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Performance of the Brooks Compact prover on air

by

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1 INTRODUCTION

The Brooks Compact prover is the first of the small volume proving devices to be marketed in the UK and, as part of the research programme of the Metrology and Standards Requirements Board, an evaluation of this prover type was carried out using the NEL oil flow measurement facilities in the first half of 1984.

During these evaluation tests in oil, which are reported elsewhere, the use of the prover in air was discussed. It seemed that the principle of operation of the prover could, in theory, be applied to any fluid, since the proving by the positive displacement of a volume of fluid by a piston in a cylinder would depend basically on the maintenance of a seal between the moving piston and the cylinder wall, which would both prevent leakage and allow smooth travel of the piston during the proving run.

Brooks Instrument therefore decided to fund a pilot series of tests to examine the behaviour of the Compact prover in low pressure air (ie up to 7 bar) and these tests were carried out on completion of the prover evaluation on oil. The results of these low pressure air tests were encouraging and showed the prover to be capable of operation on gas. Consequently Brooks Instrument funded a second series of tests on the Compact prover to investigate its performance with air at pressures up to 60 bar and this test programme has recently begun at NEL.

This paper first considers the special problems associated with the use of the prover on air and then outlines the test programmes adopted and describes the test circuits used. The results to date are then presented and discussed and the papers ends with conclusions about the potential of the Compact prover for use on high pressure gas service.

2 BROOKS COMPACT PROVER IN AIR

The schematic diagram of the Brooks Compact prover given in Fig. 1 shows the prover in the return mode with the poppet valve open and the piston being drawn upstream by the hydraulic fluid which is pumped from a reservoir into the actuator cylinder. When the flag on the position detector rod triggers the standby switch, ie the switch furthest upstream, the piston is held at this position by the hydraulic pressure which also holds the poppet valve open allowing the flow to continue uninterrupted through the prover. When the prover is set to run the hydraulic vent valve is opened dumping the hydraulic oil to the reservoir, hence allowing pressurised nitrogen to close the poppet valve and assist the piston to move with the flowing fluid. As the flag on the piston detector rod passes through the switches defining the proving volume a timer in the prover controller/computer is started and stopped. The Compact prover uses the double chronometry method of pulse interpolation and therefore a second timer records the time interval between the detection of the first pulse from the meter under test following the triggering of the first prover volume switch and the detection of the first pulse from the meter under test after the second prover volume switch has been actuated. During this second time interval the pulse output from the meter under test is totalised. The proving pass is now completed and the hydraulic vent valve is closed allowing the hydraulic fluid to be pumped into the actuator cylinder to open the poppet valve and retract the piston to the standby position in readiness for the next pass. The required number of passes is fed into the prover computer which then automatically controls the running of the prover and calculates the results.

However, when the prover is to be used with air its data collection system is inadequate because air is a compressible fluid and consequently it is necessary to measure the pressure and temperature of the air in the prover and at the meter under test while the proving volume is being displaced so that the proving volume can be adjusted to the conditions at the meter under test.

The operation of a prover which was designed for liquid service on a gas such as air might well be adversely affected by for example the lack of lubrication between the piston seals and the cylinder wall causing erratic motion of the piston and/or by leakage across the piston and poppet valve seals. However, an advantage of the Compact prover is that it should be possible to solve the problem of any seal leakage by setting the pressure in the nitrogen plenum so that the differential pressure across the piston is close to zero while it displaces the proving volume.

3 TEST PROGRAMMES

3.1 Low Pressure Tests

Initial tests at low pressure highlighted the problem of juddering motion of the prover piston at low velocity and as a result the original test programme was revised to exclude static leak tests on the piston seals and piston velocity variation measurements using a laser interferometer. The revised test programme covered the assessment of the onset of piston judder at different line pressures, the variation in piston differential pressure with nitrogen pressure and the dynamic calibration of NEL secondary standard flowmeters against the prover at different line and nitrogen pressures.

3.2 High Pressure Tests

The programme for the high pressure tests was designed to investigate more fully those aspects of the prover's performance which were highlighted during the initial tests and to try to specify the limits within which the prover could be used with confidence on gas. Thus the determination of the minimum velocity at which smooth piston travel would occur was to be extended up to line pressures of 60 bar, the influences on the setting of the nitrogen plenum pressure to give zero piston differential pressure were to be studied and the uncertainty and repeatability associated with the calibration of a flowmeter against the Compact prover were to be assessed.

4 TEST CIRCUITS

4.1 Low Pressure Tests

This test circuit is shown diagrammatically in Fig. 2. The air supply to the test rig could supply 500 l/s free air at a maximum line pressure of 7 bar. The prover investigated was a standard 12-inch model with a maximum flowrate and turndown ratio of 110 l/s and 1000:1 respectively. Two rotary positive displacement meters were used as reference meters; one of 3-inch size with a flowrate range of 9-55 l/s and a nominal meter factor of 6 pulse/l and the other of 6-inch size with a flowrate range of 30-250 l/s and a nominal meter factor of 1.5 pulse/l.

The barometric pressure, the piston differential pressure and the air pressures in the prover and at the meter under test were measured using precalibrated transducers and the air temperatures in the prover and in the meter under test were measured using platinum resistance thermometers which were also calibrated prior to the commencement of the test programme.

The test data, including those from the prover controller/computer, were all logged by a data collection system based on a Hewlett-Packard HP85 computer which also calculated the test results.

4.2 High Pressure Tests

For the high pressure tests the prover was installed in the test line of the NEL high pressure primary flow facility, shown schematically in Fig. 3, upstream of the reference meter which is a 6-inch turbine meter with a flowrate range of 9 to 180 l/s and a nominal meter factor of 1.344 pulse/l. The turbine meter was calibrated before the start of these tests against critical flow venturi nozzles which have calibration characteristics directly traceable to the primary gravimetric system.

