2-7-92
E5902

NASA Technical Memorandum 103684

Advanced Nozzle and Engine Components Test Facility

Luis R. Beltran, Richard L. Del Roso, and Ruben Del Rosario
Lewis Research Center
Cleveland, Ohio

January 1992

NASA

ADVANCED NOZZLE AND ENGINE COMPONENTS TEST FACILITY

Luis R. Beltran, Richard L. Del Roso, and Ruben Del Rosario
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

SUMMARY

This report is a general description of the CE-22 nozzle test facility located in the Engine Research Building of the NASA Lewis Research Center. The CE-22 test facility contains many systems for the economical testing of advanced scale-model nozzles and engine components.

The facility can provide 40-psig primary combustion air to a model at 40 lb/sec and can provide secondary combustion air at 40, 125, or 450 psig, with maximum airflows of 21, 2, and 8 lb/sec, respectively. The 40-psig primary combustion air and the 450-psig secondary combustion air can be heated to 370 and 250 °F, respectively. Model exhaust can be supplied at atmospheric or altitude conditions. Various simulated altitude conditions, up to 48 000 ft, can be obtained in the altitude tank to provide a wide range of test capabilities.

The facility can measure thrust in all three axes. Thrust measurements are limited to 3000 lb in the axial direction and 1000 lb in both the vertical and lateral directions. A thrust calibration structure as well as standard ASME nozzles and dead weight are available to calibrate the thrust stand. The stand is calibrated at both sea-level and altitude conditions to simulate actual model test conditions.

A color schlieren system is available for qualitative airflow analysis, and a labyrinth flow measurement system is utilized to minimize tare loads on the thrust stand. Many auxiliary systems are available, but a 3000-psig hydraulic system and a 125-psig service air system can support most programs.

An ESCORT D data acquisition system is centrally located in the control room to support secured programs. It is interfaced to an electronically scanned pressure system that can provide up to 400 steady-state pressure measurements. Signal conditioners are available to support individual strain gage measurements, and 48 temperature measurements are available for Chromel-Alumel (type K) thermocouples. Programmable stepping motor controllers are available to analyze model flow fields.

This facility is designed to be both flexible and economical and is equipped to handle a wide variety of test programs. If projects require expanded facility capabilities, these modifications can be discussed with the operations personnel at NASA Lewis.

INTRODUCTION

The development of advanced nozzle concepts for aircraft jet engines requires extensive testing to confirm theoretical performance calculations and to verify and develop new computer codes. Since the optimum design cannot be determined solely from theoretical predictions, a parametric study about the predicted optimum is performed, and these configurations are tested. Several nozzles or a single nozzle with several interchangeable parts may be used. However, testing full-scale nozzles on engines is impractical and expensive.

By testing scale models of candidate nozzle designs, one can test many nozzles for a fraction of the cost of a single full-scale nozzle engine test. Thus, performance trends, which aid not only computer code development but also evaluate promising nozzle designs, can be obtained. From these promising designs, full-scale nozzles can be fabricated and tested to verify their performance for further evaluation.

CE-22, located in the Engine Research Building (ERB) of the NASA Lewis Research Center, provides this capability. Primary airflows up to 44 lb/sec and exhaust pressures simulating altitudes up to 48 000 ft provide a wide range of test capabilities. A variety of steady-state and dynamic pressure measurements, as well as temperature measurements, allow comprehensive testing of models up to approximately one-fourth scale. A thrust measurement system and a color schlieren system are available for qualitative supersonic flow analysis. The facility is designed for easy, economical testing of scale-model nozzles that can be used to develop full-scale advanced concept nozzles. A typical model is shown in figure 1.

GENERAL DESCRIPTION

The CE-22 test cell is 60-ft long by 28-ft wide by 25-ft high. The room is vented by a 10 000 standard-cubic-feet-per-minute (SCFM) exhaust fan located at one end of the test cell. Louvers, located at the other end of the test cell, will vent 42 800 SCFM in the event of test cell overpressurization.

The altitude tank (fig. 2) has a 7-1/2 ft internal diameter and is 23-ft long. It has a two-part, stainless steel construction, with the aft portion movable to allow access to the model. An inflatable rubber seal prevents leakage at the joint between the two portions of the tank. The front portion of the altitude tank is shown in figure 7. The allowable operating pressure is 40 psig across the tank wall. Tank overpressurization is prevented by a pressure switch set for 10 psig across the tank wall, which closes the combustion air valves.

The following support systems are available in CE-22 and will be discussed in greater detail later:

(1) Primary and secondary combustion air systems

(2) Exhaust systems

(3) Three-dimensional thrust measurement system

(4) Schlieren system

(5) Instrumentation and data acquisition systems

The first two systems are provided by centrally located compressors and exhausters and are available for use throughout Lewis Research Center. These services must be scheduled through Central Systems Control (CSC) to accommodate all users.

A three-dimensional thrust measuring stand located in the tank provides axial, vertical, and lateral thrust measurements. A color schlieren system is available for flow visualization. Various auxiliary systems are available to support a large range of test programs.

COMBUSTION AIR SYSTEM

Primary Combustion Air System

The primary combustion air (C.A.) system (fig. 3) provides dry, filtered 40-psig air to the forward end of the tank. The maximum airflow available through the primary C.A. system is 40 lb/sec at ambient temperature. After July 1992, primary air will be available heated to 370 °F at 30 lbm/sec.

Valve AC166 is motor-operated from the CE-22 control room after a permissive has been obtained from CSC. Valves AC104 and AC105 are used for flow control. The servocontroller for AC105 can be used in a manual positioning mode or in an automatic closed-loop control mode that can control airflow to any analog signal; model inlet pressure and model pressure ratio are two common control parameters.

The primary airflow will be heated by a vitiated combustor (J-47) with natural gas at 50 psig, and valves AC141 and AC142 will control temperature. A servo-controller will control the airflows through AC141 (heated combustion air) and AC142 (ambient temperature combustion air) in order to reach the desirable temperature after mixing both airflows.

The primary air enters the tank axially and passes through a bellmouth flow-measuring section where the inlet is instrumented with four pressure taps. Four static pressure taps at the labyrinth seal and one Chromel-Alumel (type K) thermo-couple are used to determine the velocity and density of the primary combustion air. (Instrumentation locations are shown in fig. 4.) Stations 2 and 5 are used for airflow rate calculations. The flow is measured downstream of the labyrinth to account for the very small percentage of the primary flow lost through the seal. This seal is used as a metric break to isolate the hardware mounted on the thrust stand to the hardware fixed to ground. Three standard ASME nozzles, with throat areas of 20, 30, and 40-in.^{2}, are available to calibrate the airflow. The primary airflow measurement is accurate to within ±0.30 percent of the maximum airflow of 35 lb/sec.

The primary airflow total pressure distribution prior to entering the model is obtained at station 7, where a screen is used to provide uniform airflow to a 15-point total pressure rake. Station 8 is designated for model internal pressure measurements. (Pressure measurement quantities and ranges are discussed in the INSTRUMENTATION AND DATA ACQUISITION section.)

