Talk I
8X6' SST
CONTROL ROOM

Ram-Jet Research

It is a military axiom that no airplane can fly fast enough. The speed of an airplane is a function of its power plant. We have already exceeded the upper limit of the reciprocating engine-propeller combination, a limit of 500 miles per hour, and are now in an era of jet-propelled aircraft. Shown on the first slide Figure 69 are the probable applications of three types of jet-propelled aircraft. The simple turbo-jet engine will find application to 750 miles per hour, a speed at which turbo jet propelled aircraft are almost flying now. The turbo jet, with afterburner, will probably find application to 1500 miles per hour. The ram-jet engine, which does not have mechanical compression nor moving parts in the combustion chamber, will be used above 1200 miles per hour. It is this engine with which we are concerned.

The ram-jet engine consists merely of a long tube divided into three parts: an inlet, a combustion chamber and an exhaust nozzle. By virtue of the engine's forward motion, air is rammed into the inlet where its high velocity is converted into pressure. Fuel is then introduced, mixed with the air and burned, and the products of combustion exhausted through the exit nozzle.

Because of its simplicity the work on the ram jet at this laboratory has been divided into two parts Figure 70 (~~slide~~ ______). One phase of study concerns the inlet or supersonic diffuser, the other concerns the combustion chamber. The results of investigations made on supersonic inlets were presented at the last annual inspection. The results of work done on ram-jet combustion chambers are presented here today by another speaker.

Both phases are continuing independent of each other. In addition an investigation has been initiated on the complete ram-jet engine. One phase of the investigation on the complete engine was carried out in the 18- by 18-inch supersonic wind tunnel. (~~Slide~~ Figure 71) A 3-1/2-inch ram jet was stub-wing mounted in the test section. The engine inlet projected into the window region of the tunnel making possible photographs of the airflow about the inlet. The engine exhausted directly into the wind tunnel. Thus we have a 3-1/2-inch ram jet operating in a supersonic stream, in this case, a Mach number of 1.9.

Typical results obtained during this investigation are shown on the next slide. (~~Slide~~ Figure 72) We have plotted the maximum compression ratio as a function of heat release rate. Based upon all steady flow considerations it was theoretically anticipated that the maximum compression ratio would remain constant, independent of the heat release rate. It was determined experimentally, however, that as the heat release rate increased the maximum compression ratio fell off. In the range of practical interest this drop was as high as 25 percent of the maximum compression ratio. This decrease seriously effects the operation of the engine.

Since the theoretical curve was based upon the assumption that the flow through the engine is steady, motion pictures were taken of the exhaust of the 20-inch ram jet operating with supersonic inlet conditions to determine the validity of this assumption. (Motion pictures were shown here).

When taken at normal camera speed, the flame appears relatively steady to the eye. However, when the same flame is photographed with a high-speed camera (sixty-two times the speed at which the pictures are being viewed) the flame appears intermittent and pulsating.

What effect does this combustion pulsation have on the inlet? If it can be shown that the pressure disturbance caused by the combustion fluxuations are propagated to the inlet, then a satisfactory explanation can be offered for the decrease in maximum compression ratio with heat release rate. High-speed photographs were taken of the air flow about the inlet to the 3-1/2-inch engine. (Motion pictures were shown here). Without combustion in the engine the flow appears steady and the shock at the inlet appears stable. When fuel is burned in the combustion chamber, however, the shock about the inlet begins to oscillate. On the basis of the photographs just shown a satisfactory theoretical explanation can be offered explaining the decrease in maximum compression ratio with heat release rate.

Another phase of the investigation on the complete supersonic ram-jet engine was made by employing a free-flight drop testing technique. A ram-jet engine is carried aloft by an airplane, released from high altitude, and allowed to fall free to the earth. This investigation is being carried on in cooperation with the Langley laboratory. One of the engines used in this investigation is on display in the lobby. See photograph C-22335 ~~The next slide (number ______)~~ Figure 73 shows a cutaway of the engine. A spike inlet is used followed by an annular subsonic diffuser, a fuel injector, a flame holder, a combustion chamber, and an exhaust nozzle. Four trapezoidal fins are welded to the exhaust nozzle to provide some degree of aerodynamic stability. The combustion chamber is 16-inches in diameter. An inner body is used to carry the fuel supply, controls, and telemetering equipment. Telemetering and radar tracking are used to record the flight path and engine performance. The telemeter antenna serves the dual function of antenna and pitot-static tube. A cutaway of the inner body is located on a stand beneath the screen. See photograph C-22348

The next series of motion pictures shows the engine being carried aloft by an airplane and dropped. The first scene shows the engine suspended beneath the right wing of a F-82 airplane. The airplane is climbing for altitude. When the desired altitude has been reached, in this case 30,000 feet, fuel is turned on and ignited. When the operator is satisfied that the engine is burning satisfactorily he releases the ram jet from the airplane and allows it to fall freely to the earth. It is during this phase of the flight that the ram jet passes through the transonic speed range and reaches supersonic velocity.

Typical results obtained from one of the drops are shown in the next slide. [Figure 74] The thrust horsepower developed is presented as a function of air speed. The upper curve is the theoretically anticipated thrust horsepower and the lower curve the experimentally obtained thrust horsepower. The experimental curve follows the general trend established by the theoretical curve. The slight irregularity in the experimental curve was caused by a sudden change in the fuel flow. At all air speeds the experimental thrust horsepower was less than the theoretically expected horsepower. The data are too meager to permit a definite conclusion as to the reason for this difference. Indications are, however, that this difference is due to excessive compression ratio losses. These losses may arise from the same phenomena encountered in the tests of the 3-1/2-inch engine. Controlled studies with larger engines, studies such as will be possible in the 8- by 6-foot supersonic wind tunnel when it is completed, are necessary before definite conclusions can be drawn.

