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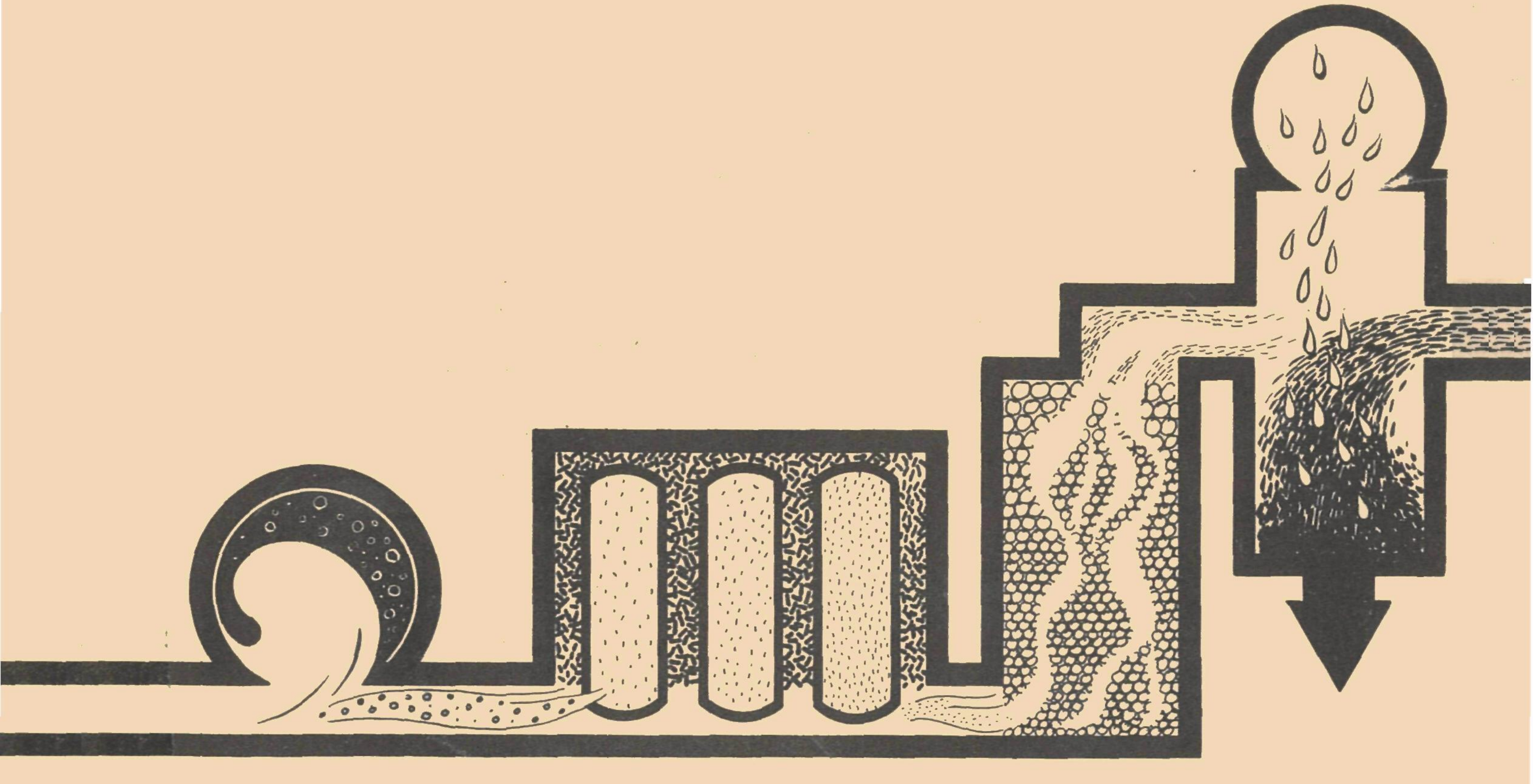
INVESTIGATION OF RESPONSE SURFACES OF THE MICROSCREEN PROCESS



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INVESTIGATION OF RESPONSE SURFACES
OF THE MICROSCREEN PROCESS

by

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for the

Office of Research and Monitoring

ENVIRONMENTAL PROTECTION AGENCY

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ABSTRACT

Field, laboratory, theoretical, and state-of-the-art studies were conducted with regard to utilization of microscreens for teritary treatment applications. Field studies were conducted with two pilot microscreen units, using a variety of screen sizes and types, for activated sludge, primary, trickling filter, and oxidation pond effluents. Particle distribution of the effluents (microscreen influents) were found to be the key characterizing parameter in determination of treatment effectiveness. Overall effectiveness of solids removal was low, and is ascribed to deficiencies in microscreen design practice for the transfer of screened solids from the screen to the backwash system and out of the microscreen unit.

A computer model of the process was developed in a format compatible with EPA Executive Program or Optimization of Treatment Systems. This project was submitted in fulfillment of Project No. 17090 EEM and Contract No. 14-12-819, under the sponsorship of the Environmental Protection Agency.

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SECTION I

CONCLUSIONS

The major conclusions reached as a result of the field, theoretical, laboratory, and state-of-the art components of the research are:

- Present-day microscreen designs show many characteristics which mitigate against the effectiveness of microscreen units for solids separation/tertiary treatment applications.

  - The microscreen process is not in fact a single process, but is composed of three essentially independent sub-processes (solids separation; transfer of screened solids to the removal zone; removal, generally by backwashing).

  - The two sub-processes of transfer and backwashing are the "weak links" in the overall process. Solids "fall back" off the screen into the drum pool during transfer, and splash effects during backwash can lead to concentration of solids in the drum pool and ineffective ultimate removal, with the process thus operating in a "liquid-separation" rather than a "solids-separation" mode.

- The "State-of-the-Art", as available in the literature, is largely descriptive and empirical; few mechanistic or theoretical predictive models have been devised or utilized.

  - As a consequence, it is difficult to compare and transfer experience from one application to another since it is not clear what the relevant parameters are.

  - Insofar as available technology is organized at all, it is presented in terms of gross parameters, such as the Filterability Index, which have not been related to, or derived from, operational or physical models of the process itself.

- A mechanical screening model of filtration appears to be an adequate "first-cut" definition of the solids separation sub-process.

  - Fundamental parameters associated with the model which can be used to transfer, compare, and predict performance of the separation sub-process are the particle size distribution and the solids loading rate of the influent to the microscreen process.

  - Given the characteristics of current microscreen design practice, it is difficult to devise theoretical or empirical models of the transfer and backwash sub-processes.

- A steady-state, gross input-output view of the microscreen process as a whole is totally at odds with the basic nature of the process, which is fundamentally that of a dynamic feedback control problem among the three sub-processes.

  - In the light of the above, the mathematical model of the microscreen process, which is steady-state, and theoretically-based in the screening sub-process, and empirical in the backwash and transfer sub-processes, is not an adequate predictor on which to base the design of microscreen units, although it can serve to delineate regions of effectiveness.

  - Accordingly, field pilot studies using small microscreen units should be conducted prior to final design and, in fact, prior to deciding definitively to use microscreening in any given application, prior experience notwithstanding. (It should be noted that, at present, a designer has essentially a binary (yes-no) decision with regard to installation of microscreens, said decision of necessity based *in toto* on information supplied by manufacturers.)

SECTION II

RECOMMENDATIONS

The principal recommendations for further effort and extension of research and design practice of the microscreen process are as follows:

- Design configurations as now utilized in most commercially available microscreens should be evaluated and modified to maximize the efficiency of the transport and backwash sub-processes, in terms of removing solids from the microscreen unit.

- The theory of microscreening behavior should be extended on the basis of:

  - delineation of the behavior of the three sub-processes of screening, transport, and backwash;

  - consideration of the dynamic feedback relationships between and among these sub-processes.

With regard to the development of a mathematical model of the microscreening process:

- It appears that the current design practices with regard to the transport and backwash sub-processes introduce a stochastic component into the performance of the overall process, making it difficult to predict process performance on a straightforward *a priori* basis. For an adequate mathematical model to be developed on the basis of physical or operational theories, the microscreen design itself must be modified to reduce the stochastic component, and make process performance more susceptible to predictive expressions.

- A dynamic formulation is appropriate and necessary.

- Particle size distribution (PSD) has been found to be a fundamental parameter in determining the effectiveness of the screening sub-process.

In an "optimal" microscreen design, the overall process performance should be controlled solely by the effectiveness of the screening sub-process, for which case the PSD will remain a fundamental parameter. It is possible to determine empirically the PSD of an effluent in an existing plant, using direct observations. However, there exists no predictive model for estimating the PSD of the effluent from a plant not yet in operation; such a capacity has not yet been developed to date because PSD has not been considered a parameter of design significance. Accordingly, a "boundary condition" for an adequate model of the microscreen process is the availability of predictive capability for determining particle size distribution as a function of design and operation parameters.

