PRACTICAL EXPERIENCES USING ULTRASONIC FLOWMETERS ON HIGH PRESSURE GAS

by

J L Holden and R J W Peters
Daniel Industries

Paper 2.1

NORTH SEA FLOW MEASUREMENT WORKSHOP 1990
23-25 October 1990

National Engineering Laboratory
East Kilbride, Glasgow

Ultra-flow project

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MR. J. L. HOLDEN AND DR. R.J.W. PETERS
DANIEL INDUSTRIES LIMITED
LOCHLANDS INDUSTRIAL ESTATE
LARBERT, FK5 3NS

S U M M A R Y

This paper presents practical experiences using Ultrasonic flowmeters on high pressure gas. Results are given from tests conducted in Norway, the U.K. and from The Netherlands. These tests include configurations giving fully developed flow profiles with no swirl and conditions with upstream disturbances.

The conclusions reached are that : (A) the 4-path Ultrasonic meter can measure high pressure gas accurately with 10D straight pipe upstream and 3D downstream of the meter, (B) the meter can indicate degrees of swirl and turbulance in a disturbed flow, and (C) acceptable results could be obtained in an installation where less than 10D was available upstream of the meter, particularly if the meter was operating at less than maximum flow.

1.0 INTRODUCTION

A multipath Ultrasonic meter for the accurate measurement of high pressure gas flow has been developed by British Gas and commercial meters are now available to cover a range of line sizes and flowrates.

The first published paper was as early as 1983 and the reasons for the development are given therein. (1)

The primary aim of the development was to produce a meter which had a performance comparable with or better than a good orifice installation without having the disadvantages of such. It was also considered essential that a suitable meter should have high reliability and no moving parts, and would be tolerant to disturbed flows.

A number of meters of different sizes were produced and installed at various British Gas sites during the period 1984 - 1986 and details have been published along with the experiences gained in operation. (2)

Comparisons between the measurements made with the meters and the Bishop Auckland test site reference meters showed that the ultrasonic meter behaved as predicted and accuracies better than 1% over turndown greater than 10:1 were achieved.

More recent tests carried out by Gasunie using 300mm and 500mm meters have shown that the performance of the ultrasonic meter with fully developed flow is comparable to that of a turbine meter. This has resulted in Ultrasonic meters being chosen to back up the turbine meters in the renovated Gasunie Export Stations.

Extensive testing has also been done on disturbed flows and the results of these indicate that the Ultrasonic meter is capable of measuring accurately under these traditionally difficult conditions.

2.0 RESULTS FROM TESTS USING FULLY DEVELOPED FLOW.

2.1 Tests at British Gas using a 300mm meter.

A 300mm meter was tested in fully developed flow by installing the meter with 117 diameters of straight pipe upstream.

From Fig. 1 it can be seen that for velocities varying between 10 and 70ft/sec. the errors between the ultrasonic meter and the reference meters lay between 0.4 and -0.8%.

2.2 Tests at K-Lab using a 150mm meter.

These tests were performed using Nitrogen over a pressure range of 55, 75, and 100 bars absolute at approximately 37°C. The calibration was undertaken at 0.8, 3.0, 6.0, 11.8, 17.4, 22.9 and 28.0m/sec. which was above the maximum design range of 21.0m/sec.

The meter was compared to the K-Lab bank of 8 toroidal throat sonic nozzles which are calibrated against a gravimetric weigh tank.

From Fig. 2 it can be seen that the differences between the measurements obtained from the ultrasonic meter and the reference meters varied from +1.4% to -1.11%. Daniel recommends a maximum velocity of 21m/s and using this limit the results obtained without any corrections being applied to the meter, over the above mentioned pressures, give accuracies between +1.4% and -0.35% i.e. a 1.75% swing.

2.3 Tests at Gasunie using 300mm and 500mm meters.

2.3.1 The results obtained at Gasunie (see Fig. 3) using a 300mm meter showed that the accuracy of the meter, with no internal corrections is well within 0.5% of reading over a range of velocities from 0.5 to 25m/sec. corresponding to a flowrange of 200 to 7200m^3/hr.

2.3.2 500mm Meter.

The results taken from the ultrasonic meter located upstream of a turbine meter (see Fig. 4) show an accuracy within ±0.4% over a flowrange of 100 to 1200m^3/hr.

3.0 RESULTS FROM TESTS USING DISTURBED FLOWS.

3.1 Selection of an Ultrasonic meter to minimise disturbance effects.

Why would an ultrasonic meter be selected in preference to other flowmeters to minimise installation effects in high pressure gas metering?

In the use of an orifice or gas turbine meter, the meter takes the total quantity of gas and when it is in the vicinity of the metering section there is an output highlighting the effect of gas on the metering element, i.e. a differential pressure in the case of the orifice plate, indicating the pressure drop through the plate or in the case of the turbine meter a pulse output indicating the momentum of the gas on the rotor.

In each case the meter will be at its most accurate condition if the gas is free from swirl and in a well defined flow profile when it meets the meter. Without any theory it is easy to imagine that swirl with the rotation of a turbine meter could indicate a high flow or an orifice meter where the flow profile is so distorted that the peak flow does not meet the orifice bore would give an incorrect result.

Knowing the problems arising from upstream disturbances with the turbine meter and the orifice meter it has been the tendency to increase the upstream straight lengths of pipe. Thus particularly with the orifice plate longer upstream lengths of pipe have resulted.

In ISO 5167 there are let out clauses in Section 6.4 "Swirl free conditions can be taken to exist when the swirl angle over the pipe is less than 2°.

Acceptable velocity profile conditions can be presumed to prevail when at each point across the pipe cross-section the ratio of the local axial velocity to the maximum axial velocity at the cross-section agrees to within ±5% with that which would be achieved in swirl-free flow at the same radial position at a cross-section located at the end of a very long straight length (over 100D) of a similar pipe."

This is virtually never performed in a production installation as it would require insertion probes to determine these effects. It is done in well equipped flow laboratories.

On the basis that this work is not undertaken it is essential that with turbine and orifice meters nothing less than the standard upstream lengths can be accepted to achieve minimum uncertainty.

It was with this background that Daniel approached the Ultrasonic meter with enthusiasm, with regard to its ability to handle flow in a less than ideal condition. The ultrasonic does not look at the total flow passing through the meter but simply looks at four cuts across the flow profile. The selection of the number of chords and their position has been based on mathematical modelling and is well documented (1 - 7). The four cuts give a sufficient sample to approximate the total flow.

However, in addition to the question of Installation effects the 4 chords give much greater information on the flow profile and the swirl. Each chord gives a measure of the velocity in each direction and as the two sets of chords are set at 45° to each other it is possible to get some guidance to the extent of swirl. Thus we can examine the fluid disturbance as it passes through the meter. In addition it should be noted that the meter does not adversely affect the flow as there are no parts protruding into the flow.

3.2 Tests with a 300mm meter at Gasunie and British Gas with disturbances at 10D, 6D, and 1.5D.

These results were presented in a paper to the Institution of Gas Engineers in 1988. (7)

The results of these tests are given in Figures 5 to 8.

From Fig. 5 it can be seen that with half moon and quarter moon plates at 10D (See Fig. 9) the results are within +1% until the flow rate approaches the limit of the meter.

Similar tests were undertaken at Gasunie again with half moon and quarter moon plates at 10D upstream. It can be seen from Fig. 6 that very similar results were obtained and it was only when very high flow rates were used that the results exceeded 1%.

With the same disturbances placed at 5 and 6D upstream of the meter, tests were conducted at British Gas and Gasunie. These results are shown in Fig. 7.

