Practical Application of Automatic Net Oil Computing Systems

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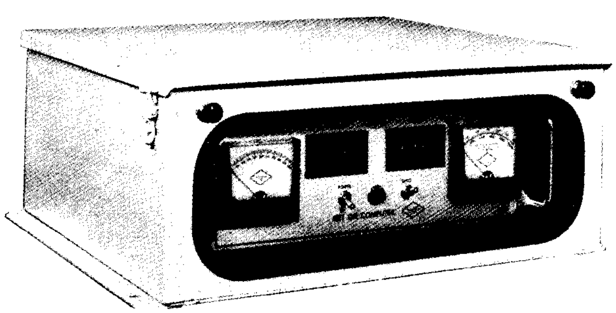
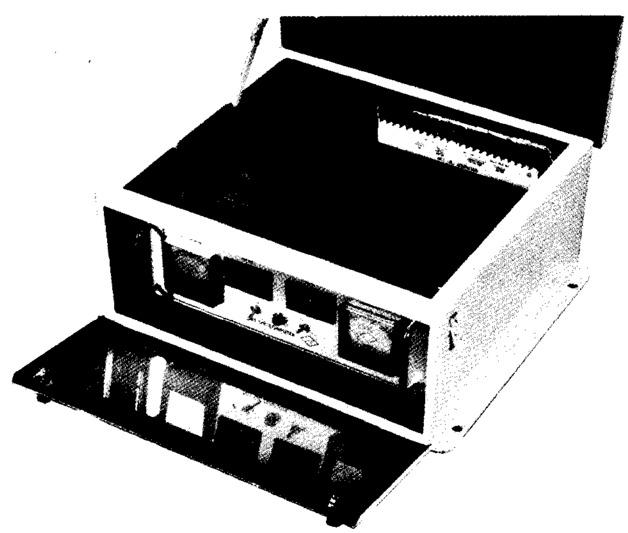
INTRODUCTION

Many oil-producing operations in widespread use today require an accurate measurement of the volume of net clean oil contained in the fluids produced by a well or a group of wells. Lease commingling and well-testing are the two most important of these operations. Conventional methods of determining the volume of net clean oil require physical separation of the oil and water prior to actual metering, either with an emulsion treater, a three-phase separator or at the very least a volumetric metering chamber and a sampler. These methods are expensive initially, costly to operate and leave much to be desired insofar as adaptability to automation is concerned.

Automatic net oil computing systems using a capacitance probe, a fluid meter and an integrating computer of one type or another have proven themselves in the past few years to be far superior in most instances to the old-fashioned methods of net oil metering. These systems automatically meter and monitor a well stream consisting of pure oil, pure water, emulsion, or any combination of these, and without requiring physical separation, automatically determine net clean oil and net water volumes. In addition, many of these sytsems provide an instantaneous analog readout of water cut and flow rate.

Although automatic net oil computing systems are now widely used and accepted, many operators continue to have operating problems with them. In nearly all such instances, the net





