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A reconciliation of turbine meter measurement with shipboard static measurement in the custody transfer of L. P. G.

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A RECONCILIATION OF TURBINE METER MEASUREMENT WITH SHIPBOARD STATIC MEASUREMENT IN THE CUSTODY TRANSFER OF L.P.G.

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SUMMARY

In the marine transportation of liquified gases, shipboard measurement is used extensively for the determination of Bill of Lading quantities. Shore measurement, which is used almost without exception for the fiscal measurement of heavier hydrocarbons such as crude oil, is now increasingly being used for Bill of Lading, Royalty and Custody Transfer purposes.

INTRODUCTION

This paper discusses the problems associated with the measurement of Liquified Gas at a Marine Loading Terminal. It reviews the uncertainties attached to two available methods, i.e. Shore Turbine Metering and Shipboard Static measurement and attempts to reconcile these by providing comparisons between the two systems.

It does not consider the use of Shore Static measurement nor the use of other types of flow meters. Neither is the content intended to be of a technical nature but merely observations based upon practical experience.

SOURCES OF ERROR

Turbine Metering

Meter

Due to the particular nature of the product; low temp, low density, low viscosity, poor lubricity and its desire to regain its natural state resulting in two phase flow, special problems have to be overcome by the Turbine Meter to achieve the same high performance as those in more viscous hydrocarbon service. Certain precautions are therefore required so as to provide the degree of reliability, repeatability and linearity necessary for fiscal or custody transfer measurement.

Two phase flow which can cause measurement errors and also possible damage to the meter due to high velocities overspinning the turbine must be avoided by ensuring that no vapours enter the loading system. An adequate back pressure must also be maintained to prevent errors due to flashing off across the meter. To prevent damage it may also be advisable to derate the meter to approximately 70% of its maximum rate on water.

The theoretical effect of low density fluids on a turbine meter is to cause a large shift in the K factor when operating at low rotational speeds. This effect, plus the derating of the meter, reduces the turn-down as can be seen in Figs 1,2,3,4 and 5, and therefore it is necessary to to operate the meter at a restricted range to maintain good linearity. Careful selection of the correct size of meter is essential so that for any given loading rate each meter is always operating within this reduced range.

Figs 1 and 2 show 4" meters on Butane service with a linearity of better than ±.25% between flow rates of 35 and 250 M3/hr. Fig 3 shows an 8" meter on Butane service with a linearity of ±.05% between 250 and 870 M3/hr and on Fig 4 ±.15% between 350 and 800 M3/hr for an 8' propane meter. The long term repeatability of these meters can be seen on the ship/shore comparison sheets.

Meter Proving

The accurate proving of the meters depends not only upon the repeatability of the meter itself, but upon the precision and performance of the Prover system.

Experience with proving 4" meters using a conventional bi-directional pipe prover has given excellent results down to temperatures of -11oC. All parts of the system have operated reliably, and five consecutive provings within a spread of ±.01% is easily achieved.

At temperatures down to -42oC (refrigerated Propane) some type of piston prover is required. The new generation of small volume compact piston provers appear ideal for this service but the type used in evaluating the performance of the 8" turbine meters in this paper has a larger degree of uncertainty than the conventional prover as the short term repeatability is not so good, i.e ±.05% spread in five consecutive provings. This reduced precision is possibly due to the distance between the detectors being less than 7 metres producing slightly over the minimum recommended 10.000 pulse counts, and the resolution of the detector switches which are of the magnetic proximity type.

Problems were experienced with obtaining a bubble-tight seal on the 4-way and twin seal valves but this was overcome by changing out the valve seat material. Other problems, such as freezing and leaking valves, switch failures, pre-amp failures, and valve leak detection malfunctions have all contributed to an unacceptable level of reliability, but nevertheless the system does function as a check on ships figures.

Cooldown

Liquified Gas Vessels often require a slow rate at the commencement of loading to enable the cargo tanks to be cooled down gradually. This may cause measurement errors if the rate required is outside the operating range of the meter, and therefore consideration may have to be given for the provision of a smaller cooldown meter specifically for this purpose.

Temperature

The accurate determination of temperature is a crucial factor in the measurement of Liquified Gas due to its large expansion coefficient. A one degree error will introduce a volumetric error of 0.3% for Propane and 0.2% for Butane. The platinum resistance thermometer is best suited for this service as calibration of these instruments has shown good long term stability. Positioning of the probe is important, for instances have occurred where the probe was determining the temperature of the lagging with the utmost precision.

Manual or automatic monitoring of each meter's dedicated temperature reading during the loading is advisable.
A difference greater than 0.3 Degrees C should cause some concern and be investigated.

Vapour Return

Vapour returned to storage from the vessels cargo tanks must be accounted for and deducted from the metered volume. Any measurement errors introduced will contribute towards the total uncertainty of the loaded quantity. The accuracy requirement for this device is really dependent on the volume of vapours returned which in turn depends upon the ability of the ships equipment to contain any boil off. In most cases the volume returned to shore represents only a small percentage of the total cargo and therefore high accuracy is not required. The worst case experienced was 1% returned which when measured with a standard orifice of an accuracy of say ± .5% would account for .05% of total cargo loaded.

Line Contents

Another source of error in shore measurement is the quantity contained in the loading lines between the point of measurement and the receiving vessel. Ideally the distance should be kept to a minimum but if not then efforts must be made to ensure the same conditions before and after the transfer. A slack line at the beginning, and a packed line at the completion of a loading would result in a short delivery to the vessel.