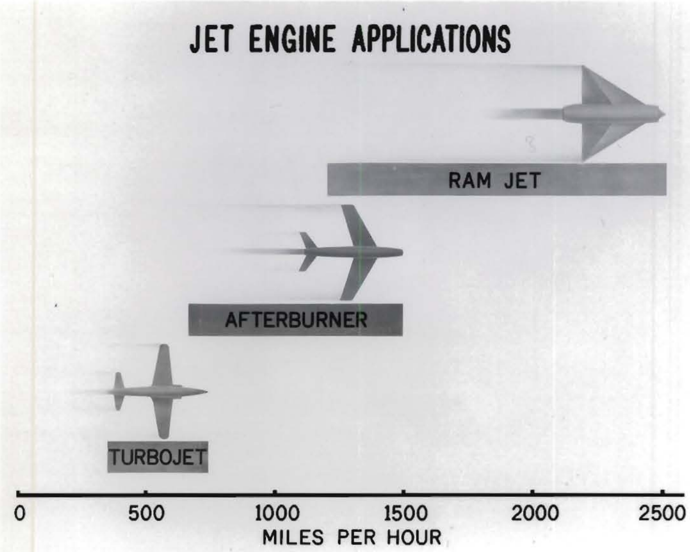

Figure 69.

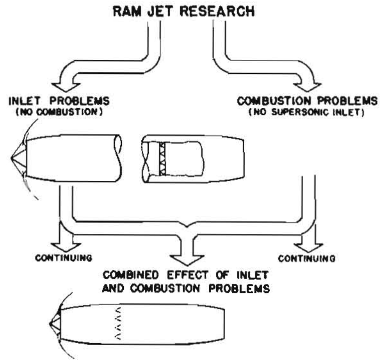

Figure 70.

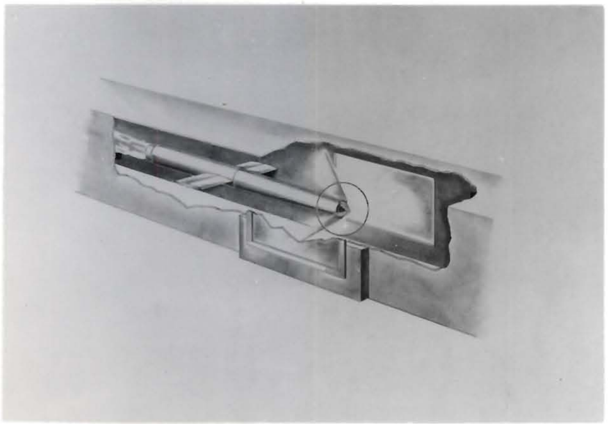

Figure 71.

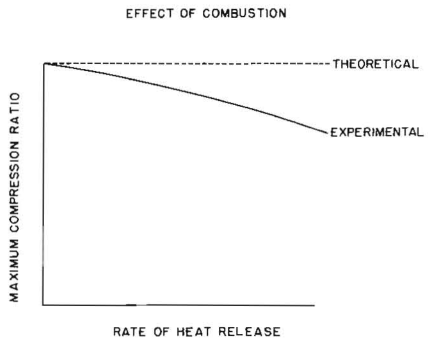

Figure 72.

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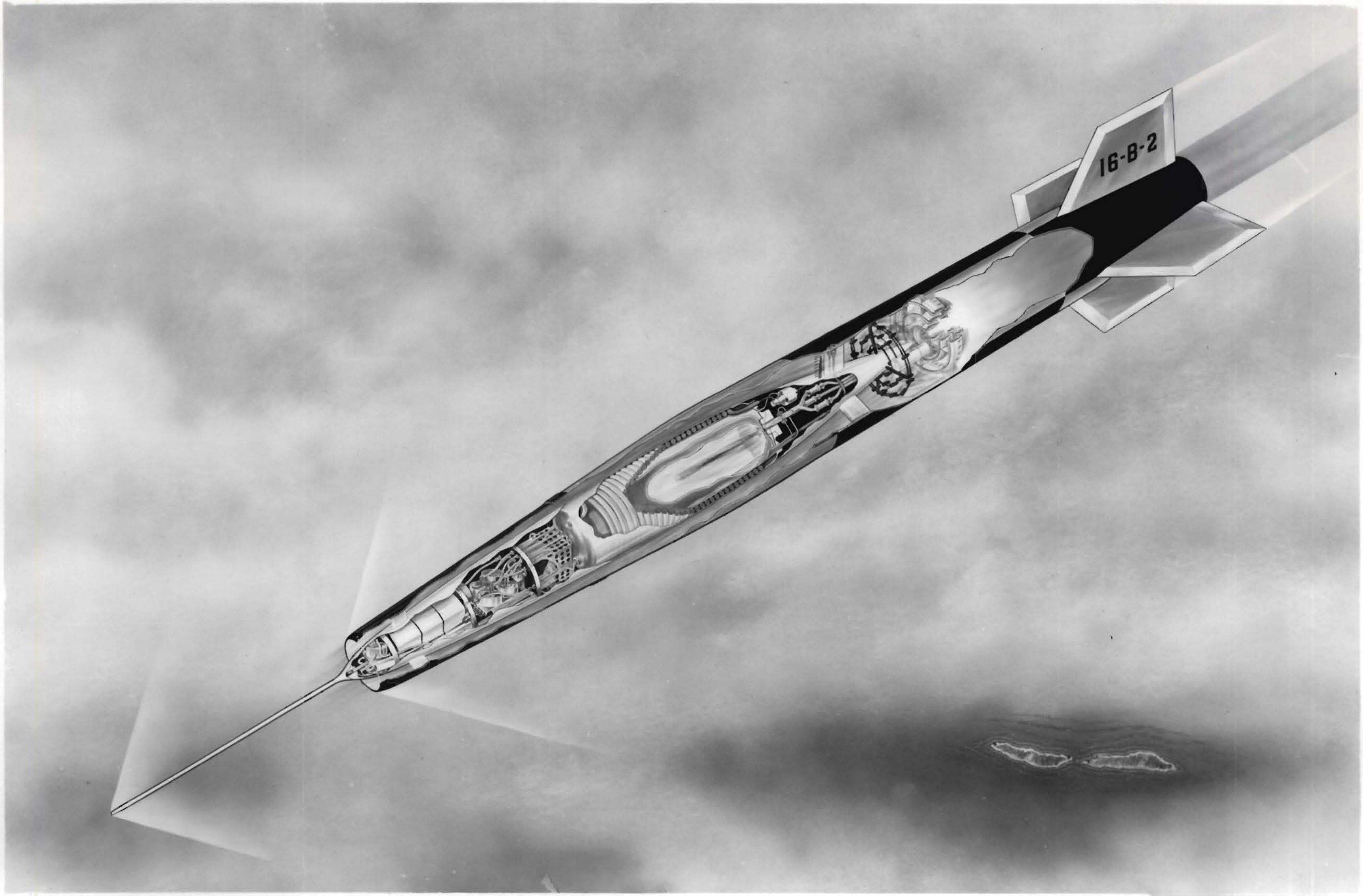

Figure 73.

