Intercomparison Between Trapil, France and NEL, UK Using Oil Flow Turbine Meters

A Report for

NMSPU, DTI
151 Buckingham Palace Road
London SW1W 9SS

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Flow Centre

National Engineering Laboratory
East Kilbride
Glasgow G75 0QU
Tel: 01355 220222
Fax: 01355 272999

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SUMMARY

As part of the DTI 1996 to 1999 flow programme for NMSPU, an intercomparison between NEL and TRAPIL in France was considered a priority as a significant number of flowmeters used in the UK sector of the North Sea are verified and calibrated at TRAPIL.

The transfer package consisted of two turbine flowmeters calibrated at NEL and TRAPIL Gas oil and Kerosene. NEL also calibrated in a third higher viscosity oil and at different temperatures to estimate the performance of the package.

Agreement in kerosene was extremely good, within 0.1 per cent. Using gas oil some discrepancies showed a wider level of agreement of some 0.25 per cent on one meter while retaining agreement to within 0.1 per cent on the other.

It is concluded that basic agreement is good but that more work to widen the intercomparison in Europe should be carried out and that a more stable package be investigated.

Prepared by: Mr R Bunch

Approved by: Mr R Paton

Date: 8 September 1999
for Dr F C Kinghorn
Director

CONTENTS

1 INTRODUCTION

The project was initiated under the DTI National Measurement System Policy Unit 1996-1999 flow programme. The objective was to provide an inter-comparison between NEL, UK and Trapil, France. NEL provides the UK National Standard for flow measurement while Trapil is one of the prime calibration facilities for oil flow meters in France. Both laboratories are accredited by their respective National authorities and provide two of the main traceability routes for North Sea oil flow meter calibrations.

This report gives an overview of the laboratories and test methods and summarises the results. The full list of tables of results and associated figures pertaining to the inter-comparison is given the report for reference but only the salient inter-comparison graphs are included in this summary. All the tables and figures referenced are available in Microsoft Excel format in NEL report number FC 305/99 -- Inter-comparison Work for 1996-99 Flow Programme. This is available from NEL as a CD-ROM. This CD includes this report and also includes the reports of all other inter-comparisons carried out within the 1996-1999 flow programme.

Using Kerosene (substitute) and Gas Oil (substitute) were used as the test fluids The objective of the project was to ensure that industry could have confidence in the calibrations of oil flowmeters carried out in UK or in France. NEL and Trapil provide a significant number of the calibrations of fiscal meters used in Europe and in the North Sea.

2 THE LABORATORIES

2.1 NEL

The National Engineering Laboratory (NEL) is an industrial research organisation concerned with many areas of mechanical engineering research. Within NEL, Flow Centre is the holder of the UK National Standards for Flow Measurement. Facilities exist for calibration and research involving water, oil, gas and multiphase flow. All the measurement components are fully traceable to Primary National Standards and most are accredited by United Kingdom Accreditation Service (UKAS).

Meters are calibrated using a standing-start-and-finish technique against gravimetric standards. A number of weigh tanks are available from 6 tonne down to 150 kg. The 6 tonne tank was used for this exercise. Temperature is controlled to within ± 1°C. Using this capability of temperature control and the availability of a second oil (7 cSt at 20°C), an estimate of the meter's viscosity and temperature coefficients can be measured.

2.2 TRAPIL

Societe des Transports Petroliers par Pipeline -- (Trapil) has a flow calibration facility based at a junction of one of the pipeline systems in France and has access to oil storage facilities. It is located to the north of Paris. Trapil is accredited by the Bureau National De Metrologie (B.N.M.) in the field of "fluid flow measurement - Dynamic volume and mass measurement". Meters are calibrated against one of two pipe prover loops.

Trapil are able to offer the calibration of flowmeters across the range 10 – 2000 m^3/h (2.8 – 556 l/s) over a range of viscosities from 0.5 to 900 cSt. All calibrations are carried out at ambient temperatures. Trapil are also able to offer calibrations at pressures up to 20 bar.

3 TEST METERS AND CONDITIONS

A twin turbine meter package was used for the inter-comparison. Halliburton Ltd provided the meters for the purposes of the project.

The details of the meters are shown below.

