SOUTH EUROPEAN PIPELINE CENTRAL PROVING FACILITY

by

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RESUME

The following text describes the experience of a user of a metering system with centralized calibration in a multi-product, multi-user crude oil pipeline. It also describes the general principles of the metering system, the precautions to be taken when designing it, the periodical on-the-spot checks and the global control, including the centralized turbine meter calibration station of Fos-sur-Mer.

1 PRESENTATION OF SOUTH EUROPEAN PIPELINE

South European Pipeline was founded in 1958 by the major oil companies supplying Western Europe.

It is one of the main pipelines supplying the center of Europe. The refineries in the Upper Rhine are supplied from the Mediterranean ports of Fos-sur-Mer and Lavera near Marseille : three refineries in the Karlsruhe area, two in the East of France, one in Switzerland and one in the Rhone valley near Lyon.

It is made up of three lines :

- one 40" pipeline connecting Fos-sur-Mer to Strasbourg and extended to Karlsruhe via a 34" line, providing a total length of 770 km,
- one 24" pipeline connecting Fos-sur-Mer to Lyon (260 km),
- one 34" pipeline connecting Fos-sur-Mer to Strasbourg, presently mothballed.

It began operating in 1962 with the 34" line up to Karlsruhe and was extended in 1972 with the 40" and 24" lines.

The 19 pumping stations spread out along the lines have provid[ed] transport of more than 800 million tons of oil since the beginning [of] operations and despite the present difficulties encountered by refineries in Europe, it will have transported more than 20 million tons in 1990, i.e. nearly a third of the French consumption of oil.

The crude oil unloaded from ships is stored in the head tank farm located in Fos-sur-Mer, then sent through pipelines one batch after another without physical separation between the batches.

2 THE PRINCIPLE OF METERING WITH CENTRAL PROVING

2.1 The importance of quantity measurements for S.E.P.L.

The unitary volume of the batches being rather low (30,000 to 50,000 m3) in relation to the total volume of the pipeline (560,000 m3 for the 40"), the line is always filled with successive sections of different crudes belonging to different clients. This type of operation necessitates strict control of the quantities delivered [at] each delivery terminal.

It should be noted that any measurement system with a systematic error would give an advantage to one client to the detriment of all the other users.

Moreover, this same systematic error would cause a false result for the balance of the refinery concerned, this balance consisting in the comparison of the total mass of the refinery's production with the total mass of the crude entering it.

These custody transfer measurements were initially carried out by gauging the refineries' tanks on the receiving end (with tank sampling for calculation of the mass).

Given the arrival of large multi-product turbines and the considerable increases in the price of crude from 1970 - 1975, it has become both possible and necessary to improve these custody transfer measurements.

South European Pipeline therefore equipped its installations with measuring systems using turbine meters which measure the quantities delivered, first for volume only and then for measurement of mass.

2.2 General principles of the S.E.P.L. custody transfer measurement system (figure 1)

The custody transfer measurements are carried out at the points of delivery, i.e. at the entrance to the client refinery.

Each point of entry is thereby equipped with a metering bench. According to the pipeline supplying the refinery, the metering bench uses two 16" turbines operating in parallel (refineries supplied by the 40" line - Maximum flow rate 6,000 m3/h) or two 12" turbines (refineries supplied by the 24" line - Maximum flow rate 4,000 m3/h).

As a back-up system, in case of a failure in the metering system, gauging is carried out in the clients' tanks.

At the beginning of each pipeline, a metering bench identical to those located at the points of delivery measure the volumes entering the pipeline, thereby ensuring global validation of the metering system.

All the turbines are regularly calibrated in a calibration station located in Fos-sur-Mer.

2.3 <u>The Fos-sur-Mer calibration station</u> (figure 2)

When the metering system was designed, 2 solutions were considered:

- The traditional solution which consists in fitting out each metering installation with a prover loop.

- The new solution at that time, which consisted in one fixed central proving station on which the periodical calibrations of all the meters being used were to be carried out.

The second solution had an obvious financial advantage (a single piece of calibration equipment instead of one per terminal, the use of series 150 equipment instead of series 300) but it necessitated great precaution in the choice of turbine meters (repeatability, resistance to wear) and also at the level of the geometry of the benches so that the meters are not influenced by local hydraulic conditions. This solution was retained and lead to the construction of a calibrating station in Fos-sur-mer, equipped with :

- a unidirectional prover loop with a maximum flow rate of 3,000 m3/h and a capacity of 15,000 liters. Volume is checked every 3 years by the French Metrological Authorities.

- a closed calibrating circuit including :

  . a variable speed pump allowing for continuous flow adjustment from 150 to 4,000 m3/h,

  . a metering bench 20 meters long for turbines having a maximum diameter of 20",

  . two metering benches also 20 meters in length for turbines having a maximum diameter of 16",

- four storage tanks each having a capacity of 80 m3 providing standard calibration liquids whenever needed,

  Standard liquids have a typical kinematic viscosity of 1 mm^2/s, 10 mm^2/s, 30 mm^2/s and 120 mm^2/s.
  Other values within these ranges can be obtained by changing the calibration temperature.

- lines connected to the head tank farm allowing for calibrations to be carried out on whatever products are contained therein (40 tanks) also providing for a wider range of viscosities which can be used,

- a double chronometer,

- an on-line viscometer,

- temperature and pressure sensors for turbine and prover loop,

- a computer making all corrections related to calibration with a print-out of results.

The station operates normally up to 3,000 m3/h in a direct comparison between a turbine meter and the prover loop according to diagram 1 (figure 3).

It can also be used between 3,000 and 4,000 m3/h according to diagram 2 by comparing the turbine to be calibrated with two master meters in parallel previously calibrated by direct comparison with the prover loop.

Calibration results are printed in the form of a certificate which mentions the conditions of each test. These results are expressed in the form of the number of pulses per m3 or in the form of an error or a correction factor (figure 4).

Moreover, the station computer prints out a table which provides the correction factor for 100 flow - viscosity values (5 viscosities ; 20 flow-rates).

This table is then manually entered in the memory of the metering bench computer which, as it continually measures the present viscosity and flow-rate, determines the correction factor to be applied by linear interpolation between the nearest values of the table (figure 5).

These results are recognized by the French Metrological Authorities and by the German PTB.

An agreement with the "Bureau National de Metrologie" is presently being worked out and will result, in the short term, in the certification of this calibration station as a "Service de Métrologie Habilité" (Recognized Metrological Service).

This calibration station was first constructed for the needs of S.E.P.L. and is now used by third parties for periodical calibrations or for acceptance tests on meters ranging from 6" to 20".

2.4 Description of a South European Pipeline metering bench

2.4.1. **Hardware** (figure 6)

- Two 16" turbines operating in parallel and each having a maximum flow rate of 3,000 m3/h , each of which is incorporated in a measurement section (figure 7) composed of :
    - . a flow-corrector which will be described in paragraph 2.5,
    - . a straight upstream length, 16" diameter and having a length 17 times this diameter, including an interior epoxy lining,
    - . a 16" flow-straightener
    - . a straight downstream length 16" in diameter having a length 5 times this diameter,
- a control valve which maintains minimum pressure downstream from the turbines,
- a measuring cabinet composed of :
    - . a flow pump
    - . a densimeter
    - . a double viscometer
    - . a temperature probe
    - . a pressure probe
- a metering computer
- a local display device
- a printer
- a device for transmission of data to the dispatching center in Fos-sur-Mer.

2.4.2 **Software**

Calculations carried out by the metering computer

- correction of the influence of the temperature on the turbines,
- correction of the influence of the viscosity and the flowrate on the turbines, using the calibration table established by the Fos calibration station and which has been entered into the computer memory,
- calculation of the volume at measuring conditions,
- mass calculation

- commercial mass calculation (deduction from the air buoyancy),

- volume calculation at 15°C (ISO 91/1),

- volume calculation at atmospheric pressure.

Validations carried out

Since the metering equipment operates in the terminals without personnel and therefore without surveillance, automatic monitoring has been especially important for the good working order of the installation.