SECTION III

INTRODUCTION AND SUMMARY

MICROSCREEN PROCESS PERSPECTIVE

The purpose of the microscreen process is to separate solids from suspensions on a continuous basis, using a separation medium which is continuously regenerated. The application of the process has evolved in recent years from that of removing gross solids (solids larger than the interstices of the separation medium) from process streams to that of fine solids separation wherein one of the dimensions of the solids is smaller than the largest dimension of the pores of the separating medium. The success of the former type of application is dependent on physical retention, whereas the latter is dependent on some form of filtration.

The latter application of the microscreen, of interest in the present study, is representative of many new and innovative applications of processes in wastewater management as a result of the rapid evolution in water quality objectives in recent years. Because of this circumstance, a historical base of performance information from which the efficacy of the microscreening process can be established does not exist. This situation is exemplified by comparing the historical data base available for the microscreen process with that for the activated sludge process and its variations.

The present report on the microscreening process is a synthesis of the findings of a two-year investigation, the principal objectives of which were:

- To characterize the microscreen process as to its component subprocesses, the mechanisms operative in the subprocesses, and the pertinent solids characteristics in microscreen influents which affect process performance.

- To operate and evaluate the performance of pilot-scale microscreen units as a tertiary treatment device for several different types of secondary effluents, using a diversity of microscreen fabrics and the full range of operating parameters available in the pilot units.

- To develop a mathematical model of the microscreen process as a computer subroutine compatible with the EPA Executive Program, and having the capability of predicting microscreen performance when the process is used for treatment of secondary effluents as well as capital, operating, and maintenance costs associated with use of the process.

The scope of the study was organized into three activity areas to achieve the above objectives:

(1) A state-of-the-art evaluation of the theoretical and practical aspects of the study as germane to defining relationships

between performance and design and operating variables for the microscreen process (response surfaces) valid in any application context.

(2) Formulation of an operational simulation model of the process as a tool for indicating probable microscreen parameter behavior to be encountered in the field study and as a basis for designing the field investigations.

(3) A field-scale pilot plant study, designed to permit validation or redefinition, of the assumptions and hypotheses of the operational model, and to provide a basis for calibration of the final, analytical, mathematical model for use in predicting microscreen performance with a large number of influent sources, fabrics, and operating modes.

INQUIRY APPROACH AND SUMMARY

The information gained in each of the above steps was used to refine the predictor mechanisms for each subprocess, and to develop the field program, as described below.

State-of-Art Evaluation

It was concluded from the state-of-the-art evaluation that:

- The conceptualization of the microscreen process is in a primitive state; efforts to date in terms of describing the operation of the microscreen as a system of interacting sub-processes, or in terms of mathematical modelling of the process, have not succeeded in forwarding the process beyond the phenomenological stage of evaluation, understanding, and application. Simply stated, there exists no unifying concept for comparing and transferring state-of-the-art data from one source to another; nor does there exist a theory of microscreening explaining why the process responds as it does in any given application.

- Much of the available information on the process, whether it be at the phenomenological or deterministic stage of process evaluation and application, is proprietary in nature and unavailable to those individuals responsible for assessing the efficacy of such microscreen applications.

- Insofar as the state-of-the-art data is organized at all, it is organized in terms of gross parameters, such as Filterability Index, which have not been related in any manner to operational or physical models of the process itself. Thus, the data appears in a traditional format of statistical correlation, with no demonstration of causation. (After a review of the potential for utilization of the gross parameters of filterability index, sludge volume index, and sludge age, it was deemed inappropriate to pursue this "statistical correlation approach" with these parameters in the project effort, for the above cited reason, hence no further investigations on these parameters were carried out.)

- There is little published information on *how* to design either the microscreen unit *per se* or the application of the microscreen unit for any general set of performance and operational objectives; each application of the process has been viewed and documented as unique rather than as an extension of process utility in a general framework.

- Performance of various microscreen installations has been tracked alternatively by: liquid balances , solids balances, screen and solids character, and screen loading rates; very few of the applications have been described with all of the types of information defined above; in fact, interpretable solids balances were reported in only two references in the entire body of literature and the role of PSD was considered in only one reference (Reference 1).

Additionally, based on a review of the solids removal mechanisms potentially operative in the microscreen process, it was concluded that:

- No presently available data or theoretical analyses indicate that one mechanism is universally responsible for particle removal; nor is it yet possible to show quantitatively which mechanism may be controlling in the solids separation subprocess under any given set of physiochemical conditions.

- In the absence of firm information, and because of the fundamental development of the microscreen as a screening process, the mechanism of mechanical screening was selected for use in the deterministic model developed in the study.

Corollary to the above, the mechanism of mechanical screening can be documented only by quantitative routing of particle populations onto and from the screen, PSD data on the influent and effluent streams being the critical mechanism-level parameter of concern in the deterministic modelling and field-scale evaluation of the process.

Anticipated Response Surfaces

Operational Mathematical Model

The operational mathematical model was developed to provide a unified concept in the form of anticipated response surfaces for the pilot study to provide a framework for examining the field data, and to serve as a nucleus for the subprogram model. The development of the model is described in References 2 and 3. Inasmuch as the development of the operational model took place prior to the field investigation, the operational model was calibrated with data developed in laboratory tests with idealized particle suspensions (Reference 4).

Response surfaces were predicted with the operational model for trickling filter and activated sludge effluents, assuming a log-normal distritubion of particle sizes in these effluents. Mean particle sizes were taken as 35μ for the trickling filter effluent, and 20μ for the activated sludge effluent, with geometric standard deviations of 2.0

and 1.5 to 4.0 respectively. The nominal pore size of the screen was assumed to be 30 μ for the response surface analysis with the trickling filter effluent, and 23μ with the activated sludge effluent.

The characteristics of the response surfaces developed in these simulations were as follows:

(1) Trapping efficiency:

- The trapping efficiency of the screen at any transverse section of screen on the screening cycle was found to be a function of vi or mi, the cumulative solids loading/unit area on a volumetric or mass basis respectively.

- The trapping efficiency of the screen was found to be a function of the relative values of initial trapping diameter of the screen, the mean drum pool particle size ($\bar{d}_p$), and the standard deviation of the uni-modal, log-normal particle size distribution (PSD); the rate of increase of trapping efficiency over the screening cycle was found to increase with decreasing values of initial trapping diameter (smaller screen pore size) or increasing values of $\bar{d}_p$.

- Conversely, the less uniform the PSD of the drum pool suspension (i.e., the lower the standard deviation σ_{LOG}), the lesser the rate of increase of trapping efficiency as solids loading increased over the screening cycle.

- The porosity of the cake formed by the retained solids was found to have little effect on the trapping efficiency.

(2) Hydraulic resistance:

- The assumed porosity of the cake formed by the retained solids was found to have a significant impact on the hydraulic resistance of the cake; the hydraulic resistance increased as porosity decreased.

- Variation of the standard deviation of the drum pool PSD was found to have only a nominal effect on the hydraulic resistance, the effect being one of decreasing hydraulic resistance as standard deviation increased.

The above indications represented the expected framework and "hypothesis" for the field investigative program delineation of the physical model of process behavior.

Observation of Physical Model

The following factors appear to dominate the overall performance of the pilot units (the *physical models* of the microscreen process used in the present study):

(1) A non-uniformity of solids retention occurs spatially across the screen during the screening cycle as a result of:

- Variation of screen pore size distribution as a result of the manner of construction, handling, and mounting of the screen.

- Solids inputs to the drum pool from fall-back, splashover, and the influent, and the loss of particles in the effluent, which serve to create non-uniformity of particle size distribution and concentration in the drum pool.

(2) Significant losses of solids captured from the drum pool suspensions occur prior to and during the transfer of the concentrated solids to the washwater collector.

(3) The key elements of the backwash subprocess appear to be:

- The energy contained in the backwash spray system.
- The speed of rotation of the drum.
- The size of the spray droplets.
- The size of the surface indentations in the screen.
- The orientation of the pores relative to the trajectory of the spray.
- The manner in which the particles (cake) are attached to the screen.
- The deformation properties of the screen fabric.

(4) A qualitative evaluation of the backwash subprocess indicated that:

- For any given type and size of nozzle and water pressure, there is a threshold pore size below which cleaning effectiveness declines rapidly, and above which the cleaning effectiveness is independent of pore size.

- For any given combination of type and size of nozzle, water pressure, and screen size, there is a speed of rotation which optimizes the synchronization of the intersection of pores and droplets; above or below this speed the cleaning effectiveness should decline rapidly.

- For any given combination of nozzle type and size, speed of rotation, and pore size, there is an optimum water pressure, above or below which cleaning efficiency decreases.

- At the upper and lower ranges of the rotational speeds, significant amounts of the retained solids removed by backwashing fall short or long of the washwater collection trough.

- Fabric flexing decreases the capacity of the solids to be held to the screen during the backwash subprocess.

