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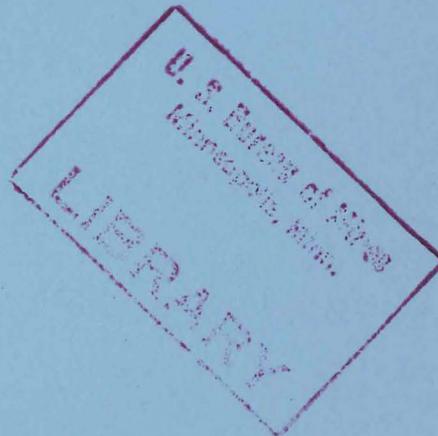
IMPROVING THE  
SELF-SEALING BRATTICE

Prepared For:

United States Department of the Interior  
Bureau of Mines

By:

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Akron, Ohio 44315



FINAL REPORT

Contract No. HO177068, Improving The Self-Sealing Brattice

September, 1978

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79-59

The views and conclusions contained in this document are those of the author's and should not be interpreted as necessarily representing the official policies or recommendations of the Interior Department's Bureau of Mines or of the U.S. Government.

(This page replaces old Title Page)

REPORT DOCUMENTATION PAGE

1. Report No.	2.	3. Recipient's Accession No.
4. Title and Subtitle IMPROVING THE SELF-SEALING BRATTICE		5. Report Date September, 1978
7. Author(s) RICHARD D. MEHRING		6.
9. Performing Organization Name and Address GOODYEAR AEROSPACE CORPORATION 1210 MASSILLON ROAD AKRON, OHIO 44315		8. Performing Organization Report No. GAC 19-1212
12. Sponsoring Organization Name and Address OFFICE OF THE ASSISTANT DIRECTOR - MINING BUREAU OF MINES DEPARTMENT OF THE INTERIOR WASHINGTON, D.C. 20241		10. Project/Task/Work Unit No.
		11. Contract or Grant No. HO 177068
		13. Type of Report FINAL
		14.

15. Supplementary Notes

16. Abstract

A refined and improved self-sealing brattice for use in coal mine rescue and recovery operations for directing the flow of air has been developed and tested by Goodyear Aerospace Corporation for the U.S. Bureau of Mines. The brattice is made from a lightweight, low cost material that meets MSHA flammability requirements. The units can be erected using pins, spads or lightweight extensible poles. Tests were conducted to determine leakage rate from minimal to a maximum of 1.5" H<sub>2</sub>O. The ability to handle reverse flows was demonstrated and a non-flammable foam was used as an auxiliary sealing agent.

17. Originator's Key Words Improved Self-Sealing Brattice Ventilation Control Stoppings	18. Availability Statement
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19. U. S. Security Classif. of the Report UNCLASSIFIED	20. U. S. Security Classif. of This Page UNCLASSIFIED	21. No. of Pages	22. Price
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FOREWORD

This report was prepared by Goodyear Aerospace Corporation, Akron, Ohio 44315 under U.S. Bureau of Mines contract number H0177068. The contract was initiated under the Bureau of Mines, Coal Mine Health And Safety (Ventilation) Program. It was administered under the technical direction of PMSRC with Mr. Edward D. Thimons acting as the technical project officer. Mr. Robert L. Carpenter was the contract administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period October 1977 to October 1978. This report was submitted by the authors on September 1978.

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## I. INTRODUCTION

### A. Background

"When an explosion occurs in an underground coal mine, the concussion blows down the block stoppings used to separate the intake and return airways. Destruction of these stoppings causes the mine ventilation air to short-circuit, preventing fresh ventilation air from reaching the region where the explosion took place and allowing explosive or harmful gases to accumulate.

To enter this region, rescue crews must reestablish the ventilation. This is generally done by carrying brattice cloth into the mine and erecting it in place of the destroyed stoppings. However, this operation may require much time and effort, especially if it is important to reduce air leakage to a minimum."<sup>1</sup>

This excerpt from the Kissell-Thimons U.S. Bureau of Mines study describes concisely and accurately the breakdown in air ventilation that occurs in a mine as a result of an explosion and the steps needed to reestablish proper ventilation. The Kissell-Thimons study goes on to say, "A self-sealing brattice intended for use during coal mine rescue and recovery operations has been designed and tested by the Bureau of Mines". Unlike conventional brattice stoppings, this type of stopping was hemispherical in shape and sealed itself against the mine walls, roof and floor with a minimal number of attachments. The authors concluded that "preliminary testing indicates that the concept is worthwhile, but that further developmental research is required".

Accordingly, the Bureau of Mines contracted Goodyear Aerospace Corporation (GAC) to further refine and improve the self-sealing brattice and to evaluate its potential capabilities and limitations.

### B. Scope

The scope of work involved selecting the best commercially available material that would have the following characteristics.

- Low Permeability
- Meet Flammability Requirements of ASTM E-162 and NFPA-701
- Low Cost
- High Tear Resistance
- Lightweight
- Strength to withstand differential pressures up to 1.5 inches water

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<sup>1</sup> Kissell, Fred N., and Thimons, Edward D., Self Sealing Brattice For Coal Mine Rescue and Recovery, Bureau of Mines, Coal Mine Health and Safety Program, Technical Progress Report TPR 98, Pittsburgh Mining and Safety Research Center, Pittsburgh, Pennsylvania, August, 1976.

Upon agreement with the Bureau's TPO, GAC was to construct sufficient number of units for test purposes.

A full-scale model coal mine entry was to be built 18' wide x 5' high equipped with fans to produce test pressures and with roughness similar to that found in a coal mine. Tests were to be conducted in the model airway to determine range of air-way sizes a self-sealing brattice could seal and how much larger the perimeter of the self-sealing brattice should be to achieve adequate sealing capability.

GAC was to evaluate installation methods for erecting and maintaining the stoppings both with the use of simulated spads or power-actuated pins and extensible poles. With the stopping erected in the manner described, tests were to be conducted to determine minimum pressure to deploy the stoppings, leakage at various differential pressures and the ability to handle reverse flows.

In addition, GAC was to evaluate the usefulness of a non-flammable foam as an auxiliary sealing agent around the brattice.

At the conclusion of the contract, GAC was to build and deliver 12 copies of a prototype brattice.

#### C. Brief Summary of Results

The following is a brief summary of the results of the effort on this contract concerning the application of the improved self-sealing brattice.

- ° The brattice can be erected at a differential pressure as low as .0022 inches of H<sub>2</sub>O and will stay erected at a differential pressure as low as .0005 inches of H<sub>2</sub>O.
- ° Leak rate of the installed brattice can be expected to be in the 300-500 CFM range at .5" H<sub>2</sub>O differential pressure with slightly higher leakage if surface is very rough.
- ° Leak rate will vary directly with change in differential pressure.
- ° Brattice can be erected using pins, spads or with adjustable poles although erection with pins or spads is preferred.
- ° Brattice can be erected in two minutes or less with two men using nails and in less than 5 minutes by one man. Two men are required for installation using poles and erection can be done in 2-3 minutes.
- ° Foam can be used as an effective auxiliary sealing agent between the brattice and the cross-cut in areas of considerable roughness.
- ° The brattice can handle reverse flows when erected with either pins, spads or poles.

## D. Summary of Effort

As a result of a kick-off meeting held at the U.S. Bureau of Mines which stressed that the most critical work on the contract was the choice of the fabric for the brattice, GAC initially concentrated its effort in this area. The criteria or goal for the physical properties of the material were established as follows.

<u>Property</u>	<u>Criteria/Goal</u>
Weight (oz/yd <sup>2</sup> )	≤1.6
Tongue Tear (lbs)	>3 x 3
Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min) @ .5" H <sub>2</sub> O	≤1.6
Flammability	
ASTM E-162 (Index)	<25
NFPA 701 (Flameout) (Sec)	<2
Strength (lb/in)	≥17.5

The above requirements were discussed with some cloth suppliers who were asked to prepare samples for evaluation. Since it was felt that most of the physical properties could be met, GAC concentrated on an evaluation of the flammability aspect of nylon and polyester cloth.

Preliminary flammability testing was performed at GAC with subsequent verification by an independent testing laboratory, Smithers Scientific Services, Akron, Ohio. As a result of these tests, GAC concluded that uncoated lightweight (3.35 oz/yd<sup>2</sup> or less) nylon or polyester would meet the contract requirements. After a trade-off between candidate materials, GAC in conjunction with the project officer chose Putnam Mills pattern 5086 nylon cloth to manufacture the test brattices. A specification for the fabric was written as follows.

TABLE 1 -- MATERIAL SPECIFICATION

Yarn - Type	Nylon
Weight	1.85 ±.15 oz/yd <sup>2</sup>
Strength	80 x 70 #/in
Tongue Tear	8 x 8 # min
Permeability	2.0 ft <sup>3</sup> /ft <sup>2</sup> /min at .5" H <sub>2</sub> O
Material	Scoured - heat set, FR treated and dyed red
Mfg.	L. Travis Textiles New York, N.Y. 10018
Note:	Cost \$.68/yd <sup>2</sup>

Upon receipt of the material, the physical properties were verified by test both at GAC and at Smithers-Scientific Laboratories.

Concurrent with the above effort, various methods were considered for transferring the brattice loads into the attachment of the brattice. GAC chose a simple attachment of a 2" wide Nomex webbing attached to the leading edge of the brattice. Tests were conducted using nails, spads and clinching strips to verify that the ultimate load on the brattice could be carried by the chosen attachment.

Since it was decided to use a single size model airway and vary the size of the stopping, a design was completed for an 18', 21' & 24' hemispherical brattice. Figure 1. One each of the designed units were fabricated for test purposes. Tests were conducted on the designed lap seam and proved more than adequate.

A model airway 18' wide and 5' high was fabricated by modifying the 10' x 7 1/2' airway previously employed for testing on Bureau of Mines contract J0166029. The airway was slightly over 20' long. One-fourth horsepower exhaust fans provided high volume - low pressure air flow while a centrifugal fan powered by a one horsepower motor was used for obtaining a pressure differential of .5" H<sub>2</sub>O across the stopping.

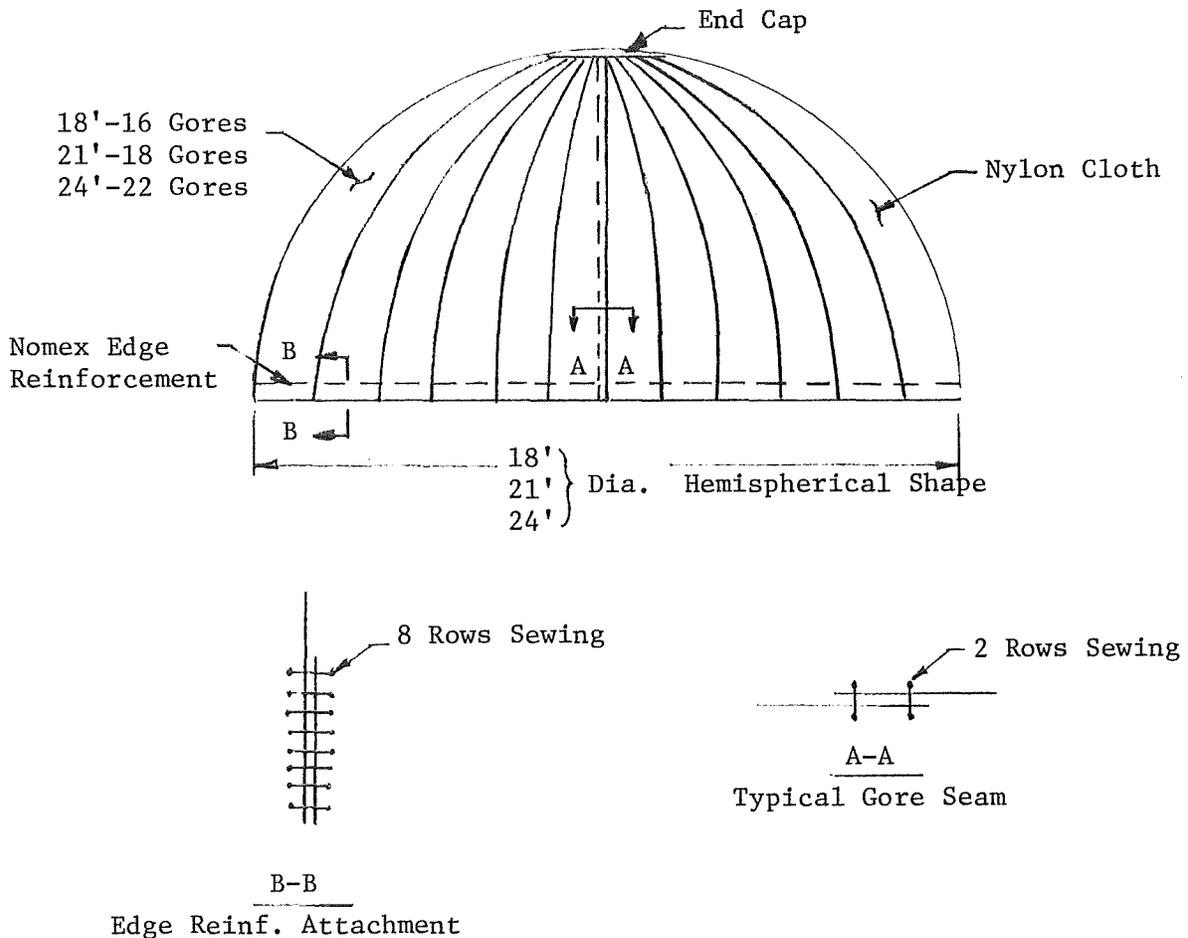


FIGURE 1 -- BRATTICE DESIGN

Corrugated aluminum sheeting was used to simulate mine surface roughness in addition to a steel channel and cardboard tube. These roughness items increased the overall periphery of the airway from 46 feet to 60 feet. See figures 2 and 3. Air flow measurements were taken using a vane-type anemometer in the openings of a TTS (Temporary Test Stopping) erected upstream of the test brattice. See figure 4. The TTS was used and calibrated on Bureau of Mines contract HO188004. The first series of tests was for the purpose of sizing the stopping and to determine leakage rates of the various brattice sizes.

Testing of the self-sealing brattices consisted of installing the units using nails and retention plates at the predetermined locations for the particular test. See figures 5 and 6. The centrifugal fan was used to erect the test article and provide the air flow into the TTS at the test windows. The air velocity was then converted to volume flow. Variables in the test series consisted of brattice size, roughness items quantity (effective periphery of the airway) and numbers and locations of attachment points. Tests indicated that basically air flow decreased with size of stopping and numbers of attachments and increased with increasing effective periphery of the airway. Flow rates as low as 325 ft<sup>3</sup>/min and as high as 1710 ft<sup>3</sup>/min were experienced. Additional attachments properly located and adjustment of the brattice cloth in the areas of the roughness items helped to lower the air flow. As the testing progressed, most of the test effort was with the 18 ft and 24 ft brattices since the 21 ft unit seemed to fall in between test points of the other two. In addition, attachment configurations were confined to 4, 6 and 8 pt attachments. Tests were also run to determine air flow versus delta pressure across the test stopping. From .5" H<sub>2</sub>O down to .1" H<sub>2</sub>O the flow (leakage) rate was essentially directly proportional to the pressure differential across the brattice.

GAC investigated various configurations of poles for erecting and maintaining the stopping in position. A lightweight, aluminum extensible pole was decided upon for the most feasible candidate. This unit #9HA from Eureka Tent, Incorporated was modified to add an adjustment at one end. The pole can be installed by a sliding extension that brings it to the height of the cross-cut where it is held with a simple locking, quick release tab. The pole then can be turned with a twist action which applies pressure to the brattice and tunnel roof and floor. Figure 7. Three poles were used to install the test brattice and the poles worked as well as the nails for maintaining the brattice in position. Figure 8.

Tests were run to demonstrate the capability of the nails and poles to handle reversal of air flows. In this case the brattice was attached with the unit essentially pointing upstream. The fan was started and the brattice allowed to reverse itself.

In the case of the nails, there was no difference in shape or performance. With the poles the brattice performed the same, but took a 2 lobe hemispherical shape since it had to wrap itself around the center pole. Figure 9.

