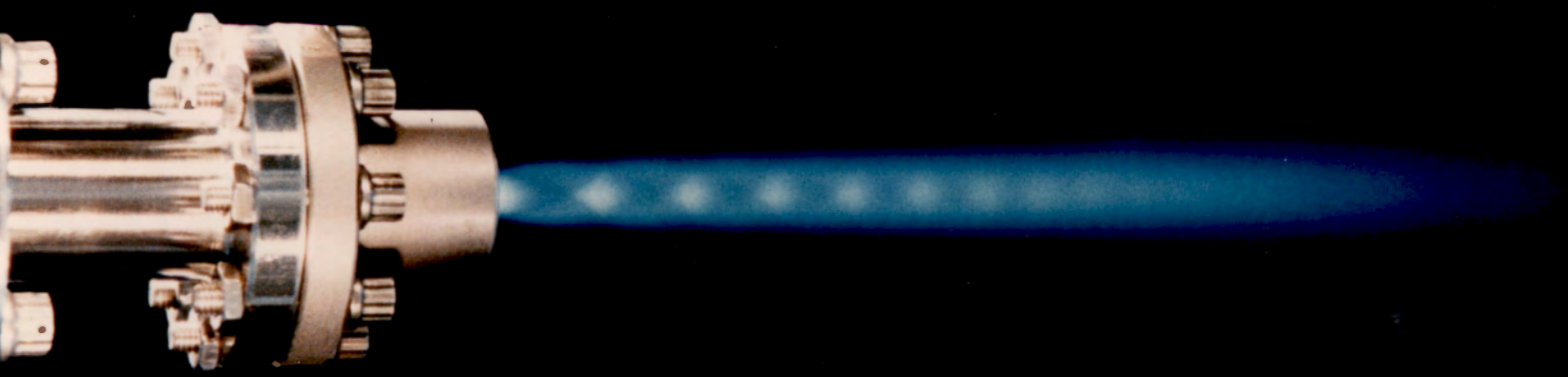
Rocket Laboratory Facilities Manual



NASA

Lewis Research Center
Cleveland, Ohio 44135

ROCKET LABORATORY

FACILITIES MANUAL

NASA Lewis Research Center
Space Propulsion Technology Division
Aerospace Engineering Branch

1991

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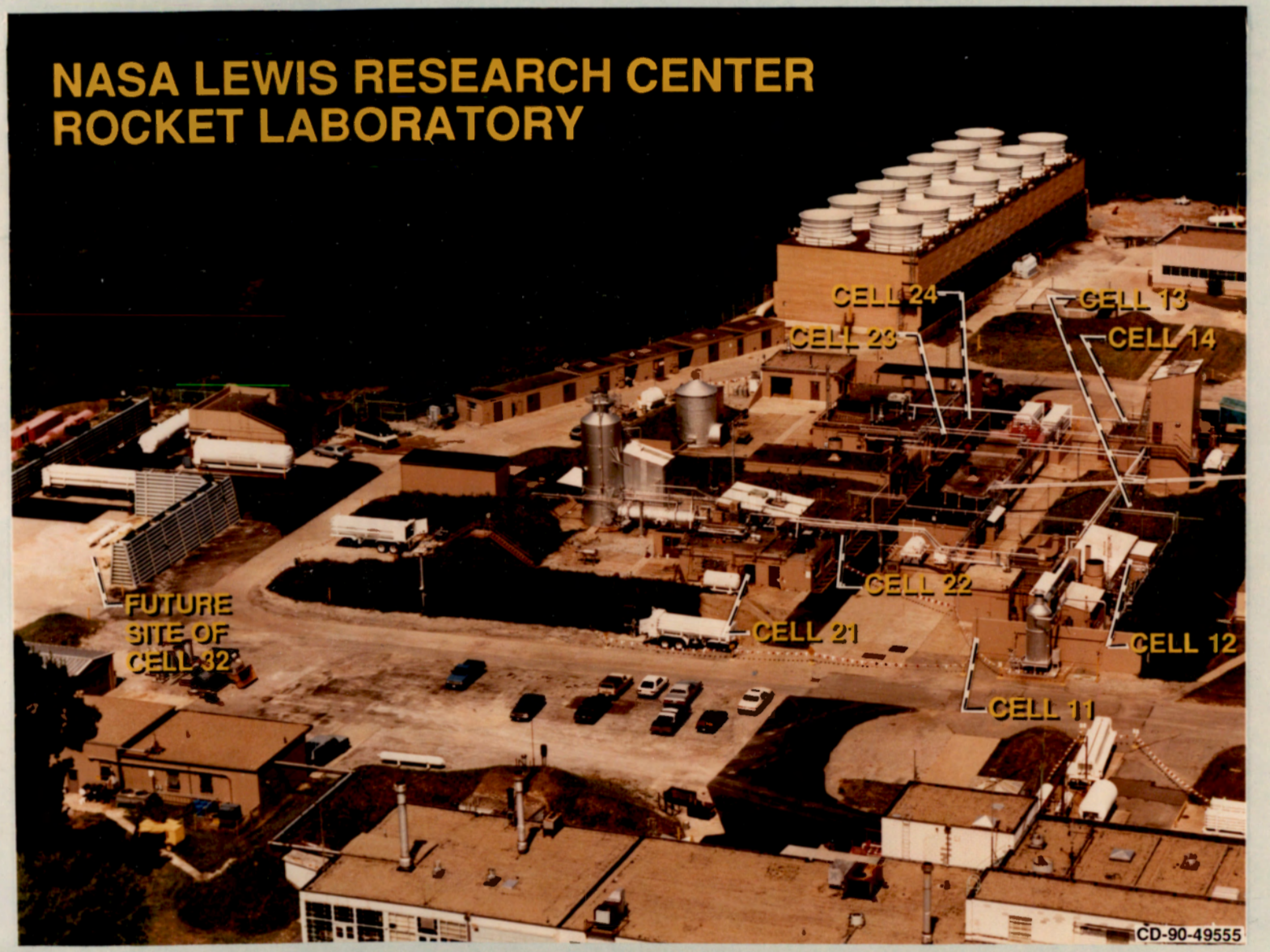

CONTENTS

1. INTRODUCTION

This manual presents an overview of the experimental testing capabilities of the Rocket Laboratory located at the NASA Lewis Research Center. There are currently nine fully operational test cells located at the laboratory which provide facilities for research in a variety of rocket propulsion technology areas. Two additional test cells are currently under construction, and are expected to become operational by the summer of 1992.

Section 2 of this manual presents a listing of current research programs. A quick reference guide to the laboratory facilities is provided in section 3. Section 4 provides a more detailed description of each test cell, and includes photographs of each cell and its control room.

2. CURRENT RESEARCH PROGRAMS

The following table lists research activities currently being pursued at the Rocket Laboratory. Detailed information about these experiments can be obtained from the engineers listed in section 3.

CURRENT RESEARCH PROGRAMS

CELL	RESEARCH PROGRAMS
11	* 25 lbf Hydrogen/Oxygen Thruster Life Tests * 25 lbf Hydrogen/Oxygen Thruster Performance * Laser Rayleigh Measurements for CFD Code Validation * Raman Temperature and Major Species Measurements for CFD Code Validation
12	* Multi-phase Flow and Fluid Spray Characterization
13	* Liquid Nitrogen Spray Nozzle Experiments
14	* Metallized Propellant Rheology * Powdered Metal Gas Entrainment and Injection Testing
21	* Multi-compartment Ignition Techniques: Combustion Wave; Laser Generated Spark * In-Situ Propellant Performance Testing * Metallized Propellant Performance Testing

22	* Ceramic Matrix Composites Testing * Cowl Lip Technology
23	* Fuel Rich Catalytic Reaction Program * Ceramic Combustion Liner Evaluation
24-A	* Long Life Turbopump Bearing Test Program
24-C	* Hydrogen Gas Detection * Optical Temperature Measurements * Raman Scattering * Optical Fiber Characterization

3. ROCKET LABORATORY FACILITIES OVERVIEW

This section highlights the main points of interest of each test cell, presenting an overview of test cell capabilities in tabular form. The type of research conducted, the range of testing capabilities, the data acquistion system(s) used, and the fluid services available in each cell are included. In addition, the engineers responsible for conducting the research in each cell are listed.

ROCKET LABORATORY FACILITIES OVERVIEW

Cell	Description	Capabilities	Data Acq.	Services	Engineers
11	Small Rocket Thruster	Long Runs (Hours) Short Run (Seconds) Cyclic Runs Altitude Testing	Daytronics System 10 FM Tape Visicorder Optical Pyrometer IR Camera Video Camera/VCR	GO2, GH2 GN2, CA CW, SA	Lynn Arrington Brian Reed Steve Schneider Wim Degroot Frank Zupanc
12	Spray Test Rig	Two-Phase Flow Data Particle Size Meas. Multi-Media Flows	ESCORT Scattered Light Scanner Video Camera/VCR	LN2, GN2 GHe, CA SA, CW	Robert Ingebo Donald Buchele
13	Cryogenic Fluid Test Rig	LN2 Cooling LN2 Flow/ Spray Tests Saturated N2 Vapor Flow/ Spray Tests	ESCORT	LN2, GN2 GHe, SA	John Jurns Naseem Saiyed

14	Metallized Propellant Flow Analysis Facility	Propellant Flow Tests System Component/ Injector Testing	ESCORT 16mm Movie Camera Video Camera/VCR	GN2, SA CW	Douglas Rapp Mike Meyer
21	Altitude Rocket Ignition Test Stand	Ignition Tests at Ambient or Altitude Cyclic Tests Long Runs	TRADAR 2.5 ESCORT Chart Recorder Video Camera/VCR	GO2, GH2 GN2, LN2 LP, RP-1 CA, SA CW Bottled Gaseous Fuels	Joe Zoeckler
22	High Temperature Thermal Shock Test Rig	Materials Testing in H2/O2 Rocket Exhaust Cyclic Tests Runs up to 10 seconds	TRADAR 2.5 Visicorder 16mm Movie Camera Video Camera/VCR 35mm Camera	GO2, GH GN2, SA CW	Joe Zoeckler

23	Hydrocarbon Fuel Combustion Test Rig	Fuel/Air Combustor Non-Vitiating Air Preheater Emission Gas Testing	ESCORT Visicorder Video Camera/VCR	GN2, CW SA, ST Natural Gas Jet-A Iso-octane	James Rollbuhler Dave Hulligan
24A	Bearing Research Laboratory	Test Speeds Up to 25,000 RPM Large Size Bearings High Test Loads	ESCORT Video Camera/VCR	Steam SA, CW CA, GN2	Gene Addy Fred Schuller
24C	Optical Instrument Laboratory	20 Watt Copper Vapor Laser 1 mW HeNe Laser GH2 Flow Chamber	Hewlett-Packard Model 3852 ESCORT	GN2, GH2 CW, SA	George Madzsar

CA - Combustion Air
CW - City Water
SA - Shop Air
ST - Steam

4. TEST CELL DESCRIPTIONS

Detailed information about the test cells in the Rocket Laboratory is given in the following pages. A brief written description of each cell is given, highlighting the main points of interest. Photographs of the test cells and their associated control rooms are included.

