 hr 5 min	
T + 30 hr	LFE	Shutdown 400-cycle MG sets and 28-v rectifier if no longer required.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 1.0

APPENDIX 2.2

AUTOMATIC CHECKOUT & CALIBRATION EQUIPMENT, ETS-1

1.0

CONTROL BUILDING EQUIPMENT

<u>Location</u>	<u>Function</u>	<u>Description</u>
Adjacent Facilities Control Panel Board	Automatic Calibration and Recording Control	<p>19 x 7 in. panel-mounted module, consisting of assembly of telephone type stepper, timer, time-delay relay, manual and automatic switch.</p> <p>Stepper contains 6 positions; self-stepping or manually advanced. Timer adjusts dwell 1.5-30 sec; 0-10-25-50-75% calibration relay busses energized successively by stepper. Approx 1 sec after energization of each bus, the time-delay relay initiates one cycle of high-speed sampling and digital recording on magnetic tape, by A-D system, of all channels on percent step selected.</p>
Adjacent Facilities Control Panel Board	Automatic Checkout and Recording Control	<p>19 x 7 in. panel-mounted module contains:</p> <ul style="list-style-type: none">(1) Relays for commanding, etc., automatic calibration to assure the 75% position.(2) A memory system capable of storing GO-NO GO acceptance-limit information applicable to each channel to be checked.(3) Means for relaying the above to the comparator in the Data Acquisition System.(4) Initiating sequential comparison in the above, of all channel outputs to be checked. <p>Checkout provided by Data Acquisition System printout of identity and readings of out-of-tolerance channels.</p>

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.0

APPENDIX 2.3

DISCUSSION ON RELIABILITY OF THE DIGITAL DATA ACQUISITION SYSTEM

1.0

INTRODUCTION

The Data Acquisition System design configurations is sufficiently well defined to permit illustrating some reliability considerations of the system. (see Section 5.0 of the criteria for a complete description of the system)

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 2.0

2.0

TEST-CELL BUILDING EQUIPMENT

Calibration and checkout modules located in the Test Cell Building are described in the Data Acquisition Lists.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.0

3.0

CALIBRATION & INSTRUMENT ROOM EQUIPMENT

Calibration equipment located in the Calibration and Instrument Room (location not specified) will be as follows:

3.1

PORTABLE

- a. Resistance (L & N-type bridges, etc.)
- b. Pulse analysis (oscilloscope, medium range)
- c. Voltage (precision vacuum-tube volt meters - VTVM)
- d. Current (ammeters, dc through thermocouple type)
- e. Event-per-unit-time meter, precision generator
- f. Gain (audio generators, VTVM's)

3.2

FIXED

- * a. ~~Flow (tank systems, volume measuring)~~
- b. Temperature (ovens and bridges)
- * c. ~~Force (jacks, secondary standard load cells; commercial test units)~~
- d. Radiation (standard radiation sample, special ranging and azimuth facility.)
- * e. Pressure (dual weight, testers, vacuum pumps)

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.0

APPENDIX 2.3

DISCUSSION ON RELIABILITY OF THE DIGITAL DATA ACQUISITION SYSTEM

1.0

INTRODUCTION

The Data Acquisition System design configurations is sufficiently well defined to permit illustrating some reliability considerations of the system. (see Section 5.0 of the criteria for a complete description of the system)

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962
Par. 2.0

2.0

BRIEF FUNCTIONAL DESCRIPTION

The functional block diagram of the system is given by ICC-091.

There are four groups (denoted by Groups A, B, C and D on ICC-091) each consisting of an analog-to-digital converter, sub-commutator, and 1 to 20 multiplexers. Each multiplexer handles 50 data channels. The number of multiplexers on each group is a function of the sampling rate desired because each group limited to 10,000 data words. For example, on ICC-091, Group C has 200 channels (4 multiplexers x 50 channels per multiplexer), and each channel is sampled at the rate of 50 samples per second. Group A has 50 channels and is sampled at a rate of 200 samples per second, while group D has 1000 channels which are sampled 10 times every second.

*

The series part of the system consists of a digitizing format control, and three tape handlers. A redundant array consisting of duplicates of each item, is under consideration to provide improved reliability if required in future operations.

*

3.0

RELIABILITY GOAL FOR THE SYSTEM

In order to have a reliable Data Acquisition System, reliability must be established as a design goal for the system. It is not enough that the system shall be specified to be reliable; it is also required that criteria for successful operation of the system be specified, and that a probability shall be attached for actual system operation in the prescribed manner. These steps should be accomplished early in the design phase.

The capability of the system should be well defined, and, in addition, the frequency (or some percentage of it) of the system meeting its capability must also be specified. In other words, it is known that the data acquisition system will be capable of acquiring data from N transducers, but the frequency at which the system is expected to retrieve all of this data, or some percentage of it, must also be defined. For example, if the data system frequently acquires only 10% of the data, it would be totally unsatisfactory.

The definition of system success that is established should be one that can reasonably be met with the available time and money. It is known that the probability of successfully acquiring data from each and every channel is minute, and it is also known that the loss of all data is complete failure. Some place within these two extremes is an acceptable definition of success that will meet the following conditions:

- (1) It is operationally adequate.
- (2) The system can be designed, fabricated, and installed with the available funds, so that it has a large probability of achieving success as given by the definition.

For example, the criteria for success might be that data should be acquired from 90% of the channels. A reliability, or probability, of 99% might be established for this definition of success; meaning, that the goal would be to receive 90% of the data for 99 out of 100 tests.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 3.0

The schedule is so tight for the I and C program that it is doubtful if any proof can be provided that the goals are or not met until after the equipment has been operational for quite some time. However, the established reliability goal for the system will have still served its purpose. The reliability goal will provide a basis for reliability improvements in the design, fabrication, and installation of the equipment, and also informs those concerned of what can reasonably be expected of the system. The following is intended to point out some of the factors to be considered in arriving at a definition of success for the data acquisition system.

4.0

CONSIDERATIONS FOR DEFINITION OF SUCCESS

Success for the system could be defined so that data must either be received from a given percentage of all channels, or from a given percentage of channels on each sampling rate. The latter seems the more plausible. It is expected that there will be comparatively few channels on a very high sampling rate, but that these channels will be the more critical ones. Now, if success were dependent on a given percentage of all channels, all of the critical high sampling rate channels could be lost and success still achieved, if the percentage allowed to fail was large enough. These critical channels would probably be repeated in the analog system and at lower sampling rates in the digital system, but it might still be that any definition of success could preclude losing all of these critical channels at their high sampling rate.

Suppose that the criteria for success shall be that data be obtained from a given percentage of channels on each sampling rate. If each of the four groups is on a different sampling rate, then loss of any whole group would mean system failure. Furthermore, if there were only two sampling rates, two groups on each sampling rate, no complete group could be lost unless at least 50% failure of channels on a given sampling rate were allowed. If there were two sampling rates with three groups on one rate and one group on the other rate, 33% failure of channels must be allowed in order to lose a whole group and still achieve success. If all four groups are on the same sampling rate a complete group could be lost if 25% loss of data is allowed. If 25% loss is too great, then only random failure of individual channels and possibly multiplexers could be permitted.

5.0

REDUNDANCY UNDER CONSIDERATION

It may be noted from ICC-091 that a redundant chain consisting of five-channel gate, format control, and two tape handlers is under consideration. This chain would serve as back-up for the complete data channel only.

The reliability configuration for the two tape handlers varies between redundant and series operation with factors of time of a test run, average time required to repair a handler, and average time required to change tapes. These times are for the most part undetermined, so for this analysis the most unfavorable case will be assumed, i.e., that the tape handlers are in series.

The reliability of the gate, format control, and tape handler system without the redundancy is given by:

$$R = R_G R_F R_T^2 \quad (1)$$

where R = reliability of the system

R_G = reliability of the 5-channel gate

R_F = reliability of the format control

R_T = reliability of the tape handlers

Using the same notation, the reliability of the system with the redundant chain is given by:

$$R = 1 - (1 - R_G R_F R_T^2)^2 \quad (2)$$

The increment of reliability that would be gained by using the redundant system is a function of the reliabilities of the individual elements. For all practical purposes, the increment becomes larger as the reliabilities of the individual elements becomes smaller. For example, if $R_G = R_F = R_T = 0.999$, the increment of reliability gained by using the redundant system would be 0.003. But if $R_G = R_F = R_T = 0.90$, the increment of

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 5.0

reliability gained by using the redundant system would be 0.23. It is highly doubtful that a 0.003 increase in reliability would be worth the cost involved, but an increase of 0.23 would be well worth the additional cost. When rough estimates of the failure rates of the individual elements become available, the reliability and cost factors can be evaluated to reach a decision on the redundancy. Also, there are other possible ways in which the redundancy might be incorporated that should be investigated.

6.0

RELIABILITY MODEL FOR THE DATA ACQUISITION SYSTEM

An illustrational reliability model for the Data Acquisition System has been formulated under an assumed definition of success.

It is assumed that the system configuration is exactly that given by ICC-091. It is further assumed that in order to achieve success, data must be acquired from 80% of the channels on each sampling rate. This means that for successful operation, data must be received from 400 of the 500 channels, on Groups A and B, 40 of 50 channels on Group C, and 800 of the 1000 channels on Group D.

The reliability block diagram for the system is shown in Fig. App. 2.3-1. It may be noted that the analog-to-digital converter and the subcommutator are series elements, rather than parallel elements, when using this definition of success.

Figure App. 2.3-1

Reliability Block Diagram of Data Acquisition
Under an Assumed Definition of Success.

The reliability of the system would be given by:

$$\begin{aligned}
 R_S = & \left[\left(\sum_{r=400}^{500} \binom{500}{r} R_C^r (1 - R_C)^{500-r} \right) R_M^{10} \right] \\
 & + \left[\left(\sum_{r=400}^{450} \binom{450}{r} R_C^r (1 - R_C)^{450-r} \right) \binom{10}{9} R_M^9 (1 - R_M)^1 \right] \\
 & + \left[R_C^{400} \binom{10}{8} R_M^8 (1 - R_M)^2 \right] R_{SC}^2 R_{ADC}^2 \\
 & \times \left[\sum_{r=40}^{50} \binom{50}{r} R_C^r (1 - R_C)^{50-r} \right] R_{SC} R_{ADC} R_M \\
 & \times \left[\left(\sum_{r=800}^{1000} \binom{1000}{r} R_C^r (1 - R_C)^{1000-r} \right) R_M^{20} \right] \\
 & + \left[\left(\sum_{r=800}^{950} \binom{950}{r} R_C^r (1 - R_C)^{950-r} \right) \binom{20}{19} R_M^{19} (1 - R_M)^1 \right] \\
 & + \left[\left(\sum_{r=800}^{900} \binom{900}{r} R_C^r (1 - R_C)^{900-r} \right) \binom{20}{18} R_M^{18} (1 - R_M)^2 \right] \\
 & + \left[\left(\sum_{r=800}^{850} \binom{850}{r} R_C^r (1 - R_C)^{850-r} \right) \binom{20}{17} R_M^{17} (1 - R_M)^3 \right]
 \end{aligned}$$

$$+ \left[R_C^{800} \quad \frac{20}{16} \quad R_M^{16} \quad (1 - R_M)^4 \right] R_{SC} R_{ADC} \\ \times R_{ST} \left[1 - (1 - R_G R_F R_T)^2 \right] \quad (3)$$

where

- R_S = Reliability of the system
- R_C = Reliability of an individual data channel
- R_M = Reliability of a multiplexer
- R_{SC} = Reliability of a subcommutator
- R_{ADC} = Reliability of an analog to digital converter
- R_{ST} = Reliability of the system timer
- R_G = Reliability of the five-channel gate
- R_F = Reliability of a format control
- R_T = Reliability of a tape recorder

Equation (3) has no provision for channels which may be placed on more than one of the four groups. If a critical channel is placed on n groups ($1 \leq n \leq 4$) the probability, P , of receiving data from that channel on at least one sampling rate (and if it is assumed that the system configuration is that given by ICC-091) is given by:

$$P = \sum_{r=1}^n \binom{n}{r} (R_C R_M R_{ADC} R_{SC})^r (1 - R_C R_M R_{ADC} R_{SC})^{n-r} \times R_{ST} \left[1 - (1 - R_G R_F R_T)^2 \right]^2 \quad (4)$$

Equation (3) presupposes that the reliabilities of the individual data channels are equal. This is not likely since each channel includes a multitude of functions such as sensing, signal conditioning, and calibration. However, for statistical analysis of the system, an average value would probably be used.

**Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC**

Date 10 Jan 1962
Par. 6.0

The illustration presented does not take into consideration the summary data because the definition of success specifies complete data. However, Equation (3) need be changed only slightly to describe the reliability of the system with respect to the summary data.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 1.0

APPENDIX 2.4

ILLUSTRATIONS OF RELIABILITY ANALYSIS OF I & C SYSTEMS

1.0

INTRODUCTION

In order to insure that a system is being designed with inherent reliability, it should be subject to reliability engineering analysis at various stages of the design. In this analysis it is necessary to derive reliability expressions or equations for the system. A system can be purported to be reliable but reliable is not a very descriptive word. If the system is described by an equation, numerical estimates of reliability can be obtained whose accuracy is limited only by the estimated failure rates of the system's component parts. A numerical value for reliability can provide the basis for improvement of the design if improvement is needed, or it can also help eliminate redundancies which are not worth their cost. Even if failure-rate estimates are not available, a reliability model is still helpful in choosing the optimum design.

Two reliability models of I & C systems are presented to illustrate the approach. Since the design is in the criteria stage, the examples are not detailed. Due to lack of detailed information about the components, no effort has been made to point out significant modes of failure in the examples. However, the examples should give a general idea of analysis procedures, and in addition, some information concerning the reliability of the particular systems chosen as examples.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.0

2.0

THE LH₂ FEED SYSTEM

The purpose of the LH₂ Feed System is to supply liquid hydrogen at a regulated pressure and flow rate to the NERVA Engine.

The system is composed of the following four major subsystems:

- * (1) LH₂ Run Tank Refill
- (2) Run-tank pressurization system
- (3) Run-tank venting system
- * (4) Engine LH₂ supply

Diagrams and functional descriptions of each of the subsystems are included in Section 3.5.2.1 of the criteria.

For purposes of illustration, two definitions of success have been assumed. One definition is oriented toward the normal operation of the system, and the other is safety oriented.

- * All subsystems will be involved in engine tests of longer duration than 540 seconds. This will necessitate replenishing of the supply of LH₂ in the run tank while the test is in progress.

If it is presumed that the criteria for success is

that the system shall work in an optimum manner;
that no stand-by measures, such as venting of the run tank, are necessary;
that failures of such elements as indicator lights are not considered because failure rates of such elements are insignificant compared to those of the operating elements considered;
and that perfect operation of the system when test time exceeds 540 seconds, will involve transferring LH₂ from the remote storage tank to the engine run tank, pressurization of the run tank to some predetermined level at various times, and the efficient and safe transfer of LH₂ from the engine run tank to the engine; then for this definition of success, the system reliability configuration may be shown by Figure App. 2.4-1.

Figure App. 2.4-1

Reliability Configuration of the LH₂ Feed System,
With Success as Defined Above

The elements are all in series (from the reliability viewpoint), which means that each one must function for system success as defined here. If the reliabilities of the individual elements are independent, the reliability of the system, R , would be the product of the reliabilities of the individual elements. It should be noted that system reliability, in this case, will be less than the smallest of the individual element reliabilities. Therefore, it is important that the design organization exercise particular caution in choice of the more complex elements such as the Servo System. In addition, special attention should be given to the flow transducer between the run tank outlet valve and engine inlet valve, because malfunction of this element could be cause for a Scram condition. Redundancy should be considered for this element, although it may not be possible due to size and space limitations.

Suppose success were defined as the prevention of overpressurization of the engine run tank. Overpressurization of the tank could represent a compromise to personnel safety so the system must be reliable.

In normal operation, the run tank pressurizes if the tank pressure is below a set point signal in a Servo System. However, if the system fails and the pressure goes above the desired level,

a number of methods are available to reduce the pressure level. The configuration of possible methods to avoid overpressurization of the tank is shown on Fig. App. 2.4-2. Reliabilities, R_1 , R_2 R_{14} are also assigned to the individual elements on this figure.

Figure App. 2.4-2
Reliability Configuration of Methods to Relieve Pressure in the Engine Run Tank

The configuration is one of stand-by redundancy with test personnel accomplishing the switching from one path to another. If we assume that the switching action is 100% reliable, and that the paths are parallel operating redundancies, the reliability, R , for the system is given by:

$$R = 1 - \left[1 - R_1 R_2 \left[1 - (1 - R_5 R_6)(1 - R_3 R_4) \right] \right] \left[1 - R_7 \right] \left[1 - R_8 \left[1 - (1 - R_9)(1 - R_{10} R_{11} R_{12}) \right] \right] \left[1 - R_{13} R_{14} \right] \quad (1)$$

Although the R_i ($1 \leq i \leq 14$) could be small, the system reliability, R , with such a configuration is comparatively high. For example, suppose $R_1 = R_2 = \dots = R_{14} = 0.8$. The system reliability, R , would be 0.99, which illustrates the safety inherent in the system subject to the assumptions mentioned previously.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.0

3.0

MALFUNCTION CONTROL SYSTEM

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APPENDIX 2.5

AREA WARNING

1.0

PURPOSE

The Area Warning System is a system of red, yellow, green, and magenta lights, and sirens or gongs, to warn personnel of dangerous areas of operation. This is accomplished by means of rotating beacons and "traffic" signals on the test stand, buildings, and roadways, thus providing visual notice of these conditions to the areas of operation and to personnel approaching the site. The sirens serve to warn of a dangerous condition or an impending test. It is intended that this system supplement the Public Address System.

2.0

USE AND SEQUENCE

The use and sequence of the Area Warning System of lights and sirens shall be as follows:

- (a) Green - A green light shall indicate safe exit from building, and safe entrance to areas. All green lights shall be steady.
- (b) Yellow - A yellow light shall indicate a potentially hazardous condition, or shall be a warning period preceding a "red" signal.
- (c) Red - A red light shall mean no passage through the door, and/or no entrance to the area. No person may pass a red light except in the direction of safety.
- (d) Flashing Red - Flashing red shall be reserved for special warning to be designated. Rotating beacons are not intended to be included in this definition.
- (e) Magenta - A magenta light shall indicate radiation danger, with steady, flashing, and rotating lights indicating progressively increasing dangerous conditions.

3.0

SYSTEM OPERATION

The control signals for the lights and sirens originate from the Safety Console in the Control Center and in the control racks in the Forward Control Room, and are transmitted as 28 v. dc. (see Dwg. ICC-037) The standard control circuits shall be employed as far as possible.

The control signals operate relays which in turn switch 115 v, ac power to the selected light. The ac power is obtained from a local lighting panel.

4.0

SYSTEM FUNCTIONS

4.1

CONTROL CENTER

The Control Center control functions are

- (a) Area Green - all green lights are on.
- (b) Area Yellow - all green lights are off, all yellow lights are on.
- (c) Area Red - all green lights are off, all yellow lights are off, all red lights are on.
- (d) Area Red Flashing - all green lights are off, all yellow lights are off, all red lights flash, beacons do not "flash" electrically but continue to run.
- (e) Test Stand Yellow - all green lights in the test stand area are off, all other green lights are on. Yellow lights in the test stand area are on.
- (f) Test Stand Red - all green and yellow lights in the test stand area are off, all other green lights are on. The red lights in the Test Stand area are on.
- (g) Siren - the siren on the test stand and on the Fill Station Building are on.

4.2

FORWARD CONTROL ROOM

The following functions shall be controlled from the Forward Control Room:

I, App. 2.5-2

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 4.2

(a) Fill Station Yellow

The beacon on the Fill Station Building will be "yellow"; all other lights remain green.

(b) Fill Station Red

The beacon on the Fill Station Building will be "red"; all other lights remain green or yellow.

(c) Relay Box Operation

The green lights shall be "On" when there is an absence of any signal otherwise. Since this is the usual condition, no relay need be energized for this condition.

The yellow lights shall turn On with the presence of polarized 28 v, dc on a pair of wires. The "yellow" relay shall be interlocked to turn off the green light.

The red light shall turn on when the proper signal is supplied. The "red" relay shall be interlocked to turn off the yellow and the green lights.

The flasher system shall operate when a signal for flashing red is present. The "flasher" relay shall turn on a flasher and shall turn off the steady red, the yellow, and the green lights.

