AN INVESTIGATION OF VELOCITY DISTRIBUTION IN TEST SECTION OF WRIGHT BROTHERS WIND TUNNEL

by

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Submitted in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Aeronautical Engineering, from the Massachusetts Institute of Technology

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Acceptance:

Professor in Charge of Thesis:

May 18, 1939

Professor George W. Swett,
Secretary of the Faculty,
Massachusetts Institute of Technology,
Cambridge, Massachusetts

Dear Sir:

I submit herewith a thesis entitled "AN INVESTIGATION OF VELOCITY DISTRIBUTION IN TEST SECTION OF WRIGHT BROTHERS WIND TUNNEL" in partial fulfillment of the requirements for the degree of Bachelor of Science in Aeronautical Engineering.

Yours very truly,

Holden W. Withington

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Purpose of Investigation

The purpose of this investigation was to determine the velocity distribution in the test section of the Wright Brothers Wind Tunnel.

The results of this investigation should show the irregularities in the velocity distribution, making it possible to correct most of them. Provision for the correction of a general shift in the airstream had been made in the construction of the trailing edges of the corner vanes immediately upstream from the test section. The last three inches of each vane may be bent, thereby changing the effective angle of attack of the vane. Other irregularities, such as those caused by interference or local turbulence must be corrected by other means.

Method of Investigation

The method used to determine the velocity distribution was to compare the total head pressure at the various points in the cross-section with the total head pressure of a pitot-static tube. A diagram of the apparatus (Fig. 6, page) shows how this was accomplished.

A variation of the velocity at a point in the cross-section from the velocity at the pitot static tube showed as a difference in those total head pressures, - the velocity being proportional to the total head pressure of the static pressure remains constant. In this case where the section traversed was either in the plane of the pitot tube or immediately adjacent, (Fig. 4, page) the static pressure could be considered constant.

The blade pitch and speed of the propeller were kept constant throughout the entire investigation. The pitot-static velocity remained very nearly constant, changing only with temperature. This slight change was recognized by taking velocity readings at the beginning and end of each run and using the average value. The greatest change recorded being 1.9% while most runs were made with no apparent change in this velocity.

The first traverse was made with a screen in the lower three-quarters of the second set of corner vanes upstream from the test section (See Fig. 4). This screen consisted of cheese cloth soaked with oil and backed with wide mesh "chicken" screening. The purpose of this screen was to remove from the tunnel the very fine particles of metal dust and other hard materials which had been scarring the propeller blades. In this first traverse, only one section was investigated.

The screen was removed before the second traverse was made. In this traverse two sections were investigated. As there were two struts and nine stations in each cross-section, it was necessary to make a traverse in five runs of two stations each with one duplication to check any doubtful data. The following pairs were chosen to give minimum interference: B and F, D and H, J and E, A and G, C and any other. (see Fig. 5).

The location of the two cross-sections chosen are shown in Fig. 4. Cross-section I was taken in the plane of the pitot static tube. Cross-section II was arbitrarily taken four feet downstream from cross-section I. It was planned that one more section further downstream would be investigated.

In each cross-section, the points investigated were taken at 12 inch intervals starting from the horizontal and vertical center-lines. (see Fig. 5). However, the shape of the tunnel and the length of the short strut determined the position of the points in the outside stations.

Description of Apparatus

Total Head Tubes: Fig.9

These tubes, eleven in number, were made from ¼" x .065 brass tubing with one end beveled and the other turned down and rounded to fit standard 3/16 rubber tubing. The threaded brass collar (B) was soldered to that tube. The threaded plug (C) was soldered into the streamline strut.

Total Head Struts: Fig. 7

The struts which carry the total head tubes were made from 1¾" nominal x .040 streamline tubing. The short strut was used at stations A, B, H, and J, while the long strut was used at stations C, D, E, F, & G. These struts were fastened by bolts to the floor of the test section. Streamline holes were cut in the top wall so that the upper ends fitted through. Thus the rubber tubes attached to the total head tubes were brought up inside the struts and out of the test section. from there they went to the common connecting tube.

Common Connection: Fig. 8

This connection consisted of a 1" O.D. brass tube with inlets for all the total head tubes and one outlet which was connected to the manometer. It simplified the measuring of the individual total head differences, by serving as a simple switching device by which any desired total pressure could be used without changing the tubes on the manometer. Each of the incoming tubes has a single rubber hose clamp which acted as a valve.

Airspeed meter:

A standard airspeed meter was used as a rough measure of the velocity.

Manometer: Prandtl type.

This manometer was used to measure the difference between the total head pressure at the various points in the cross-section and the total head pressure of the pitot-static tube. It was also used to obtain the absolute pitot-static velocity in the test section.

RESULTS

The results of this investigation are shown by the three velocity distribution plots. (Figs. 1,2,3)

The difference in velocity, as measured by the difference in total head pressure , was changed to a non-dimensional quantity by dividing it by the velocity pressure $(p_t - p_s)$ of the pitot-static tube.

$$\frac{p_t}{p_t - p_s}$$

The values plotted are numbers representing the ratio of total pressure difference to velocity pressure. When multiplied by 100 they represent that difference as a percentage of the velocity pressure. Thus these numbers, and hence the plots, are independent of the wind velocity in the test section.

Discussion of Results

1st Traverse Cross-Section I (fig. I).

The velocity distribution of the first traverse clearly shows the effect of the screen in the corner vane. The velocity at the bottom is from 5% to 7% lower than at the top. There is also a noticeable decrease in velocity in the left side of the section (looking up stream) and an increase in the upper right side.

2nd Traverse Cross-Section I (fig. 2):

This traverse shows a more uniform vertical distribution than the 1st traverse which is to be expected from the removal of the screen. However, the horizontal distribution still shows a region of lower velocity on the left side.

2nd Traverse Cross-Section II (Fig. 3):

This traverse shows a more constant distribution than section I. The lower velocity on the left side is still present.

Conclusions

1. The vertical velocity distribution is satisfactory with the exception of a slightly high velocity region in the upper central portion of the cross-section. This may possibly be the result of a faulty total head tube which should be checked.

