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A LOW-PRESSURE CYCLONE FOR DESANDING INDUSTRIAL WATER

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A LOW-PRESSURE CYCLONE FOR DESANDING INDUSTRIAL WATER

by

J. Visman* and C.F.J. Rozenhart**

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SUMMARY

The treatment of water before and after its use in an industrial plant or municipal system is of growing importance in view of the ever-expanding demand for pure water and the increasing pollution of water in industrial areas.

The first step in the process of purification is to remove solids from the water as it enters the plant or leaves the system.

In this report a description is given of a cyclone separator for solids removal at low pressure. Compact construction, low power consumption, and sharp separation (10 to 20 microns) are the features that make this cyclone a desirable, and often necessary, separator for eliminating highly variable amounts of solids from industrial waters, plant effluents, and municipal sewage.

Performance data of a commercial installation are presented as an illustration of the applicability of this separator for the primary purification of industrial water.

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Direction des mines

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CYCLONE À BASSE PRESSION POUR DESSABLER LES EAUX INDUSTRIELLES

par

J. Visman* et C.F.J. Rozenhart**

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RÉSUMÉ

Le traitement de l'eau, avant et après son utilisation dans une usine industrielle ou un réseau municipal, a de plus en plus d'importance en vue de la demande toujours plus grande pour de l'eau pure, ainsi que la pollution croissante de l'eau dans les régions industrielles.

Le premier pas dans le processus de l'épuration est l'extraction des solides de l'eau entrant ou quittant le système.

Dans ce rapport, on donne une description d'un séparateur à cyclone pour éliminer les solides à basse pression. Une construction compacte, une faible consommation d'énergie et une séparation précise (10 à 20 microns) sont les caractéristiques qui font de ce cyclone un séparateur désirable et souvent nécessaire pour éliminer les quantités très variables de solides des eaux industrielles, des effluents d'usines et des eaux d'égouts municipaux.

Les résultats de performance d'une installation commerciale sont presentés pour illustrer l'applicabilité de ce séparateur à l'épuration primaire de l'eau industrielle.

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INTRODUCTION

Industrial waters and effluents containing solids are conventionally purified by screening, filtering, hydraulic classification, and chemical treatment. The method used depends on the type of material and on the specifications for the finished product.

In this report, only one aspect is discussed, namely the removal of solids heavier than water. This type of treatment is part of the primary purification procedure and deals generally with particles larger than 1 micron (0.00004 in.). Removal of solid fragments larger than 4 mesh (0.185 in.) poses no problem for commercial-scale operations. The smaller particles of 4 mesh x 1 micron, however, are often difficult to separate, especially when large quantities of solids and high flow rates are involved, or when a high degree of efficiency is required and specifications require that the water be purified to exacting standards.

The hydrocyclone is one of a series of five separator types (including screens, hydroseparators, hydroclassifiers, and centrifuges). The hydrocyclone has certain advantages over the other equipment types, by virtue of its simple design (no moving parts), high capacity, and low cost. It also has certain limitations, for which reason it is often used in conjunction with other equipment, as is illustrated later on. In this report the removal of sand from river water used for a natural-gas conservation plant is discussed. Maximum removal of solids from the raw water is desirable and this, in turn, means that the desander unit should not only remove the coarse particles that cause mechanical damage, but should also remove the more abundant slime fraction (less than 100 microns diameter) in order to alleviate the problems that attend subsequent filtration.

The "separating particle size" of the cyclone is commonly used as the main characteristic for expressing its classification ability. This is the size of the particles that, in passing through the cyclone, have an even chance of discharging with the clean water (overflow) or with the reject (apex or underflow). The smaller the separating particle size, the better the desanding efficiency.

The equation that expresses the separating particle size (d_{50}) as a function of the cyclone diameter (D), the fluid viscosity (v), the density (d) of the solids, the density (w) of the fluid and, finally, the pressure (p), is, by first approximation:[1]

$$d_{50} = \left[\sqrt{\frac{D \cdot v}{(d - w)\sqrt{p}}} \right]^n$$

All units are in the cgs system, except p, which is expressed in atmospheres (kg/sq cm) and d_{50} itself, which is expressed in microns; n is a constant with values from 0.6 to 1.5, depending on the geometry and the settings of the cyclone.

