THE USE OF THE COULTER COUNTER IN OIL FIELD APPLICATIONS

CALVIN K. DEEM and DAVID HUNTER
C-E Natco Research and Development

INTRODUCTION

Two predominant methods, millipore filtration and turbidity, have been used in the past to measure the efficiency of filters. These methods are useful for empirical measurements of filtration but do nothing to quantify the various sizes of interest. The introduction of the Coulter Counter to industrial application has presented a new method for monitoring filter performance. Now, the efficiency of the filter can be determined at any size from 0.4 to 800 microns.

This paper illustrates the use of the Coulter Counter in the development of a new filter design. The testing involved laboratory testing of the pilot filter, on site location of the pilot filter, and final on-site testing of a full size vessel.

EXPERIMENTAL

Coulter Counter analyses were run on a Model TA II equipped with a population accessory. Isoton I was initially used as a diluent but later replaced with Isoton II (azide free). An aperture size of 70 micron or 100 micron was used. Samples were run using the manometer (0.5 ml). Instrument setting and calibration were as specified in the instruction manual.

Background and sample count were measured for each sample. By use of the following formula, the counts/ml for each size were determined.

$$C/\text{ml} = (S - B) \times \left(\frac{V.S.}{V.S. + V.I.}\right) \times \left(\frac{1}{A.S.}\right)$$

where

C/ml = Corrected counts/ml
S = Sample count
B = Background count
V.S. = Volume of sample
V.I. = Volume of Isoton
A.S. = Amount of solution sampled by manometer

The percentage of removal was determined by the following formula.

$$\% R = \left(\frac{I - O}{I}\right) \times 100$$

where

% R = Percent removal
I = Corrected inlet counts/ml
O = Corrected outlet counts/ml

The ppm volume was calculated by the following formula.

$$ppm_v = (C/ml) \times GMV \times 10^{-6}$$

where GMV = Geometric mean volume in μ^3

The ppm weight was calculated by the following formula.

$$ppm_w = ppm_v \cdot D$$

where D = Density of the material in g/cc

Initial Laboratory Tests

A hydrocyclone was designed and fabricated in the laboratory. The diameter was 2-3/4-inches with 10-degree sides. The vessel was 14-1/4-inches long. Flow used in the lab was 13 GPM. The diatomaceous earth filter (DE) was a Sta-Rite Model 8457202 assembled in the laboratory. The filter leaves were precoated with 13.5-pounds of Celite No. 545 diatomaceous earth. Flow rate was 50 GPM (approximately 0.65 GPM/sq ft of filter leaf area) or one-third of maximum. A standard high rate sand filter (HRSF) model (conventional downflow) was assembled in the laboratory from a diatomaceous-earth filter shell. It was loaded with No. 3 Flint-brasive, the standard medium used in the field. The depth of medium was similar to that used in a field unit. Flow rates were 10 GPM/sq ft. The new high rate filter (DFX) model was designed and built in the laboratory. (The flow diagram for filtration and backwash is shown in figure 1.) The medium consisted of 12 inches of No. 25 garnet on the bottom, 24 inches of number 60-80 garnet in the middle, and 12 inches of number 1 coal on the top. Flow rates were 40 GPM/sq ft. In all cases, the solution filtered was a fresh-water system containing 300 ppm silicone carbide (SiC).

Initial Field Evaluation

The filter model used in the lab was taken to Chevron's SACROC No. 75 water conditioning plant at Snyder, Texas. The medium consisted of 12 inches of No. 25 garnet, 24 inches of number 40 garnet, and 12 inches of No. 2 coal. The filter was located upstream of all other processing equipment except the free-water knockout. Flow rates were 40 GPM/sq ft. The Coulter Counter was used on site. Power facilities were provided by an auxiliary generator in a mobile home.

Production Size Vessel

A 6-ft commercial-size DFX dual-flow filter was fabricated in the Tulsa shop. It was tested in the same Snyder field at a location just ahead of the injection wells. Two different mixed-media systems similar to those used in the test vessel were used. The first consisted of 1 foot of No. 25 garnet, 5 feet of No. 60-80 garnet, and 1 foot of No. 1 coal. This was later replaced with 1 foot of No. 25 garnet, 4-1/2 feet of No. 30-40 garnet, and 1 foot of No. 2 coal. In addition to test readings on this vessel, comparisons were also made on the high-rate sand filters also on location. A schematic of the DFX is shown in Figure 1.

