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PROVING LIQUID FLOWMETERS - CONVENTIONAL METHODS

Lecturer: Dr W C Pursley, Section Manager
National Engineering Laboratory

CONTENTS

1 INTRODUCTION

The method of measuring flowrate in a pipeline by timing the passage of a tightly-fitting displacer, which is carried by the flow over a pre-determined distance or volume, has been known and used for many years. The technique originated from the use of cleaning pigs which were found, for given line flowrates, to cover large distances with remarkably repeatable times. From this originated 'measured mile' techniques for measuring flow, which in turn led to the development of dedicated loops separate from the main line, sphere displacers, sophisticated mechanical switches, bi- and uni-directional proving methods, and the generally complex metering stations which are in use throughout the world today.

Until comparatively recently, however, no scientific systematic study of pipe prover performance had been carried out. In 1975 NEL began a programme of work aimed primarily at investigating the potential sources of error in conventional ball provers. This project was co-ordinated by the Institute of Petroleum and was funded by a range of sponsors including meter prover manufacturers, calibration service companies and government (UK and Norwegian) authorities.

The purpose of this lecture is to consider briefly the potential sources of error in conventional pipe provers, to report some of the results of the NEL project and to discuss possible future development of conventional pipe provers.

2 SOURCES OF ERROR

As with all measuring instruments, the errors associated with the use of conventional pipe provers can be divided into two categories - systematic and random.

2.1 Systematic Errors

The main potential sources of systematic error in pipe provers arise from the calibration of the device. The use of a different fluid as the calibration medium, or calibrating at flowrates which are substantially lower than the operating flowrate, can give rise to systematic errors. These however are normally outside the control of the prover operator. Other sources of systematic error arise from the malfunctioning of a switch or from leakage across critical valves. Sphere damage or inadequate sphere inflation may also cause inordinate leakage which will be reflected in a systematic error, although it is likely that in this case the error would include a random component arising from poor repeatability.

In general however, provided reasonable care is taken in the use of the prover the systematic component can be kept to a relatively low level. The results of different investigations show that for a properly designed prover and carefully controlled calibration procedures, the effects of viscosity and small changes in flowrate during calibration are negligibly small.

2.2 Random Errors

The largest source of random error, reflected in the scatter of the measuremen is from the operation of the mechanical detectors in conventional provers and is probably the largest single source of error associated with pipe provers. Other smaller sources are damage to the sphere displacer or incorrect inflation, variations in flowrate during calibration or the malfunctioning of secondary instrumentation such as thermometers. The factors contributing to the random error are considered in the following section.

In common with other measuring instruments, the pipe prover has been found to have both a short and a long-term random error or repeatability. The latter, often referred to as the 'reproducibility', is generally of a value significantly greater than the short term repeatability. This is illustrated in Figs 1 and 2.

3 SOME FACTORS AFFECTING REPEATABILITY

3.1 Effect of Sphere Material

It has been found that the sphere material affects the short-term repeatability rather than the long-term repeatability, with better performance being obtained with the softer materials such as neoprene, rather than harder spheres such as polyurethane.

3.2 Effect of Inflation

At low sphere inflations the repeatability increases, while at high inflations increased sphere wear must be taken into account. In addition at the high inflations, especially for low viscosity liquids such as water, the sphere will tend to move erratically or stop altogether at the lower flowrates.

3.3 Effect of Flowrate

In general the repeatability of the prover appears to be unaffected by variations in flowrate over a range of about 0.07 to 3.0 m/s.

3.4 Effect of Detector Type

Significant variations in performance were found between the different types of detector tested. These variations seemed to derive from the stiffness of the return springs, the switches with 'lighter' springs performing significantly better than those with stiffer springs. It was also found that switches of the 'lever' type performed as well as the best of the 'plunger' type switches.

4 NON-MECHANICAL DETECTORS

In recent years alternatives to the mechanical detector have been under development; the obvious advantages of freedom from mechanical wear and the prospect of improved performance made these devices an attractive proposition. During the NEL project two such techniques were tested. The first was a commercially available detector of the ultrasonic type which could be strapped to the prover wall at any desired position. Thus not only did the switch not intrude into the inside of the prover but it required no permanent access to the wall of the pipe.

The second technique tested as part of the NEL/IP project was a magnetic type switch developed by NEL and used in conjunction with a displacer consisting of a disc-shaped magnet held between two conventional spheres which were rigidly bolted together. The unit was tested in a straight length of prover pipework.