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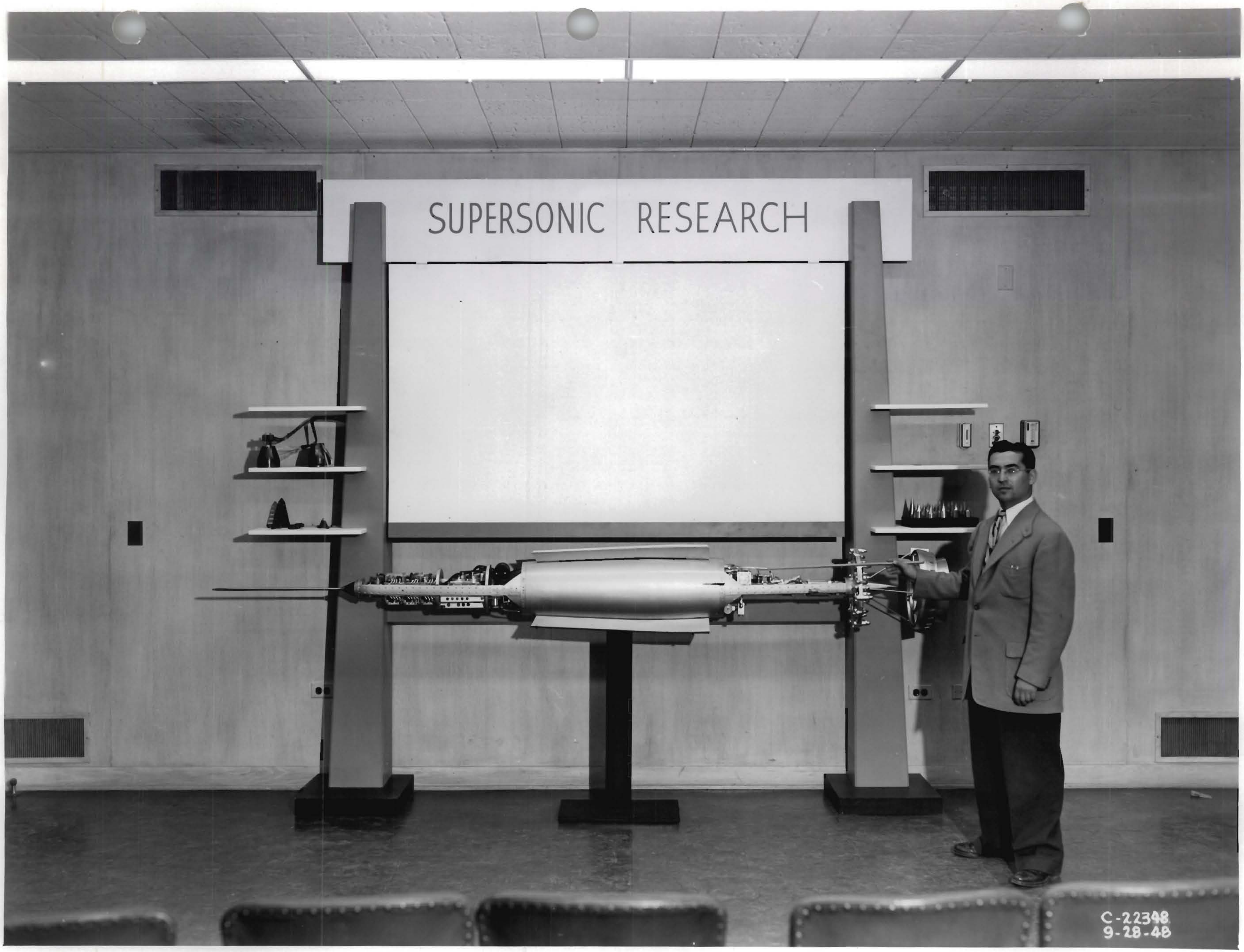

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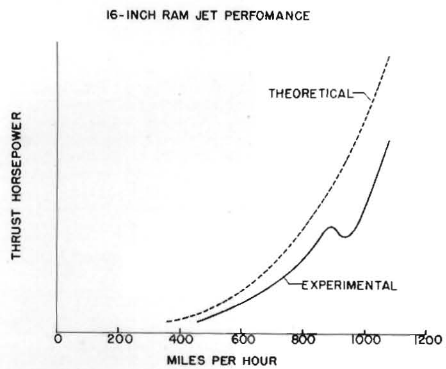

Figure 74.

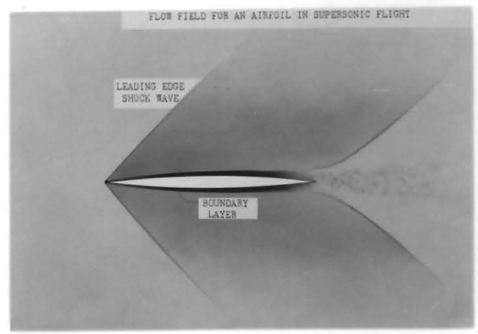

Figure 75.

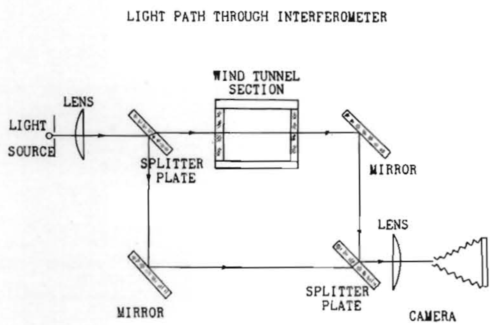

Figure 76.