Oil Coalescing Study

A vertical vessel was set up in a downflow configuration. The vessel contained 4 inches of No. 2 coal, and 18 inches of No. 40 garnet. Tap water and SAE 5 Genmac oil from the DX Refinery were used to generate the emulsion. After the initial runs, sufficient sodium chloride was added to bring the solution strength to 1 percent.

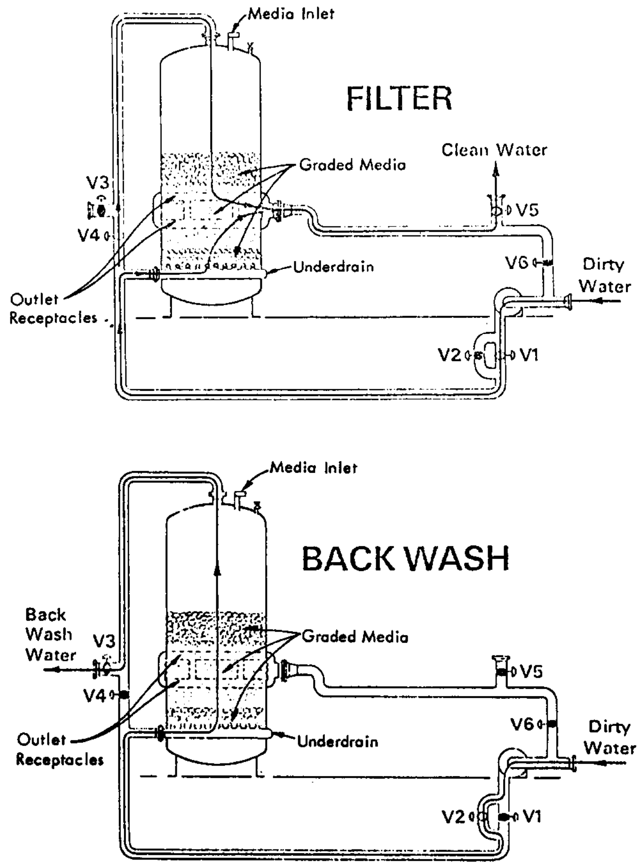

FIG. 1—SCHEMATIC OF OPERATION OF THE DFX

RESULTS AND DISCUSSION

Initial measurements for particle size on the lab filter system were made by a manual method. A photograph of the dirt particles was made and projected on a glass screen. By use of a template, the approximate size of the dirt particles was measured. These measurements were very time-consuming. Several weeks work was repeated in one afternoon using a Coulter Counter. Figure 2 presents the data obtained from the runs. As can be readily seen, the efficiency at each particle size can be obtained from the graph. This graph shows that the performance of the DFX is similar to the DE filter and much better than the cyclone or HRSF. Table 1 presents turbidity readings from the same test. As can be

