ALTITUDE FACILITIES

Talk No. 1

Speakers: O. Smith
E. Samfield

Today at this laboratory you will see many research demonstrations. But we are going to show you something entirely different. We shall discuss the unique altitude facilities that make this research possible. The air services are the life-blood of all experimental engine work, since the scope of testing depends on the extensiveness and flexibility of the air-handling systems. Because of our large air facilities, we have the most complete full-scale aircraft engine laboratory in this country.

Current turbojet engines now being used in military aircraft have been operated in the altitude chambers of this building at simulated altitudes to 65,000 feet and at speeds twice that of sound. Ram-jet engines, 38 inches in diameter, have been operated at altitudes to 80,000 feet and three times the speed of sound. You will see the air systems that are required to permit engine research at these extreme conditions, and the manner in which these systems are utilized.

This central control room is the nerve center of the air systems. It is possible that we may be interrupted by

phone calls to the service dispatcher who is seated at his desk. These calls will be from various research setups in which some change in service is required. Work is now in progress.

Why do we need altitude facilities? Conditions of pressure, temperature, and speed that are encountered at altitudes must be duplicated on the ground. This slide (fig. 1) shows the variation in pressure and temperature of the air above us. These graphs represent NACA data for a standard atmosphere. Notice that from a sea-level pressure of 14.7 psi, the pressure diminishes until at an altitude of 35,000 feet it is 3.5 psi. At 100,000 feet it is only 0.2 of a pound per square inch.

In like manner, temperature diminishes with altitude. From an NACA standard of 59° F at sea level, the temperature decreases until at 35,000 feet it is -67° F. From this point to 100,000 feet the temperature remains substantially constant.

Our test air does not necessarily follow this pattern since both the pressure and temperature of the engine air are affected by the speed of the airplane. For example, in flight at 35,000 feet and at a speed twice that of sound, the ram of the air as it enters the engine causes a pressure rise from 3.5 to 27 pounds per square inch and a temperature rise from -67° to 250° F.

Here are some examples of altitude research investigations that have been conducted at the Lewis laboratory.

This slide (fig. 2) shows a full-scale turbojet engine installed in an altitude chamber. The hatch (which is shown in an open position) is, of course, closed and bolted before testing. This is the air inlet of the engine, the compressor section, the combustion chambers, the turbine and the tailpipe. Compressed air at the required pressure is supplied through the bulkhead on the left. The air can be cooled or heated to the desired temperature. Exhaust gases are removed to the right by the laboratory exhauster system. A more detailed description of this installation will be given later and you will have an opportunity to inspect it as you leave the building.

Research problems are often limited to one of the component parts of the engine. As, for example, the compressor. This slide (fig. 3) shows a large multistage axial-flow compressor driven by a variable-frequency 15,000-horsepower motor. Conditioned air is supplied through the surge chamber shown on the left, and the compressor discharges into the two vertical pipes shown here.

Next (fig. 4) is a setup of a single combustion chamber. In this apparatus we can study combustor operation using only one of the several combustors that normally power an engine. Laboratory systems supply air at the left and remove exhaust gas at the right. In order to make the results applicable

to the engine, the air supplied to the combustor must be compressed and heated to simulate the action of the engine compressor. The discharged gases likewise must be subjected to the same conditions that are encountered in flight.

A typical turbine research investigation is shown on the next slide (fig. 5). This shows a full-scale turbine to which heated compressed air is supplied through the overhead pipes. The turbine discharges into the large pipe shown in the foreground. Mounted behind the turbine, but not visible in this photograph, is an absorption dynamometer.

There are over 100 test installations in this building alone. All of the buildings at this laboratory are supplied air services which are controlled from this room. Each research scientist is interested in the progress of his own work. In fact, he probably believes his project is the most important one at the laboratory. Thus coordination and supervision are necessary to obtain a maximum economy of test time, consistent with the available altitude services. Much thought is given to the scheduling and dispatching of these facilities, since many users normally operate simultaneously from the same supply and exhaust systems.

Lewis

ALTITUDE FACILITIES

Talk No. 2

Speakers: F. U. Hill
A. Brandt

The previous speaker has told you of some of the research methods employed at this laboratory. I would now like to elaborate on the equipment which is used to supply the altitude services for these research programs.

Let us consider a typical research setup (fig. 6). Such a setup would be a full-scale engine mounted in an altitude chamber. Air is supplied by a compressor, and let us assume that for this particular case, the air must be refrigerated. This is done by passing the compressed air through a cooler where it is cooled by means of a refrigeration system. The air must then pass through a shut-off valve which is controlled by the Central Control Room. Then the air enters the altitude chamber to the test cell throttling valve which is controlled by the operator of the test setup. The air passes through a temperature controller where a particular altitude and flight speed temperature is duplicated. Hot gas leaving the engine enters a primary cooler and then passes through another control valve to a shut-off valve which is controlled by the dispatcher in this control room. The gas is further cooled by

a secondary cooler, and finally back through the building exhaust system where it is discharged to the outside. This arrangement typifies the research setups in this building.

To your left you will notice five control panels. The first panel is sued to supervise the distribution of the altitude exhaust system. If you will look at this panel, you will see a large number of colored lights enclosed by a white border. The white border represents the outer walls of this building. The brown lines mark out the various test cells. These red and green lines represent the altitude and atmospheric piping. A green light represents a machine ready to run and a red light represents a machine that is running. Each pair of white and blue lights represents a valve. There are over 300 valves ranging from 3 inches in diameter to 72 inches in diameter controlled from this room.

Located on the first floor and in the basement of this building are large vacuum pumps or exhausters. This slide (fig. 7) shows four centrifugal exhausters, each with a rated capacity of 100,000 cfm. The exhausters are located at this point (indicating on Panel 1) in the building and the background noises you now hear are these exhausters in operation. Six rotary type exhausters, with a combined capacity of 120,000 cfm are located at this point in this building. This next slide (fig. 8) illustrates one of these rotary exhausters.

Let us trace a typical path. If we follow this red line from the exhausters, we find it is a main distributing line running the length of the building. This test cell feeds into it. You will notice that the blue light is on. This indicates that the control room shut-off valve is closed. Should the test cell operator require altitude exhaust service, he would call this control room. The dispatcher would turn the switch and the white light would come on. When the blue light goes out, the dispatcher would know the valve is fully open.

A centralized control is very important from the safety angle. You will notice a number of caps over the valve switches. These indicate that the lines served by the valves are out of service. The Central Control Room dispatcher is responsible for the signing out of valves and equipment to prevent injury in case a pressurized line is opened or a machine started in error.

The knobs and lights you see on the aprons are also safety features. Should am emergency arise somewhere in the building, and the equipment operator could not get to his controls, each major piece of equipment supplying altitude services could be shut down from here.

The second board is used for supervising the distribution of the 10 pound per square inch refrigerated air. The next slide (fig. 9) illustrates a portion of the ammonia refrigeration equipment. Here air can be lowered to a temperature of -70° F. The operation of this board and the

remaining boards is the same as the altitude board, but each board is an entirely separate system.

