HOW TO REDUCE PUMP REPAIR COSTS BY RESIZING CYCLONES ON HYDRAULIC PUMPING UNITS

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Hydraulic pumping systems for oil wells have been in existence since 1932. High-pressure power fluid (produced oil or water) is supplied to a subsurface engine-pump assembly. The power fluid exhausted from the engine is returned to the surface along with produced fluids from the well. The earlier hydraulic systems employed one or more high-pressure pumps on the surface to furnish power fluid to one or more wells. Large tanks were used to settle out water and solids from power oil.

In 1970, single-well power fluid conditioning units (PFCU's) were introduced to the oil industry. The surface unit which is located at the well consists primarily of a vertical separator, horizontal volume tank, cyclone separator, and a high-pressure pump, see Fig. 1. The vertical separator serves as a fluid-gas separator. The horizontal tank serves as a suction tank for the high-pressure pump. The fluid velocity through the vertical separator and suction tank is usually such that solids do not settle out. In lieu of settling tank(s), centrifugal separators (usually termed cyclones) are installed upstream of the suction tank to remove solids from the power fluid. If the production from the well changes appreciably, the cyclone must be resized. In order to achieve the maximum life of the surface power pump and the subsurface engine, the power fluids should contain a minimum of abrasive solids.

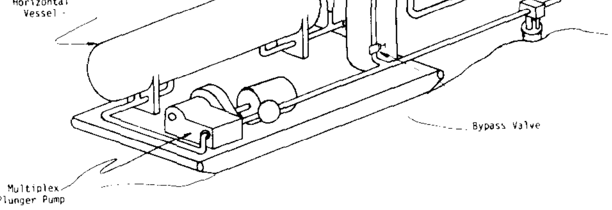


FIG. 1 –FLOW DIAGRAM POWER FLUID CONDITIONING UNIT

A study of the operation and performance of cyclones was conducted in a secondary recovery unit in West Texas. Thirty-nine of the wells in the unit are lifted by single-well PFCU's. The subsurface pump repair history of each PFCU installation was studied. Figures 2 and 3 show the average pump run time between failures and the total monthly repair costs. Various changes in operation were made in early 1975 in an attempt to reduce subsurface hydraulic pump failures and costs. The PFCU's as received had needle valves in the underflow line (dirty fluid line) on the cyclones. The small ports in the needle valves frequently plugged with solids. When the underflow line plugged, all solids were recycled in the hydraulic system. The needle valves were replaced with gate valves which contained a fixed orifice in the gate. Delta X current sensing pump-off controllers were installed on hydraulic units which were oversized and subject to pumping off. The data shown on Figs. 2 and 3 indicate that the installation of the gate valves and the pump-off devices did not increase the life of the subsurface engine-pump assemblies.

Data from one well in the unit is used in this paper to show how longer pump runs can be achieved by properly sizing cyclone components. The information which was developed should be applicable to other hydraulically pumped wells. Table 1 shows the pump repair history of the test well. The failures were caused by excessive wear of the hydraulic engine. The average engine life of six pumps was 31 days and the average repair cost was $1,025. Since the engine in the subsurface pump is