SHIPBOARD STATIC MEASUREMENT

Tank Calibration

The design of cargo tanks in liquified gas tankers presents the tank calibrator with special problems in computing precise volumetric tables. These tanks vary in shape from the membrane type to free standing prismatic and pressure vessel type tanks. Large errors can be built into these tables, particularly if the gauge point is not situated in the exact geometric centre of the tank and allowances have to be made for the trim and list of the vessel. Some ship owners employ specialised companies to prepare these tables so that any errors are minimised. Nevertheless there are some vessels in service with calibration tables of doubtful accuracy and origin, probably prepared from Shipyard drawings without any physical check measurements being made.

Level Gauges

The most common method encountered on board ship of determining the liquid level is the float gauge type. This type appears to give the necessary reliability and accuracy when operating in a marine environment although other devices such as Slip Tubes, Capacitance and Ultrasonic gauges are also used. Each type have their own degree of uncertainty but large systematic errors can also be introduced if the equipment is not set up correctly so that zero reading corresponds to the datum point shown on the calibration tables.

Another source of error connected with level measurement is the condition of the liquid surface. Considerable agitation of the surface due to boiling can effect the readings at the end of the loading when conditions in the tanks have not yet reached equilibrium.

Temperature

The necessity for accurate determination of liquid temperature has already been mentioned due to the large expansion coefficiency of liquified gas. It is a fact that some wide variations in temperature accuracy is encountered in shipboard measurement. Thermometers are usually not of the same precision or calibrated as frequenrly as shore instruments but this is understandable as they have to operate in a much harsher environment and it is usually a compromise between accuracy and reliability. Nevertheless some vessels are able to determine the temperature with reasonable precision while others fail miserably. An example of the latter is a vessel which lowers a thermometer down a thermowell into fully refrigerated iso-butane and insists that the temperature is+5oC.

Sufficient temperature points should be mounted in the tank and positioned so that the liquid and vapour temperature can be determined accurately. There are some vessels in service with only one temperature point in each tank and therefore may have problems in obtaining a truly representative temperature.

Pressure

Pressure determination is not usually a critical factor in cargo measurement. Its use is confined to the calculation of vapour quantities, although theoretically there is argument for its use in the computation of a compressed liquid density rather than the Orthobaric density which is commonly used in the cargo calculation.

Part Cargoes

On examining ship/shore differences there is one fact which is particularly noticeable. This is the deviation away from the normal difference when part cargoes are loaded resulting in slack tanks (see comparison Vessel D). This may be due to using a reading in the averaging of the liquid temperature when it is actually in the vapour phase, but the most likely reason is an error in the calibration tables at that particular level. Differences of up to 5% have been noted.

On Board Quantity

The calculation of the quantity loaded on board a vessel is done in two stages. First, the amount of O.B.Q. consisting of vapour and liquid heel on board is calculated, and then on completion the total quantity of liquid and vapour on board. The difference being the quantity loaded. Measurement errors can occur at both stages, but the estimation of the quantity of liquid heel or any residue from previous cargo can be a large source of error. The calibration tables in the bottom section of the tank can be unreliable and also the wedge of liquid may even be outside the range of the level instrument, particularly if the vessel is well trimmed by the stern.

Venting Inerts

Vessels occasionally present themselves for loading with cargo tanks containing inerts, particularly after having arrived from dry-dock. The vessel may then require to dispose of these contaminants by venting off to atmosphere as the ships reliquification equipment cannot contain it on board. The quantities so vented are difficult to assess accurately and therefore contribute to the uncertainty of the final loaded quantities.

Calulation Methods

Different calculation methods of converting the observed volume of both liquid and vapour quantities to volume at standard conditions, and the method used to determine densities for weight conversion give slightly different results. This often leads to disputes as does the old problem of whether the final result is Mass or Weight in Air.

It is not intended to dwell upon this subject as the previous speaker will have covered this thoroughly, except to say for the purpose of the comparisons contained in this paper the COSTALD method, which was developed by Phillips Petroleum Company was used throughout.

Conclusions

The comparison sheets (Appendix 1-6 inclusive) show the Ship/Shore difference between four vessels (A, B, C, and D) and four different meter stations (2, 4, 6 and 8) each with its own dedicated prover.

These differences can be shown as follows:-

Station	Ship A	Ship B	Ship C	Ship D
2	-0.02%	-1.0%	+1.5%	+0.03%
4	+0.06%	-1.7%	-	-
6	-	-1.36%	+1.28%	+0.07%
8	-	-	+0.72%	-0.11%

The above results would indicate that:-

a) The meter stations are in close agreement with each other.

b) Vessels A and B are well calibrated with good instrumentation.