Two categories of alarm signals transmitted to the dispatching center have been defined :

- Major alarms corresponding to a serious alteration in metering and necessitating an immediate pipeline stop and the use of a back-up method for measuring quantities delivered (gauging of tanks).

  Examples are as follows :

  . abnormal flowrate deviation between the two turbines,

  . densimeter flow pump stop,

  . computer failure.

- The minor alarms, corresponding to an abnormal condition which has been detected and either having a negligible influence on the metering or able to be corrected. For example, failure of a pressure probe or of a viscometer. In all cases, a minor alarm necessitates a counter-investigation afterwards.

2.4.3 **Periodical check-ups**

The temperature, pressure, density and viscosity measuring systems are checked every month in relation to the corresponding standards.

Every year (in France) or every 6 months to two years according to th different sites in Germany, the turbines with their related flow-straighteners are replaced by a pair of spare turbines which have been calibrated at the Fos-sur-Mer calibration station. The turbine/flow-straightener assemblies which have been removed are sent to Fos-sur-Mer where they are recalibrated for use in another terminal.

2.5 Usefulness of flow-correctors

In the beginning, the geometry of the metering benches and especially of the straight lengths preceding the turbines were different according to the space available at each metering bench. These lengths varied from 6 to 14 meters.

Moreover, the geometry of the pipes upstream from the straight lengths were different according to the sites and in certain cases included several 90° elbows near the straight lengths of pipe.

We wanted to know the influence of these geometrical differences on the metering results.

We therefore reconstituted, in Fos-sur-Mer, a replica of two metering benches including the one having the most irregular geometry (Karlsruhe) and we installed them in the calibration station circuit (figure 8).

We were thus able to compare the behavior of the same turbine installed in the 20 meter straight length at the calibration station and installed in the metering benches.

The results are found in the calibration curves A and B (figure 9).

These curves were traced in the following conditions :

- On the **x** axis, instead of showing the flowrate, we showed the flowrate/viscosity ratio as a logarithmic value. This ratio is more or less comparable to a Reynolds number and provides for better comparison between the curves by eliminating the influence of the slight viscosity deviations which may exist between two tests.

- The **y** axis (the turbine coefficient) was extremely dilated thereby showing very small deviations more clearly.

  . Curve A - turbine n° 9965 - Karlsruhe Terminal

  . Curve B - turbine n° 9966 - Woerth Terminal

Comparison of the two curves shows a systematic deviation of approximately 0.04 % to 0.08 %.

Although slight and within the tolerances generally deemed acceptable, we have not considered that these systematic deviations between metering benches were satisfactory, especially for a shared network such as the South European Pipeline.

We therefore searched for a device capable of destroying the hydraulic influence of each upstream pipe configuration. For this reason, we used a blending device which we call a "flow corrector" followed by strictly identical straight lengths of pipe on all the metering benches and the calibration station. Consequently, a turbine calibrated at the calibration station preceded by a flow-corrector operates in exactly the same conditions in any delivery terminal.

Replica testing rebegan after installation of flow-correctors.

Curve C (figure 10) shows an excellent superposition of the results over the whole range of viscosities. The deviation between the calibration station and the metering bench replicas does not exceed 0.03% and is not systematic.

We therefore generalized the use of flow correctors to all metering benches equipped with 16" turbines.

Details of these tests are found in a report presented at the International Organization of Legal Metrology which was held in Arles, France in May 1987 (1).

3 RESULTS

We do not have the means for measuring the accuracy of a metering system with centralized proving.

However, certain control procedures ensure us that there is no systematic deviation in the system taken as a whole.

Three types of control procedures are thus carried out :

. Follow-up of the evolution of the turbines calibration curves

Every time a calibration is made, we compare the curve obtained with the preceding one. Experience has shown that within a one-year period of use, the average deviation is generally less than 0.05 % (figure 11).

. Comparison with clients' tanks

The clients' tanks are equipped with gauging systems, allowing for a comparison between the volume measured in the tank and the volume indicated by the meter. Although tank-gauging can not be considered as a reference, this comparison allows for long-term detection of a deviation in one measuring system or the other (figure 12).

An examination of such a curve - example 1 - shows that the deviations vary from 0 to 0.2 %. We have noted that changes of turbines have no influence on the result of these comparisons.

In example 2, for which tank measurements are carried out by manual gauging and manual temperature determination, deviations vary from +0.2% to -0.2%. In this case, we note annual periodical fluctuations corresponding to an over-estimation of the gauging in winter and under-estimation in the summer. This phenomenon has not bee explained but it is reasonable to think that it is related to manu temperature measurements in the tanks.

. Comparison between volumes entering and volumes leaving the pipeline

Figure 13 shows the monthly and accumulated deviations between volumes entering the pipeline measured by the metering bench at the point of departure and the volumes coming out of the line as measured by the delivery terminal metering benches. Here we note that the difference over a one year period is approximately 0.01 %.

4 CONCLUSION

A metering system with centralized proving provides the following advantages :

- to reduce investments by avoiding implantation of prover loops on every metering installation,
- to reduce operating costs by avoiding maintenance and periodical recalibration of several prover loops,
- to control the flowrates and calibration viscosities which is particularly important for acceptance tests of meters, whether new or after repairs.

On the other hand, when great accuracy is required, this method necessitates that extensive care be taken in regards to the choice of turbine meters and the geometry of the metering benches in order to avoid irregularities in flow due to pipe configurations.

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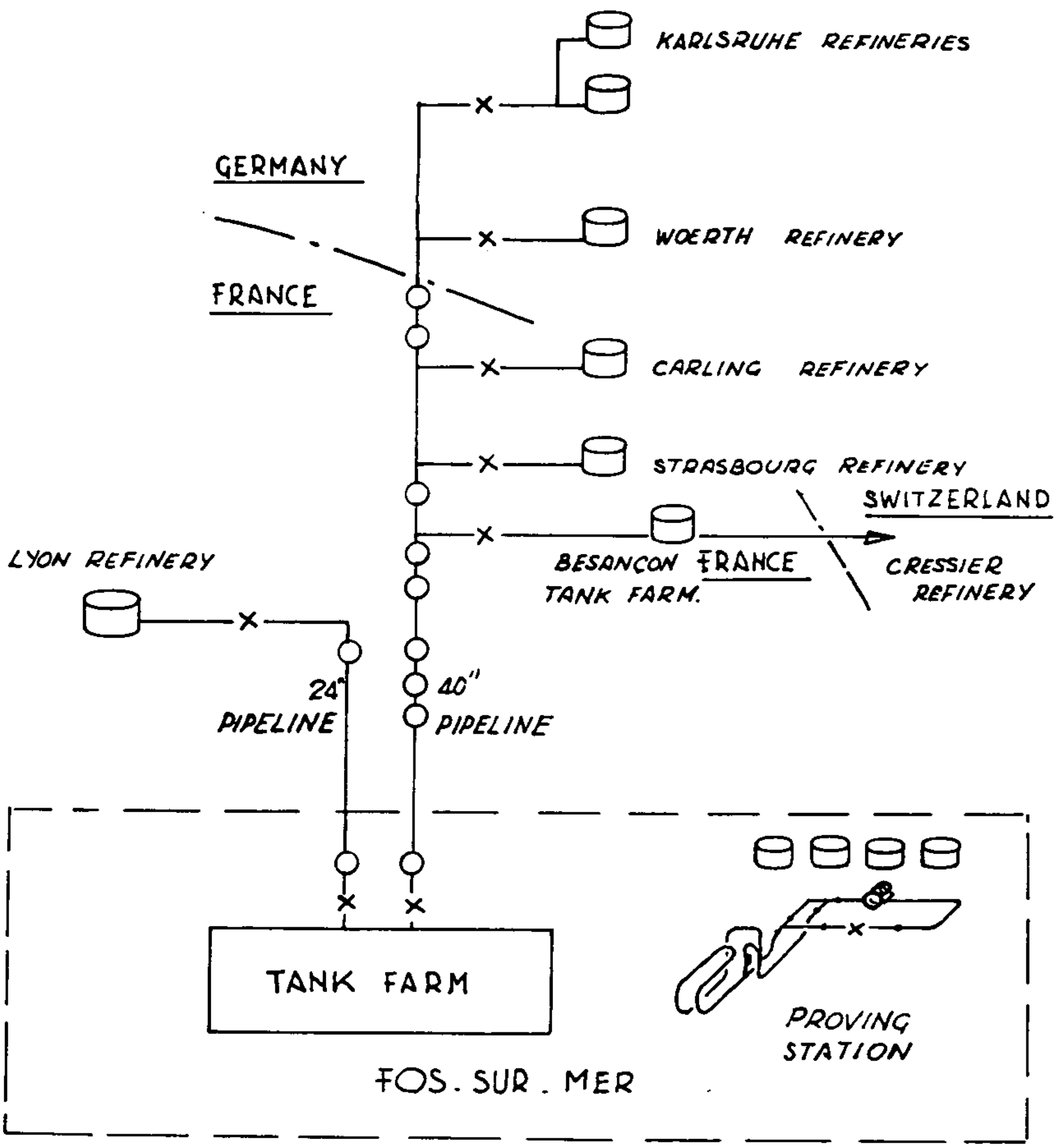
Reference