NET OIL COMPUTER IN WEATHER-PROOF HOUSING

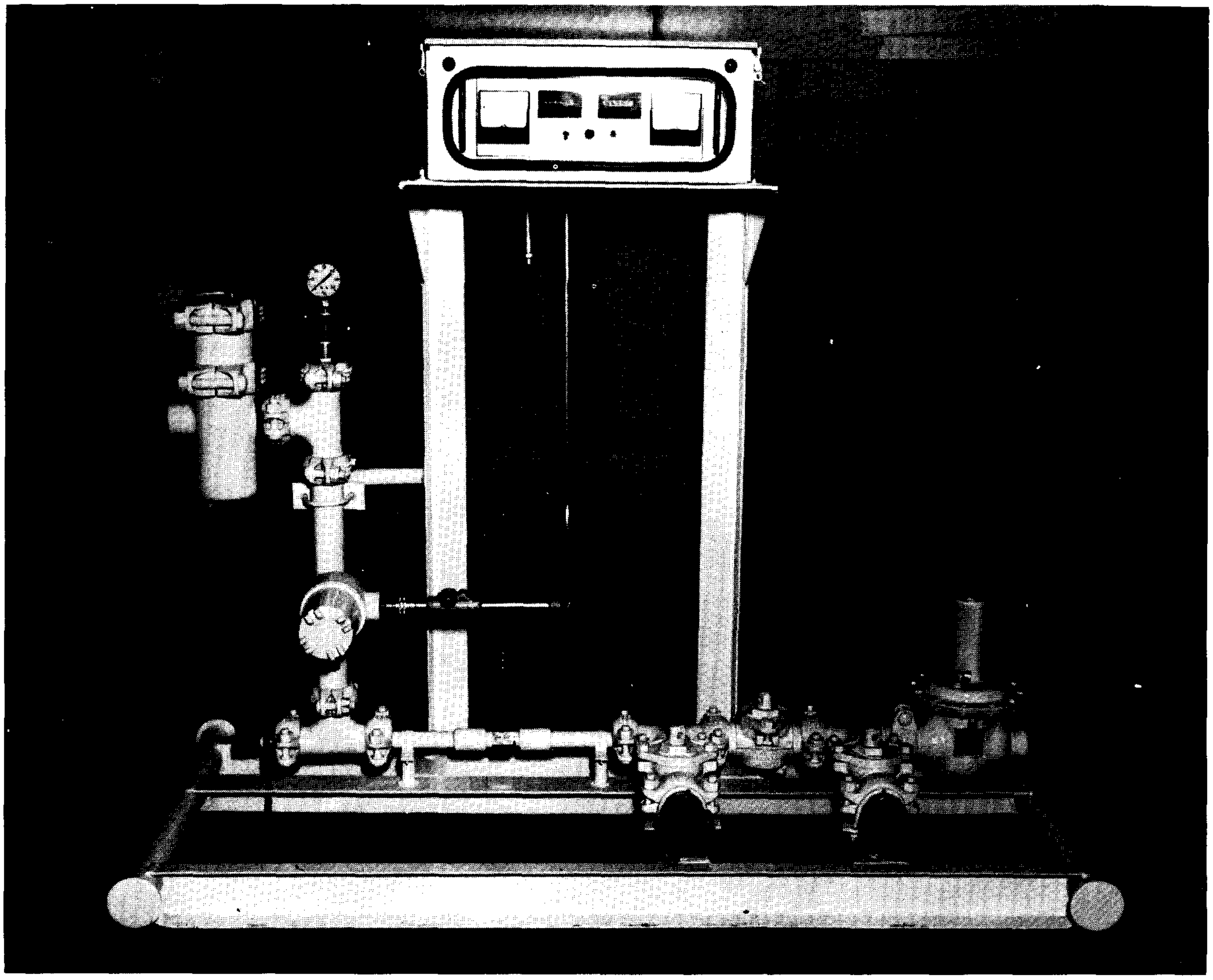
FIGURE I

oil computing system is mis-applied or improperly installed. The purpose of this paper is to explain the operation of net oil computing systems and point out several common mistakes in their practical application.

OPERATION

An automatic NOC system consists of three basic components: (1) a fluid meter, (2) a capacitance probe and (3) an integrating computer. The fluid meter provides an electronic output proportional to instantaneous gross fluid flow rate; the capacitance probe provides an electronic output proportional to instantaneous water cut of the fluid stream. The computer integrates these two signals and provides a direct digital readout of net oil volume and net water volume as well as analog outputs of fluid flow rate and per cent water cut (refer to Fig. 1 and Fig. 2).

Fluid meters can be of either the positive displacement type with a suitable high-speed electrical pulse transmitter or of the turbine meter type with its inherent high speed electrical output signal. By high speed transmitter we are referring to something generating 1000 pulses per bbl or more, usually 10,000 pulses per bbl. The reasons for this will be discussed later. Older types of NOC systems used transmitters generating only 10 or 100 pulses per bbl with proportionately lower resolution. Some much older types of meters used mechanical cables connected to the meter and/or mechanical clutches. The whole idea of the electrical transmitters or cables is simply to get an analog input from the fluid meter into the computer. It is obvious that the more pulses per bbl throughput and per unit of time the computer has to work with, the



higher will be the resolution of the integrated output.

The capacitance probe operates on the well-known principle that as the percentage of water in an oil-water emulsion increases, the dielectric constant of the mixture will increase. Dielectric constant is an inherent basic physical property of a material. Air has a constant of about 1.0: most oils have constants of 2.0 to 2.3 and most waters have constants of the order of 80.0. Therefore, relatively small amounts of water in any oil-water mixture will greatly affect and increase the composite dielectric constant of the mixture.