From this Figure it can be seen that there is very good agreement between the two laboratories. There is still a very good performance by the meter at the lower flow rates, but we can now see clear indications that the performance of the meter has been affected by the plate. For example the maximum flow was reduced slightly with the quarter moon plate. In addition the meter was not measuring properly at flows of about 4,300m^3/hr. with the half moon plate. The meter highlighted this fact by rejections on all four chords and relatively large errors with both the orientations tested giving scattered results outwith the ±1% band.

Fig. 8 summarises the results at the British Gas Site by plotting the velocity ratio, i.e. the individual velocity measurement (Vi) to the mean flow velocity (V).

With a long straight length of pipe of the order of 130D the central chords show a higher than average velocity whereas the other two chords show lower velocity and the ultrasonic meter agrees with the master meter to 0.28%.

At 10D with the opening at the bottom of the pipe with guarter and half moon plates it is interesting to note that there is a higher velocity measured in the top chords than in the bottom chords. It appears that from the plate, where the velocity is higher in the bottom of the pipe, the flow must sweep back to the top half of the pipe in the 10D from the plate to the meter. (NOTE this effect would not be seen in a turbine meter or in an orifice meter).

With the half moon plate set vertically it can be seen that there is a more even distribution which might be expected with the criss-cross arrangement of the chords.

Again with the half moon plate set at 6D the peculiar situation is found once more where the velocity in the meter is greater in the top chords than in the bottom area whereas the gas is flowing through the restriction plate in the bottom area.

By chance the average in this situation agreed with the master meter to 0.17%.

As an extremely severe test a half moon plate was put on the front flange of the ultrasonic meter, i.e. 1.1/2D from the metering section. Once more the meter is able to give very interesting information with regard to the flow through meter. The bottom chords see the very high velocity in the bottom half of the pipe but the top chords show that the gas is flowing in the opposite direction. The gas is showing a swirl pattern behind the half moon plate.

3.3 Tests with a 150mm meter at the K-Lab in Norway

The tests were conducted as discussed in Section 2.2

The arrangement of the pipework prior to the meter is as shown in Fig. 10 It should be noted that the meter was tested with a flow conditioner upstream of the meter and also without the conditioner. When the conditioner was removed it was replaced by a spool piece of the same length.

The results of these tests are shown in Fig. 2 from which it can be seen that the ultrasonic meter performs within specification except at very high and very low flow rates after a 90° bend approximately 11D from the meter. This was the case with or without the flow conditioner. It is not to say that the flow conditioner was not effective but simply that the meter was capable of metering the disturbance with a 90° single bend. If this had been a check on the conditioner a much more severe flow disturbance would have been necessary to study the effect.

3.4 Tests on a 300mm meter with two 90° bends in different planes set 10D upstream of the meter.

The meter was tested at the Bishop Auckland test facilities of British Gas over a flow range from 10 to 70ft/sec. To ascertain the effect of the 2, 90° bends in different planes the meter was tested with 117 diameter of straight pipe upstream of the meter at a pressure of 59-61 bar during the test period. Following this test the following tests were conducted.

1 Fully developed flow

2 Swirling flow at 56/59 bar (u/s chords horizontal)

3 Swirling flow at 56/59 bar (with the chords vertical)

4 Swirling flow at 34/35 bar (chords horizontal)

Figs, 1, 11, 12, 13, show the results for each condition.

It can be seen from these tests that even with the maximum swirl from two bends in different planes the bulk of the results are within 0.6% of those obtained from the turbine meter. The only results outwith ±1% were at maximum velocity when the meter had been rotated through 90% and even then the result was about +1.2% variation from 3 turbine meters.

It can be concluded from these tests that a 300mm Ultrasonic Gas meter can measure gas precisely if 10D of straight pipe is upstream of two 90° bends in different planes.

3.5 Tests at Gasunie with a 300mm meter.

As was mentioned in Section 3.2 tests were conducted in Gasunie of a similar nature to those by British Gas in Bishop Auckland. These included introducing quarter and half moon orifice plates at 5D and 10D from the upstream of the ultrasonic meter and similar results were achieved.

Gasunie concluded after these tests that "The accuracy of the meter with a disturbed velocity profile stays within 1% of reading. If the disturbance is very large and close to the meter (5D) the flow range is reduced to a maximum of 4500m^3/hour in a 12" pipe (20m/sec.)".

NOTE Daniel would only recommend a maximum of 21m/sec. from this size of meter.

4.0 CONCLUSION

4.1 The 4 path ultrasonic high pressure gas meter is capable of metering accurately (i.e. to the best standards achieved by an orifice meter run or a gas turbine meter) with 10D straight pipe upstream and 3D downstream.

4.2 A meter can indicate degrees of swirl and turbulance in a disturbed flow.

4.3 There are definite indications that the meter could be used in installation where 10D was not available upstream of the meter and still provide acceptable results, particularly if the meter was not operating at the maximum end of the flow range. An advantage of the ultrasonic meter would be that it would indicate if the results were not likely to be acceptable.