(1) Y. BARRIOL and J.L. CONVERT - "Improvement of the accuracy of the measuring stations of South European Pipeline"
Bulletin de l'Organisation Internationale de Métrologie Légale - N° 112 - September 1988 - pages 27 - 31.

GENERAL PRINCIPLES OF THE S.E.P.L. CUSTODY TRANSFER MEASUREMENT SYSTEM.



× Metering Station

○ Pumping Station

FIGURE 1

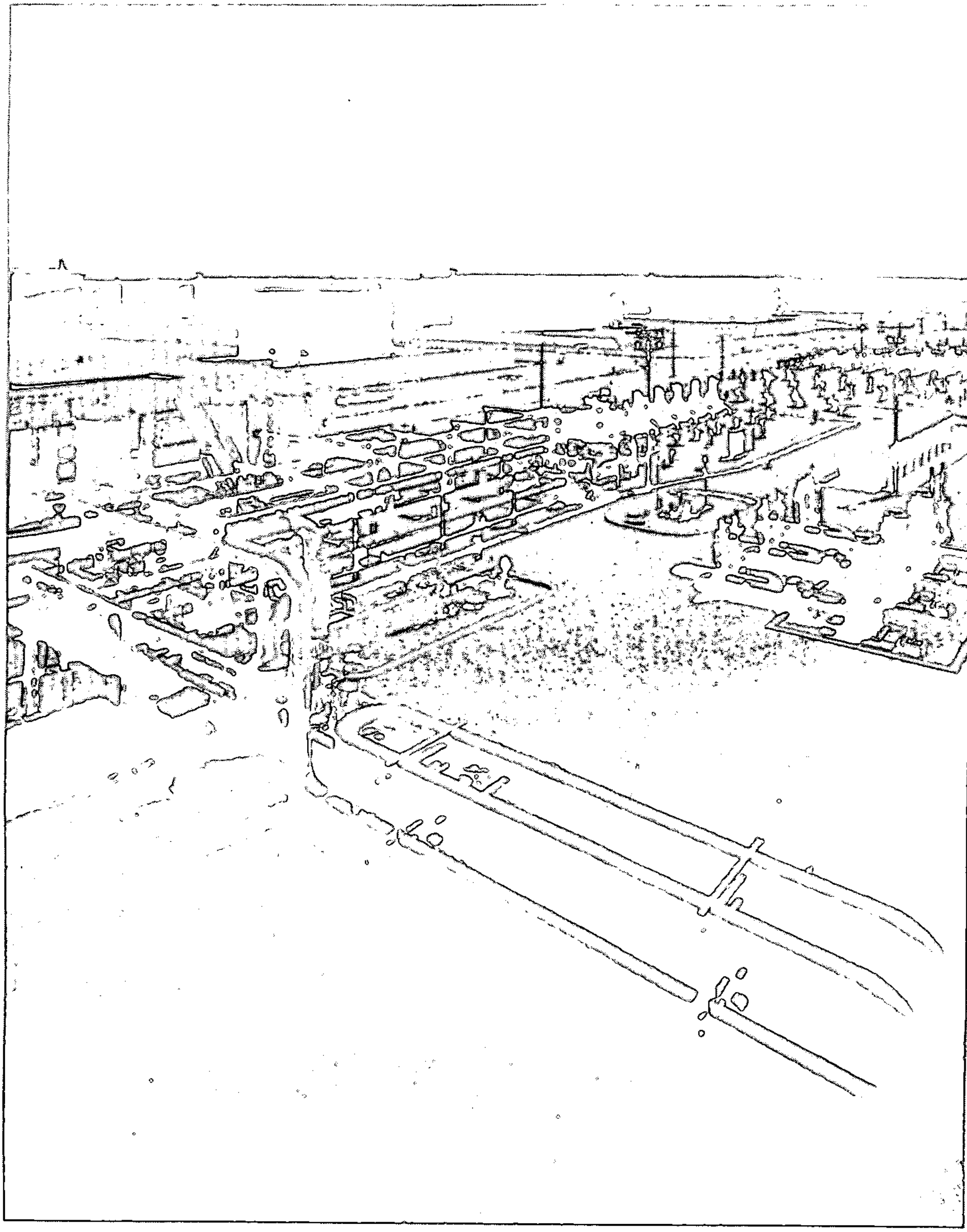
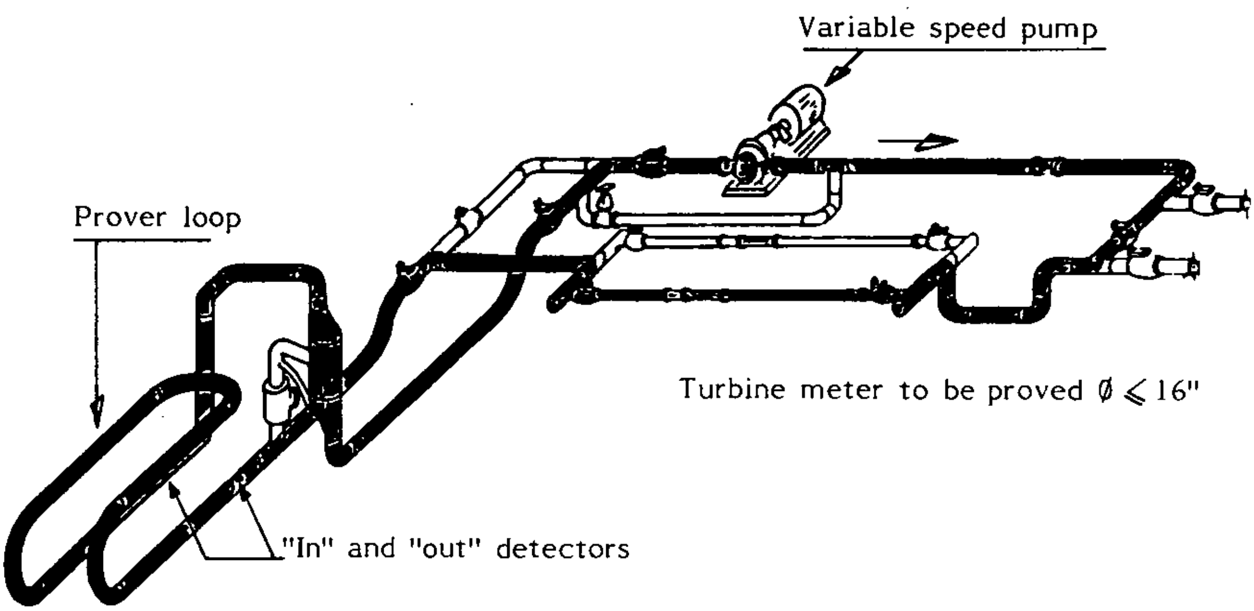


FIGURE 2

TURBINE METERS PROVING STATION - PROVING METHODS.