The third panel controls the distribution of the 40 pound air. This is used for testing full-scale engines and some engine components.

The fourth panel supervises the distribution of the 125 and 450 pound air. This air is used primarily in burner research. For example, the combustors behind the compressor operate at a much higher pressure than that at the inlet of the engine.

The next slide (fig. 10) illustrates three of the group of centrifugal compressors that can supply compressed air from 10 to 450 pounds per square inch, controlled from the two boards just described.

The final board controls the distribution of the 2 pound engine cooling air. At present its use is very limited.

Several years ago, this laboratory, anticipating the speed and size of present day engines, planned new and larger engine test facilities. A part of this program is to increase the exhaust capacity of the altitude wind tunnel by an additional 75 percent. In addition, new propulsion facilities are being completed. This is a model of the new facility. During the day, as you travel from one exhibit to the other, you will notice this large construction project. It will be used for testing the large full-scale turbojet and ram-jet engines. The service facilities are similar to those for this building, except that

the capacity is almost double.

Let us examine this model. Outside air will be drawn in and compressed in this location. The air will pass through large drying tanks which do not appear on the model. It passes through these specially designed heaters, mixing stations, throttling valves and enters the altitude tanks in which the engines are mounted. Hot exhaust gases are first cooled in the primary coolers, pass through a control valve and the large piping to the secondary cooler. The cooled gas is drawn into the exhauster located here before being discharged to the atmosphere through this stack.

The hot gases from the engines may reach temperatures as high as 3500° F. These gases must be cooled by water until they reach a temperature that can be handled by the exhausters. Since large quantities of water are required for this and numerous other cooling applications, three cooling towers are in use. You will see one of these cooling towers as you leave this building.

Shown on this illustration are the Engine Research Building, in which you are now, the new Propulsion Facilities, which I just described, and the Altitude Wind Tunnel, which you will visit or have visited during the day. Large connecting piping or tie lines now being constructed will allow the combined capacity of all major services to be available at any of the three locations.

When our present program of expansion is completed, it will be possible to test 15,000 pound thrust turbojet engines at 60,000 feet and twice the speed of sound.

I should now like to introduce the next speaker, Mr. _____, who will show how this control room operates in coordinating the use of several of the services at this laboratory.

ALTITUDE FACILITIES

Talk No. 3

Speakers: B. R. Leonard
E. Corsetti

Mr. Smith has described the services that are required to test a modern aircraft engine in the laboratory. Mr. Hill has illustrated some of the service facilities available at the Lewis laboratory for investigating today's -- and tomorrow's -- aircraft engines.

We are now ready to see how the service facilities are made available to operate an actual research installation. Let us presume that we are going to conduct altitude tests on a full-scale turbojet engine here in the altitude test cell, designated SW-23.

Since it would be inconvenient to actually tour the entire area, we shall view the operation with the aid of a motion-picture camera. (Movie starts)

Here we see the complete turbojet engine housed in an altitude chamber 10 feet in diameter. The research engineer is in the process of completing the check-off list to make certain that the equipment is in proper working order.

He and the chief mechanic discuss the installation, and the mechanic makes minor adjustments prior to the run.

We are now ready to close the hatch and go to the test cell control room to start the engine. As the hatch is closed, let's take a brief look behind the scenes at the preparation and activity that has preceded this moment.

The test actually began some time ago when these research scientists found it was necessary to obtain certain altitude information for a turbojet engine.

They have requested that the engine be instrumented and assembled for testing. This is done in the Engine Overhaul Section. When the engine is ready for the test, the service facilities are scheduled.

Here we see a scheduling conference in session. Members of the research and service divisions meet every Friday and analyze the requests for services from all the research scientists. The most efficient operating schedule is agreed upon, and the finished schedule is distrubuted to research and service personnel.

Our test is scheduled for 8:30 a.m. and it begins for us at 8 o'clock here in the Central Control Room. The service dispatcher, seeing that a run is scheduled for 8:30, calls the equipment operators and initiates the starting of additional machinery that will be necessary for our test.

The equipment operator for the air compressors is stationed in the basement of this building. He receives his instructions from the service dispatcher, sets the valves to connect the proper machines to the air-supply headers, and starts the compressors.

Here we see the reciprocating machinery starting to compress air at 125 pounds per square inch for operation of test instruments and auxiliary equipment.

These are the centrifugal compressors which will furnish the combustion air for our jet engine test. The controls have been set to deliver air at 40 pounds per square inch.

Our next stop is in the exhauster room. The centrifugal exhausters shown here are used to simulate engine exhaust conditions. We will have an opportunity to observe these machines in operation following this film.

The starting procedure for the exhausters is similar to that for the compressors. The equipment operator, having received his instructions from the service dispatcher, signals the electrical operator to start the motors. As each motor comes up to speed, the equipment operator engages a hydraulic coupling between the motor and the exhauster. As the exhauster starts to rotate, the operator checks the gages, adjusts the controls, and calls back here to the Central Control Room to notify the service dispatcher that the requested equipment is in operation.

The service dispatcher, after receiving word from all the equipment operators that the machinery has been started, gives the signal for the main valves to be opened to route the required services to the test cell. The control is set, the valve opens, and 40 pound per square inch combustion air is delivered to the test cell. In the same manner, the

remainder of the services are made available for use by the research engineer.

We may now rejoin the engineer and mechanic in the test cell control room.

At this point, the research engineer makes a final clearance with the Central Control Room and proceeds. He opens the test cell control valves for combustion air and altitude exhaust, and signals the mechanic to start the turbojet engine. The mechanic turns on the ignition, starts the fuel pumps and opens the throttle; the engine flames into action; and the take-taking process begins. After the data are analyzed and evaluated, the information is prepared for use by industry, military, and research organizations in the form of NACA reports. (Movie ends)

This concludes the description of the altitude facilities. You will now leave the Central Control Room and go on a brief tour. You will see the centrifugal exhausters in operation, the Engine Overhaul and Thermocouple Section, where the engines are actually being prepared for testing, and the altitude test area where we have just conducted our jet-engine test.

