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## RESEARCH MEMORANDUM

AIR-FLOW CHARACTERISTICS OF BRAZED AND ROLLED WIRE FILTER  
CLOTH FOR TRANSPIRATION-COOLED AFTERBURNERS

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RESEARCH MEMORANDUMAIR-FLOW CHARACTERISTICS OF BRAZED AND ROLLED WIRE FILTER  
CLOTH FOR TRANSPIRATION-COOLED AFTERBURNERS

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## SUMMARY

An experimental investigation was made of the permeability and air-flow uniformity of wire filter cloth for application of transpiration cooling to afterburner combustion-chamber walls. The permeability coefficients of five meshes of wire cloth investigated in the as-woven condition ranged from about  $3.82 \times 10^{-7}$  to  $6.46 \times 10^{-8}$  square inch. Permeability coefficients in the desired range of about  $10^{-8}$  to  $10^{-9}$  square inch for transpiration cooling of afterburner combustion-chamber walls were obtained by combining brazing and rolling of the wire cloth.

Thickness variations due to rolling tolerances were about  $\pm 0.0003$  inch. These variations in thickness in combination with initial non-uniformities in the air-flow passages through the wire cloth as woven were largely responsible for localized variations in air-flow uniformity within a given piece of brazed and rolled wire cloth. Over a total area of 37.5 square feet of 21x70 mesh twilled Dutch weave that had been brazed after spraying three coats of silver solder per side and then rolled to a 35-percent reduction in original thickness, 79 percent of the cloth had air flows -20 to +25 percent of the mean air-flow rate per unit of surface area; however, there were localized extreme variations of -40 to +55 percent of the mean air-flow rate per unit area. Undoubtedly the air-flow uniformity can be improved somewhat by controlled production techniques.

The effect of oxidation of the silver solder on the pressure-square difference per unit of thickness was found to vary almost linearly with time of heating in still air. The increases in the pressure-square difference per unit of thickness after 7 hours at 1260°, 1460°, and 1560° R were respectively 1, 3.5, and 7 percent for 21x70 mesh twilled Dutch weave wire cloth sprayed with three coats of silver solder per side, brazed, and rolled to a 35-percent reduction in original thickness. The effect of rolling on strength of the same cloth was such that a decrease of 42.5 percent in original thickness increased the ultimate tensile strength 30,000 pounds per square inch above the ultimate tensile strength of 25,000 pounds per square inch for the unrolled cloth. The short-time ultimate tensile strength of monel 21x70 mesh twilled Dutch weave wire

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cloth sprayed with three coats of silver solder per side, brazed and rolled to a 35-percent reduction in original thickness was about 23,000 pounds per square inch at 1000° F (1460° R).

An experimental afterburner having a porous combustion-chamber wall fabricated from brazed and rolled wire cloth was still in serviceable condition after 4 hours and 10 minutes of afterburning at fuel-air ratios from about 0.030 to 0.050.

## INTRODUCTION

Increasing interest in the application of transpiration cooling to the combustion-chamber walls of turbojet afterburners has led to a search for suitable porous materials. Sintered porous metal compacts have been considered (ref. 1) but have the disadvantages of low strength, poor formability, high cost, and limitations in maximum sheet sizes available. These factors led to the consideration of wire filter cloth which has higher tensile strength than the sintered porous metal compacts, has good formability, is relatively cheap, and is available in wide rolls. Wire cloth in the as-woven condition is too permeable for the contemplated applications so that several layers would be necessary to obtain the required pressure drop across the porous wall. A multiple-layer porous wall adds weight and increases fabrication problems. Permeabilities producing the required range of pressure drop across a single layer of wire cloth have been obtained by cold-rolling (sometimes referred to as calendering) brazed wire cloth (refs. 2 and 3). The investigations of references 2 and 3 were made with wire cloths 0.0169 to 0.0307 inch thick as woven, and reductions of 25 to 45 percent in original thickness were required to obtain the ranges of permeability or pressure drop desired. However, small variations in total thickness of the wire cloth due to tolerances in rolling were found to produce rather large changes in permeability (ref. 3), thus making the attainment of uniform permeability in a large sheet of wire cloth a difficult problem. Inasmuch as the percentage variation in thickness for a given rolling tolerance decreases as the total thickness is increased, it appeared that the uniformity of permeability in rolled wire cloth might be improved by the use of thicker cloth. The investigation reported herein was made to determine the effect of thicker cloth and, in addition, the effect of brazing alloy deposition on the magnitude and uniformity of permeability of brazed and rolled wire filter cloth, and to make this information available in a form useful to the aircraft industry.

The greater thicknesses of the wire filter cloths of this investigation than for the wire cloths investigated in references 2 and 3 are the result of weaving of multiple strands of fine wires as though they were single wire threads. This weaving produces a wire filter cloth of different appearance and texture which has many fine and tortuous air passages.

Because of variation in the static-pressure drop across the porous material and in the cooling air required along the length of afterburner combustion chambers, a prescribed distribution of permeability is usually necessary. However, as a preliminary investigation, this report is concerned only with the attainment of uniform permeability.

The results of an experimental investigation, conducted at the NACA Lewis laboratory, to determine the permeabilities of five thick meshes of wire filter cloth are presented herein. The control of permeability by varying the amount of brazing alloy and by rolling the brazed cloth is shown. The factors affecting uniformity of permeability, and the degree of uniformity, that has been obtained in pieces of wire cloth large enough to be fabricated into an afterburner combustion chamber are discussed. The rate of change in permeability due to oxidation of the brazing alloy and the effect of temperature on the ultimate strength of brazed and rolled wire cloth are presented. The fabrication techniques and operational experience for brazed and rolled wire cloth used as the porous combustion-chamber wall in an experimental transpiration-cooled afterburner are described.

## APPARATUS AND PROCEDURE

### Description and Preparation of Wire Cloth

Air-flow pressure-drop data were obtained for five meshes of wire filter cloth, the specifications of which are listed in table I. Wire cloths A, B, and C were woven from monel wires, cloth D from nickel, and cloth E from AISI type 304 stainless steel. The cloths investigated can be woven from various alloy wires but the meshes and weaves were of principal interest from the standpoint of permeability. The mesh of wire cloth is usually designated as the number of openings per inch between wires in the warp and woof, respectively. (The warp wires run parallel to the length of the loom and woof wires cross the warp.) In all the meshes of wire cloth considered in this investigation, groups of three to eight wires were woven collectively as a single strand of warp or woof so that the number of openings per inch is considered in this report to equal the number of groups of multiple strands per inch.

Cloths A to D (fig. 1 to 4, respectively) were twilled Dutch weave, whereas cloth E (fig. 5) was a plain twilled weave. Specifications for the 20×200 mesh wire cloth from reference 2 are included in table I for comparative purposes.

It is difficult to illustrate the interstices that make up the principal air passages through the wire filter cloths investigated. The uniformity of spacing and sizes of the air passages are indicated only approximately by back lighting in parts (c) of figures 1 to 5. It should

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be noted first of all that the twilled Dutch weave wire cloths investigated passed practically no light directly through when viewed normal to the surface. Some light could pass directly through when the cloths were viewed obliquely along the warp (horizontal wires, figs. 1 to 5). All the light visible in part (c) of figures 1 to 4 is reflected and most of the light in figure 5(c) is reflected.

Preparation of brazed wire cloth. - The initial step in the brazing process consisted in scrubbing the wire cloth in acetone to remove oil and grease and adherent dust or dirt particles. The clean grease-free cloth was dried, tacked to a clean piece of plywood, and placed on the table of a metal planer (fig. 6). Two pieces of wire cloth up to 45 by 22 inches each could be sprayed in tandem at one time. A wire metalizing spray gun was mounted in the clapper box of the planer and adjusted so that the fan spray from the gun tip was normal to the direction of travel. The following conditions were maintained for spraying silver solder onto the cloth:

- Height of spray tip above cloth, in. . . . . 5
- Speed of 1/8-inch-diameter wire through metalizing gun, ft/min . . . 3
- Speed of table traverse in both directions, ft/min . . . . . 50
- Cross feed of gun per stroke of planer, in. . . . . 1

These conditions were chosen so that each spray coat of silver solder would be relatively thin, in order that the overlapping strokes from several coats would result in a uniform deposition of silver solder. After the cloth was sprayed with silver solder, two coats of thinned silver solder flux were brushed on each side. The fluxed cloth was dried and brazed by dipping into a molten salt bath at 1500° to 1600° F. Pieces of cloth less than 1 foot in length were immersed in the salt bath for 30 seconds and pieces 45 inches in length were immersed a total of 45 seconds because of the additional time used in lowering and withdrawing the longer pieces. The brazed cloth was quenched in cold water and then boiled in water a minimum of 3 hours to remove any trace of salt or flux.

A brief investigation was made to determine the most favorable composition of silver solder for uniform permeability of wire cloth after brazing. Five specimens of wire cloth B were each sprayed four coats per side with one of the five compositions of silver solders listed in table II. The solder composition used on the specimen having the most nearly uniform permeability was used in later investigations of the effects of solder deposition on the uniformity and level of permeability.

Strips of the brazed wire cloth were rolled in the direction of the larger number of (woof) wires in a four-high rolling mill having rolls 8 inches wide.

Rolling of wire cloth. - None of the unbrazed cloth was rolled because the inherent resiliency of the weaves investigated make it very difficult to maintain close tolerances on thickness. Thickness variations

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tend to cause large pieces of unbrazed cloth to ripple or to run askew. These difficulties are decreased by brazing, which unites the wires into a more rigid sheet that can then be rolled almost the same way as sheet steel.

#### Thickness and Air-Flow Measurements

The uniformity of thickness over the area of a given piece of cloth was determined from thickness measurements made at intervals of 2 to 6 inches. The arithmetic average of these thickness measurements was used as the nominal thickness at any location where air-flow measurements were taken within that piece.

The apparatus (fig. 7) and the procedure used to obtain air-flow pressure-drop data were similar to those used in references 2 and 3. In order to perform a nondestructive air-flow calibration at several locations over the surface of a large piece of wire cloth, the cloth was sealed by means of an O-ring between two steel platens that were clamped by a constant force. Only one layer of wire cloth was flow-tested in this investigation. The pressure drop across several layers of the same cloth or at other temperatures and pressure levels can be accurately determined from correlations similar to those in references 2 to 5.

#### Strength Measurements

Strength measurements were made of cloth B at room temperature, and short-time tensile tests were also made at equilibrium temperatures up to 1000° F. In addition, several specimens from one large piece of cloth B that had been brazed and rolled were heated for several hours in still air and pulled at room temperature to determine the loss in strength for various exposure temperatures. In all the tensile tests, the load was increased continuously at a constant rate in the direction of the greater number of wires.

### METHODS OF CORRELATION AND CALCULATION

#### Reduction of Air-Flow Data to Standard Temperature

The determination of the permeability coefficient and examination of the air-flow data for the effects of braze alloy deposition on the level and uniformity of permeability are based on equation (1), given in reference 4, for the flow of a gas through a plane wall of porous material.

$$\frac{p_1^2 - p_2^2}{\tau} = \alpha \frac{2RT}{g} \mu(\rho V) + \beta \frac{2RT}{g} (\rho V)^2 \quad (1)$$

where  $\alpha$  is referred to as the viscous resistance coefficient and  $\beta$  as the inertial resistance coefficient. (Symbols are defined in the appendix.) As noted in reference 5, equation (1) when solved for  $(\rho V)$  gives

$$\frac{(\rho V)}{\mu} = \sqrt{C_1^2 + C_2 \frac{p_1^2 - p_2^2}{\mu^2 T \tau}} - C_1 \quad (2)$$

where  $C_1 = \frac{\alpha g}{2\beta}$  and  $C_2 = \frac{g}{2\beta R}$  are constants for each specimen so that

$$\frac{(\rho V)}{\mu} = f_1 \left( \frac{p_1^2 - p_2^2}{\mu^2 T \tau} \right) \quad (3)$$

Air-flow data can be reduced to standard temperature by the introduction of  $\mu_o$  and  $\mu_o^2 T_o$  into equation (3) where the subscript  $o$  refers to NACA standard temperature of 518.4° R. When this is done, equation (3) becomes

$$(\rho V) \frac{\mu_o}{\mu} = f_2 \left[ \frac{p_1^2 - p_2^2}{\tau} \left( \frac{\mu_o}{\mu} \right)^2 \frac{T_o}{T} \right] \quad (4)$$

With the notation  $\frac{\Delta(p^2)}{\tau}$  for  $\frac{p_1^2 - p_2^2}{\tau}$ , equation (4) is used as the correlation equation for air-flow data in this report by plotting  $\frac{\Delta(p^2)}{\tau} \left( \frac{\mu_o}{\mu} \right)^2 \frac{T_o}{T}$  against  $(\rho V)_a \frac{\mu_o}{\mu}$  for each specimen of wire cloth (the subscript  $a$  refers to cooling air). The logarithm of  $\frac{\Delta(p^2)}{\tau} \left( \frac{\mu_o}{\mu} \right)^2 \frac{T_o}{T}$  is referred to in later discussion as the pressure-drop parameter. The absolute viscosity  $\mu$  of air and the factors  $\mu_o$  and  $\left( \frac{\mu_o}{\mu} \right)^2 \frac{T_o}{T}$  are tabulated as functions of the temperature  $T$  in table I of reference 3 and are presented graphically in figure 8 of reference 1.

### Calculation of Permeability, Porosity, and Strength

For comparison of test results of various porous materials, the permeabilities are usually stated in terms of a permeability coefficient  $K$  that was originally based on Darcy's law. Darcy's law can be written as

$$\frac{\Delta(p^2)}{\tau} = \frac{1}{K} 2RT\mu (\rho V) \quad (5)$$

However, equation (1) derived by Green has been demonstrated conclusively in reference 4 to fit more accurately the air-flow data for porous materials. The permeability coefficients  $K$  in this report are computed in the same manner as for references 2 and 3 from the equation

$$K = \frac{1}{\alpha} \frac{1}{1 + \frac{\beta}{\alpha \mu g}} (\rho V) \quad (6)$$

which was obtained by equating the right-hand sides of equations (1) and (5) and solving for  $K$ . In evaluating  $K$  from equation (6),  $\alpha$  and  $\beta$  were first determined from equation (1) from a series of readings of  $\frac{\Delta(p^2)}{\tau}$  and mass flows for each specimen using the method of least squares (ref. 6). In order to compare  $K$  from equation (6) with the results of previous investigations using  $K$  defined by equation (5), the value of  $(\rho V)$  was taken as zero, in which case  $K$  is the reciprocal of  $\alpha$ .

The porosity is defined as the ratio of the volume of voids to the total enclosed volume. The equation used for calculating the porosity of brazed wire cloth, derived in reference 2, is

$$f = 1 - \frac{1}{\tau} \left( \frac{1}{\rho_w} \frac{W_c}{A} + \frac{1}{\rho_b} \frac{W_b}{A} \right) \quad (7)$$

The weight of braze alloy per unit of surface area  $W_b/A$  is taken as the difference between the weights per unit of surface area after brazing and for the cloth as woven. The specific weights of monel and AISI type 304 stainless steel were taken, respectively, as 0.319 and 0.285 pounds per cubic inch, and  $\rho_b$  was taken as 0.343 pounds per cubic inch.

The ultimate tensile strength  $\sigma$  of wire cloth was obtained by dividing the breaking force per unit of width by the average thickness of the respective specimens. Because of the importance of high strength

per unit of weight for aircraft materials, the ratio of tensile strength  $\sigma$  to the specific weight of the cloth  $\rho$  is a more suitable criterion for comparing different materials than the tensile strength alone. A reduced tensile strength, proposed in reference 2, is obtained by multiplying the strength to specific weight ratio by the specific weight  $\rho_w$  of the alloy in the wire cloth as woven:

$$\sigma' = \frac{\sigma}{\rho} \rho_w = \frac{F}{W/L} \rho_w \quad (8)$$

This value can be compared with familiar strength values for the same solid alloys, for which  $\rho = \rho_w$ .

## RESULTS AND DISCUSSION

### Air-Flow Calibrations for Several Meshes and Weaves of Wire Filter Cloth as Woven

Correlations of pressure-drop parameter  $\log_{10} \frac{\Delta(p^2)}{\tau} \frac{\mu_0}{\mu} \frac{T_0}{T}$  with the generalized weight flow per unit area  $(\rho V)_a \frac{\mu_0}{\mu}$ , reduced to standard temperature  $T_0$ , are shown in figure 8 for several meshes and weaves of wire filter cloth in the as-woven condition. For comparison, the dashed line represents the 20x200 mesh cloth, which was the thickest wire cloth investigated in references 2 and 3. The curves for cloths A to D have about the same slope. As would be expected for a given weave, air-flow rate, and temperature, the pressure-square difference per unit of thickness  $\frac{\Delta(p^2)}{\tau}$  increased with the number of groups of wool wires per inch inasmuch as the number of warp wires per inch was nearly constant. Cloth E had next to the lowest permeability coefficient as woven; the thicker filter cloths, however, were of greater interest for brazing and rolling.

The permeability coefficients of the filter cloths investigated ranged from about  $3.82 \times 10^{-7}$  to  $6.46 \times 10^{-8}$  square inch in the as-woven condition as compared with the desired value of  $10^{-8}$  to  $10^{-9}$  square inch for transpiration-cooled afterburner combustion-chamber liners. Thus the applications of these wire cloths in the as-woven condition would require several layers to obtain the desired flow resistance. The data of references 2 and 3 indicated that the required flow resistance and the corresponding permeability coefficient might be obtained with one layer of rolled wire cloth; however, the permeability coefficient was very sensitive to variations in thickness. Although no consistent significant differences were found between the permeability coefficients of brazed and

unbrazed rolled cloth in reference 2, it was felt that heavier applications of braze metal than used in the previous investigations might make it possible to obtain the desired range of permeability coefficients with smaller percentage reductions in original thickness by the rolling process. Consequently, for a given tolerance in thickness, the percentage variation in total thickness would be reduced and the uniformity of permeability of large pieces of wire cloth should be improved. Similar benefits might also be expected from the choice of initially thicker weaves of wire cloth.

#### Choice of Silver Solder

Initial attempts to deposit fairly heavy coats of braze metal to reduce the permeability of wire cloth, as woven, caused irregular spotting and sometimes complete plugging of the cloth due to nonuniform or excessive deposition of braze metal. However, it was found that complete plugging could be eliminated by lighter depositions, and that spotting was dependent upon the uniformity of the spray technique and upon the fluidity and wettability of the brazing alloys used. Five compositions of silver solder listed in table II were therefore chosen for a brief investigation of the effects of their fluidity and wettability on the uniformity of braze deposition.

A severe test was chosen as a check on the effect of fluidity and wettability on the uniformity of brazed wire cloth. The silver solders designated A to E in table II were sprayed four coats per side on cloth B and, after fluxing, the cloth was dipped into a molten salt bath at 1600° F (2060° R). Solder E was also applied in varying amounts as a thin paste mixture of powdered solder and flux. The specimen brazed with solder A was acceptable, but specimens brazed with solders B to D were predominately plugged and the thicknesses of their brazed coatings were nonuniform. All specimens brazed with solder E were plugged. Therefore, silver solder A was chosen for investigating the effects of brazing and rolling on the uniformity and control of permeability of wire filter cloth. Hereafter, it will be assumed that silver solder A is referred to whenever silver solder or brazing is mentioned in the discussion of results.

