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Norwegian
Society of
Chartered Engineers

NORTH SEA FLOW MEASUREMENT WORKSHOP

OCTOBER 22. - 24. 1991
SOLSTRAND FJORD HOTEL, BERGEN - NORWAY

A NEW OIL AND MULTI-PHASE FLOW LABORATORY AT NEL

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22-23 October 1991

SUMMARY

NEL is currently building a new and larger Oil and Multiphase Flow Measurement Laboratory as part of the UK National Flow Measurement Standard. A description of the new laboratory is given, and in particular the new Multiphase Flow Measurement Standard which will be the first of its kind in the world.

Because the laboratory has been built as a service to the oil industry it is important that the new laboratory meets the present and future needs of that industry. This paper is therefore presented firstly to inform the oil industry of the capabilities of the new UK Standard for Oil and Multiphase Flow Measurement, and secondly to invite comments and suggestions from all those with an interest in oil and multiphase flow measurement.

INTRODUCTION

NEL has had a long involvement with the Offshore industry and has developed many skills and facilities in the fields of structures, materials, pump and valve design and testing, and particularly in the flow measurement of oil, gas and water.

NEL is the custodian of the UK National Flow Measurement Standards for oil, water, and gas with separate laboratories for each of these three fluids. Because of the increasing demand from the North Sea oil industry it became necessary to expand the size and capability of the oil flow laboratory, not only in flow range, but also in the type of oils used and the testing capability. Funding of $5 million was therefore provided for the construction of a totally new and larger Oil Flow Measurement Laboratory. Named after James 'Paraffin' Young, the nineteenth century Scottish entrepreneur who is widely regarded as the founder of the world's mineral oil industry, the building to house the new laboratory was initiated in August 1990 and completed in May 1991. The first facilities were installed for the official opening of the laboratory which was performed by Robert Horton, the Chairman and Chief Executive of BP in September 1991. Design and construction of the remaining facilities and the multiphase flow measurement facility are presently underway and all facilities are expected to be commissioned by early 1993.

SPECIFICATION OF THE NEW OIL AND MULTIPHASE FLOW LABORATORY

Working on the experience gained from operating the original Oil Flow laboratory and in anticipation of future needs, the specifications for the new laboratory were set as:-

* Three Gravimetric Flow Measurement Primary Standards, 1 to 100 l/s flowrate for each of kerosine, Gas Oil and 15 cSt oil. Measurement uncertainty to be better than 0.05 per cent of volume at the 95 per cent confidence level.

* One high Flow Measurement Secondary Standard of 1 to 200 l/s using any one of the above oils.

* Two small Gravimetric Flow Measurement Primary Standards of 0.1 to 10 l/s and 0.01 to 2.5 l/s of user defined oils. Measurement uncertainty to be better than 0.05 per cent of volume at the 95 per cent confidence level.

* One Water-in-oil Flow Facility of 1 to 50 l/s for flow studies.

* One Multiphase Flow measurement Secondary Standard of 1 to 80 l/s oil and water flow and 1 to 100 l/s of air or nitrogen flow with 60m of horizontal and 12m of vertical pipe runs.

* All liquids and gases to be safe for use at all operating conditions.

* All facilities to be capable of pressures up to 8 bar and temperatures from 0 to 70^{o}C to $\pm$ 1^{o}C control.

In addition, all the test facilities, including the control and data acquisition systems, should be adaptable and capable of further expansion to meet future needs.

Descriptions of the James Young building and each flow facility are given below:-

THE JAMES YOUNG BUILDING

The main working bay of the James Young building measures some 80m long by 20m wide by 11m high and is serviced by two 5 tonne overhead travelling cranes. A separated and ventilated basement 4.5m deep has been built under part of the working floor space to accommodate oil storage tanks and the pump room. Entrance foyer, office accommodation, plant room and other services are provided in a single storey 16m by 15m annex at one end of the main building.

A schematic of the general building layout is given in fig. 1 which shows the various facilities and the control rooms sited at each end of the laboratory for control and data logging purposes. Attached to one of the control rooms are three small laboratories to accommodate chemical analysis equipment and special facilities which can include the use of crude oils.