Secondary Combustion Air System

The secondary C.A. system (fig. 5), which enters through two ports in the top of the tank, can provide air to the model at three different pressures: 40, 125, or 450 psig. The maximum flow rates of the three supplies, as presently configured, are tabulated in the following table:

Supply pressure, psig	Maximum flow rate, lb/sec
40	21
125	2
450	8

The 450- and 150-psi secondary airflows are supplied from one pipe in the test cell. Valve AC181 is a pneumatically actuated valve operated from the CE-22 control room once a permissive has been obtained from CSC. Flow and temperature are controlled with valves AC320 (an electropneumatically actuated butterfly valve) and AC321 (an electropneumatically actuated globe valve). The servocontroller for these valves can be operated in either a manual-positioning mode or in a closed-loop, automatic control mode. Control can be by any analog signal. Venturi AC307 measures flow. Two 2.0-in. electropneumatically actuated globe valves, AC302 and AC303, can provide separate flow control to the model. The airflow through each system is measured by a 2-in. venturi tube, and a steam heat exchanger can heat secondary airflow to 250 °F.

The 40-psig secondary air system is supplied from the same 12-in. pipe that provides the primary airflow. Valve AC115, a 6-in. butterfly valve, is the secondary system shutoff valve. Valves AC131 and AC132 are both 4-in., electropneumatically actuated globe valves used for flow control. These controllers can be used in a manual-positioning mode or in a closed-loop, automatic control mode. Control can be by any analog signal. Airflow is measured by orifices AC123 and AC124, which can be changed to match the model airflow requirements up to the system capacity of 21 lb/sec.

EXHAUST SYSTEM

The exhaust system can provide two different types of exhaust: altitude or atmospheric exhaust. Altitude exhaust is provided by centrally located exhausters and must be scheduled through CSC. This system is shown schematically in figure 6. Atmospheric exhaust is easily provided by opening the exhaust header to ambient pressure: the flow exhausts to the atmosphere on the ERB roof. This type of operation has a much lower operating cost since the exhausters are not needed. However, conflicts can arise with other cells connected to the same exhaust header, if they require altitude exhaust.

Altitude exhaust is generally available at 4.9 or 1.9 psia which, for altitude modeling, represent 27 500 and 48 000 ft, respectively. Valve EL2018 is controlled by CSC, and a permissive must be obtained to open valve EL177. The general operating procedure is to open valves EL157 and EL158 fully to obtain the full altitude exhaust pressure inside the tank. Once model airflow has been established, valves EL157 and EL158 can be closed down to back-pressure the test tank and vary the static pressure inside the tank.

The altitude exhaust pressure can vary because of users coming on or off line, and because of transients caused by large users. In the past, this phenomena has created problems by causing fluctuations in the tank static pressure. To correct this problem, an electropneumatic operator was installed on valve EL158. This operator allows manual-position control or closed-loop, automatic control with tank static pressure as the control signal.

A similar problem occurs during low model airflows or no-flow tests. Effective tank pressure control is not possible at these test conditions. To correct this problem, a 40-psig C.A. line was installed. This line bypasses the tank and provides airflow directly to the exhaust system. Bypass airflows up to 10 lb/sec are controlled by valve AC103. The combination of the bypass airflow and the closed-loop tank pressure control AC103 now allows tank pressure to be controlled over the entire range of testing from flow to no-flow conditions.

Several exhaust collector extensions are available to minimize recirculation of airflow into the tank. These extensions are mounted on the exhaust piping inlet and are positioned about 6 in. from the model exit. Other extensions can be designed and fabricated to meet specific requirements.

MULTI-AXIS THRUST MEASUREMENT SYSTEM

The multi-axis thrust measurement system (fig. 7) can simultaneously measure thrust in the axial, vertical, and lateral directions. The system or thrust stand is composed of one ground (or fixed) frame, which is anchored to the tank, and two live frames. An elastic hinge placed between the front live frame and the rear live frame eliminates the interactions between the lateral and axial force measuring systems. The front live frame is supported by one lateral load cell string, two axial load cell strings, two vertical load cell strings, and the stabilizing moment acting through the elastic hinge from the rear frame. The rear live frame is supported by the moment at the hinge, the shear load at the hinge, one lateral load cell string, and two vertical load cell strings.

The thrust stand has a total of eight load cell strings - two for measurements in the axial direction, two for the lateral direction, and four for the vertical direction - all of which have a correctly located anchor on the ground frame. In addition, all load cell pairs operate with one load cell in tension and one in compression for error cancellation. Each load cell string consists of one stepper motor, one calibration load cell, one measurement load cell, and two universal flexures per load cell. The stepper motors apply forces to the system, the measurement load cells obtain the actual loads applied, and the calibration load cells calibrate the measurement load cells prior to testing. The purpose of the two universal flexures per load cell is to eliminate any off-axis load components. A maximum of 3000 lb in the axial direction and 1000 lb in both vertical and lateral directions can be measured by this system.

The thrust measurement stand can be calibrated applying load with the stepper motors, by using dead weights, and by testing ASME standard nozzles. With the use of stepper motors to control load conditions, thrust calibration can be performed for a matrix of load applications. Simulated load conditions can be performed at both sea-level and altitude conditions. The maximum load that can be applied is 1000 lb in the vertical and lateral directions and 2000 lb in the axial direction. Dead weights up to 350 lb can also be used to calibrate the thrust stand at sea-level conditions. Finally, the thrust stand can be calibrated with a standard ASME nozzle assembly. Three standard ASME nozzles, with throat areas of 20, 30, and 40 in.^{2}, are available to perform this calibration. Three wedge spools, simulating 5°, 10°, and 15° vectoring, are available for test programs requiring vectored airflow.

A full-scale thrust stand calibration is performed annually. In addition to the monitoring of interactions coefficients for changes, partial thrust stand calibrations are performed between test programs or as time permits.

The calibration load cells, which are removable, are also calibrated once a year. Then, load cells calibration coefficients are entered into the data acquisition system, which provides an on-line calibration of all load cells prior to testing. The load cells are Ormond Model BUL-MML69 tension/compression cells that are temperature compensated and vented for altitude conditions.

SCHLIEREN SYSTEM

A schlieren system for supersonic flow visualization is available to qualitatively analyze the airflow. This color schlieren system has a 23-in.-diameter viewing field (fig. 8) with the viewing port windows made of 1.75-in.-thick borosilicate crown glass, machined to meet schlieren specifications. The system consists of a 75-W xenon light source, two 16-in.-diameter flat mirrors, two 24-in. parabolic mirrors, and a Sony color video camera.

The schlieren system is presently operated in a continuous mode, with the output forwarded to a video cassette recorder and television display in the control room. The system can also operate in a flash mode to take instantaneous photos of the flow pattern.

This system is used to obtain qualitative flow analysis of the flow patterns at the exit of a model. Quantitative data analysis can also be obtained, but this requires the services of a user-supplied Schlieren system expert. Since the view ports are mounted on the movable half of the altitude tank, the length the model is limited if this system is used (see section Model Size for model length limitations). A shorter model length can be accommodated by the schlieren system if an adapter spool piece is added to position the model at the appropriate location in the viewing field.

