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RESEARCH MEMORANDUM

SOME SCREECHING-COMBUSTION CHARACTERISTICS OF A TRANSPIRATION-COOLED AFTERBURNER HAVING A POROUS WALL OF WIRE CLOTH

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON
November 29, 1954

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RESEARCH MEMORANDUM

SOME SCREECHING-COMBUSTION CHARACTERISTICS OF A TRANSPIRATION-COOLED AFTERBURNER HAVING A POROUS WALL OF WIRE CLOTH

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SUMMARY

A preliminary investigation was made of the screeching characteristics of two flame-holder configurations in a full-scale transpiration-cooled afterburner. The porous combustion-chamber wall was made of brazed and rolled wire cloth. The range of operating conditions included total fuel-air ratios of 0.04 to 0.08 and burner-inlet total pressures of 13 to 29 inches of mercury (920 to 2050 lb/sq ft abs) at a burner-inlet total temperature of 1710° R.

No screech was encountered with a diametrical V-gutter 8 inches wide. Very weak screech was encountered with a single-ring V-gutter having a gutter width of 4.59 inches. These same flame holders had screeched severely in a conventional burner under similar test conditions. There was no deterioration of the wire cloth in 1 hour 47 minutes of operation in weak screech at combustion-chamber-inlet total pressures up to 29 inches of mercury absolute.

This investigation indicates that a porous wall of wire cloth may be effective in eliminating or reducing the tendency to screech in some high-performance afterburners. However, the effectiveness in eliminating screech or reducing its detrimental effects at combustion-chamber pressures greater than atmospheric is not known.

INTRODUCTION

In addition to research directed toward improving afterburner performance, the NACA is studying means for eliminating high-frequency pressure pulsations and high wall temperatures that compromise the performance and reliability of high-performance afterburners. High-frequency pressure pulsations, often called screeching combustion or "screech," are frequently encountered at the high exhaust-gas temperatures associated with high performance, and these high-frequency

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pulsations cause rapid deterioration of the combustion chamber (ref. 1). The mechanism of screech and some methods for its elimination have been investigated and are reported in references 1 to 3. It was experimentally demonstrated that screech could be eliminated by the installation of a perforated combustion-chamber liner that acted as an acoustical absorber (ref. 2). In the same experiments, afterburner shell temperatures were considerably reduced by the flow of turbine-discharge gas into the upstream end of the perforated liner.

Because of the high heat-transfer rates encountered in high- 3480
performance afterburners, very effective cooling methods are required to keep wall temperatures low and cooling-air flow at a miniumm. Previous research has shown that transpiration-cooling of afterburner combustion chambers can meet these requirements (refs. 4 and 5).

It appeared, therefore, that a wire-cloth liner in the afterburner combustion chamber should not only permit transpiration-cooling, but might also eliminate screeching combustion. A brief investigation was conducted at the NACA Lewis laboratory to evaluate this idea. The combustion chamber of the wire-cloth afterburner of reference 5 was operated in a duct rig with two flame-holder configurations that were found in reference 2 to produce high-intensity screech in a 26-inch-diameter combustion chamber without a perforated liner. The range of conditions investigated included burner total pressures from about 13 to 29 inches of mercury (920 to 2050 lb/sq ft) absolute, burner-inlet total temperature of 1710° R, and total fuel-air ratios of 0.04 to 0.08.

APPARATUS

Test Installation

The wire-cloth afterburner was installed in the duct rig used for the investigation of screech reported in reference 2 (fig. 1). Combustion air from the laboratory services was preheated to 1710° R in the combustion-type preheater upstream of the mixing tank. Temperature profiles were reasonably uniform in the inlet section, which had no innerbody. Fuel was injected into the air stream 28 inches upstream of the flame holder through 24 equally spaced fuel bars. Each bar had six 0.020-inch-diameter holes that directed jets of fuel spray upstream. Hole spacing along the bars was made on the basis of equal air-flow areas. Ignition was provided by an ignitor 17 inches upstream of the flame holder. The fuel used in the air preheater and in the combustion chamber was MIL-F-5624A, grade JP-4.