METHOD OF CALIBRATION

All three Flow Measurement Standards at NEL, ie those for oil, water and gas, are based on gravimetric standards, as opposed to volumetric standards used by some other standards laboratories. The NEL standards therefore measure the total mass of fluid passed through the flowmeter in a given time, so that Flow is measured against traceable mass and time standards.

In oil flow measurement it is more common that a flowmeter is used to measure total bulk flow, rather than flowrates and hence normal calibration is by the 'Standing start and finish' method. In this a flowmeter is installed in a test line and oil circulated through the lines to remove all trapped air. The stop/start valve is then closed and the weightank is weighed empty and the meter readings noted or set to zero. The stop/start valve is then opened and the weigh tank filled. The stop/start valve is then closed and the weight of oil in the weigh tank measured after a constant level drain device has settled to its permanent level and the readings on the meter recorded. The net weight of oil, after correction for air buoyancy, when divided by the oil density at the prevailing temperature gives the volume to be compared with the meter reading.

For those flowmeters which may be affected by an abrupt flow change a 'Flying start and finish' calibration is used. In this the meter is calibrated against a high quality reference meter, usually of positive displacement type and so unaffected by flow changes. This can either be accomplished while the reference meter is itself being calibrated against the gravimetric standard, or if this is not practical, then directly against the reference flowmeter which is then checked against the gravimetric standard at the start and finish of the calibration.

A more detailed explanation of the flow measurement standards at NEL can be obtained from ref. 1 and of flow measurement principles in general from ref. 2.

MAIN FLOW MEASUREMENT PRIMARY STANDARD

The main primary standard comprises three separate flow circuits using Kerosine, Gas Oil and 15 cSt oils respectively and each with a flow capacity of 100 l/s - lines a, b and c in fig 1. By controlling the operating temperature it is possible to obtain any viscosity required over the continuous range between 1.5 and 20 cSt. All oils are refined mineral oils with flash points in excess of 70°C.

Fig. 2 shows a schematic of one of the three flow circuits which comprise the main primary flow standard. All pipework and tanks, except for the main test lines, slope slightly so that liquids can be drained from the low points and gases vented from the high points. The oil for each circuit is stored in 30 m^3 tanks located in the basement and maintained within ± 1°C of a pre-determined temperature anywhere between 0 and 70°C. Temperature control is effected by circulating the contents of the tank via a 10 l/s pump through heat exchangers for heating using the building heating water supply, or cooling using a supply of cooled glycol pumped from chiller units outside the building. The chiller units are linked to all the facilities in the James Young building and have a total cooling capacity of 300 kw. A 100 micron filter circuit is also installed so that the oil in the tanks can be regularly cleaned.

Each flow circuit is designed to operate either two independent test lines at half full flow capacity or one test line at full flow capacity depending on demand. There is accordingly provision for two test lines in each circuit which can be used either as independent test lines or to allow one test line to be built up or dismantled while the other line is in use.

To enable this dual test line utilisation, two separate variable speed positive displacement screw pumps of 50 l/s capacity at 8 bar head receive oil via 200mm diameter outlets from each storage tank. Separate 150mm diameter pipes lead from each pump along under-floor conduits to the inlet of the test lines at the other end of the laboratory. A system of cross-over valves enables the two pumps to be used either independently or together, and also allows one or two test lines to be accommodated in each circuit.

The test lines themselves consist of 30m straight horizontal runs across the main floor of the laboratory. A collection of reducer and expansion pieces and telescopic joints allow a range of flowmeter sizes and types to be accommodated in the test lines and also a wide range of pipe configurations to be used as required. The long horizontal lengths allow for adequate upstream and downstream straight sections to ensure minimal installation effects on the calibrations.

At the outlet end of each test line, valves direct the flow directly back to the storage tanks or to either the 6 tonne or the 1.5 tonne weigh tanks shown in fig. 3. Each weigh tank comprises an appropriate capacity tank mounted on a precision weighing platform with a resolution of 1 in 50,000 which in turn is mounted on a support stand. Although calibrated by the supplier and stated to have negligible drift, because they are used as part of the National Flow Measurement Standard, it is necessary to re-calibrate the weighing platforms at regular intervals. This is achieved relatively quickly by a system of dedicated calibration weights mounted on hydraulic jacks beneath the platforms which can be operated in such a way that a sequence of three calibration weighings can be made. The weights themselves can be removed from the weightank assembly for recalibration. Using this system, measurement uncertainty better than 0.01 per cent of mass and 0.05 per cent of volume at the 95 per cent confidence level is expected.