INSTRUMENTATION AND DATA ACQUISITION

The CE-22 test cell is currently equipped to acquire steady-state data. The control room is shown in figure 9. A computer-based, software-supported data acquisition system, ESCORT D, is the main component of the steady-state system. ESCORT D can digitize 200 different measurements from any millivolt source, (i.e., load cells, thermocouples, pressure transducers, etc.). These millivolt input signals are preconditioned to 11 programmable gain ranges from 5 to 5120 mV into a multiplexor digitizer. The digitizer sampling rate filter is switch selectable from 1.25 to 10 kHz, and the analog to digital convertor has 14-bit resolution. In addition to the analog input channels, ESCORT D is interfaced to an electronically scanned pressure measurement system (ESP). Data recording is initiated by push-button command. The heart of the ESCORT D system is a DEC micro VAX II computer in the facility which handles the real-time processing of the data and which can be interfaced to a centrally located VAX cluster for development of test software and post-run processing of data. A color alphanumeric CRT and a color graphic CRT are provided to monitor test status and display values of test data, which they update every 2 sec during testing. An 8-pages-per-minute laser printer is available to obtain hard copies of data displayed on the CRT's. In the case of secure testing, a 71-megabyte Winchester disk drive is provided to record data. The secure data disk can then be removed and taken to a secure computer for processing.

Most of the pressure measurements are handled by the 480-channel ESP system. The ESP system consists of 30 interchangeable pressure modules, each containing 16 transducers. One transducer from each module is used as a reference pressure measurement for comparison with the barometric pressure. The following table is a list of current ESP system pressure ranges available and the maximum number of pressure measurements available for model instrumentation:

Pressure range, psig	Maximum pressure measurement available
0 to 15	35
0 to 45	270
0 to 100	60
0 to 500	4

The advantage to using the ESP system is that individual transducers, scanned at 10 000 samples/sec, are used for each channel. On-line, three-point calibration of the transducers ensures measurement accuracies of 0.1 percent of full-scale of the digiquartz standard transducer. Three full-scale ranges of digiquartz standard are used: 30, 100, and 500 psia. The transducers are calibrated over the range of expected pressures instead of over the full range of the transducer to ensure the most accurate data. The system is microprocessor controlled and interfaced to a desk-top computer that controls the ESP system, averages a predetermined number of samples, and returns the data to ESCORT D in engineering units.

There are 40 channels of signal conditioning for the strain gage instruments. The strain gage conditioners are calibrated devices that provide electrical excitation for load cells, pressure transducers, and strain gages and that provide outputs to the recording system. These conditioners are self-standardized by ESCORT D through software programming called "Knobless Calibration." Calibration parameters, slope, and sensitivity are stored in the minicomputer and are invoked by the operator when calibration is desired or at predetermined time intervals.

Forty-eight channels are available for temperature measurements with NBS standardized Chromel-Alumel (type K) thermocouples. The reference junctions are regulated at 150 °F for standard-millivolt-to-temperature conversions.

Programmable stepping motor controllers are available for detailed X-Y mapping of model flow fields. Four channels are provided to control pressure or temperature probe actuators, which can be used simultaneously. The actuators position a probe radially 10 in. with 0.01-in. resolution and in yaw 360° with 0.36° resolution. An X-Y-Y Plotter and a strip-chart Visicorder are also available to meet special test requirements.

AUXILIARY SYSTEMS

There are several auxiliary services available in the CE-22 test cell. This section describes only the services that presently exist; other services could be made available to service a particular test.

Hydraulic System

There are four hydraulic ports available in the tank to position or actuate the model. The system capacity is 20 gal/min at 3000 psi; the normal system operating condition is 13 gal/min at 2000 psi.

Service Air System

Service air is available at 125 psi for cooling, model actuation, and other uses at flow rates up to 1.4 lb/sec.

Television System

Television coverage of the test section is provided by one color television camera which is mounted on a base with automatic pan, tilt, and focus adjustment. A camera light and tank lights provide optimum model lighting, and the camera and light positions can be changed to accommodate a specific model. The camera output can be displayed on a 13-in. or a 19-in. color monitor in the control room, and two VHS cassette recorders are available to record model testing.

Electrical Power System

There are 120 Vac available in the tank that can be used by the model or supporting systems. There are also 24 Vdc available in the tank if required.

SUPPORTING HARDWARE

Swirl Vane Spool

The swirl vane spool can simulate airflow swirl up to 30° before air enters the model, see (fig. 10). The swirl is manually adjusted up to 20°. The swirl vanes were calibrated in June 1989, and corrections for model inlet total pressure and actual swirl angle were incorporated in the data acquisition program.

Model Size

The model should be scaled to have an inside diameter of 8.75 in. Models with other diameters will have to include an adapter spool to match the desired diameter. For all tests, the model length should not exceed 5 ft. If the schlieren system is to be used, model length should not exceed 3 ft if the swirl vane spool is included in the assembly, and 4 ft if the swirl vane spool is not used. Any adapting and instrumentation spool pieces should also be included in these lengths.

Model Instrumentation

Model instrumentation should be limited to 370 pressure measurements and 38 temperature measurements. (The quantity and ranges of the pressure measurements are discussed in the Instrumentation section.) The pressure-sensing tubes outside the model should have a nominal outside diameter of 1/16 in. to attach onto the flexible tubing available at the test cell. Annealed stainless steel tubing can be used to avoid fatigue during installation and testing and should extend about 1 ft from the model. The thermocouples should include a standard two-pole male Chromel-Alumel connector, and the wires should extend about 15 ft from the model.

Model Design

Models are usually designed using aluminum since it is easier to machine and minimizes the weight on the thrust stand. Contact the facility operations engineer for design details for mounting onto facility hardware. A minimum safety factor of four is recommended for the design of all model parts. All model parts that can withstand hydrostatic pressurization to 150 percent of the maximum system operating pressure should be pressurized to this level prior to model delivery. The model should include lifting eyes, if possible, for installation purposes.

Actuators and Position Indicators

Actuators for model positioning can use the test cell hydraulic system (13 GPM at 3000 psi) or 125 psi service air for operation. Any position indicator required should be included as part of the actuator.

SECURITY

The test facility and control room have been modified for special projects requiring security. All viewing areas in the test cell and control room are covered with sheet metal. The model is maintained inside the altitude tank at all times. The altitude tank and cell doors are locked with combination locks, and two safes are available to store model parts.

Model performance data is processed at the control room. The VAX for the ESCORT D data acquisition is located in the control room. All data acquisition programs and data processing are accomplished through this system. Data can be stored on disk or tape (see Instrumentation section for more information). Secured data can be stored in a safe in the control room. Additional security-related information can be obtained if required.

PROGRAM REQUIREMENTS

Approval to perform any model testing at the CE-22 test facility must be obtained through the Aeronautics Directorate at NASA Lewis Research Center. This process can be initiated by contacting the facility manager of the Aeropropulsion Facilities and Experiments Division.

After obtaining approval for testing, a Research Requirements Document should be prepared which contains the following information:

(1) Introduction and objectives of test program

(2) Model description

(3) Instrumentation

(4) Test schedule requirements

(5) Test requirements

(6) Data reduction and performance equations requirements

(7) Security requirements (if required)

This document should be available to NASA personnel at least 4 months before the test program is scheduled for testing.

OPERATIONAL EXPERIENCE

This section reports some of the practical operational experience gained since the test facility was reactivated in 1983. Since 1983, several successful tests have been run in the CE-22 test facility. These include a transition duct program, a seven-hole-probe flow-direction calibration program, a General Electric inlet studies program, and an advanced concept nozzle program. The General Electric Advanced Inlet Test involved a complicated model requiring many model changes.

