ANNUAL INSPECTION - ROCKET SECTION

Upon their arrival at the rocket lab, the guests were seated in the shop. After an introduction by the attache in charge of the group, a 10 minute talk was delivered by either Mr. John Sloop or Mr. Don Bellman. The talk was illustrated by a group of 7 charts.

After the talk the guests were taken through cells 4 and 3 and through the central instrument room. They were then taken to a point in the field at the rear of the lab where a good view of a rocket in operation could be obtained. A one minute talk briefly describing the operation of the particular rocket was given just before the rocket was fired. The groups were shown the operation of either the 500 pound thrust hydrogen peroxide-alcohol rocket in cell 4 or the 1000 pound thrust acid-aniline rocket in cell 2. Mr. John Diehl operated the peroxide-alcohol rocket and Mr. George Kinney operated the acid-aniline rocket. All the remainder of the personnel of the rocket lab participated in the show in various ways.

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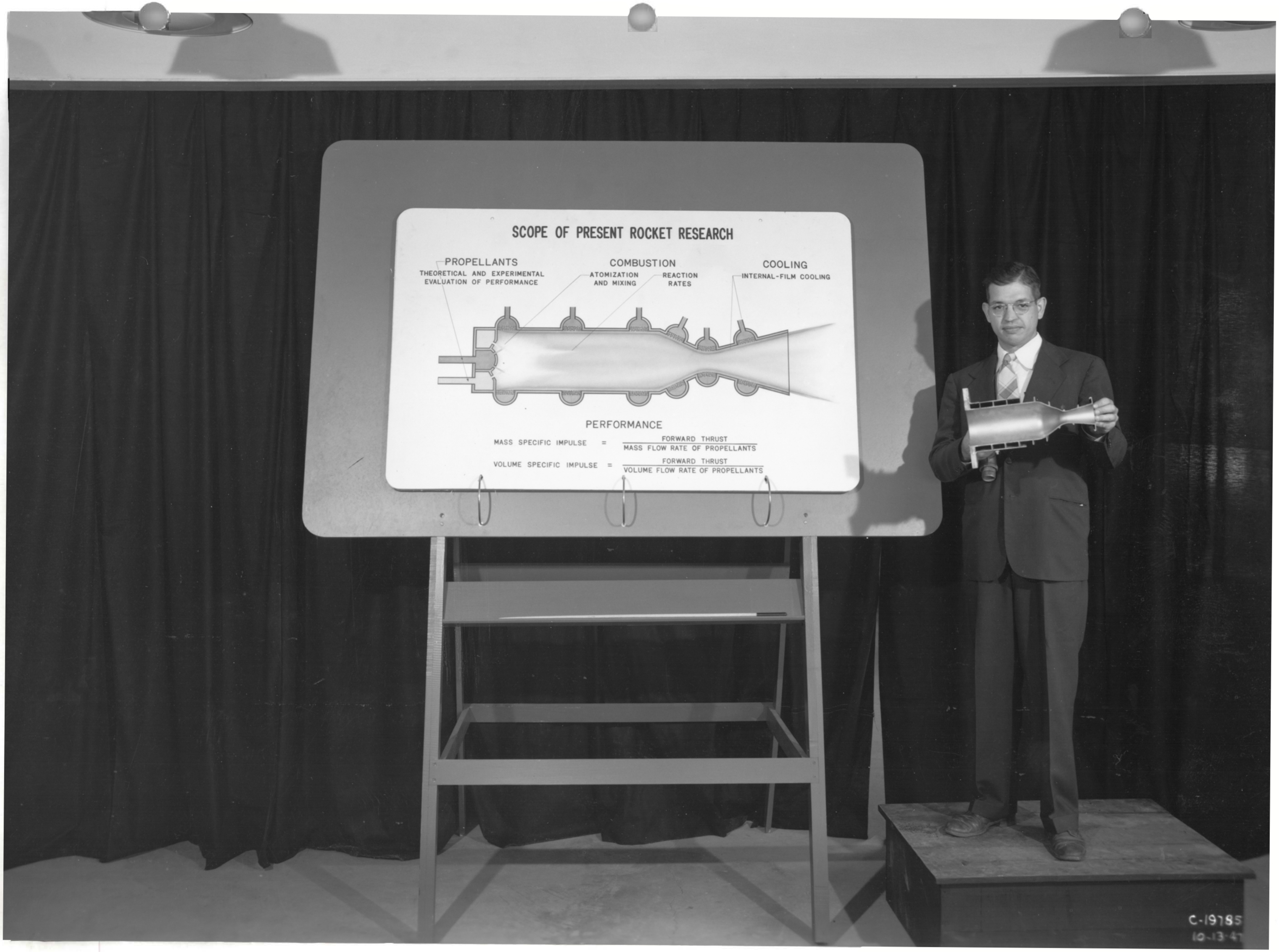

SCOPE OF PRESENT ROCKET RESEARCH

PROPELLANTS
THEORETICAL AND EXPERIMENTAL EVALUATION OF PERFORMANCE

COMBUSTION
ATOMIZATION AND MIXING
REACTION RATES

COOLING
INTERNAL-FILM COOLING

PERFORMANCE

$$\text{MASS SPECIFIC IMPULSE} = \frac{\text{FORWARD THRUST}}{\text{MASS FLOW RATE OF PROPELLANTS}}$$

$$\text{VOLUME SPECIFIC IMPULSE} = \frac{\text{FORWARD THRUST}}{\text{VOLUME FLOW RATE OF PROPELLANTS}}$$