The weightanks have a closed venting system so that vapour displaced on filling is channelled to the storage tanks in the basement, hence reducing oil losses. On discharge from the weightanks, the oil is directed by means of a three way diverter, down into the respective storage tank.

HIGH FLOW MEASUREMENT SECONDARY STANDARD

The maximum flow obtainable in the original oil flow laboratory was 80 l/s and this was too low to calibrate 150 or 200mm turbine flowmeters. The new facility therefore has the capability to calibrate up to 200 l/s in a high flow measurement secondary standard - line d in fig. 1.

Essentially line d is identical to lines a, b and c except that variable speed centrifugal pumps are used and the pipeline sizes are larger, 200mm instead of 150mm diameter on the main lines for instance. Pipework is provided to transfer either the Kerosine, Gas Oil or 15 cSt oil of lines a, b or c, into the storage tank of line d.

Two or more reference flowmeters calibrated up to 100 l/s in either lines a b or c, depending on the oil required, can be inserted into line d to give a total reference flow of 200 l/s. Because the test meter is calibrated against the reference flowmeters and not against the weightanks, this is a secondary standard with a correspondingly higher measurement uncertainty of about 0.1 per cent of volume.

SMALL FLOW MEASUREMENT PRIMARY STANDARDS

An increasing amount of work performed in the 'mezzanine' section of the original oil lab was performed on flows less than 10 l/s. To meet this demand in the new laboratory, two small Gravimetric Flow Measurement Primary Standards of 0.1 to 10 l/s and 0.01 to 2.5 l/s of user defined oils are to be built - lines e and f in fig. 1. These will be built on the floor of the main bay with their storage tanks and pumps in the basement. Each of the lines will have its own weightank built to an essentially scaled down design of the weightanks used in lines a, b and c. Again, measurement uncertainty better than 0.05 per cent of volume at the 95 per cent confidence level is expected.

WATER-IN-OIL FLOW FACILITY

The NEL has gained considerable experience in water-in-oil flow studies, especially in conducting research on automatic samplers for a consortium of oil companies (ref. 3). A purpose designed facility (ref. 4) was built for this work and this will be transferred to the James Young building. The facility can circulate water and oil flows up to 50 l/s, either on a constantly mixed recirculation basis, or on a constant injection and separation of water basis and some gas injection is also possible. The water-in-oil facility is not in itself a flowmeter calibration facility but more a tool for quality rather than quantity measurements. Modular viewing perspex test sections have therefore been provided which can be mounted either in a horizontal line or a vertically upwards or downwards line.

MULTIPHASE FLOW MEASUREMENT SECONDARY STANDARD

The NEL's capability in multiphase flow measurement has steadily increased (refs. 5 to 7) and several multiphase flow facilities for the testing and development of multiphase flowmeters have been built. The drive for multiphase flowmeters for offshore use has been very intense in recent years and several developments will be installed offshore in the near future as indicated in the separate papers by Dean, Smorgrav, Frantzen and Gaisford in ref. 8. At the moment the only means of calibrating such multiphase flowmeters is against a test separator with single phase flow measurement on the outlet streams. However, the inherent large measurement uncertainties of the method combined with the lack of flow control make this of dubious advantage. Several multiphase flow facilities are available about the world, but these have been built for flow studies or meter development, and not for meter calibration. The multiphase flowmeter calibration facility currently being built at the NEL will, as far as is known, be the only such facility in the world.

As holder of the UK National Flow Measurement Standard, the NEL sees the construction of a multiphase flowmeter standard as a natural and necessary supplement to the existing single phase standards. The task of providing such a multiphase calibration facility is not an easy one however. It is not just a question of mixing together individually metered supplies of oil, water and gas and passing them through the meter to be calibrated. The phases may not necessarily flow at the same velocity, ie there may be slip between them, and the gas phase may dissolve in, or evolve, from the liquid phase depending on pressure and temperature conditions. The water may mix with the oil, or it may drop out and flow along the bottom of the pipe depending on the flow velocity and turbulence. Further, and more difficult, is the fact that a multitude of flow regimes are possible in multi-phase flow and the calibration facility will have to reproduce those regimes in which the meter to be calibrated is expected to work.