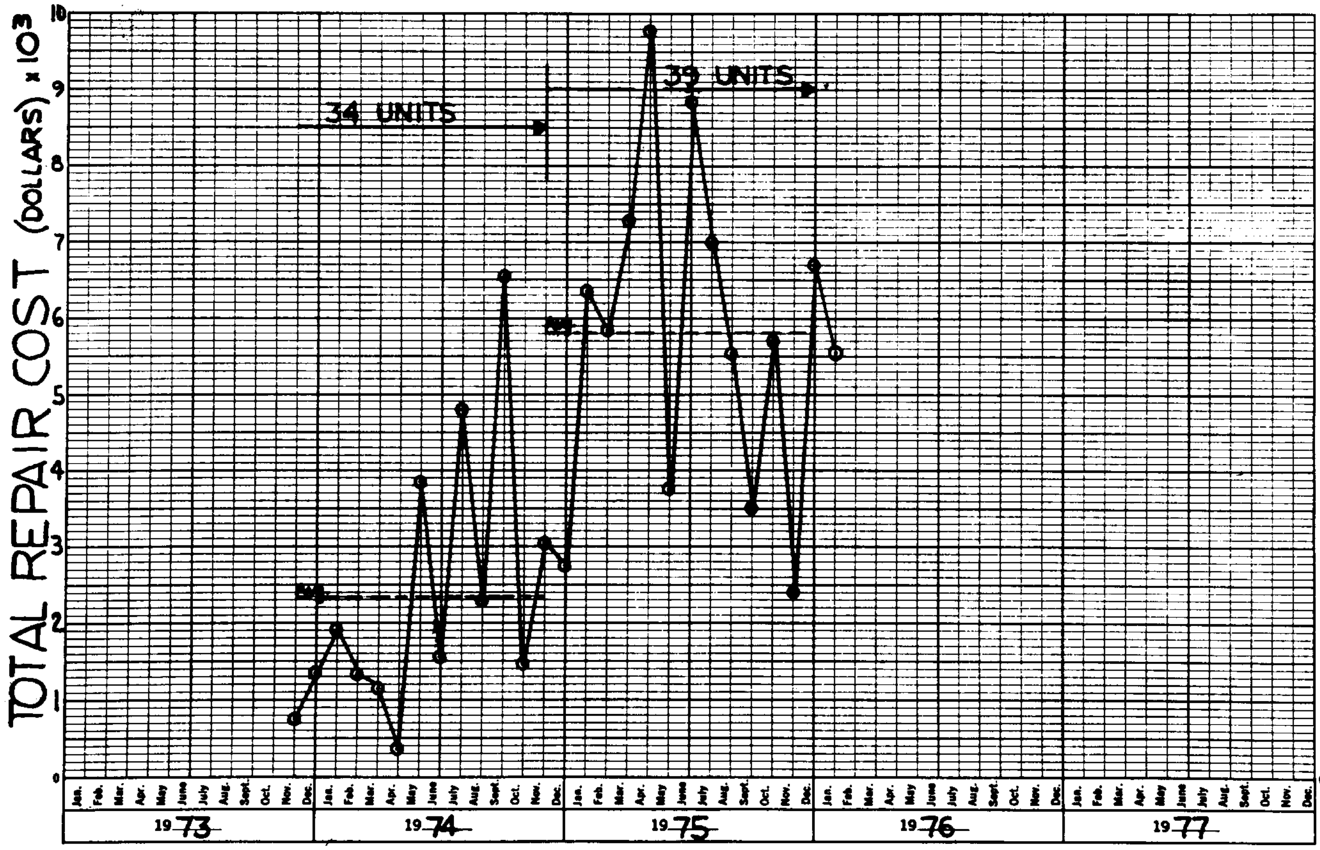


FIG. 2—HYDRAULIC SUBSURFACE PUMP REPAIR COST

exposed only to power fluid, the high frequency of failures indicated that the power fluid contained abrasive solids.

Stream samples of the PFCU fluids were collected and analyzed to determine the size of particles, the size distribution, and quantity of particles entrained in the various fluid streams. The analyses and microphotographs of the solids are shown in Figs. 4, 5 and 6. Figure 4 shows that there were large quantities of abrasive solids from less than 20 up to 500 microns in size in the fluid at the cyclone inlet. Solids in the inlet stream should be removed by the cyclone. The particles were primarily sand which had been produced from the wellbore. Solids in the cyclone overflow (clean fluid) also ranged in size from less than 20 up to 500 microns, see Fig. 5. Since a new hydraulic subsurface pump engine has a mechanical clearance of 0.002 inches, the largest abrasive particle which can be tolerated would be approximately 50 microns in size. A table showing size conversions is shown in Table 2. Therefore, the power fluid (cyclone overflow) must not contain abrasive particles above 50 microns in size. However, abrasive solids as small as 5 microns will accelerate wear in a hydraulic system. Properly sized cyclones, operated within design parameters, would remove particles down to a minimum size of about 25 microns.

TABLE 1—HYDRAULIC PUMP REPAIR HISTORY

Date Run	Repair Cost ($)	Run Time (Days)	Failure Reason
1-12-75	1241	50	Excessive Abrasion, Engine Valve and Production Rod Scored
3-06-75	617	26	Engine Valve Scored Severely
3-25-75	967	13	Engine Valve Scored Severely
4-07-75	1001	22	Engine Valve Scored Severely
4-28-75	1550	56	Engine Valve Scored Severely
6-23-75	773	21	Engine Valve Scored Severely
AVERAGE	1025	31	
7-14-75	1389	142	Lower Pilot Rod Severely Worn