A capacitor in its simplest form is nothing more than two metallic plates separated by a dielectric material. In our case the dielectric material is the oil-water emulsion stream. Since it is not practical to flow fluid between two parallel plates, a coaxial capacitor of special design is employed, with the fluid flowing in the annulus between the outer pipe wall and the electrically isolated center element (refer to Fig. 3).

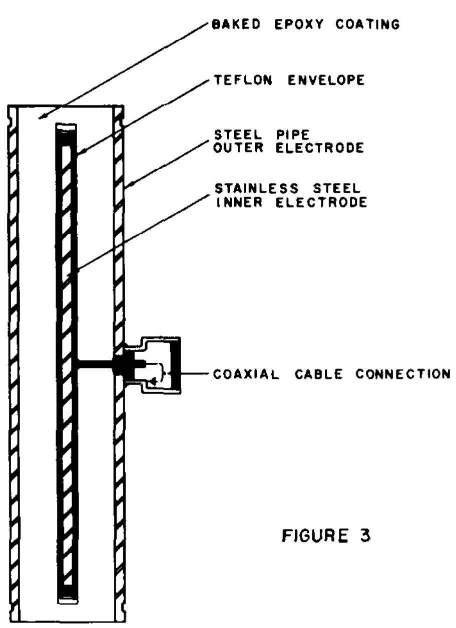


FIGURE 3

The capacitance exhibited by this probe, due to its special design, is directly proportional to the water cut of the fluid stream, i.e. some low value for pure oil, some high value for pure water, and some intermediate value, proportional and linear at all points in between. Not all probes exhibit perfectly linear characteristics due to their construction; several types are limited to about seventy per cent water cut on the high end of the scale.

The integrating computer now has two electrical variables to integrate: (1) fluid flow rate and (2) probe capacitance. There are two basic types of computers in widespread use: (1) the electromechanical type (Fig. 4) which uses an electrical servomotor and a cam-type integrator.

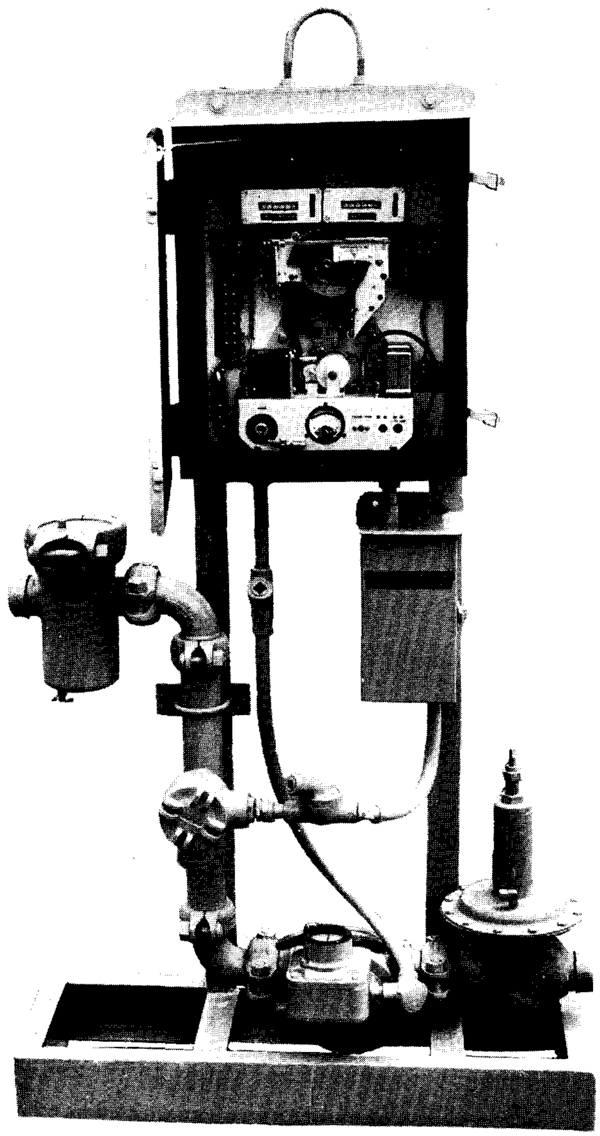


FIGURE 4

and (2) the all solid-state electronic type (Fig. 5) which has absolutely no moving parts. Both types have their advantages; one is slightly lower in cost and the other is much faster in speed of response. Certain applications demand the higher-speed unit if consistently high accuracy is to be achieved.