There are generally three types of multiphase flowmeter - a total flow meter of all phases, a phase fraction meter to measure the proportions of each phase, and a combination of these in an individual phase flowrate meter. Because of the additional problems of multiphase flow measurement, the measurement uncertainties are much higher than those experienced with single phase flowmeters with current developments indicating uncertainties of 5 per cent of volume though future developments are expected to improve on this.

NEL commissioned a survey of potential users, manufacturers and government agencies to identify the major requirements and usage of a multiphase flow facility. Based on this information, a calibration facility shown in schematic form in fig. 4, will be built.

The total inventory of the oil and water will be held in a vessel which will act as a combined storage tank and multiphase separator. The oil and water will be drawn from the vessel into the respective liquid pumps while the gas will be injected after the water and oil have been mixed. Reference flowmeters, calibrated in the single phase oil, water and gas flow measurement laboratories at NEL will be installed in each line prior to mixing. The design of the separator will be such that the three phases can be stored in a separated condition within the separator so that the opportunity for biological fouling is reduced.

Combined oil and water flowrates of 1 to 80 l/s and air or Nitrogen flowrates of 1 to 100 l/s will be achievable. To enable developed multiphase flow regimes to occur, a horizontal run of 60m and vertically upwards and vertically downwards runs of 12m will be provided. More severe slugging flows can be produced by controlled intermittent supply of one or more of the phases to the test section or by mixing the phases at different locations along the test lines.

MISCELLANEOUS FACILITIES

The main bay of the James Young building will have space for the construction of special purpose facilities, or to accommodate any large or complicated meter system. Provision is also made to extend the lines outside the laboratory for the testing of large equipment such as meter provers. In addition, the three laboratories attached to the control rooms will house special applications such as an oil-in-crude oil monitor evaluation facility which requires special safety provisions and ventilation. Facilities have also been provided for chemical analysis, viscosity and density measurements to be undertaken.

INSTRUMENTATION AND CONTROL

The new laboratory employs the latest instrumentation and control technology which has been designed with future expansion and greater capability in mind. A local Ethernet system provides fast communications between sensors, Progammable Logic Controllers (PLC's), dataloggers and computers in such a way that fast response times are possible and multiple redundancy and inter-changability of important components is possible for fully versatile data acquisition and control.

SUMMARY

The new UK Oil and Multiphase Flow Measurement Standard being built at NEL replaces the existing standard with a much greater capability not only in terms of flow rates and fluids available, but also with the ability to calibrate multiphase flowmeters. The investment represents the Government's commitment to helping the Oil industry and to make effective use of this investment it is necessary that NEL is advised on a regular basis of the present and future needs of the industry.