The siren shall turn on and run only when the siren signal is present. It shall not affect the lights or be affected by them.

- (d) The above description implies a built-in priority system. If then two signals from two places, or the same place, are present, the signal calling for the higher level or warning shall have priority.

4.2.1

Beacons

The rotating beacons shall be continuous duty, with 500-watt bulbs. The cover shall be pyrex glass. One unit shall have green glass,

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 4.2.1

one yellow glass, one red glass. They shall be so mounted that the red unit is above the other two, the yellow unit below the red, and the green unit below the yellow unit. A siren, or dual units if required, can be mounted on the same standard, below the green light.

4.2.2

Sirens

Sirens shall be weather proof and of such a size as to properly blanket the area with sound.

4.2.3

Door Lights

Door lights shall have 100-watt incandescent bulbs. The left bulb shall have a green glass cover; the center bulb, a yellow glass cover; and the right hand unit, a red glass cover. They shall also be provided with metal guards.

5.0

LIST OF LIGHT LOCATIONS

(a)	Top of Test Stand	Beacons, siren
(b)	Test Cell Equipment Room	Door lights
(c)	Test Cell Building Corridor	Door lights
(d)	Forward Control Room	Door lights
(e)	Top of Fill Station	Beacons, siren
(f)	Inside Fill Station Building Elect. Equipment Room	Door lights
(g)	Entrance to Tunnel	Door lights
(h)	Stairway Exit from Control Point Building	Door lights
(i)	Tunnel Exit from Control Point Building	Door lights
(j)	Utility Equipment Building inside Door	Door lights

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 5, 0

(k)	Utility Equipment Building
Roof	Beacons
(l)	Roadways at Test-Site Entry
Points	Traffic lights

TABLE APP. 2.5-1

SAFETY SYSTEM WARNING DEVICES — VISUAL AND AURAL

Type Warning Sign	Visual Warning Light	Aural Warning	Hazard	Use
DANGER	1. Red, blinking		Stored energy devices such as: voltage, magnetic fields, pressure, explosives	
DANGER		Bell, single stroke	Magnetic fields	Magnets
DANGER		Bell, single stroke	High pressure	High pressure systems
DANGER		Horn, steady	High explosives explosive gases	Test facilities ready to fire, potential explo- sive atmosphere
			Other (red blinking light is not limited to the above)	
DANGER	2. Red, steady		High voltage on	Power supplies
DANGER	3. Red, rotating beacon		See 1 and 2	Used for large area coverage
CAUTION	4. Yellow, blinking		Excavations, road- blocks, hazardous operating areas	Where extreme caution is necessary
CAUTION	5. Yellow, steady		Potential hazard in area	Safety-run box. Not limited to this however

I, App. 2.5-6

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date
Par.

TABLE APP. 2.5-1 (cont.)

Type Warning Sign	Visual Warning Light	Aural Warning	Hazard	Use
CAUTION	6. Yellow, rotating		Potential hazard in area	Used for large area coverage
CAUTION		Bell, multi-stroke	Any heavy moving object	Crane in motion
CAUTION OR DANGER		Bell, multi-stroke	Various types of equipment malfunction	Trouble alarm
EVACUATION (Building Emergency)	7. None	Horn, Klaxon type	Evacuation of building for any reason - fires, toxic materials, etc.	Building evacuation
SAFE	8. Green, steady		None - example: high voltage off	Safe condition
RADIATION	9. Magenta, blinking	Chime, pulsed	Radiation existing	Indicates beam or other radiation coming on. Do not enter.
RADIATION	10. Magenta, steady	Horn, pulsed	Radiation imminent	Indicates beam or other radiation coming on. Do not enter.
RADIATION	11. Magenta, rotating beacon	Chime, pulsed	Radiation existing	Large area coverage. do not enter.
RADIATION		Siren, inside building only	Criticality accident	Building area evacu- uation criticality

I, App. 2.5-7

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	2.6

APPENDIX 2.6

RADIATION MEASUREMENT EQUIPMENT

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APPENDIX 4.1

FACILITIES SYSTEMS

Various facility systems are necessary to accomplish the overall objective of testing nuclear rocket engines. Each of the facility systems in turn will have several functions which it must be capable of performing in order to achieve the objective. The various facility systems and their functions are tabulated below. Numbers shown are paragraphs in this appendix describing sequence of operations of these systems.

<u>Paragraph</u>	<u>Page</u>	
<u>1.0</u>	1.0-1	<u>HYDROGEN SYSTEM</u>
<u>1.1</u>	-1	LH ₂ transfer from truck to main LH ₂ storage dewar.
<u>1.2</u>	-4	Pressurization of main LH ₂ storage dewar with GH ₂ .
<u>1.3</u>	-5	LH ₂ transfer from main LH ₂ storage dewar to H. P. LH ₂ run tank.
<u>1.4</u>	-7	Pressurization of H. P. LH ₂ run tank with GH ₂ .
<u>1.5</u>	-8	LH ₂ transfer from main LH ₂ storage dewar to engine run tank.
<u>1.6</u>	-10	LH ₂ transfer from main LH ₂ storage dewar to H. P. GH ₂ storage bottle.
<u>1.7</u>	-12	GH ₂ transfer to GH ₂ headers.
<u>2.0</u>	2.0-1	<u>OXYGEN SYSTEM</u>
<u>2.1</u>	-1	LO ₂ transfer from truck to main LO ₂ storage dewar.
<u>2.2</u>	-3	Pressurization of main LO ₂ storage dewar with GN ₂ .
<u>2.3</u>	-4	LO ₂ transfer from main LO ₂ storage dewar to H. P. LO ₂ run tank.
<u>2.4</u>	-5	Pressurization of H. P. LO ₂ run tank with GN ₂ .
<u>2.5</u>	-6	LO ₂ transfer from main LO ₂ storage dewar to steam generator.
<u>3.0</u>	3.0-1	<u>HELIUM SYSTEM</u>
<u>3.1</u>	-1	Helium transfer from truck to 3600-psig storage bottles.
<u>3.2</u>	-4	Helium transfer from 3600-psig storage bottles to helium headers.

<u>Paragraph</u>	<u>Page</u>	
<u>4.0</u>	4.0-1	<u>NITROGEN SYSTEM</u>
<u>4.1</u>	-1	LN ₂ transfer from truck to LN ₂ storage dewar.
<u>4.2</u>	-2	Pressurization of LN ₂ storage dewar with GN ₂ .
<u>4.3</u>	-3	LN ₂ transfer from LN ₂ storage dewar to cooling-gas system.
<u>4.4</u>	-4	GN ₂ transfer from truck to 3600-psig gas storage bottles.
<u>4.5</u>	-5	GN ₂ transfer from 3600-psig gas storage bottles to GN ₂ headers.
<u>5.0</u>	5.0-1	<u>PROPANE SYSTEM</u>
<u>5.1</u>	-1	Propane transfer from truck to propane storage tank.
<u>5.2</u>	-2	Pressurization of propane storage tank with GN ₂ .
<u>5.3</u>	-3	Propane transfer from propane storage tank to steam generators.
<u>5.4</u>	-4	Propane transfer from propane storage tank to hydrogen flares.
<u>6.0</u>	6.0-1	<u>COLD GAS SYSTEM</u>
<u>6.1</u>	-1	Startup operations
<u>6.2</u>	-2	Cooling operations
<u>6.3</u>	-3	Shutdown operations
<u>7.0</u>	7.0-1	<u>STEAM GENERATOR SYSTEM</u>
<u>8.0</u>	8.0-1	<u>HYDROGEN GAS FLARE SYSTEM</u>
<u>8.1</u>	-1	GH ₂ burning flare stack for main LH ₂ storage Dewar.
<u>8.2</u>	-3	GH ₂ burning flare stack for engine test stand.
<u>8.3</u>	-4	GH ₂ burning flare for outlet of test stand deflector duct.
<u>8.4</u>	-5	GH ₂ burning flare stack for engine gas generator.
<u>9.0</u>	9.0-1	<u>VACUUM SYSTEM</u>
<u>10.0</u>	10.0-1	<u>GAS COMPRESSION SYSTEM</u>
<u>11.0</u>	11.0-1	<u>PROCESS WATER SYSTEM</u>
<u>11.1</u>	-1	Process water from demineralizing water plant to main storage tank.
<u>11.2</u>		Process water from main storage tank to test facility.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par.

<u>Paragraph</u>	<u>Page</u>
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<u>11.3</u>	Demineralized water plant.
<u>11.4</u>	Demineralized water to test stand radiation shields.
<u>11.5</u>	Demineralized water for deflector duct cooling.
<u>11.6</u>	Facilities safety water deluge system.
<u>11.7</u>	Process feed water to steam generator.

1.0

HYDROGEN SYSTEM

The Hydrogen System is provided for safely handling, storing, and transferring liquid and gaseous hydrogen in conducting test programs in support of development of nuclear rockets. The sequence of operation of the Hydrogen System is described in the following paragraphs:

1.1

LH₂ TRANSFER FROM TRUCK TO MAIN LH₂ STORAGE DEWAR

- (1) Place truck on scales in unloading position.
- (2) Remove scale safety stops.
- (3) Weigh and record gross truck weight.
- (4) Connect grounding cable to truck.
- (5) Check truck unloading area water sprinkler pressure.
- (6) Check for proper operation of main LH₂ storage dewar flare stack FS-3801.
- (7) Check GHe purge header pressure.
- (8) Precheck valves for correct position:

<u>Close Valves</u>	<u>Open Valves</u>
38-GLV-23 and flange	38-RSV-257
38-PCV-179	27-GLV-17
38-RSV-80	27-GLV-376
38-GLV-14	
38-DV-3	
38-DV-4	
38-RSV-219	
38-GLV-1	
27-GLV-13	
27-GLV-327	
27-GLV-329	
27-RSV-26

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.0

- (9) Start Vacuum Pump VP-3801.
- * (10) Open Valve 27-RSV-265 from Control Center to provide helium to Valve 27-PRV-15, pressure indicated on 27-PI-65.
- (11) Open Valves 38-RSV-219, 38-DV-4, 38-GLV-14.
- (12) Pump Line 17-VA-1"-AV to 1-mm Hg, as indicated by 38-PI-93.
- (13) Close Valve 38-DV-4.
- (14) Open Valve 27-GLV-13 to allow helium transfer to Line 1-LH-2"-LV.
- (15) Open Valve 38-GLV-1 and allow helium flow for 10 sec.
- (16) Close Valves 27-GLV-13 and 38-GLV-1.
- (17) Open Valves 38-DV-4 until 38-PI-93 reads 1-mm Hg.
- (18) Close Valve 38-DV-4.
- (19) Open Valve 27-GLV-13 to allow helium to enter Run Line 1-LH-2"-LV until line pressure is 5 psig.
- (20) Open Valve 38-GLV-1 and run full helium flow for 10 sec.
- (21) Close valves in following sequence:
 - 27-GLV-13
 - 38-GLV-1
 - 38-GLV-14
 - 27-GLV-17
- (22) Open Valves 27-GLV-13 and 27-GLV-9 to purge hose connection to truck, and continue to slow purge while connecting hose to truck.
- (23) Close Valve 27-GLV-13.
- (24) Pressurize truck system (by truck supply).

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.0

- (25) Open Valves 38-RSV-80 and 38-RSV-257 from the Control Center.
- (26) Open truck discharge valve and transfer LH_2 from truck to LH_2 Storage Dewar V-3801.
- (27) Close Valve 27-GLV-9.
- (28) Open Valve 27-GLV-13 and purge line with helium gas for 10 sec.
- (29) Close Valve 27-GLV-17.
- (30) Open Valve 27-GLV-9 to purge truck connecting hose and truck discharge valve with helium.
- (31) Shut off truck discharge valve.
- (32) Close Valve 38-RSV-80 from the Control Center to maintain GH_2 atmosphere in Line 1-LH-2"-LV for standby.
- (33) Close Valve 27-RSV-265 from Control Center.
- (34) From the Control Center, set the desired control pressure on 38-PCV-179 and close Valve 38-RSV-257.
- (35) Disconnect truck discharge hose and replace dust cap on facility discharge line.
- (36) Disconnect grounding cable between truck and facilities ground and replace on facility grounding lug.
- (37) Weigh empty truck and print ticket.
- (38) Reposition scale platform and beam safety lock.
- (39) Remove truck from scale platform.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 1.2

1.2

PRESSURIZATION OF MAIN LH₂ STORAGE DEWAR WITH GH

- (1) It shall be established, for operating purposes, that the LH₂ Storage Dewar V-3801 contains liquid hydrogen, and that all necessary safety precautions have been taken. Before pressurizing the LH₂ Storage Dewar, all valves shall be in the shut-off position, EXCEPT Valve 38-GLV-380. Valve position lights shall be located on the Facilities Picture Graphic Control Panel located in the Control Center.
- (2) Position set-point on 38-PIC-248, located in the Control Center, to zero, closing Valves 38-PCV-248 and 38-PCV-179. Valve 38-PCV-179 is positioned from the output of Controller 38-PIC-248 on Valve 38-PCV-248.

By manual operation, SLOWLY, position control set point for Valve 38-PCV-248 to desired operating vessel pressure which will be indicated on Pressure Indicator 38-PI-68A located on Facilities Panel in the Control Center. After vessel has reached desired pressure, switch controller to automatic operation. The vessel will now be ready for transfer of LH₂ to any desired transfer point. The maximum pressure for the LH₂ Storage Dewar V-3801 is 100 psig.

1.3

LH₂ TRANSFER FROM MAIN LH STORAGE DEWAR TO H.P.
LH RUN TANK

- (1) Position valves for evacuation of H.P. LH₂ Run Tank, V-5002

Close Valves

Open Valves

38-RSV-83	38-GLV-640
50-RSV-252	50-RSV-106
50-RSV-107	50-RSV-119
50-RSV-109	50-RSV-183
50-DV-45	50-GLV-53
50-DV-41	50-GLV-185
38-DV-6	50-RSV-110
38-RSV-255	50-DV-1043
50-RSV-143	50-RSV-254
50-RSV-188	50-RSV-253
50-DV-691	
50-DV-79	
50-DV-63	
50-RSV-138	

- (2) Open Valve 50-RSV-218 and 50-DV-1043, which is a hand valve, normally open.
- (3) Start Vacuum Pump VP-5001 and pump system down to 1-mm Hg.
- (4) Close Valves 50-RSV-218.
- (5) Shut off Vacuum Pump V-5001.
- (6) Purge evacuated system with helium by opening Valve 38-RSV-255 until system reaches 5-psig pressure, as indicated by Pressure Gauge 50-PI-97A located on Facilities Panel in Control Center.
- (7) Close Valves 38-RSV-255, 50-RSV-183, and 50-RSV-110.
- (8) Open Valve 50-RSV-109 to vent header.
- (9) Open Valve 38-RSV-83 to allow LH₂ to pass into H.P. LH₂ Run Tank from pressurized main LH₂ storage dewar.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.3

- (10) Watch Liquid Level Recorder 50-LR-17 located in Control Center until desired level is reached in H. P. LH_2 Run Tank.
- (11) Close Valve 38-RSV-83 to stop LH_2 flow.
- (12) Open Valve 38-RSV-255 and purge for 10 sec to empty Line 5-LH-2"-HV of LH_2 .
- (13) Close Valves 38-RSV-255, 50-RSV-106 and 50-RSV-109. The H. P. LH_2 Run Tank, V-5002, is now ready for pressurization.

1.4

PRESSURIZATION OF H. P. LH₂ RUN TANK WITH GH₂

- (1) Position valves for evacuation and purge of Pressurization Header

Closed Valves

50-RSV-106
50-RSV-107
50-RSV-110
50-RSV-253
50-RSV-285
50-PCV-250
50-RSV-254

Open Valves

50-RSV-185
50-RSV-109
50-RSV-286

- (2) Position set point on pressure indicator controller 50-PIC-250 to zero (0) to close valve 50-PCV-250.
- (3) Open valve 50-RSV-185.
- (4) Open valve 50-RSV-286.
- (5) Slowly open valve 50-PCV-250 manually until desired header pressure is reached and place 50-PIC-250 on automatic control. The high pressure liquid hydrogen run tank is now ready for transfer of LH₂ contents to other systems.

1.5

LH₂ TRANSFER FROM MAIN LH₂ STORAGE DEWAR TO
ENGINE RUN TANK

It shall be established that all safety precautions for both personnel and equipment will have been taken before LH₂ is transferred from the LH₂ Storage Dewar, V-3801, to the Engine Run Tank, V-5001.

- (1) Position valves for system evacuation

Close Valves

50-RSV-132
50-RSV-142
50-RSV-284
50-RSV-283
50-RSV-261
50-RSV-83
50-RSV-188
50-RSV-143
50-RSV-287
50-RSV-255
50-RSV-150
50-RSV-136
50-RSV-106

Open Valves

50-PCV-165
50-RSV-186
50-RSV-252
50-RSV-129
50-RSV-128
50-PCV-180

- (2) Open Valve 50-RSV-138.
- * (3) Start Vacuum Pump VP-5001, and evacuate to 1 mm Hg of water, as indicated on Pressure Gauge 50-PI-99A located in Control Center.
- (4) Close Valve 50-RSV-138.
- (5) Open Valve 50-RSV-287, allowing low-pressure purge helium, to fill evacuated vessel and piping.
- (6) Pressurize system with helium to 5 psig, as indicated on Pressure Gauge 50-PI-99A, located in Control Center, and close Valve 50-RSV-287.

- (7) Close Valve 50-RSV-186 to entrap helium purge gas in Line 4GH-6"-AS between Valves 50-RSV-283 and 50-RSV-186.
- (8) Open valves 50-RSV-128 and 50-RSV-130, allowing helium purge pressure to bleed off to Vent Header 20-GH-12-AS, which runs to Flare Stack FS-5001.
- (9) Open Valve 38-RSV-83, allowing transfer of LH₂ from LH₂ Storage Dewar, V-3801, to Engine Run Tank, V-5001.
- (10) Liquid level will be recorded on Liquid Level Recorder 50-LR-10 located in Control Center.
- (11) Close Valves 38-RSV-83 to stop flow of LH₂ from storage dewar.
- (12) Open Valve 38-RSV-255 and allow helium to purge Line 3-LH-6"-LV for 10 sec.
- (13) Close Valves 38-RSV-255, 50-RSV-252 and 50-RSV-129, 50-RSV-128 and 50-RSV-132. The LH₂ Engine Run Tank, V-5001 is now ready for pressurization.
- (14) Position control set point on Pressure Indicator Controller to zero, closing Valve 50-PCV-165.
- (15) Open Valve 50-RSV-283.
- (16) MANUALLY and SLOWLY, raise pressure control set point, on Pressure Controller 50-PC-165, to desired tank pressure as noted on Pressure Gauge 50-PI-99A located in Control Center. After desired pressure has stabilized, switch Pressure Controller 50-PC-165 to automatic operation.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.6

1.6

LH₂ TRANSFER FROM MAIN LH₂ STORAGE DEWAR TO
H. P. GH STORAGE BOTTLES

- (1) All safety precautions, established by operations, shall be observed at all times. This involves the precalibration and testing of all pressure-relief valves, pressure-reducing valves, car-seal-open or shut-off valves to pressure-relief valves, proper water pressure in the sprinkling and deluge systems, control of operations personnel in transfer and equipment areas, and to be sure that all lines are purged and contain the proper gases. All purge gases shall discharge to flare stacks.
- (2) Hydrogen lines and vessels shall be purged with helium.
- (3) Oxygen lines and vessels shall be purged with nitrogen.
- (4) Propane and nitrogen lines and vessels shall be pressurized with nitrogen.
- (5) H. P. GH₂ storage bottles may be filled from either the truck unloading station, or the main LH₂ storage dewar.
- (6) To fill the H. P. GH₂ Storage Bottles, the piping system shall be properly evacuated and purged with helium.
- * (7) By use of proper valving, controlled from the Control Center, the hydrogen shall be discharged from the main LH₂ storage dewar to Compressor C-3001, with a suction pressure of 5 psig, and a discharge pressure of 300 psig.
- (8) From the discharge of Compressor C-3001, GH₂ can be piped to either of two diaphragm compressors, C-3002A or C-3002B, by proper valving.
- (9) The suction pressure on the diaphragm compressors is 300 psig, and the discharge pressure, 3600 psig.
- (10) From the H. P. diaphragm compressor, GH₂ passes through either Pipe Header 25-HN-1-1/2"-FC or 26-HN-1"-FC, to one or more of the Storage Bottles, V-3201, V-3202, V-3203, V-3204, V-3205, or V-3206.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.6

- (11) GH_2 may be discharged from any of the H. P. hydrogen bottles to Headers 25-HN-1-1/2"-FC, 26-HN-1"-FC, 1-GN-8"-FC, 1-GH-6"-FC, and 1-HE-2"-FC, by preselection and removing blanking plates from desired header.
- (12) The controls for operating the equipment and valves to fill the H. P. GH_2 bottles are made from the Control Center.
- (13) The controls for transferring H. P. GH_2 from the Storage area to the various headers and equipment shall be operated from the Control Center.

