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METERING MULTIPHASE WELL FLOW.
MEASUREMENT TASK AND POTENTIAL SOLUTIONS.

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Foreleser:
B.I.Kalland
Statoil

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1. Introduction

To make future marginal and deep-water field economically viable, development concepts based on subsea technology to a large extent are required. For advanced subsea production systems, where unprocessed or partially processed wellstreams are transported in pipelines from remote manifold centres at the well site to distant processing facilities on production platforms or onshore, key critical equipment still remains to be qualified. Metering equipment for periodic well production testing located at a remote well site are one of those critical components not yet available, considered to have a high potential in such subsea field developments. This measurement problem definitely represents an extremely complex flow metering task, and a number of oil companies and manufacturers are presently running development projects on various more or less sophisticated concepts to possibly solve this problem.

2. The need

As a part of the well production testing programme for a producing field, periodic production testing is needed, i.e. at regular intervals determine gas, oil (condensate) and water production rates from individual wells under normal production conditions.

From an operational point of view this information in general is needed for the following purposes:

1. Reservoir management

Close reservoir monitoring for updating of reservoir models is needed to enable reliable prediction of future reservoir behaviour as a basis for planning of later optimal production strategy.

2. Operational supervision and control

Flow rate information is needed for well production rate optimization, detection of gas or water breakthrough, and monitoring of well condition, i.e. indicative information on equipment failure, perforation/gravel pack failure etc.

3. Production allocation

In case multiple wellstreams from different owners are commingled into common pipelines or separator trains, upstream well production testing data may provide the basis for production allocation.

To what extent well production rate information is needed in terms of flow parameters, accuracy and frequency for the above purposes is determined by highly field specific factors such as

- reservoir properties
- overall field development concept
- operational strategy

3. Present technology

Existing solutions to periodic production testing of wells being commingled into a single pipeline at a distance from a central processing facility include the following alternatives:

- Testline from subsea (or wellhead platform) manifold centre to test separator at processing facility.

- Riser from subsea installation to test separator on surface vessel.

- Well shut-down and measurement of corresponding change in wellhead pressure or in production separator output.

Between tests the wellhead pressure provides flow measurement data based on updated pressure-flow rate correlations, and additionally signals well problems.

In the latter case above excessive production testing after workover or on problem wells is supposed to be carried out from a surface vessel.

4. Potential of new technology

In general, the following factors will characterise field development concepts where direct well flow metering at the well site represents a possible technical-economical attractive alternative to the above conventional solutions:

- stringent production testing requirements with respect to accuracy and/or frequency

- long distance well site - processing facilities (typ. > 30 km)

- oil or low GOR gas/condensate reservoirs (typ. GOR < 5000)

- large number of wells (typ. > 4)

At unmanned wellhead platforms direct well flow metering equipment has a potential compared to conventional test separator designs in terms of reduced weight, volume, cost or maintenance needs.

Such equipment similarly will make an attractive alternative to test separator for allocation purposes at production platforms where production from new fields are brought into existing separator trains.

In short, well flow metering equipment may have an economical impact in the above field cases, through reduced investment and operating costs, and increased recovery by better reservoir management, and additionally allow for increased flexibility in phased field developments.

However, the actual potential of such equipment in a give field development to a large extent depends on highly field-specific factors, such as:

* Type of reservoir
* Field development concept
* Operating philosophy

i.e. the field concept has to be developed to a sufficiently specified, conceptual level before assessment of the real potential of multiphase metering equipment can be done.

5. Measurement task

The actual measurement information needed is well production rates of gas, oil and water, i.e. flow rates averaged over a sufficiently long interval to be representative for long term mean production rates. (For test separators: up to 24 hours).

The overall key equipment requirements are (guideline data):

Absolute accuracy	:	5% of measured value
	:	lower range: 2% FSD
Max. rates	:	30000 bbl/d
GOR	:	0 - 20
WOR	:	0 - 4
Measurement interval	:	1 - 2 months
Reliability	:	MTBF = 5 years
Unit lifetime	:	20 years

Key critical process condition, installation and maintenance requirements include (guideline data):

* Design pressure : 300 bar
* Temperature : 150 bar
* Complex time-varying inlet flow patterns
* Phase composition variation
* Erosion
* Corrosion
* Scaling
* Wax
* Emulsion
* Foaming
* Wet system
* Essentially no in-situ calibration options
* Long maintenance intervals

Meeting the above combined measurement performance and reliability requirements under the conditions as indicated definitely represent an extremely complex flow measurement task.

