ENHANCE PRODUCED WATER MANAGEMENT WITH OIL-IN-WATER MONITORING SYSTEMS

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Abstract:

Texaco E & P Technology Dept., under the supervision of Dr. Dale Brost, has developed Oil-in-Water (OIW) Monitoring Systems. This five year project was initiated to provide an on-line monitoring system that would be instrumental in providing clean water to address the environmental issue, reduce chemical costs in water treating systems, provide recorded water monitoring every second of every day, and set off alarms. Based on this research, the EOA (Environmental Oil Alert) OIW monitor, (fluorescence method) was developed through joint efforts by Texaco and Houston Photonics, Inc.

Through continuous research, an additional on-line monitoring system, the *SpectraScan* OIW Monitor, an absorbance method for running oil-in-water ppm, was developed. The *SpectraScan* OIW Analyzer for bench top analysis was also developed to replace the freon solvent extraction method (IR) of running oil-in-water ppm.

A major producer in the Permian Basin would have had the capability of reducing the $3.3 mm spent annually on injection well work-overs and filter media replacement with the use of a OIW on-line Monitor. In conjunction with the savings, the effectiveness of the CO_2 water flood would have been greatly enhanced.

Introduction:

Managing produced water has posed problems for the oil industry since the early 60's. At the beginning, producers were faced with improper equipment design and the challenge of accurately measuring oil ppm in produced water on a day to day basis. From all indications, the first attempt to measure oil-in-water was performed with a light meter for Chevron Oil Company, Main Pass Blk. 30 in the mid 60's. A water treating barge was designed and installed in order to provide clean water as a means to protect nearby oyster beds. This experience presented quite a learning curve for both the producer and service companies. The importance of running oil ppm at the location in a timely manner was clearly evident. Equipment retention time proved to be an essential part of water cleanup and chemical application and dosage were also critical in providing clean water in a highly visible area.

The Water Quality Improvement Act directed by the President of the United States regulating the discharge of oil into territorial waters of the U.S. has played a major role in providing accurate methods of measuring oil-in-water. Continuous oil in water monitoring assures the industry that it is complying with the Water Quality Improvement Act every second of every day.

Scope of Research Project:

The environmental concerns on the West Coast prompted the development of the EOA OIW Monitor. This on-line monitor was instrumental in "Real Time" measuring of oil ppm in water being discharged in rivers and irrigation canals. The specifications of the discharge waters is less than 1ppm, consequently, it is essential that the oil is monitored every second of every day. This monitoring method accomplished numerous benefits. It eliminated the use of solvents to run oil-in-water, reduced man-power and reduced chemical consumption for water clarification.

With the success of the EOA Unit, the Texaco Research Team developed the *SpectraScan* Oil-in-Water Monitor, an on-line monitor that uses the absorbance method to measure oil-in-water. This method enabled the research team to further develop the *SpectraScan* Analyzer, a benchtop instrument for discrete sampling, which requires no organic solvents and can be calibrated to all compliance needs within a 5-tenths ppm range. The *SpectraScan* Analyzer can replace the freon solvent extraction method (IR) of running oil-in-water ppm which will soon be banned for analytical use.

EOA On Line Monitor:

The Environmental Oil Alert (EOA) system is an on-line oil-in-water monitoring system. This system was developed jointly with Texaco EPTD Research Group and Houston Photonics, Inc. primarily for the West Coast area to determine low oil ppm in heavy crude and fresh water. Because of its unique blend of instrumental and chemical technologies, the EOA is capable of monitoring any produced water stream regardless of oil gravity, salinity or temperature. Special non-fouling water samplers allow the system to operate for long periods without maintenance. This system has been tested over a four year period and the performance and reliability has been proven in a variety of produced water environments from the sands and heat of Saudi Arabia to offshore and onshore USA. The EOA System is an ultraviolet fluorescence with actual wavelength selection by interchangeable filter modules. Readings evaluated under actual field conditions range from 0 to 200 ppm.

The EOA OIW Monitoring System offers both analog and digital outputs for trending data, process control capabilities for chemical pump operation, alarm systems and other applications. These instruments enable continuous real-time monitoring and is the first step to automated treatment of produced water. These capabilities allowed the oil producers on the West Coast to fine-tune their chemical program and decrease chemical expenditures, consequently justifying the purchase of the EOA OIW Monitoring Systems.

EOA Operating System:

The EOA System obtains its evaluation/sampling water directly from a small three-quarter (3/4) inch line tapped into the main water source efflux. This water line feeds directly to the EOA System's water pump which provides a controlled 0.5 gpm steady-state flow rate to the Falling Stream Sampler Unit where water quality is monitored and evaluated. When the Fluoro-Plus chemical additive pump assembly is used, the EOA System injects the Fluoro-Plus additive into the small 3/4 inch water line as near its source as possible via an Injector Assembly. **(Fig. 1)**

A Xenon light source within the Photometer Unit transmits high intensity light pulses by optical fiber cable to the Falling Stream Sampler, where the light impinges upon the falling stream causing the oil within the water to fluoresce. A sensing optical cable receives the fluorescent light pulse as seen from the water column and transmits it back to the evaluating PMT and its circuits in the Photometer Unit. An evaluation is performed versus established calibration standards, with the results available as ppm of oil-in-water. Once calibrated, the EOA System provides an update approximately every two (2) seconds to the local control panel LCD display or in the form of analog or digital formats at the output terminal. The processed output is automatically scaled to the calibrated operating range and may be used externally by PC's, PLC's, etc., *in conjunction with the user's appropriate facility controls.*

Output terminal/port available formats are: **(Fig. 2)**

Analog: 4-20 ma

0-1, 2.5, 5, & 10 VDC

Digital: RS232C or RS485

When necessary, a Fluoro-Plus additive is added via the metered chemical pump, to clarify and enhance the system oil-in-water's fluorescence to improve the sensor's ability to accurately "read" the water column. To further enhance the reliability and performance while minimizing maintenance needs, filtered air is introduced into the Falling Stream Sampler Unit. This prevents condensation and or fogging of the internal optics. A drain fitting on the Falling Stream Sampler is provided for test water removal.

