NASA Technical Memorandum 84585

Aeroacoustic Research Facilities at NASA Langley Research Center

Description and Operational Characteristics

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and Space Administration

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INTRODUCTION

Over a period of about 20 years, a number of facilities have been developed at the NASA Langley Research Center for experimental research in aeroacoustics. These facilities are characterized by special features to minimize unwanted noise due to air handling machinery, valves, etc., and to provide suitable environments for aeroacoustic measurements.

The present paper documents the significant physical characteristics and operating conditions of facilities, devices, and equipment that provide unique capabilities for aeroacoustic research. General layouts, dimensions, flow rates, background noise levels, and some research applications are given for the quiet flow facility in the Langley Aircraft Noise Reduction Laboratory, the Langley Anechoic Noise Facility, the Langley Jet-Noise Laboratory, and the flow impedance test laboratory.

QUIET FLOW FACILITY IN THE LANGLEY AIRCRAFT NOISE REDUCTION LABORATORY

The quiet flow facility is located in the Langley Aircraft Noise Reduction Laboratory (Building 1208). It consists of an anechoic room in which quiet airflows are available for aeroacoustic testing of model components such as rotors, propellers, inlets, discharge ducts, wings, flaps, struts, cavities, and streamlined bodies. The facility is arranged so that the effects on radiated noise of the interactions of airflows with solid bodies and surfaces can be studied. Special provisions are made for noise control in the low pressure, high pressure, and model air supply systems. These systems are described in the following sections along with their operating characteristics and potential for research.

The flow controls are interlocked to prevent both the low pressure system and the high pressure system from operating at the same time. The model air supply system can be operated, as required, parallel with either of the other systems. The spinning mode synthesizer provides realistic turbomachinery noises for duct propagation and radiation studies and thus is configured to operate in conjunction with the high pressure system.

Low Pressure Air System

The main components of the low pressure air system are the fan, the acoustically treated diffuser, the entrance plenum, the nozzle, the anechoic test area, and the eductor system. These are shown schematically in figure 1. Each of these components has special features to enhance the aeroacoustic performance of the system.

Low pressure fan.- The fan is a low pressure design of the type used in large industrial ventilation systems. It is rated at 40.7 m^3/sec (86 240 ft^3/min) at a back pressure of 20.3 cm (8 in.) of water for a power absorption of 124 kW (166.2 hp) at 382 rpm. A performance map of the present fan during normal operations is given in figure 2. The fan is driven through an oil-cooled magnetic clutch to provide vernier control of the test flow conditions.

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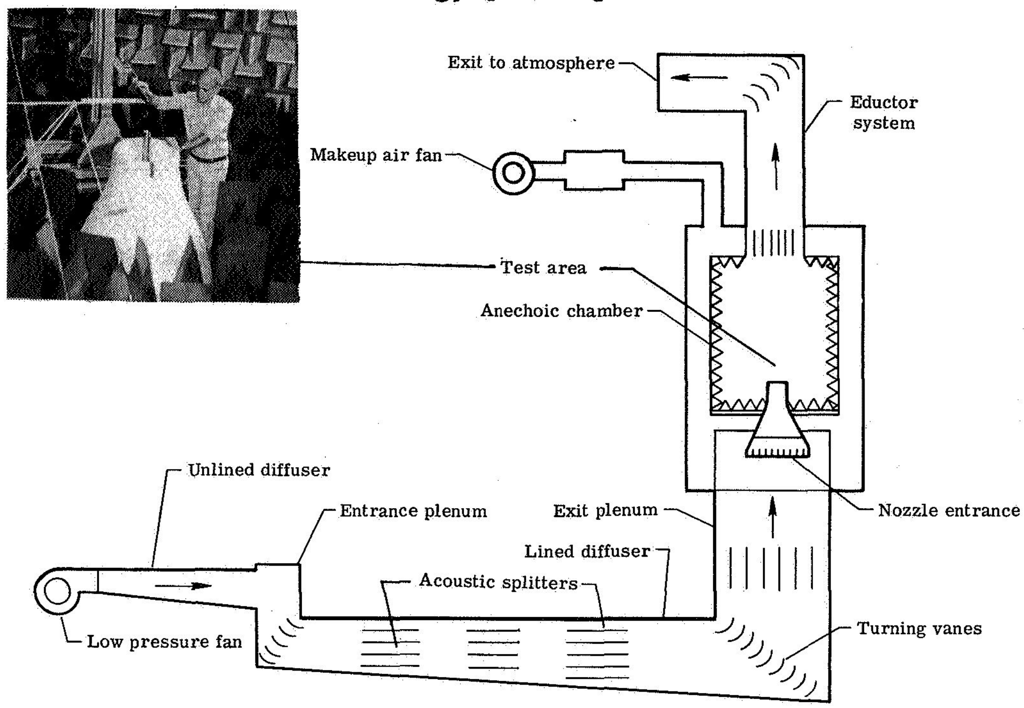

Figure 1.- Schematic of the low pressure air system of the quiet flow facility. Inset photograph shows jet nozzle set up for acoustic tests.

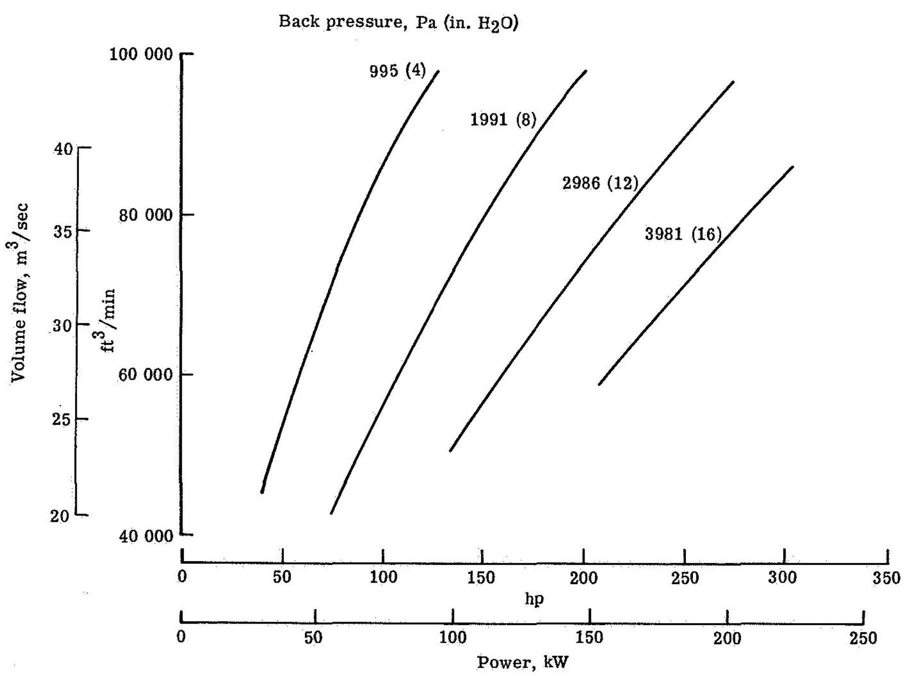

Figure 2.- Performance map for the 250-hp fan of the low pressure air system.

Air duct system.- Air is discharged from the low pressure fan into an air duct system consisting of an unlined diffuser, an entrance plenum, a lined diffuser with four sets of acoustic splitters, and an exit plenum. The duct geometry and the acoustical liner and splitters are designed to minimize the noise of the fan at the test area. Duct open area is controlled so that local flow velocities in the region of the splitters are limited to a maximum of 6 m/sec (20 ft/sec) and in other sections of the lined duct to less than 3 m/sec (10 ft/sec). Flow velocities in the exit plenum near the nozzle entrance are limited to about 0.6 m/sec (2 ft/sec). Note that the flow turns 90° from horizontal to vertical after it enters the exit plenum. Flow velocity control is imposed to limit noise generated by aerodynamic scrubbing of the exposed surfaces. A 5-cm-thick lining of fiberglass is applied to the walls and ceiling of the diffuser and plenum regions identified in figure 1.

Anechoic test area.- Figure 3 shows the general construction and layout of the anechoic test area. The flow is exhausted vertically out of the test area through an

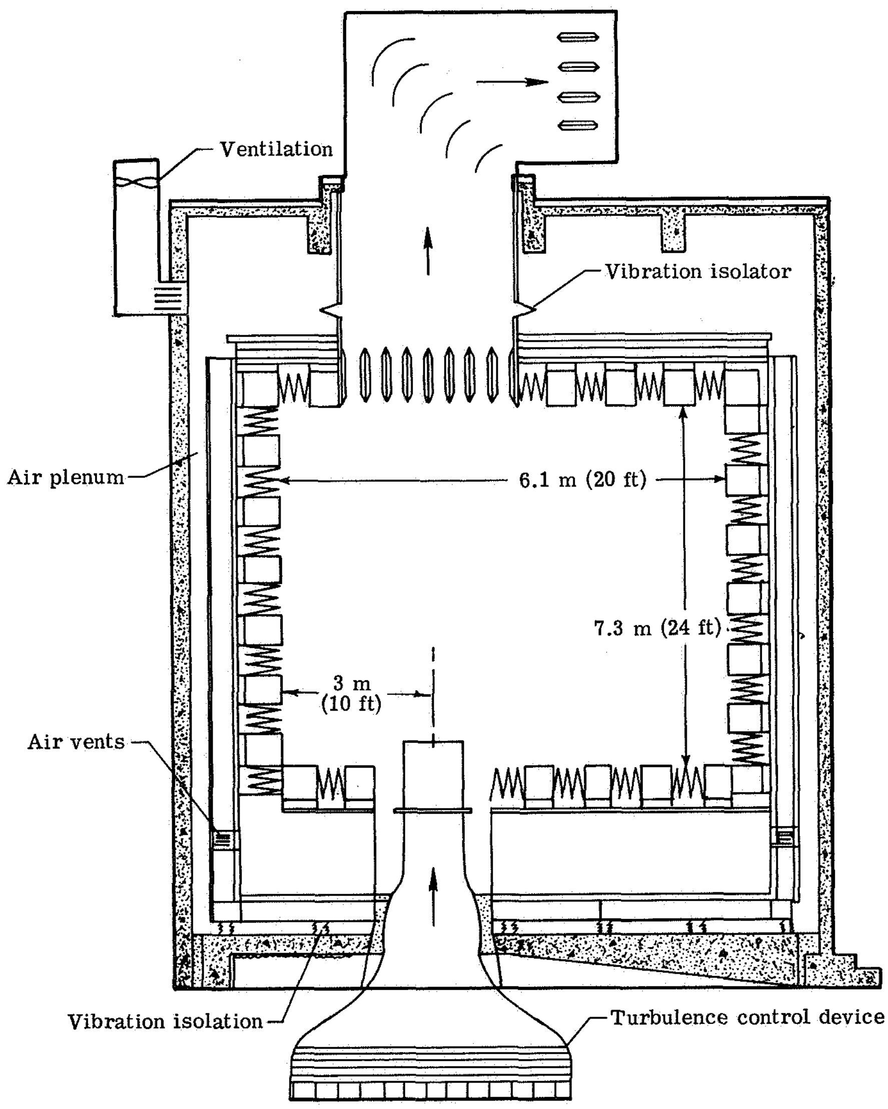

Figure 3.- Vertical section view of the anechoic test area of the quiet flow facility.

eductor system in the ceiling to the atmosphere. The eductor entrance is larger than the wetted area of the flow to allow for lateral spillage. Thus, the flow can be captured even when it is deflected sideways by the action of a research model such as a propeller.