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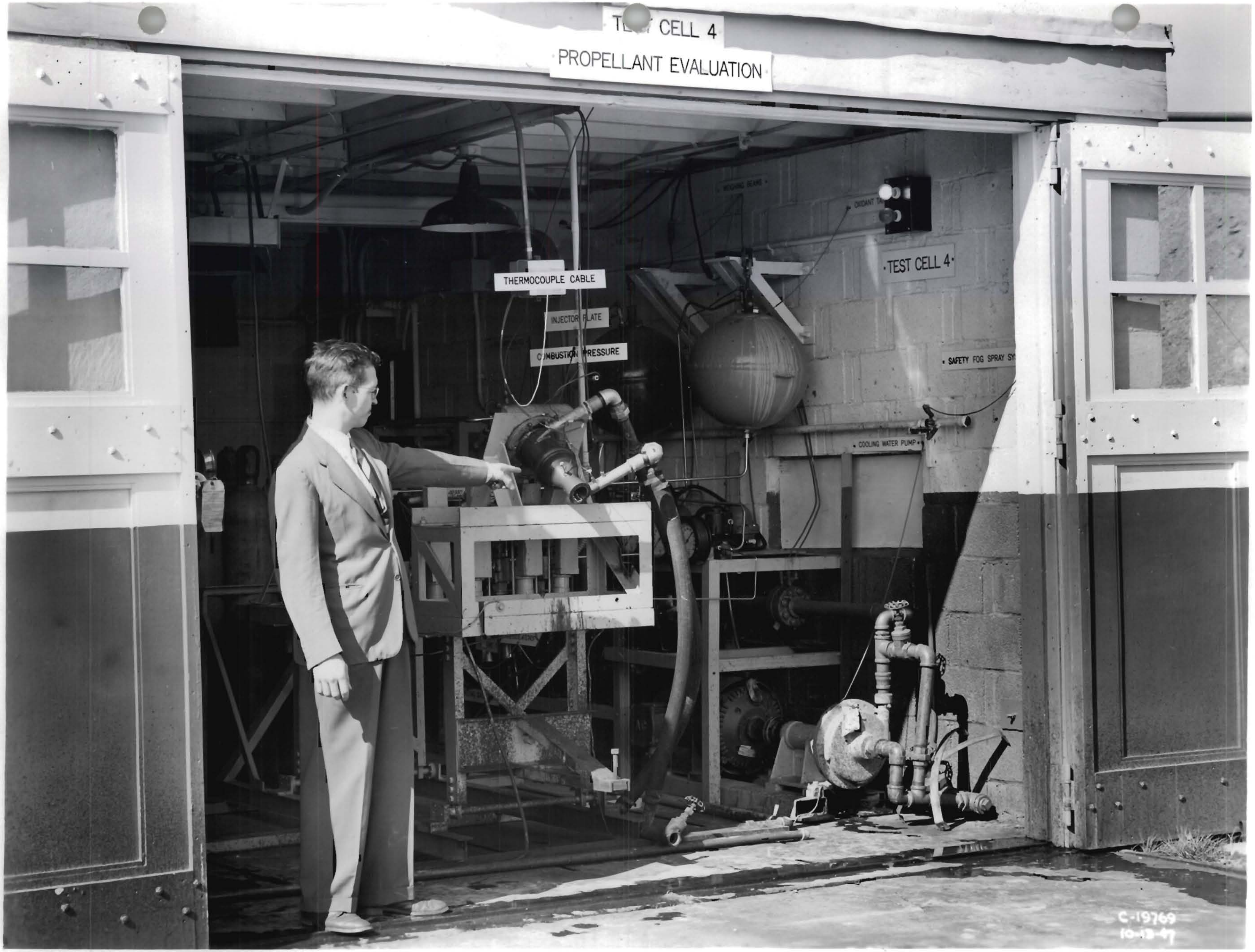
TE CELL 4
PROPELLANT EVALUATION
WEIGHING BEAMS
OXIDANT TA
TEST CELL 4
THERMOCOUPLE CABLE
INJECTOR PLATE
COMBUSTION PRESSURE
SAFETY FOG SPRAY SYS
COOLING WATER PUMP
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ROCKET RESEARCH

John Sloop or Don Bellman

Talk Given in Shop

The rocket engine is one of the simplest, most compact and powerful heat engines devised for propulsion. For example, this is a section of an experimental NACA rocket engine, externally cooled, that gives 500 pounds thrust which if travelling at 600 miles per hour, would develop 800 horsepower. In addition to being powerful and compact, the rocket engine is the only one capable of operating completely independent of the earth's atmosphere because it carries its own oxygen.

An illustration of a rocket engine is shown by this chart. (CHART 1) Fig. 78 The propellants, that is, the oxidant and fuel, are pumped to the engine and injected, mixed, and burned in the combustion chamber. The hot gases are expanded through the nozzle to give thrust. Also indicated on this chart are the three main fields of NACA research on rocket engines: liquid propellants, combustion, and cooling. The research programs in these fields are integrated with those of the Air Force and the Navy.

The first step in the process of finding better propellants is to make computations on the theoretical performance of a series of suitable materials of which there are many. This chart (CHART 2) Fig. 79 shows several promising propellant combinations. One performance criterion is specific impulse which is the amount of thrust produced per pound consumption of propellants. The theoretical values of specific impulse have been placed on a comparative basis with a propellant combination used at the present time: liquid oxygen and alcohol. The gain in specific impulse ranges from 13 percent for oxygen-hydrazine to 59 percent for fluorine-hydrogen. These gains are significant because the range of a missile without drag is proportional to the square of the specific impulse. The range is shown in the next column. The increase in range varies from 20 percent for oxygen-hydrazine to 53 percent for fluorine-hydrogen. For flight within the earth's atmosphere, aerodynamic drag must be considered and hence the density of the propellants becomes important. On an equal weight basis, the fluorine-hydrazine combination would occupy one-fourth the volume of the fluorine-hydrogen combination because hydrazine has a much greater density than hydrogen. Oxygen-lithium has a high specific impulse and density but the reaction temperature, as shown by the third column, is more than twice that of oxygen-hydrazine and hence would involve a greater cooling problem. Note that the rocket gas temperatures vary from about 5000 to over 10,000 degrees Fahrenheit. Some of these propellants are thermally unstable and require special handling and injection procedures. It is hence evident that propellants can be found that give a much greater range than present-day propellants but their use considerably increases the problems of cooling and engine design.

The computation of theoretical performance, such as shown by this chart, is a laborious process and to facilitate it the NACA has prepared thermodynamic charts which are to be published. Using these charts a study of propellants involving only oxygen, hydrogen, and nitrogen has been completed.

The second step in propellant research is the experimental evaluation of promising propellant combinations. Among the promising fuels are hydrazine and boron compounds and these are being experimentally investigated by the NACA in cooperation with the Army and Navy. A theoretical and laboratory study of hydrazine has been completed and rocket experiments will follow. Two runs have been made with diborane as a fuel with hydrogen peroxide as the oxidant. The diborane was supplied by the Navy. The results of the second run are shown by this chart (CHART 3.) Fig. 80 During the run the thrust increased and the flow rates, initially high, settled to a fairly constant value. The specific impulse increased during the run and reached a maximum of 200 pound-seconds per pound which is about 81 percent of the theoretical value. Even higher performance can be obtained at other mixture ratios and these conditions are to be investigated.