Sketch 1 STANDARD PROVING



Operated circuit

Sketch 2 PROVING WITH MASTER METERS

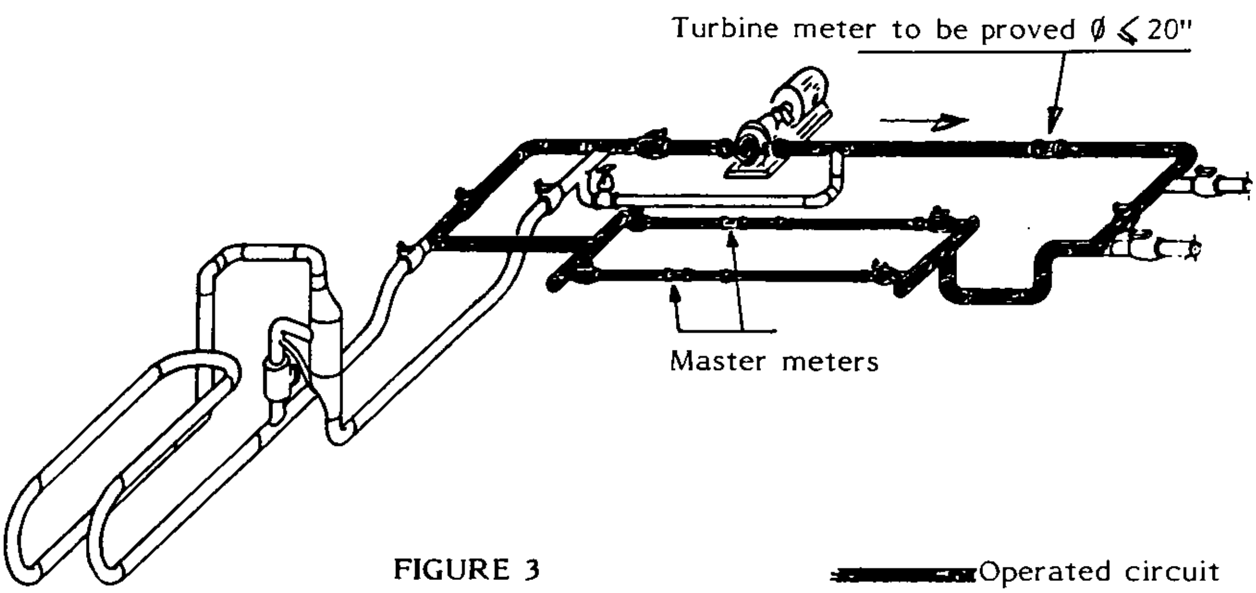


FIGURE 3

Operated circuit

SOCIETE DU PIPELINE SUD-EUROPEEN STATION D'ETALONNAGE DE FOS SUR MER

CERTIFICAT D'ETALONNAGE DU MESUREUR HELIFLU 4000 16" NUMERO 6683 01-FEB-80 OURAL

	TUBE ETALON			MESUREUR								VISCOSITE		
NO	PSS.	TEMP	VOLUME	TEMP	N	T1	T2	N'	VOLUME	ERREUR	FCM	DEBIT	D.VISCO	N U	Q/NU
1	4.3	22.1	15170.44	22.1	2426	188273.	188324.	2426.66	15174.04	0.2	0.9998	290.	1.530	11.0	26.48
2	4.3	21.8	15170.29	21.8	2428	163757.	163782.	2428.07	15182.58	0.8	0.9992	334.	1.531	11.0	30.43
3	4.2	21.4	15170.04	21.4	2429	132834.	132817.	2428.69	15186.01	1.1	0.9989	412.	1.537	11.1	37.23
4	4.1	21.0	15169.78	21.0	2428	112361.	112403.	2428.91	15186.96	1.1	0.9989	486.	1.546	11.2	43.46
5	4.0	20.3	15169.38	20.3	2428	80689.	80703.	2429.11	15187.47	1.2	0.9988	603.	1.558	11.4	53.00
6	4.0	20.2	15169.34	20.2	2429	72980.	72880.	2429.00	15186.70	1.1	0.9989	749.	1.561	11.4	65.60
7	4.0	20.0	15169.24	20.0	2428	60307.	80320.	2428.52	15183.51	0.9	0.9991	906.	1.564	11.5	79.04
8	4.0	19.9	15169.19	19.9	2428	50048.	50048.	2428.00	15180.13	0.7	0.9993	1092.	1.568	11.5	94.99
9	4.0	19.9	15169.19	19.9	2427	42256.	42269.	2427.75	15178.55	0.6	0.9994	1283.	1.569	11.5	112.01
10	4.0	19.8	15169.14	19.8	2428	36081.	36081.	2428.00	15180.02	0.7	0.9993	1515.	1.570	11.6	131.07
11	4.0	19.9	15169.19	19.9	2429	31043.	31037.	2428.53	15183.45	0.9	0.9991	1761.	1.571	11.6	152.19
12	4.1	19.8	15169.23	19.9	2429	26828.	26827.	2428.91	15185.82	1.1	0.9989	2038.	1.570	11.6	176.33
13	4.1	20.1	15169.33	20.1	2429	23254.	23255.	2429.10	15187.25	1.2	0.9988	2351.	1.568	11.5	203.96
14	4.2	20.3	15169.48	20.3	2429	20553.	20555.	2429.24	15188.28	1.2	0.9988	2660.	1.564	11.5	231.98
15	4.2	20.6	15169.63	20.6	2429	18149.	18151.	2429.27	15188.79	1.3	0.9987	3012.	1.560	11.4	264.08
16	4.1	21.0	15169.78	21.0	2429	26860.	26858.	2428.82	15186.40	1.1	0.9989	2036.	1.556	11.3	179.36
17	4.0	21.0	15169.75	21.0	2429	81265.	81268.	2429.08	15188.03	1.2	0.9988	599.	1.547	11.2	53.45

MESUREUR TURBINE INSTALLE SUIVANT PLAN PB CR 73 REVISION 1.
UNITES UTILISEES:PRESSION=BAR, TEMPERATURE=DEGRE CELSIUS, VOLUME=DM3, T1 & T2=MILLISECONDE, DEBIT=M3/H,
DUREE VISCO=SECONDE, VISCOSITE CINEMATIQUE NU=MM2/S.
CONSTANTE VOLUMETRIQUE DU MESUREUR TURBINE: 1 IMPULSION = 12,5 DM3.
ORIGINE DE LA PLAGE DES DEBITS AUTORISES:
VISCOSITE CINEMATIQUE COMPRISE ENTRE 1 ET 20 MM2/S: 300 M3/H.
VISCOSITE CINEMATIQUE COMPRISE ENTRE 20 ET 60 MM2/S: 600 M3/H.
VISCOSITE CINEMATIQUE COMPRISE ENTRE 60 ET 100 MM2/S: 1200 M3/H.
SUIVANT D.A. NUMERO 76.1.01.439.2.3. DU 26 FEVRIER 1976.
LES ESSAIS METROLOGIQUES INDIQUES CI-DESSUS ONT ETE REALISES AU MOYEN D'UN TUBE ETALON
AGREE PAR LE SERVICE DE METROLOGIE SUIVANT LETTRE SM.ST/MDF 86 NUMERO 586.