CELL 11

Cell 11 is designed for long duration operation of gaseous hydrogen/gaseous oxygen rocket engines ranging from 5 to 50 lbf thrust, as well as short duration performance characterizations. The facility incorporates laser based diagnostics for flow property measurements in order to improve the predictive technology for low thrust chemical rockets. The test facility consists of the test cell, adjacent control room, and combustion air driven ejectors for altitude capability, as well as gaseous hydrogen, gaseous oxygen, and gaseous nitrogen services. A programmable controller is used to sequence thruster startup and shutdown, while a data acquisition system signals run duration and number of cycles in addition to collecting data. Performance data is displayed on-line and is stored on floppy disks for further post-run analysis.

Capabilities :

* Long Duration Tests (Hours)
* Short Duration Tests (Seconds)
* Cyclic Tests
* Rayleigh Scattering Velocity and Temperature Measurements
* Raman Scattering Temperature and Species Concentration Measurements

Data Acquisition System :

* Daytronic System 10 Modular Data Acquisition System
  - Up to 1000 channels at 2.5 samples/sec/channel
* FM Tape Recorder
  - 14 data channels
* Visicorder Chart Recorder
  - 8 data channels
* Infrared Camera and VCR
* High Temperature Optical Pyrometer

Services :

* GO_2 :

  1 trailer at 2400 psig maximum; 50,000 standard cubic foot capacity; .08 pps max flow rate at 1000 psi*

* GH_2 :

  1 trailer at 2400 psig maximum; 70,000 standard cubic foot capacity; .022 pps max flow rate at 1200 psi*

* GN_2 :

  From Rocket Laboratory central supply; 2200 psig maximum; 1.2 pps max flow rate

* Shop Air :

  From Engine Research Building (ERB) central supply; 125 psig maximum

* Combustion Air :

  From ERB central supply; 125 psig maximum; 10 pps max flow rate

* Water :

  City water at 40 psig

* Water Pump :

  50 gpm at 125 psig

* Allowable flow rates per current safety permit.

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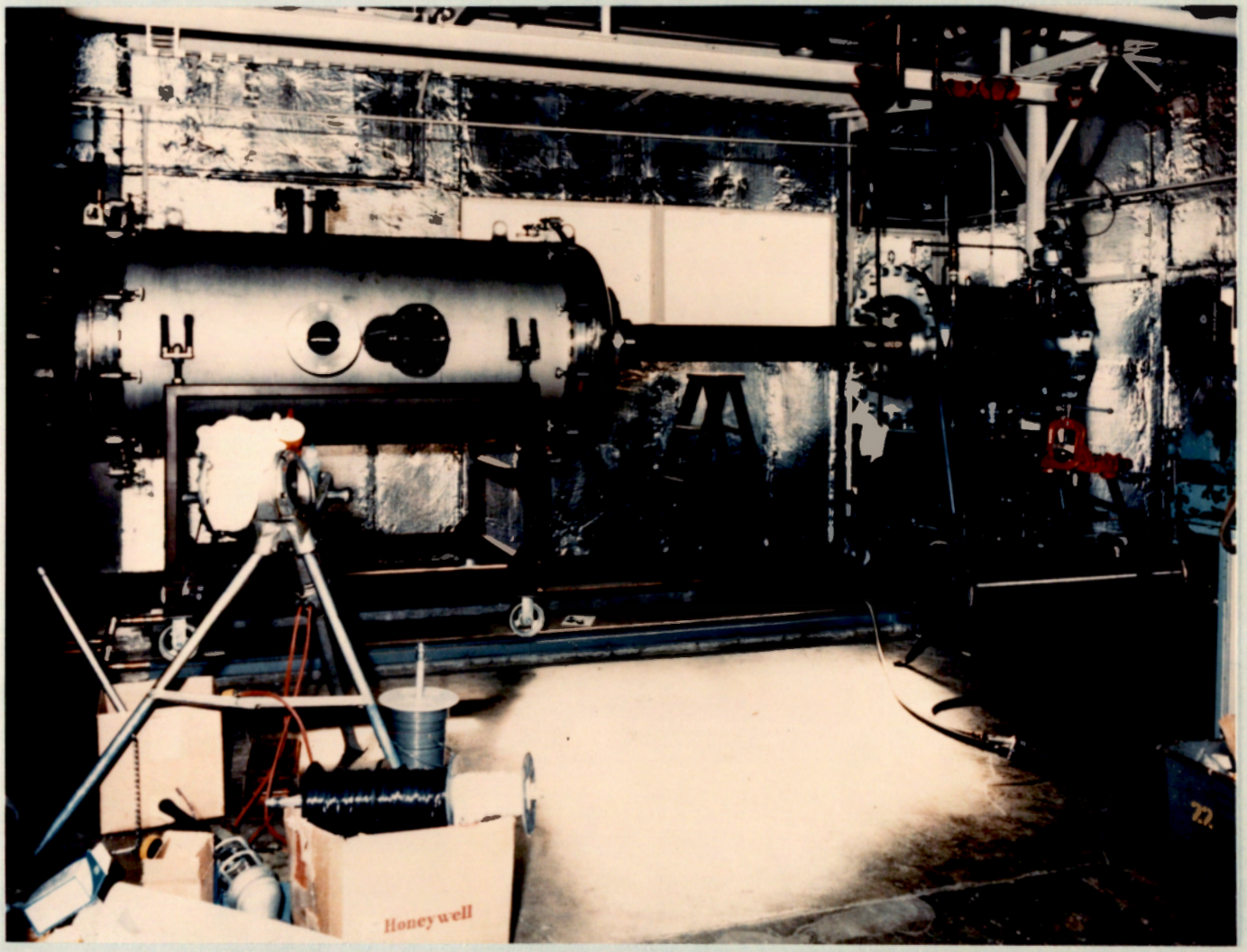
ROCKET LABORATORY
CELL 11



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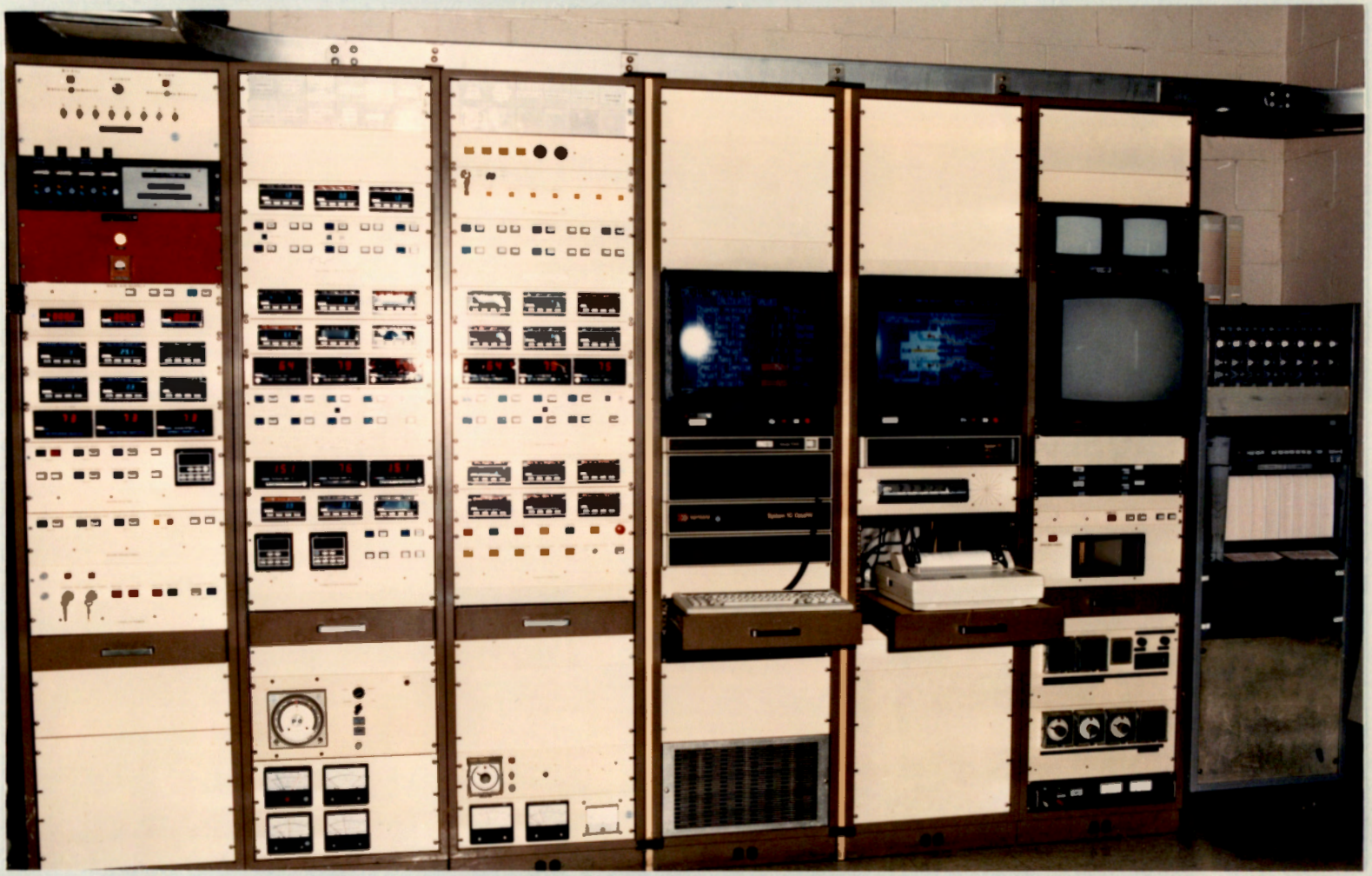
ROCKET LABORATORY
CELL 11 CONTROL ROOM



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CELL 12

RL Cell 12 contains a Spray Test Rig and instrumentation for studying multi-phase flow. The facility consists of a test cell, adjacent control room, an outside water storage tank next to the cell, a portable liquid nitrogen dewar, and gaseous nitrogen, service-air, and combustion air services. Escort service is used to record data and calibrate flow rates, and a Norland computer is used to process dropsize measurement data obtained with the NASA-Lewis developed Scattered Light Scanner. Data reduction is obtained for the tests by using main-line computer systems.