1.7 GH_2 TRANSFER TO GH HEADERS

Refer to schematics ICC-025, ICC-084, ICC-076, and ICC-097. GH_2 may be received by transport trailer or provided from the LH_2 boil-off in Storage Dewar V-3801.

- (1) Unloading the storage of GH_2 is handled similarly to gaseous helium, as described in par. 3.0. Since any one or more of the 3600-psig storage bottles may be used for storing GH_2 , the only difference will be in the value numbers shown on ICC-097.
- (2) GH_2 from hydrogen boil-off passes through Valve 38-RSV-81, to the intake of Compressor C-3001 with a discharge pressure of 300 psig. This 300-psig GH_2 passes through a two-stage diaphragm Compressor, C-3002B, and is discharged at 3600 psig to one or more of the storage bottles (see ICC-025 and ICC-097) as selected by operations.
- (3) The stored GH_2 provides 3600-psig GH_2 through valves to one or more of the gas headers, as shown on ICC-084. By removing Blind Flange 32-LB-09, and opening 32-RSV-15 and 32-RSV-11, Line 1-GH-6"-FC is provided with 3600-psig GH_2 . This main GH_2 header provides 3600-psig GH_2 header pressurization are located on the Facility Picture Graphic Control Panel in the Control Center.
- (4) Hydrogen pressurization gas to the LH_2 Storage Dewar, V-3801, is provided by opening Valve 38-RSV-276, and setting the desired pressure on Pressure Controller 38-PIC-248 from the Control Center.
- (5) Hydrogen pressurization gas is provided to the Engine Run Tank V-5001 by opening Valve 50-RSV-283, and setting the desired pressure on Pressure Controller 50-PIC-165 in the Control Center.
- (6) Helium purge gas is provided to the Engine Run Tank by opening Hand Valve 50-GLV-422, and setting the Pressure Reducing Valve 50-PRV-26 to the desired pressure in the field.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.7

- (7) Reactor cooling GH_2 is provided to the cooling-gas system by opening Valve 50-RSV-201, and setting the Pressure Controller 50-PIC-251 from the Control Center (see ICC-077).

2.0OXYGEN SYSTEM

The oxygen system is provided for safely handling, storing, and transferring liquid oxygen used in large quantities in the steam generator. Liquid oxygen may be transferred to the high pressure LO₂ Run Tank, and used in turbine gas generators.

2.1LO₂ TRANSFER FROM TRUCK TO MAIN LO₂ STORAGE DEWAR

- (1) Place transport truck in unloading position, connect facility grounding cable, connect truck discharge hose. Refer to Schematic ICC-019.

Valves 50-RSV-72, 50-RSV-335, 28-NV-90, and 28-RSV-281, are to be in the off-position throughout the transfer of LO₂ from transport truck to LO₂ Storage Dewar V-2801. Valve 28-GLV-92 is to be open at all times.
- (2) Close Valves 27-GLV-81, 28-GLV-91, and 28-RSV-69.
- * (3) Open Valves 28-GLV-715, 28-GLV-632, 27-NV-80 and 28-GLV-323.
- (4) Purge LO₂ transfer line with nitrogen gas for 30 sec, and close Valve 27-NV-80.
- (5) Close Valves 28-GLV-632 and 28-GLV-715.
- (6) Open Valve 28-RSV-69 to vent V-2801 to atmosphere.
- (7) Open Valve 28-RSV-68, and purge LO₂ Storage Dewar V-2801 for 5 min. (Note: If Vessel V-2801 contains LO₂, steps (6) and (7) may be eliminated.)
- (8) Close Valve 28-RSV-68 and 28-GLV-323.
- (9) Open Valves 28-GLV-91 and 27-GLV-81.
- (10) Open transport truck discharge valve, and transfer LO₂ from truck to main LO₂ storage Dewar V-2801.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.1

- (11) Empty truck tank and close truck discharge valve.
- (12) Close Valves 27-GLV-81 and 28-GLV-91.
- (13) Close V-2801 Vent Valve 28-RSV-69.
- (14) Open line vent Valve 27-NV-80 and Valves 28-GLV-632, 28-GLV-715, 28-GLV-323, and flush transfer line of all LO_2 with GN_2 .
- (15) Close Valve 27-NV-80 to atmosphere.
- (16) Close Valves 28-GLV-632, 28-GLV-715, and 28-GLV-323, leaving a nitrogen gas atmosphere in transfer line.
- (17) Disconnect discharge hose from LO_2 transport truck.
- (18) Disconnect grounding cable from vehicle and remove vehicle.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.2

2.2

PRESSURIZATION OF MAIN LO_2 STORAGE DEWAR,
V-2801, WITH GN_2

- (1) Valve 28-GLV-92 shall be in the open position at all times. Refer to schematic ICC-019.
- (2) The GN_2 pressure reducing Valve 28-PRV-09 shall be set for the desired outlet pressure.
- (3) Close Valves 28-GLV-715, 28-GLV-632, 28-GLV-91, 28-RSV-281, and 28-RSV-92.
- (4) Open Valve 28-GLV-323.
- (5) Open Valve 28-RSV-08 to pressurize LO_2 storage Dewar, V-2801, to the desired pressure which will be indicated on 28-PI-49A.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 1 June 1962

Par. 2.3

2.3

LO₂ TRANSFER FROM MAIN LO₂ DEWAR TO H. P. LO₂
RUN TANK

- (1) Close Valves 50-RSV-70, 50-DV-95, 50-RSV-73, 28-NV-90, and 28-RSV-92. Refer to schematic on Dwhs. LCC 017 and -019.
- (2) Valve 50-GLV-630 shall be open at all times.
- (3) Open Valves 50-RSV-71, 50-RSV-72, 28-RSV-281, 28-GLV-715, and 28-GLV-323, and flush transfer line and vessel with nitrogen gas for 30 second.
- (4) Close Valves 28-RSV-281 and 28-GLV-715.
- (5) Open Valve 28-RSV-92, and transfer LO₂ to the H. P. LO₂ run tank to desired level as indicated on Liquid Level Indicator 50-LI-03 located in Control Center.
- (6) Close Valves 28-RSV-92, 50-RSV-72, and vent Valve 50-RSV-71.
- (7) Open Valves 28-NV-90, 28-RSV-281, 28-GLV-715, and purge LO₂ to atmosphere with GN₂.
- (8) Close Valves 28-NV-90, 28-RSV-281, and 28-GLV-715 to entrap nitrogen in transfer line.

2.4PRESSURIZATION OF H.P. LO_2 RUN TANK WITH GN_2

- (1) Close Valves 50-RSV-72, 50-RSV-73, and 50-RSV-71.
- (2) Open Valves 50-FSV-70 and 50-GLV-399
- (3) Manually position set point on pressure indicator of Controller 50-PIC-249 to desired LO_2 run-tank pressure, and set on automatic control. 50-PIC-249 shall be located on the Facility Picture Graphic Control Panel in the Control Center.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	1 June 1962
Par.	2.5

2.5

LO₂ TRANSFER FROM MAIN LO₂ STORAGE DEWAR TO
STEAM GENERATOR

- (1) Refer to schematic ICC-017. Liquid may be transferred to the steam generator from either the 550-gallon 1200 psig
* LO₂ Run Tank, V-5003; or from the 22,000-gallon 400-psig, LO₂ Storage Dewar, V-2801.
- (2) In either case, the transfer-pipe nitrogen purge is the same. Valving and controls at the steam generators will not be known until the steam generator manufacturer submits final drawings and operating instructions.
- (3) To purge the LO₂ transfer line with nitrogen gas from the LO₂ storage to the steam generator, close Valves 50-RSV-72, 28-NV-90, and 28-RSV-92.
- (4) Open Valve 50-NV-636 to atmosphere.
- (5) Open Valves 50-RSV-335, 28-RSV-281, 28, GLV-715, and 28-GLV-323.
- (6) Flush lines with GN₂ for 30 seconds, and close Valves 50-NV-636, 28-RSV-281, and 28-GLV-715.
- (7) Open Valve 28-RSV-92 and 50-RSV-335 to transfer LO₂ from main LO₂ storage dewar, V-2801, to steam-generator LO₂ feed line.
- (8) Close Valve 28-RSV-92 and open Valves 50-RSV-72 and 50-RSV-335 to transfer LO₂ from the H.P. LO₂ run tank to the steam generator LO₂ feed line.
- (9) After using the LO₂ transfer line from either the H.P. LO₂ run tank, or the main LO₂ storage dewar, the transfer line must be purged with nitrogen as covered in (3) through (6), above.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.0

3.0

HELIUM SYSTEMS

The helium system is provided for safely unloading, storing, and transferring gaseous helium to be used for purging and pressurizing the hydrogen system when the low temperature of the hydrogen system would cause freezing out of the gaseous nitrogen. Helium will be received in a gaseous state, unloaded, and stored in one or more of the six 3600-psig storage bottles. Helium gas can be passed through any one of several headers to be used for systems and vessel purging and pressurizing by removal of proper flange blanks.

Helium-transfer pipe lines and vessels shall be purged with helium. Unloading of the helium transport trailer shall be a manual contact operation through the use of manually operated valves located in the unloading area. High pressure helium shall be transferred directly from the transport trailer to the helium storage bottle until the pressure is equalized, at which time the proper hand valves shall be set to transfer the helium through the Gas Compressors C-3001, C-3002A, and C-3002B into one or more of the gas storage bottles.

Helium storage bottle pressure and transfer controls to those areas requiring helium during a test run are located in the Control Center.

3.1

HELIUM TRANSFER FROM TRUCK TO 3600 PSIG STORAGE BOTTLES

- (1) Position truck on weigh scales, record gross weight, connect facility grounding cable to truck, and connect truck discharge hose to proper facility transfer discharge pipe header. Refer to schematic on Dwg. CC-097A.
- (2) Position valves as shown in Table I, line (2).

Open Helium Purge Valve 27-GLV-179, flush line 30 seconds with 10-psig helium gas, and close Valve 27-GLV-179.

- (3) Position valves as shown in Table I, line (3).

Start Diaphragm Compressor C-3002B, open Helium Purge Valve 27-GLV-179, continue to pump to atmosphere discharge for 3 min., shut off compressor, and close Valve 27-GLV-179.

TABLE I

TRUCK UNLOADING OF HELIUM TO STORAGE BOTTLES

	☐ Valve Closed	☒ Valve Opened	☒ Valve Opened - Closed	27GLV179	27GLV184	30GLV189	30GLV191	30RSV59	30RSV58	30GLV236	30RSV60	30GLV651	32RSV04	32RSV207	32RSV01	32RSV28	32RSV29	32RSV03
(2) Purge Transfer Line	/	X	X	X	X											X	X	
(3) Purge Compressor Line	/	X	X	X		X	X	X	X	X	X	X	X				X	
(4) Transfer Helium		X	X	X	X								X	X	X			
(5) Start Compressor C-3002-B		X	X	X		X	X	X	X	X	X	X	X	X	X			
(6) Close Truck Valve		X	X	X		X	X	X	X	X	X	X	X	X	X			
(7) Purge System	/	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X
(8) Shut Down Compressor	/	X	X	X	X								X			X	X	
(9) Shut Down System																		

The following valves are placed in the off-position before helium transfer is made, and are not used throughout the helium transfer: 30GLV192, 30GLV206, 30GLV241, 30RSV264, 30RSV206, 30GLV249, 30GLV652, 32NV261, 32RSV190, 32RSV05, 32RSV195, 32RSV27, and 32RSV212.

- (4) Position valves as shown in Table I, line (4).

Open truck discharge valve and transfer helium to desired gas storage bottle, i. e., V-3201, until pressure in truck bottle equals storage bottle pressure as shown on Pressure Indicator 32-PI-01B.

- (5) Position valves as shown in Table I, line (5).

Start diaphragm compressor C-3002B and continue to transfer helium from transport truck to gas storage bottle at 3600 psig. (WARNING - TRANSPORT TRUCK BOTTLE PRESSURE SHALL NOT BE HIGHER THAN RATED INLET PRESSURE OF PRESSURE REDUCING VALVE 30-PRV-04).

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	3.1

- (6) Position valves as shown in Table I, line (6).

Continue compressor operation until storage bottle pressure reaches 3600 psig, or until truck is empty, and close transport truck discharge valve.

- (7) Position valves as shown in Table I, line (7).

Open 10-psig Helium Gas Purge Valve 27-GLV-179, flush line 30 sec, and close Valve 27-GLV-179.

- (8) Position valves as shown in Table I, line (8).

Turn off Diaphragm Compressor C-3002B, and close valves as shown. Open 10-psig Helium Gas Purge Valve 27-GLV-179, flush line for 30 sec, and turn off Valve 27-GLV-179.

- (9) Close all valves for system shutdown, disconnect truck discharge hose, remove grounding cable, weigh truck, stamp weight ticket, replace scale safety stops, and remove truck from scales. See Table I, line (9).

3.2

HELIUM TRANSFER FROM 3600-PSIG GAS STORAGE BOTTLES
TO HELIUM HEADERS

- (1) Open Valves 32-RSV-01 and 32-RSV-05 to pressurize the 3600-psig helium gas header.
- (2) The 3600-psig helium gas header, 1-He-2"-AC, is run to 5 branch lines with filters, pressure reducing valves, and pressure indicators for providing 10-psig purging helium gas.
- (3) Branch line, 2-He-2"-AC, provides 10-psig purging helium to the truck unloading station.
- (4) Branch line 10-He-2"-FS goes to purge the 3600-psig headers and gas storage area.
- (5) Branch line 3-He-2"-AS goes to purge the 250,000-gallon LH_2 storage Dewar, V-3801.
- (6) Branch line 4-He-2"-AS goes to purge the Run Tank, V-5001 and outlet connection.
- (7) Branch line 5-He-1"-AS goes to purge the LH_2 transfer line, 4-LH-2"-HV.

4.0

NITROGEN SYSTEM

The nitrogen system is provided for safely unloading, storing, and transferring liquid and gaseous nitrogen. Nitrogen gas is used to purge and pressurize the oxygen lines and vessels. Gaseous nitrogen at 500 psig, and at ambient temperature, is used for operating all cryogenic valves and replaces instrument air in all hazardous areas. Nitrogen gas is mixed with liquid nitrogen in atomizers to produce large quantities of cooling gas for purging and after-cooling of the engine reactor for varying periods of time at the termination of a test run. Gaseous nitrogen is used to purge the steam generators after usage to remove propane and oxygen atmosphere. It is also used as a nitrogen blanket in the hydrogen flare stacks during discharge of large quantities of hydrogen.

4.1

LN₂ TRANSFER FROM TRUCK TO LN₂ STORAGE DEWAR

- (1) Position liquid nitrogen transport trailer on scales. Remove scale safety stops, establish gross weight of trailer, and print weigh ticket. Connect facility grounding cable to grounding lug on truck, and connect transfer hose to either the liquid or gas-storage piping as required.
- (2) Liquid hydrogen is transferred from transport trucks to the LN₂ Storage Dewar, V-3601, by opening Vent Valve 36-RSV-327, Hand Valves 36-GLV-585, 27-GLV-582, and truck discharge valve.
- (3) After contents from transport truck have been discharged, close truck discharge valve, and Valves 27-GLV-582 and 36-GLV-585. Close Vent Valve 36-RSV-327, and be sure Valve 36-GLV-589 is open to pressure-relief valves.
- (4) Removes discharge hose between truck and facility piping, disconnect ground cable from truck, weigh empty transport truck, print ticket, replace scale safety locks, and remove truck.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 4.2

4.2

PRESSURIZATION OF LN_2 STORAGE DEWAR WITH GN_2

Pressurization of the LN_2 Storage Dewar, V-3601, is accomplished by the introduction of GN_2 through Line 18-GN-1"-AC and Valve 36-RSV-325 operated from the Control Center.

The Liquid level within the nitrogen vessel is indicated in the Control Center on Level Indicator 36-LI-26. The vessel pressure is indicated on Pressure Indicator 36-PI-181A in the Control Center.

4.3

TRANSFER OF LN₂ TO THE COOLING GAS SYSTEM
(REF. ICC-015)

Liquid nitrogen is transferred to the mixing chamber in the cooling-gas system through Valve 36-RSV-326 and Line 2-LN-4"-BS, and is controlled from the Control Center by Cascaded Flow Controllers 50-FRC-50, 50-FRC-51, 50-FIC-53, and 50-FIC-52.

4.4**GN₂ TRANSFER FROM TRUCK TO 3600-PSIG
GAS-STORAGE BOTTLES**

- (1) Position truck in area for transfer of GN₂.
- (2) Connect grounding cable between truck and facility ground.
- (3) Connect high-pressure truck discharge hose to facility discharge line.
- (4) Close all valves to inlet and discharge of compressors and hydrogen headers.
- (5) Open hand valves to transfer line and on-off valves to the 3600-psig gas storage bottle selected for storage of GN₂.
- (6) Start the 3600-psig discharge pump located on transport truck and discharge GN₂ directly to gas storage bottle. Note: GN₂ transfer from truck to gas storage bottles shall bypass the facilities gas compressors.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.5

4.5

GN₂ TRANSFER FROM 3600-PSIG GAS STORAGE BOTTLES
TO NITROGEN HEADERS

Nitrogen gas may be stored in one or more of the six 3600-psig storage bottles. To transfer 3600-psig GN₂ from storage bottles V-3206, two valves, 32-RSV-26 and 32-RSV-30, are opened and Line Blind 32-LB-19 removed. The 3600-psig nitrogen header 1-GN-8"-FC has seven branch lines with PRV's to provide low-pressure nitrogen, gas to propane storage Vessel V-3401, LO₂ Storage Dewar Pressure Vessel V-2801, LN₂ storage dewar Pressure Vessel V-3601, molecular gas seal for FS-38-1, H. P. LO₂ Storage Vessel V-5003 pressure, radiation shield pressure and seal purge, deflector duct purge, and steam generator purge.

**

Refer to schematic on Dwgs. ICC-025A and -078A.

5.0

PROPANE SYSTEM

Propane is used in a gaseous state for burning hydrogen gas in three flare stacks. Propane in a liquid state is transferred to the steam generators.

Transfer of propane from the transportation truck to the Propane Storage Tank, V-3401, is done by use of local hand valves. Pressurization of the vessel is accomplished by introducing gaseous nitrogen through Valve 34-RSV-330 controlled from the Control Center.

Liquid level in the propane storage vessel will be noted on Level Indicator, 34-LI-11B, mounted locally, and on 34-LI-11A mounted in the Control Center.

5.1

PROPANE TRANSFER FROM TRUCK TO PROPANE STORAGE TANK

- (1) Position transport, truck on scales, remove scale safety stops, weigh, and print out gross weight on weigh ticket.
- (2) Connect facility grounding cable to truck ground lug, connect transfer hose between facility transfer piping and truck. By proper hand valving, vent and purge Line 1-LP-2"-BD, and transfer propane from truck to Propane Storage Vessel V-3401.
- (3) After propane transfer from the truck to the Propane Storage, close hand valves in proper sequence, vent hose, disconnect hose, replace dust caps, disconnect facility grounding cable from truck, and replace on facility grounding lug. Establish truck weight and print out weigh ticket. Replace scale safety stops and remove truck.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 5.2

5.2

PRESSURIZATION OF PROPANE STORAGE TANK WITH GN₂

Pressurization of the Propane Storage Tank with GN₂ is through Line 5-GN-1"-BC with a preset Pressure Reducing Valve 34-PRV-104 and Off-On control by Valve 34-RSV-330, operated from the Control Center.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 5.3

5.3

PROPANE TRANSFER FROM PROPANE STORAGE TANK
TO STEAM GENERATORS

Transfer of liquid propane from the Propane Storage Tank, V-3401, to the steam-generator equipment is made through Line 2-LP-4"-BD by Valve 34-RSV-329 controlled from the Control Center.