2. The horizontal distribution is not satisfactory. This should be corrected by an adjustment of the trailing edges of the corner vanes immediately upstream. The effective angle of attack should be lowered until a satisfactory traverse has been made.

3. As this investigation was carried on at one propeller blade setting and R.P.M., these conclusions apply only to these conditions. A check should be made at some other blade setting and R.P.M.

Suggestions for Further Investigation

1. Traverses at another R.P.M. and blade setting should be made.

2. A determination of the rotation of the air stream should be made before adjusting the corner vanes.

CALCULATIONS

CALCULATIONS

1st Traverse -- with screen

Cross-section I

$$\frac{pt}{p_t - p_s}$$

Vertical position	A	B	C	D	E	F	G
1	-.093	-.070					
2	-.111	-.078	-.056	-.052	-.046	-.041	-.049
3	-.082	-.091	-.057	-.039	-.035	-.037	-.040
4	-.062	-.078	-.063	-.042	-.031	-.023	-.017
5		-.064	-.057	-.039	-.019	-.005	-.007
6			-.045	0.030	-.006	+.020	+.012
7			-.008	-.002	+.019	+.016	+.013

	H	J
1	-.045	-.049
2	-.035	-.047
3	-.027	-.035
4	-.016	-.014
5	-.005	
6		
7		

2nd traverse -- without screen

Cross-section I

$$\frac{p_t}{p_t - p_s}$$

Vertical position	A	B	C	D	E	F	G
1	-.083	-.053					
2	-.101	-.061	-.039	-.023	-.023	-.022	-.033
3	-.083	-.073	-.042	-.017	0	-.017	-.030
4	-.060	-.073	-.057	-.013	+.006	-.008	-.018
5		-.056	-.047	-.008	+.020	+.006	+.004
6			-.035	-.020	-.006	-.025	-.034

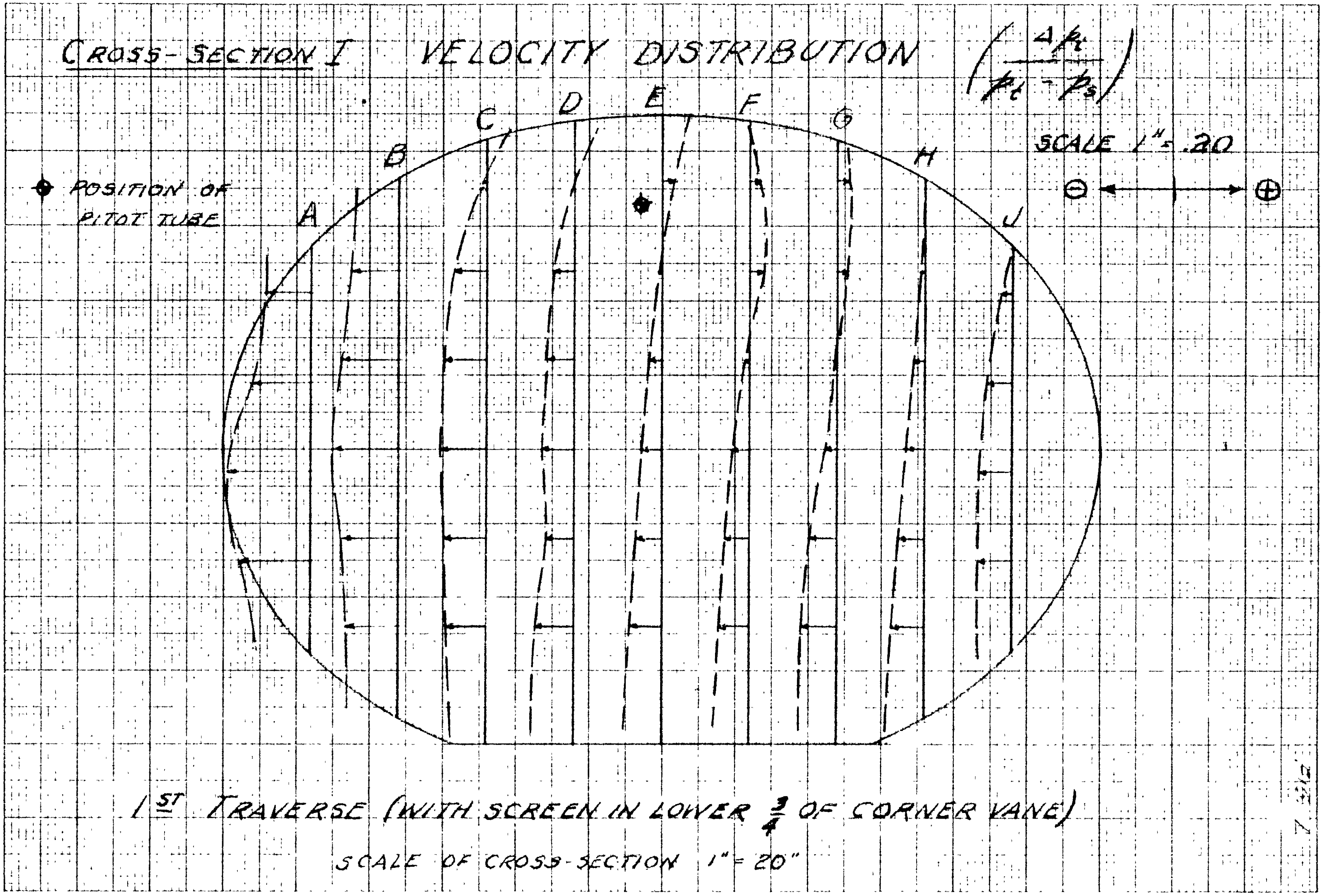
Vertical position	H	J
1	-.038	-.052
2	-.046	-.067
3	-.045	-.065
4	-.037	-.065
5	-.103	
6		
7		