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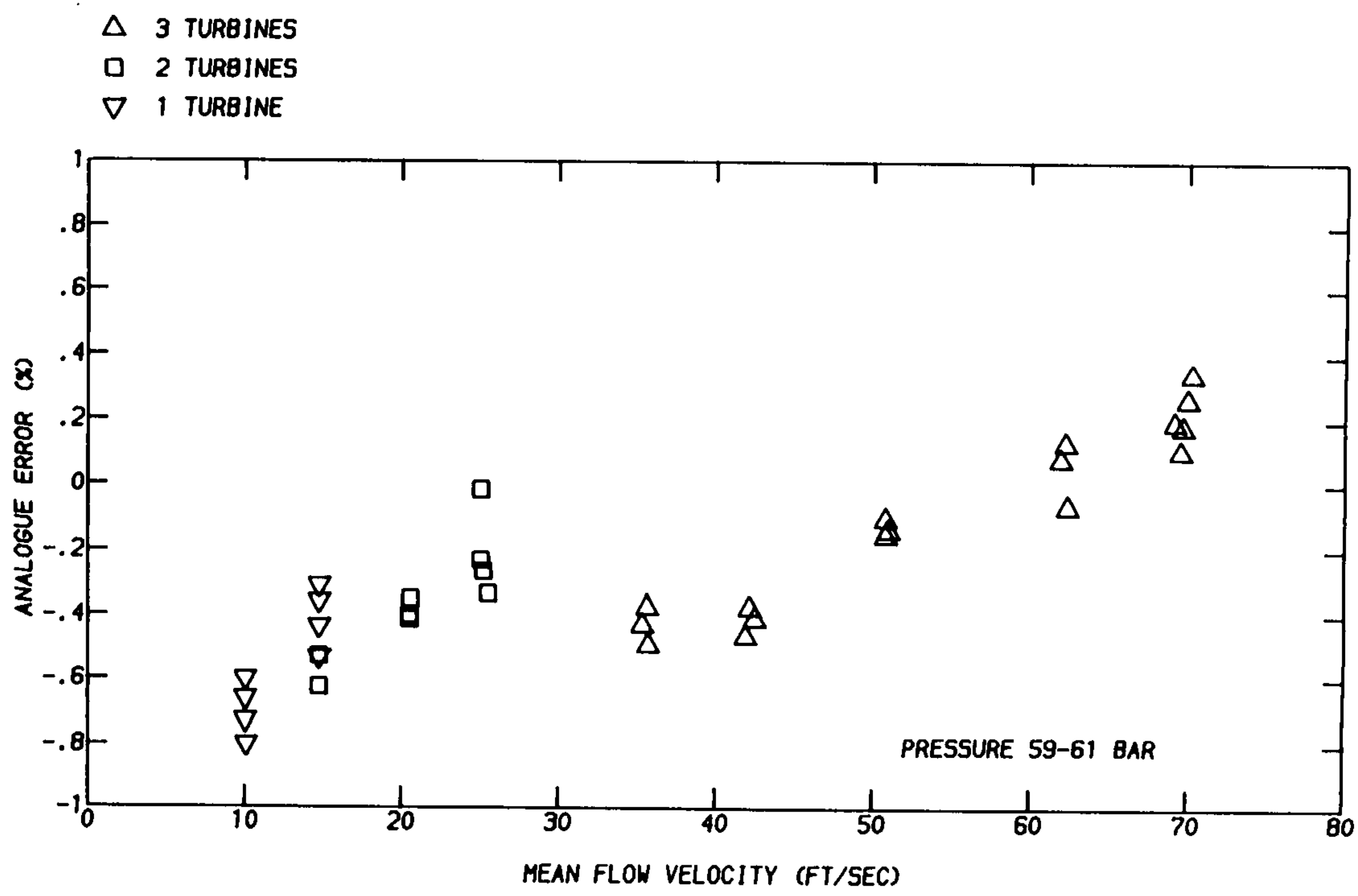
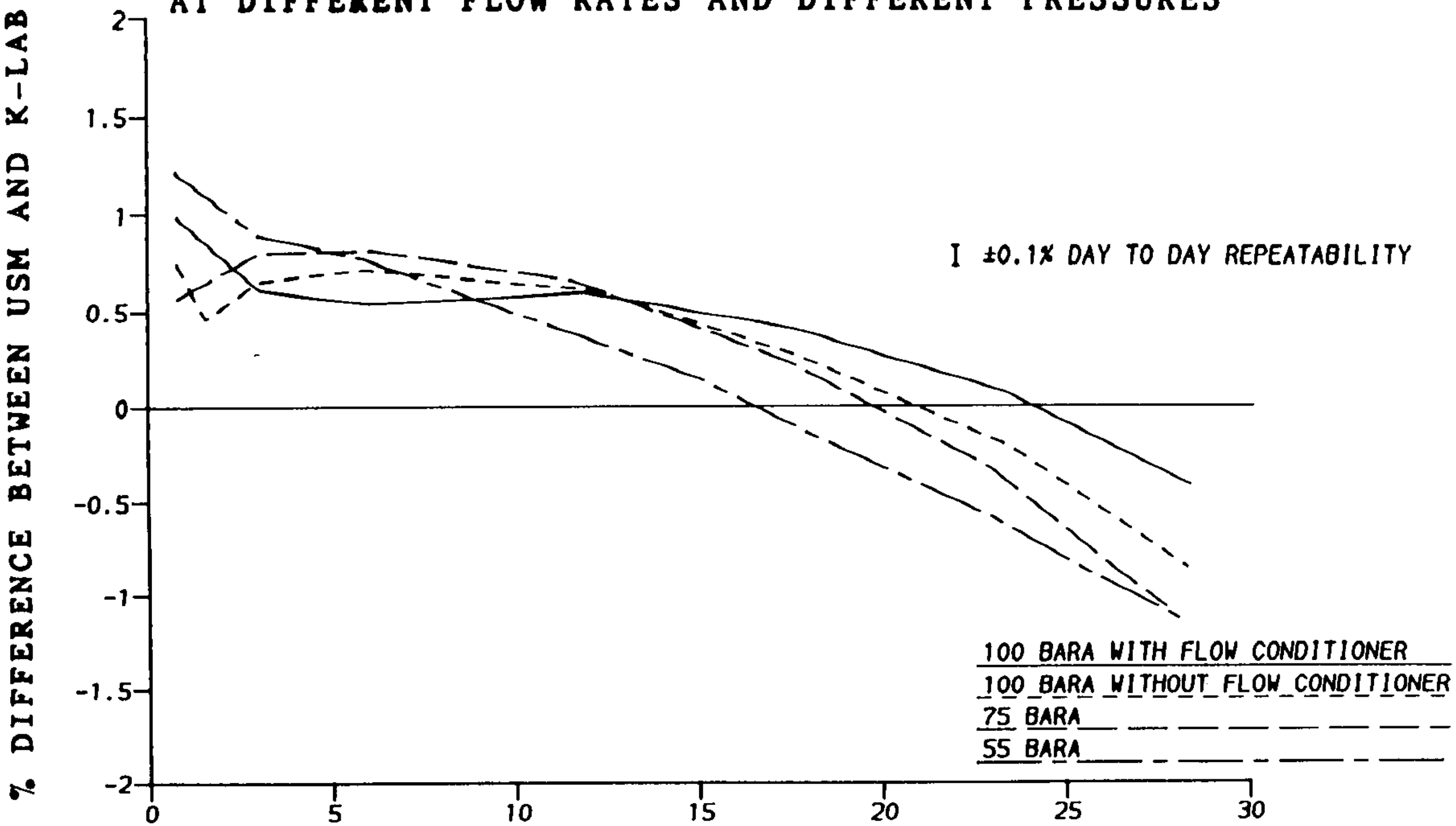


