4-1980

The Effect of Stock Temperature on Centrifugal Cleaner Efficiency

Randall J. Stoykovich
Western Michigan University

THE EFFECT OF STOCK TEMPERATURE ON CENTRIFUGAL CLEANER EFFICIENCY

by

Randall J. Stoykovich

A Thesis submitted
in partial fulfillment of
the course requirements for
The Bachelor of Science Degree

Western Michigan University
Kalamazoo, Michigan

April, 1980

ABSTRACT

As of age, the requirements of paper and pulp quality have multiplied. Optimizing the efficiency of the stock preparation system is a primary concern. The centrifugal cleaner represents an almost universal aspect of pulp cleaning. In an attempt to maximize contaminant content of the rejects with as little fiberous material as possible, the temperature was varied in a closed loop system which incorporated a Bolton-Emerson Albia 300SC centrifugal cleaner so as to determine an optimum range for operation.

The "cleaning" of a fibrous suspension, that is, the removal of foriegn material unsuitable to the papermaking process, basically entails two operations: one of screening and the other of cleaning. Screening operations remove undesirable factions by the means of a horizontal or centrifugal arrangement of slotted or perforated plates. Cleaning involves the sedimentation, by centrifugal force, of impurities onto the cleaner wall and rejecting them by gravitation into the reject stream.

The cleaners used today consist of a truncated cone with or without a cylindrical extension at the large diameter and with a tangential inlet at the top. (3) A typical unit is illustrated in Figure 1. Various design modifications have evolved over the years in an attempt to get better contaminant removal. One such design utilizes a downward spiral helix cast into the cleaner body in an attempt to provide a more controlled flow pattern of both rejects and accepts. This cleaner is manufactured by Bolton Emerson and a study will be presented later. The angle incorporated by the cone has also been experimented with. However, test results showed that the cone angle (6 - 12^{o}) exerted only a compatatively small influence on the tengential velocity and thus on the radial speed of sedimentation of the dirt particles. (1)

Materials used in cleaner design must exhibit corrosion resistance, a low coeeficient of friction with water, and a resistance to abrasion. Corrosion resistance is virtually synonomous with stainless steel and most designs utilize it for the upper part of the cleaner. To maintain the high velocities which are necessary to generate separating forces, a substance with a low friction cooefficient is needed. Characteristically, plastics

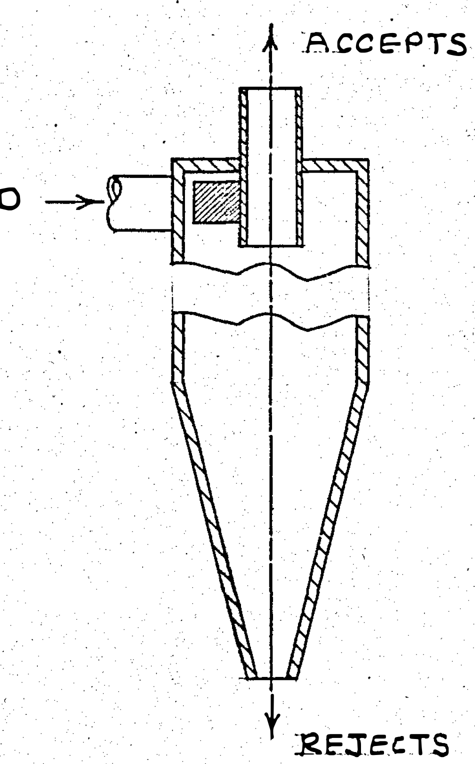


FIG. 1

fall into this catagory as they can be manufactured with a very smooth surface by using highly polished molds. Certain ceramics can also be utilized and are often produced with a high aluminun oxide content so as to provide abrasion resistance in the lower part of the cleaner where the dirt concentration and velocity reach maximum values. (3)

An innovation currently used to aid cleaner efficiency is an elutriator. At the reject orifice of the cleaner, the downward vortex has been reduced in thickness as the cone decreases in diameter, and there is some random transfer of dirt from the downward to the upper vortex. Adding an elutriator allows the use of a 1 1/8 inch orifice rather than the customary 3/8 inch orifice and substantially reduces the random transfer effect, thereby improving the separating efficiency. (3) The rejects, with a portion of pulp, discharge through a large orifice into the elutriator, where the area is more than four times as large as that of the cone orifice. The increased volume is filled with water entering through the two tangential ports, reducing the consistency to a level where effective separation of dirt and fiber is again possible. This water enters under a pressure of 18 - 30psi, which imparts a strong rotary motion to the diluted pulp suspension. This causes the elutriator to function as an auxiliary cleaner, with the fibers moving with the water to the upward vortex and the dirt continuing downward along the wall, discharging through the reject orifice. (3) Valves on the water supply and reject lines control reject rate. See Figure 2.