c) There is a possible problem with the measurement of Vessels B and C

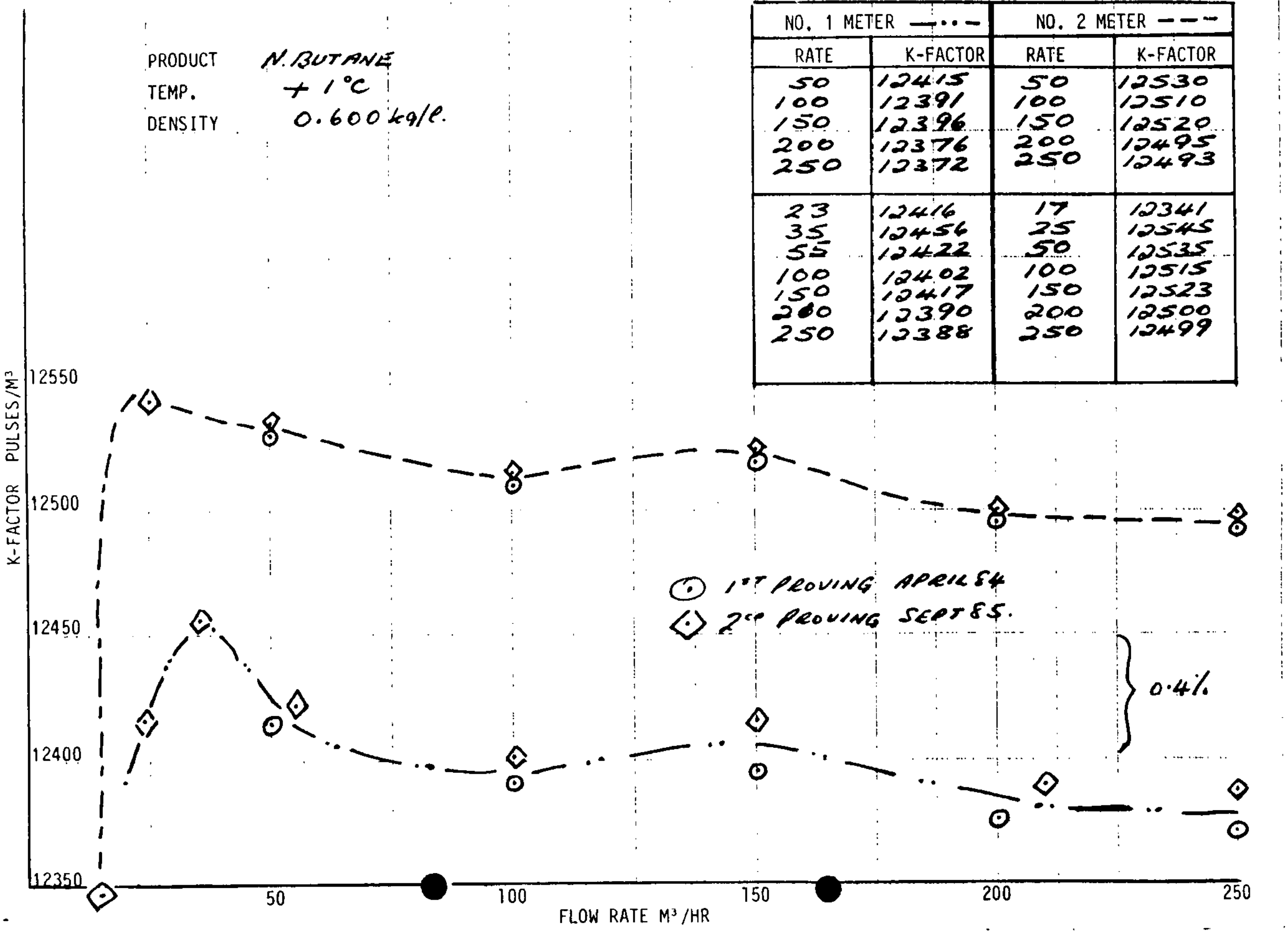
On comparison sheets (Appendix 1-8 incl) are shown the K-Factors of the meters which were proved on each loading. These K-Factors, and others which have been obtained over a number of years, show all turbine meters in Liquified Gas service to have a standard deviation of ±0.1% which is comparable to the long term repeatability of those in other services.

STATION 6 (4" TURBINE WITH 10" BI-DIRECTIONAL PROVER)

FIGURE 1

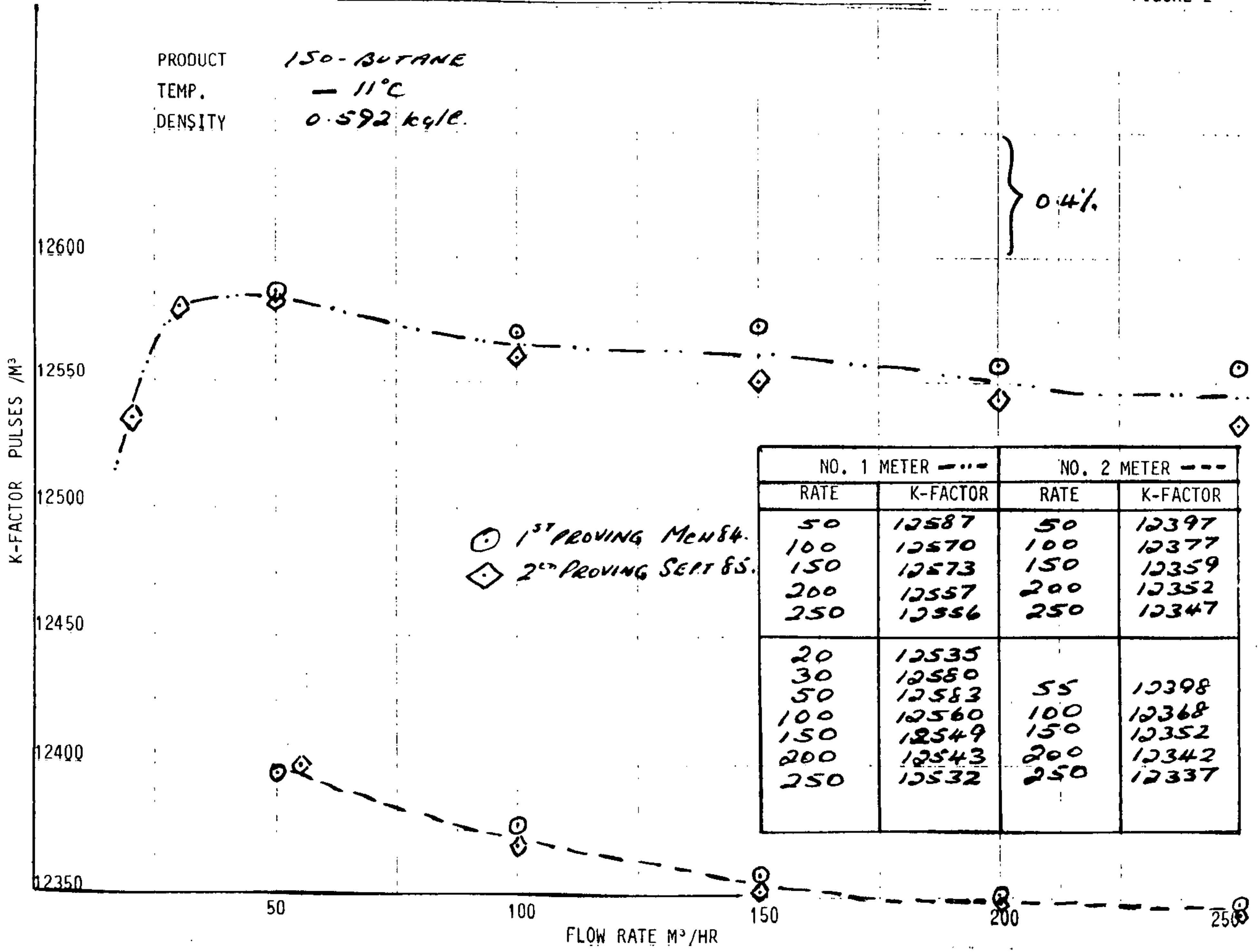
PRODUCT N. BUTANE
TEMP. + 1°C
DENSITY 0.600 kg/l.