FIG.1
300mm METER IN FULLY DEVELOPED FLOW

FIG.2
COMPARISON BETWEEN USM AND K-LAB
AT DIFFERENT FLOW RATES AND DIFFERENT PRESSURES



DANIEL

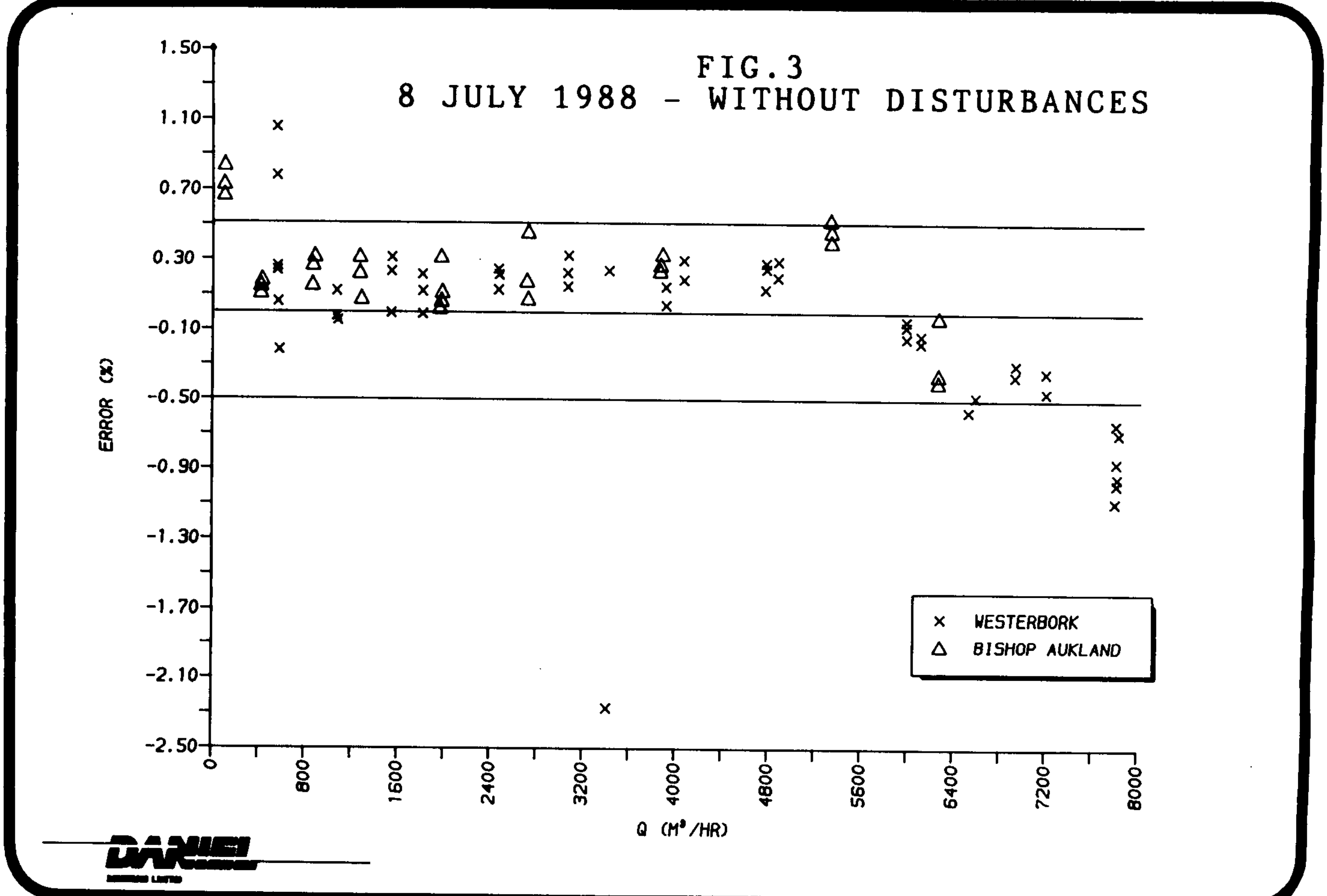
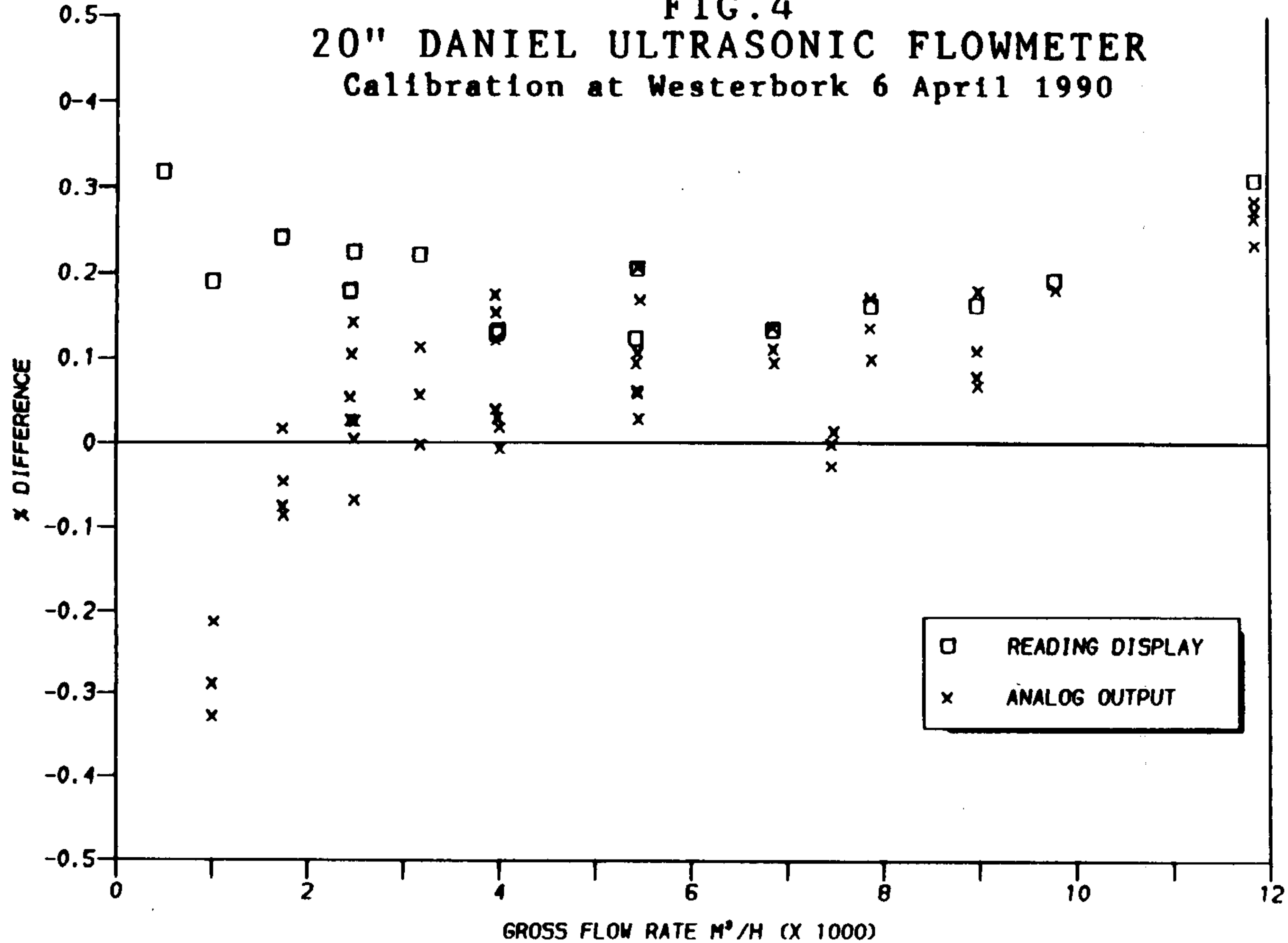


FIG.3
8 JULY 1988 - WITHOUT DISTURBANCES
1.50
1.10
0.70
0.30
-0.10
-0.50
-0.90
-1.30
-1.70
-2.10
-2.50
ERROR (%)
0
800
1600
2400
3200
4000
4800
5600
6400
7200
8000
Q (M³/HR)
WESTERBORK
BISHOP AUKLAND