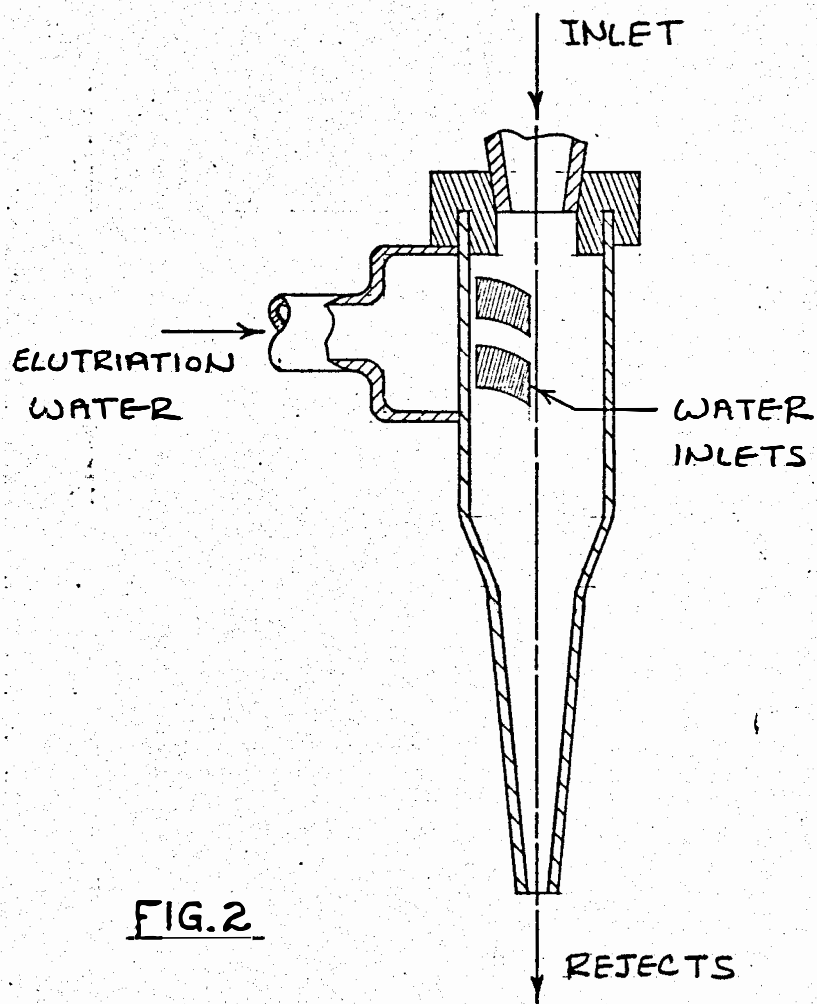


FIG.2

Traditionally, cleaners have been arranged ahead of the machine in benks of primary, secondary, and possibly tertiary systems. The rejects are dumped onto the respective chest and then pumped to the next stage with the accepts allowed into the system. This arrangement has worked successfully through the years; however, considerable horsepower was required to pump from one stage to the next. In an effort to improve plant design, the Bauer Brothers Company has introduced a vertical arrangement of cleaner banks which is claimed to reduce floor space and horsepower requirements, allow easier installation and maintenance of the system. With the current trend of linearity and rising energy costs in plant design and operation, the Bauer system appears to be a viable innovation.

The fact that the cleaner serves to remove abrasive types of contaminants precludes the need for some type of periodic inspection to prevent unit failure and to also keep operating efficiency at a maximum. Since the greatest concentration of dirt will be located in the tertiary stream, indications of wear will appear in this system first. However; being primarily of ceramic construction, this lower portion will wear quite slowly. Flushing the system preparatory to shut down will forego any possibilities of a unit plugging. (3)

As an operational variable, the consistency of the incoming stock becomes important. Low consistencies offer better dirt removal but also include the possibility of fiber separation by spring wood - summer wood or by species difference. It was this operating characteristic that allowed Jones, Campbell, and Nelson (4) to separate spring and summer wood fibers to utilize the particular advantageous properties of each. A difference in settling rate prompted the use of the hydrocyclone in the process. Experimentally, the best differentiation of properties was obtained when the feed pulp was diluted to 0.1-0.2% consistency before separation. (4) A closed loop was used for the trial incorporating a Bauer 3" Centri-Cleaner operating at 35 - 40psi pressure drop. The separated fractions were caught on screen boxes while the white water was recirculated to recover any fines. Evaluation of the trial handsheets was by standard mullen, tear, tensile, and porosity. A number of other variables such as flocculation, mechanical damage of the fibers, slurry temperature, operating pressure, and tip size served to control various aspects relating to accepts - rejects ratio but apparently the feed consistency had the greatest effect on operation.

The operation of the hydrocyclone is controlled by the following laws: (1)

The distribution of tangential velocity at various radial distances from the center of the hydrocyclone is;

$$vr^n = \text{constant}$$

Centrifugal acceleration is;

$$b = v^2/r$$

Speed of sedimentation in radial direction is in accordance with Stokes' Law;

$$vs = \frac{d^2}{18\eta}(\rho_p - \rho) \cdot b$$

Where:

- v is tangential velocity (m/sec)
- r is the radius of reference (meters)
- n is the exponent of r, approximately 0.5 - 0.7
- vs is the speed of sedimentation in a radial direction (m/sec)
- d_p is the diameter of particle (meters)
- ρ_p is the density of particle (kg sec^2/m^4)
- ρ is the density of the suspension (kg sec^2/m^4)
- η is the viscosity of the suspension (kg sec/m^2)

As with any rotating body or fluid, the tangential velocity is greatest at a point nearest the center - so it is with a rotating suspension inside the cleaner. The decreasing velocity as the datum nears the inner circumference is the square of the pressure at that particular datum, as per Bernoulli's Equation.

To determine a plot of the velocity and pressure distribution across the cleaner diameter, a hydrocyclone manufactured by Escher Wyss was modified for the addition of taps at various locations along the wall. The taps were provided to introduce Pitot' tubes capable of being moved across the entire cross-section of the cleaner. At each point it was possible to measure pressure conditions in any direction desired. Groups of four directions at a time were selected, always at angles of 90° to one another. The maximum pressure, which was in all cases measured in a tangential direction, produced the figure for impact pressure (p_1) and the minimum one that for static pressure (p_2). From these two measurements, tangential velocity was computed in accordance with: (1)

$$v = \sqrt{2g_c(p_1 - p_2)}$$

The trials were conducted with no fiber content so as to prevent plugging of the Pitot' tube - similar hydrodynamics of stock at 1% consistency and water provided the justification. Figure 3 illustrates the results. Note that the tangential velocity decreases from the center to the wall while the static pressure increases. At the center, the tangential velocity falls to zero and the static pressure may have negative values. (1)

The speed of sedimentation of a particular particle is a function of its' diameter and density, the viscosity and density of the transport meduim, and its' centrifugal acceleration, as per Stokes' Law. A comparatively large particle will settle out faster than a smaller one of equivalent density. The viscosity and density of the transport medium have a substantial effect on sedimentation - cleaner efficiency. As both are dependent upon the temperature that the system is operated at, an optimum tem-