#### Effect of Solder Application on the Magnitude

#### and Uniformity of Permeability

The appearance of several meshes of wire cloth after spraying and brazing is shown in the photographs of figures 9 to 12, taken at X15. The left photograph of each figure is front lighted and the photograph on the right is back lighted. Only cloth A transmitted enough reflected back light to be photographed under combined front and back lighting (fig. 9(b)). The deposition of brazing alloy is believed to be quite

uniform because of the mechanical accuracy with which the coats were sprayed, and because of the fluidity of the silver solder which produced an evenly "tinned" coating. The amounts of silver solder applied by spraying were less than that required to cause a run-off of solder into the molten salt bath during the brazing process. The principal effect of brazing on the permeability of wire filter cloth is illustrated by comparison of figures 9(c) and 1(c). The individual strands in each group of wires have been enveloped and filleted by the silver solder, leaving the primary air-flow passages open. Heavier applications (more coats sprayed per side) of solder produced more generous fillets (figs. 10 and 11) and reduced the sizes of the air-flow passages. Any variation in the apparent size of the passages in a given piece of cloth, due to normal weaving tolerances and the random twisting and crowding of individual wires in each group of wires, becomes exaggerated by each successive coat of silver solder (see figs. 10(b) and 11(b)). In figure 10(b), one air passage appears to be plugged near the lower right corner (dark spot where light should indicate an air passage) while several large passages are evident, along the left side, by the large areas of reflected light. An occasional dark spot is not serious and the absence of light does not always mean the passage is plugged. The passage may be open but the light obstructed by a "bridge" such as appears to the left of center in figure 11(a). The spotted appearance of figure 11(b) indicates that four coats per side of cloth B is past the optimum amount of solder deposition for air-flow uniformity on a microscopic scale. Over a larger area, however, this material may be considered fairly uniform.

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The denser weaves of filter cloth plugged more readily because of initially smaller air-flow passages and greater surface area for solder retention. Cloth C was almost completely plugged by three coats of silver solder sprayed on only one side (fig. 12). The tendency for the solder to form a uniform coating was substantiated by the fact that the specimen in figure 12 was well "tinned" on the back, which had not been sprayed with silver solder.

The uniformity of air flow through cloth B sprayed with three and four coats of silver solder per side is shown in figure 13. For a constant temperature and pressure drop across the cloth, the weight flow of air per unit area varied up to -16 and +23 percent from the arithmetic mean flow for the sample sprayed with three coats of silver solder per side (fig. 13(a)), and up to -10 and +16 percent for the sample given four coats per side (fig. 13(b)). The closer air-flow tolerance obtained with the latter sample is attributed to the smaller area with half as many flow determinations as for the sample given three coats per side.

#### Effect of Rolling on Pressure-Drop Parameter, Permeability

#### Coefficient, Porosity, and Specific Weight

The effect of a 35-percent reduction in original thickness of cloth B sprayed with three coats of silver solder per side is visually indicated

by comparison of figures 14(c) and 10(b).

It should be noted that uniform reductions in thickness by rolling produce the same effect as successive uniform coats of silver solder, that is, to exaggerate the extremes in the normal random variation in flow areas of individual air passages. For example, compare figures 15(c) and 5(d). One coat of silver solder per side of cloth E reduced 48 percent in original thickness appears to have practically closed 40 percent of the air passages, and the ratio of maximum to minimum flow areas for individual unplugged passages is greater than 50 to 1. Hence, it is important that the interstitial openings in a wire cloth as woven should be as uniform as possible.

Pressure-drop parameter. - The quantitative effects of rolling on the pressure-drop parameter of brazed wire cloth are shown in the correlation of air-flow data reduced to standard temperature (fig. 16) for cloth B. The spread between curves having the same nominal reduction in thickness is believed to be the combined result of local initial variation in thickness from the average original thickness and the previously discussed exaggeration of air-passage flow-area distribution by brazing and rolling. The latter effects are especially noticeable for high reductions in original thickness (fig. 16(a)). Reductions in original thickness of 40 percent or less produced total variations of about 10 percent in air flow per unit area for a given reduction in thickness in figures 16(a) and 16(b).

The effects of rolling are more obvious when the curves of figures 16(a) and 16(b) are cross-plotted against reduction in original thickness (fig. 17). The trends were similar for three and four coats of silver solder per side of the wire cloth. The first 15 or 20 percent reduction in original thickness produced a slight increase in the pressure-drop parameter, because most of the initial reduction in thickness just tended to flatten and smooth the surface. Greater reductions in thickness caused deformation within the cloth and progressively reduced the flow areas of the air passages, thereby causing a more rapid increase in pressure-drop parameter.

Permeability coefficient. - The decrease in permeability coefficient  $K$  with reduction in original thickness and with the deposition of silver solder is shown in figure 18. The solid curves are for cloth B sprayed with three and four coats of silver solder per side. The dashed curves are from references 2 and 3, for brazed 20×200, 20×250, 20×350, and 28×500 mesh cloth. The permeability coefficient was about  $2.0 \times 10^{-7}$  ( $\log K = -6.7$ ) for unrolled cloth A with two coats of silver solder per side and about  $7.94 \times 10^{-8}$  ( $\log K = -7.1$ ) and  $2.88 \times 10^{-8}$  ( $\log K = -7.54$ ), respectively, for unrolled cloth B with three and four

coats of silver solder per side. The permeability coefficients for the latter two materials decreased gradually with reduction in original thickness up to about 40 percent, at which point the permeability coefficient  $K$  was about  $3.98 \times 10^{-9}$  ( $\log K = -8.4$ ) and  $10^{-9}$  ( $\log K = -9.0$ ) square inches, respectively, for three and four coats of silver solder per side. The lower rate of change of permeability coefficient for cloth B with reduction in original thickness than for the 20x200, 20x250, 20x350, and 28x350 mesh cloths is probably because the irregularly shaped air passages between the surfaces of adjacent or crossing groups of wires did not deform in the same manner as the more regularly shaped air passages in the latter mesh cloths. It is noteworthy that the increase from three to four coats of solder per side of cloth B decreased the permeability coefficient about 64 percent and 75 percent, respectively, for 0 and 40 percent reduction in original thickness.

Porosity. - The effect of reduction in original thickness and of the deposition of silver solder on the porosity of cloth B is shown in figure 19. Porosity decreased approximately linearly with reduction in original thickness up to about 40 percent. The increase from three to four coats of silver solder per side lowered the porosity about 2.5 points over the same range of thicknesses.

Specific weight. - The specific weight of brazed wire cloth is of design interest and it also enters into the equation (8) for reduced tensile strength. Figure 20 shows the effect of rolling on the specific weight of monel cloth B sprayed with three and four coats of silver solder A per side and brazed. The specific weight increased almost linearly with percentage reduction in original thickness, and the actual values are intermediate between the values 0.130 for monel cloth B as woven and 0.3194 pounds per cubic inch for solid monel.

Correlation of permeability coefficient and porosity. - Inasmuch as the permeability coefficient and porosity are both functions of the reduction in original thickness, a cross plot of figures 18 and 19 yields a characteristic curve (fig. 21) relating porosity and the permeability coefficient for each wire cloth. Such characteristic curves are useful for comparing the range of application of various porous materials. Characteristic curves from other investigations of brazed wire cloth and for sintered porous stainless-steel compacts have been included in figure 21 with the curves of this investigation. The trends of brazed wire cloth B are similar to those for brazed 20x250 and 20x200 mesh wire cloth (refs. 2 and 3). For the same permeability coefficients, the porosities of brazed cloth B are higher than for the 20x250 and 20x200 mesh cloths. For the same range of porosities, brazed wire cloth had a greater range of permeability coefficient than the sintered metal compacts investigated in references 7, 8, and 9. It is of interest to note that for the same level of porosity, the permeability coefficients for the brazed wire cloth were about one order of magnitude larger than for the sintered metal compacts.

### Uniformity and Reproducibility of Brazed and Rolled Wire Cloth

Twenty pieces of wire cloth B (total area, 37.5 sq ft) were brazed and rolled under the same conditions, for fabrication into the porous combustion-chamber wall of an experimental afterburner. Typical results of tests for thickness uniformity and for air-flow uniformity for one of these pieces are presented in the following sections.

Thickness uniformity. - The uniformity of thickness and of air-flow data with a 6- by 42-inch piece of wire cloth B sprayed with three coats of silver solder per side and reduced 35 percent in original thickness is shown in figure 22. The maximum variation in thickness (fig. 22(a)) across the width was 0.0003 inch, and in the direction of rolling  $\pm 0.0003$  inch from the arithmetic mean thickness.

Air-flow uniformity. - With a constant temperature and pressure drop across the wire cloth, the weight flow of air per unit area varied -25 to +18 percent from the arithmetic mean air flow per unit of surface area (fig. 22(b)).

A check on the reproducibility of several pieces was determined from surveys of the pressure-drop parameter for constant air flow along the longitudinal center lines of the 20 strips of brazed and rolled cloth B. The pressure-drop parameter corresponding to  $(\rho V)_a \frac{\mu_0}{\mu}$  of 0.001 pound per second per square inch is plotted against distance in figure 23. The spread in pressure-drop parameter shown can generally be traced back to variations in thickness.

The number of occurrences of each value of the pressure-drop parameter (rounded off to the nearest tenth) was plotted against the respective values of the pressure-drop parameter (fig. 24) at a generalized weight flow of 0.001 pounds per second per square inch, to obtain the normal distribution curve of the pressure-drop parameter for the 20 pieces of cloth B. The pressure-drop parameter for 79 percent of processed cloth was  $3.25 \pm 0.15$ . The corresponding mean air-flow calibration curve is shown in figure 25 bracketed by dashed lines representing the extremes for the material and the tolerances for 79 percent of the processed material. From the curves of figure 25, it can be seen that the extremes in the pressure-drop parameter, and hence in the uniformity of permeability for this material, can produce local extremes in flow rate from -40 to +55 percent of the mean weight flow per unit of surface area; however, 79 percent of the surface area had local weight flows within -20 to +25 percent of the mean flow per unit area. Undoubtedly, the air-flow uniformity can be improved somewhat by controlled production techniques. One method of improving the air-flow uniformity would be to use fewer coats of silver solder and lower reductions in original thickness for applications that can utilize a permeability coefficient

higher than  $1 \times 10^{-8}$  square inch. In those applications requiring a high pressure drop across the porous wall, together with high air-flow uniformity, it might be preferable to use several layers of wire cloth with lighter applications of silver solder and lower reductions in thickness than to obtain the same pressure drop with one layer of less permeable wire cloth. Close tolerances in air-flow uniformity can also be obtained by selection where small pieces are required.

#### Effect of Oxidation on Permeability of Brazed and Rolled Wire Cloth

The limiting service temperature for brazed and rolled wire cloth is determined by the strength at elevated temperatures and by the tendency of oxides of the brazing alloy to partly plug the air passages through the cloth. The effect of oxide formation is shown in figure 26 for specimens of cloth B sprayed with three coats of silver solder A per side, brazed and reduced 35 percent in original thickness. These specimens were heated up to 7 hours in still air at temperatures from  $1060^{\circ}$  to  $1560^{\circ}$  R (7 hours of afterburning operation is approximately equivalent to about 75 to 150 hours of flying time at subsonic speeds). The ratio of the pressure-drop parameter after heating to its initial value increased almost linearly with time of heating. After 7 hours, the pressure-drop parameter had increased about 1.5, 1.0, 3.5, and 7 percent, respectively, for specimen temperatures of  $1060^{\circ}$ ,  $1260^{\circ}$ ,  $1460^{\circ}$ , and  $1560^{\circ}$  R. It is believed that with further research silver solder could be replaced by an aluminizing process or by a ceramic coating that would practically eliminate oxidation problems from the consideration of maximum service temperature for coated wire cloth.

#### Tensile Strength

Figure 27 shows the effect of rolling on the ultimate tensile strength, at room temperature, for monel cloth B sprayed with three coats of silver solder A per side and brazed. The ultimate tensile strength  $\sigma$  was about 25,000 pounds per square inch of as-woven area. Rolling to a 42.5-percent reduction in thickness increased the ultimate tensile strength 30,000 pounds per square inch. The reduced ultimate tensile strengths  $\sigma'$  were about 49,000, 64,000, and 74,000 pounds per square inch, respectively, for reductions of 0, 35, and 42.5 percent in original thickness. These tensile strengths could be increased 15 to 20 percent by using AISI type-304 stainless steel.

The ultimate tensile strengths for specimens of monel wire cloth B at equilibrium temperatures up to  $1000^{\circ}$  F ( $1460^{\circ}$  R) are shown in figure 28. The coating of silver solder contributed only slightly to the

tensile strength of the wire cloth. Cold work, caused by rolling to a 35-percent reduction in original thickness, approximately doubled the ultimate tensile strength over the as-woven condition up to temperatures of about 750° F (1210° R). For higher temperatures, the strength of the brazed and rolled sample decreased rapidly so that at a temperature of 1000° F it was only 1.23 times as strong as the woven sample. The reduced ultimate tensile strength of the brazed and rolled cloth was slightly greater than for the as-woven condition up to about 750° F (1210° R), at which point the reduced tensile strength of the brazed and rolled cloth started to decrease more rapidly than that for the as-woven cloth. For the as-woven, brazed, and brazed-and-rolled wire cloth, the reduced tensile strengths at 1000° F (1460° R) were, respectively, about 43,000, 31,000, and 31,000 pounds per square inch. The corresponding reduced tensile strengths at room temperature were about 56,000, 49,500, and 64,000 pounds per square inch.

Several specimens from one piece of monel wire cloth B were sprayed with three coats of silver solder per side, brazed, and reduced 42.5 percent in original thickness; they were then heated 7 hours in still air. The ultimate tensile strengths at room temperature, after heating at elevated temperatures, are shown in the following table:

Temperature of specimen		Ultimate tensile strength, $\sigma$ , psi	Reduced ultimate tensile strength, $\sigma'$ , psi
°F	°R		
75	535	54,750	74,100
800	1260	52,100	70,500
1000	1460	42,900	58,050
1100	1560	47,050	63,700

The annealing resulting from the 7-hour exposure at 1000° and 1100° F caused corresponding reductions of about 22 and 14 percent in the ultimate tensile strength.

#### Fabrication Techniques and Operational Experience

The twenty 6- by 45-inch pieces of monel cloth B sprayed with three coats of silver solder A per side that were brazed and reduced 35 percent in original thickness were fabricated into the porous combustion-chamber wall of an experimental transpiration-cooled afterburner (fig. 29).

Each piece of cloth was trimmed and formed into tapered longitudinal channels 3.5 to 4 inches in width by 41 inches in length. The channels were attached to the structural cooling shroud by means of stainless-steel angle strips (fig. 30) that were spot-welded to the wire cloth channels. In operation, the pressure drop across the wire cloth caused the channels to bulge inward in a catenary curve. This construction successfully withstood pressure differences across the cloth as high as 11 inches of mercury at cloth temperatures up to 1000° F (1460° R). The porous wall of wire cloth withstood repeated engine and afterburner starts and the usual pressure amplitudes and frequencies of "normal steady-state" afterburning. Figure 31 shows the appearance of the cloth channels at the conclusion of an investigation of the cooling performance, during which 4 hours and 10 minutes of afterburning time was accumulated at fuel-air ratios between approximately 0.030 and 0.050. The wire-cloth combustion-chamber wall was still in serviceable condition. The lighter-colored areas of wire cloth were almost like new, and the darker patches showed the effects of gradual oxidation of the silver solder.

Cold working, caused by rolling to a 35-percent reduction in original thickness and by the 1/8-inch-inside-radius bend along each side of the channels, caused some of the warp wires to crack at the bend. These cracks were discovered after the first 15 minutes of afterburning and were successfully repaired by silver soldering.

#### SUMMARY OF RESULTS

An experimental investigation was made of the permeability and air-flow uniformity of wire filter cloth for application of transpiration cooling to afterburner combustion-chamber walls. The permeability coefficients for five meshes of wire filter cloth in the as-woven condition and for one mesh after brazing and rolling were as follows:

Cloth designation	Mesh	Condition of cloth	Reduction in original thickness, percent	Permeability coefficient, sq in.
A	20x57	As woven	0	$3.82 \times 10^{-7}$
B	21x70	As woven	0	$1.64 \times 10^{-7}$
C	21x81	As woven	0	$1.26 \times 10^{-7}$
D	20x85	As woven	0	$6.46 \times 10^{-8}$
E	36x38	As woven	0	$9.88 \times 10^{-8}$
B	21x70	Brazed, 3 coats of silver solder per side	0	$7.94 \times 10^{-8}$
B	21x70	Brazed, 3 coats of silver solder per side	40	$3.98 \times 10^{-9}$
B	21x70	Brazed, 4 coats of silver solder per side	0	$2.88 \times 10^{-8}$
B	21x70	Brazed, 4 coats of silver solder per side	40	$10^{-9}$

The table indicates that permeability coefficients in the desired range of about  $10^{-8}$  to  $10^{-9}$  square inch for transpiration cooling of afterburner combustion-chamber walls can be obtained by combined brazing and rolling. Increases from 64 to 75 percent in the permeability coefficient of cloth B were obtained by an increase from three to four coats of silver solder per side.

The following results were obtained from monel wire cloth B that was brazed after having been sprayed with three coats of silver solder per side:

Thickness variations due to rolling tolerances were about  $\pm 0.0003$  inch. These variations in thickness, in combination with initial non-uniformities in the air-flow passages through the wire cloth as woven, were largely responsible for localized variations in air-flow uniformity within a given piece of brazed and rolled wire cloth. Over a total area of 37.5 square feet of cloth rolled to a 35-percent reduction in original thickness, 79 percent of the cloth had air flows -20 to +25 percent of the mean air flow per unit area; however, there were localized extreme variations of -40 to +55 percent of the mean air flow per unit area.

The effect of oxidation of the silver solder on the pressure-square difference per unit thickness  $\Delta(p^2)/\tau$ , was found to vary almost linearly with time of heating in still air. The increases in  $\Delta(p^2)/\tau$  after 7 hours at  $1260^\circ$ ,  $1460^\circ$ , and  $1560^\circ$  R were 1, 3.5, and 7 percent, respectively.

The effect of rolling on strength was such that a decrease of 42.5 percent in original thickness increased the ultimate tensile strength 30,000 pounds per square inch above the ultimate tensile strength of 25,000 pounds per square inch for the unrolled cloth. The short-time ultimate tensile strength at a temperature of  $1000^\circ$  F ( $1460^\circ$  R), for cloth rolled to a 35-percent reduction in original thickness, was about 23,000 pounds per square inch.

An experimental afterburner having a porous combustion-chamber wall fabricated from brazed and rolled wire cloth was still in serviceable condition after 4 hours and 10 minutes of afterburner operation at fuel-air ratios from about 0.030 to 0.050.