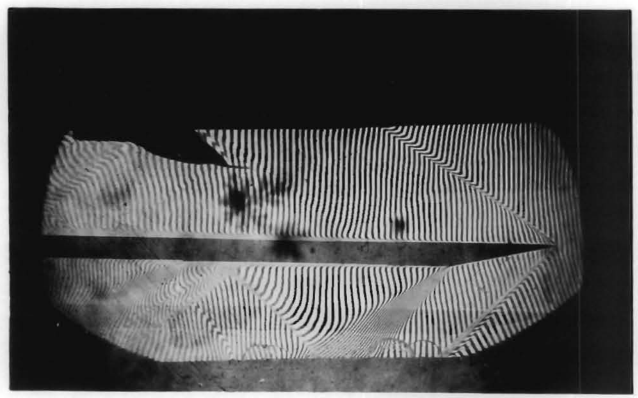

Figure 77.

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Talk II
8X6'557
CONTROL ROOM

Supersonic Boundary Layer Measurement Techniques

Suppose we consider the airflow about a wing traveling at supersonic velocity as indicated on the first slide. Figure 15 The shock-wave formations shown are probably familiar to all of you.

Now imagine yourself moving along with the wing. The air would appear to be flowing past you in this direction at about flight velocity except in this region where the velocity would drop quite sharply from flight velocity here to zero velocity here as if the layers of air in this region were sliding over one another and in so doing were encountering friction. It is the existence of this region - the boundary layer - that is responsible for the friction drag of the wing. The thickness of the boundary layer has been exaggerated on the slide.

A boundary-layer region will develop in any flow passage as in ram jets and wind tunnels even at low speeds. At high speeds, however, compressibility changes the nature of the boundary layer flow. Heat-transfer effects and interaction of shock waves with the boundary layer are of such complexity that we must resort to experimental investigations.

If we insert a tube open at one end into an airstream we measure an impact pressure from which the stream velocity can be calculated. Such tubes are used for boundary-layer measurements. However, any instrument that must be inserted into an airstream will disturb the flow. The use of a beam of light to probe the flow would avoid such disturbances.

A method based on this optical technique was already available, making use of the principle of light interference through an interferometer arrangement suggested many years ago. This laboratory has developed the application of these interferometer techniques to boundary-layer density measurements.

The next slide (Figure 76) shows the interferometer arrangement used. Light from the source which is made parallel by this lens is split into two parts by this lightly silvered plate which reflects half of the light and transmits the other half. The transmitted part is sent through the wind-tunnel test section which contains the model. After passing through the tunnel the beam is reflected at this point to the second plate where it is joined by the light beam that was reflected down along this path. The second plate combines the two beams and an interference pattern is set up which can be made to appear as a series of vertical light and dark bands if the density field in the tunnel is uniform. Think of light as a wave motion similar to the motion of water waves. Where the wave crests of the two beams come together they combine to form a bright region; where a wave crest and a wave trough come together they cancel to form a dark region.

A non-uniform density field resulting from the presence of a model will distort the vertical pattern because there is a difference in the velocity of light through the various density regions. Because band distortion and air density are related, the band distortions can be used to obtain quantitative values of relative density. The next slide (Figure 77) shows the pattern obtained with a wedge-shaped plate in a supersonic stream having a Mach number of 1.8. Here we see the band distortions caused by the leading-edge shock wave and here the distortion caused by the boundary layer. The pressure tube used to obtain an independent survey of this boundary layer can also be noticed. An enlargement of the boundary layer regions is shown on the next slide. (Figure 78) Here the distortion caused by the boundary layer is plainly visible. The layer is 0.050 inch thick at this location. You can see the disturbance of the pressure tube upon the flow. This tube has an internal opening of 0.002 inch and an over-all thickness of 0.005 inch. Boundary-layer densities obtained from pressure tube and interferometer techniques are compared in the next slide. (Figure 79) The vertical scale represents density at any point in the boundary layer. The horizontal scale represents distance from the plate surface. The quantities are given in terms of stream density and boundary-layer thickness, respectively.

The mutual agreement between the interferometer and pressure tube techniques indicates that in this particular case the two methods are equally satisfactory. In general, each method will have its own field of application. These techniques are being used in our research programs to obtain a more complete understanding of the boundary layer in compressible flow.

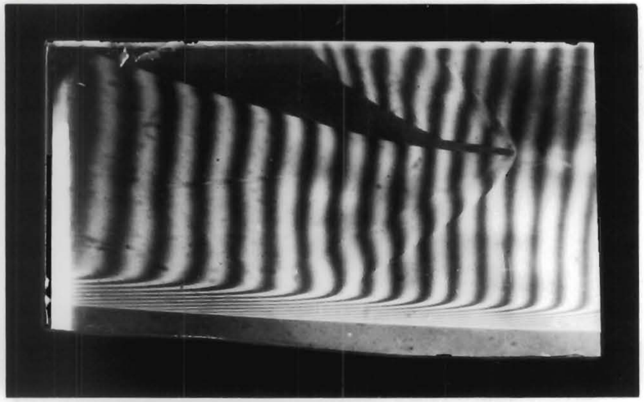

Figure 78.

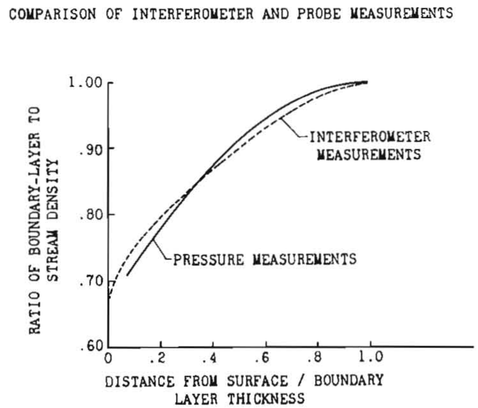

Figure 79

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11-29-48

TALK III
8x6' SST
CONTROL ROOM

The 8- by 6-Foot Supersonic Tunnel

The last two speakers have described some of the work being conducted in the small and medium-size supersonic tunnels and illustrated the contributions of these tunnels to the research program. However, some components of supersonic propulsive devices, particularly the power plant, cannot be scaled down and tested successfully in small tunnels. The 8- by 6-foot supersonic tunnel (Figure 80) is being built as a first step in filling this gap in the research equipment and larger tunnels may be required as the size of the power plants increase. The tunnel test section is 8 feet high and 6 feet wide and will operate over a range of speeds up to 1500 miles per hour. The tunnel is still under construction but is expected to be in operation soon.