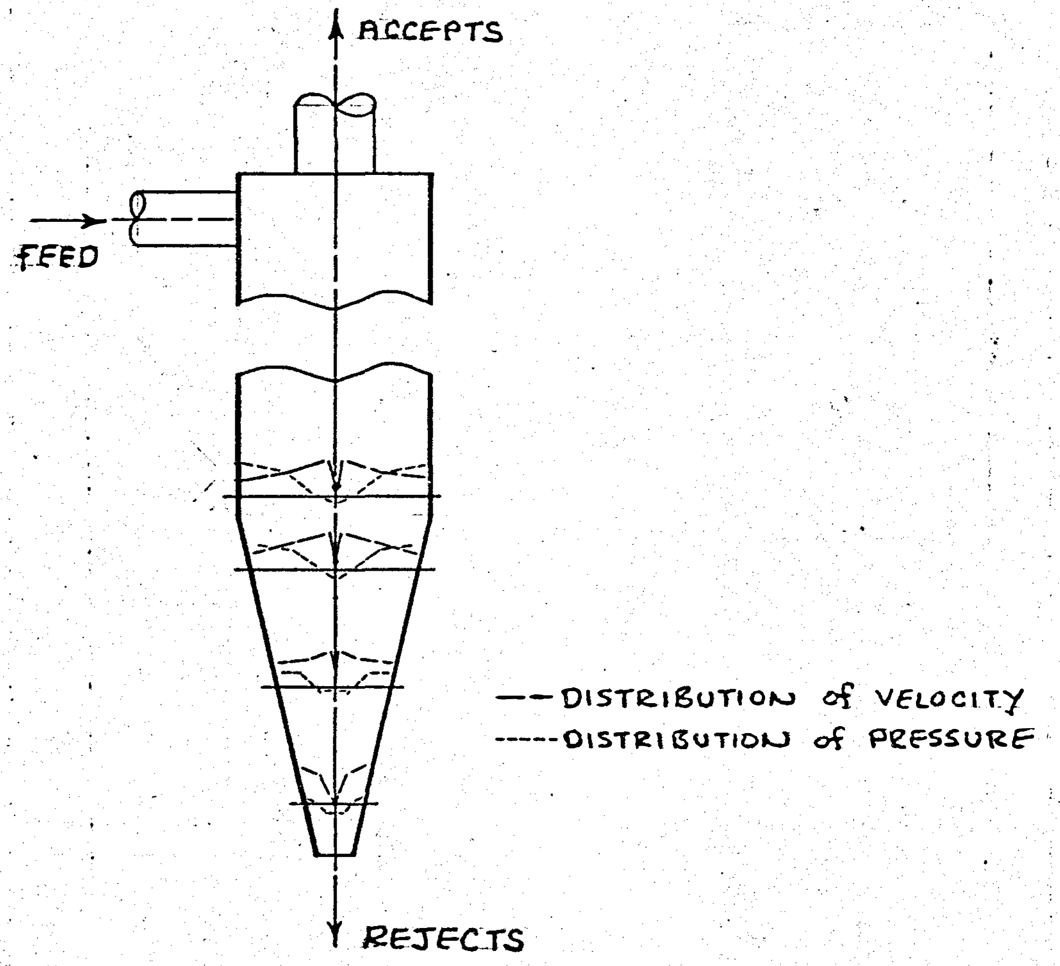

ACCEPTS
FEED
REJECTS
-- DISTRIBUTION of VELOCITY
----- DISTRIBUTION of PRESSURE

FIG. 3

perature should exist for that system at which a maximum amount of undesirables is removed for a given throughput.

The effect of stock temperature on cleaner accepts - rejects ratio was noted especially during the trials conducted that attempted to separate spring - summer wood. The stock used, (Southern Pine) has a spring to summer wood ratio of approximately 50:50, therefore, the closer their system would operate to a 50% accepts-50% rejects rate, the better separation would result. Table 1 indicates that as the feed slurry temperature increases, better fiber separation resulted. Had the temperature been increased further, an accept - reject ratio more near ideal might have been realized. (4)

TABLE 1:

Effect of Stock Temperature on Separation Efficiency

	Feed temp.(^{o}F)			
	80	86	92	105
Accepts, % of feed	75	67	61	44
Springwood, %	60	63	65	74
Rejects, % of feed	25	33	39	56
Summerwood, %	70	69	70	67

Particle shape is another variable which affects sedimentation velocity as a function of centrifugal acceleration. Pulp fibers are "accepted" by centrifugal cleaners because the hydraulic drag is greater than the centrifugal force. If a contaminant is disk ahaped, its' chances of responding to the hydraulic drag are greater than if it is spherical. Within this classification, the drag coefficient of the particle is primarily important. Using the aforementioned disk as an example, the projected area (A_p) is inversely proportional to its' drag coefficient by the following equation: (5)

$$C_d = \frac{F_d 2rw^2}{A_p u_o^2 \rho}$$

Where:

u_o is the velocity of the stream
ρ is the density of the medium
rw^2 is the radial acceleration
A_p is the projected area
F_d is the drag force

Therefore, a smaller projected area will increase the drag force and enable the centrifugal action to overcome the hydraulic forces which effectively results in rejection. In other words, when the flat side of such a disk is frontal to the inward radial flow in the cleaner, it is carried to the upper vortex and accepted. When the disk has its' edge toward the inward flow of liquid, the hydraulic drag is less than the centrifugal force, allowing the particle to move toward the wall where it is carried downward with the rejects. Some types of plastic and latex will have a specific gravity very close to that of water and thus settle so slowly that some of them are accepted. (3)

EXPERIMENTAL TRIAL:

Introduction-

The laboratory proceedings will primarily indicate the type and quantity of contaminant removed at each temperature. Cleaner operating efficiency will be based on a percent dirt removal format. Each of three types of contaminant will therefore exhibit an indication as to an optimum temperature at which it is best removed.

The furnish is to be computer card stock to eliminate the need for refining and to provide a constant supply. The slurry will not be deinked as pulp quality is not the concern. The stock will be diluted to 0.8% consistency and seeded with three contaminants: beach sand, iron filings (40 mesh), and sawdust (30 mesh). Contaminant level will be 0.6% based on weight of dry fiber.

It is expected that at the lower temperatures, the sand and filings will be rejected readily while the lighter sawdust will not. At the higher temperatures, the reject rate of the sawdust should increase due to the lower viscosity of the water fraction.

The apparatus consisted of a 30 gallon tank, a Bolton-Emerson Albia 300SC centrifugal cleaner, and a Goulds Mod. 3196 $1\frac{1}{2}$ x 3 - 8" pump. See Fig. 5 next page.

The stock was pulped in a Morden Slushmaker for 30 minutes at an initial temperature of 70^{o}F. A batch size of 20 gallons was used.