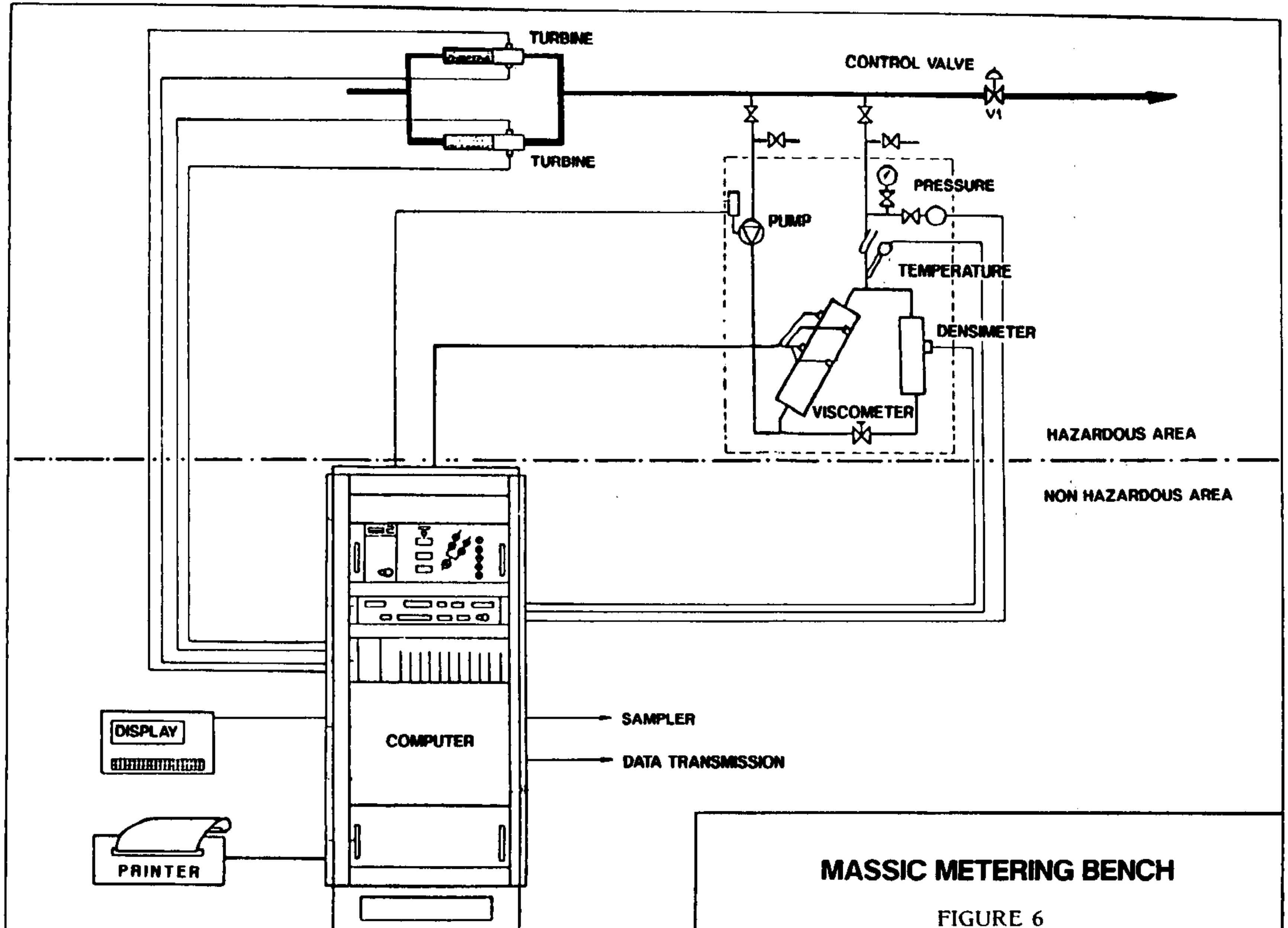
FIGURE 4

HELIFLU 4000 16" NUMERO 6683 18-JUL-90

		VISCOSITE DES DIFFERENTES COURBES				
		0.90	11.37	27.71	38.07	121.18
NO	DEBITS	COEFFICIENTS INTERPOLES				
1	300	1.0021	0.9998	1.0043	1.0087	1.0293
2	400	1.0005	0.9990	1.0021	1.0056	1.0234
3	500	1.0000	0.9989	1.0005	1.0034	1.0191
4	600	0.9997	0.9988	0.9997	1.0019	1.0158
5	700	0.9995	0.9988	0.9993	1.0007	1.0128
6	800	0.9994	0.9989	0.9992	1.0000	1.0103
7	900	0.9992	0.9991	0.9991	0.9995	1.0086
8	1000	0.9992	0.9992	0.9991	0.9992	1.0074
9	1100	0.9992	0.9993	0.9991	0.9990	1.0064
10	1200	0.9992	0.9994	0.9991	0.9988	1.0055
11	1300	0.9993	0.9994	0.9990	0.9988	1.0047
12	1400	0.9994	0.9993	0.9990	0.9987	1.0040
13	1600	0.9995	0.9992	0.9990	0.9987	1.0028
14	1800	0.9995	0.9990	0.9991	0.9988	1.0018
15	2000	0.9995	0.9989	0.9992	0.9988	1.0012
16	2200	0.9995	0.9988	0.9994	0.9988	1.0006
17	2400	0.9994	0.9988	0.9995	0.9988	1.0003
18	2600	0.9994	0.9988	0.9996	0.9989	1.0001
19	2800	0.9994	0.9987	0.9996	0.9990	0.9999
20	3000	0.9994	0.9987	0.9997	0.9991	0.9998

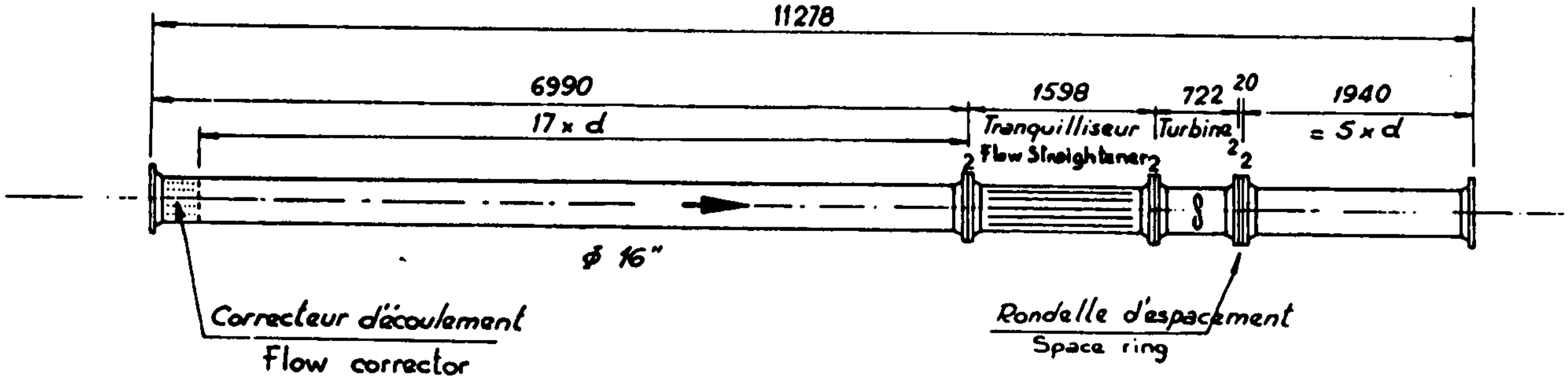
DEBIT MAXIMAL: 4000 M3/H.
DEBIT MINIMAL EN FONCTION DE LA VISCOSITE CINEMATIQUE
DU PRODUIT MESURE:
VISCOSITE COMPRISE ENTRE 1 ET 20 MM2/S: 300 M3/H.
VISCOSITE COMPRISE ENTRE 20 ET 60 MM2/S: 600 M3/H.
VISCOSITE COMPRISE ENTRE 60 ET 100 MM2/S: 1200 M3/H.
CONFORMEMENT A LA D.A. 76.1.01.439.2.3. DU 26 FEVRIER 1976.