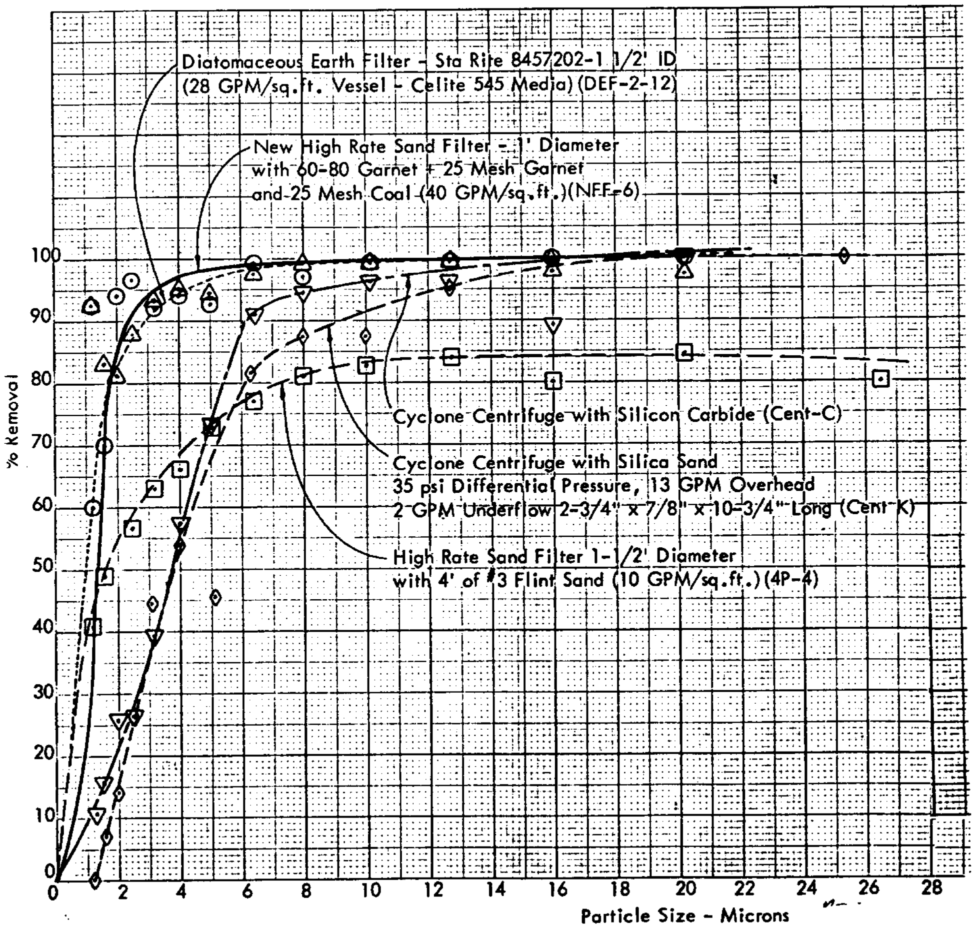

FIG. 2—COMPARISON OF SOLIDS REMOVING DEVICES. SILICON CARBIDE PARTICLES UNLESS NOTED IN TULSA TAP WATER. PARTICLE COUNT BY COULTER COUNTER

seen, from this data it is very hard to determine filter efficiency.

The filter model was transported to Snyder, Texas, for the next series of tests. The secondary recovery used there depends upon both gas (carbon dioxide) and water injection. The samples of water collected there tend to change after about 10 minutes exposure to air. For that reason, it was necessary to take the Coulter Counter to the field. For the first several tests, the Coulter Counter was of no use because of fluctuating voltage supplied by the water treatment plant. Accurate results were not obtained until a motor home with its own electrical source was used. Figure 3 presents typical counter data, and Table 2 presents corresponding turbidity data. The DFX model was adjacent to the free-water knockout, whereas the HRSF was just upstream of the water-injection system. Therefore, the inlet to the DFX contained a large amount of free oil and also droplets (estimated 400-700 ppm). Any of the free oil or droplets that were not coalesced and held by the bed would be counted as dirt particles.

TABLE 1—TURBIDITY READING ON VARIOUS LABORTORY FILTERING EQUIPMENT

	Run	Inlet (NTU)	Outlet (NTU)	Rate GPM	(GPM/sq ft)
Hydrocyclone	C	80	17	15	
	J	82	18	13	
DE	(DEF-1, 2:50)	84	0.68	50	(0.65)
	(DEF-1, 4:00)	80	0.47	50	(0.65)
	(DEF-2, 1:30)	86	0.41	50	(0.65)
HRSF	(4P, 2:00)	87	36	17	(10)
	(4Q, 4:10)	87	47	35.6	(20)
	(4R, 9:30)	89	9.6	8.9	(5)
DFX	(NFF-4)	90	1.4	27.9	(35)
	(NFF-6)	92	1.6	27.6	(35)
	(NFF-9)	97	2.7	27.0	(35)