Our combustion research is directed towards increasing combustion efficiency and decreasing combustion volume. The first step in this investigation has been photographic studies of injection, mixing, and burning of gasoline and liquid oxygen in a two-dimensional, transparent rocket engine. You will see this engine later. At present photographs are taken at speeds up to 2500 frames per second but later photographs may be taken up to speeds of 40,000 frames per second with a special NACA camera. Photographs taken this far indicate a cycling in the combustion process which can affect combustion efficiency and cause engine vibrations. The next chart (CHART 4) Fig. 81 shows a sequence of photographs covering such a cycle. They were taken at a rate of 1300 frames per second from which the cycle was found to be 240 times per second. The injection streams can be seen in the upper end of the combustion chamber (the engine was mounted on an angle). Note the growth of the luminous combustion on the first four frames. In the fifth a break appears in the luminous zone and this break is complete in the sixth. In the 7th the downstream luminous zone has been exhausted and a new cycle begins as indicated by the last frame. Work is continuing to get a further insight into this phenomenon, and to more extensively study the various combustion processes.

You saw, from a previous chart, that rocket gas temperatures are very high - from 5000 to over 10,000 degrees Fahrenheit. These high temperatures create a critical cooling problem. A promising method of meeting this problem is internal-film or boundary-layer cooling where a coolant film is maintained on the inner surfaces of the engine to shield the walls from the hot gases. The next chart (CHART 5) Fig. 82 shows equipment used to study internal-film cooling of nozzles. A 1000 pound thrust engine was used with a copper nozzle, a thin-wall nozzle, and several cooling rings placed between combustion chamber and nozzle. The first was an uncooled ring; the second, a ring of water jets directed along the nozzle wall; the third, a porous metal ring with water seeping through it; the fourth, a ring for radial injection of water away from the wall for a control comparison. The curves show the effect of water on heat absorbed by the copper nozzle and on specific impulse. With either the jets or porous ring the heat absorption was cut in half with a water flow rate of about 3 percent of the propellant flow rate. When an 8 percent rate of water was directed away from the wall the heat absorption was about the same as for uncooled runs so the reduction observed was caused by effective cooling at the boundary layer. Experiments with the thin-wall nozzle showed that the porous wall gave a better distribution of coolant than the jets but for the conditions used both methods failed to stabilize wall temperatures in the throat and divergent sections. Additional cooling is needed in those regions. Specific impulse was reduced about in the same proportion as the amount of water to amount of propellant.

Gentlemen, in a few minutes you will see some of our research facilities and witness the operation of a rocket engine. A typical rocket set-up, such as you will see, is shown by this chart (CHART 6). Fig. 83 Thrust is measured by mounting the engine on a movable platform so that the thrust acts on a bar spring equipped with strain gages. Propellant flow rates are measured by continuously weighing the tanks with a bar spring and strain gages. Combustion pressures are measured by gages and temperatures by thermocouples.

Our facility layout is shown by this chart (CHART 7). Fig. 84 There are 4 test cells, control rooms, service rooms, and a central instrument room. Your inspection tour is indicated. You will see first a 500 pound thrust engine used for propellant research; note its small size. It is the engine you will see operate. In Cell 3 you will see the transparent rocket engine previously mentioned. You will next see the central instrument room which contains the instruments for all 4 test cells. All instruments in this room can be made available to any of the 4 test cells by a flip of a master switch. After the instrument room you will walk to the location indicated where you will see the rocket engine operate. Please do not smoke until you reach this spot.

Now, gentlemen, if you will follow the guide in the back of the room, we will proceed.