6.. Potential concept solutions

6.1 General characteristics

At an overall level realistic system concepts will functionally consist of two different parts: flow conditioning devices and a set of measurement instruments. Physically the two types of components will be more or less integrated.

A complete measurement system will be located in a test line within the field installation, coupled to individual wells via a test/kill manifold, see Fig. 1.

Flow conditioning devices

In practice, each of the potential attractive partial measurement systems in question will need a high degree of local flow conditioning to function satisfactory. Essentially, homogeneity and no slip conditions, or separated gas and liquid rate measurements are needed. Thus homogenization and/or separation devices are required, to be installed in the main test line and/or in a by-pass loop, see Fig. 2.

The practical problem relates to designing rugged an reliable equipment that can perform the conditioning function as required over a large span of mean production rates, and for worst case transient conditions.

Two- or three-phase test separators custom designed for the given conditions would represent the highest level of such a flow conditioning device.

Measurement instruments

Parallel measurements of a minimum set of flow parameters are needed to enable extraction of gas, oil and water flow rates. In addition to standard pressure and temperature measurements, suitable combinations of partial measurement equipment for phase fractions and bulk velocity or volumetric/mass flow rates are required.

6.2 Partial measurement methods

The partial measurement methods considered to have a potential in multiphase flow metering systems are essentially modified versions of commercially available equipment widely used in single and two-phase flow in industrial applications.

The problem of adapting these systems to our application in general relates to the following limiting factors:

Accuracy:

- time response
- measurement range
- sensitivity to deviation from ideal local flow condition
- phase composition sensitivity
- pressure and temperature sensitivity

Long term stability:

- sensor/interface electronics stability
- erosion/corrosion/scaling sensitivity

Reliability:

- sensor/electronics complexity
- resistance to hostile conditions

Unit lifetime:

- lifetime of hardware components
- resistance to inner/outer enviroment.

To meet the accuracy and reliability requirements auto-calibration, self-checking functions and redundancy systems must be built-in at different system levels.

Beneath are listed the partial measurement methods considered to be most attractive. The methods listed appear in different versions in system concepts developed by oil companies, manufacturers and institutions.

Water fraction	:	capacitance microwave low energy gamma neutron-based method
Gas fraction	:	gamma densitometry impedance neutron-based method
Bulk velocity	:	acoustic cross-correlation pulsed neutron activation
Mass/volumetric flow rate	:	coriolis diff. pressure (orifice, venturi) turbine acceleration force

Assessing the feasibility of any partial measurement method has to be done against a sufficiently defined total system concept, i.e. the complementary measurement methods and flow conditioning devices to be applied must be specified.

7.. Examples of complete measurement systems

In fig. 3 and 4 two measurement systems are given that have both reached a high level of development. The systems are developed by Texaco USA at Texaco's Houston Research Center and by Euromatic Machine & Oil Company Ltd, UK respectively. The system block descriptions serve to illustrate the overall system complexity that is considered needed to practically solve the multiphase well flow metering task.

8. Conclusion

After intensive parallel R&D-work during the latest 5-7 years among oil companies, manufacturers and R&D-institutions direct multiphase well flow metering equipment is still not qualified for field applications.

However, the potential impact of such equipment on future marginal and deepwater field economy will remain a driving force for continuing development work in this area.

The level of development currently reached for different concepts being recently launched certainly indicates that this metering task will be solved for specific field applications within the next 3-5 years.