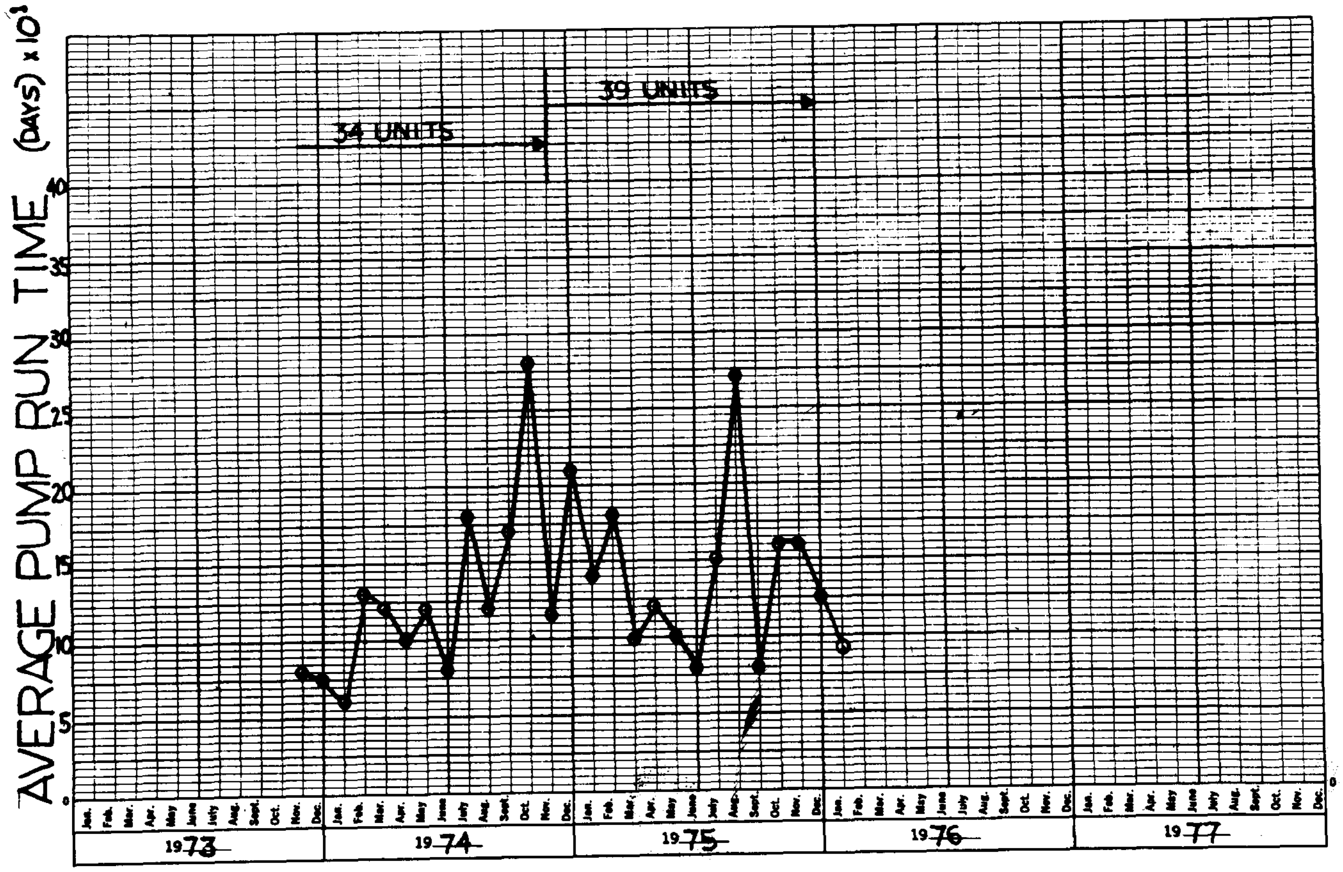
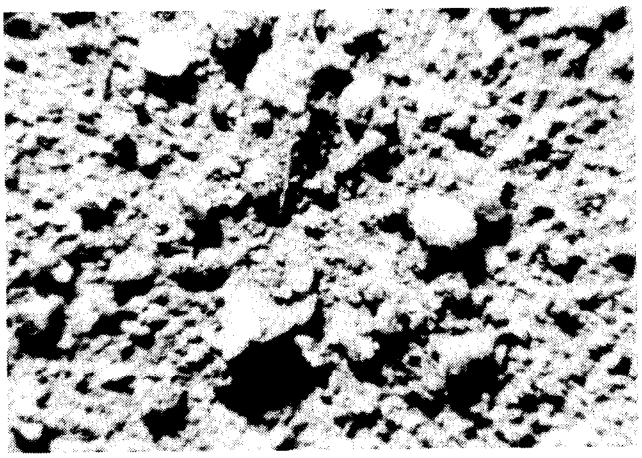
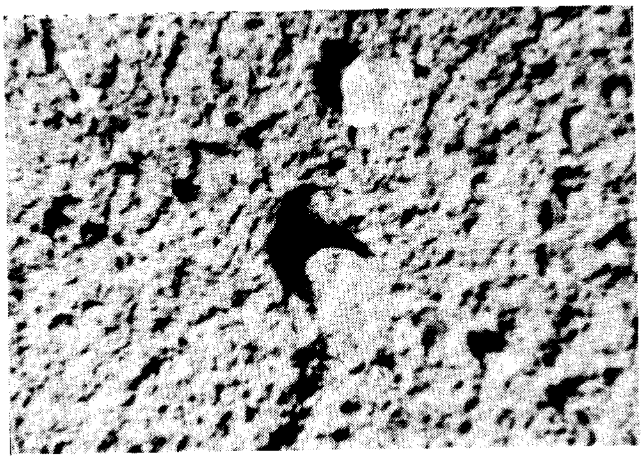