Meter_1
Manufacturer: Halliburton
Type/model: 4-inch turbine flowmeter
Serial No: 4SF6903
Date received: 12 August 1998
Date calibrated: 11 November 1998 - 20 May 1999

Meter_2
Manufacturer: Halliburton
Type/model: 4-inch turbine flowmeter
Serial No: 4SBF6922
Date received: 12 August 1998
Date calibrated: 11 November 1998 - 20 May 1999

Calibration Fluid(s) NEL: Approximate Specification

Test Fluid_1 Kerosene Substitute
Density at 20ºC 0.7992 kg/l
Viscosity at 20ºC 2.5 cSt
Viscosity at 5ºC 3.4 cSt

Test Fluid_2 Gas Oil Substitute
Density at 20ºC 0.8261 kg/l
Viscosity at 20ºC 7.2 cSt
Viscosity at 5ºC 11.2 cSt

Calibration Fluid(s) Trapil: Approximate Specification

Test Fluid_1 Kerosene Substitute
Density at 15ºC 0.8023 kg/l
Viscosity at 20ºC 1.64 cSt
Estimated Viscosity at 10ºC is 2.1 cSt

Test Fluid_2 Gas Oil
Density at 15ºC 0.8531 kg/l
Viscosity at 20ºC 5.2 cSt
Estimated Viscosity at 10ºC is 6.4 cSt.

Estimates are based on NEL curves for similar products and indicated viscosities for each of fluids at a temperature of 20ºC.

Test parameters NEL

Calibration Range:	7.8 – 78 l/s
Test temperature:	5ºC and 20ºC
Pressure downstream:	2 bar gauge

Test parameters Trapil

Calibration Range:	7.8 – 78 l/s
Test temperature:	8.2 – 12ºC
Pressure downstream:	2 bar gauge

Both meters were 100 mm nominal bore turbine flowmeters. Meter_1 was a standard flange type turbine flowmeter. Meter_2 was a wafer type (EZ-IN) turbine flowmeter that was sandwiched between flanges. Both meters were assembled in a package consisting of 20 diameters of 100 mm straight pipe before the meter and 10 diameters of straight pipe after the meter. A flow straightener of the tube bundle type was installed between the two meters to eliminate the possibility of interference from flow profiles from one meter to another. The package was transported as two parts. Each part of the package consisted of the flowmeter with its associated upstream and downstream pipework. Neither part was split during the intercomparison. The two parts were transported separately and then assembled as shown in Fig. 1 at each laboratory.

A schematic diagram of the package is given in Fig. 1.

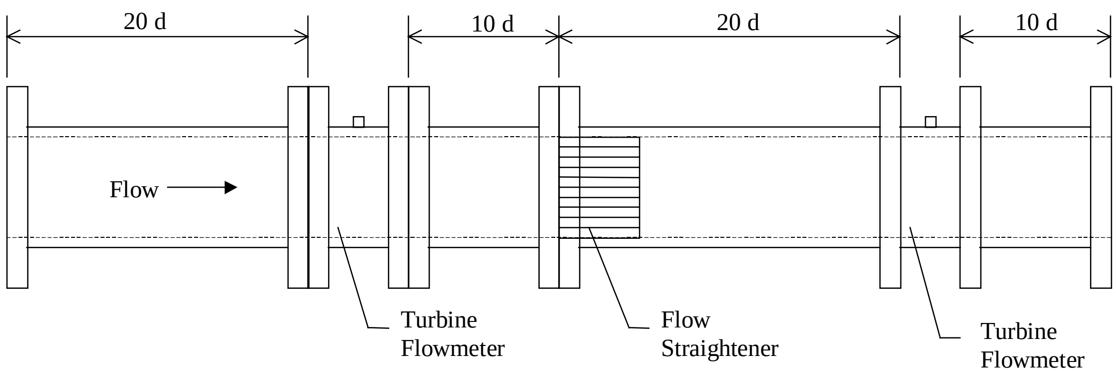

Fig.1 Schematic diagram of meter package

4 TEST FACILITIES, MEASUREMENTS AND METHOD

4.1 NEL

The flowmeter package was installed in the NEL National Standards Oil Flow Measurement Facility, lines A (Kerosene) and B (Gas Oil) as shown in Fig. 2. These test lines are identical in all aspects except for the test fluids used. Both are fed from separate storage tanks via suitable pumps to a 6 tonne weighbridge. The oil from the weighbridge is returned to the original storage tank.