The anechoic room surrounding the test area is lined with wedges, 91.5 cm (3 ft) deep, to provide an essentially echo-free environment (absorption coefficient of 0.995) for acoustic measurements down to about 70 Hz. The dimensions of the 410-m^3 (14 400-ft^3) room are about 6.1 m × 7.3 m × 9.2 m (20 ft × 24 ft × 30 ft). The nozzle centerline is about 3 m (10 ft) from the nearest wall to allow a nominal measurement distance from the source of about 5 m (16 ft).

The room is constructed of reinforced concrete with a 91.5-cm air space between double walls. This air space serves as a plenum chamber for the makeup air which is required to stabilize ambient pressure during operation of the free jet. The normal aspirating action of the free jet lowers the pressure in the test area and thus induces the makeup air to flow into the chamber. Makeup airflow is supplied to the plenum from a roof vent and can be induced either by the pressure differential established during free jet operation or by a forced draft fan. The makeup air enters the anechoic chamber through vents located between the wedges below floor level.

The entire anechoic room structure is mounted on springs to isolate it structurally from the remainder of the building and thus to minimize the transmission of structureborne noise arising from other parts of the building.

Example background noise spectra in the test area with and without flow are shown in figure 4 for the 1.21-m (4-ft) diameter circular nozzle of the low pressure

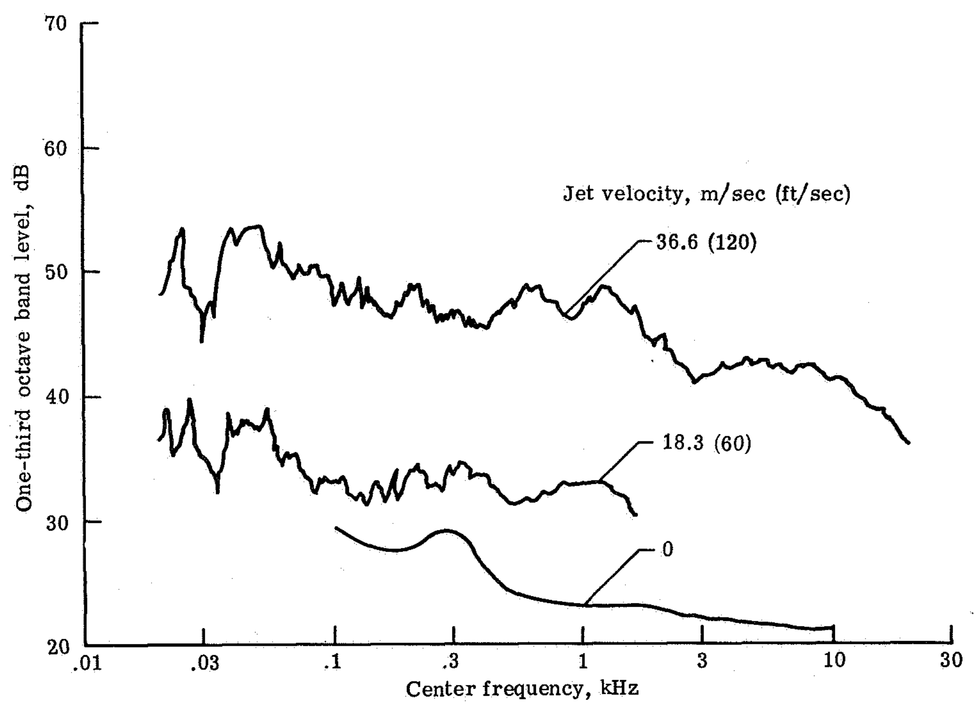

Figure 4.- Example ambient noise levels in the anechoic test area of the quiet flow facility with and without airflow. Data are for the 1.21-m (4-ft) diameter circular nozzle of the low pressure air system.

air system. Without flow, the background noise spectrum has a low frequency peak, and the levels decrease rapidly at higher frequencies. With flow, the mixing noise of the free jet is the dominant component and causes the background noise to peak broadly at higher frequencies. The location of this high frequency peak is related to flow velocity, higher frequencies being associated with higher velocities.

Since the test area is relatively close to the free jet mixing region and thus in its near acoustic field, and the effects of jet velocity on the free jet noise can be expected to vary considerably depending on measuring location. Thus, the data of figure 4 are only examples and do not necessarily apply to other locations in the test area. If signal-to-noise ratio is of concern, the experimenter should check the background noise at each measurement location, for each test nozzle, and for each nozzle exit velocity.

The flow from the free jet issues vertically from a 1.21-m (4-ft) diameter circular nozzle at floor level. The maximum velocity in this circular nozzle is 36.6 m/sec (120 ft/sec). Several smaller test nozzles with rectangular exits can be adapted to the 1.21-m-diameter nozzle to increase the flow speed for testing. An example test nozzle has a 30 cm × 45 cm (1 ft × 1.5 ft) exit for which the maximum velocity in the potential core region of the free jet is about 76 m/sec (250 ft/sec). The area contraction ratio of this nozzle is about 130. The associated mean velocity and root-mean-square turbulence profiles are shown in figures 5 and 6.

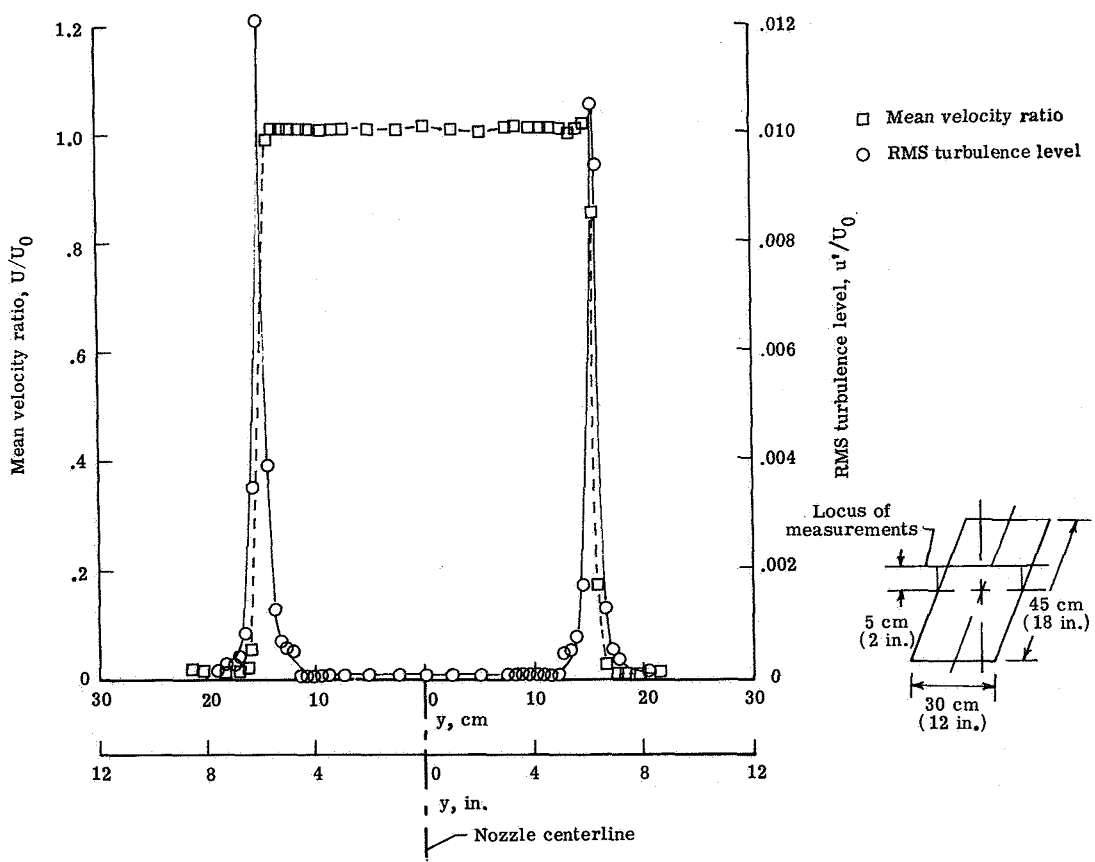

Figure 5.- Velocity and root-mean-square turbulence profiles near the exit of the 30 cm × 45 cm (1 ft × 1.5 ft) rectangular nozzle of the low pressure air system. Maximum flow velocity U_0 of 71 m/sec (233 ft/sec).

