FIELD EXPERIENCE AND DEVELOPMENT WORK WITH HYDRIL BS AND W MEASUREMENT SYSTEM

by

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AOT HYDRIL

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1) INTRODUCTION

The measurement of crude oil water content in a continuous on-line fashion is extemely attractive in comparison with sampling techniques. The availability of real-time data provides the operator with a wealth of information relating to well performance, separator efficiency, etc.

However, to date the various methods employed have not been entirely successful and have not always demonstrated the levels of accuracy required.

Techniques currently employed are generally influenced by variations in temperature and composition or density of the crude oil as well as with water content variation.

This paper will look specifically at one such inferential technique based on the measurement of the dielectric constant of crude oil and water mixtures.

New development will be examined which promise to make such instruments independant of density, composition, pressure and temperature effects.

2) PRINCIPLE OF OPERATION

2.1 Theoretical Response

The Dielectric constant of a given fluid is a fundamental property such as for example, density.

Additionally, provided fluids can be mixed together in the form of an emulsion then the volume or mass ratio of the fluids concerned is directly related to the dielectric constant of the mixture.

It follows that if there are only 2 constituents in the mixture and that if the individual dielectric constants are known then the volume ratio of the mixture can be determined by measuring the mixture dielectric.

In order for this to be true for immiscible fluids one of the two constituents must be completely emulsified in the second.

In the case of oil and water the emulsion must be oil external and the water content should be less than 20% by volume as a guide. The onset of free-water breakout for a given emulsion will be determined by the properties of the crude oil and and the prevailing process conditions. In some instances it is possible to retain much higher percentages of water in an emulsion.

In order to measure the mixture dielectric and hence water content the Hydril BS & W Probe is constructed to measure the prevailing capacitance between a concentric electrode and the probe body as shown in figure 1. Provided the instrument is constructed in a rigid fashion such that no dimensional variation is possible, then the measured system capacitance is related directly to the fluid dielectric.

The probe capacitance may be expressed as follows:-

$$C = C_1 + \frac{2\pi \varepsilon_0 L}{\frac{1}{K_1} \ln \left\{ \frac{b}{a + 2t} \right\} + \frac{1}{K_2} \ln \left\{ \frac{a + 2t}{a} \right\}}$$

Where: C_1 = Standing capacitance produced by the mounting arrangement for the electrode assembly (figure 2).

And:

L	=	Inner element length.
a	=	Electrode radius.
b	=	Body Radius.
t	=	Coating thickness.
K_1	=	Fluid dieletric.
K_2	=	Insulation dielectric.
ε_0	=	Constant (permittivity)

The variable of interest is the fluid dieletric K_1 which is related to the individual dieletrics of the crude oil and water.

If the volume percentage of the oil and water constituents are expressed as V_0 and V_W giving a total mixture volume of V_T, then the mixture dielectric may be expressed as follows:

$$K_1 = \frac{1}{\left\{ \dfrac{V_0}{K_0 V_T} + \dfrac{V_W}{K_W V_T} \right\}}$$

From this it may be observed that since water dielectric constants are two orders of magnitude greater than those of hydrocarbons the total dielectric is very much dependant upon the value of the crude oil dielectric.

It follows that if the dry crude oil dielectric is unkown then significant errors may occur using an assumed figure. In addition, for a given water percentage in the emulsion, the total dielectric will be relatively insensitive to variations in formation water dielectric constant.

Reference to figures 3 and 4 will show how emulsion dielectrics and measured capacitances vary with water percentage changes and with different base water and crude oil dielectric valves.

From these tables the relative system sensitivity to base dielectric is graphically illustrated.

In addition it may be observed that the output is virtually independant of formation water properties. (Dielectric constant variation).

A graphical representation of this performance characteristic is shown in figure 5.

2.2 Base Oil Dielectric Variation

Following the foregoing analysis recent efforts have been made to define the effects of temperature, pressure and composition changes on the dielectric constant of crude oils.

A test facility was constructed (shown diagrammitically in figure 6) to measure the dielectric of a range of crude oils and investigate the dependance of dielectric constant on temperature, pressure and API gravity.

The results of the test programme to date are shown in figures 7 and 8.

It will be observed that where the crude composition (gravity) varies and where the temperature changes the response curves always exhibit the same shape but are displaced vertically. It is important to note that the response characteristic is thus fundamentally unaffected by base crude dielectric changes, which produce only a vertical shift in the response curve positions.

3) FIELD APPLICATIONS

3.1 Calibration

From the foregoing it follows that provided at a given measurement point the crude gravity and temperature are constant, gravity and temperature are constant, accurate measurements may be made. In addition if a dry sample of crude oil is not available for laboratory calibration and on calibration may be undertaken during flowing conditions irrespective of the prevailing water content within the span capability of the probe.

This is provided an accurate means of water determination is available to allow the probe output to be set. This method is illustrated in figure 9 which shows how a predicted response may be corrected by a single point field calibration. All Hydril BS & W Probes are equipped with series and parallel trimming capacitances to permit field calibration to be undertaken in this way.

3.2 Accuracy

In the North Sea, crude oil water content has up until recently been very small. Even with a 2% water content the change in capacitance to produce this is typically only 3-4% of the zero water or standing probe capacitance.

From the signal conditioning viewpoint this presents a major design challenge in producing de-modulation and amplification circuitry which is very stable.

Traditionally, such signal conditioning hardware has been based on the use of analogue techniques using the best specification components, etc.