Lewis Flight Propulsion Laboratory  
National Advisory Committee for Aeronautics  
Cleveland, Ohio, August 27, 1953

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## APPENDIX - SYMBOLS

The following symbols are used in this report:

A	surface area, sq in.
a	cross-sectional area, sq in.
$C_1$	$ag/2\beta$ , $\text{sec}^{-2}$
$C_2$	$g/2\beta R$ , $(\text{in.})(^\circ\text{R})/\text{sec}^2$
F	rupture force, lb
f	porosity, dimensionless
$f_1, f_2$	functions
g	gravitational constant, $\text{in.}/\text{sec}^2$
K	permeability coefficient, sq in.
L	length, in.
p	static pressure, lb/sq in. abs
$\Delta(p^2)$	$p_1^2 - p_2^2$ , $\text{lb}^2/\text{in.}^4$
R	gas constant for air, $\text{in.}/^\circ\text{R}$
T	static temperature of air, $^\circ\text{R}$
V	velocity, $\text{in.}/\text{sec}$
W	weight, lb
x	direction perpendicular to rolling or direction of warp wires
y	direction parallel to rolling, or direction of woof wire
$\alpha$	viscous resistance coefficient, $\text{in.}^{-2}$
$\beta$	inertial resistance coefficient, $\text{in.}^{-1}$
$\mu$	absolute viscosity of air, $(\text{lb})(\text{sec})/\text{sq in.}$
$\rho$	weight density of air or specific weight of specimen, $\text{lb}/\text{cu in.}$

- $\sigma$  tensile strength, psi  
 $\sigma'$  reduced tensile strength, psi  
 $\tau$  thickness of porous material, in.

## Subscripts:

- a cooling air  
b braze alloy  
c cloth as woven  
w alloy in wire cloth as woven  
o at NACA standard temperature, 518.4° R  
t total  
1 high-pressure side of porous material  
2 low-pressure side of porous material

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2. Eckert, E. R. G., Kinsler, Martin R., and Cochran, Reeves P.: Wire Cloth as Porous Material for Transpiration-Cooled Walls. NACA RM E51H23, 1951.
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8. Grinthal, Robert D., Bradbury, John C., Mott, Lambert H., and Comstock, Gregory J.: Navy Project for Investigation of Porous Material from Spherical Metal Powders. Bi-Monthly Prog. Rep. No. 6, Aug. 1, 1951 - Sept. 30, 1951, Ind. Fellowship Div., Powder Metallurgy Lab., Stevens Inst. Tech., Hoboken (N. J.). (BuAer Contract NOas-51-185-c.)
9. Hill, M., Reen, O. W., Vermilyea, D. A., and Lenel, F. V.: Production of Porous Metal Compacts. Bi-Monthly Prog. Rep. No. 3, Powder Metallurgy Lab., Rensselaer Polytechnic Inst., Troy (N. Y.), Oct. 6, 1950. (Navy Res. Contract Noa(s) 11022.)

TABLE I. - SPECIFICATIONS FOR SIX MESHES OF WIRE CLOTH

Cloth designation	Mesh	Lengthwise wires, warp			Crosswise wires, woof			Average thickness as woven, in.	Permeability coefficient (as woven), sq in.	Specific weight, lb/cu in.	Wire alloy
		Wires per group	Total wires per inch	Wire diameter, in.	Wires per group	Total wires per inch	Wire diameter, in.				
A	<sup>b</sup> 20x57	<sup>a</sup> 4	81	0.007	<sup>d</sup> 4	227	0.007	0.0565	$5.82 \times 10^{-7}$	0.118	Monel
B	<sup>b</sup> 21x70	<sup>a</sup> 4	84	.0065	<sup>d</sup> 4	278	.007	.0405	$1.64 \times 10^{-7}$	.131	Monel
C	<sup>b</sup> 21x81	<sup>c</sup> 5	63	.008	<sup>d</sup> 4	324	.007	.0448	$1.26 \times 10^{-7}$	.143	Monel
D	<sup>b</sup> 20x85	<sup>a</sup> 4	81	.007	<sup>d</sup> 4	341	.007	.0435	$8.46 \times 10^{-8}$	.138	Nickel
E	<sup>e</sup> 36x58	<sup>f</sup> 5	180	.007	<sup>f</sup> 8	303	.005	.0540	$9.88 \times 10^{-8}$	.124	AISI type 304 stainless steel
-	<sup>b, g</sup> 20x200	1	20	.011	1	200	.005	.0307	$5.01 \times 10^{-7}$	-----	AISI type 304 stainless steel

NACA

<sup>a</sup>Average determined from wire count of actual samples.

<sup>b</sup>Twilled Dutch weave.

<sup>c</sup>Wires are woven side by side in a flat group.

<sup>d</sup>Each group of wires is loosely twisted.

<sup>e</sup>Twilled weave.

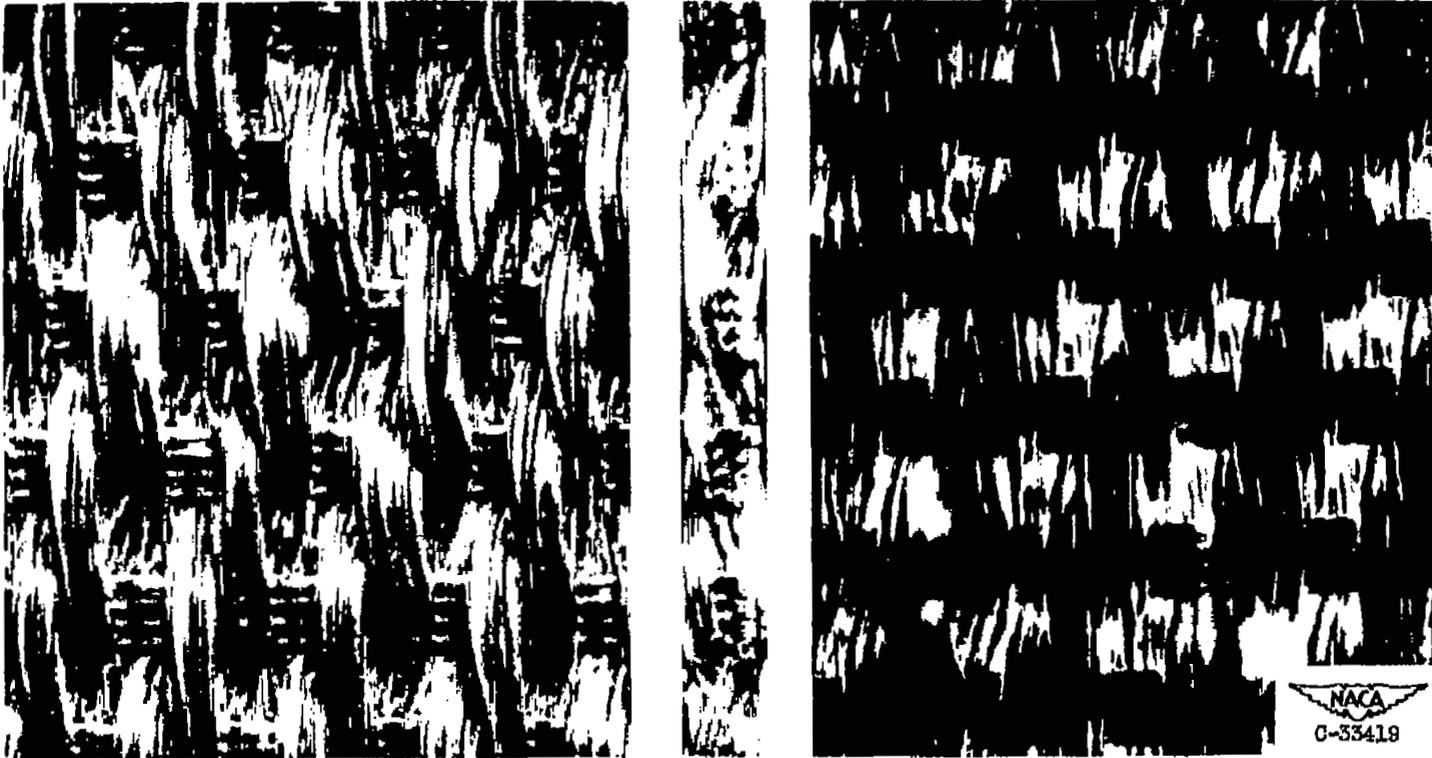
<sup>f</sup>Groups of wires are mostly flat with some cross-over and bunching.

<sup>g</sup>Data from reference 2.

TABLE II. - SILVER SOLDERS INVESTIGATED FOR BRAZING WIRE CLOTH

Solder	Composition, percent				Solidus, °F	Liquidus, °F	Brazing range, °F	Specific weight, lb/cu in.
	Silver	Copper	Zinc	Others				
A	49-51	14.5-16.5	14.5-18.5	Cadmium, 17-19	1160	1175	1175-1400	0.343
B	49-51	14.5-16.5	13.5-17.5	Cadmium, 15-17 Nickel, 2.5-3.5	1195	1270	1270-1500	-----
C	59-61	24-26	13-17	-----	1260	1325	1325-1550	-----
D	64-66	19-21	13-17	-----	1280	1325	1325-1550	-----
E	71-73	27-29	-----	-----	1435	1435	1435-1800	-----



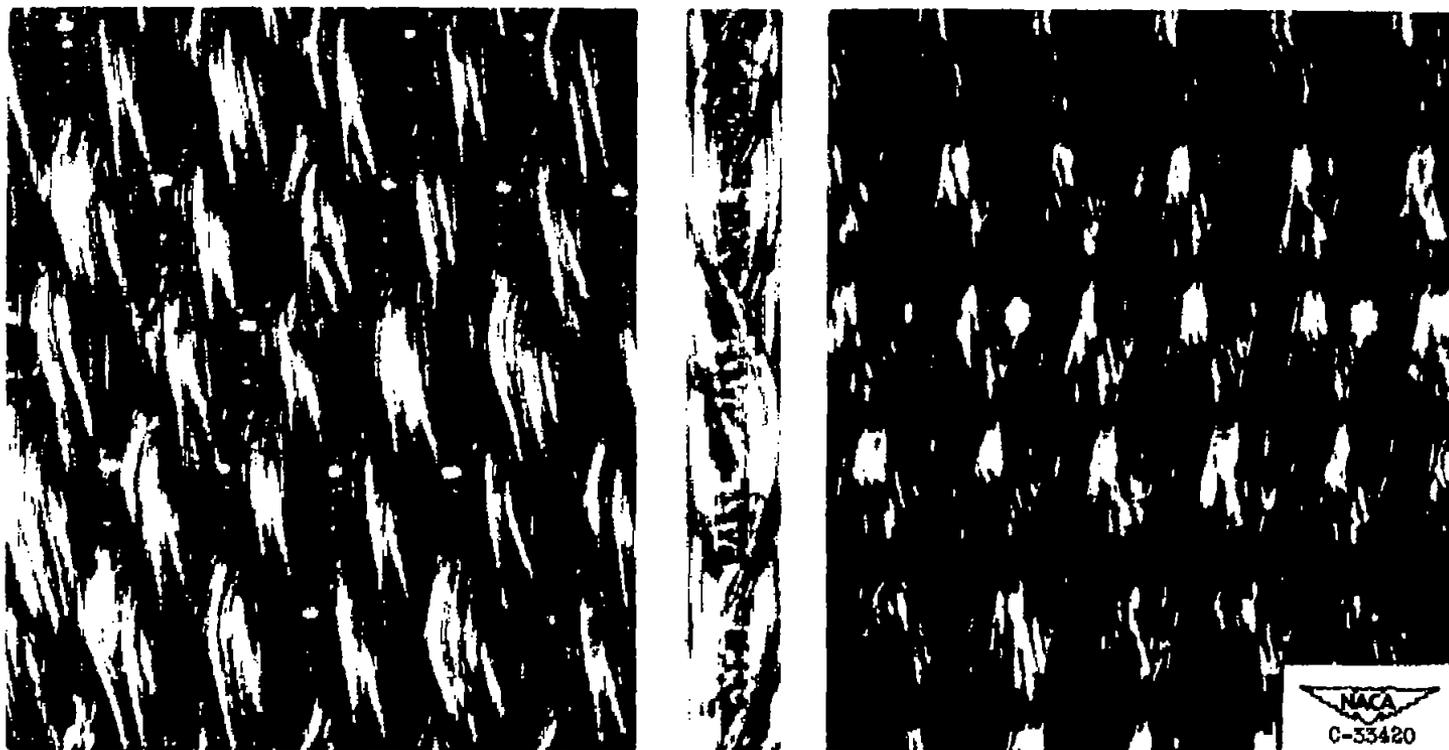


(a) Front view, front lighted.

(b) Side view.

(c) Front view, back lighted.

Figure 1. - Cloth A as woven. Average thickness, 0.0363 inch; X15.

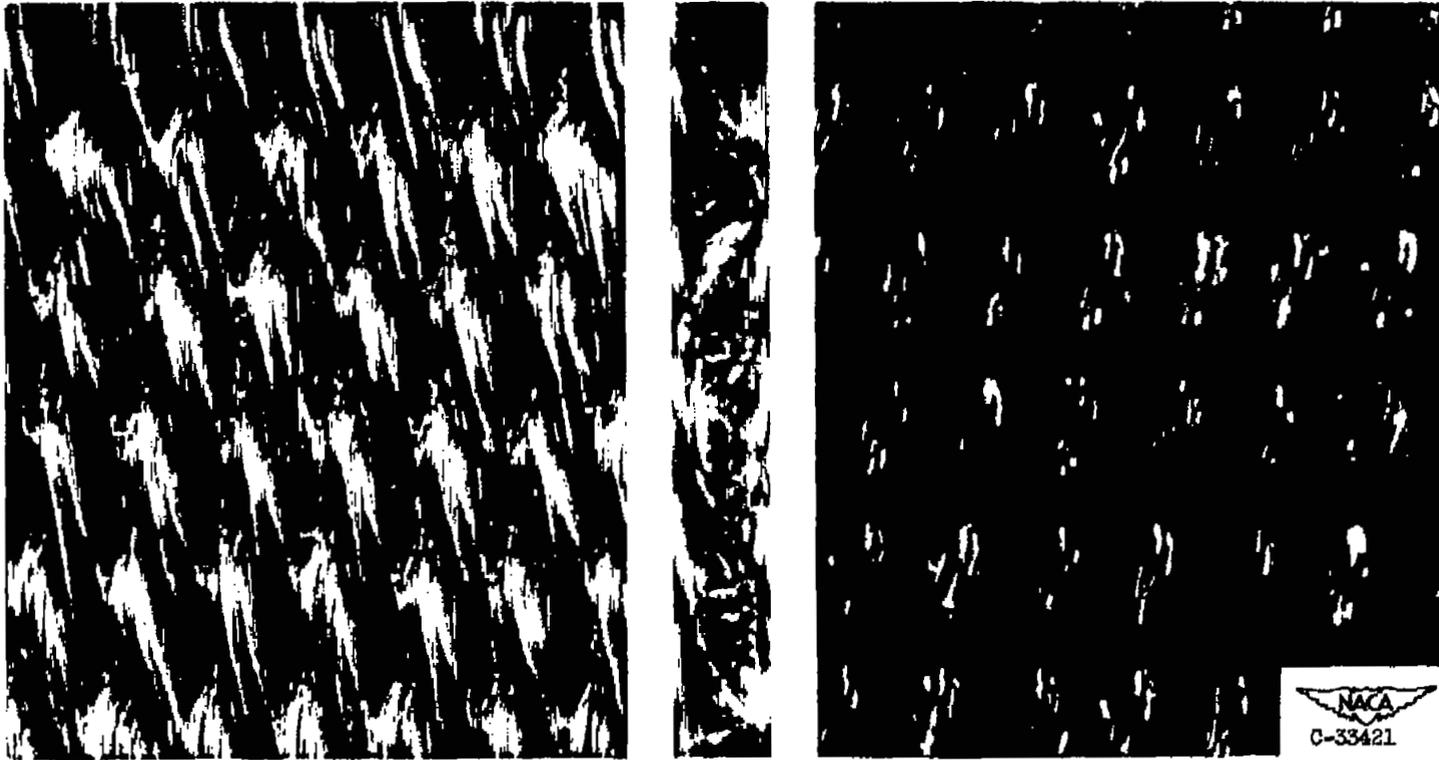


(a) Front view, front lighted.

(b) Side view.

(c) Front view, back lighted.

Figure 2. - Cloth B as woven. Average thickness, 0.0405 inch; X15.



(a) Front view, front lighted.

(b) Side view.

(c) Front view, back lighted.

Figure 3. - Cloth C as woven. Average thickness, 0.0445 inch; X15.

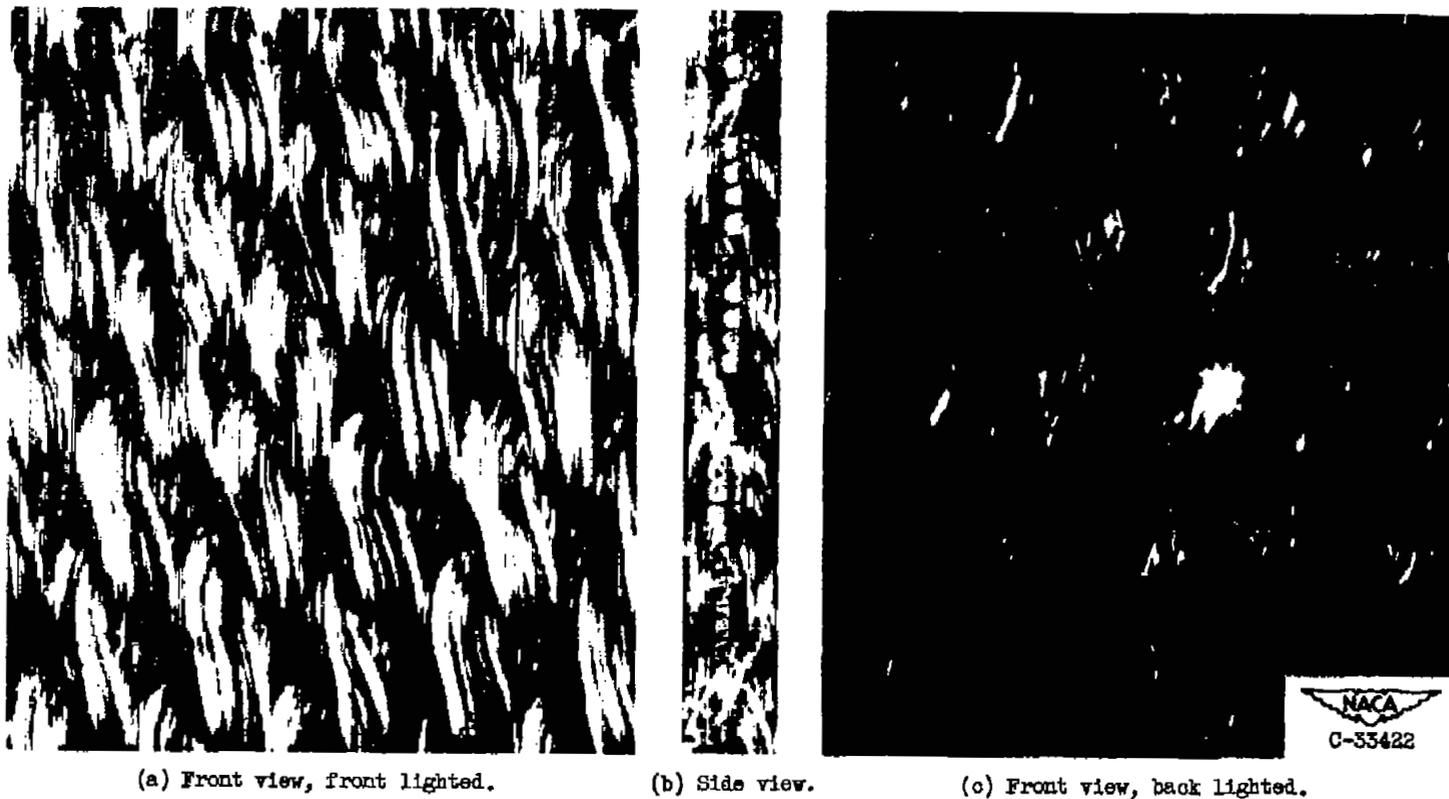
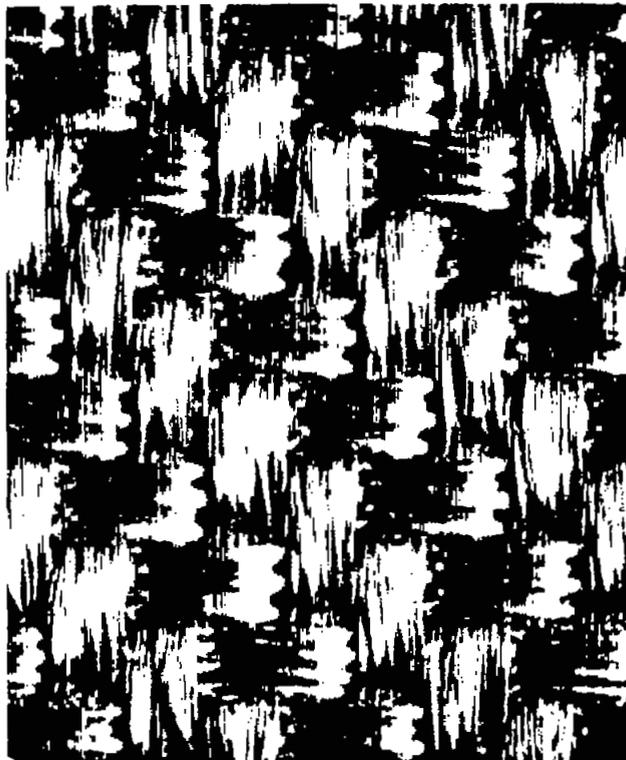


Figure 4. - Cloth D as woven. Average thickness, 0.0435 inch; X15.