Capabilities :

* Basic two-phase flow measurements including liquid particle-size measurements of sprays with characteristic drop sizes as small as 5 micron
* Liquid-nitrogen pressures up to 325 psia and water pressure up to 1000 psia
* Nitrogen gas pressure up to 1000 psia
* Combustion air up to 2 lb/sec at 125 psia
* Service air at 40 psia

Computer Support:

* Access to mainframes via modem
* Norland computer

Data Acquisition Systems:

* ESCORT system
  - 80 data channels at 1 sample/sec./channel
* Scattered Light Scanner
  - Developed at NASA-Lewis
* Video Camera and VCR
  - Monitored from control room

Services:

* LN_2 :

  Dewar supply

* GN_2 :

  From central supply; 2200 psig max

* Air :

  From central supply; 125 psig max

* Water :

  City water at 40 psig

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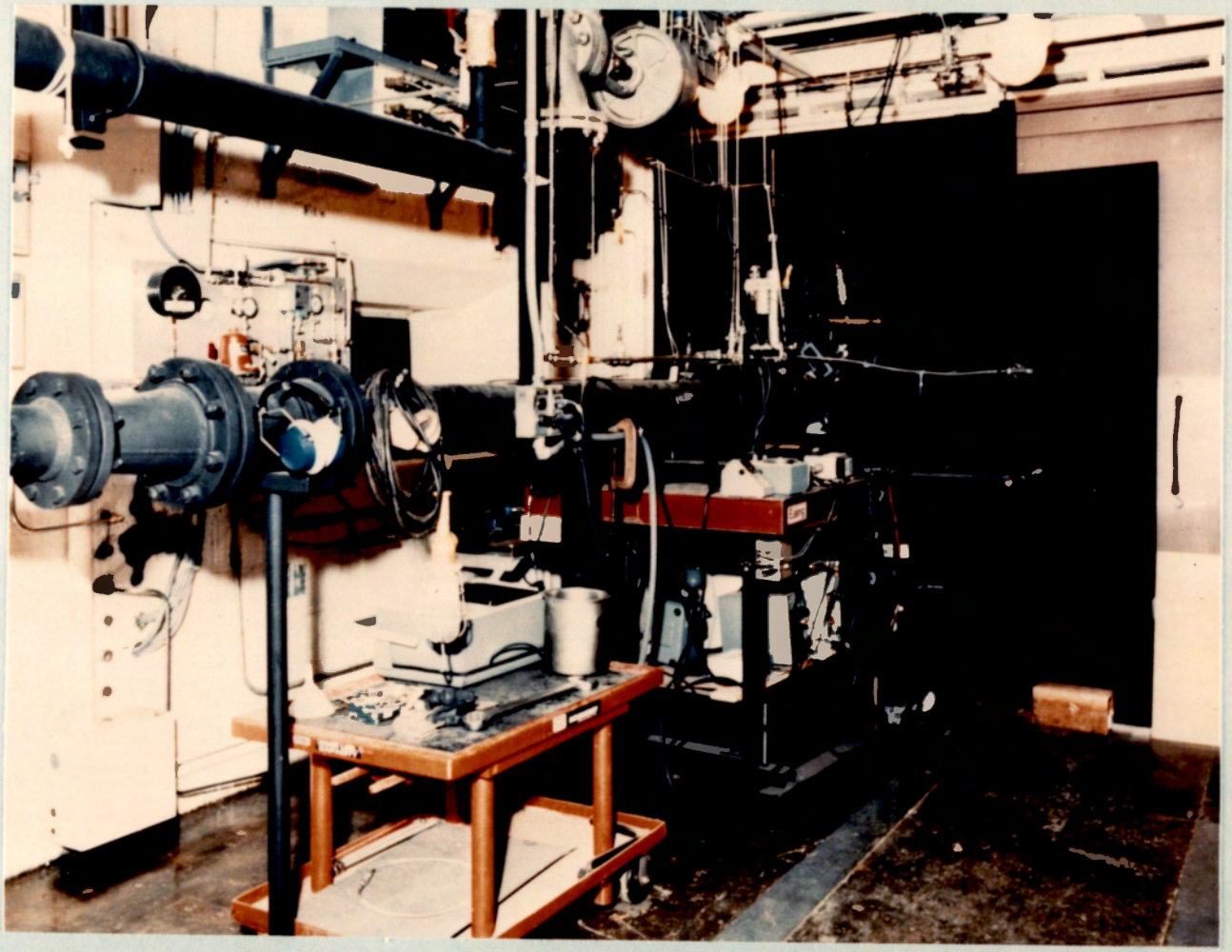
ROCKET LABORATORY
CELL 12



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ROCKET LABORATORY
CELL 12 CONTROL ROOM

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CELL 13

The Cryogenics Fluids Technology Office uses RL Cell 13 as a general purpose liquid nitrogen (LN_2) test area. RL-13 consists of a 12' x 20' test area, a 13' x 13' high bay area accessible from the test cell which exits outside through roll-up doors, a 12' x 19' shop area (most of which houses a control room), a 300 gallon LN_2 supply dewar positioned in the test cell, GN_2 service supplied from the RL central accumulator, and GHe from gas cylinders. The basic rig includes an insulated 65 gallon LN_2 tank (2 foot diameter vertical cylinder) containing two 6-inch sight glasses in the tank shell and one 2-inch sight glass in the tank top head. The stainless steel tank was designed for operation at full vacuum to 150 PSIG internal pressure at -320 F. The tank is equipped with an external heating cable (60 Watts/foot maximum) and an external LN_2 cold wall to reduce heat input into the tank. The tank has a liquid level control and pressure control. A vacuum pump provides low pressure vent capabilities to 2 psia. A THERMAX unit supplies LN_2 saturated vapor at various pressures and temperatures. An ESCORT II data system has been installed for steady-state testing.

Capabilities:

* Controlled LN_2 subcooling in tank for internal tests or for supplying external test devices

* LN_2 for spray nozzle tests in tank
  - Inlet: 25 to 150 psia at 139 R
  - Flow Rate: 100 to 1000 lb/hr

* Saturated N_2 vapor for spray nozzle tests in tank
  - Inlet: 14.7 to 45 psia at 140 to 160 R
  - Flow Rate: 5 to 125 lb/hr

Data Acquisition System:

* ESCORT II system for steady state data; 256 channels at 1 sample/sec./channel

Services:

* GN_2 :

  From RL central supply; 2200 psig max

* GHe :

  From cylinder supply; 2200 psig max

* Air :

  From central supply; 125 psig max

* Water :

  City water at 40 psig

* LN_2 :

  Dewar supply; 150 psig, 300 gal max

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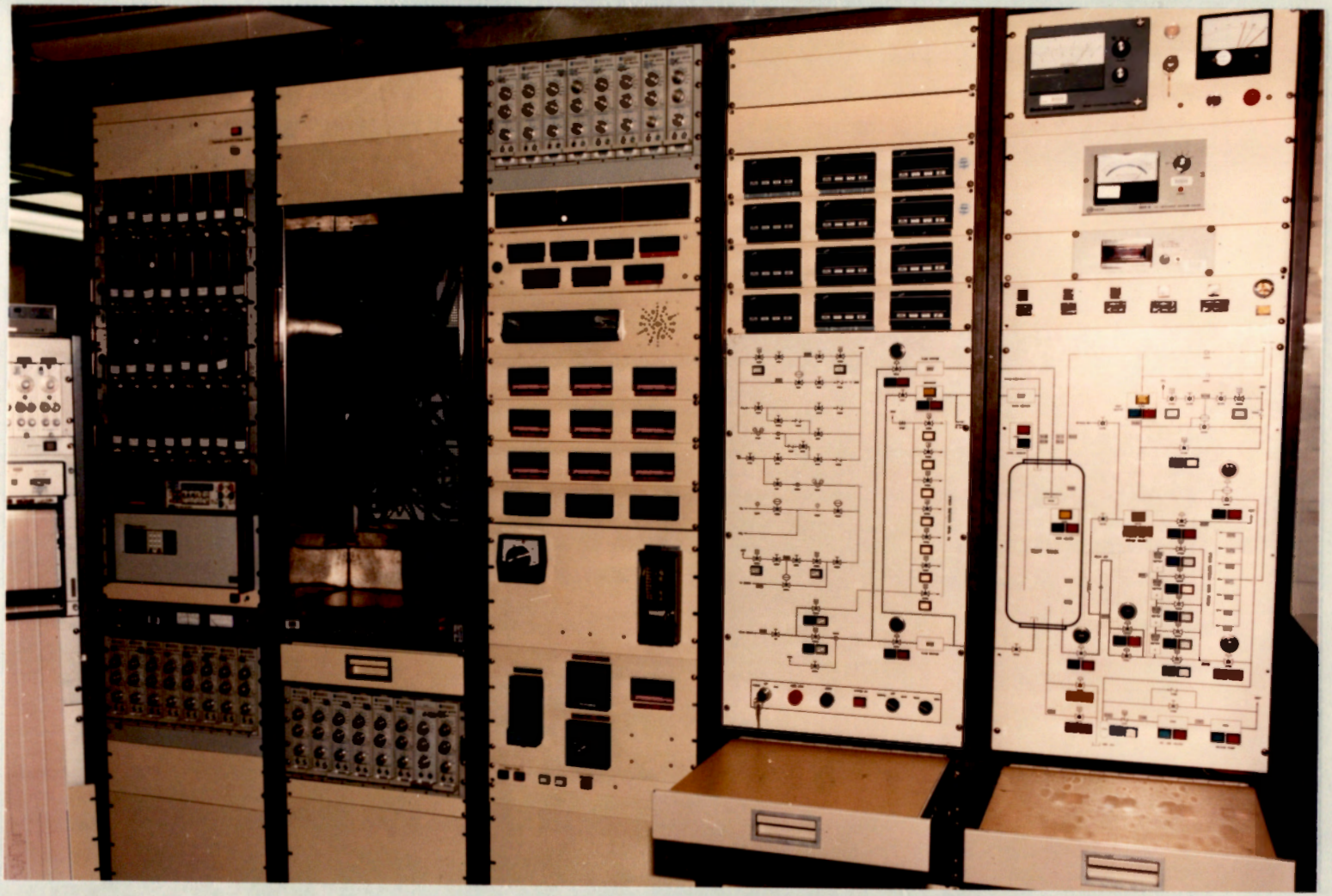
ROCKET LABORATORY
CELL 13 CONTROL ROOM



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ROCKET LABORATORY
CELL 13

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CELL 14

RL Cell 14 contains multiple test rigs collectively known as the Metallized Flow Analysis Facility. The cold flow experimental investigations are conducted with various bench scale test rigs: the High Pressure Reciprocating Flow Rig, including the Single Element Spray Rig; the Low Pressure Positive Expulsion Flow Rig; and the Pump Evaluation Test Rig. In addition to the Metallized Propellant Flow Analysis Facility, Cell 14 also contains the Powdered Metal Gas Entrainment/ Injection Rig used to evaluate powdered fuel feed system components. The testing facility consists of the test cell, an adjacent control room and nitrogen gas services. An ESCORT II data acquisition system, along with manual push buttons, is used for sequential control of test rig valves. Test data recording is accomplished via digital data transmission lines to the Scientific VAX Cluster located at the Research Analysis Center (RAC) building. Data reduction and recovery can be performed by batch processing programs provided through the Computer Services Division.