The combustion chamber shown in figure 1(a) was cylindrical for a distance of 25 inches downstream of the flame-holder center line. The inside diameter was 25.5 inches. The wall was impermeable and convectively cooled by atmospheric air throttled into the cooling-air plenum chamber. The cylindrical section was followed by a tapered section 41 inches long that had an exit diameter of 22 inches. The tapered section was transpiration-cooled by the flow of cooling air, from the cylindrical section, through the wall of brazed and rolled wire cloth into the combustion region. Physical characteristics of the wire cloth and its fabrication into the wire-cloth afterburner are described in reference 6.

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The impermeable-wall combustion chamber and the tapered combustion chamber used in a previous screech investigation (ref. 2) are shown in figures 1(b) and (c), respectively, for comparison with the wire-cloth combustion chamber.

Flame-Holder Configurations

Figure 2 shows the flame holders used in this investigation. The diametrical V-gutter (fig. 2(a)) was 8 inches wide. A faired 1-inch-diameter tube prevented rotation of the gutter around its axis. The single-ring V-gutter (fig. 2(b)) was 4.59 inches wide and had a pitch diameter of 13 inches.

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Instrumentation

Rakes were installed for measurement of burner-inlet total pressure and temperature, and static wall taps were used in determining the burner-inlet velocity. Combustion-air flow was measured by means of an choked nozzle at the outlet of the air preheater. Combustion-chamber and preheater fuel flows were indicated on rotameters. The locations of temperature and pressure instrumentation that indicated operating conditions of the porous wall, and microphones on the combustion chamber for the detection of screech are shown in figure 3. Microphone 1, at the flame holder, was connected to the impermeable combustion-chamber wall, but microphones 2 and 3 were connected to the cooling shroud. Details of the microphone installation and their electronic apparatus are described in reference 2.

PROCEDURE

Screeching combustion was obtained by varying the burner-inlet pressure for constant values of air flow, fuel-air ratio, and burner-inlet air temperature. The pressure levels were recorded at which screech was encountered and at which screech degenerated into rough combustion. The small amount of fuel consumed in preheating the combustion air was added to the fuel flow to the combustion chamber in obtaining the values of total fuel-air ratio reported herein.

Cooling-air flows were not measured, but were sufficient to hold the wire-cloth temperatures between about 1060° and 1210° R.

RESULTS AND DISCUSSION

The conditions for which screech was encountered are enclosed by curves showing the simultaneous values of burner-inlet total pressure and burner-inlet velocity against total fuel-air ratio in figures 4 and 5. These curves are referred to as "screech boundaries." The pressures and velocities shown in the screech boundaries of figures 4 and 5 do not vary independently, because they are for constant air flows and fixed exhaust flow area. Hence, the shape of the curves is due in part to the manner of conducting the tests. 3480

Comparisons are made of the screech boundaries of the flame holders in the 26-inch-diameter combustion chamber (referred to hereafter as the impermeable-wall burner) and in the wire-cloth combustion chamber. The taper of the wire-cloth combustion chamber was considered to have no influence on screech boundaries. In reference 2, it was established that there was no difference in screech tendency between the cylindrical and tapered combustion chambers shown in figures 1(b) and (c).

Diametrical V-Gutter

Complete screech boundaries were determined for a diametrical V-gutter 7 inches in width during the screech investigation of reference 2, although the data were not tabulated in that report. The width of this gutter was later increased to 8 inches, but its new screech boundaries were not systematically surveyed. The range of fuel-air ratios over which screech was encountered, for given burner-inlet temperatures and pressures, was generally similar for the two gutter widths, although screech intensity was somewhat greater for the 8-inch width.

Screech was encountered with the 7-inch diametrical V-gutter in the impermeable-wall burner over the area enclosed by irregular curves (fig. 4(a)). Screech was encountered at total fuel-air ratios between about 0.065 and 0.078 when the burner-inlet total pressure exceeded about 9.5 inches of mercury (670 lb/sq ft) absolute. Screech was encountered over a greater range of fuel-air ratios as the pressure level increased. However, above the dashed lines, screech having a regular wave form and a definite frequency degenerated into irregular pressure pulsations referred to as rough combustion. In either region, the intensity of screech or roughness increased as the pressure level increased.