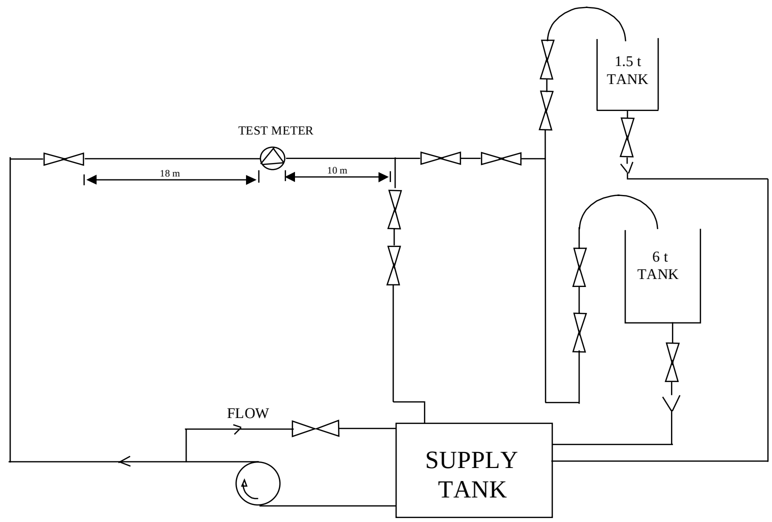

FIG.2 SCHEMATIC DIAGRAM OF TEST CIRCUIT

The calibrations were carried out using a standing start and finish gravimetric test method

The K-factor (K) was calculated in the following way:

$$K = \frac{Total\ pulses\ from\ meter}{Volume}$$

The flowrate was calculated using the time taken to collect the quantity of fluid passed through the meter.

4.2 Trapil

The flowmeter package was installed within the Trapil test facility. The test facility comprises of a unidirectional prover loop connected to two, 10 m test benches where the meter package is installed. The loop is a closed circuit consisting of a variable speed circulating pump, test section and prover. The test line is kept full and at constant static pressure using a compensation reservoir (balancing tank) and pressurization pump. The loop is filled with fluid from one of six available storage tanks.

5 UNCERTAINTY

5.1 NEL

Using the test method outlined, the accredited standard uncertainty in the measurement of the quantity of fluid passed through the meter is estimated to be 0.03 per cent with a coverage factor *k*=2.

5.2 Trapil

Using the test method outlined, the uncertainty in the measurement of the quantity of fluid passed through the meter (Vm) is dependent upon the fluid and also the flowrate. Details are given below.

Kerosene flow > $40m^3/h$: 3.7E-4.Vm
Kerosene flow < $40m^3/h$: 3.9E-4.Vm
Gas Oil flow > $40m^3/h$: 3.8E-4.Vm
Gas Oil flow < $40m^3/h$: 4.1E-4.Vm

This can be rounded to 0.05%. The coverage has not been provided.

6 TEST RESULTS

All the results of the calibrations and the associated graphs are listed at the end of this report. All the tables of results and figures are available in NEL Report FC 305/99 issued as a CD-ROM. Only the figures pertinent to the conclusions are included here. The figure numbers used reference to those provided in the full data set on the CD-ROM.

6.1 Kerosine Calibrations

Fig. 3 below shows the calibration of meter_1 in Kerosene at both NEL and Trapil. Two calibrations are shown for NEL (5°C and 20°C) and a single calibration at ambient temperature of between 8.2°C and 12°C for Trapil. This corresponds to oil viscosities of 3.4 cSt and 2.5 cSt for NEL and 2.1 cSt for Trapil.