ACKNOWLEDGEMENT

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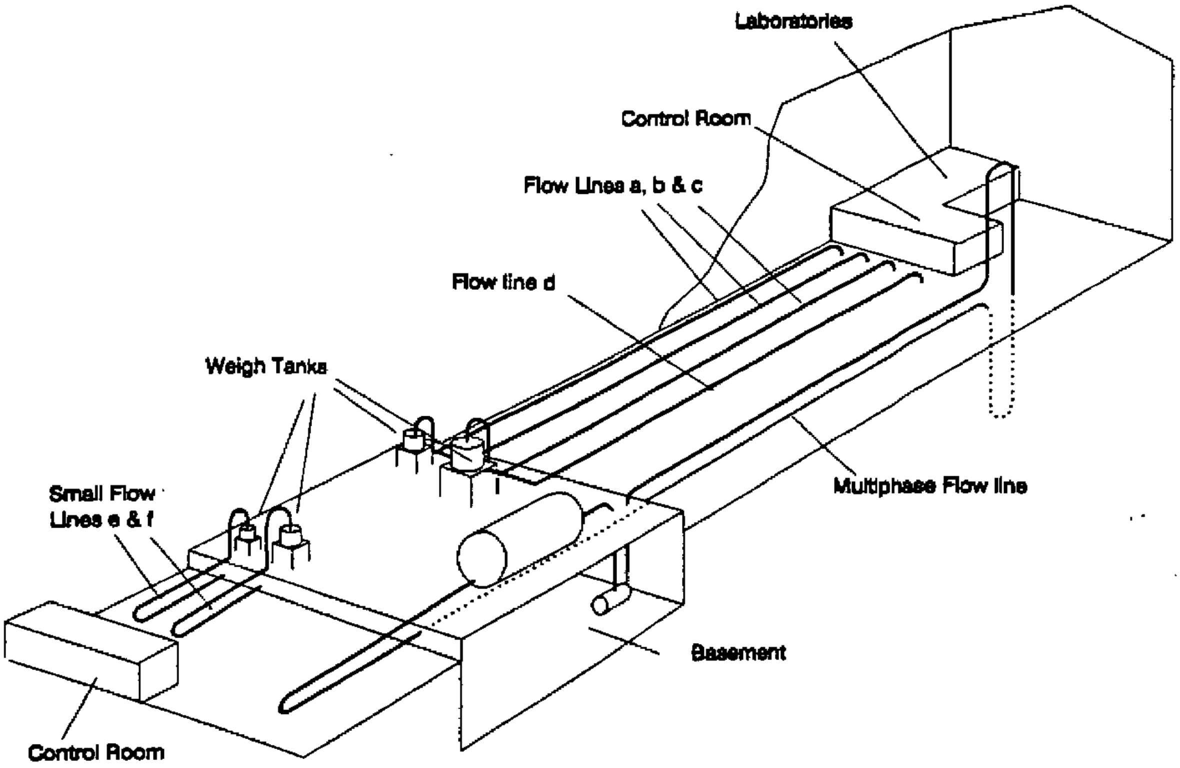