NO. 1 METER —··—		NO. 2 METER — — —	
RATE	K-FACTOR	RATE	K-FACTOR
50	12415	50	12530
100	12391	100	12510
150	12396	150	12520
200	12376	200	12495
250	12372	250	12493
23	12416	17	12341
35	12456	25	12545
55	12422	50	12535
100	12402	100	12515
150	12417	150	12523
200	12390	200	12500
250	12388	250	12499



STATION [illegible] (4" TURBINE METER WITH 10" BI-DIRECTIONAL PROVER)

FIGURE 2

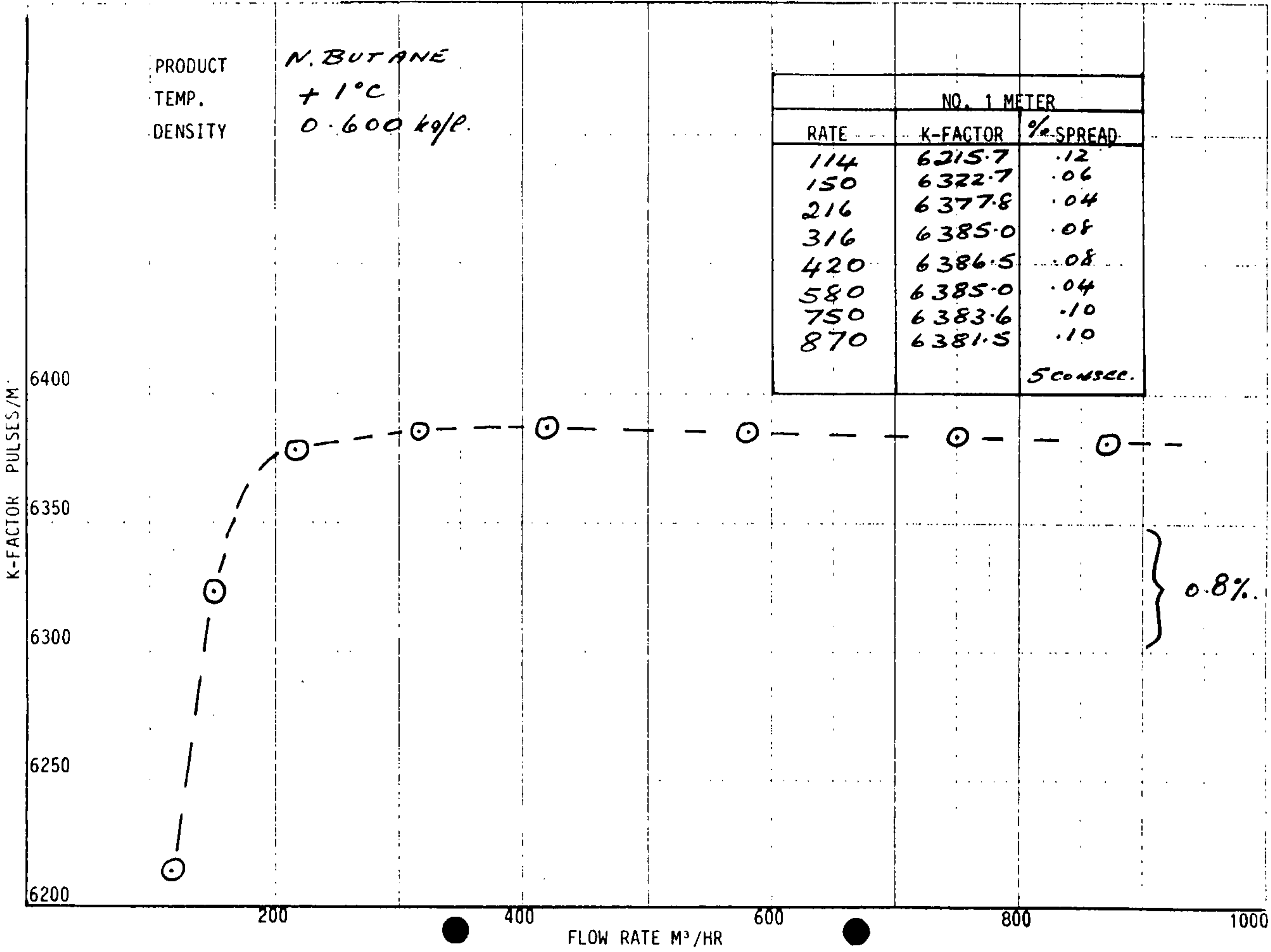


PRODUCT ISO-BUTANE
TEMP. − 11°C
DENSITY 0.592 kg/l.