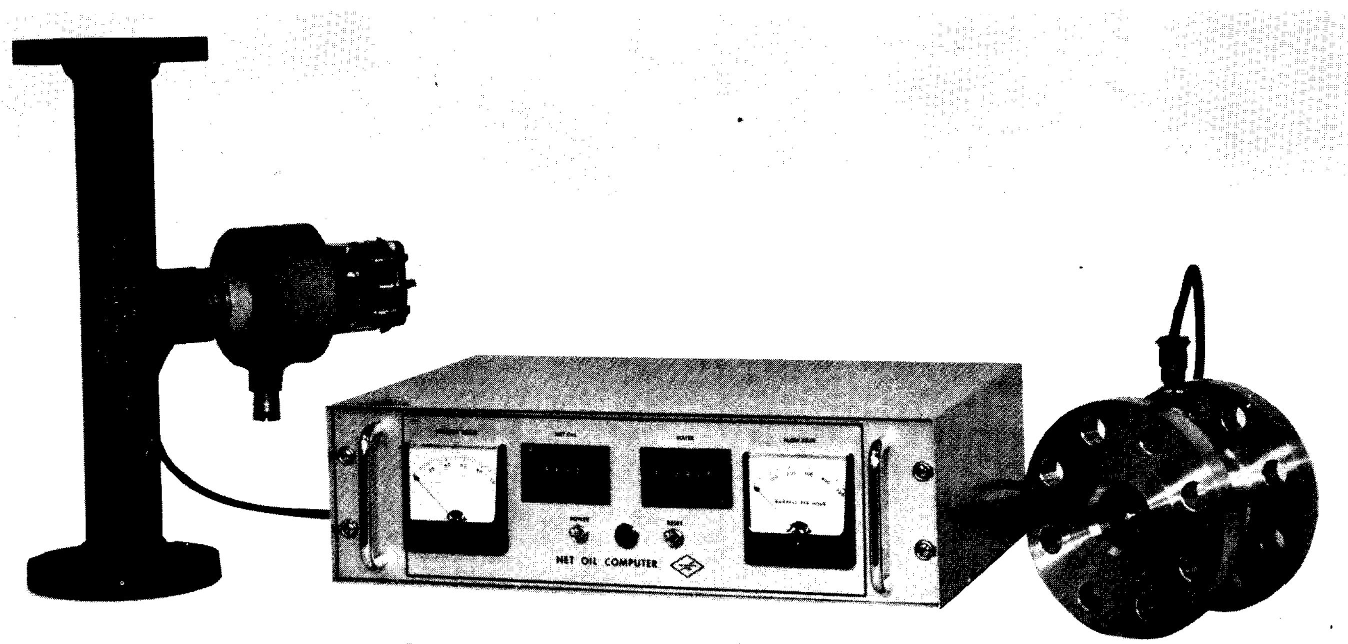
It would be worthwhile to review the operation of the solid-state net oil computing system shown in Fig. 6.

(1) The turbine flow meter produces an alternating current signal whose pulse rate or frequency is directly proportional to gross fluid flow rate. This signal is amplified and clipped producing a signal of constant amplitude, varying only in frequency. A typical 1-in. turbine flow meter generates exactly 39,400 pulses per bbl.

(2) The capacitance converter senses probe capacitance, which is directly proportional to water content, and produces a linear DC output signal which varies from 5 to 15 volts as the water cut varies from 0 to 100 per cent.

(3) The analog to digital converter receives the square wave AC signal from the turbine meter and the 5-15 VDC signal from the capacitance converter. The A to D converter generates a fixed time base linear sawtooth signal whose amplitude is proportional to time. The DC input signal from the capacitance converter is constantly compared with the linear sawtooth signal. The output from the comparator is used to operate gating circuits which route the AC turbine meter signal to one of two outputs. The amount of AC signal diverted to the two outputs is dependent only on the analog signal from the converter.

