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Air flow distribution at low velocities in the 86” inlet duct of No. 4 test cell

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NATIONAL RESEARCH COUNCIL
DIVISION OF MECHANICAL ENGINEERING
OTTAWA, CANADA
LABORATORY MEMORANDUM

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PAGE 1 OF 6

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SECURITY CLASSIFICATION Open

SUBJECT Air Flow Distribution at Low Velocities in the 86"
Inlet Duct of No. 4 Test Cell.

PREPARED BY T. Guthrie, W. Grabe.

ISSUED TO

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NATIONAL RESEARCH COUNCIL
DIVISION OF MECHANICAL ENGINEERING
LABORATORY MEMORANDUM

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1.0 Introduction

In order to measure air mass flow rates through the 86" duct in No. 4 test cell of the Engine Laboratory, an average total head is obtained from a 25-point rake, and an average static head from four wall taps. A graph, based on compressible flow theory, facilitates the conversion from dynamic head to air mass flow rates. While this measuring arrangement has given very good results with the mass flow rates encountered in the past (approximately 75 to 350 lbm/sec), it was felt that its accuracy and readability would be questionable for the mass flow range of the forthcoming icing program. The maximum combined air flow rate for the engine and a blower providing spillage flow has been estimated to be about 85 lbm/sec; the minimum flow rate would be about 27 lbm/sec.

A fluidic anemometer, similar to one developed by J. Tanney*, Low Speed Aerodynamics Section, has been designed by the Engine Laboratory Design Office and built by the Experimental Work Shops. This anemometer is based on the principle of fluidic amplification where a primary, constant, air jet is deflected by the secondary flow to be measured. It lends itself especially to low velocity flows and is capable of measuring air velocities from 0 to 50 ft/sec. with an accuracy within 1%.

*B.R. Robinson, J.W. Tanney, "A Secondary Standard Fluid Jet Anemometer", LTR-LA-7, 27 June 1968.

2.0 Objective

A single anemometer is to be mounted at the longitudinal axis of the duct. In order to obtain the total air mass flow rate, a functional relationship had to be found between the local air velocity at the central axis and a mean velocity in the duct.

3.0 Apparatus

The instrument used for determining the velocity profiles was a hot-wire anemometer (Flowtronic Air Velocity Meter, Model 55A, by Flow Corporation, Cambridge, Massachusetts). Two very thin filaments (.0005" dia.), one of which is heated electrically, are exposed to the air stream to be measured. Convective heat transfer from the heated filament will tend to lower its temperature and thus its resistance. A transistorized feedback amplifier maintains a constant resistance ratio between this heated and the unheated filament by increasing or decreasing the current flow through the heated filament. The potential required for the instantaneous current flow is a function of the air stream velocity. A calibrated voltmeter permits direct reading of the velocity in "feet per minute". The range of this instrument is from 60 to 4200 ft/min.

4.0 Tests and Results

A series of tests were conducted in which local velocities in the 86" duct were measured by means of the above described hot-wire anemometer. The air flow was induced by atomizing air flow through the icing-spray-mast nozzles, and air velocities between 4 and 14 ft/sec were obtained in the intake duct. Readings were taken at seven radial positions, at three circumferential positions, about 10 inches upstream of the spray mast, see Fig. 1. The averages of the three equi-radii readings, which were within 5% of the mean, are plotted in Fig. 2. As can be seen, the velocity profile is nearly square, with the exception of the highest velocity.

Next, an area-weighted mean velocity was computed for each test point condition, and the ratios of mean velocity to velocity at central axis were established. These ratios, also called correction factors (C.F.) are plotted in Fig. 3. For high accuracy, a large scale was chosen for the ordinate which leads to the impression that the C.F. fluctuates wildly over the velocity range under investigation. In actual fact, the maximum error from the mean, at 14.2 ft/sec, amounts to only 2.89%. The maximum air flow which could be induced by means of the spray nozzles is slightly higher than the highest plot on this survey, while the anticipated maximum velocity in the icing tests is approximately 28 ft/sec.