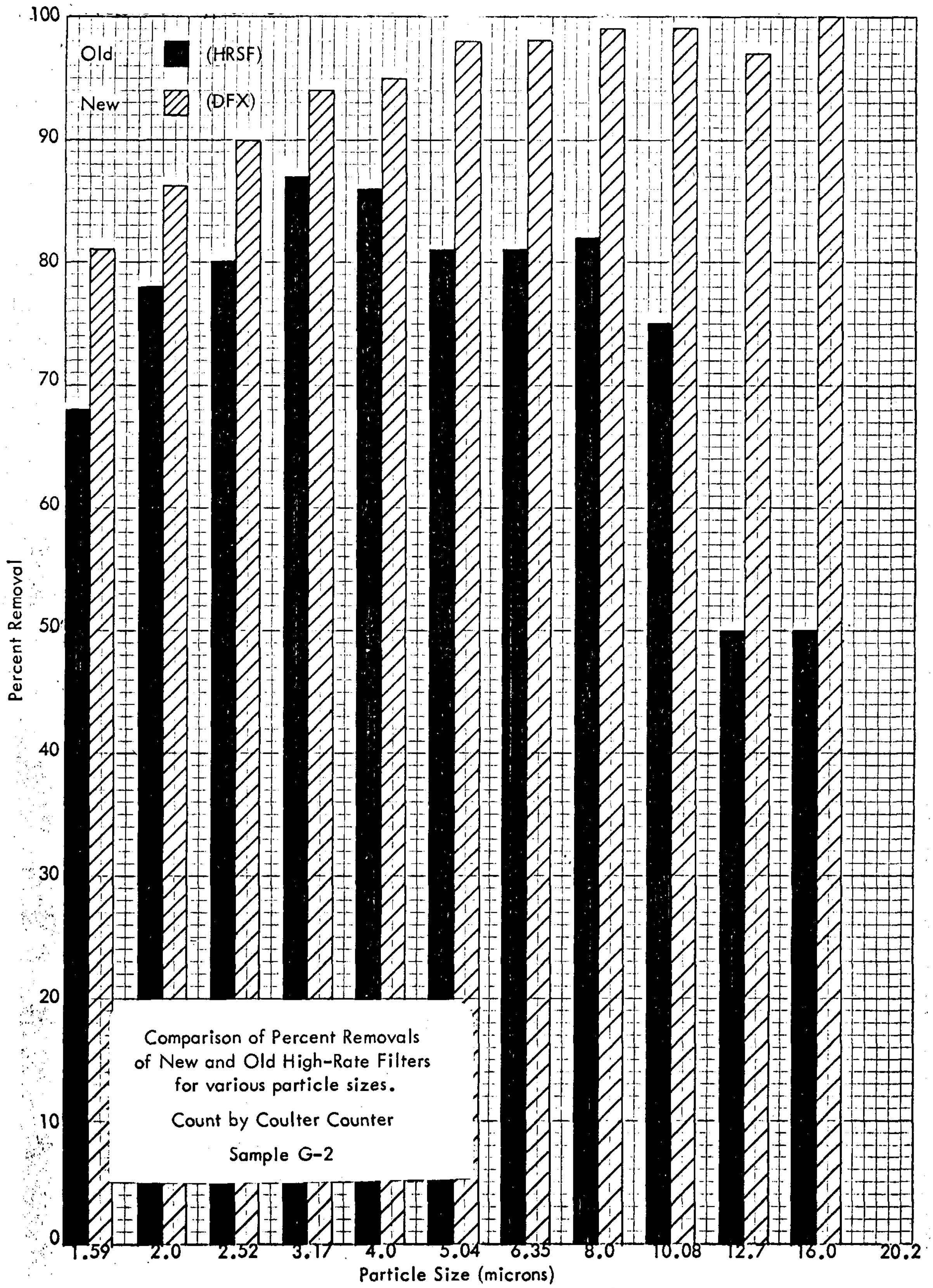

FIG. 3—TYPICAL COUNTER DATA OBTAINED FROM FILTER COMPARISON AT SACROC NO. 75, SNYDER, TEXAS

TABLE 2—COMPARATIVE TUBIDITY DATA FROM SACROC No. 75, SNYDER, TEXAS

Sample	Date	Time	Turbidity (FTU) Old Filter Inlet	Old Filter Outlet	New Filter Inlet	New Filter Outlet
Sny G-1	10-25-75	12:15 p.m.				
-2		12:45	15	6.0	15	1.5
-3		1:15	16	5.8	16	2.1
-4		3:00	17	6.0	17	1.5
-5		3:24	20	5.8	20	2.0
-6		4:03	20	5.3	20	2.0

Table 3 presents typical data from the 6-foot DFX. The efficiency (ppm percent removal) is calculated at each of several sizes. The overall total efficiency is calculated from total inlet and outlet ppm. Table 4 presents data from all runs.

The table shows excellent results for the smaller micron particle sizes. It indicates that in most cases, large particles are not removed as efficiently as are smaller particles. In some cases, there are more large particles in outlet stream than in the inlet stream. This information is misleading and should not be interpreted to mean that large, solid particles are not filtered out. This discrepancy has two causes. First, there are fewer particles in the large micron ranges, and this smaller number of counts results in less statistical accuracy than does a large number of counts. Second the filter tends to coalesce oily emulsions which then appear as larger droplets in the outlet, increasing the number of counts in the large micron range.

From Coulter Counter data, there appears to be little difference in percentage of removal for the various types of media used in the dual-flow filter.

TABLE 4—COMPOSITE DATA COMPARING HRSF AND DFX AT SACROC NO. 75, SNYDER, TEXAS

Channel #	Particle Size Microns	Dual Flow Filter Coarse Media (5 samples)*	Dual Flow Filter Fine Media (15 samples)†	Dual Flow Filter Total (20 samples)	High Rate Filters (9 samples)
3	2.0	98	93	94	74
4	2.52	98	96	97	77
5	3.17	98	96	97	75
6	4.0	98	96	97	74
7	5.04	98	96	96	73
8	6.35	98	94	95	70
9	8.0	96	90	92	64
10	10.08	89	79	82	50
11	12.7	79	53	60	42
12	16.0	78	48	51	35
13	20.2	77	25	38	15
14	25.4	20	32	29	33
15	32.0	40	33	35	33
16	40.3	40	46	44	11
Total		84	90	88	50

*40 Mesh garnet in the center section.