FIG.4
20" DANIEL ULTRASONIC FLOWMETER
Calibration at Westerbork 6 April 1990



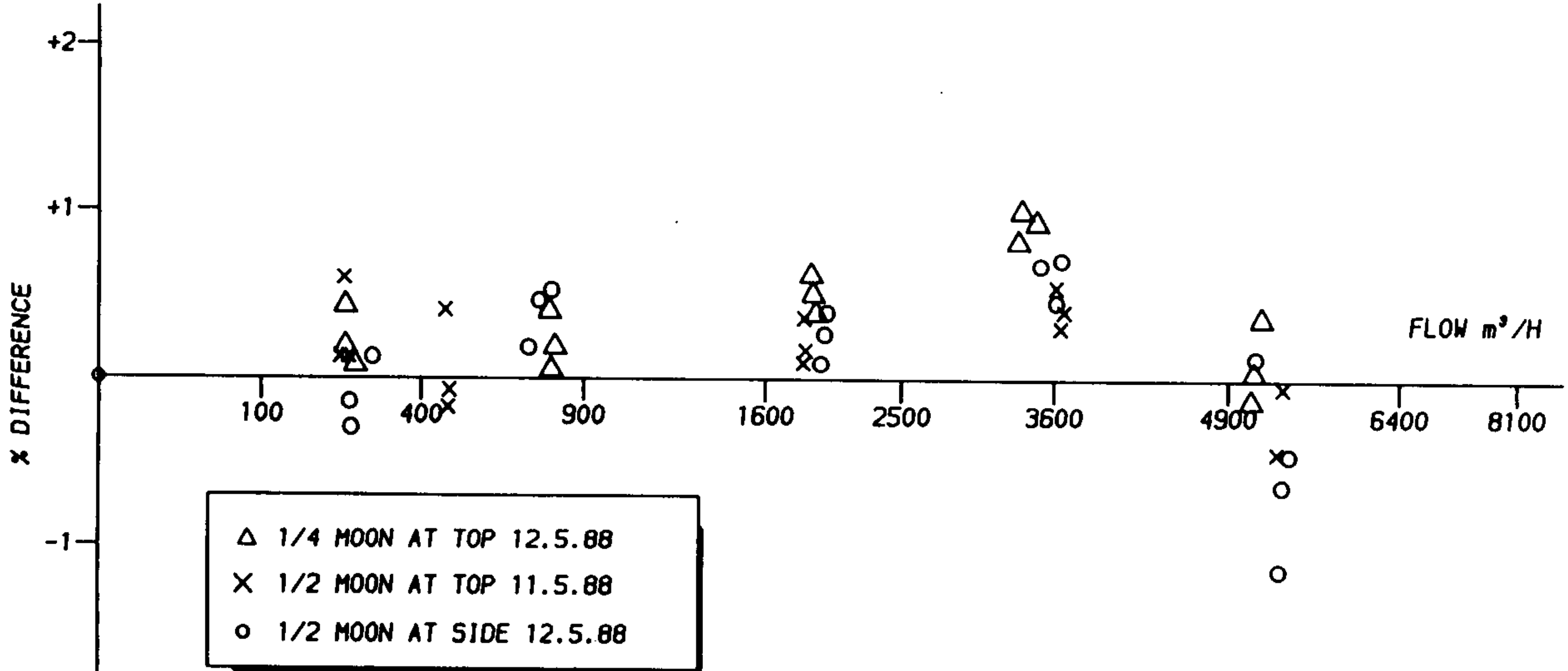


FIG.5

RESULTS WITH DISTURBANCES
10D UPSTREAM
AT BRITISH GAS TEST SITE

DANIEL

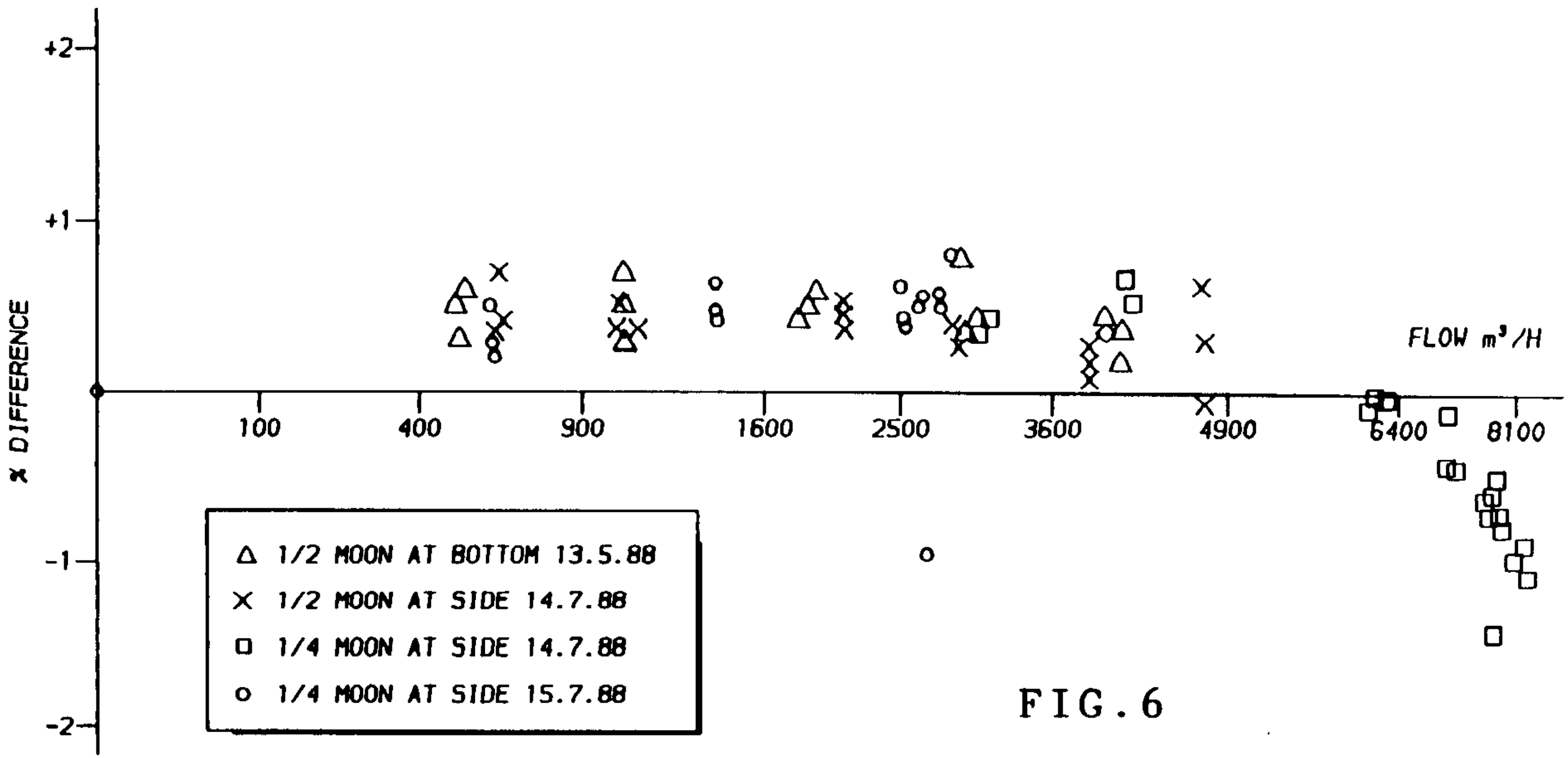