More recently digital techniques have been used to improved stability and to allow the effects of ambient temperature to be compensated for.

A new signal conditional technique has been recently developed and tested by Hydril which has built in temperature compensation. In addition, the capacitance measurement is based on microprocessor controlled charge/discharge cycles rather than a conventional AC bridge. It is anticipated that this method will enable smaller changes in capacitance to be resolved.

3.3 North Sea Applications

BS & W Probes are currently used on a number of North Sea Offshore platforms for water in crude oil and water in condensate measurement.

Normally the probes are fitted downstream of separators or de-hydrators to monitor performance. Where a calibration which has been carried out on an annual or 6 monthly basis long term results have been consistantly good.

Best results are achieved if the probe is mounted vertically and where the fluid velocity and turbulance is high enough to prevent deposition or free water drop out. For most practical applications these two installation requirements are essential.

Accuracies of ± 0.1% water have been consistently demonstrated on probes with a 3% or 5% water span.

4) NEW DEVELOPMENTS

4.1 Dry Sample Compensation

As previously stated the capacitance of an oil water mixture is dependant upon many variables apart from the water percentage.

An ideal measurement system should be insensitive to all physical variables with the exception of the measure quantity. (i.e. water percentage). In order to achieve this the concept of the Dry Reference System was developed, tested and is now in production.

This is shown diagrammatically in figure 10 which functions in the following manner:

The crude/water mixture is taken through a separator to remove free water. Retention time in the separator is arranged to ensure no free water remains in emulsion in a quasi-stable state. The emulsion is enhanced strengthened by an on-line mixer where a continuous sample is removed for measurement.

The sample capacitance is measured with the prevailing water content which is taken via a heat exchanger into a centrifuge. A small quantity is extracted from the centrifuge which is completely dry and passes via the same heat exchanger into a second capacitance probe.

These two capacitance probes are carefully matched and have the same characteristics. In this way the difference in capacitance is directly related to the water content alone.

Prototypes of this system have been under test and have produced encouraging results as illustrated in figure 11.

These test results come from comparisons with crude oil samples of a known water content as determined by laboratory analysis.

At present such a system in modified form is being supplied to the Alberta Gas and Oil Company for continuous BS & W monitoring on a pipeline where the crude oil characteristics vary.

5) CONCLUSIONS

Effort is now being devoted in developing a compact Dry Reference BS & W system which is completely self contained for use where crude oil properties and temperatures vary.

In addition, using new signal conditioning methods development work is continuing to improve the stability of the capacitance sensing circuitry to allow much smaller water content variations to be reliably determined.