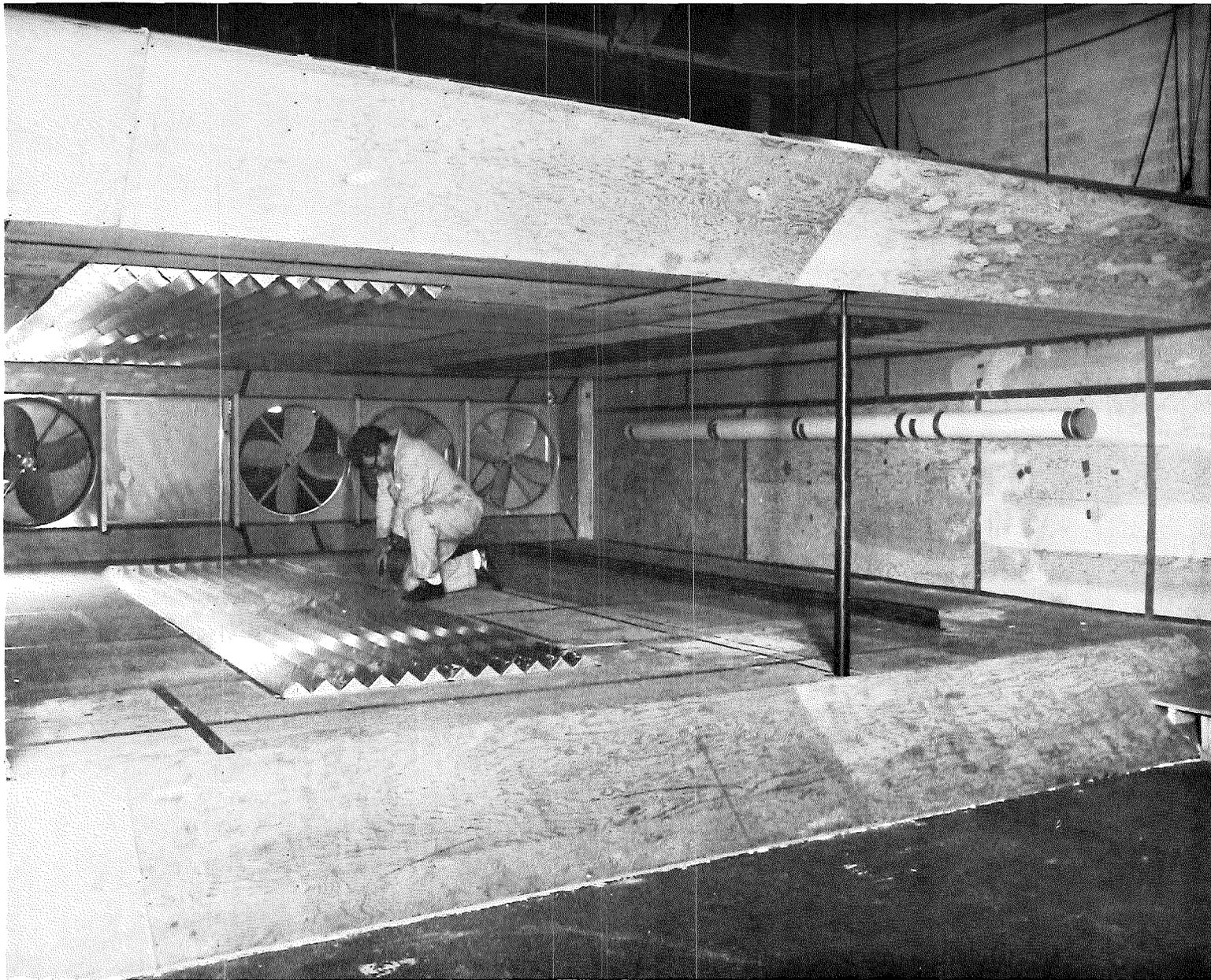


FIGURE 2 -- 50% ROUGHNESS ITEMS IN FULL-SCALE MODEL ENTRY INCLUDING CIRCULAR TUBE

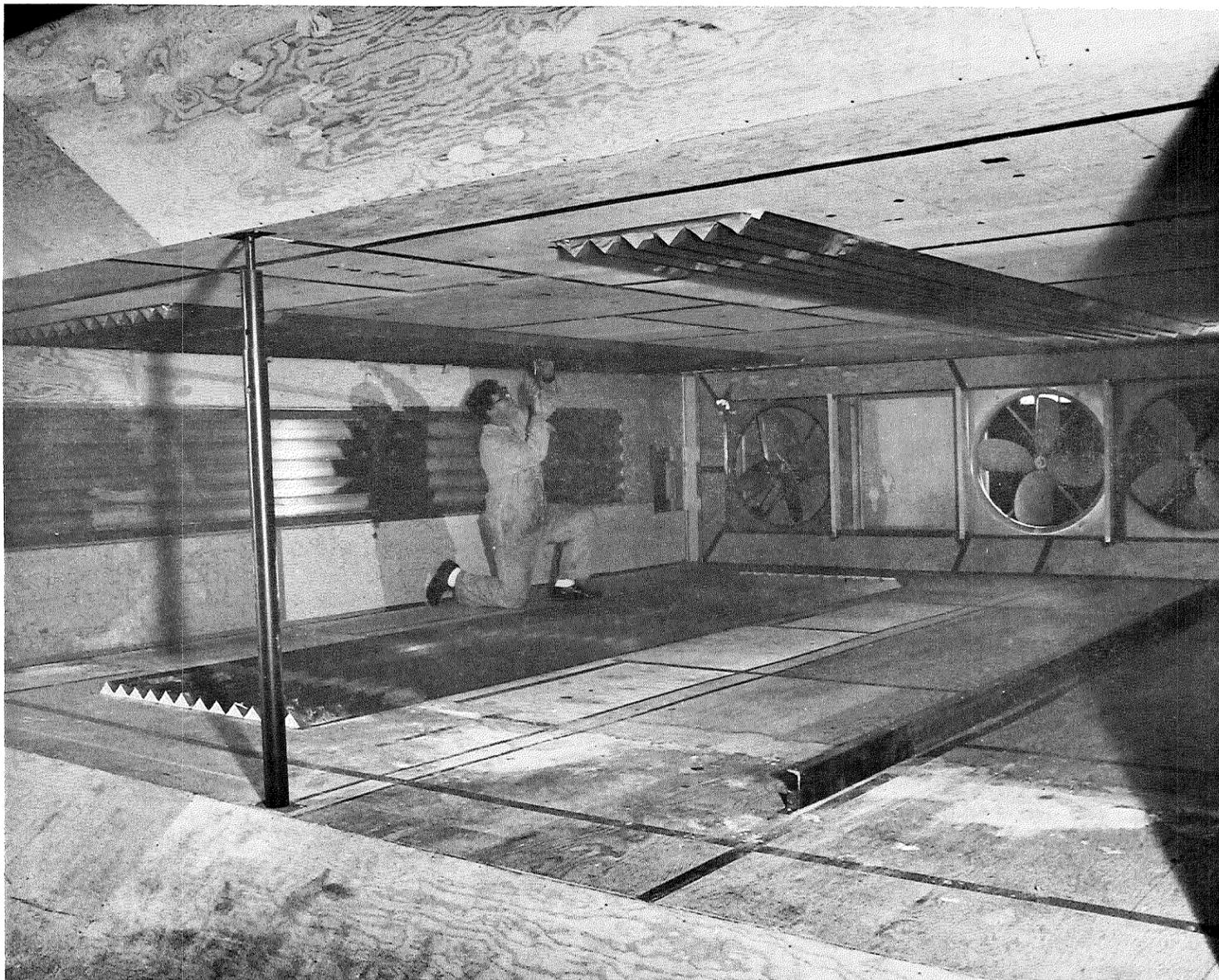


FIGURE 3 -- 50% ROUGHNESS ITEMS IN FULL-SCALE MODEL ENTRY

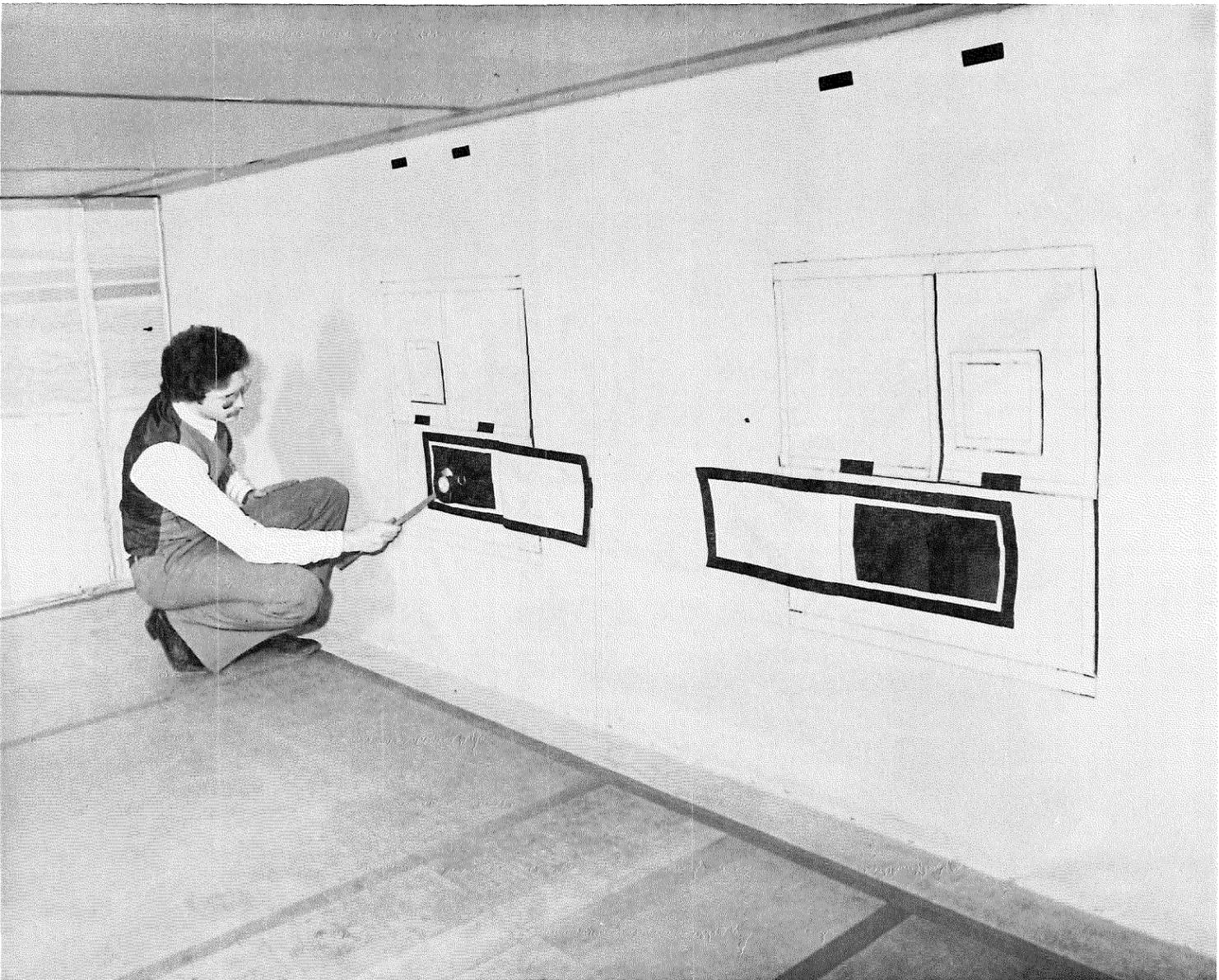


FIGURE 4 — FLOW MEASUREMENT WITH TEMPORARY TEST STOP IN PLACE

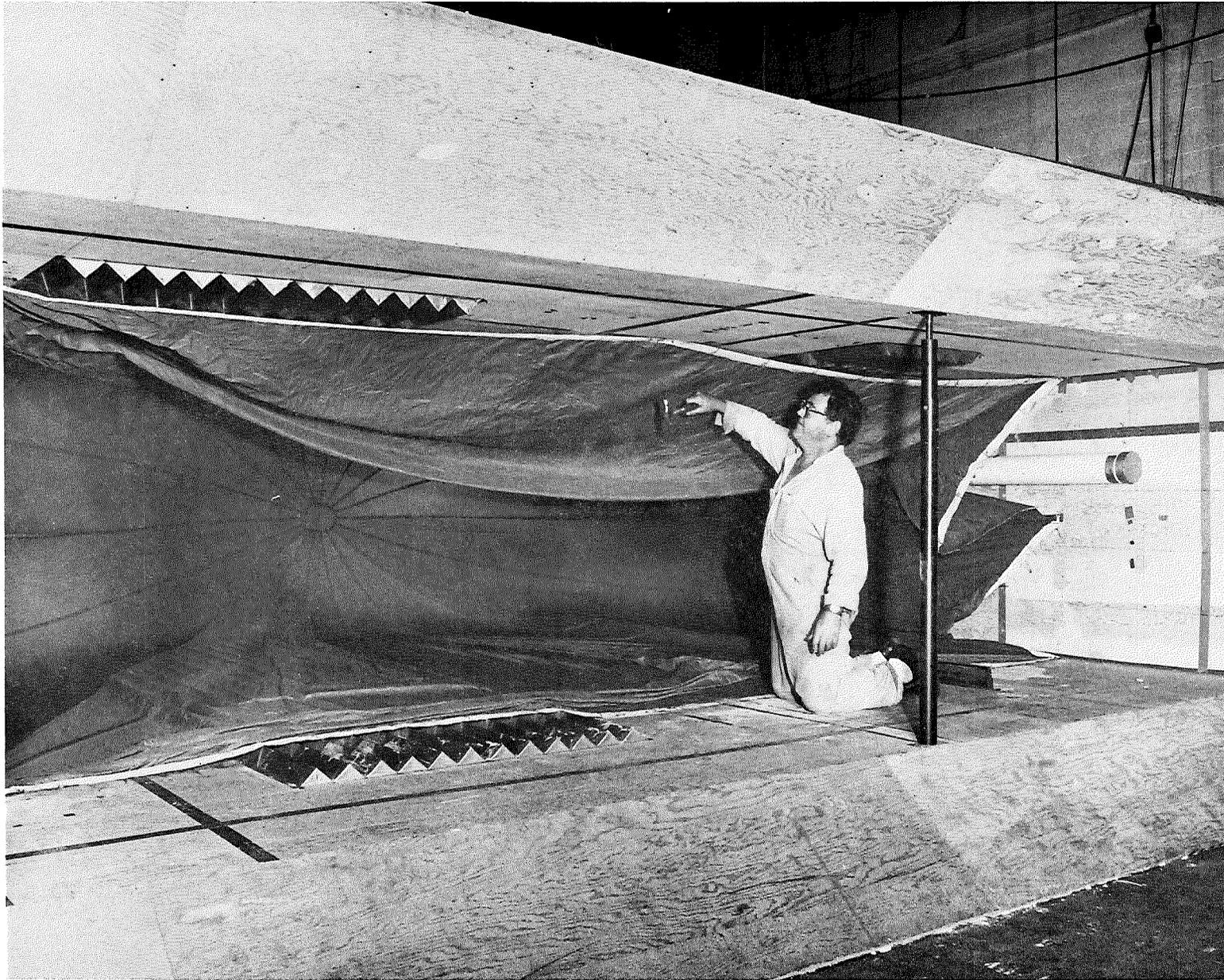


FIGURE 5 -- TEST BRATTICE INSTALLATION - NAIL ATTACHMENT



FIGURE 6 -- TEST BRATTICE INSTALLATION - NAILS WITH RETENTION PLATES



FIGURE 7 -- TEST BRATTICE INSTALLATION - POLE ADJUSTMENT

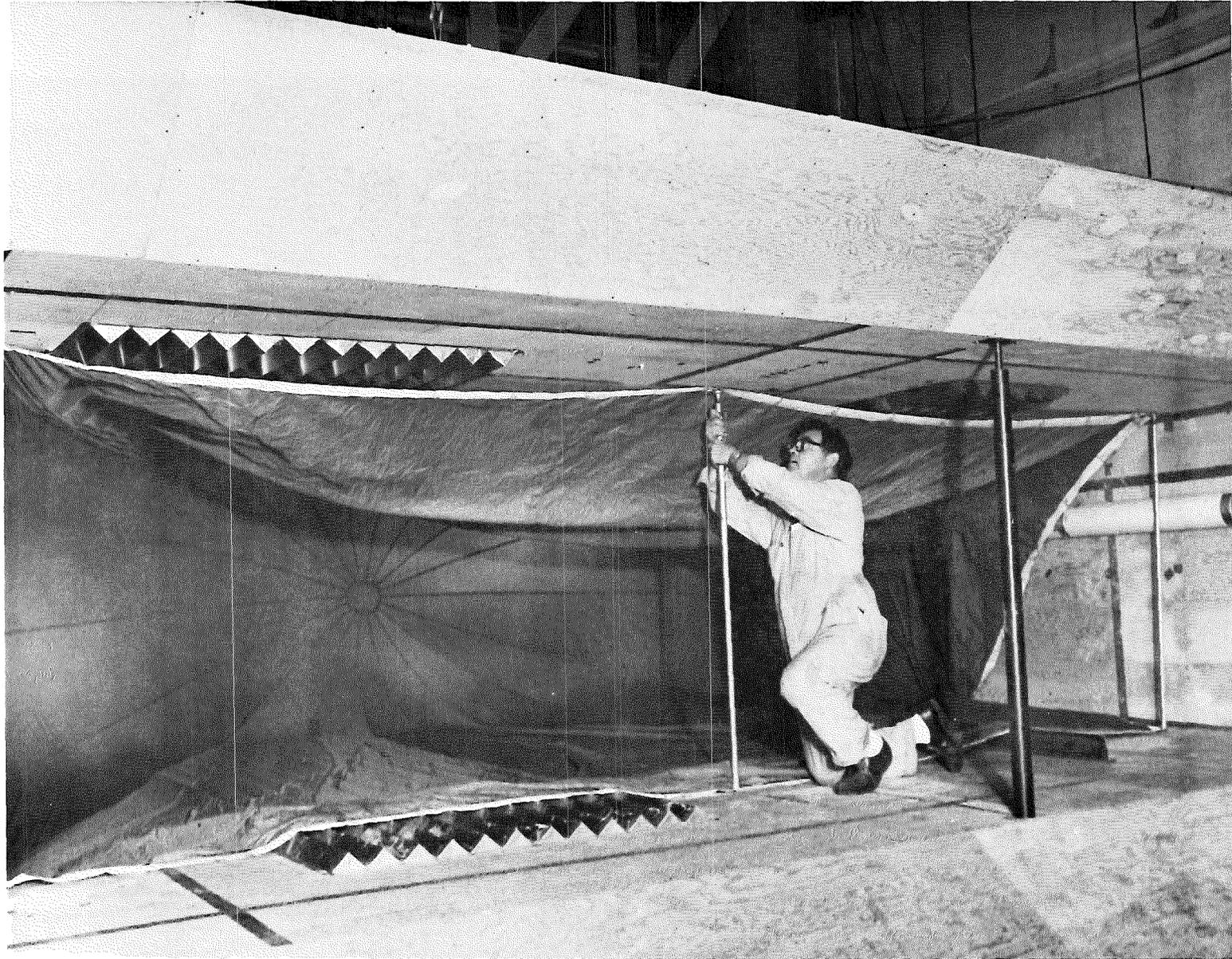


FIGURE 8 -- TEST BRATTICE - 3 POLE SUPPORTED

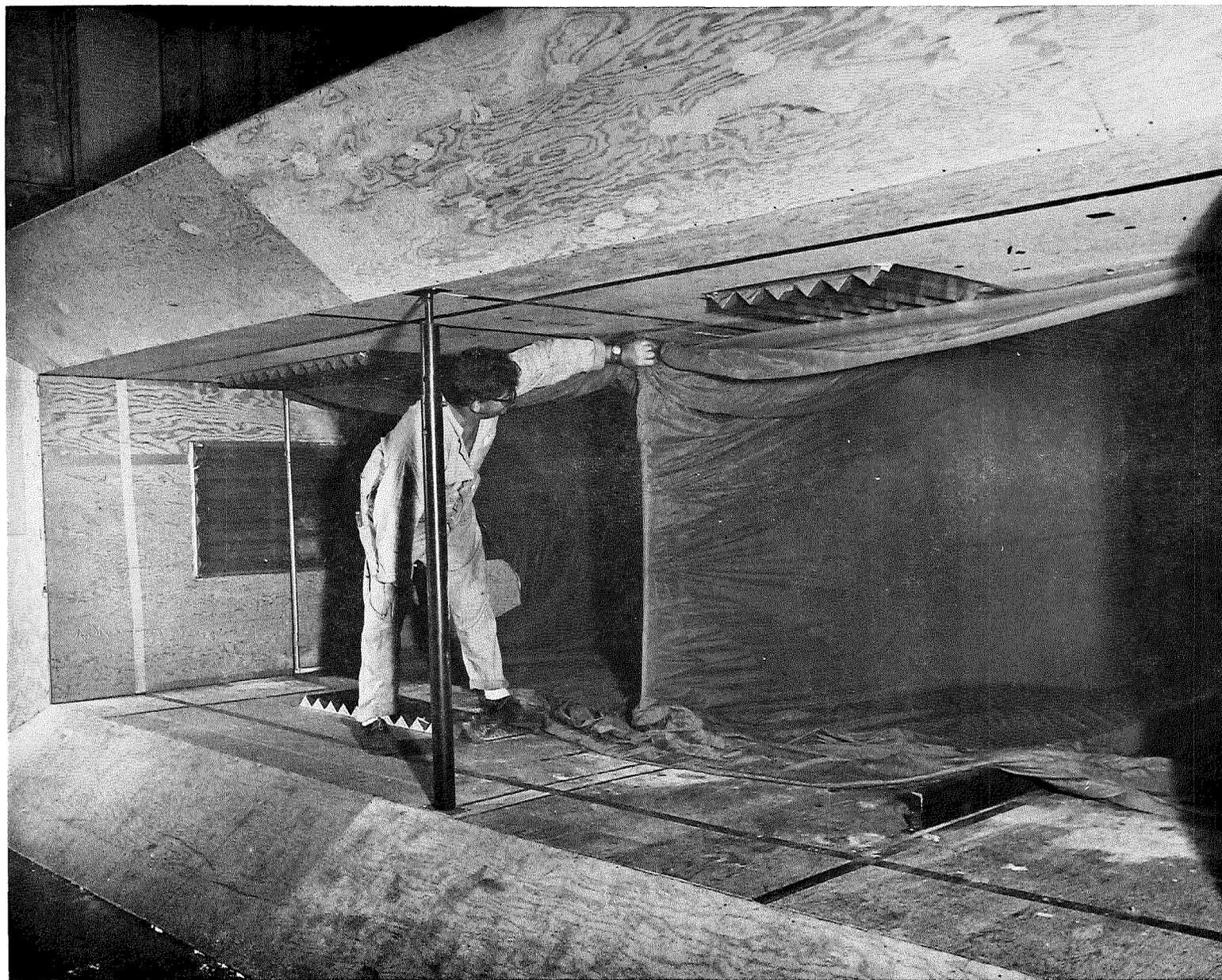


FIGURE 9 -- TEST BRATTICE - POLE SUPPORTED - REVERSE FLOW

Tests were conducted to determine the minimum pressures for erecting and maintaining the stopping in place. Erection was considered the point at which the top of the brattice contacted the air way roof in most places and deflation when the brattice started to drop away from the roof.

Both 18 ft and 24 ft brattices were tested with nails and poles. There was very little difference in performance with any of the above variables. Erection pressures were in the .0022 to .0036 in. H<sub>2</sub>O range and maintaining pressures were in the .0005 - .0011 in. H<sub>2</sub>O range.

A search was made for applicable foam materials to use as an auxiliary sealing agent. The particular problem in the choice of a foaming material was the requirement for a non-flammable material. A lead supplied by the technical project officer led to the choice of a urea-formaldehyde foam extensively used in the West German mining industry. The material RAPCO-FOAM\* met the flammability requirement, and most of the other requirements specified by GAC in its specification to foam suppliers. A successful demonstration of its capability was performed by the Adams-Barre Corp., Findlay, Ohio in sealing the 24 ft brattice test unit in the airway at GAC. Figures 10 and 11.

GAC filed a permissable status request with MSHA for the cloth used in the manufacture of the brattice. Approval of the material was given per MSHA letter A & CC: DM & E: Par #0023745. The material was assigned MSHA number IC-41 which will be marked on the product.

There were no "Subject Inventions" made in performance of the work under this contract or any sub-contract thereunder.

During the course of the contract, Mr. T.J. Crocker, Bethlehem, Penna., furnished consulting services to GAC.

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\* TM - Rapperswill Corp., New York, N.Y.

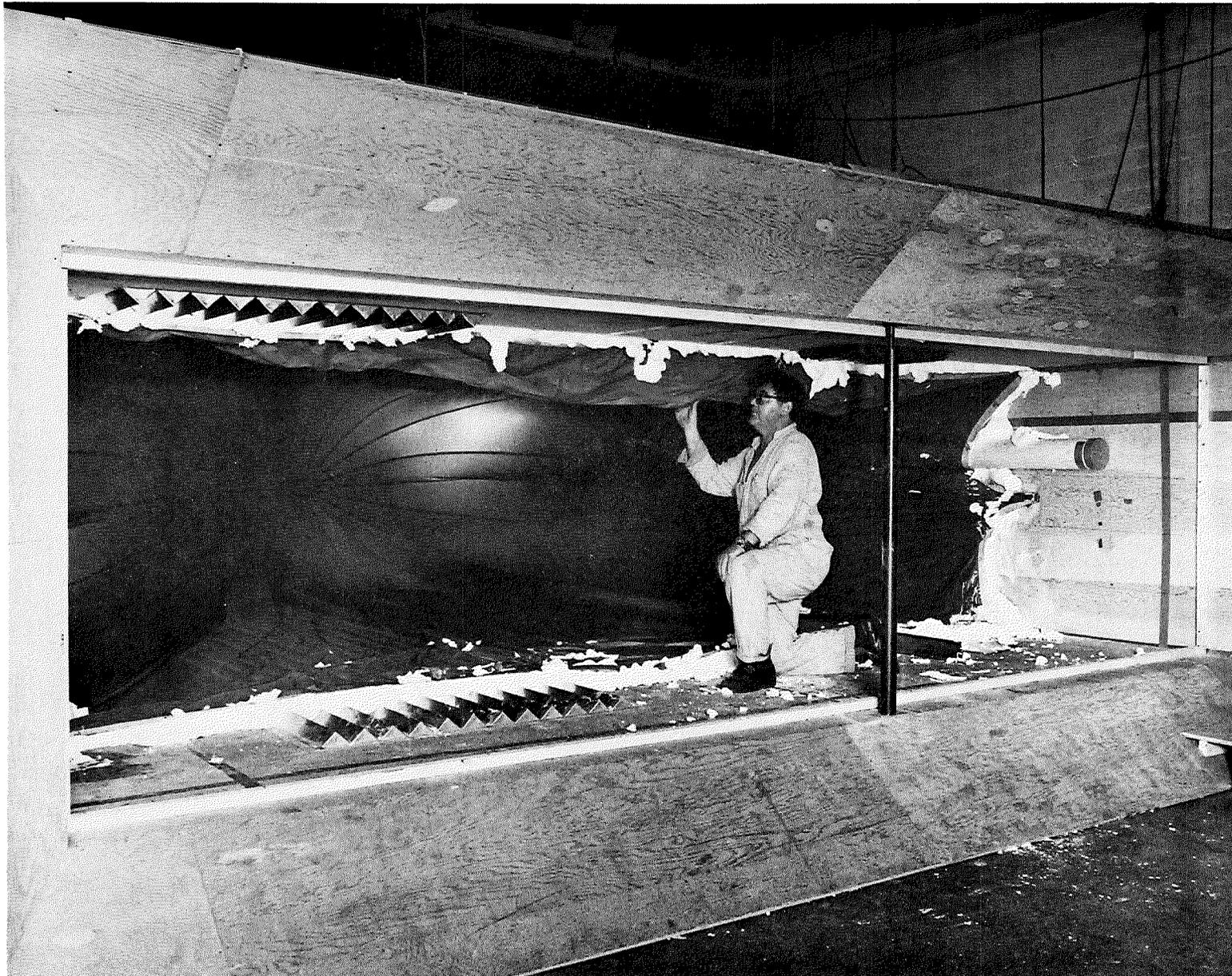


FIGURE 10 -- 24' DIA. TEST BRATTICE - USING FOAM FOR AUXILIARY SEALING

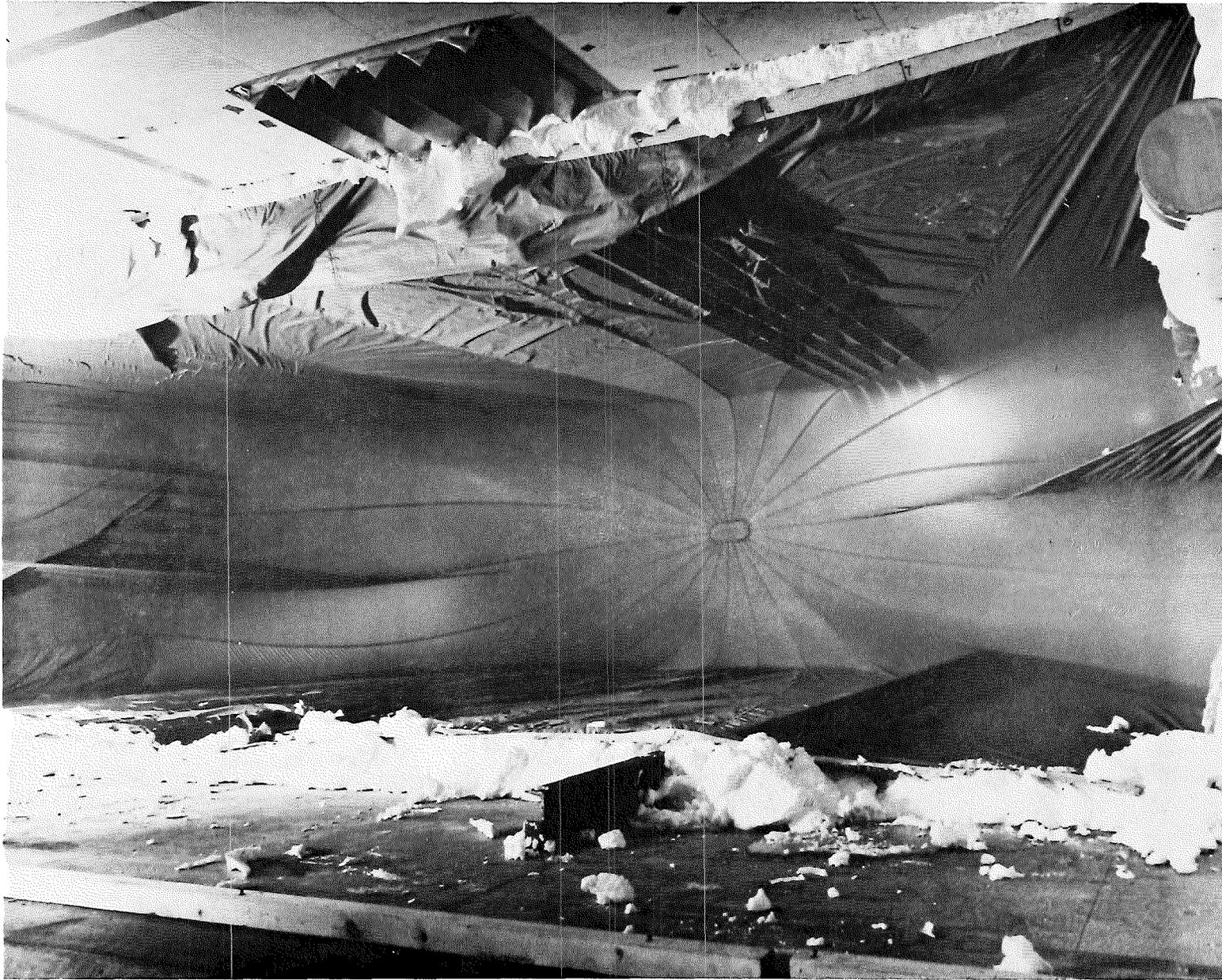


FIGURE 11 -- 24' DIA. TEST BRATTICE - FOAM SEALANT

## II. TEST FACILITIES AND EQUIPMENT

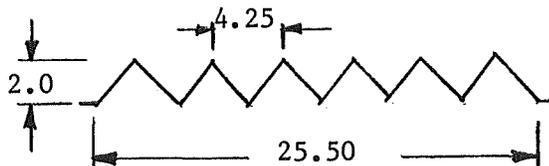
### A. Full-Scale Model Entry

The full-scale entry facility is shown schematically in Figure 12. The entry has a finished passageway cross-section of 18 ft x 5 ft. The unit was built by modifying an existing 10' x 7 1/2' airway. An inlet bell mouth is located forward of the passageway and a converging section to five fans is located after the passageway. The geometry and the fan location at the rear of the entry was selected to induce smooth air flow through the passageway. Five doors were located one behind each of the axial-exhaust fans. These can provide large air flows at low pressure although they were not used since the brattices could be erected with the low volume centrifugal fan. The centrifugal fan had a blocking plate at its exhaust. Using this blocking plate, the pressure differential across the brattice could be adjusted. The test brattices were erected using the centrifugal fan and tests were conducted at .5 inch of water differential pressure across the test brattice. The entry was constructed of 3/4 inch plywood attached to 2 x 8 frames on 16 inch centers. The overall length of the entry was slightly over 27 feet. The length of the straight passageway section was slightly over 21 feet.

### B. Model Entry Roughness Items

Roughness items were added to the entry wall, roof and floor to simulate roughness of the actual mine and to change the effective periphery of the passageway. Three different roughness items were used as follows.

$R_1$  -- These were corrugated aluminum sheets .032' thick and made specifically for the task since existing off-the-shelf material did not provide the proper ratio of corrugated length to flat width. A ratio of at least 1.3 was required so that the periphery of the passageway could be increased to approximately 60 feet from the 46 feet with the bare walls and still allow working area in the airway. The corrugated panels were made to the following cross-sectional shape.



$R_2$  -- This was a 6.50 O.D. cardboard tube used to simulate conduit passageways.