(b) Top view.



(a) Front view, front lighted.



(c) Side view.



(d) Front view, back lighted.

Figure 5. - Cloth E as woven. Average thickness, 0.0340 inch; X15.

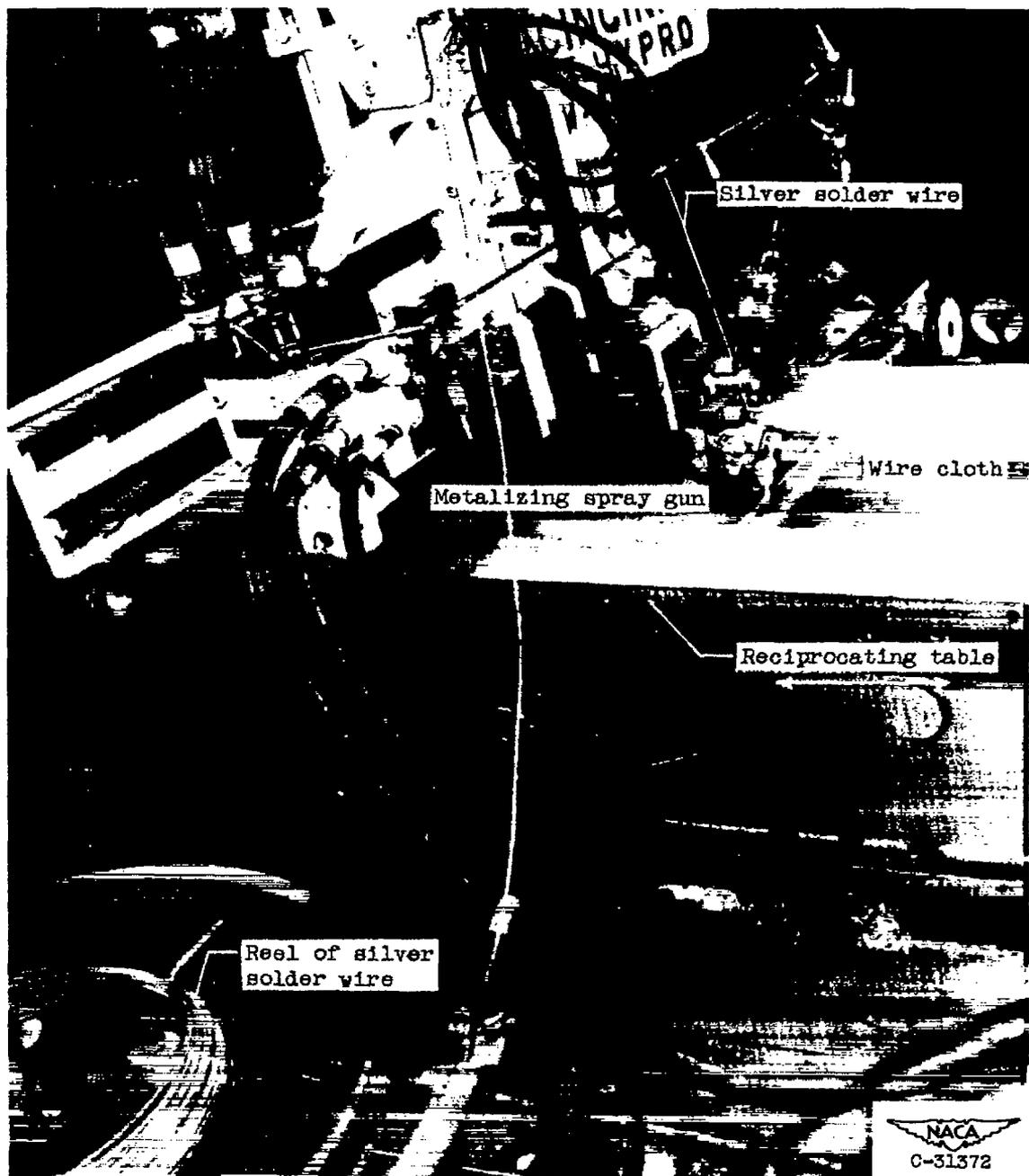


Figure 6. - Setup used for spraying wire cloth with silver solder.

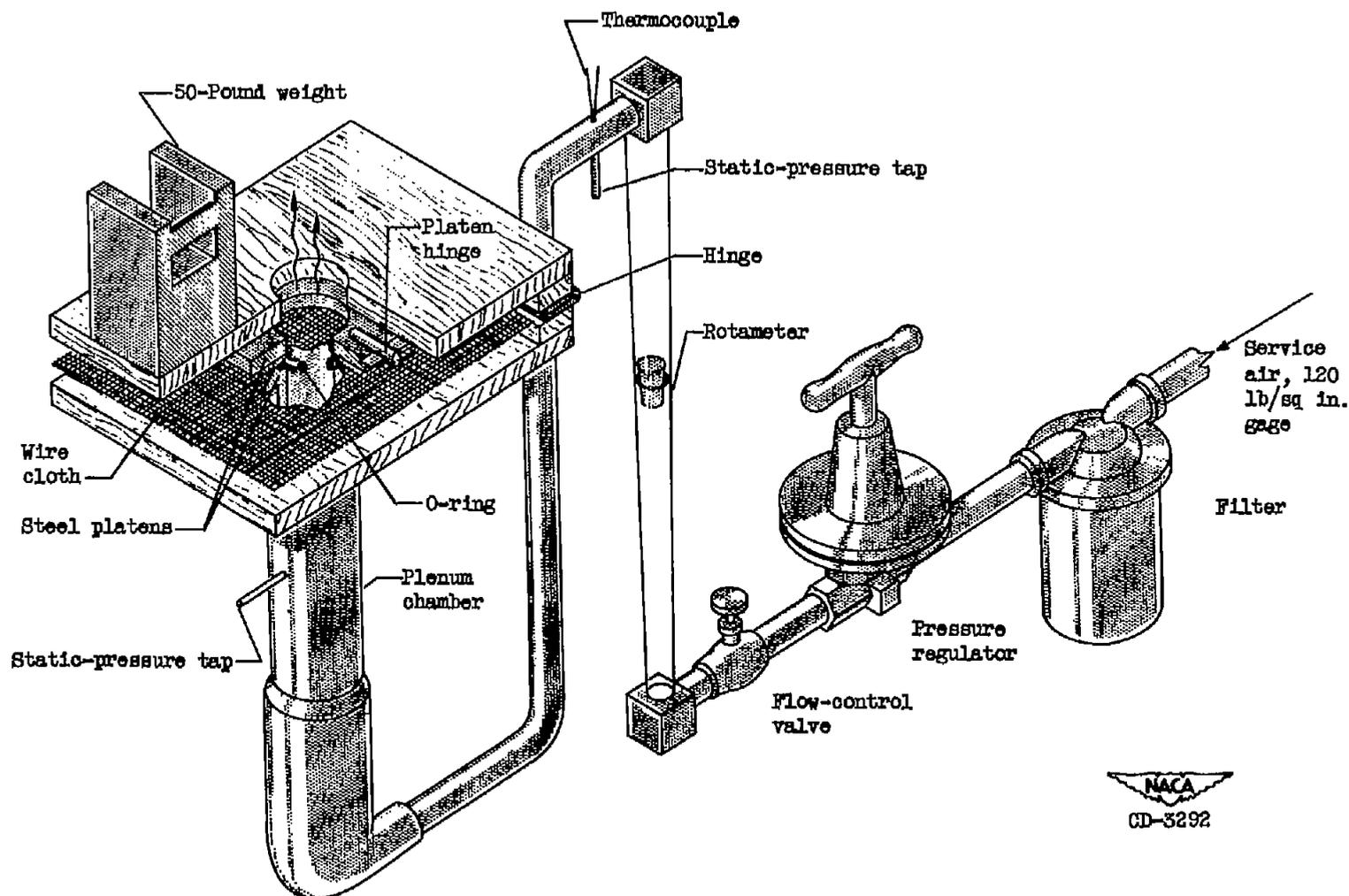


Figure 7. - Apparatus for measuring air-flow pressure drop.

	Cloth designation	Mesh of wire cloth	Original thickness of cloth as woven, $\tau$ , in.	Permeability coefficient, sq in.
○	E	36x38	0.0340	$9.88 \times 10^{-8}$
□	A	20x57	.0363	$3.82 \times 10^{-7}$
◇	B	21x70	.0405	$1.64 \times 10^{-7}$
△	C	21x81	.0445	$1.26 \times 10^{-7}$
▽	D	20x85	.0435	$6.46 \times 10^{-8}$
---		20x200	.0307	$5.01 \times 10^{-7}$
		(ref. 3)		

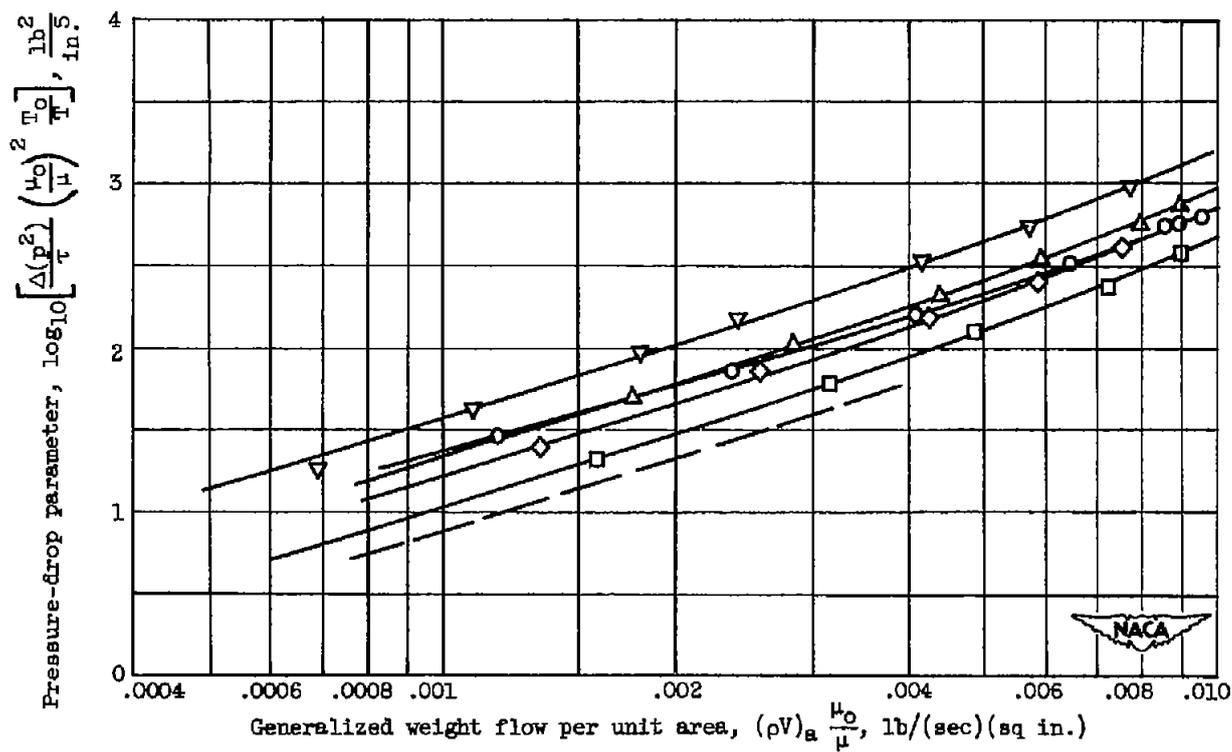
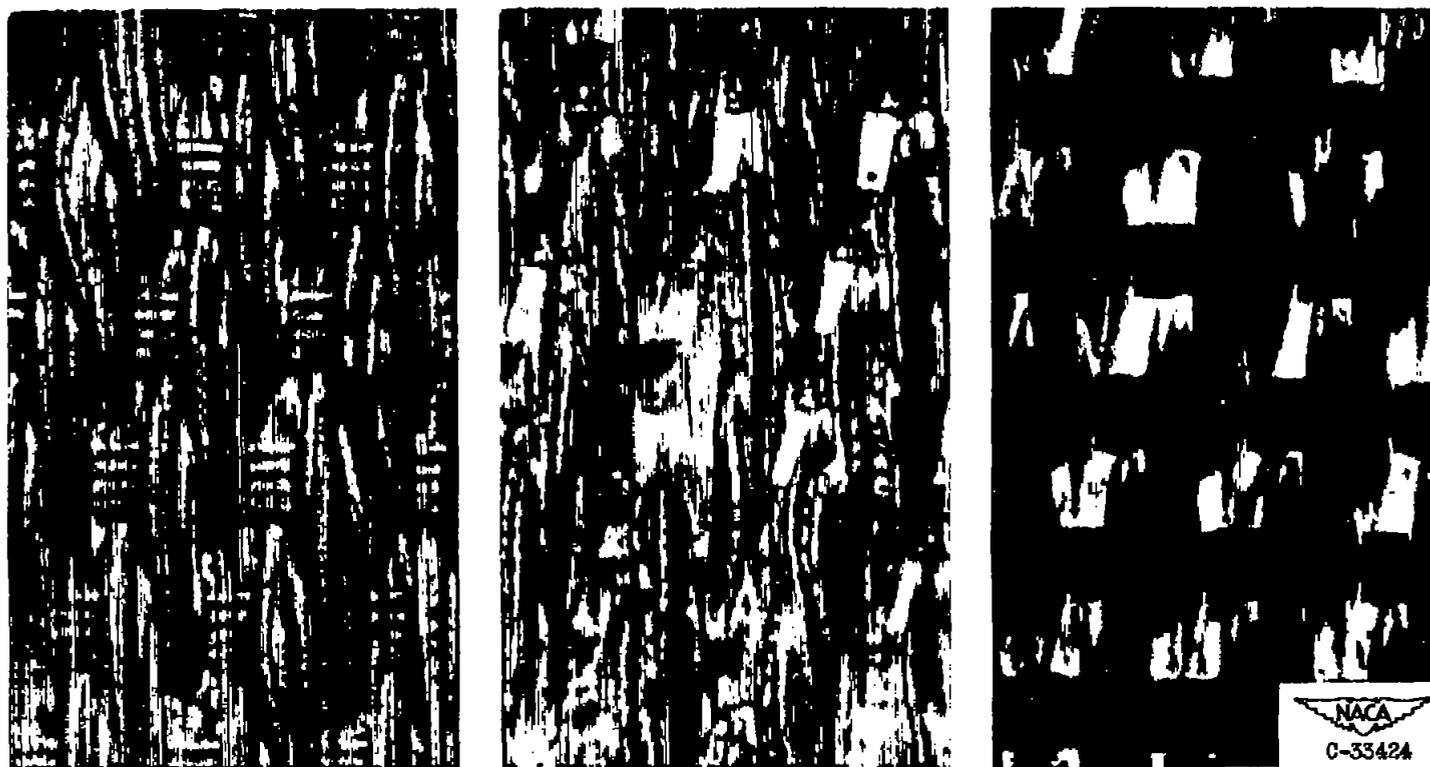


Figure 8. - Correlation of air-flow data reduced to standard temperature for several weaves and meshes of wire cloth as woven.

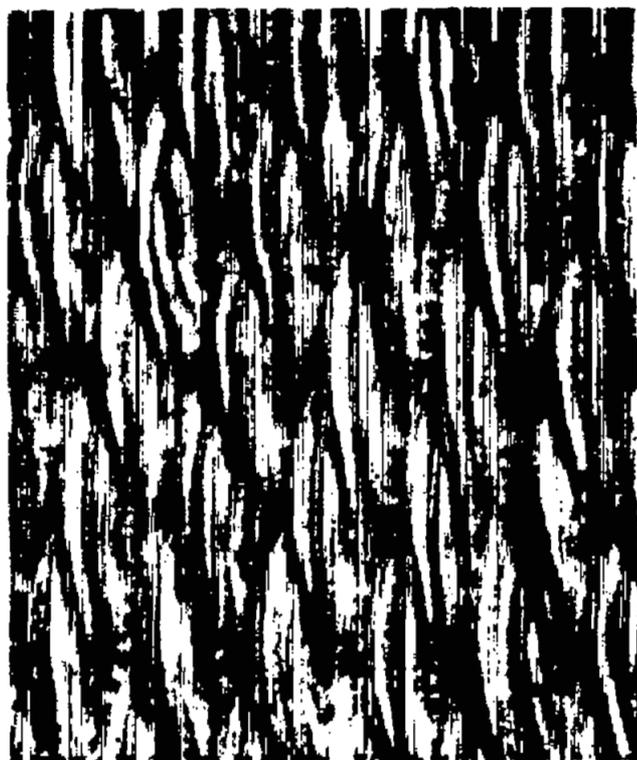


(a) Front Lighted.

(b) Lighted both sides.

(c) Back lighted.

Figure 9. - Front view of cloth A sprayed with two coats of silver solder A per side and brazed. Average thickness brazed, 0.0380 inch; X15.

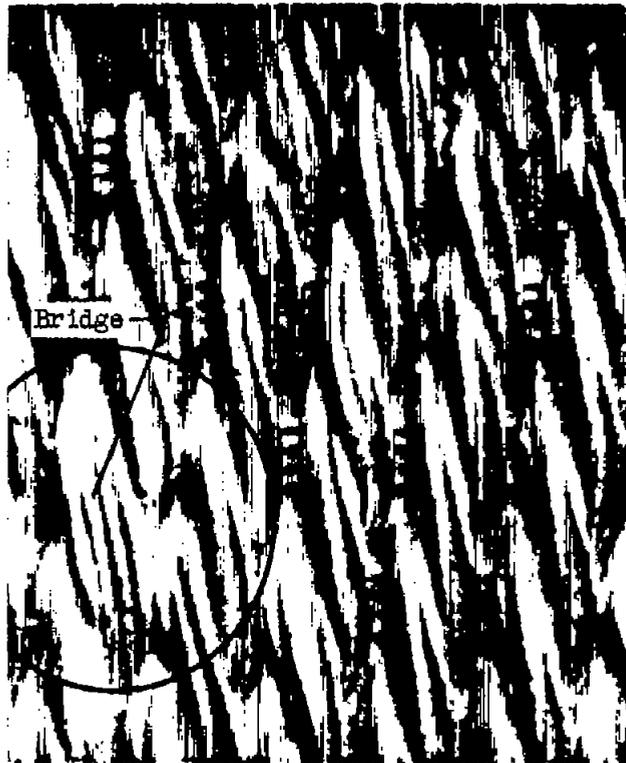


(a) Front lighted.