Accuracy of the EOA System:

The EOA System signal processing electronics incorporates 12 Bit precision with a total unadjusted error over the specified operating temperature range of +-1/2 LSB. Field results have shown that quantitative results are affected foremost by the ability to identify and control external parameters such as sample conditioning, and methodology (such as EPA IR Freon oil-in-water method 413.3 which as well as others have inherent uncertainties) therefore, repeatable results are dependent upon the consistency with which the samples are processed while calibrating the system under actual field operating conditions.

Field tests have shown that short term (10-20 minutes) and long term (24 hours) precision is possible as follows:

Calibrated range from 0 to 3 ppm to be +-0.1 ppm

Calibrated range from 0 to 20 ppm to be +-0.5 ppm

Calibrated range from 0 to 50 ppm to be +-2 ppm

Calibrated range from 0 to 100 ppm to be +-5 ppm

(Fig. 3)

SpectraScan :

The *SpectraScan* light measurement system is based on recent developments in miniaturized opto-electronics. As illustrated in **Fig. 4,** the optical system consists of a mercury-argon light source, a water sampler, and a miniature spectrometer mounted on a data acquisition card. The card fits into a standard "AT" slot of an IBM-compatible computer. The components are linked together by fiber optic cables. The spectrometer is a sealed, solid state device that operates without moving parts. Inside the spectrometer, light is separated into its component wavelengths and imaged onto a CCD array detector. The detector simultaneously monitors up to 7 wavelengths of light from 254 to 578 nm. Wavelength accuracy and response stability are assured by software routines that automatically adjust the spectrometer every time a measurement is made. Performance is equivalent to most laboratory spectrophotometers.

SpectraScan OIW Monitor:

The *SpectraScan* OIW Monitor uses a non-fouling, falling stream water sampler for on-line oil-in-water measurements.**(Fig. 5)** The sampler contains a compressed air, steam removal system to prevent condensation when monitoring high temperature water streams.

(Fig. 6)

The optical and electronic components are packaged in a NEMA 4X or NEMA 7X enclosure that can be located up to 50 ft. from the falling stream water sampler. In addition to the *SpectraScan* optical system and supporting electronics, the enclosure contains a programmable process controller and a full compliment of analog and digital interfaces. These features allow the *SpectraScan* OIW Monitor to actuate alarms or to automatically control water purification facilities.

On-line monitoring makes it possible for operators to "see" the water quality in real time, and to immediately observe the consequences of actions taken. This is illustrated in **Fig.** 7 with data collected by the *SpectraScan* OIW Monitor during a water quality upset on an offshore platform.

Initial oil concentration was approximately 50ppm (EPA 413.2). Just after 18:00 on June 18, the flotation cell hatch was opened to permit inspection of the vessel. This allowed air to immediately saturate the vessel, causing oil concentration to rapidly increase to 98 ppm. The ensuing water quality upset took several hours to dissipate. At 21:00 on June 18, the choke was pulled from one of the producing wells causing water production to increase by 1000 BPD. This eventually caused the water level in the treater to short out the grid, making it necessary to bypass the treater and go directly to the skimmer. On June 19, water volumes went down and platform operations (and water quality) returned to normal.

This type of information is impossible to obtain by collecting and analyzing individual water samples. Even if samples are analyzed every two hours, many events will go completely unnoticed. In reality, current man-power in most locations simply can not deal with more than one sample per shift, especially if operators are busy solving problems within the facilities.

A typical installation of the ***SpectraScan* OIW Monitor** is shown in **Fig. 8.**

SpectraScan OIW Analyzer:

The *SpectraScan* OIW Analyzer uses a fiber optic transmission probe for the analysis of individual water samples. It is a "virtual instrument". That is, it appears to the user as a display on the computer's monitor, and is controlled completely by software. **(Fig. 9)**

The software was written specifically for the analysis of oil-in-water. It takes full advantage of *SpectraScan's* sophisticated hardware, while presenting the operator with an extremely simple user interface. The operator simply clicks a mouse on a few buttons, and the oil concentration is displayed. All the complex spectral measurements and computations are carried out automatically in the background. **(Fig. 2)**

With different sample preparation procedures, the *SpectraScan* Analyzers can be used to measure either total oil or dispersed oil concentration. The relative concentration of water-soluble organic compounds (dissolved oil) can also be monitored. In all cases, the operator makes a measurement by placing the probe in an oil-free blank, clicking on a (Blank) button, and then placing the probe in a prepared sample and clicking on a (Sample) button. After a few seconds, oil concentration appears in the center of the screen.**(Fig. 10)**

To date, *SpectraScan* OIW Analyzers have been installed in numerous locations worldwide. Without exception, the Solvent-Free analysis method has produced excellent results. *SpectraScan* response has been found to correlate well with many of the traditional solvent-extraction methods. A recent installation of the *SpectraScan* OIW Analyzer on a offshore platform in the Gulf of Mexico indicates that the repeatability of the *SpectraScan* OIW Analyzer exceeds the IR method. **(Fig. 11)** The *SpectraScan* Oil-in-water Analyzer also provides excellent accuracy when calibrated with the gravimetric method of running oil-in-water.**(Fig. 12)**

Produced Water Management:

Through the years, as the volume of water in produced fluid has increased, the role of the producer has shifted somewhat from being in the oil business to being in the produced water management business.

The importance of effectively managing produced water was introduced through a paper presented in 1989 at the Southwest Petroleum Short Course. As the volume of produced oil increases, so will the volume of produced water increase at a startling rate of approximately 80%. It is estimated that the industry loses over 1mm barrels of oil annually due to poor water quality either through re-injection or over-board dumping.