(5) The above relationships give rise to a multi-dimensional response surface for the backwash subprocess, with each combination of dimensions exhibiting either optimal levels or saturation levels of cleaning efficiency with increasing parameter values.

SUMMARY OBSERVATIONS

As noted above, there was a significant discrepancy between the anticipated response surfaces derived from the operational model, and the response surfaces derived from the physical model, i.e., the field program observations. In keeping with the overall inquiry approach, this discrepancy indicated that the backwash and transfer subprocess models should be re-formulated for greater congruence with the "realities" of process performance. (It should be noted that, in this case, greater congruence with reality does not imply that the subprocess conceptions were inadequate, but rather that the transfer and backwash subprocesses are the major weak links in the typically-constituted commercially-available microscreen). The problem with these subprocesses is that solids captured from the drum pool suspension are not effectively transferred to the washwater collector from whence they can be removed from the system. The solids losses occurring in these subprocesses are recycled directly to the drum pool suspension, with the result that the drum pool suspended solids concentration exceeds the influent suspended solids concentration. The result of this "concentration" effect in the drum pool is that, while the overall microscreen process is evaluated and used on the basis of solids reduction between the influent and effluent, the mechanism effecting solids reduction is operating against a much greater solids concentration gradient between the drum pool and effluent than exists between the influent and effluent. The resolution of this problem will require the development of microscreen designs to achieve the removal of solids retained during the separation subprocess cleanly out and away from the drum pool during the transfer and backwash subprocesses.

The remaining sections present a more detailed description of the investigative procedure, and consequent delineation, of the currently perceived microscreen process model and response surface. Insofar as possible, this information was incorporated into the sub-program model of microscreen behavior, presented in Appendix D of this report.

SECTION IV

CHARACTERIZATION OF MICROSCREEN PROCESS

THE UNIT PROCESS

Microscreening involves the passing of a suspension through a moving medium. The suspended particles which are removed may be discrete (mineral) or flocculant (organic or non-organic) and may vary in size from colloidal ($\leq$ 1 micron) to coarse suspended particles. Solids separation by microscreening is accomplished by a series of complex interactions between three phases:

- A moving solid phase (the screen and cake);
- A discontinuous solid phase (the material to be removed);
- A liquid phase (usually water).

The two fundamental system aspects of microscreening are:

- The screening cycle, during which the suspended solids are removed and a clarified effluent is produced;
- The backwash cycle, which involves flushing the collected solids from the medium.

The screening cycle is an operation analogous to the declining rate filter; as the screen passes from submergence to emergence during the screening cycle, the headloss characteristics of the developing cake increase and cause a concurrent decrease in the throughput rate. The screening cycle is terminated when a segment of the medium emerges from the liquid pool. During the backwash cycle the accumulated solids are removed from the medium by the several mechanisms usually associated with hydraulic, air, or sonic cleaning. Generally, microscreen effluent water is used for hydraulic cleaning. The yield of the microscreen is the difference between the quantity of water produced during the filtration cycle and the quantity of water consumed during the backwash cycle.

Process Components

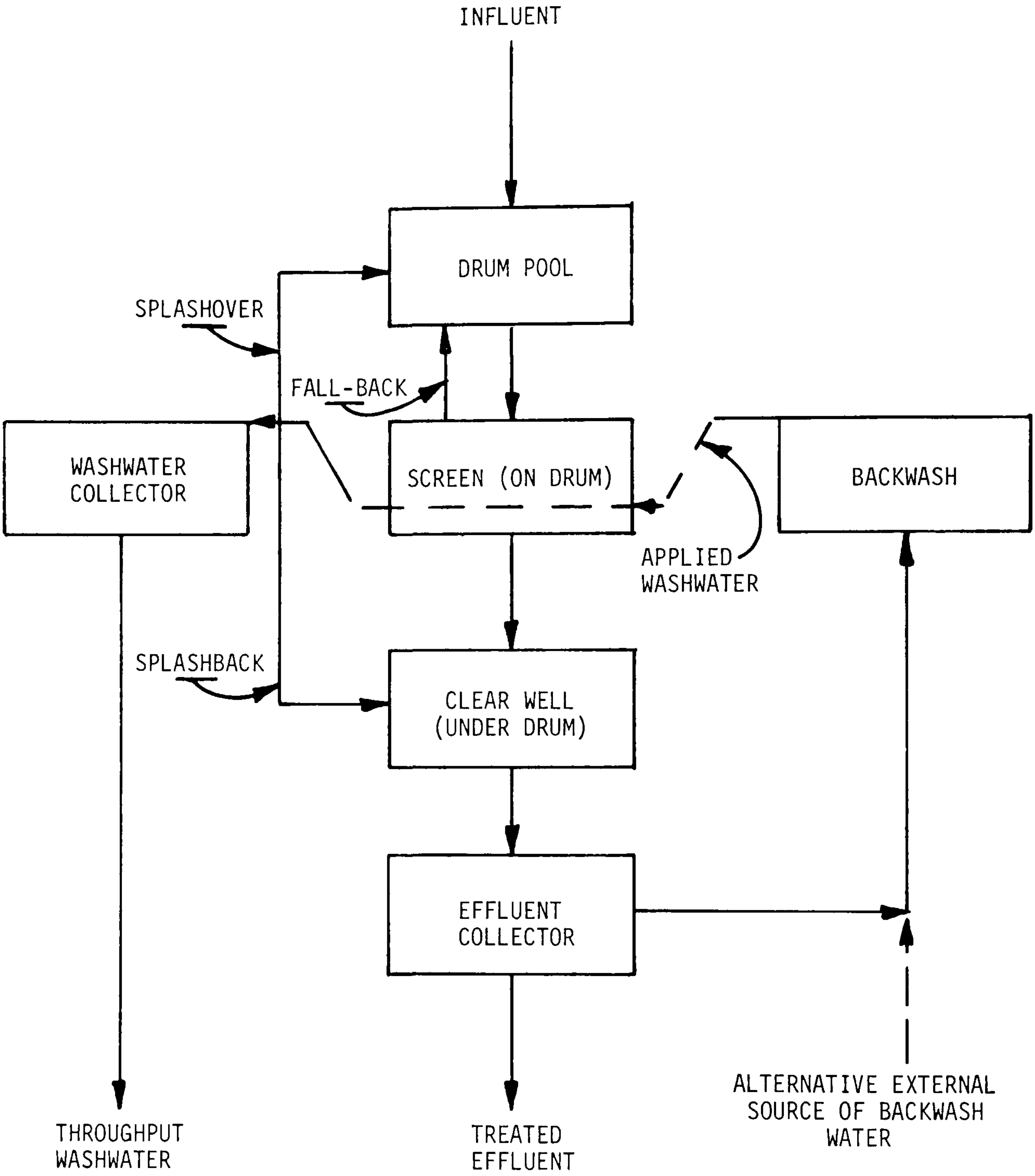
The microscreen process, as constituted in the pilot plants used in the present study, has six interrelated components as shown in Figure 1:

(1) The Drum Pool, serving as a reservoir for the solids suspension to be microscreened. Based on observations of the pilot plant operation, the solids in the drum pool are derived from three sources:

(a) The microscreen influent suspension (primary source).

(b) The fall-back of solids from the screen-solids-water complex during the portion of the drum cycle between emergence of a transverse segment of screen and movement of the segment into the zone of influence of the backwash sprays.

FIGURE 1



FLOW DIAGRAM FOR MICROSCREEN SYSTEM

(c) The splashover of solids-laden backwash spray water that falls short or long of the washwater collector rather than into the collector as intended.

As a result of the above, the characteristics (concentration, particle size distribution, etc.) of the suspension in the drum pool are generally dissimilar to those of the influent stream with drum pool suspended solids concentrations generally exceeding influent suspended solids concentration.

(2) The Screen (or microscreen fabric), serving as the matrix on which the screen-solids-water medium effecting particle removal is formed.

(3) The Backwash System, serving the dual function of:

(a) Applying energy (in the form of a pressurized spray of washwater) to the screen to dislodge retained particles;

(b) Effecting the collection and transport of solids-laden washwater away from the microscreen in the Washwater Collector.

Because of the fall-back of retained solids from the screen after emergence from the drum pool, not all particles captured in the screening cycle are actually transferred to the zone of influence of the backwash system. Splashover (defined above) occurs as a result of the size, shape, and location of the washwater collector relative to the trajectory of the "shower" of backwash water passing through the moving screen. Splashback occurs as a result of the capture of water from the backwash spray on the outer surface of the drum, from where it is conveyed (with the rotation of the drum) directly to the clear well without passing through the screen. Because of splashback and splashover, the throughput washwater flow rate (as measured in the washwater collector) can be significantly less than the applied washwater flow rate, depending upon operating conditions.

(4) The Clear Well, containing not only screened process effluent but also splashback from the backwash system.