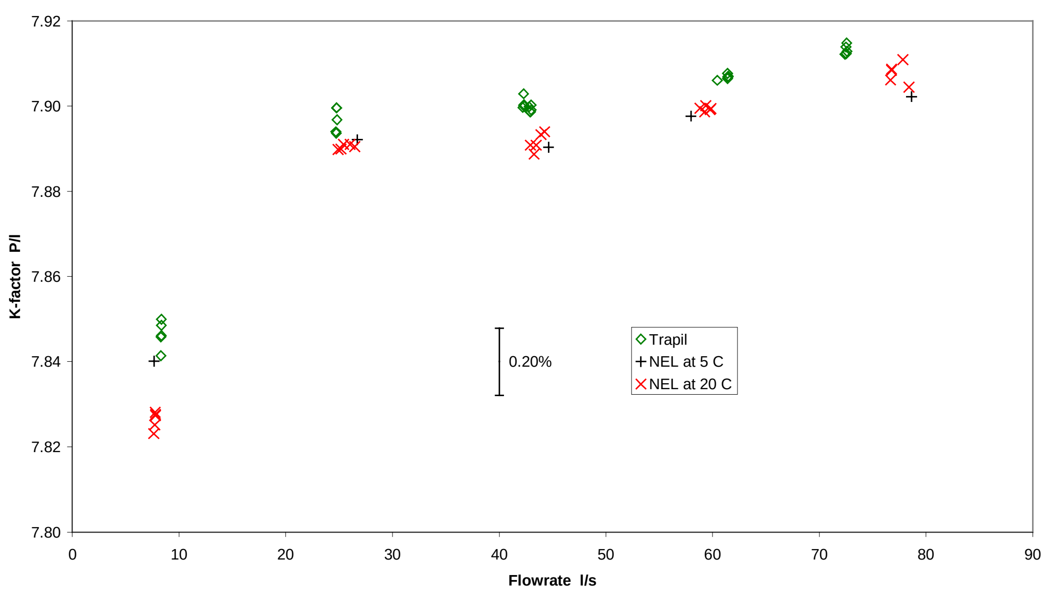

Fig.3 Calibration of Meter_1 in Kerosene

The calibration curves shown by all three calibrations are similar with a linearity of some 0.1 per cent from 80 l/s down to 20 l/s. in this region the Trapil results are some 0.12 per cent higher than the NEL results which agree to within 0.025 per cent. Below 20 l/s the k factor drops rapidly and while the three curves follow each other closely some separation between NEL and Trapil is noted but this may be due to the increased linearity and the sensitivity to viscosity at this flow rate.

Fig. 4 below shows the calibration of meter_2 for the same test parameters and was calibrated at the same time in series with meter_1.

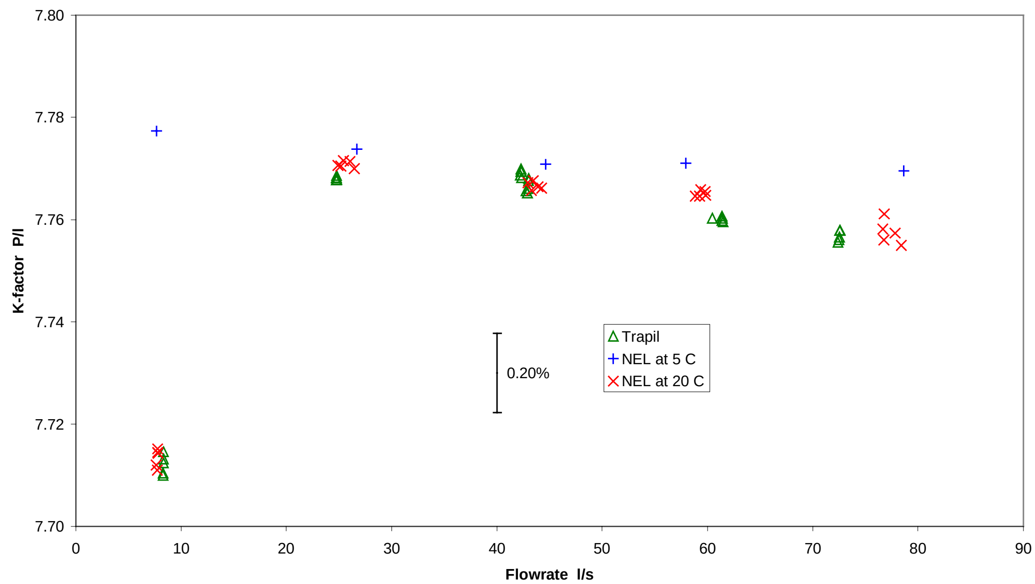

Fig.4 Calibration of Meter_2 in Kerosene

The NEL results at 20 C and the Trapil results follow the same calibration curve and agree within 0.1 per cent across the range. Both calibrations show repeatability of around 0.02%

The NEL 5C calibration shows a more linear calibration curve without the drop in k-factor at both extremes of the flow range shown by the other two curves.