Briefly, in operation of the tunnel, air is drawn from the atmosphere, passed through a large air dryer and into a plenum chamber at one end of the drive motor building. From there it continues through a compressor, a flexible wall nozzle, the test section, and into a diffuser which recovers the kinetic energy of the air and thereby reduces the power requirements of the tunnel. In the tour of the project, the tunnel equipment will be discussed in more detail. An outline of the tour is as follows: From the observation room, where you are now seated, we shall proceed to the downstream end of the air dryer for our first stop. From there we will go to the upper level of the drive equipment building to view the drive motor and compressor installation. We will then leave the building and pass through the shop to the upper level of the test chamber. We will now start the tour by entering the main control room from which the operation of the entire project is controlled.

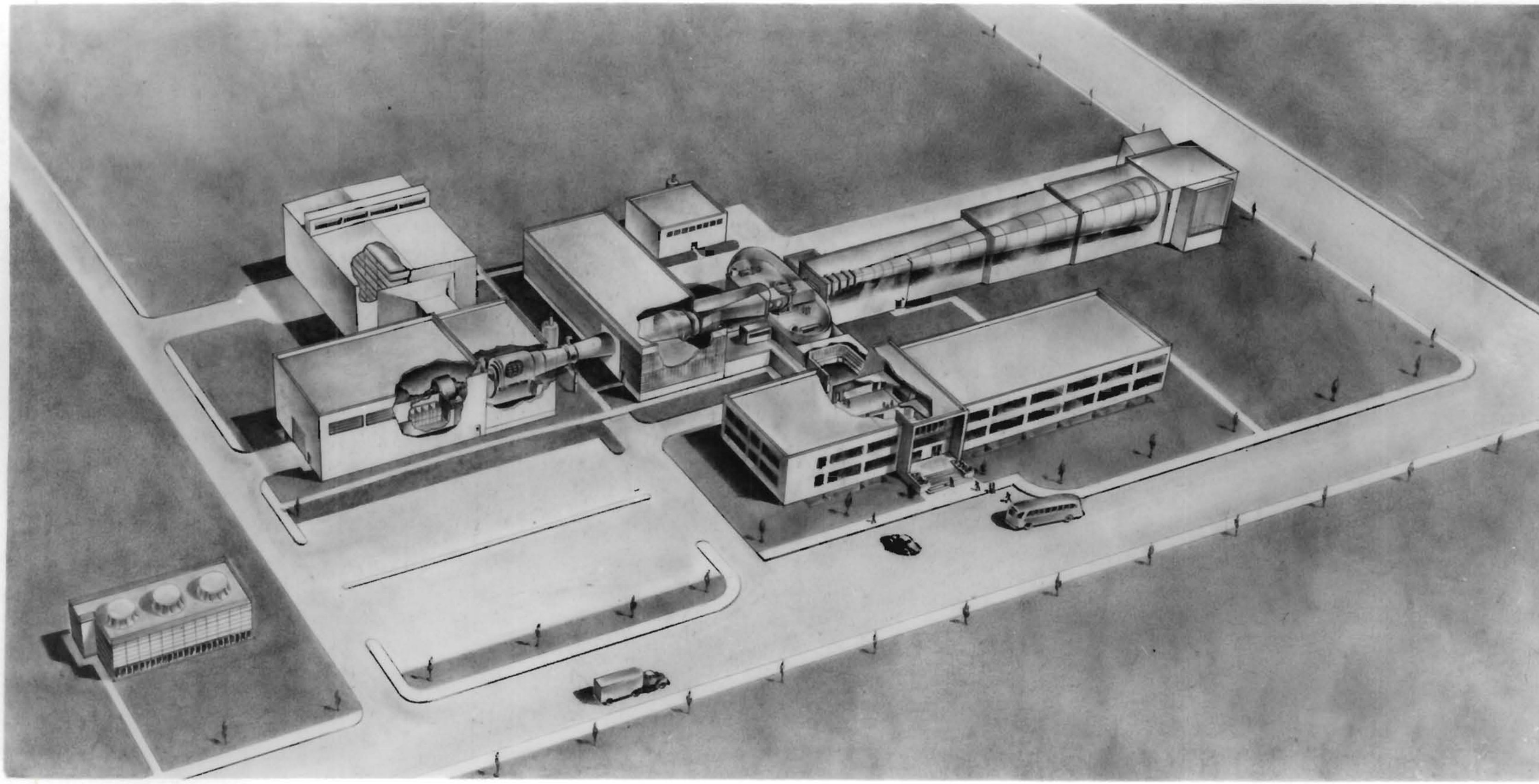

Figure 80.

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Talk in Air Dryer Building

You are now at the downstream end of the air dryer building. To review briefly, the air enters the far side of the building and must pass through at least one dryer bed before moving to the plenum chamber. The purpose of the air dryer is to remove the moisture from the air entering the tunnel, to prevent condensation from occuring in the test section as a result of the large temperature drop experienced by the air in expanding to supersonic speeds. It is by far the largest such piece of equipment ever built and handles about 2800 pounds per second of air or approximately 25 times as much air as the dryer now in use at the altitude wind tunnel. The dryer contains 1100 tons of activated alumina evenly distributed in 8 dryer beds. The activated alumina which acts somewhat like a blotter can adsorb only so much moisture. When this condition is attained the alumina must be dried or reactivated by passing heated air through the beds for several hours; an operation which will require heat at the rate of 160,000,000 Btu per hour.

upper level of drive equipment bldg.

Talk in Drive Equipment Building

Our last stop was over here at the downstream end of the dryer building. The wall which seals the plenum chamber from the drive equipment will go here. The axial-flow compressor which you see ahead of you will have an entrance bell attached to the front to guide the air into the blower. The compressor is a seven-stage unit and contains approximately 1000 blades. The inside diameter of the casing is 17 feet, 8 inches at the inlet and tapers to 16 feet, 2 inches at the outlet. The rotor has a constant diameter of 13 feet, 2 inches and weighs approximately 160 tons. Two rotor blades are shown on the table. The larger blade is for the first stage and the small one for the last. These blades are fixed in the rotor, while the stator blades can be adjusted to different angles. All of the blades are made of dural.
The compressor is driven by these three wound rotor motors, coupled on a common shaft, and having a rated total power of 87,000 horsepower. Liquid rheostats at the lower level of the drive equipment building control the speed of the motors from 770 to 880 rpm.