Test results obtained from the ASME nozzle calibrations are plotted in figure 11. These plots indicate the test facility operational limits for models with thrust areas of 20 and 40 $in.^2$ The model flow rate and tank exhaust pressure are plotted as a function of model inlet total pressure. These test results can be used for sizing a model.

CONCLUDING REMARKS

The CE-22 test facility at Lewis Research Center is an altitude chamber capable of testing models up to approximately one-fourth scale. Primary airflows up to 40 lb/sec and exhaust pressures simulating up to 48 000-ft altitude provide a wide range of test capabilities. Steady-state and dynamic pressure measurements and temperature measurements provide detailed aerodynamic performance data.

Since 1983, many modifications have been made to upgrade the flow measurement system, pressure and temperature measurements system, thrust measurement system, and test cell operational control systems. These modifications have improved the operational efficiency of the test facility, have increased measurement accuracy, and have greatly reduced testing time. CE-22 has proven to be a valuable test facility.

The CE-22 facility has been used for a variety of test programs. These tests have demonstrated that CE-22 has not only great potential for future tests but also a proven record of successfully completed tests. The facility provides an economical test site for models and can provide performance data and aerodynamic data that can be used for code verification and system development.

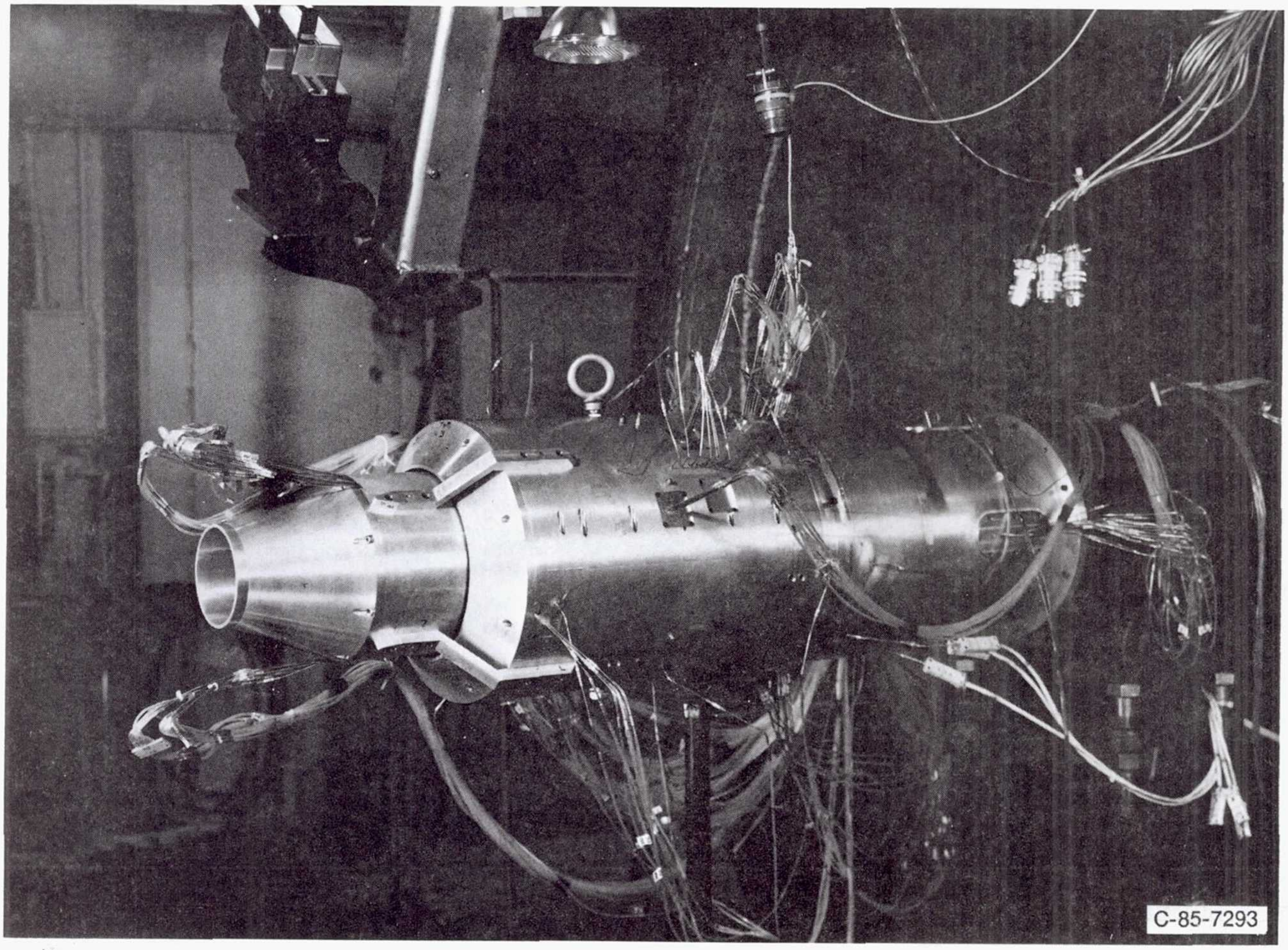


Figure 1.—Typical model installation.