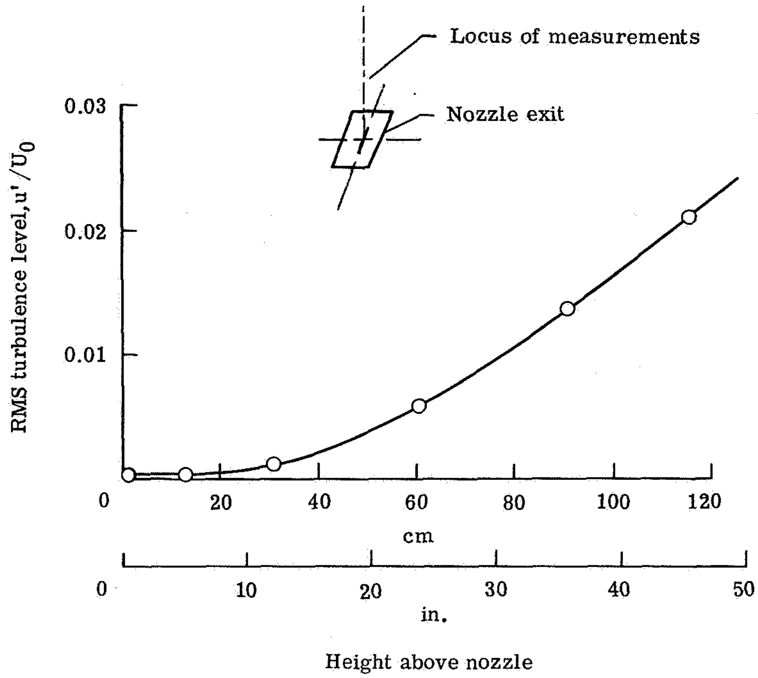

Figure 6.- Root-mean-square turbulence levels on the nozzle centerline as a function of height above the plane of the nozzle.

The square data points of figure 5 indicate the mean velocity profile measured 5 cm (2 in.) from the nozzle exit. In the region of the potential core and away from the influence of the nozzle boundary layer, the velocity is uniform. Turbulence levels, represented by the circular data points, are a maximum in the high-velocity-gradient region around the periphery of the jet and are a minimum in the potential core. These fluctuating velocities in the potential core are about 0.05 percent of the free-stream velocity and are largely dominated by the low frequency components. Figure 6 shows turbulence levels measured on the nozzle centerline at various distances from the plane of the nozzle for a maximum flow velocity of 71 m/sec (233 ft/sec). Turbulence levels increase with distance.

With adapters, other test nozzle sizes and shapes can be tested, including circular exits 0.45 m (1.5 ft) and 1.21 m (4 ft) in diameter.

Eductor system.- The eductor system for exiting air to the atmosphere terminates in a lined duct with splitters which are designed to limit both the noise that is radiated to the outside from the test area and the background noise in the test area. The components of background noise due to the air blower, the interaction of the flow with the ducting, and the noise in other parts of the building are all minimal. The background noise is frequently established by the noise coming through the eductor system from outside the building, particularly from overflying airplanes. Another source of ambient noise is the interaction of the free jet exhaust flow with the eductor elements which are sharp-edged splitters. This noise is expected to be the greatest when the test model deflects the free stream from its nominal vertical direction.

High Pressure Air System

The main components of the high pressure air system are the centrifugal compressor, the noise control plenum, the acoustically treated duct system, the reverberation room, the duct test area including the duct propagation test area and the spinning mode synthesizer, the anechoic test area, and the eductor system. These are shown schematically in figures 7 and 8 and described in the following section. One of the significant features of the high pressure air system is that it can be configured to produce flow in either direction in the test area.

Centrifugal compressor.- Air is provided by a 1100-kW (1500-hp) centrifugal compressor. It is driven by an electric motor through a magnetic clutch to provide vernier speed control. Interchangeable piping fixtures provide for air to be forced in either direction in the test areas. When operating in the compression mode, that is when the flow is expelled into the anechoic room from the test duct, the compressor is capable of delivering 20.8 m^3/sec (44 000 ft^3/min) against a pressure differential of 3.6 m (142 in.) of water (35.9 kPa (5.2 psi)). In the compression mode, the compressor provides flow velocities up to 210 m/sec (700 ft/sec) in the duct test area. When operating in the exhausting mode, that is when the flow is induced into the test duct from the anechoic room, the compressor is capable of delivering about 17.0 m^3/sec (36 000 ft^3/min) against a pressure differential of 2.90 m (114 in.) of water (28.3 kPa (4.1 psi)). In the exhausting mode, the compressor and ducting provide flow velocities up to aerodynamic choking, for constrictions to about half

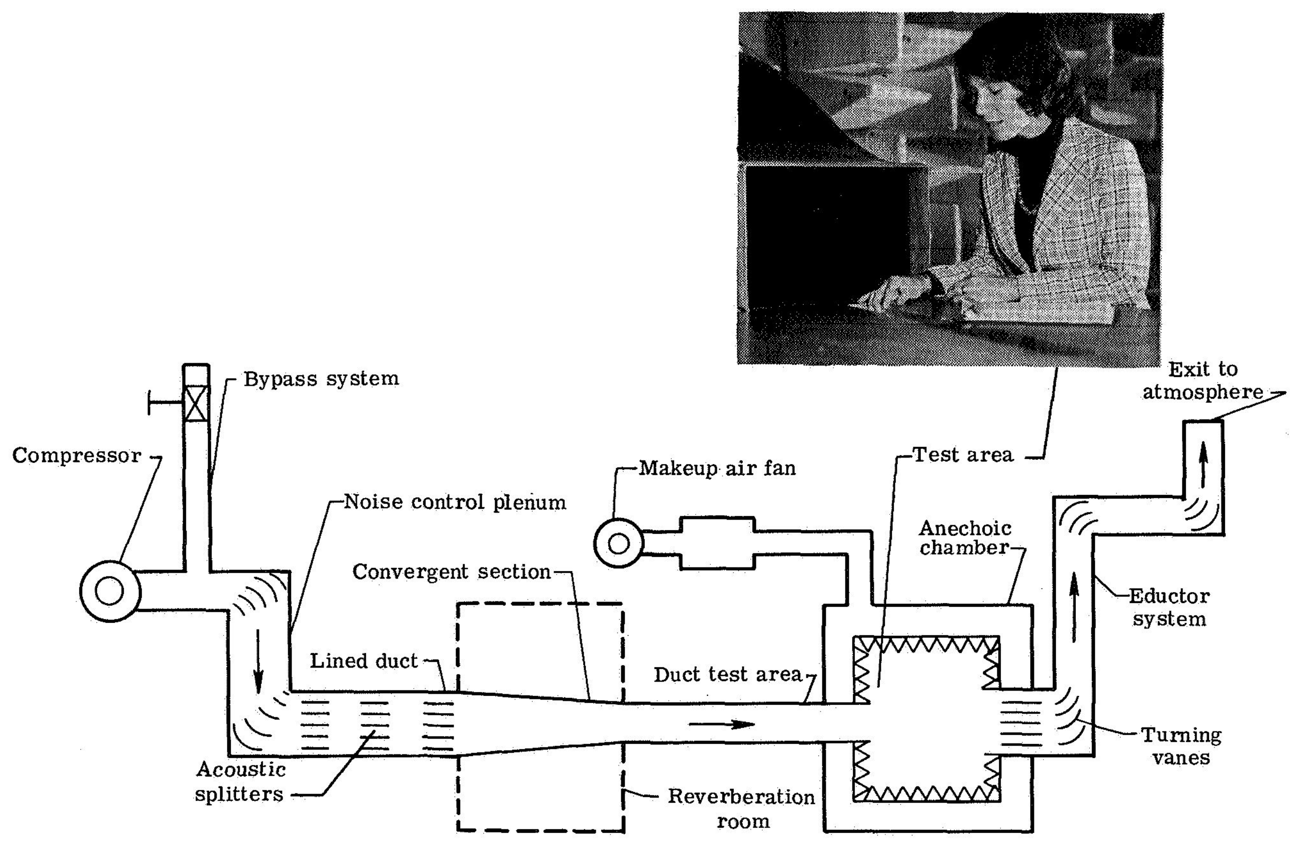

Figure 7.- Schematic of the high pressure air system of the quiet flow facility operating in the compression mode. Inset photograph shows a setup for acoustic tests on flow-excited cavities.