Talk in Test Chamber

You are now in the test chamber. The test chamber contains the test section where the test model will be located, the balance frame and scale equipment for transmitting and recording the forces on the model and the schlieren system which is used for qualitative analysis of the air flow around the model. The 4-foot-diameter parabolic mirror located behind you is a part of the schlieren equipment.

Earlier in this tour it was stated that the tunnel airspeed could be varied over a range of speeds up to 1500 miles per hour. The variation in airspeed is obtained by moving the two 35-foot long and 8-foot high vertical walls of the tunnel. Flexible walls are being used because a different tunnel contour is required for each supersonic airspeed. The flexible walls are moved by hydraulically driven jack screws located along the length of each wall. All jack screws move simultaneously and are positioned by individual cams through a hydraulic follower system. You may now step over here to look at the flexible wall and into the tunnel.

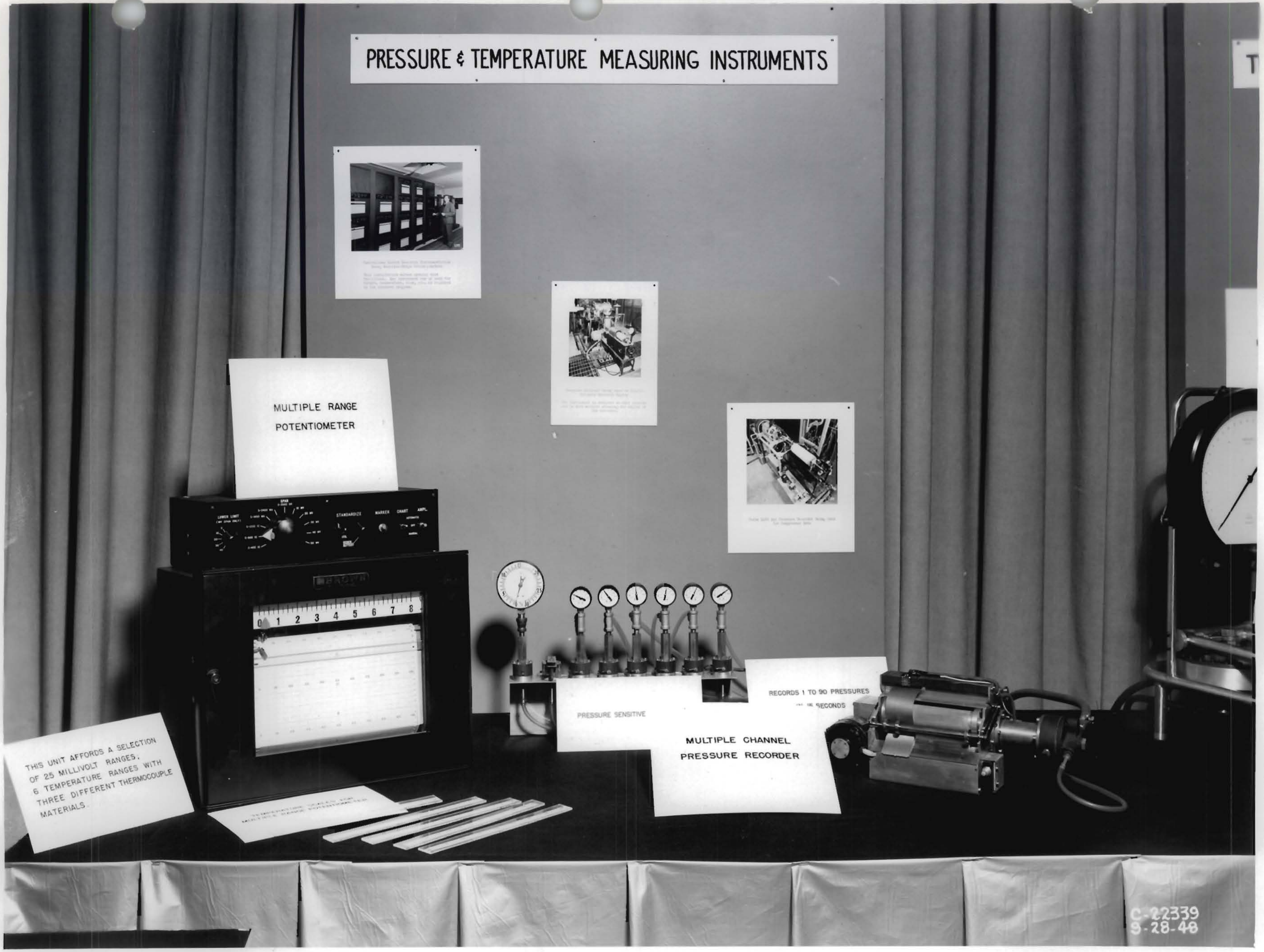
The photographs on the six following pages show the display of instruments on the stage of the Auditorium, available for inspection immediately following the luncheon.

C-22336
C-22338
C-22339
C-22340
C-22341
C-22342


NACA
RESEARCH INSTRUMENTS
PRESSURE & TEMPERATURE MEASURING INSTRUMENTS
THRUST & TORQUE MEASURING INSTRUMENTS
DISPLACEMENT INDICATING INSTRUMENTS
C-22336
9-28-48


OPTICAL WINDOWS FOR
SUPERSONIC
AIR FLOW STUDY
SIDE PLATES FOR
TWO DIMENSIONAL DIFFUSER
SCHLIEREN WINDOWS
FOR VARIABLE
OBSERVATION WINDOWS
AND
BLADE CASCADE ASSEMBLY
C-22338
9-28-48

NACA


PRESSURE & TEMPERATURE MEASURING INSTRUMENTS
MULTIPLE RANGE
POTENTIOMETER
THIS UNIT AFFORDS A SELECTION
OF 25 MILLIVOLT RANGES,
6 TEMPERATURE RANGES WITH
THREE DIFFERENT THERMOCOUPLE
MATERIALS.
PRESSURE SENSITIVE
RECORDS 1 TO 90 PRESSURES
MULTIPLE CHANNEL
PRESSURE RECORDER
C-22339
9-28-48