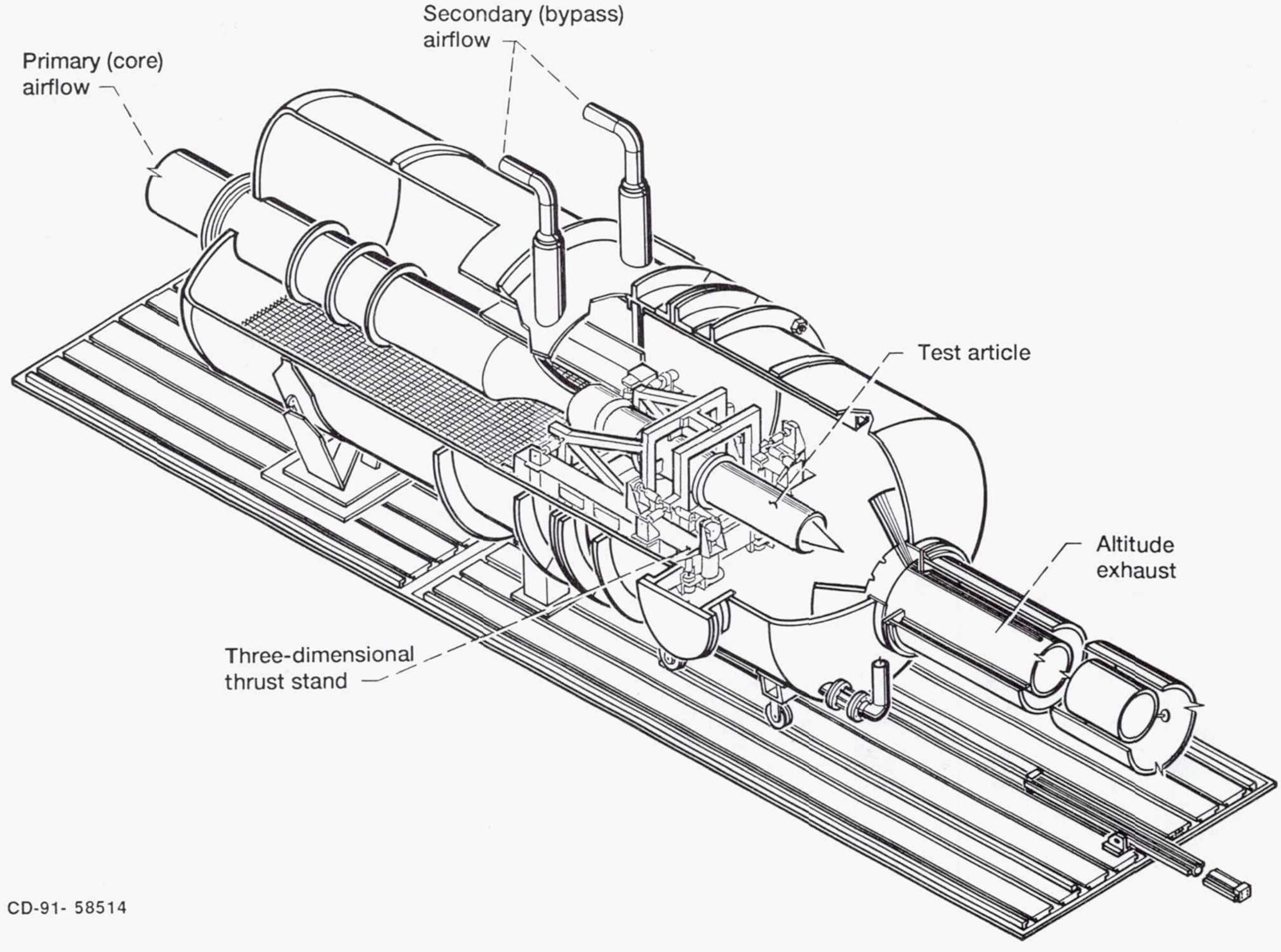


Figure 2.—CE-22 test facility.

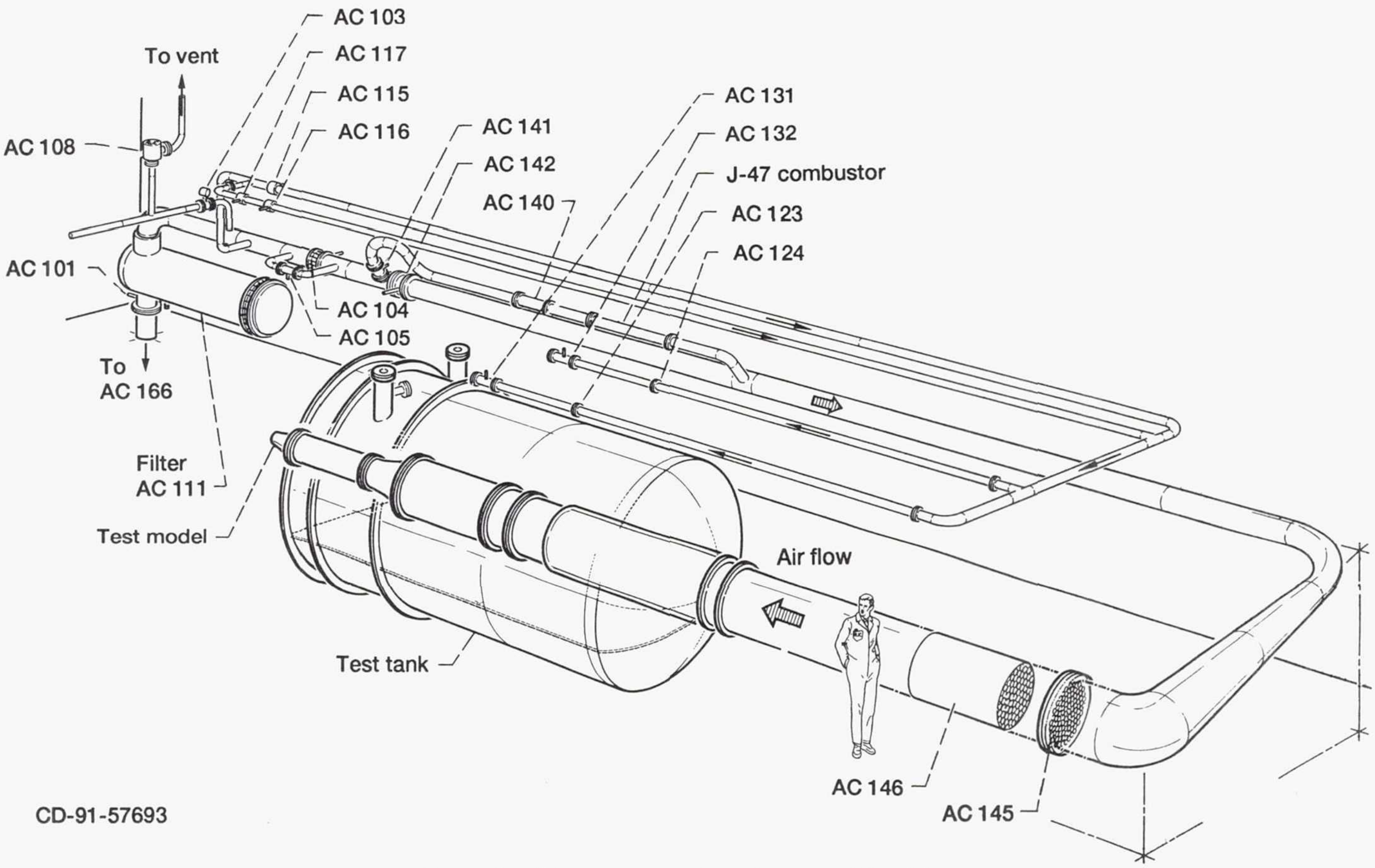
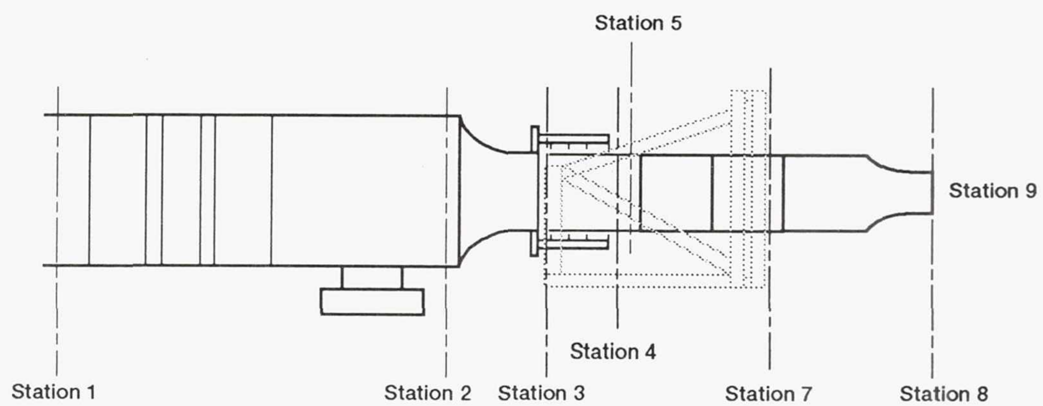


Figure 3.—Primary combustion air system (40 psig).