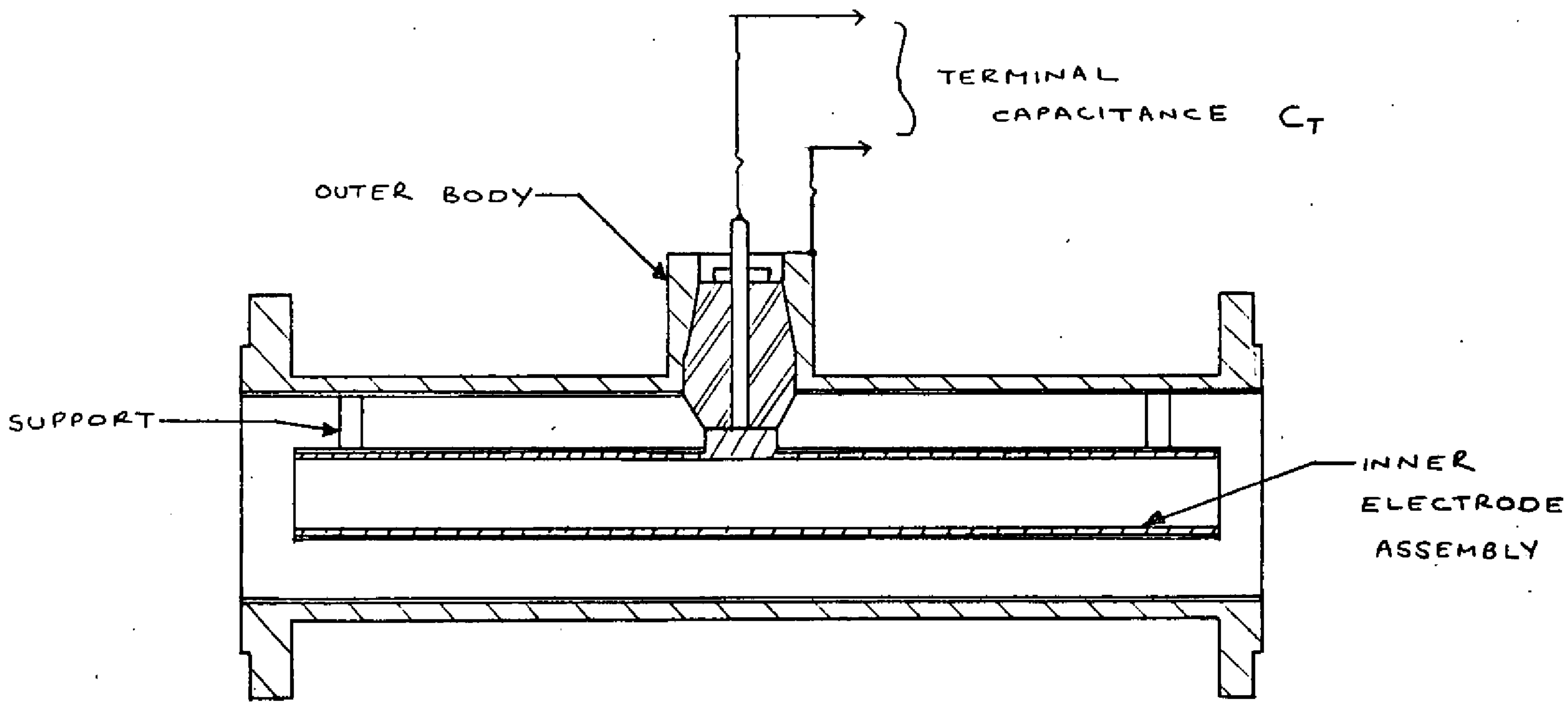


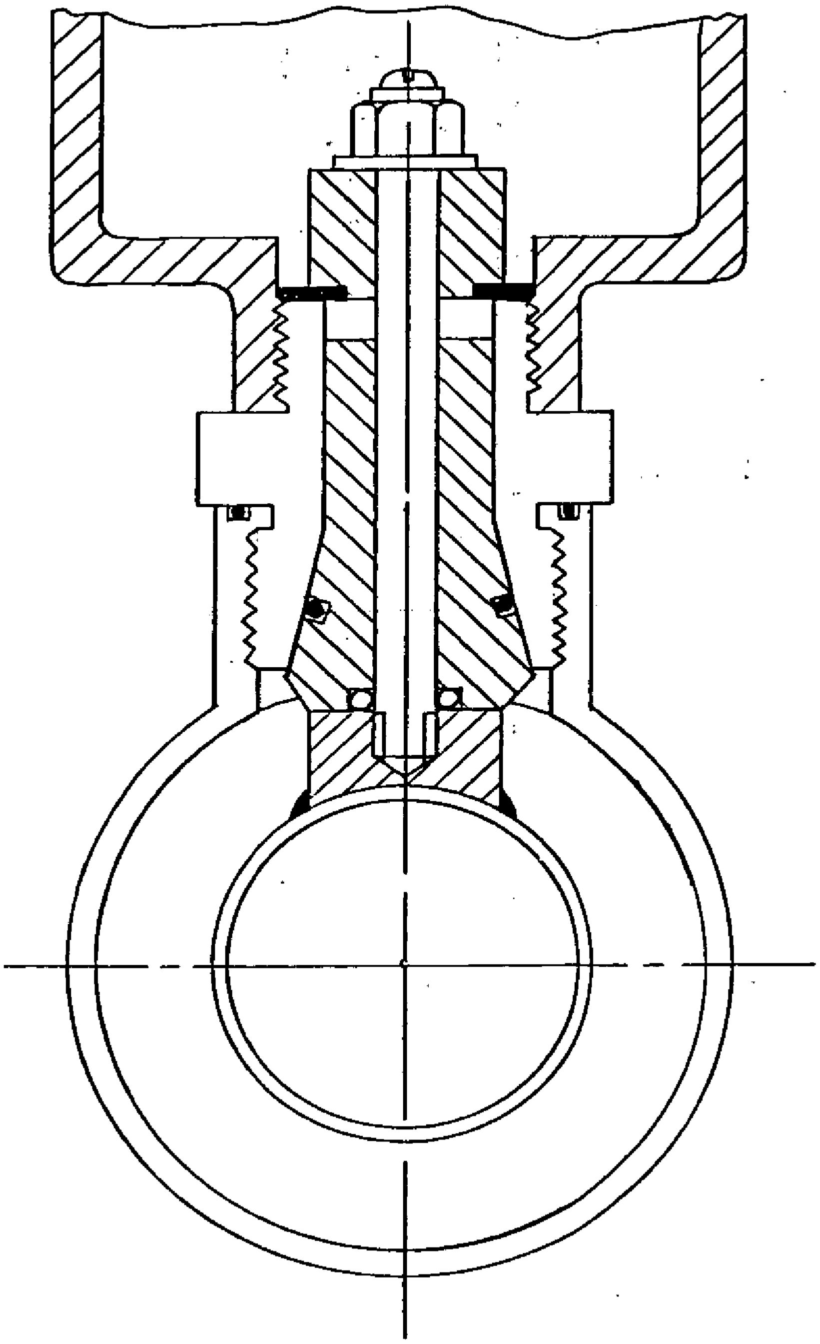
FIGURE 1

BS&W PROBE ARRANGEMENT.

FIGURE 2

OIL WATER PROBE

ELECTRODE MOUNTING



% Water	A $K_o = 2.0$ $K_w = 300$	B $K_o = 2.0$ $K_w = 200$	C $K_o = 2.2$ $K_w = 200$	D $K_o = 2.2$ $K_w = 150$	% Error A - B	% Error C - D
0%	2.0	2.0	2.2	2.2	0	0
5%	2.1045	2.1042	2.3144	2.3140	.29%	.35%
10%	2.2206	2.2198	2.4415	2.4405	.36%	.41%
20%	2.4958	2.4938	2.7425	2.7400	.40%	.46%
30%	2.8490	2.8450	3.1281	3.1232	.47%	.53%
40%	3.3186	3.113	3.6400	3.6312	.55%	.61%
50%	3.9735	3.9604	4.3521	4.3364	.66%	.73%
SPAN =	1.9735	1.9604	2.1521	2.1364		