6.2 Gas Oil Calibrations

Fig. 5 below shows the calibration of meter_1 in Gas Oil at both NEL and Trapil. Two calibrations are shown for NEL (5°C and 20°C) and a single calibration at ambient temperature of between 8.2°C and 12°C for Trapil. This corresponds to oil viscosities of 11.2 cSt and 7.2 cSt for NEL and 6.4 cSt for Trapil.

This set of results shows the Trapil result following a different curve from that demonstrated for the Kerosene calibration. The curve drops slightly at 20 l/s then rises to again at 10 l/s rather than dropping further as shown by the kerosene tests. The NEL 5C result generally follows the same curve shape but the curve is more pronounced with differences from Trapil of up to 0.1 per cent.

The main 20ºC calibration from NEL demonstrates a very different curve and while agreeing closely at 80l/s with the other tests drops rapidly to give a 0.3 per cent difference at 10L/s.

Repeatability for all three calibrations is excellent.

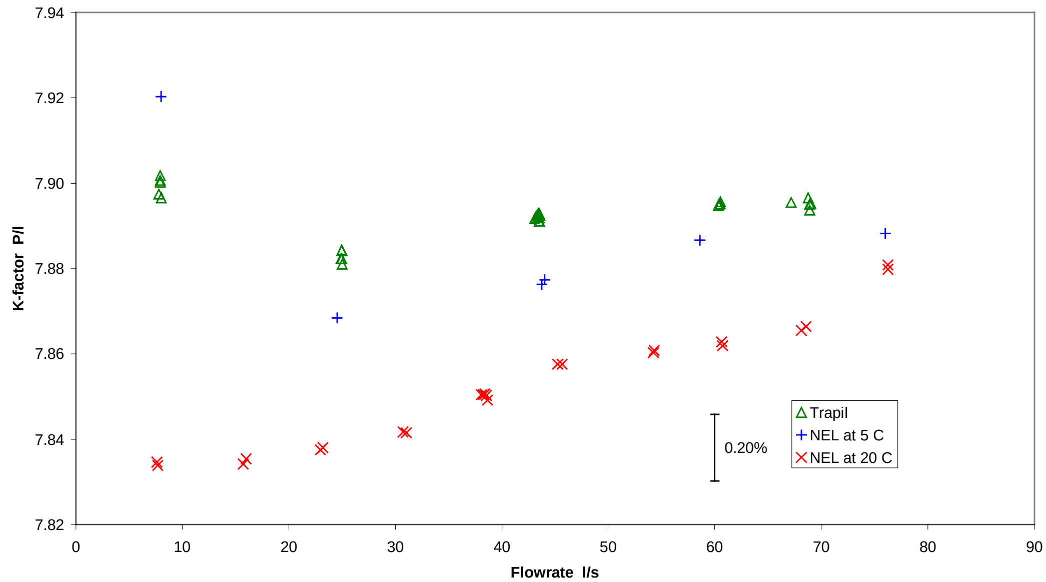

Fig.5 Calibration of Meter_1 in Gas Oil

Fig. 6 below shows the calibration of meter_2 for the same test parameters and was calibrated at the same time in series with meter_1.