The Propane Storage Vessel, V-3401, is pressurized with gaseous nitrogen through Line 5-GN-1"-BS and Valve 34-RSV-330 controlled from the Control Center.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	5.4

5.4

PROPANE TRANSFER FROM PROPANE STORAGE TANK TO
HYDROGEN FLARES

Propane is transferred from the Propane Storage Vessel V-3401 through Line 3-LP-1"-BD and a Pressure Reducing Valve, 34-PRV-105, to the Propane Vaporizer V-3401. From the vaporizer, gaseous propane pressure is controlled by a locally preset pressure reducing valve to Line 4-GP-3"-AD and four Solenoid Valves 38-SV-178, 50-SV-176, 50-SV-175, and 50-SV-118, controlled from the Control Center.

6.0

COLD GAS SYSTEM

The function of the Cold-Gas System is to provide a controlled cold gaseous nitrogen supply for cooling nuclear rocket engines after testing. The cold temperature of the gas is maintained by controlling liquid nitrogen into two atomizers (50-NA-1 and 50-NA-2). One atomizer is sized for a flow rate of 3 to 30 pounds per second, and the other is sized for a flow rate of 0.3 to 3 pounds per second.

6.1

STARTUP OPERATION

- (1) Preset Flow Recorder Controllers 50-FRC-50 and 50-FRC-51 to the predetermined desired flow rate.
- (2) Preset Pressure Reducing Valves 50-PRV-106 and 50-PRV-107 to a predetermined pressure.
- (3)

<u>Closed Valves</u>	<u>Open Valves</u>
36-RSV-326	50-FCV-50
50-RSV-134	50-FCV-51
50-RSV-324	50-FCV-52
50-RSV-334	50-FCV-53
50-RSV-338	
- (4) Open Hand Valves 50-GLV-314 and pressurize Line 30-GN-6"-FS with GN₂ up to Valves 50-FCV-50, 50-FCV-51, and 50-RSV-334.
- (5) Open Valve 50-RSV-326, and fill Line 2-LN-4"-BS to Valves 50-FCV-52 and 50-FCV-53.
- (6) Open Valves 50-RSV-338, 50-FCV-53, and 36-RSV-336.
- (7) When Line 2-LN-4"-BS is full, close Valve 50-FCV-53 (Note: Crack Valve 50-FCV-53 to allow any boiloff gas).

6.2

COOLING OPERATING

- (1) Open Valve 50-RSV-334.
- (2) Open Valve 50-FCV-53 by placing 50-FIC-53 to full-open position.
- (3) Use 50-FIC-53 for cool-down of header and stabilizing temperature of flowing gas. 50-FIC-52 may be also used if necessary.
- (4) Set cooling flow requirement for reactor cooling on 50-FIC-52 and place on Automatic Control.
- (5) Open Valves 50-RSV-134 and 50-RSV-338.
- (6) After reactor engine has stabilized at a predetermined temperature, the programmer will control 50-FIC-52 and 50-FIC-53 for cycling of cooling nitrogen.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 6.3

6.3

SHUTDOWN OPERATION

- (1) Open Valve 50-RSV-338.
- (2) Close Valve 50-RSV-134.
- (3) Close Valve 50-FCV-52 from 50-FIC-52 located in the Control Center.
- (4) Close Valve 50-FCV-53 from 50-FIC-53 located in the Control Center.
- (5) Close Valves 50-RSV-334 and 36-RSV-326.
- (6) Purge Line 2-LN-4"-BS until empty of LN_2 and close Valve 50-RSV-338.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 7.0

7.0

STEAM GENERATOR SYSTEM

The function of the Steam Generator System is to provide large quantities of steam for relatively short periods of time to operate a steam ejector for drawing down the pressure around the nuclear rocket engine to simulate high altitude operation. The system will be made up of two or more generators burning propane and oxygen with water injection.

Details for operation and controls are unavailable, as firm engineering requirements have not been established.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 8.0

8.0 HYDROGEN GAS FLARE SYSTEM

The function of the flares is to eliminate the waste hydrogen (from boil-off, venting and pressure relief, etc.) in the various areas. The ignition panels have the capability of being locally or remotely energized. While energized and upon loss of pilot flame the units automatically attempt relight, and continue to attempt relight until the pilot flame is established or the units are de-energized.

8.1 GH₂ BURNING FLARE STACK FOR MAIN LH₂ STORAGE DEWAR (FS-3801)

8.1.1 Function

The LH₂ Storage Flare, FS-3801, is used to eliminate waste hydrogen from the LH₂ Storage Dewar V-3801 and associated piping.

8.1.2 Description

The assembly consists of a stock, three pilot burners with pilot-flame indicators, remote igniter, acetylene-flame indicator, and a molecular seal to eliminate air from the flare system.

8.1.3 Operation

(a) Startup

- (1) Open 38-NV-550 for N₂ to molecular seal.
- (2) Open 38-SV-178 for propane supply.
- (3) Energize igniter.

(b) Flare Check

To check if pilots are burning, open 38-SV-341. If black smoke is visible, the pilot is burning.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 8.1.3

- (c) Shut-down
 - (1) De-energize igniter.
 - (2) Close 38-SV-178.
 - (3) Close 38-NV-550.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	8.2

8.2 GN₂ BURNING FLARE STACK FOR ENGINE TEST
STAND (FS-5001)

8.2.1 Function

The Test Stand Flare FS-5001 is used to eliminate waste hydrogen from the Run Tank V-5001 and the high-pressure LH₂ Run Tank V-5002 and their associated piping.

8.2.2 Description

The assembly consists of a stock, three pilot burners with flame indicators, remote igniter, acetylene flame indicator, a knock-out drum to vaporize liquid hydrogen before it reaches the burners, and a molecular seal to eliminate air from the flare system.

8.2.3 Operation

(a) Startup

- (1) Open 50-SV-169 for N₂ to molecular seal.
- (2) Open 50-SV-175 for propane supply.
- (3) Energize igniter.

(b) Flame Check

To check if pilots are burning, open 50-SV-339. If black smoke is visible, pilot is burning.

(c) Shut-down

- (1) De-energize igniter.
- (2) Close 50-SV-175.
- (3) Close 50-SV-169.

8.3 GH_2 BURNING FLARE FOR OUTLET OF TEST STAND
DEFLECTOR DUCT

8.3.1 Function

The Deflector Duct Burners, FS-5002, are used to burn the engine exhaust gas as it leaves the deflector duct.

8.3.2 Description

The assembly consists of four pilot burners with flame indicators and two remote igniters (one igniter for each two burners).

8.3.3 Operation

(a) Startup

- (1) Open 50-SV-118 for propane supply.
- (2) Energize both igniters.

(b) Shut-down

- (1) De-energize both igniters.
- (2) Close 50-SV-118.

8.4 GH_2 BURNING FLARE STACK FOR ENGINE GAS GENERATOR

8.4.1 Function

The Gas Generator Flare, FS-5003, is used to eliminate waste gas from the turbopump and gas generator.

8.4.2 Description

The assembly consists of a stock, three pilot burners with flame indicators, remote igniter, acetylene flame indicator and a N_2 purge used to eliminate air from flare system.

8.4.3 Operation

(a) Startup

- (1) Open 50-SV-170 for N_2 purge.
- (2) Open 50-SV-176 for propane supply.
- (3) Energize igniter.

(b) Flame Check

To check if pilots are burning, open 50-SV-340. If black smoke is visible, the pilot is burning.

(c) Shut-down

- (1) De-energize igniter.
- (2) Close 50-SV-176.
- (3) Close 50-SV-170.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	9.0

9.0

VACUUM SYSTEMS

The function of the stationary vacuum pumps and associated headers is to evacuate air and gas from vessels and pipe lines prior to transfer and storage of cryogenic liquids and gases in support of test programs for development of nuclear rocket engines .

Connections have been provided, on cryogenic Dewars requiring evacuated jackets, for use of portable vacuum pumps.

9.1

Vacuum Pump VP-3801 is used for evacuating the LH₂ Storage Dewar and piping system used in storing and transferring liquid and gaseous hydrogen. This vacuum pump is started and monitored at the control panel located at the vacuum pump.

9.2

Vacuum Pump VP-5001 is used for evacuating the Engine Run Tank V-5001, H.P. LH₂ Run Tank V-5002, and associated piping system. This vacuum pump is started and monitored from a control panel located in the test stand equipment room.

10.0 GAS COMPRESSION SYSTEM

10.1 FUNCTION

The Gas Compression System is used for receiving gases from various sources (unloading area, cryogenic vessels, from gas storage area, etc.) and compressing them into the high pressure storage tanks.

10.2 Description

The system consists of a first-stage Compressor, C-3001, and two second-stage Compressors C-3002A and B, which will be used alternately. The system is capable of compressing gases from 0 to 3600 psig. Compressor C-3001 has a range of 0 to 315 psig, and compressors C-3002A and B have a range of 315 to 3600 psig.

10.3 Operation-Startup

- (a) Use the second stage (C-3002A used; C-3002B standby) if the gas supply is above 315 psig.
 - (1) Open 30-GLV-234, -241, -650, and 30-RSV-58 and -61.
 - (2) Close 30-GLV-236 and -652, and 30-RSV-205, -263 and -264.
 - (3) Start Compressor.
 - (4) Operate until suction pressure falls below 315 psi.
- (b) Use C-3001 as follows if the gas supply is below 315 psig.
 - (1) Open 30-GLV-191, -192, and -206.
 - (2) Close 30-GLV-173, -189, -190, -234, and 30-RSV-58.
 - (3) Start compressor.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 10.3

(c) Shutdown

- (1) Stop C-3002A.
- (2) Stop C-3001.
- (3) Close 30-GLV-241 and 30-RSV-61.
- (4) Open 30-GL-173, -190, -193, and 30-RSV-205 and -264 for line venting.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 11.0

11.0

PROCESS WATER SYSTEM

The function of the process water system is to provide water treatment, storage, and distribution of demineralized water throughout the Test Facilities Complex, to be used for cooling and emergency fire requirements in support of nuclear rocket test programs.

11.1

PROCESS WATER FROM DEMINERALIZING WATER PLANT TO MAIN STORAGE TANK

Raw water from area ground wells is treated in a demineralizer Plant D-2001, located in the Equipment Building near the Control Point Building. Demineralized water is processed and pumped by P-2001 at the rate of 150 gpm through Line 64-PW-3"-BS into the 42-inch main process water feed line 35-PW-42"-AW, and stored in a 2,500,000 gal. storage tank, T-3302. A flow recorder controller, 20-FRC-295, located in the Equipment Building, maintains control and record of all demineralized water.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 11.2

11.2

PROCESS WATER FROM MAIN STORAGE TANKS TO TEST
FACILITY

* The 2,500,000-gallon process water storage tank T-3302 is located approximately 8000 feet from the Test Facilities at an elevation about 400 feet higher than the Test Stand. Process water is discharged from this storage tank into a 42-inch main header 35-PW-42"-AW running from the storage tank to the test facility area. Hand operated shutoff valves, 06-BFV-661 and 06-BFV are provided in the 42-inch line near the storage tank. The storage tank is also provided with a drain valve, 06-BFV-660, and a tank mounted liquid level indicator, 06-LI-07.

From the main 42-inch header, a number of subheaders are provided for water distribution to the deluge system, deflector vault movable door fill, engine deflector duct coolant, steam generator, radiation shields, and other equipment coolant headers.

11.3

DEMINERALIZED WATER PLANT

The water demineralizer water plant will be furnished as a packaged plant. Sulfuric acid will be stored in a 4500-gallon tank, T-2003. Caustic soda will be stored in a 4500-gallon tank, T-2002. All the equipment and controls for this plant will be located in the Equipment Building located near the Control Point Building.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 11.4

11.4

DEMINERALIZED WATER TO TEST STAND RADIATION SHIELDS

A 24-inch header feeds water to the four subheaders, providing water for the Test Stand Radiation Shield. A 10-inch line with an 8-inch block valve, 50-RSV-303, provides water to the top shield. A 10-inch line with an 8-inch block valve, 50-RSV-305 provides water to the west-side shield. An 8-inch line with an 8-inch block valve, 50-RSV-306, provides water to the bottom shield. A 10-inch line with an 8-inch block valve, 50-RSV-304, provides water to the east-side shield. The operation of these four block valves is provided on the Facility Graphic Control Panel located in the Control Center.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 11.5

11.5

DEMINERALIZED WATER FOR DEFLECTOR DUCT COOLING

Demineralized water for cooling the Test Stand engine-deflector-duct three subheaders, 38-PW-36"-AW, 49-PW-4"-AW, and 50-PW-12"-AW, is taken from main 42-inch header, 35-PW-42"-AW. These three subheaders have valves, 50-RSV-298 (36"), 50-RSV-296 (4"), and 50-RSV-297 (2"), which are controlled from the Facility Graphic Control Panel located in the Control Center. Three deflector duct outlet valves, 50-FCV-30 (1-1/2"), 50-FCV-31 (6"), and 50-FCV-32 (20"), takeoff from the duct outlet header, 43-PW-36"-AW, and are controlled from three flow indicator controllers, 50-FIC-32, 50-FIC-31, and 50-FIC-30, located on the Facility Graphic Control Panel in the Control Center.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 11.6

11.6

FACILITIES SAFETY WATER DELUGE SYSTEM

The details of this system are not complete because the design is being completed under a separate contract. There will be a number of subheaders provided from take-offs from the 42-inch main header. The block valves and emergency deluge and sprinkler valves will be located and controlled from the Safety Console located in the Control Center.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	11.7

11.7

PROCESS FEED WATER TO STEAM GENERATOR

A 14-inch subheader with a 12-inch block valve 50-RSV-309 is provided from a 24-inch header 35-PW-24"-AW. Details as to control of process water to the steam generator downstream of this block valve are unavailable at this time because engineering design is not complete.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A	
Date	1 June 1962
Par.	1.0

APPENDIX 4.2

ETS-1 INSTRUMENTATION AND CONTROL INTERFACE AREAS⁽¹⁾⁽²⁾

1.0 FILL STATION, AREAS 27, 28, 30 AND 34

1.1 FILL STATION VALVES

- * (a) The following valves shall be terminated at control panels in the Control Point Building, for fill-station operation (flow sheet 3305-M13).

30-RSV-58	30-RSV-61	30-RSV-263
30-RSV-59	30-RSV-205	30-RSV-264
30-RSV-60	30-RSV-206	27-RSV-265

- * (b) "Deleted"

1.2 FILL STATION INSTRUMENT CHANNELS

- * (a) The following pressure transducers shall be furnished by the contractor, and shall be terminated at signal conditioning equipment in the Test Cell Building (flow sheet 3305-M13).

30-PT-36A	30-PT-43A	30-PT-110A
30-PT-37A	30-PT-44A	30-PT-111A

- * (b) To Complete - These channels of data will be required at the Control Point Building.

1.3 PROPANE VALVES

- (a) The cables from the following valves at the propane area shall be terminated in terminal boxes in the Control Point Building (flow sheet 3305-M10).

⁽¹⁾ Drawing or flow-sheet references are to AETRON drawings, accompanying their design in 1961 of Project 400, at NTS, for the AEC, unless identified as ICC drawings.

⁽²⁾ The interface areas, as defined in this appendix, are the divisions between work completed under previous contracts and the work necessary to complete the I & C System.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.3

34-RSV-330 34-RSV-331 34-RSV-329

- * (b) To Complete - Add cables from terminal box to control panels in Control Center.

1.4 LO₂ VALVES

- * (a) The cables from the following valves at the LO₂ Storage Dewar shall be terminated in terminal boxes in the Control Point Building (flow sheet 3305-M8).

28-RSV-68 28-RSV-92
28-RSV-69 28-RSV-281

- * (b) To Complete - Add cables from terminal box to control panels in Control Center.

1.5 PROPANE INSTRUMENT CHANNELS

- * (a) The following instrument channels from the propane tank shall be terminated at signal-conditioning equipment in the Test Cell Building (flow sheet 3305-M10); the transmitters shall be supplied by the contractor.

34-LT-11A 34-PT-118A

- * (b) To Complete - These channels of data will be required at the Control Point Building.

1.6 LO₂ INSTRUMENT CHANNELS

- * (a) The following instrument channels from the LO₂ Storage Dewar shall be terminated at signal conditioning equipment in the Test Cell Building (flow sheet 3305-M8); transmitters, except 28-VT-05, shall be supplied by the contractor.

28-LT-01A 28-VT-05 28-PT-49A

- * (b) To Complete - These channels of data will be required at the Control Point Building.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.7

1.7 DELUGE

This system has not been designed. Details must be obtained from contractor's drawings.

1.8 MISCELLANEOUS EQUIPMENT

- * (a) The following equipment is also in this area (flow sheets 3305-M8, 3305-M10, 3305-M12, and 3305-M13):

30-FS-01	30-PS-01	27-PS-55	28-PdS-33
30-FS-02	30-PS-02	30-PdS-09	27-PdS-48
30-FS-03	30-PS-14	30-PdS-11	36-PdS-59
30-LS-12	30-PS-15	30-PdS-27	30-PdS-67
30-LS-13	30-PS-17	30-PdS-28	30-SV-65
30-FS-20	30-PS-22	27-PdS-29	30-SV-66
30-FS-21	27-PS-53	27-PdS-30	30-SV-67
	34-PS-54	30-PdS-32	

- (b) To Complete - Most of these are involved only with fill operations and are not required elsewhere. For those required, add cable to terminal box Control Point Building, and to monitor-alarm panels.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.0

2.0 H P. GAS STORAGE, AREA 32

(See Flow Sheets 3305-M14, M15, M17)

2.1 VALVES

- (a) The following valves shall be terminated on control panels in the Control Point Building:

32-RSV-01	32-RSV-14	32-RSV-28	32-RSV-212
32-RSV-02	32-RSV-15	32-RSV-29	32-RSV-245
32-RSV-03	32-RSV-16	32-RSV-30	32-RSV-246
32-RSV-04	32-RSV-17	32-RSV-190	32-RSV-247
32-RSV-05	32-RSV-18	32-RSV-191	32-RSV-273
32-RSV-06	32-RSV-19	32-RSV-192	32-RSV-274
32-RSV-07	32-RSV-20	32-RSV-193	32-RSV-275
32-RSV-08	32-RSV-21	32-RSV-194	32-RSV-314
32-RSV-09	32-RSV-22	32-RSV-195	32-SV-218
32-RSV-10	32-RSV-23	32-RSV-207	32-SV-219
32-RSV-11	32-RSV-24	32-RSV-208	32-SV-279
32-RSV-12	32-RSV-25	32-RSV-209	32-SV-280
32-RSV-13	32-RSV-26	32-RSV-210	32-SV-288
	32-RSV-27	32-RSV-211	

2.2 INSTRUMENT CHANNELS

- * (a) The following instrument channels shall be terminated in signal conditioning equipment in the Test Cell Building. The transmitters shall be furnished by the contractor.

32-TT-01	32-TT-05	32-PT-03A	32-PT-10A
32-TT-02	32-TT-06	32-PT-04A	32-PT-13A
32-TT-03	32-PT-01A	32-PT-05A	32-PT-16A
32-TT-04	32-PT-02A	32-PT-07A	32-PT-85A

- * (b) To Complete - These channels of data will be required at the Control Point Building.

2.3 DELUGE

This system has not been designed Details must be obtained from contractor drawings

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.4

2.4 MISCELLANEOUS EQUIPMENT

- * (a) The following items shall be terminated at terminal boxes in the Control Point Building:

32-PS-03	32-PdS-25	32-PS-35
32-PS-23	32-PdS-34	32-PdS-47
32-PS-24		32-PS-51

- * (b) To Complete - Add cables from terminal box to alarm-monitor panels in the Control Center.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 3.0

3.0 LIQUID HYDROGEN STORAGE, AREA 38

(See Flow Sheet 3305-M5)

3.1 VALVES

- * (a) The following valves shall be terminated in terminal boxes in the Control Point Building:

38-RSV-80	38-RSV-88	38-RSV-255	38-RSV-271
38-RSV-81	38-RSV-180	38-RSV-256	38-RSV-276
38-RSV-83	38-RSV-181	38-RSV-257	38-RSV-327
38-RSV-87	38-RSV-219	38-RSV-258	

- (b) To Complete - Add cables from terminal box, to control panels in Control Center.