(4) For 30 per cent water content, 30 per cent of the pulses during a fixed time period would be diverted to the output that drives the water counter. The remaining 70 per cent of the pulses would be diverted to the oil output. Both of the outputs are routed to individual dividing



CAPACITANCE PROBE AND DETECTOR

NET OIL COMPUTER

TURBINE FLOWMETER

FIGURE 5

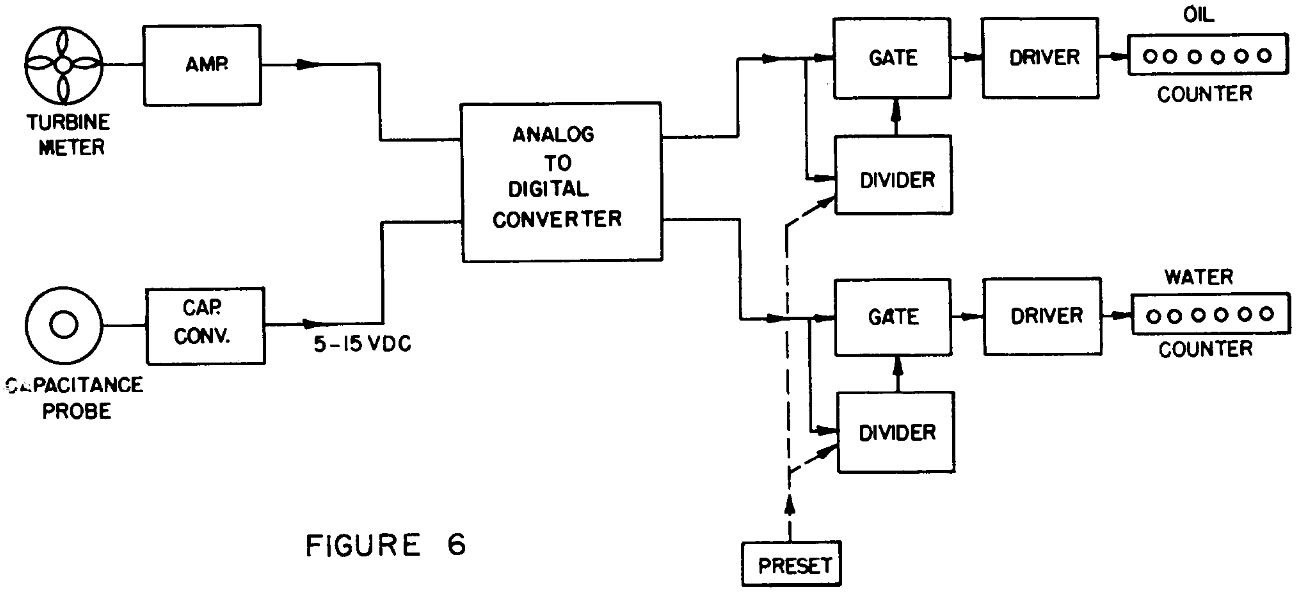


FIGURE 6

and gating circuits.

(5) The divider circuits store a fixed number of pulses and then produce one output pulse to the gate and driver circuits. The number of pulses stored in the divider is pre-set to correspond to the actual turbine meter factor. If a turbine meter generated 39,400 pulses per bbl, the divider would produce one output pulse for every 39,400 input pulses. This would allow the counter to read directly in barrels. The dividers can easily be preset to any other number, thus allowing the counters to read out in other units, such as gallons, tenths of barrels and so forth.

(6) When the gate circuit produces an output it automatically resets the divider circuit.

(7) The driver circuit accepts the output pulse from the gating circuit and amplifies it to a pulse of sufficient width and amplitude to drive a digital readout counter; thus we have one counter indicating net oil volume and one counter indicating net water volume.

(8) The AC signal from the turbine meter and the current signal from the capacitance converter are used to drive electrical meters indicating instantaneous water cut and instantaneous flow rate.

PRACTICAL APPLICATION

We have discussed in some detail the three primary elements of a net oil computing system. The characteristics, capabilities and limitations of these elements are pretty much "built-in" by the equipment manufacturer at the factory and the producer cannot do much to change these basic features. What the producer can and must do, if successful operation is to be realized, is to see that the equipment is properly installed and calibrated.

Proper installation of any system requires as a minimum the equipment shown in Fig. 7, which is as follows:

Separator: This vessel must remove all free gas from the fluid at whatever operating pressure is selected. It should be sized for at least a one minute fluid retention time and even more in the case of gas-lifted streams, foamy streams or sandy streams. The vessel must be large enough to accommodate fluid or gas volume surges, to provide a quieting section to separate the bulk of free water from the emulsion, and of a large enough diameter to permit a maximum volume of fluid to be dumped during each cycle.