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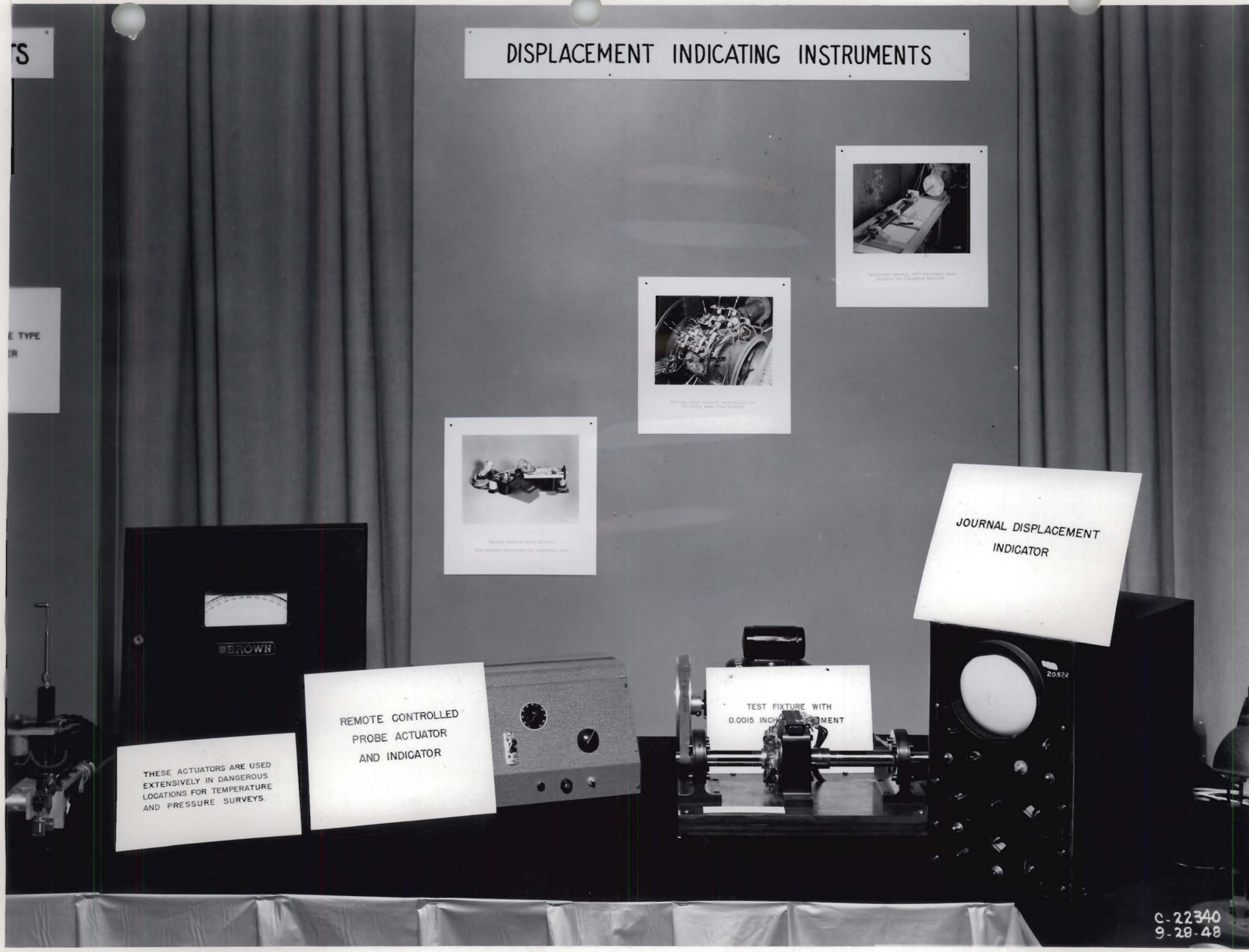
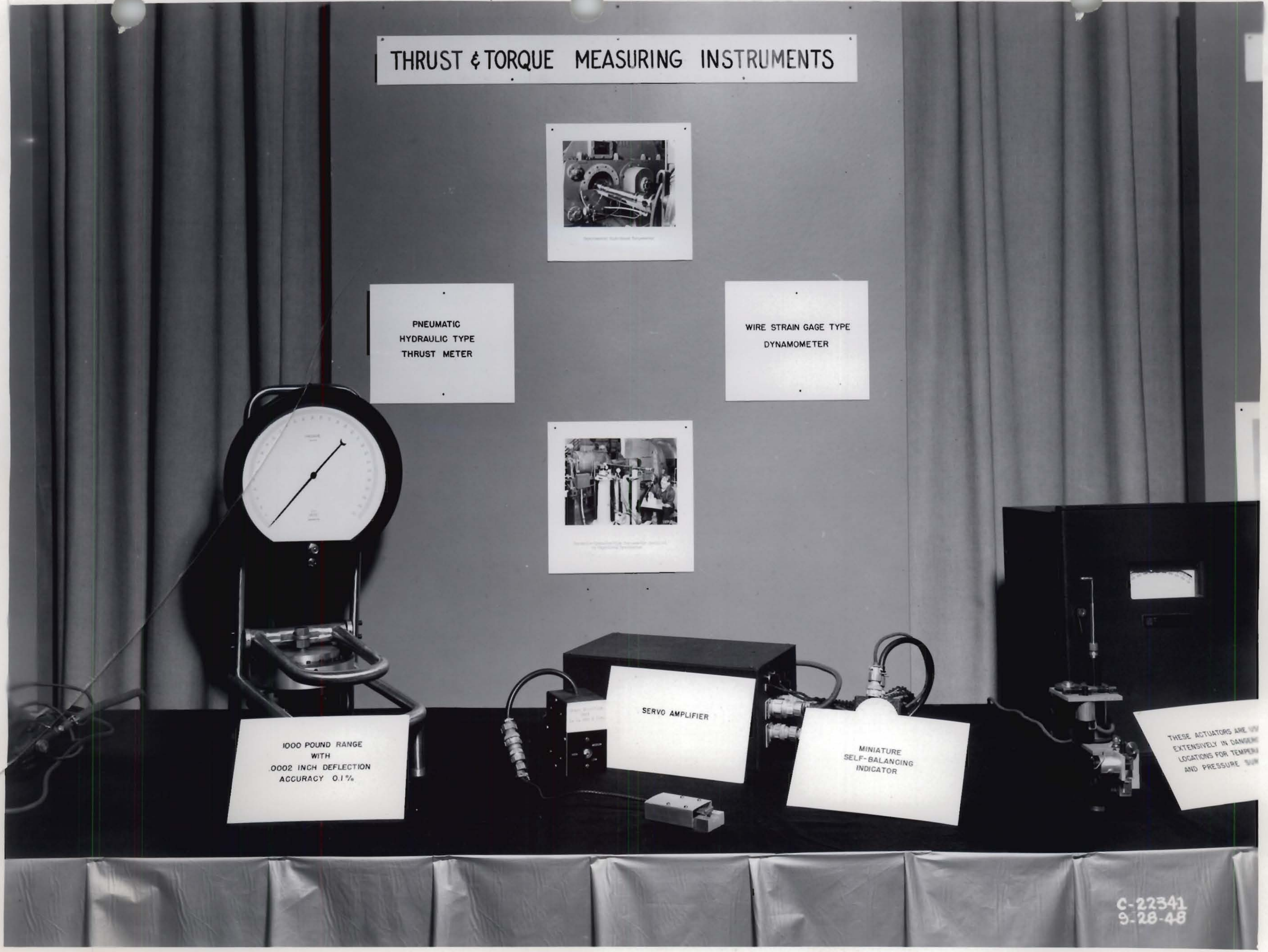