(5) The Effluent Collector, conveying effluent from the clear well to ultimate disposal, and serving as an intake pool for backwash system water.

BPROCESS

The microscreen system as described above has three distinct subprocesses operative over the drum cycle, viz:

(1) Separation Subprocess, in which solids are captured on, or passed through, a transverse segment of screen as the screen is transferred through the drum pool from submergence to emergence.

(2) Transfer Subprocess, in which the captured solids on the screen segment are transferred from the point of emergence of the segment

from the drum pool to the zone of influence of the backwash sprays.

(3) Backwash Subprocess, during which energy is transferred at some level of efficiency from the applied backwash stream to the screen segment in order to remove retained solids and to rejuvenate the solids retention and hydraulic capacities of the screen segment.

The impact of each subprocess on overall process behavior can be envisioned in terms of a profile of the retained solids on the screen segment during a drum cycle. Such a profile, developed on the basis of observation of the microscreen pilot units, is shown in Figure 2. The key features of the profile are:

(1) The accumulation of retained solids on the segment in the separation subprocess at a decreasing rate over the screening cycle (submergence → emergence), corresponding to a decreasing rate of liquid throughput as the hydraulic resistance of the screening medium increased at constant hydraulic head.

(2) The fall-back of solids from the screen-solid-water complex during the transfer subprocess, due to:

(a) Erosion of solids from the complex at emergence as a result of surface turbulence in the drum pool.

(b) Drainage of water from the complex.

(3) The reduction of retained solids to a residual level during the backwash subprocess, the residual level representing the initial mass of retained solids on the segment as it is submerged and enters the next screening cycle.

Subprocess Elements

The microscreen process, when viewed at the level of a transverse segment of screen passing through the drum cycle, is analogous to a declining rate filter and the liquid and solids transfers and the physical state of the system occurring therein can be described in terms of the elements operative in a granular bed filter system. A listing of these elements, and the information required to describe each is presented in Table I. The elements can be categorized as associated with operation (liquid throughput rate, solids input and emission rate, solids retention), control (headloss, backwash, surface renewal), or system state (solids character, filter medium).

The distinction made between the screening medium and solids retention in the elements of the microscreen is fundamental to the inquiry approach used in the present study. The screening medium is defined as the physical-chemical-biological medium on which the solids are captured and retained. The components of the medium are water, suspended solids, colloidal solids, dissolved solids, and the screen and the mechanisms operative in this environment are those related to inertial, electrical, concentration, and chemical forces effecting solids capture and imparting

SEPARATION, TRANSFER, AND BACKWASH SUBPROCESSES
IN MICROSCREEN PROCESS

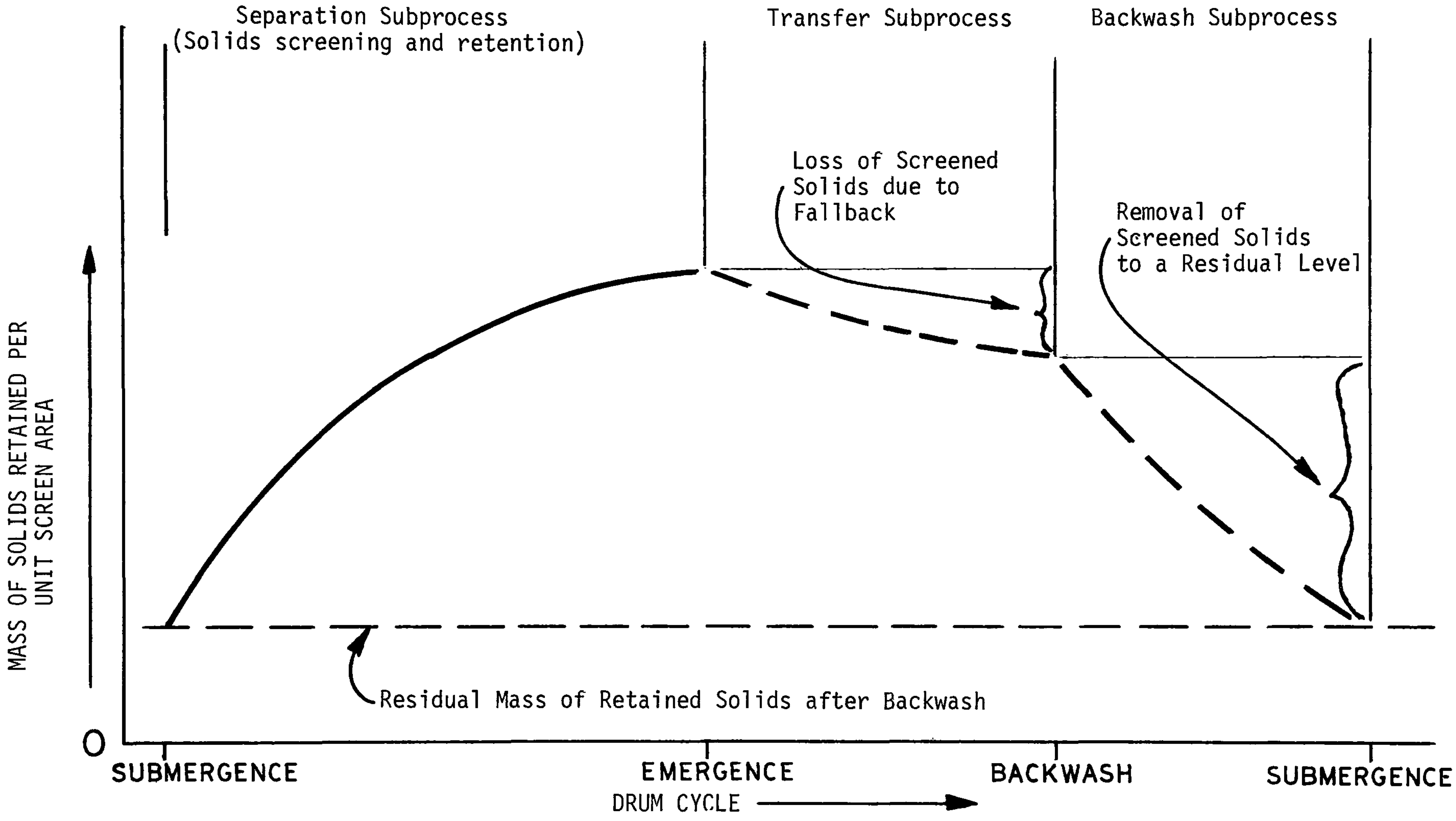


FIGURE 2

TABLE 1

ELEMENTS AND INFORMATION REQUIREMENTS FOR MICROSCREEN PROCESS

Element	Information Requirements
Liquid Throughput Rate	Influent liquid flow rate; liquid physical properties
Solids Input and Emission Rate	Mass rates for dissolved, colloidal, and suspended solids
Solids Character	Type of pretreatment; particle description; particle size distribution; particle shear strength
Screen (microscreen fabric)	Nominal aperture; weave; material; clean screen headloss factor; effective pore (or particle trapping) diameter; and rate of presentation
Solids Retention	Residual retention of dissolved, colloidal, and suspended solids on filter after backwash; retention of dissolved, colloidal, and suspended solids on filter during screening cycle (both retentions analogous to a surface density mass/area)
Filter Medium	Effective pore diameter; cake porosity, depth, and density; composite headloss character; solids separation mechanism
Surface Renewal	Rate of drum rotation
Backwash	Applied rate of backwash; net rate of backwash, pressure; cleaning efficiency
Headloss	Pressure drop

a hydraulic resistance to the captured solids. The interaction of the components and dominant mechanisms in the medium serves to establish the behavior of the separation subprocess. Solids retention represents, at any point in the drum cycle, the inventory of suspended, colloidal, and dissolved solids stored on the screen (Figure 2). Solid retention is characterized in the present study by a surface density parameter (MC, mass of solids retainer per unit area).

The elements listed in Table I can be interrelated and summarized in the form of a feedback model having the following cause → effect relationships (Reference 1):

(1) The liquid throughput rate and headloss on a screen segment being a function of the available head (drum pool → clear well) and the screening medium hydraulic resistance.

(2) Solids retention being a function of the solids character, solids input rate (drum pool → screen), liquid throughput rate (drum pool → clear well), and screening medium.

(3) Rejuvenation of the medium being a function of the efficiency of the backwash subprocess and the rate of drum rotation.

SECTION V

EXPERIMENTAL PROGRAM

The experimental program was organized around an equipment system consisting of two microscreen units, a head tank unit, and appurtenances. With this basic equipment an experimental program was developed using combinations of different fabrics and five different wastewaters at two different sewage treatment plants as described below.