The data logging system used in these tests is the same one used for the low pressure tests and as before all the pressure transducers and platinum resistance thermometers were calibrated before the test programme was begun.

5 TEST RESULTS

5.1 Low Pressure Test Results

The results of the tests to investigate the onset of piston judder are presented in the plot of minimum judder-free prover flowrate against prover line pressure given in Fig. 4.

Fig. 5 gives the results of the tests where the nitrogen plenum pressure was varied in the form of plots of piston differential pressure against nitrogen pressure.

A great many tests were carried out where the prover was used as the calibrator and the results are too numerous to present in this paper. The tests of most interest and value were those carried out on the 6-inch N3 meter with the nitrogen plenum pressure set to give piston differential pressures close to zero and the results of these tests, at different prover line pressures, are presented in Fig. 6 as a plot of meter factor against volume flowrate.

5.2 High Pressure Test Results

Since these tests are still in progress the results presented and discussed here must clearly be considered to be of a provisional nature.

The results from the tests to determine the minimum judder-free piston velocity over a range of prover pressures are presented in Fig. 7 in the form of a plot of minimum judder-free prover flowrate against prover line pressure.

In these tests to determine the minimum judder-free piston velocity the nitrogen plenum pressure was set to give piston differential pressures close to zero and Fig. 8 plots the nitrogen pressure for zero piston differential against prover line pressure.

Testing the prover as the calibrator has just commenced and therefore it is not possible as yet to compare the NEL calibration for the turbine meter with results obtained against the prover. Nevertheless some interesting data have been obtained and these show that the nitrogen plenum pressure for zero piston differential varies with prover flowrate for a given prover line pressure. These data are shown plotted in Fig. 9.

6 DISCUSSION

The results of the initial tests on low pressure air highlighted a number of aspects of prover performance which were significantly affected by the change from liquid to gas service.

The juddering motion of the piston which became apparent early in the test programme seriously restricted the rangeability of the prover but as shown by Fig. 4 the minimum judder-free prover flowrate appeared to be dependent on line pressure. The results from the current tests, given in Fig. 7, confirm that the minimum judder-free prover flowrate is dependent on line pressure but more importantly show that at pressures of 20 bar or greater the minimum smooth flowrate attained can be close to the lower limit of 0.11 l/s specified for liquid service. Fig. 8 shows that, as well as being dependent on the prover line pressure, the minimum judder-free flowrate is affected by the nitrogen plenum pressure. It is therefore clear that on gas service the nitrogen plenum pressure is an extremely important variable and that further investigation of its effect on prover performance is vital.

The results from the tests on the prover at low pressure showed that leakage past the piston/poppet valve seals occurred when the piston differential pressure was much greater than zero. Tests were therefore carried out to determine how the piston differential varied with nitrogen plenum pressure and the results presented in Fig. 5 showed that the piston differential varied linearly with nitrogen pressure and that the nitrogen pressure for zero piston differential varied with line pressure but not as predicted in the manufacturer's literature. The latest results, given in Figs 8 and 9, also show that the nitrogen pressure for zero piston differential varies with line pressure but additionally, that the prover flowrate has an effect on the nitrogen pressure required to give zero piston differential. These results again stress the important part that the nitrogen plenum pressure plays in the behaviour of the prover on gas.

The results from the tests on the N3 meter, with prover line pressures in the range 1 to 7 bar and piston differential pressures close to zero, which are presented in Fig. 6 show that in general the calibration data obtained against the prover agree with the NEL calibration data to within 1 per cent. The agreement between the two calibrations is much better than 1 per cent at the prover pressures and flowrates at which the piston differentials were closest to zero.

The repeatability of the test data was very good on most occasions with spreads of less than or equal to 0.25 per cent within a single test run. This figure should be able to be improved if meters of higher resolution are used. When the prover piston was moving smoothly over the proving length the repeatability from test run to test run was also good.

Operation of the prover at higher speeds caused no major problems but the maximum flowrate with gas might be limited by the speed of data collection rather than by any limit on prover piston speed.

7 CONCLUSIONS

A Brooks Instrument 12-inch Compact prover has been tested on low pressure air and its performance is currently being investigated on high pressure air at NEL.

The results to date are most encouraging and show that the prover has considerable potential for operation on gas especially at higher pressures where indications are that its turndown ratio may well be in excess of 100:1. However the prover's behaviour on gas is much more complex than on liquids and this is particularly the case in the setting of the nitrogen plenum pressure because of the effect this pressure has been shown to have on both the rangeability of the prover and on leakage across the piston/poppet valve seals. If the Compact prover is to be used with confidence on gas with its existing seals it is most important to have a method of predicting the nitrogen pressure to give zero piston differential and also of determining how closely this pressure must be controlled to keep any seal leakage contribution to the prover uncertainty to a minimum.

Alternatively the piston differential pressure could be set to zero and controlled within defined limits by some automatic system or perhaps the piston seals could be replaced by seals specially designed for gas service.

The repeatability of the results of the tests is good and meter calibrations against the prover have shown reasonable agreement with calibrations obtained against recognised standards. These aspects of its performance are further evidence of the Compact prover's potential for gas service.