This equation shows that the diameter (D) of the cyclone is the major factor, apart from the viscosity (v) and the densities (d,w), which are given quantities. The pressure (p) has much less influence on d_{50}, because it occurs under two square-root signs. Of the many considerations that go into the design of a cyclone, the choice of the diameter (D) is the major one: small d_{50}-values are primarily attained with small-diameter cyclones.

A second consideration is the capacity of the cyclone as expressed by its flowrate, Q. A first-order estimate of Q is obtained from the equation: [2]

$$Q = D_o D_1 \sqrt{p}$$

where

Q = flowrate in cu. m/hour;

D_o = diameter of cyclone inlet orifice, in cm Φ ;

D_1 = diameter of cyclone vortex finder, in cm.; and

p = pressure, in kg/sq. cm. (atmospheres).

This equation shows that a maximum flowrate is obtained by making D_o, D_1 and p as large as possible. Of these three factors, it is least desirable to increase p, because, firstly, Q varies only as the root of p, and, secondly, high pressure requires a more expensive pump and cyclone wear increases in direct proportion to the square of the pressure.

The above considerations led to the development of a multiple classifier cyclone unit that can be operated efficiently with a low-pressure pump (min. inlet pressure, 6 psi).

MULTIPLE CLASSIFIER-CYCLONE DESIGN

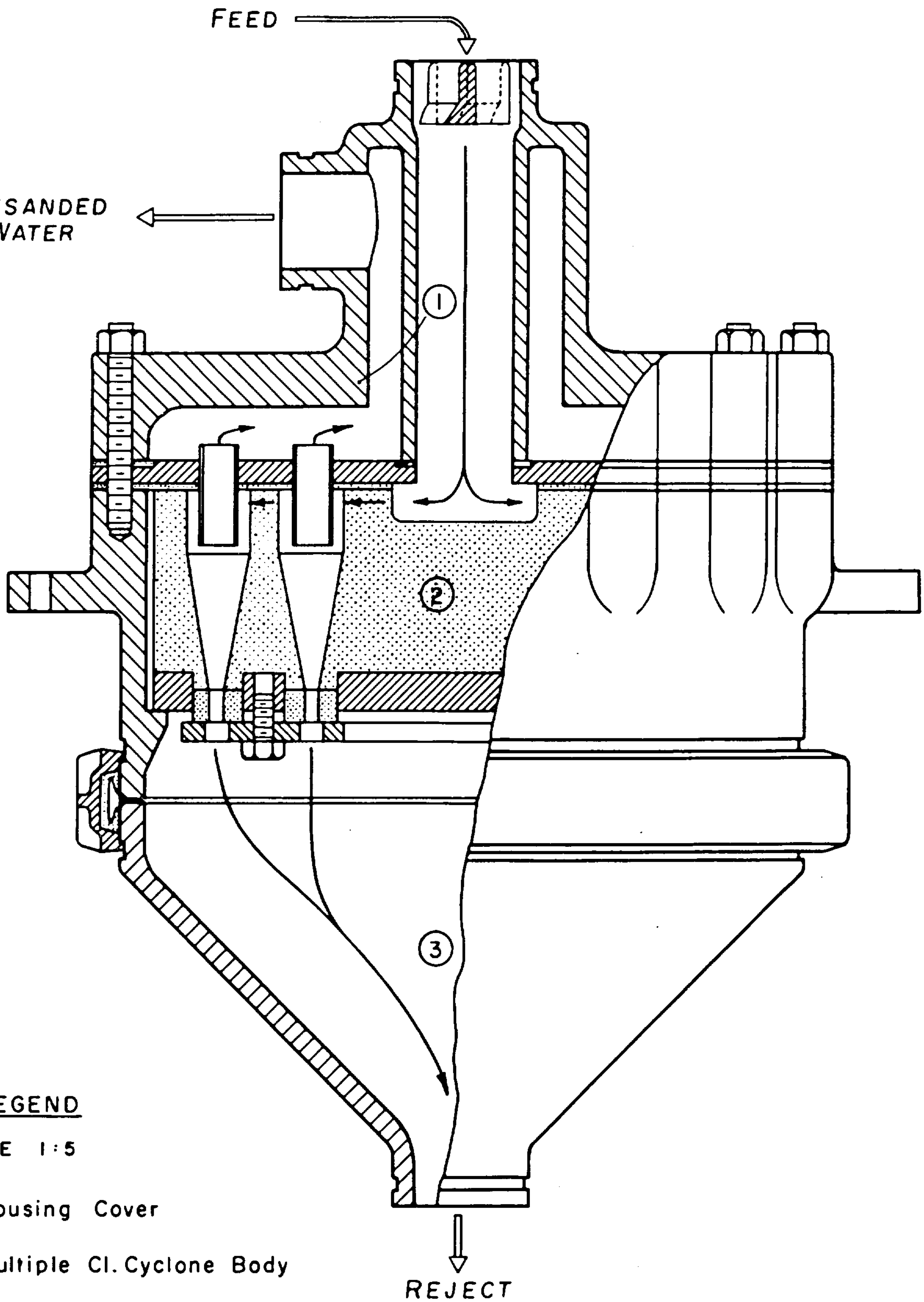
Figure 1, a cut-away aketch, shows the assembly of twenty-four 2-in. cyclones in a housing, with a common feed, overflow discharge and underflow discharge. This unit weighs approximately 790 lb and has 3-in. ID pipe connections (4 in. Victaulic). The main operating statistics of this unit are:

Flowrate, cu. m/h	-	40 - 80
(Water only) Imp gpm	-	147 - 294
US gpm	-	175 - 350
Inlet pressure, psi	-	6 - 25 [1)]
Power (12 ft head extra), Hp	-	3 - 22
Cut point d_{50}, microns	-	15 $\pm$ 5

1) The unit is designed for 50 psi, to allow for 2-stage operation.

FIG. 1 - DESANDER CYCLONE

(CL. C - 2M)



LEGEND

SCALE 1:5

1 - Housing Cover

2 - Multiple Cl. Cyclone Body

3 - Housing Cone

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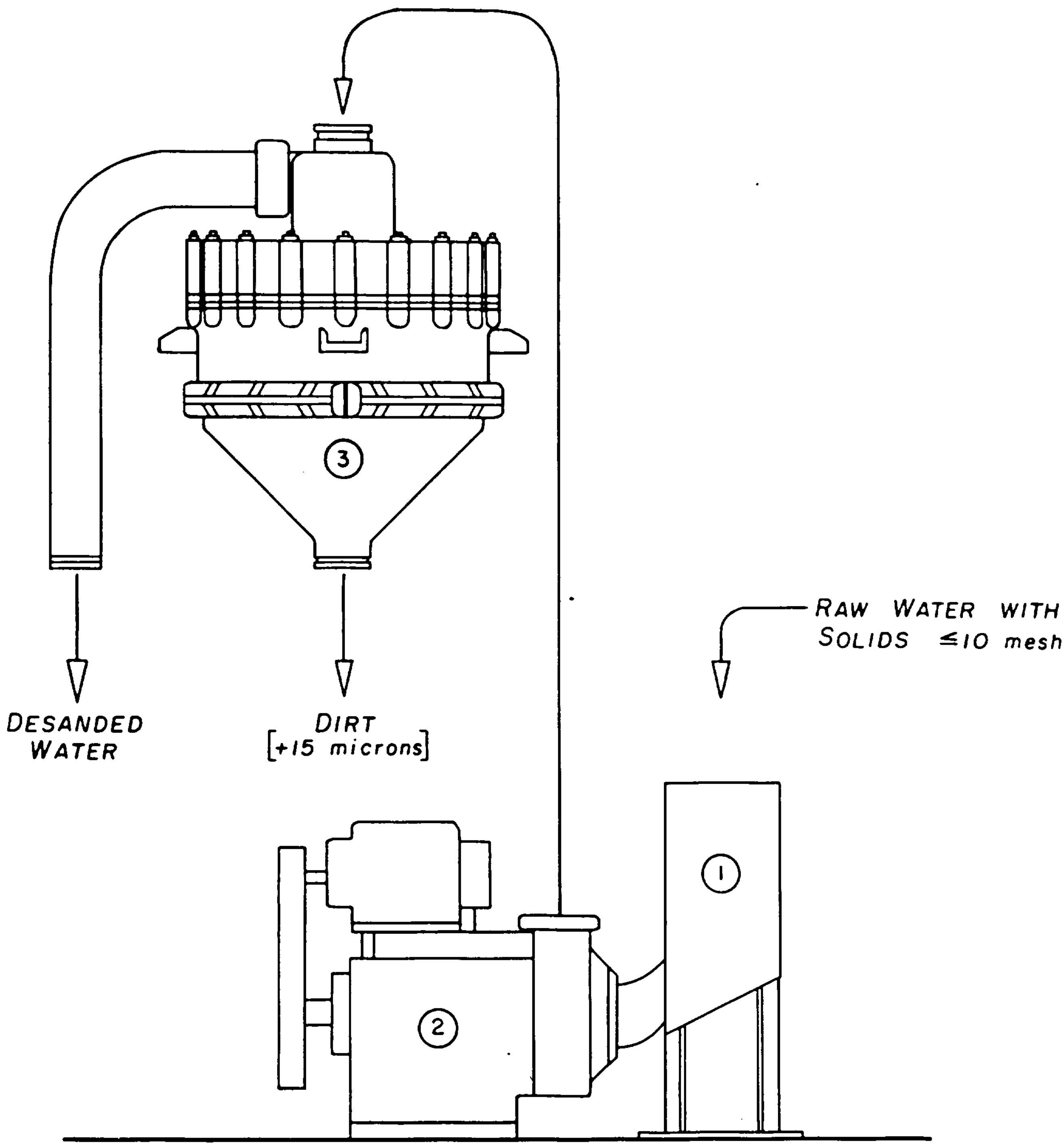
Fig. 2 - Multiple 2-in. Classifying Cyclone

(PILOT PLANT ASSEMBLY)



LEGEND

(1) - Tank

(2) - Pump

(3) - Desander Cyclone, Cl.C-2M

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The approximate dimensions are given in Figure 1, whereas Figure 2 shows the basic assembly and flow diagram for a single unit.

The recovery of clean water is high (≈ 98 per cent) when the desander is operated with an open underflow discharge orifice and with the overflow discharge pipe having its orifice at approximately the same height, as shown in Figure 2. When circumstances prevent open discharge of the overflow (as in the application discussed below), more water will be discharged with the reject. To avoid excessive water loss, the orifice of the common reject discharge is then reduced by inserting an adjustable rubber restriction valve. In addition, each classifier cyclone has an adjustable and replaceable rubber restriction valve.

The nominal top size of the material that can be passed through the cyclone is 20 mesh (0.0328 in.), allowing 15 per cent oversize with an absolute top size of 10 mesh. A positive cut-off at 10 mesh may pose a problem; for instance, when a slotted slurry screen is used ahead of the desander cyclone. The oversize in the underflow of such a screen normally constitutes a small fraction of the total underflow solids, unless the screen is overloaded or defective. A trap of suitable design (e.g. a degritting cone, or a large-diameter cyclone) is then used to scalp the feed to the desander. It is not necessary that this trap have a continuous discharge, as will be demonstrated.

The desander is easily disassembled for inspection, by lifting the housing cover (214 lb) with a light pulley or "come-along". A minimum of 1½ ft of head room is recommended for this purpose.

PERFORMANCE

A sample of waterborne silt (top size 100 mesh) from the N. Saskatchewan River was circulated in the pilot plant assembly shown in Figure 2, at an inlet pressure of 10 psi.