FIGURE 5



MASSIC METERING BENCH

FIGURE 6



CONFIGURATION TYPE D'UNE BRANCHE DE BANC DE COMPTAGE

TYPICAL BRANCH CONFIGURATION OF A METERING BENCH

FIGURE 7

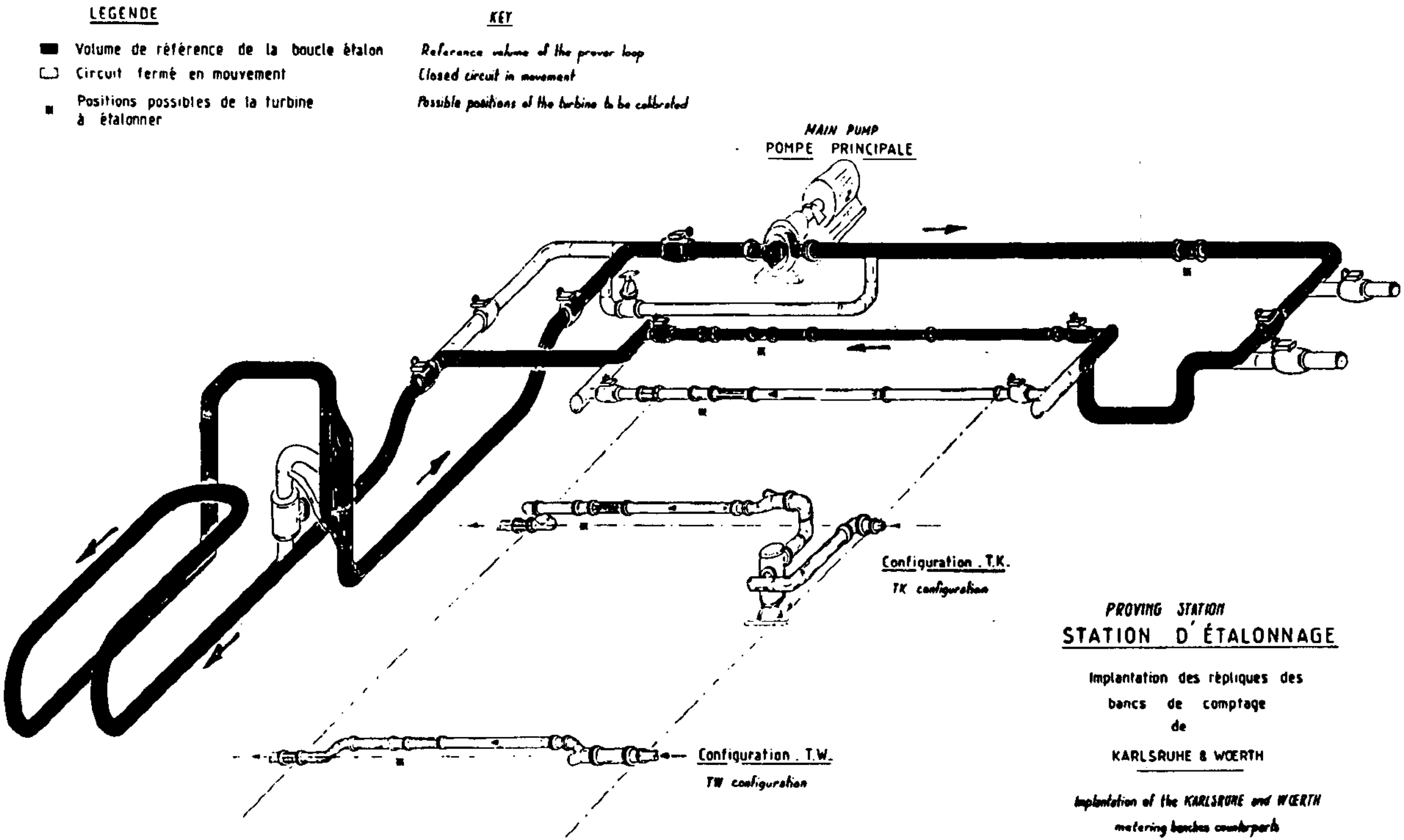
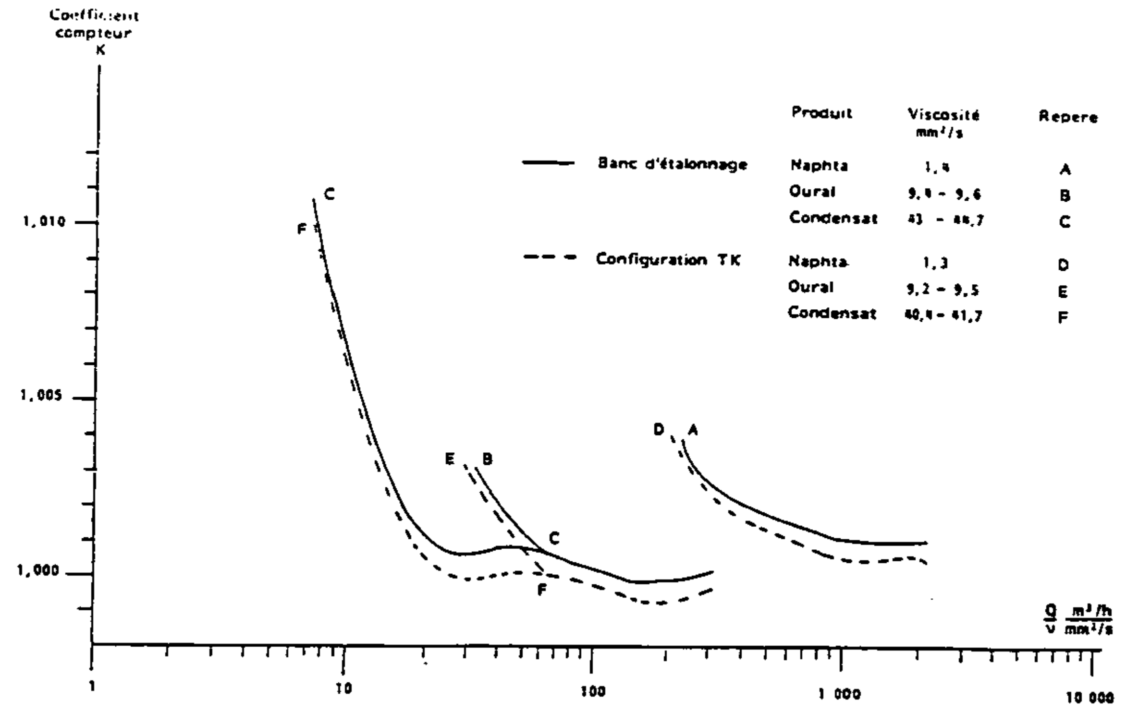
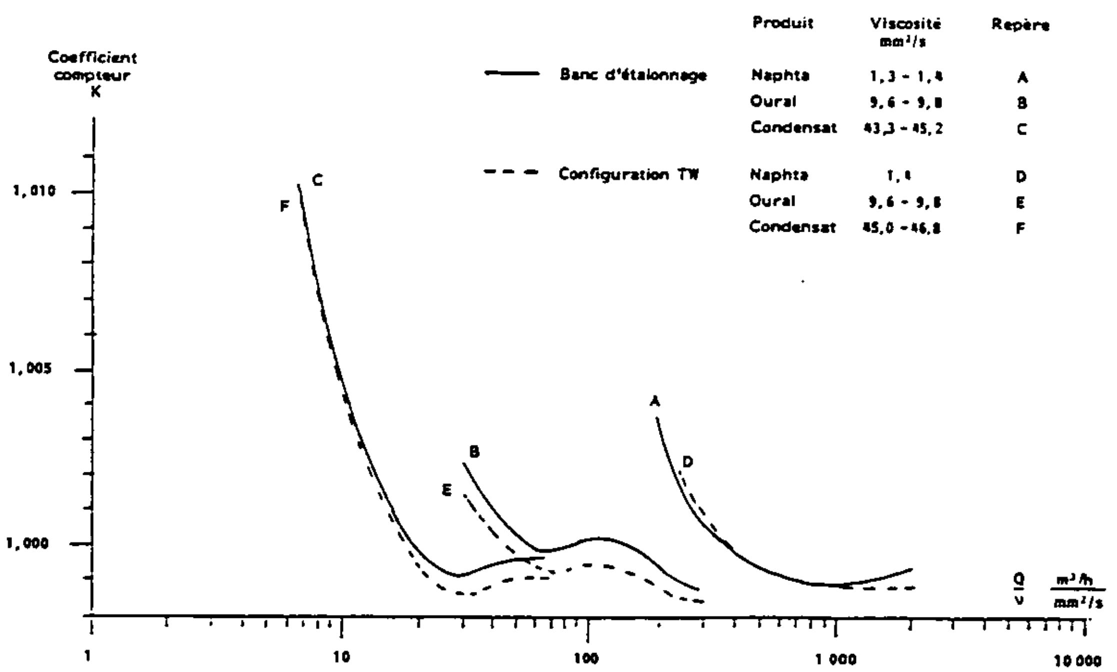

LEGENDE
KEY
Volume de référence de la boucle étalon
Reference volume of the prover loop
Circuit fermé en mouvement
Closed circuit in movement
Positions possibles de la turbine à étalonner
Possible positions of the turbine to be calibrated
MAIN PUMP
POMPE PRINCIPALE
Configuration . T.K.
TK configuration
Configuration . T.W.
TW configuration
PROVING STATION
STATION D'ÉTALONNAGE
Implantation des répliques des bancs de comptage de
KARLSRUHE & WOERTH
Implantation of the KARLSRUHE and WOERTH metering benches counterparts

FIGURE 8



A — Comparaison des coefficients obtenus avec la turbine Heliflu 4000 N° 9965 installée sur un alignement droit de la station d'étalonnage et avec la même turbine installée sur la réplique (TK) du banc de comptage de Karlsruhe.