The system was designed so that both accepts and rejects returned to the supply tank.

Grab samples were taken at each of 9 temperatures (from 80-160°F) from the feed stock, the accepts line, and the rejects line. Handsheets were made from the samples and visually counted for dirt using a modified Tappi Standard T-213 (ts-65).

Operation-

The cleaner was run at an inlet pressure of 27psi and a rejects pressure of 4psi (20psi pressure drop recommended). No external temperature input was required as the pump supplied enough attrition to the closed system to adequately elevate the temperature.

RESULTS:

As expected, more effective dirt removal resulted as the temperature increased. The following graphs (Graphs 1 - 4) illustrate a % removal plotted against temperature and indicate that, at temperatures above 130°F, better than 90% efficiency resulted.

To consider any changes in refining action on the stock, the bulk density of each feed temperature handsheet was determined. See Graph 5. The attrition supplied by the pump served to refine the stock somewhat; however, even as the bulk density increased (a decrease in freeness) at the higher temperatures, the cleaner operated more efficiently.

CONCLUSIONS:

Based on the above experimental results, for optimum cleaning with the Albia 300SC, the feed stock temperature should be kept at approximately 150°F. It is reasonable to assume that other cleaner systems will also operate well at these higher temperatures.

The data presented illustrate cleaner efficiency with one-pass operation. A secondary cleaner stage could easily handle the remaining contaminants resulting in appreciable energy savings as a tertiary cleaner stage would not be required.

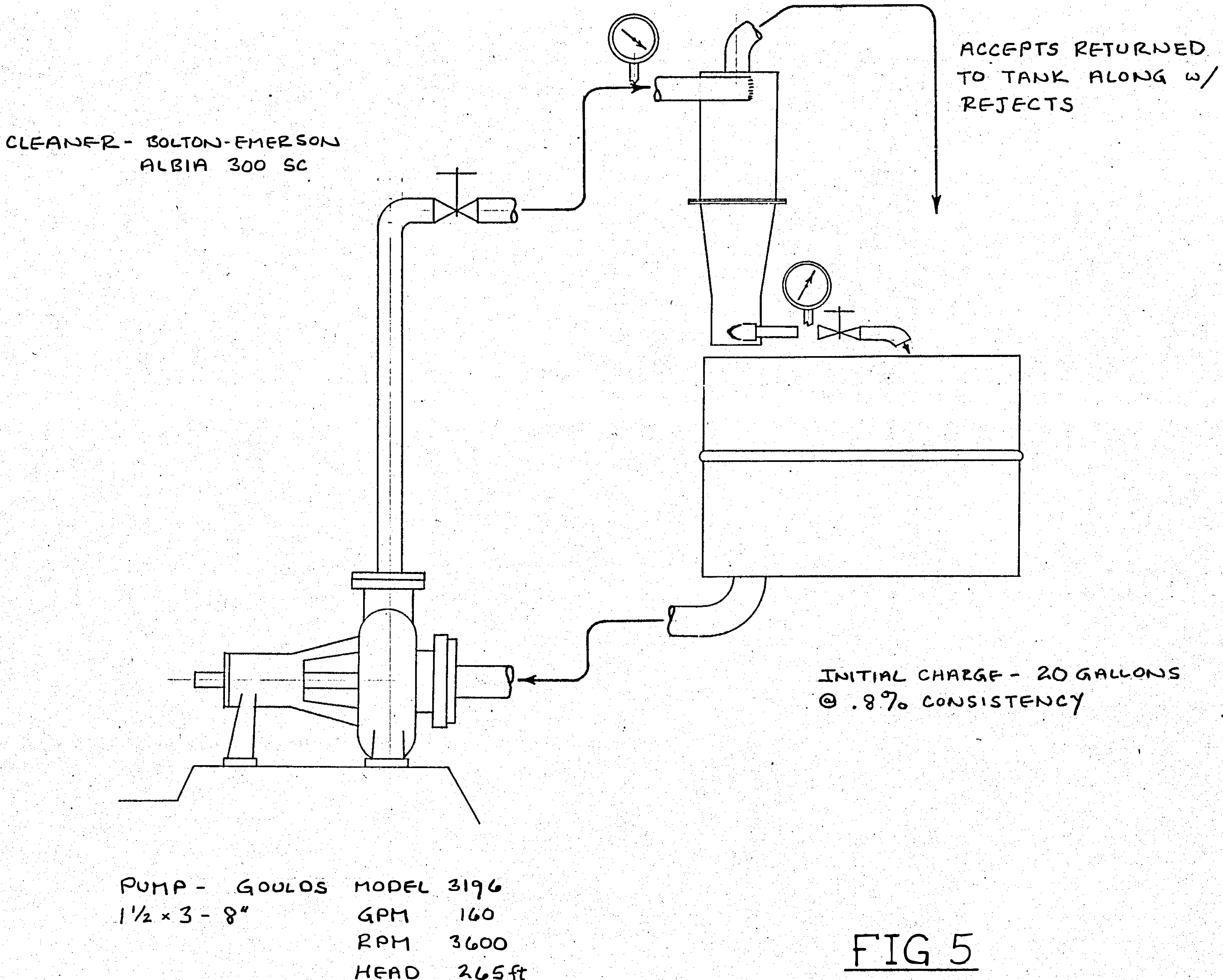
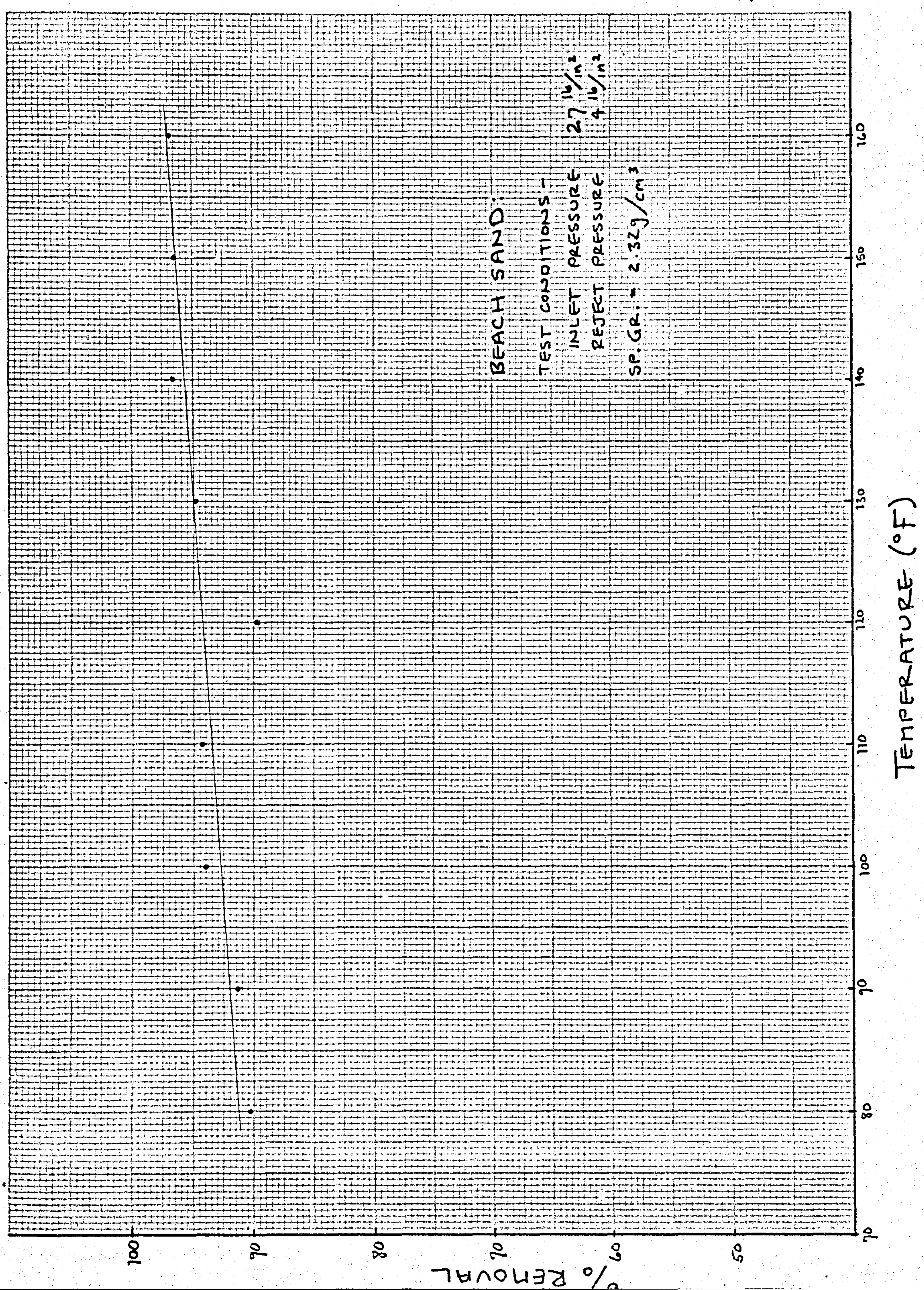