FIG. 3—HYDRAULIC SUBSURFACE PUMP RUN TIME



Solvent extracted solids
Cyclone Inlet. Sand Grains.
100 to 400 microns = 20%
20 to 100 microns = 70%
Less than 20 microns = 10%
Total Suspended Solids Content = 96 Pounds Per 1,000 Barrels
Microphotograph

FIGURE 4



Solvent extracted solids
Cyclone Overflow. Sand Grains.
100 to 500 microns = 10%
20 to 100 microns = 70%
Less than 20 microns = 20%
Total Suspended Solids Content = 12 Pounds Per 1,000 Barrels
Microphotograph

FIGURE 5

Solvent extracted solids
Cyclone Underflow. Sand Grains.
100 to 300 microns = 80%
20 to 100 microns = 10%
Less than 20 microns = 10%
Total Suspended Solids Content = 19 Pounds Per 1,000 Barrels
Microphotograph
FIGURE 6

After it had been established that the power fluid contained large-sized abrasive material, efforts were directed toward removal of the particles. A complete analysis of the design and operation of cyclones was made.

The determination of the proper sizing and operating parameters of a cyclone on a PFCU include the following considerations.

Power Fluid

The fluid volume to be handled in a PFCU includes total well production plus the volume of power fluid pumped by the multiplex plunger pump. Well production records are usually readily available. The volume of power fluid can either be metered or it can be calculated from data contained in the pump manufacturers' bulletins. Information on displacement volumes for a typical multiplex plunger pump is shown in Table 3. If the pump speed is not known, it can be measured with a tachometer. The operating speed of a pump can also be calculated if the motor speed and gear ratio are known.