Setup -- Altitude Facilities Demonstration

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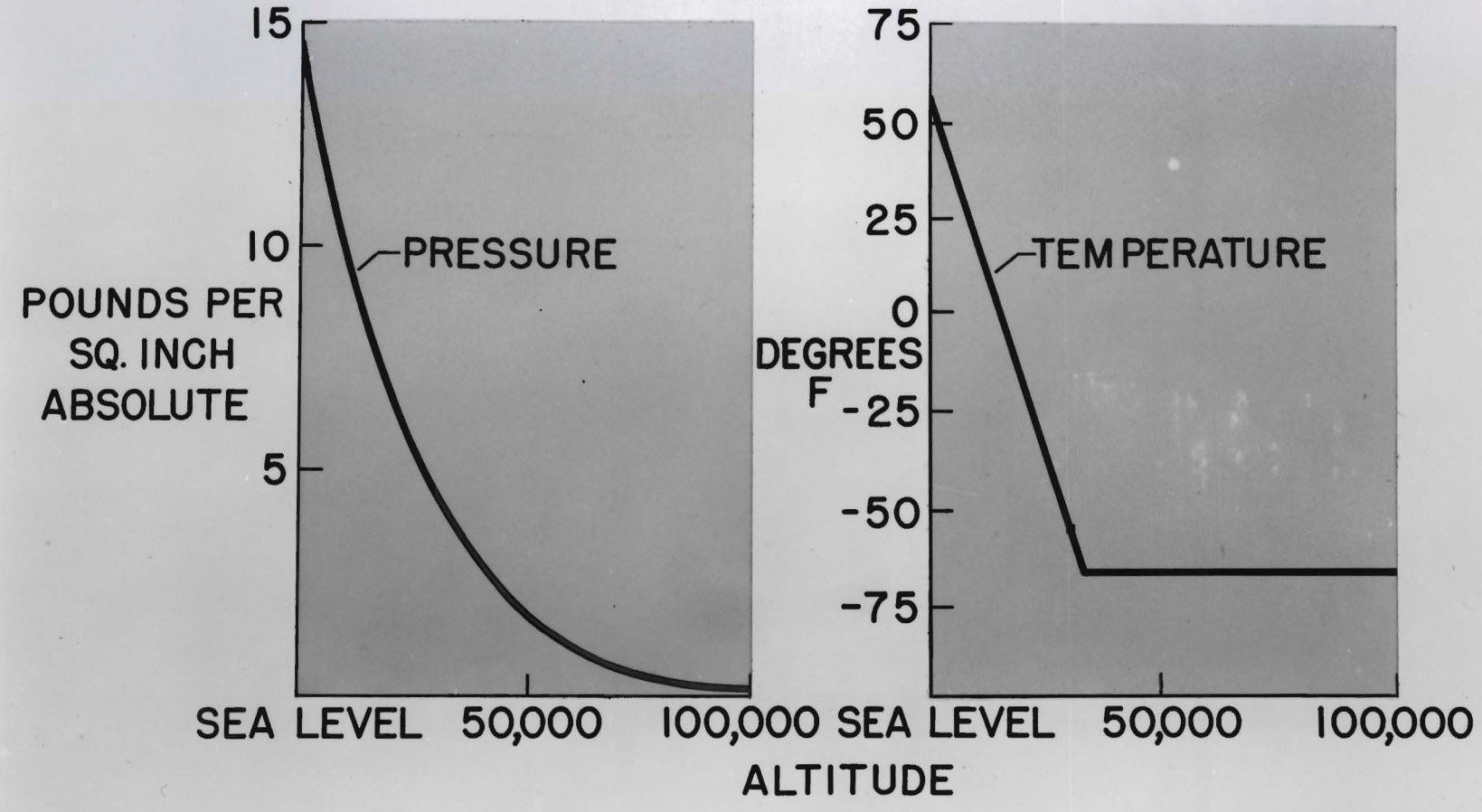

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Altitude Facilities -- Figure 1

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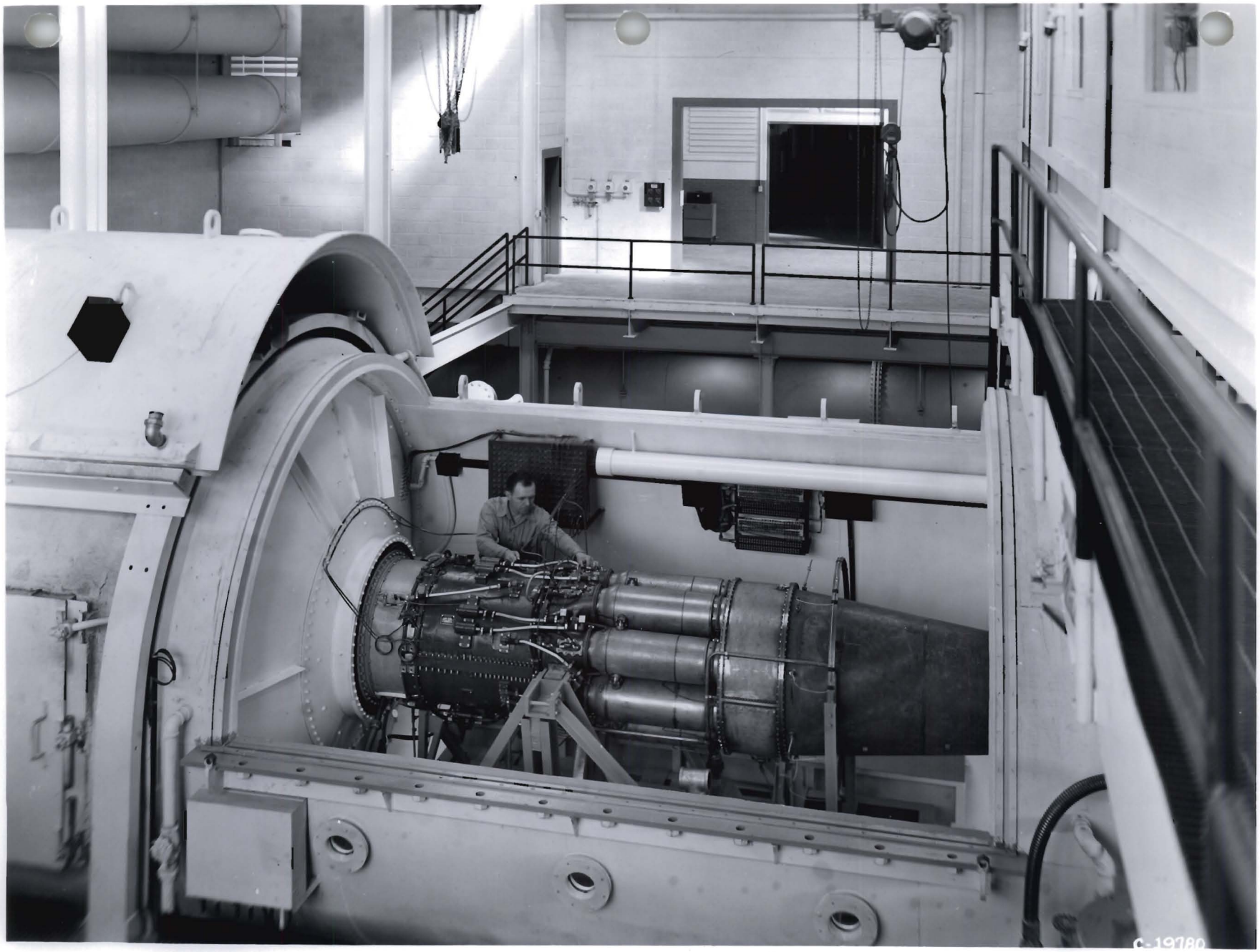