MICROSCREEN AND CHEMICAL PRETREATMENT UNITS

Process Flow Sheet

The basic equipment used in the study consisted of two microscreen units and one chemical pretreatment unit, each of which was mounted individually on trailers to expedite mobility. A process flow sheet for the chemical pretreatment unit and one microscreen is shown in Figure 3. The principal characteristics and components on the units are listed in Table 2. The piping system (Figure 3) is designed to allow the transfer, by either gravity or pumping of:

(1) Process influent to the head tank unit (HTU) or, bypassing the HTU, to the microscreen unit.

(2) HTU effluent to the microscreen unit.

(3) Microscreen effluent and throughput washwater from the microscreen unit.

The piping system also permits applied washwater to be transferred via the backwash pump from either of two sources: the microscreen effluent, or an external washwater source (e.g., tap water).

A manometer system was installed to permit measurement of liquid levels in each microscreen unit and simultaneously in the drum pool (upstream of the screen), in the clear well under the screen, and in the backwater of the weir box.

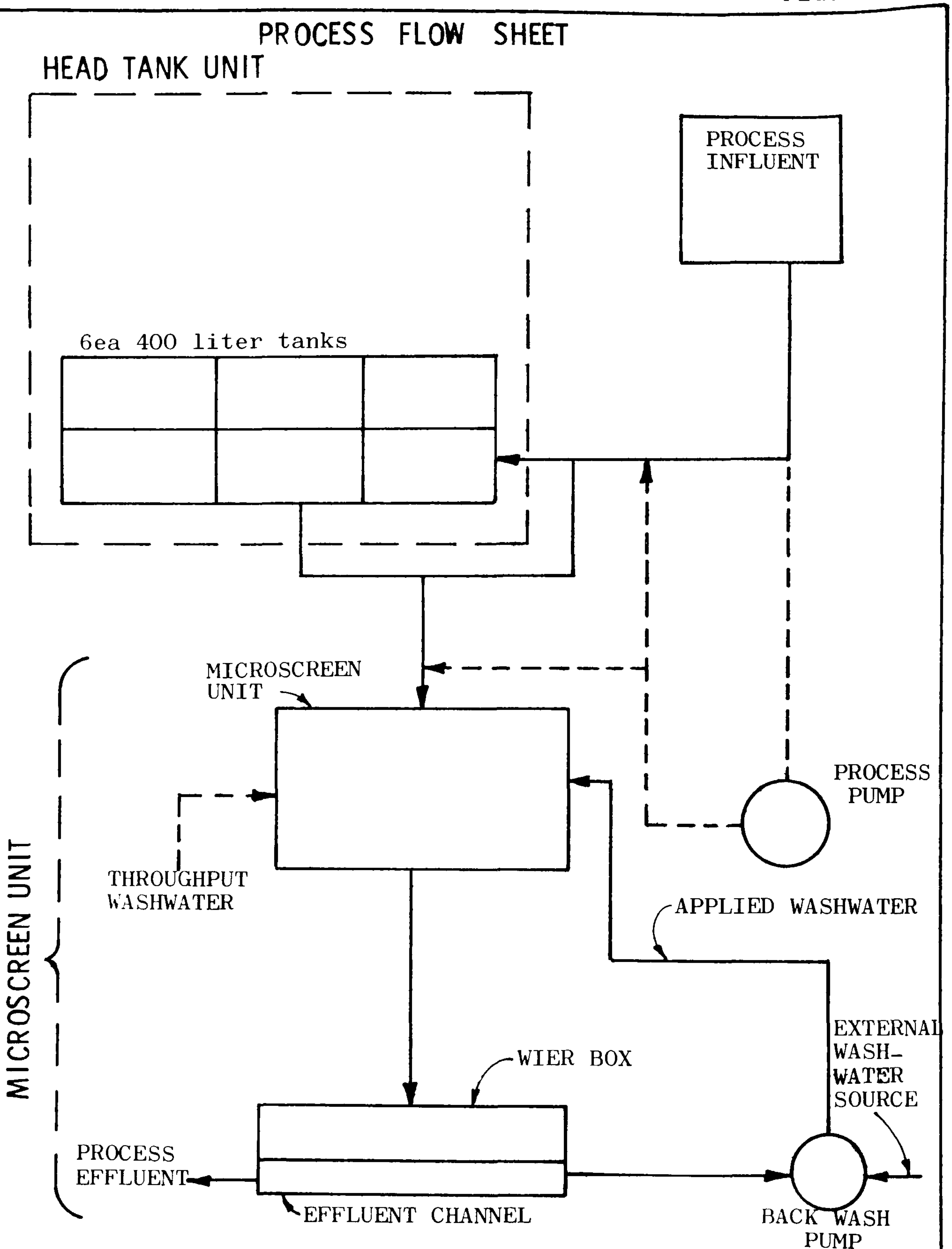
Control Variables

The principal control variables with the experimental equipment are:

(1) Source and character of process influent.
(2) Type and character of fabric.
(3) Headloss across the screen from submergence to emergence.
(4) Backwash pressure (and flow rate).
(5) Drum rotational speed.

Five types of influent streams were used in the present study:

(1) Clarified standard rate activated sludge process effluent.
(2) Clarified high rate trickling filter effluent.



NOTE: PROCESS PUMP CAN ALSO BE USED TO PUMP EFFLUENT FROM EFFLUENT CHANNEL AND/OR THROUGHPUT WASHWATER

TABLE 2

PRINCIPAL CHARACTERISTICS AND COMPONENTS OF MICROSCREEN AND CHEMICAL PRETREATMENT UNITS

UNIT	ITEM	DESCRIPTION
Microscreen	Drum size	4-ft diameter x 1-ft wide; 0.8 sq m screen area
	Drum submergence	50 to 65 percent of drum diameter
	Drum rotation rate	Variable from one to 12 rpm, or 12 to 150 ft/min, or 0.8 to 9.6 sq m screen area/min
	Maximum headloss through screen	20 cm (8 inches)
	Process pump capacity	Variable to 240 lpm (liters/minute)
	Backwash system capacity	Variable to 35 psig and to a maximum backwash rate of 35 lpm
Head Tank	Individual tanks	Tank volume, 400 l (6 each, interconnected)

(3) Unclarified high rate trickling filter effluent.
(4) Primary effluent.
(5) Oxidation pond effluent.

The characteristics of these individual streams are described in Appendix A.

The types of fabrics used in the experimental program are listed in Table 3. The selection used included a total of eight stainless steel fabrics having a nominal pore size (NPS) of 12 to 40μ. The other fabrics used in the selection were made of nylon, polyethylene, and polyester, having a range of NPS from 10 to 25μ. The detailed characteristics of all fabrics are discussed in Reference 4.

System Operations

The chemical pretreatment and microscreen units were used consistently in one of two operating modes (Mode A or B) for the runs made in the experimental program. The common aspects of the two modes were:

(1) The HTU (head tank unit) was used to provide for gravity transfer of flow into the microscreen units.

(2) Two one-HP, 1-1/2 inch diameter intake/discharge Marlow pumps were used (one per microscreen unit) to transfer process influent from the source to the HTU (these pumps were not supplied with the microscreens).

(3) The microscreen process pumps (one per unit) were used to transfer the microscreen effluent flow from the effluent channel to the point of ultimate liquid disposal (this latter flow option is not illustrated in Figure 3).

(4) Tap water was used for screen backwashing.

In the Mode A operations, both microscreen units were supplied from a common influent source (the CPU), although each unit was operated independently. Mode A was used for most of the runs in the field program and the experimental protocol for these runs is described subsequently.

In the Mode B operation, one of the microscreen units (Unit A) was used solely to produce a throughput backwash stream containing selectively larger particles as a function of the screen size used. The throughput backwash stream from Unit A was mixed with the HTU effluent to form a composite process influent to Unit B containing a controlled range of particle sizes and suspended solids concentrations. With appropriate screen selection in Unit A and proportioning of the throughput backwash stream from Unit A with HTU effluent, it was possible in Mode B to selectively control the particle size distribution and concentration of suspended solids in the drum pool of Unit B.

EXPERIMENTAL PROGRAM

The general approach taken in the field program was as outlined in Reference 4. This approach was comprised of three phases of activity:

TABLE 3

MICROSCREEN FABRICS AVAILABLE WITH THE PILOT PLANTS

Manufacturers Nominal Pore Rating (microns)	Material	Weave	Mesh Count	Pore Census (No./sq.in.)
40	Stainless Steel	Dutch Twill	120/400	96,000
30	Stainless Steel	Dutch Twill	120/600	144,000
23	Stainless Steel	Dutch Double Warp Twill	120/600	144,000
21	Stainless Steel	Dutch Twill	200/830	330,000
18 - 22	Stainless Steel	Reverse Dutch Twill	600/125	150,000
13 - 18	Stainless Steel	Single Dutch Twill	165/800	264,000
12 - 15	Stainless Steel	Reverse Dutch Twill	720/140	200,000
25	Nylon	Square	462/462	420,000
25	Polyethylene	Rectangular	112/48	10,500
20	Polyester	Square	200/400	160,000
10	Nylon	Calendared Square	462/462	420,000

(1) Physical characterization of the microscreen.