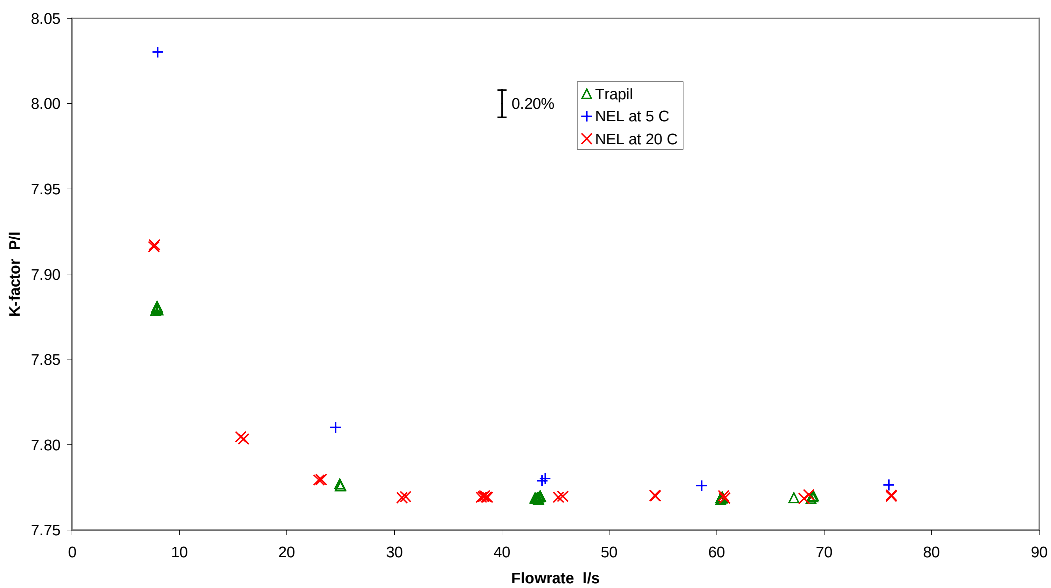

Fig.6 Calibration of Meter_2 in Gas Oil

In this case the NEL 20°C and the Trapil calibration agree very closely, with the NEL 5°C about 0.1 percent higher. All the results show a curve which is linear from 80 l/s down to 15 l/s. Below 15 l/s the k-factor rises steeply.

The above results have not had any corrections made for either temperature effects or viscosity.

7 ADDITIONAL CALIBRATION OF METERS BY NEL

NEL carried out some additional calibrations upon the meter package to better understand the performance in relation to both temperature and viscosity. This involved calibration of the meters in a third oil (Velocite) at varying temperatures (12°C, 20°C and 45°C) as well as an additional calibration in both original test fluids at a higher temperature (45°C). Details of the additional calibrations and their associated graphs can be found on the CD-ROM.

Fig. 29 below shows the calibration of meter_1 over all three-test fluids at all three temperatures. Details of the fluid viscosities are given on the graph to allow an assimilation of the data provided.

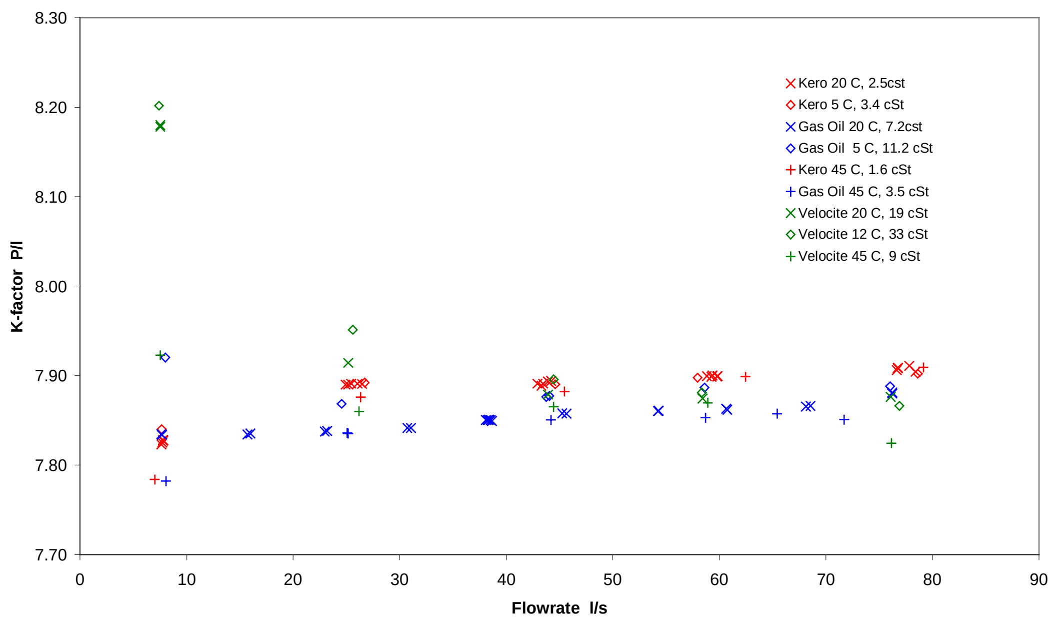

Fig.29 NEL calibration of Meter_1

The calibration curves show the effects of both viscosity and temperature upon meter_1 with the greatest effects being shown for the calibration using the thicker viscosity oil. This is especially true at flowrates below 25 l/s where the calibration curves rises rapidly as the viscosity increases. This trend changes as the oil viscosities thin and from the graph it can be seen that the curves actually drop off as the flowrates decrease.