The performance (repeatability) of each of the non-mechanical devices are shown in Figs 3 and 4. When compared to the typical performance of a conventional mechanical switch, it can be seen that the ultrasonic type has a comparable repeatability, while the magnetic type shows considerable improvement in performance. It should be noted that the manufacturers of the ultrasonic switch have advised that the performance of this device improves with increasing pipe diameter, ie with decreasing curvature of the pipe wall.

5 FUTURE OF CONVENTIONAL PROVERS

As the overall quantity of crude oil being produced from beneath the North Sea diminishes, it is to be expected that by the end of this century production will be concentrated less in the very large fields and more in the marginal fields which will become more commercially viable as crude oil prices rise. In these marginal fields flowrates and pipeline sizes will be considerably smaller. The cost of and the space occupied by conventional meter proving systems would be inordinately large in terms of the overall cost and area of the production platform.

One alternative to the conventional pipe prover is to calibrate by means of a reference meter which itself must be calibrated at regular intervals. The advantages of relative cheapness and compactness, however, are gained at the expense of accuracy, since the reference meter is an additional link in the traceability chain. Moreover, the expense and inconvenience of regular calibration, which may involve transporting the reference meter to a central proving station many hundreds of miles distant, will be considerable, and could cause production delays.

A more likely successor to the conventional prover is the compact device which offers the advantage of economy of space while maintaining the overall accuracy level associated with the conventional version. The compact prover is further discussed in the remaining lectures of this session.