3.2 PROPORTIONAL VALVES

- (a) The following control valves are terminated at the storage Dewar:

38-PCV-179 38-PCV-248 38-PCV-259

- (b) To Complete - Add cables from valve positioners and position potentiometers to valve controller. See Dwg ICC-009.
Required conduit is existing

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	3.4

3.3 INSTRUMENT CHANNELS

- * (a) The following instrument transducers are terminated at the storage area, with cables to Test Cell Building. The transmitter, except 38-VT-06, shall be furnished by the Contractor.

38-PT-68 38-LT-16 38-VT-06

- * (b) To Complete - These channels of data will be required at the Control Point Building.

3.4 TRANSDUCERS REQUIRED

- * (a) The following transducers are not supplied.

38-LT-02 32-TT-02

- (b) To Complete - Add transducers, conduit, black boxes, cable.

3.5 DELUGE

This system has not been designed. Details must be obtained from contractor drawings.

3.6 MISCELLANEOUS EQUIPMENT

- (a) The following items shall be terminated at terminal boxes in the Control Point Building:

* 38-PdS-36 38-PdS-38 38-PS-19
 38-PdS-37 38-PdS-39 38-FS-08
 38-PdS-67

- (b) To Complete - Add cables from terminal box to alarm-monitor panels in the Control Center.
*

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 4.0

4.0 LIQUID NITROGEN, AREA 38

(See Flow Sheet 3305-M25)

4.1 VALVES, TERMINATED

- * (a) The following valves at Area 36 shall be terminated in terminal boxes in the Control Point Building.

36-RSV-325 36-RSV-326 36-RSV-327

- * (b) To Complete - Add cables from terminal boxes to control panels in the Control Center.

4.2 INSTRUMENT CHANNELS, TERMINATED

- * (a) The following instrument channels shall have cables terminated at signal conditioning equipment in the Test Cell Building. Transmitters, except 36-VT-09, shall be furnished by the contractor.

36-LT-26 36-PT-181 36-VT-09

- * (b) To Complete - These channels of data will be required at the Control Point Building.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	5.0

5.0 TEST STAND, AREA 50

(See Flow Sheets 3305-M6, M7, M8, M18)

5.1 VALVES, TERMINATED

- (a) The following valves are terminated at the Test Stand:

50-RSV-106	50-RSV-107	50-RSV-305	50-RSV-201
50-RSV-109	50-RSV-70	50-RSV-306	50-RSV-218
50-RSV-128	50-RSV-73	50-RSV-309	50-RSV-315
50-RSV-129	50-RSV-254	50-RSV-328	50-RSV-316
50-RSV-130	50-RSV-142	50-RSV-186	50-RSV-317
50-RSV-282	50-RSV-108	50-RSV-261	50-RSV-318
50-RSV-105	50-RSV-143	50-RSV-111	50-RSV-307
50-RSV-110	50-RSV-188	50-RSV-126	50-RSV-308
50-RSV-183	50-RSV-133	50-RSV-125	50-RSV-336
50-RSV-285	50-RSV-322	50-RSV-320	50-RSV-337
50-RSV-284	50-RSV-138	50-RSV-319	50-RSV-136
50-RSV-283	50-RSV-296	50-RSV-134	50-RSV-132
50-RSV-234	50-RSV-297	50-RSV-338	50-RSV-334
50-RSV-252	50-RSV-298	50-RSV-221	50-RSV-72
50-RSV-253	50-RSV-303	50-RSV-222	50-RSV-71
50-RSV-185	50-RSV-304	50-RSV-286	50-RSV-324
			50-SV-282

- (b) To Complete - Add cables from 50-SVB-6 & 7 to control panels. Run 28 v dc power from control power switch panels to boxes.

5.2 WATER CONTROL VALVES, TERMINATED

- (a) The following water control valves are terminated in 50-SVB-6 & 7:

50-FCV-30 50-FCV-31 50-FCV-32

- (b) To Complete - Add cables from SVB to controllers. See Dwg. ICC-010.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.3

5.3

CONTROL VALVES, TERMINATED

- * (a) The following control valves are terminated at the Test Stand:
- 50-PCV-180 50-PC-249 50-PC-250 50-PC-251
50-PCV-165
- (b) To Complete - Add cables from valves to controllers. Conduit is existing. See Dwgs. ICC-011, -012, and -013. Provide necessary controllers.

5.4

CONTROL VALVES, COOL GAS SYSTEM

- * (a) The following control valves are terminated near the Test Stand:
- 50-FCV-50 50-FCV-51 50-FCV-52 50-FCV-53
- (b) To Complete - Add cables from valve controller. Conduit is existing. See Dwg. ICC-012. Provide necessary controllers.

5.5

INSTRUMENT CHANNELS

- * (a) The following transducers shall be terminated in signal conditioning equipment in the Test Cell Building:
50-TT-51	50-FE-52	50-LT-09	50-TT-32
50-TT-52	50-FE-53	50-LT-10	50-TT-36
50-VT-04	50-FT-19	50-PT-194	50-TT-37
50-VT-07	50-FT-52	50-PT-202	50-TT-49
50-VT-08	50-FT-53	50-TT-25	50-TT-50
- (b) To Complete - Terminate cables at signal conditioning equipment.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 5.5

5.6

MISCELLANEOUS EQUIPMENT

- * (a) The following additional equipment is terminated in the Test Stand area:

50-FS-09	50-Pds-45	50-PS-69
50-PdS-40	50-PdS-46	50-PS-70
50-PdS-41	50-PdS-75	50-PS-71
50-PdS-42	50-PS-56	50-PS-72
50-PdS-43	50-PS-68	50-PS-73
50-PdS-45		50-PS-74

- (b) To Complete - Add cables from solenoid valve boxes to control and alarm panels.

5.7

ADDITIONAL MISCELLANEOUS EQUIPMENT

- * (a) The following items are also terminated in this area:

50-PdS-40	50-PdS-46	50-PS-69
50-PdS-41	50-PdS-56	50-PS-70
50-PdS-42	50-PS-13	50-PS-71
50-PdS-43	50-PS-20	50-PS-72
50-PdS-44	50-PS-26	50-PS-73
50-PdS-45		50-PS-74

- (b) To Complete - Add cables from 50-SVB-6 & 7 to alarm-monitor panels.

6.0 MISCELLANEOUS SYSTEMS6.1 FLARE STACKS

- (a) Following are the hydrogen gas flare systems:

LH Storage Area	FS-3801
Gas Generator	FS-5003
Test Stand	FS-5001
Deflector Tube	FS-5002

- (b) To Complete - Run control and alarm channel cable from local control box (existing) near each unit to remote control panels.

* 6.2 SIDE SHIELDS (S-1 and S-2)

6.2.1 Control

- (a) Control relay box will be mounted at the Test Cell Mechanical Equipment Room.
- (b) To Complete - Run cables from relay box to control panels.

6.2.2 Valve Control

- (a) Control units on the shield carts will be wired to connectors that mate automatically.
- (b) To complete - Add cables from fixed connector on test stand, to control panels.

6.2.3 Instrument Channels

- (a) Channels on shield carts will be wired to connectors.
- (b) To Complete - Add cables from fixed connector to test stand to signal conditioning equipment.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	6.3

6.3 TOP AND BOTTOM SHIELDS

- (a) These will be instrumented and cables run to the Test Cell Building.
- (b) To Complete - Terminate cables at signal conditioning equipment.

6.4 DUCT

6.4.1 Duct Positioning

- * (a) Duct positioning control will be completed up to a relay box in equipment chase.
- (b) To Complete - Add cables from relay box, equipment chase, to control panels.

6.4.2 Duct Instrumentation

- (a) Duct instrument channels will be carried through the connector and will terminate in a terminal box in the equipment chase.
- (b) To Complete - Add cables from terminal box, equipment chase, to signal conditioning equipment.

6.5 STEAM GENERATOR

6.5.1 Steam Generator Control

- (a) The control package will be part of the steam-generator "package." Provision will be made for remote control.
- (b) To Complete - Add cables from steam generator control box and pipe chase, to control panel.

6.5.2 Instruments

- (a) All of the instruments relating to the operation of the generator will be a part of the "package."

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
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Par.	6.5.2
------	-------

- * (b) To Complete - Add cables from steam generator in pipe chase, to signal conditioning equipment.

6.6

DUCT ENTRANCE MOVABLE SHIELD

- * (a) Control will have a relay box in the test stand equipment room.
- (b) To Complete - Add cables from relay box, T.S. equipment room, to control panels.

6.7

dc POWER

- * (a) Space has been provided for a rectifier and battery room at the Test Cell Building and in the Utility Equipment Building, for control and indication.
- * (b) To Complete - Add the necessary rectifiers, batteries, switch units, and cables.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	1.0

APPENDIX 4.4

PUBLIC ADDRESS AND INTERPHONE CONSIDERATIONS

1.0 OPERATING MODES

The following list suggests the various operating modes to be expected throughout the test complex in this communication concept:

Multiple checkout and operation of huge rack bays. Personnel are congested in these areas and in many cases will be working side-by-side - possibly at adjoining racks.

Multiple checkout and operation of consoles. Key personnel are working in these areas. and the utmost in flexibility is mandatory.

Office areas where in-and-out traffic is expected.

Supporting rooms. mostly maintenance, requiring modest facilities.

Test-stand and gas-storage areas where personnel cannot expect to be located in the immediate vicinity of a communication outlet most of the time.

Cost versus convenience.

Push-to-talk requirements.

Multi-party conference calls.

1.1 NEED FOR INTERPHONES

In view of these expected conditions, the need for an intercom or interphone system becomes immediately apparent and the advantages and disadvantages of these two systems must be compared.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.1

In general, an intercom system is an open system utilizing small "speakers" or "squawk boxes" which is not adaptable to the multiple checkout, or congested areas. Furthermore, the problems of volume, range, and distortion become very annoying and contribute to requests for message repeats. Therefore, a headset type operation must be made available. However, to satisfy the requirements of the test-stand or gas-storage areas, the system cannot be restricted to headsets, but must have available a means of converting to a speaker system for that particular area.

With these factors taken into consideration, an interphone trunk system with plug-in "speaker-boxes" for listening is suggested. Listening remotely is required for the reasons of headset fatigue, and since many specific working locations are not close enough to an outlet for headset usage, that a speaker must still be used to make it possible for personnel to be called to the headset outlet.

- * The requirement to "talk-back" a short distance from a station is not anticipated to occur frequently, but can be accomplished by using longer cord lengths, thereby preserving the advantages of an interphone over an intercom or "open system."

It is therefore established that headset and small speaker box usage is required for particular locations.

1.2 CONCEPT OF TRUNK SYSTEM

- * A trunk system is necessary to fulfill the requirements of the individual NERVA systems, the Test Director, the LSE, etc. Although it is not difficult to ascertain the required number and type of networks for a given test complex, it is difficult to ascertain the required amount of cross patching, so that a Patch System becomes necessary.

The type of patch system chosen should not be limited to a Central Office system requiring special communication personnel, because it is not flexible enough and does not allow monitoring of all trunks at all stations. Instead, a switch patch system is recommended, wherein individual communication panels are

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	1.2

provided in strategic positions in all high and medium density communication areas. These panels will be serviced by all trunk lines, including local P. A. lines.

* Small transistorized isolation amplifiers for each headset will be grouped and mounted in the communication panel to prevent line loading due to mismatch when so many headsets are connected to a common trunk. These amplifiers will provide high impedance loads to the signal sources during both transmission and reception, allowing approximately 30 headsets to be paralleled with "five" microphones at losses of only 6 decibels.

This feature is unique and does not restrict the system to "push-to-talk." However, "push-to-talk" is a desirable feature, and the mike switch should include a third position for keeping the mike "alive."

1.3 COMMUNICATION PANELS
(deleted)

1.4 P. A. SYSTEM ON COMMUNICATION PANELS
(deleted)

1.5 OVERALL P. A. SYSTEM

The "local" P. A. system as described can be considered to be an adjunct to the interphone system, providing a close-talking, remote-listening intercom. Such a P. A. system, however, will not be entirely adequate.

General paging, safety warnings, announcements, and countdown procedures will require the usage of an overall P. A. system utilizing multiple horn-driver type speakers. This system will provide service for the Test Director, Safety Director, Countdown Reader, and Control Office, and for simultaneous coverage of the entire test complex, or coverage of individual buildings and work areas, including the Test Stand.

Selection of a particular building for coverage will be accomplished at the test consoles by switching a remote unit located in the vicinity of the power amplifier. The relay unit will select groups of speakers

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	1.5

and automatically terminate open lines or line-transformer secondaries, and will also accommodate mike input selection for the Safety Director override feature mentioned earlier, and for the individual mike positions.

Individual microphones will be coupled to the main amplifier via "mixing" amplifiers which, in turn, will be controlled remotely by the console switches and relay unit.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.0

APPENDIX 4.5

PROPOSED ETS-1 FACILITY MODIFICATIONS

1.0 PROPOSED FACILITY MODIFICATIONS AND ADDITIONS

** The following modifications and additions to the ETS-1 Facilities are required in order to conform with the intent of the I & C criteria. These modifications and additions should be reviewed and revised as necessary to comply with the final design of the ETS-1 I & C System.

1.1 (deleted)

1.2 INSTALL FILTER IN LINE 15GH-6"-FC
(deleted)

1.3 PROVIDE GASEOUS HYDROGEN SYSTEM FOR ENGINE ACTUATION SYSTEM

- (a) Provide a pipe takeoff line from Line 15GH-6"-FC to provide 650-psig gaseous hydrogen to three engine control systems actuation tanks.
- ** (aa) Install equipment to provide GH_2 actuation supply to engine.
- (b) Install 3600-psig gaseous hydrogen filter at takeoff point from Line 15GH-6"-FC.
- (c) Provide stainless steel pipe and components from line filter to the three 650-psig tanks.
- * (d) Provide a D/P switch across the filter with a D-P alarm light to be located at the facilities picture graphic panel control board in the Control Center.
- (e) Provide an in-line pressure reducing valve (PRV) to reduce the 3600-psig GH_2 line pressure to approximately 900 psig.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	1.3

- (f) Provide an On-Off 500-psig GN_2 operated remote shutoff block valve (RSV) downstream from the PRV.
- (g) Provide a pressure control valve (PCV), pressure transmitter (PT), and pressure indicator controller (PIC) downstream from the RSV block valve. The PIC shall be located on the Test Operations Console in the Control Center.
- (h) Provide a relief valve (RV) with CSO handle valve and a bypass normally closed On-Off RSV, with the discharge from the RV and the RSV discharging to Lines 21-GH-6"-AS, 20-GH-12"-AS, and KD-5001.
- (i) Provide a check valve (CHV) in line.
- (j) Provide pressure tap, pressure transmitter (PT), local pressure gauge (PI), and remote pressure indicator (PI). The line pressure indicator shall be combined with the PIC provided under par. (g) above.
- (k) Provide necessary pipes and valves to tie the gaseous hydrogen line to the vacuum system, and the He gases purge line with necessary block valves.
- (l) Terminate 650-psig GH_2 line with necessary couplings to attach to engine actuation accumulation tanks.

1.4

PROVIDE HYDROGEN VENTING

- (a) Provide means for venting to test stand the flow stack gaseous or liquid hydrogen entrapped between Engine Run Tank (V-5001) tank discharge valve and the engine inlet valve. This should include a pressure relief valve (RV) with CSO hand valve and a bypass On-Off valve (RSV). The On-Off (RSV) valve shall be actuated from the Test Operations Console in the Control Center.
- ** (b) Provide a mechanical relief valve and a remotely operated shutoff valve for relief purposes in line between tank and engine. This is required to vent gas or liquid trapped in the line between the tank shutoff valve and the engine inlet valve.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.5

1.5

COMPLETE BLOCK VALVE DESIGN

- (a) Complete engineering, design, and specifications of Block Valves 50-RSV-132, 50-FE-14, 50-FT-14, 50-FR-14, 50-PI-100B, 50-PT-100, and 50-PT-100A, located between the Engine Run Tank V-5001 and the engine inlet valve.

The total pressure drop between the Engine Run Tank V-5001 and engine inlet valve shall not exceed 6 psi at 75 lb/sec LH_2 flow rate.

**

- (b) Provide flow metering system between run tank and engine. This is required to determine flow of LH_2 to the engine, and to complete the facility as originally proposed.

1.6

PROVIDE LH_2 BLEED VALVE FROM LINE 9-LH-6"-HV

- (a) Install a line and On-Off (RSV) block valve from Line 9-LH-6"-HV near Block Valve 50-RSV-320. Discharge of new block bleed valve shall pass into GH_2 Vent Line 20-GH-12"-AS.
- (b) This new block-bleed valve shall be actuated from a switch located on the Test Operations Console in the Control Center.

1.7

TEMPERATURE MONITOR LINE 9LH-6"-HV

- (a) Install temperature resistance bulb (TE) in Line 9-LH-6"-HV to determine line temperature and availability of LH_2 at Valve 50-RSV-320.
- (b) Provide temperature transmitter (TT) and temperature indicator (TI) with TI located on Test Operations Console in the Control Center.

**

- (c) Install temperature transducer at the point where RSV 50-RV-686 connects into line 9LH-6"-HV, for the purpose of determining status of emergency LH_2 coolant liquid or vapor, or both.

1.8

RELOCATE 50-PT-192 AND 50-TT-53
(deleted)

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	1.9

1.9

COMPLETE ENGINEERING, DESIGN, DRAFTING, AND
SPECIFICATIONS ON PRESSURE AND TEMPERATURE
INDICATORS IN EMERGENCY LH₂ COOLDOWN LINE
4-LH-6"-HV

- (a) Provide flow element (FE), flow transmitter (FT), flow indicator (FI), pressure tap, pressure transmitter (PT), pressure indicator (PI), temperature element (TE), temperature transmitter (TT) and temperature indicator (TI) on liquid hydrogen emergency cooldown line 4-LH-6"-HV.
- (b) FI shall be mounted on engine picture graphic.
- (c) PI shall be recorded on remote strip chart in Control Center.
- (d) TI shall be recorded on Test Operations Oscillographic recorder in Control Center.
- (e) Provide flow metering system in line 4-LH-6"-HV.

*

1.10

I & C POWER SYSTEM

- (a) Provide a 100-amp, 28-volt rectifier and 100 amp-hour battery in the Utility Equipment Bldg (No. 3320) and a new dc panel, No. DC-10A, with 1-pole breakers in the Control Point Building (No. 3310). This panel shall supply power primarily to data acquisition, pilot valves, and relay control.
- (b) Provide two 5-kw, 120/208v, 3 phase, 400-cycle motor-generator sets operating in parallel in the Fill Station Building (No. 3330) and 2 new 400-cycle panels, No. 400-P-10A, in the Control Point Building (No. 3310) and No. 400-P-40A in the Test Cell Building (No. 3340). The 400-cycle requirements of the engine and reactor shall be supplied from these panels.
- (c) Provide a 400-amp. 28-v rectifier, and a 200-amp-hour battery in the Mechanical and Electrical Equipment and Battery Rooms. A new dc panel with 1-pole breaker (No. DC-40A) in the Electronics Room shall supply the dc

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A	
Date	1 June 1962
Par.	1.10

power requirements, primarily for valves, relays, instrumentation, and control.

- (d) Install a new 45-KVA 4160/480 v, 3 phase, transformer, primary switch, and motor control center, MCC-40I, in the Mechanical and Electrical Equipment Room to supply power to the 28-v rectifier.
- (e) Split the I & C power system in such a manner that two diesel generators shall supply power for the instrumentation, while the remaining generator supplies the motor loads (see Dwg. ICC-006B); for the purpose of preventing transients and modulation in the instrumentation system. To accomplish this, it will be necessary to furnish and install additional switch gear, sync control panels, conduit, wire, etc.

1.11

FUTURE I & C POWER REQUIREMENTS

The design of the exhaust eductor system is not firm at this time, but it is anticipated that there will be requirements for large power loads. These loads must be isolated from the instrumentation bus and connected to a firm and reliable source of power for the tests.

1.12

NETC POWER REQUIREMENTS

Provide a well regulated 200-amp, 28-v dc rectifier and battery, and a 120/208 v, 400 cps, 5-kw motor-generator set and required panel boards, all to be housed in an additional separate building immediately adjacent to the Test-Cell Building. These units will be supplied from a 4160-v utility box feeder through appropriate transformers, air switches, fuses, and motor control center. Service outlets shall provide for all NETC Test Stand and Test-Cell Building requirements. See Dwg. ICC-103.