2nd Traverse -- without Screen

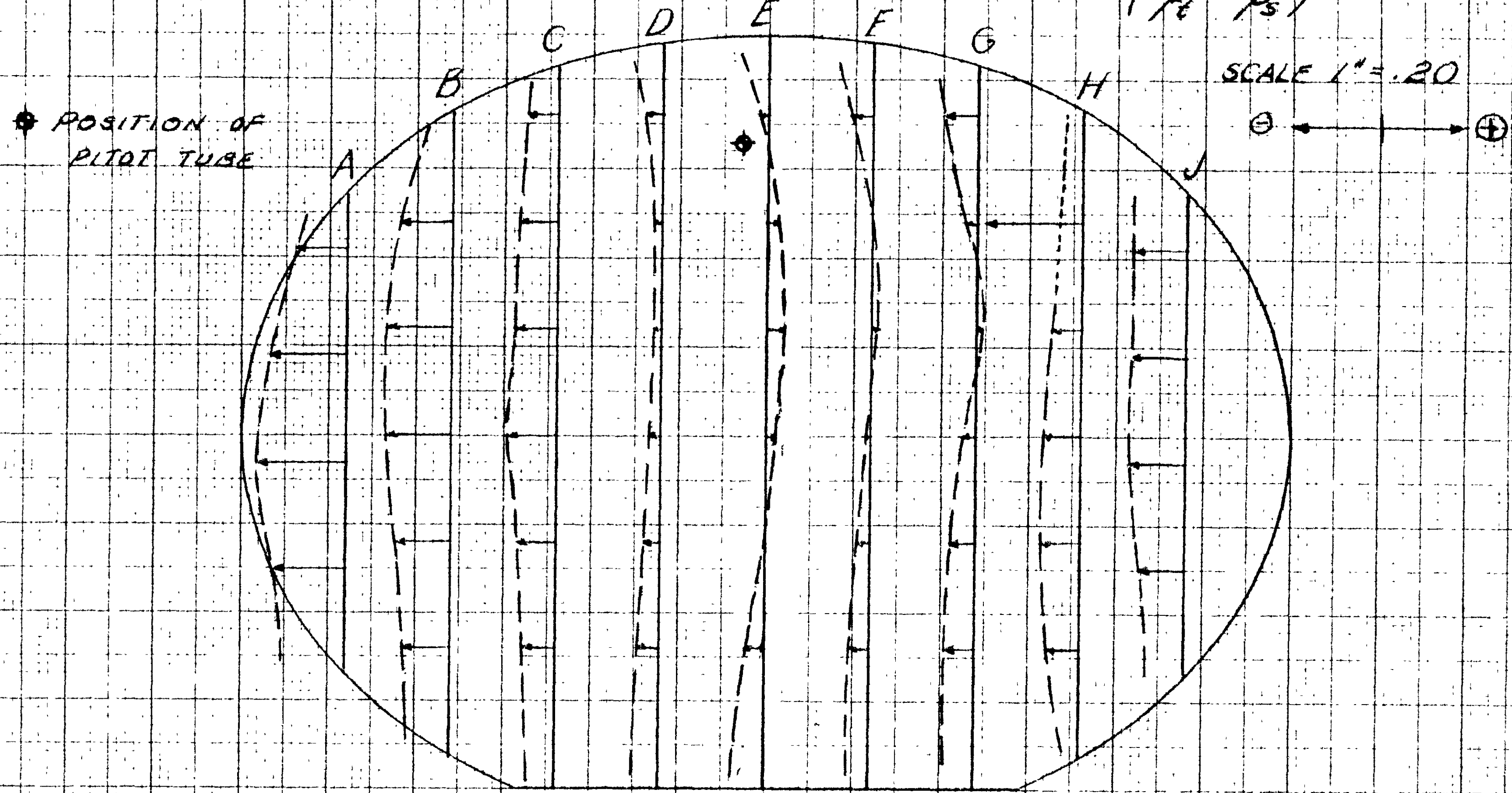
Cross-section II

$$\frac{pt}{p_t - p_s}$$

Vertical Position	B	D	F	H
1	-.060			-.040
2	-.080	-.022	-.028	-.048
3	-.100	-.017	-.017	-.045
4	-.086	-.019	-.009	-.047
5	-.103	-.014	+.012	-.089
6		-.014	-.005	
7		-.017	-.021	


CROSS-SECTION I VELOCITY DISTRIBUTION $\left(\frac{\Delta p_t}{p_t - p_s}\right)$
SCALE 1" = .20
POSITION OF PITOT TUBE
A
B
C
D
E
F
G
H
J
1ST TRAVERSE (WITH SCREEN IN LOWER 3/4 OF CORNER VANE)
SCALE OF CROSS-SECTION 1" = 20"