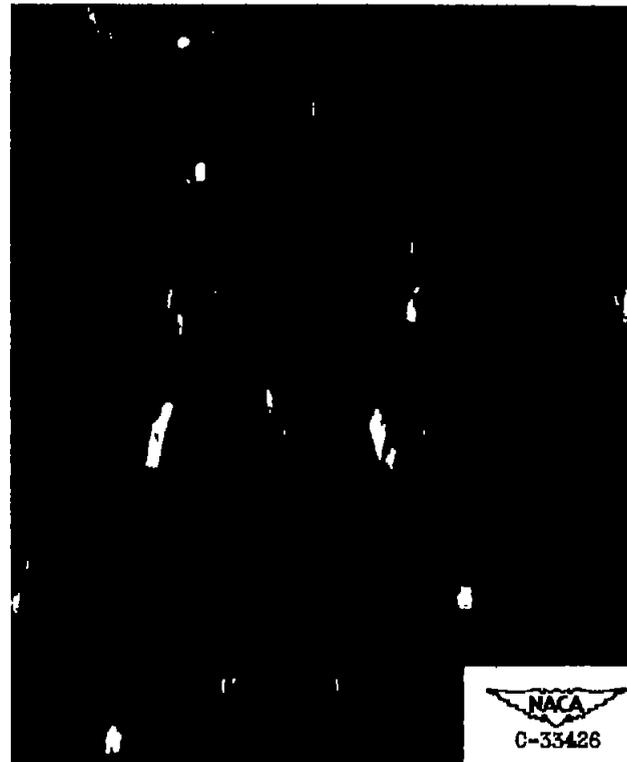


(b) Back lighted.

Figure 10. - Front view of cloth B sprayed with three coats of silver solder A per side and brazed. Average thickness brazed, 0.0421 inch; X15.



(a) Front lighted.



(b) Back lighted.

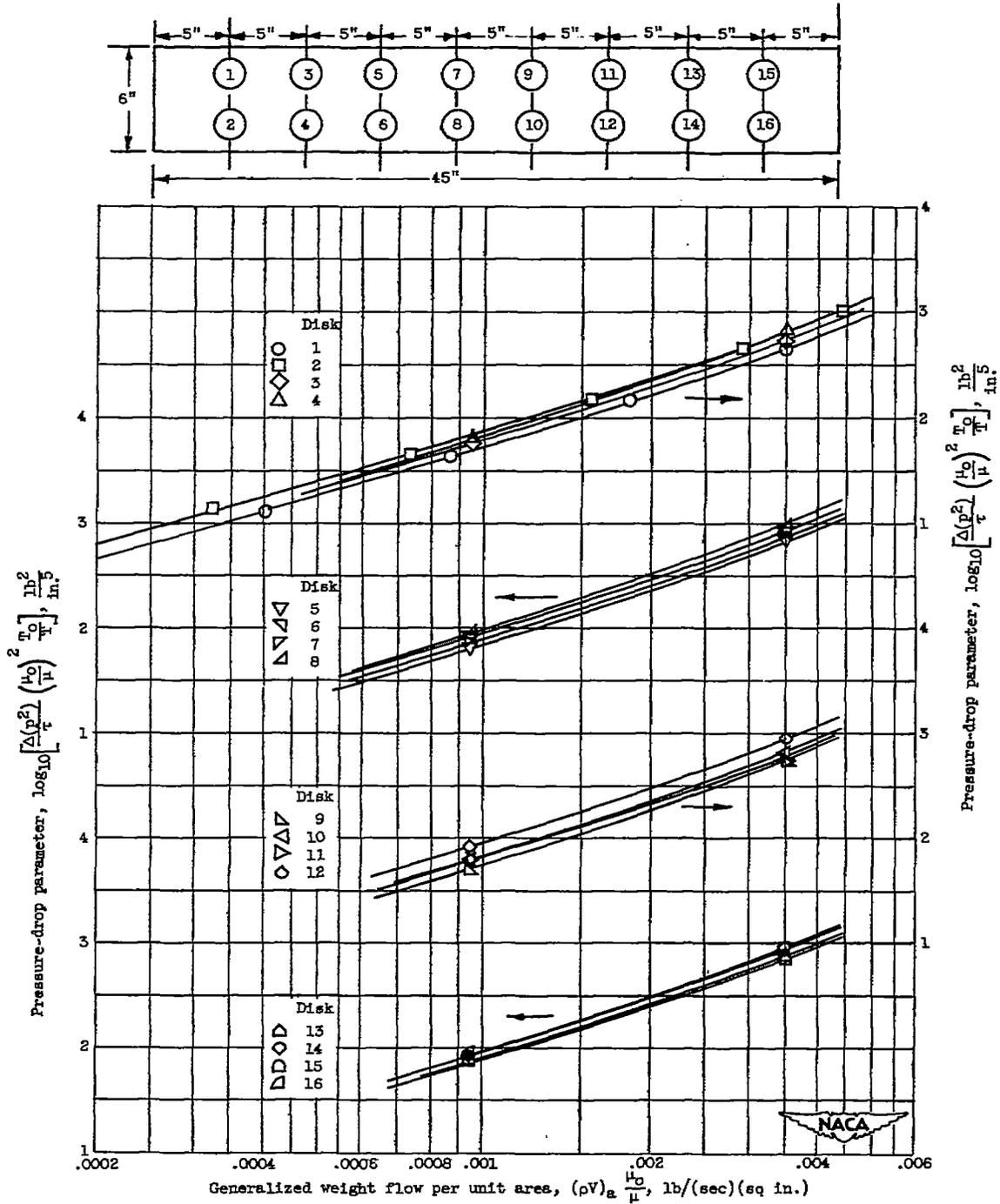
Figure 11. - Front view of cloth B sprayed with four coats of silver solder A per side and brazed. Average thickness brazed, 0.0430 inch; X15.



Figure 12. - Front view of cloth C sprayed with three coats of silver solder A on one side and brazed. Average thickness brazed, 0.045 inch; X15.

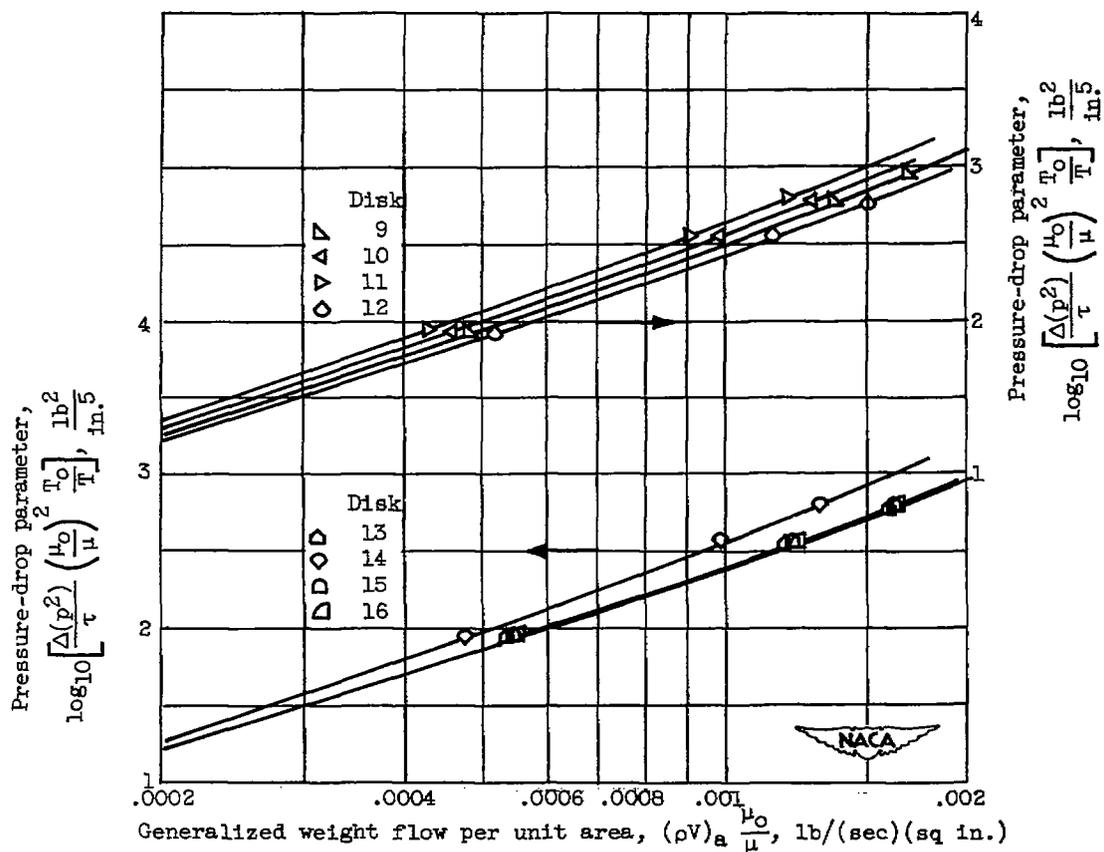
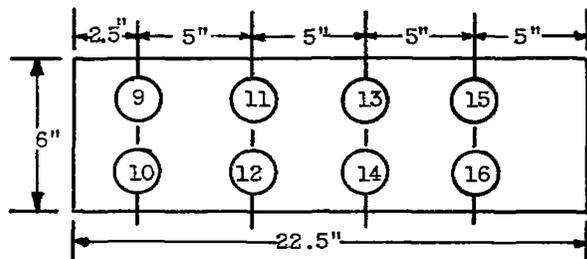
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CZ-5 back



(a) Sprayed with three coats of silver solder A per side.

Figure 13. - Uniformity of air flow through brazed cloth B. Unrolled.



(b) Sprayed with four coats of silver solder A per side.

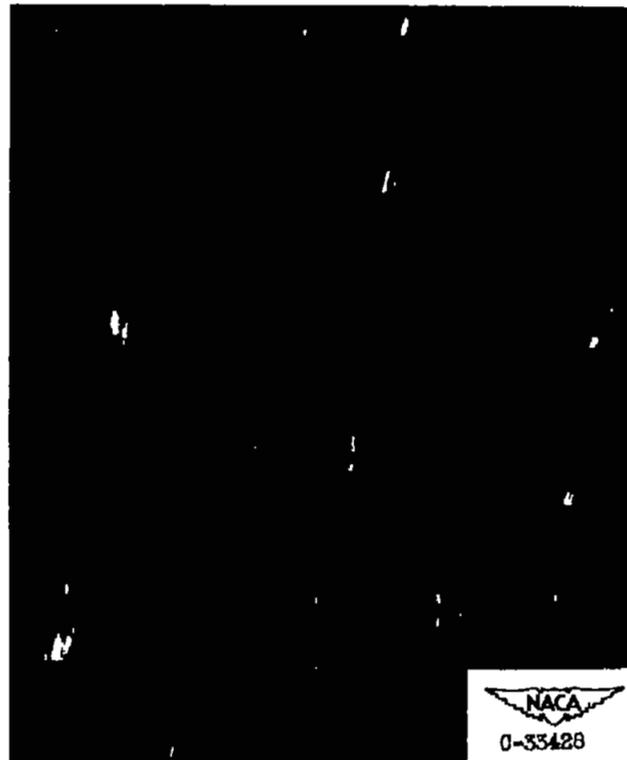
Figure 13. - Concluded. Uniformity of air flow through brazed cloth B. Unrolled.



(a) Front lighted.



(b) Side view.



(c) Back lighted.

Figure 14. - Cloth B sprayed with three coats of silver solder A per side, brazed, and rolled to a 35-percent reduction in original thickness. Final thickness, 0.0274 inch; X15.

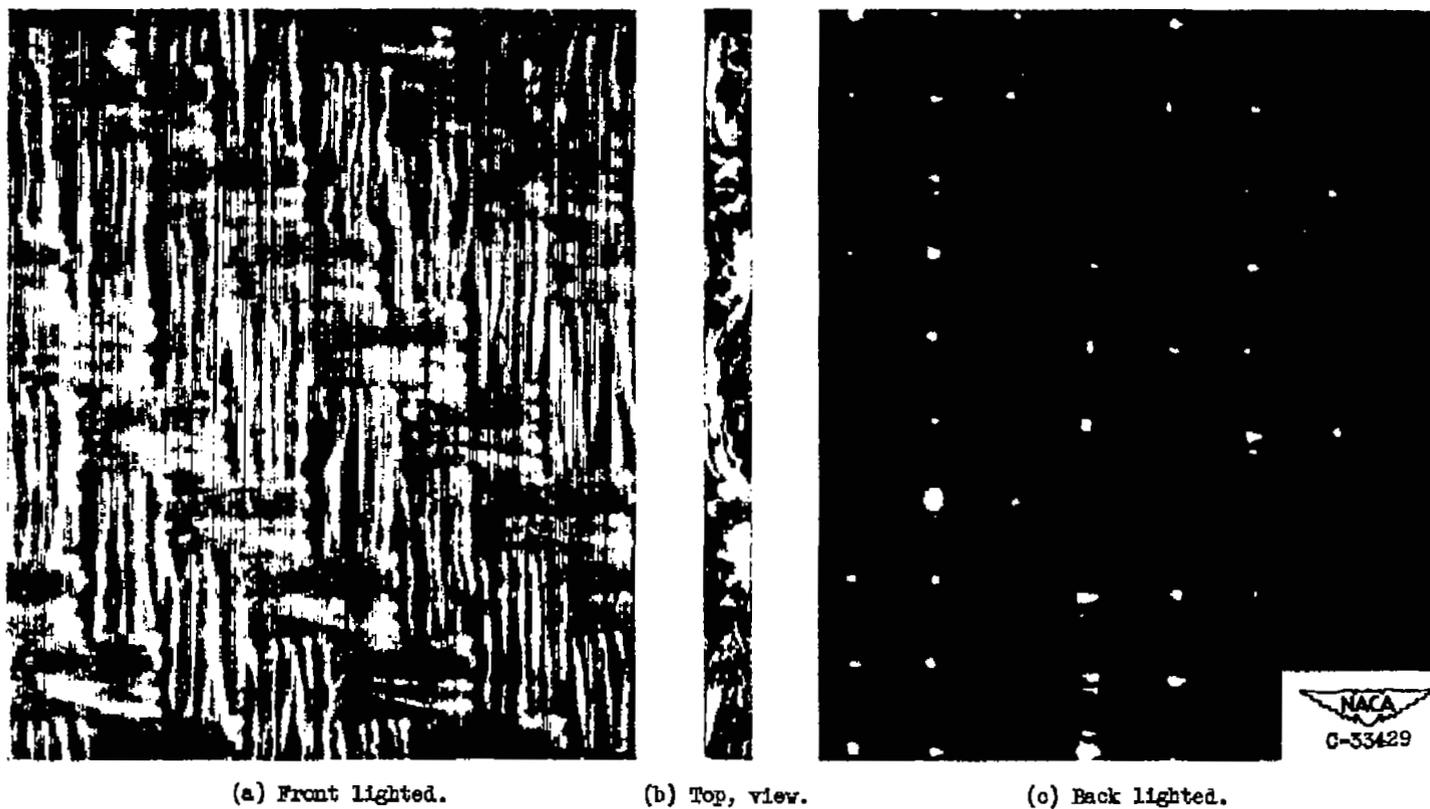
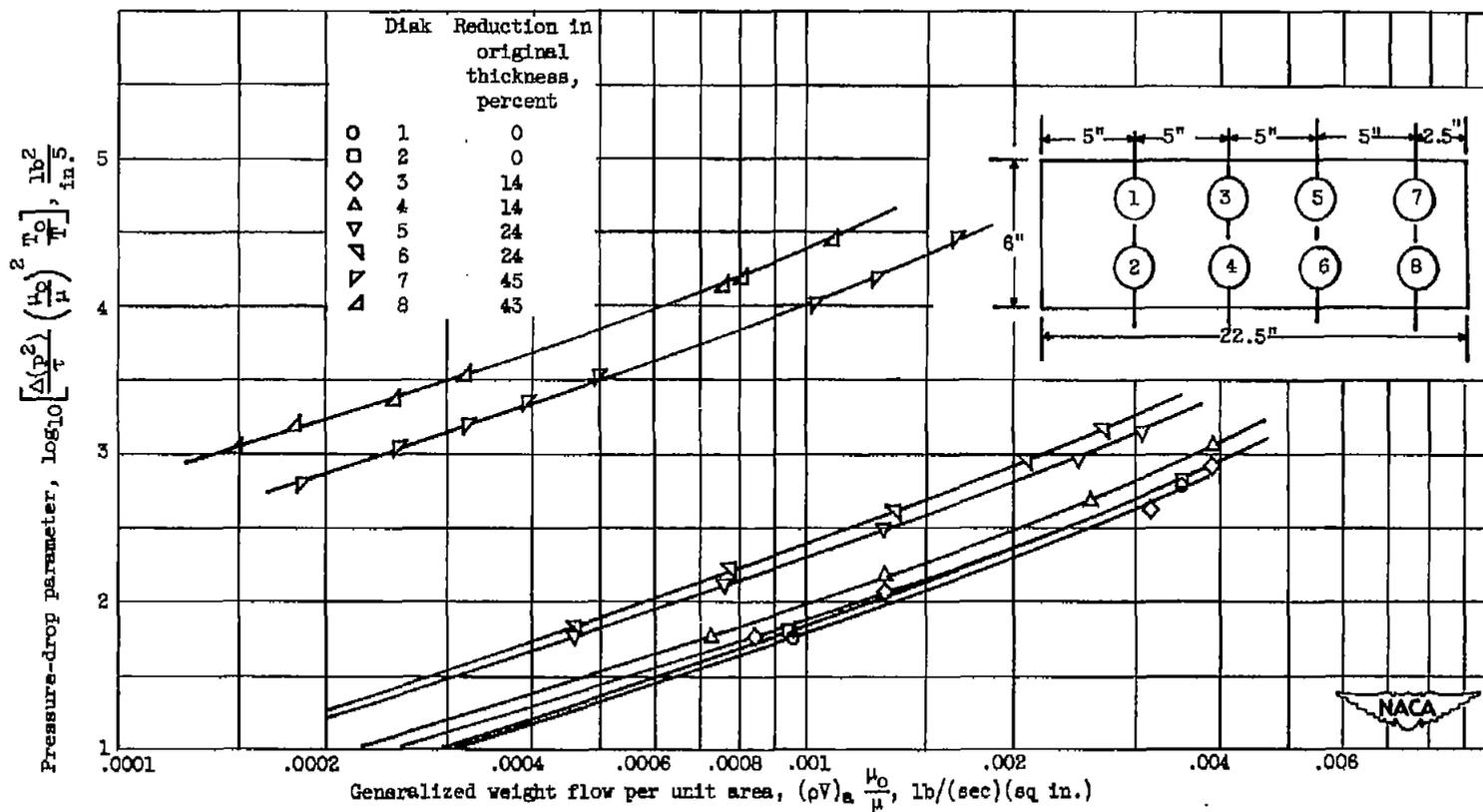


Figure 15. - Cloth E sprayed with one coat of silver solder B per side, brazed, and rolled to a 48-percent reduction in original thickness. Final thickness, 0.0187 inch; X15.