1.13

NETC TRANSMISSION CABLE SPACE REQUIREMENTS

Provide additional cable tray capacity in the tunnel to accommodate the additional cable requirements of the NETC I & C system.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date	1 June 1962
Par.	1.14

1.14

TUNNEL

The section of tunnel extending from the Control Point Building to the Y will be shared, but tunnel modification will be required in the vicinity of the Forward Control Room for the purpose of increasing the capacity of the cable entry from the tunnel to the Forward Control Room. Present capacity of the existing two-tunnel flow or trenches must be tripled. Two separate additional trenches of the same width (2ft 8 in.), but of twice the depth (new trench depth 2 ft) must be located inboard of the existing trenches as shown on Dwgs ICC-206 and 202. Maximum separation will be provided between control and data acquisition cabling. In addition, each of these two main divisions will be further separated into such groupings as low level, high level, pulsed circuit, etc.

A new extension of the tunnel from the knockout existing at the Y will be provided to ETS-2 (See Dwg ICC-196, -205, and -206. When the ETS-2 tunnel entry to the existing tunnel knockout near the tunnel Y is added, the small portion of tunnel wall between the knockout and the Y will require relocation, as shown in Dwg ICC-205, in order to permit access of equipment past the Y to ETS-2.

The six cable trays in the new section of tunnel to ETS-2 should be increased in size from 3 x 18-in., to 6 x 24-in.

1.15

CONTROL POINT BUILDING

Initially, the Control Point Building will be modified slightly to house the two separate control centers in addition to the other minimized, but necessary, control and recording facilities (see Fig. ICC-204). The wall between the Recorder Room and the Terminal Room will require modification to allow the movement of equipment racks. A temporary separation will have to be added between the Recorder Room and the temporary ETS-1 control center.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	

APPENDIX 4.6

FACILITIES CONTROL VALVES

A = Facility Graphic Control Panel
B = Facility Console

C = Safety Console
D = Test Stand Console

Valve No.	Flow Sheet No.	Valve Location	Control Location				
			Local	A	B	C	D
32-RSV-01	M-14	V-3201 Main Block Valve		X			
32-RSV-02	M-14	V-3201 Pressure Valve		X			
32-RSV-03	M-14	V-3201 Vent Valve		X			
32-RSV-04	M-14	V-3201 Return Valve		X			
32-RSV-05	M-14	V-3201 Distribution Valve		X			
32-RSV-06	M-14	V-3202 Main Block Valve		X			
32-RSV-07	M-14	V-3202 Pressure Valve		X			
32-RSV-08	M-14	V-3202 Vent Valve		X			
32-RSV-09	M-14	V-3202 Return Valve		X			
32-RSV-10	M-14	V-3202 Distribution Valve		X			
32-RSV-11	M-14	V-3203 Main Block Valve		X			
32-RSV-12	M-14	V-3203 Pressure Valve		X			
32-RSV-13	M-14	V-3203 Vent Valve		X			
32-RSV-14	M-14	V-3203 Return Valve		X			
32-RSV-15	M-14	V-3203 Distribution Valve		X			
32-RSV-16	M-15	V-3204 Main Block Valve		X			
32-RSV-17	M-15	V-3204 Pressure Valve		X			
32-RSV-18	M-15	V-3204 Vent Valve		X			
32-RSV-19	M-15	V-3204 Return Valve		X			
32-RSV-20	M-15	V-3204 Distribution Valve		X			
32-RSV-21	M-15	V-3205 Main Block Valve		X			
32-RSV-22	M-15	V-3205 Pressure Valve		X			
32-RSV-23	M-15	V-3205 Vent Valve		X

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	

Valve No.	Flow Sheet No.	Valve Location	Control Location				
			Local	Control Center			
				A	B	C	D
32-RSV-24	M-15	V-3205 Return Valve					
32-RSV-25	M-15	V-3205 Distribution Valve		X			
32-RSV-26	M-15	V-3206 Pressure Valve		X			
32-RSV-27	M-15	V-3206 Pressure Valve		X			
32-RSV-28	M-15	V-3206 Vent Valve		X			
32-RSV-29	M-15	V-3206 Return Valve		X			
32-RSV-30	M-15	V-3206 Distribution Valve		X			
30-RSV-58	M-13	Compressor C-2002 A & B Suction					
30-RSV-59	M-13	HP Storage to Compression		X			
30-RSV-60	M-13	Compressor C-3002 A & B Discharge		X			
30-RSV-61	M-13	Compressor C-3002 A & B Discharge		X			
30-SV-65	M-12	C-3001 Coolant Water	X				
30-SV-66	M-13	C-3002A After-Cooler Water	X				
30-RSV-67	M-13	C-3002B After-Cooler Water	X				
28-RSV-68	M-8	LO ₂ Storage Pressurization			X		
28-RSV-69	M-8	LO ₂ Storage Vent			X		
50-RSV-70	M-8	H. P. LO ₂ Press.			X		
50-RSV-71	M-8	H. P. LO ₂ Vent			X		
50-RSV-72	M-8	H. P. LO ₂ Fill		X			
50-RSV-73	M-8	H. P. Transfer to Turbine			X		
38-RSV-80	M-5	LH ₂ Storage Fill	X	X			
38-RSV-81	M-5	LH ₂ Run Tank Return		X		X	
38-RSV-83		LH ₂ to Run Tank		X			
38-RSV-87	M-5	LH ₂ Storage Press.			X		
38-RSV-88	M-5	V-3801 GH ₂ Discharge to Compressor		X

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	

Valve No.	Flow Sheet No.	Valve Location	Control Location				
			Local	Control Center			
				A	B	C	D
28-RSV-92	M-8	LO ₂ Storage Dewar Discharge		X			
50-RSV-105	M-6	He Purge to Line 4-LH-6"		X			
50-RSV-106	M-6	H. P. LH ₂ Run Tank Discharge		X			
50-RSV-107	M-6	H. P. LH ₂ Run Tank to Gas Generator		X			
50-RSV-108	M-7	He Purge to Engine Feed		X			
50-RSV-109	M-6	H. P. LH ₂ Run Tank Vent			X		
50-RSV-110	M-6	H. P. LH ₂ Run Tank to Vacuum		X			
50-RSV-111	M-7	H. P. LH ₂ Tank			X		
50-SV-118	M-20	FS5002 Propane Flare		X			
30-SV-123	M-9	Air Compressor Coolant Water	X				
50-RSV-125	M-7	LH ₂ Cold Flow to LH ₂ Storage V-3801			X		
50-RSV-126	M-7	H. P. LO ₂ Transfer to Turbo-pump			X		
50-RSV-128	M-7	V-5001 Run Tank Vent Block					X
50-RSV-129	M-7	Main LH ₂ Feed From V-3801					X
50-RSV-130	M-7	V-5001 - Run Tank Vent					X
50-RSV-132	M-7	Main LH ₂ Run Tank Discharge to Engine					X
50-RSV-133	M-7	Line 8-LH-9" Main Block		X			
50-RSV-134	M-7	Main Engine Coolant Gas Block		X			
50-RSV-136	M-7	V-5001 Jacket Vacuum Block		X			
50-RSV-138	M-7	Vent Line to vacuum		X			
50-RSV-142	M-7	Main He Purge to Engine Block		X			
50-RSV-143	M-7	Engine Feed Line to Vacuum Block		X			
50-SV-169	M-20		X				
50-SV-170	M-20		X				
50-SV-175	M-20		X				
50-SV-176	M-20		X

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	

Valve No.	Flow Sheet No.	Valve Location	Control Location			
			Local	Control Center		
			A	B	C	D
38-SV-178	M-20	FS 3801 Propane Flare	X			
38-RSV-180	M-5	Block LH Cold Flow to Vac.	X			
38-RSV-181	M-5	LH STG Jacket to Vac. Block	X			
50-RSV-183	M-6	H. P. LH Run Tank to Vac.	X			
50-RSV-185	M-6	H. P. LH Run Time GH Press				X
50-RSV-186	M-7	V-5001 GH Press. Block				X
50-RSV-188	M-7	H. P. LH Block to Line 16-VA-2	X			
32-RSV-190	M-14	V-3201 Gas STG Bottle Fill	X			
32-RSV-191	M-14	V-3202 Gas STG Bottle Fill	X			
32-RSV-192	M-14	V-3203 Gas STG Bottle Fill	X			
32-RSV-193	M-15	V-3204 Gas STG Bottle Fill	X			
32-RSV-194	M-15	V-3205 Gas STG Bottle Fill	X			
32-RSV-195	M-15	V-3206 Gas STG Bottle Fill	X			
50-RSV-201	M-18	GH Coolant to Reactor	X			
30-RSV-205	M-13	C-3002A Comp. Vent	X			
30-RSV-206	M-13	C-3002B Comp. Vent	X			
32-RSV-207	M-14	V-3201 Fill Line Double Block	X			
32-RSV-208	M-14	V-3202 Fill Line Double Block	X			
32-RSV-209	M-14	V-3203 Fill Line Double Block	X			
32-RSV-210	M-15	V-3204 Fill Line Double Block	X			
32-RSV-211	M-15	V-3205 Fill Line Double Block	X			
32-RSV-212	M-15	V-3206 Fill Line Double Block	X			
30-SV-214	M-9	Comp. C-3003A Cooling Water	X

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	

Valve No.	Flow Sheet No.	Valve Location	Control Location				
			Local	Control Center			
				A	B	C	D
30-SV-215	M-9	Comp. C-3003B Cooling Water	X				
50-RSV-218	M-11	Vac. Pump VP 5001 Suction		X			
38-RSV-219	M-11	Vac. Pump VA 3801 Suction		X			
50-RSV-221	M-7	GN to Seal Purge		X			
50-RSV-222	M-7	GN Deflector Duct Purge		X			
32-RSV-245	M-16	GN Header Shutoff		X			
32-RSV-246	M-16	GN Header Shutoff		X			
32-RSV-247	M-16	He Header Shutoff		X			
50-RSV-252	M-6	LH STG Line 3-LH-6" to Run Tank		X			
50-RSV-253	M-6	H. P. LH Run Tank to Vent			X		
50-RSV-254	M-6	Block From 5-GH-2" to Vac.		X			
38-RSV-255	M-5	He Purge Block to V-3801		X			
38-RSV-256	M-5	Block Between 7-LH12" and Flare		X			X
38-RSV-257	M-5	LH STG Dewar Vent	X		X		
38-RSV-258	M-5	LH STG Dewar Vent		X			
50-RSV-261	M-7	Block From 4-GH-6" to 27 GH 1"		X			
30-RSV-263	M-13	Atmos. Block From 8-HN-1-1/2"		X			
30-RSV-264	M-13	Atmos. Block From 8-HN-1-1/2"		X			
27-RSV-265	M-17	LH Unloading STA. Purge		X			
32-RSV-269	M-17	GN ₂ Pressure to SVB H. P. Gas Storage		X			
32-RSV-270	M-17	H. P. Header Gas Bottle Purge		X			
38-RSV-271	M-17	GN ₂ Gas Seal Flare FS-3801		X			
32-RSV-273	M-16	GN ₂ Header Block Bypass		X			
32-RSV-274	M-16	GN ₂ Header Block Bypass		X			
32-RSV-275	M-16	He Header Block Bypass		X			
38-RSV-276	M-18	LH ₂ Storage Dewar Pressure		X			

Valve No.	Flow Sheet No.	Valve Location	Local	Control Location			
				Control Center			
				A	B	C	D
30-SV-279	M-17	Instr. GN ₂ Cylinder Backup	X				
32-SV-280	M-17	Instr. GN ₂ Cylinder Backup 3332	X				
28-RSV-281	M-8	LO ₂ Transfer Line Purge		X			
50-SV-282	M-18	Instr. GN ₂ Cylinder to 16-GN-1 ⁿ	X				
50-RSV-283	M-18	LH ₂ Run Tank Pressure			X		
50-RSV-284	M-18	LH ₂ Run Tank Pressure 0.8 Purge		X			
50-RSV-285	M-18	H. P. LH ₂ Dewar Pressure and Purge		X			
50-RSV-286	M-18	H. P. LH ₂ Dewar Pressure			X		
50-RSV-287	M-7	Purge to Relief Header		X			
38-SV-288	M-18	Instr. GN ₂ Cylinder to 15 GN-1 ⁿ	X				
50-RSV-296		Duct Water Low Flow		X			
50-RSV-297		Duct Water Medium Flow		X			
50-RSV-298		Duct Water High Flow		X			
50-RSV-303		Top Shield Water		X			
50-RSV-304		S1 Shield Water		X			
50-RSV-305		S1 Shield Water		X			
50-RSV-306		Bottom Shield Water		X			
* 32-RSV-314		Process Water To Steam Generator		X			
** 50-RSV-309		Steam Generator Water Supply		X			
50-RSV-319	7	LH ₂ To Engine Bypass					X
50-RSV-320	7	4-LH-6 To 15-GH8 Valve		X			
50-RSV-322	7	HE Purge to GH ₂ Coolant Line			X		
50-RSV-323	7	2-LN-4 Line Valve		X			
50-RSV-324	7	LN ₂ Storage Pressure			X		
36-RSV-325	25	LN ₂ Storage Vent	X

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par.

Valve No.	Flow Sheet No.	Valve Location	Control Location				
			Local	Control Center			
				A	B	C	D
36-RSV-326	25	LN ₂ Transfer Line	X				
36-RSV-327	25	LN ₂ Storage Vent	X	X			
50-RSV-328	21	C'P' LG's & Jack Coolant Water		X			
34-RSV-329	10	Liquid Propane Transfer		X			
34-RSV-330	10	Propane Tank Pressure		X			
34-RSV-331	10	Propane Tank Vent		X			
28-SV-332	8	Vacuum Line To V-2801	X				
36-SV-333	25	Vacuum Line to V-3601	X				
50-RSV-334	7	GN ₂ To Small Atomizer		X			
50-RSV-335	8	LO ₂ To Steam Generator			X		
50-RSV-338	7	Coolant To Reactor Line Vent		X			
50-SV-339	19	Acetylene T.S. Flame Indicator	X				
50-SV-340	19	Acetylene G.G. Flame Indicator	X				
38-SV-341	19	Acetylene LH ₂ Storage Flame Indicator	X				
20-SV-342		Set Point for Demineralized Water Flow Generator	X				
20-SV-343		Set Point for Demineralized Water Flow Generator	X				
50-RSV-344		Test Stand Radiation Shield		X			
50-RSV-345		Test Stand Radiation Shield		X			
50-RSV-346		Test Stand Radiation Shield		X			
50-RSV-347		Test Stand Radiation Shield		X			
50-RSV-348		Test Stand Radiation Shield		X			
50-RSV-349		Test Stand Radiation Shield		X			
50-RSV-350		Test Stand Radiation Shield		X

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par.

Valve No.	Flow Sheet No.	Valve Location	Control Location				
			Local	Control Center			
				A	B	C	D
50-RSV-351		Test Stand Radiation Shield		X			
50-RSV-352		Test Stand Radiation Shield		X			
50-RSV-353		Test Stand Radiation Shield		X			
50-RSV-354		Test Stand Radiation Shield		X			
50-RSV-355		Test Stand Radiation Shield		X			
50-RSV-356		Test Stand Radiation Shield		X			
50-RSV-357		Test Stand Radiation Shield		X			
50-RSV-358		Test Stand Radiation Shield		X			
50-RSV-359		Engine Deflector Duct		X			
-RSV-360		Engine Deflector Duct		X			
50-RSV-361		Engine Deflector Duct		X			
50-RSV-362		Engine Deflector Duct		X			
50-RSV-363		Engine Deflector Duct		X			
50-RSV-364		Engine Deflector Duct		X			
50-RSV-365		Engine Deflector Duct		X			
38-RSV-383		He Reduced Press Purge GH ₂		X			

APPENDIX 5.1

CONSIDERATIONS OF HANDLING

CHANNEL INFORMATION

1.0CHANNELIZATION

An adequate philosophy or concept for identification, routing, or grouping of the many hundreds of control, checkout, and data acquisition channels, and the associated equipment involved is important to the design and operation of the I & C Systems. These must be identified from the design standpoint to provide ease of tabulation and record keeping for channel engineering; it is also necessary that functional and descriptive identification be included in the design, so that minimum reference material will be required to comprehend, set-up, or operate the various systems or subsystems. Functional and descriptive identification must be provided to operating personnel, in addition to a summary picture of the configuration of system or subsystem details with respect to specific channels.

The identification information required for tabulation and records keeping does not necessarily satisfy the operational requirement for functional and descriptive identification. The latter must be easily relatable to such items as use, function, type, or group, whereas coding unrelated to these is often used for tabulation and records which require a reference document for deciphering. It is obvious that for direct operational purposes, identification requiring deciphering would cloud comprehension and be inefficient. The functional and descriptive identification, and the tabulation and records identification should be accomplished together, simultaneously with design, as a system concept.

A method for providing up-to-date records of channel information is proposed in par. 3.0, below.

2.0CHANNEL ENGINEERING

The specific purpose of this task is to process channel requests and to make a few basic decisions as follows:

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	2.0

- (a) Determine the channel number. For typical channel number see Figure App. 5.1-1.

Example of Channel Number

T-1001-DA = Engine Temperature No. 1 in the Data Acquisition System

T-1002-DA = Engine Temperature No. 2 in the Data Acquisition System

- (b) Produce "A" size drawings from end instruments to the first patch panel. This drawing should also cover a note about the type of signal conditioning required for this channel.

2.1 HISTORY FILE

Channel Engineering is also responsible for maintaining a systematic history file on all of these activities, such as a master file by system of the drawings, a channel status log, i.e., (how many channels of the "X" system have been allocated?)

2.2 BLOCK DIAGRAM

Due to the vast size of this type of data-acquisition system, a block diagram of the overall system would prove to be too large a drawing to be a useful tool. It is, however, the responsibility of Channel Engineering to provide block diagrams of the individual systems, including parameter type information, i.e., [alarm channel (Min-Max) and valve command channel (Open-Closed)] and indications to verify that functions were performed.

3.0 CHANNEL RECORDS

The specific function of this task is to document specific identification and routing information on each channel, and to tabulate this information in the form of IBM punch cards for each channel. In a system of this size the IBM electrical accounting machines have proved to be efficient weapons to assault the problem of handling, fast and efficiently, large amounts of information.

These channel records shall provide for three functions.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	3.0

- (a) Provide a Channel Data Log to be used by the Test Engineering Dept. (See Figure App. 5.1-2, Typical Channel Data Log)
- (b) Provide a Bay wiring list, to remain in the bay, and to be updated as modifications occur. (See Figure App. 5.1-3, Typical Bay List)
- (c) Maintain a master history file. (This may be in the form of a tray of IBM cards.)

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	3.0

FIGURE APP. 5.1-1

TYPICAL CHANNEL NUMBER

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	15 Feb 1962
Par.	3.0

FIGURE APP. 5.1-2

TYPICAL CHANNEL DATA LOG

Channel No. and System	Rv	XDC Typ	Required Range	Units	Signal Conditioner	Zero Cal.	Amplifier	Cal. Inh.	Disp. Loc.	Alarm
Revision										
Transducer Type										
Min. Full Scale			Required Range							
Units (in., degrees, G's)										
Location Type			Signal Conditioner							
Zero Calibration										
Location Gain Type Full Scale			Amplifier							
Calibrate Inhibit										
Display Location										
Max. Min. Type			Alarm							

FIGURE APP. 5.1-3

TYPICAL BAY LIST

Location within Complex	Rack No.	Panel Location	Terminal Strip	Terminal Cable No.	Wire Color	Destination	Terminal Strip	Terminal Term. Chan. No.
Rack No.	Z3-135	A	1	X 0077	9/20	Z1 B003	1	1
Location within Rack								
Top to Bottom A X								
Terminal Strips Numbered								
Terminals Numbered								
Type of Cable								
Cable No.								
Wh Ex. Retma								
Rd/Blk Color Code								
Location within Complex								
Terminal Box No.								
Terminals Numbered Strip								
Terminals Numbered								
Type of Measurement								
Chan. No.								
System								

APPENDIX 5.3

DATA PROCESSING COMPUTATION

1.0DATA CONVERSION

The processing of computation which is required to convert raw-data input to a final-data output presentation requires the consideration of certain linearizing corrections. It is suggested that for the requirements of this program the corrections considered in this conversion should be no greater than a fifth-degree polynomial. To substantiate this suggestion, an evaluation was conducted to establish the normal errors which might occur when using this type of data correction. Since thermocouples are considered to be the most commonly used nonlinear measuring devices, the study was based upon thermocouple data corrections over the temperature range between 150 and 4812°R.