Samples were collected simultaneously from the overflow and underflow products, and these were weighed, filtered, dried, and weighed again, for determination of solids concentration. The overall results of this test were as follows:

	Desanded water	Reject	Feed (reconst.)
Flowrate, igpm	208	2	210
Solids, wt. %	0.00262	4.51	0.04846
Solids, ppm.	26.2	45,100	485
Solids, in wt % of feed solids	10.53	89.47	100.00

The solid residue of the desanded water and the reject were analysed for size consist, by elutriation. The results are shown on Table 1. The partition curve data in the last column of Table 1 are illustrated in Figure 3, where it is shown that the silt was separated at a separating particle size d_{50} = 14.3 microns; the probable error was r = 2.5 microns. It is noted that the presence of small clay agglomerates had a beneficial effect on the separation, in that it increased the reject solids fraction by about 8 per cent. These clay agglomerates were dispersed during the elutriation analysis and consequently reported with the minus 1-micron fraction (see Table 1, column 5).

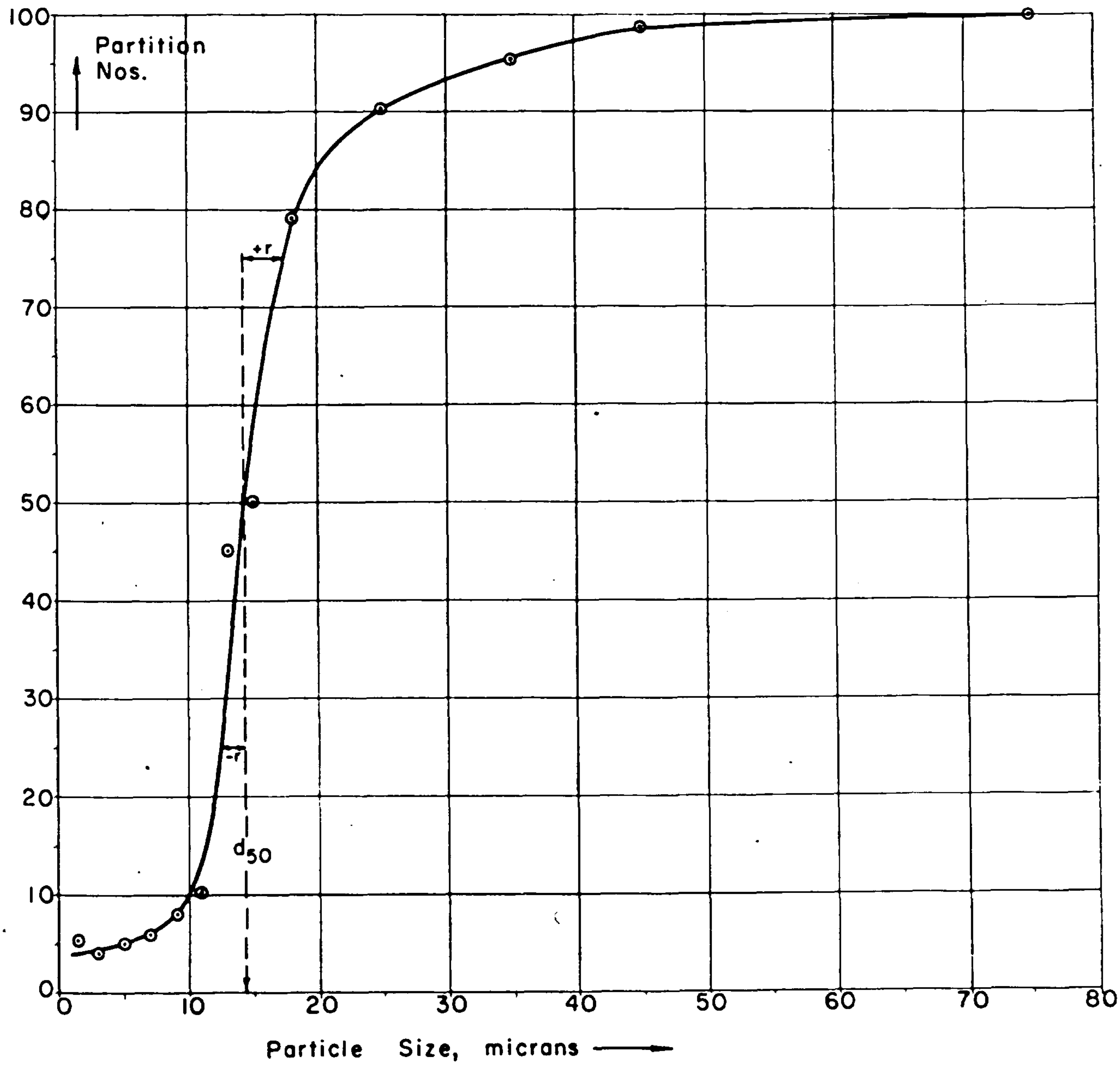
If all the clay had been dispersed, the reject solids fraction would have been smaller (approx. 82 per cent by weight instead of 89.47 per cent). The partition curve itself, however, would not have changed, because it is independent of variation of the feed size consist.