Capabilities:

* Cold flow testing of high energy-density propellants in pressure-fed and pump-fed modes
* Propellant feed system component testing from 10 to 1500 psig
* Injector cold flow testing from 10 to 1000 psig
* Propellant tank expulsion testing from 10 to 100 psig
* Pump testing from 250 to 950 psig pump discharge pressures at 5 to 0.5 gpm of Al/RP-1
* Powder entrainment and injection testing to 100 psig

Computer Support:

* Access to mainframe via modem

Data Acquisition Systems:

* Primary data acquisition using ESCORT II system
  - 128 channels at up to 2 samples/sec/channel

* High Speed Movie Cameras
  - 16mm, 4000 fps

* Video camera and VCR
  - Monitored from control room

Services:

* GN_2 :

  From RL central supply, 2200 psig max

* Air :

  From central supply, 125 psig max

* Water :

  City water at 40 psig

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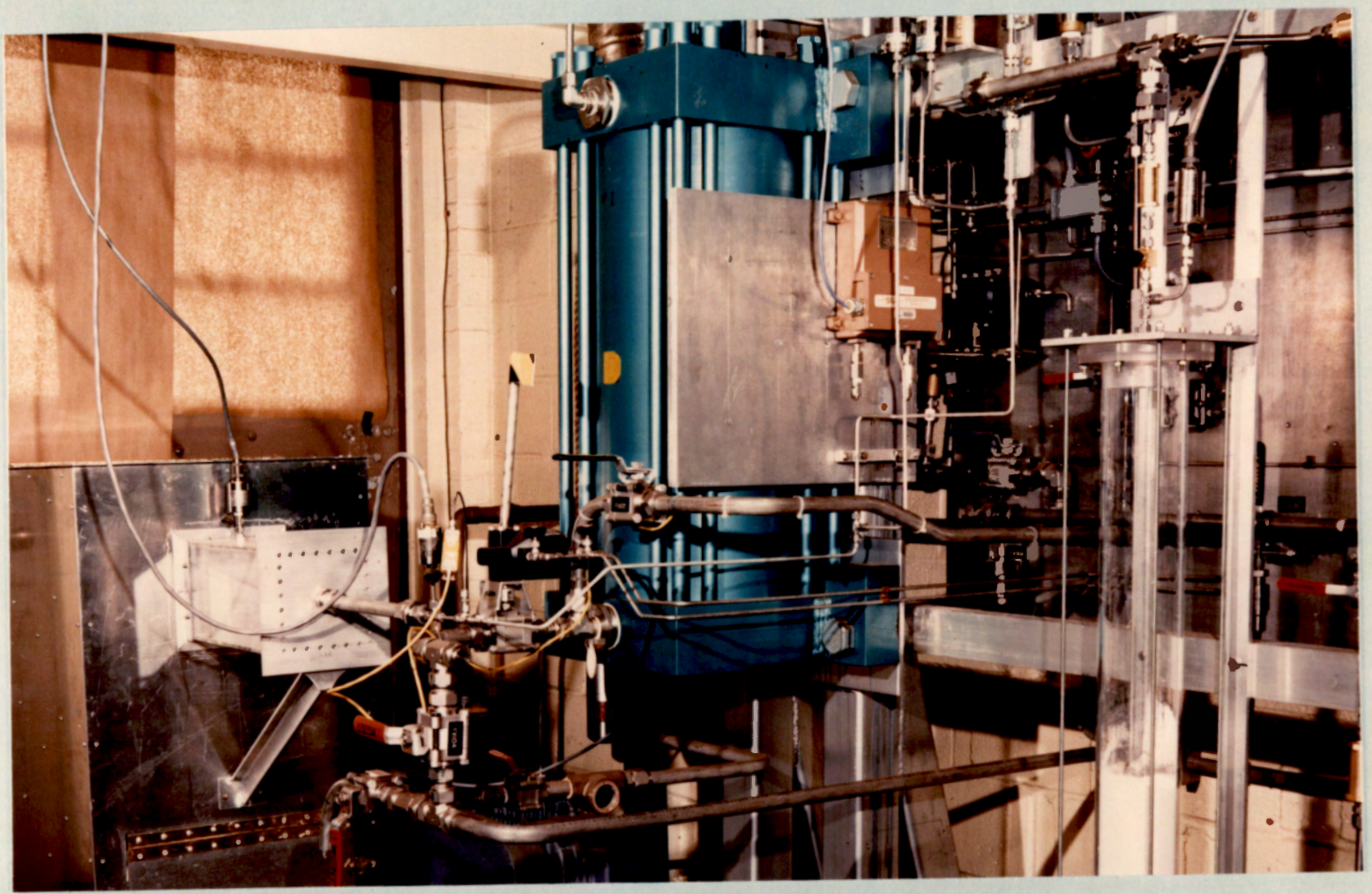
ROCKET LABORATORY
CELL 14



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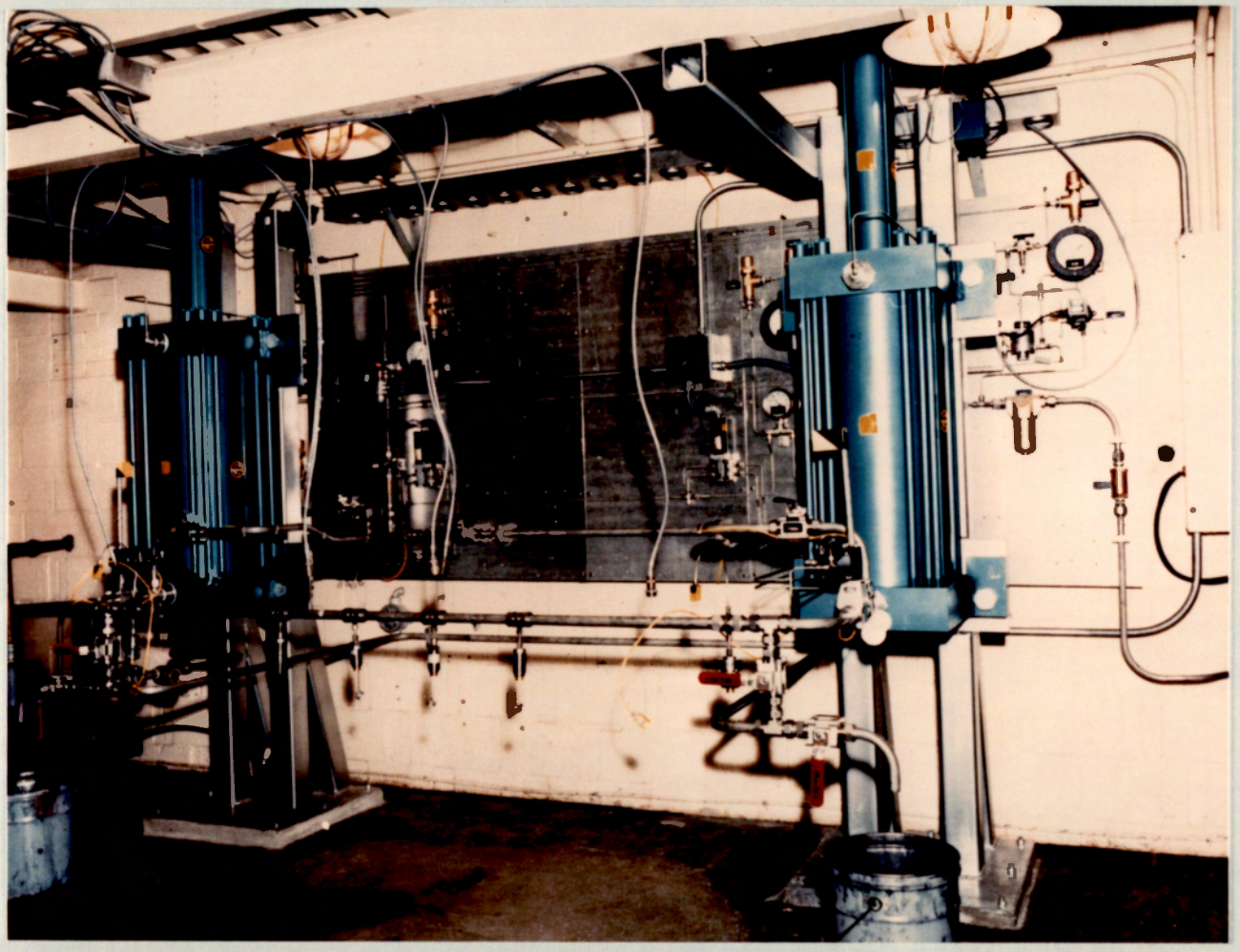
ROCKET LABORATORY
CELL 14