FIGURE 3 OIL/WATER MIXTURE DIELECTRICS

% Water	$K_o = 2.0$ $K_w = 300$	$K_o = 2.0$ $K_w = 200$	$K_o = 2.2$ $K_w = 200$	$K_o = 2.2$ $K_w = 150$
0	31.76	31.76	34.02	34.02
5%	32.96	32.95	35.25	35.25
10%	34.24	34.23	36.58	36.57
20%	37.14	37.12	39.57	39.54
30%	40.57	40.53	43.08	43.04
40%	44.70	44.64	46.28	47.22
50%	49.77	49.68	52.39	52.29

FIGURE 4
ELECTRODE CAPACITANCE VARIATION
WITH WATER PERCENTAGE

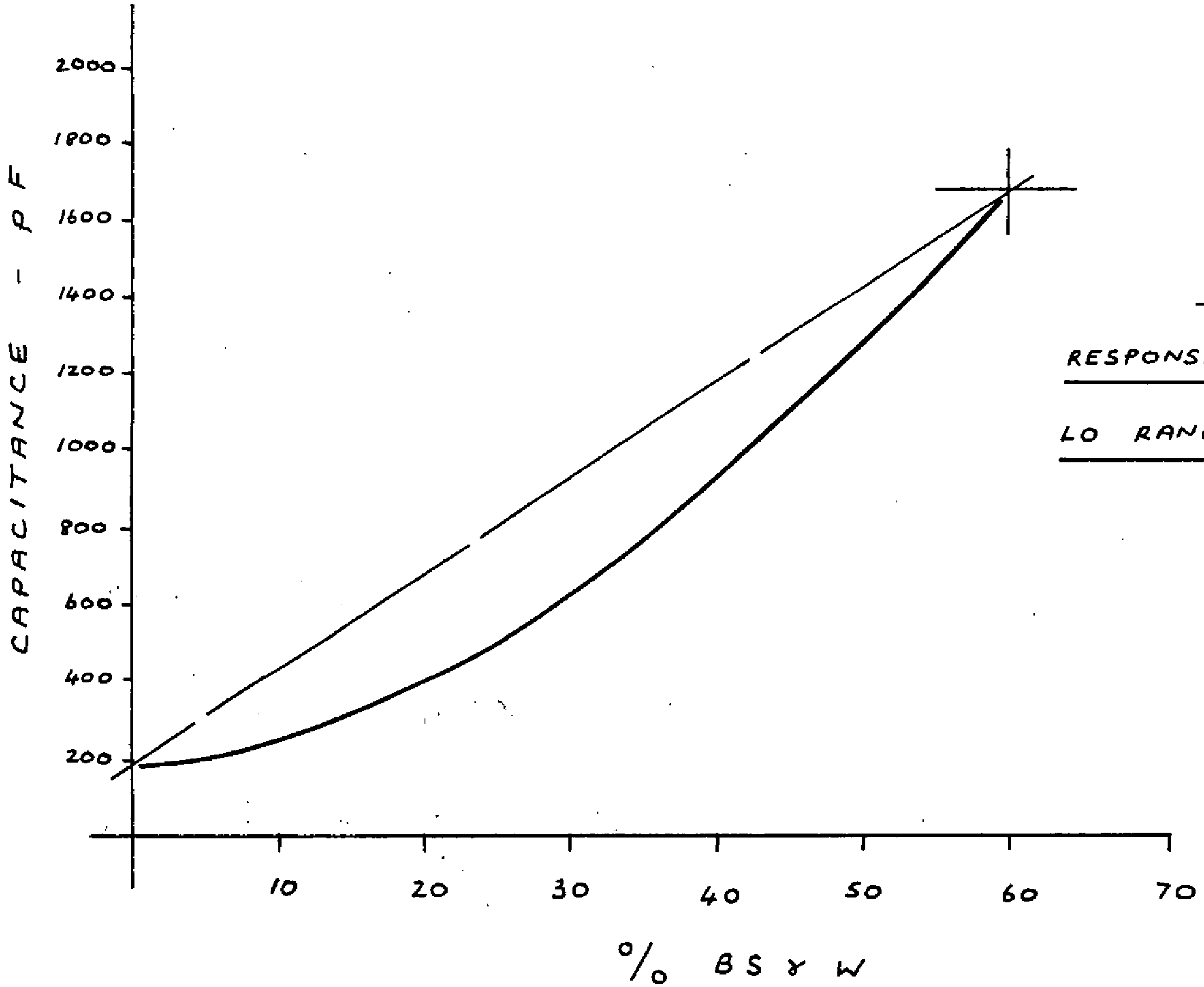
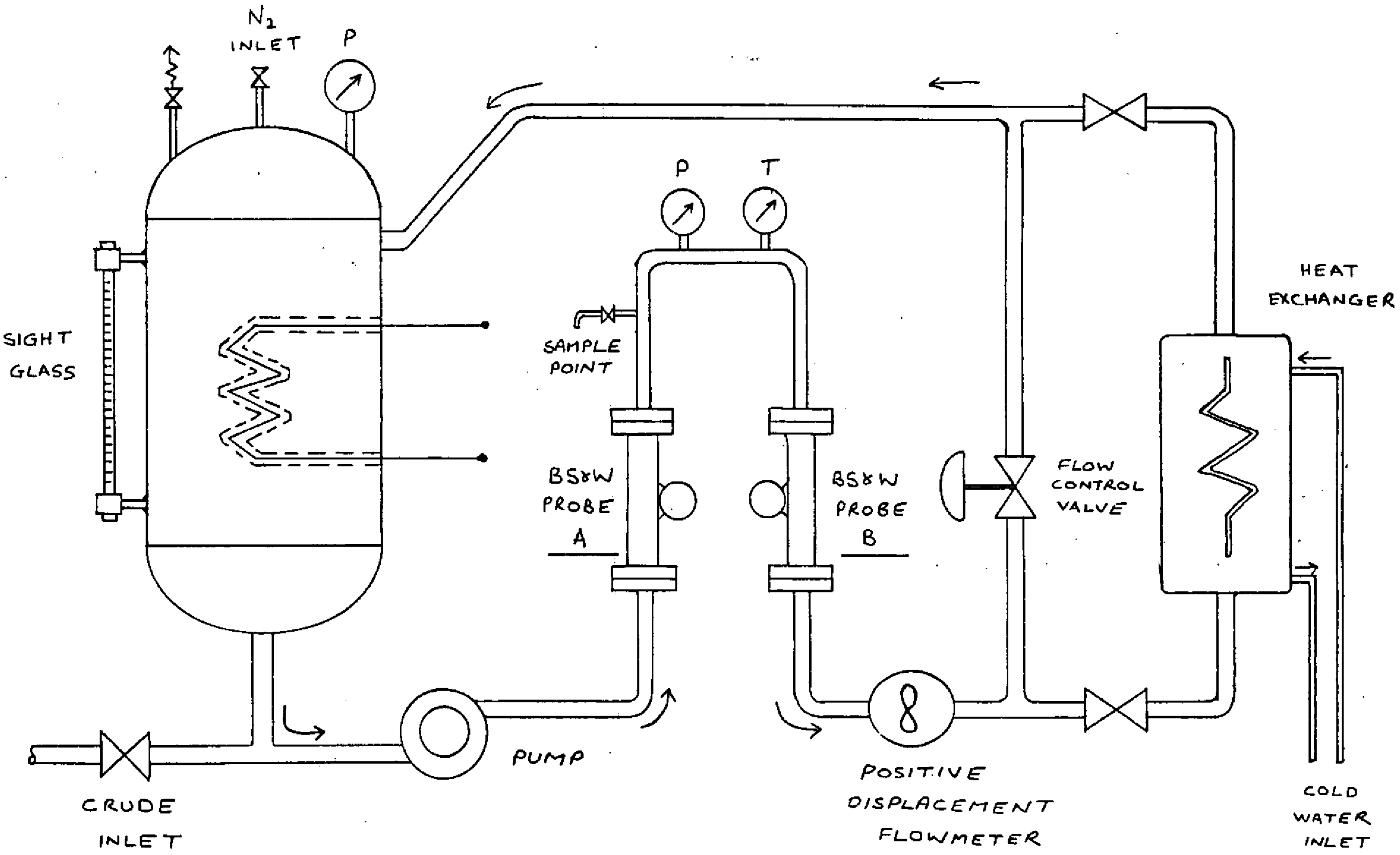