Station	
1	1 thermocouple, 2 static pressures
2	4 static pressures
3	4 static pressures
4	4 static pressures
5	4 static pressures
7	15 total pressures
8	model pressures
9	model external pressures

Figure 4.—Primary combustion air stations and instrumentation designations.,

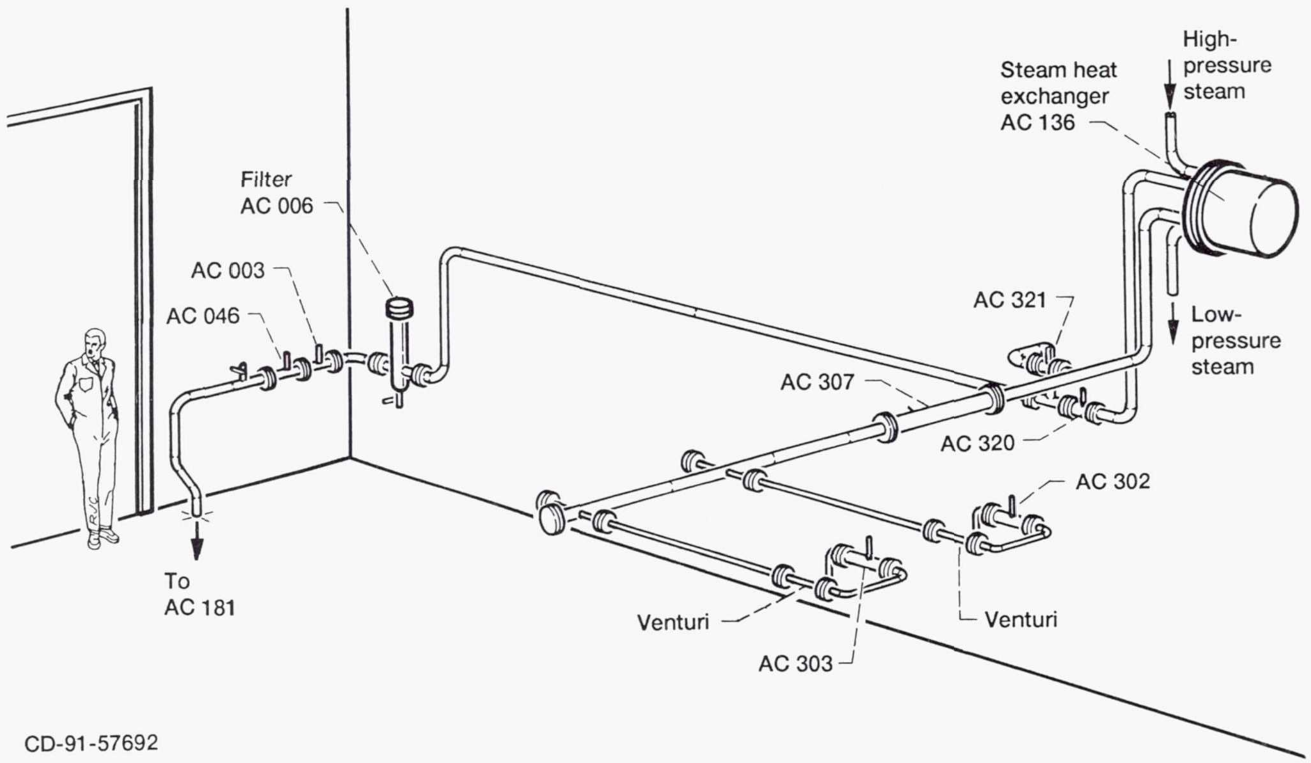


Figure 5.—Secondary combustion air system (450 psig).

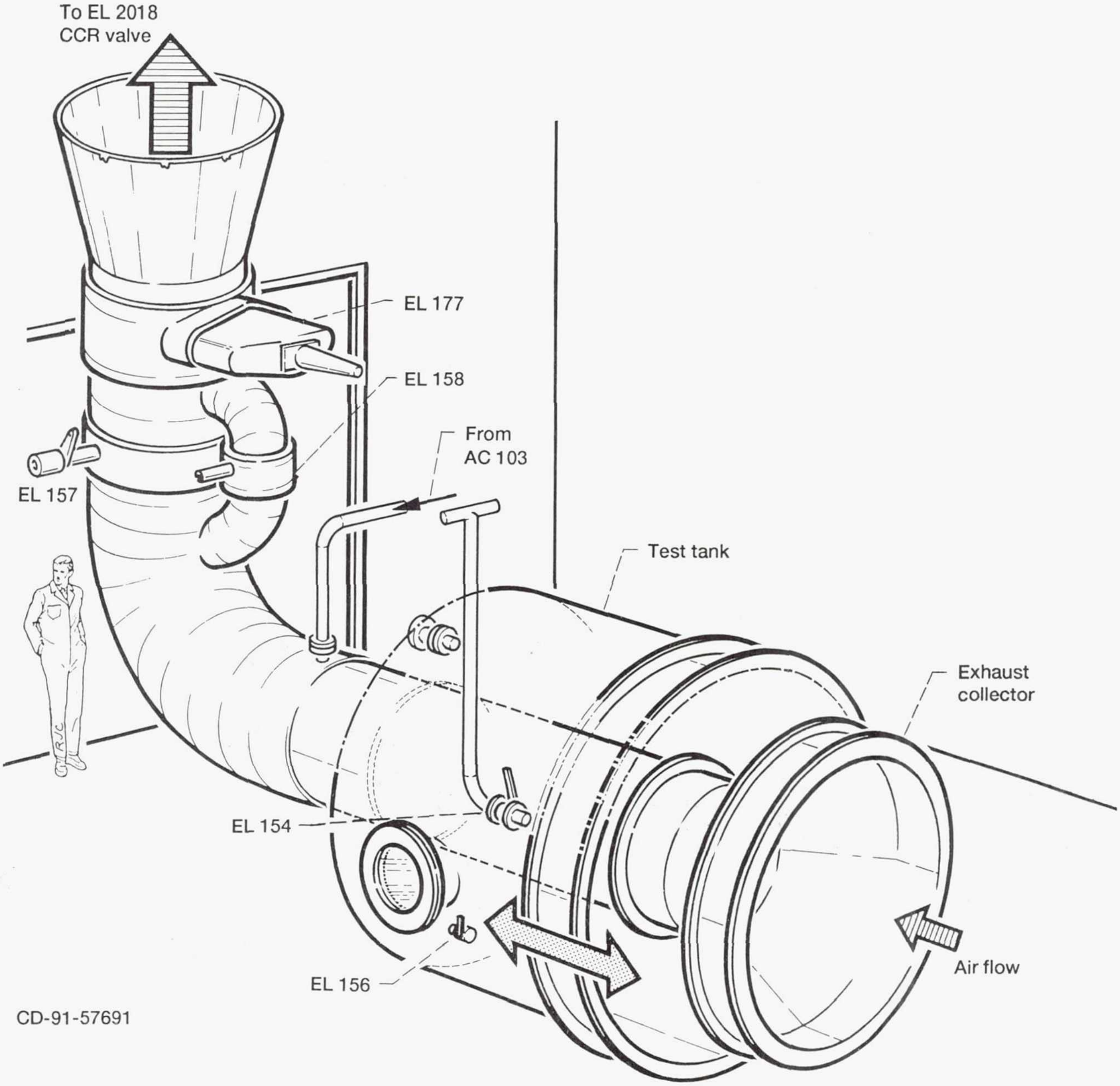


Figure 6.—Altitude exhaust system.