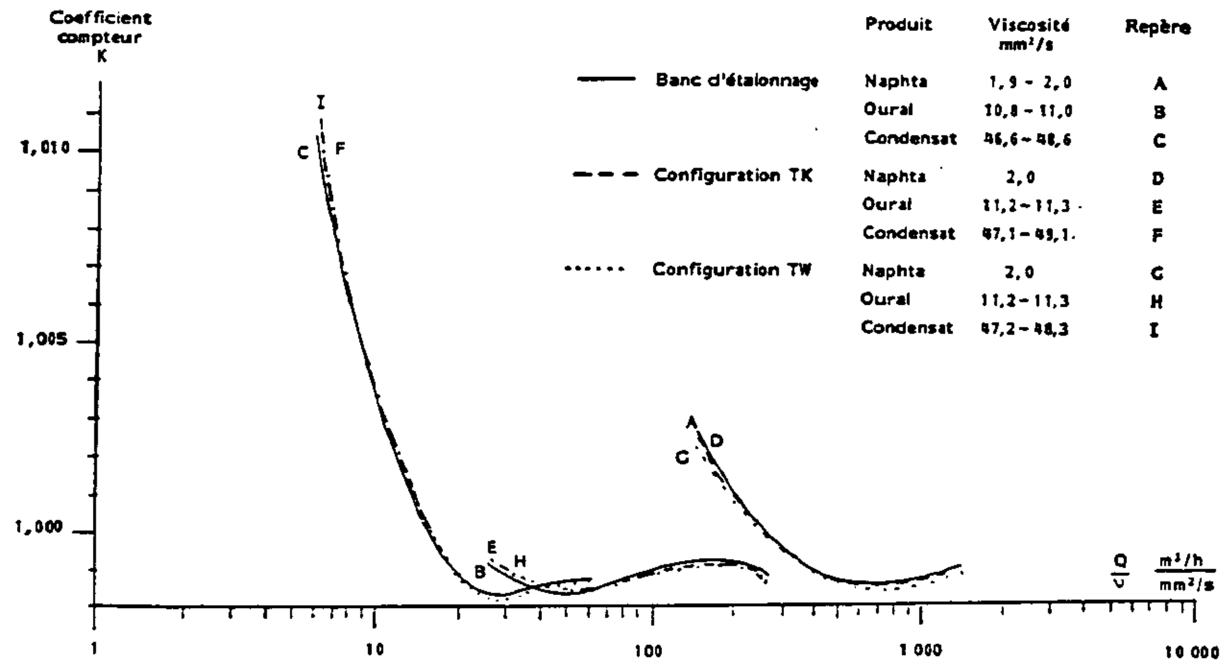
Comparison of the meter factors obtained with the turbine Heliflu 4000 No 9965 installed on the streight part of the calibration station and with the same turbine installed in a replica (TK) of the metering station at Karlsruhe.



B — Comparaison des coefficients obtenus avec la turbine Heliflu 4000 N° 9966 installée sur un alignement droit de la station d'étalonnage et avec la même turbine installée sur la réplique (TW) du banc de comptage de Wörth.

Comparison of the meter factors obtained with the turbine Heliflu 4000 No 9966 installed on the streight part of the calibration station and with the same turbine installed in the replica (TW) of the metering station at Wörth.

FIGURE 9

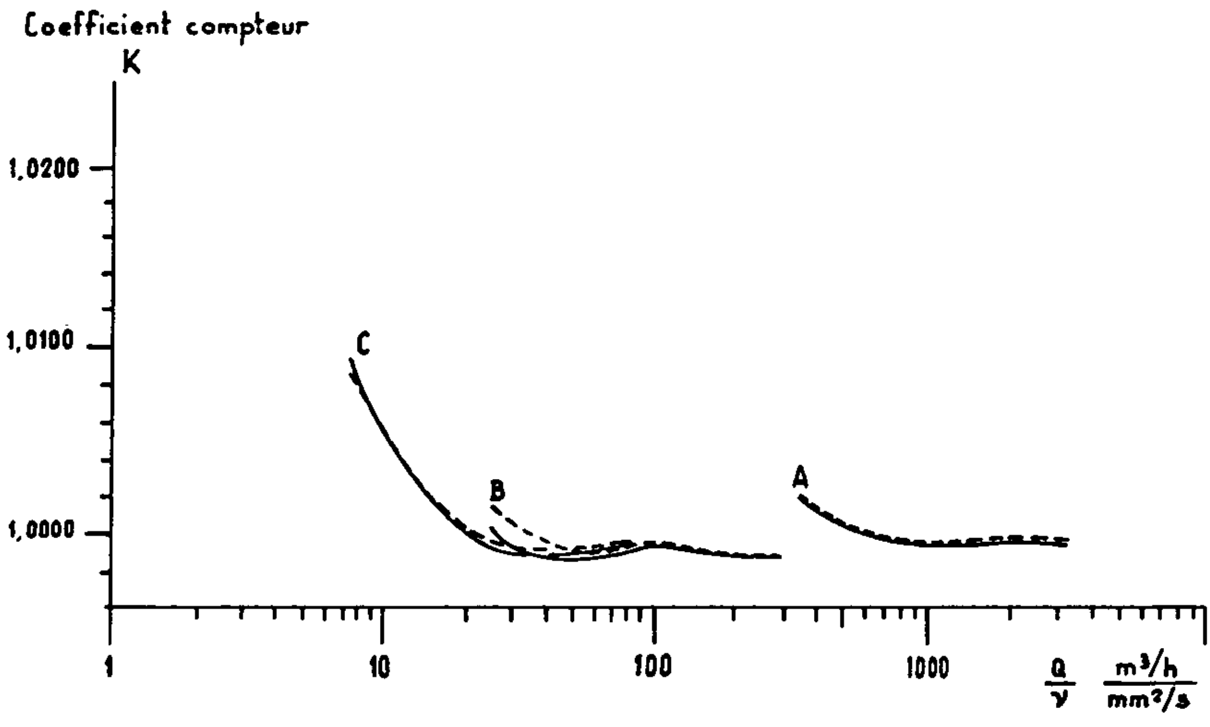


C — Comparaison de la configuration type équipée de la turbine Heliflu 4000 N° 9960 installée sur un alignement droit de la station d'étalonnage et sur les répliques TK et TW et en utilisant des produits ayant des viscosités différentes.

Comparison of the standardized configuration equipped with turbine Heliflu 4000 No 9960 and installed on a streight part of the calibration station and on the replicas TK and TW and by using products of different viscosity.