FIG 5

RESPONSE CHARACTERISTIC

LO RANGE OWM PROBE



BS&W PROBE TEST CALIBRATION LOOP

FIGURE 6.

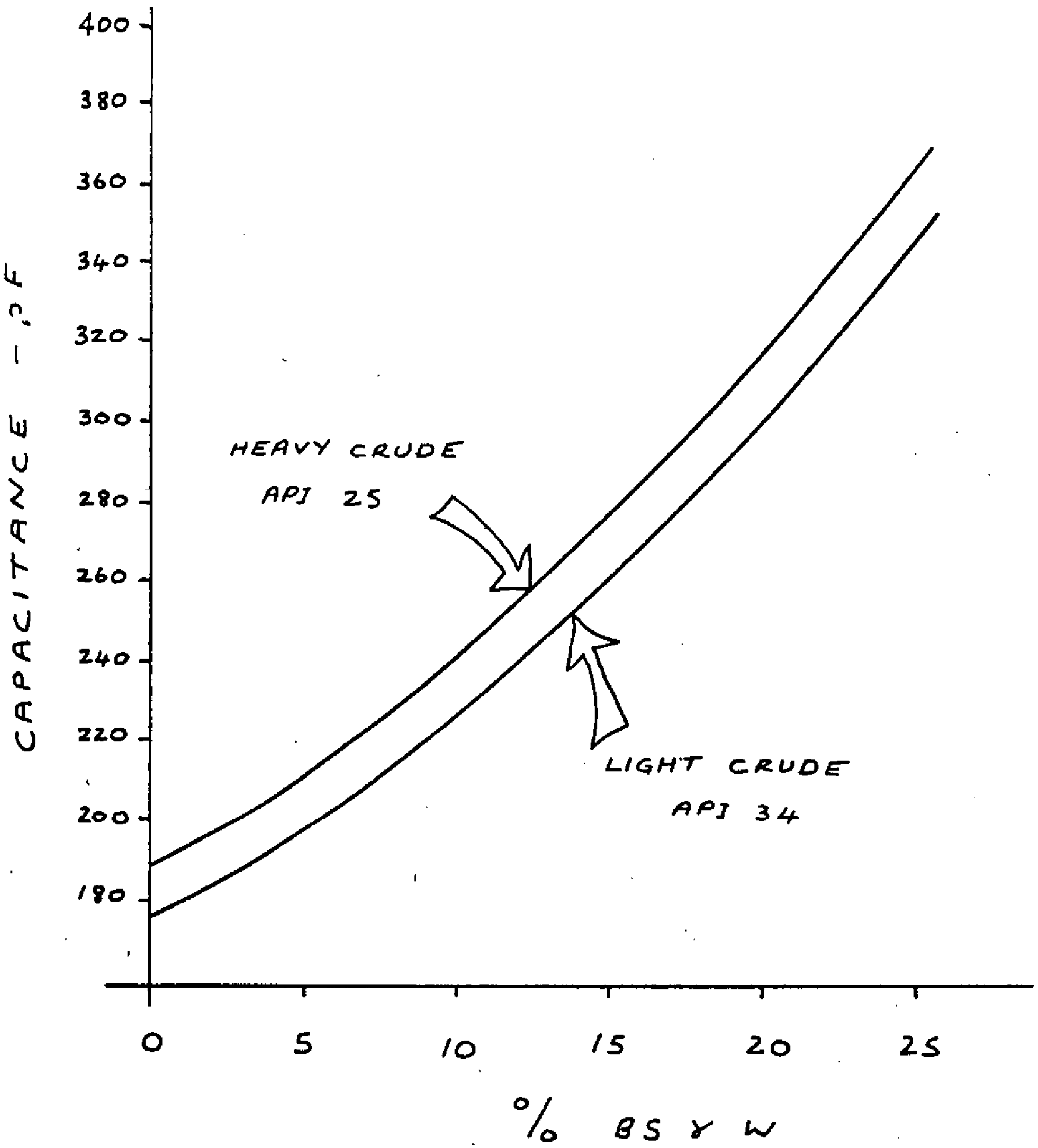


FIG 7

RESPONSE CHARACTERISTIC

LO RANGE OWM PROBE

VARIATION IN CRUDE GRAVITY

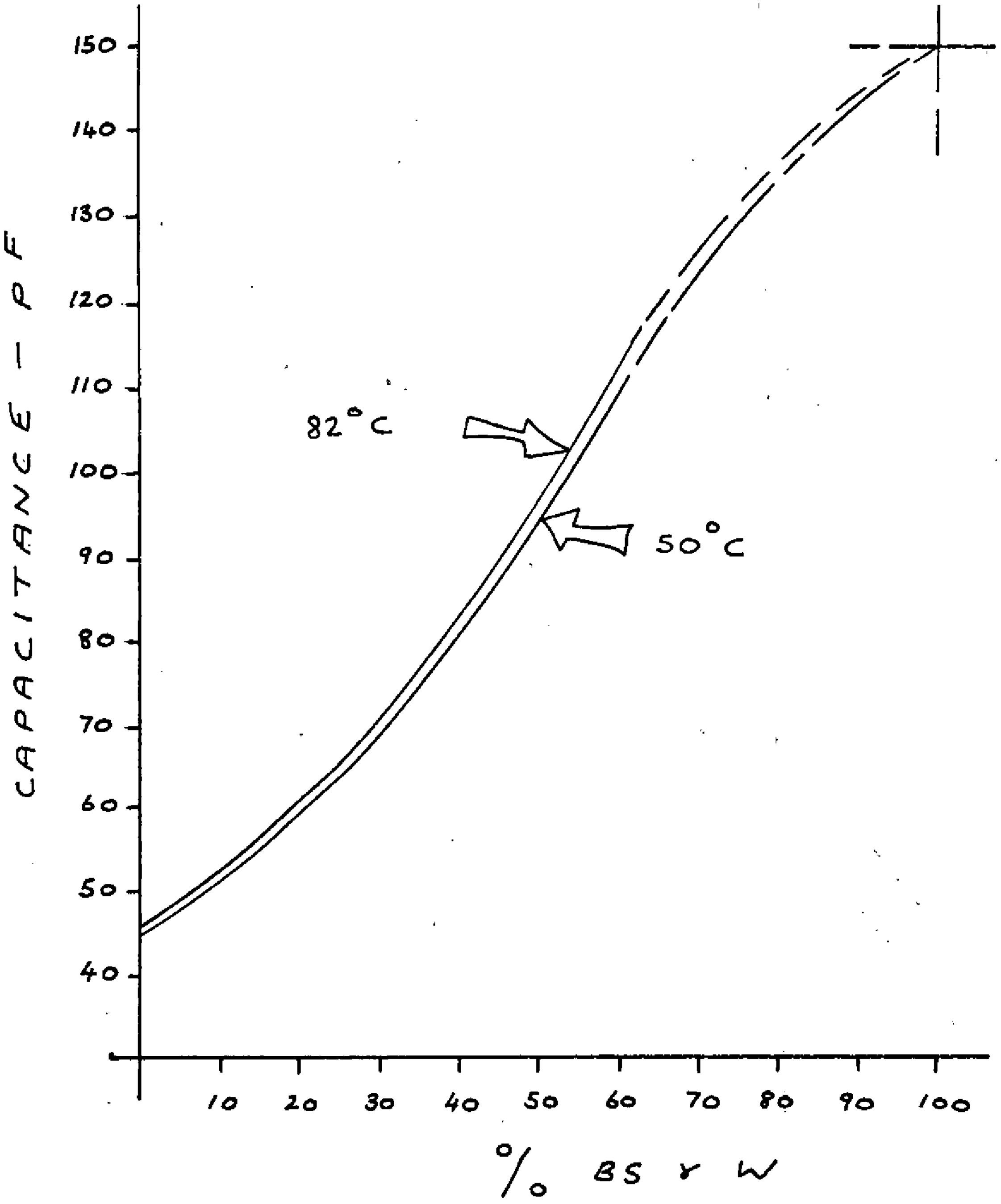


FIG 8

RESPONSE CHARACTERISTIC

HI RANGE NET OIL PROBE

TEMPERATURE VARIATION

HEAVY CRUDE.