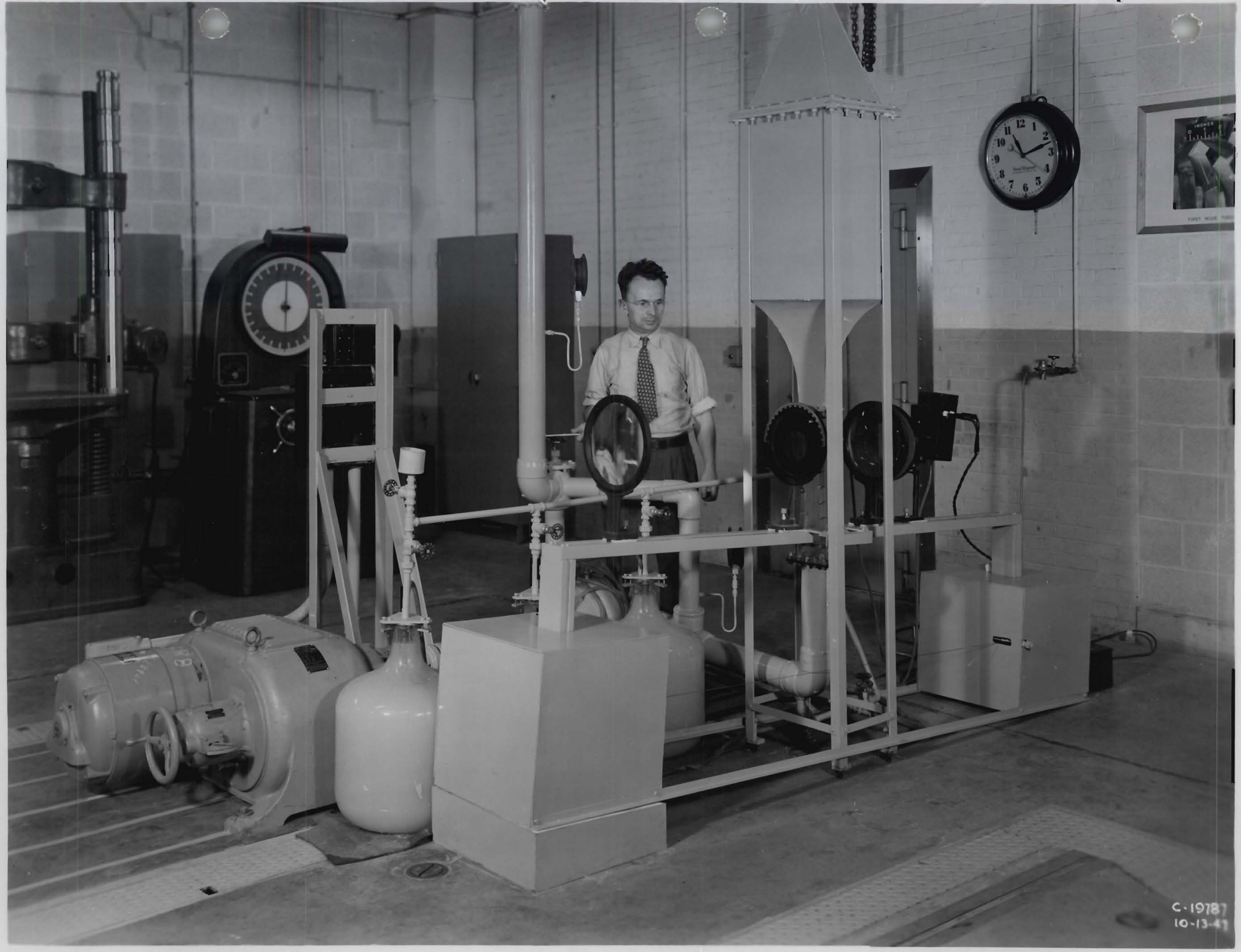

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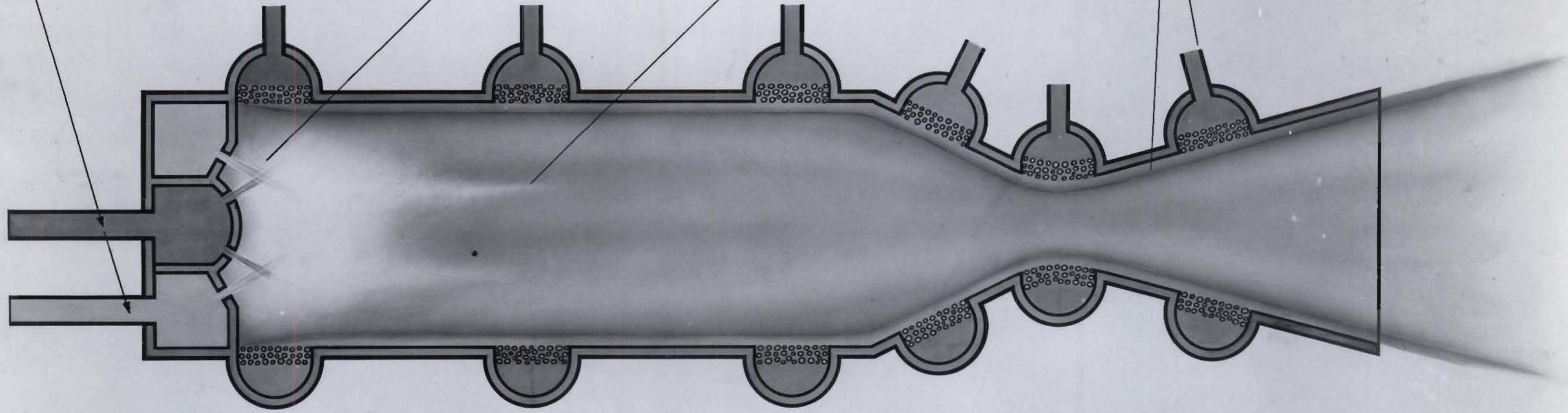
Fig. 77

SCOPE OF PRESENT ROCKET RESEARCH



PROPELLANTS

THEORETICAL AND EXPERIMENTAL
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Fig 78