(2) Description of the response surfaces of the subprocesses in the microscreen.

(3) Evaluation of the general applicability of the response surfaces for a variety of influent solids sources and microscreen fabrics.

On overview summary of the experimental program is presented in Table 4. Eighteen run sets (numbered 0 to 17) were made using Units A and B, and a total of 34 individual runs were made using 11 different fabrics. The field program was conducted at the San Leandro and Concord sewage treatment facilities, both located in the San Francisco Bay area (Appendix A). The San Leandro facility has dual biological waste treatment systems, a standard rate activated sludge system for treatment of domestic wastes and a high-rate trickling filter system for treatment of combined domestic and industrial wastes. The Concord facility is equipped with a high-rate trickling filter system followed by an aerobic pond system and is used to treat both domestic and light industrial wastes.

The first phase of activity in the field program was conducted prior to the start of the run sets. Phase 2 consisted of Run Sets 0 to 4, 16, and 17; Phase 3 consisted of Run Sets 5 to 15 as outlined in Table 3. Individual operating protocols were used for Run Sets 0 to 4 and standardized operating protocols were used for Run Sets 5 to 15 (Mode A) and Run Sets 16 and 17 (Mode B). These and the analytical procedures used in the field program are described in Appendix B.

TABLE 4

OVERVIEW OF EXPERIMENTAL PROGRAM

TREATMENT PLANT	RUN NO.	DATE (1971)	WASTE SOURCE	UNIT	MICROSCREEN FABRIC	SUBRUN BACKWASH PRESSURES (psig)	NOTES
San Leandro	0	16-17 Feb	AS	A	30μ SS	7-1/2 to 20	Fabric acclimatization run
				B	21μ SS	4-1/2 to 32	Fabric acclimatization run
	1	19-20 Feb	AS	A	30μ SS	8 to 35	24-hour run
				B	21μ SS	5 to 32	24-hour run
	2	23-24 Feb	AS	A	30μ SS	25	Backwash subprocess run
				B	21μ SS	10 to 40	Backwash subprocess run
	3	25 Feb	TF	A	30μ SS	10 to 15	12-hour run
				B	40μ SS; 21μ SS	10 to 20	12-hour run
	4	2 Mar	AS	A	30μ SS	30	Final shakedown run
				B	21μ SS	30	Final shakedown run
	5	3 Mar	AS	A	12-15μ SS	15, 23, 30	Start of Mode A operations
				B	20μ Polyester	15, 23-30, 35	
	6	4 Mar	AS	A	23μ SS	15, 23, 30	
	6	4 Mar	AS	B	25μ Polyethyl.	15, 23-30, 35	
	7	5 Mar	AS	A	15-18μ SS	15, 25, 35	
				B	10μ Nylon	15, 25, 35	
	8	9 Mar	TF	B	10μ Nylon	25, 35	
	9	10 Mar	TF	B	23μ SS	15, 20, 25	
	10	17 Mar	TF	A	15-18μ SS	15	
				B	21μ SS	15	
	11	18 Mar	TF	A	18-22μ SS	15	
				B	21μ SS	15	
	12	19 Mar	TF	A	20μ Polyester	15, 20	
				B	10μ Nylon	15, 20	
Concord	13	25 Mar	PE	A	12-15μ SS	15	
				B	10μ Nylon	15, 20,25	
	14	26 Mar	UTF	A	12-15μ SS	15	
				B	18-22μ SS	15, 20, 25	
	15a	30 Mar	PE	A	12-15μ SS	20	
				B	18-22μ SS	20	
	15b	30 Mar	TF	A	12-15μ SS	20	
				B	18-22μ SS	20	
	16	1 Apr	OP	A	12-15μ SS	15 to 20	)Finish of Mode A Operation
				B	18-22μ SS	20 to 30	)
	17	2 Apr	TF	A	Varying	20	)Mode B Operation
				B	15-18μ SS	20 to 30	)

Notes: (1) AS - clarified activated sludge effluent

(2) TF - clarified trickling filter effluent (high rate at San Leandro and Concord)

(3) PE - primary effluent - trickling filter recycle mixture used as influent to trickling filter

(4) UTF - trickling filter effluent (unclarified)

(5) OP - oxidation pond effluent

SECTION VI

RESULTS OF FIELD INVESTIGATIONS

The field investigation was developed in consideration of the observations presented in Section IV and with the overall objective of defining quantitively the behavior of the pilot plant systems. The basic data requirements of the model development necessitated that process behavior be examined from a steady-state rather than a feedback basis as appeared appropriate (Section IV). Because of the overriding requirement for a steady-state profile of the process, the approach taken in data analysis was to plot against a time-scale all of the parameters observed in the individual runs, and to select from these profiles the points in time, and associated parameter values, for which process behavior was judged to be quasi-steady-state. With the steady-state criterion used (discussed below), it was possible to obtain over 50 quasi-steady-state points which, in the subsequent presentation, have been treated as representative of microscreen process behavior in the quasi-steady-state mode. The basic data obtained in the field investigations are presented in Tables 14 to 30 of Appendix C.

The steady-state criterion used in the data analysis required that process performance be stable with respect to suspended solids removal, drum speed, backwash pressure, and solids loading. Trapping efficiency in terms of suspended solids removal was measured across the screen (drum pool → effluent) rather than through the unit (influent → effluent) in view of the "concentration effect" described in Section IV. Because of the multi-dimensional response surfaces that are operative in the microscreen process, it is recognized that the above criterion may have biased the selection of the data, i.e., that one or more of the variables considered or not considered in selecting a steady-state point may have been located in a zone of instability in the response surface region sampled (in a region where a slight shift in the magnitude of the variable would result in a significant shift in process efficiency). Within the scope of information that could be developed in the present study, the researchers had no other alternative but to accept the above criterion.

Trapping efficiency across the screen was computed as follows:

$$f = 100\frac{MC}{MI} \qquad (1)$$

where: f = Suspended solids removal efficiency, percent

MC = Mass of suspended solids retained per unit area of screen over the screening cycle (see Figure 2)

MI = Mass of suspended solids loaded per unit area of screen over the screening cycle

(Note: All symbols are defined in the Glossary of Section XI)

The parameters MC and MI were calculated as follows:

$$MC = \frac{[Q_I X_P^S - Q_E X_E^S]\ (\text{mg/l} \cdot \text{l/min})}{S\ (\text{sq m/min})} \qquad (2)$$

$$MI = \frac{[Q_I X_P^S] \ (mg/l \cdot l/min)}{S \ (sq\ m/min)} \qquad (3)$$

where: Q_I = Influent volumetric flow rate (l/min)

Q_E = Effluent volumetric flow rate (l/min)

X_P^S = Drum pool suspended solids concentration (mg/l)

X_E^S = Composite effluent suspended solids concentration (mg/l)

S = Rate of screen presentation, sq m/min

The hydraulic parameter was computed as:

$$\frac{X_P^S H_L A}{\rho S} \text{ (units of cm-sec)}$$

where: ρ = Density of suspended solids (assumed to be 1.05 gm/cc)

H_L = Headloss across screen, cm

A = Submerged area of screen, sq cm

It was found from an analysis of the PSD (particle size distribution) data obtained for the influent, drum pool, and effluent suspensions that the PSD's of the particles could be characterized as log-normal. The PSD's were characterized in terms of two parameters, $\bar{d}$ and σ_{LOG}, where $\bar{d}$ is the mean (50 percentile) particle size on the log-normal distribution, $d_{84.3\%\text{-ile}}$ is the 84.3 percentile particle size and:

$$\sigma_{LOG} = \frac{\log(d_{84.3\%\text{-ile}}/\bar{d})}{\log \bar{d}} \qquad (4)$$

It is noted that PSD was the only parameter defined for the solids suspensions examined in the field program. Gross empirical parameters such as Filterability Index, SVI, and sludge age were neither considered nor measured in the field program for reasons cited in Section IV.

The parameter values for the steady-state points obtained from the data analysis are tabulated in Table 30 of Appendix C. Most of the steady-state points were obtained for runs in which clarified activated sludge effluent (AS) and clarified trickling filter effluents (TF) were used as pilot plant influents. Three steady-state points were obtained with primary effluents (PE), ten with unclarified trickling filter effluents (UTF), and two with oxidation pond effluents (OP).

The numerical values of MC, MI, and the hydraulic parameter for the steady-state points as reported in Table 30, represent process performance on an *overall* run basis and not at any point during or at the end of the screening cycle. That is, the parameters MC and MI represent solids retention and loading respectively given *not only* the positive (separation) effect of the separation subprocess *but also* the negative effects, on trapping efficiency, of the transfer and backwash subprocesses as described in Section IV. The hydraulic parameter is computed in terms of an overall headloss across the screen and an averaged flow rate over the screening cycle. Nineteen of the steady-state points (identified by number in Table 30) were used for subprogram model calibration purposes as described in Appendix C.