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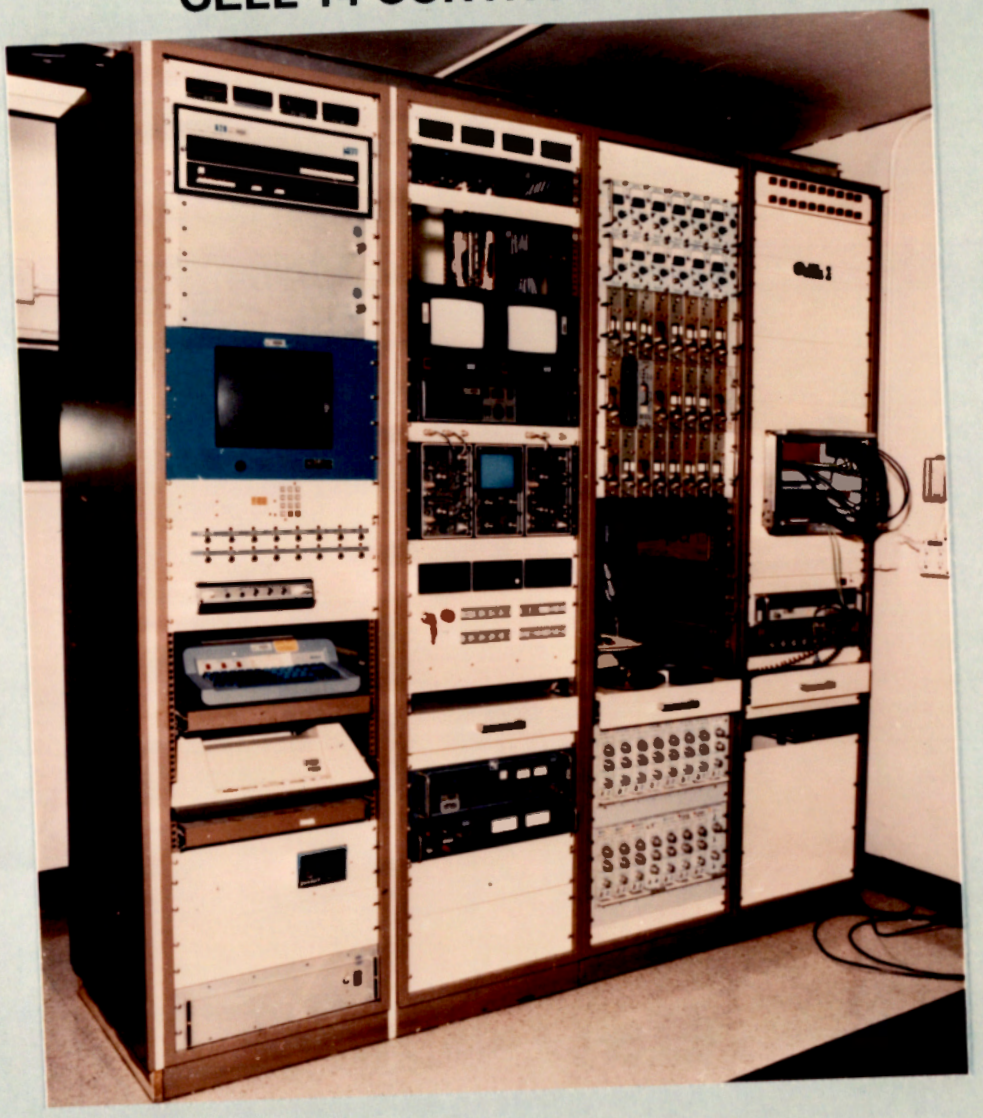
ROCKET LABORATORY
CELL 14 CONTROL ROOM



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CELL 21

RL Cell 21 contains an Altitude Rocket Ignition Test Stand. Ignition tests are performed at altitude or sea-level conditions and use gaseous oxygen and either hydrogen, methane, or RP-1 as propellants. Testing of more novel propellants including carbon monoxide and aluminum/RP-1 gel is also done. A programmable controller is used to tailor each test run to desired duration and number of cycles. Transient data recording is available via analog data transmission lines to the TRADAR 2.5 computer. Digitized data is then transmitted to the VAX cluster for reduction using programs provided by the Computer Services Division.

Capabilities:

* Rocket engine ignition testing at sea-level or altitude conditions
* Low thrust propellant performance evaluation
* Cycle tests
* Long duration tests

Computer Support:

* Access to VAX cluster; DECwriter terminal for hardcopy printout
* IBM compatible personal computer

Data Acquisition Systems:

* High speed data acquisition using TRADAR 2.5 computer
  - Maximum 50 kHz sampling rate with 100 available channels
* ASTROMED chart recorder
  - 16 channels with data capture capability at up to 200 kHz sampling rate
* ESCORT system
  - 111 data channels at 1 sample/sec./channel

* Air :

  From central supply; 125 psig max

* Water :

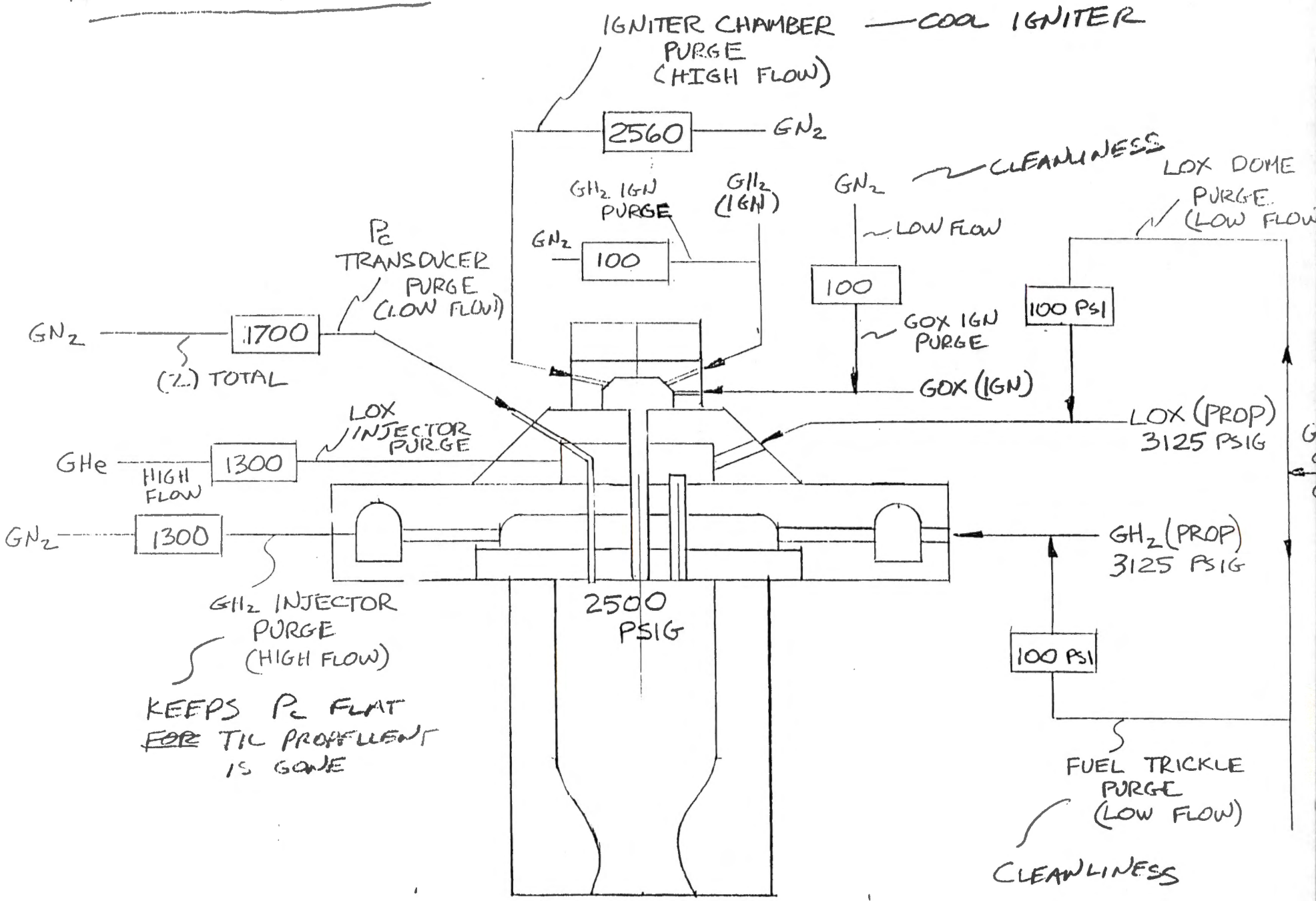
  City water at 40 psig; 50 gpm centrifugal pump at 85 psi boost pressure

Rocket Lab Test Cell 21

Test Cell 21 of the Rocket Laboratory at NASA Lewis was originally designed and built by the Space Propulsion Technology Division for the testing of ignition systems and small rocket engines, up to 100 lb_f thrust. Since the facility came on line in 1987, it has supported a large number of diverse research projects. The propellants initially used in the cell were gaseous hydrogen and oxygen, with many additional fuels being tested throughout the past four years, including methane, RP-1, metallized propellants, and carbon monoxide. The facility also has altitude capability and the gases can be chilled using a liquid nitrogen heat exchanger. The vast number of propellant combinations that can be tested, combined with the large amounts of data that can be generated in this small cell have made Cell 21 an extremely productive facility since its completion in 1987.

The research projects supported in Cell 21 have covered a wide range of propulsion areas, being supported mainly by Base Research and Technology funding and the Earth-to-orbit program. The test cell was initially built and used for research on the catalytic ignition of hydrogen and oxygen. This program built on previous work and improved the design and performance of catalytic igniters. Additional ignition testing was done on a variety of different concepts for hydrocarbon ignition, including conventional spark-torch igniters for use with liquid hydrocarbons, detonation wave testing for multi-compartment ignition, and the study of laser ignition. Alternate fuels for improving launch capabilities and for use on the moon or Mars have also been studied in Cell 21. Aluminum/hydrocarbon metallized propellants were fired for the first time in Cell 21, proving the promise of the metallized concept and defining further areas of research. Fundamental cold flow work on the atomization characteristics of gelled propellants was also done. Carbon monoxide fuel, which could be produced on the surface of Mars, was fired in the cell to study the performance and ignition characteristics of the CO/O_2 propellant combination. In a cooperative program with the Materials Division, a ceramic nozzle was tested in Cell 21 to study the performance and durability of the ceramic nozzle design.