ACCEPTS RETURNED TO TANK ALONG w/ REJECTS
CLEANER - BOLTON-EMERSON ALBIA 300 SC
INITIAL CHARGE - 20 GALLONS @ .8% CONSISTENCY
PUMP - GOULDS MODEL 3196
1 1/2 × 3 - 8"
GPM 160
RPM 3600
HEAD 265 ft

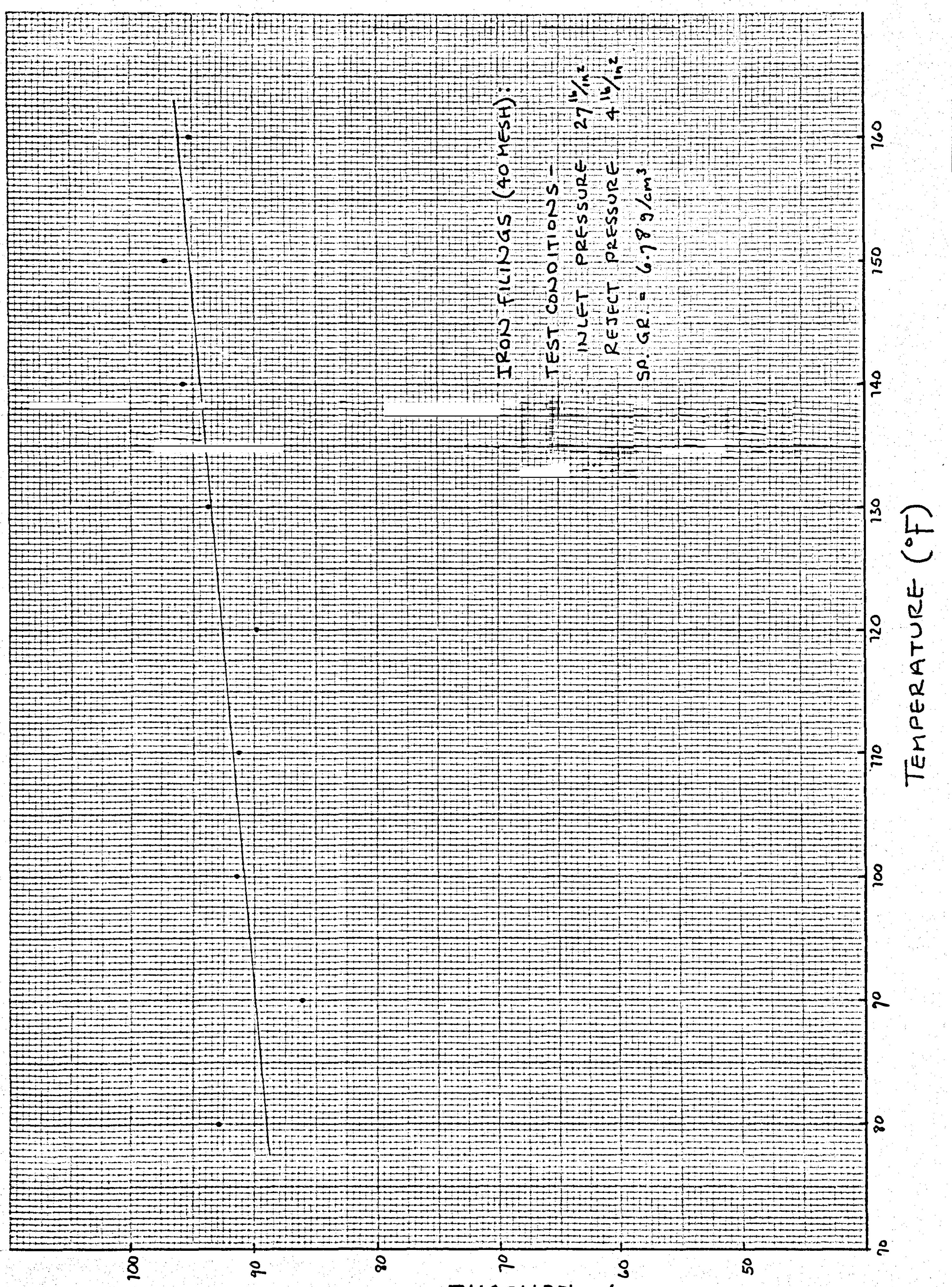
FIG 5

GRAPH 1



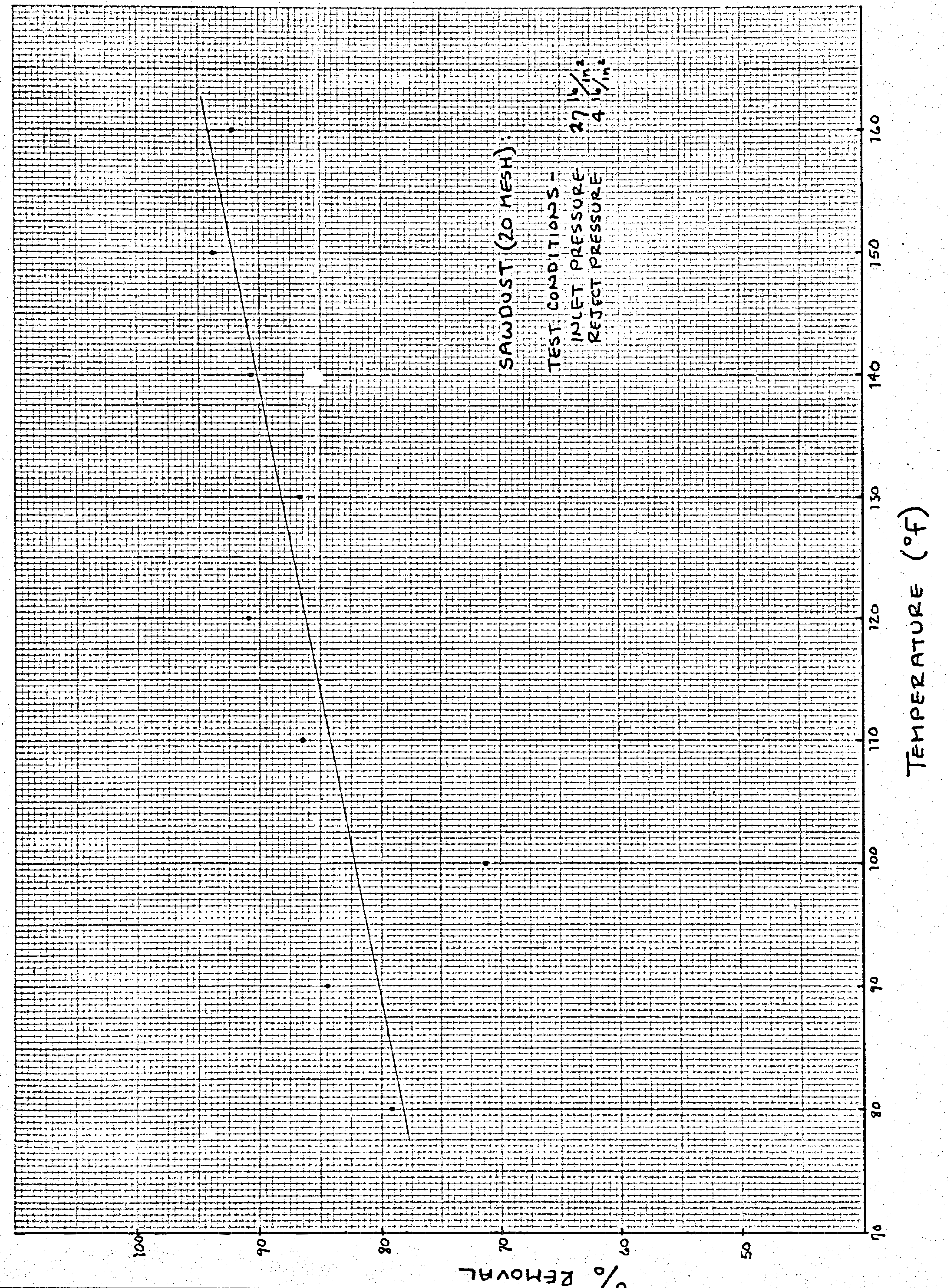
BEACH SAND:
TEST CONDITIONS:-
INLET PRESSURE 27 lb/in²
REJECT PRESSURE 4 lb/in²
SP. GR. = 2.32g/cm³
TEMPERATURE (°F)
% REMOVAL
70
80
90
100
110
120
130
140
150
160
100
90
80
70
60
50