The oil producers can increase profitability by millions of dollars annually through produced water management. A major ingredient in managing produced water is monitoring oil-in-water carryover. Listed are three case histories where properly produced water management through oil-in-water monitoring could have drastically increased profits.

Case History No. 1

Water Flood:
A major producer in West Texas selected a field for chemical evaluation. Chemical expenditures were 15% of the total field's operating expenses on this CO_2 Flood. The producer also expressed concern over the response of the CO_2 Flood, high expenditures revolving around repairs on injection and producing wells and lost oil sales. During the evaluation, it became quite evident that there were also serious problems in the produced water quality. The filter media was plugged, the water treating equipment was loaded with solids and oil carryover in some cases exceeded 1000 ppm. At times, quality of the water leaving the filters was worse than that of the filter feed water. The chemical evaluation and re-designing of tanks improved the water quality, (In most cases, oil ppm carryover is less than 10ppm.) and savings listed below totaled over $3mm.

- Chemical reduction - $350,000
- Recharged filter media - $125,000
- Reduction in injection well repair - $300,000
- Increased oil sales - over $600,000
- Over 2mm savings in well repairs

The modifications have proven to be very effective, however, it is imperative that monitoring oil-in-water ppm continue in order to determine time for equipment clean-up, skimming operations and preventing excessive chemical usage.

Case History No. 2

Water Injection:
The old theory that a disposal well's reservoir can handle anything that is pumped into it has proved to be a fallacy. The industry has spent mega-bucks to get oil to the surface. Caution should be taken not to inject it back into the ground. By reclaiming salable oil, even in a disposal system that can handle an enormous amount of solids and oil, it would be feasible to put treating equipment and an oil-in-water monitoring system that can effectively salvage and sell reclaimed oil.

Oil carryover in a water treating system recently evaluated was so extreme that it was recommended that the internal tank be re-designed and equipped with an oil skimmer. Once the recommendations were carried out, the producer was able to reclaim over 40 barrels of oil per day plus an additional $200,000 savings on filter media replacement. At this time a *SpectraScan* oil-in-water monitor that would perform the following functions is being considered.

- Reduction in manpower to monitor oil-in-water ppm
- Elimination of hazardous materials to run oil ppm
- Chemical consumption would be controlled by monitor
- Skimming operations would be controlled by monitor
- Set off alarm to divert flow to eliminate filter plugging

This is one of six locations in the field which should be evaluated for potential savings through oil-in-water monitoring, equipment evaluation and skimming.

Case History No. 3

Offshore:
A recent mishap on the Gulf coast of Louisiana resulted in oil being washed up on the beaches. Apparently there was an increase in oil carryover due to equipment failure on an offshore production platform. The operator increased the amount of water clarification chemical and for some reason, the oil concentration continued to increase. The operator, unaware that a slick had formed on the water , continued to increase the water clarification product which consequently submerged the oil into the gulf. As the oil surfaced, a leak in the pipeline was believed to be causing the problem. After a great expense of hiring divers to find the leak, it was discovered that the oil slick was coming from the platform due to excessive oil carryover which was submerged due to the increase in water clarification products. The operator incurred exorbitant expenses during this mishap including divers looking for a pipeline leak, the clean-up process for the oil on the beaches, plus whatever fines were levied by the EPA. A *SpectraScan* Oil-in-water monitor could have prevented the problems by:

- Measuring water quality every second of every day
- Setting off an alarm indicating problems with overboard water
- Properly increasing chemical pump - not saturation
- An aid to trouble shooting problems before they occur
- Proper evaluation of offshore water treating equipment
- Predicting necessity for equipment cleanup

Produced water management is the wave of the future. Producers who place emphasis on effectively monitoring produced water through an in-line monitoring system can increase profitability through reclaimed oil sales, enhance effectiveness of the water flood system and meet the EPA requirements of the Water Quality Improvement Act that will protect the environment.

Summary:

Although emphasis has been placed on monitoring oil-in-water in environmental sensitive areas such as the Gulf Coast and the West Coast, we have found that accurately monitoring produced water in water floods and disposal systems can be highly beneficial to producers in the following manner:

- Reduction in water treating products
- Determine adequate tank designs
- Improve oil skimming
- Eliminate excessive oil treating chemicals
- Eliminate the use of water soluble surfactants
- Reduce excessive down hole chemicals

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3. Brost , Dale F.; Winslow, Greg; Rexach, Frank; "Optical Methods for Monitoring Treating Chemical in Oilfield Water Systems" SPE Oct. 1991 #22781
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About The Authors

Bob Sevin, a native of Grand Isle, Louisiana has been affiliated with the oil and gas industry for over 35 years including 25 years with a major chemical company in various managerial positions covering the Continental U.S. and Alaska. Bob was an instructor on Water Treating Technology for PETEX from 1981 to 1990, guest speaker for SPE, A.P.I., N.A.C.E. and N.G.P.L. He has written and presented six technical papers on Water Treating Technology and his technical paper on Water Treating Equipment was published in Petroleum Engineers, International.
Bob Sevin is presently Vice President of Marketing and Alliances for Filco Int., Inc. Lafayette, La.

Ralph Saujon a native of South Louisiana, has been working in the electronics field for the past 20 years. Ralph served in the United States Air Force from 1975 to 1979. He has since worked for EG&G at several government test ranges including Nevada Test Site, Dugway Proving Grounds, China Lake Range, and White Sands Missile Range.
Ralph is currently working with Filco International, Inc. as a Electronics Technologist. He has been working with Dr. Dale Brost of Texaco for the past 9 months on the Oil-In-Water Monitoring Systems.