Gas Back-Pressure Regulator: The regulator is necessary to control separator operating pressure within a one or two psig variation. Large pressure variations will cause large changes in fluid dumping rate resulting in fluid meter factor variations. The valve must be large enough to

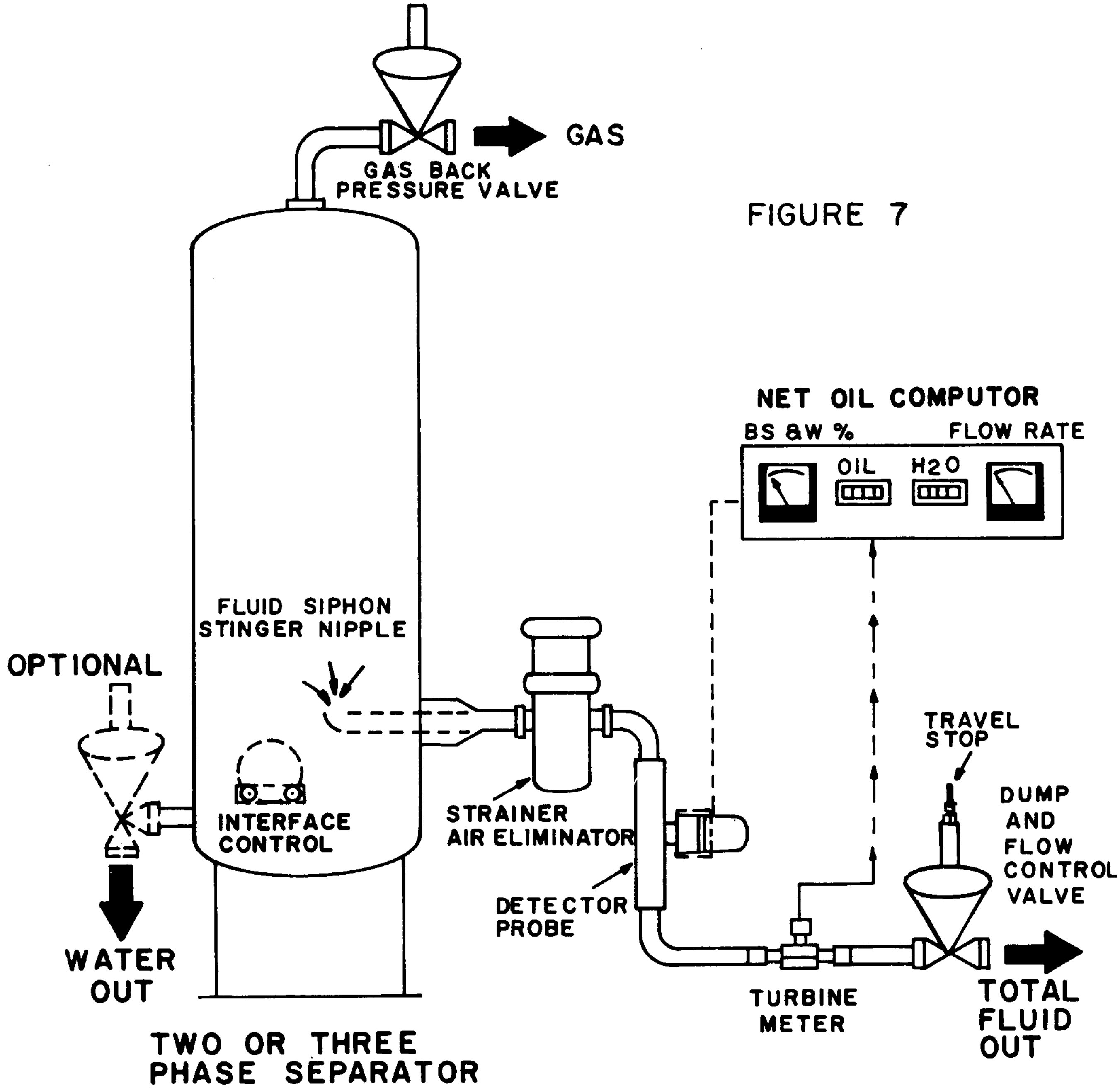


FIGURE 7

handle the maximum instantaneous gas flow rate.