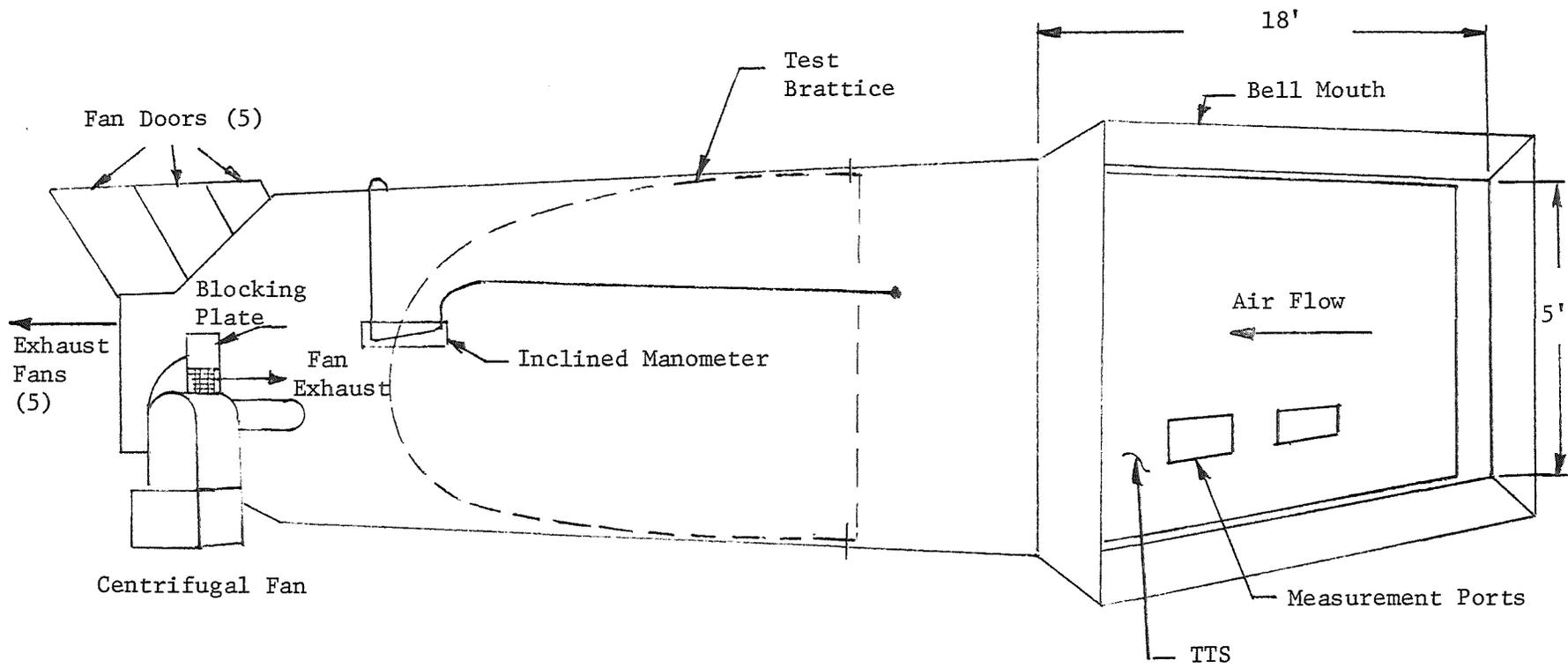


FIGURE 12 -- FULL SCALE MODEL ENTRY

$R_3$  — This was a steel channel section 4" high with 1.5 inch legs.

$R_1$ ,  $R_2$ , &  $R_3$  all extended approximately 16 feet down the passageway.

Two configurations of roughness items were used, hereafter referred to as 100% and 50% roughness. For the 100% roughness configuration 12 each  $R_1 + 1$  each ( $R_2 + R_3$ ) yielded an effective passageway periphery of 59 feet. See figure 13. For the 50% roughness configuration, figure 14, 6 each  $R_1 + 1$  each  $R_2$  and  $R_3$  gave a periphery of 54 feet. Roughness items were attached to the passageway with wood screws and taped to prevent air leakage underneath them. The roughness items used were considered a more severe test of the brattice than would actually be encountered in real use.

#### C. Model Entry Flow Equipment

##### 1. High Volume/Low Pressure Fan

Five 1/4 horsepower exhaust fans were installed in the downstream end of the passageway. Two of these were added under this scope of work in addition to the three fans already installed. These fans were each capable of 10,000 CFM and were originally intended to provide initial inflation of the test brattice. They were not used since it was found that the single centrifugal fan was capable of erection of the units.

##### 2. Centrifugal Medium Volume/Medium Pressure Fan

The centrifugal fan powered by a one horsepower motor was used for erection of the test brattices and to maintain the test pressure of .5 in  $H_2O$ . Desired pressure differentials across the test brattice were obtained by blocking portions of the exhaust area from the centrifugal fan.

#### D. Instrumentation For Model Entry

##### 1. Flow Velocity Measurements

Concurrent with this contract GAC, under Bureau of Mines Contract HO 188004 designed, fabricated and calibrated a Temporary Test Stopping (TTS) to measure air flows past block stoppings in coal mines. For testing of the brattices the TTS was installed upstream of the test brattice and the 6" x 12" openings were used for measuring air flows. See Figure 4. The instrument for measuring flow was a Davis Instrument Mfg. Co., 4 inch low speed, ball bearing vane type anemometer which measures air velocity. Readings were taken for a one minute period by two people, (one for each 6" x 12" window). Values were averaged and a correction factor of .67 was applied to obtain the volume of air flowing through the TTS in cubic feet per minute.

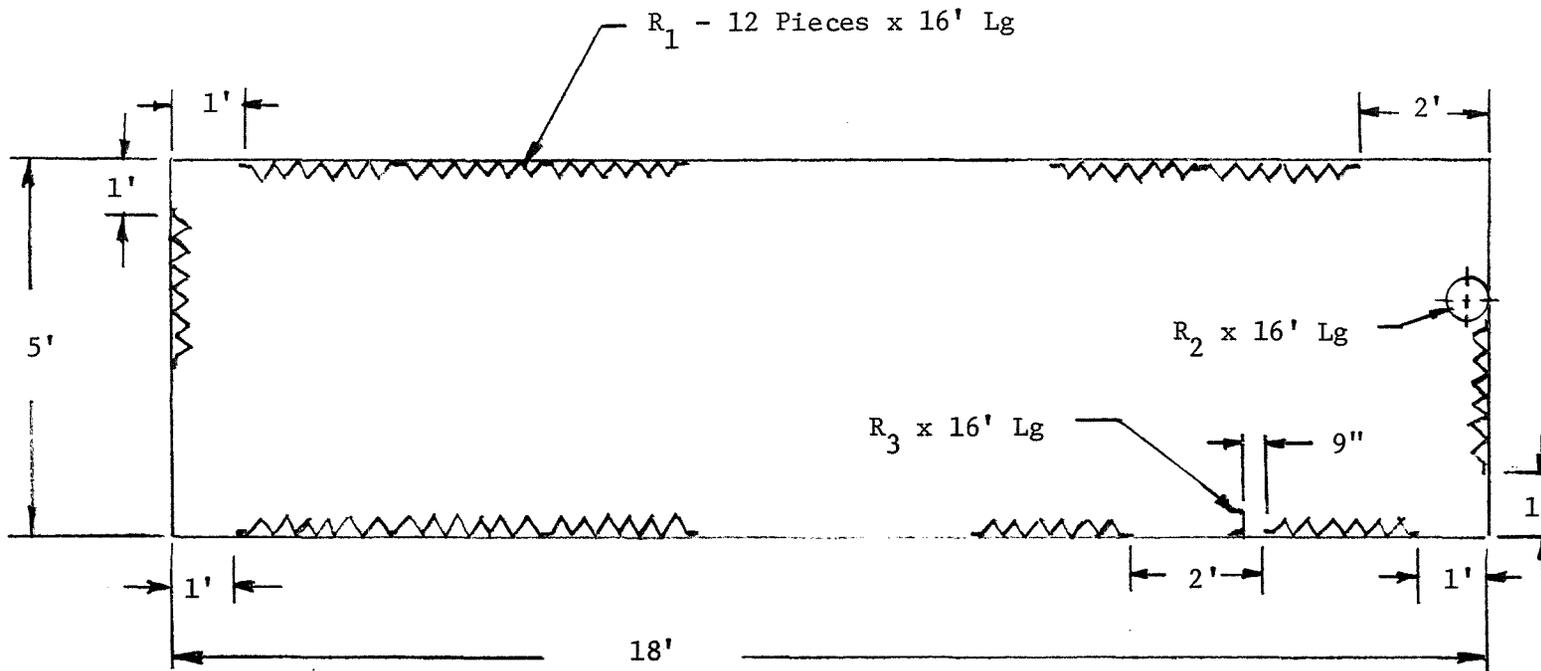


FIGURE 13 -- 100% ROUGHNESS ITEMS IN MODEL ENTRY

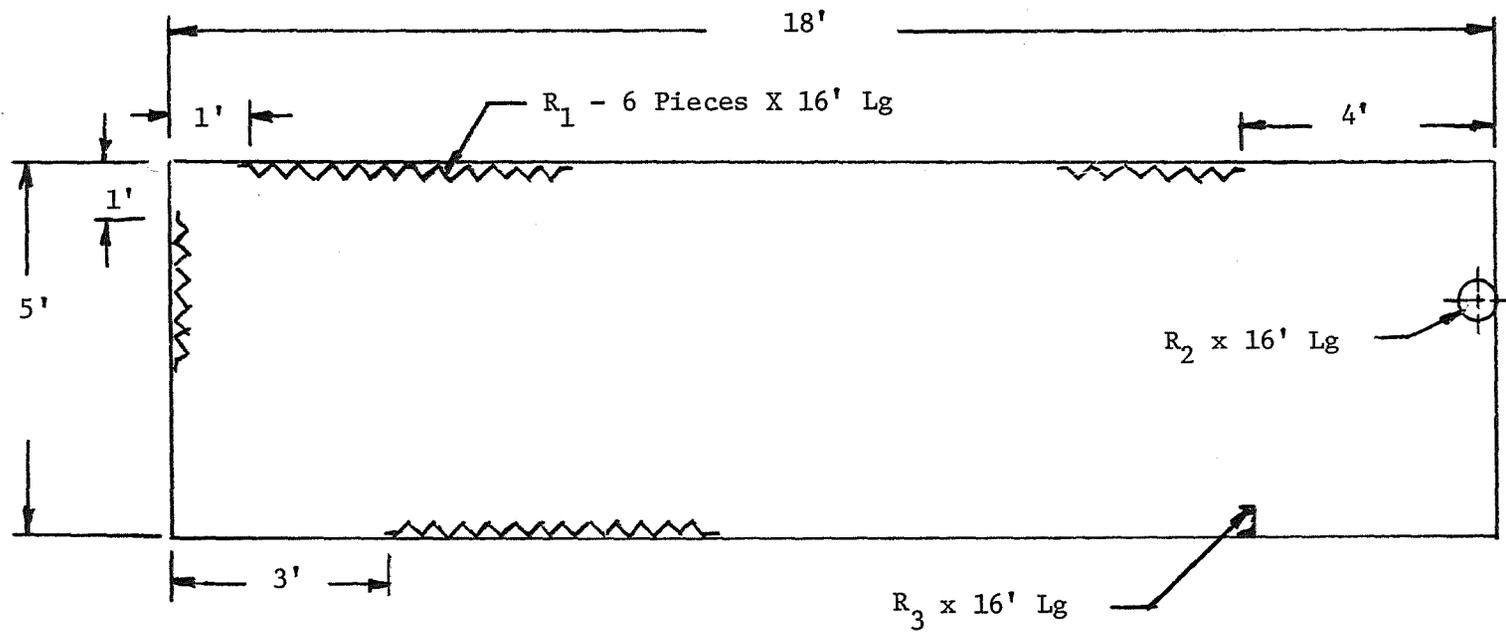


FIGURE 14 -- 50% ROUGHNESS ITEMS IN MODEL ENTRY

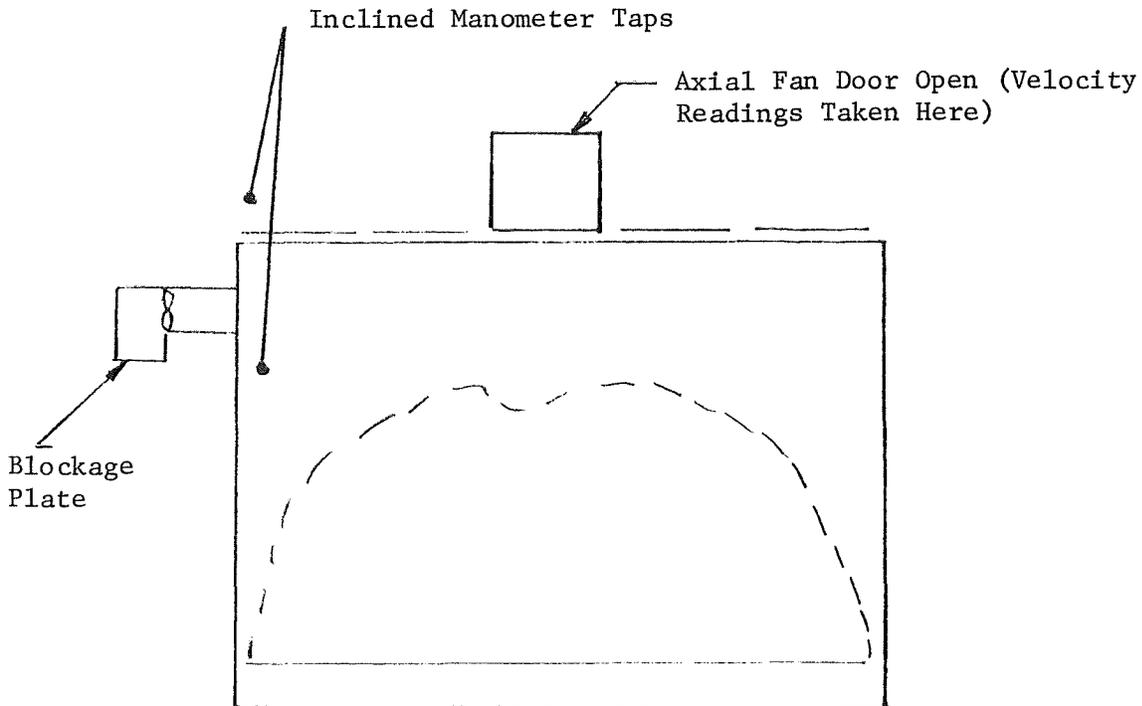
## 2. Pressure Measurements

An inclined manometer was used to measure the pressure differential across the stopping. One side was connected into the passageway through a static port in the roof region of the passageway downstream of the test brattice. The other side of the manometer was connected into the side of the passageway upstream of the test brattice. Graduations on the inclined manometer were in .01 in. of H<sub>2</sub>O increments. For the minimum erection pressure tests, pressures were exceedingly low and difficult to read on the inclined manometer. For these tests, velocity was measured in the opening in the rear of the passageway with one of the doors open behind one of the axial fans. Flow was controlled by the blocking plate on the centrifugal fan. Flow readings thus taken with the vane-type anemometer were converted to  $\Delta p$  using the equation:

$$\Delta p = \frac{1}{2} \rho v^2 \quad (\text{Velocity pressure from Bernoulli's Theorem})$$

$$\rho = \text{standard sea level } (.002378 \text{ slugs/ft}^3)$$

A cross check was made using the inclined manometer with the pressure taps located as shown below.



### III. IMPROVED SELF-SEALING BRATTICES AND AIDS TESTED

#### A. Improved Self-Sealing Brattice

##### 1. Material Screening

At the start of the effort on this contract, GAC established a set of criteria or goals for the physical properties of the material for the manufacture of the brattice as shown in Table 2.

TABLE 2  
SPECIFICATION: MATERIAL PHYSICAL PROPERTIES

<u>Property</u>	<u>Criteria/Goal</u>
Weight (oz/yd <sup>2</sup> )	≤1.6 (Goal)
Tongue Tear (lbs)	>3 x 3 (Goal)
Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min)	≤1.6 (Goal)
Strength (lb/in)	≥17.5 (Criteria)
Flammability	
ASTM E-162 (Index)	<25 (Criteria)
NFPA 701 (Flameout) (Sec.)	<2 (Criteria)

The above properties were established as follows.

Weight -- By contract

Tongue Tear -- This is a range compatible with the above weight goal, the attachment reinforcement was designed to transfer loads gradually from the canopy.

Permeability -- Considering a brattice of 20 foot diameter, the cloth area is

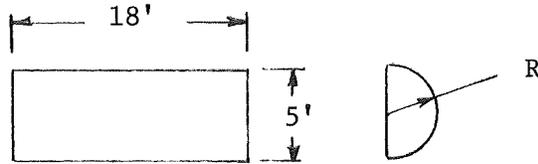
$$\begin{aligned}
 A &= \frac{\pi D^2}{2} \\
 &= \frac{\pi (20)^2}{2} = 628 \text{ ft}^2
 \end{aligned}$$

Assuming a leak rate of 1,000 cfm as a maximum goal the desired permeability must be less than:

$$\begin{aligned}
 \text{Leak rate} &= \text{cloth area (permeability)} \\
 \text{Porosity} &= \frac{1000}{628} = 1.6 \text{ ft}^3/\text{ft}^2/\text{min}
 \end{aligned}$$

GAC felt that this was conservative (area was larger than it actually

would be) since the stoppings will tend to become two dimensional, especially the larger ones. In this case the area would be as follows.



$$\frac{\pi d}{2} \times 18 = 141 \text{ ft}^2$$

For this case the acceptable permeability could be as high as:

$$\text{Porosity} = \frac{1000}{141} = 7.09 \text{ ft}^3/\text{ft}^2/\text{min}$$

The actual inflated area is somewhere between the 628 and 141 ft<sup>2</sup>.

Flammability -- Contract requirement.

Strength -- Maximum stresses in the fabric attached at ribs would be PR

$$P = 1.5'' \text{ H}_2\text{O} \text{ or } 7.8 \text{ PSF}$$

$$R = 9 \text{ ft}$$

$$\text{Stress} = \frac{7.8 \times 9}{12} = 5.85 \text{ \#/in}$$

using a factor of three (3) yields a fabric strength requirement of 17.5 #/in.

The above requirements were given to some weaving companies and the following materials were forwarded to GAC for their consideration as shown in Table 3. In addition, Table 3 shows physical properties of on-hand materials GAC used in independent laboratories flammability testing. These were the only materials received that were close to the requirement.

TABLE 3  
SUMMARY -- CANDIDATE MATERIAL PROPERTIES

Pattern No.	Material	Wt. Oz/Yd <sup>2</sup>	Tear Strength #	Permeability		Cost \$/yd <sup>2</sup>	Vendor
				Ft <sup>3</sup> /Ft <sup>2</sup> /Min @ .5" H <sub>2</sub> O	Strength #/in.		
15518	Polyester	2.15	4.0 x 3.9	1.73	77.5 x 71.5	2.58	Stern & Stern
15286	Polyester	3.3	5 x 4.9	2.5	125 x 85	-	On-hand
A4355	Nylon	1.64	1.5 x 2.7	2.61	43 x 76	2.30	Stern & Stern
5086 Treated	Nylon	2.05*	10.2 x 12.6*	1.44*	90 x 81*	.68	Putnam Mills
A4904	Nylon	3.3	10 x 10	2.21	180 x 185	-	On-hand

\*GAC Test Data

## 2. Flammability Requirements Analysis & Testing

Mr. Verakes, Mine Safety and Health Administration (MSHA), was contacted on November 10, 1977 to discuss the flame test requirements and acceptance criteria. MSHA, indicated that both ASTM-E-162 and NFPA-701 test specifications were to be employed. The acceptance criteria for NFPA-701 is that the flame extinguishes itself within 2 seconds after the burner is removed. There is no requirement for char length and the test to be used is the small scale test only. The acceptance test for ASTM-E-162 is a spread index of 25 or less.

Some preliminary flame testing was performed at GAC. The purpose of these tests was to get a feel for the degree of difficulty that might be encountered in getting a material to pass the NFPA 701 small scale test.

The initial materials selected for testing were:

- a. Nylon cloth, MIL-C-7020, Type III, 1.6 oz/sq yd
- b. Polyester cloth, GER-15023, 1.5 oz/sq yd

These two materials were selected because they were in the desired weight range and they were on the shelf at GAC. They did not meet the porosity requirements for the brattice material.

These materials were treated with flame retardant formulas 2, 3, and 6 as defined in NFPA 701. To screen the materials, a match was held under a sample of each one until the material started to flame. During the screening operation, the match was moved upward to keep the flame in contact with the fabric until ignition took place. The only specimen that showed promise during the screening tests was the polyester cloth treated with Formula No. 6.

FORMULA NO. 6

Diammonium Phosphate  $(\text{NH}_4)_2 \text{HPO}_4$  100 pounds  
 Water 50 gallons

Consequently, the above material, along with a piece of the untreated nylon and polyester were taken to GAC's Physical Test Laboratory for evaluation. The materials were tested in accordance with Federal Standard 191, Method 5903.2. This procedure is in very close agreement with the NFPA 701 small scale test. The results for each of these specimens were identical. As the flame came into contact with the specimen, the cloth would immediately melt away from the flame and by the end of twelve seconds the fabric was no longer burning. NOTE: 12 Sec. is the length of time specified for the test.

It was assumed that these specimens passed the test because of their light weight, but if there were more bulk, the untreated cloth may burn more readily once the flame has a good start. Various weights of untreated nylon and polyester were then obtained and tested in the same manner. The following is a list of the additional materials tested.

Polyester, 2.25 oz/sq yd  
 Polyester, 4.5 oz/sq yd  
 Polyester, 15.5 oz/sq yd  
 Nylon, 3.35 oz/sq yd  
 Nylon, 4.75 oz/sq yd  
 Nylon, 20.0 oz/sq yd

Of the above materials, the only ones that continued to burn after the flame was removed was the 4.5 and 15.5 oz polyesters and the 20 oz nylon.

As a result of these tests conducted at GAC, tests were run at an independent facility, Smithers Scientific Services, Akron, Ohio to verify GAC testing and to establish that uncoated lightweight nylon and polyester would satisfy the flammability requirements. Tests were conducted in accordance with ASTM E-162 and also NFPA 701 on the materials shown in Table 4.

TABLE 4  
 FLAMMABILITY TEST MATERIALS

<u>Pattern No./ Material</u>	<u>Wt. Oz/Yd<sup>2</sup></u>	<u>Permeability Ft<sup>3</sup>/Ft<sup>2</sup>/Min at .5" H<sub>2</sub>O</u>	<u>Tensile Strength #/Inch</u>	<u>Tongue Tear Strength #</u>
15286-Polyester	3.3	2.5	125 x 85	
15518-Polyester	2.15	1.73	77.5 x 71.5	4.0 x 3.9
4355A-Nylon	1.64	2.61	43 x 36	1.5 x 2.7
4904A-Nylon	3.3	2.21	180 x 185	

All of the materials successfully passed the tests indicating that the flammability requirements can be met with lightweight polyester or nylon cloth.

Note: Flame spread index was between 1 and 2 since the flame was extinguished almost immediately.

GAC did not, at this time, test Putnam Mills #5086 fabric since there was not sufficient material to do so.

### 3. Material Trade-Off and Specification

During the time period that flammability screening tests were performed no additional candidate materials were received. Table 5 shows the comparison between the requirements/goals and the two candidate materials received at the time when material procurement had to proceed.

TABLE 5  
MATERIAL-REQUIREMENTS/AVAILABILITY

<u>Property</u>	<u>Goal/Req.</u>	<u>Stern &amp; Stern Polyester #15518 (Untreated)</u>	<u>Putnam Mills Nylon #5086 (Treated)</u>
Weight Oz/Yd <sup>2</sup>	≤ 1.6	2.15	2.05
Tongue Tear Lbs	> 3 x 3	4 x 3.9	10.0 x 12.6
Permeability Ft <sup>3</sup> /Ft <sup>2</sup> /Min @ .5" H <sub>2</sub> O	≤ 1.6	1.73	1.44
Strength #/in	≥ 17.5	77.5 x 71.5	90 x 81
Flammability			
ASTM E-162 (Index)	< 25	Tested OK	Will Pass Test
NFPA 701 (Flameout) (Sec.)	< 2	Tested OK	By Comparison With Other Material
Cost \$/yd <sup>2</sup>	-	2.58	.68

As can be seen from the above comparison with the goals/requirements, the Putnam Mills #5086 treated cloth met the requirements from a standpoint of tongue tear, permeability, strength, flammability. The cost of this material was much below any of the materials investigated. The weight of the material is somewhat above what is desired, but the requirements for weight and porosity as previously set forth are somewhat incompatible.

Flammability tests showed that there was no requirement for the use of the much more expensive aramid fibers (Nomex\* or Kevlar-29\*) which would also not approach the weight and permeability requirements due to non-availability of low denier yarns for weaving.

The investigation of film-fabrics was not pursued due to the known development and production costs involved with these materials. A look at available off-the-shelf materials of this category indicated that the flammability requirements could not be met. In addition, the assembly and edge reinforcement would be much more expensive.

With the concurrence of the Bureau of Mines Technical Project Officer, GAC procured sufficient quantity of cloth similar to Putnam Mills pattern 5086. Since the properties of the material shown in Table 5 were GAC test values the specification written by GAC (RF-391) for the brattice cloth was slightly different at the manufacturer's request. Table 6 shows final specification requirements for the cloth.

TABLE 6  
GAC RF-391 -- MATERIAL SPECIFICATION

Weight (oz/yd <sup>2</sup> )	1.85 ±.20
Tongue Tear (lbs)	8 x 8 min
Permeability (ft <sup>3</sup> /ft <sup>2</sup> /min) @ .5" H <sub>2</sub> O	2.0 max
Strength (#/in)	80 x 70 min

FR (Flame Retarded Treatment) & Dyed Red  
NOTE: FR treatment added as extra protection at no cost.