TABLE 2—CONVERSION, MICRONS TO INCHES

MICRONS		INCHES
25	=	.001
50	=	.002
75	=	.003
100	=	.004
1 MICRON	=	.00003937 INCH

TABLE 3—TRIPLEX PLUNGER PUMP

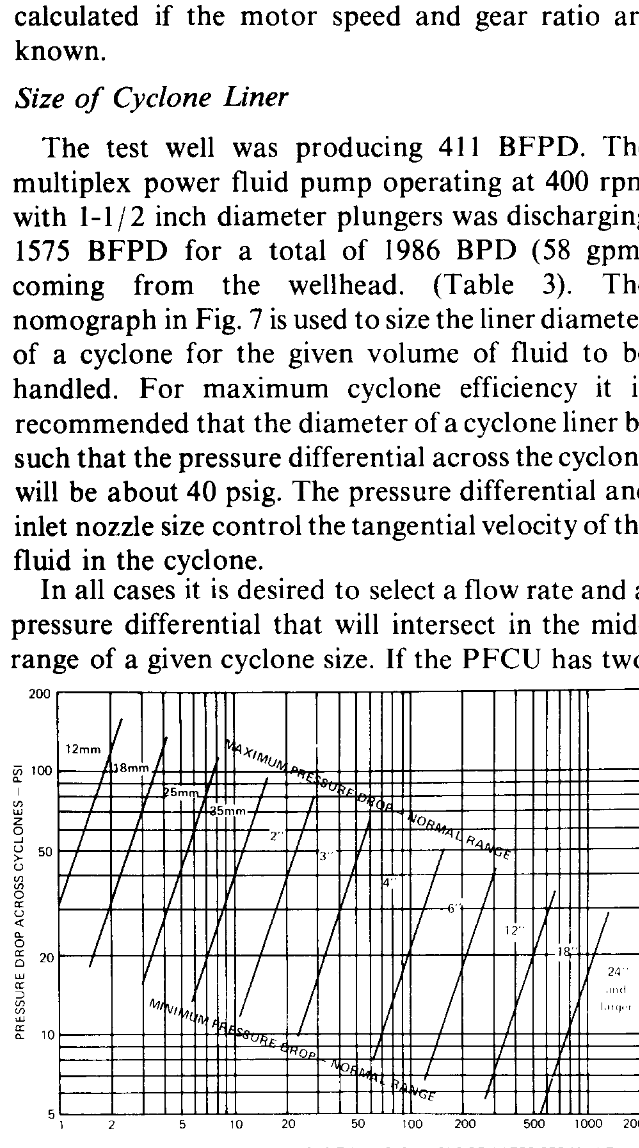
100% VOLUMETRIC DISPLACEMENT

PLUNGER SIZE (INCH)	2	1-7/8	1-3/4	1-5/8	1-1/2	1-3/8
PUMP SPEED (RPM)	BPD	BPD	BPD	BPD	BPD	BPD
400	2800	2460	2140	1845	1575	1320
350	2450	2150	1875	1615	1375	1155
300	2100	1845	1610	1385	1180	990
250	1750	1535	1340	1155	985	825
200	1400	1230	1070	925	785	660
150	1050	920	800	695	590	495
100	700	615	535	460	395	330

Size of Cyclone Liner

The test well was producing 411 BFPD. The multiplex power fluid pump operating at 400 rpm with 1-1/2 inch diameter plungers was discharging 1575 BFPD for a total of 1986 BPD (58 gpm) coming from the wellhead. (Table 3). The nomograph in Fig. 7 is used to size the liner diameter of a cyclone for the given volume of fluid to be handled. For maximum cyclone efficiency it is recommended that the diameter of a cyclone liner be such that the pressure differential across the cyclone will be about 40 psig. The pressure differential and inlet nozzle size control the tangential velocity of the fluid in the cyclone.

In all cases it is desired to select a flow rate and a pressure differential that will intersect in the mid-range of a given cyclone size. If the PFCU has two



Courtesy of Pioneer Centrifuging Co.

FIG. 7—CYCLONE CAPACITY NOMOGRAPH

TABLE 4—3" PIONEER CYCLONE

Feed Nozzle I. D.	Vortex Type & I. D.	Pressure Drop (PSI)	B. P. D.
.625" Apex			
.500"	Standard .75" ID	30	612
		40	714
		50	782
.500"	Spiral .75" ID	30	680
		40	816
		50	884
.500"	Spiral 1.00" ID	30	816
		40	918
		50	936
.500"	Spiral 1.25" ID	30	850
		40	838
		50	1,122
.600"	Standard .75" ID	30	782
		40	884
		50	952
.600"	Spiral .75" ID	30	850
		40	952
		50	1,088
.600"	Spiral 1.00" ID	30	1,020
		40	1,190
		50	1,292
.600"	Spiral 1.25" ID	30	1,156
		40	1,360
		50	1,496

Courtesy of Pioneer Centrifuging Co.

TABLE 5—4" PIONEER CYCLONE

Effect of Feed Nozzle Size and Vortex Finder on Capacity:

Feed Nozzle I.D.	Pressure Drop (PSI)	B.P.D.
1-1/2" I.D. Standard Vortex .688" Apex		
.500"	20	857
	30	1,074
	40	1,226
.600"	20	1,131
	30	1,334
	40	1,532
.700"	20	1,227
	30	1,467
	40	1,651
.800"	20	1,255
	30	1,499
	40	1,717
1-1/2" I.D. Spiral Vortex .688" Apex		
.500"	20	924
	30	1,234
	40	1,389
.600"	20	1,260
	30	1,608
	40	1,776
.700"	20	1,430
	30	1,783
	40	1,975
.800"	20	1,474
	30	1,819
	40	2,039

Courtesy of Pioneer Centrifuging Company

cyclones, then the flow rate (58 gpm) must be divided by two (29 gpm) in order to give equal flow through each cyclone. The example shown in Fig. 7 uses a flow rate of 29 gpm at a pressure differential of 40 psig.

Feed Nozzle and Vortex

After the diameter of the cyclone has been selected, information shown in Tables 4 and 5, can be used to determine the correct size feed nozzle and vortex (commonly called trim) for the pressure differential and flow desired. There are two types of vortexes, the standard and the spiral. A cyclone equipped with a spiral vortex has a greater flow capacity than a cyclone with a standard vortex (Fig. 8).