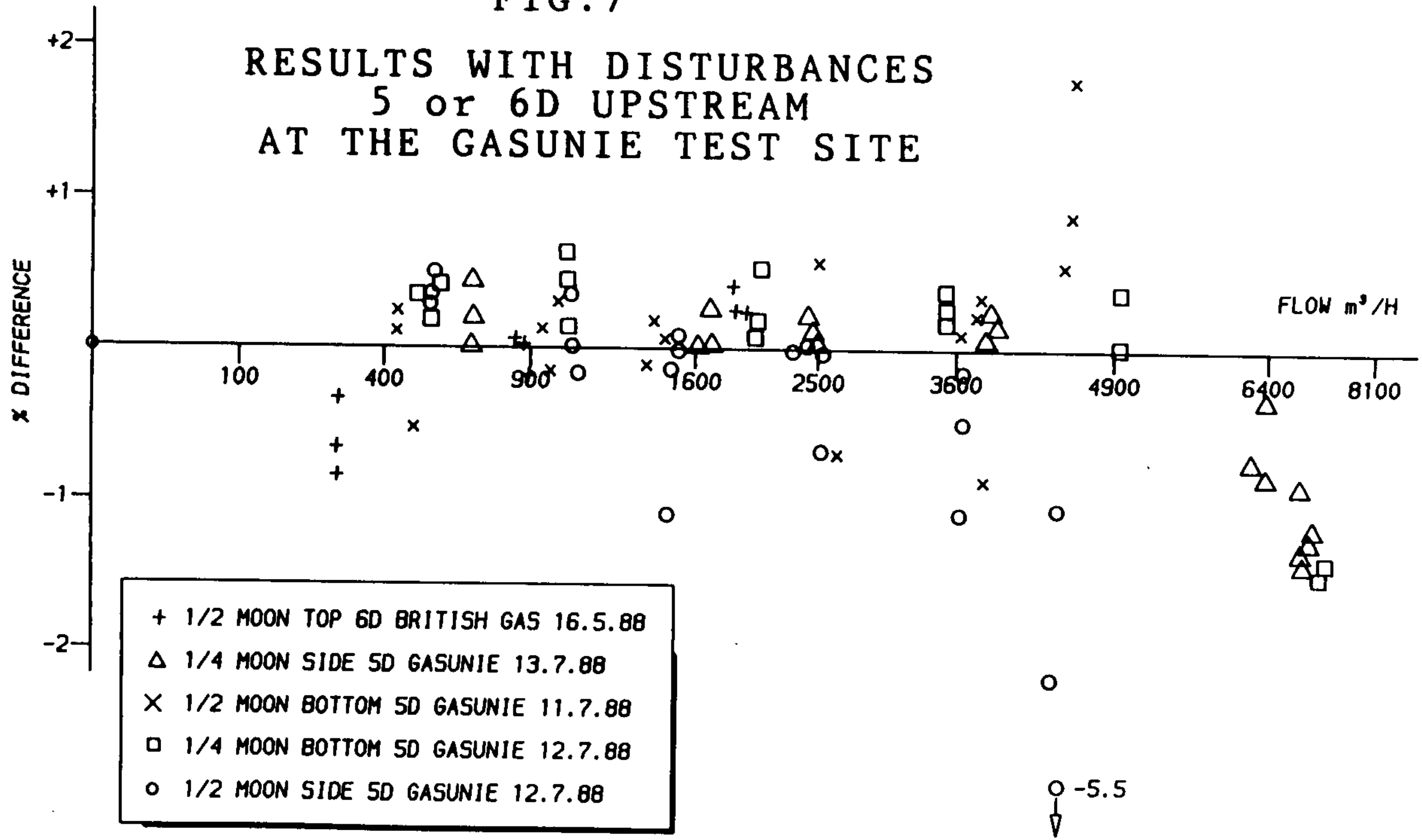
FIG.6

RESULTS WITH DISTURBANCES
10D UPSTREAM
AT THE GASUNIE TEST SITE

DANIEL

FIG.7

RESULTS WITH DISTURBANCES
5 or 6D UPSTREAM
AT THE GASUNIE TEST SITE



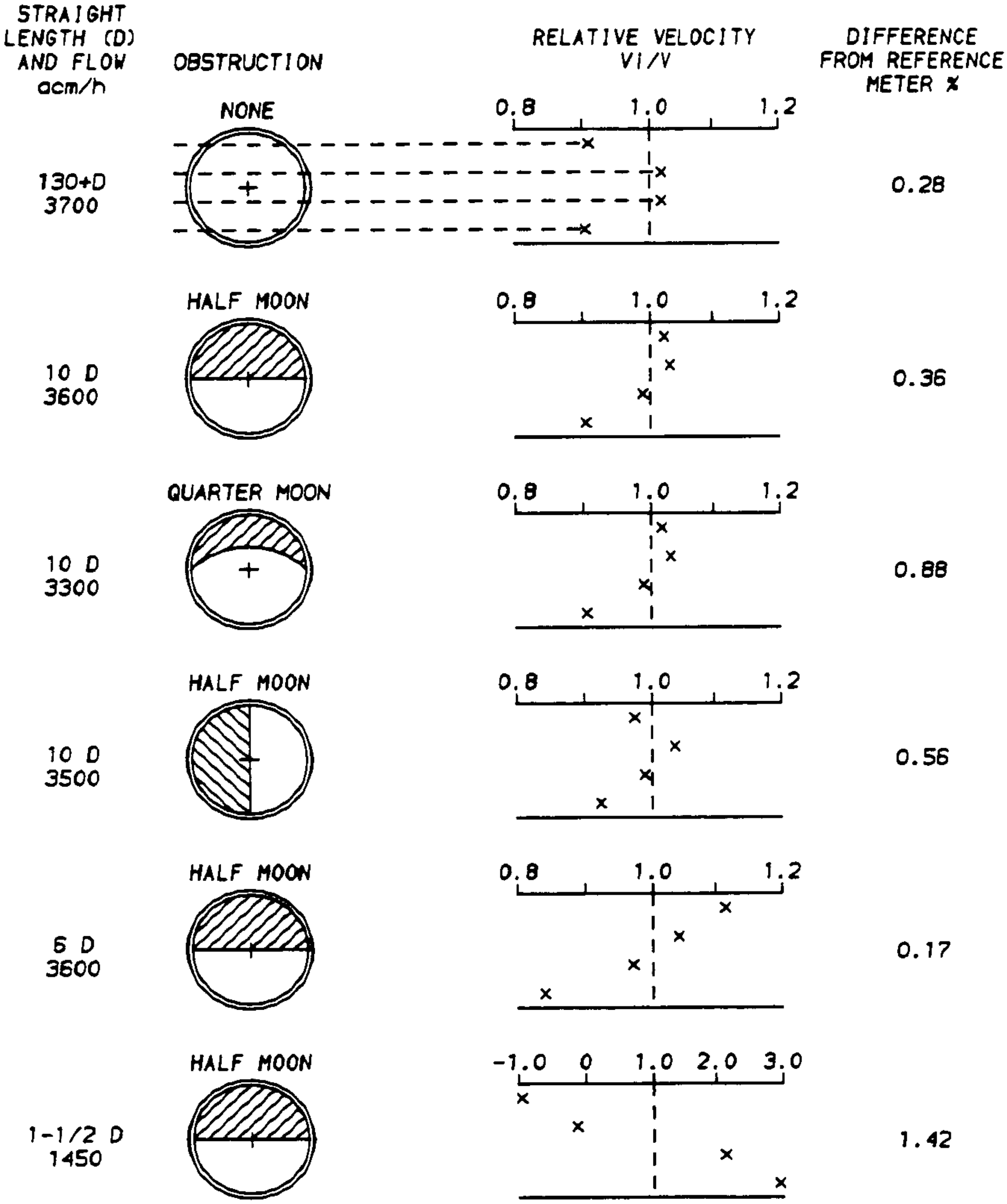


FIG.8