†60-80 Mesh garnet in the center section.

TABLE 3—TYPICAL DATA FROM 6-FEET DFX AT SACROC NO. 75, SNYDER, TEXAS

Channel No.	Particle Size Microns	Particles/ml Inlet	Particles/ml Outlet	ppm (Weight) Inlet	ppm (Weight) Outlet	ppm Percent Removal
2	1.59					
3	2.0	234,996	8,649	2.26	0.08	96
4	2.52	126,372	2,898	2.44	0.06	98
5	3.17	96,782	1,380	3.71	0.05	99
6	4.0	71,780	1,085	5.53	0.08	99
7	5.04	48,716	728	7.51	0.11	99
8	6.35	27,358	388	8.44	0.12	99
9	8.0	13,423	279	8.28	0.17	98
10	10.08	3,658	124	4.51	0.15	97
11	12.7	620	31	1.53	0.08	95
12	16.0	124	16	0.61	0.08	87
13	20.2	0	16	0	0.16	--
14	25.4	0	0	0	0	--
15	32.0	16	31	0.63	1.22	--
16	40.3	16	0	1.26	0	100
Total		623,860	15,624	46.71	2.36	95

TABLE 5—COALESCING ABILITY OF GARNET MEDIA IN FRESH WATER

Channel No.	Particle Size Microns	Particles/ml Inlet	Particles/ml Outlet	ppm (Weight) Inlet	ppm (Weight) Outlet	ppm Percent Removal
2	1.59	------	------	----	----	--
3	2.0	541,450	405,790	2.0	1.5	26
4	2.52	215,152	172,788	1.6	1.2	22
5	3.17	82,824	65,926	1.2	1.0	21
6	4.0	36,652	18,802	1.0	0.5	50
7	5.04	15,470	7,616	0.9	0.4	50
8	6.35	7,140	2,142	0.9	0.3	70
9	8.0	7,140	1,190	1.6	0.3	84
10	10.08	6,664	714	3.1	0.4	89
11	12.7	4,998	476	4.7	0.4	91
12	16.0	2,380	238	4.4	0.4	90
13	20.2	1,904	238	7.1	0.9	88
14	25.4	476	476	3.6	3.6	--
15	32.0	------	952	----	14.2	--
16	40.3	952	476	28.4	14.2	50
Total		923,202	677,824	60.6	39.2	35

TABLE 6—COALESCING ABILITY OF GARNET MEDIA IN SALT WATER

Channel No.	Particle Size Microns	Particles/ml Inlet	Particles/ml Outlet	ppm (Weight) Inlet	ppm (Weight) Outlet	ppm Percent Removal
2	1.59	------	------	----	----	--
3	2.0	221,816	10,710	0.8	< 0.1	96
4	2.52	174,454	3,570	1.3	< 0.1	98
5	3.17	120,904	1,904	1.7	< 0.1	98
6	4.0	91,154	1,428	2.6	< 0.1	98
7	5.04	64,022	714	3.7	< 0.1	99
8	6.35	39,746	714	4.6	0.1	98
9	8.0	38,080	------	8.9	---	100
10	10.08	27,370	------	12.8	----	100
11	12.7	20,468	------	19.1	----	100
12	16.0	7,378	------	13.8	----	100
13	20.2	4,046	------	15.2	----	100
14	25.4	3,094	------	23.1	----	100
15	32.0	1,190	------	17.8	----	100
16	40.3	------	------	----	----	--
Total		811,342	17,612	125.4	0.3	99+

The finer media averaged 90-percent removal of particles over 2 microns for 15 samples, and the coarser media averaged 84-percent removal of particles over 2 microns for five samples. The high-rate filters averaged 50-percent removal of particles over 2 microns for nine samples.

Tables 5 and 6 show the coalescing ability of the garnet media, with fresh and salt water respectively. These tables very clearly show how this particular type of system works as a coalescer. They also supports the previous observation made at SACROC No. 75.

CONCLUSION

The effectiveness of the Coulter Counter in the development of a new type of filter is illustrated in the data presented. The utility of this instrument in the area of coalescing is also shown in the data. Although laboratory operation is preferred, field operation can be used when necessary.