Altitude Facilities -- Figure 2

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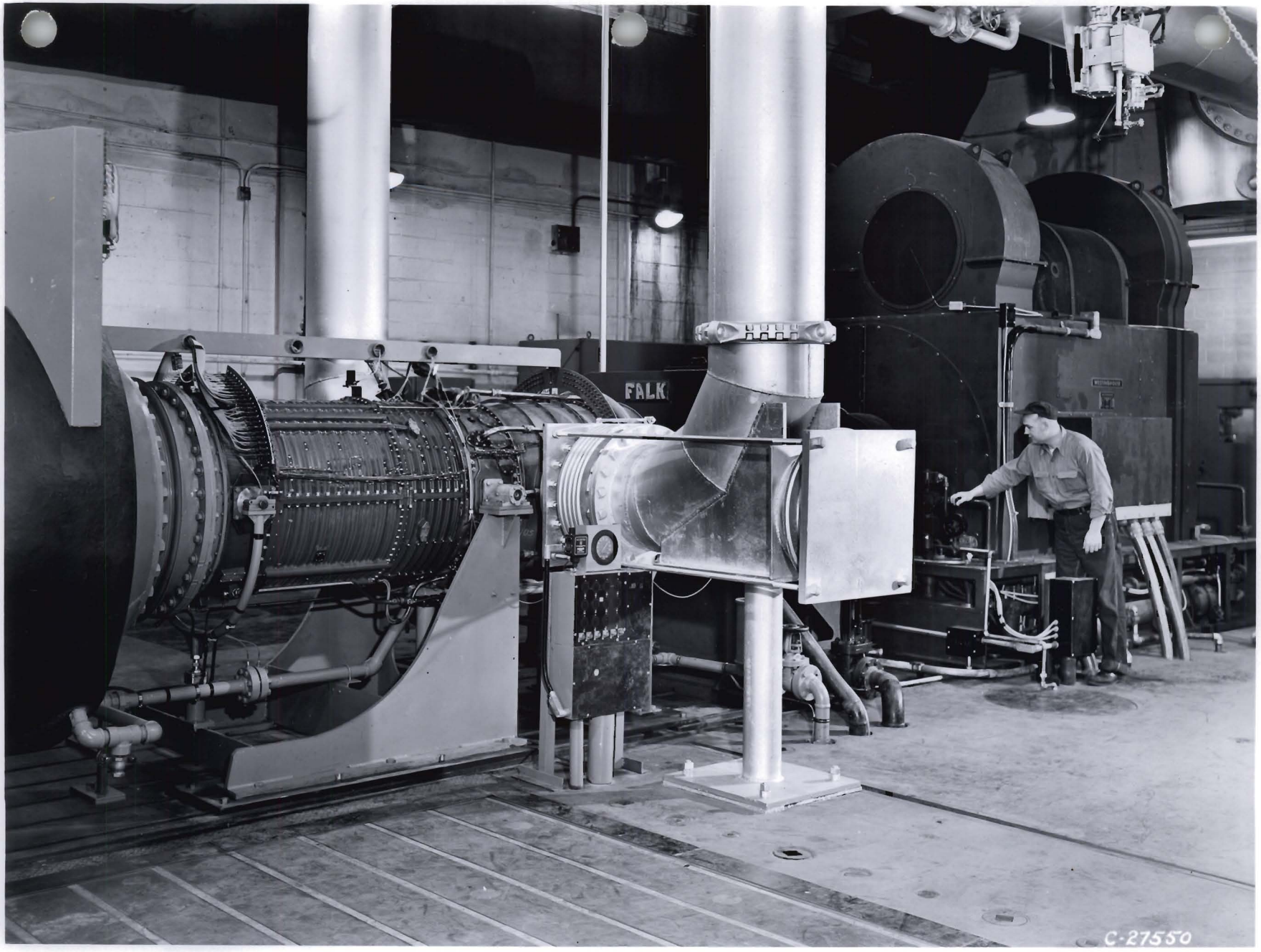
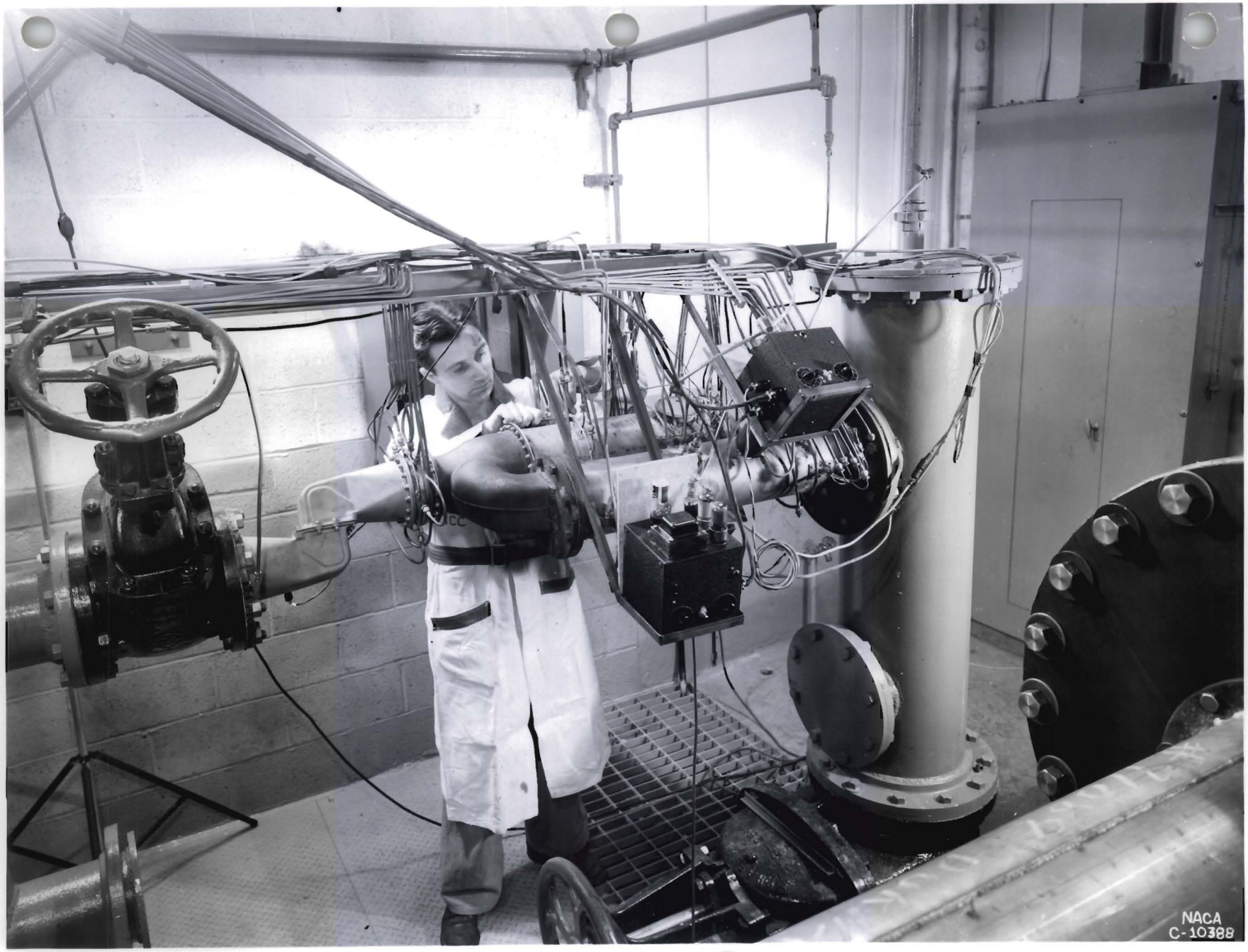
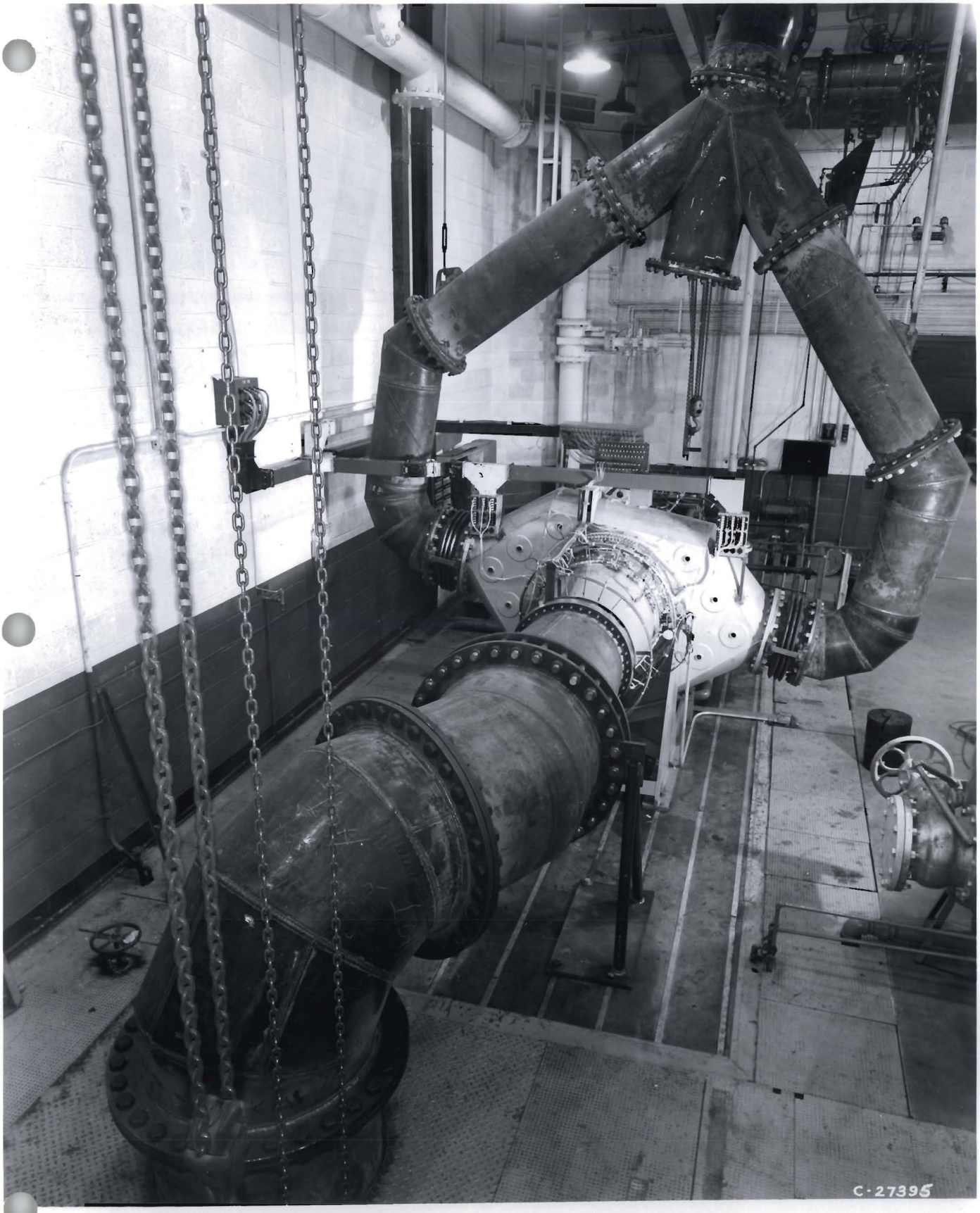