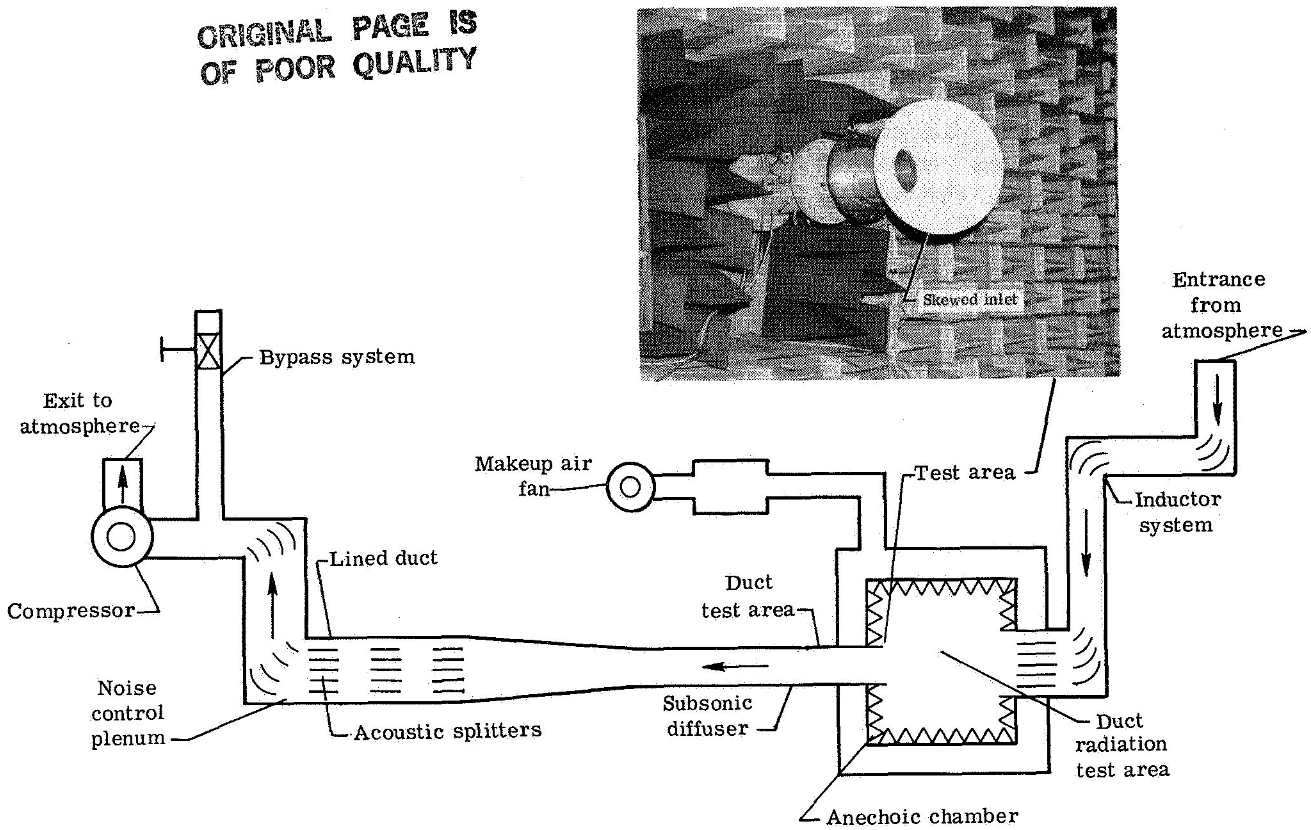

Figure 8.- Schematic of the high pressure air system of the quiet flow facility operating in the exhausting mode. Inset photograph shows a skewed inlet mounted for acoustic tests.

the normal cross-sectional area in the duct test area. Figure 9 is a performance map for the normal operating range of the compressor.

<u>Noise control plenum and ducts</u>.- The noise control plenum, attached to the compressor, is designed to minimize the compressor noise that would otherwise propagate toward the duct test area (see figs. 7 and 8). The plenum surfaces are covered with 10-cm (4-in.) thick fiberglass blankets to provide acoustic absorption. The acoustic performance of the plenum lining is enhanced by vanes and ducting which deflect the incoming flow through six 90° turns before it exits at the other side of the plenum.

Adjacent to the plenum is a lined (5-cm (2-in.) thick fiberglass) duct containing three sets of flow splitters. As previously noted for the low pressure air system, the combined performance of the lined ducts and plenum effectively eliminate compressor noise and control plenum noise in the test areas, regardless of the direction of airflow in the ducts. Limiting airflow velocities to a maximum of 6 m/sec (20 ft/sec) also effectively controls the aerodynamic scrubbing noise that would otherwise propagate along the duct toward the test areas.

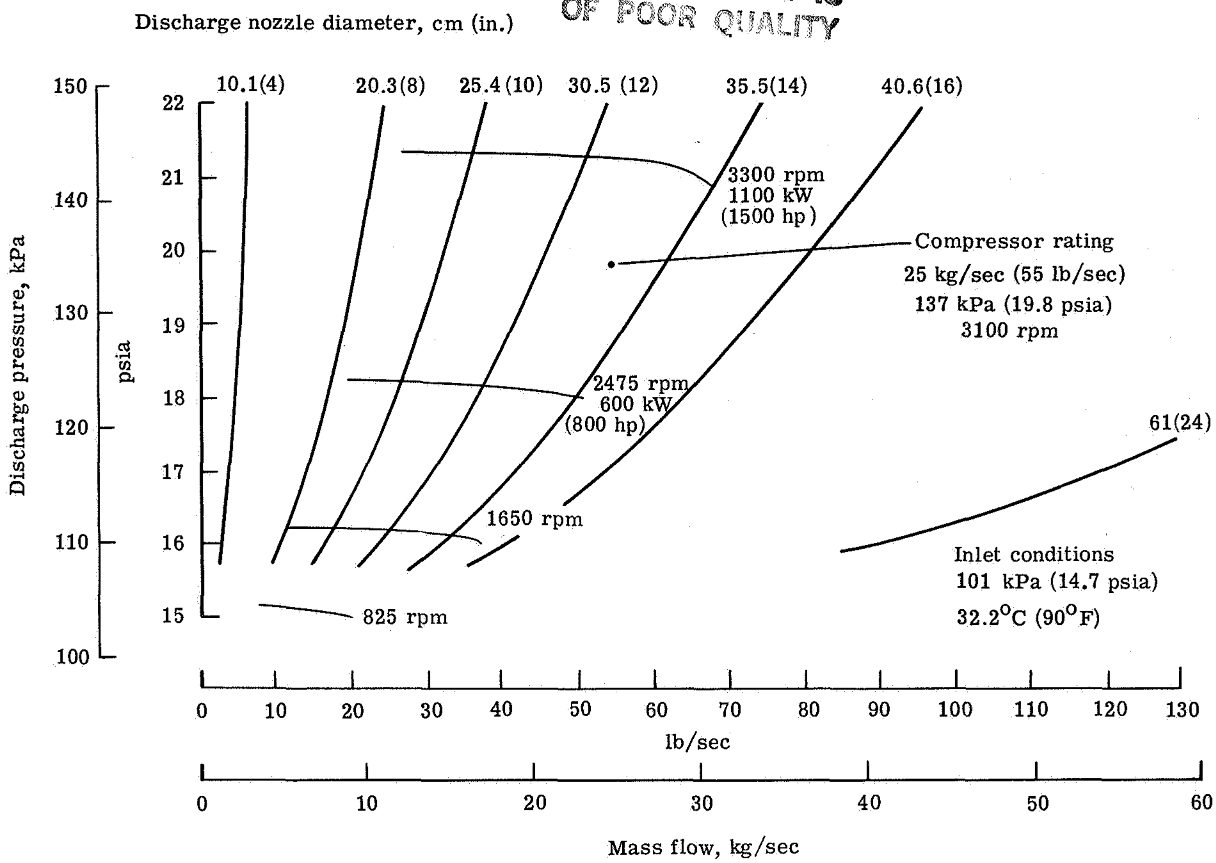

Figure 9.- Performance map for the 1100-kW (1500-hp) centrifugal compressor of the high pressure air system.

Duct propagation test area.- Adjacent to the anechoic room is a 0.3-m (1-ft) diameter circular section of ducting, portions of which can be replaced with specially instrumented sections. Provisions are made for probe microphone measurements in both the circumferential and the radial direction, to measure propagation of sound in the same direction as the flow or in the opposite direction, with and without acoustic treatments in the duct.

Operation in the compression mode simulates conditions when sound propagation and flow are in the same direction, as in the discharge ducts of a fan engine. In this mode, velocities range up to 210 m/sec (700 ft/sec). Operation in the exhausting mode simulates conditions when sound propagation and flow are in opposite directions, as in an engine inlet. In this mode, velocities range up to aerodynamic choking.

The acoustic signals used for test purposes are provided by the spinning mode synthesizer, described in a subsequent section of this paper. The synthesizer is a computer-controlled device that generates within the duct sound fields that have the significant features of those arising from turbomachinery components of jet engines.

Anechoic chamber.- The anechoic chamber, which serves as the termination of the test duct, can be used for measurements of the sound radiation either from simulated exhaust ducts or from inlets, depending on the flow direction. The construction, general layout, and significant design features were described previously in the discussion of the anechoic test area of the low pressure air system.

Eductor and inductor system.- When the system operates in the compression mode, the eductor shown schematically in figure 7 collects the exhaust flow from the high pressure nozzle exit and provides an escape to the atmosphere through an acoustically treated duct. The same system serves an an inductor (fig. 8) when the high pressure air system operates in the exhausting mode.

Reverberation room.- The reverberation room indicated by dashed lines in figure 7 can be used as an independent facility as described in reference 1 or as an integral part of the high pressure air system. Model subsonic jet nozzles and suppression devices from 5 to 30 cm (2 to 12 in.) in diameter can be operated in a reverberant environment. A bypass valving system (see fig. 7) provides an outlet to the atmosphere for excess air from the compressor during small nozzle operation, and thus allows for precise control of the model nozzle flows.

Model Air Supply System

The model air supply system is represented by the schematic in figure 10. Air at pressures up to 1030 kPa (150 psig) and at flow rates from 0.23 to 2.72 kg/sec (0.5 to 6.0 lb/sec) is supplied through appropriate piping and valving to three research areas of the quiet flow facility, namely, to the duct test area (fig. 7), to the exit plenum beside the anechoic chamber (fig. 1), and to the anechoic chamber (fig. 3). This air is available for operation of model jet exhausts and for pneumatic actuation and control of other research models. The model air system can be used with the low pressure air system, the high pressure air system, or the spinning mode synthesizer.

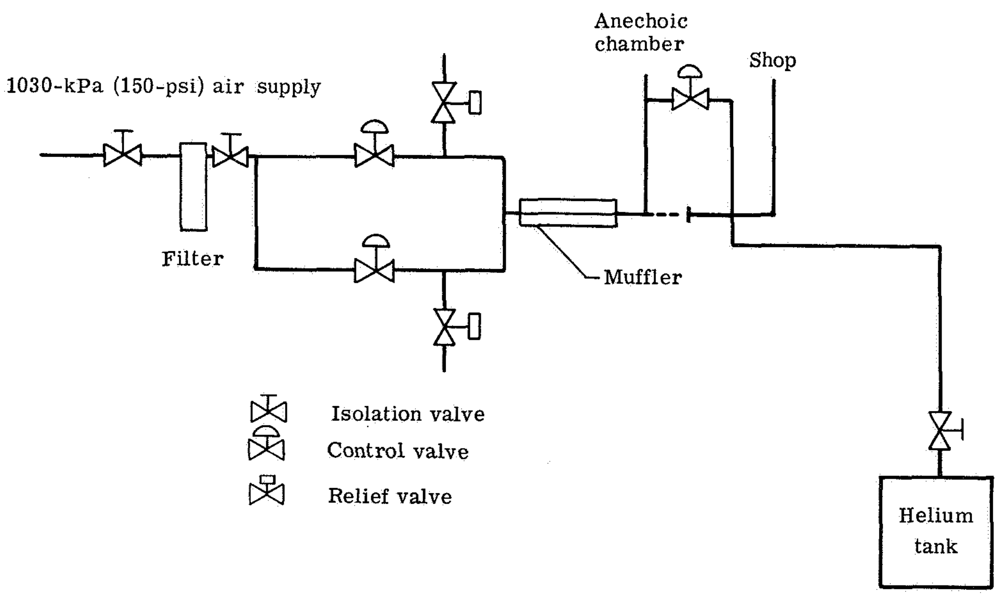

Figure 10.- Schematic of the model air supply system in the quiet flow facility.