At flowrates above 25 l/s the general linearity of the meter is within the 0.15% as would be expected for each calibration. The overall agreement between each separate calibration is 0.6. Fig. 30 below shows the calibration of meter_2 for the same test parameters.

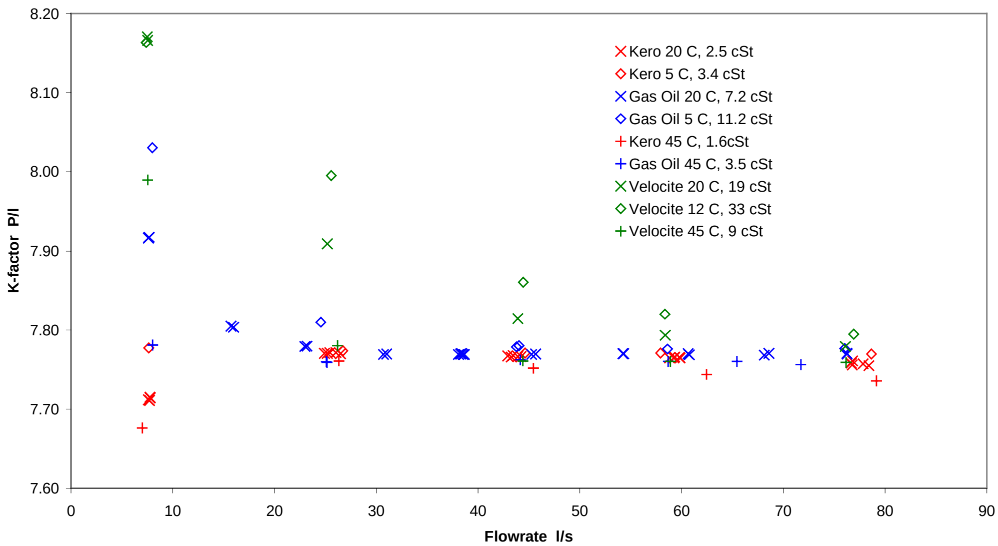

Fig. 30 NEL Calibration of Meter_2

The calibration curves show the effects of both viscosity and temperature upon meter_2 with the greatest effects being shown for the calibration using the thicker viscosity oil. This is especially true at flowrates below 20 l/s where the calibration curves rises rapidly as the viscosity increases. This trend changes as the oil viscosities thin and from the graph it can be seen that the curves actually drop off as the flowrates decrease.

At flowrates above 20 l/s the general linearity of the meter is within the 0.15% as would be expected for each calibration. The overall agreement between each separate calibration is 0.6%.

8 CONCLUSIONS

1) The agreement between Trapil and NEL for meter_1 in Kerosene was found to be within 0.1%, with the Gas Oil results within 0.25%.
2) For meter_1 the agreement using gas oil was within 0.25 per cent but this is mostly due to the 20C 7.6 cSt result which does not fit well with the other data.
3) The agreement between Trapil and NEL for meter_2 in both Kerosene and Gas Oil was found to be better than 0.1%.
4) Repeatability for both meters was better than ±0.02% in both labs.
5) Variations in viscosity and temperature on the meters leads to variations in K-factor of up to 0.6% over the range 1.6 to 33 cSt, and 5 to 45 C. Some general trends could be discerned from the data , but it was not considered practical to derive and apply corrections to the results of the intercomparison.
6) With the level of agreement showing agreement around 0.1% future intercomparisons should concentrate on widening the covering of commercial laboratories in France (Fos-Sur-Mer and Faure-Harman are examples) and other similar laboratories in Europe.

9 ACKNOWLEDGEMENT

NEL would like to thank Halliburton for their assistance with the supply of two turbine flowmeters. Appreciation is also shown to the staff at Trapil for their co-operation in this project and their welcome during the visit to the facility.

List of Tables and Figures provided in NEL Report No 305/99; entitled "Inter-comparison Work for 1996-99 Flow Programme".