#### 4. Attachment Analysis and Test

Various methods were considered for transferring the brattice loads into the pin attachment and GAC decided that testing must be done in this area.

GAC chose the simplest edge attachment as the choice for test and that is the attachment of a 2" nylon webbing to the edge of the brattice. GAC chose 2" wide material since it was available for test and would reduce brattice weight.

---

\* Trade Name -- E.I. DuPont De Nemours Company

The ultimate load (criteria for test) was calculated as follows assuming a minimum of 4 attachments per brattice.

$$\text{Max Press} - 1.5'' \text{ H}_2\text{O} = 7.8 \text{ P.S.F.}$$

$$\text{Cross-Cut Opening} - 5' \times 18' = 90 \text{ ft}^2$$

$$\text{Max Load} = \frac{90 \times 7.8}{4} = 176 \text{ \#/Attach}$$

The attachment devices were as follows:

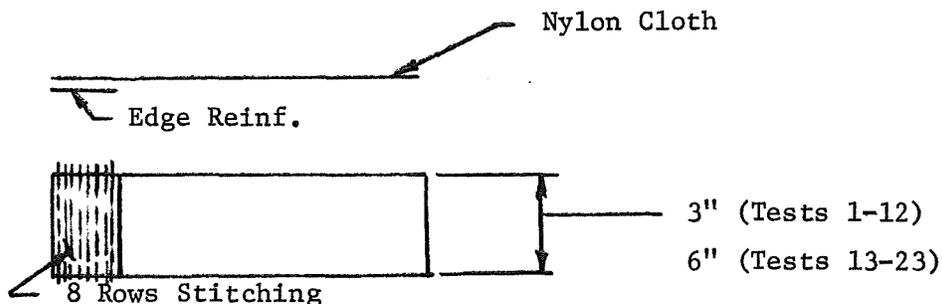
Nail -- 8 penny common nail with 7/16 O.D. x 1/16 T. washer

Spad -- 1/16 T. - 4130 STL 1/2"  1 1/2"

Materials used in the test program were as follows.

- a. Basic cloth -- Nylon -- 100 x 100 #/in (Tests 1 - 23)
  - 75 x 75 #/in (Tests 24, 25, 26)
- b. Edge Reinf Webbing -- 2000 # Nylon (Tests 1 - 15)
  - 2000 # Nomex (Tests 16-20, 24-26)
  - 225# X 230# Brattice (Tests 21 - 23)
  - (ABC Vinolin - FR Plastic)

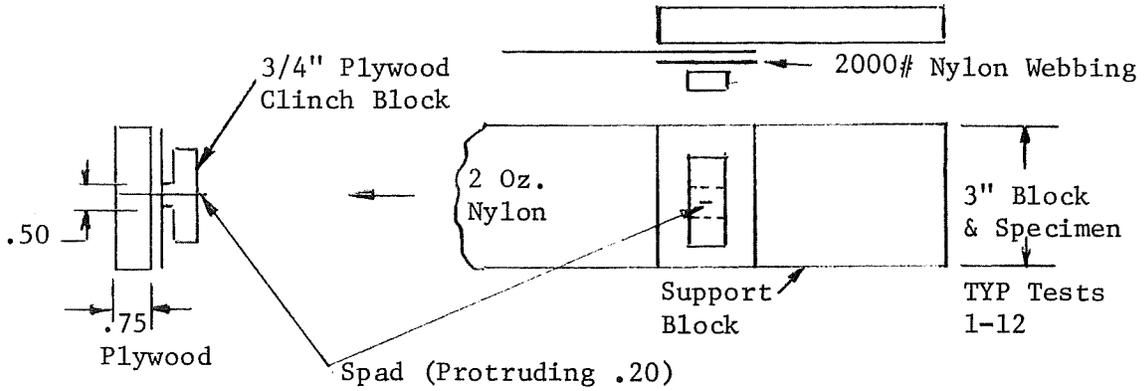
Test panels were as follows:



Testing was conducted at GAC in an Instron Test Machine, serrated grips for the plywood and rubber faced for the cloth were used and the load rate was 12 inches per minute.

Configurations for attachment were as follows.

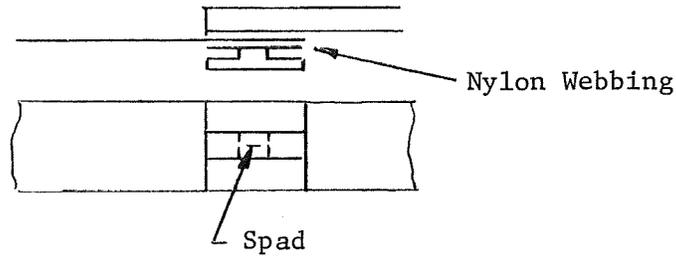
TEST #1



TEST #2

Same as No. 1 Except -- Spad was Installed Flush in Clinch Block

TEST #3

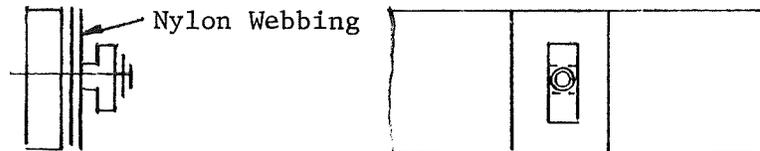


Same as No. 1 Except -- Clinch Block & Spad Rotated 90° - Spad Installed .10 Protruding

TEST #4

Same as No. 3 Except - Spad Installed Flush in Clinch Block

TEST #5

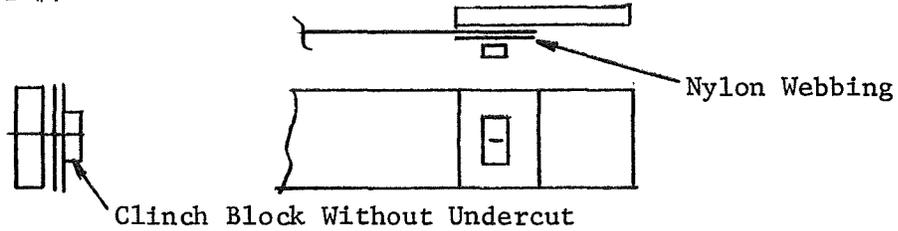


Same as No. 1 Except - Nail & Washer in Place of Spad

TEST #6

Same as No. 5

TEST #7

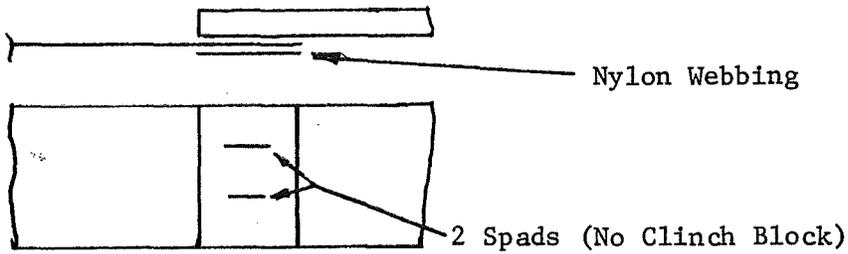


Same as #1 Except for Clinch Block (No Undercut)

TEST #8

Same as #7

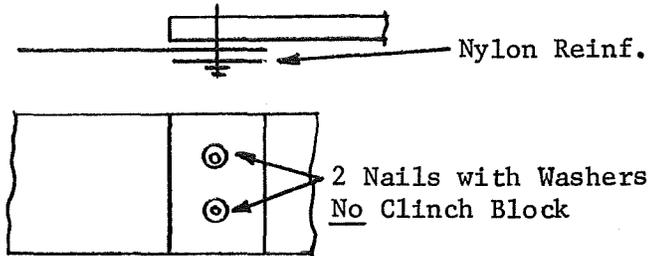
TEST #9



TEST #10

Same as #9

TEST #11

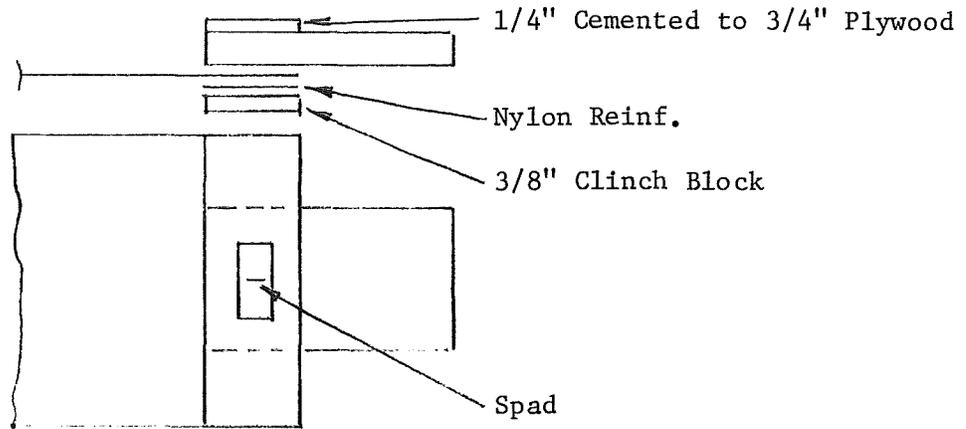


TEST #12

Same as #1 -- 1 nail with Washer - No Clinch Block

NOTE: Since a number of failures occurred in parent material and the 3" wide specimen was felt to be conservative (stress concentration in parent material) the remaining tests were conducted with 6" wide fabric specimens.

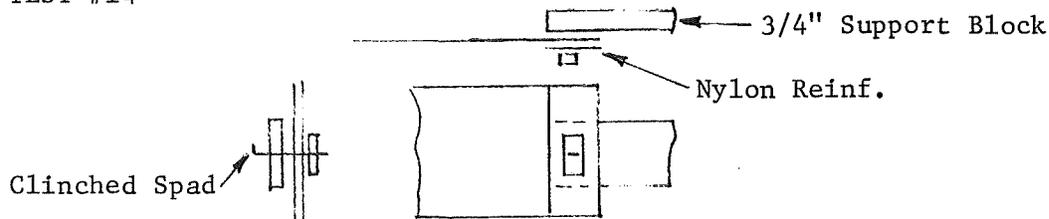
## TEST #13



Similar to #1 with following changes:

- 6" wide specimen
- 3/8" clinch block (no undercut)
- 1/2" plywood added to 3/4" support block to clinch spad more tightly

## TEST #14



Same as #13, Without 1/4" support and spad clinched

## TEST #15

Same as #14 - Clinching Operation Loosened Spad

## TEST #16

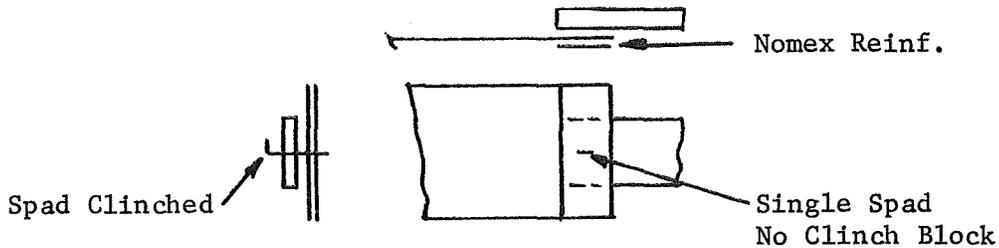
Same as #14 - But 2" wide Nomex Webbing in place of 2" Wide Nylon.

Note: Nomex webbing approximately same strength, but heavier denier material.

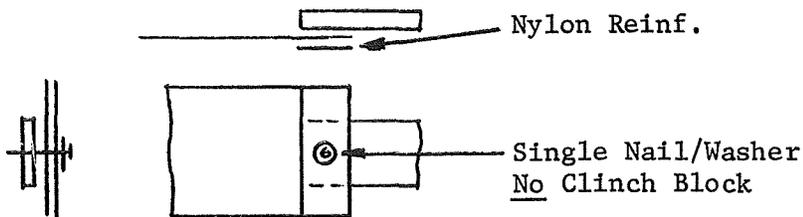
## TEST #17

Same as #16

TEST #18



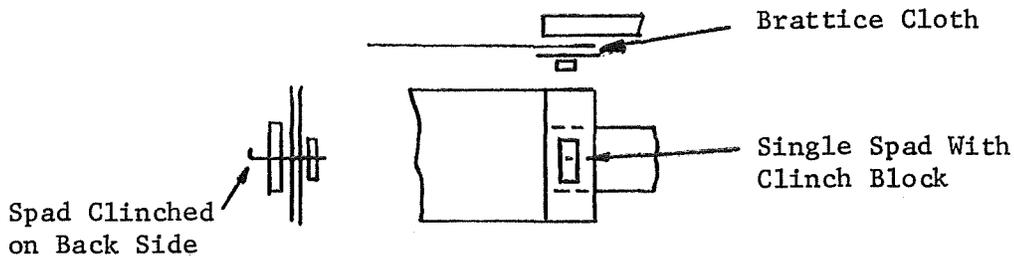
TEST #19



TEST #20

Same as #19 -- Nomex Reinf. in place of Nylon

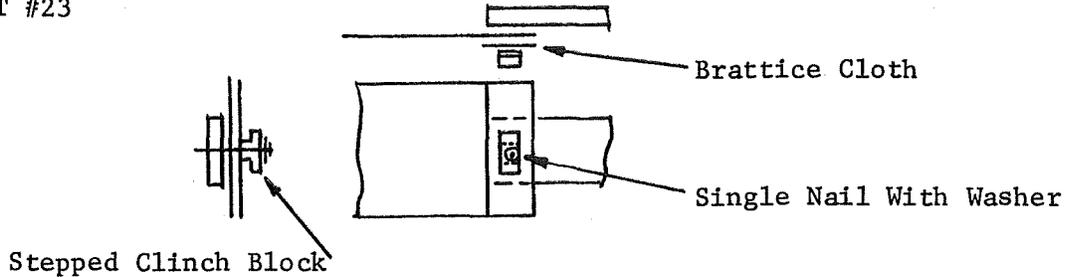
TEST #21



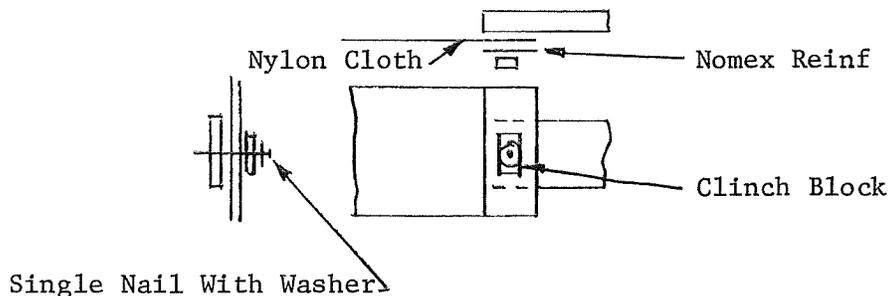
TEST #22

Same as #21

TEST #23



TEST #24



TEST #25

Same as #24

TEST #26

Same as #24

Table 7 shows the results of the attachment tests including ultimate loads and type of failure.

TABLE 7  
ATTACHMENT - TEST RESULTS

<u>Test No.</u>	<u>Ult Load (Lbs)</u>	<u>Type Failure</u>
1	125	At Spad
2	137	At Spad
3	145	Cloth at 1st Row Stitching
4	140	Cloth at 1st Row Stitching
5	180	Cloth at 1st Row Stitching
6	172	Cloth at 1st Row Stitching
7	163	At Spad
*8	100	At Spad
9	144	Cloth at 1st Row Stitching
10	138	Cloth at 1st Row Stitching
11	182	Cloth at 1st Row Stitching
12	160	Cloth at 1st Row Stitching
13	140	At Spad
14	193	At Spad
*15	107	At Spad
16	256	Cloth at 1st Row Stitching
17	194	At Spad
18	162	At Spad
19	210	Cloth at 1st Row Stitching
20	231	Cloth at 1st Row Stitching

...continued

TABLE 7 -- CONTINUED  
ATTACHMENT - TEST RESULTS

<u>Test No.</u>	<u>Ult Load (Lbs)</u>	<u>Type Failure</u>
21	152	At Spad
22	150	At Spad
23	150	At Nail - Then Sewing
24	204	Cloth at 1st Row Stitching
25	200	Cloth at 1st Row Stitching
26	196	Cloth at 1st Row Stitching

\*Loose Spad

As a result of the above tests, GAC concluded that.

- a. A single 2" wide webbing sewn to edge of brattice is adequate reinf. and simplest design to fabricate.
- b. Nomex webbing due to larger denier material is preferred reinf. and it also is permissible material. Note: Per MSHA this does not have to be permissible material.
- c. Spads in wood are sensitive and must be adequately clinched and clinch block must be used.
- d. Nails in wood will do the job with or without clinch block.
- e. All tests were conservative due to stress concentration of fabric at attachment that will probably not be as severe in actual usage.
- f. Brattice tests in test entry would be with nails for ease of installation.

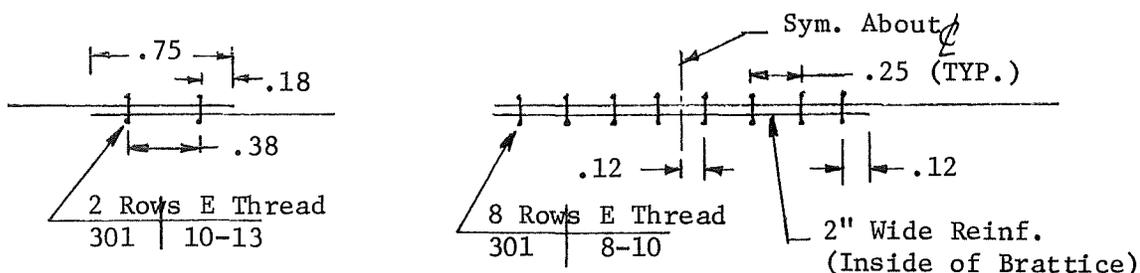
##### 5. Brattice Design and Weights Analysis

With the analysis, test and choice of the brattice cloth completed GAC designed and fabricated the brattice units for test. To minimize the cost of fabrication and since the units were for emergency use only, simple lap seams were chosen for the assembly. Three different size (18', 21' and 24' dia.) hemispherical brattices were designed. Since the cloth was being procured in a 45" width, the units were constructed with the following number of gore patterns.

<u>Size</u>	<u>Gore Pattern (Qty)</u>
18'	16
21'	18
24'	22

Figure 15 shows the attachment of the gore patterns and attachment of the edge reinforcement.

FIGURE 15  
BRATTICE SEAMS



Gore Seam

Reinforcement Attachment

To close off the hemispherical end of the brattice a 9.50 inch dia. end cap was added.

The calculated weight of the three different brattices is shown in Table 8.

TABLE 8  
BRATTICE - CALCULATED WEIGHT

	<u>18' Dia</u>	<u>21' Dia</u>	<u>24' Dia</u>
Canopy & Seams (.75 Lap Seam)	7.26#	9.87#	12.82#
Reinforcement	1.53#	1.79#	2.04#
Total	8.79#	11.66#	14.86#

A comparison of calculated and "As Built" particulars of the brattices is shown in Table 9.

TABLE 9  
BRATTICE ASSEMBLY - CALCULATED VERSUS AS BUILT

<u>Nom. Dia.</u>	<u>Calc Circ</u> ( $\pi D$ )	<u>As Built Circ.</u> (Taken at Edge Reinforcement)	<u>Calc Wt.</u>	<u>As Built Wt.</u>
18'	56.5'	55.2'	8.79#	9.2#
21'	66.0'	63.8'	11.66#	12.1#
24'	75.4'	72.7'	14.86#	15.3#

The decrease in actual circumference from the calculated is due to the attachment of the reinforcement which tends to gather the material. The increase in weight is attributed to the edge reinforcement whose actual weight was higher than estimated.

## 6. Material Verification Testing

Upon receipt of the fabric for the manufacture of the brattice assemblies tests were run to verify the conformance of the material with the specification requirements. Table 10 summarizes the test data with a comparison of the design goals and specification requirements.

TABLE 10  
MATERIAL TEST RESULTS

	<u>Design Goal</u>	<u>Vendor Mat'l Requirements</u>		<u>Test Results</u>		F.
		W.	F.	W.	F.	
Tensile Strength (#/in)	>17.5	80	x 70	91	x 87	
Tongue Tear (#)	>3 x 3	8	x 8	10.3	x 9.5	
Weight (oz/yd <sup>2</sup> )	<1.60	1.85	+ .2	1.99		
Permeability (Ft <sup>3</sup> /Ft <sup>2</sup> /Min) @ .5 in. H <sub>2</sub> O	<1.60	<2.00		1.75		

In addition, seam tests were run on the material using the seam configuration called for on the manufacturing drawing.

Test results were 78#/in. warp and 83#/in. fill which were more than adequate for the design of the brattice.

Successful flammability tests were conducted by Smithers Scientific Services, Akron, Ohio on the brattice cloth. Tests were conducted in accordance with ASTM E-162 and NFPA 701 (small scale procedure). Test summary is shown in Table 11.

TABLE 11  
FLAMMABILITY TEST RESULTS

<u>Test Spec.</u>	<u>Acceptance Criteria</u>	<u>Results</u>
ASTM E-162	Index (I <sub>s</sub> ) Less than 25	I <sub>s</sub> = 0
NFPA 701	Flame extinguished in less than 2 seconds when burner is removed. (No requirement for char length.)	Flame extinguished immediately

GAC test data sheets are included as Appendix A to this report and the Smithers Scientific test reports are included as Appendix B.

The Bureau of Mines Project Officer forwarded samples of two materials for comparison of permeability measurements of the materials presently being used or tested by the Bureau of Mines with the cloth chosen for this program. The material was identified as "Jute Brattice" and "Sail-Cloth". Permeability was 150 ft<sup>3</sup>/Ft<sup>2</sup>/Min and .5 to 1.0 Ft<sup>3</sup>/Ft<sup>2</sup>/Min measured at .5 inch of H<sub>2</sub>O.

## 7. Permissible Status Request

GAC made application to the U.S. Mine Safety and Health Administration to obtain a permissible status for the nylon cloth used in the improved brattices. The application included identification number, manufacturer, product description, formulation, flammability test data, shrinkage @ 300°F and quality assurance provisions. A copy of this application and GAC's request letter is included as Appendix C to this report. After submittal of the permissible status request, GAC was contacted by MSHA with questions, which GAC answered and submitted in writing. They were as follows.

MSHA Question #1 -- What weight or percent of cloth weight is the flame retardant?

GAC Answer -- 2 - 5% by weight (.04 to .10 oz/sq yd).

MSHA Question #2 -- Is there anything else in the Thiourea Compound besides Thiourea?

GAC Answer -- The flame retardant is a Thiourea Compound containing a resinous material to make it adhere to the cloth. The total compound is proprietary in nature. The flame retardancy is obtained with the Thiourea.

MSHA Question #3 -- Would Goodyear be willing to add a statement under toxicity that the flame retardant will not come off of the cloth under normal storage and handling?

GAC Answer -- The flame retardant is cured onto the cloth and will not undergo any change of state or come off of the cloth under normal storage and handling conditions.

MSHA Question #4 -- Would Goodyear be willing to add a statement under the Quality Assurance Provisions that says Goodyear will maintain a record of the units built and who they were sold to?

GAC Answer -- In addition to the Quality Control Provisions stated in the application, Goodyear will keep a complete record of the number of self-sealing brattices that are built from this material along with a record of who procured them.

GAC obtained permissible status of this material per MSHA letter A&CC: DM&E: Par #0023745 which is included as Appendix D of this report.

## B. Installation Aids

### 1. Spads or Power-Actuated Pins

The design and test of the attachment with simulated spads or pins has been discussed in detail in Section III-A-4 of this report. All testing of the brattices in the model entry (except for the poles to be discussed later) used nails with a clinch strip made from .12 T aluminum .50 wide x 2.00 long since the wood strips used in the bench testing did not prove to be re-usable. Nails used in the tests were a two-headed 8 penny nail.

### 2. Poles

Poles were investigated for installation of the brattice since in actual use they would possibly be more quickly installed than spads or power-actuated pins.

GAC established the following guidelines for selection of suitable designs for the poles.

- a. Off the shelf hardware
- b. Ease and quickness of installation
- c. Ability to adapt to a range of heights
- d. Ability to apply a compressive force of approximately 120#

The 120# figure was arrived at as follows. Assuming 3 poles minimum would be used, 5 x 18 ft (90 ft<sup>2</sup>) entry, friction coefficient ( $\mu$ ) of 1, and using maximum pressure of 1.5" H<sub>2</sub>O (3 x design load) = (7.8 psf)

$$\begin{aligned} \text{Load per attachment} &= \frac{\text{Area, pressure}}{\text{No. of support points}} \\ &= \frac{90 \times 7.8}{6} = 120\# \end{aligned}$$

$$\begin{aligned} \text{Axial Load in pole} &= \text{Attachment load} \times \mu \\ \text{(Normal Force)} &= 120 \times 1 = 120\# \end{aligned}$$

Folding poles were ruled out since it is felt they are more cumbersome to use than telescoping poles. Springs on the ends of the poles were also ruled out since, if the spring had a force of 120# or more, the pole would be difficult to install. GAC concentrated then on extendable telescoping tubes that could quickly and easily be adjusted to desired height and be self locking and then be adjusted by screw thread arrangements to provide the desired compressive load.

Several types of adjustable poles were investigated. The primary difference between the poles is the method of maintaining the chosen pole height. Several of the poles offered an axial holding action by a

pin-in-the hole and key-in-the-slot arrangement; however, they had the disadvantage of a limited number of adjustments for any standard design. One pole with a quick-lock latch and one with a hose clamp for locking in the extended position offered infinite height adjustments within their length range. GAC chose a tent pole #9HA from Eureka Tent, Inc., Binghamton, N.Y.