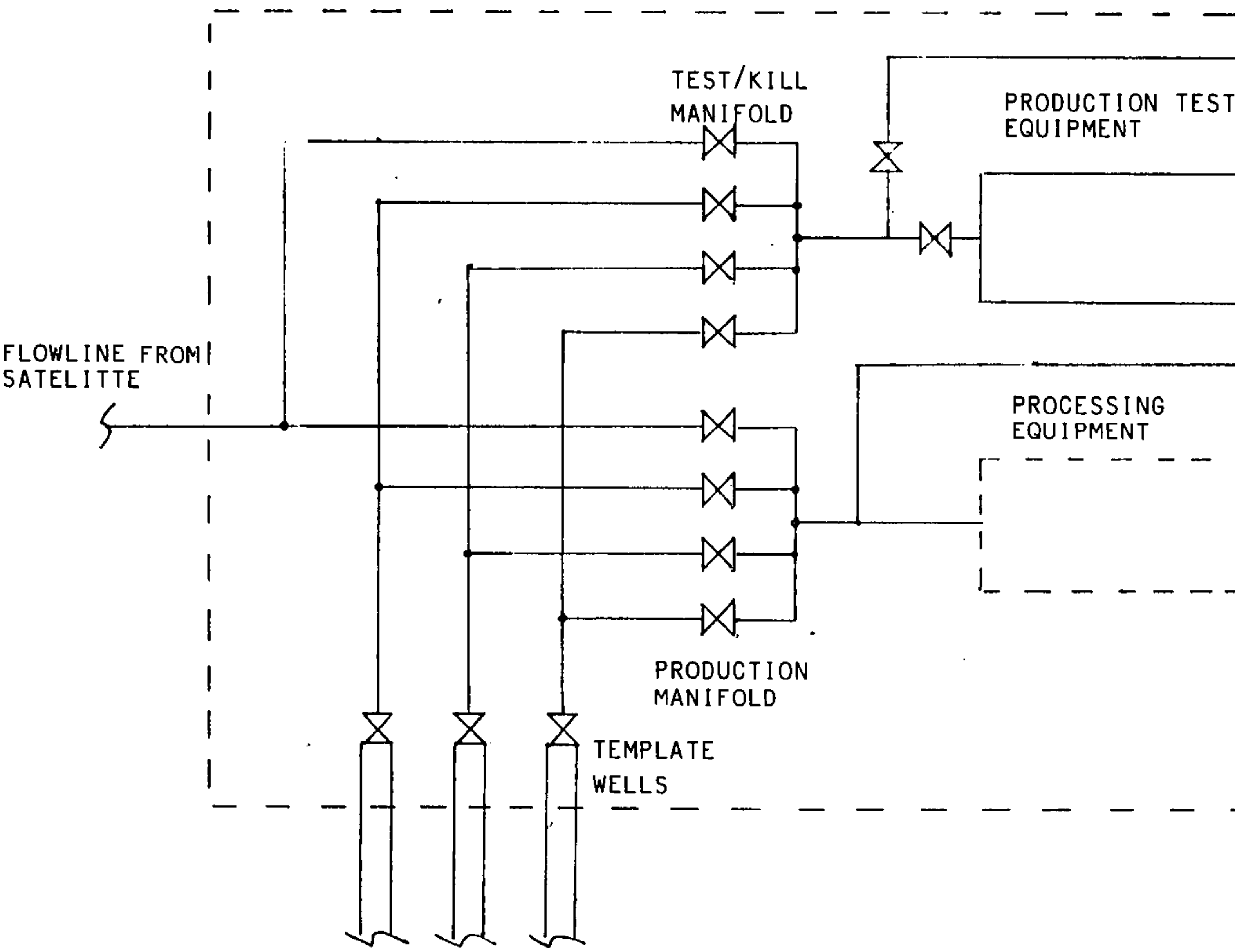