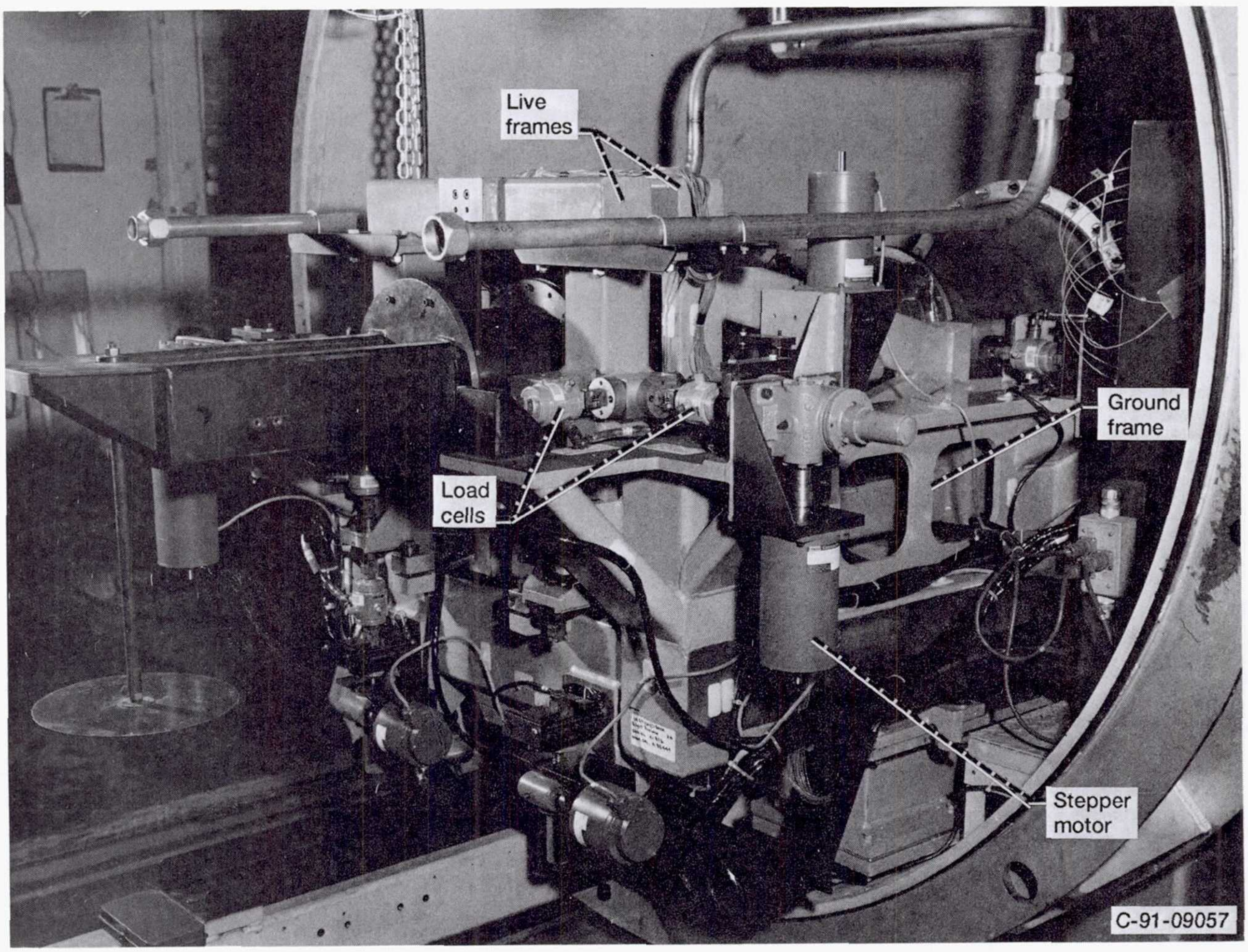


Figure 7.—Thrust and flow measurement systems.

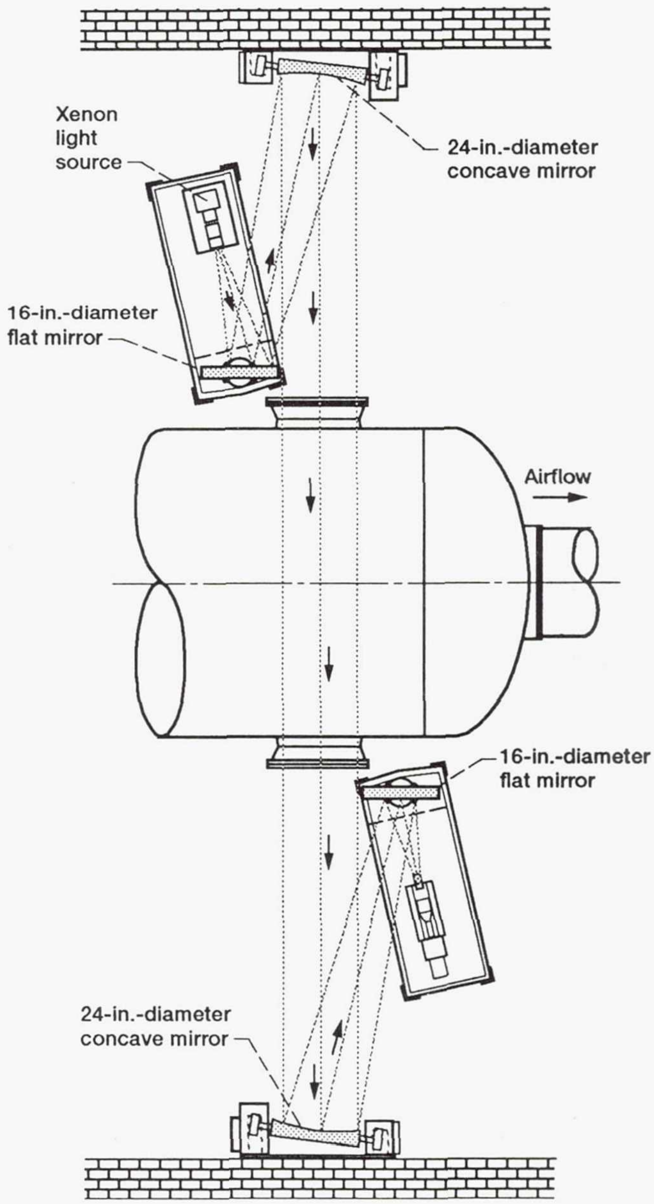


Figure 8.—Schlieren system schematic (plan view).