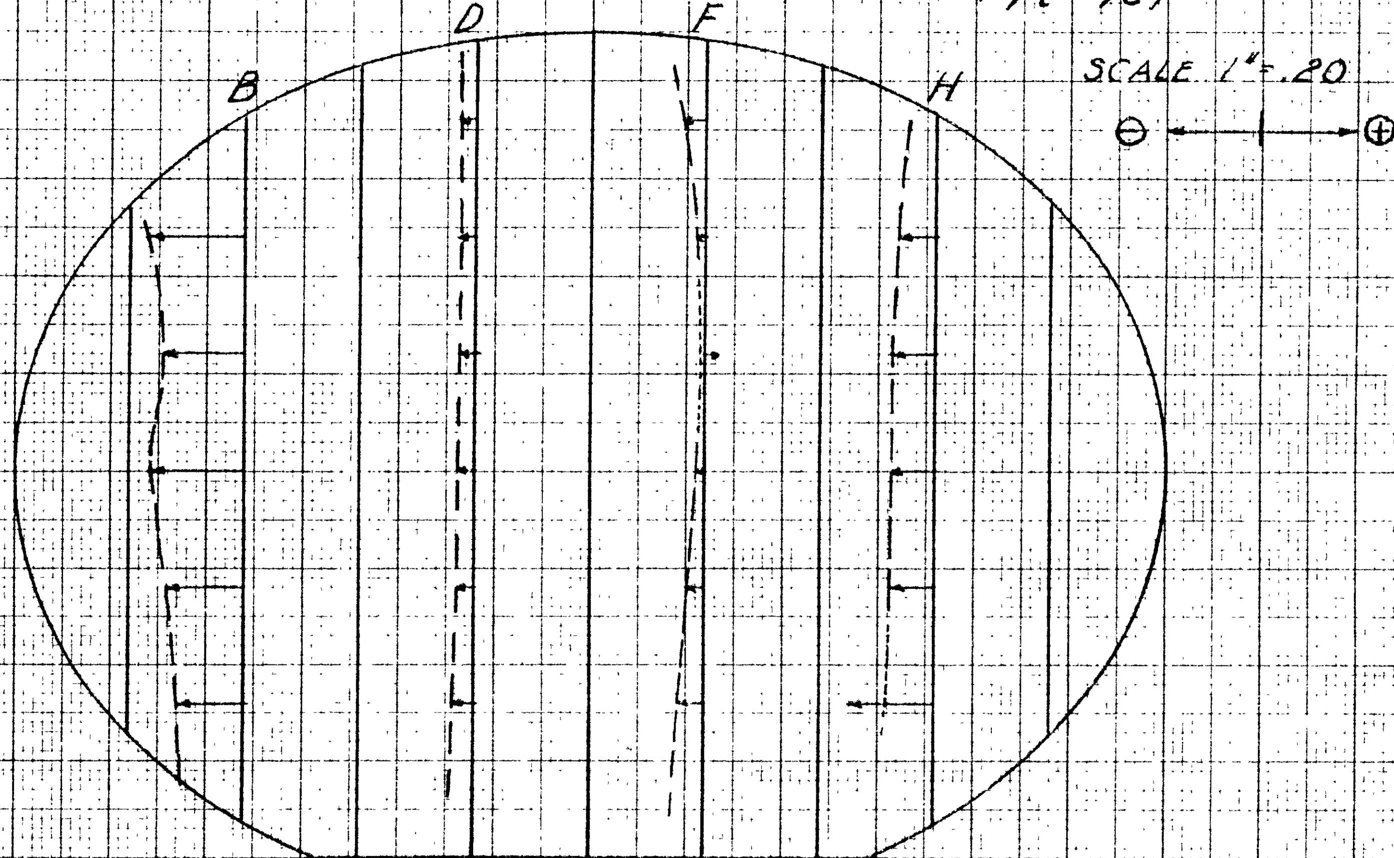
CROSS-SECTION I VELOCITY DISTRIBUTION $\left(\frac{\Delta p_t}{p_t - p_s}\right)$



2nd TRAVERSE (NO SCREEN)

SCALE OF CROSS-SECTION 1" = 20'

CROSS-SECTION II VELOCITY DISTRIBUTION $\left(\frac{\Delta p_t}{p_t - p_s}\right)$

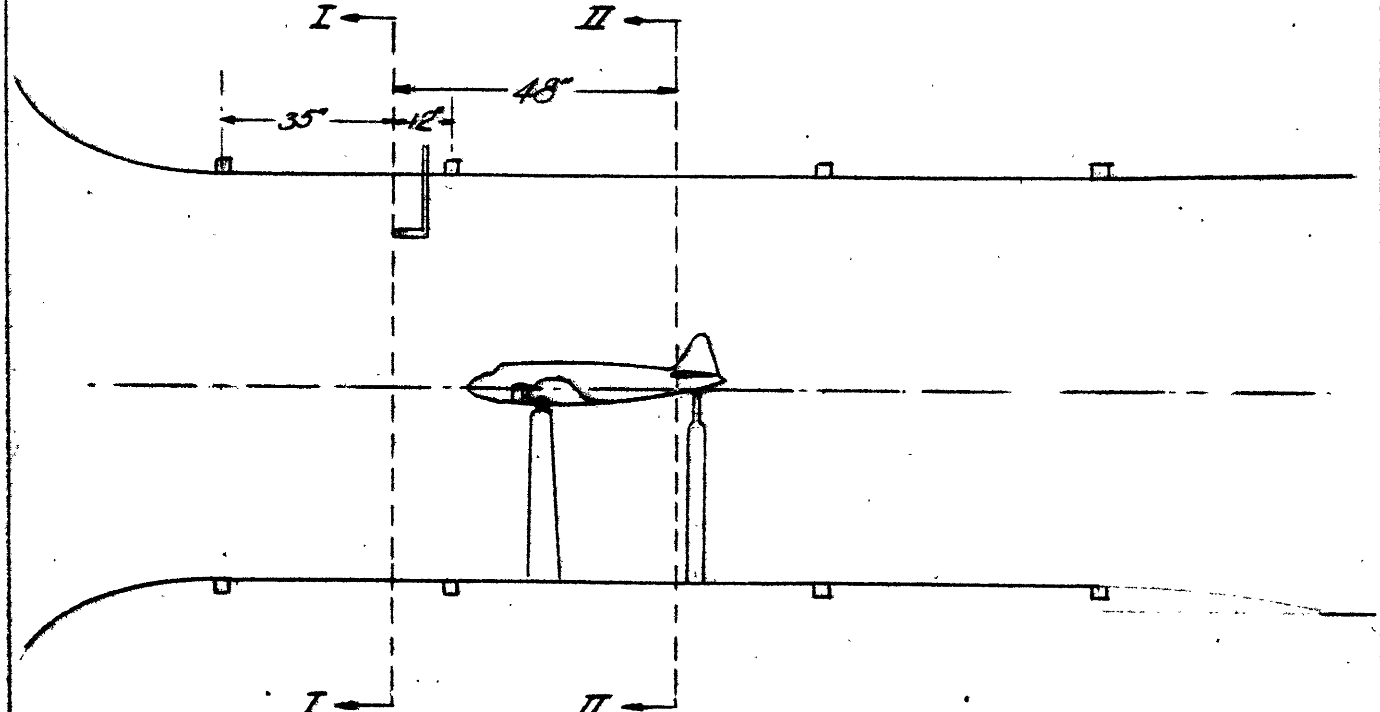


2nd TRAVERSE (NO SCREEN)