LIST OF FIGURES

1 Schematic arrangement of Brooks Compact prover

2 Diagrammatic layout of test rig

3 Simplified diagram of gravimetric gas flow system

4 Minimum judder-free prover flowrate against prover line pressure

5 Piston differential against nitrogen plenum pressure

6 Meter factor against flowrate for N3 meter: prover nitrogen for zero diff

7 Minimum judder-free prover flowrate against prover line pressure

8 Nitrogen press for zero piston diff against prover line pressure

9 Piston differential against nitrogen pressure.

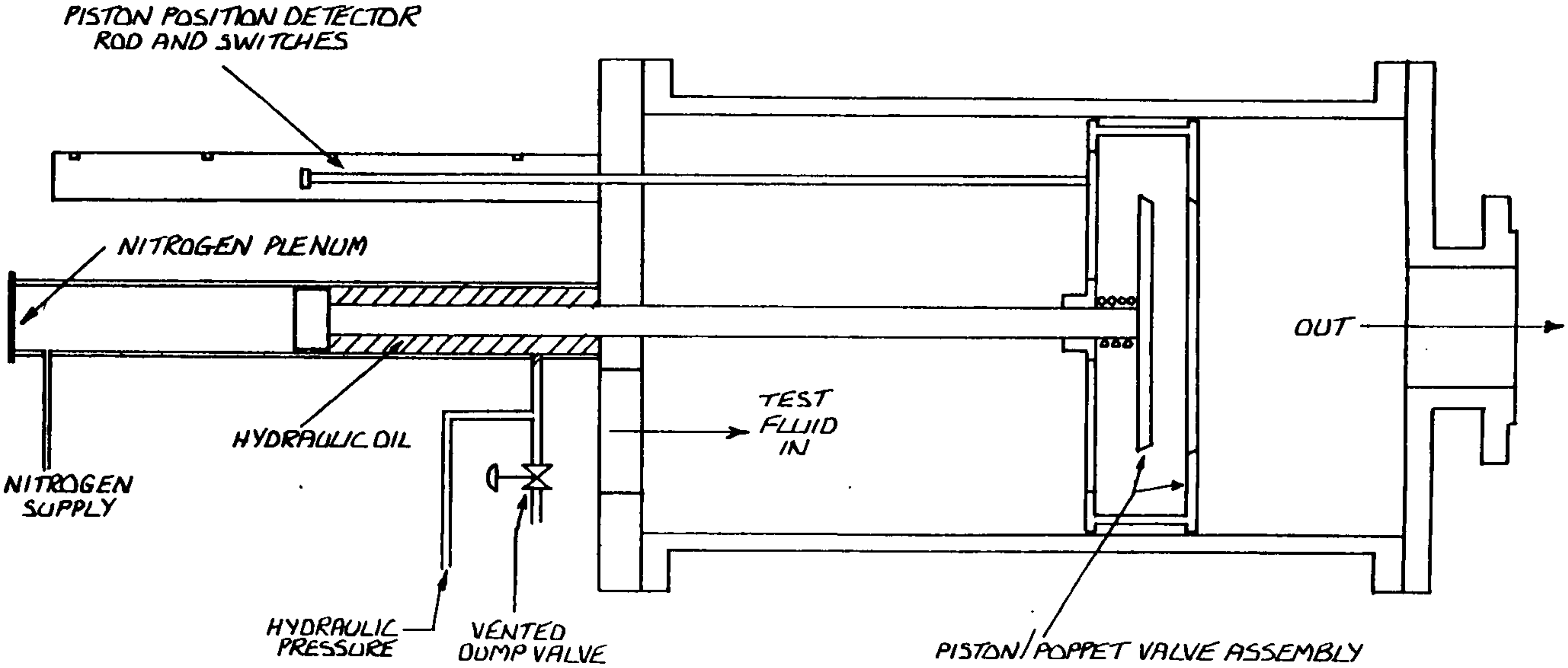

FIG. 1 SCHEMATIC ARRANGEMENT OF BROOKS COMPACT PROVER.