Table 1. Desanding of River Water with a Multiple 2-in. Classifier Cyclone

Size, in microns	Overflow (O) solids, wt %	Underflow(U) solids, wt%	Weight in % of Feed (F)		Feed(reconstituted)	Partition numbers, 100 U/F
			O	U	F	
- 1	51.0	9.20	5.37	(8.23)+	13.60	-
1 - 2	6.9	0.05	0.73	0.04	0.77	5.2
2 - 4	9.0	0.05	0.95	0.04	0.99	4.0
4 - 6	7.2	0.05	0.76	0.04	0.80	5.0
6 - 8	6.1	0.05	0.64	0.04	0.68	5.9
8 - 10	4.4	0.05	0.46	0.04	0.50	8.0
10 - 12	3.3	0.05	0.35	0.04	0.39	10.3
12 - 16	3.8	0.40	0.40	0.36	0.76	47.4
16 - 20	2.3	1.00	0.24	0.90	1.14	79.0
20 - 30	3.2	3.60	0.34	3.22	3.56	90.4
30 - 40	1.9	4.70	0.20	4.21	4.41	95.5
40 - 50	0.9	7.10	0.09	6.35	6.44	98.6
50 - 100	-	37.70	-	33.74	33.74	100.0
100 - 200	-	36.00	-	32.22	32.22	100.0
+ 200	-	-	-	-	-	-
	100.00	100.00	10.53	89.47	100.00	

+) Sub-micron material originates from small clay agglomerates that were dispersed during the elutriation analysis.

FIG. 3 - C.L.C.-2M, SIZE ERROR CURVE FOR SAND (SP. GR. = 2.70)



INDUSTRIAL APPLICATION

A river water pump station of a major oil company was designed to accommodate a single desander unit for the removal of sand and silt from the water being fed to a gas conservation plant. When the river level is high, the water entering the pump station contains sand particles up to ¼ in. size, as well as plant debris of even larger size and irregular shape. This material is removed by passing the incoming water through two trash screens having round holes of 4 mesh. These screens are back-flushed automatically at regular intervals. The water passing the screens contains sand, silt and small organic debris, substantially in 10 mesh x 0 size range, with only a small amount of 4 x 10 mesh material. The latter size-fraction is trapped in a degritting cone of special design. The feed and overflow pipe are arranged in such a manner that only the undesirable oversize is trapped and a minimum pressure loss is sustained.