FIGURE 10

DATE	PRODUIT	VISCOSITE mm²/s	REPERE
—— 01 - 1990	Naphta	0,9 - 0,9	A
	Oural	11,0 - 11,6	B
	Condensat	35,3 - 39,0	C
---- 10 - 1988	Naphta	0,9 - 0,9	A
	Brega	10,7 - 11,0	B
	Condensat	35,3 - 37,0	C

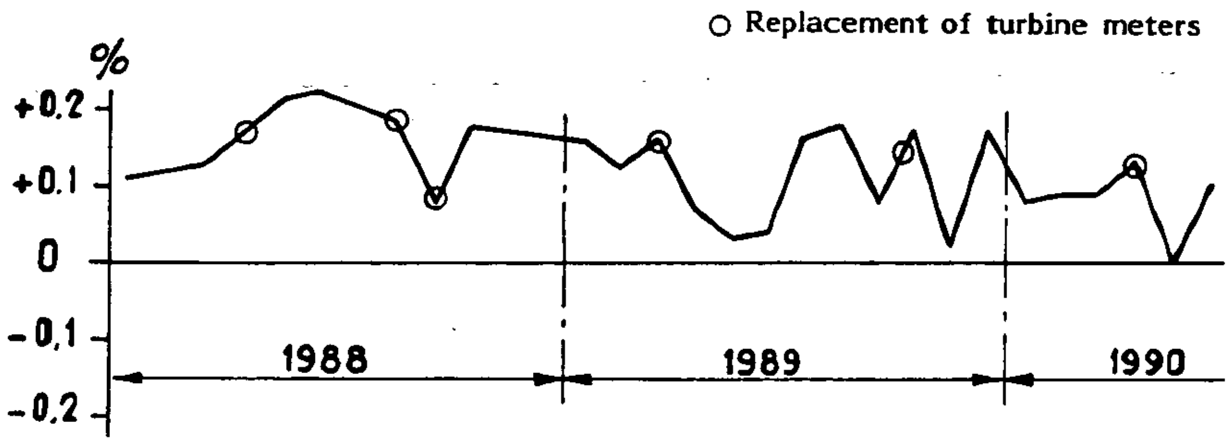


VARIATIONS IN THE COEFFICIENT OF THE HELIFLU 4000 N° 6689 TURBINE METER AFTER A ONE YEAR PERIOD OF USE AT THE BESANÇON DELIVERY TERMINAL

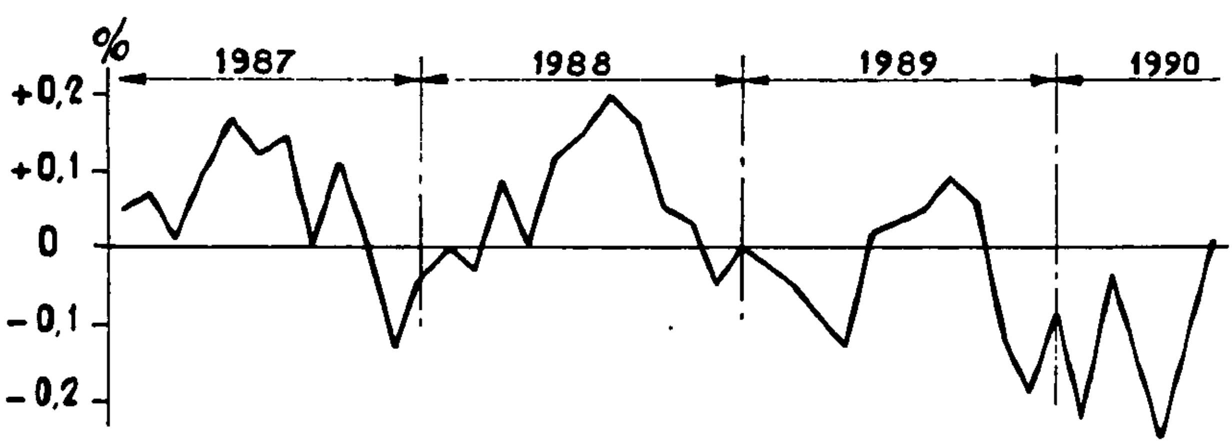
FIGURE 11

DEVIATION

(METERING - TANK GAUGING) / METERING.



1/ COMPARISON WITH A REFINERY EQUIPPED WITH AUTOMATIC TANK GAUGING AND AUTOMATIC TANK TEMPERATURE MEASUREMENT



2/ COMPARISON WITH A REFINERY CARRYING OUT MANUAL TANK GAUGING AND MANUAL TEMPERATURE MEASUREMENTS

FIGURE 12

MONTHLY AND ACCUMULATED DEVIATIONS BETWEEN THE QUANTITIES MEASURED UPON DEPARTURE FROM FOS SUR MER AND THE TOTAL QUANTITIES MEASURED AT THE DELIVERY TERMINALS.
(DEPARTURE - DELIVERY) / DELIVERY.

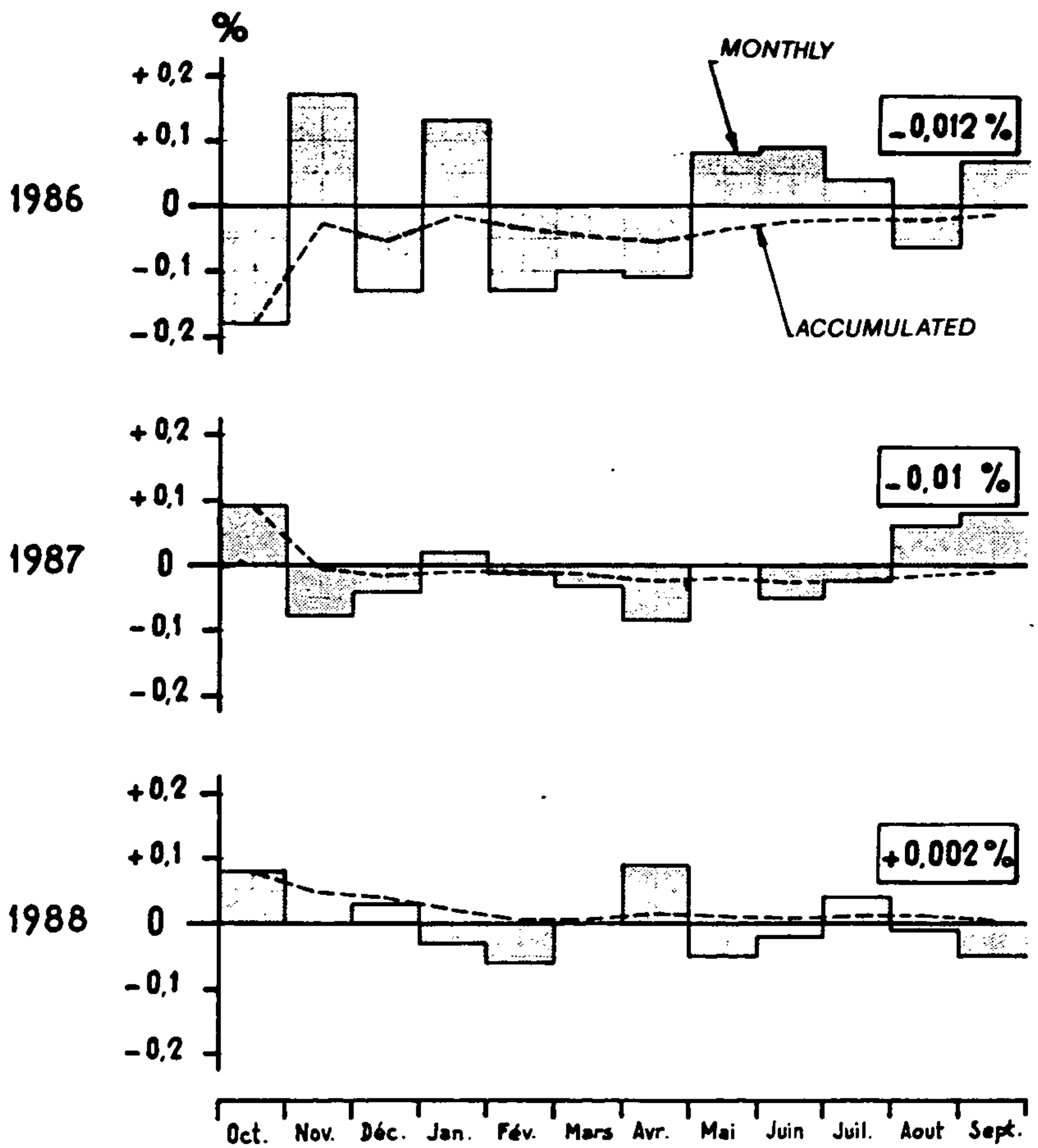


FIGURE 13