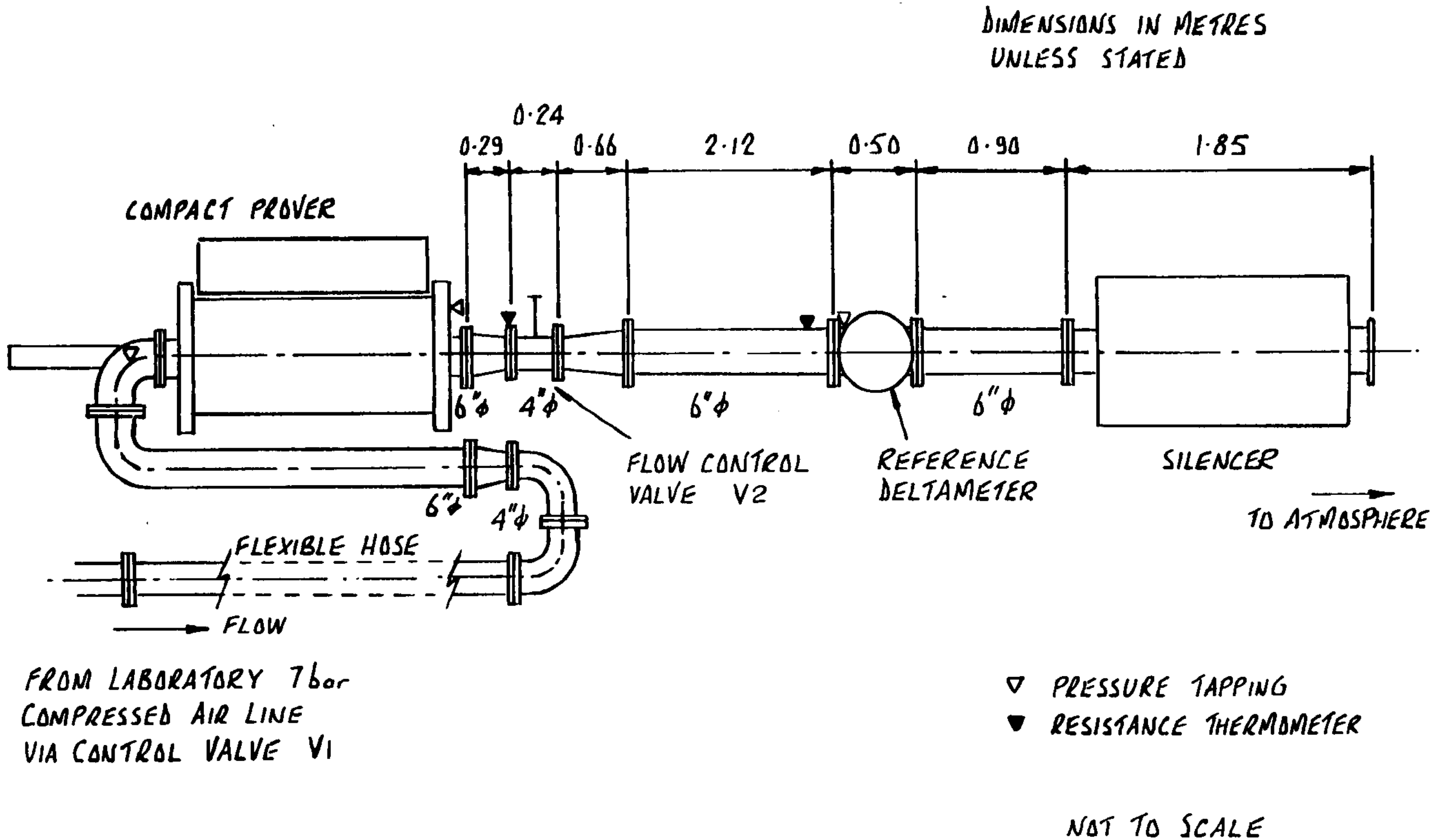

FIG. 2 DIAGRAMMATIC LAYOUT OF TEST RIG

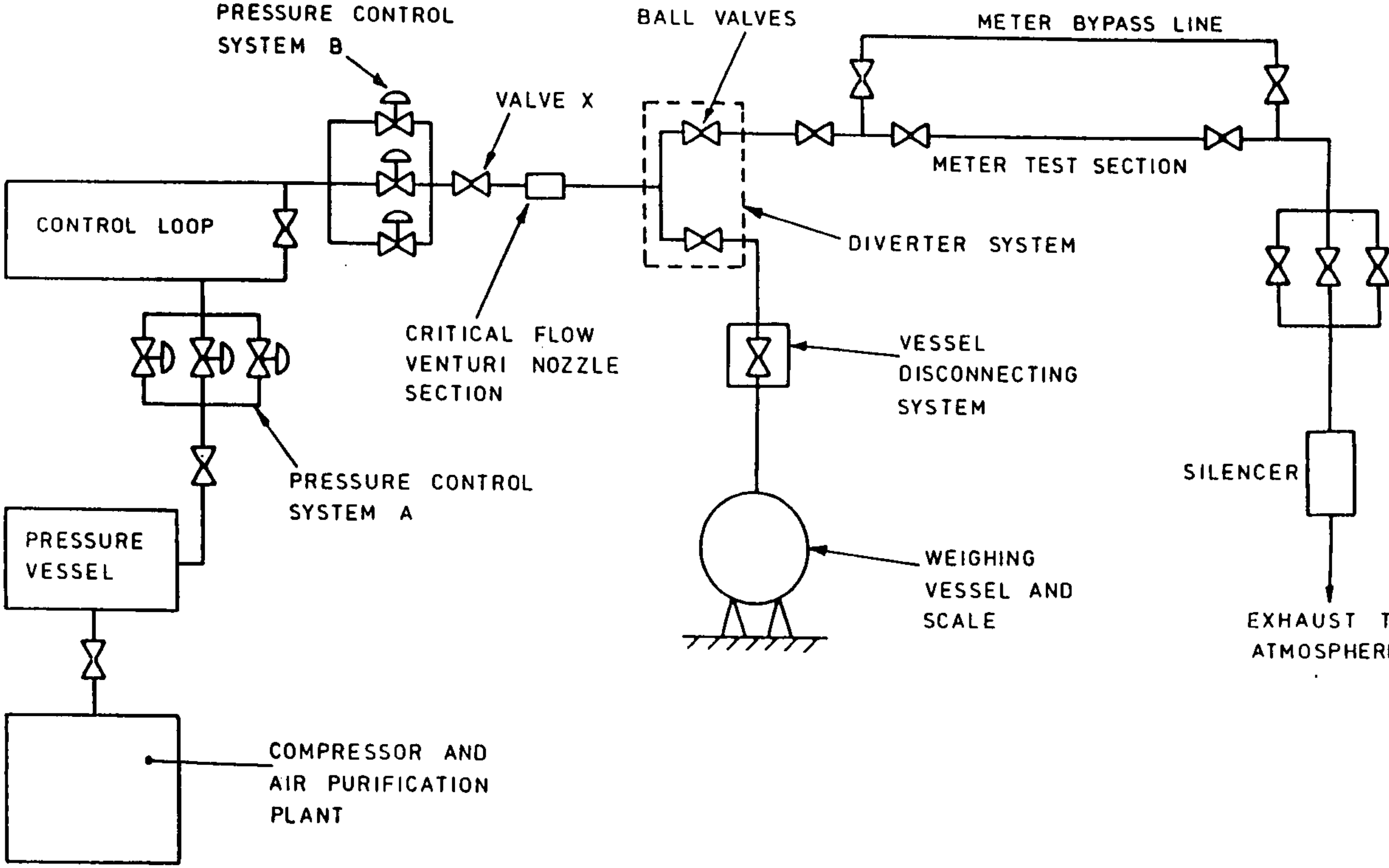

FIG 3 SIMPLIFIED DIAGRAM OF GRAVIMETRIC GAS FLOW SYSTEM