Figure 4(b) shows burner-inlet velocities for constant air flows at which screech and rough combustion were encountered. Screech occurred between velocities of 920 and 400 feet per second. The burner-inlet velocities during rough combustion were between 150 and 360 feet per second.

In contrast to the screech boundaries in the impermeable-wall burner, no screech was encountered at any condition covered in the tests with the transpiration-cooled combustion chamber.

Single-Ring V-Gutter

The single-ring V-gutter screeched over a wide range of conditions in the impermeable-wall afterburner. Exact limits were not determined but screech often existed from lean to rich blow-out at burner-inlet total pressures from 10 to 30 inches of mercury absolute. Approximate screech boundaries are indicated by the wavy lines in figure 5. As with the diametrical V-gutter, the screech data were obtained during the investigation of reference 2 but were not published in that report.

In the wire-cloth combustion chamber, the single-ring V-gutter produced very weak (barely audible) screech over a range of fuel-air ratios from about 0.04 to 0.073 (fig. 5(a)). The pressure at which screech was encountered increased with air flow. Screech was very sensitive to pressure level; the pressure level for rough combustion was less than 2.5 inches of mercury greater than the pressure at which screech was first detected. The entire region of screech occurred between burner-inlet velocities of about 400 to 560 feet per second (fig. 5(b)).

The screech frequency was significantly different when the single-ring V-gutter flame holder was operated in the impermeable-wall burner or in the wire-cloth combustion chamber. The frequency in the impermeable-wall burner was 590 cycles per second but only 370 cycles per second in the wire-cloth combustion chamber. By phase and frequency measurements, the standing waves in the impermeable-wall burner were found (ref. 2) to correspond to the first transverse mode of acoustic oscillation. A longitudinal mode of oscillation must have been present in the wire-cloth combustion chamber, because the wave lengths associated with the frequency of 370 cycles per second are too large for any transverse or radial modes. Apparently, the wire cloth suppressed the transverse modes but was less effective in eliminating the longitudinal oscillations.

Durability of Wire Cloth

The wire-cloth afterburner was operated in weak screech up to burner-inlet total pressures of about 29 inches of mercury, which was the limit of the test facility. There was no deterioration of the wire cloth from 1 hour 47 minutes of operation in weak screech. However, it is possible that the screech or rough combustion at higher pressures might be detrimental.

CONCLUDING REMARKS

The screeching tendencies of two flame holders that produced high-intensity screech in an impermeable-wall burner were investigated in a transpiration-cooled afterburner. The porous combustion-chamber wall of the afterburner was made of brazed and rolled wire cloth.

No screech was detected with a diametrical V-gutter 8 inches in width. Very weak screech occurred with a single-ring V-gutter 4.59 inches in width. There was no deterioration of the wire cloth from 1 hour 47 minutes of operation in weak screech up to combustion-chamber-inlet pressures of about 29 inches of mercury absolute.

The investigation of screech in this transpiration-cooled afterburner indicates that a porous wall of wire cloth may be effective in eliminating or reducing the tendency to screech in some high-performance afterburners. However, the effectiveness of eliminating screech or of reducing its detrimental effects at combustion-chamber pressures greater than atmospheric is not known.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, September 13, 1954