Altitude Facilities -- Figure 3



Altitude Facilities -- Figure 4



Altitude Facilities -- Figure 5

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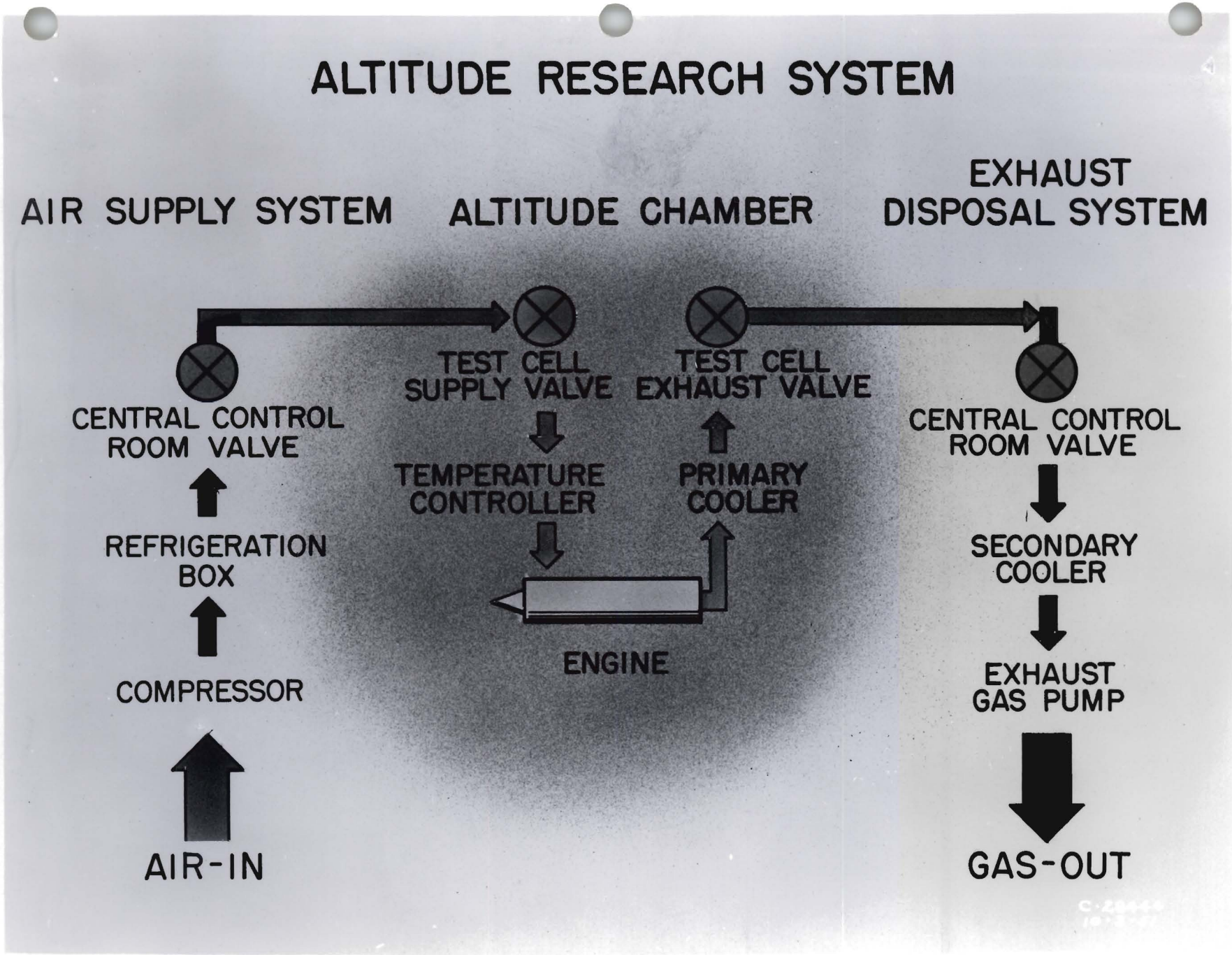
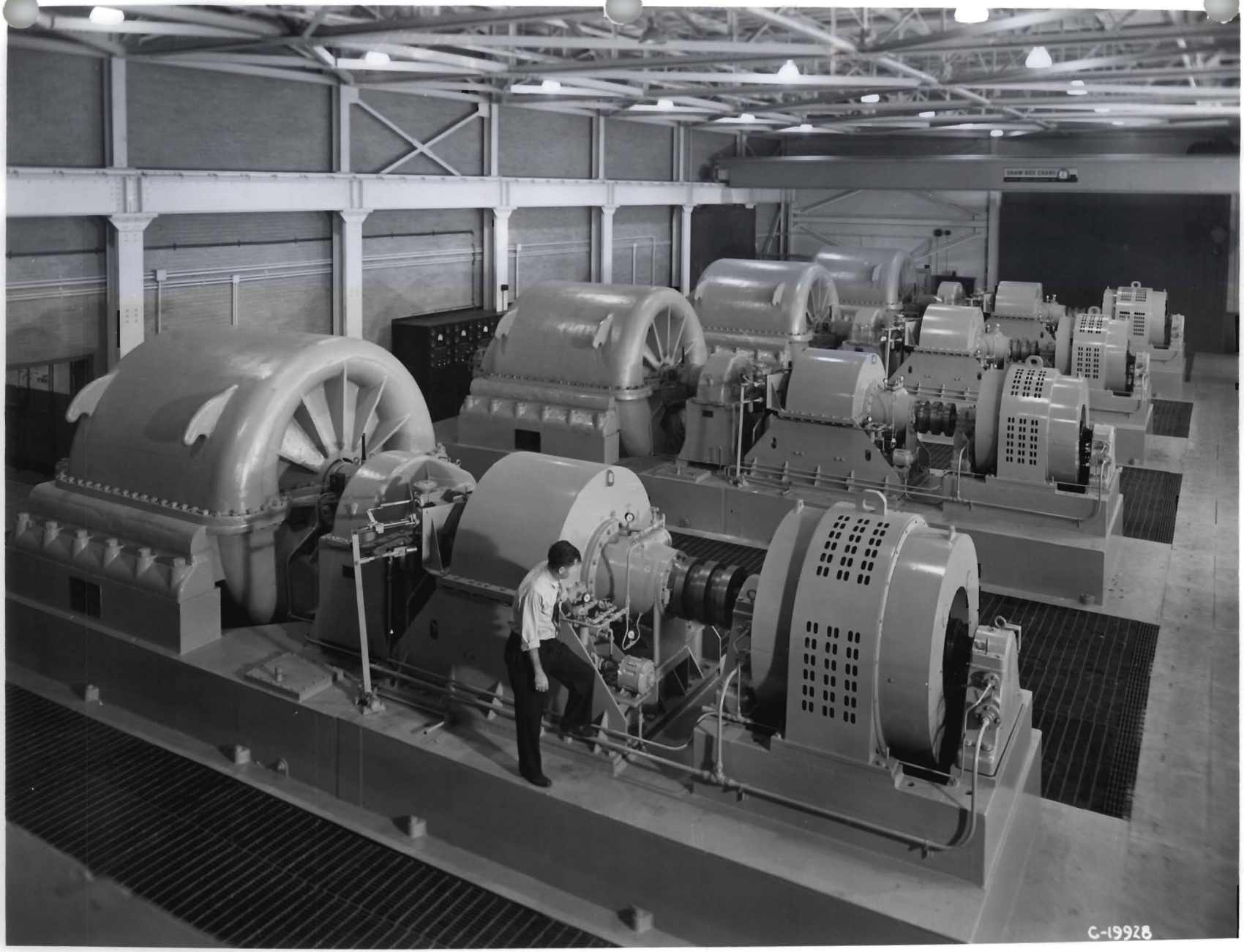