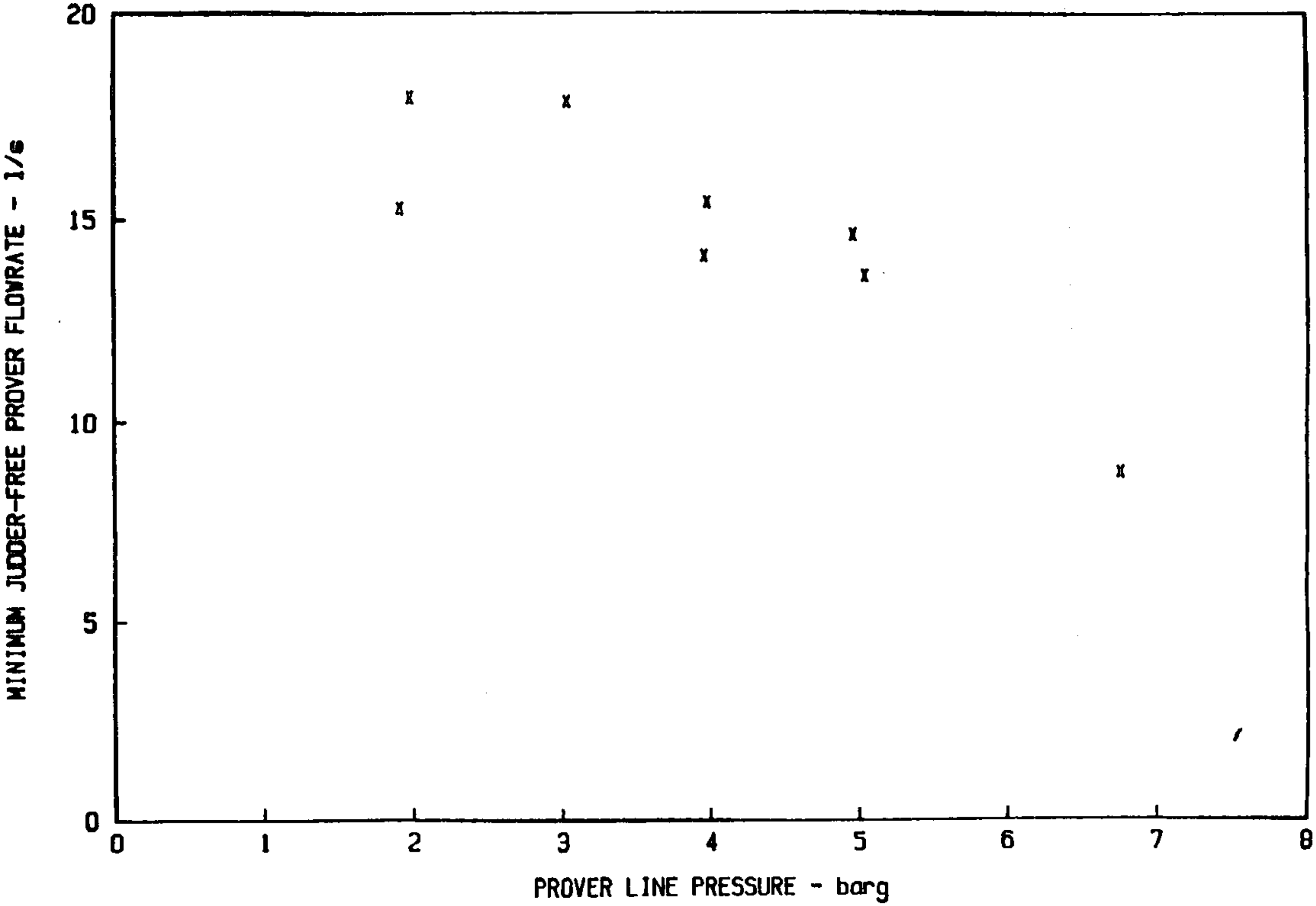

FIG. 4 MINIMUM JUDDER-FREE PROVER FLOWRATE AGAINST PROVER LINE PRESSURE

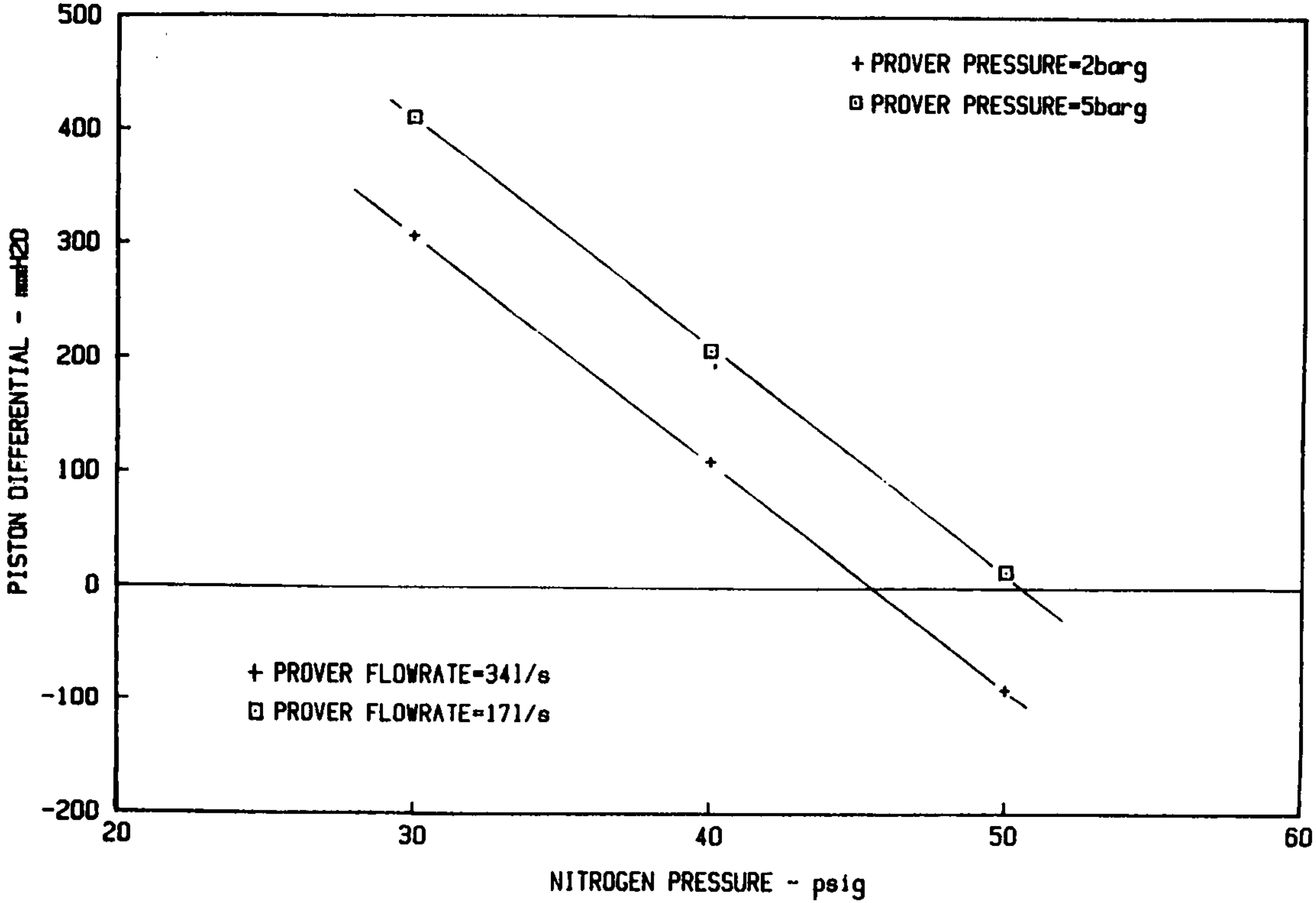