(a) Sprayed with three coats of silver solder A per side.

Figure 16. - Correlation of air-flow data reduced to standard temperature for cloth B brazed and rolled.

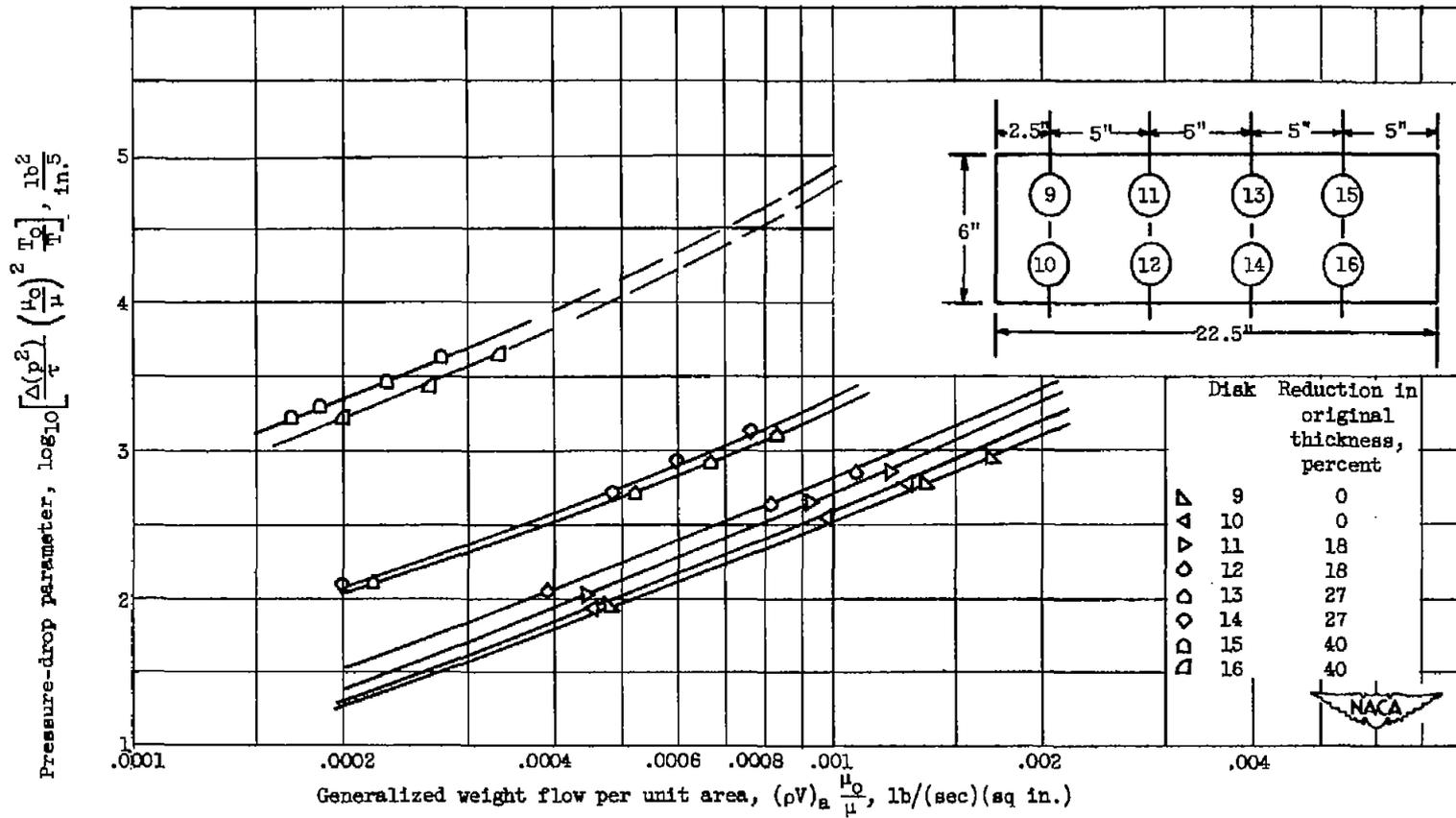


Figure 16. - Concluded. Correlation of air-flow data reduced to standard temperature for cloth B brazed and rolled.

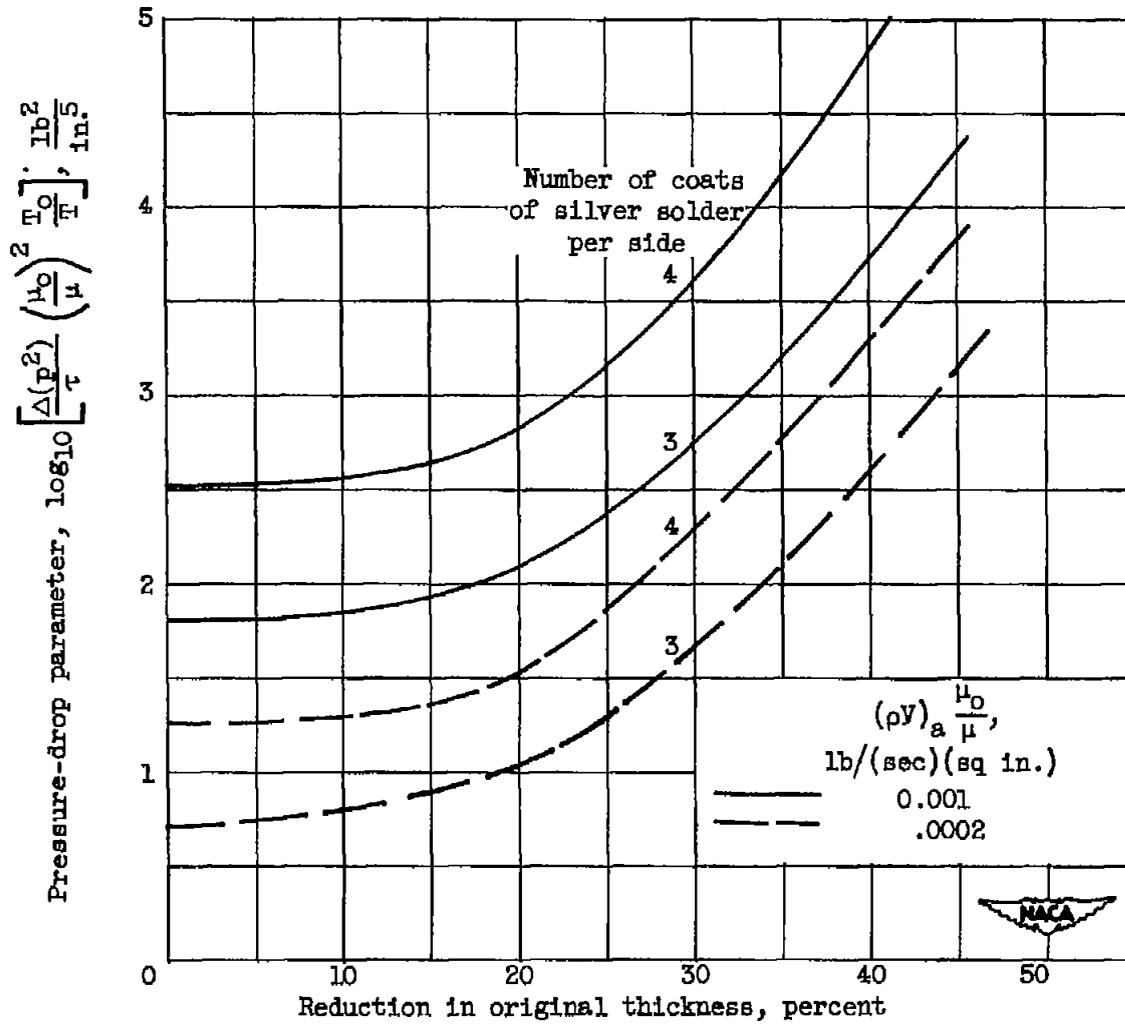


Figure 17. - Effect of rolling on pressure-drop parameter of wire cloth B sprayed with several coats of silver solder A and brazed. Original thickness after brazing, 0.042 to 0.043 inch.

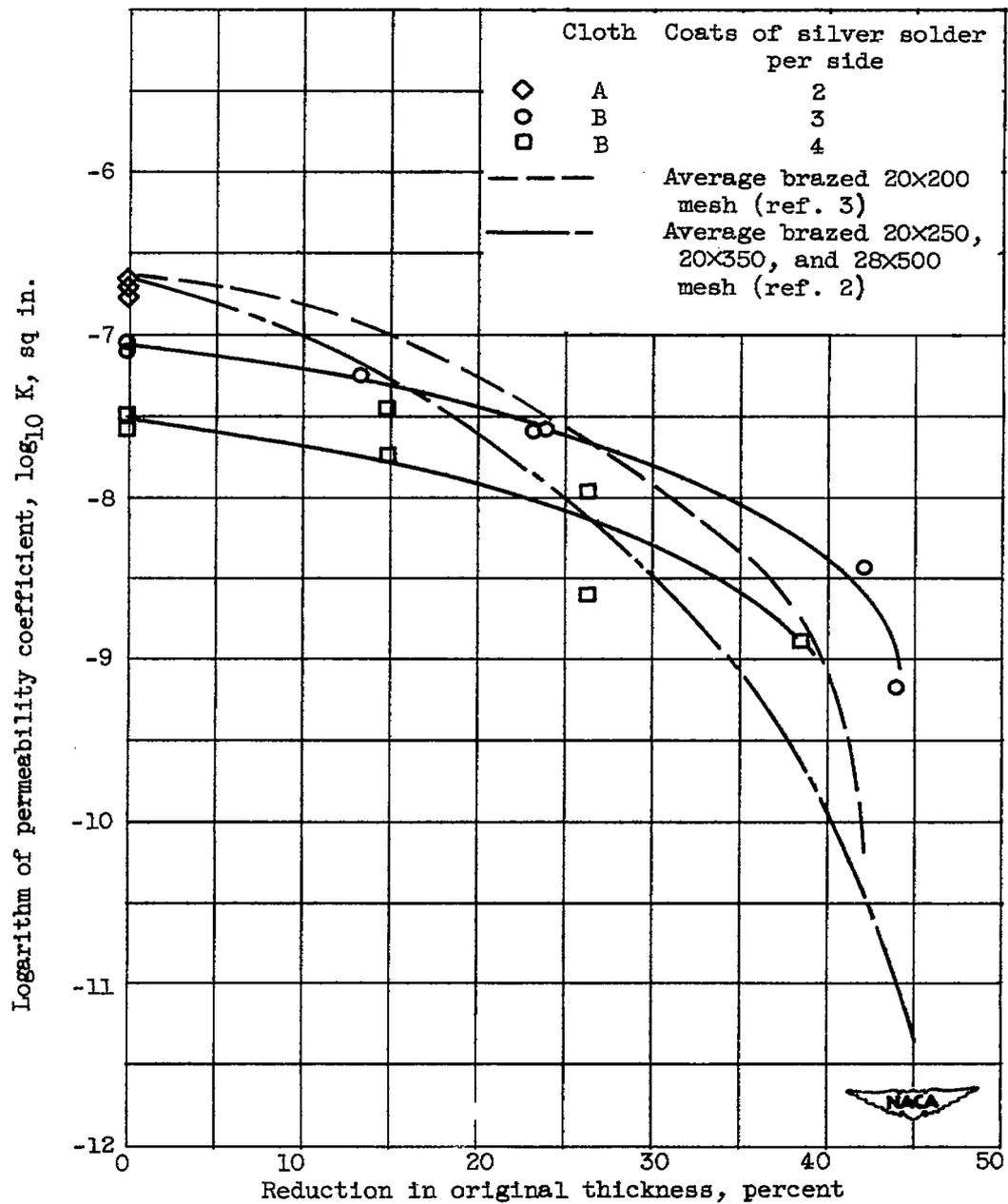


Figure 18. - Effect of rolling and deposition of brazing alloy on permeability coefficients of several meshes of wire cloth.

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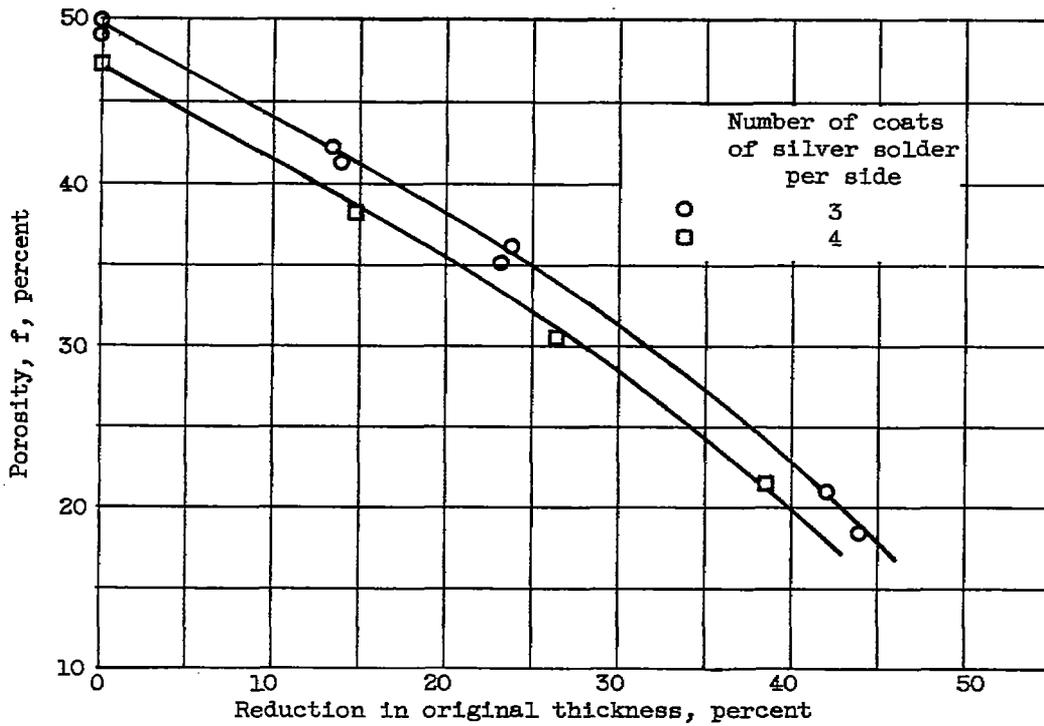


Figure 19. - Effect of rolling and deposition of silver solder A on porosity of wire cloth B.

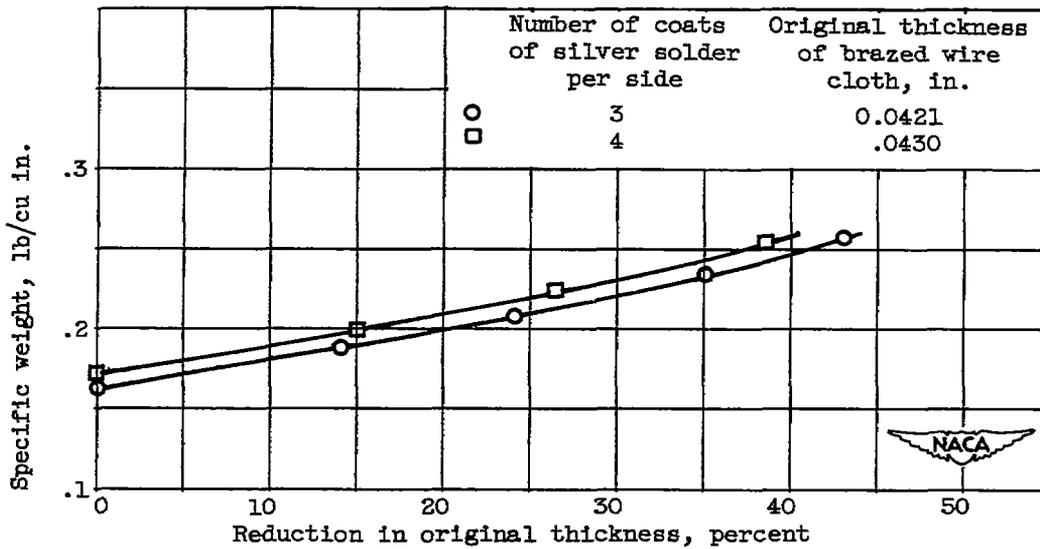


Figure 20. - Effect of rolling on specific weight of monel cloth B sprayed with silver solder A and brazed.