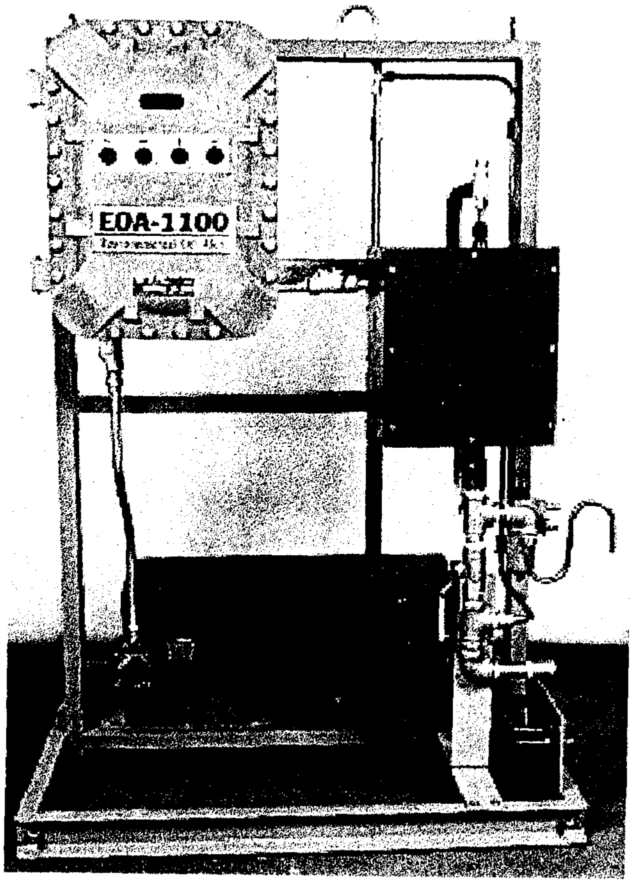
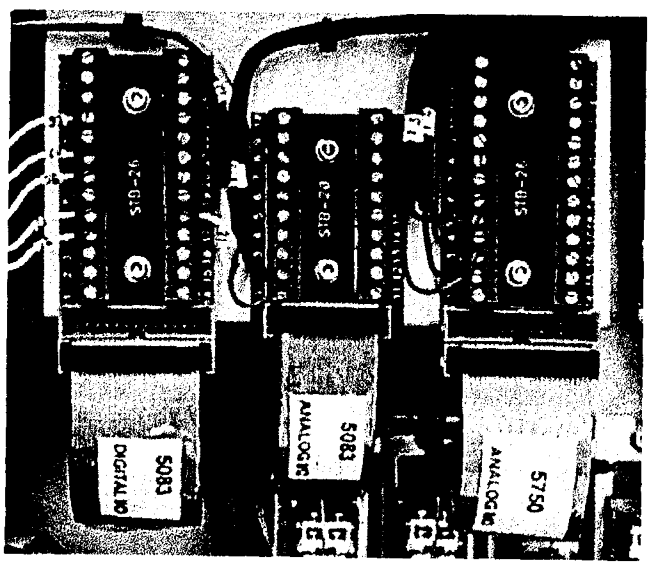


Figure 1



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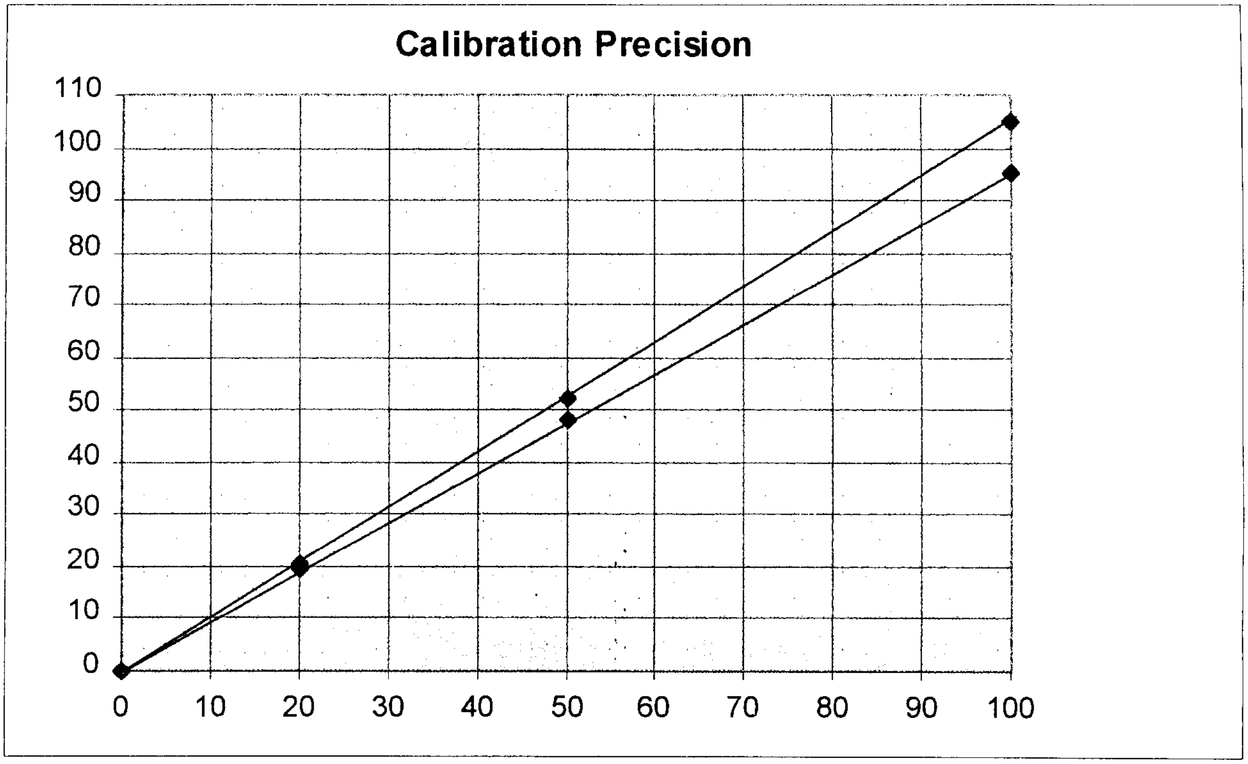