NO. 1 METER —··—		NO. 2 METER — — —	
RATE	K-FACTOR	RATE	K-FACTOR
50	12587	50	12397
100	12570	100	12377
150	12573	150	12359
200	12557	200	12352
250	12556	250	12347
20	12535		
30	12580		
50	12583	55	12398
100	12560	100	12368
150	12549	150	12352
200	12543	200	12342
250	12532	250	12337

STATION 4 (8" TURBINE METER WITH 24" PISTON PROVER)

FIGURE 3

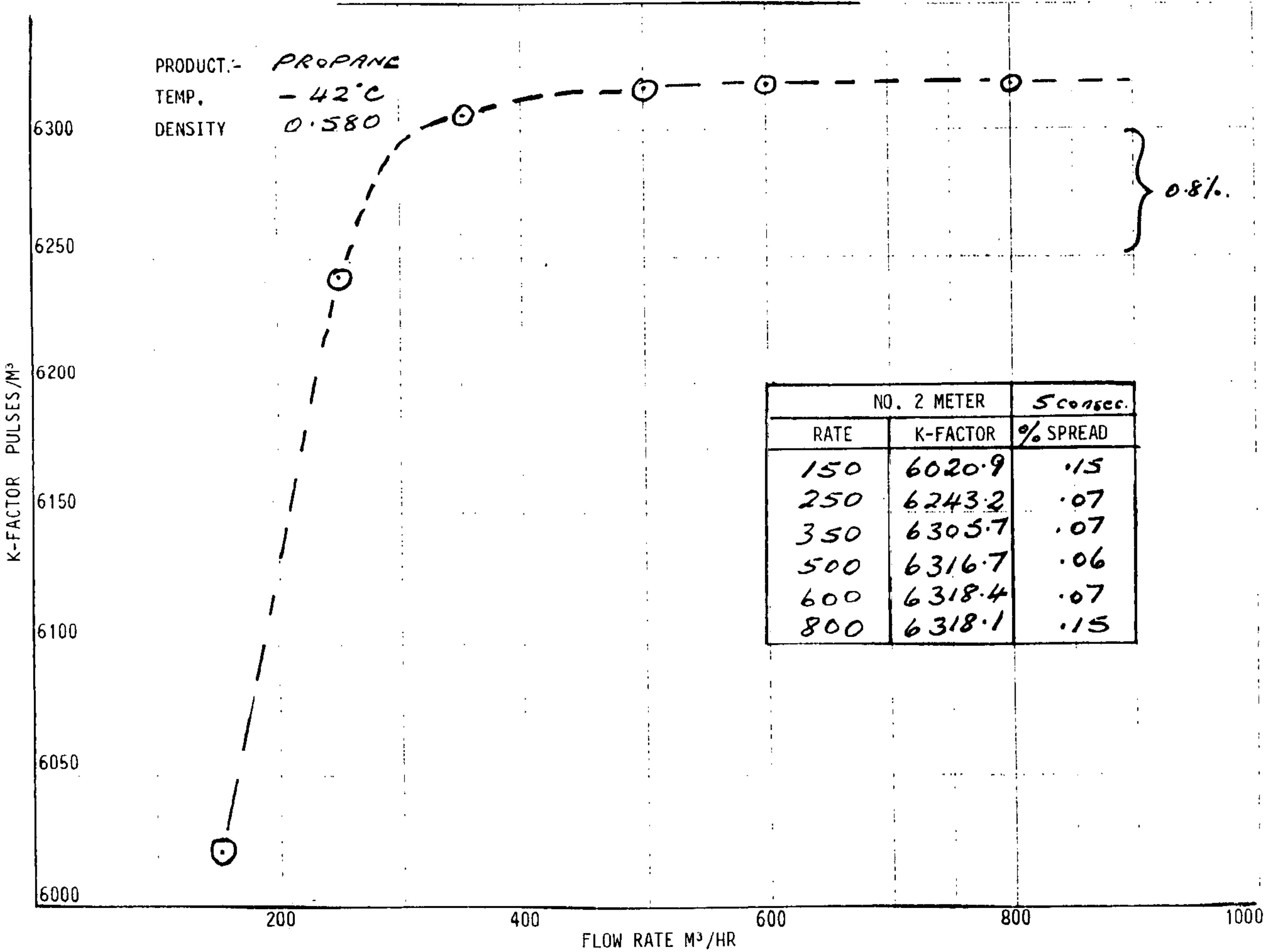


PRODUCT N. BUTANE
TEMP. + 1°C
DENSITY 0·600 kg/l.

NO. 1 METER		
RATE	K-FACTOR	% SPREAD
114	6215·7	·12
150	6322·7	·06
216	6377·8	·04
316	6385·0	·08
420	6386·5	·08
580	6385·0	·04
750	6383·6	·10
870	6381·5	·10
		5 consec.