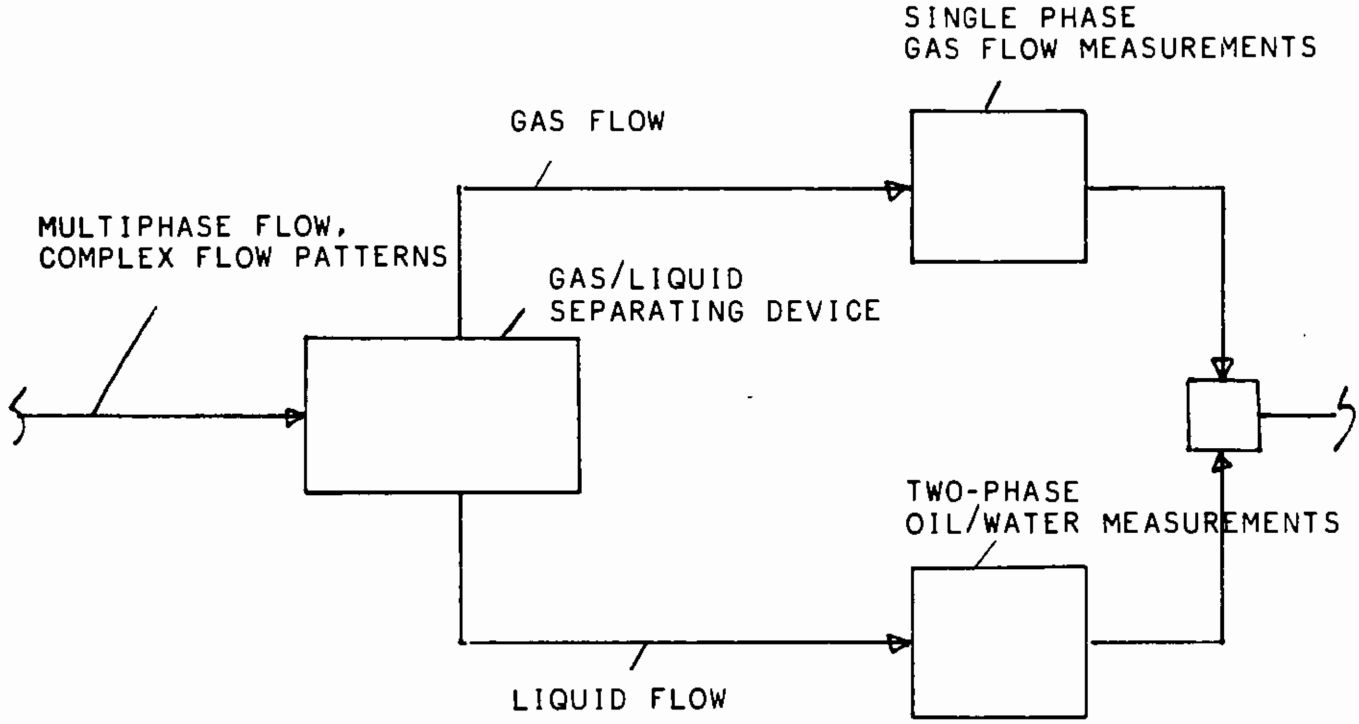