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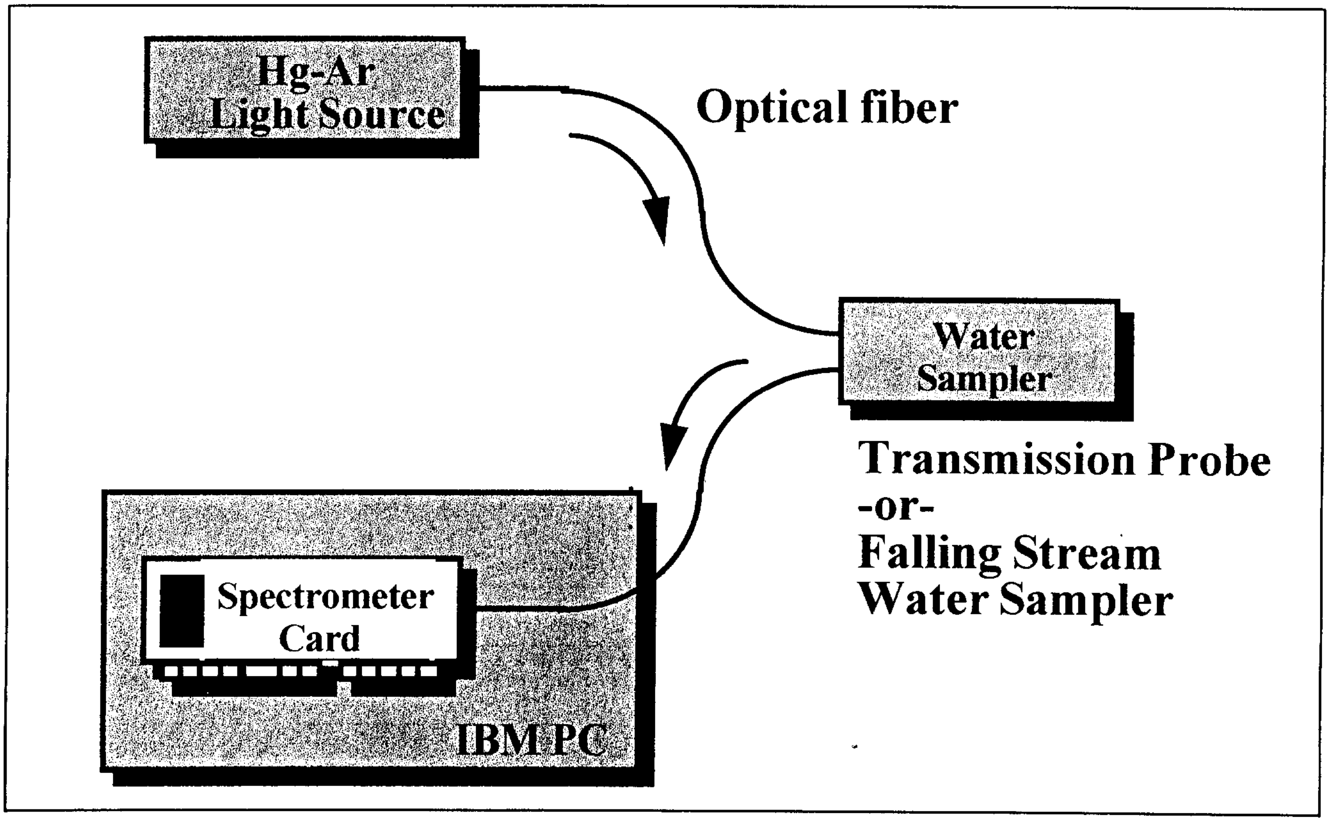

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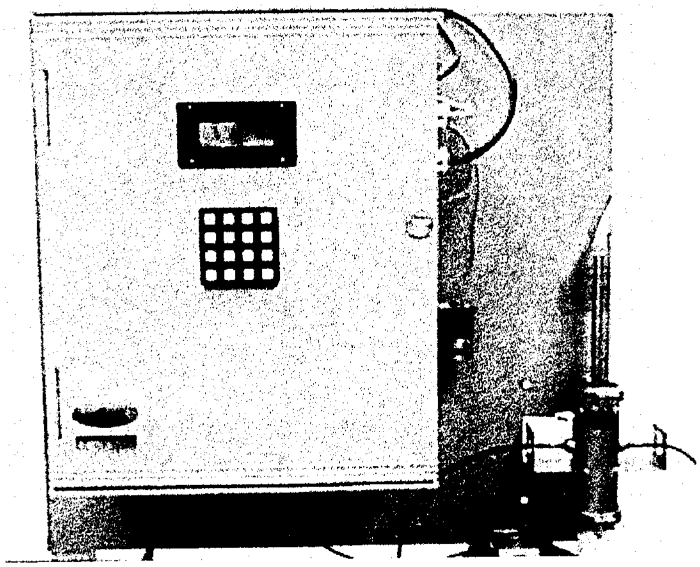