ENGINE SYSTEMS



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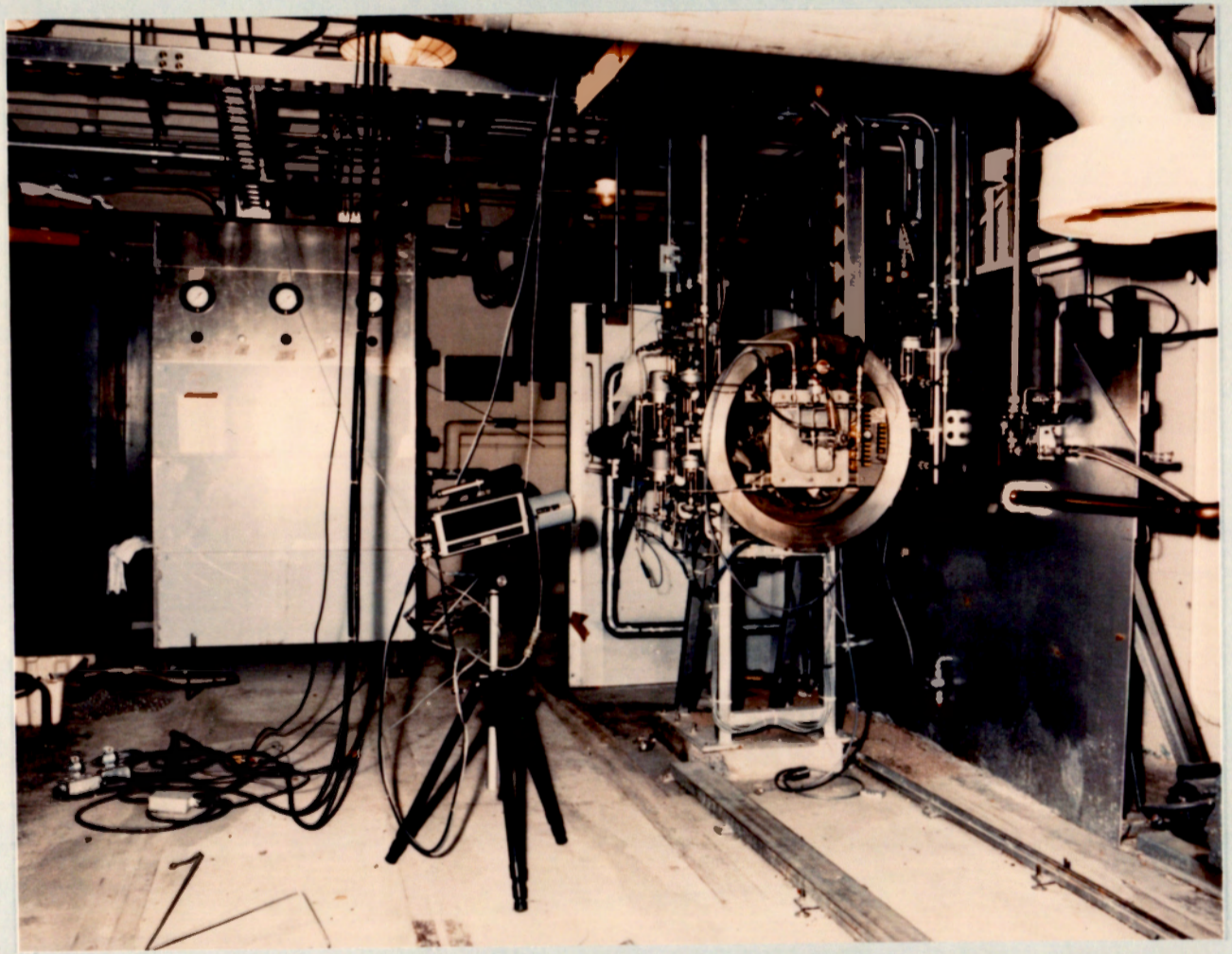
ROCKET LABORATORY
CELL 21



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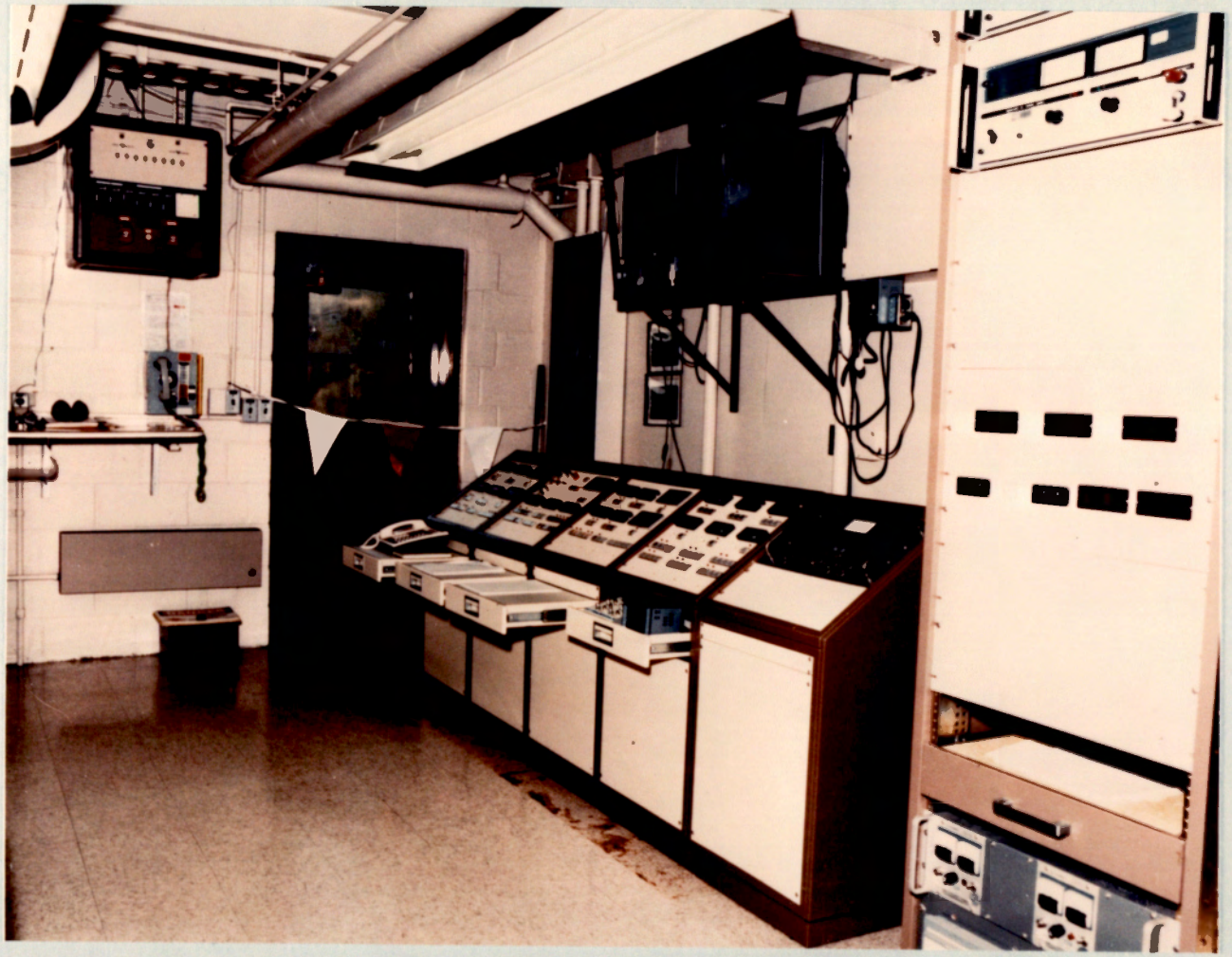
ROCKET LABORATORY
CELL 21 CONTROL ROOM



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CELL 22

RL Cell 22 contains a hydrogen/oxygen rocket engine designed for use as a High Temperature Thermal Shock Test Rig. The testing facility consists of the test cell, an adjacent control room, an exhaust gas scrubber (currently inoperative) and oxygen, hydrogen and nitrogen gas services. A programmable controller is used to tailor each test run to desired duration and number of cycles. Transient data recording is available via analog data transmission lines to the TRADAR 2.5 computer. Data reduction is achieved by sending digitized data to the VAX cluster and utilizing programs provided by the Computer Services Division.

Capabilities:

* Thermal shock testing of materials in hydrogen/oxygen rocket engine exhaust

* Engine chamber pressure from 100 to 600 psia

* Engine design O/F range from 1 to 22; test proven O/F range from 1 to 6

* Cycle tests
  - Up to 10 cycles of 1 second duration at O/F=1

* Long duration tests
  - Up to 10 seconds at O/F=1

Computer Support:

* Access to VAX cluster; DECwriter terminal for hardcopy printout

* IBM compatible personal computer

* Water :

  City water at 40 psig; 150 gpm centrifugal boost pump at 60 psi boost pressure

* Water cooling system for test specimens :

  Up to 70 gpm at 1500 psig max (from 150 gallon blow down tank)

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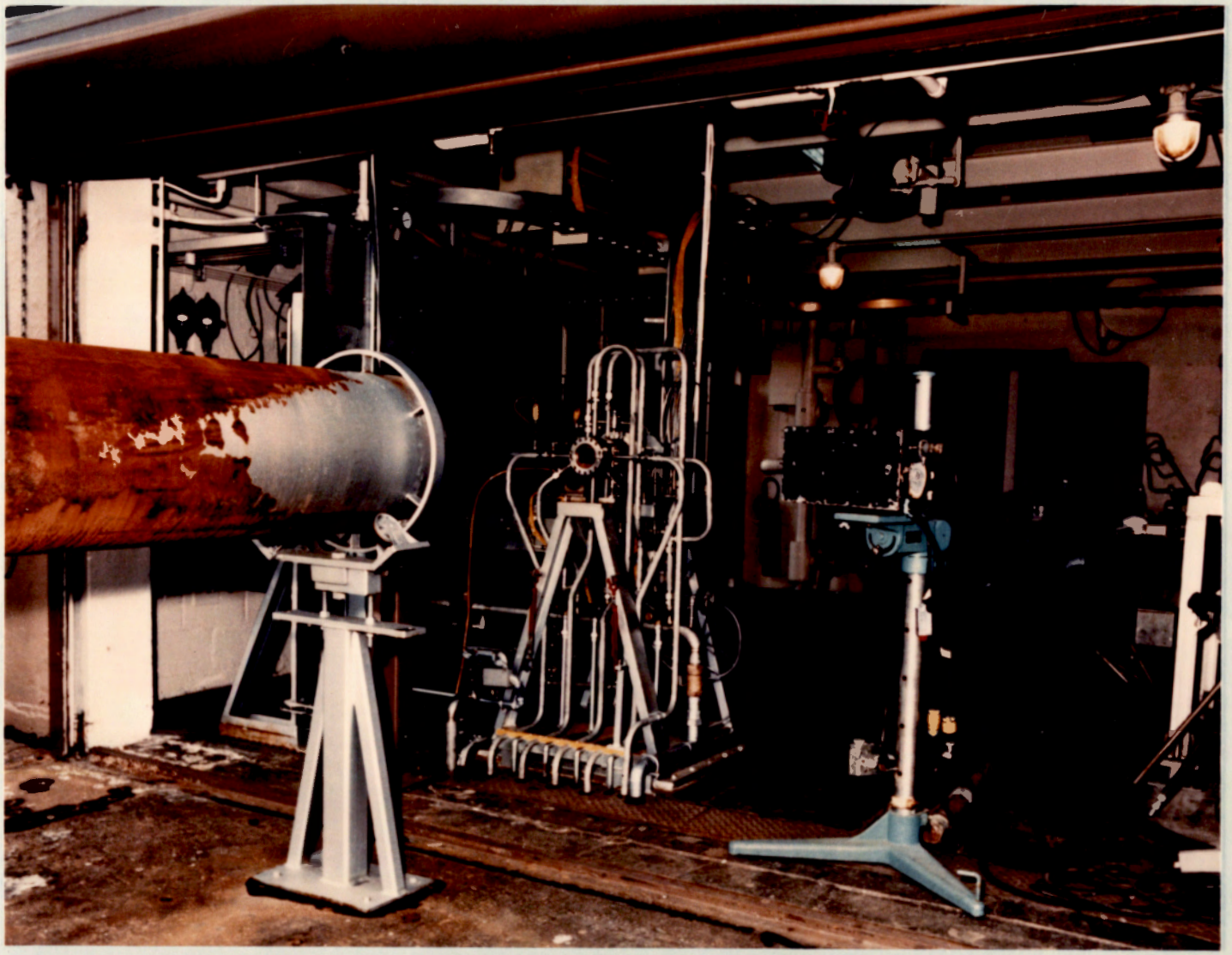
ROCKET LABORATORY
CELL 22