2.0CONVERSION EQUATIONS

The following equations have been used to convert thermocouple output in mv, (X) to engineering units in °R (T) with an rms linear error (Sy) indicated in °R and % full scale.

(a) Range 1 - 150 to 650°R

Type of thermocouple - Chromel-Alumel

Third-order fit.

Based on the equation, $T = 4.921 + 44.662x - 1.032x^2 + .297x^3$,
then $Sy = 1.63^{\circ}R$ or 0.3% full scale.

(b) Range 2 - 150 to 1125°R

Type of thermocouple - Chromel-Alumel

Fourth-order fit.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.0

Based on the equation, $T = 493.933 + 46.162 x - 1.257 x^2$
 $+ .175 x^3 - .007 x^4$,
then $Sy = 2.3^{\circ}R$, or 0.2% full scale.

- (c) Range 3 - 150 to 1990 $^{\circ}R$

Type of thermocouple - Chromel-Alumel

Fifth-order fit.

Based on the equation, $T = 491.986 + 48.760 x - 1.110 x^2$
 $+ .090 x^3 - .0031 x^4 + .000045 x^5$,
then $Sy = 4.4^{\circ}R$ or 0.2% full scale.

- (d) Range 4 - 150 to 2670 $^{\circ}R$

Type of thermocouple - Chromel-Alumel

Fifth-order fit.

Based on the equation, $T = 486.44 + 50.195 x - 0.822 x^2$
 $+ .039 x^3 - .00082 x^4 + .0000066 x^5$,
then $Sy = 6.0^{\circ}R$ or 0.2% full scale.

- (e) Range 5 - 492 to 942 $^{\circ}R$

Type of thermocouple - Chromel-Alumel

Third-order fit.

Based on the equation, $T = 493.174 + 43.659 x - .0073 x^2 + .0068 x^3$,
then $Sy = 0.4^{\circ}R$ or 0.08% full scale.

- (f) Range 6 - 492 to 1370 $^{\circ}R$

Type of thermocouple - Chromel-Alumel

Third-order fit.

Based on the equation, $T = 492.776 + 43.532 x + 0.1213 x^2 - .00602 x^3$,
then $Sy = 0.5^{\circ}R$ or 0.05% full scale.

- (g) Range 7 - 492 to 2250 $^{\circ}R$

Type of thermocouple - Chromel-Alumel

Third-order fit.

Based on the equation, $T = 488.404 + 46.142 x - .1731 x^2 + .0027 x^3$,
Then $Sy = 1.4^{\circ}R$ or 0.07% full scale.

- (h) Range 8 - 492 to 2942 $^{\circ}R$

Type of thermocouple - Chromel-Alumel

Third-order fit.

Based on the equation, $T = 487.799 + 46.362 x - .1883 x^2 + .00298 x^3$,
then $Sy = 1.0^{\circ}R$ or 0.05% full scale.

- (i) Range 9 - 852 to 2022 $^{\circ}R$

Type of thermocouple - Tungsten-Tungsten - 25% Rhenium

Fifth-order fit.

Based on the equation, $T = 839.565 + 370.057 x - 110.653 x^2$
 $+ 23.983 x^3 - 2.522 x^4 + 0.1005 x^5$,
then $Sy = 4.8^{\circ}R$ or 0.2% full scale.

- (j) Range 10 - 852 to 2922 $^{\circ}R$

Type of thermocouple - Tungsten-Tungsten - 25% Rhenium

Fifth-order fit.

Based on the equation, $T = 676.214 + 192.55 x - 13.954 x^2$
 $+ .9636 x^3 - 0.03415 x^4 + 0.000483 x^5$,
then $Sy = 1.8^{\circ}R$ or 0.06% full scale.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.0

(k) Range 11 - 825 to 4812[°]R

Type of thermocouple - Tungsten-Tungsten - 25% Rhenium

Fifth-order fit.

Based on the equation, $T = 705.623 + 166.865 x - 7.694 x^2$
 $+ 0.3475 x^3 - 0.00771 x^4 + 0.0000693 x^5$,
then $S_y = 5.7^{\circ}\text{R}$ or 0.1% full scale.

(l) Range 12 - 1460 to 2020[°]R

Type of thermocouple - Platinum-6% Rhodium - Platinum-30% Rhodium

Third-order fit.

Based on the equation, $T = 868.977 + 503.94 x - 75.303 x^2 + 7.015 x^3$,
then $S_y = 0.9^{\circ}\text{R}$ or 0.04% full scale.

(m) Range 13 - 1460 to 3610[°]R

Type of thermocouple - Platinum-6% Rhodium-Platinum-30% Rhodium

Fourth-order fit.

Based on the equation, $T = 962.870 + 391.649 x - 33.195 x^2$
 $+ 2.1254 x^3 - .0514 x^4$,
then $S_y = 0.6^{\circ}\text{R}$ or 0.02% full scale.

3.0

CONCLUSION

In the examples, it has been demonstrated that it is possible to perform data linearization corrections by the use of fifth-degree polynomial equations to produce final data with normal errors not greater than 0.3%.

APPENDIX 5.4

ERROR EVALUATION

1.0

SYSTEM ACCURACY LIMITATIONS

Any discussion of system accuracy must consider the errors contributed to the system by the interrelation of subsystem and component errors. While it is intuitively obvious that system accuracy is limited by the most inaccurate element, this avoids the issue of error percentage contribution by various subparts. This discussion will evaluate error contributions in a system in which there exists a relatively large constant error, which is modified by a relatively small variable error. A quantitative illustration of the system error, assuming specific random errors, can be developed as follows:

2.0

ILLUSTRATION OF SYSTEM ERROR

Assume that a component error (e_c) and a subsystem error (e_s) are zero-mean random errors of arbitrary distribution. If the errors are statistically independent, the total error variance, σ^2 , is given by

$$\sigma^2 = \sigma_c^2 + \sigma_s^2$$

Figure App. 5.4-1 shows the relationship of $\frac{\sigma}{\sigma_c}$ vs $\frac{\sigma_s}{\sigma_c}$. It

is clear that there are "diminishing returns" relationships between total system error and the ratio of subsystem to component error. For example, if there is a reduction of the subsystem error standard deviation below a value of 0.46 times, the component error standard deviation cannot improve the total error standard deviation by any more than 10%. Thus, a break-even point of

$$\frac{\sigma_s}{\sigma_c} = 0.5$$

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 2.0

may be used to derive the desired subsystem error specification from the known or assumed component error standard deviation. The small gain in system error resulting from even greater subsystem accuracy normally cannot be justified because of the attendant cost and reduced reliability.

Appendix 5.4, Figure 1

TOTAL VARIANCE VS RATIO OF SUBSYSTEM
TO COMPONENT ERROR

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.0

APPENDIX 5.5

DISCUSSION ON COMPUTER OPERATIONS

1.0 DATA REQUIREMENTS - TEST FACILITY

1.1 "QUICK-LOOK DATA RETRIEVAL (See Figure App. 5.5-1)

- * (a) Limited data-reduction capability requirements are anticipated for on-site operations.
- (b) Requirements for "Quick-Look" data retrieval will include availability of data, on-site, from analog and digital display units within a 12-hour period.
- (c) If such "Quick-Look" data, in a form presentable for engineering analysis, cannot be obtained within this time limit from available analog and digital units, then a Data-Processing System will be required.
- (d) Either future current requirements (or both) for on-site editing and data processing may be fulfilled through use of various, commercially-available, "Small" general-purpose computers, which have compatibility features for IBM high-density tape, either binary or BCD format.
- (e) The preliminary, or "Quick-Look," Data Facility will be required to report upon a maximum of 200 channels at (probably) maximum recording rates. If 200 channels were processed at half speed for 1% of run time, this would be recordation of 20,000 data words.

1.2 FORMAT OF "QUICK-LOOK" DATA

- (a) Engineering and Test Personnel Management must decide in what form "Quick-Look" data must be supplied for convenient engineering analysis:

20,000 data words could produce a minimum of 4,000 lines of tabular data, non-edited; and the same information could be supplied on low-speed graphical recorders, resulting in "N" graphs.

- (b) For amounts of "Quick-Look" data anticipated and in order to meet time schedules, it appears graphical presentation is required, with tabular data supplied for critically resolved areas, or for transient conditions.
- (c) It is assumed that state-of-the-art methods exist for both tabular and graphical presentations of data on-site.

2.0 COMPUTER REQUIREMENTS-TEST FACILITY (See Figure App. 5.5.2)

2.1 PURPOSE

The computer facility will provide, within state-of-the-art limits, all necessary data processing operations as required by the engineering and test projects.

2.2 DATA PROCESSING CAPABILITY

2.2.1 Equipment

An IBM 7090 Digital Computer and required peripheral equipment will be available and maintained to process project test recording system and to meet project test schedules.

Provision for priority interrupt for immediate access to 7090 computer processing will be established.

Special equipment will be necessary to furnish capabilities such as high-speed continuous plotting and other special reporting requirements. This equipment will be in addition to standard high-speed printers, CRT Displays, etc.

2.2.2 Processing Data

All test data from a specific run will be processed to provide a complete time history of all designated recording channels, and will be returned to the project as a usable engineering-data package within a predetermined elapsed time.

Priority editing for "Quick-Look" review of critical parameters will be provided.

Processing time, for either Priority "Quick-Look" review, or for total output, will be a function of quantity of data input and desired output. It appears that the project requirement of 4 to 7 days elapsed time can be achieved.

2.2.3 Personnel Requirements

Technical staff personnel will be available and assigned full responsibility for coordinating analysis, programming, and processing of test data with the project, and for maintaining state-of-the-art developments within the processing program system.

Additional personnel will be available to handle peak load conditions, or to undertake and develop new processing techniques.

2.3 DATA PROCESSING PROGRAM

2.3.1 General Program

The Data Processing Program and method of processing will be a function of the general test recording scheme, at NNRDC either binary or BCD.

An IBM 7090 program will be developed as a general method of processing IBM compatible magnetic tapes as furnished by the project.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	2.3.2

2.3.2 Binary Input Scheme

All processing of preliminary and summary test tapes will be done by the IBM 7090. Magnetic tapes from the project will be IBM compatible, and may be processed directly into the 7090 at full-transfer rate. Internal machine computing rates should not slow down tape transfer rates, or vice versa.

Current proposed data word size (12 bits) makes storage and editing very efficient and economical, but increased word size will not effect efficiency or economics to any great extent.

This method allows the minimum of tape handling and the minimum of required processing equipment. All equipment (hardware) is currently available and in use (excluding IBM 729 VI) by customers.

2.3.3. BCD Input Scheme

All tapes must be pre-processed "Off-Line" to 7090 operation, which would allow pre-editing, sorting, and some engineering computations.

BCD input requires high-speed, high-storage capacity, random-access, disk files for ease of communication with the 7090. Some of the necessary equipment is not currently available, or in use by customers (IBM 729 VI, IBM 1301).

More basic experience is required in handling this type of processing system before final criteria can be developed.

2.3.4 Computer Usage

It appears that the majority of the IBM 7090 computer time will be used in calibration (5th order polynomial) of data, engineering computations, and detailed editing. "Off-Line" editing from BCD format does not appear to save enough 7090 computer time to justify the use of the additional equipment or data-handling required. Sorting, editing, and necessary rearranging of the binary tape data should be a relatively short time function as compared to the total processing operation.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 2.3.4

The economics and elapsed time processing capabilities or either the binary or BCD modes will probably not differ appreciably. System reliability (hardware) and availability for checkout and testing will be a major consideration.

2.3.5 Required Liaison

Direct coordination and liaison will be maintained between Project and Computer Facility throughout all phases of program development.

2.4 SCHEDULING

2.4.1 Computer Time

The Aerojet Azusa Computer Facility will install an IBM 7090 in May 1962, and in addition, 7090 time is currently available from IBM for system and program checkout. The Azusa Computer Facility of Aerojet is currently involved in no large-scale data reduction or engineering computing activities which prohibit immediate Priority interrupt provisions for access to the 7090.

It is probable that acceptance by Azusa of responsibility for full-data processing on the 7090 for the Test Complex uses will not create serious overloads in time scheduling of other current or anticipated engineering computer applications at Azusa.

It is planned that system hardware compatibility shall exist between Aerojet Computer Facilities at Azusa and Sacramento, to enable either facility to handle peak overloads of the other, as time is available.

2.4.2 Data Processing Program

Regardless of the recording scheme selected, whether binary or BCD, it will require full-time efforts of several analysts to analyze, develop, program, and check out a processing program package.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	2.4.2

In order to have this program package available to meet project test schedules, work should begin at once. It is probable that it will take many man months to obtain an efficient program, and will require full time support of several professional and non-professional personnel to maintain and use the system after checkout.

3.0

SUMMARY OF DISCUSSION

An IBM 7090 digital computer facility will be available at the Azusa Plant for processing all test data supplied by the project.

Schedules will be established and maintained for total elapsed processing time as well as for Priority requirements for "Quick-Look" review of critical parameters.

A data-processing program will be developed to process magnetic tape (IBM compatible) in either binary or BCD mode. Selection of mode and system specifications will be determined by the Project and coordinated with the Computer Facility.

Work authorization should be initiated as soon as possible for development of the processing program in order to meet project test schedules.

Coordination and liaison between project and computer facility must be maintained throughout all phases of program development and testing.

NERVA
PROGRAM

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par.

Figure App. 5.5-1

FACILITY REQUIREMENTS AT TEST COMPLEX

Figure App. 5.5-2

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	1.0

APPENDIX 5.6

COMPARISON OF BINARY CODED DECIMAL
AND STRAIGHT BINARY SYSTEMS

1.0

INTRODUCTION

The primary purpose of a digital recording system is to retain a physical variable in a fashion which will not degrade with time, system noise, or data processing. The method of achieving this is to record the number as a digital value rather than to retain an analog equivalent. A basic question which must be evaluated prior to the design of a digital system is the structure of the digital indicator. This question resolves into a discussion of number counting schemes which are usable by magnetic recording devices and eventually utilized by computing devices. Digital terms utilized herein are defined in Appendix 1.0.

2.0

RECORDING REQUIREMENTS

2.1

DATA FORMAT

When information is recorded on 1/2-in. magnetic tape in the digital domain, it is conventionally recorded in 7 parallel lines of bits. The 7th line is reserved for parity check (which is actually a recording accuracy check), and therefore 6 parallel lines of bits are usable for data recording.

This document will evaluate two techniques of recording data in 6-bit character groups. One method is BCD, which relates to Base-10 counting, and the other is straight binary, which relates to Base-2 counting. Base-10 counting is preferred, because this is the way humans naturally count; any other method is normally foreign to human comprehension. Tape format is important in this evaluation, since it determines the amount of information which may be packed on a tape, and it thus affects system cost and operational complexity.

2.1.1BCD Tape Format

Four binary bits are required to describe any number between 0 and 15. A resolution of 0.1% is described by a 3-character BCD word; however, it is more desirable to utilize 4 characters, and the BCD system uses a 4-bit binary word to describe any number between 0 and 9 by arranging the number as a vertical character on the tape. The two remaining bits are used to identify bi-polar data, and as a tape record mark.

Thus, one tape character is ± 0 to 9; 2 characters would be ± 0 to 99; 3 characters, ± 0 to 999; and 4 characters, ± 0 to 9999. This provides a system with a possible resolution of one part in 20,000, uni-polar; or one part in 10,000, bi-polar; and a printout in a form that personnel like to read. However, to do this it is required to utilize 24 bits, which calls for a total tape length of 0.005 in.

2.1.2Binary Tape Format

When a straight binary tape format is utilized, the number is written as a binary number in as many bits as required to describe the accuracy and resolution specified. The use of six binary bits provides a quanta of 64; 12 binary bits, a quanta of 4096; 18 binary bits, a quanta of 265,344. A resolution of 0.1% requires a minimum quanta of 1000. Therefore, 12 binary bits is an excellent choice since it also mates with the tape arrangement of 2 characters of 6 bits each.

The tape required for 12 bits is 0.0025-in., or 1/2 the amount required for BCD. While this method has fine tape-packing density, it has the disadvantage of arranging data in a manner which is foreign to human comprehension (Base 2). It may be easily converted to octal; however, this is still a foreign form to most engineers. It should also be noted that this format is uni-polar, that is, it has no sign. The ETS-1 data acquisition system does not require bi-polar data.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	2.2

2.2

TAPE RECORDS

In any data-recording operation, a basic frame of data must be identified. A record is a basic frame of data covering the occurrence of one or more of all events. It is desirable that the basic length of a record shall match the input capabilities of the computer which must process that data.

In a binary tape of the 12-bit type described above, the only way to identify a record is by providing gaps in the tape. An IBM End of Record Gap (EOR) is $3/4$ inch. During the EOR time, which is 7.5 milliseconds at 100-in. per sec tape speed, no information may be recorded on tape. This is done by the use of an accordion-type buffer; or by completely stopping data flow for 7.5 milliseconds; naturally, if any event occurred during this gap time, it would not be recorded.

In BCD tape records as described above, tape records are identified by a bit used as a flag in one of the extra columns. Gapping, therefore, is not required, and thus no data is lost.

3.0

COMPUTER OPERATIONS

The IBM-7090 is a binary machine. It will process BCD data, but this is only done at the expense of first converting the BCD data to straight binary, either as an initial operation or a subroutine. For the proposed NERVA data operations, the 7090 will be limited by the speed of data input, and it is therefore undesirable to further restrict input capabilities by data-input format alterations. The optimum data entry for the 7090 is a high-density binary magnetic tape, with long record lengths, entered into the computer memory at maximum speed.

The selection of peripheral computational equipment is dependent upon the mode of data. The IBM machines, such as the 1401 or 1410, are BCD machines which will handle Binary data, but they cannot make computations on Binary data. For Binary data, a machine similar to the CDC-160 is available which has all the capabilities required for the NERVA operations. Peripheral equipment required to support computer operations is available for any machine mentioned above.

4.0

SUMMATION

Binary requires only one-half the recording volume of BCD.

A 12 Binary word fits the NERVA accuracy and resolution requirements better than a 4-digit BCD word.

Data-reduction operations for NERVA will be large-scale efforts. Only an IBM-7090 can process this data in the period of time required for a final data report, and the IBM-7090 is a Binary machine. Binary mode data would provide an optimum data entry format for final data reduction.

A binary system requires fewer recording machines, less storage register complexity, and fewer final computer operations; and therefore has a cost advantage.

BCD requires twice the tape recording capability, twice as many data bits, and greater storage register complexity; the Binary system therefore has a reliability advantage.

5.0

CONCLUSION

Based on the summation in section 4.0, the advantages of a 12-bit Binary data word with respect to compliance with operational requirements, reduced recording requirements, computational advantages, reliability considerations, and overall system cost reduction, dictate its use for the ETS-1 Data Acquisition System.

APPENDIX 5.7

SUPPORT FACILITY REQUIREMENTS

1.0 CALIBRATION LABORATORY AND FACILITIES1.1 EQUIPMENT REQUIRED FOR CALIBRATION

It is difficult to make specific recommendations for equipment deemed necessary for a recalibration laboratory to work with the various transducers required for this application. The problem of economics versus convenience or time in calibration work must be thoroughly investigated. Many laboratories exist that could perform the necessary maintenance or calibration tasks, but in most cases, the time lag associated with the use of outside vendors for calibration is infeasible. For this reason at least, a minimal laboratory must be supplied as a part of the test complex. A list of items deemed necessary for this application should include the following equipment:

1.1.1 Strain-Gage Pressure Calibration

Required are items such as:

Type "C" AB-2 Calibrator
L & N galvanometer (Model 243OC)
Amthor Dead-Weight Tester
Dead weights for tester
Microvoltmeter
L & N Bridge Test Set No. 5430-AM
Precision power supply
Decade resistance boxes covering the ranges of 0.01 to 100, 0.1 to 1,000, and 1 to 10,000 ohms
Conrad Oven Model FD-10-2-2
Microscope (Bausch and Lomb Model YD6062)
Manometer
Wallace and Tiernan vacuum gage
Alphatron vacuum gage
Necessary benches, storage cabinets, and bench lights.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962

Par. 1.1.2

1.1.2 Load-Cell Force Systems

Requirements for load cell calibration include those listed for strain-gage pressure transducers with the addition of:

A Baldwin press (200,000-lb cap.)
Baldwin-Lima-Hamilton standard cells and readouts.

1.1.3 Pressure Potentiometers and Visual Gages

The pressure potentiometers may be calibrated through the use of the L & N Bridge and the Wallace and Tiernan pressure gage, or manometer, depending upon pressure range. No additional equipment is required for this calibration.