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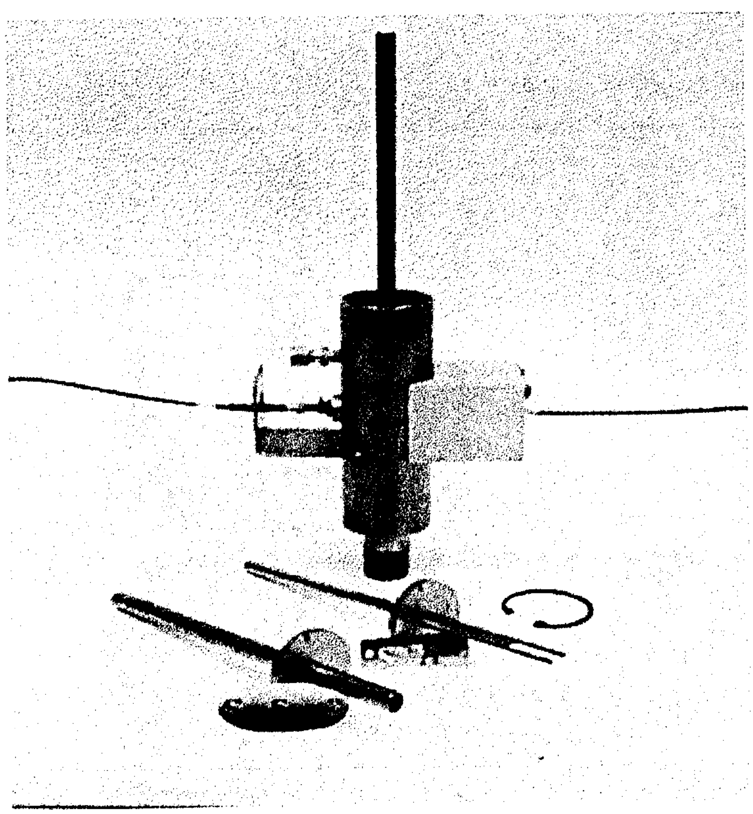

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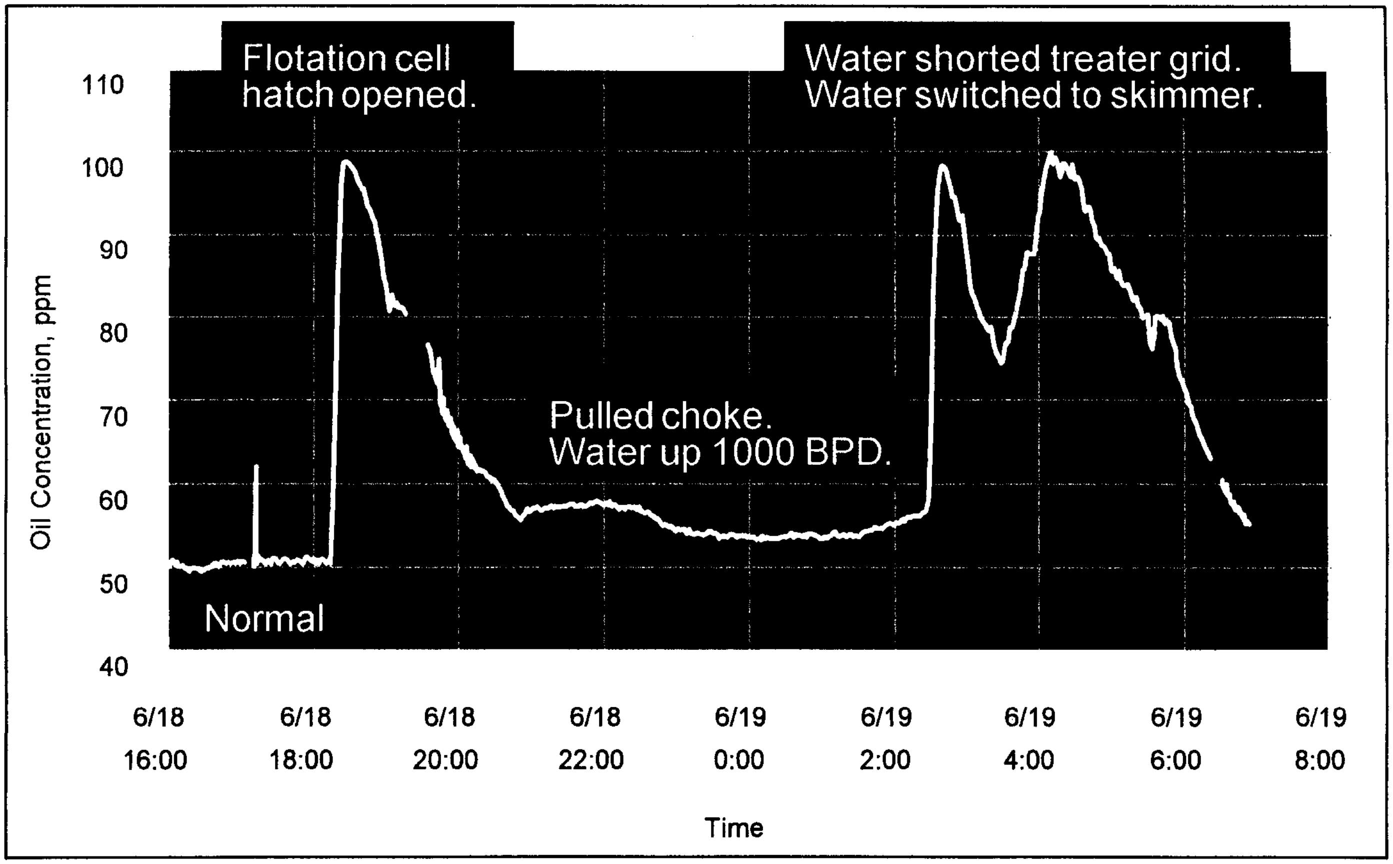