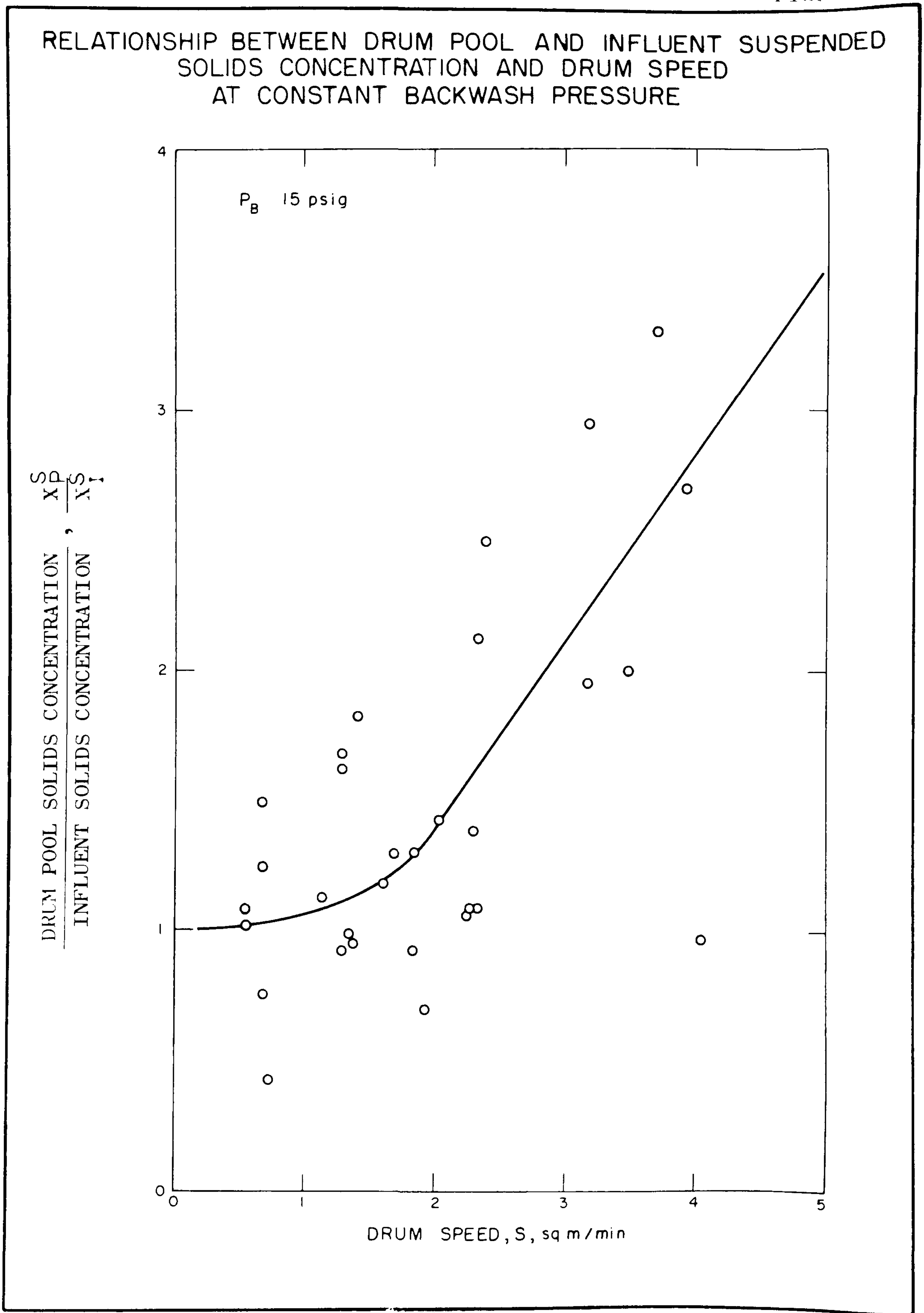
SEPARATION SUBPROCESS

Introduction of Solids to Drum Pool

The initial transfer taking place in the microscreen process is the transfer of influent to the drum pool. As observed previously, solids are transferred to the drum pool not only from the influent but also as a result of solids recycling to the drum pool resulting from inefficiencies and/or inadequacies inherent in the transfer and backwash subprocesses. The drum pool was also postulated to act as a solids transformer, in that particle shear caused by turbulence in the drum pool is expected to result in a transformation of the characteristics of the PSD's. Because of either circumstance (solids recycle and/or particle shear), the concentration and PSD characteristics of the solids suspension in the drum pool are not expected to be uniform throughout the pool; additionally, it is apparent that the concentration and PSD characteristics of the influent and drum pool suspensions will be dissimilar in all but fortuitous circumstances.

Within the range of sensitivity of the data, it was possible to examine the impact of two operational variables (P_B, backwash pressure, and S, rate of screen presentation, area/time) on the parameters defining the influent and drum pool suspensions (X^S; $\bar{d}$; and σ_{LOG} as defined above). The approach used in defining the response surfaces for each parameter was first to examine the impact of varying S on parameter ratios (drum pool/influent) at constant P_B and then to examine the effect of varying P_B at constant S.

The relationship between the ratio of drum pool and influent suspended solids concentration and speed (at constant P_B of 15 psig) is illustrated by the data on Figure 4. (Because of transient influent quality, several data points were observed at values of X_P^S/X_I^S less than 1, as shown in Figure 4). A curve of best-fit relating the ratio X_P^S/X_I^S and speed is shown in Figure 4; the lower boundary of the curve was assumed to be defined by $X_P^S/X_I^S \rightarrow 1$ as $S \rightarrow 0$, for which case the process cannot be operated without rotation of the drum. The relationship between X_P^S/X_I^S and S defined by the best-fit curve has two distinct zones; the first (for


RELATIONSHIP BETWEEN DRUM POOL AND INFLUENT SUSPENDED SOLIDS CONCENTRATION AND DRUM SPEED AT CONSTANT BACKWASH PRESSURE
P_B 15 psig
DRUM POOL SOLIDS CONCENTRATION / INFLUENT SOLIDS CONCENTRATION, X_P^S / X_I^S
0
1
2
3
4
0
1
2
3
4
5
DRUM SPEED, S, sq m/min

0<S<2 sq m/min) in which X_P^S/X_I^S increases geometrically from 1 to 1.4; and the second (for 2<S<4 sq m/min) in which X_P^S/X_I^S increases linearly to a ratio of 2.7 at S = 4 sq m/min. No data were available for defining the relationship for drum speeds greater than 4 sq m/min.

The relationship between X_P^S/X_I^S and P_B for all observations made in the narrow range of drum speeds for 1.8<S<2.5 sq m/min is illustrated by the data presented in Figure 5. It was necessary to use the date within this range of drum speeds because of the limited data base available. Based on the relationship in Figure 4 it is expected that the ratio X_P^S/X_I^S would vary at P_B of 15 psig from 1.25 to 1.75 for 1.8<S<2.5 sq m/min; the variation of the X_P^S/X_I^S data presented in Figure 5 exceeds this range considerably. The trend defined by the best-fit curve of the data in Figure 5 indicates that X_P^S/X_I^S increased slightly with increasing P_B over the range of observation ($15<P_B<35$ psig). However, because the magnitude of the increase in X_P^S/X_I^S (1.25 to 1.60) over the range of P_B values is less than that predicted from the relationship of Figure 4, it was concluded that within the range of sensitivity of the data the ratio X_P^S/X_I^S does not vary with varying P_B.

In view of the above, all observations of X_P^S/X_I^S vs S at all P_B values were plotted on a single graph as shown in Figure 6. The best-fit curve obtained for all the data points in Figure 6 is similar to that obtained for the data in Figure 4, and, for purposes of inclusion in the subprogram model, can be defined in the following terms:

(1) for $0 \leq S \leq 2$ sq m/min; $X_P^S/X_I^S = 1 + 0.1\ S^2$ (5)

(2) for $2 \leq S \leq 4$ sq m/min; $X_P^S/X_I^S = 1.4 + (0.725)\ (S-2)$ (6)

The relationships presented in Figures 4 and 6 are strong indications that the drum pool served as a concentrator of solids in the pilot plants used in the present study.