FIG. 1 LOCATION OF PRODUCTION TESTING EQUIPMENT WITHIN SUBSEA STATION

SEPARATION:



HOMOGENIZATION:

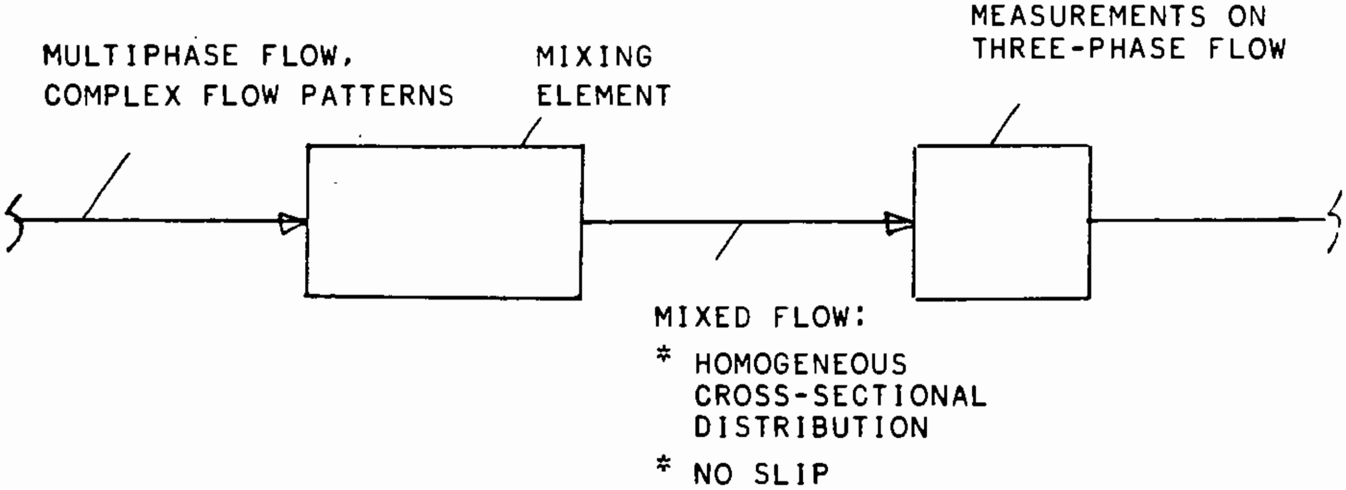
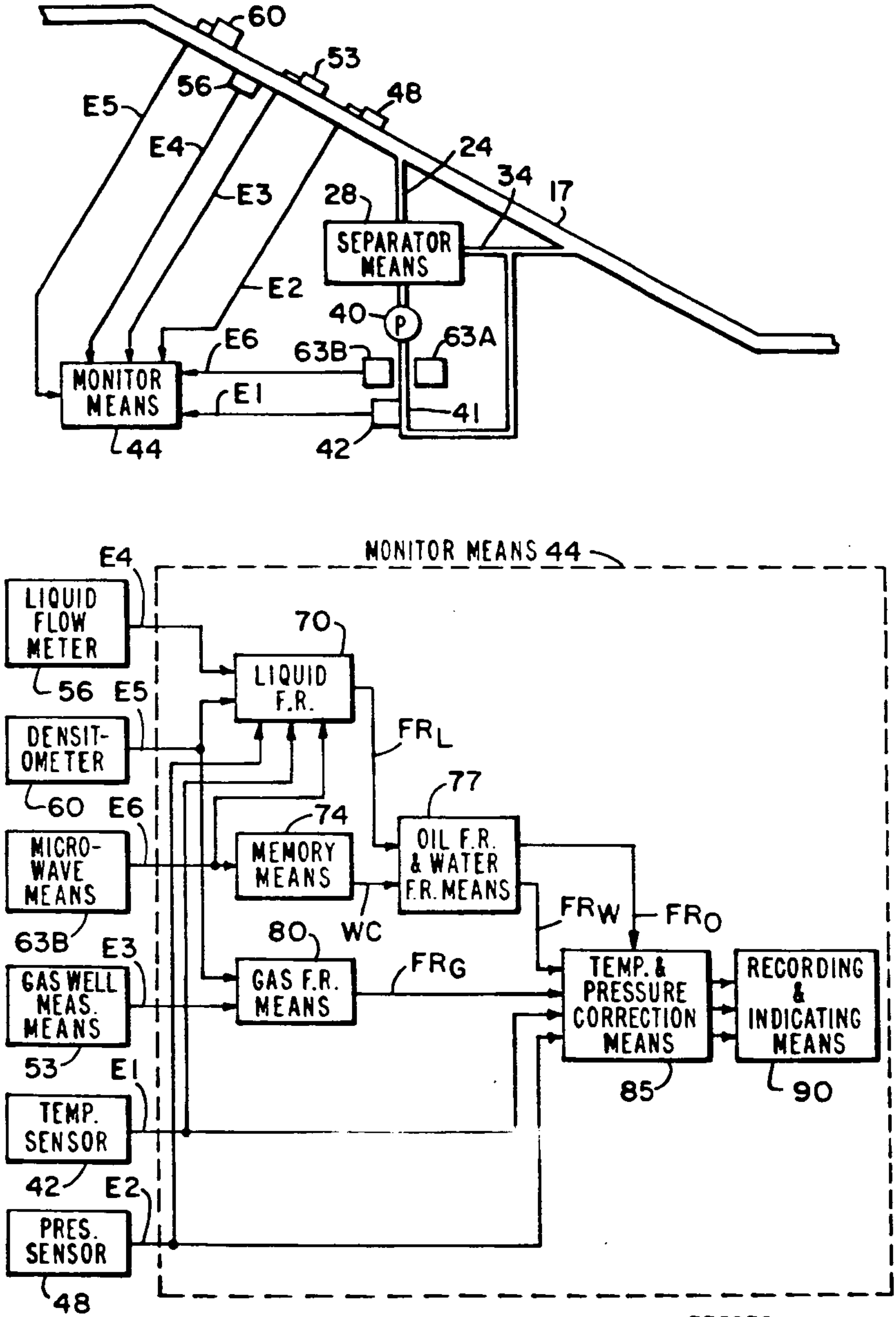


FIG. 2 FLOW CONDITIONING ELEMENTS LOCATED IN MAIN TEST LINE OR BY-PASS LOOP.