Fig. 1 General Schematic of the James Young Building

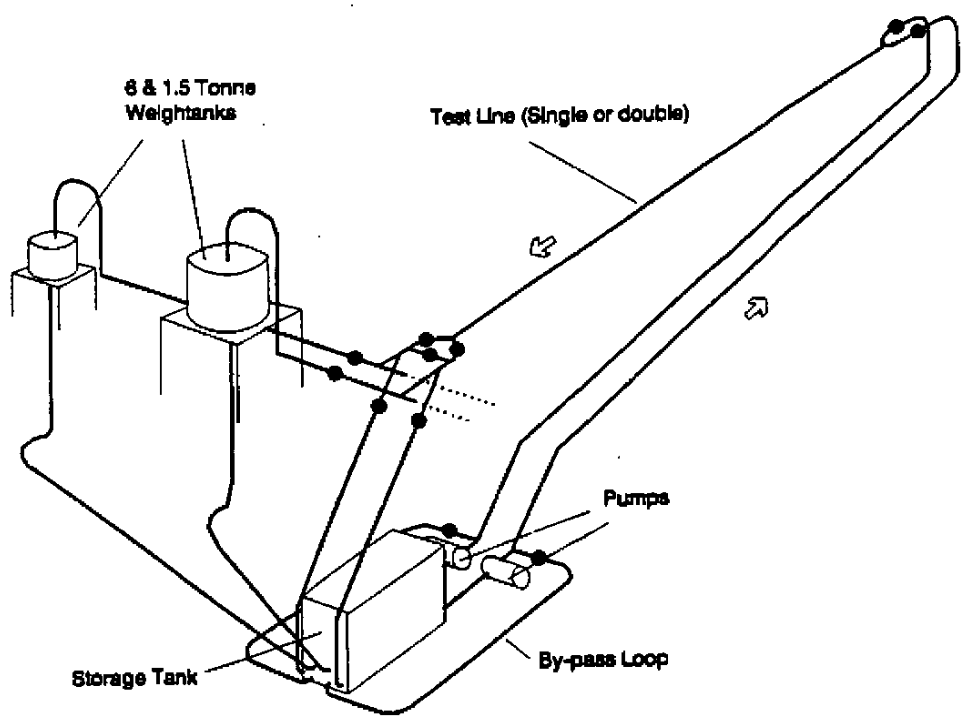

Fig. 2 Schematic of the Main Primary Flow Measurement Standard

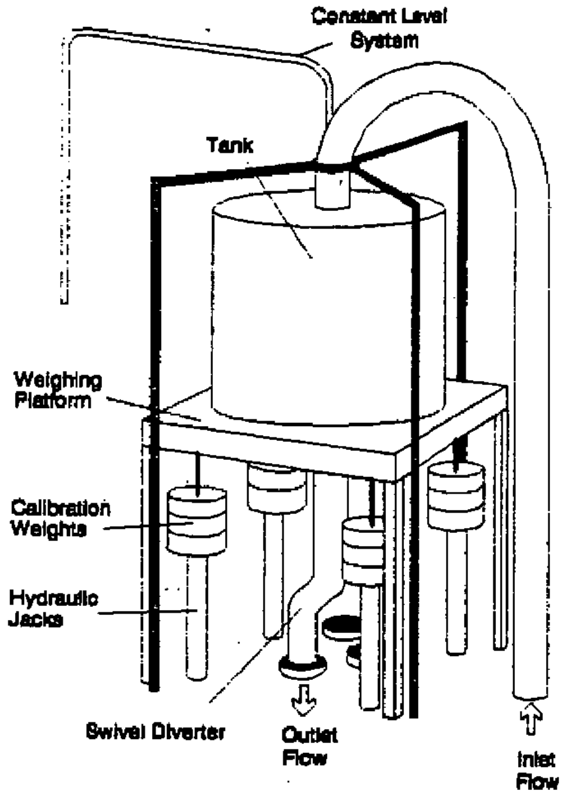

Fig. 3 Weightank System

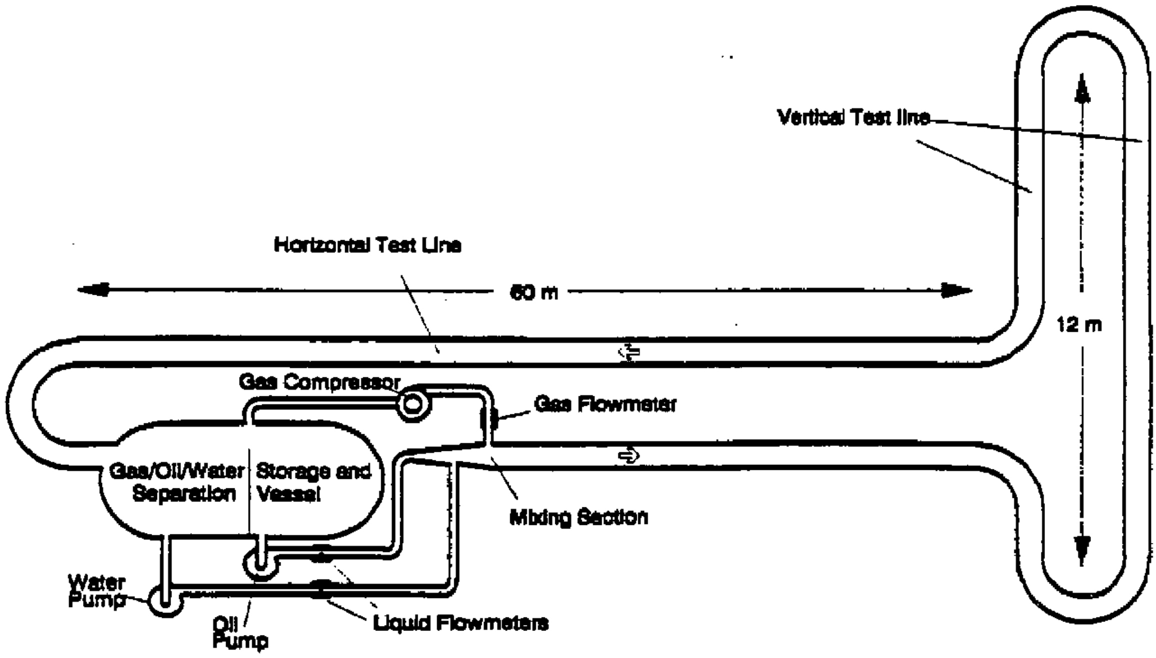

Fig. 4 Schematic of NEL Multiphase Flowmeter Calibration Facility