A light-weight adjustable furniture glide was modified to fit into one end of the pole with the quick-lock latch. This arrangement is similar to that used on the end of household or construction-type adjustable posts. See Figure 16 for pole details. Length of the sliding tubes was changed so that poles could be used in an airway height from 50" to 90".

This modified pole was inserted into a Baldwin test machine and loaded in compression by adjusting the glide at the end of the pole mechanically to a load of 150#.

The load was maintained on the pole for over 18 hours. The load on the pole stabilized at 120 pounds after a period of 2-1/2 hours which is considered sufficient force for holding the brattice in position during normal operation.

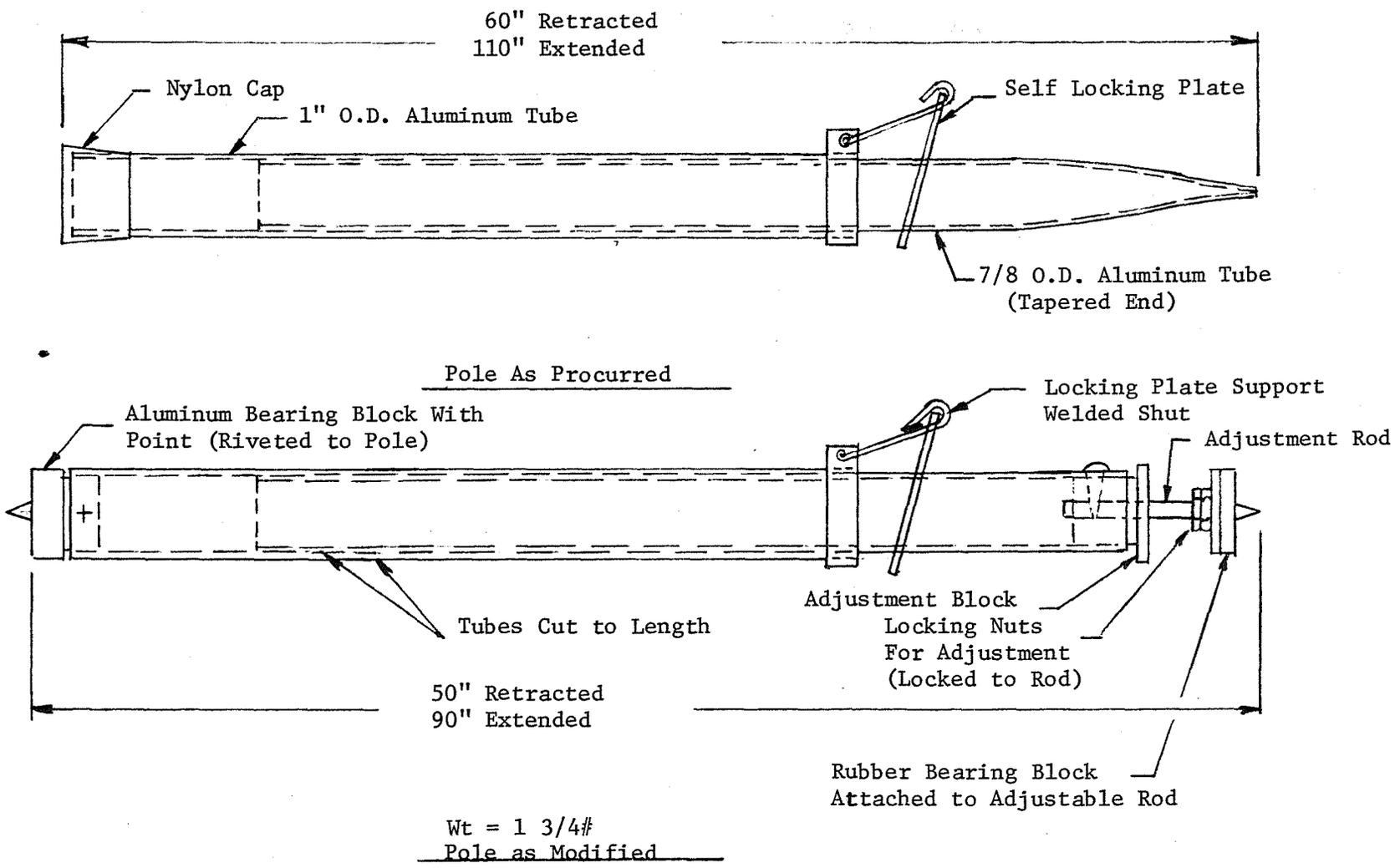
Since the pole proved structurally sound, easy to install and used essentially off-the-shelf hardware, this configuration was chosen for test of the brattice.

#### C. Auxiliary Sealing Agent

An investigation was performed to determine a suitable non-flammable foam that could be used around the stopping perimeter to fill gaps between the stopping and the walls, roof and floor. An initial search indicated there were no non-flammable foaming materials available and so GAC sent a form letter to 18 candidate foam suppliers outlining the desired properties of a material as follows.

- Easy to apply
- Fast Setting
- Portable Application Equipment
- Non-Flammable
- Adhere to Lightweight Nylon Cloth
- High Expansion ratio
- Low Permeability at .5" H<sub>2</sub>O - Delta Pressure

The following list of suppliers were contacted either by letter or phone.



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FIGURE 16 -- EXTENSIBLE POLE DETAILS

MAIL

Allied Plastics	Marine Plastics
Almac Plastics	Olefoam
Arlon Products	General Plastics Mfg.
Donray Products	Trend Mfg. of America
Dow Chemical	Atlas Industries
Foam Corp. of America	Gusmer Corporation
Foam Molders & Specialties	Gitco
Foam Products	Eltron, Inc.
Foammade Industries	H.S. Bancroft
Herman A. Gelman	

PHONE

Emerson and Cuming, Inc.  
 Conap, Inc.  
 Ferw Corp.  
 Deccofelt Corp.  
 General Latex  
 Stephau Chemical  
 MR Plastics  
 Freeman Chemical

Very few responses were received and no candidate materials were uncovered. Polyurethane was mentioned by some as a good candidate, but, of course, it does not meet the non-flammability requirement.

The Bureau of Mines project officer advised GAC of a possible lead in obtaining a non-flammable foam. This was a West German paper.<sup>2</sup> GAC obtained copies and since it looked promising made contact with Dr. Reisner. GAC was advised that the material, ISO-FOAM, is marketed in the United States under the trade name RAPCO-FOAM by the Rapperswill Corp., Chanin Building- Suite 4900, 122 East 42nd Street., New York, N.Y. 10017. The local area distributor, Adams-Barre Corp of Columbus, Ohio, was contacted and GAC witnessed a demonstration of application of the material at their Findlay, Ohio facility.

The material is a urea-formaldehyde foam. The primary use of the material is for thermal and acoustical insulation in private residences, commercial and industrial buildings and hospitals, creation of sound partitions and for ventilation control in foreign underground coal mines. The foam is a thermosetting plastic composed of urea-formaldehyde resins, air and a foaming agent which contains a catalyst (hardening agent). It is made using a cold setting process - expansion is mechanical rather than chemical. Therefore, no expansion takes place once the foam is generated in the generating equipment. The foam can be generated either continuously or in

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<sup>2</sup>Reisner, W., Investigation Of The Burning Behavior of ISO-FOAM, Glückauf-Forschungshefte, Vol 38, No. 4, August 1977, 139-143.

batches. The foaming agent, an aqueous solution containing the catalyst is foamed up in a continuous stream after which the urea-formaldehyde resin is added. The catalyst in the foaming agent causes the resin to harden. The strength and amount of resin determines the setting time. Once generated, it takes between 1-2 minutes for the foam to set, during which time the foam is fluid and can be injected in forms and troweled to conform to shape.

Some of the significant properties of the material are shown in Table 12.

TABLE 12  
PROPERTIES - RAPCO-FOAM

Weight	.6 to 1.0 #/ft <sup>3</sup> (Dry)
Permeability (4" thick)	.004 ft <sup>3</sup> /ft <sup>2</sup> /min @ .5" H <sub>2</sub> O
Cost	\$.75/ft <sup>3</sup> (using 55 gal drum) (2 - 55 gal drums yield 360 ft <sup>3</sup> foam)
Water Absorption	1-2% by weight
Shrinkage	Less than 3%

The material is relatively easy to apply with the mixing being accomplished automatically and the application technique no more complicated than applying a caulking compound.

With regard to its flammability properties, the urea-formaldehyde foam does not have the severe flammability properties associated with polyurethane and polystyrene and other plastic foams. Laboratory tests have been performed to determine the properties of Rapco-Foam. The conclusions include the following.

- ° RAPCO-Foam is a modified urea-formaldehyde thermosetting foam with a maximum continuous service temperature of ...210°F (99°C).
- ° It is stable up to ...428°F (220°C)
- ° Heated up to its ignition temperature...1200°F (650°C) it will smolder and release smoke.
- ° Upon further heating it will ignite and burn, releasing...924 BTU's per board foot @ 0.7 lbs/cu ft. However, it will not melt away. It will char, lose weight and volume, but remain in place as a foam.
- ° The gases generated when burning are less toxic than those of either plywood or paper.

The material was tested by Dr. Reisner as reported in his paper to ASTM D 1692-59T and the results showed that the material did not burn.

During the test demonstration at Findlay, Ohio the material showed that it would adhere to the nylon cloth used in the brattice. Since the material met most of the requirements set forth in the initial requirements, GAC requested the Adams-Barre Company to demonstrate its capability at GAC.

Demonstration of foaming of a brattice in the model entry is documented in the test section of this report.

#### IV. TEST RESULTS

##### A. General

The purpose of the test program was to determine the characteristics of the improved brattice as designed and to evaluate auxiliary devices and techniques for installation of the self-sealing brattice. Specifically the goals were as follows.

- ° Determine how much larger the perimeter of the self-sealing brattice should be than the airway perimeters.
- ° Determine the range of airway sizes a self-sealing brattice can seal with reasonable efficiency.
- ° Assess erection of the self-sealing brattice using both spads or power actuated pins and lightweight extendable poles.
- ° Determine minimum pressures for erection and maintaining the stopping in place.
- ° Leakage at differential pressures ranging from the minimum to .5 inch H<sub>2</sub>O differential pressure.
- ° Stopping ability to handle reverse flows.
- ° Evaluate foam material as an auxiliary sealing agent.

Testing was conducted in the model 5' x 18' airway with bare walls. 100% roughness and 50% roughness as described in Section II, B. of this report. Instrumentation was as shown in Section II, D of this report. The brattices tested were 18', 21' and 24' manufactured as described in Section III, A. 5. of this report. The details of the brattice attachment, poles and foam were as described in Section III, B. and C. of this report. All testing was conducted at .5 inch of H<sub>2</sub>O differential pressure across the brattice except for the flow rate tests conducted from .5 inch of H<sub>2</sub>O down to a minimum.

##### B. Sizing Tests

###### 1. Test Conclusions

The sizing testing resulted in the following conclusions.

- ° Assuming a fairly smooth mine passage, a brattice will adequately seal any perimeter of passageway up to equal or slightly smaller than the brattice perimeter.
- ° If the surface roughness is similar to the test roughness configuration the brattice perimeter should be approximately 50% larger than the basic passage perimeter for adequate sealing.

- ° The larger the brattice, the lower the leak rates.
- ° Flow rates with any specific attachment arrangement generally decrease with increasing size of brattice.
- ° There are not large changes in flow rate when changing either brattice diameter or number of attachments.
- ° The roughness items as tested were considered an extremely severe case.
- ° Brattice conforms well to such things as tubes or channels.
- ° The sealing capability of the brattice can be helped by adjustment to get the excess brattice material in the roughness areas.
- ° Leakage is most evident in roof area where weight of the brattice pulls itself down and added attachments are advantageous in this area.

## 2. Test Details

To analyze the results of the test quantitatively, some calculations for expected flow rates can be made.

Assuming the smallest brattice tested (Dia = 18') the area of the cloth is:

$$\frac{\pi d^2}{2} = \frac{\pi (18)^2}{2} = 510 \text{ ft}^2$$

The flow rate if the brattice became hemispherical and there were no leaks at the wall would be:

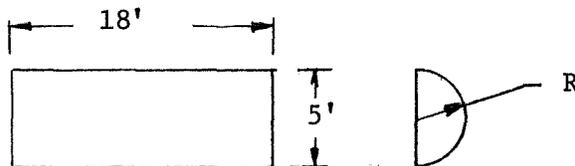
$$\text{Area} \times \text{Porosity} = \text{Flow Rate}$$

$$510 \times 1.75 = 893 \text{ Ft}^3/\text{Min}$$

(Test Value)

For the 24' diameter brattice this figure would be 1588 ft<sup>3</sup>/min.

If the brattice conformed to the test passage such that a semi-cylindrical shape resulted, then the flow rate could be calculated as follows.



$$A = \frac{\pi D}{2} \times 18 = \frac{\pi (5) (18)}{2} = 141 \text{ Ft}^2$$

$$A \times \text{Porosity} = \text{Flow}$$

$$141 \times 1.75 = 247 \text{ Ft}^3/\text{Min}$$

The flow rate in actual test should therefore be somewhere between a minimum of 247 ft<sup>3</sup>/min and a maximum 1588 ft<sup>3</sup>/min and probably more closely to the minimum calculated.

The results of the testing shows that flow rates (in a bare passageway) in the 300 - 400 ft<sup>3</sup>/min range are obtainable with any of the brattice configurations and with most of the attachment arrangements.

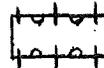
Table 13 is a summary of the sizing testing showing brattice size, number of attachments (nails in all cases), attachment pattern and measured flow rates. The first 13 tests are not included since they were made to debug the test set-up and procedure. Tests 14 thru 29 were all with the 18' diameter brattice to choose the candidate attachment configuration for the 21' and 24' diameter brattice. Some tests were run where the attachment points were not in a vertical plane (typical test No. 19) to analyze the effect of misplacement of the attachment. No significant change in flow rates was in evidence and since this is not probably too practical of an installation arrangement, remaining tests were done with the attachments in a vertical plane.

These tests did show that the brattice is not sensitive to placement of the attachment with respect to in-line vertical plane.

Tests 14 - 51 were all conducted with a bare passageway (no roughness items). Tests 52 - 55 were run with a bare passageway but with a 6" x 12" miter in the corner instead of a right angle corner. This was done to better simulate an actual coal mine. The brattice did conform better although the leak rate was not changed significantly. Tests 56 - 69 included 100% roughness items. Tests 70 - 84 were with 50% roughness items.

It was noted in the first tests that there was excess material on the sides and insufficient material on the top and bottom. The reason for this was that in all tests up thru test 60, the relationship of the stopping to the periphery of the cross-cut was as shown in Figure 17.

In tests from 61 on, where attachment is shown



the attachment of the brattice was as shown in Figure 18.

TABLE 13  
BRATTICE TEST DATA

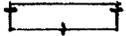
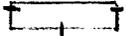
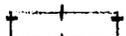
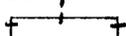
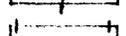
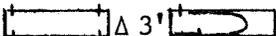
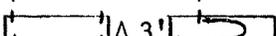
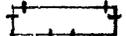
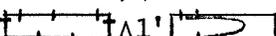
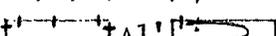
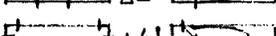
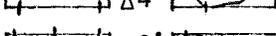
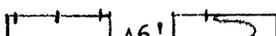
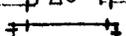
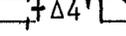
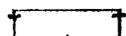
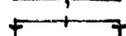
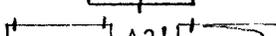
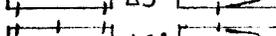
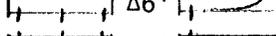
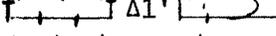
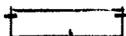
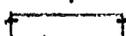
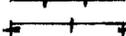
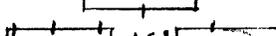
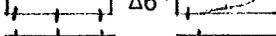
Test Number	Stopping Size (Dia)	Passageway	Number of Attachments	Pattern	Flow Quantity (CFM) @ .5" H <sub>2</sub> O	
14	18'	↑ Bare ↓	3		465	
15	"		3		465	
16	"		4		N/A	
17	"		4		1000	
18	"		4		400	
19	"		4		340	
20	"		4		345	
<hr/>						
21	"		6		750	
22	"		7		365	
23	"		7		640	
24	"		6		615	
25	"		6		430	
<hr/>						
26	"		6		380	
27	"		8		440	
28	"		8		370	
29	"		8		530	
30	21'		3		370	
<hr/>						
31A	"	3		540		
31B	"	4		355		
32	"	4		400		
33	"	6		340		
34	"	7		390		
35	"	8		420		
<hr/>						
36	24'	3		360		
37	"	4		370		
38	"	4		345		
39	"	6		320		
40	"	Bare	8		425	

TABLE 13 -- CONTINUED

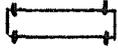
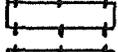
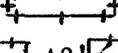
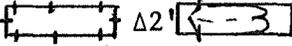
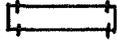
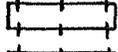
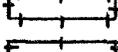
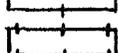
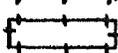
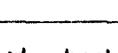
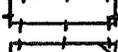
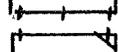
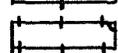
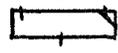
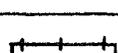
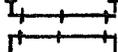
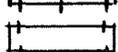
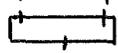
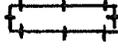
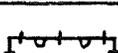
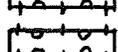
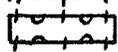
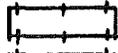
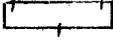
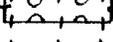
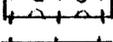
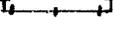
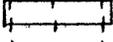
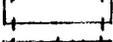
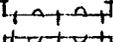
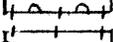
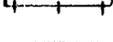
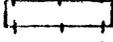
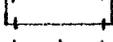
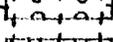
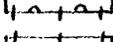
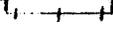
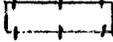
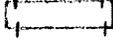
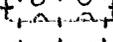
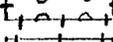
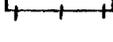
Test Number	Stopping Size (Dia)	Passageway	Number of Attachments	Pattern	Flow Quantity (CFM) @ .5" H <sub>2</sub> O	
41	24'	Bare	4		385	
42	"	↑	6		375	
43	"		8		325	
44	"		8		350	
45	21'		4		435	
<hr/>						
46	"	↓	6		415	
47	"		8		445	
48	18'		4		500	
49	"		6		320	
50	"		8		395	
<hr/>						
51	21'		↓	8		515
52	24'			6		380
53	"			3		410
54	18'			6		375
55	"	Bare		3		475
<hr/>						
56	18'	100% Roughness	8		1660	
57	"	↑	6		1670	
58	"		4		1710	
59	"		3		1670	
60	24'		8		1150	
<hr/>						
61	"	↓	8		920	
62	"		6		830	
63	"		6		920	
64	"		6		1470	
65	"		100% Roughness	4		1690

TABLE 13 -- CONTINUED

Test Number	Stopping (Size (Dia)	Passageway	Number of Attachments	Pattern	Flow Quantity (CFM) @ .5" H <sub>2</sub> O
66	24'	100% Roughness	4		870
67	"	↕	3		1370
68	18'		8		1260
69	"	100% Roughness	6		1225
70	"	50% Roughness	8		960
<hr/>					
71	"	↑	6		1050
72	"		4		1080
73	"		8		890
74	"		6		1020
75	21'		8		940
<hr/>					
76	"	↑	6		1055
77	"		4		1155
78	"		8		775
79	"		6		790
80	24'		8		800
<hr/>					
81	"	↓	6		780
82	"		4		1090
83	"		8		765
83A	"		8		665
84	"		50% Roughness	6	

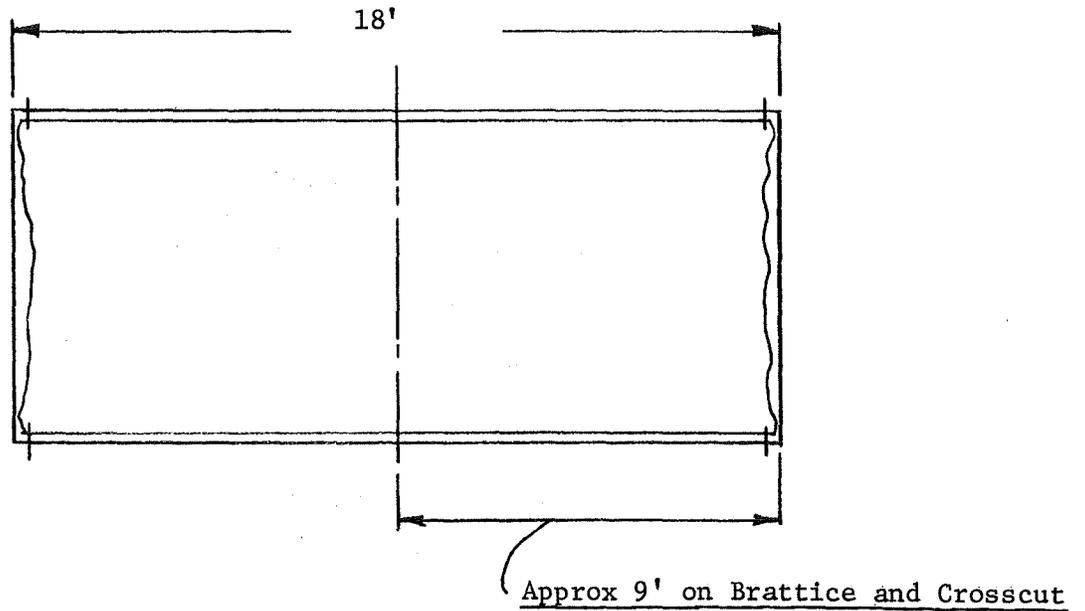


FIGURE 17 -- BRATTICE TEST INSTALLATION

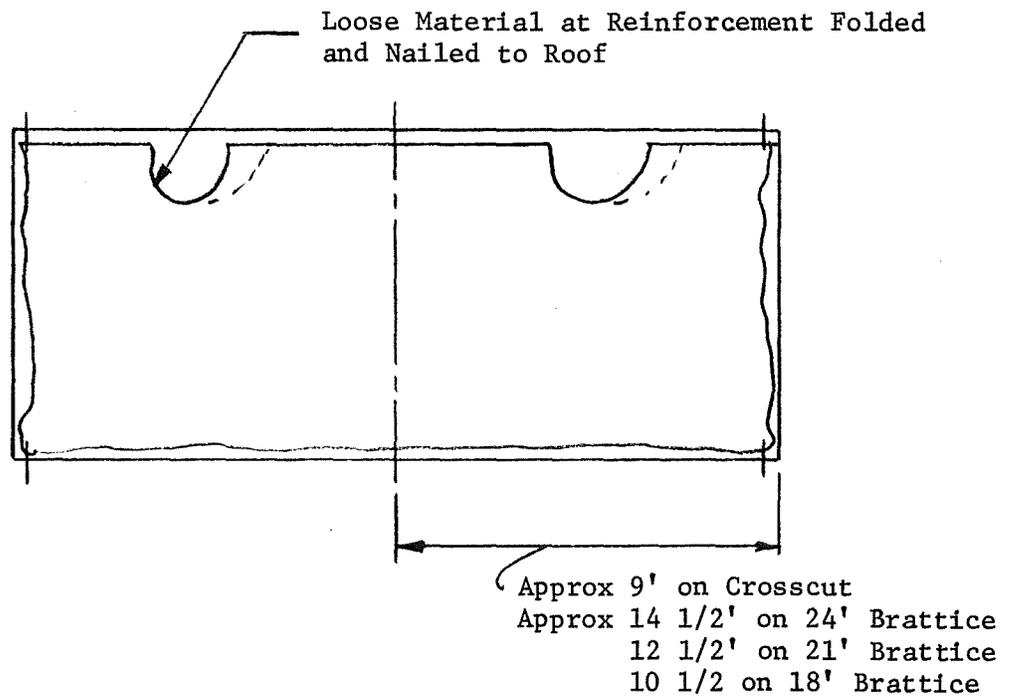


FIGURE 18 -- BRATTICE MODIFIED TEST INSTALLATION

Miscellaneous comments on the tests 56 thru 69 are as follows.

Tests 56-60 -- Attached at 9' pt. on brattice

61 -- Attached at 14 1/2 pt. on brattice

62 -- Added nail in top for loose material

63 -- Removed nail

64-65 -- Attached at 9' mark

66 -- Attached at 14 1/2 pt. with 2 added nails in top for  
loose material

67 -- Attached at 9' pt.

68-69 -- Attached at 10 1/2' pt.

Since the Bureau of Mines and GAC felt that the original roughness items added were a severe case, 50% of the items were removed (retaining the channel and tube) and tests 70-84 were run. As was expected, leak rates dropped considerably.

A summary of test data is presented in the following figures.