Since the size of the trim in the cyclone is extremely important, a more detailed explanation is included. For example: If there are 2050 BFPD (1575 bbl of power fluid and 475 bbl of production), available to flow through a 4-in. cyclone, a 0.7-in. feed nozzle with a 1-1/2 in. spiral vortex should be used (Table 5). The designed pressure drop between the inlet and the outlet of the cyclone should be 40 psig. The extra 75 BFPD would be routed to the flowline from the vertical separator upstream of the cyclone. If the 0.8-in. feed nozzle is used, then the total volume of fluid is passed through the cyclone. If the well decreases slightly in production to reduce the total amount of fluid, then there is a possibility of free gas entering the cyclone. Gas in the cyclone decreases its efficiency. The 1975 bbl of fluid entering the cyclone will be split to the overflow and the underflow line. Fifteen-hundred seventy-five barrels (1575) of power fluid should go to the overflow to replenish the fluid in the horizontal vessel that supplies the suction to the multiplex pump. The other 400 bbl will go to the underflow and be routed to the flowline. Abrasive solids removed from the cyclone are thus carried out the underflow and into the flowline. If the ratio of flow rate between the inlet and underflow is low, the efficiency of the cyclone will decrease. An acceptable

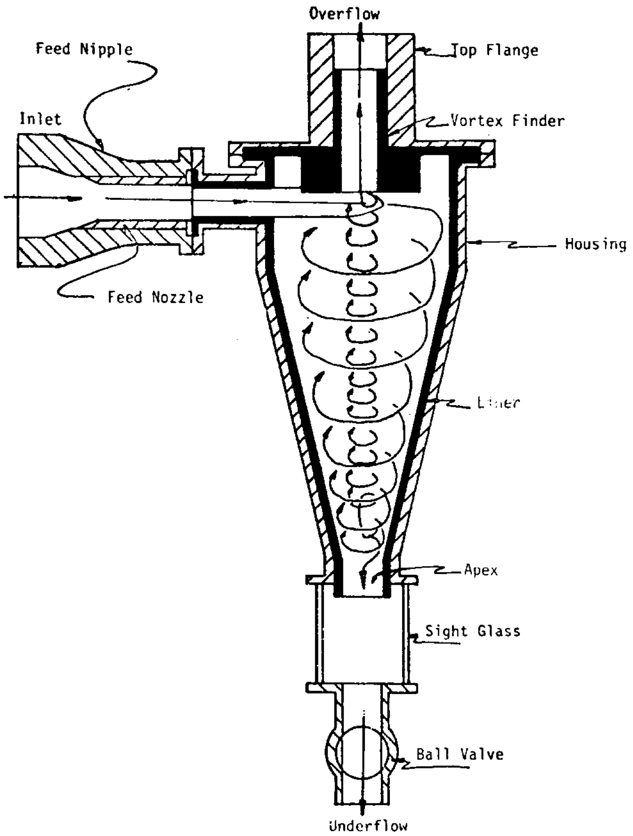


FIGURE 8

quantity is that one-fourth of the inlet should be discharged out the underflow for maximum solids removal. Therefore, when well production changes appreciably, the cyclones must be resized to maintain the most efficient operation.

Data from the test well is used to illustrate the importance of checking cyclones for proper operation. Initially, the well was making 400 BFPD. The multiplex power fluid pump, operating at 400 rpm with 1-1/2 in. plungers, was discharging 1575 BFPD (Table 3). The total amount of fluid available at the inlet of the cyclones was 1986 BFPD (58 gpm). The 150-hp PFCU was originally equipped with two 4-in. cyclones, each handling 993 BFPD (29 gpm). The cyclones contained 0.5-in. ID feed nozzles and 1-1/2 in. spiral vortexes. Information shown in Fig. 7 indicates that a 3-in. cyclone rather than a 4-in. cyclone must be used when the flow rate is 29 gpm to provide a 40 psig pressure differential. The 3-in. cyclone will remove smaller-size abrasive particles at greater efficiencies. Table 5 shows that the 0.5-in. feed nozzle with a 1-1/2 in. spiral vortex will handle 995 BFPD. However, the pressure drop through the cyclone would only be approximately 22 psig (Table 5), which is not adequate for maximum efficiency of cyclones in terms of solids removal. The initial 4-in. liners in the cyclones were replaced with 3-in. liners. The 1-1/2 in. spiral vortexes were replaced with 1-1/4 in. spiral vortexes. The ID of the feed nozzles was reduced from 0.5 in. to 0.4 in. which provided a 40 psi differential pressure across the cyclones. The 0.5-in. feed nozzle did not achieve the desired pressure differential. On all other units, the nozzle-sizing nomographs produced the correct nozzle size and desired pressure differential.