Altitude Facilities -- Figure 6



Altitude Facilities -- Figure 7

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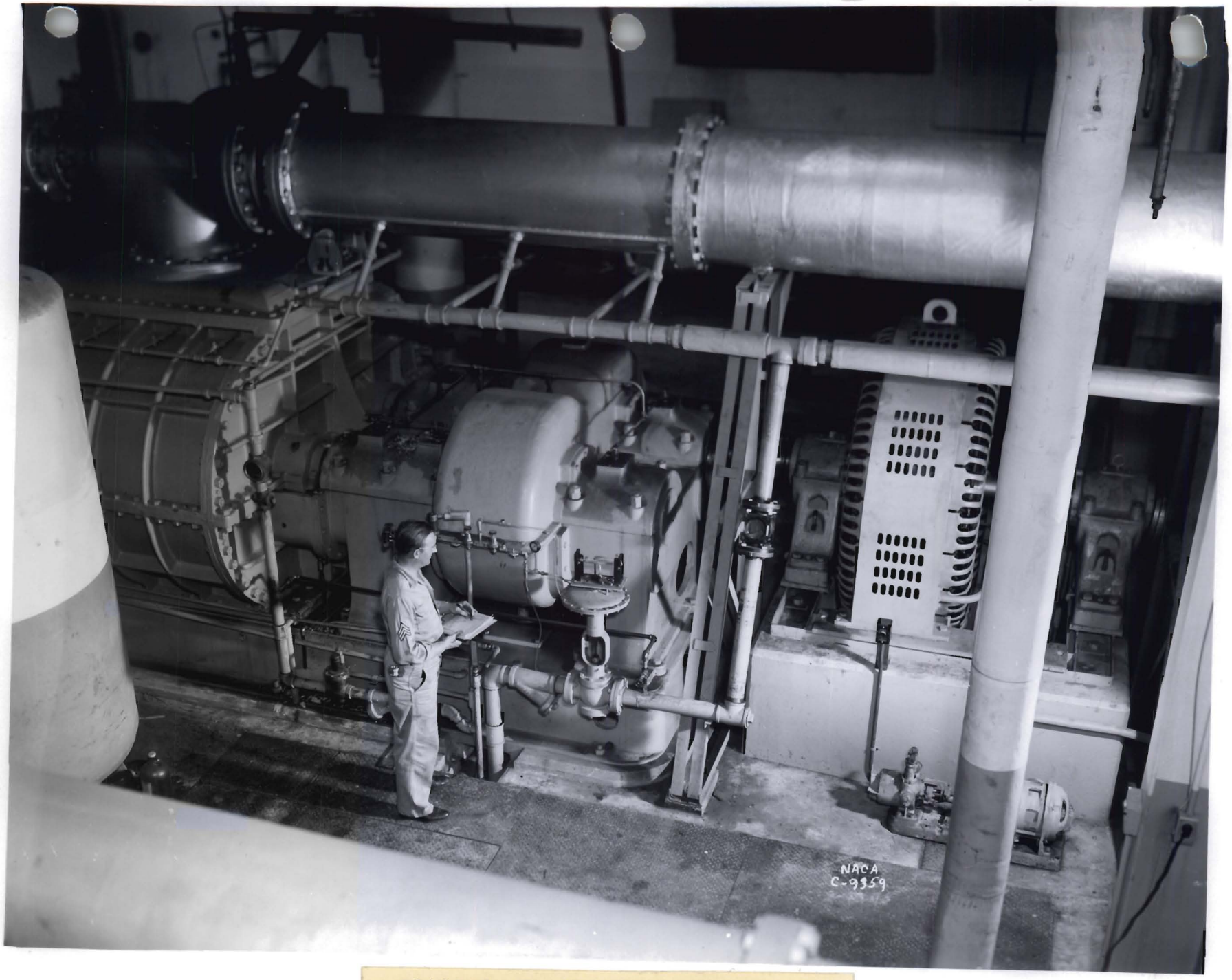
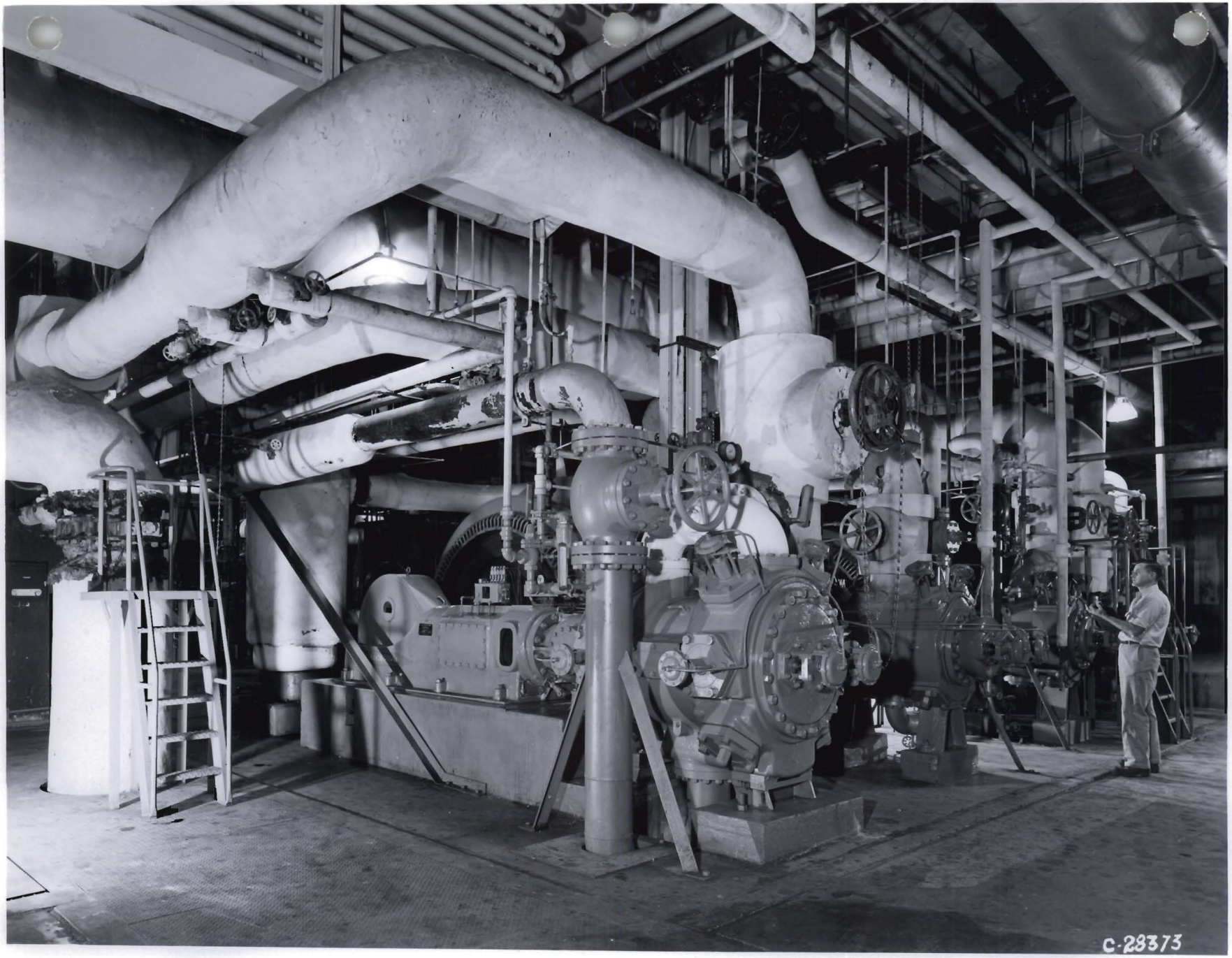