DISPLACEMENT INDICATING INSTRUMENTS
JOURNAL DISPLACEMENT INDICATOR
BROWN
REMOTE CONTROLLED PROBE ACTUATOR AND INDICATOR
THESE ACTUATORS ARE USED EXTENSIVELY IN DANGEROUS LOCATIONS FOR TEMPERATURE AND PRESSURE SURVEYS.
TEST FIXTURE WITH
20922
C-22340
9-28-48



THRUST & TORQUE MEASURING INSTRUMENTS
PNEUMATIC
HYDRAULIC TYPE
THRUST METER
WIRE STRAIN GAGE TYPE
DYNAMOMETER
1000 POUND RANGE
WITH
.0002 INCH DEFLECTION
ACCURACY 0.1%
SERVO AMPLIFIER
MINIATURE
SELF-BALANCING
INDICATOR
THESE ACTUATORS ARE
EXTENSIVELY IN DANG
LOCATIONS FOR TEMPE
AND PRESSURE
C-22341
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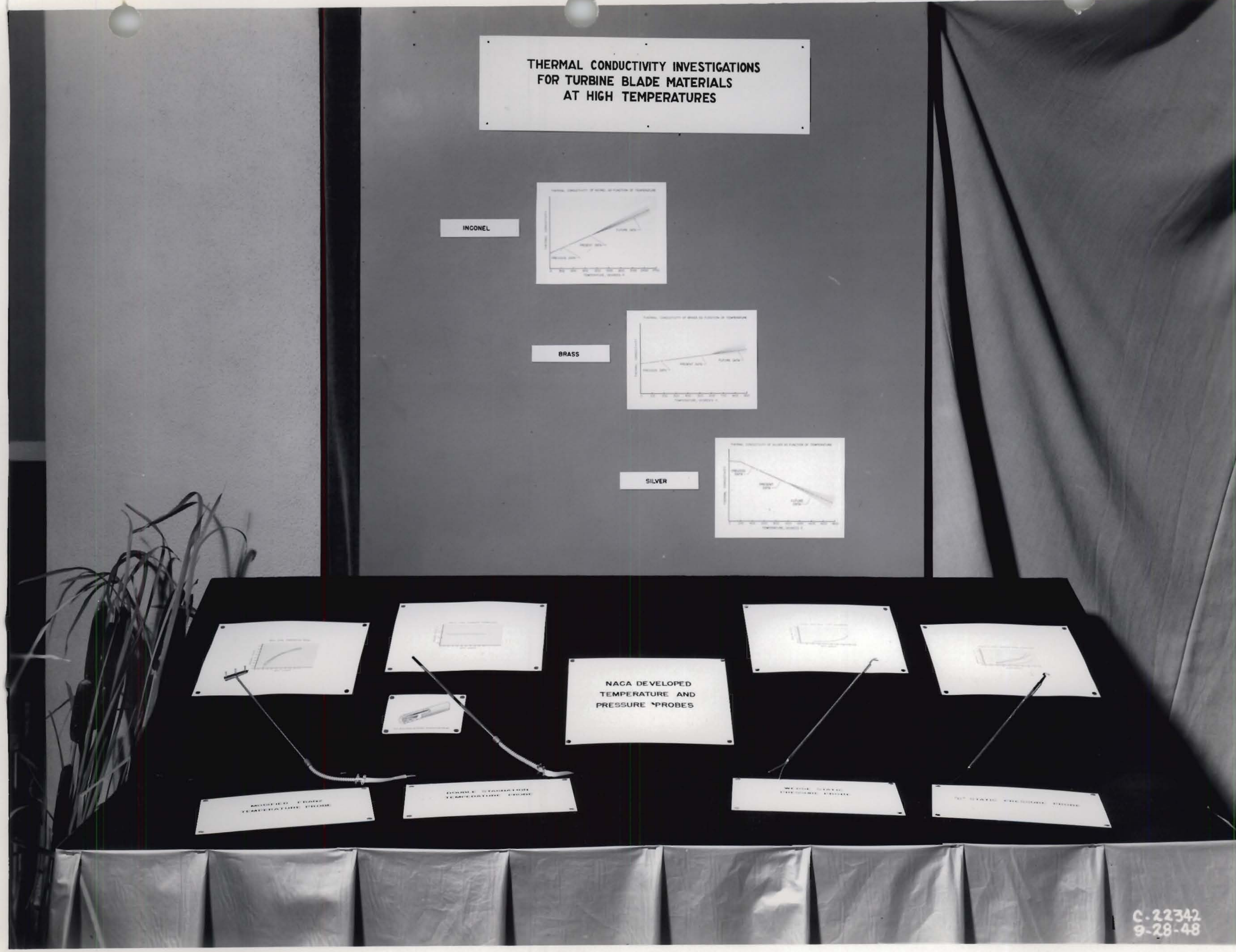
NACA


THERMAL CONDUCTIVITY INVESTIGATIONS
FOR TURBINE BLADE MATERIALS
AT HIGH TEMPERATURES
INCONEL
BRASS
SILVER
NACA DEVELOPED
TEMPERATURE AND
PRESSURE PROBES
C-22342
9-28-48

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