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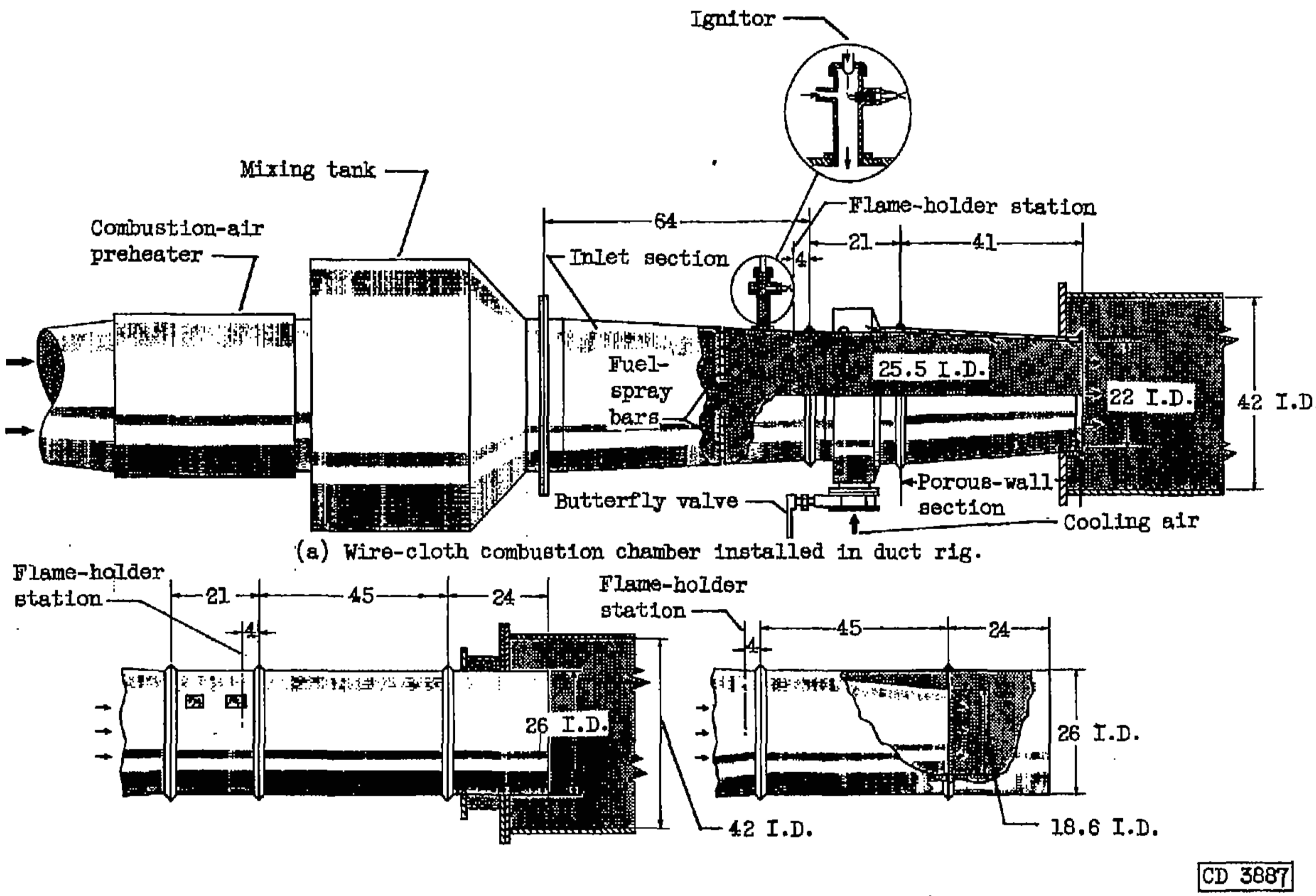
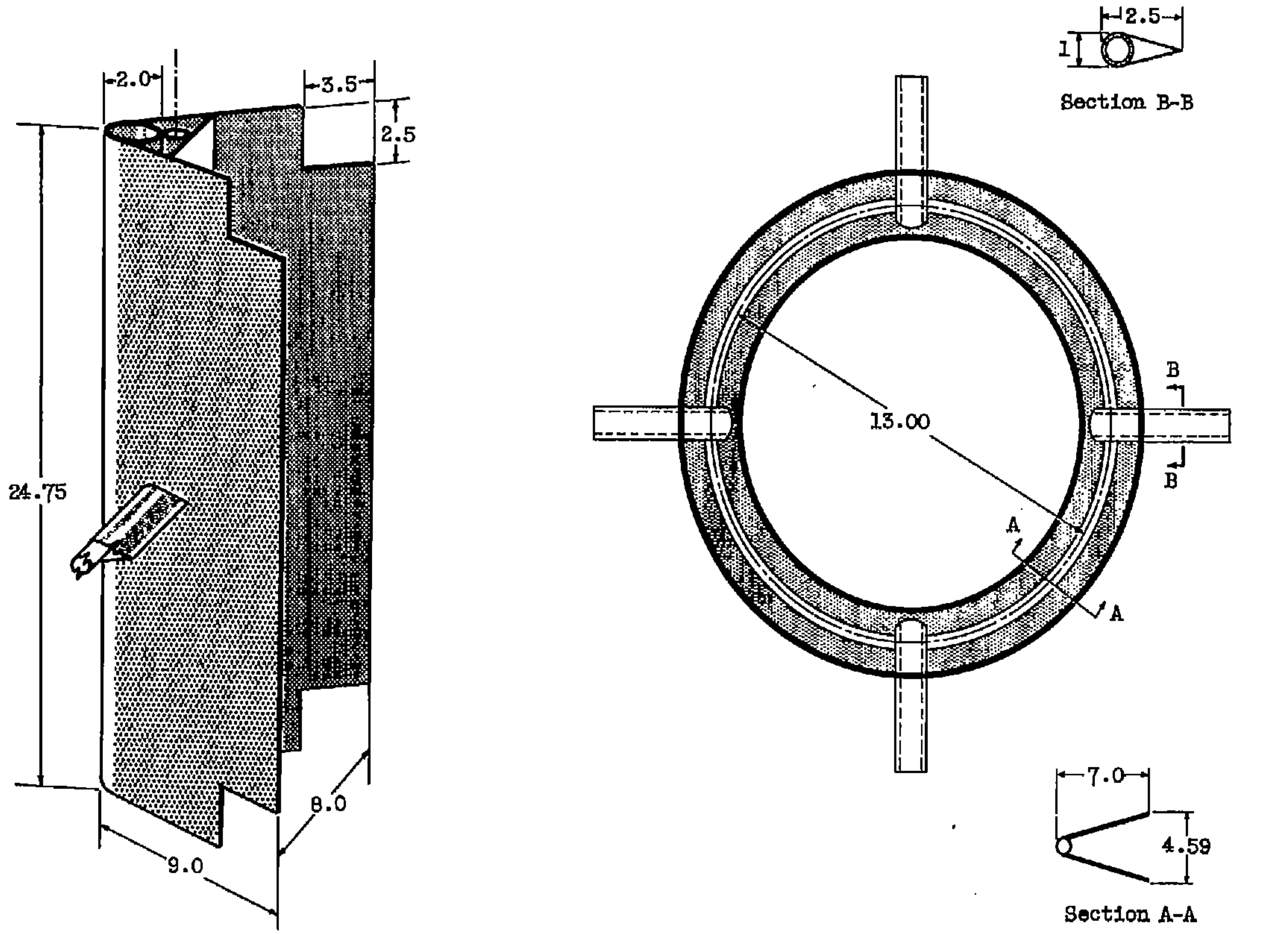