GRAPH 2

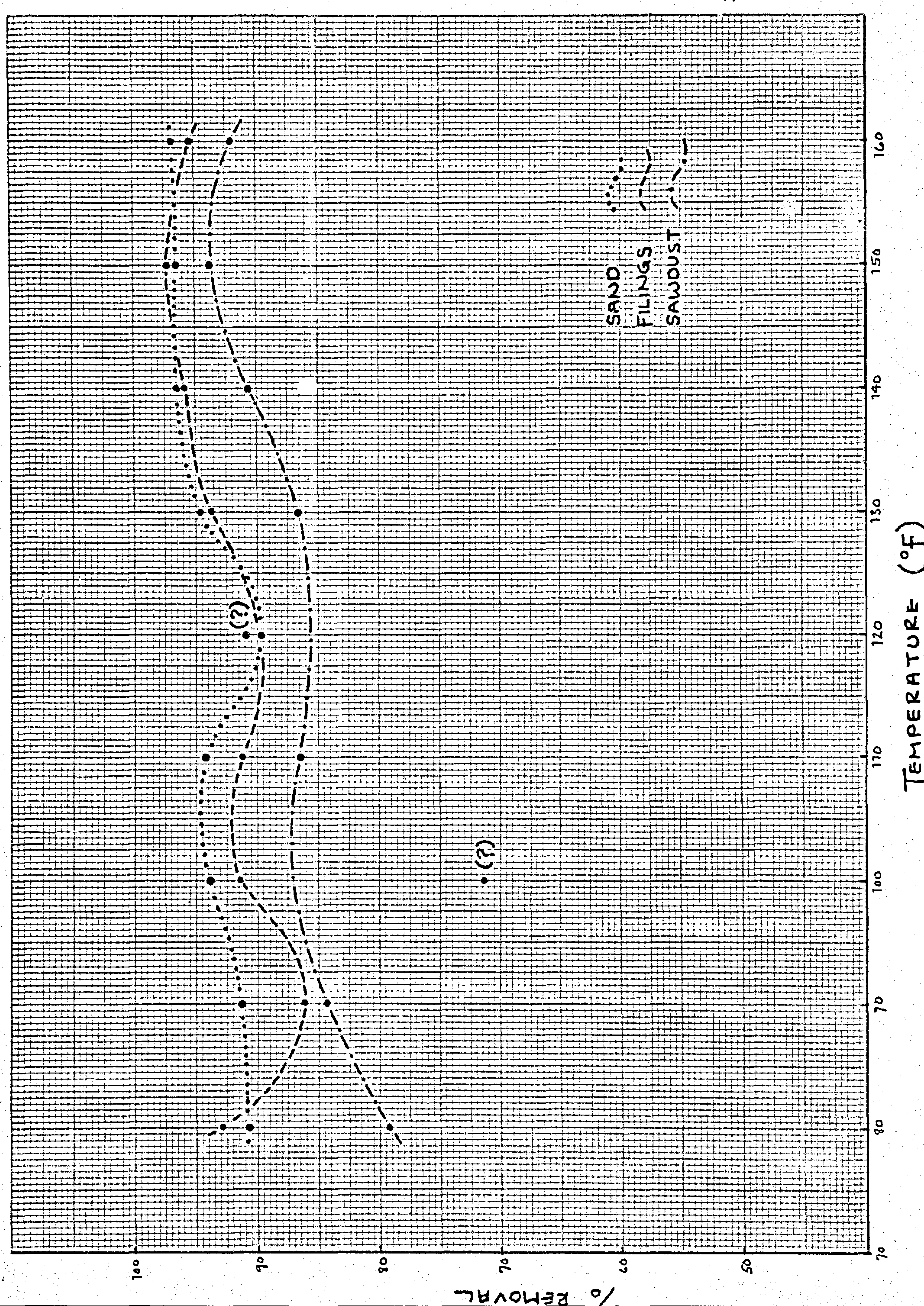


IRON FILINGS (40 MESH):
TEST CONDITIONS -
INLET PRESSURE 27 lb/in²
REJECT PRESSURE 4 lb/in²
SP. GR. = 6.78 g/cm³
TEMPERATURE (°F)
% REMOVAL
70
80
90
100
110
120
130
140
150
160
50
60
70
80
90
100