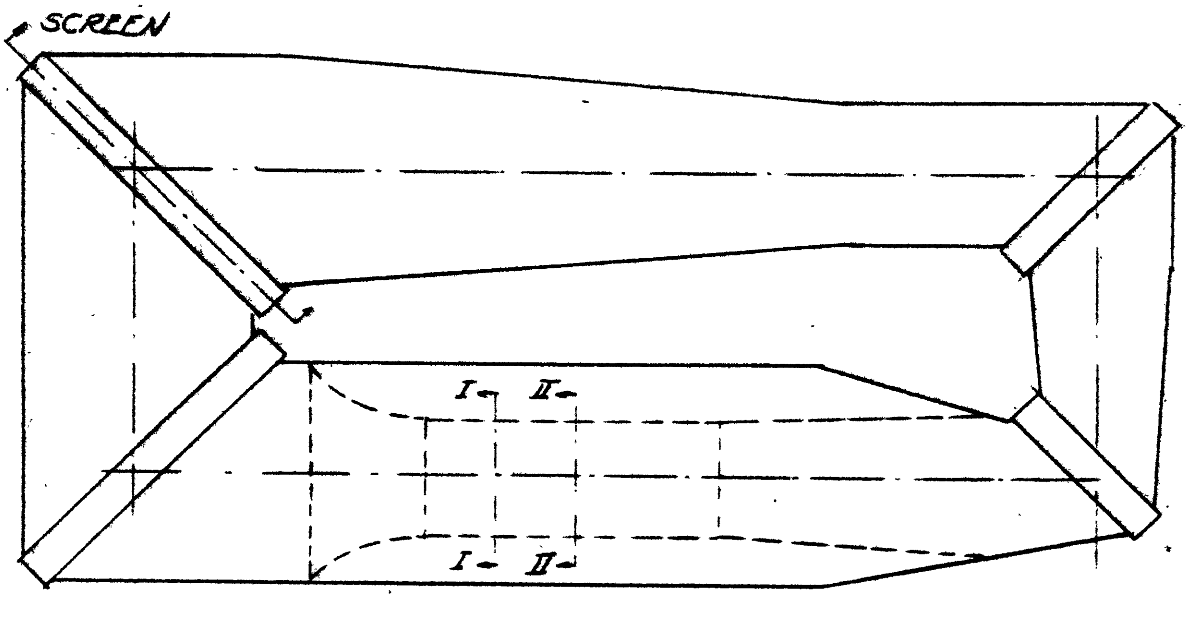
SCALE OF CROSS-SECTION 1" = 20'

FIG 4

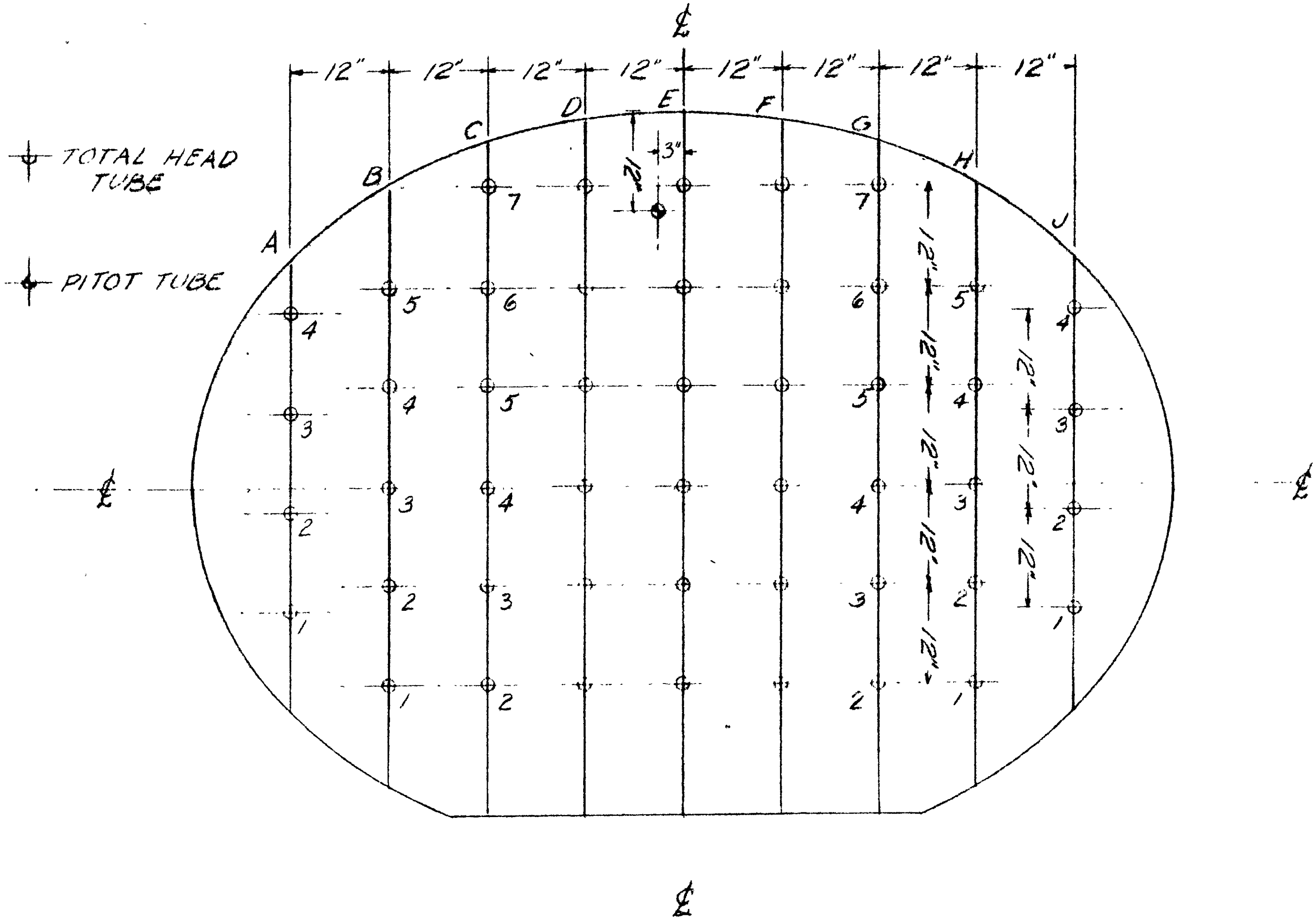
LOCATION OF SECTIONS TRAVERSED



TEST SECTION



PLAN OF TUNNEL



POSITION OF STATIONS (LOOKING UPSTREAM)