(a) Wire-cloth combustion chamber installed in duct rig.

(b) Impermeable-wall combustion chamber.

(c) Tapered combustion chamber.

Figure 1. - Test installation. (All dimensions in inches.)



(a) Diametrical V-gutter.

(b) Single-ring V-gutter.

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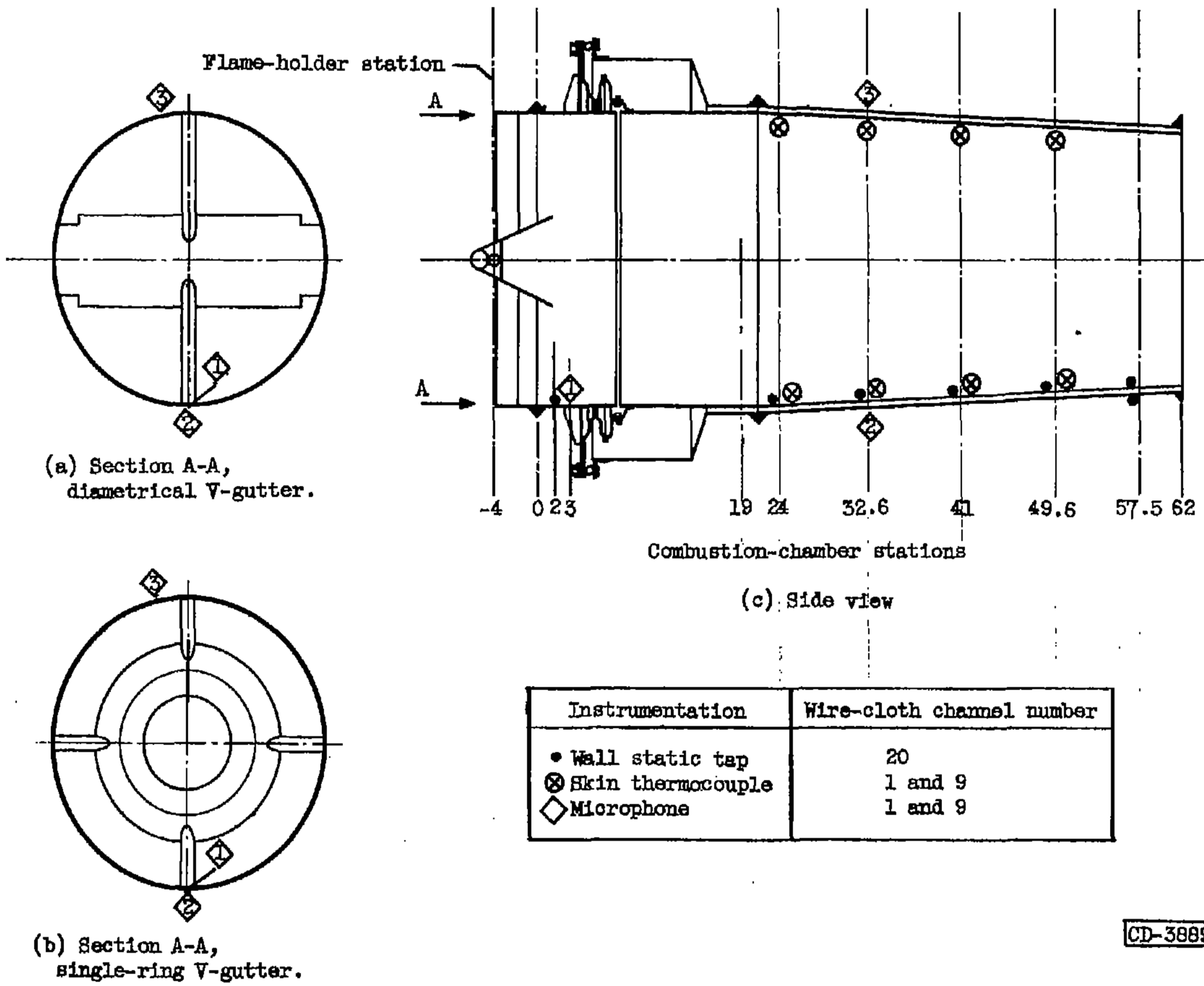
Figure 2. - Flame-holder configurations. (All dimensions in inches.)



Instrumentation	Wire-cloth channel number
• Wall static tap	20
⊗ Skin thermocouple	1 and 9
◇ Microphone	1 and 9