HIGH PERFORMANCE PROPELLANT RESEARCH

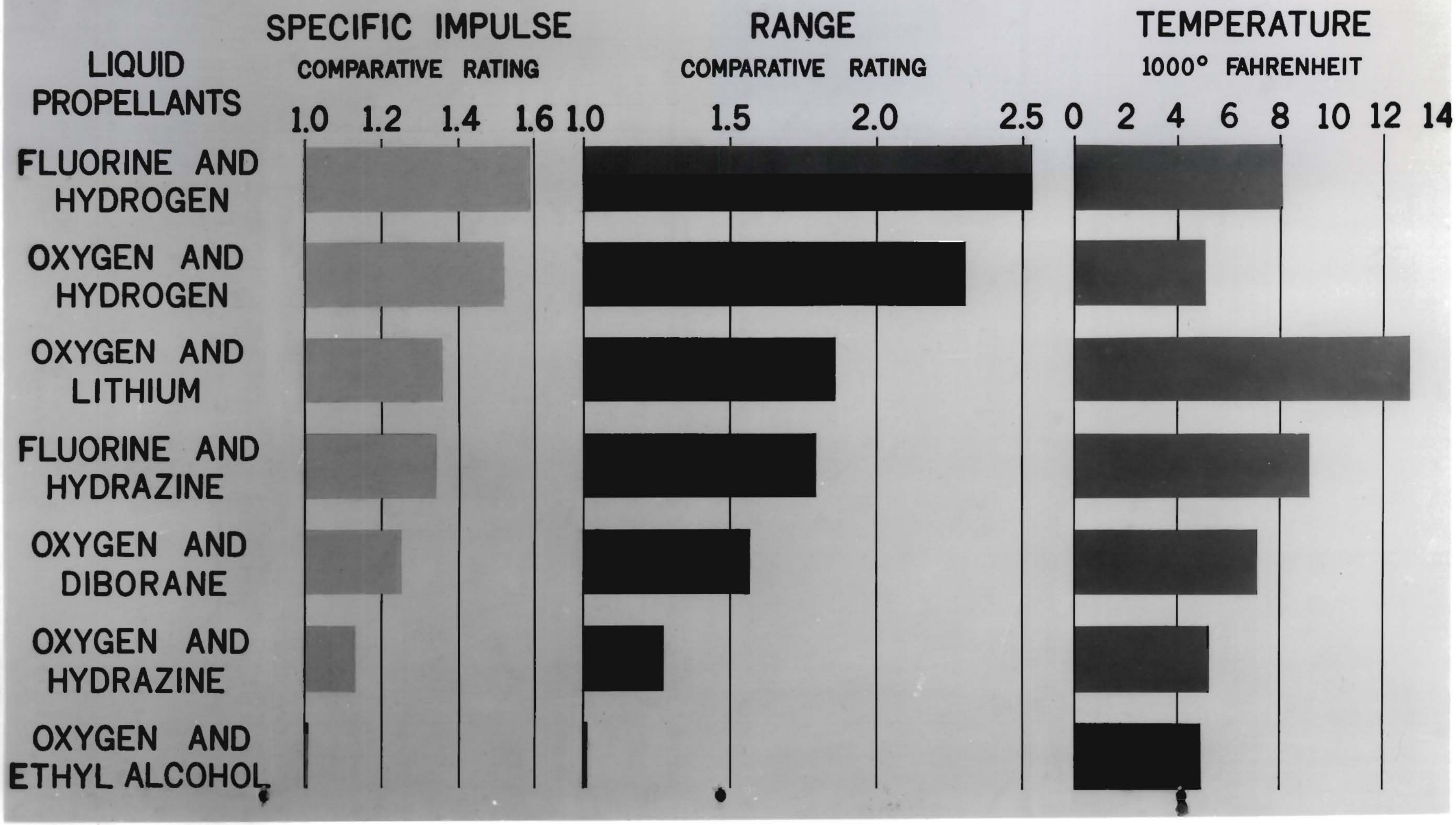

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Fig 79

EXPERIMENTAL RESULTS WITH DIBORANE

100 POUND THRUST ENGINE

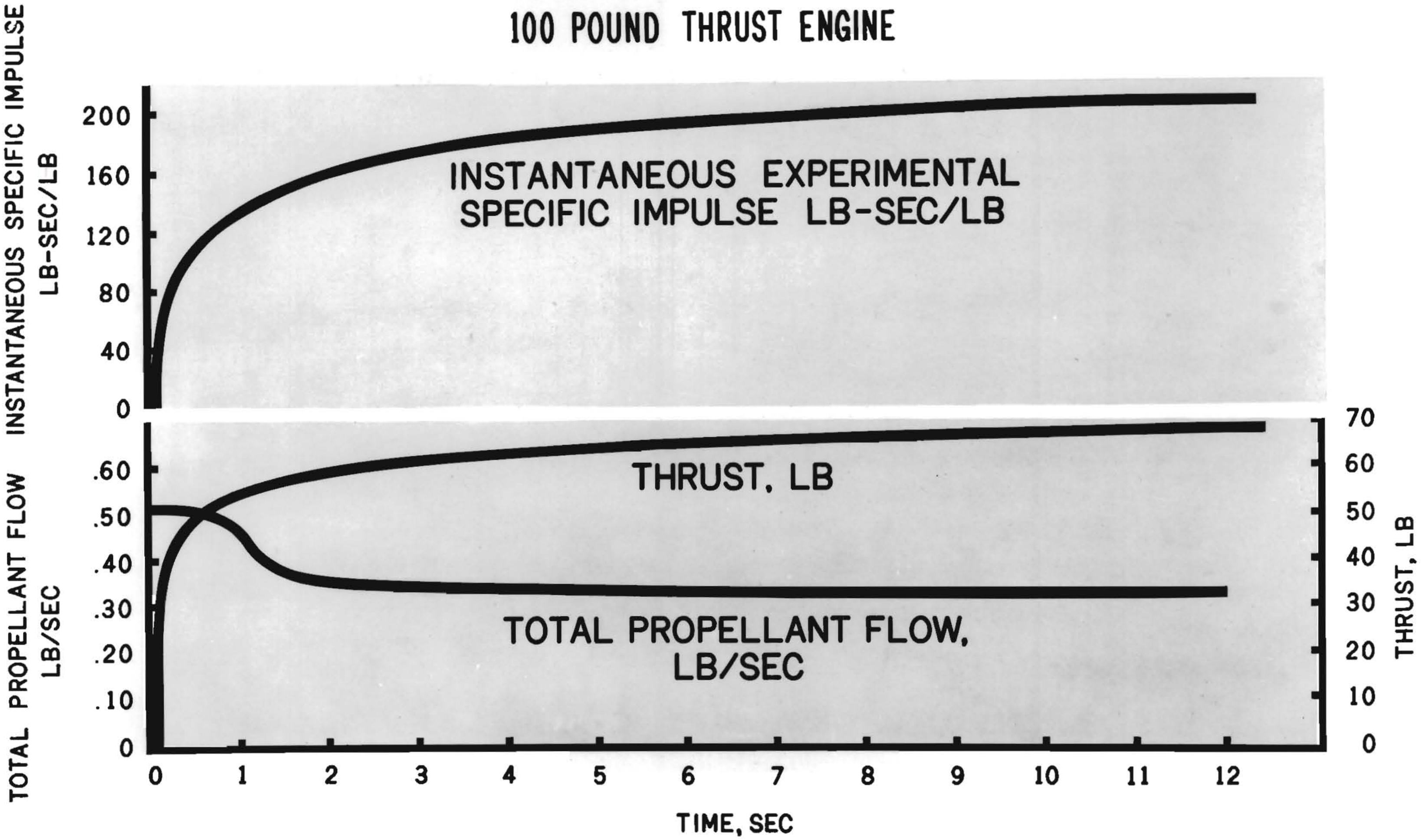

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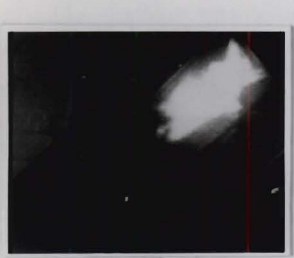