The raw water enters the desander cyclone under a pressure that varies between 6 and 17 psi, depending on the pumping and back-flushing sequence of the station. The average feed pressure is approximately 14 psi and the amount of desanded water produced at that pressure is 183 Imp. gpm, against a static head of 3 ft of water in the overflow discharge pipe. The back-pressure on the desander overflow is caused by the fact that the overflow discharge pipe is submerged 3 ft below the surface of the water in the adjoining reservoir. Excessive loss of water with the reject is avoided by constricting the underflow discharge orifice. A rubber restriction valve with an adjustable orifice was installed in the apex of the housing cone. The orifice diameter is 0.5 in. A test of the installation was conducted over a period of 2 hours, when the unit operated at 10 psi inlet pressure on the desander. Details of this test are shown on the flow diagram, Figure 4. The unit was kept under surveillance for one month, during which period the river level was very high. Weekly inspection showed that the amount of solids carried over into the reservoir was reduced to approximately one-seventh of what it was before, in accordance with the test results obtained in the pilot plant. During this period the degritting cone was emptied once a week, by momentarily opening the bottom valve. At the end of the one-month period the desander unit was opened for inspection, as the clean water flowrate appeared to be slightly lower than before. A small amount of organic debris (8 grams of small twigs and wood fragments) was found to be partially blocking some of the channels leading to the cyclones and was removed.

The multiple cyclone body made of 90 durometer rubber had lost 170 grams through wear, mainly in the lower part of the cyclones. The rubber restriction valves of individual cyclones which were made of 35 durometer rubber showed hardly any wear. The unit was put back on stream and a subsequent measurement showed that the original flowrate had been restored.