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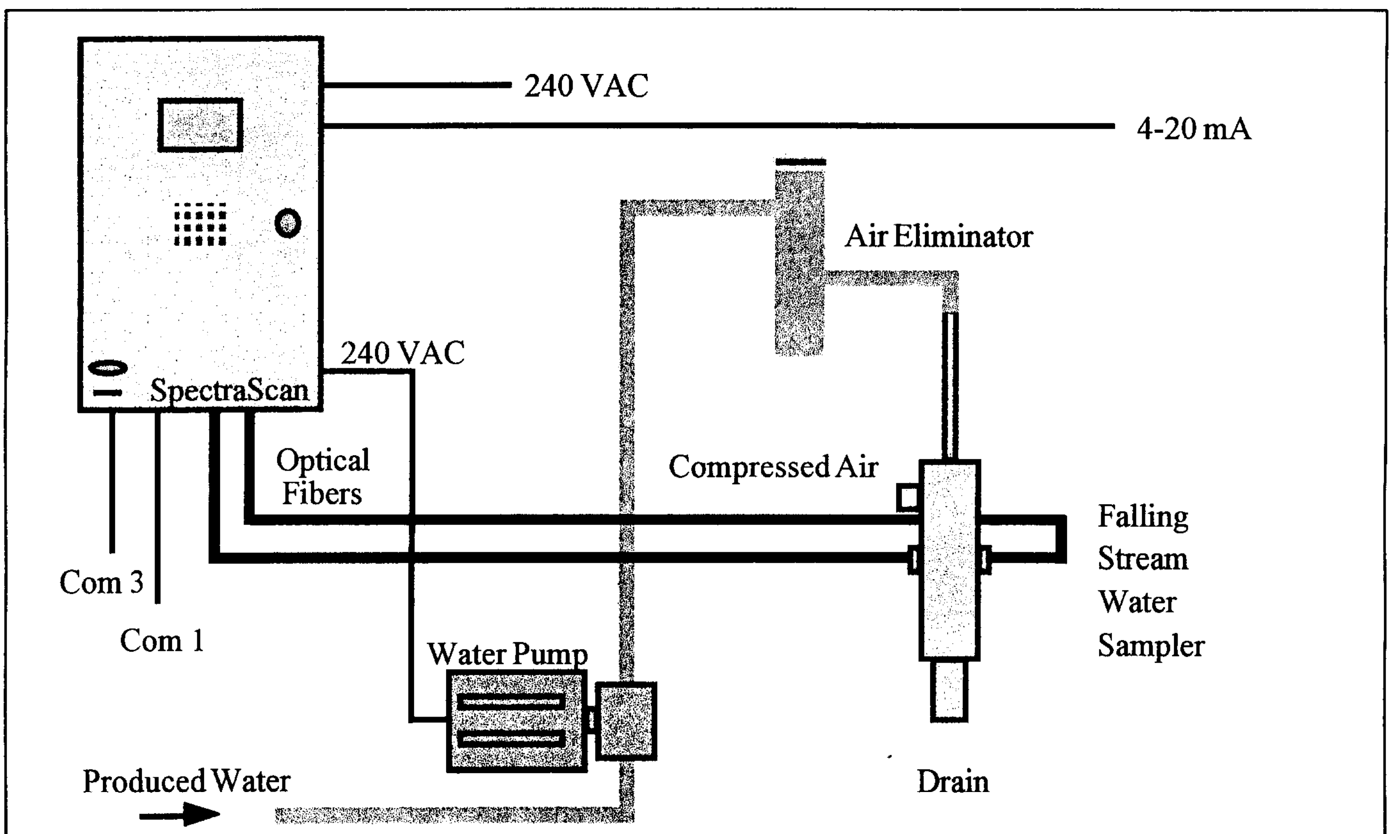
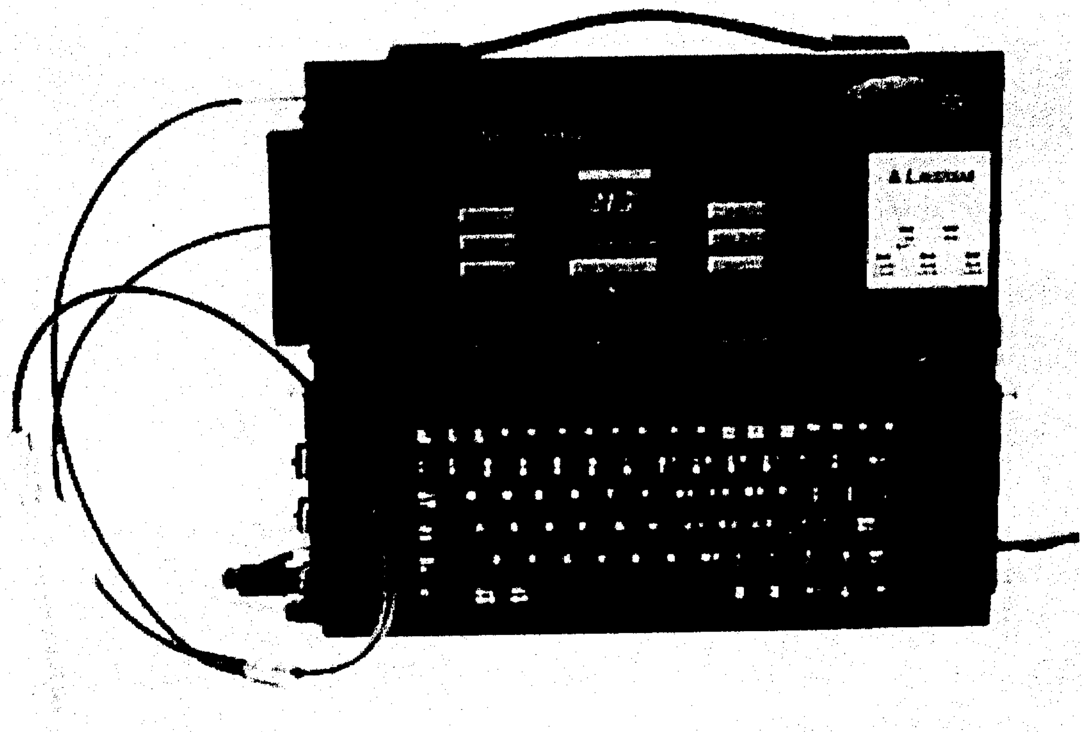