Figure 19 -- Summary Test Data - Test No. Vs. Flow Rate

Figure 20 -- Flow Rate Vs. Test No. - 18' Dia. Brattice

Figure 21 -- Flow Rate Vs. Test No. - 21' Dia. Brattice

Figure 22 -- Flow Rate Vs. Test No. - 24' Dia. Brattice

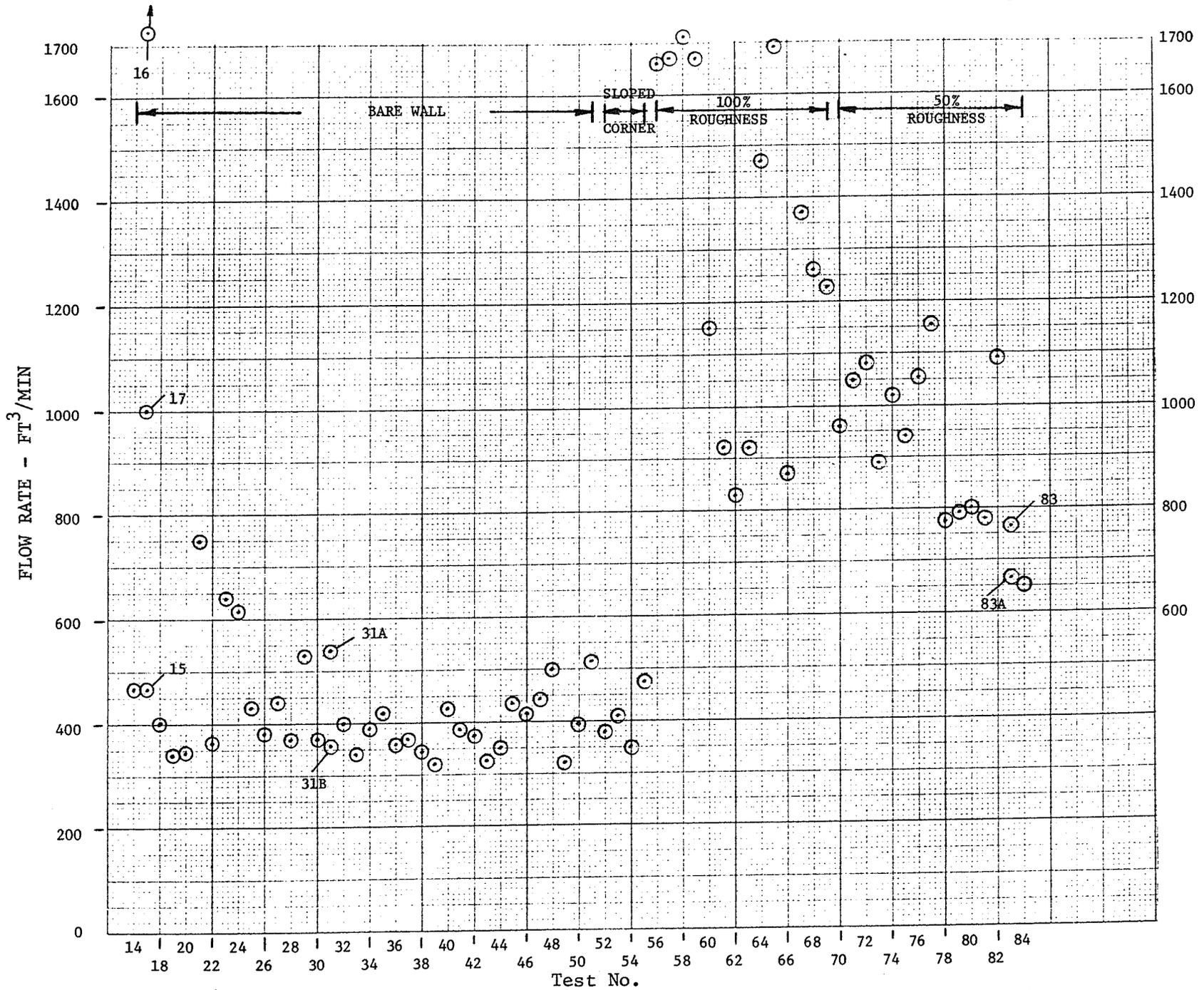


FIGURE 19 -- SUMMARY TEST DATA - TEST NO. VS. FLOW RATE (@ .5" H<sub>2</sub>O)

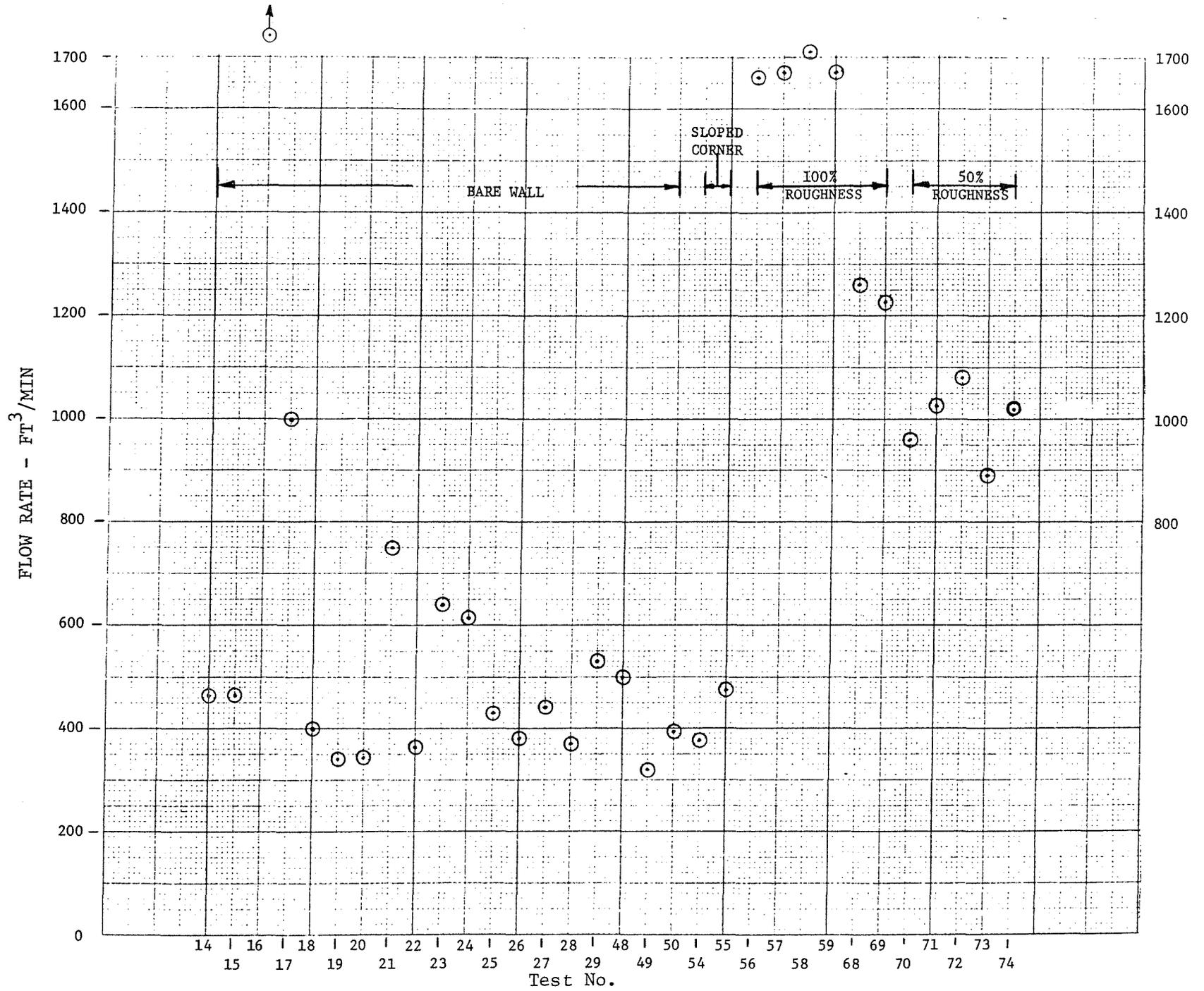


FIGURE 20 -- FLOW RATE VS. TEST NO. - 18' DIA BRATTICE (@ .5" H<sub>2</sub>O)

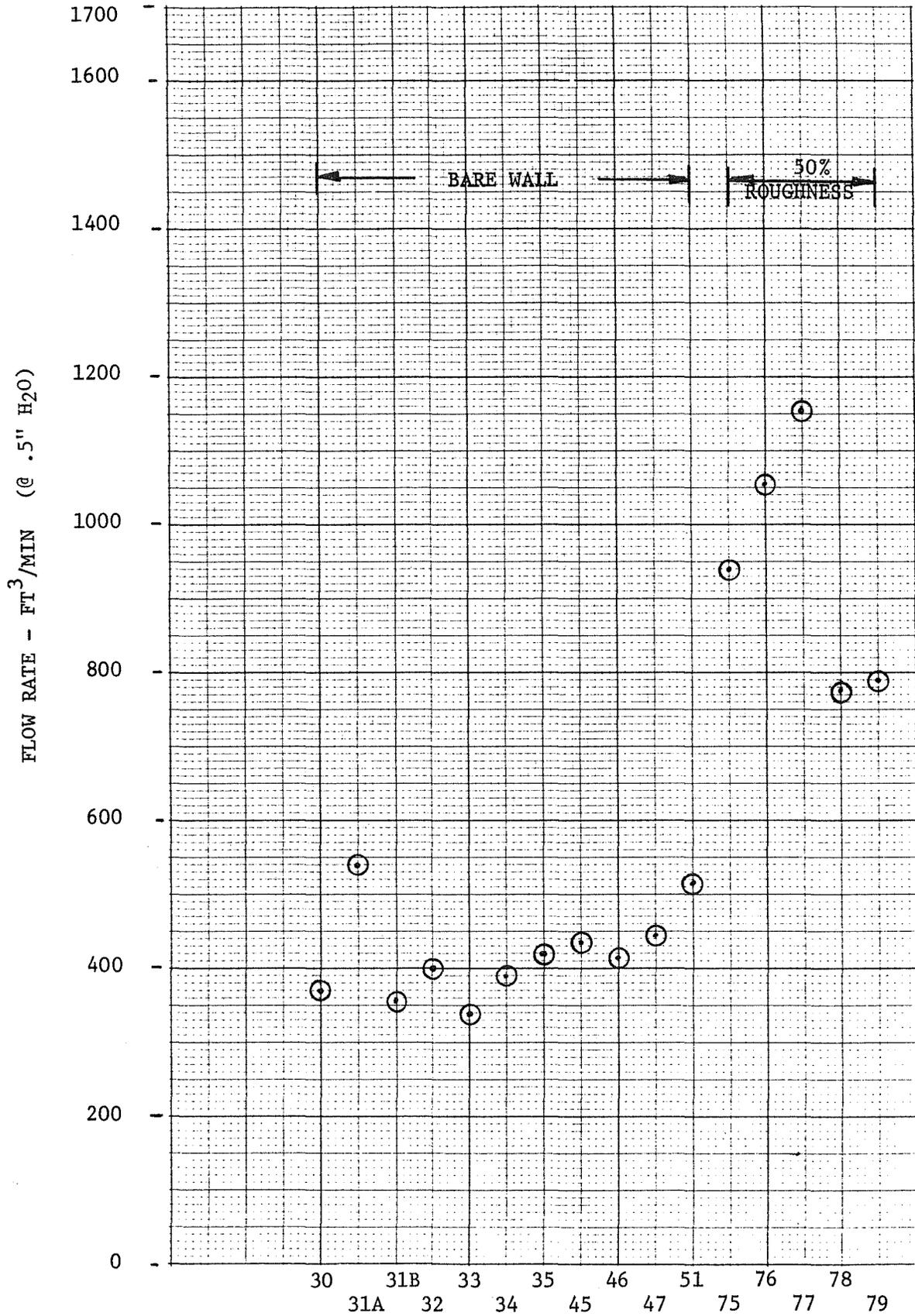


FIGURE 21 -- FLOW RATE VS. TEST NO. 21' DIA. BRATTICE

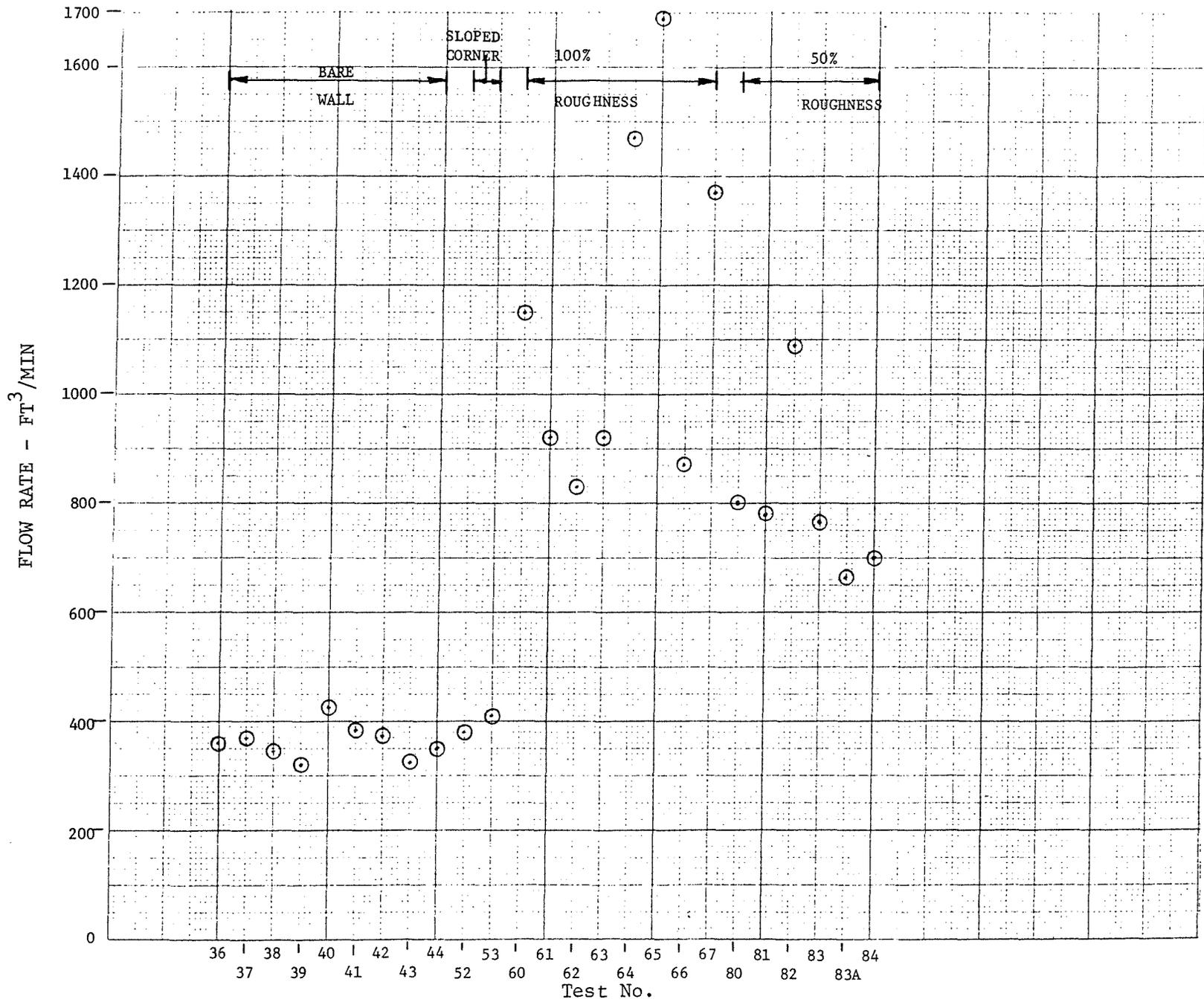


FIGURE 22 -- FLOW RATE VS. TEST NO. - 24' DIA BRATTICE (@ .5" H<sub>2</sub>O)

The following figures plot flow rate versus brattice diameter for most of the attachment configurations tested. Figures include test number and passageway configuration.

Figure 23 -- Flow Rate Vs. Brattice Dia. - 3 Pt. Attachment  
 Figure 24 -- Flow Rate Vs. Brattice Dia. - 4 Pt. Attachment  
 Figure 25 -- Flow Rate Vs. Brattice Dia. - 6 Pt. Attachment  
 Figure 26 -- Flow Rate Vs. Brattice Dia. - 8 Pt. Attachment  
 Figure 27 -- Flow Rate Vs. Brattice Dia. - 4 Pt. Attachment Modified  
 Figure 28 -- Flow Rate Vs. Brattice Dia. - 6 Pt. Attachment Modified  
 Figure 29 -- Flow Rate Vs. Brattice Dia. - 8 Pt. Attachment Modified

### C. Installation Aids Testing

#### 1. Test Conclusions

As a result of the testing in this area, the following conclusions can be made.

- ° The self-sealing brattice performs the same whether erected with pins or poles.
- ° Reverse flows can be handled with either pins or poles and the brattice performs the same in either case.
- ° Flow rate (leakage) varies directly with change in pressure.
- ° Air pressures to deploy and maintain the stopping in place are very low.

#### 2. Leakage Versus Differential Pressure

Tests were run to determine leakage rates as a function of delta air pressure. On all three brattice sizes the brattices were attached in the bare test passage with a 6 Pt. attachment configuration. As noted, the flow rates varies essentially directly as the delta pressure.

Figure 30 is a plot of the test data for the 24' brattice. Data for the 18' and 21' were similar. The two data points shown for the 24' brattice at the low pressures below .1" H<sub>2</sub>O were taken with 24' brattice installed in the passageway with 50% roughness items and after foam had been used as an auxiliary sealing agent.

#### 3. Minimum Erection and Maintaining Pressures

Test data for this series of tests was taken as shown in Section II, D, 2 of this report. Inflation for these tests was considered the point at which the brattice top contacted in most places the roof of the model entry and deflation or minimum to maintain was considered to be when the brattice started to drop away from the roof.

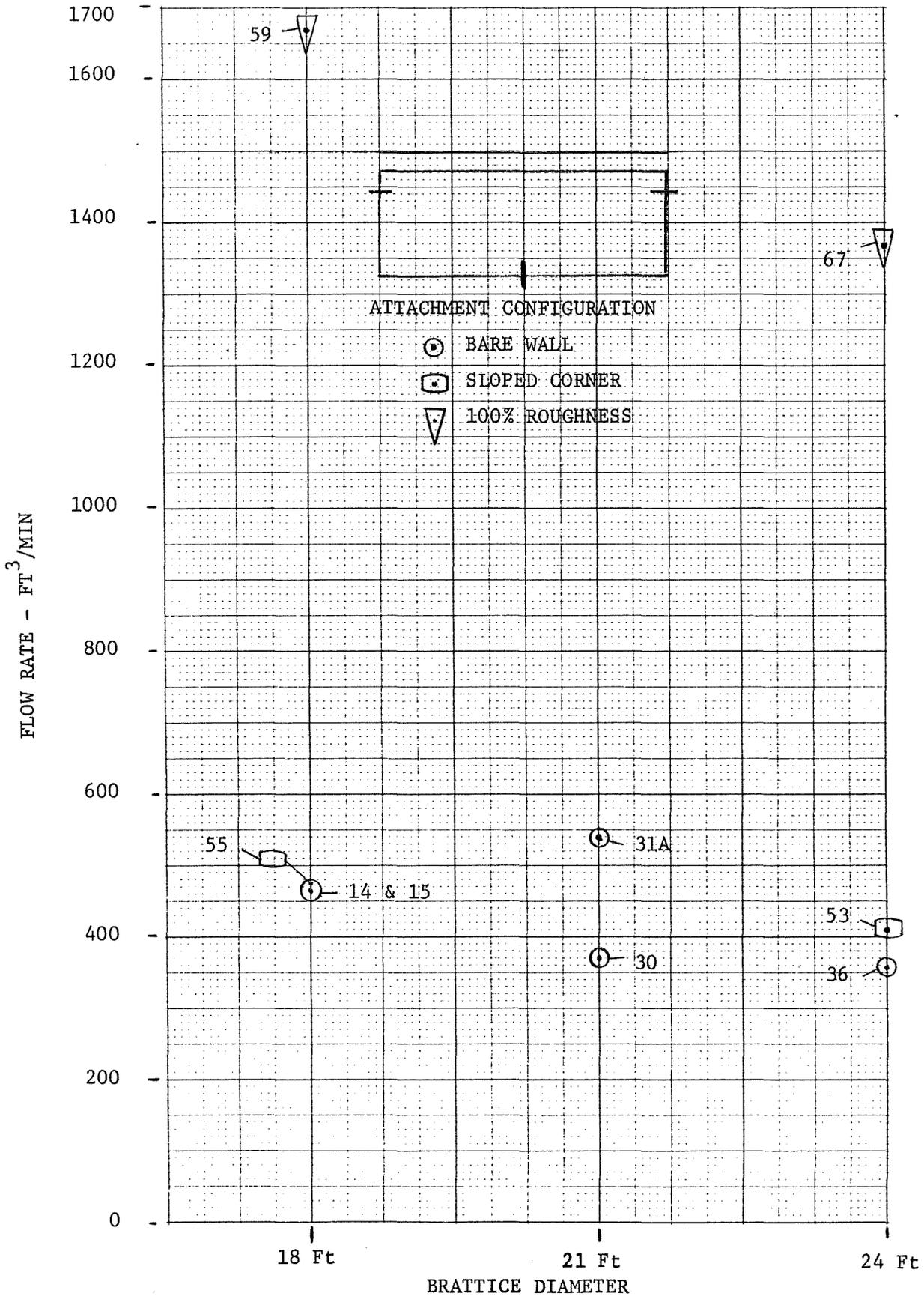


FIGURE 23 -- FLOW RATE VS. BRATTICE DIA. 3 PT ATTACHMENT (@ .5" H<sub>2</sub>O)

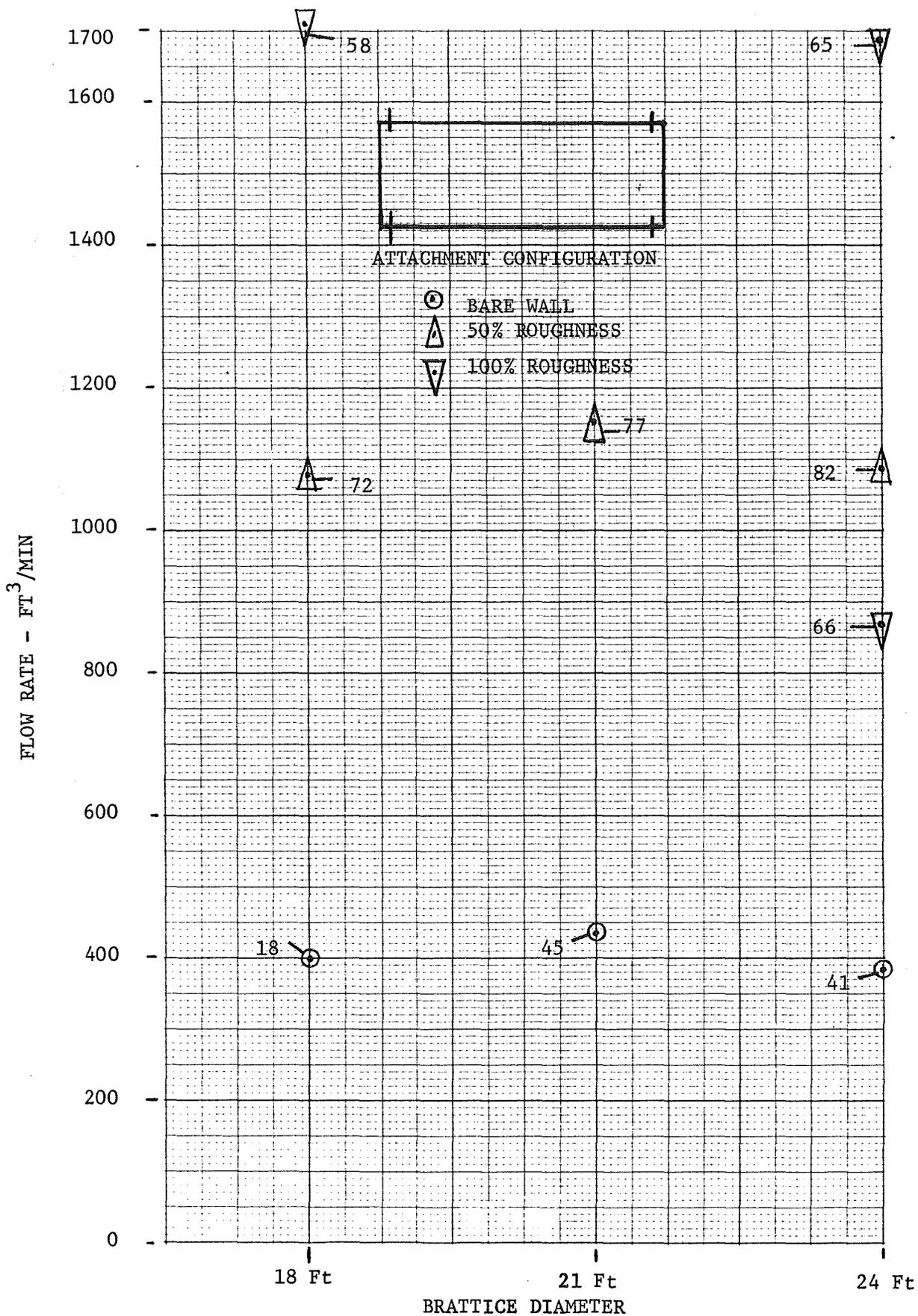


FIGURE 24 -- FLOW RATE VS. BRATTICE DIA. 4 PT. ATTACHMENT (@ .5" H<sub>2</sub>O)