1/20 SCALE

FIG. 5

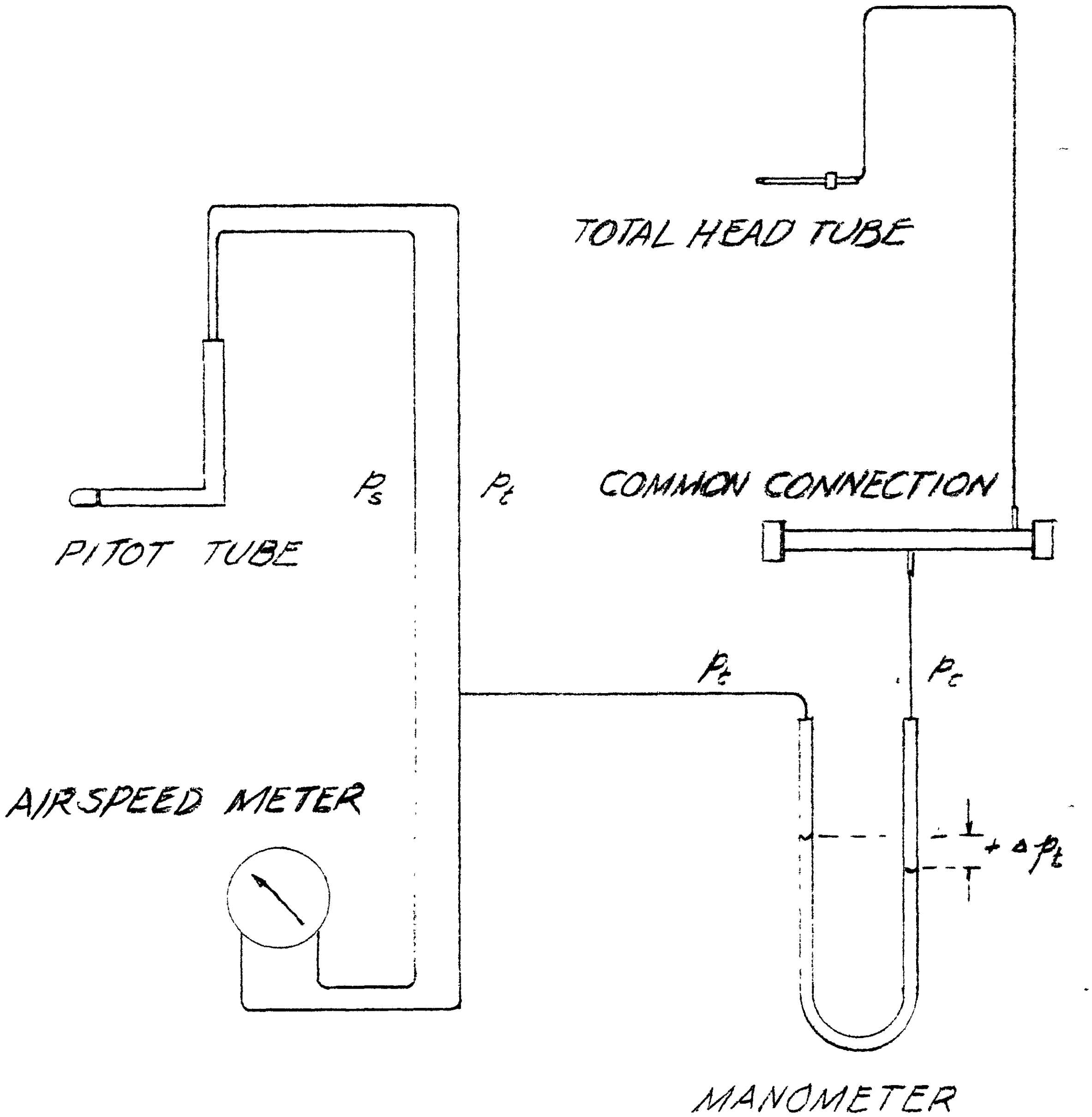