FIG. 5 PISTON DIFFERENTIAL AGAINST NITROGEN PLENUM PRESSURE

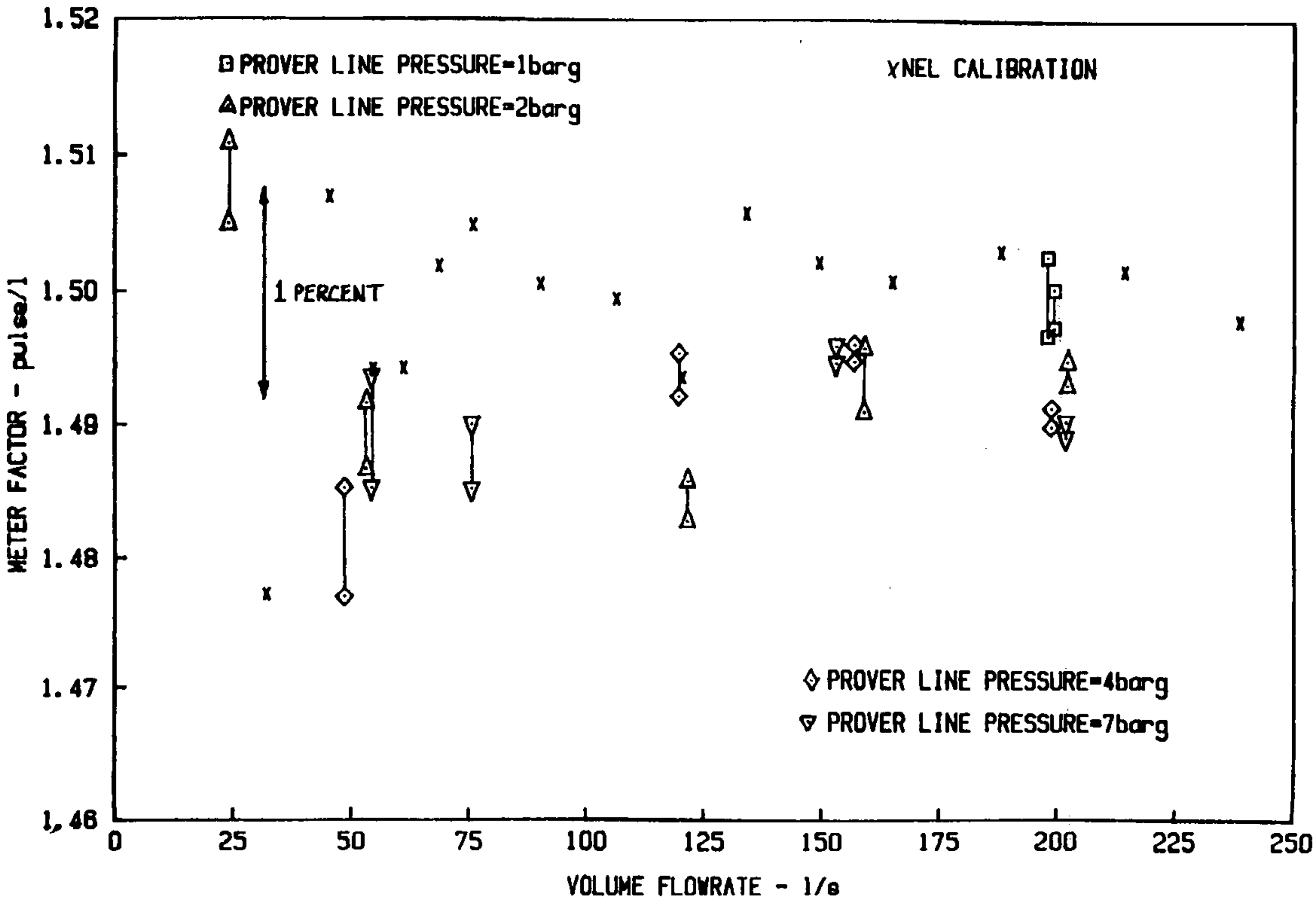

FIG.6 METER FACTOR AGAINST FLOWRATE FOR N3 METER : PROVER NITROGEN FOR ZERO DIFF