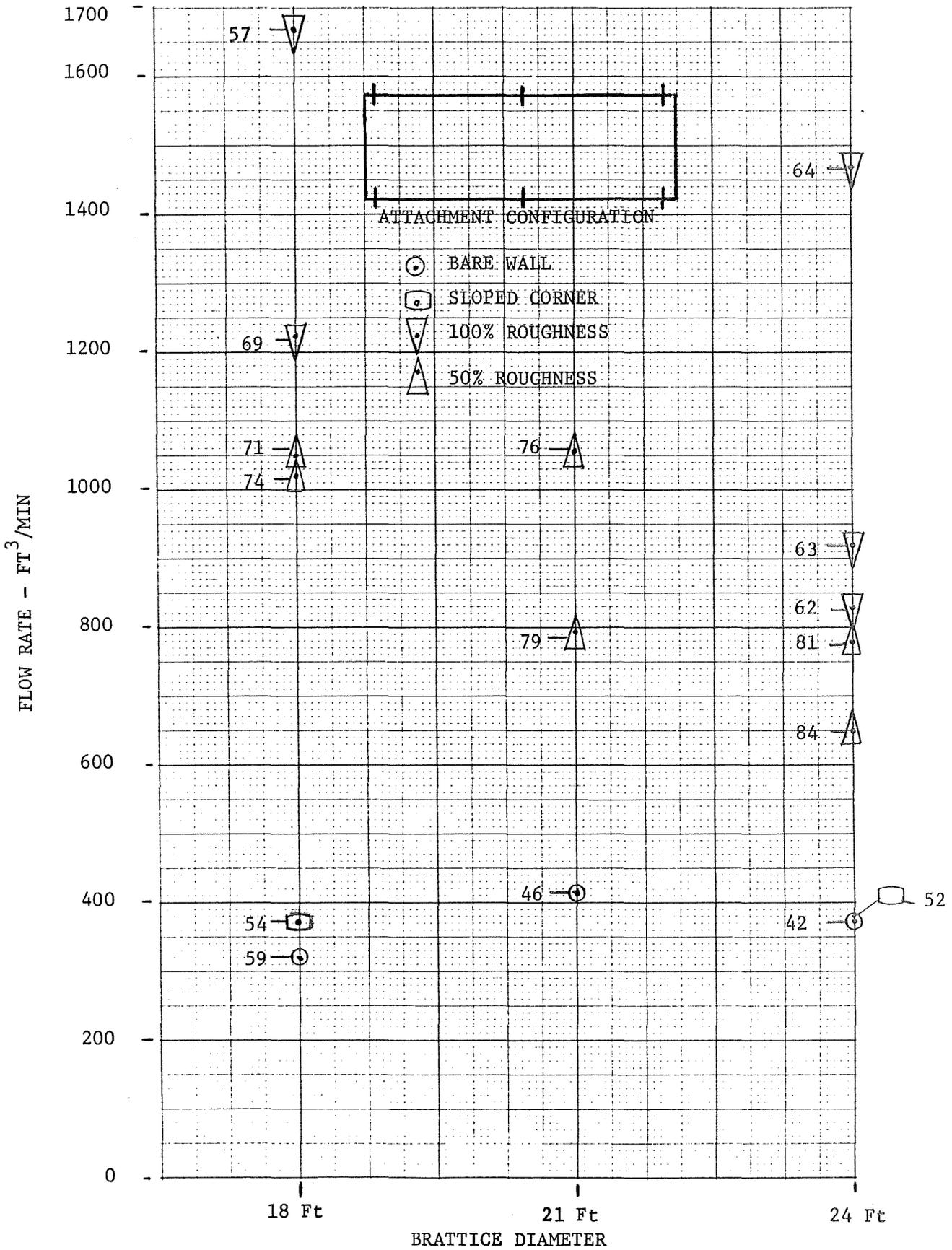


FIGURE 25 -- FLOW RATE VS. BRATTICE DIA. 6 PT. ATTACHMENT (@ .5" H<sub>2</sub>O)

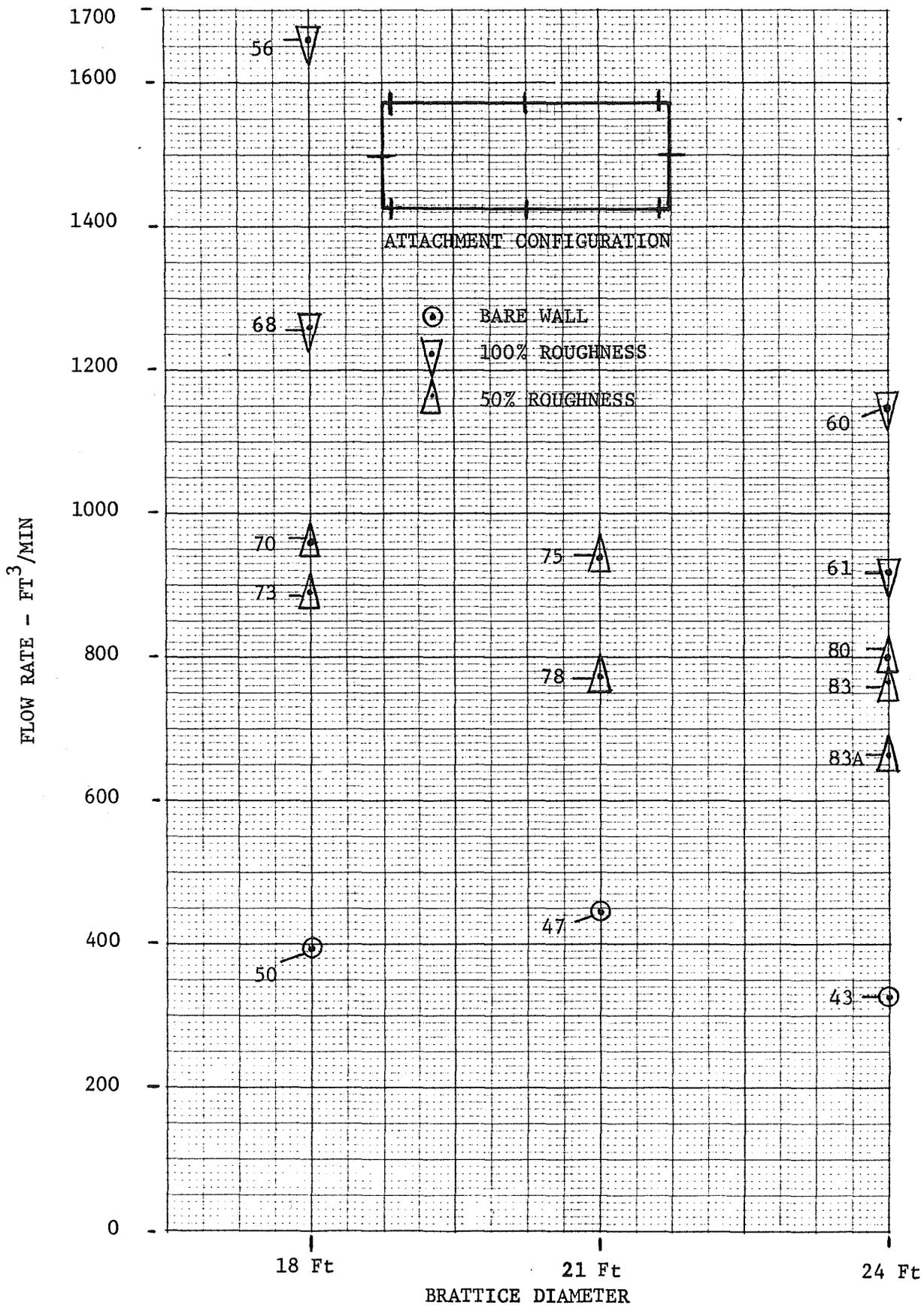
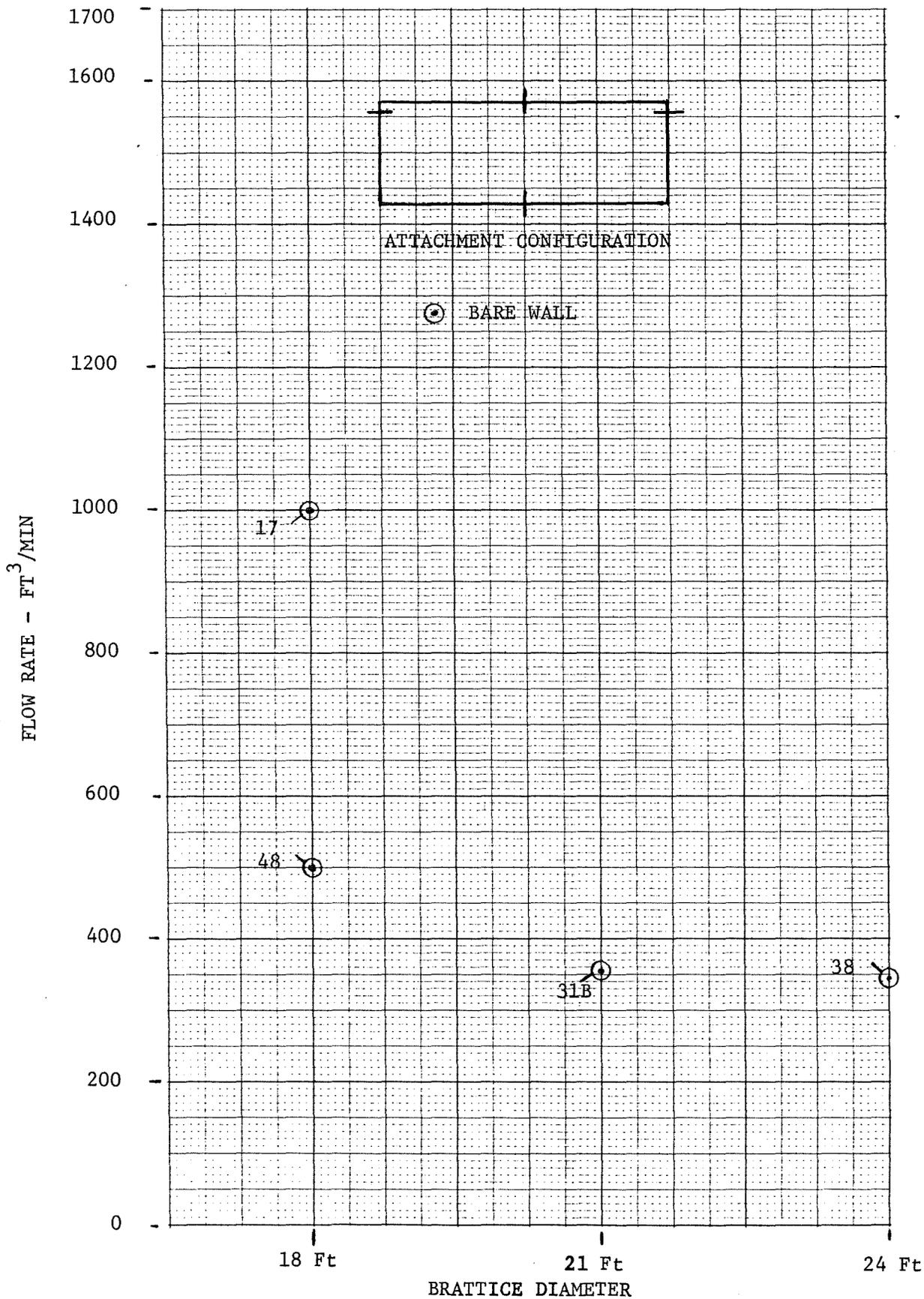


FIGURE 26 -- FLOW RATE VS. BRATTICE DIA. 8 PT. ATTACHMENT (@ .5" H<sub>2</sub>O)

FIGURE 27 -- FLOW RATE VS. BRATTICE DIA. MODIFIED 4 PT. ATTACHMENT (@ .5" H<sub>2</sub>O)

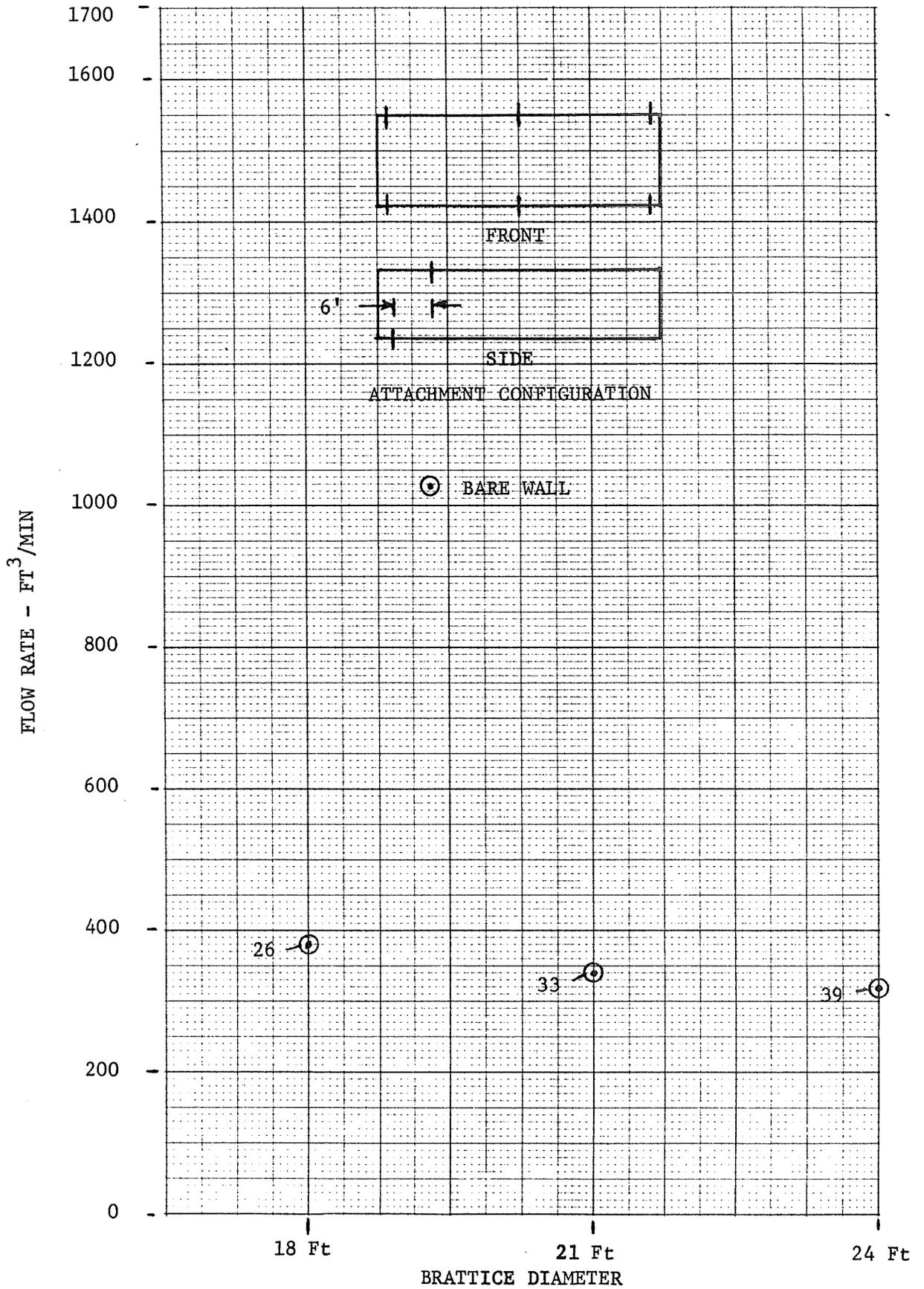


FIGURE 28 — FLOW RATE VS. BRATTICE DIA. MODIFIED 6 PT. ATTACHMENT (@ .5" H<sub>2</sub>O)

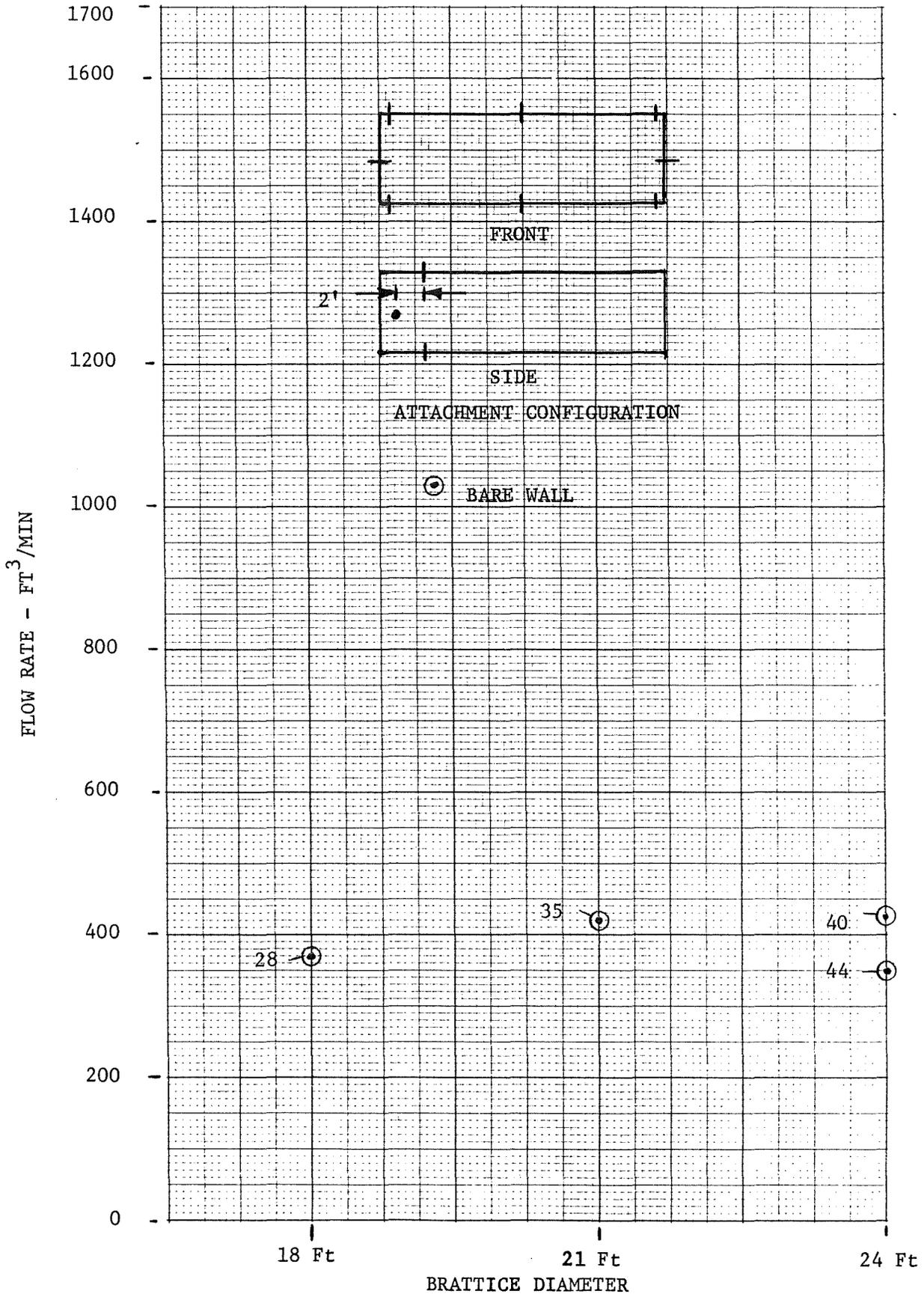


FIGURE 29 — FLOW RATE VS. BRATTICE DIA. MODIFIED 8 PT. ATTACHMENT (@.5" H<sub>2</sub>O)

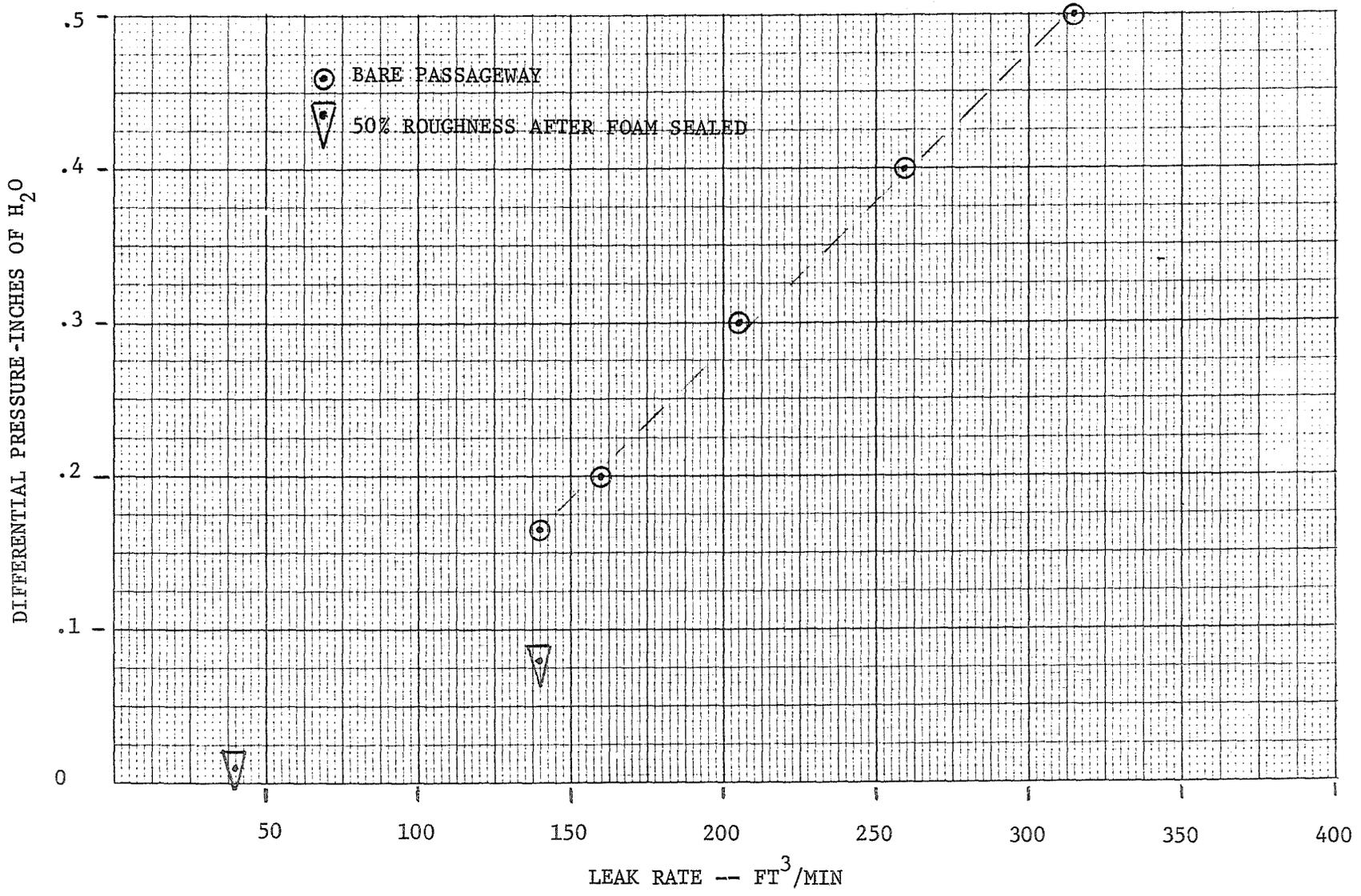


FIGURE 30 -- LEAK RATE VERSUS DIFFERENTIAL PRESSURE 24' BRATTICE

Erection methods used for this series of tests included nails to simulate the pins as was done in all previous testing and poles. The poles used were those shown in Section III of this report. Tests were only conducted with 8 and 6 nail attachment, 3 poles and 18' and 24' brattice units. Minimum pressures to erect and maintain shape were very close to the same, regardless of size of brattice, no. of supports or attachments, and whether nails or poles were used.

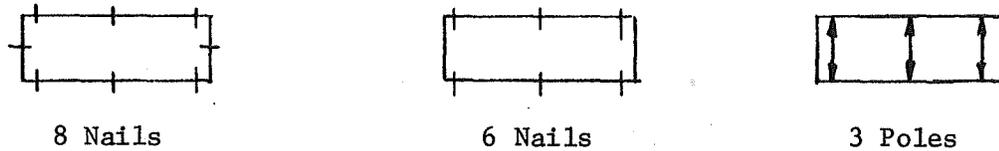
Table 14 is a summary of the significant test data.

TABLE 14  
MINIMUM BRATTICE ERECTION AND MAINTAINING PRESSURES

Condition, Supports	V FPM	Inclined Manometer Reading (Inch H <sub>2</sub> O)	$\Delta P$ (Inches of H <sub>2</sub> O) Calc.	
			Erecting	Maintaining
24', 8 Nails (Bunched)	228	.015	.00332	.00111
	126	.010		
24', 8 Nails (Deployed)	217	.015	.00305	.00083
	112	.005		
24', 6 Nails (Bunched)	235	.015	.00360	.00083
	109	.005		
24', 3 Poles	190	.010	.00221	.00055
	97	.005		
18', 6 Nails (Bunched)	214	.015	.00305	.00055
	98	.005		
18', 8 Nails (Bunched)	186	.010	.00221	.00055
	91	.005		
18', 3 Poles	211	.010	.00277	.00083
	109	.005		
18', 6 Nails (Deployed)	188	.010	.00221	.00083
	106	.005		

In the above table "Bunched/Deployed" refers to brattice condition when test started, with "bunched" meaning most of the material was in close proximity to line of attachments and "deployed" meaning material was pulled downstream of attachment. After the 3 pole erection with the 18' brattice, the pressure was increased to approximately .25" H<sub>2</sub>O at which time the side poles slipped in the cross-cut since only one end of the poles had been modified to add the end point on the pole.