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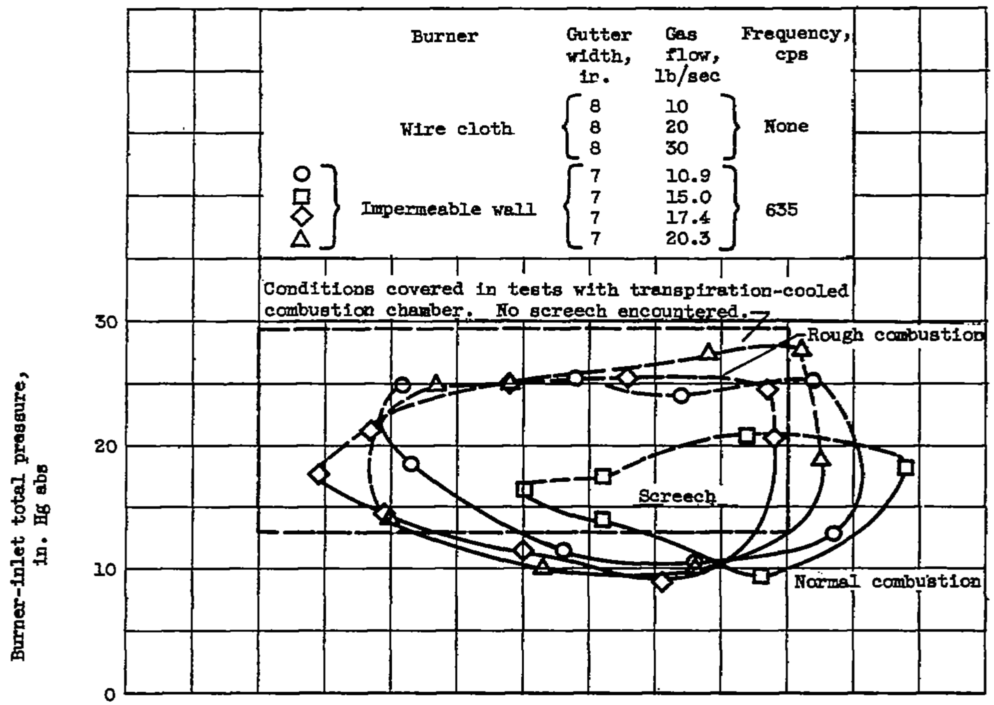
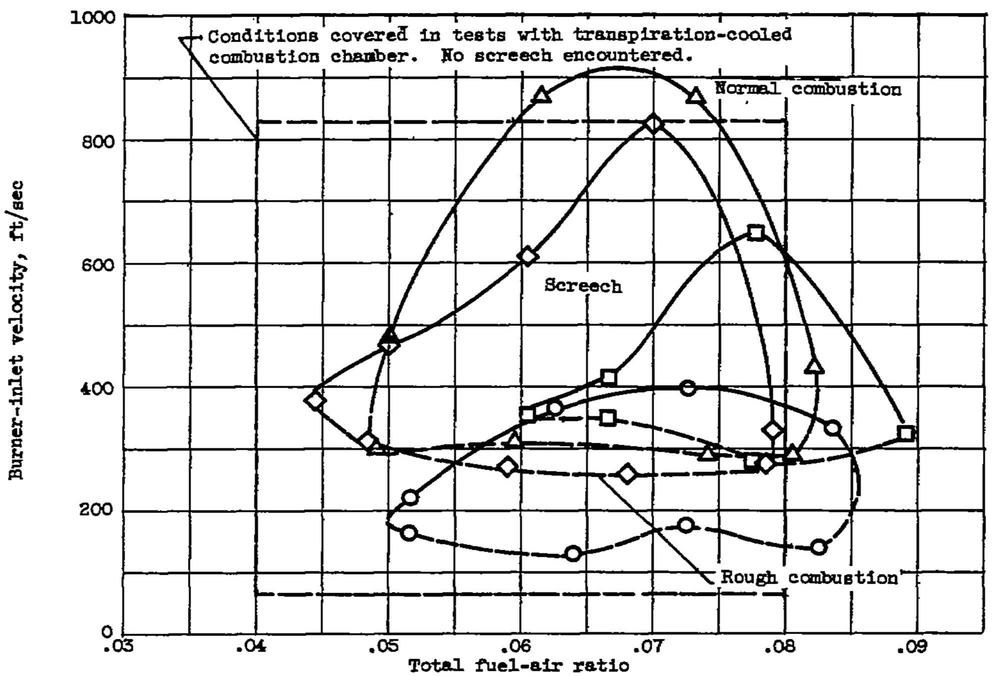
Figure 3. - Instrumentation location on wire-cloth combustion chamber. (All dimensions in inches.)



(a) Inlet total pressure.



(b) Inlet velocity.

Figure 4. - Screech boundaries of burner-inlet velocity and total pressure for diametrical V-gutter flame holder.