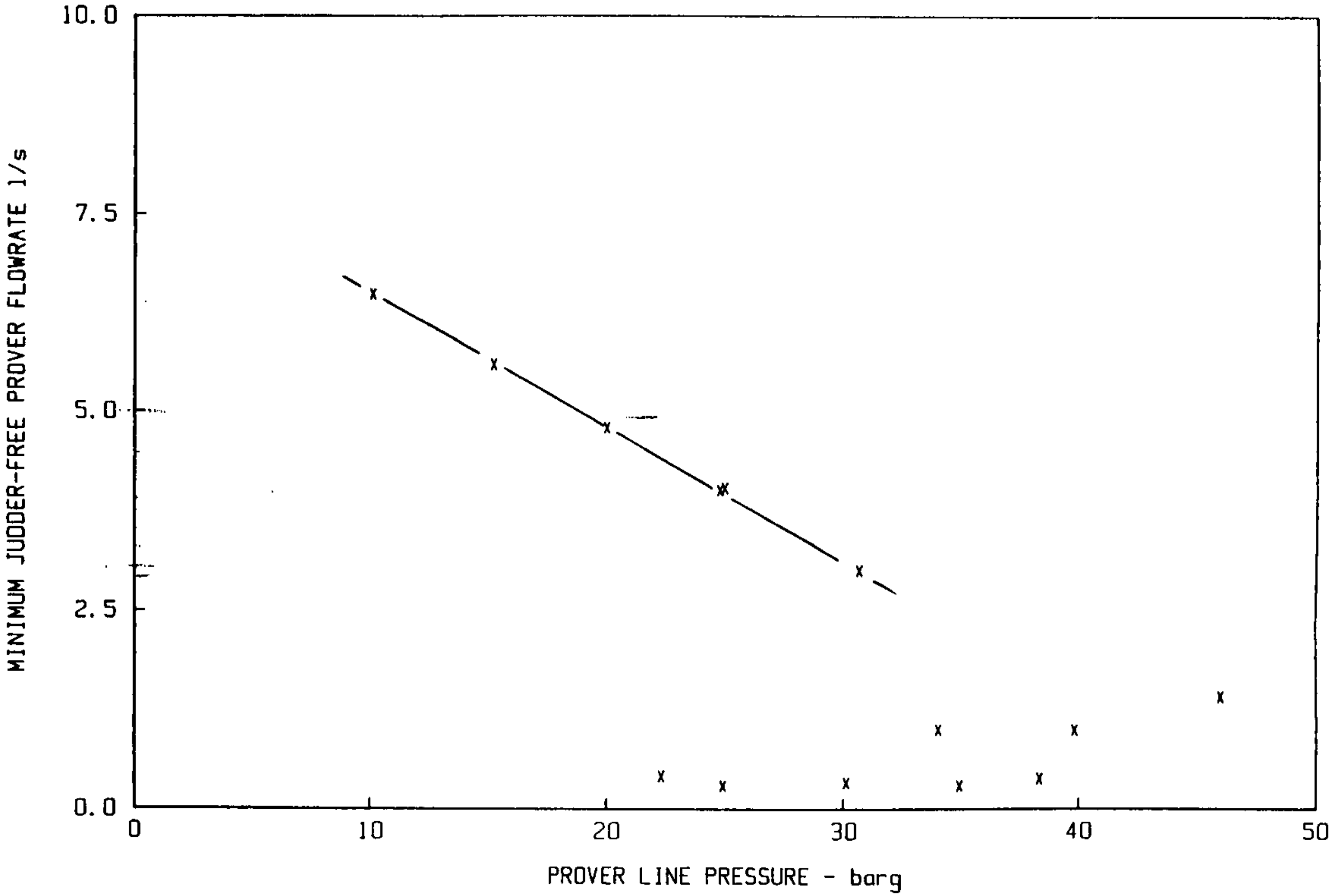

FIG. 7 MINIMUM JUDDER-FREE PROVER FLOWRATE AGAINST PROVER LINE PRESSURE

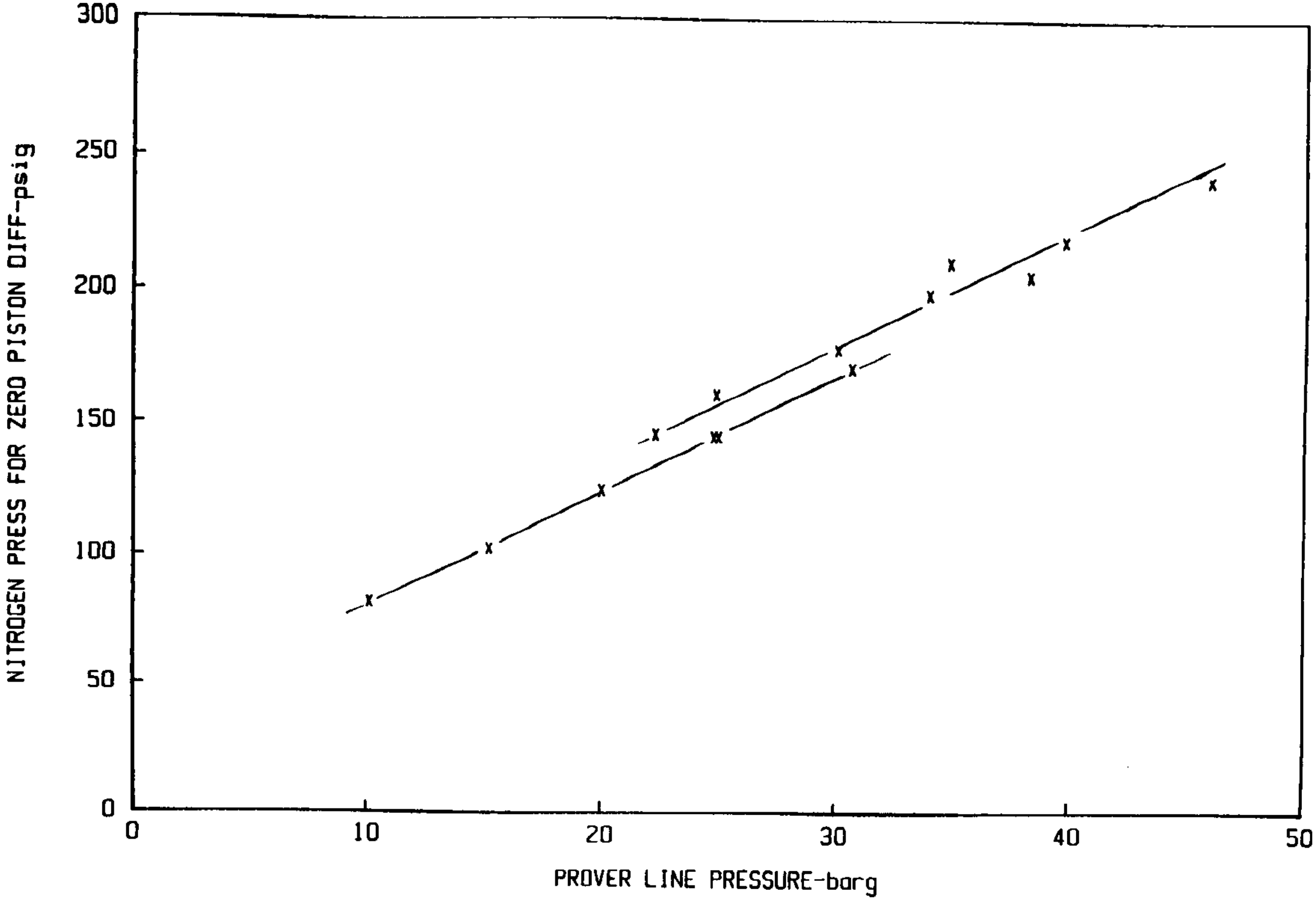

FIG. 8 NITROGEN PRESS FOR ZERO PISTON DIFF