Internal Fluid Siphon Stinger: The stinger should be the same size as the detector probe and be equipped with a 90° ell or fabricated "window" which should always be open in the upward direction. This device is used to minimize the "oil-stringer" effect which usually occurs when the oil-water interface level approaches a side-outlet type opening. Another use of the stinger is to permit any water which may enter the stinger opening to displace the oil in the detector probe so that at the start of the next dump cycle the probe content will approximate that in the separator at the stinger opening level. This will reduce the number of interfaces the instrument will be required to detect while the system is dumping. This is especially beneficial to the electromechanical systems which are much slower in response, requiring roughly 10 seconds to range full scale, as compared to the solid-state computer's instantaneous response.

Strainer-Air Eliminator: This device is used to remove solid particles and small amounts of free gas which may be present. The solid particles are detrimental to the proper operation of the detector probe, meter, and dump valve. The air eliminator is desirable to remove free gas which will cause error in the detector probe and fluid meter. The strainer-air eliminator should always be installed ahead of the equipment it is to protect and at the highest elevation.

Detector Probe: Since gas has a dielectric value less than oil, it is important that free gas not be allowed to enter the detector probe as it will result in values less than the true value of the fluid medium passing through the probe. The probe must always be installed in the vertical position and should be located lower than the separator outlet. This will permit any water present at the stinger opening to drain into the probe and displace the oil. Valves, ells, and other restrictions upstream of the probe should be kept to a minimum and there should be no "piping loops" upstream of the probe. In some installations, due to low pressure or low gravities and viscosities, it may become necessary to utilize a pump to remove the fluid from the separator. If this is the case, the system will usually work better by placing the pump downstream of the probe thereby eliminating any possibilities of the probe having to detect reverse emulsions created by the pump.

Meter: It is very important that the fluid be essentially void of free gas or it will not only cause a meter error, but very possibly will result in damage to the meter. The meter should always be located downstream of the probe and upstream of the back-pressure valve.

Dump Valve and Rate Controller: This may be a single combination device or it may be two separate devices. The requirement is for a snap-acting dump valve with a positive shut-off, to be used in conjunction with a device for restricting or "leveling-out" the flow rate when the unit is dumping. The flow rate control feature is necessary so that the rate of dump will be within the range of the meter, otherwise the meter accuracy will be affected. Normally a combination type valve is used, as it is simple and easily adjusted, but other arrangements such as a dump valve and a choke nipple or a dump valve and a back-pressure valve may also be used. The travel stop, in addition, serves to lengthen or "stretch-out" the dump cycle thereby allowing the detection and integration equipment to have a longer look at the gross fluid flowing through the system. This greatly improves the overall accuracy of the system.

Liquid Level Control: This should be a reliable snap-acting type control with a float arm of sufficient length to obtain a maximum fluid volume each dump cycle. It should be located and installed so the incoming fluid will not interfere with its proper operation and it should be so adjusted to trip well above the fluid outlet or gas will be permitted to enter into the detector probe.

System Accuracy: Assuming the producer has purchased a high-quality fluid meter, capacitance probe and integrating computer and has installed these components in accordance with the foregoing discussion, he may reasonably expect readings accurate to within one water per cent of the true water cut. When proper meter and shrinkage factors are applied, the digital net oil and net water volumes will be within one water per cent of their true volumes.

The sensitivity of the capacitance probe is the main limiting factor governing accuracy that can be obtained. A typical probe designed for use in streams containing up to 100 per cent water has a sensitivity of about 1/2 per cent water. This means that it takes a 1/2 per cent change in water cut for the probe to sense any change at all; this is true whether the water cut is 20 per cent or 80 per cent. The water cut has to increase or decrease by 1/2 per cent or the instrument will not see the change.

Since the cut could conceivably change almost 1/2 per cent, up or down, before the instrument will respond, the overall accuracy cannot exceed one per cent. Now let's see what this means in terms of accuracy expressed as a percentage of net oil:

(1) If 100 bbl of 20 per cent cut emulsion flowed through the system, the net oil computer should read 80 bbl; but since we could be off by one water per cent, the counter might read 79 bbl. Therefore we have missed one barrel out of eighty which represents 1.25 per cent error when expressed as a percentage of net oil.

(2) If 100 bbl of 80 per cent cut emulsion flowed through the system, the net oil counter should read 20 bbl; once again we could be off one water per cent so the counter might read 19 bbl. In this case we have missed one barrel out of twenty which is a 5 per cent error expressed as a percentage of net oil.

In actual practice, the errors will be high one dump and low the next and should average out much better than in these illustrations, but it is important to know the difference between accuracy figures when expressed as a percentage of net oil and when merely expressed as per cent.