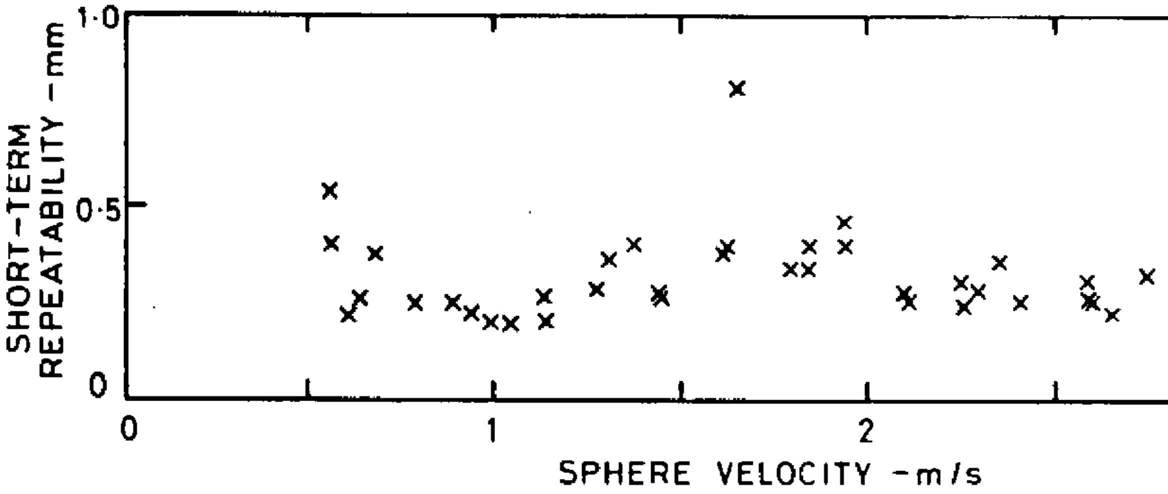


FIG 1 TYPICAL RESULTS FOR THE SHORT-TERM REPEATA
MECHANICALLY OPERATED DETECTOR

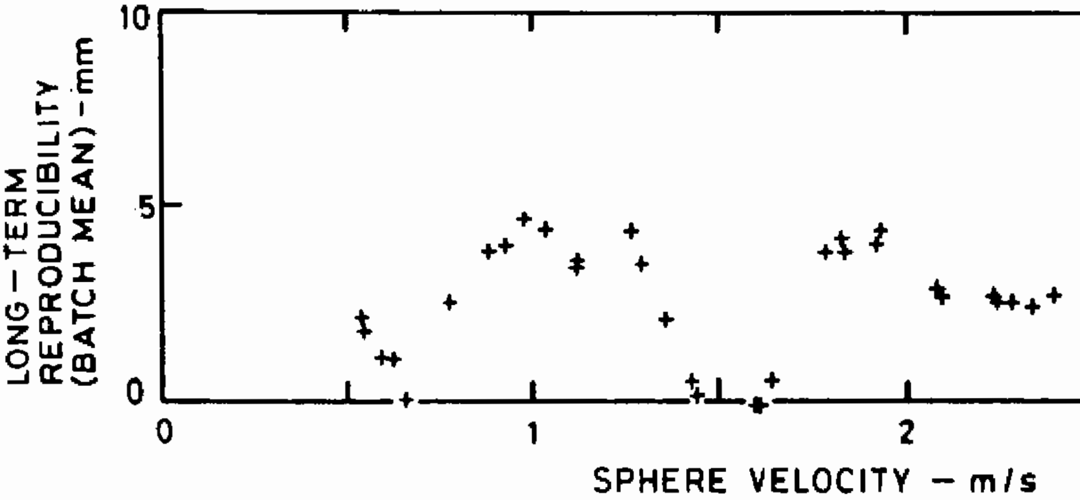


FIG 2 TYPICAL RESULTS OBTAINED FOR THE LONG-
OF A MECHANICALLY OPERATED DETECTOR