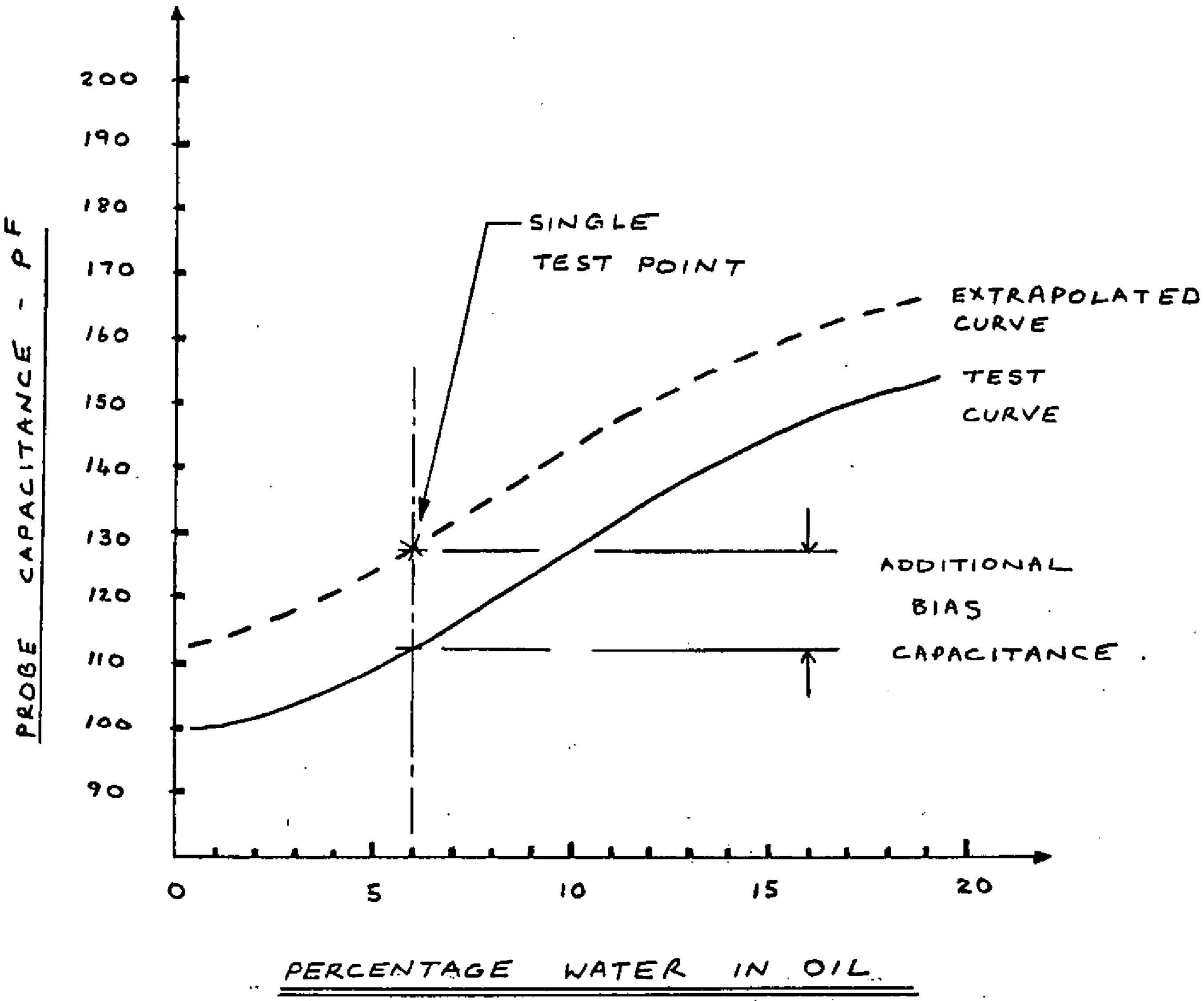
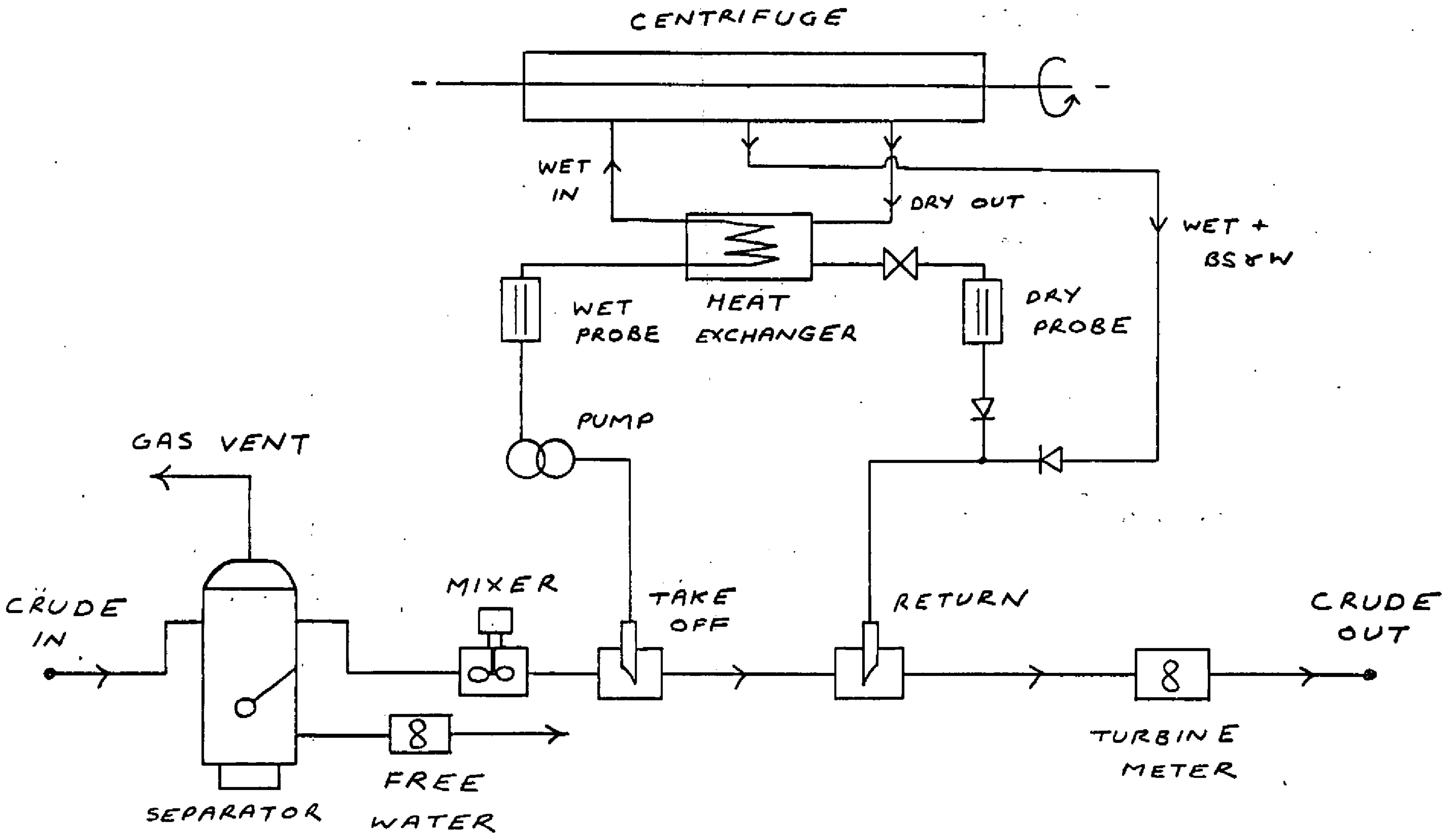