- 1 Unexcelled powder, AISI type 302 (ref. 9)
- 2 -200+325 mesh, Hardy, AISI type 302, sintered metal compact (ref. 9)
- 3 -100+200 mesh, Hardy, AISI type 302, sintered metal compact (ref. 9)
- 4 -100+200 mesh, VA, AISI type 316 CB (ref. 7)
- 5 -150+200 mesh, (coined), AISI type 301 (ref. 8)
- 6 Cloth B, 4 coats of silver solder per side, brazed
- 7 Cloth B, 3 coats of silver solder per side, brazed
- 8 20x250 mesh, brazed (ref. 2)
- 9 20x200 mesh, brazed (ref. 3)

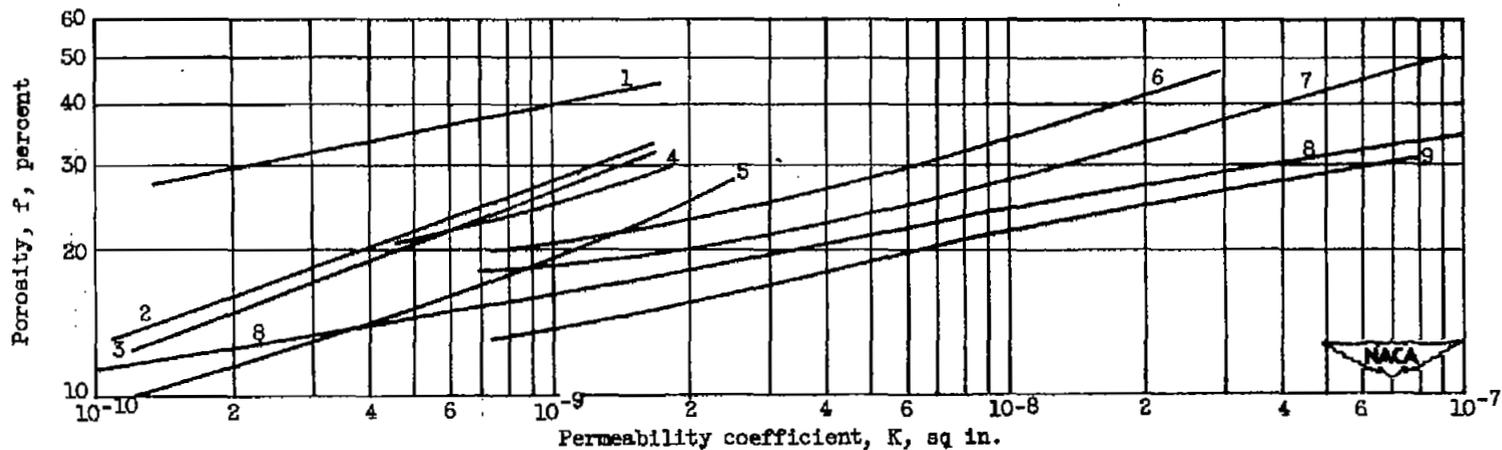
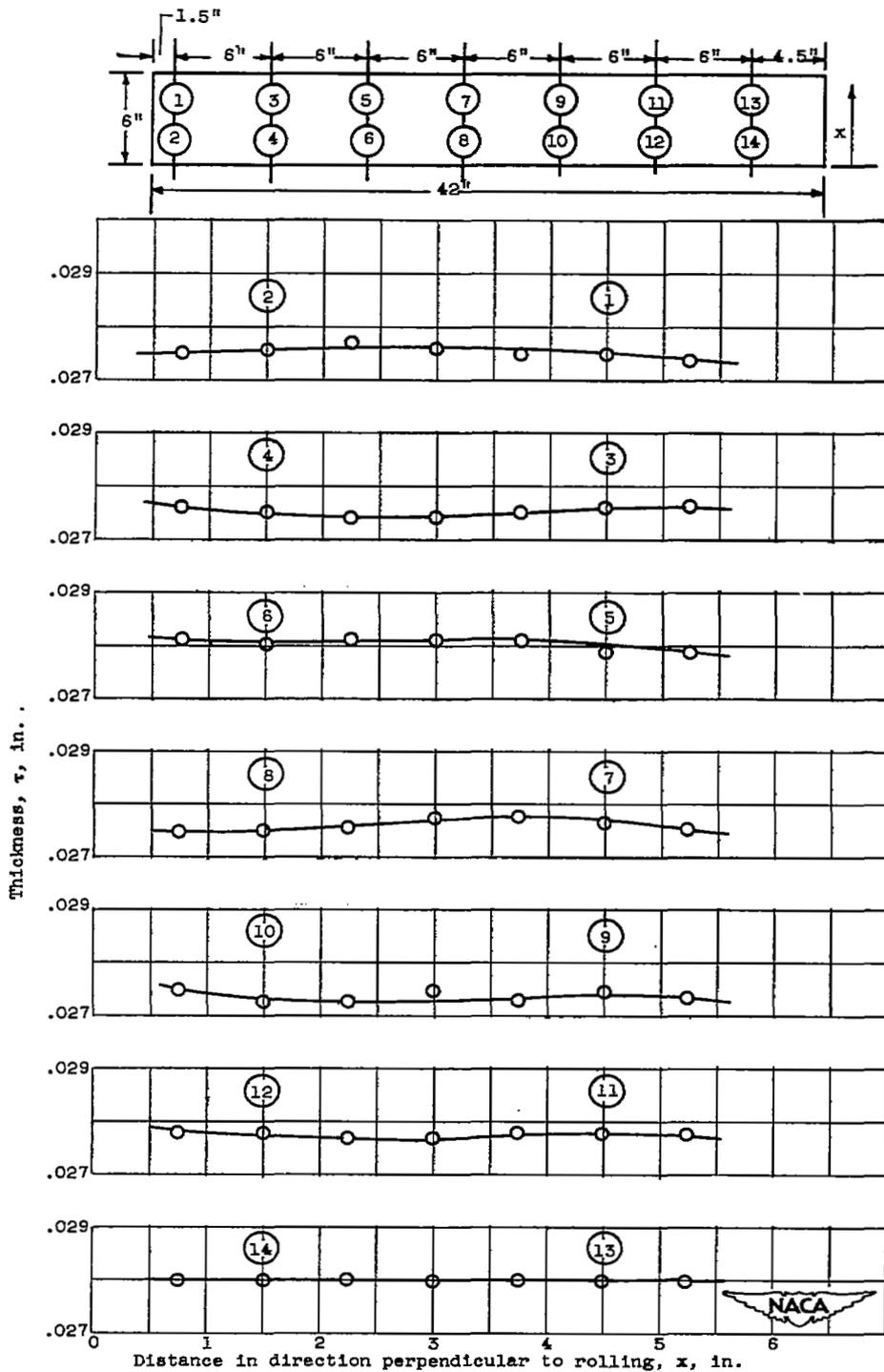


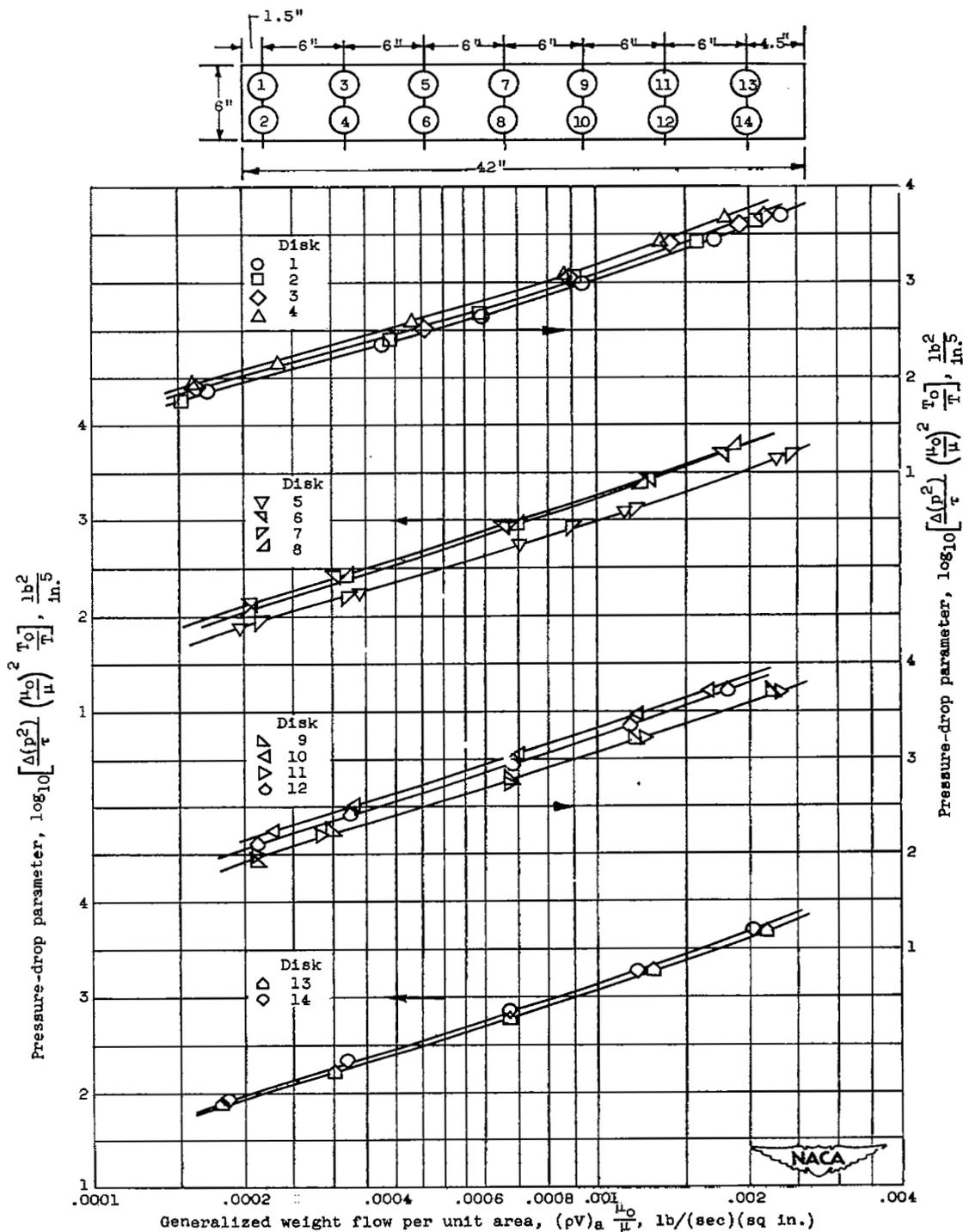
Figure 21. - Comparison of porosity and permeability coefficient for brazed wire cloth and some sintered metal compacts.

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(a) Thickness measurements.

Figure 22. - Thickness measurements and air-flow data of wire cloth B sprayed with three coats of silver solder A per side, brazed, and rolled. Reduction in original thickness, 35 percent.



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Figure 22. - Concluded. Thickness measurements and air-flow data of wire cloth B sprayed with three coats of silver solder A per side, brazed, and rolled. Reduction in original thickness, 35 percent.

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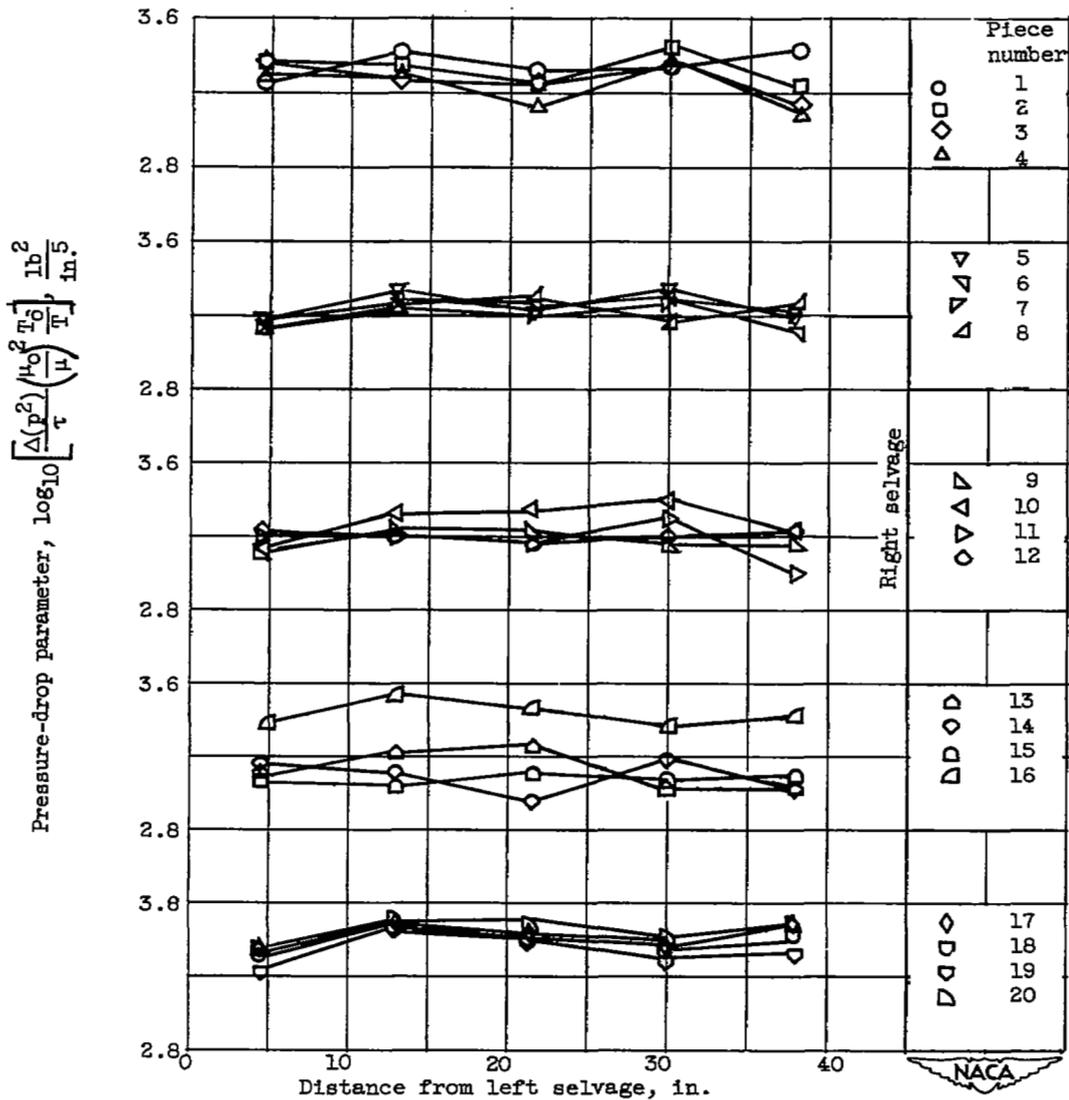


Figure 23. - Longitudinal variation of pressure-drop parameter along center line of twenty 6- by 45-inch pieces of brazed and rolled wire cloth B. Number of coats of silver solder per side, three; original thickness, 0.042 inch; reduction in original thickness, 35 percent; generalized weight flow per unit area, 0.001 pound per second per square inch.

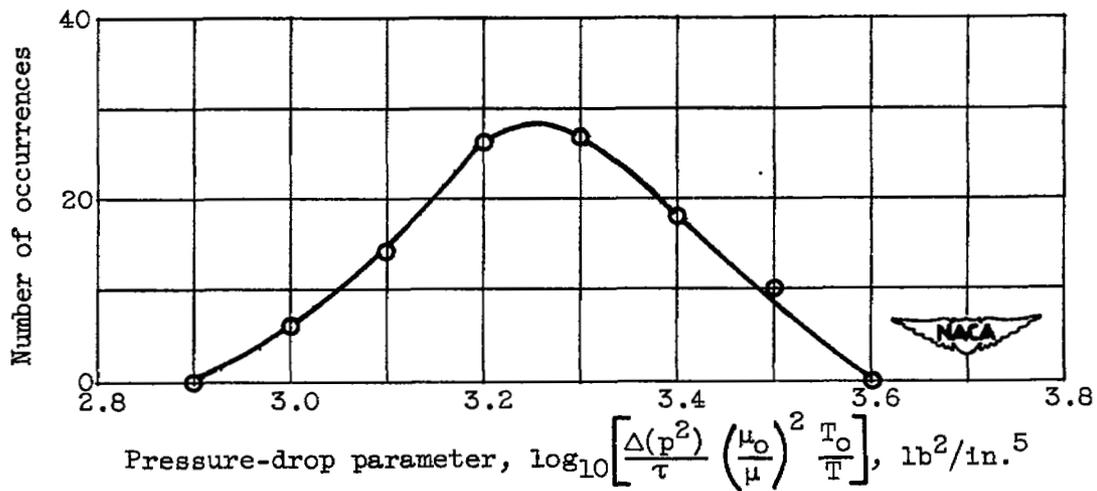


Figure 24. - Normal distribution curve of pressure-drop parameter for twenty 6- by 45-inch pieces of wire cloth B sprayed with three coats of silver solder A per side and brazed. Reduction in original thickness, 35 percent; generalized weight flow per unit area, 0.001 pound per second per square inch.

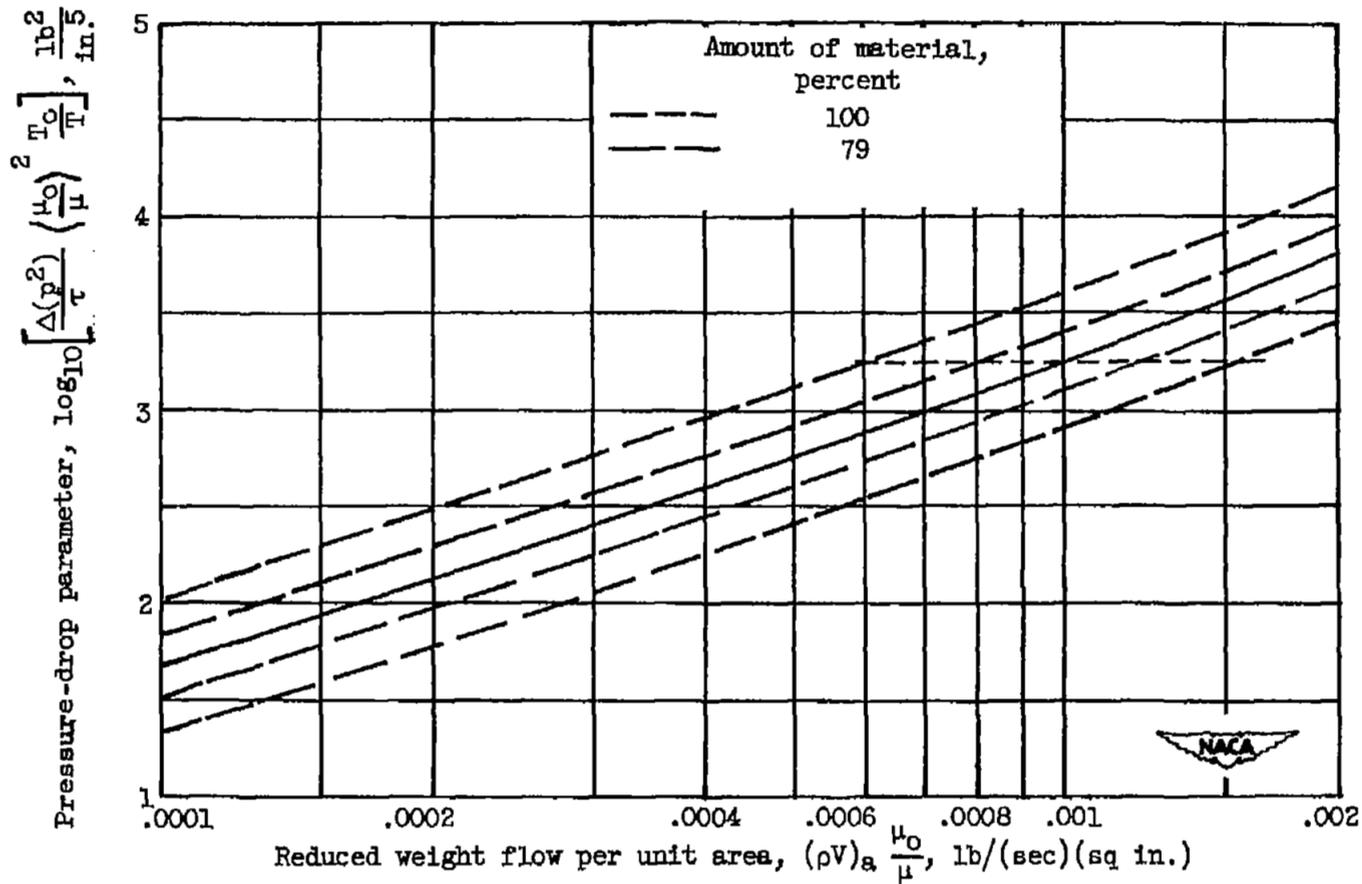


Figure 25. - Mean air-flow calibration for wire filter cloth B sprayed with three coats of silver solder A per side and brazed. Reduction in original thickness, 35 percent.