GRAPH 3

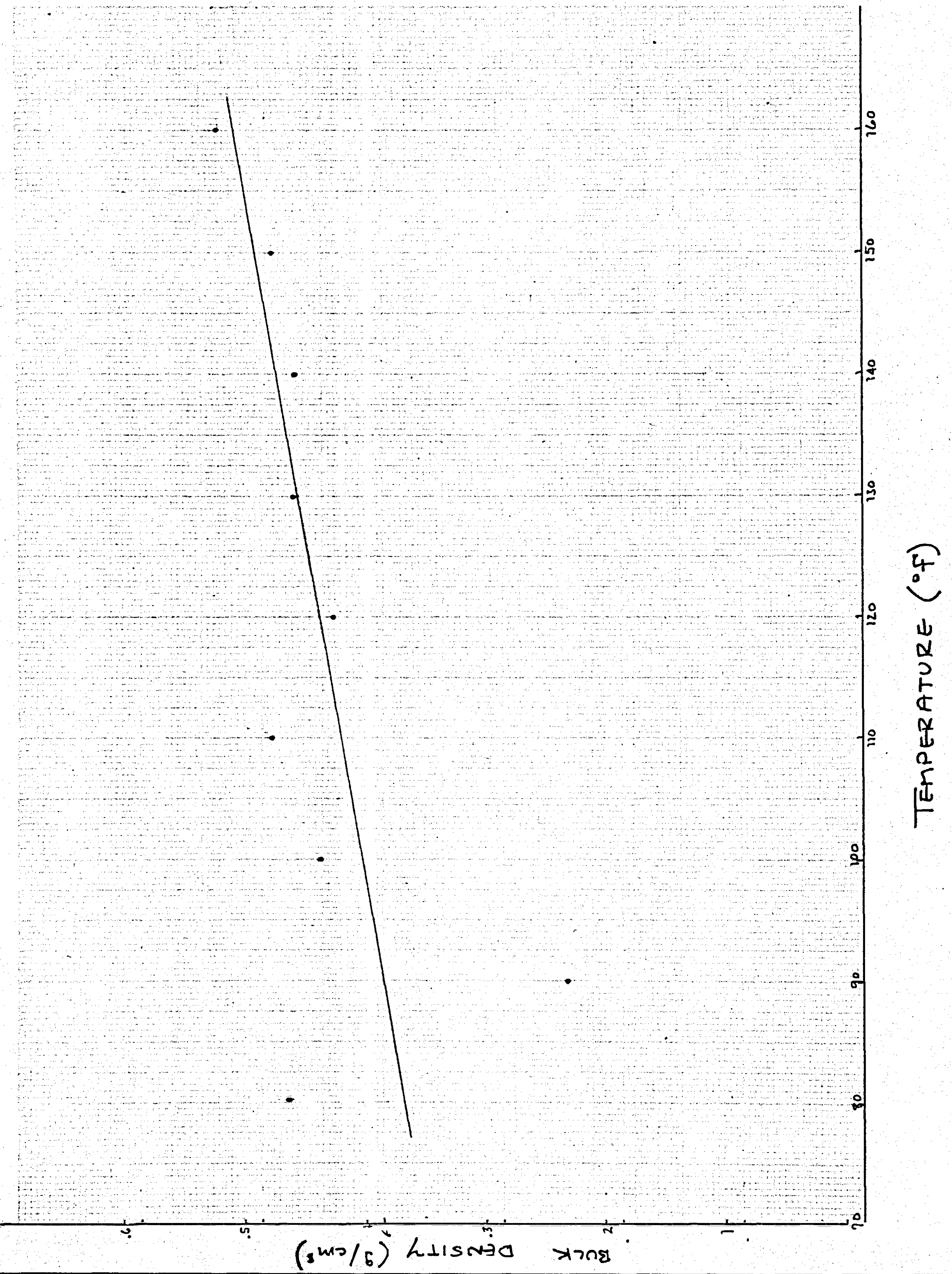

SAWDUST (20 MESH):
TEST CONDITIONS -
INLET PRESSURE 27 lb/in²
REJECT PRESSURE 4 lb/in²
TEMPERATURE (°F)
% REMOVAL
70 80 90 100 110 120 130 140 150 160
100 90 80 70 60 50

GRAPH 4



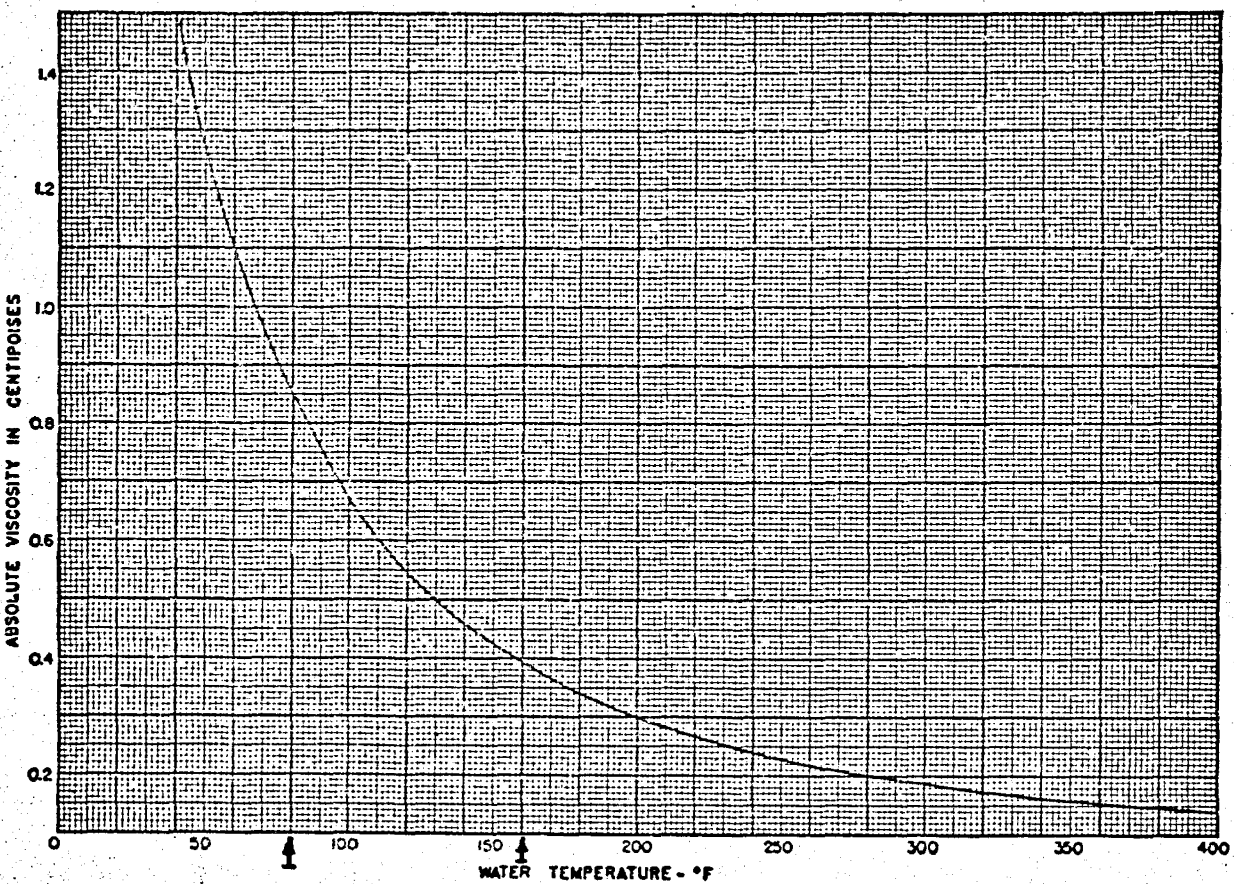
TEMPERATURE (°F)
% REMOVAL
SAND
FILINGS
SAWDUST
70
80
90
100
110
120
130
140
150
160
100
90
80
70
60
50
(?)
(?)

GRAPH 5



TEMPERATURE (°F)
70
80
90
100
110
120
130
140
150
160
BULK DENSITY (g/cm³)
.1
.2
.3
.4
.5
.6

Viscosity of Water



BIBLIOGRAPHY/FOOTNOTES

1) "Distribution of Pressure and Velocity in a Hydrocyclone." The Paper Maker, August, 1968.

2) "Prediction of the Performance Characteristics of a Centrifugal Cleaner." Tappi, Vol. 60, No. 8, August, 1977.

3) "Centrifugal Cleaning of Secondary Fibers." Tappi, Vol. 54, No. 7, July, 1971.

4) "Springwood - Summerwood Separation of Southern Pine Pulp to Improve Paper Qualities." Tappi, Vol. 49, No. 9, September, 1966.

5) McCabe, Warren L., and Julian C. Smith. Unit Operations of Chemical Engineering. McGraw-Hill, 1976.

Beery, J. P., Bauer Brothers Company. Multiple Hydrocyclone Arrangement. U. S. pat. 4019980. (Issued April 26, 1977)

"A Cleaning System for Low-Consistency Pulp." Tappi, Vol. 61, No. 8, August, 1978.