Fig 80

PHOTOGRAPHS OF ROCKET COMBUSTION

(1300 FRAMES PER SECOND)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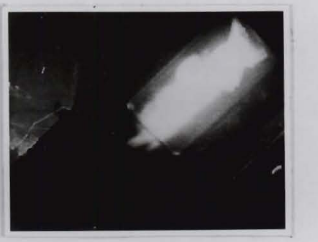
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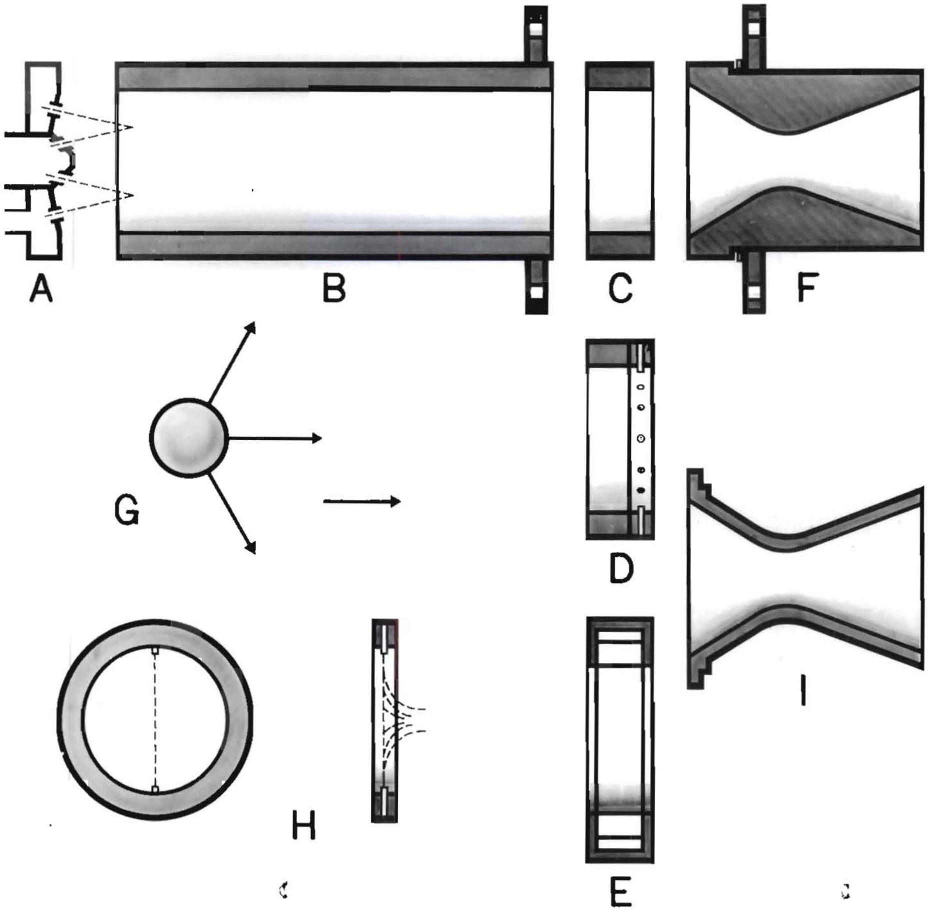
Fig 81