SUMMARY

Automatic net oil computing systems are a useful tool in lease commingling and well testing operations, but their ultimate success depends on the quality of the basic components, the proper installation and calibration of the system and the understanding by the producer of the inherent capabilities and limitations of the system.

BASE MAP

SHOWING RELATIONSHIP OF THE ODESSA COMPLEX & DISPOSAL WELL TO THE CITY OF ODESSA.

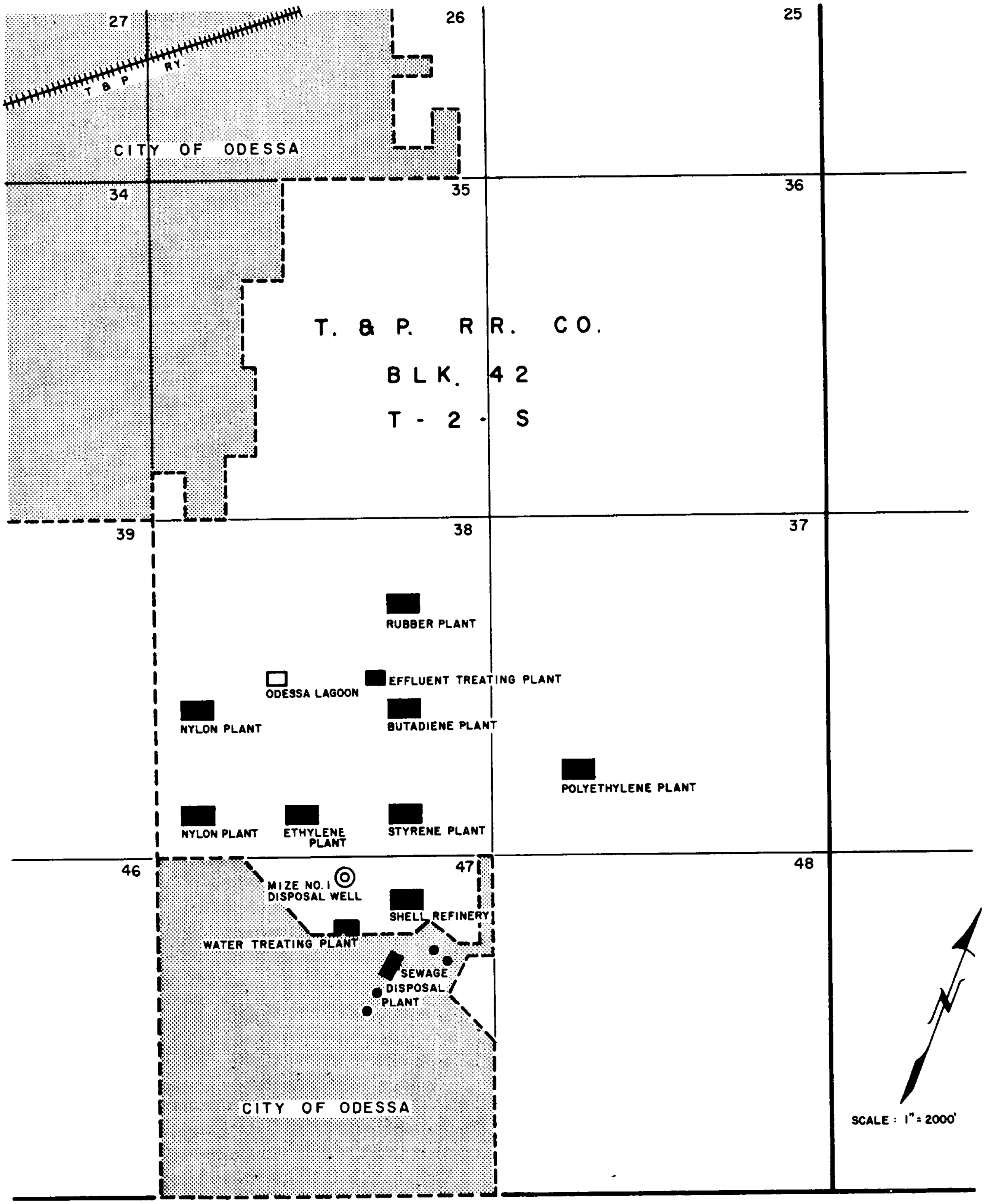


FIGURE 1