Spinning Mode Synthesizer

The spinning mode synthesizer is designed to operate with the high pressure air system to produce, under close control, arbitrary sound fields in the duct test area. The device, shown in the schematic of figure 11 and the photograph of figure 12,

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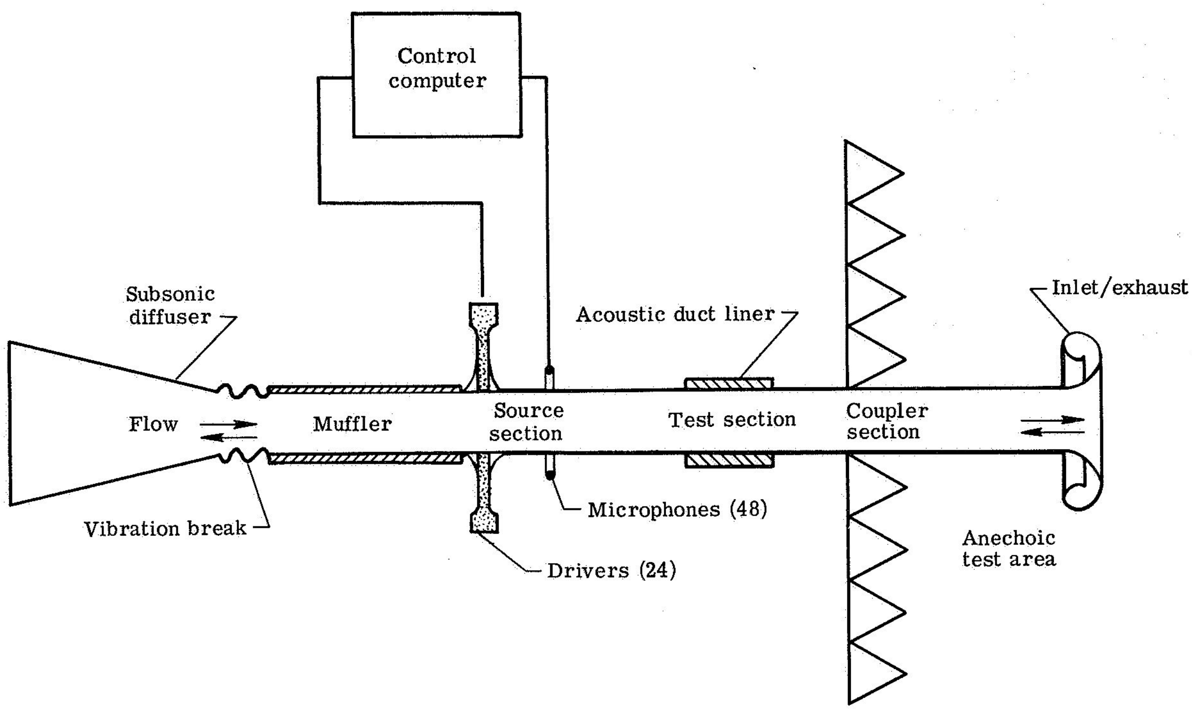

Figure 11.- Schematic of spinning mode synthesizer.

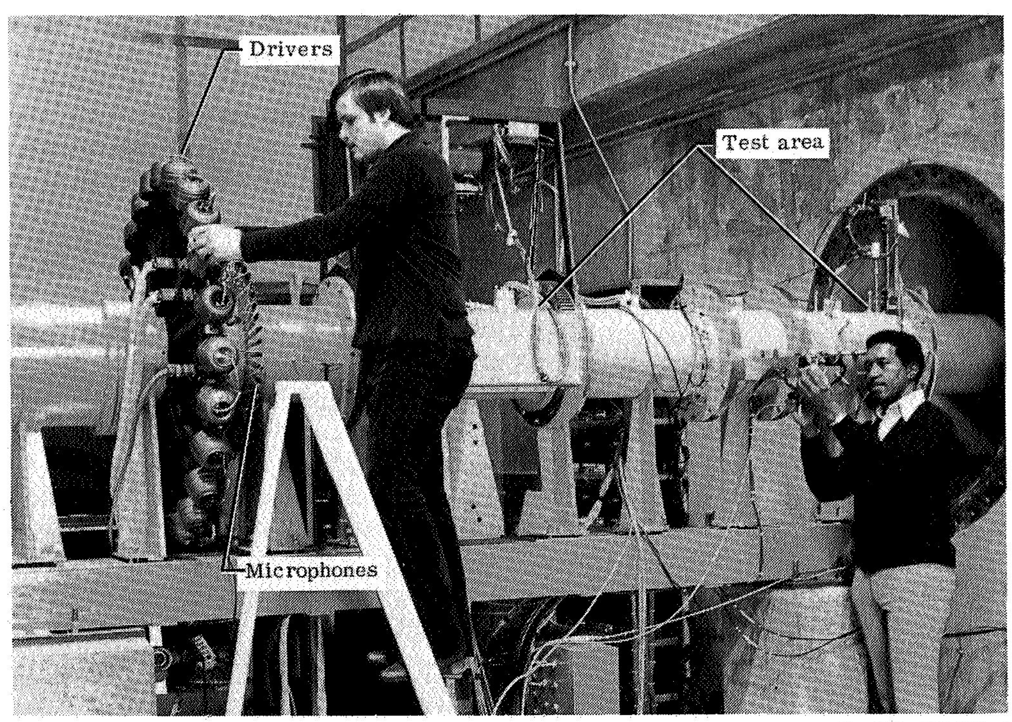

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Figure 12.- Photograph of spinning mode synthesizer.

supports research into control of noise generated by rotating blade machinery of jet engines. This research includes studies of sound propagation in the same direction as the flow, as in the case of fan bypass ducts, and studies of sound propagation in the direction opposite to the flow, as in the case of inlets. Acoustic measurements in ducts with and without acoustic liners and free field noise radiation measurements can be made. By controlling the amplitude and phase of 24 acoustic drivers located around the test duct in a plane perpendicular to the centerline (see fig. 11) a researcher can generate specified acoustic modes. The acoustic signals are monitored by a peripheral array of 48 wall-mounted microphones as a means of shaping the sound field. The measured signals are compared with the desired ones by a control computer which then generates corrections to the driver inputs. In this way, the acoustic pressure field is converged to within some accuracy desired by the researcher. Sound generated by electronic means is independent of any aerodynamic inhomogeneities which would affect the aerodynamic sound generation processes. The propagation of the signals can, however, be affected by flow disturbances, and thus the flow patterns must be carefully calibrated to interpret the acoustic measurements properly. Examples of the types of calibrations that have been made are given in reference 2. Included are axial, radial, and circumferential velocity profiles at various locations in the duct test area and for a range of inlet flow Mach numbers.

Specific research supported by the spinning mode synthesizer includes the effects of inlet geometry on noise radiation patterns and the effects of acoustic liner design and velocity gradients on the propagation of sound in flow ducts.

LANGLEY ANECHOIC NOISE FACILITY

The Langley Anechoic Noise Facility, located in Building 1218A, consists of an anechoic room in which jet noise experiments, compressor and fan noise experiments, and duct propagation experiments can be conducted. An air supply system for model jet operation and an air induction and exhaust system required for operation of a research compressor are provided. A schematic of the system layout with the main components identified is given in figure 13. Each of the system components is described in the following sections along with its operating characteristics and potential for research.

Test Area

The test area is an anechoic chamber having wedges 91.5 cm (3 ft) deep on the walls, floor, and ceiling. The wedges are placed directly on the floor and are movable, whereas on the walls and ceiling, they are installed permanently over a 15-cm (6-in.) air space. This type of treatment absorbs at least 99 percent of incident sound in the frequency range above about 100 Hz. The dimensions of the 500-m^3 (17 700-ft^3) test area within the wedge tips are approximately 8.4 m × 8.2 m × 7.3 m (27.5 ft × 27 ft × 24 ft). For jet noise directivity studies, a microphone boom allows measurements up to 5 m (16 ft) from the jet over an arc of about 135°. Access for heavy equipment is provided at ground level. Floor level entry and model setup are facilitated by first removing and then repositioning the floor wedges.

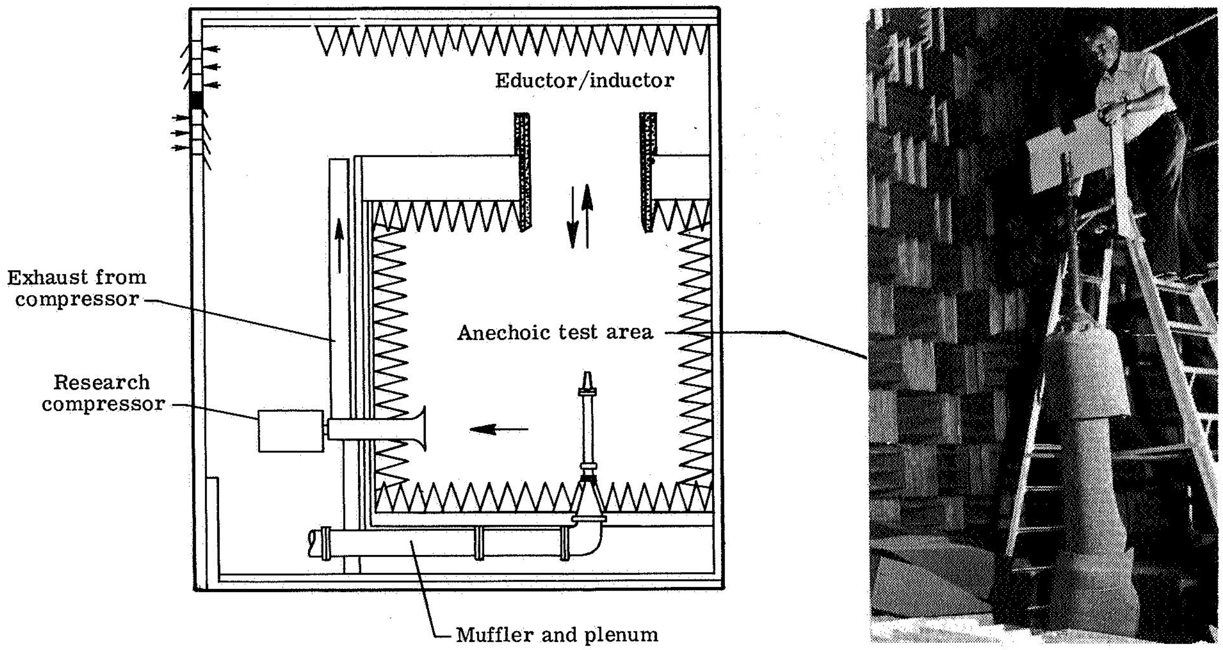

Figure 13.- Vertical section view of the test area of the Langley Anechoic Noise Facility. Inset photograph shows jet nozzle test setup.