PLOTS OF MEASURED VELOCITY RATIOS

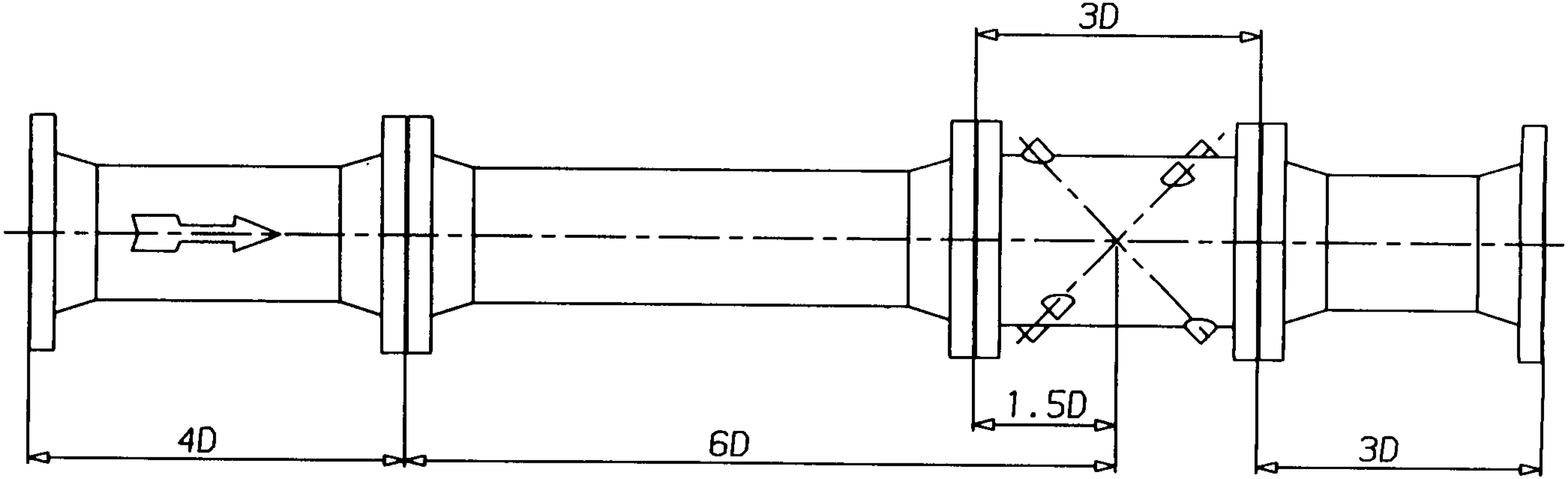


FIG 9.
LAYOUT OF METERING SECTION
SHOWING LOCATION OF FLOW
DISTURBANCE PLATES
FOR BRITISH GAS & GASUNIE TESTS

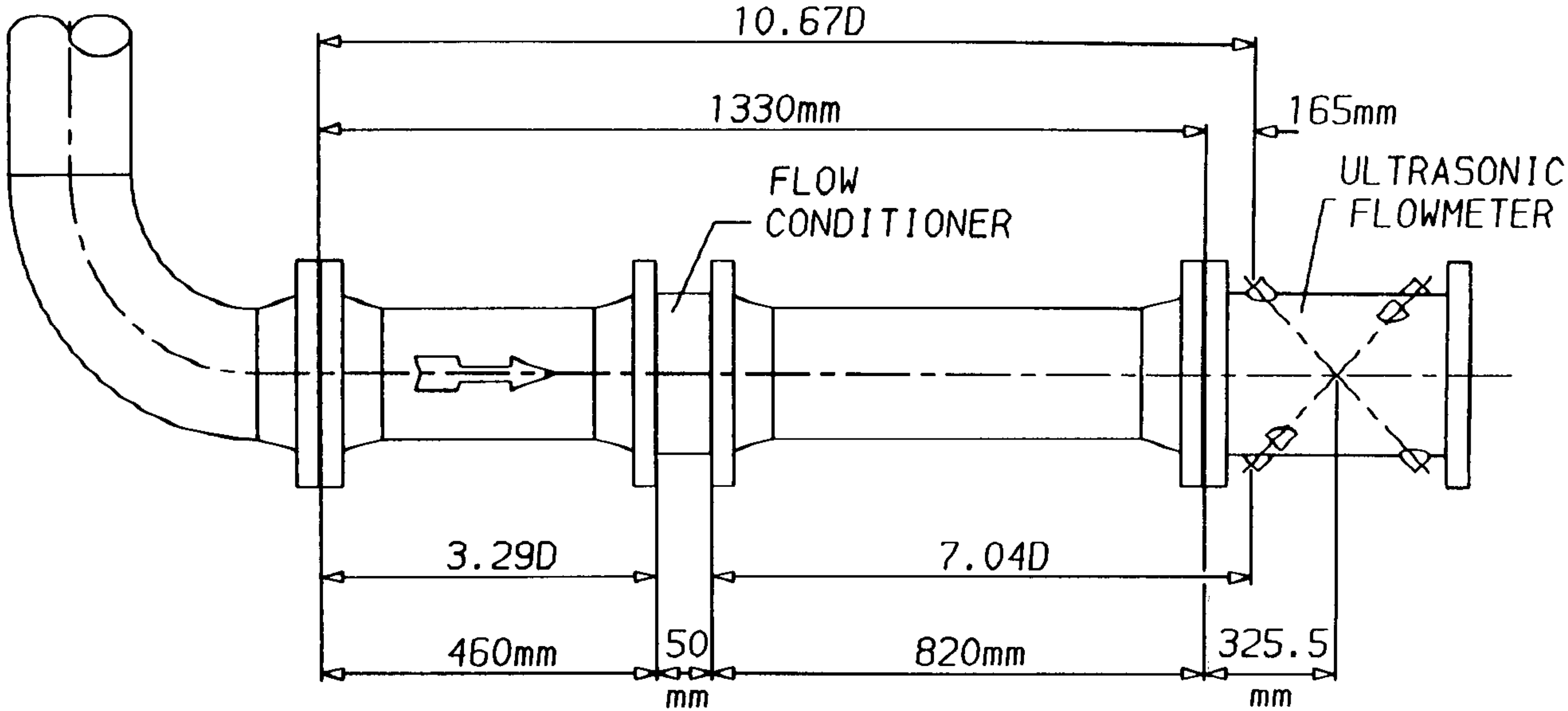


FIG 10.
PIPING CONFIGURATION FOR
K-LAB TESTS