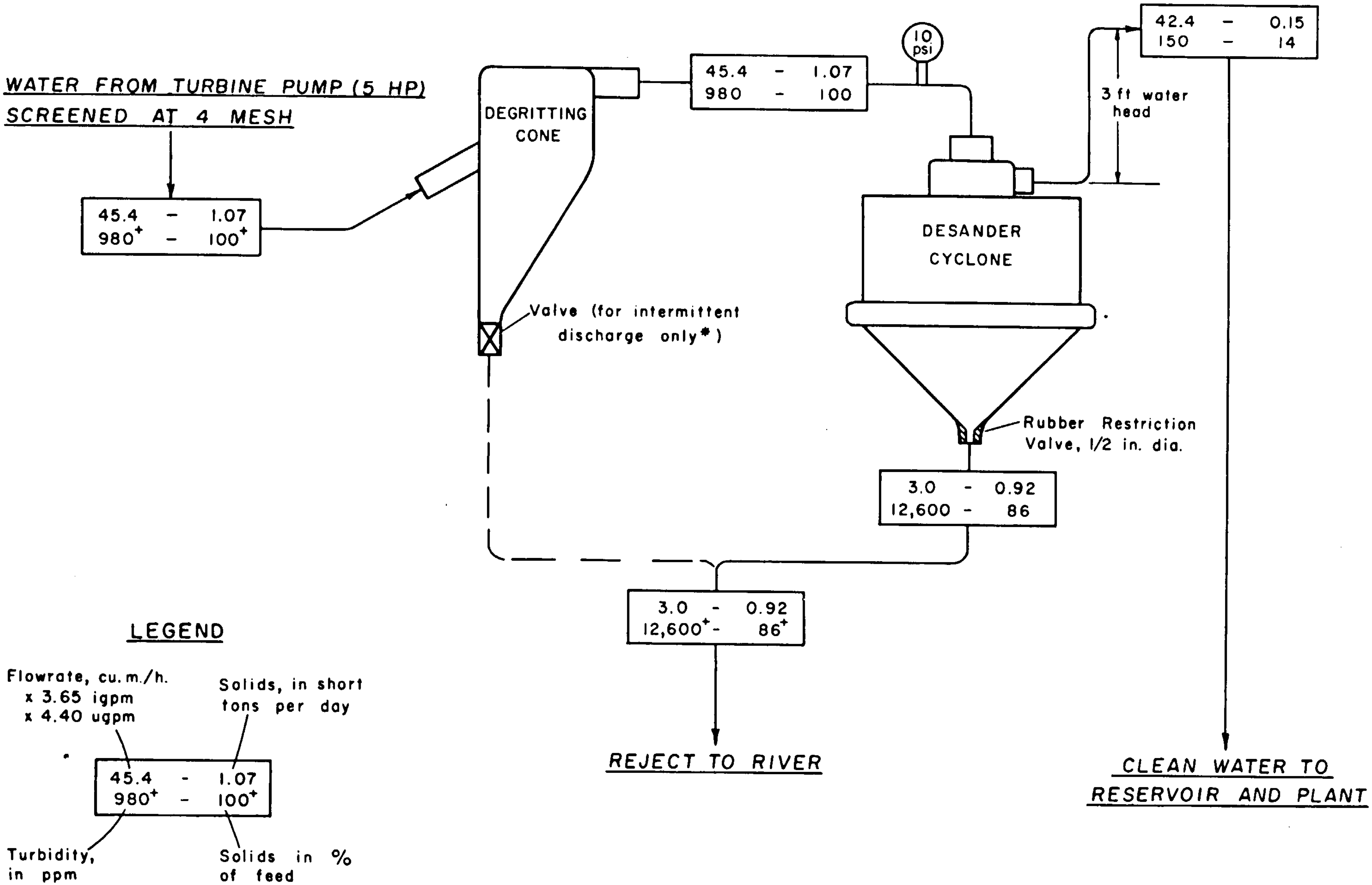
WEAR OF THE DESANDER CYCLONE

After one year of operation the body of the desander was inspected again, before (June 16, 1966) and after (September 7, 1966) a period of high water (see Table 2). The weight losses on these occasions were 83 and 117 grams respectively. The total weight loss since initial installation was 370 grams.

Inspection of the individual cyclones showed that the conical sections of 12 units were worn to approximately 2 in. diameter. Six units showed medium wear and six units were near normal.

The bottom plate, that supports the rubber body, showed some wear, especially at places where the wear of the individual cyclone was greatest. The apex restriction valves of the individual cyclones are made of 35 durometer

FIG. 4 - DESANDER FOR RIVER WATER PUMP STATION



*An amount of 127 grams of grit was found over a period of 2 hours.

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Table 2. Water Levels and Solids Contents Observed During Test Period

Month	River Elevation in Feet			Max. Turbidity, ppm
	Max.	Min.	Average	
1965				
May	66.0	55.2	57.2	1200
June	74.5	61.5	64.5	3000
July	69.5	59.0	62.4	2000
August	61.0	58.0	59.6	800
Sept.	60.8	56.6	58.3	500
1966				
May	59.4	54.7	56.6	800
June	59.3	56.8	58.0	450
July	69.0	57.5	61.5	800
August	66.6	57.9	60.7	1500
Sept.	59.0	56.5	57.6	800

rubber and showed some wear, but much less than the body.

CONCLUSIONS AND RECOMMENDATIONS

1. The 2-in. multiple classifier cyclone (CL.C-2M) separates river sand at 15 microns with a probable error of 2.5 microns.

2. The desanding equipment described in this report, namely the CL. cyclone, degritting cone, and trash screens with automated periodic back-flush, reduces the turbidity of the river water from 980 ppm to 150 ppm at inlet pressures of 6 to 17 psi. The power required for this assembly is provided by two 5-Hp turbine pumps, which produce 183 Imp gpm (220 US gpm) of desanded water at an average inlet pressure of 14 psi to the multiple classifier cyclone.

3. Results obtained from wear tests carried out with the CL.C-2M cyclone and in the pilot plant of the Western Regional Laboratory confirm that natural rubber has a higher resistance to abrasion for this specific application and is superior to the hard rubber initially used in the CL.C-2M.

4. For protection of the multiple cyclone unit and in order to reduce the need for periodic inspection, it is recommended that a 10-mesh wire screen be installed in the feed entrance immediately ahead of the CL.C-2M, for the removal of any stray organic fragments that may accidentally pass the trash screen and the degritting cone.

5. From tests over a one-year period, it was found that soft natural rubber has a higher resistance against abrasive material (such as river sand) than hard rubber. It is recommended that there be installed a new body made of a rubber with a low durometer value, or a body made of silicon carbides, both of which are available to industry.

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