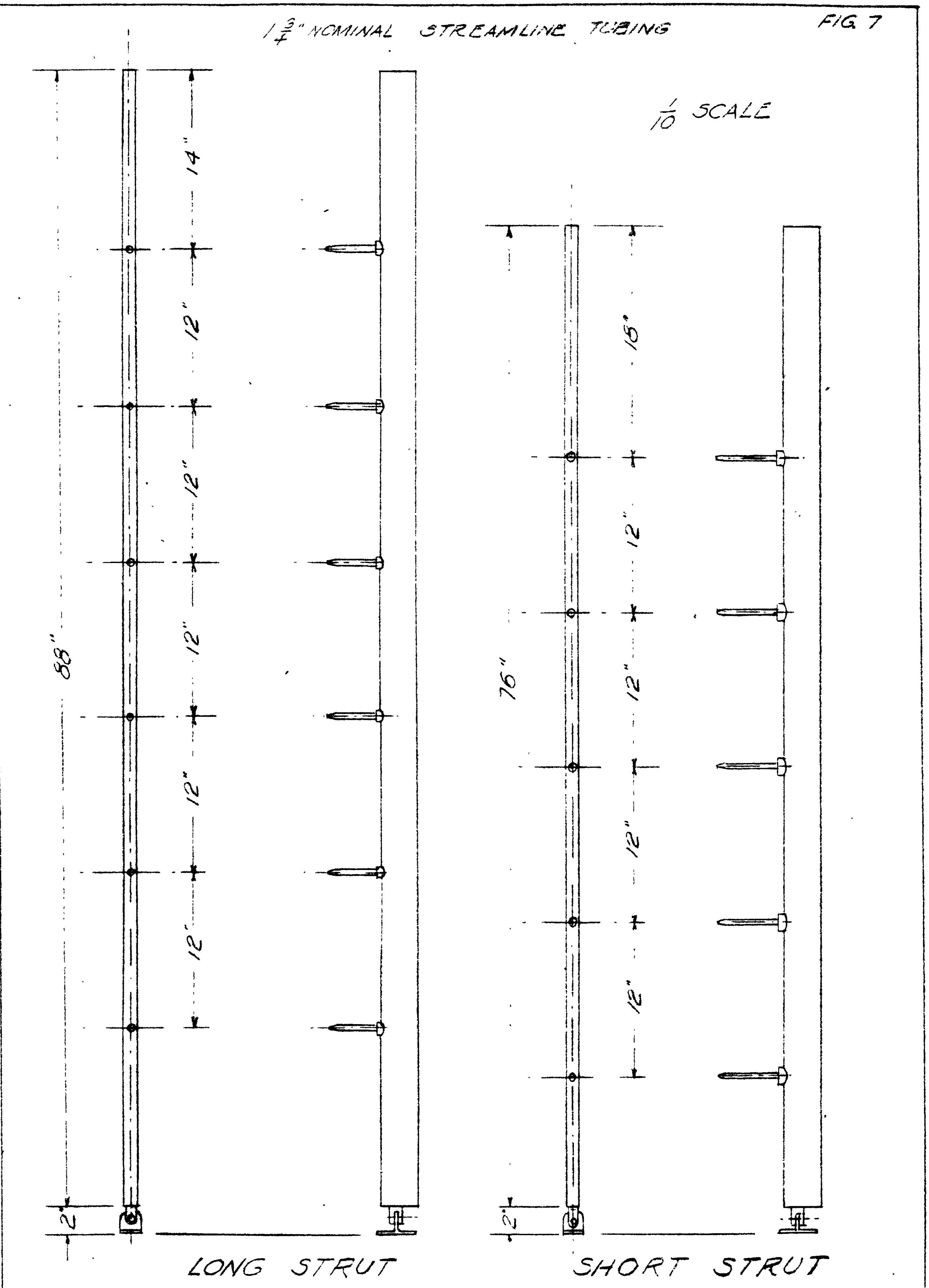
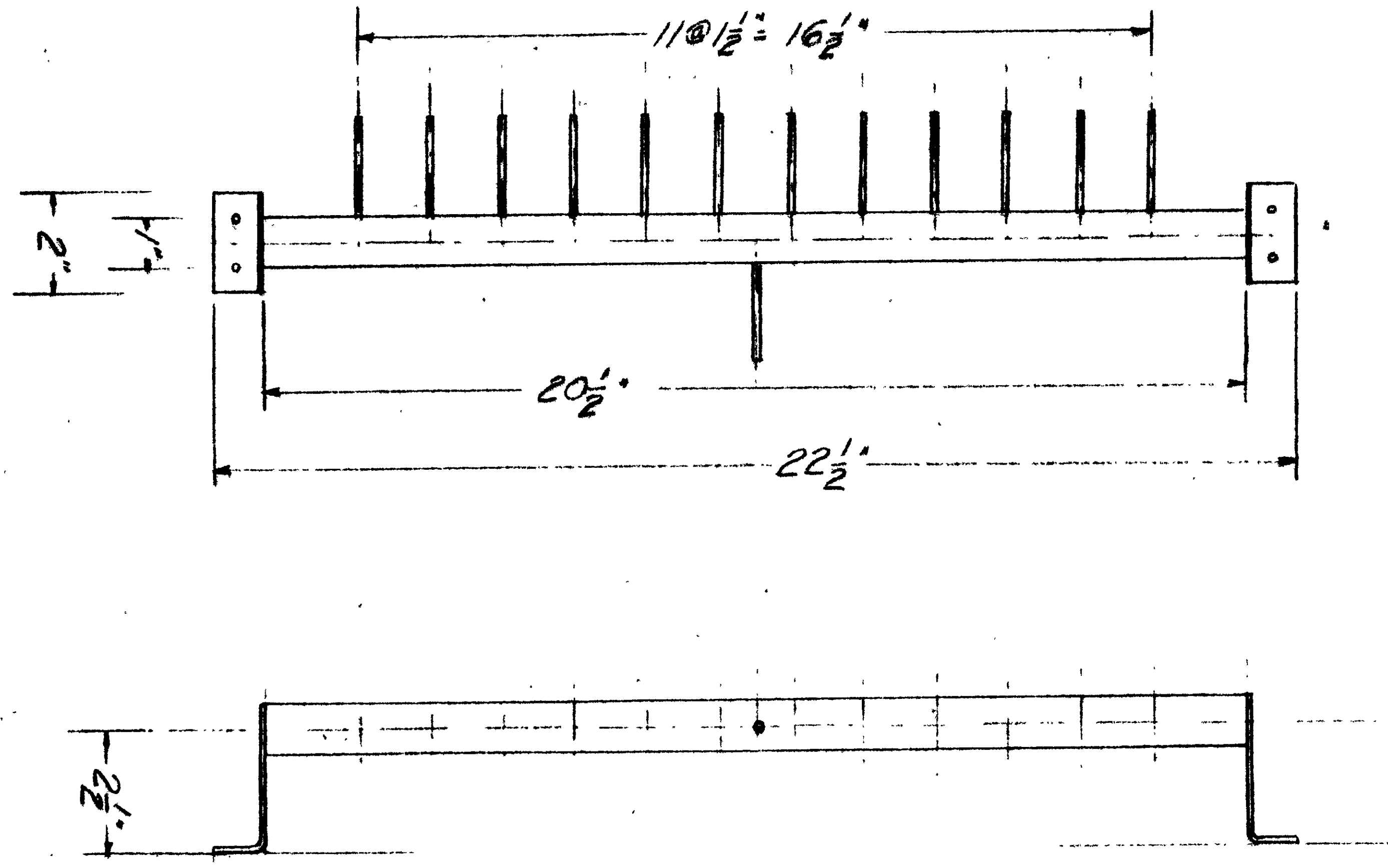