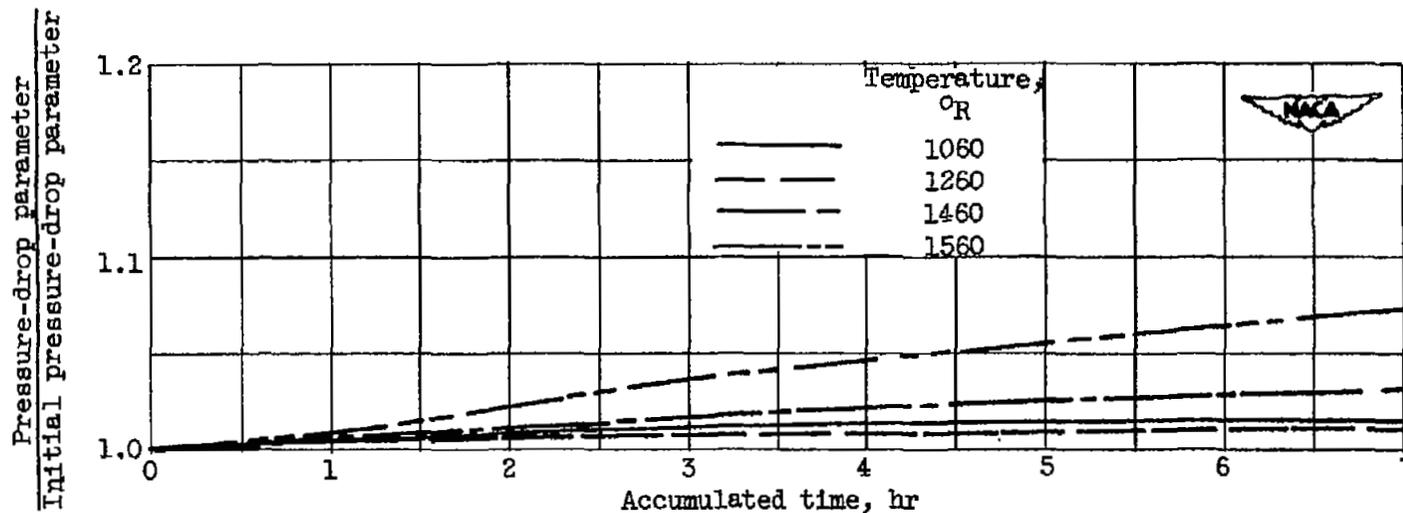


Figure 26. - Effect of duration at several temperatures in an oxidizing atmosphere on pressure-drop parameter of brazed and rolled wire cloth B. Number of coats of silver solder A per side, three; reduction in original thickness, 35 percent; generalized weight flow per unit area, 0.001 pound per second per square inch.

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CZ-7 back

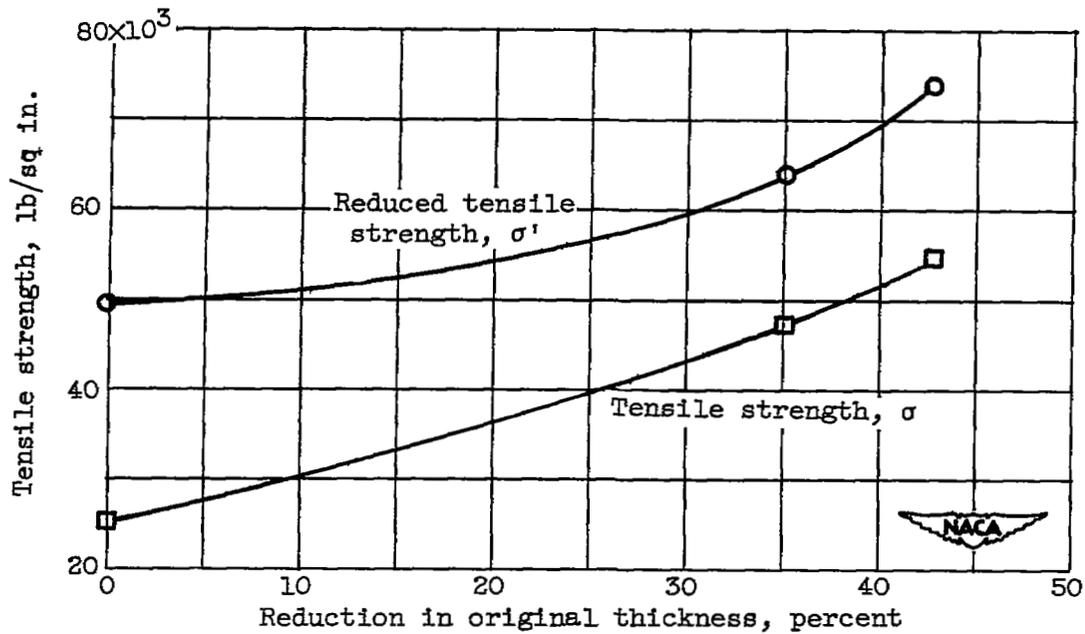


Figure 27. - Effect of rolling on ultimate tensile strength of monel wire cloth B sprayed with three coats of silver solder A per side and brazed. Original thickness of brazed cloth, 0.0421 inch. Specimens pulled parallel to greater number of wires at room temperature.

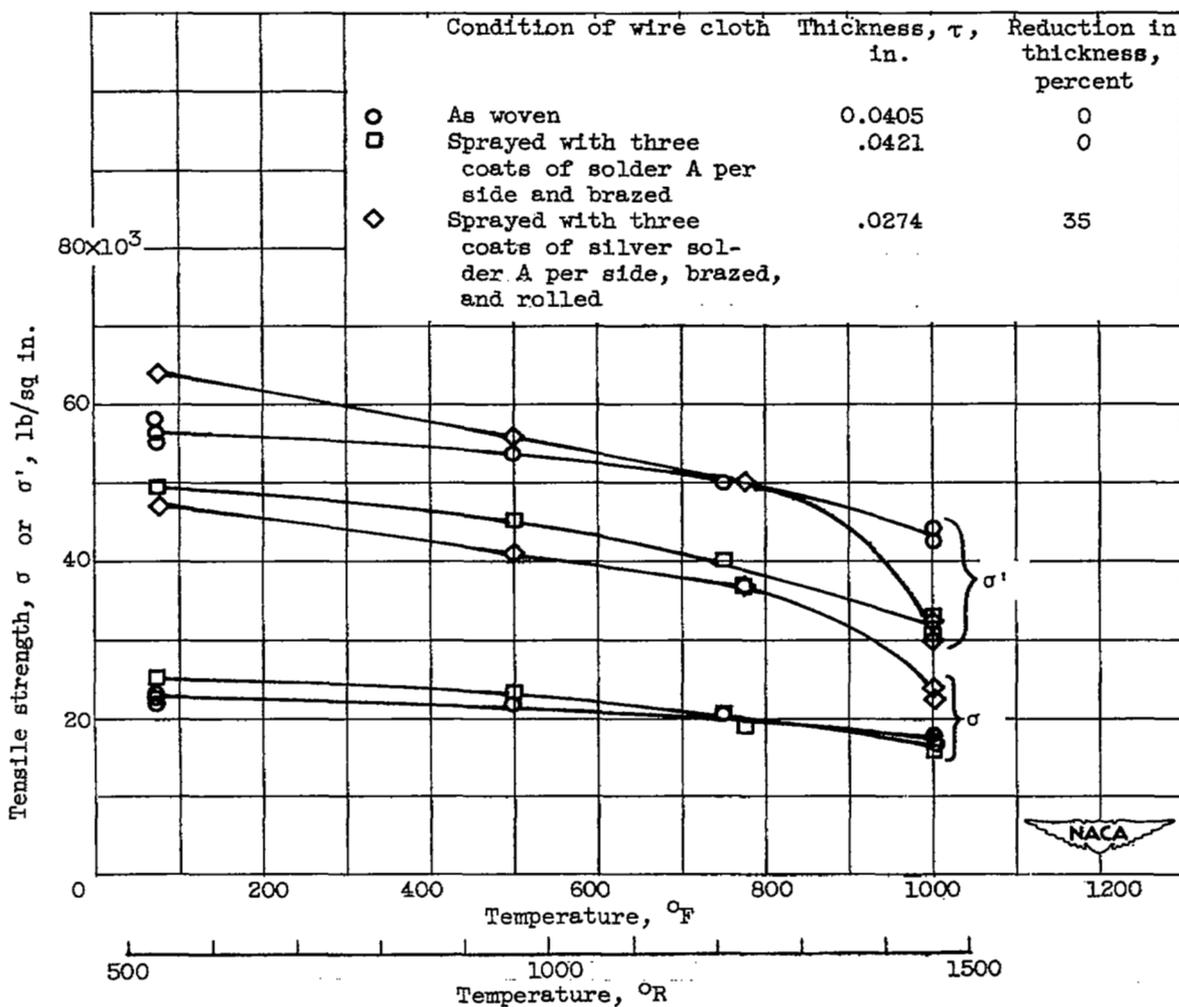


Figure 28. - Effect of temperature and treatment on ultimate tensile strength of monel wire cloth B. Specimens pulled parallel to greater number of wires.

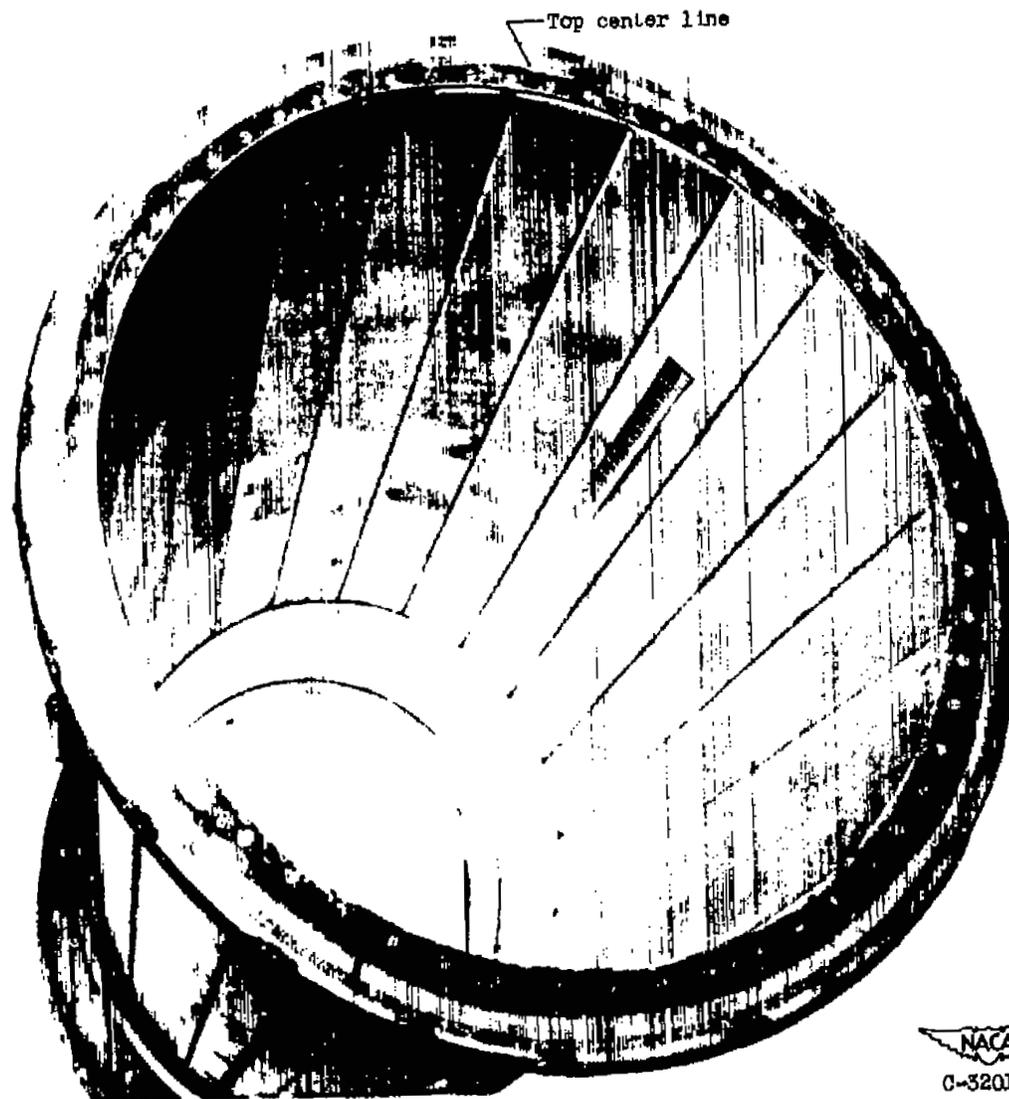


Figure 29. - Interior view of experimental transpiration-cooled afterburner with porous combustion-chamber wall fabricated from brazed and rolled wire cloth. Exhaust nozzle removed.

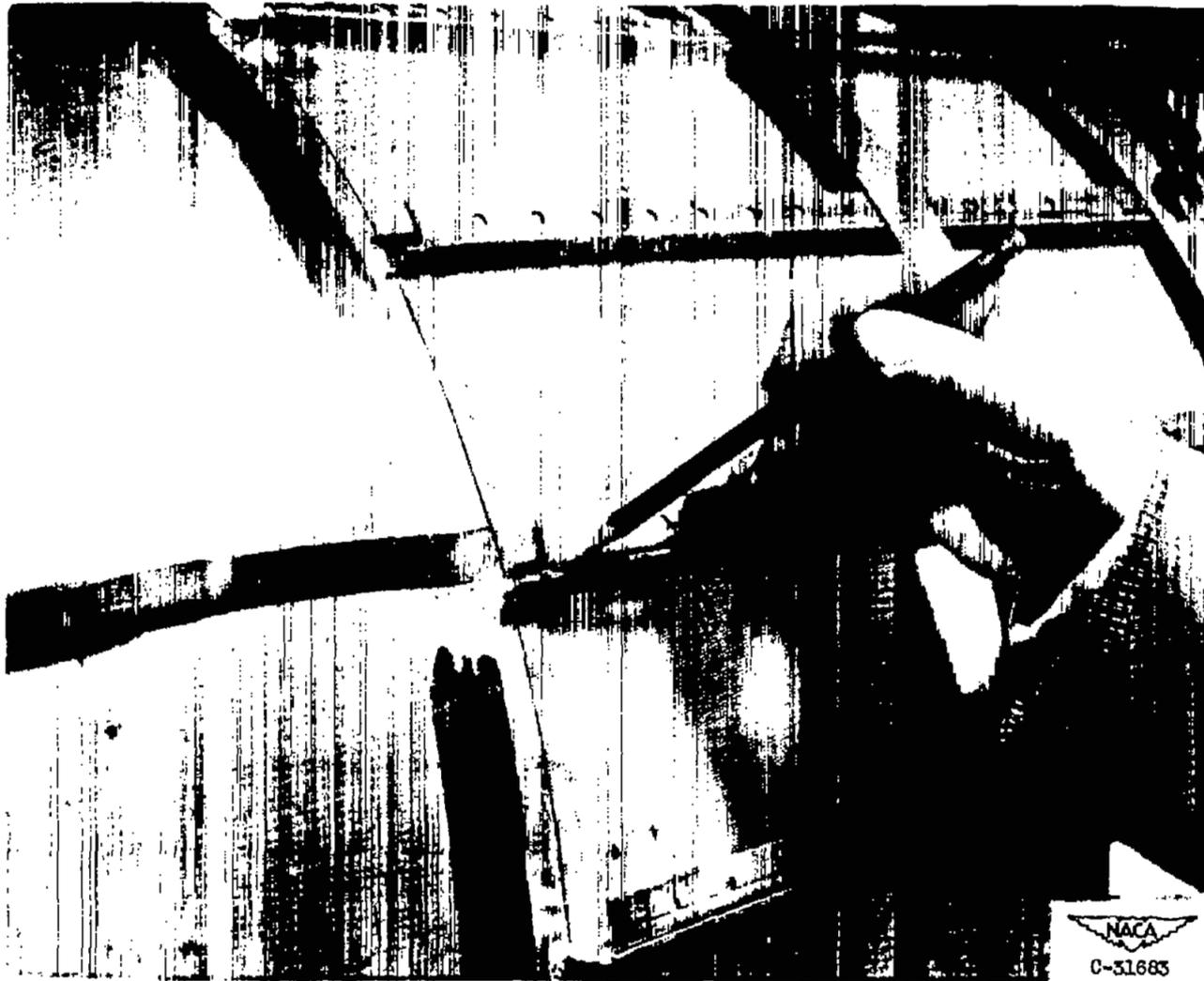


Figure 30. - Exterior view of porous wire cloth channels and supporting angles before installation of structural cooling-air shroud on experimental transpiration-cooled afterburner.

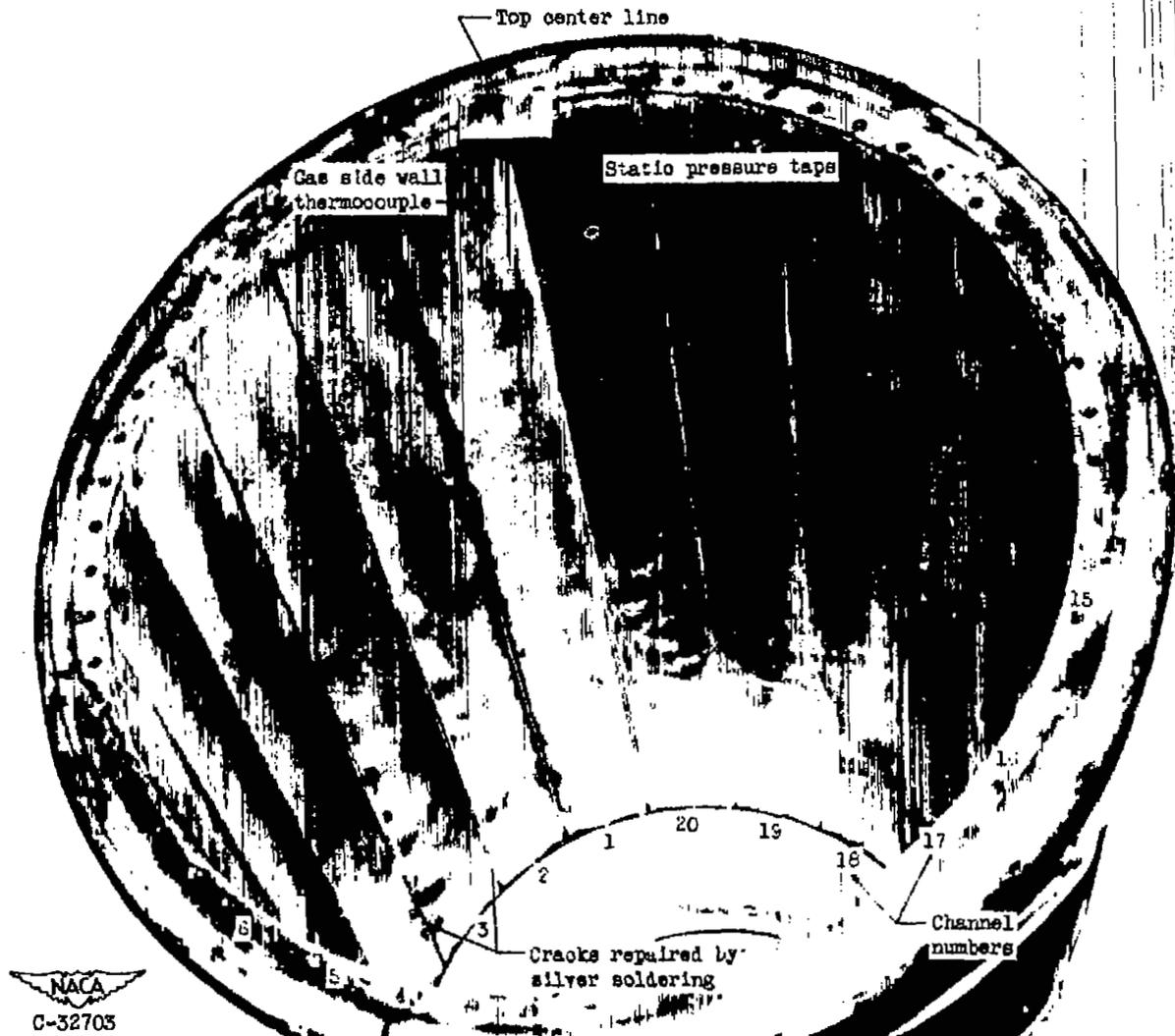


Figure 31. - Condition of wire-cloth combustion-chamber wall in experimental transpiration-cooled afterburner after 4 hours and 10 minutes of afterburning.

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