FIGURE 9 : FIELD CALIBRATION METHOD

FIGURE 10

DRY REFERENCE ON LINE BS&W SYSTEM



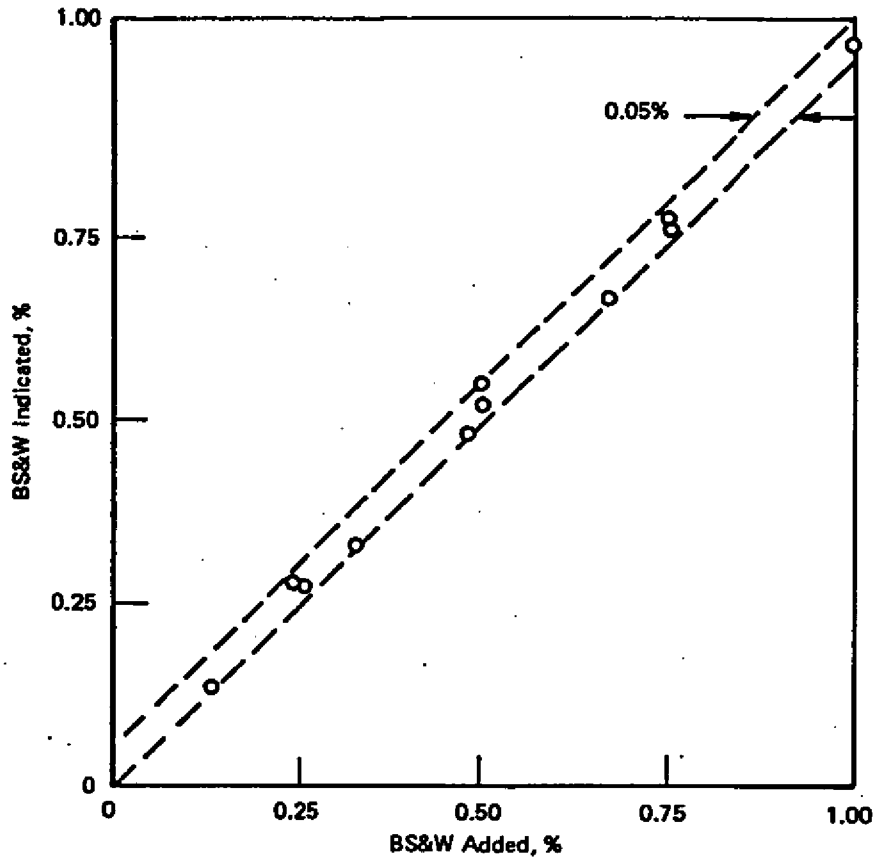


FIGURE 11

DRY REFERENCE SYSTEM PERFORMANCE

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.