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ROCKET LABORATORY
CELL 22 CONTROL ROOM

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CELL 23

RL Cell 23 contains a Hydrocarbon Fuel Combustion Test Rig. In this facility, various fuels are burned in pre-heated air to determine fuel performance characteristics and emission levels. The maximum fuel flow rate is 5 gpm at ambient temperature and 200 psi pump pressure. The combustor operating pressure is approximately 2 atmospheres at maximum inlet air flows. The air heater which provides the oxidizing air can provide a flow rate from 0.5 to 2.0 pps at 10 atmospheres pressure and can heat air to 1500 F. Exhaust gases from the combustion tests are vented through a roof-top flare stack burner where any unburned fuel entrained in the exhaust is oxidized. The cell 23 control room provides direct observation of the test rig during operation. Data acquisition is performed using an ESCORT II Data Acquisition System. A visicorder data logger is used to observe transient data.

Capabilities:

* Combustion testing of hydrocarbon fuels (Jet-A/Iso-octane and natural gas) at controlled temperatures and pressures
  - 5 gpm maximum, 200 psi

* Non-vitiating air pre-heater
  - 0.5 to 2.0 pps at 10 atmospheres and 1500 F

* Variable duration runs
  - From seconds to hours

* Emission gas measuring system

Data Acquisition Systems:

* ESCORT system
  - 256 channels at 1 sample/sec./channel

* Visicorder chart recorder

* Video camera
  - Monitored from control room

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ROCKET LABORATORY
CELL 23 CONTROL ROOM

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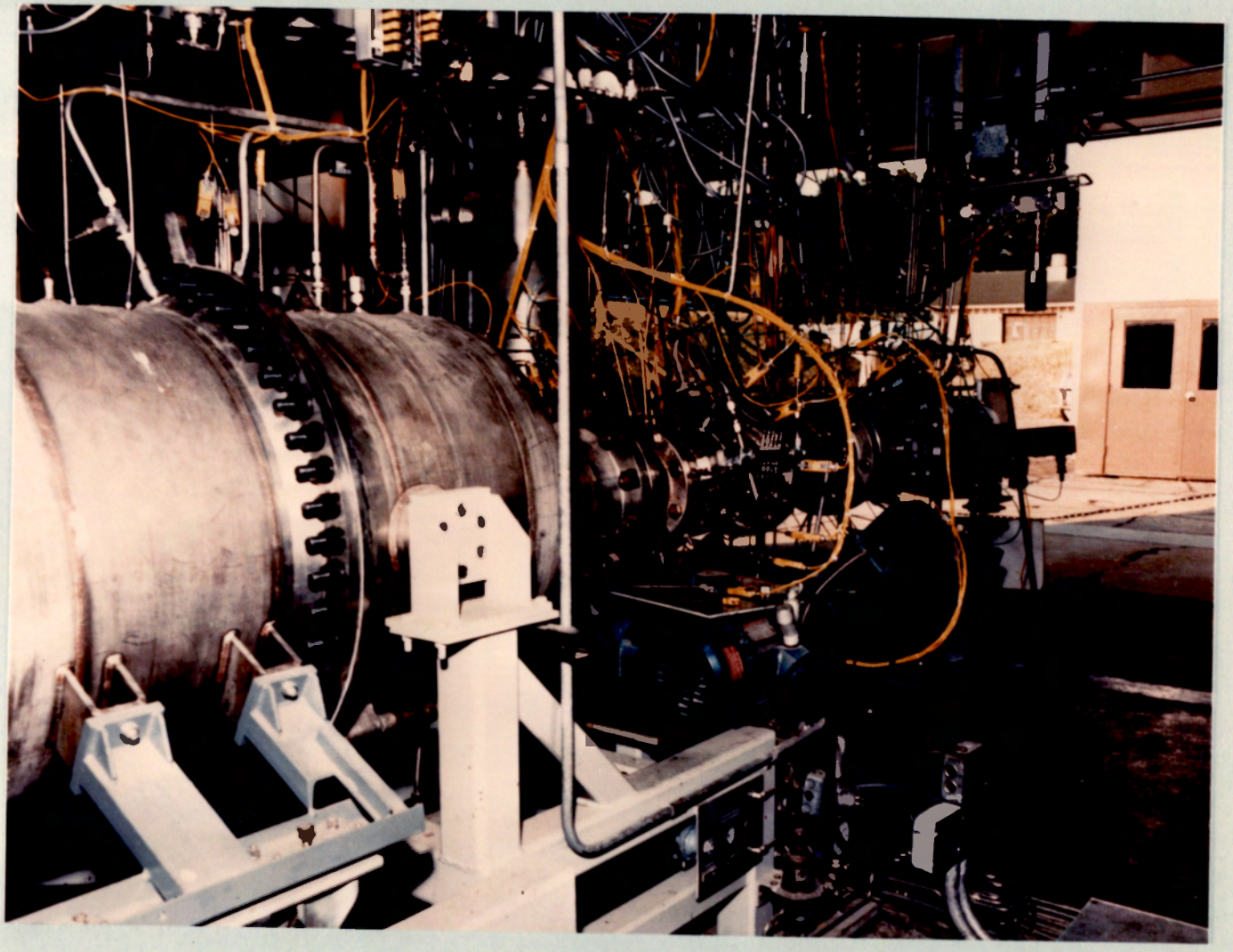
ROCKET LABORATORY
CELL 23



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CELL 24A

Capability to test large size rolling-element bearings exists in RL Cell 24A. This facility has the capability of testing bearings under conditions similar to the conditions found in large thrust rocket engine turbopumps. Because turbopump bearings are cooled with the pumped fluid, the facility has the capability of supplying the test bearings with non-cryogenic propellants used in rocket engines. The test rig can apply large thrust and radial loads on the bearings in addition to operating the bearings at high speeds. The rig is fully instrumented to determine the operating characteristics of the bearing and the lubrication and cooling capability of the propellant. Data reduction and recovery is accomplished through an ESCORT II system.

Capabilities:

* High speed shaft, air turbine driven
  - 25000 rpm
* Large size bearings
  - 85 mm
* Non-cryogenic fluids (RP-1)
* Large thrust and radial loads
  - Up to 5000 lbs

Data Acquisition Systems:

* ESCORT II system
  - 128 data channels at 1 sample/sec./channel

Services:

* GN2 :

  From central supply; 2200 psig

* Steam :

  From central supply; 85 psig, 385 F

* Air :

  From central supply; 125 psig max

* Water :

  City water at 40 psig

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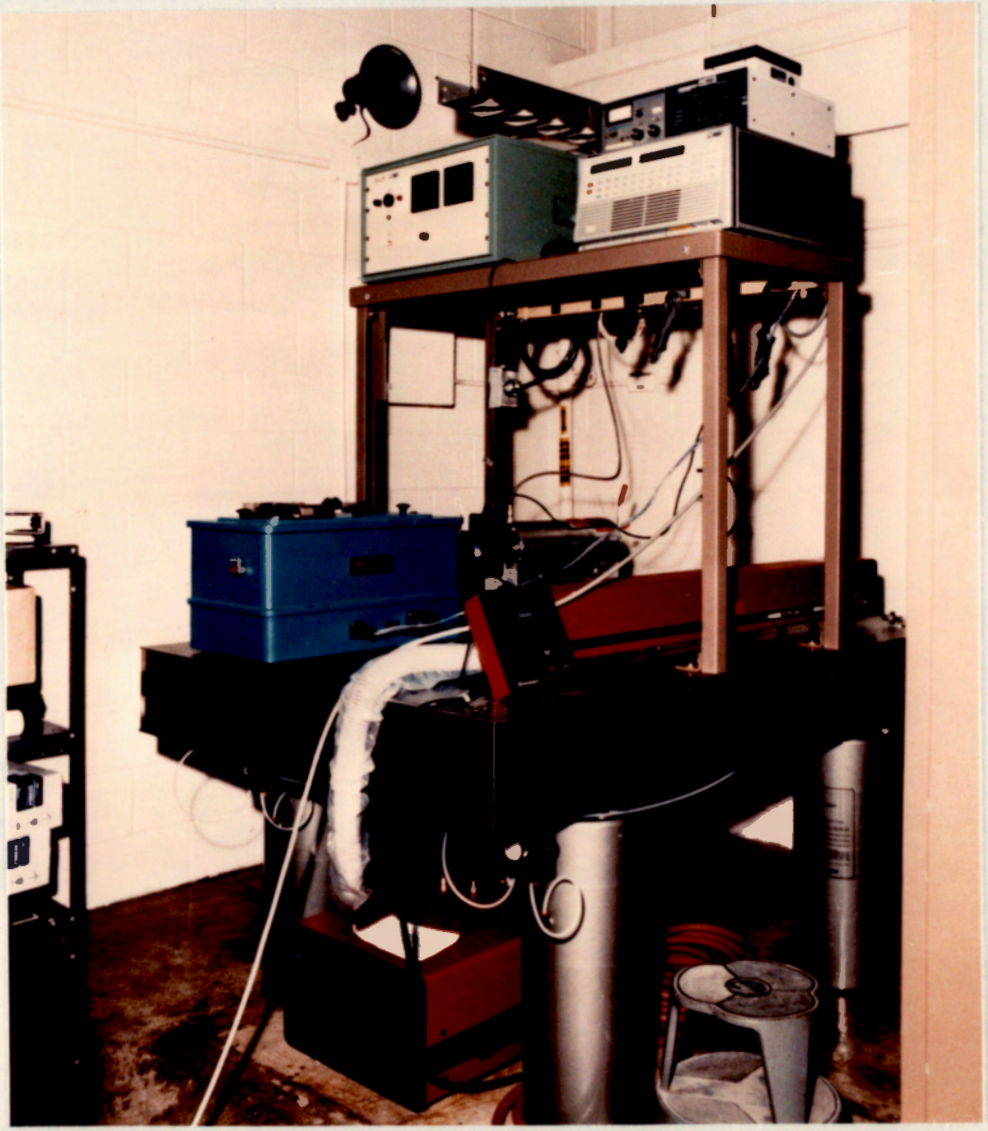
ROCKET LABORATORY
CELL 24C