A new subsurface pump was installed in the test well on July 14, 1975, two days before the cyclones were resized. During the next five months of the test period, the pump was operated at 125 spm. The pump failed in December, 1975, after a service life of five months. See the last entry in Table 1. The pump failure was due to worn standing valves. Some abrasion in the engine end of the unit was observed; however, the failure was not caused by this wear. Examination of solids in the hydraulic fluid of the test well indicated that the fluid entering the cyclone still contained solids ranging in size from about 20 - 400 microns. The volume and size of solids in the cyclone overflow had been substantially reduced. Observed solids in the power fluid had been reduced to about 20-60 microns in size. Photomicrographs of the solids in the clean fluid are shown in Fig. 9

The reduction of solids in the power fluid and the five-fold increase in the life of a subsurface engine correlate very well. A savings of $5125 in subsurface pump repair costs was realized by cleaning up the

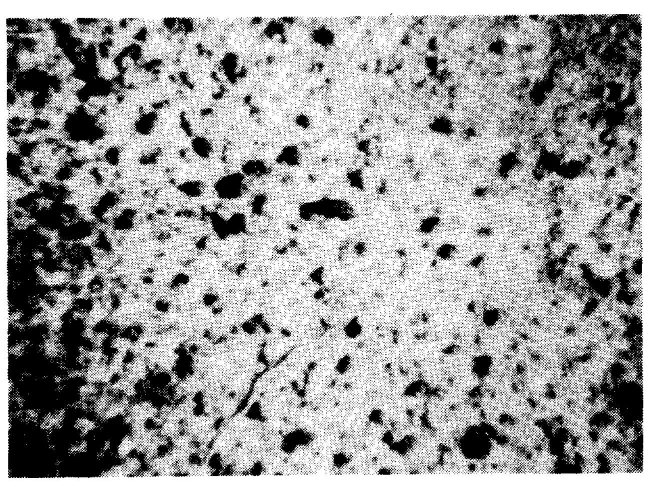


FIGURE 9

power fluid. The total cost of changing the liners and the vortexes was \$150 plus \$30 for installation.

Subsequent to the work that was done on the test well, the nozzles in all other cyclones in the field have been resized in accordance with the information presented in this paper.

H_2S GAS DETECTION

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INTRODUCTION

The purpose of portable or continuous hydrogen sulfide gas detection equipment is to provide a method for monitoring a condition which could result in the formation of a toxic atmosphere.

Gas detection techniques have evolved from rather primitive methods to modern electronic instruments capable of detecting minute toxic gas conditions.

While some types of oilfield equipment can be misused with little or no long range effects, the wrong choice of hydrogen sulfide detection equipment or its improper use can result in death or injury.

In a hydrogen sulfide safety program it is not enough to merely be aware of a potentially toxic situation. Today, the legal and moral climate is such that it is now necessary to monitor these potentially toxic conditions to insure a high degree of safety for all operating personnel. When this type of equipment is placed in operation it is necessary that the operators be educated in its use and a regularly scheduled maintenance and calibration program be strictly adhered to.

LEGAL AND MORAL ASPECTS OF GAS DETECTION EQUIPMENT

Changes in the laws regarding safety have contributed to the growing use of toxic gas detectors, but some users, unfortunately, have complied with the letter of the law by purchasing detector units and then ignoring them. For any toxic gas detector to be effective, the user must understand the principles of its operation, and its limitations. He must also be trained in the proper installation and maintenance of the equipment.

In the case of a major accident where life is lost or serious injuries sustained, there is always a substantial investment in time and money due to legal action. The outcome of such lawsuits may also include jail terms for those deemed negligent in the performance of their duty.

It is necessary that each of us actively participate in establishing and maintaining a good safety program founded on the use of prudent and reasonable actions.

DEVELOPMENT OF PRESENT DAY TECHNIQUES OF DETECTION

Modern day methods of electronic gas detection began many years ago with the wet chemistry approach. Since that time other techniques have been used, and today the newest is CHEMI-PHYSICS (metal oxide sensor) which is used primarily in the detection of various toxic gases. Chemi-physics utilizes the conductivity capabilities of certain metal oxides. When these oxides are exposed to various gases or vapors their ability to conduct is changed due to an oxidation reduction process. This change in conductivity is interpreted as a change due to the specific gas being detected.

While this principle is relatively new, it is generally considered to be the most promising approach for future toxic gas detection. It has the ability to provide continuous monitoring (as opposed to sample tubes which can only be used for intermittent or "grab sample" testing), and it can be exposed to high concentrations of hydrogen sulfide, provide quick recovery, and continue to give quality detection.