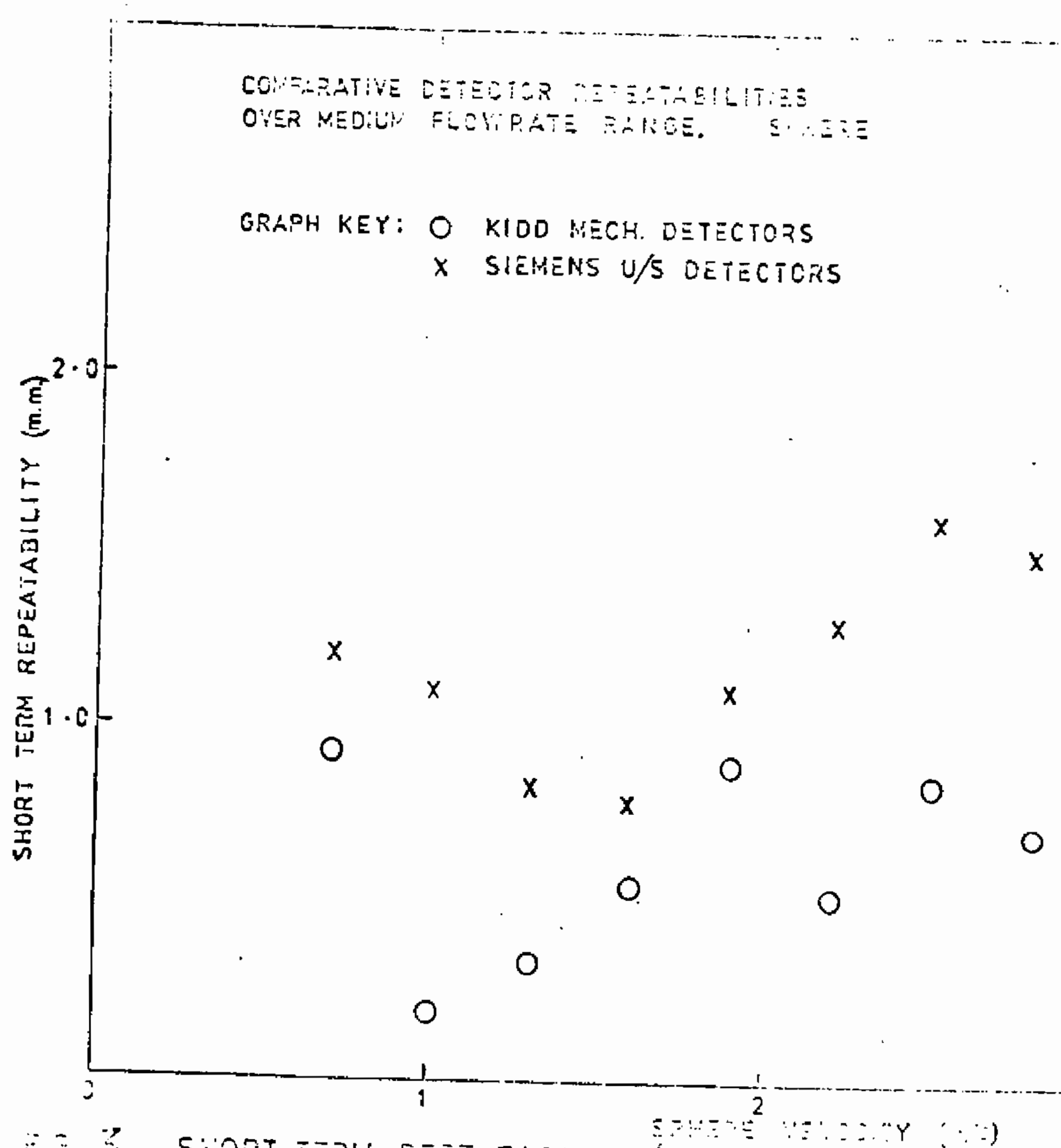
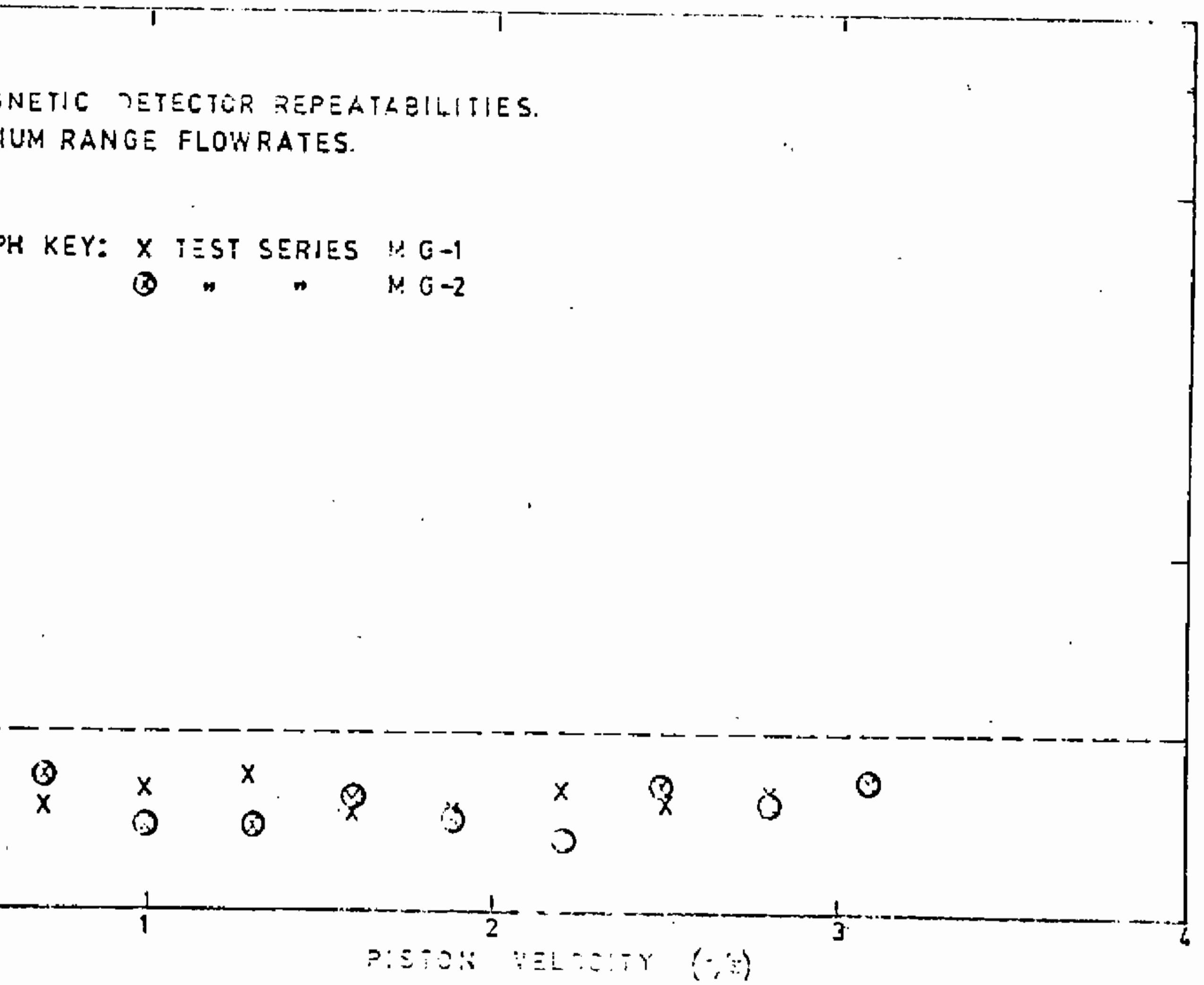


FIG. 3 SHORT TERM REPEATABILITIES [illegible]



ERM REPEATABILITY V. PISTON VELOCITY (LEFT-TO-RIGHT) FIGURE 2 [illegible]

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.