The configuration for the attachments was as follows.



8 Nails

6 Nails

3 Poles

#### 4. Reverse Flow Testing

In this case the brattice was attached to the cross-cut in reverse position as shown in Figure 31 prior to start of test.

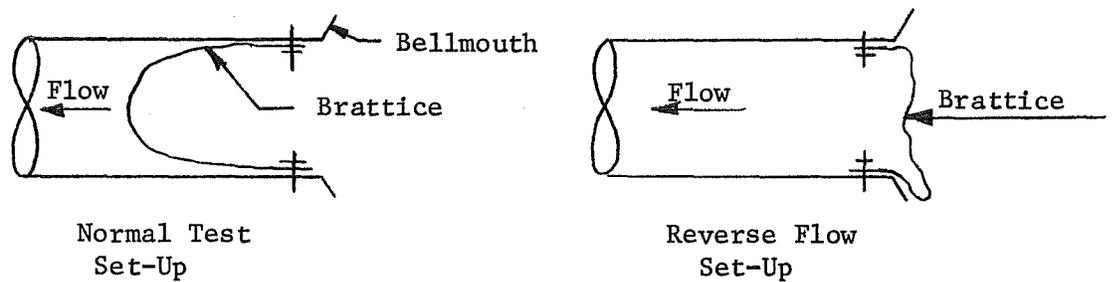
Normal Test  
Set-UpReverse Flow  
Set-Up

FIGURE 31 -- REVERSE FLOW - TEST SET-UP

Tests were conducted with both 18' and 24' brattice, 6 nails and 3 pole arrangements. In all cases minimum erection pressures were about the same as previously noted in the last series of tests. There was no problem for both the 18' and 24' brattice to handle reverse flows up to the .5" of H<sub>2</sub>O test requirement. Maximum delta pressures for reverse flows using the 3 pole arrangement was approximately .3" H<sub>2</sub>O and was only limited by the capability of the pole to resist slippage in the cross-cut. This condition, again, was due to only one end of the pole having a pointed end. Since, for normal erection, 3 poles would be erected (1 on each side and 1 in the middle of the cross-cut) of particular concern was the manner of the shape of the reverse flow condition. With this condition, the brattice took a 2 lobe-hemispherical condition and did an excellent job of sealing. See Figure 32.

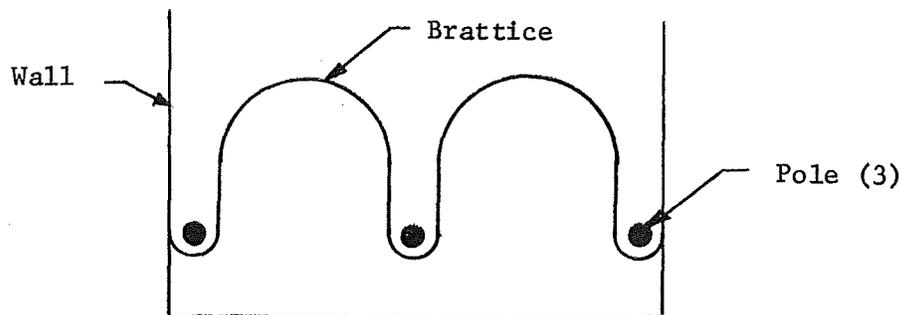


FIGURE 32 -- REVERSE FLOW TEST WITH POLES

## 5. Auxiliary Sealing Techniques

For demonstration testing of using the recommended foam for auxiliary sealing GAC installed the 24 ft. test brattice with 8 nails in the model entry that had 50% roughness items installed. The brattice was deployed and a differential pressure maintained across the stopping of .5" H<sub>2</sub>O. The urea-formaldehyde foam was applied by personnel of the Adams-Barre Corp at the upstream edge of the brattice in the gaps between the stopping and the passageway roof, walls and floor. See figures 10 and 11 of this report. Total time for sealing the periphery was approximately 2 minutes. After the test, it was determined that approximately 6 ft<sup>3</sup> of foam was used. Flow rates were taken prior to and after foam application. There was a reduction in leakage from 800 CFM to 550 CFM. As a result of this demonstration GAC concluded the following significant points about the use of the foam as an auxiliary sealing agent.

- ° The foam adhered satisfactorily to both the passageway surface and the brattice cloth.
- ° The foam is capable of sealing any size gaps.
- ° The amount of foam used can be minimized by tucking and nailing the material where it is attached to the passageway.
- ° Although it was not demonstrated GAC sees no reason why a foam filled stopping will not handle reverse air flows.
- ° Leakage of the brattice is significantly reduced with the application of foam.

In addition to the urea-formaldehyde foam GAC tried aerosol cans of polyurethane foam to compare the sealing capability. Since the polyurethane expands after release from the cans it is difficult to judge how much of the gap to fill and as such over-filling was required. The small aerosol cans proved to be difficult to use especially at the top of the passageway since the can must be inverted for use. The polyurethane is messy from a clean-up standpoint. It does adhere to the cloth better than the Rapco-Foam and to the passageway, adhesion was about the same or slightly superior to the Rapco-Foam. The polyurethane dries harder than the urea-formaldehyde. Since the urethane is flammable and gives off very toxic fumes when burning it did not meet the contract requirements.

## 6. Brattice Erection Procedure

The method of erection to provide for the most effective sealing arrangement was determined to be as follows. Note: Two yellow streamers attached to the leading edge of the brattice are positioned at 180° apart on the periphery.

- Step 1. Remove brattice from container with leading edge facing air flow and stretch unit downstream.

- Step 2. Attach brattice at approximate centerline of floor at position of one streamer, nailing through white edge reinforcement into the floor.
- Step 3. Attach brattice at approximate centerline of roof at position of the other streamer.
- Step 4. Stretch brattice along floor from centerline to lower corner of cross-cut and nail close to the corner.
- Step 5. Stretch brattice on same side along roof from centerline to upper corner of cross-cut and nail in place close to the corner.
- Step 6. Repeat steps 4 and 5 for the other side of the cross-cut. Brattice will now be inflated.
- Step 7. Add additional nails if required to seal off loose areas and foam any areas where excessive leak paths are noted. (Particularly important in excessive roughness areas.)

#### V. PROTOTYPE DELIVERY

GAC recommended and obtained agreement from the Bureau of Mines Project Officer that the prototype units be manufactured to the 24 foot configuration. Although the 24 foot brattice did not show a significantly lower leak rate compared to the 18 and 24 foot units, it does give the user increased flexibility for larger mine crosscuts and more severe roughness conditions. GAC built and delivered 12 prototype brattice assemblies identified as Part No. 2F1-6-43362-105, serial numbers 2 thru 13.

#### VI. CONCLUSIONS & RECOMMENDATIONS

##### A. Conclusions

1. The improved self-sealing brattice made from a "permissable" nylon fabric is a lightweight, low cost stopping that will adequately serve as a mine stopping to temporarily replace permanent stoppings in the event of a disaster.
2. The improved self-sealing brattice performs well from .5" H<sub>2</sub>O differential pressure down to very minimal pressures and is capable of pressures up to 1.5" H<sub>2</sub>O.
3. The brattice may be quickly and adequately installed using pins/power actuated spads or extensible poles.
4. Assuming a fairly smooth mine passageway, the brattice will adequately seal any passageway perimeter up to or slightly smaller than the brattice perimeter.

5. For passageways exhibiting extreme roughness, the brattice perimeter should be approximately 50% larger than the basic passage perimeter.
6. The larger the brattice, the lower the leak rates.
7. There are not significant changes in leakage rates when changing either the brattice diameter or numbers of attachments.
8. The brattice conforms well to tubing and channel shaped roughness items.
9. The sealing capability of the brattice can be helped by adjustment of the material in the rougher areas of the passageway.
10. Leakage of the brattice is most pronounced in the roof area and added attachments are advantageous in this area.
11. The self-sealing brattice can be inflated when installed with either pins or poles at a differential pressure as low as .0022" H<sub>2</sub>O and will stay erected at pressures as low as .0005" H<sub>2</sub>O.
12. Leakage of the brattice varies directly as the differential pressure across the unit.
13. The self-sealing brattice has the ability to handle reverse flows when installed with either pins or poles.
14. Urea-formaldehyde foam is a non-flammable foam that can be used as an auxiliary sealing agent between the brattice and the passageway.
15. Foam sealant can be easily applied and is effective with all sizes of gaps.

B. Recommendations

1. Steps should be taken to educate the mining industry with the potential of the self-sealing brattice.
2. Additional effort should be undertaken to expand on the use of the Rapco-Foam with respect to minimizing the size of the equipment and possible other applications in the mining industry.
3. Testing should be done to further evaluate the improved self-sealing brattice under actual mining conditions.

APPENDIX A

PROJECT <b>BUREAU MINES - BRATTICE</b> REF. OR EI. NO.	<b>INSTRON TEST DATA RECORD</b> ADVANCED MATERIALS LABORATORY	TEST NO. <b>I-6887</b>	SHEET <b>1</b>	OF <b>3</b>
		DATE TEST REC'D. <b>4-5-78</b>	DATE OF TEST <b>4-5-78</b>	
TYPE TEST <b>STRIP TENSILE</b>		REQUESTED BY: <b>J. BLIGHTON</b>		CHARGE NO. <b>856230</b>

SPECIMEN DESCRIPTION	TEST PROCEDURE		
MATERIAL <b>CLOTH CODE RF-391 NYLON</b> COATING	TEMPERATURE <b>75°F. 50% RH</b>	HEATING OR COOLING DEVICE -	
EXPOSURE CONDITIONS	HEAT RATE -	SOAK TIME -	
	GAUGE LENGTH <b>3.0 IN.</b>	LOAD RATE <b>12.0 IN/MIN</b>	
	CHART SPEED <b>12.0 IN/MIN.</b>	JAW TYPE <b>RF</b>	SIZE <b>2X2</b>

TEST RECORD							
SPECIMEN NUMBER	DIMENSIONS	YIELD LOAD	ULTIMATE LOAD	YIELD STRESS	ULTIMATE STRESS	ELONGATION %	OTHER
	<b>RAVELED 1.0 IN. WIDTH</b>						<b>TYPE FAILURE</b>
<b>WARP-1</b>			<b>90</b>				<b>G.I.</b>
<b>2</b>			<b>90</b>				"
<b>3</b>			<b>92</b>				"
<b>4</b>			<b>93</b>				"
<b>5</b>			<b>92</b>				"
		<b>AVG.</b>	<b>91</b>				
<b>Fill-1</b>			<b>86</b>				<b>G.I.</b>
<b>2</b>			<b>87</b>				"
<b>3</b>			<b>87</b>				"
<b>4</b>			<b>87</b>				"
<b>5</b>			<b>86</b>				"
		<b>AVG.</b>	<b>87</b>				

REMARKS

TESTED BY <i>R. Sladwell</i>	WITNESS <i>J. Blighton</i>	WITNESS
DEPT <b>486</b> EXT <b>7466</b> DATE <b>4-5-78</b>	DEPT <b>495</b> DATE <b>4-5-78</b>	DEPT _____ DATE _____

*TEST*

PROJECT <b>BUREAU MINES - BRATTLE</b> REF. OR E.I. NO.	<b>INSTRON TEST DATA RECORD</b> ADVANCED MATERIALS LABORATORY	TEST NO. <b>I-6887</b> DATE TEST REC'D. <b>4-5-78</b>	SHEET <b>2</b>	OF <b>3</b>	DATE OF TEST <b>4-5-78</b>
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TYPE TEST <b>SEAM TENSILE</b>	REQUESTED BY: <b>J. BLIGHTON</b>	CHARGE NO. <b>856230</b>
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SPECIMEN DESCRIPTION	TEST PROCEDURE	
MATERIAL <b>CLOTH COPE RF-391</b>	TEMPERATURE <b>75°F. 50% RH</b>	HEATING OR COOLING DEVICE <b>—</b>
COATING	HEAT RATE <b>—</b>	SOAK TIME <b>—</b>
<b>SEWING - 2 ROWS "E" THREAD</b>	GAUGE LENGTH <b>6.0 IN.</b>	LOAD RATE <b>12.0 IN/MIN</b>
EXPOSURE CONDITIONS <b>8 TO 10 S.P.I. 301 STITCH</b>	CHART SPEED <b>12.0 IN./MIN.</b>	JAW TYPE <b>RF</b>
		SIZE <b>2 X 2</b>

TEST RECORD							
SPECIMEN NUMBER	DIMENSIONS	YIELD LOAD	ULTIMATE LOAD	YIELD STRESS	ULTIMATE STRESS	ELONGATION %	OTHER
	<i>RAVELED 1.0 IN. WIDTH</i>						<b>TYPE FAILURE</b>
<b>WARP-1</b>			<b>80</b>				<b>CLOTH @ SEWING</b>
<b>2</b>			<b>69</b>				" " "
<b>3</b>			<b>84</b>				" " "
<b>4</b>			<b>77</b>				" " "
<b>5</b>			<b>80</b>				" " "
		<b>AVG.</b>	<b>78</b>				
<b>FILL-1</b>			<b>85</b>				<b>CLOTH @ SEWING.</b>
<b>2</b>			<b>82</b>				" " "
<b>3</b>			<b>82</b>				" " "
<b>4</b>			<b>82</b>				" " "
<b>5</b>			<b>84</b>				" " "
		<b>AVG.</b>	<b>83</b>				

REMARKS

TESTED BY <i>R. Bladwell</i>	WITNESS	WITNESS
DEPT <b>486</b> EXT. <b>7466</b> DATE <b>4-5-78</b>	DEPT	DATE

PROJECT <b>BUREAU MINES - BRATTICE</b>		INSTRON TEST DATA RECORD		TEST NO. <b>T06887</b>	SHEET <b>3</b>	OF <b>3</b>
F BUREL NO.		ADVANCED MATERIALS LABORATORY		DATE TEST REC'D. <b>4-5-78</b>	DATE OF TEST <b>4-5-78</b>	
TYPE TEST <b>TONGUE TEAR</b>			REQUESTED BY: <b>J. BLIGHTON</b>		CHARGE NO. <b>856230</b>	

SPECIMEN DESCRIPTION		TEST PROCEDURE			
MATERIAL <b>CLOTH CODE - RF-391 NYLON</b>		TEMPERATURE <b>75°F 50% RH</b>	HEATING OR COOLING DEVICE —		
COATING		HEAT RATE —	SOAK TIME —		
EXPOSURE CONDITIONS		GAUGE LENGTH <b>3.0 IN.</b>	LOAD RATE <b>12.0 IN/MIN</b>		
		CHART SPEED <b>12.0 IN./MIN.</b>	JAW TYPE <b>RF</b>	SIZE <b>2x2</b>	

TEST RECORD							
SPECIMEN NUMBER	DIMENSIONS	YIELD LOAD	ULTIMATE LOAD	YIELD STRESS	ULTIMATE STRESS	ELONGATION %	OTHER
	<b>3" x 8"</b>						
<b>FILL - 1</b>			<b>9.1</b>				
<b>2</b>			<b>9.2</b>				
<b>3</b>			<b>10.2</b>				
<b>4</b>			<b>9.5</b>				
<b>5</b>			<b>9.3</b>				
		<b>AVG.</b>	<b>9.5</b>				
<b>WARP - 1</b>			<b>11.0</b>				
<b>2</b>			<b>10.0</b>				
<b>3</b>			<b>9.5</b>				
<b>4</b>			<b>10.6</b>				
<b>5</b>			<b>10.5</b>				
		<b>AVG.</b>	<b>10.3</b>				

REMARKS  
**VALUES RECORDED ARE AVERAGES OF 5 HIGHEST PEAKS AFTER INITIAL PEAK.**

TESTED BY <b>R. Gladwell</b>	WITNESS <b>J. Blight</b>	WITNESS
DEPT <b>486</b> EXT. <b>7466</b> DATE <b>4-5-78</b>	DEPT <b>4931</b> DATE <b>4-5-78</b>	DEPT _____ DATE _____

L-1254(8-66)

ADVANCED MATERIALS LABORATORY  
DEPARTMENT 486 PLANT C  
DIFFUSION TEST DATA

Test No.

D-1076  
I-6887

Type of Test: PERMEABILITY-WEIGHT Date Rec'd: 4-4-78Project: BUREAU MINES-BRATTICE (RFT) or EI No.: J. BLIGHTONCHARGE NO. 856230Specimen Description Material: CLOTH - CODE RF-391 NYLON

Coating: \_\_\_\_\_

Exposure Conditions: \_\_\_\_\_

Equipment used: \_\_\_\_\_  
Dow Cell No.: \_\_\_\_\_ Void Volume: \_\_\_\_\_Other: FRAZIERTest Conditions:  
Test Gas: AIR Test Gas Pressure: 0.5 in. H<sub>2</sub>OAtmos. Press.: \_\_\_\_\_ Temperature: 75°F. R.H.: 50%

Specimen Number	Diffusion Rate K	WEIGHT 12" X 12"		Other
		GRAMS	OZ./YR. <sup>2</sup>	
1	1.57	6.0931	1.93	
2	1.81	6.4068	2.03	
3	1.57	6.3550	2.02	
4	1.70			
5	2.08			
AVG.	1.75	AVG.	1.99	

Remarks: K = FT.<sup>3</sup>/FT.<sup>2</sup>/MIN.Tested By: R. Hadwell Witness: J. Blighton Date: 4-5-78

APPENDIX B



Smithers Scientific Services, Inc.

425 W. MARKET STREET • AKRON, OHIO U. S. A. 44303

TWX NO. 810 431-2112 SMITHERS

TELEPHONE 216/762-7441

RECEIVED

APR 24 1978

D/493

CUSTOMER: Goodyear Tire & Rubber Company  
1144 E. Market Street  
Akron, Ohio 44316

PO# 784749  
Attn: Mr. Jerry Blyden

SUBJECT: The above company submitted a sample of red fabric identified as RF-391 Nylon (2.0 oz/yd<sup>2</sup>) for testing according to ASTM E162 and NFPA 701 (small scale procedures).

Effective as of September 18, 1978, ASTM affixed the following caveat to the E162 and all other flammability tests:

"This standard should be used solely to measure and describe the properties of materials, products or systems in response to heat and flame under controlled laboratory conditions and should not be considered or used for the description, appraisal, or regulation of the fire hazard of materials, products or systems under actual fire conditions."

RESULTS: E-162

Sample was cut to test size by Smithers' personnel.

<u>Sample No</u>	<u>F<sub>s</sub>*</u>	<u>Q</u>	<u>I<sub>s</sub>*</u>
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0

\*When exposed to the radiant heat source and pilot flame, the material immediately melted and shrunk to the 12 inch mark within 15 seconds. But, there was no flame front.



# Smithers Scientific Services, Inc.

425 W. MARKET STREET • AKRON, OHIO U. S. A. 44303

TWX NO. 810-431-2112 SMITHERS

TELEPHONE 216/762-7441

Goodyear Tire & Rubber Company

Page 2

## RESULTS (continued)

### NFPA 701 (Small Scale)

Samples were tested according to the procedures of NFPA 701 (Small Scale).

<u>Sample No.</u>	<u>Warp Direction</u>	<u>Char Length</u>
1	No flaming after removing burner	4-1/4 inches
2	" " " " "	3-1/2 inches
3	" " " " "	4-1/4 inches
4	" " " " "	4-3/8 inches
5	" " " " "	<u>3-3/4 inches</u>

AVERAGE 4 inches

<u>Sample No.</u>	<u>Fill Direction</u>	<u>Char Length</u>
1	No flaming after removing burner	3-1/2 inches
2	" " " " "	4-3/4 inches
3	" " " " "	6-1/2 inches
4	" " " " "	5-3/8 inches
5	" " " " "	<u>6-1/4 inches</u>

AVERAGE 5-1/4 inches

OVERALL AVERAGE -----4-5/8 inches

This material (RF-391 Nylon) meets the requirements of NFPA 701 (small Scale).

*William A. Rains*  
 William A. Rains, Project Manager, Special Projects  
 Smithers Laboratories Division of Smithers Scientific Services, Inc.  
 Qualified Laboratory No 17370 QLL 22 1 March 1977 Defense Supply Agency

G7483  
April 17, 1978

WAR:rp

APPENDIX C

# GOODYEAR AEROSPACE CORPORATION

AKRON, OHIO 44315

Engineered Fabrics Division

May 9, 1978  
Refer to: 3591-EF-493

U.S. Mining Safety and Health Association  
Box 201 B  
Industrial Park Road  
Dallas Pike  
Triadelphia, West Virginia 26059

Attention: Mr. H. Verakes

Dear Mr. Verakes:

Attached, hereto, is an application for obtaining a "permissible" status for a nylon cloth treated with a flame retardant. The cloth is a plain weave with a rip-stop construction and having a weight of 2 oz/sq yd. The material will be employed in a parachute type mine stopping brattice. Goodyear Aerospace has been under contract to the Bureau of Mines (Contract HO17068) to improve the self-sealing brattice.

I have tried to provide all the required information as we discussed in a telephone conversation on 13 January 1978. If there is any additional information required, please contact me.

GOODYEAR AEROSPACE CORPORATION

*J. L. Blighton*  
Jerry L. Blighton  
Engineered Fabrics Systems  
Dept 493, G-2  
1210 Massillon Road  
Akron, Ohio 44315  
Phone: 216/794-3794

attachments:

JLB/jed

## APPLICATION FOR MATERIAL ACCEPTANCE

The following item number reference the numbers on check list of page 13 of MESA document.

10.1 Identification Number: 391

Manufacturer: Goodyear Aerospace Corporation  
1210 Massillon Road  
Akron, Ohio 44315

10.2 Product: Parachute-Type Mine Stopping

Product Description: This product is a hemispherically shaped fabric structure with the intended use of being strategically placed in mine passageways during an emergency situation to redirect air flow as desired. The structure is made up primarily of nylon cloth treated with a flame retardant. The hem of the structure has a two-inch wide piece of Nomex webbing attached. The only other material in the structure is nylon sewing thread used to make the seams. The Nomex webbing and nylon sewing thread make up less than 2% of the total area of the structure. Consequently, the testing performed and information provided, herein, is on the nylon cloth.

This self-sealing brattice will be installed in the passageway through the use of spads or extensible metal poles.

10.3 Formulation: Cloth - Nylon 66  
Flame Retardant - Thiourea Compound

10.4 Flammability Test Data: Flammability tests were performed by an independent test lab, Smithers Scientific Services, in compliance with ASTM E-162 and NFPA-701, small scale testing. The cloth passed both tests and the certified test report is attached.

Note: During our initial investigation, several untreated samples of nylon and polyester cloths were tested to the above specifications and all specimens having a weight of less than 5 oz/sq yd passed the tests. The flame retardant was added to our material only as an added precaution.

Shrinkage @ 300°F: A shrinkage test was performed in accordance with paragraph 6.3.1 of the "Interim Fire and Toxicity Criteria for Acceptance of Products Taken Into Underground Mines". The results were 1.45% shrinkage in the warp direction and 1.23% shrinkage in the fill direction.

10.5 Not Applicable

10.6 Not Applicable

10.7 Quality Assurance Provisions: For any future orders, Goodyear will require certification from L. Travis Textiles that the material has been treated with the same flame retardant and using the same process as was employed for this lot of material. Also a test report which indicates that the material meets the requirements of CPAI-84\*.

In addition, Goodyear will supply certification with each unit that the material meets the above flammability specifications.

\*CPAI-84 is the vendor's standard method for conducting flame tests.

APPENDIX D

U.S. DEPARTMENT OF LABOR  
MINE SAFETY AND HEALTH ADMINISTRATION  
APPROVAL AND CERTIFICATION CENTER

Box 201B, Route 1  
Industrial Park Blvd.  
Triadelphia, West Virginia 26059



AUG 14 1978

In Reply Refer to:  
A&CC:DM&E:PAR #0023745

Goodyear Aerospace Corporation  
Engineered Fabrics Division  
Attention: Mr. Jerry Blighton  
1210 Market Street  
Akron, Ohio 44315

Gentlemen:

Your application dated May 9, 1978, requesting acceptance of Parachute-Type Mine Stopping brattice cloth for use in underground mines was evaluated by the Division of Materials and Explosives, Approval and Certification Center.

This product and the information provided meet the requirements of the "Interim Fire and Toxicity Criteria for Acceptance of Products Taken Into Underground Mines, dated March 22, 1977." Your product acceptance will be listed in Circular Letter Number 1104. Circular Letters are issued monthly by the Approval and Certification Center and a copy will be forwarded to you upon request. The formulation of this material was presented in accordance with paragraph 3.3(c) of the Interim Fire and Toxicity Criteria. This method of reporting requires that you certify each cloth meets the requirements of L. Travis Textile flame test CPAI-84.

This product is assigned Mine Safety and Health Administration (MSHA) Number IC-41 and may be referred to as "accepted for underground mines when used in accordance with the manufacturers health and safety instructions and recommendations."

"MSHA IC-41" shall be permanently marked on the product with numbers and letters at least one-quarter inch high, not more than 10 feet apart and approximately mid-height. Other types of permanent markings may be used with prior approval of MSHA. A sample showing this designation shall be submitted to this office for examination. Failure to submit this sample in a timely manner may result in revocation of the acceptance.

Change in composition of the product or other factors which may affect the acceptance issued under the Interim Fire and Toxicity Criteria must not be made without prior authorization from the Approval and Certification Center.

Sincerely,

A handwritten signature in cursive script that reads "Harry C. Verakis". The signature is written in dark ink and is positioned above the typed name and title.

Harry C. Verakis  
Chief, Division of Materials  
and Explosives  
Approval and Certificaton Center