Altitude Facilities -- Figure 8



Altitude Facilities -- Figure 9

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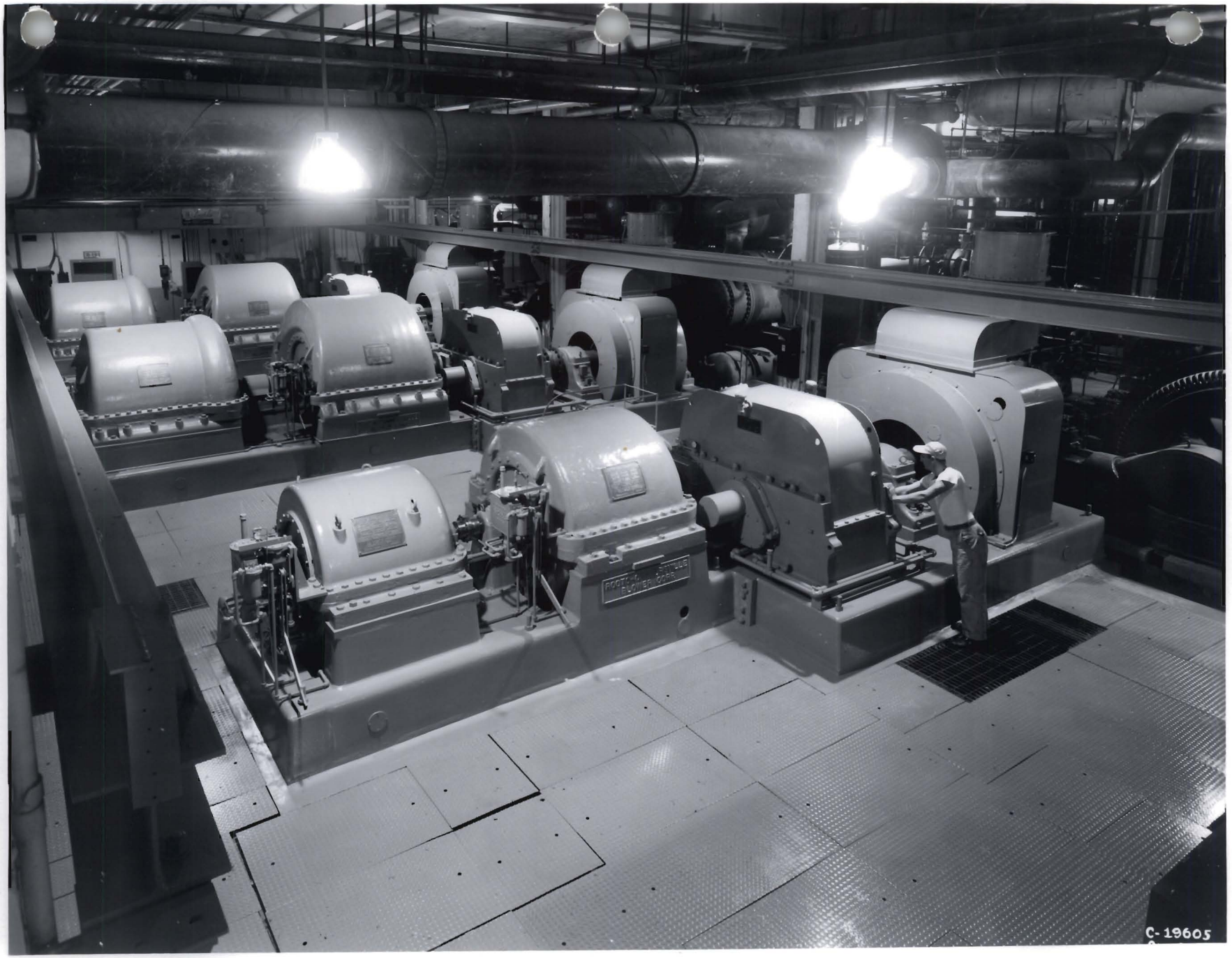
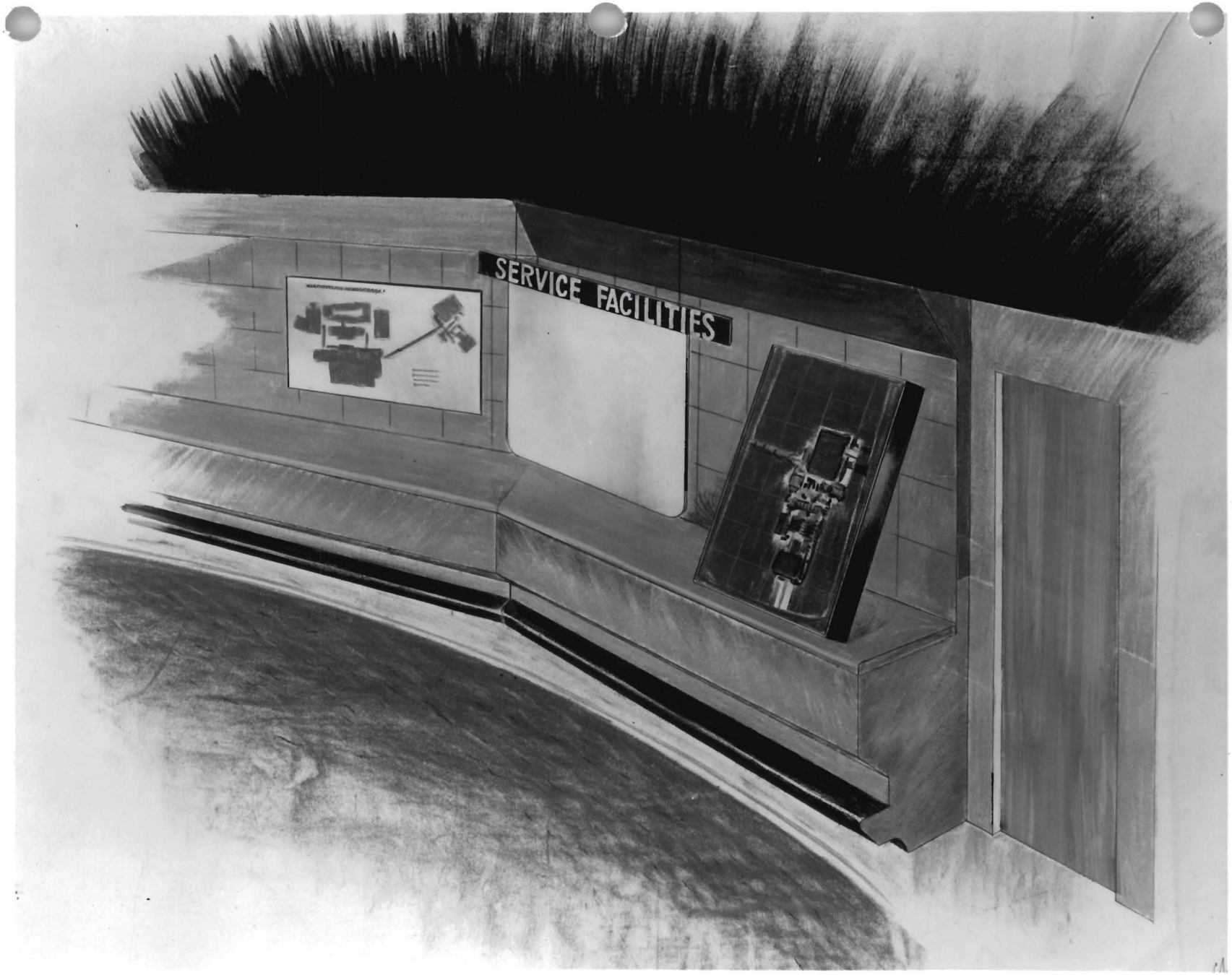


Altitude Facilities -- Figure 10



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