Figure 8



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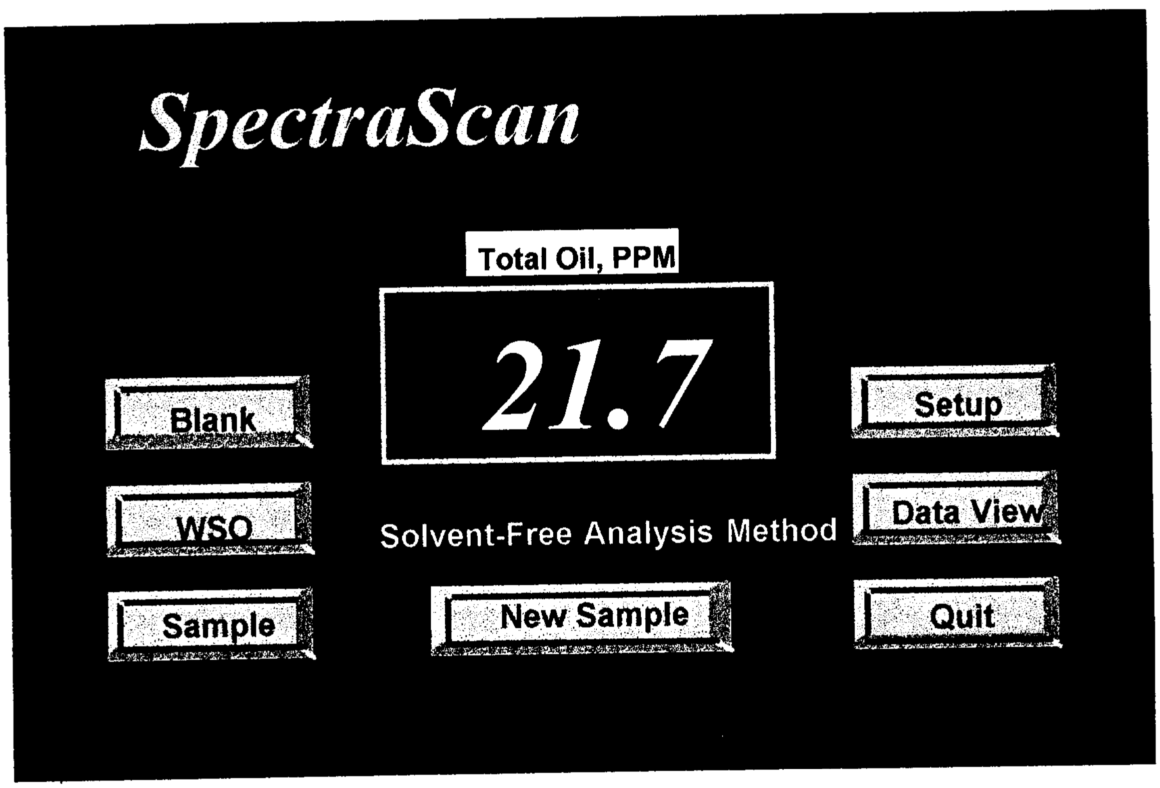

Figure 10

- *SpectraScan* measurement error
  - +/- 0.5 ppm
- Freon / IR measurement error
  - +/- 1-2 ppm
- Sampling errors
  - +/- 2-20 ppm ?

Random errors cancel if enough samples are collected! (5-30, depending on range)

Figure 11

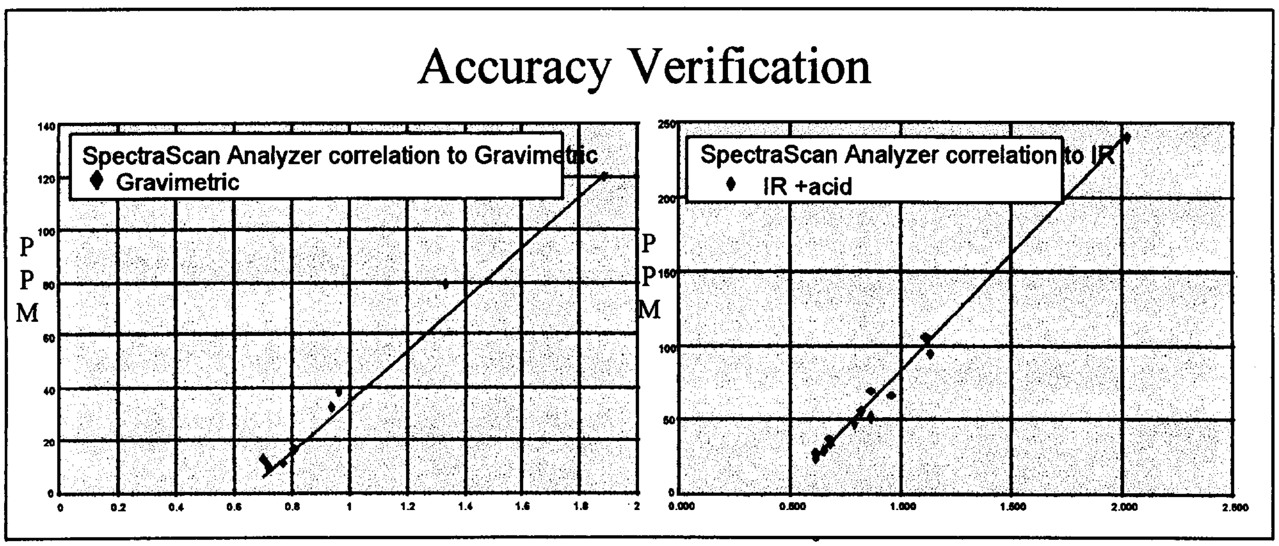

Figure 12