EXPERIMENTAL ENGINE FOR NOZZLE FILM COOLING



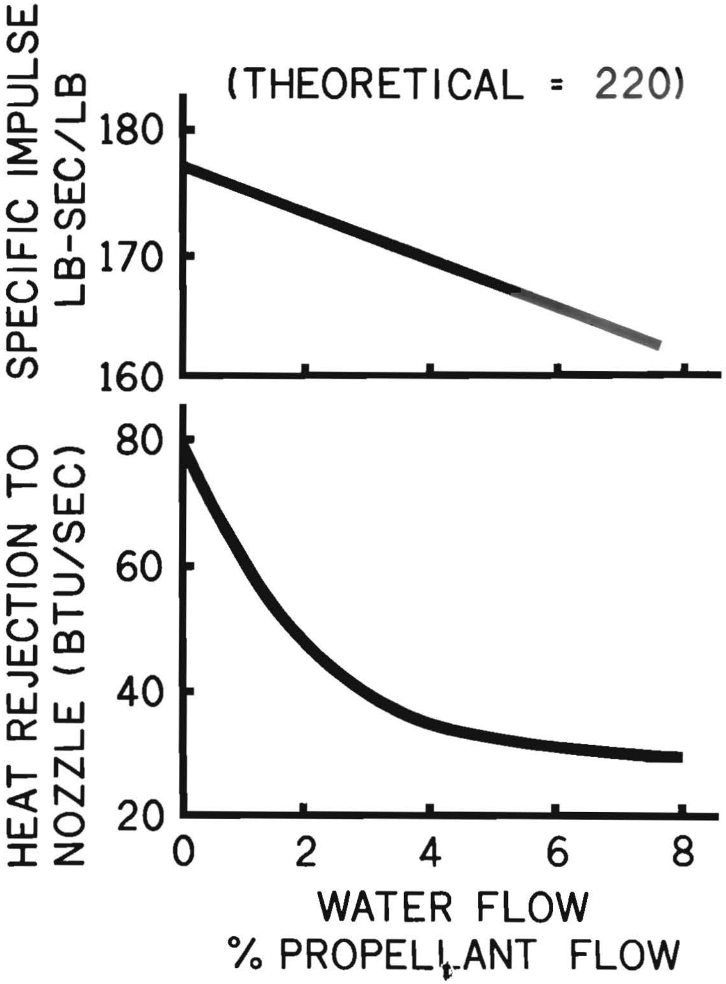


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Fig 82

TYPICAL ROCKET EXPERIMENTAL SETUP

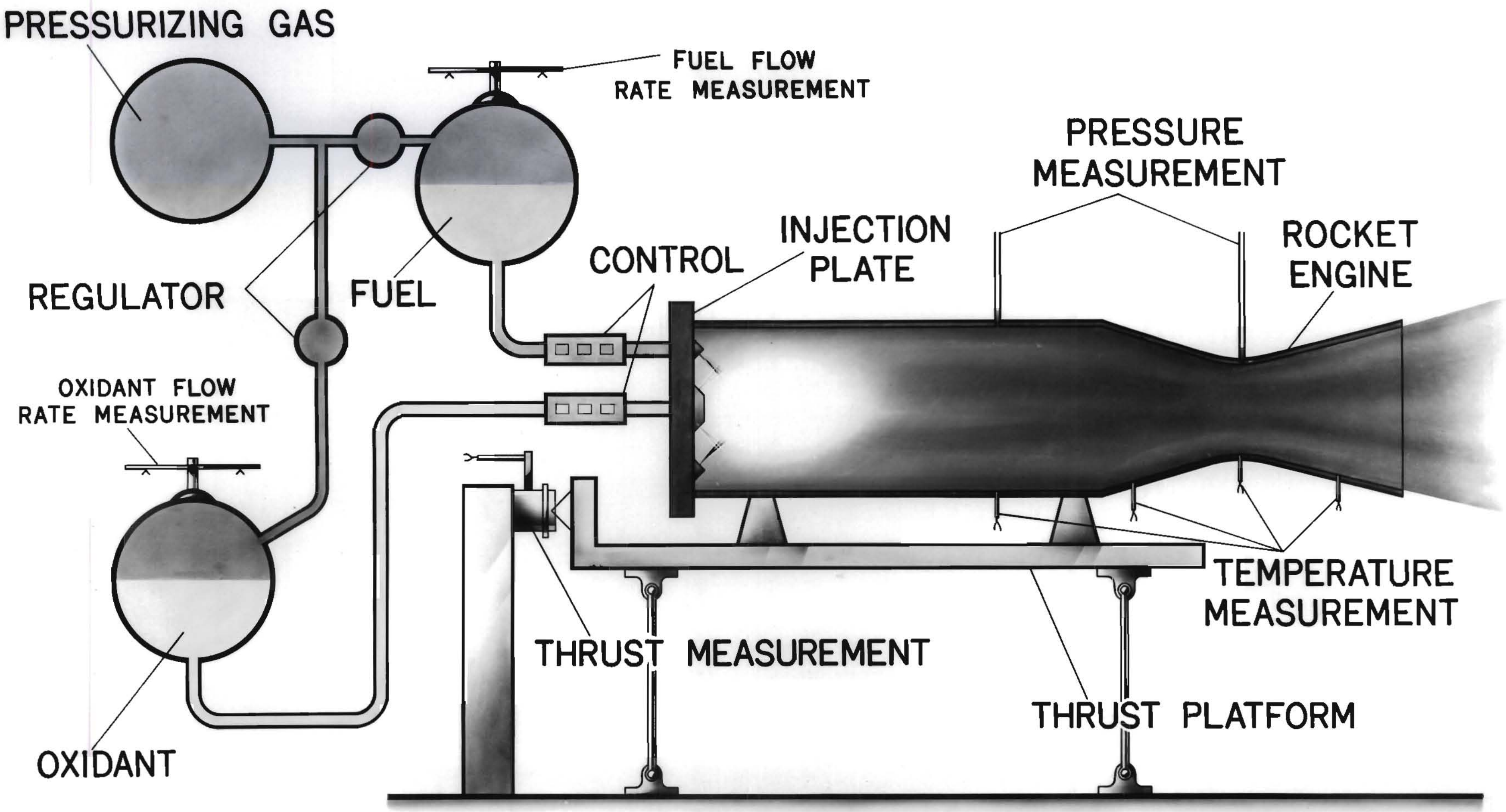

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Fig 83

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ROCKET RESEARCH FACILITIES

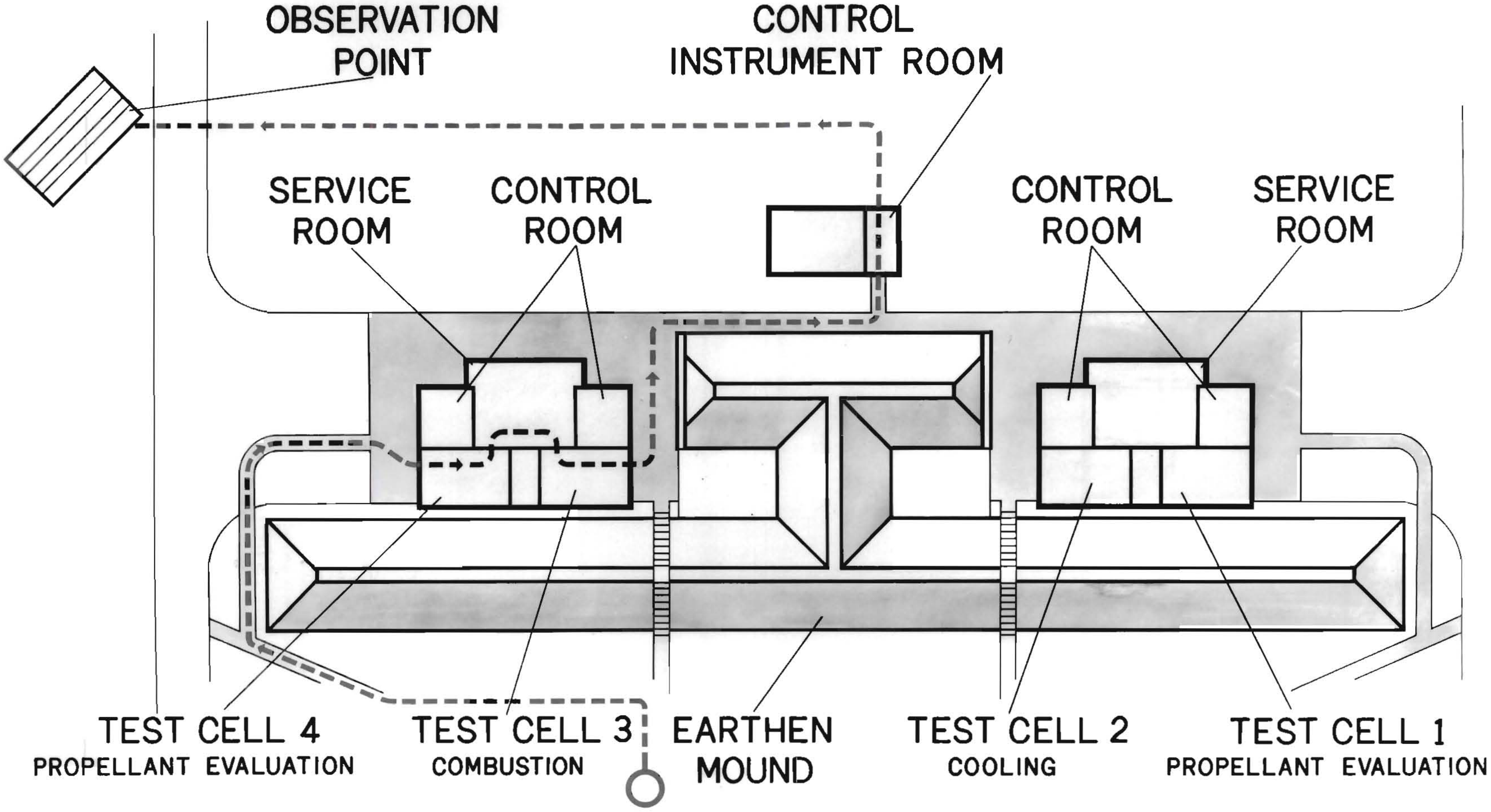

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Fig 84

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Talk Given in Field Just Before Firing

Gentlemen, the rocket engine that you will see operate in a few moments gives 500 pounds thrust and is the same size as this sectioned engine previously shown to you. The propellants are hydrogen peroxide and methyl alcohol. A catalyst, sodium permanganate, is used to decompose the hydrogen peroxide at the start of the run. The sequence of operation is as follows. First, catalyst injection is started and you will see it emerge as a purple liquid at the beginning of the run. Second, the hydrogen peroxide is injected and it is decomposed by the catalyst into oxygen and water vapor. Third, the methyl alcohol is admitted and combustion starts. The combustion pressure is 300 pounds per square inch. During the run note the shock patterns in the exhaust stream.

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Preparations for the run have been completed and if you will look at the end cell, you will see the run start fifteen seconds after the start of the safety siren.