5.0 Conclusion

Within the velocity range under consideration, namely 4 to 14 ft/sec (corresponding to mass flow rates of about 12 to 43 lbm/sec), a single correction factor of .968 can be used in correlating the duct mean velocity to the local velocity at the central axis. This C.F. will yield velocities with a mean error of 1.6% or a maximum error of 2.9%. If the velocity profile should change substantially toward a parabolic one, sizable errors in mass flow measurement could occur.

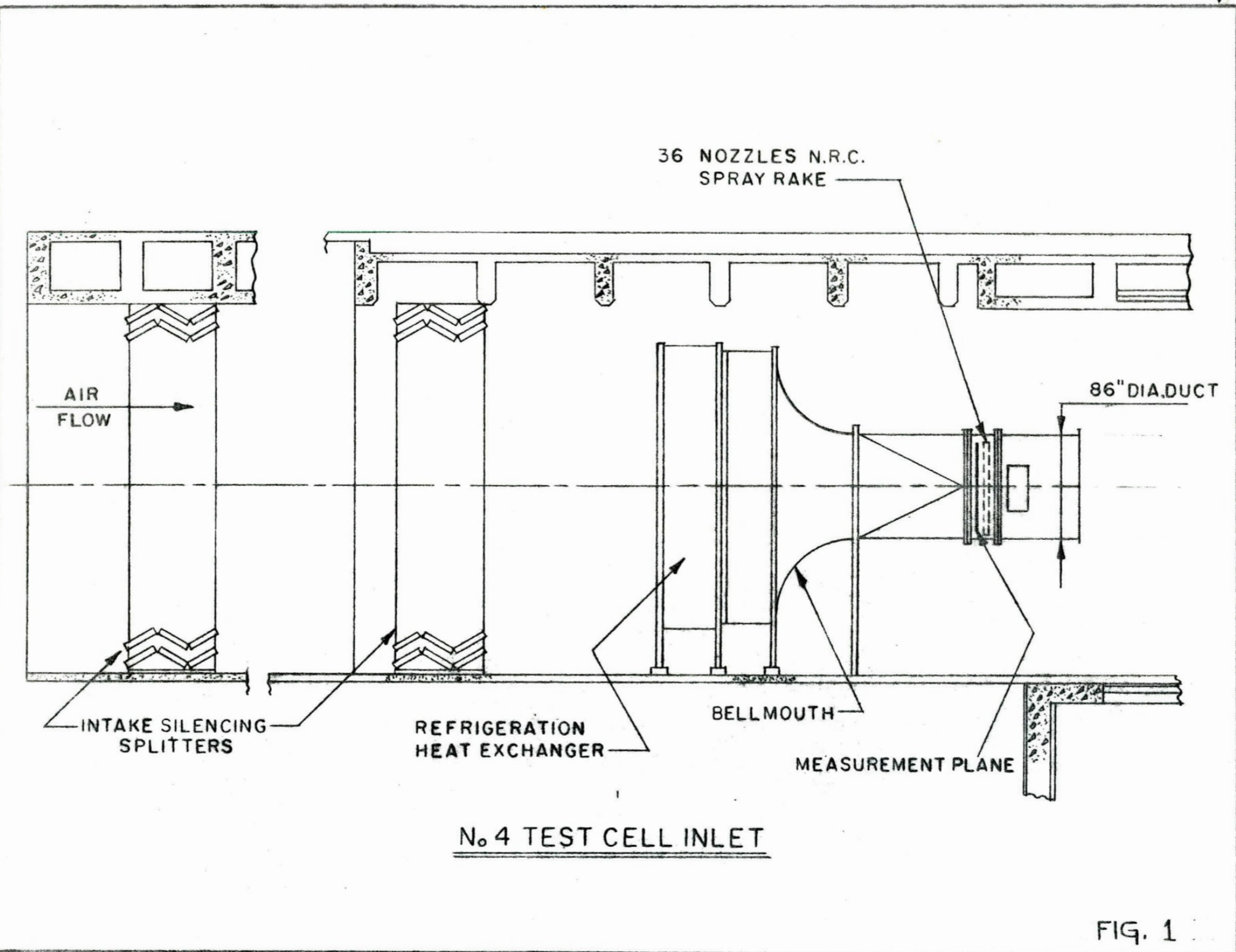


FIG. 1

VELOCITY PROFILES IN 8" DUCT OF NO. 4 CELL
 AT LOW AIR VELOCITIES

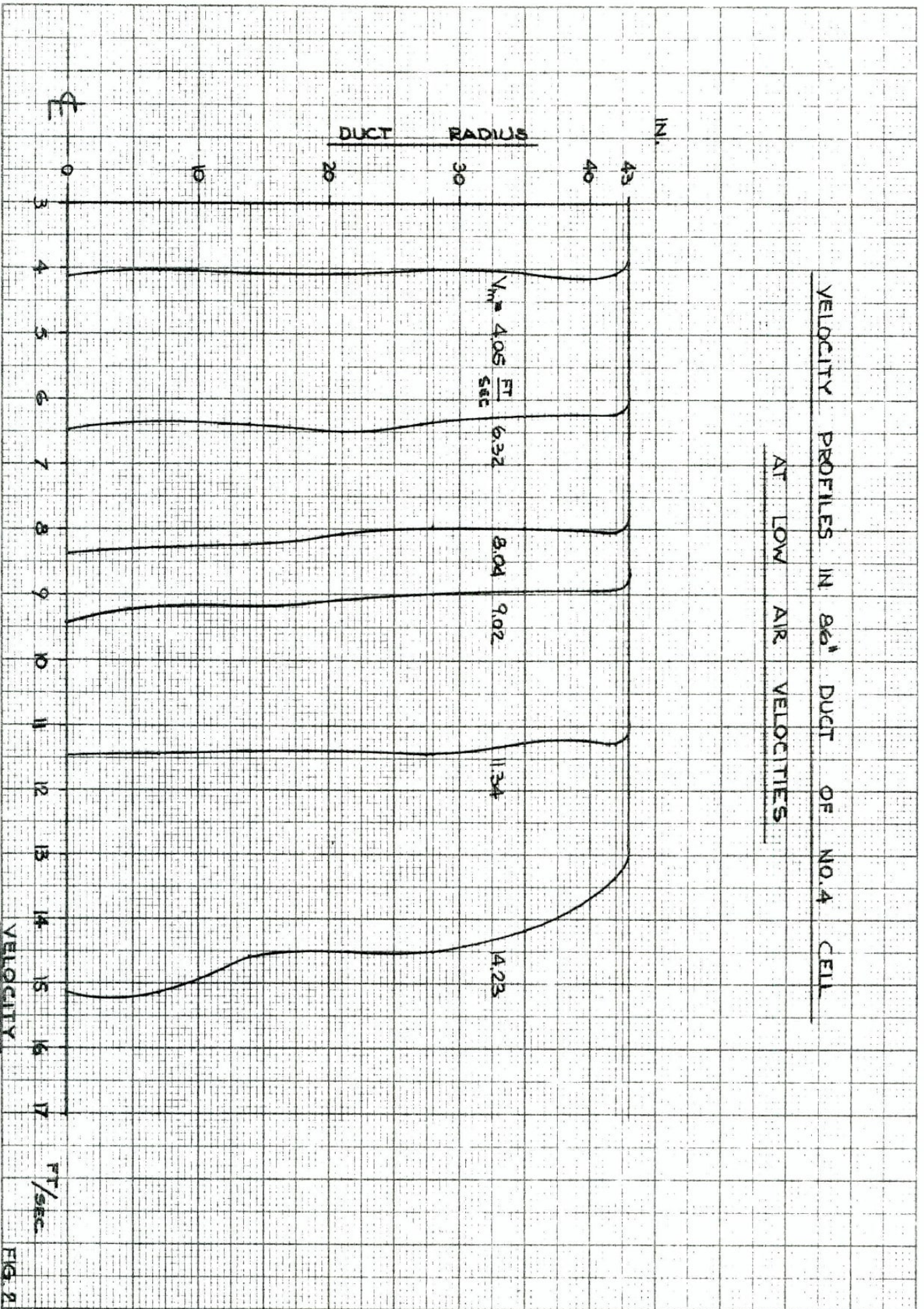
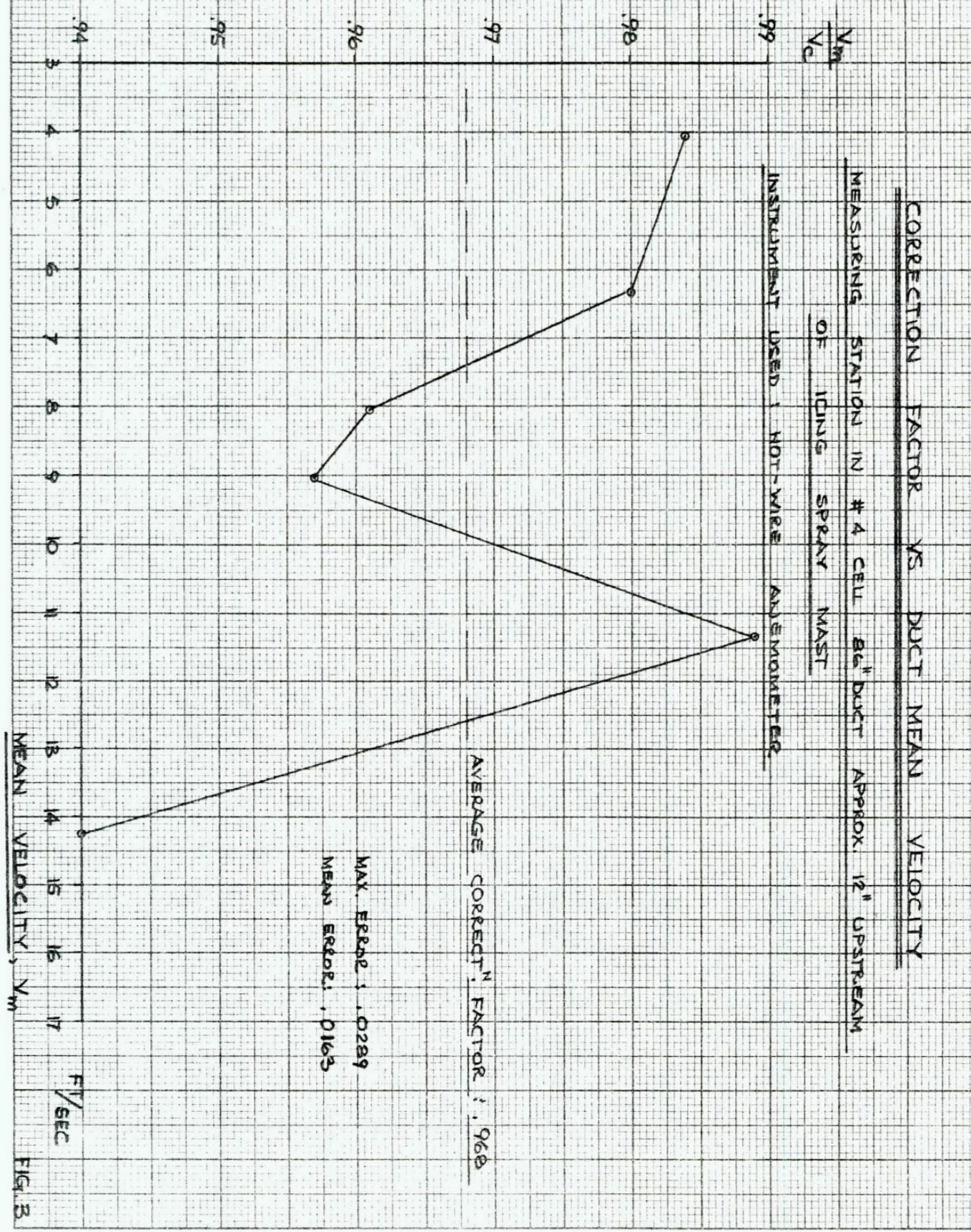


FIG. 2

$$\text{CORRECTION FACTOR} = \frac{\text{MEAN VELOCITY}}{\text{VELOCITY AT CENTRAL AXIS}}$$



CORRECTION FACTOR VS DUCT MEAN VELOCITY

MEASURING STATION IN #4 CELL 86" DUCT APPROX 12" UPSTREAM
 OF IDING SPRAY MAST

INSTRUMENT USED: HOT-WIRE ANEMOMETER

AVERAGE CORRECT'N FACTOR: .968

MAX ERROR: .0289
 MEAN ERROR: .0163

MEAN VELOCITY, V_m FT/SEC
 FIG. 3