ACCURACY VERSUS RELIABILITY

The acceptable toxic levels of various substances (TLV's) are usually determined in laboratory tests. The results, therefore, are of rather academic nature. In real life situations, the actual levels of gas may vary widely from those normally considered to be safe.

One of the most difficult phases of toxic gas detection is attempting to establish an accurate zero and calibration point. The ultimate accuracy of these devices, dealing in parts per million, is definitely a function of how well these adjustments can be made.

As with many instruments it is often more valuable to have a device which can be depended upon to give reliable and repeatable answers than it is to have a device designed for absolute accuracy.

To offset these problems in determining and maintaining extreme accuracies in the parts per million range, many users are adopting the philosophy that any indication of the presence of a toxic gas represents an unacceptable situation. Detectors used in this fashion could be considered go-no-go devices.

In the case of oil production, this may not be a practical approach, as some producing areas have a constant background level of hydrogen sulfide. In these cases, an absolute maximum level must be established and then monitoring for that level provided.

Gas detectors must operate in constantly changing environments, and a detector which can detect toxic gas conditions under varied temperatures and pressures is far more valuable than an instrument which is accurate but limited in its operating use. In safety instrumentation these are mutual goals.

LIMITATIONS OF GAS DETECTORS

When selecting a gas detector a number of factors must be taken into consideration. These include:

- Select a detector which is limited to the gas or vapor of interest.
- With most metal oxide sensors, oxygen is necessary to return the detector to a zero condition following a gas indication.
- The output of most gas detectors can be affected by a change in supply voltage. Make sure that the detector is receiving the specified line or battery voltage.
- The sensing elements of most detectors can be affected by what is termed "poisons". These substances are ones which can chemically or mechanically isolate the sensor from the sample and thus render it "blind" to the condition it's supposed to sense.
- The detector element can only sense the condition which actually contacts the surface of the sensing element. The gas detection sensor cannot see or hear a hazardous condition. It can only "sniff" the condition. While this seems like an elementary concept, it is important.
- General ambient conditions may affect the detection process; e.g., extremes in temperature, wind movement, ventilation (in enclosed areas), humidity, and certain general process factors.
- The performance of any gas detection system is only as good as the training and the conscientious attitude of the people who use and maintain it.

MAINTENANCE

As with any safety device, the degree of dependability of a hydrogen sulfide gas detector is directly proportional to the care it receives. These detectors require routine maintenance which includes a "check" of general unit performance and regular "calibration".

One of the most dangerous effects on employee morale is a series of false alarms generated by incorrectly installed or malfunctioning detectors.

Check - All gas detectors should be given a regular go-no-go check, perhaps once a shift or once a week to determine that the device is functioning. This can be accomplished by applying a gross sample of the type of gas to be detected and watching the instrument for an indication.

Calibration - Includes applying a known concentration of gas and adjusting the device for a resultant indication. Calibration should be performed at routine intervals, as specified by the manufacturer or the using organization.

The actual period of time between checks and calibration is usually a function of the confidence level of the operating personnel.

TRAINING

The best equipment is no better than the ability of the operator using it. Without thorough, comprehensive training, an operator cannot be expected to safely operate and depend on his equipment. Improper or incomplete training can lead an operator into a false sense of security which could cost him his life.

Some manufacturers of gas detection equipment realize the importance of training and offer training programs. The user should insist on this type of support from his supplier. If it is not readily available, he should consider another supplier.

LOGGING

In the event of a lawsuit resulting from an accident, evidence (logs) indicating proper training and maintenance may serve as proof of good intentions on the part of the employer. Proper logging procedures also help to emphasize the importance of the entire program to the operator and his supervisor.

CONCLUSION

While most gas detection instrumentation is sound in design and function, it can in no way replace the ultimate knowledge and decision-making capabilities of a well-trained operator. Except in cases where a control function is provided, this equipment will not in itself "protect" a worker. Its sole function is to monitor a situation and inform personnel of a potential hazard. Interpretation of warnings given by detection equipment must be left in the hands of a responsible individual.

GLOSSARY OF TERMS

There are a number of terms used in gas detection that are rather specific and often misunderstood. The following are defined as they apply to the field of gas detection.

T.L.V. - Threshold Limit Value

Poisoning - A chemical or mechanical coating of the sensor which renders it "blind" to the condition to be sensed

System - A group of detecting components working together to provide continuous monitoring

Calibration - Applying a gas of known concentration with adjustments as required in order to make the instrument indicate the level of the known sample

Check - Applying a gross sample of gas, noting general performance of the entire unit including alarm, lights, meters, etc.

PPM - Parts Per Million. One or more parts of a substance in a million parts of background. (1% by volume of any gas equals 10,000 ppm)