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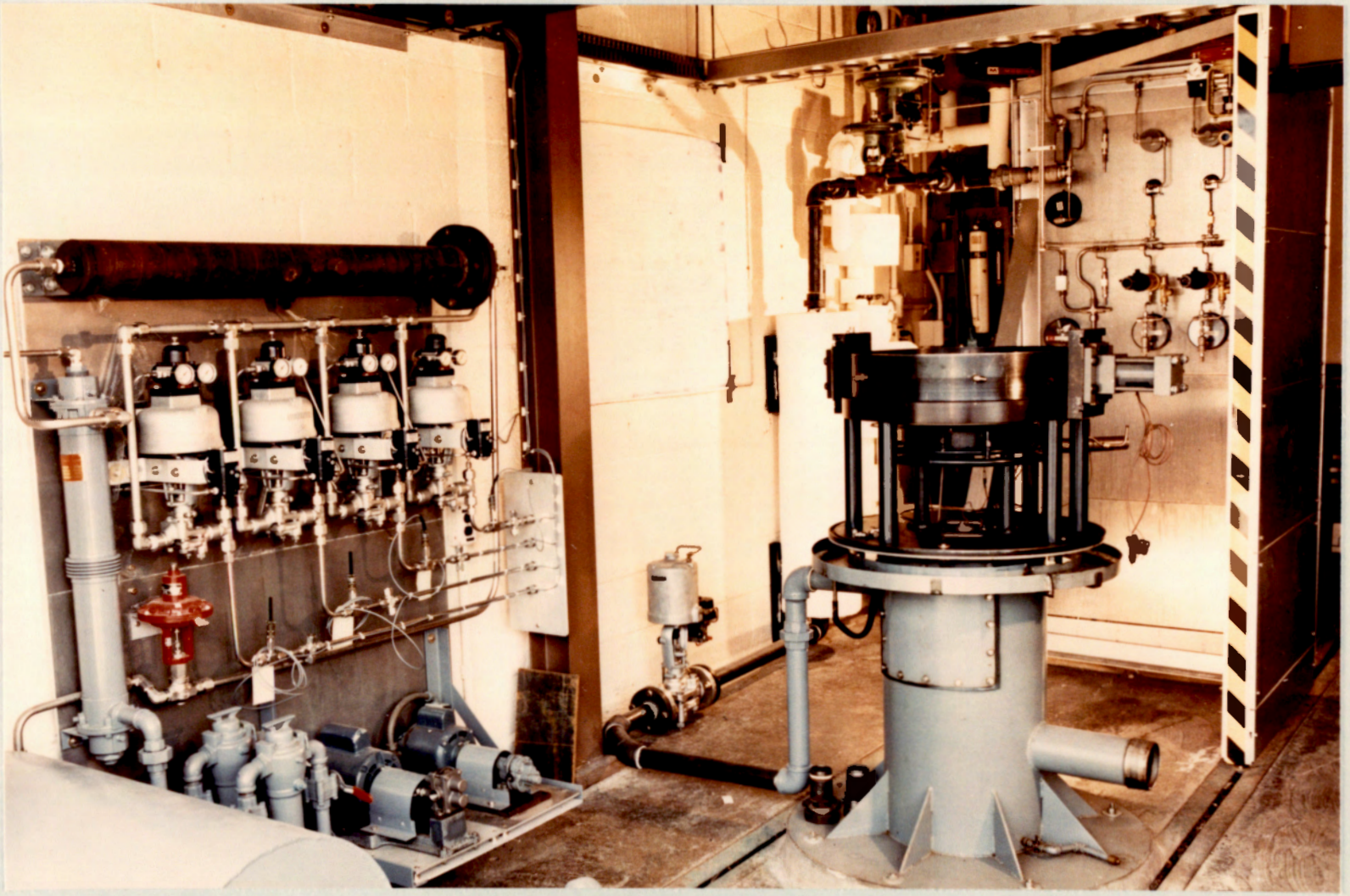
ROCKET LABORATORY
CELL 24A



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CELL 24C

RL Cell 24C is an optical instrumentation laboratory utilized for research and development of optical measurement technologies. The facility consists of a 9' x 13' test cell with an adjacent control room (shared with Cell 24A), and an Escort data acquisition system. A Hewlett-Packard model 330C mini-computer is used for control and data analysis, with a Hewlett-Packard model 3852 system being used for data acquisition.

Experimental Equipment:

* 20 Watt copper-vapor laser
* 1 mW helium-neon laser
* Internally heated pressure vessel with optical access
  - 6000 psi, 1000 C
* 4' x 6' pneumatically suspended optic table
* 2' x 3' optic table
* 1200 C infrared calibration source
* 0.5 meter scanning monochrometer
* Air conditioned test cell

Computer Support:

* Hewlett-Packard Model 330C

Data Acquisition Systems:

* ESCORT II system
  - 128 data channels at 1 sample/sec./channel
* Hewlett-Packard Model 3852
  - 40 channels

Services:

* GN_2 :

  From RL central supply; 2200 psig max

* GH_2 :

  From cylinder supply

* Air :

  From central supply; 125 psig max

* Water :

  City water at 40 psig

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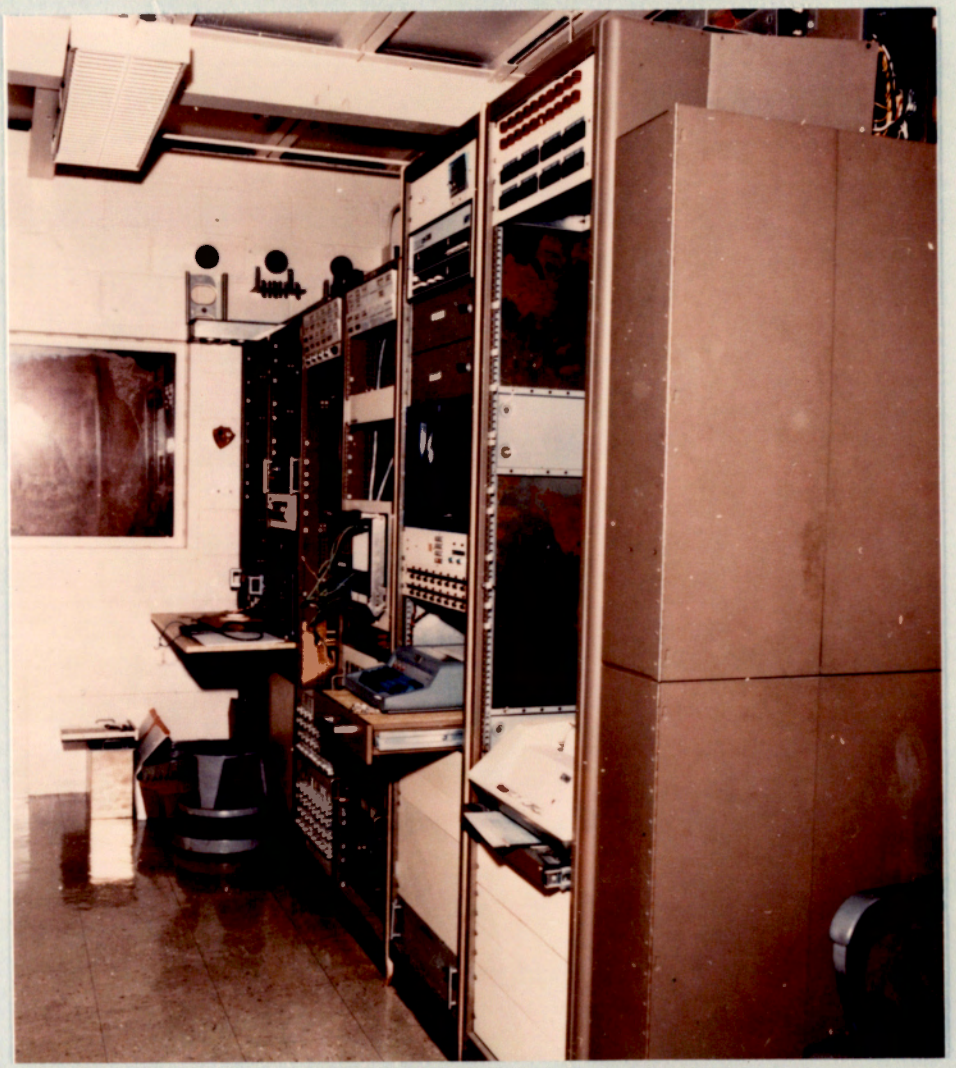
ROCKET LABORATORY
CELL 24A&C CONTROL ROOM



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CELLS 32A & B

Construction of a new test building is currently underway which will contain two test cells for research on liquid propellant rockets. The building is designed especially for the extensive use of laser based diagnostic techniques for fluid and droplet velocity measurements, spray droplet analysis, high speed particle tracking, and species and temperature measurements. A laser diagnostic equipment room is located between the test cells and the main control room, providing space for optical benches and associated control and measurement electronics. Several ports for optical access are located in the main blast wall which seperates the test cells from the laser room.

Propellant systems are being designed to provide the capability of running test engines of up to 1000 pounds of thrust. Initial testing will be done with liquid oxygen and gaseous hydrogen, then expanded to include use of RP-1 as fuel.

A phase/Doppler droplet analyzer will be employed to study injector spray droplet size and velocity characteristics. The techniques developed will eventually be used to examine injector spray behavior under hot fire conditions and to correlate the results to combustion instabilities.

A two component laser Doppler velocimetry system will be employed to map out injector spray velocity fields. Two dimensional flow visualization will also be performed using laser illumination in conjunction with high speed photography.

Future work will include studies of metallized propellants, particularly aluminum/RP-1, and "in-situ" propellants which would be available on the moon and other planets, most notably aluminum and carbon monoxide.