1.1.4 LVDT Systems

Additional equipment required for calibration of this system include:

Precision ac power supply
Micrometer test fixture (for displacement)
Precision demodulator

1.1.5 Variable Inductance

No additional equipment is required for calibration of this transducer.

1.1.6 Flow

A flow-calibration facility is not deemed necessary for this facility. The use of outside calibration facilities such as at Sacramento should be made.

1.1.7 Accelerometer

Accelerometer calibration could also be made at commercial facilities, but the addition of the following equipment would

provide an adequate calibration facility at minimum cost:

MB vibration fixture (Model C-11-25-31) with amplifier and power supply
Tektronic scope (Model 536)
H.P. VTVM meter (Model 400H)
H.P. counter (Model 522B).

1.1.8

Temperature

Resistance-temperature transmitters (RTT) require calibration in the region of liquid hydrogen. Calibration at this point is difficult to achieve, and requires considerable equipment. Until a more definite need arises, the manufacturer of the various RTT probes will be required to furnish a certified calibration certificate with each delivered transducer.

Thermocouple calibration checks will require some special equipment, foremost of which will be an oven capable of producing high calibration temperatures to a maximum 4500°F. The oven may be either a resistance or an induction heated tube, properly insulated, with an optical pyrometer serving as a high-temperature reference. Other, but lower, hot temperatures may use a tungsten RTT as the reference. Readout equipment for the calibration systems will also serve for this calibration.

1.1.9

Radiation Monitor

Calibration of the radiation monitors, especially at levels to be encountered in operation, is not feasible. State-of-the-art units will require vendor calibration, and a comparison of readings on an actual firing will be used to verify the calibration.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.2

1.2 ROM ESTIMATE - CALIBRATION LABORATORY -
NERVA ETS-1

Item No.	Description	Quantity
1	Type C calibrator	3
2	L & N galvanometer	4
3	Dead weight tester w/weights	3
4	Micro-voltmeter	3
5	Bridge test set	3
6	Precision dc power supply	2
7	Decade resistance boxes	5
8	Conrad oven	1
9	Microscope	1
10	Manometer	2
11	Vacuum gages	2
12	Vacuum gages	2
13	Deleted	-
14	Precision ac power supply	2
15	Micrometer test fixture	1
16	Precision demodulator	1
17	M-B vibration system	1
18	Tektronic scope	2
19	Frequency meter	1
20	Frequency counter	1
21	T/C reference oven	1
** 22	Vacuum pump	1
23	Triple point cell	1
24	Pressure gages	6
25	Ultrasonic cleaner	1
26	Strip-chart recorder	2
27	Mueller bridge	1
28	Thermocouple welder	1
29	L & N K-3 potentiometer	2
30	Cryostat	1
31	4 Pen Sandborn recorder	1
32	Millivolt recorder	2
33	Multirange temperature recorder	1
34	Anthony bridge resistor winder	1

2.0 ELECTRONIC AND ELECTRICAL REPAIR SHOPS

2.1 EQUIPMENT REQUIRED

2.1.1 Electronic Shop

No special or unusual equipment items are deemed necessary for maintenance or special fabrication work to be accomplished at the shops, the normal testing instruments and repair tools and fixtures being required. Benches, adequate lighting, power outlets, etc., require close design scrutiny.

The normal testing equipment required will include:

Digital voltmeter
Counter
V.T.V.M.
Oscilloscope
Frequency meters
Frequency generators
Tube testers
B & K TV analyst
Time mark generator
Microvoltmeter
Differential amplifier
Test bridge
Resistor and capacitor decade units
Weston dc and ac 1/2% voltmeters covering the ranges from
0 to 150 volts
Ammeters with 1/2% ranges of 0 to 1 mil to 0-50 amps
RMS voltmeter, scales 0 to 1, 0 to 5, and 0 to 30 lb
Load resistors, 1000 watt in 1 ohm, 10 ohm, 100 ohm, and
1000 ohm
Wattmeters, 0 to 500 and 0 to 1000 watt, ac and dc, 1/4%,
0 to 1000 cps.

2.1.2

Electric Shop

Equipment, other than hand tools and benches required for maintenance of electric systems, should contain such items as:

Meggers, Wire markers

Drill press

Rotary grinder

Power supply (dc)

Many Simpson (Model 260 or equivalent) multimeters.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A
Date 1 June 1962
Par. 2.2

2.2

ROM ESTIMATE - ELECTRONIC AND ELECTRICAL
TEST SHOPS - NERVA ETS-1

Item No.	Description	Quantity
1	Digital voltmeter	2
2	Counter	2
3	V. T. V. M.	4
4	Oscilloscope	3
5	Frequency meter	2
6	Frequency generators	4
7	Deleted	-
8	TV analyst	1
9	Time mark generator	1
10	Microvolt meter	2
11	Differential amplifier	4
12	Test bridge	2
13	Resistor decades	6
14	Capacitor decades	2
15	1/2% voltmeter	6
16	1/2% ampmeters	6
17	RMS voltmeter	2
18	Scales	1
19	1,000-watt load resistors	4
20	Wattmeters	2
21	Wire marker	2
22	Tera-ohmmeter	2
23	Meggers	2
24	Drill press	1
25	Grinder	1
26	dc power supply	3
27	Multimeters	20
28	EMF precision cell	1
29	Oscilloscope camera	1
30	Graphic recorder	1
31	Small lathe	1
32	Magnetic tape degauser	1
33	Transistor tester	1
34	Variac	1

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A	
Date	1 June 1962
Par.	3.0

3.0

PHOTOGRAPHIC SERVICES

Equipment must be provided by photographic services to develop the magazines from the oscillographs, develop the radiation badges, and to develop the film exposed by the group. High-speed processors are now available for this type of development, but this sort of unit is not deemed necessary for this application. Low-speed semi-automatic processors are available for a reasonable price, and should prove entirely adequate. Darkroom space for the processors and other development equipment should also provide room for loading the oscillograph magazines and film packs. Movie-camera film development is not necessary, since commercially available firms will provide overnight service in a more economical manner than would result from purchasing the required color processors.

3.1

ROM COST ESTIMATE - PHOTOGRAPHIC SERVICES -
NERVA ETS-1

*	Item	Description	Quantity
	No.		
	1	Oscillograph processor	2 ea
	2	Folding machine for oscillograph records	1 ea
	3	Projector, 16 mm	1 ea
	4	Benches, ventilation, darkroom, storage

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date 10 Jan 1962
Par. 1.0

APPENDIX 5.8

MEASUREMENT ACCURACY GOALS

The test instrumentation of the NERVA Nuclear Rocket Engine is based on philosophies existing for R & D Testing of liquid-rocket engines. Hence, the accuracy requirements for instrumentation of liquid-engine development should also hold true for nuclear engine development. The following general survey of accuracies attained in liquid rocket R & D Testing will indicate the accuracy design goals for the instrumenting of the Nuclear Rocket Engine with the exception, of course, of the nuclear measurements.

1.0 PRESSURE

The accuracies required for pressure measurements for development of chemical liquid rocket engines are categorized as: those required for performance calculations, and those required for all other measurements required for developmental and environmental determinations. Normally those pressure measurements required for performance data are redundantly monitored to insure reliability of measurement.

Present pressure measuring techniques give system accuracies for performance measurements of $\pm 0.16\%$ (one standard deviation) of the point. A maximum error of $\pm 0.48\%$ of the point may be expected for a normal operating range of 60 to 80% of full-scale for the transducer and the recording system combined.

Redundant chamber pressure measurements are made on all current tests. For computed performance, the individual measurements are averaged.

System accuracies for parameters other than chamber pressure are normally $\pm 1.0\%$ (3 standard deviations) of the point. Thus, a standard deviation of $\pm 0.33\%$ of the point is to be expected.

High-frequency pressure measurements are required to indicate stability of combustion or gas expansion in the thrust chamber. Accuracies of $\pm 0.50\%$ (3 standard deviations) for the frequency measured, and $\pm 5\%$ (3 standard deviations) for the pressure measured, are acceptable.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	2.0

2.0 TEMPERATURE

The required temperature measurement accuracy for liquid oxygen will also be used as criteria for temperature measurement of liquid hydrogen. Present technology, using a platinum resistance temperature transmitter and a digital recording system, results in system accuracies of $\pm 0.44^{\circ}\text{F}$ (3 standard deviations). Since the temperature range of the nuclear rocket gas to be measured is lower and in the lower $\Delta R/R$ range of platinum, an expected measurement accuracy of one standard deviation $\pm 0.25^{\circ}\text{F}$ may be expected.

The above stated figure does not take into account the normal errors attributable to temperature gradients across a pipe. However, this factor is probably small, in the vicinity of $\pm 0.1^{\circ}\text{F}$, since turbulence is normally high.

3.0 FLOW

The techniques used in measuring flow of liquid oxygen are comparable to techniques which will be used in measuring flow of liquid hydrogen. Weight flow of liquid oxygen is measured by a combination of volumetric flow, temperature, and pressure measurements, with an accuracy of $\pm 0.29\%$ (one standard deviation) of the point. This accuracy is based upon using flowmeters in ideal straight pipe sections. If measured at the discharge of a pump, the accuracy may be in the vicinity of $\pm 1.8\%$ (3 standard deviations).

Initial tests using a dual turbine-type mass flowmeter for measuring cryogenic flow indicate a system accuracy of one standard deviation $\pm 0.1\%$.

4.0 AREA

The throat area, A_t , of a thrust-chamber assembly is now measured with inside micrometers to an accuracy of 0.3% of the diameter. Several diameter measurements at varying points on the circumference are normally made. Since the throat area is proportional to the square of the diameter, the maximum error in the throat area will be $\pm 0.6\%$ of the point, with a standard deviation of $\pm 0.2\%$.

5.0 POSITION

Valve position using potentiometric circuitry results in accuracies of $\pm 3\%$ (3 standard deviations) of the point of $\pm 3^\circ$ (3 standard deviations) of the angle for angular displacement.

6.0 ACCELERATION

Acceleration measurements are made to determine resonant frequencies of components and assemblies. Measurement may be made in all three axes using strain gage, crystal (piezoelectric), or electromagnetic accelerometers. The accuracies for vibration measurements are approximately as follows:

Crystal accelerometer - 3% (3 standard deviations) of the point.

Strain gage system - 10% (3 standard deviations) of the point.

7.0 FORCE (THRUST)

The accuracy of a load-cell-type force measuring system is affected by many factors. Frequency of calibration and accuracy of the calibration system will be major contributing factors. For purposes of determining accuracy, assume an N.B.S. certified proving ring and secondary standard cell calibration combined error of less than $\pm 0.2\%$ of point, and a measuring system with a repeatable bias effect of $\pm 0.5\%$ of the point, and other effects such as system degradation and environmental effects, $\pm 0.5\%$. Combining the individual errors results in a maximum error of $\pm 0.74\%$ of the point at normal operating range of 80% full scale, with a standard deviation of 0.25%. Actual experience indicates that accuracy of measurement lower than this figure may be achieved.

8.0 NUCLEAR MEASUREMENTS

Neutron detectors for control will be furnished as a part of the engine and/or reactor. I & C System Criteria is concerned only

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Date	10 Jan 1962
Par.	8.0

with neutron-flux-density measurement equipment such as neutron detectors, external to the engine and inside the circular shields, used as backup for engine contained neutronics; and area radiological monitoring equipment.

Accuracy and stability for the external detectors will be in the order of 10% and 5% respectively over a range of 1 to 20,000 counts per second. Source power may be estimated as equal to 2 counts per second.

Accuracy specifications for radiological monitoring equipment are in the order of 10% over one of the following ranges.

0.01 mc/hr to 10 R/hr
0.1 mc/hr to 100 R/hr
1 mc/hr to 1000 R/hr

The foregoing accuracies are of course dependent upon the equipment not being subjected to extreme environmental conditions and also upon stable power supplies. Typical effects of varying power supply or environmental conditions are:

- (1) Line Voltage - up to 0.03% change for a 1% variation in line voltage
- (2) Temperature - up to 0.1% change per degree Fahrenheit
- (3) Photon Energy - less than 20% for 100 kev to 2.5 mev.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.0

APPENDIX 5.9

TEMPERATURE MEASUREMENT

1.0

GENERAL

The present state-of-the-art for thermocouples indicates that a Tungsten/Tungsten-26% Rhenium combination shows the best characteristics for high temperature measurements in the NERVA reactor.

Chromel/Alumel thermocouples have been used extensively in the temperature range between 700 and 2000^oR, and have proven to be highly resistant to radiation damage, of the order of 4×10^{20} nvt.

Platinum resistance elements have been recommended as most suitable for cryogenic and low temperatures up to 700^oR, and will be used unless future testing discloses undesirable radiation effects.

1.1

RANGES

A convenient range application guide as given below, has been used in the absence of more specific requirements:

Tungsten/Tungsten-26% Rhenium	2000 to 5200 ^o R
Chromel/Alumel	700 to 2000 ^o R
Platinum Resistance element	40 to 700 ^o R

1.2

THERMOCOUPLE OUTPUT

The millivolt output of the thermocouples that will probably be used in the NERVA engine are given below for the indicated temperature ranges, but for reference only, and not with the intention of reflecting actual engine operation measurements.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par. 1.2

It should be noted that the low output at lower temperatures makes accurate measurements impracticable when using the thermocouples that have been proposed for the NERVA engine.

<u>Operating Range</u>	<u>Corresponding Millivolts</u>
------------------------	---------------------------------

Chromel/Alumel
(32°F, 491°R Ref. Junction)

460° to 490°R	-0.68 to -0.04 (1)
---------------	--------------------

500° to 2960°R	0.18 to 54.92 (1)
----------------	-------------------

Tungsten/Tungsten-26% Rhenium
(32°F, 491°R Ref. Junction)

560° to 4660°R	0.103 to 38.474 (2)
----------------	---------------------

(1) International Temperature Scale of 1948.

(2) New Developments in Tungsten/Tungsten-Rhenium Thermocouples, J. C. Lachman, Paper presented at 16th National Conference of Instrument Society of America, 11 September 1961.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par.

APPENDIX 5.10

DETERMINATION OF DIGITAL
DATA VOLUME AND RESULTING TAPE FORMAT

Tables App. 5.10-1, -2, -3, -4, and -5, attached, present information assembled for the purpose of establishing the required data volume for the digital data system. This information was utilized as the criteria for the selection of a standard tape density. Table -1 is a summation of Table -4, which shows accuracy as a function of time resolution, as specified by Table 5.2-2, "Detailed Measurement Summary." Table -2 shows various sampling distributions which might be utilized to comply with Table -1. Table -5 shows various record arrangements which might be utilized to accomplish Tables -1 and -2, and identifies advantages of different record lengths.

Based upon this information, a tape format of the following structure has been recommended:

Tape speed	112.5 ips
Bit rate	800 bpi
Tape density	90,000 characters/sec
Data word density	40,000 12-bit binary words/sec
Record length	9000 characters
Record rate	10 per sec
Sampling speeds	200, 100, 50, 10 samples/sec
Channel distribution	50 channels, 200 s/s; 100 channels, 100 s/s; 100 channels, 50 s/s; 1500 channels, 10 s/s.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A	
Date	1 June 1962
Par.	

TABLE APP 5.10-1

DIGITAL DATA SYSTEM REQUIREMENTS
TABULATED DATA VOLUME

<u>Millisec Resolution</u>	<u>Number of Channels</u>	<u>Samples Per Sec</u>	<u>Data Words Per Sec</u>
1000	61	1	61
500	28	2	56
100	1269	10	12,690
25	55	40	2,200
10	39	100	3,900
5	79	200	15,800
	<hr/> 1531		<hr/> 34,707
	549 Events at 100 MS ⁽¹⁾		500
	Tabulated Data Volume		<hr/> 35,207

⁽¹⁾ 600 Events = 100 char x 10/min
= 1000 ch
= 500 wd

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par.

TABLE APP 5.10-2

SAMPLING DISTRIBUTIONS

Tape System Capabilities = 800 bpi 112.5 ips

= 90,000 char/sec

= 45,000 wd/sec

Record Identification and Fix Data Requirements

= Time, ID, Direct Digital, Gap

= 832 Bytes/R

= 8320/sec²

= 4520 wd/sec

Data Volume cannot exceed 40,750 wd/sec

<u>Resolution</u>	<u>s/s</u>	<u>Channels</u>	<u>wd/sec</u>	<u>Channels</u>	<u>wd/sec</u>	<u>Channels</u>	<u>wd/sec</u>
100 MS	10	1400	14,000	1,250	1,250	1,500	15,000
20 MS	50	50	2,500	50	2,500	100	5,000
10 MS	100	50	5,000	50	5,000	100	10,000
5 MS	200	100	20,000	100	20,000	50	10,000
Total		1600	41,500	1,450	40,000	1,750	40,000

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par.

TABLE APP 5.10-3

TAPE DENSITIES AVAILABLE
FOR SYSTEM APPLICATION

<u>Bit Rate</u> bpi	<u>Tape Speed</u> ips	<u>Character Density</u> bps	<u>Data Word Density</u> wd/sec
200	75	15,000	7,500
200	112.5	22,500	11,250
200	150	30,000	15,000
556	75	41,500	20,750
556	112.5	62,500	31,250
556	150	83,400	41,700
800	75	60,000	30,000
800	112.5	90,000	45,000
800	150	120,000	60,000

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par.

TABLE APP 5.10-4

ACCURACY AS A FUNCTION OF TIME
RESOLUTION FOR REQUIRED 1531 MEASUREMENTS

Tab Page No.	Time Resolution in Millisec											
	1000		500		100		25		10		5	
	Accuracy											
	> 0.5%	<0.5%	> 0.5%	<0.5%	> 0.5%	<0.5%	> 0.5%	<0.5%	> 0.5%	<0.5%	> 0.5%	<0.5%
1						9		2				2
2			2	2	2	8	11	23				4
3					153							
4					116							
5					14	10					5	
6					1						3	
7						179						
8						150						
9						48						
10						20						
11				16		22						
12						4						
13				8		21						
16						22		2		13		
17						30						
19	8	19										
20		18						2				
22					2							
23						36			8			1
24						19						19
25						23						31
27		2				8						
28						4		7		10		
29						36						
30	3	9			6	3		8		8		
31												
32						41						
33						32						
35	2											
36						117						
37								1				14
	13	48	2	26	294	975	11	44	8	31	8	74
	61		28			1269	55		39		82	

Derived from unpublished tabulation of ETS-1 data-volume requirements, based on Data Acquisition Measurement List, Table 5.2-2.

Test Stand ETS-1
Instrumentation & Control
System Criteria
NNRDC

Revision A

Date 1 June 1962

Par.

TABLE 5.10-5

COMPARISON OF VARIOUS RECORD LENGTHS

TABLE 5.10-5

COMPARISON OF VARIOUS RECORD LENGTHS

Records/Sec	20	10	5	4	2	1
Record Length ⁽¹⁾	2,250	4,500	9,000	11,250	22,500	45,000
Record Volume ⁽²⁾	27,000	54,000	108,000	135,000	270,000	540,000
Unusable ⁽³⁾ Volume in %	32	16	8	6.4	3.2	1.8
Sample Speeds Per Sec ⁽⁴⁾	20,50, 100,200	10,50 100,200	5,10,50 100,200	4,8,20, 100,200	2,10,50 100,200	1 to 200
Minimum Time Resolution in Millisec	50	100	200	250	500	1000
% of Record Available in % for High Sample Rate	44	67	84	87	93.3	96.3
Computer Memory Size in Words ⁽⁵⁾	4096	8000	12,000 to 16,000	16,000	32,000	32,000
On-Site Com- puter as Suggested	PDP-I	PDP-I RR 1218	RR 1218	RR 1218 IBM 7040	IBM 7040	IBM 7040

Notes: (1) Record length measured in 12-bit data words (2 char/word).

(2) In bits, parity not counted

(3) Unusable Part - Range time, 5 char/word;
Test identification, 4 Bytes;
Count time, 7 Bytes;
Events, 100 Bytes;
Gap, 600 Bytes;
Total is 716 Bytes/Record

(4) Other sample speeds are possible, however lowest speed and multiple speeds are determined by record rate.

(5) Computer words are not same length as data word.

(6) Tape Speed 112.5 ips
Bit Rate 800 bpi
Data Volume 90,000 char/sec = 45,000 12-bit Wd
Assume 1500-Channel System