DIAGRAM OF APPARATUS

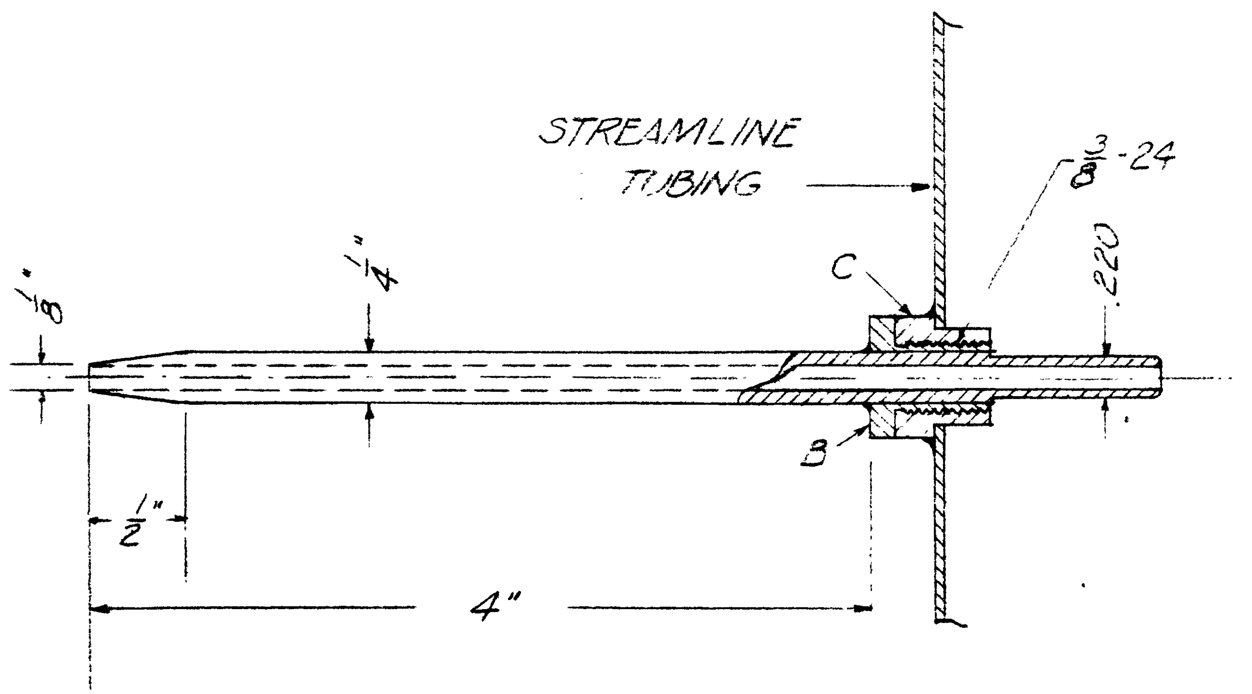

1 3/4" NOMINAL STREAMLINE TUBING
1/10 SCALE
14"
12"
12"
12"
12"
12"
88"
2"
18"
12"
12"
12"
12"
76"
2"
LONG STRUT
SHORT STRUT



COMMON CONNECTION FOR TOTAL HEAD TUBES

1/40 SCALE

FIG. 8



TOTAL HEAD TUBE
ASSEMBLY

FULL SIZE

DATA

See Fig. #5 for key to positions

p_t = see Fig. 6

p_t = total pressure in pitot tube

p_s = static pressure in pitot tube

(all pressures in m.m. of alcohol)

DATA

1st Traverse - with screen in corner vane

2nd speed 600 R.P.M.

Blade pitch 9.6^{o}

Cross - section I

Vertical Position	Sta. B & F p_t	Sta. B & F p_t-p_s	Sta. D & H p_t	Sta. D & H p_t-p_s	Sta. J & E p_t	Sta. J & E p_t-p_s
S-1	-11.9	170.0	-7.5	170.3	-8.4	170.6
S-2	-13.4		-5.9		-8.1	
S-3	-15.5		-4.5		-5.9	
S-4	-13.4		-2.7		-2.4	
S-5	-10.8		-0.8			
L-2	-7.0		-8.9		-7.8	
L-3	-6.3		-6.6		-6.0	
L-4	-4.1		-7.0		-5.2	
L-5	-0.9		-6.6		-3.3	
L-6	+3.5		-5.0		-1.1	
L-7	+2.8	170.0	-0.3	167.2	+3.2	170.7

Vertical Position	Sta. A & G p_t	Sta. A & G p_t-p_s	Sta. A & C p_t	Sta. A & C p_t-p_s
S-1	-15.8	170.6	-16.7	170.7
S-2	-19.0		-20.0	
S-3	-14.0		-14.2	
S-4	-10.5		-10.0	
S-5				
L-2	-8.4		-9.5	
L-3	-6.8		-9.6	
L-4	-2.9		-10.8	
L-5	-1.2		-9.8	
L-6	+2.1		-7.7	
L-7	+2.2	170.0	-1.4	170.1

2nd Traverse -- without screen in corner vane

2nd speed 600 R.P.M.

Blade pitch 9.6°

Cross-section I

Vertical position	Sta. B & F p_t	$p_t - p_s$	Sta. D & H p_t	$p_t - p_s$	Sta. C & J p_t	$p_t - p_s$
S-1	-10.7	171.4	-6.5	173.5	-9.0	173.5
S-2	-12.8		-7.9		-11.6	
S-3	-17.5		-7.7		-11.2	
S-4	-13.3		-6.4		-11.2	
S-5	-20.0		-18.0			
L-2	-3.8		-4.1		-6.8	
L-3	-2.9		-2.9		-7.3	
L-4	-1.4		-2.3		-9.9	
L-5	+1.0		-1.4		-8.2	
L-6	0		-1.6		-7.3	
L-7	-4.3		-3.5	173.5	-6.0	173.5

2nd Traverse -- without screen in corner vane

2nd speed 600 R.P.M.

Blade pitch 9.6^{o}

Cross section II

Vertical position	Sta. pt	D & H p_t-p_s	Sta. pt	F & B p_t-p_s
S-1	-6.9	172.3	-10.3	171.0
S-2	-8.2		-13.7	
S-3	-7.7		-17.2	
S-4	-8.0		-14.8	
S-5	-15.2		-17.7	
L-2	-3.8		-4.9	
L-3	-3.0		-2.9	
L-4	-3.3		-1.5	
L-5	-2.4		+2.0	
L-6	-2.4		-0.9	
L-7	-3.0	172.0	-3.6	171.5