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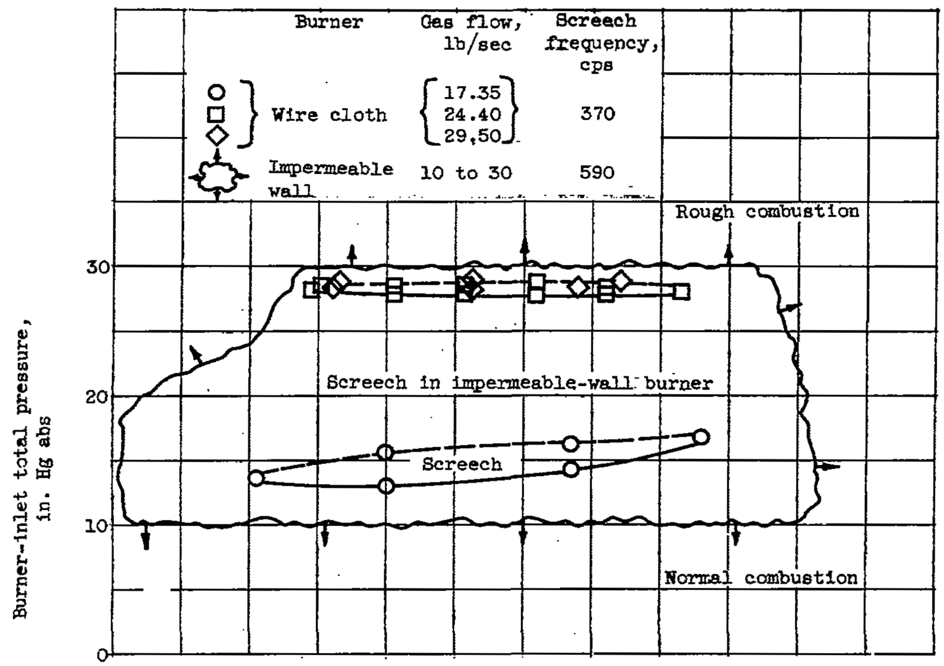

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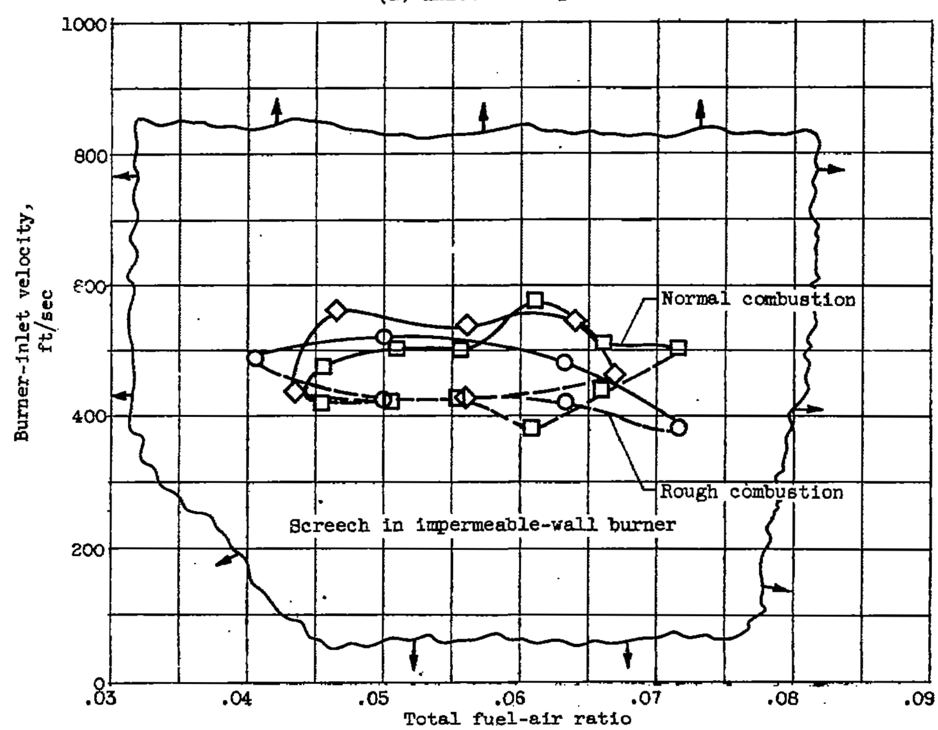

(b) Inlet velocity.

Figure 5. - Screech boundaries of burner-inlet velocity and total pressure for single-ring V-gutter flame holder.

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