Model Air Supply

The model air system has the capacity to supply dry air at pressures up to 1758 kPa (255 psig), the limit of the muffler system, and at flow rates up to 4.54 kg/sec (10 lb/sec) to research nozzles. Appropriate control valves, mufflers, and a settling chamber are provided to ensure quiet airflow for jet nozzle experiments. Gases other than air can be used.

Eductor and Inductor System

An eductor and inductor system on the roof provides for the passage of air in or out of the test area and for the discharge of exhaust gases. A reverse flow passage with acoustic lining minimizes noise escaping to the outside from tests inside as well as outside ambient noises propagating into the test area. Two-way louvers are open during airflow conditions but are otherwise closed. The duct cross-sectional areas are sized to accommodate the exhausting of up to 11.32 kg/sec (25 lb/sec) of air from test nozzles or the ingestion of up to 11.32 kg/sec of air by the research compressor.

Research Compressor

The research compressor, which is currently in "mothball" status, is shown in the plan-view schematic of figure 14. It includes a bellmouth inlet, a downstream radial diffuser, and back-pressure control valves (not shown in the figure) for adjusting the overall pressure ratio. The compressor is driven by a 2237-kW (3000-hp) variable-speed (up to 6600 rpm) electric motor through a 4 to 1 speed increaser. The air for the compressor is brought into the test chamber through the acoustically treated inductor in the chamber ceiling and is discharged from the radial diffuser through an acoustically treated exhaust stack to the roof.

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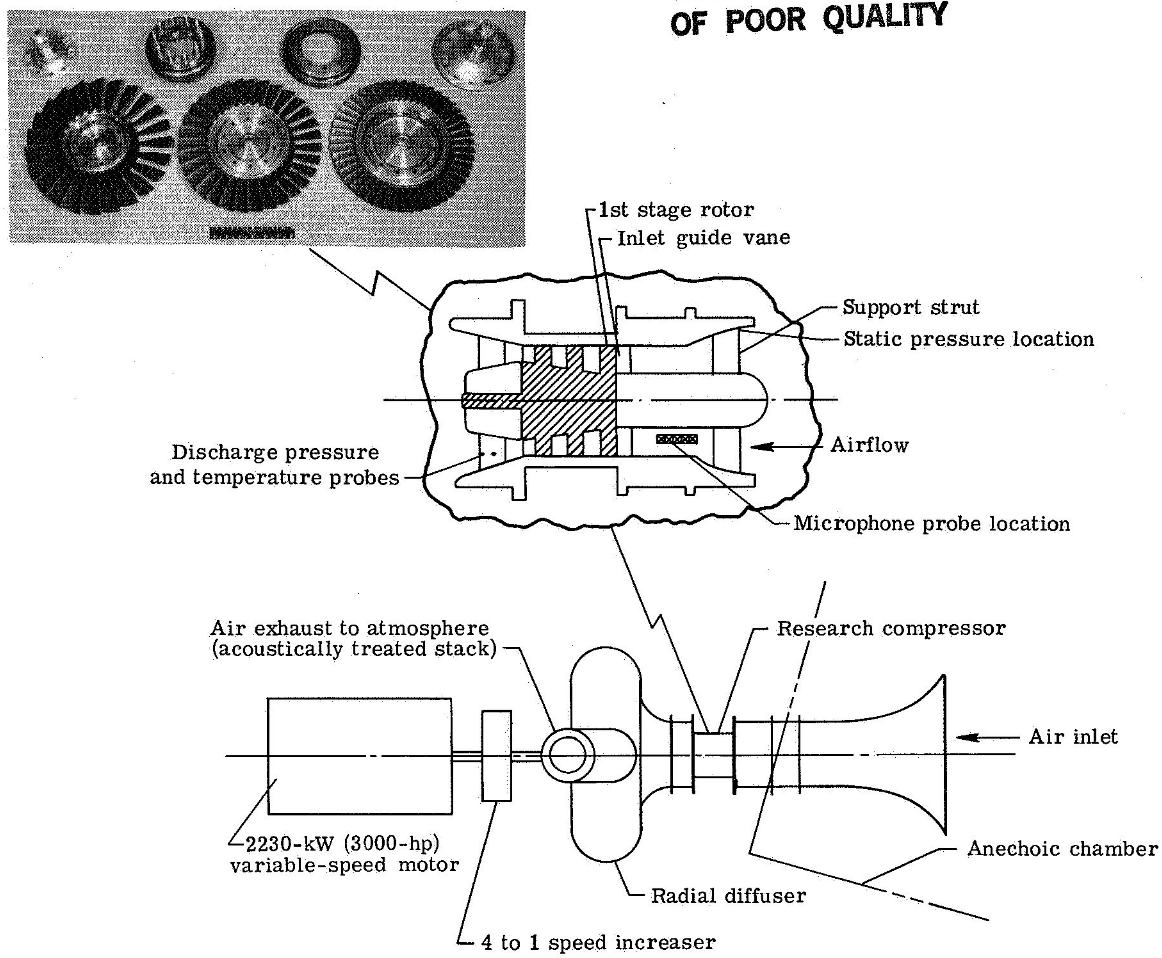

Figure 14.- Schematic of research compressor installation in the anechoic noise facility. Inset sketch shows sectional view of research compressor. The photograph shows the first-, second-, and third-stage rotors, from left to right.

The compressor is an axial-flow machine having a design airflow of 11.32 kg/sec (25 lb/sec) at a pressure ratio of 3. It has three rotor stages designed for transonic operation with a design corrected rotational speed of 24 850 rpm and a maximum power absorption of 1752 kW (2350 hp). It operates as a one-, two-, or three-stage machine with a design rated efficiency of 82 percent. The rotor blades have double circular-arc airfoil sections having root and tip diameters of 152.4 and 304.8 mm (6 and 12 in.), respectively, at the entrance to the first-stage rotor. There are 23 blades in the first-stage rotor, 31 blades in the second-stage rotor, and 47 blades in the third-stage rotor (see inset photograph in fig. 14). The number of blades in each rotor can be increased by 30 percent or decreased by 10 percent. Likewise, there are 30 vanes in the first-stage stator, 48 vanes in the second-stage stator, and 68 vanes in the third-stage stator, with provisions for increasing the number of vanes in each stator by 10 percent and 30 percent or decreasing the number in each stator by 5 percent and 10 percent. Guide vanes can be located at axial distances from 1/2 to 5 mean guide vane chords ahead of the rotor.

LANGLEY JET-NOISE LABORATORY

The main components of the Langley Jet-Noise Laboratory apparatus, located in Building 1221, are an air system capable of supplying the required flow for supersonic nozzles up to 5 cm (2 in.) in diameter in each of two airstreams (6-cm (2.5-in.) diameter for single nozzle operation with interior plug), dual electric heater units, a test area, eductor and inductor systems, and a small anechoic calibration chamber. Research activities include basic studies of the relationships between the radiated noise and the large scale flow structures in both subsonic and supersonic jets. Shock structure control is also under study. Since small changes in aerodynamic conditions can result in large changes in noise, measurement of time dependent flow quantities for correlation with acoustic data is emphasized.

Both manual and computer methods are available for independent, continuous control of air pressure (within ±1.4 kPa (0.2 psi)) and temperature (within ±11°C (20°F)) in each of the two airstreams. The accuracies can be improved for short periods of time by means of computer methods.

Model Air Supply System

Schematics of the air supply system for the Langley Jet-Noise Laboratory are shown in figures 15 and 16. Air is supplied from a 4140-kPa (600-psig) central air system to the facility, where the working pressure is limited to 1172 kPa (170 psig). The model air system can supply dry air at pressures up to 1030 kPa and at flow rates of 4.54 kg/sec (10 lb/sec) to both airstreams of coannular jet nozzles. Each airstream has two stages of electrical resistance heaters, each stage having a 315 kV-A capacity. The heaters at full power can heat air in each airstream to 538°C (1000°F) with a maximum flow rate of 0.91 kg/sec (2 lb/sec). Higher mass flow rates result in lower maximum temperatures.

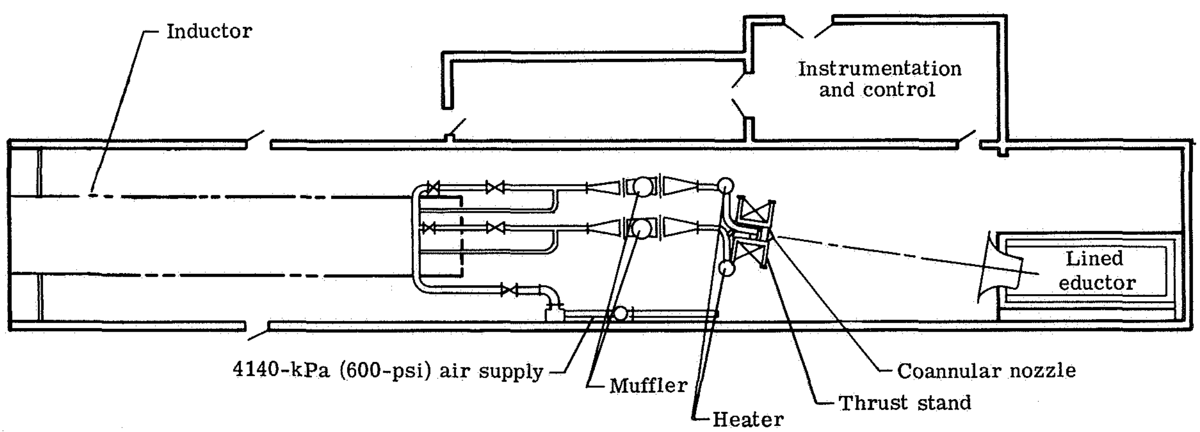

Figure 15.- Plan-view sketch of the jet noise laboratory and supporting equipment.