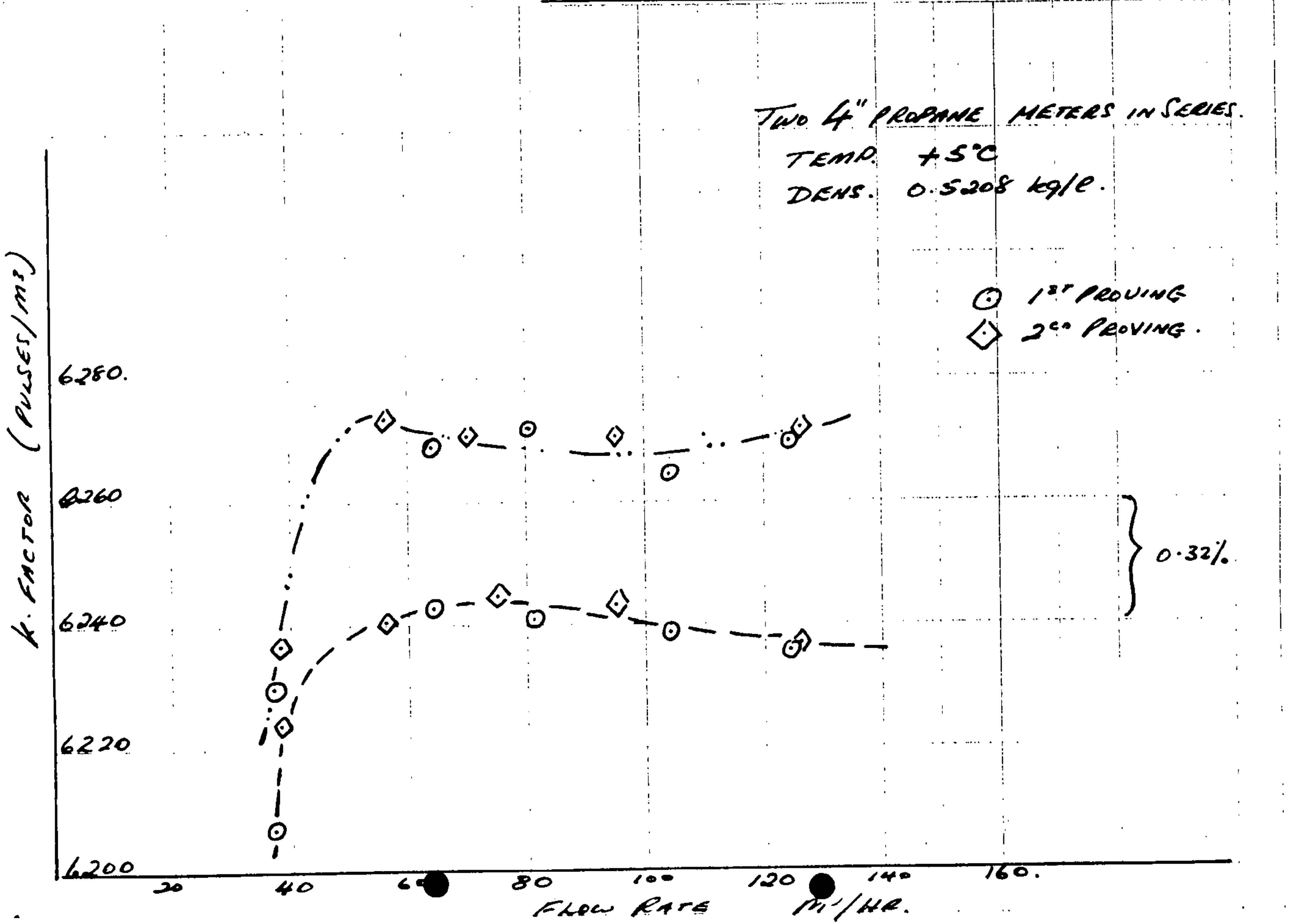
FIGURE 4

STATION 6 (8" TURBINE METER WITH 24" PISTON PROVER)



NO. 2 METER		5 consec.
RATE	K-FACTOR	% SPREAD
150	6020·9	·15
250	6243·2	·07
350	6305·7	·07
500	6316·7	·06
600	6318·4	·07
800	6318·1	·15

4" PROPANE METER - PORTABLE PROVER. FIG. 5.



TWO 4" PROPANE METERS IN SERIES.
TEMP. +5°C
DENS. 0.5208 kg/l.

COMPARISON BETWEEN SHIPS FIGURES AND METER FIGURES FOR GAS VESSELS APPENDIX 1

VESSEL	JETTY NO.	METER STATN	PRODUCT	LOADED QUANTITY (TONNES)		METER DIFF. %	METER K-FACTOR			REMARKS
				METER	SHIP		1	2	3	
"A"	6	2	iC4	1872.9	1872.1	+.04	12340	12467		
	"	"	"	12598	1259.2	+.05	12346	12482		Vessel "A"
	"	"	"	1864.2	1864.1	Nil	12337	12473		STATION 2
	"	"	"	1858.2	1857.8	+.02	12336	12471		ISO BUTANE
	"	"	"	1864.2	1874.6	-.56	12345	12467		
	"	"	"	1868.0	1865.5	+.13	12338	12464		4" METER
	"	"	"	1864.1	1864.0	Nil	12347	12488		BI-DIR. PROVER.
	"	"	"	1158.2	1159.4	-.10	12338	12484		
	"	"	"	1867.1	1868.9	-.10	12343	12488		
	"	"	"	1865.4	1865.6	-.01	12341	12475		
	"	"	"	1863.5	1867.8	-.23	12337	12464		
	"	"	"	1863.6	1866.2	-.14	12341	12471		
	"	"	"	1863.4	1864.7	-.07	12343	12471		
	"	"	"	1858.7	1861.5	-.15	12344	12466		
	"	"	"	1866.6	1862.7	+.21	12340	12475		
	"	"	"	1273.4	1271.5	+.15	12345	12478		
	"	"	"	1233.6	1228.9	+.38	12342	12476		
	"	"	"	1861.5	1858.6	+.16	12347	12476		
	"	"	"	1155.1	1156.9	-.16	12345	12486		
	"	"	"	1867.7	1866.7	+.05	12342	12481		
		MEAN:				-.02	12342	12475		