AGAINST PROVER LINE PRESSURE

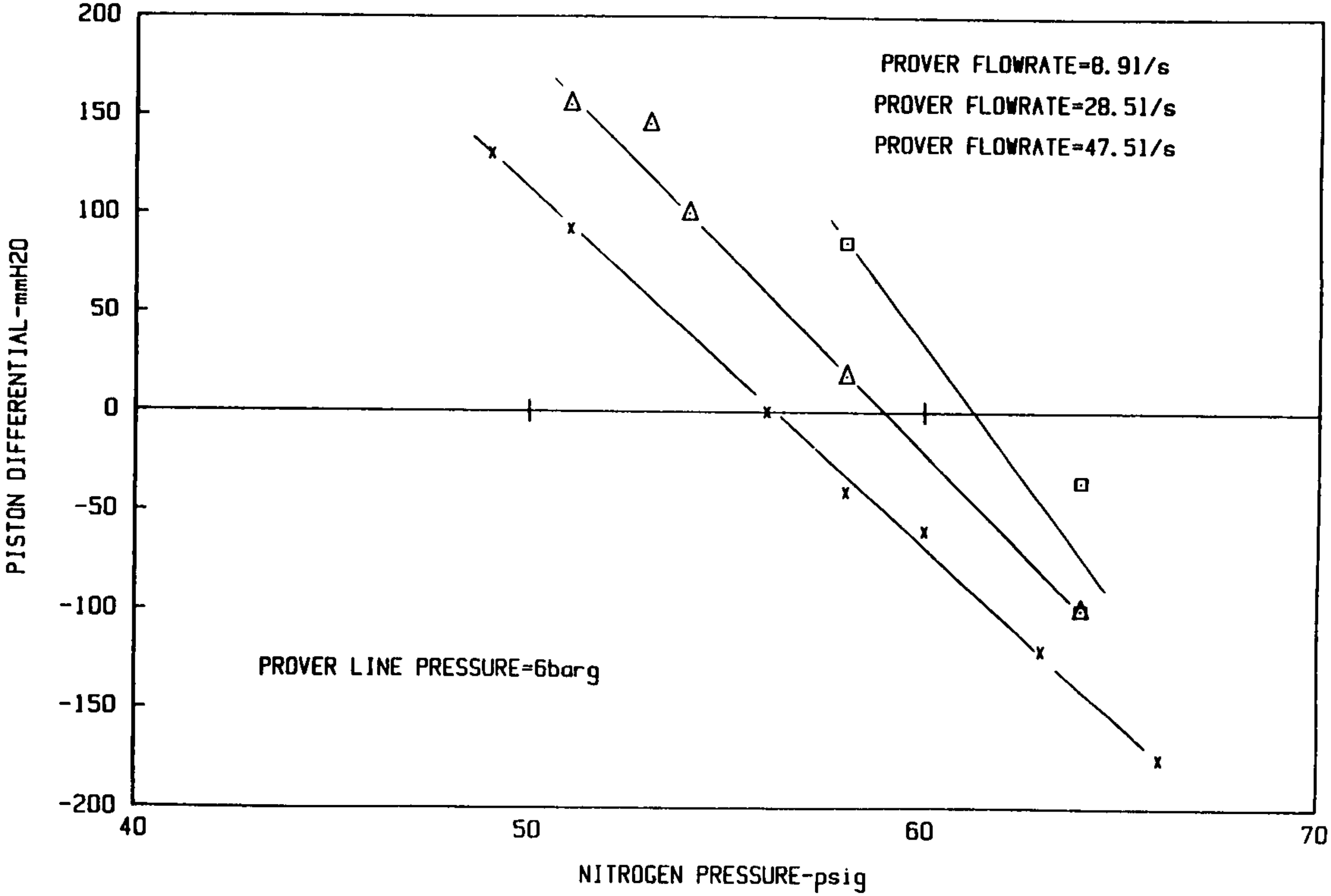

FIG. 9 PISTON DIFFERENTIAL AGAINST NITROGEN PRESSURE

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.