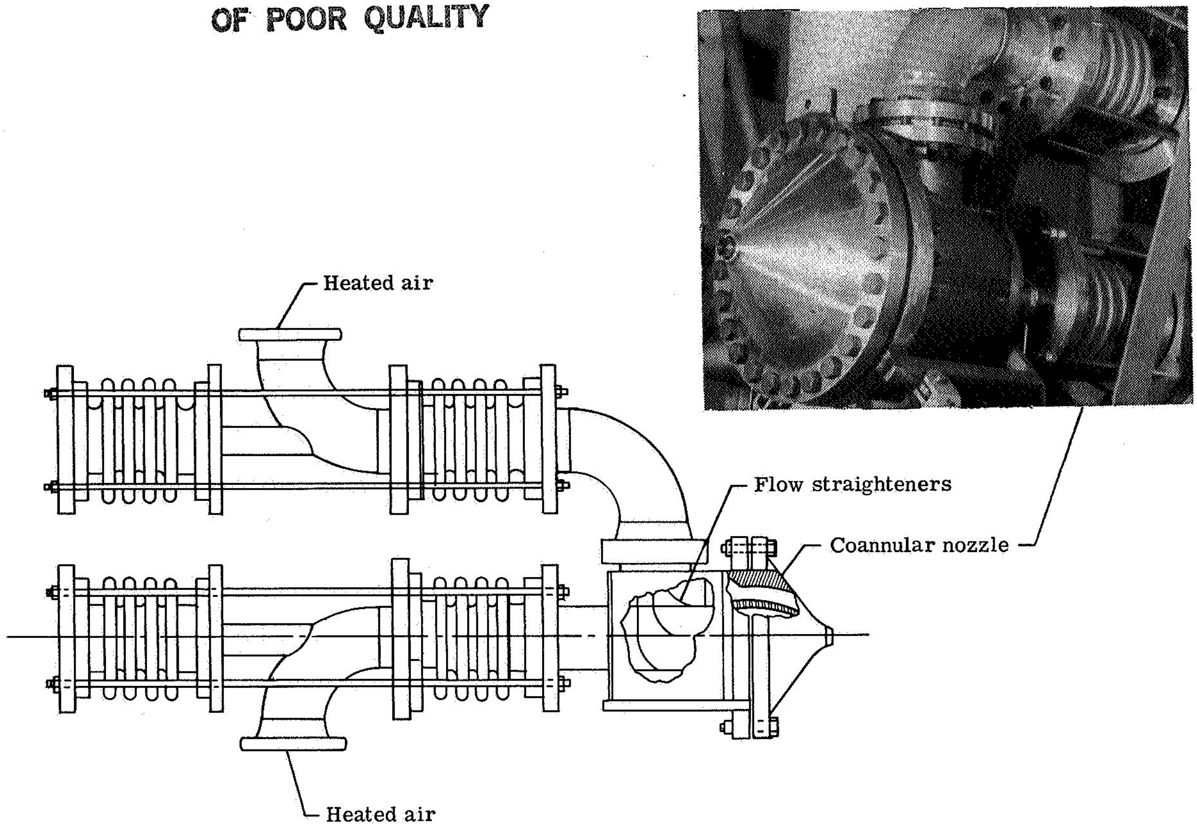

Figure 16.- Section view of the heated air systems for the coannular jet noise apparatus. Inset photograph shows nozzle hardware.

Eductor and Inductor System

The exhaust air from the jets is directed toward a collector and then flows up through an acoustically treated eductor stack to the atmosphere (see fig. 15). During normal operation of the jets, air is induced from outside through the inductor system into the test area. The inductor is designed so that the incoming air passes through acoustically treated vanes and a light trap to minimize transmission of test area noise to the outside and to minimize transmission of ambient noise and sunlight into the test area.

Test Area

The test area is approximately 8 m (26 ft) wide by 30 m (100 ft) long by 7 m (23 ft) high. The interior surfaces except for the floor are covered with 5-cm (2-in.) thick fiberglass batts. Acoustically absorbent floor covering blankets can be moved into place for acoustic measurements. Hard-wired connections are provided to the instrumentation and control room which is remotely located. On-site equipment provides computerized control of experiments and processing of data.

Anechoic Calibration Chamber

A relatively small prefabricated anechoic room is located near the test area for calibration of microphones and associated instrumentation (see fig. 17). It has 60.9-cm (2-ft) deep fiberglass wedges on the walls, ceiling, and floor giving it a nominal cutoff frequency of 150 Hz. Test area dimensions from wedge tip to wedge tip are about 3.86 m × 3.25 m × 2.52 m (12.7 ft × 10.7 ft × 8.3 ft). Calibration indicates close adherence to inverse square law behavior, after correction for atmospheric absorption, at frequencies from about 200 Hz to 50 000 Hz. Access is at floor level, and floor wedges are moved aside to provide a work area for installation of models and equipment.

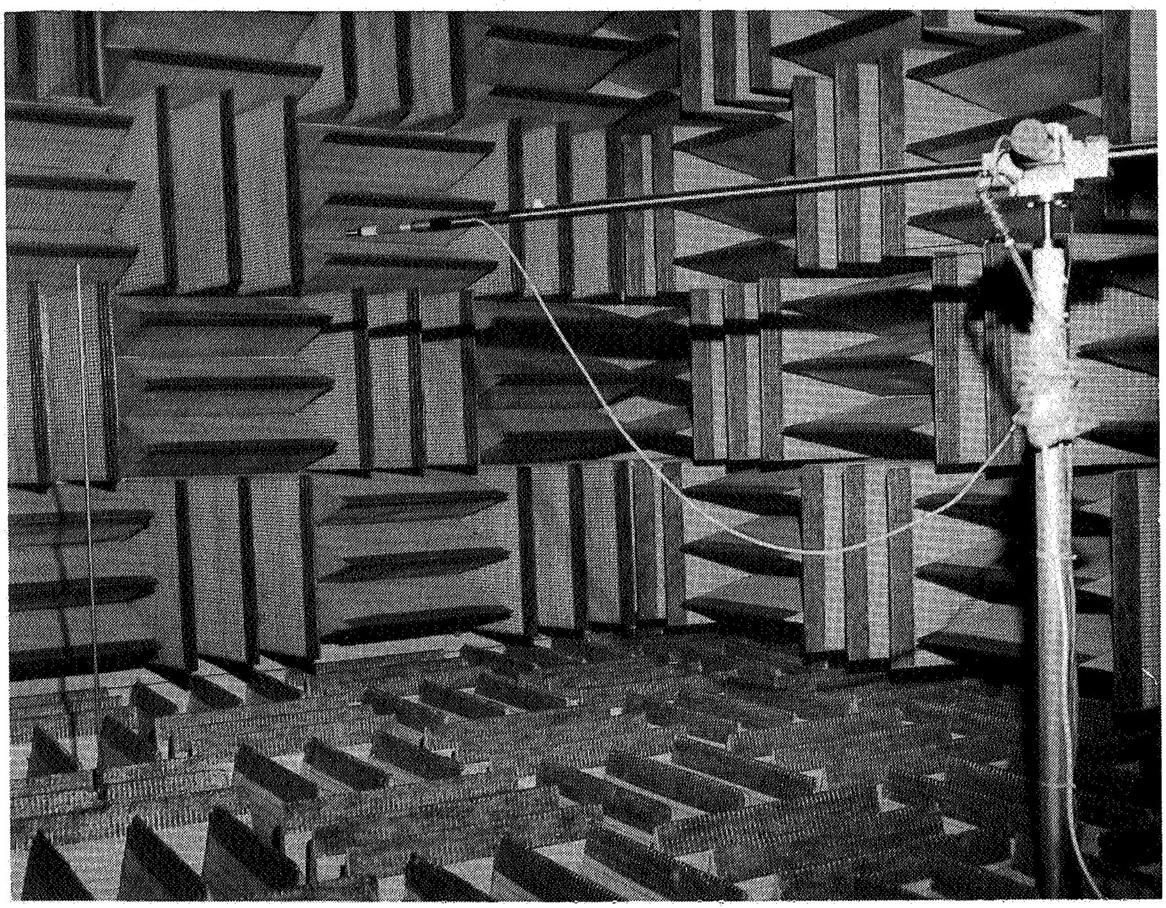

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Figure 17.- Interior of small anechoic room used primarily for calibration of microphones and associated equipment.

FLOW IMPEDANCE TEST LABORATORY

The flow impedance test laboratory, located in Building 1287, provides the capability for testing the acoustic performance of duct lining materials in an aeroacoustic enviroment (see ref. 3). The main components of the apparatus are the air and vacuum systems, the acoustic source, the test section including the branch tube, and the termination section (see fig. 18).