COMPARISON BETWEEN SHIPS FIGURES AND METER FIGURES FOR GAS VESSELS APPENDIX 2

VESSEL	JETTY NO.	METER STATN	PRODUCT	LOADED QUANTITY (TONNES)		METER DIFF. %	METER K-FACTOR			REMARKS
				METER	SHIP		1	2	3	
"A"	8	4	iC4	1871.3	1871.9	-.03	12560	12362		
	"	"	"	1868.3	1869.2	-.05	12572	12358		VESSEL "A"
	"	"	"	1874.8	1874.7	Nil	12574	12362		STATION 4
	"	"	"	1873.5	1872.4	+.06	12566	12363		ISO BUTANE
	"	"	"	1863.8	1862.4	+.08	12563	12356		
	"	"	"	1863.9	1862.0	+.10	12564	12354		4" METER
	"	"	"	1870.1	1866.5	+.19	12564	12354		BI-DIR. PROVER
	"	"	"	1869.2	1868.1	+.06	12572	12356		
	"	"	"	1870.9	1869.1	+.09	12562	12365		
	"	"	"	1865.1	1863.4	+.09	12573	12360		
	"	"	"	1863.7	1864.6	-.05	12572	12358		
	"	"	"	1864.0	1864.5	-.03	12569	12360		
	"	"	"	1862.7	1863.6	-.05	12567	12357		
	"	"	"	1867.9	1861.7	+.33	-	12353		
	"	"	"	1863.4	1860.4	+.16	12579	12362		
		MEAN:				+.06	12568	12359		

COMPARISON BETWEEN SHIPS FIGURES AND METER FIGURES FOR GAS VESSELS APPENDIX 3

VESSEL	JETTY NO.	METER STATN	PRODUCT	LOADED QUANTITY (TONNES)		METER DIFF. %	METER K-FACTOR			REMARKS
				METER	SHIP		1	2	3	
"B"	6	2	iC4	1375.8	1392.1	-1.18	12344	12464		
	"	"	"	1381.2	1393.2	-.94	12331	12453		VESSEL "B"
	"	"	"	1371.0	1369.0	+.14	12335	12449	12366	
	"	"	"	1371.2	1387.3	-1.17	12338	-	-	STATION 2
	"	"	"	1374.1	1391.9	-1.29	12337		12372	ISO BUTANE
	"	"	"	1371.6	1391.0	-1.41	12335		12371	
	"	"	"	1373.6	1391.5	-1.30	-	12457	12365	4" METER
	"	"	"	1376.8	1392.5	-1.14	12325		12365	BI-DIR PROVER
	"	"	"	1378.0	1390.5	-.93	12319	-	-	
	"	"	"	1095.0	1104.4	-.81	12329	-	-	
		MEAN:				-1.00	12333	12456	12368	
"B"	8	4	iC4	1371.8	1394.5	-1.65	-	12370	12461	STATION 4
	"	"	"	1386.4	1391.6	-.37	12569	-	-	ISO BUTANE
	"	"	"	1374.8	1392.0	-1.25	-	12346	12450	
	"	"	"	1376.5	1392.7	-1.17	12569	-	-	
		MEAN:				-1.11	12569	12358	12455	
"B"	6	6	nC4	1398.8	1417.9	-1.36	12387	12497	12386	STATION 6
										NORMAL BUTANE.

COMPARISON BETWEEN SHIPS FIGURES AND METER FIGURES FOR GAS VESSELS APPENDIX 4

VESSEL	JETTY NO.	METER STATN	PRODUCT	LOADED QUANTITY (TONNES)		METER DIFF. %	METER K-FACTOR			REMARKS
				METER	SHIP		1	2	3	VESSEL "C"
"C"	6	2	iC4	1165.4	1152.0	+1.06	12333	12458	12365	STATION 2
	"	"	"	1163.1	1148.5	+1.25	12318	12450	12360	ISO BUTANE
		MEAN:				+1.15	12326	12454	12362	
										4" METER
										BI-DIR. PROVER
"C"	6	6	nC4	1380.5	1357.7	+1.65	-	12484		STATION 6
	"	"	"	1256.9	1249.2	+.61	12404	12516		NORMAL
	"	"	"	1469.9	1452.2	+1.20	12400	12520		BUTANE.
	"	"	"	1469.9	1445.3	+1.67	12400	12521		
		MEAN:				+1.28	12401	12510		
"C"	8	8	nC4	1468.9	1453.7	+1.03	12320	12478		STATION 8
	"	"	"	1452.6	1446.6	+.41	12317	12464		NORMAL
		MEAN:				+.72	12318	12471		BUTANE.

COMPARISON BETWEEN SHIPS FIGURES AND METER FIGURES FOR GAS VESSELS APPENDIX 5

VESSEL	JETTY NO.	METER STATN	PRODUCT	LOADED QUANTITY (TONNES)		METER DIFF. %	METER K-FACTOR			REMARKS
				METER	SHIP		1	2	3	
"D"	6	2	iC4	952.5	963.2	-1,12	12344	12487		VESSEL "D"
	"	"	"	1409.8	1410.8	-.07	12331	12457		STATION 2
	"	"	"	1364.9	1365.6	-.05	12336	12461		ISO BUTANE
	"	"	"	1399.9	1398.3	+.11	12326	12460		
	"	"	"	1365.0	1363.1	+.14	12346	12481		4" METER
		MEAN:				+.03	12337	12468		BI-DIR PROVER.
"D"	8	8	nC4	1429.4	1432.5	-.22	12308	12489		STATION 8
	"	"	"	1441.8	1442.1	-.02	12311	12468		NORMAL
	"	"	"	1434.7	1437.4	-.19	12303	12492		BUTANE.
	"	"	"	1436.7	1433.1	+.25	12285	12499		
	"	"	"	1259.8	1261.2	-.11	12313	12499		
	"	"	"	1154.2	1158.7	-.39	12312	12483		
		MEAN:				-.11	12305	12488		