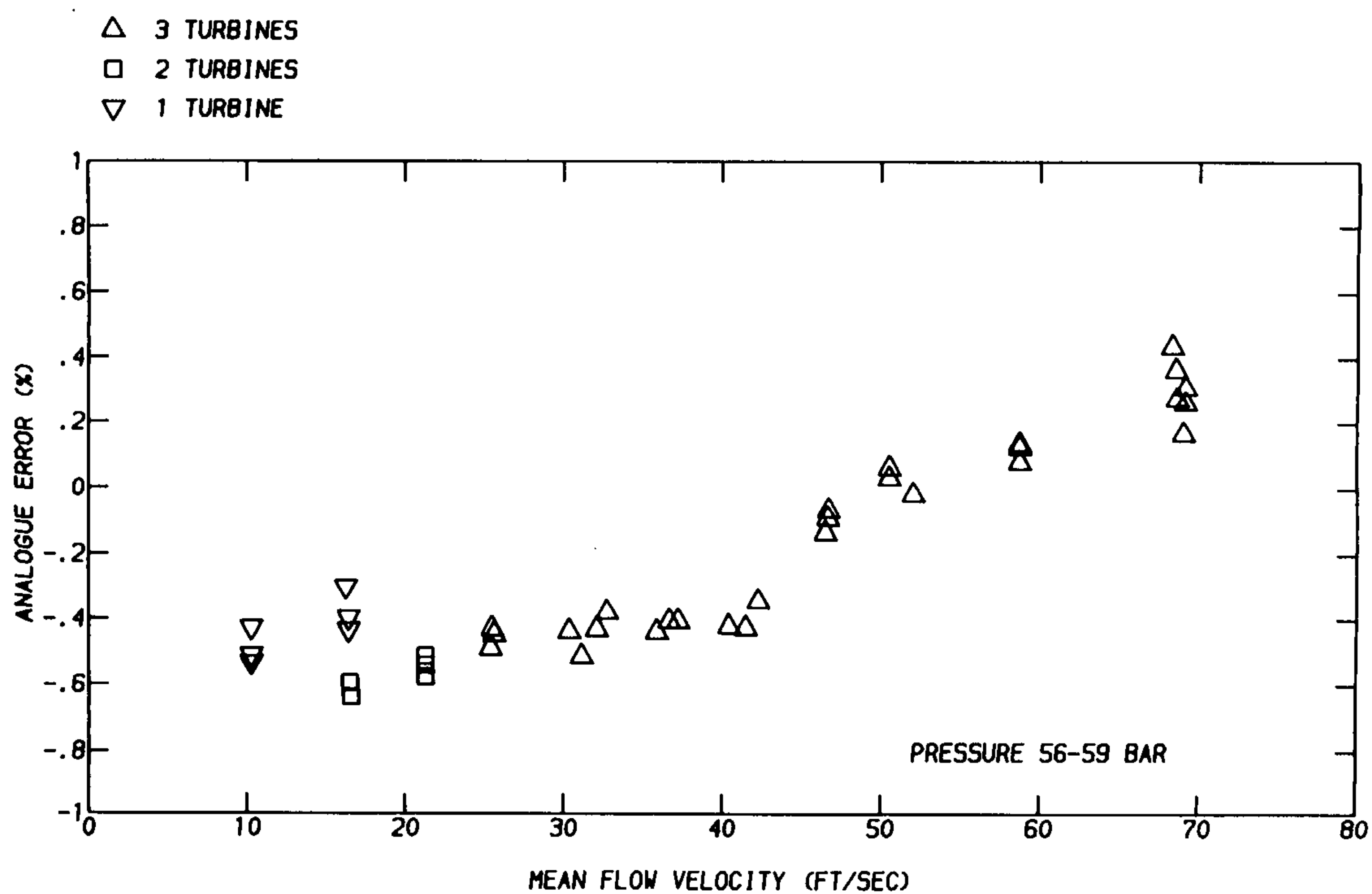


FIG.11
300mm METER IN SWIRLING FLOW

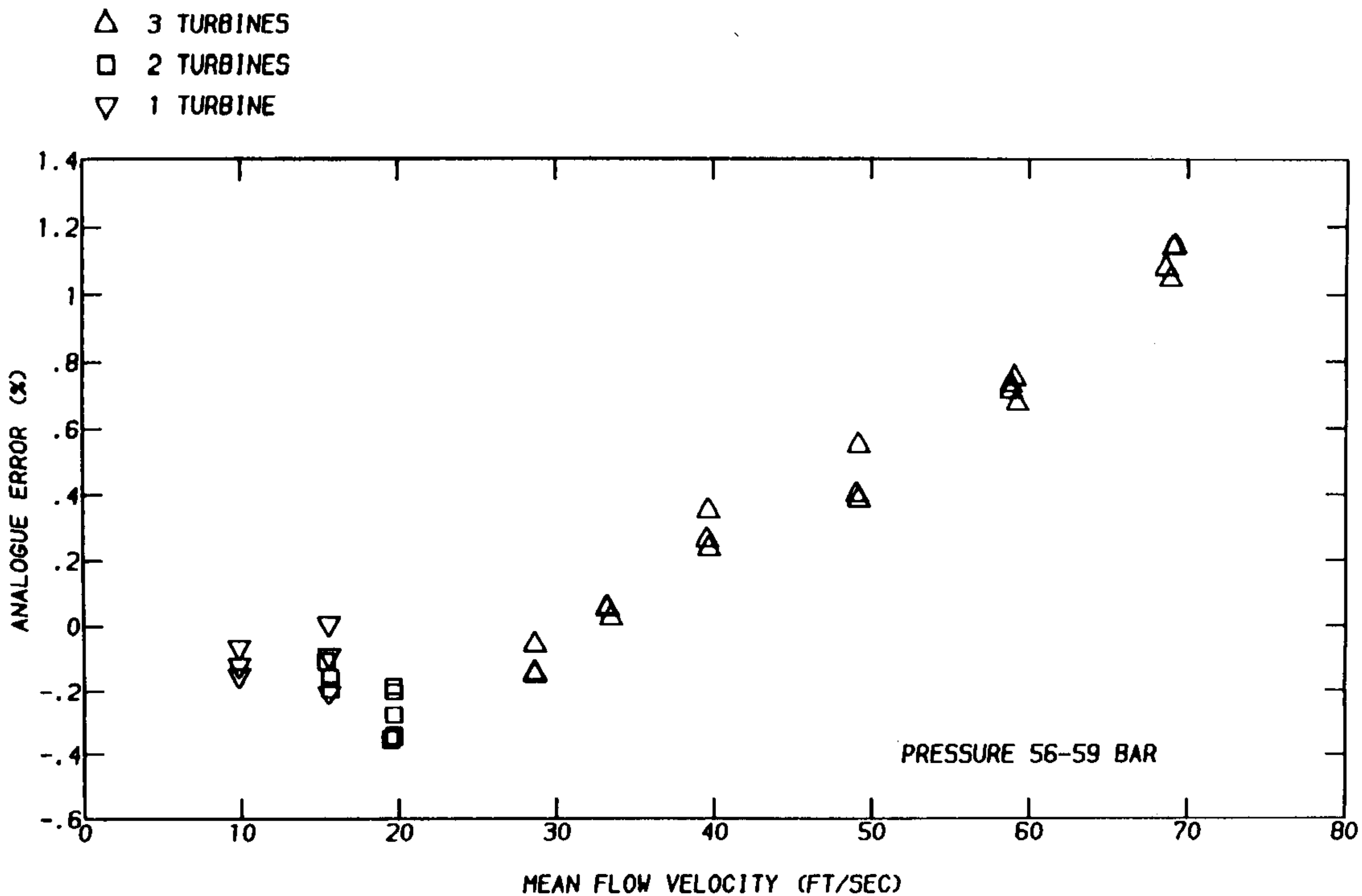


FIG.12
300mm METER ROTATED 90°
IN SWIRLING FLOW

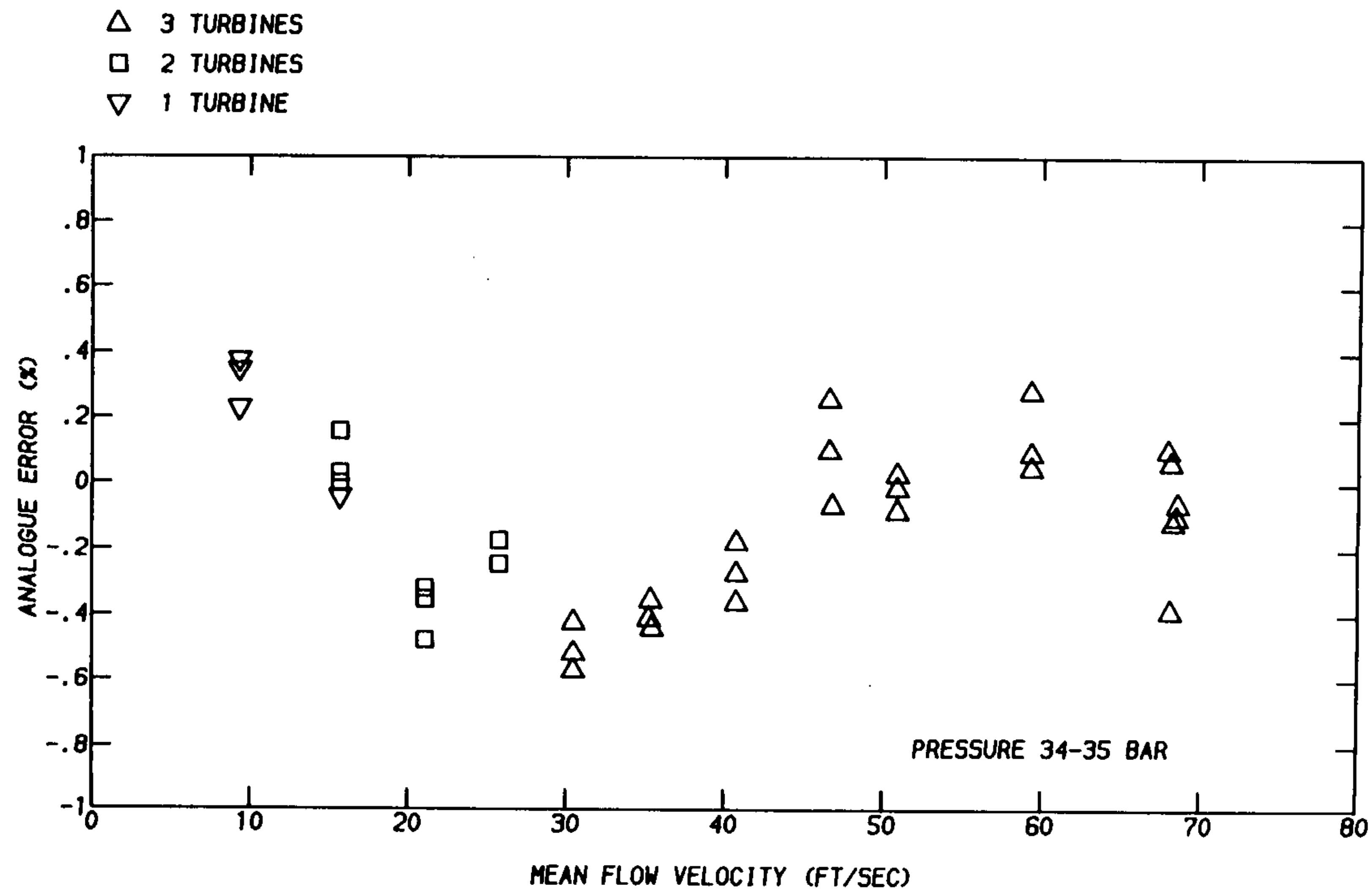


FIG.13
300mm METER IN SWIRLING FLOW