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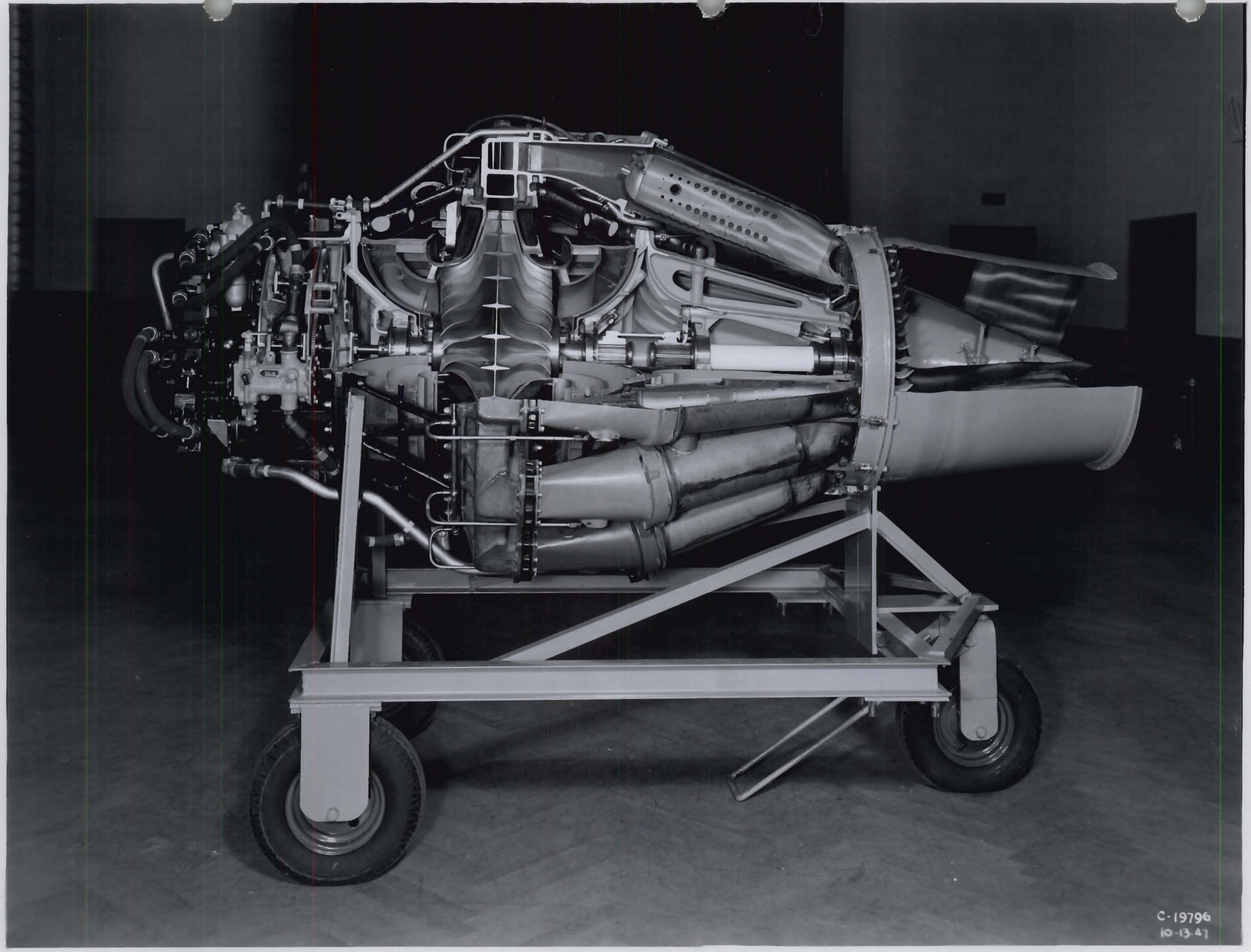

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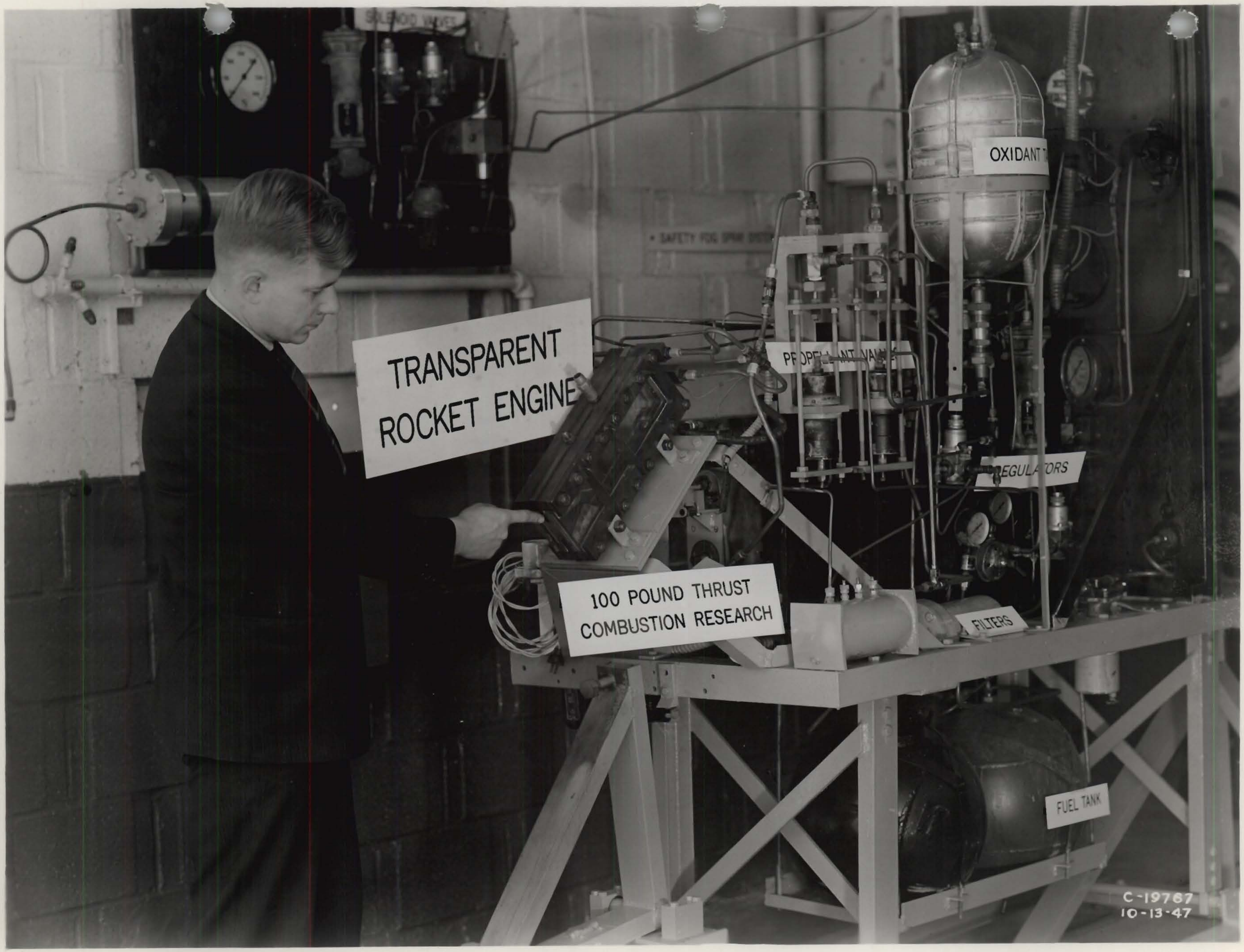

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