COMPARISON BETWEEN SHIPS FIGURES AND METER FIGURES FOR GAS VESSELS APPENDIX 6

VESSEL	JETTY NO.	METER STATN	PRODUCT	LOADED QUANTITY (TONNES)		METER DIFF. %	METER K-FACTOR			REMARKS
				METER	SHIP		1	2	3	
"D"		6	nC4	1446.9	1447.9	-.07	12391	12504	12382	VESSEL D.
	"	"	"	1441.9	1442.1	-.01	12408	12511	12373	
	"	"	"	1439.8	1439.6	+.01	12403	12510		STATION 6
	"	"	"	1432.2	1431.7	-.03		12495	12375	NORMAL
	"	"	"	1431.4	1430.5	+.06	12378	12516	12382	BUTANE
	"	"	"	1428.4	1430.5	-.13	12385	12504		
	"	"	"	1435.9	1430.5	+.38	12390	12516		4" METER
	"	"	"	1434.3	1429.9	+.30	12386	12513		BI-DIR.
	"	"	"	1438.6	1440.5	-.13	12400	12522		PROVER.
	"	"	"	1433.6	1435.6	-.14	12403	12516		
	"	"	"	1436.9	1432.2	+.26	12383	12520		
	"	"	"	1435.6	1434.5	+.08	12402	12518		
	"	"	"	1441.1	1437.1	+.28	12402	12501		
	"	"	"	1432.8	1433.6	-.06	12419	12512		
	"	"	"	1428.3	1430.3	-.14	12400	12511		
	"	"	"	1430.5	1439.4	+.08	12404	12507		
	"	"	"	1443.7	1441.8	+.13	12401	12515		
	"	"	"	1433.1	1428.2	+.34	12418	12505		
		MEAN:				+.07	12398	12511	12378	

COMPARISON BETWEEN SHIPS FIGURES AND METER FIGURES FOR GAS VESSELS APPENDIX 7

VESSEL	JETTY NO.	METER STATN	PRODUCT	LOADED QUANTITY (TONNES)		METER DIFF. %	METER K-FACTOR			REMARKS
				METER	SHIP		1	2	3	
"X"	3	3	REFnC4	3380.4	3385.5	-.15	6380	6416	6343	
	"	"	"	3373.3	3376.5	-.09		6411	6332	
	"	"	"	3336.4	3336.9	Nil	6390	6410		NORMAL
	"	"	"	3351.2	3348.6	+.08	6389	6413		BUTANE
	"	"	"	3340.8	3345.2	-.13	6390	6415		
	"	"	"	3351.5	3360.2	-.26	6394	6416		8" METER
	"	"	"	3360.5	3366.4	-.17	6389	6414		PISTON
	"	"	"	3345.9	3350.7	-.14	6393	6411		PROVER
	"	"	"	3339.3	3350.4	-.33	6384	6411		
	"	"	"	3331.1	3340.5	-.28	6389	6416		
	"	"	"	3340.2	3351.5	-.34	6387	6412		
	"	"	"	3361.8	3369.8	-.24	6389	6420		
	"	"	"	3346.3	3361.3	-.44	6393	6419		
	"	"	"	3350.8	3353.3	-.07	6379	6424	6340	
	"	"	"	3349.8	3353.3	-.10	6382	6412	6340	
		MEAN:				-.16	6388	6415	6339	
"Y"	"	"	"	3350.6	3353.9	-.09	6378	6411		
	"	"	"	3354.8	3364.9	-.30	6393	6416		
	"	"	"	3344.3	3348.2	-.12	6385	6412		
	"	"	"	3346.5	3343.9	+.07	6385	6415		
		MEAN:				-.11	6385	6413		
"Z"	"	"	"	3474.1	3482.5	-.24	6381	6412	6338	
	"	"	"	3479.1	3481.5	-.07	6383	6416	6343	
		MEAN:				-.15	6382	6414	6340	

COMPARISON BETWEEN SHIPS FIGURES AND METER FIGURES FOR GAS VESSELS APPENDIX 8

VESSEL	JETTY NO.	METER STATN	PRODUCT	LOADED QUANTITY (TONNES)		METER DIFF. %	METER K-FACTOR			REMARKS
				METER	SHIP		1	2	3	
"X"	4	6	REF C3	6784.0	6786.0	-.03	6466	6312		
	"	"	"	5228.3	5225.5	+.05	6460	6316		
	"	"	"	6773.0	6775.0	-.03	6464	6312		PROPANE
	"	"	"	6800.3	6796.7	+.05		6313	6296	
	"	"	"	6771.2	6777.5	-.09		6320	6302	8" METER
	"	"	"	6809.3	6806.2	+.05		6316	6303	PISTON
	"	"	"	3573.9	3570.3	+.10		6318	6300	PROVER
	"	"	"	6802.6	6810.2	-.10	6463	6304		
	"	"	"	3564.2	3566.2	-.05			6305	
	"	"	"	3562.4	3569.2	-.20	6466	6315		
	"	"	"	6799.3	6823.6	-.36	6465	6323		
	"	"	"	6777.3	6797.9	-.30	6466		6298	
	"	"	"	6785.7	6814.3	-.40		6318	6300	
	"	"	"	3572.9	3582.0	-.25		6314	6301	
	"	"	"	3578.0	3594.2	-.45		6290	6314	
	"	"	"	6799.6	6831.6	-.47		6320	6305	
	"	"	"	6803.1	6836.6	-.52		6312	6304	
		MEAN:				-.20	6464	6314	6303	
"Y"	"	"	"	3551.9	3571.7	-.56		6316	6311	
	"	"	"	6762.0	6806.2	-.65		6318	6312	
		MEAN:				-.60		6317	6311	
"Z"	"	"	"	13542.3	13560.5	-.13		6307		

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.