COPY FROM US PATENT NO. 775073

FIG. 3 WELL FLOW METERING SYSTEM DEVELOPED BY TEXACO, HOUSTON RESEARCH CENTER, USA

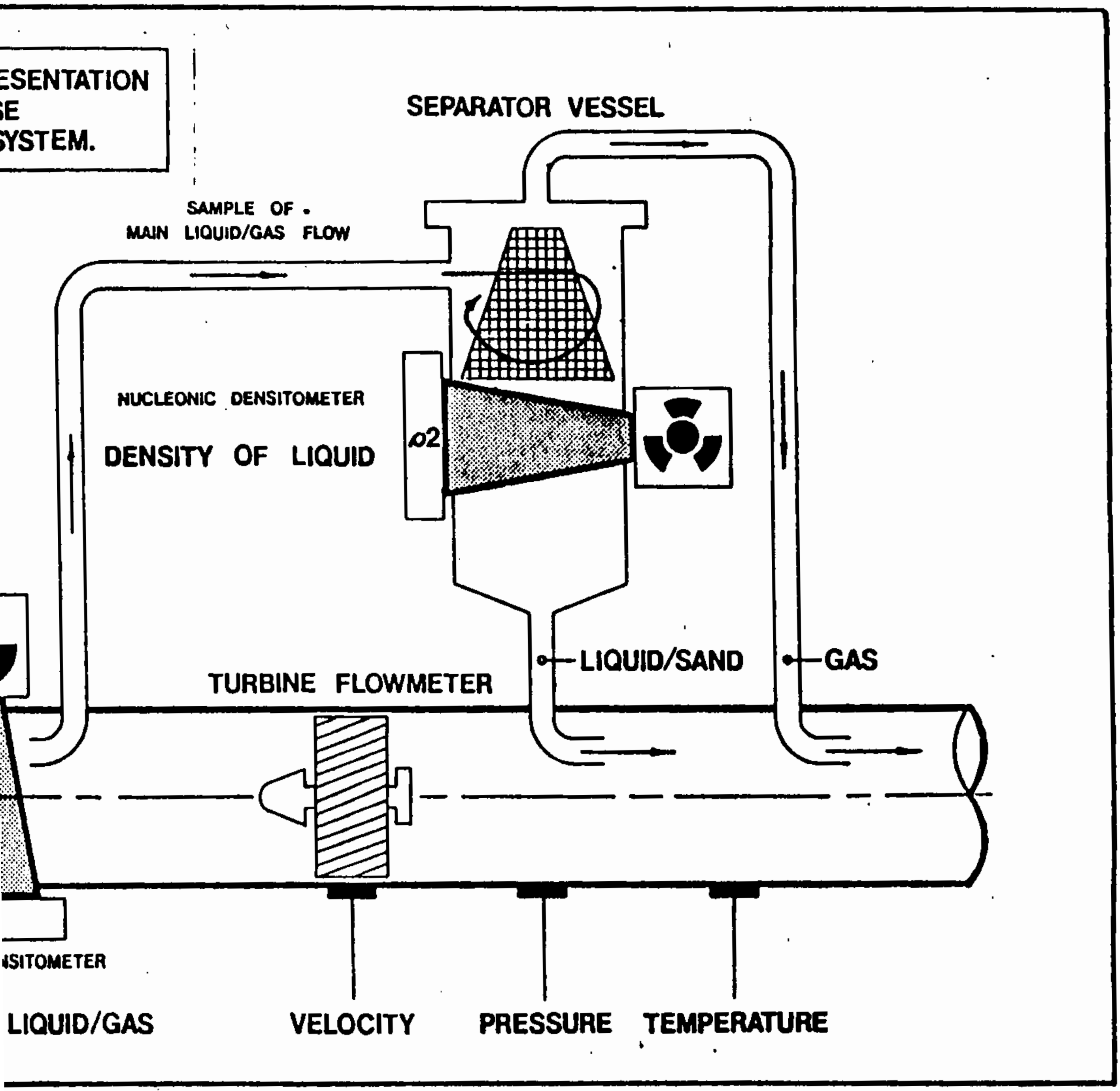


FIG. 4 WELL FLOW METERING SYSTEM DEVELOPED BY EUROMATIC MACHINE & OIL COMPANY LTD., UK

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.