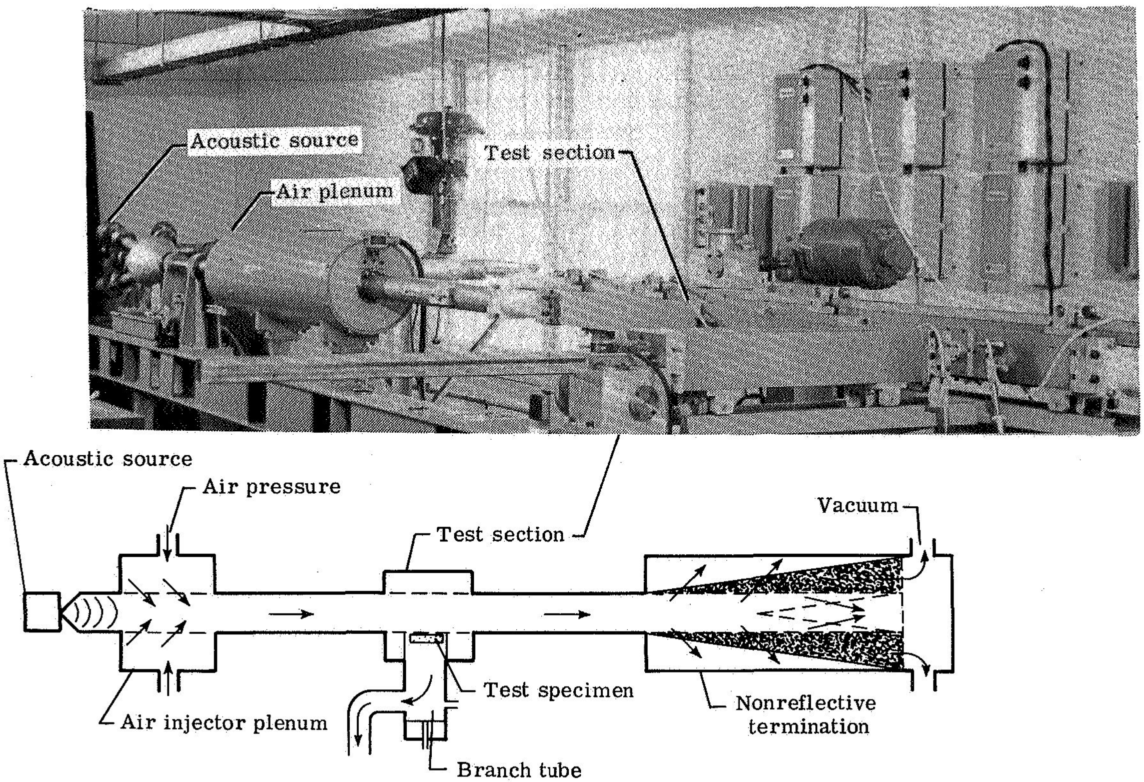

Figure 18.- Plan-view sketch of grazing flow impedance apparatus. Inset photograph shows test section area.

Air Supply

The flow through the test section of the flow impedance test laboratory is controlled by applying pressure to the upstream side and a vacuum to the downstream side. By this means the static and total temperature and pressure in the duct area can be controlled over a small range about ambient conditions.

Air is furnished from a high pressure air line through a pressure reduction system and a quiet regulatory valve to the plenum over a pressure range from 0 to 6890 kPa (0 to 100 psig). It is then injected into the flow channel through a perforated metal cylinder having a flow resistance of 25 000 N-sec/m^3 (2500 cgs rayls). By means of differential pressure control, the test section static pressure is controllable over a range of 101.3 kPa (1 atm) ±20 percent, and the flow rate is controllable up to a maximum Mach number of about 0.40 in the 25.8-cm^2 (4-in^2) test section. The air then flows into the termination section where it is removed through porous liners in the termination channel by means of a vacuum pump and is exhausted to the atmosphere.

Acoustic Source

The source of the acoustic test signals is an array of five 60-watt drivers that are operated in the range from 100 to 3500 Hz. They are ganged together and phased to provide maximum efficiency of coupling to the test section. Inside the plenum, the acoustic signals are superposed on the airflow to provide a controlled aeroacoustic environment in the test section. The maximum sound pressure levels attainable in the test section are about 125 dB for discrete frequency testing; thus a good signal-to-noise ratio is provided while nonlinear propagation effects are avoided or minimized. There is also provision for the sound to propagate opposite to the flow direction by coupling the drivers to the main channel downstream of the test section.

Test Section

The main channel through which the air passes is 5.08 cm (2 in.) square in cross section and about 3.66 m (12 ft) long, with a wall thickness of 2.54 cm (1 in.). A traversing boom for transporting a probe microphone is mounted in an airtight slot in the top of the main channel. A digital stepping motor under computer control or a hand crank can be used to position the traversing boom over a 122-cm (48-in.) section of the channel. Access openings (5.08 cm square) are located on opposite sidewalls of the test section and a rectangular opening (5.08 cm × 40.64 cm (2 in. × 16 in.)) is located on the bottom for installing samples of materials for grazing flow tests. A side branch tube can be attached to the side openings for providing variable reactive impedance for acoustic components having thin face sheets. In addition, controlled suction or blowing can be implemented to study boundary layer effects.

Acoustic Termination

The termination channel is a 5.08-cm (2-in.) duct with 2.54-cm (1-in.) thick steel strips on the top and bottom and perforated panels on the sides. Strips 5.08 cm wide of reticulated foam (density of 0.089 g/cm^3 (0.0032 lb/in^3)) are placed on the outer side of the perforated panels. The density of the foam material is varied by means of adjustable screws that press it against the perforated panels.

The purpose of the acoustic termination is to provide a controlled aeroacoustic environment in the test section by minimizing reflections back into the test section. To reduce reflections caused by the sudden transition from hard walls to soft walls at the end of the termination channel, a gradual transition is provided by progressively compressing the foam material. The more it is compressed the higher the density and the greater its resistance.

Supporting Equipment

Two other pieces of apparatus are used in the flow impedance test laboratory in supporting roles, namely the no-flow impedance tube and the flow resistance apparatus. The no-flow impedance tube is used to measure the normal impedance of a sample of acoustical material by means of standard techniques for analyzing standing wave patterns within the tube. The flow resistance apparatus is used to measure the resistance to airflow through a sample of material in order to characterize some of its properties which are significant for sound absorption.

No-flow impedance tube.- The no-flow impedance tube is a widely accepted instrument for standardized measurement of acoustic impedance of materials. A schematic of the apparatus is shown in figure 19. The main components are a movable piston termination, an acoustic driver, two probe microphones, and a main tube into which the test specimen is placed.

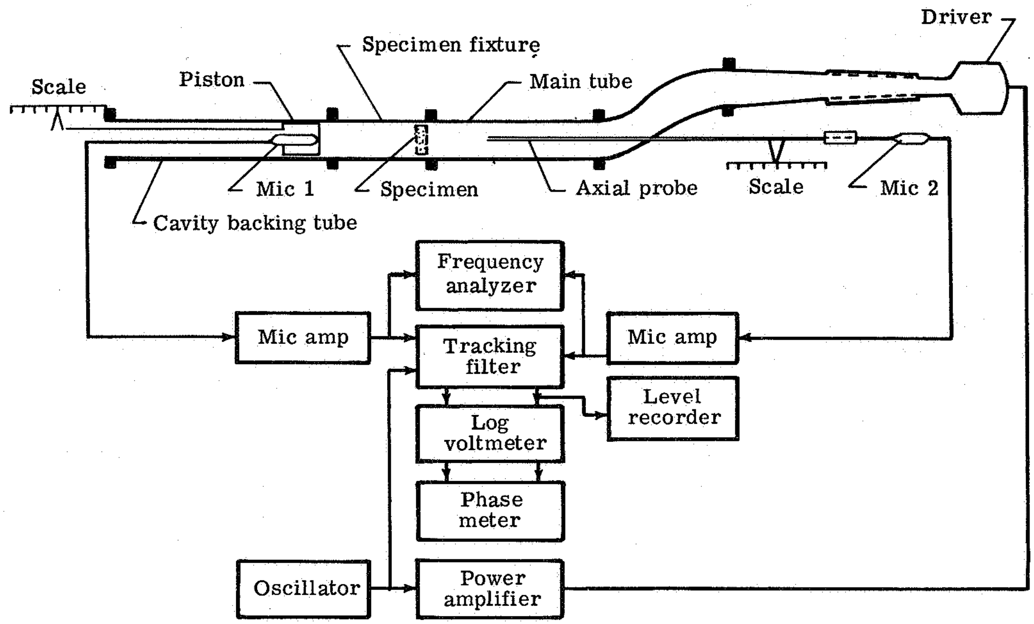

Figure 19.- Schematic of no-flow impedance tube and associated instrumentation.

Flow resistance apparatus.- One of the quantities that best characterizes the acoustical behavior of a material is its flow resistance. This is the resistance to continuous airflow established by a pressure differential across a sample specimen. The main components of the system required to make such measurements are shown in the schematic of figure 20. They consist of a tube for mounting the test sample, a system for causing air to flow at a uniform rate through the sample, and a means for measuring the pressure drop across the sample and the volume flow through it (see ref. 4, pp. 844-854).

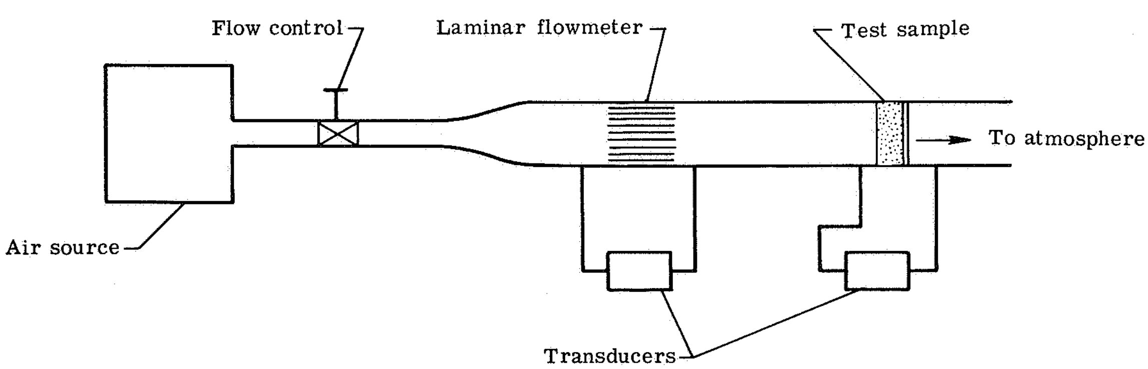

Figure 20.- Schematic of flow resistance measurement device.

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