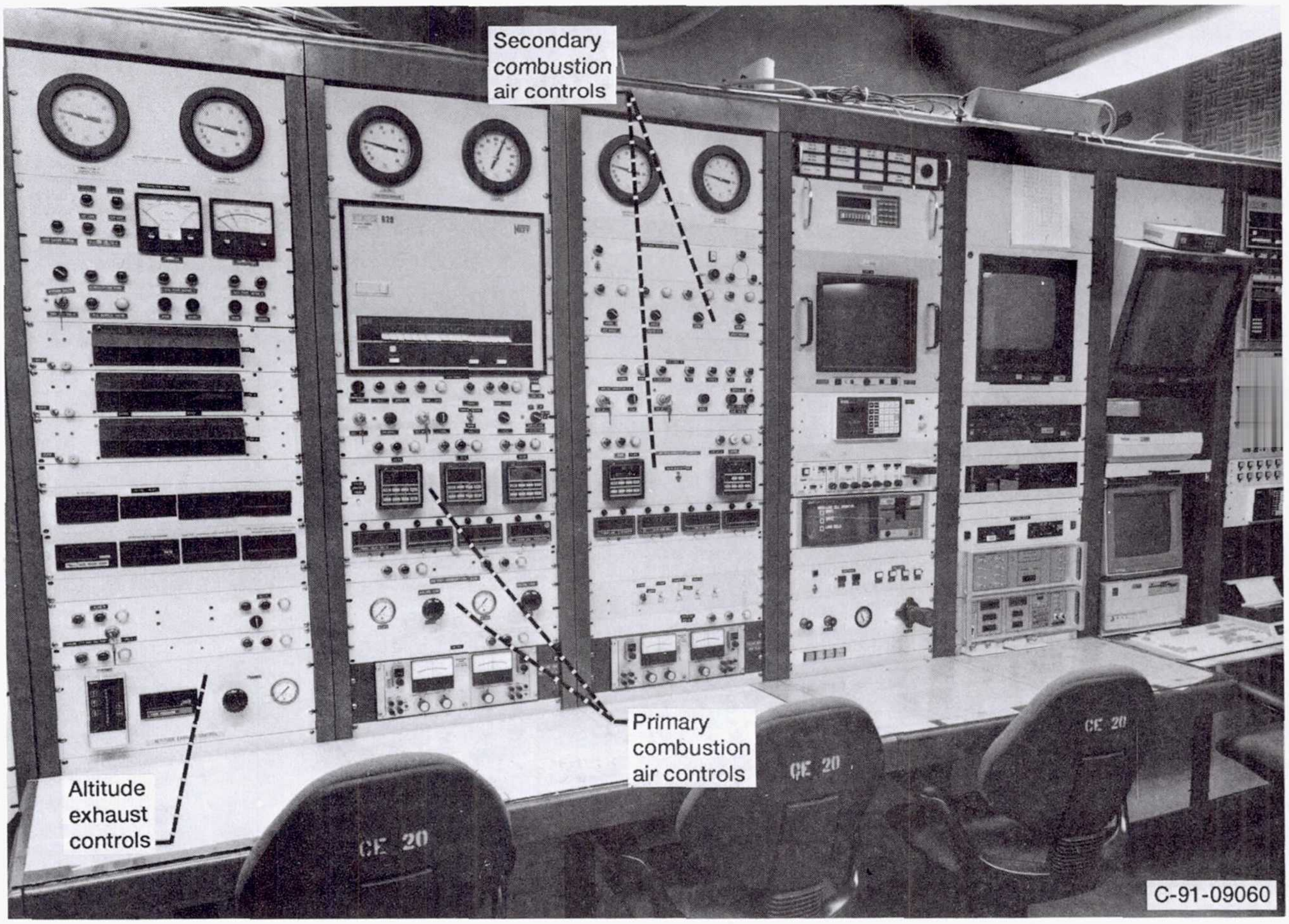


Figure 9.—Control room.

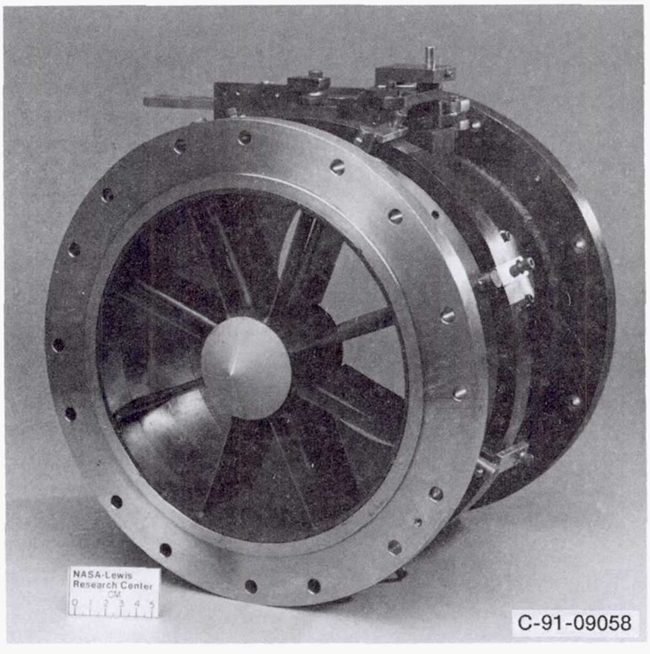


Figure 10.—Swirl vane spool.

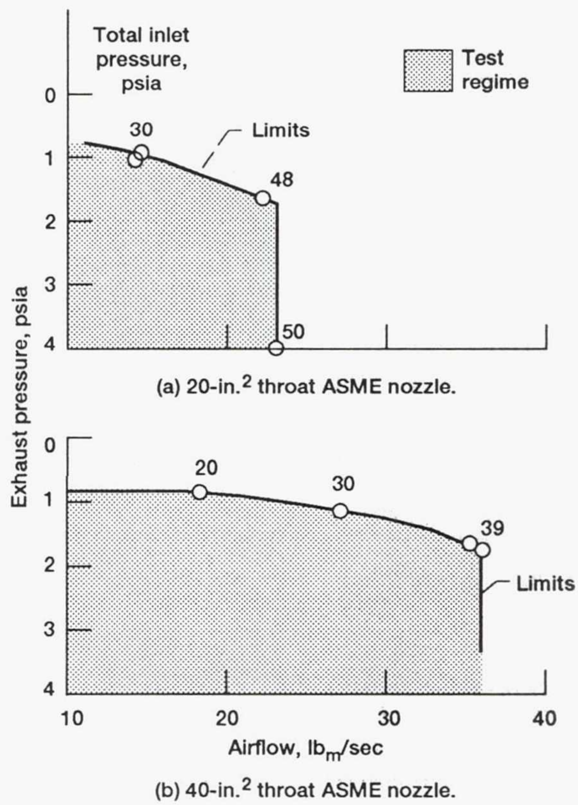


Figure 11.—Test facility operational limits.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	January 1992	Technical Memorandum

4. TITLE AND SUBTITLE

Advanced Nozzle and Engine Components Test Facility

5. FUNDING NUMBERS

WU-505-62-84

6. AUTHOR(S)

Luis R. Beltran, Richard L. Del Roso, and Ruben Del Rosario

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135-3191

8. PERFORMING ORGANIZATION REPORT NUMBER

E-5902

9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, D.C. 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA TM-103684

11. SUPPLEMENTARY NOTES

Responsible person, Ruben Del Rosario, (216) 433 - 5679.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Category 9

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

A test facility for conducting scaled advanced nozzle and engine component research is described. The CE-22 test facility, located in the Engine Research Building of the NASA Lewis Research Center, contains many systems for the economical testing of advanced scale-model nozzles and engine components. The combustion air and altitude exhaust systems are described. Combustion air can be supplied to a model up to 40 psig for primary air flow, and 40, 125, and 450 psig for secondary air flow. Altitude exhaust can be simulated up to 48 000 ft, or the exhaust can be atmospheric. Descriptions of the multiaxis thrust stand, a color schlieren flow visualization system used for qualitative flow analysis, a labyrinth flow measurement system, a data acquisition system, and auxiliary systems are discussed. Model recommended design information and temperature and pressure instrumentation recommendations are included.

14. SUBJECT TERMS

Nozzles; Engine testing laboratories; Altitude simulation; High altitude tests; Test facilities

15. NUMBER OF PAGES 20

16. PRICE CODE A03

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	