Correlations were developed between the ratios $\overline{d}_P/\overline{d}_I$ and P_B, S and ($\sigma_{LOG-P} - \sigma_{LOG-I}$) and P_B, S insofar as the available data permitted. The context used in approaching the data analysis was developed on the premises that all particles entering the drum pool are either shearable, nonshearable, screenable, and/or nonscreenable, and that increasing turbulence (resulting from greater drum speeds) will result in an attrition of the shearable fraction of particles, or an increase in the uniformity of particles in the drum pool. On the other hand, there exists a range of combination of S and P_B in which optimum backwash efficiency is obtained (as discussed later) and which should result in an increased removal from the system (via the washwater collector) of shearable or nonshearable particles that are screenable at some point in the screening cycle. Thus, to some operating point beyond which the backwash efficiency saturates and then decreases with increasing S and P_B, it is expected that increasing levels of S and P_B will result in a minimizing of the recycling of particles from the backwash zone into the drum pool, and in a minimization of the differences in the PSD characteristics of the influent and drum pool suspensions. Thus the increasing effect of shear with increasing drum speed on the relative PSD characteristics of influent and drum pool suspensions should be countered up to a certain level

RELATIONSHIP FOR DRUM POOL AND INFLUENT SUSPENDED SOLIDS CONCENTRATION AND BACKWASH PRESSURE, DRUM SPEED = 1.8 to 2.5 sq m/min

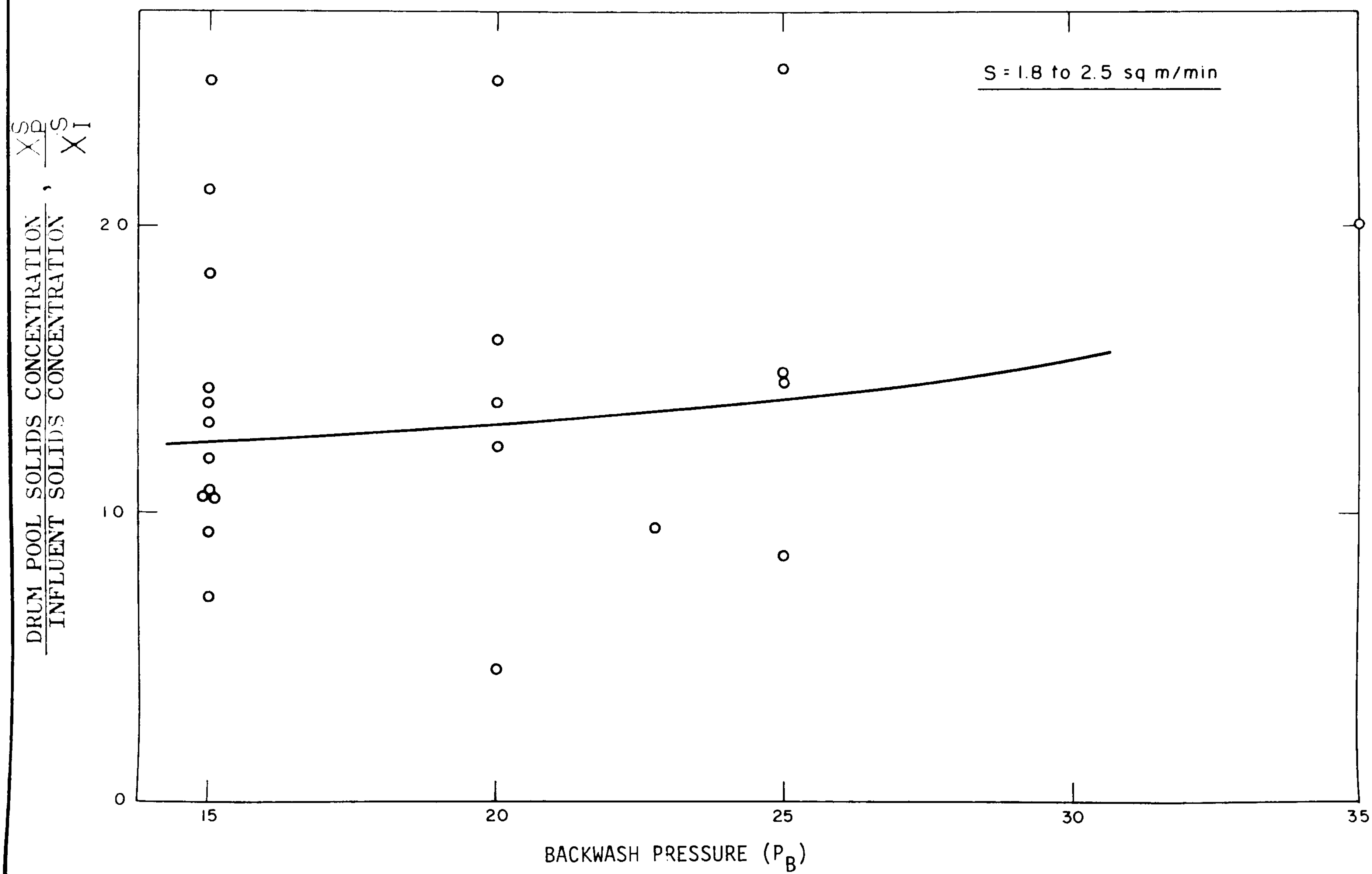
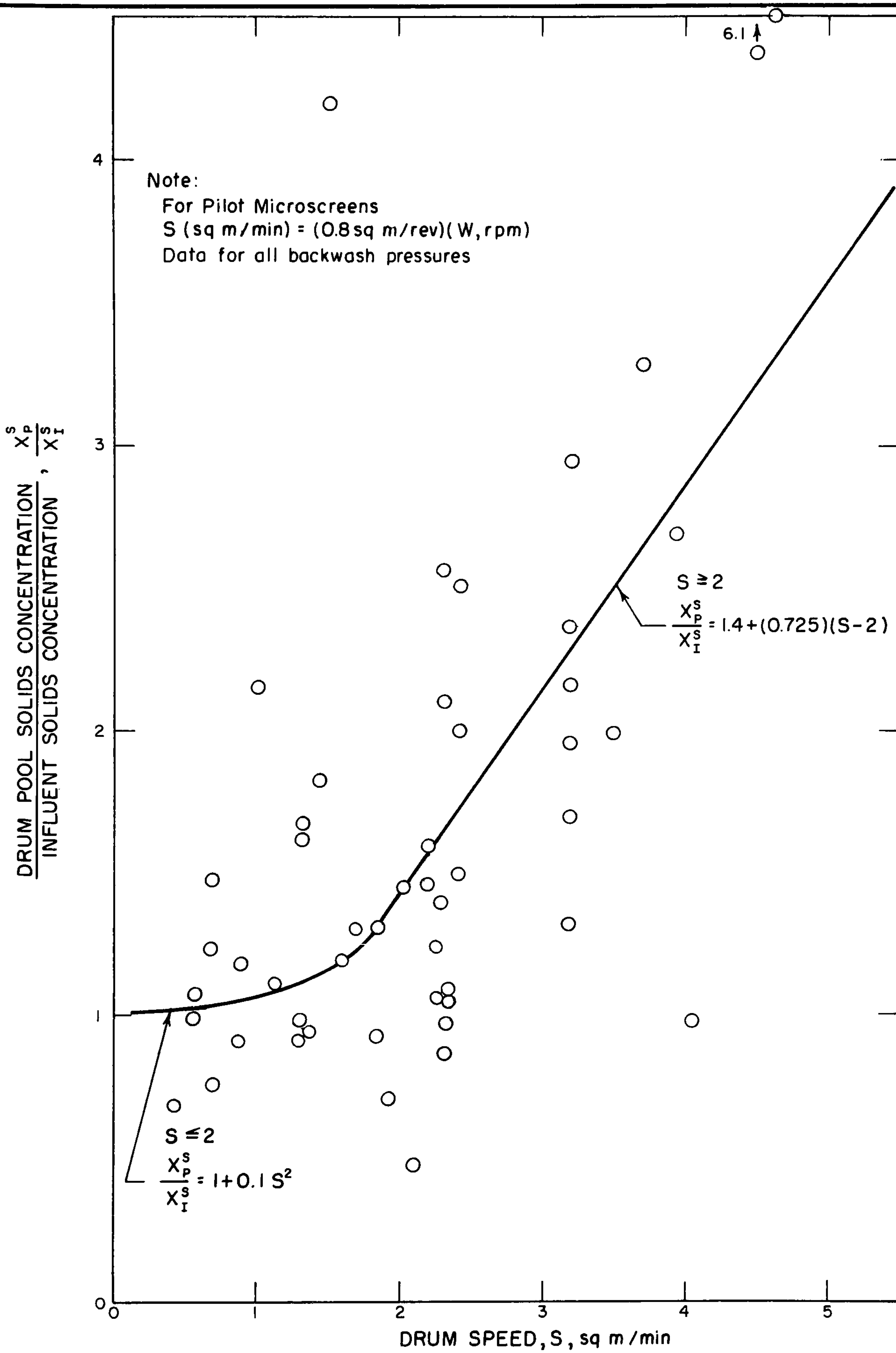


FIGURE 5



RELATIONSHIP BETWEEN DRUM POOL AND INFLUENT SUSPENDED SOLIDS CONCENTRATION AT VARIOUS DRUM SPEED of drum speed and pressure by the optimization of the backwash subprocess.

The relationship between $\overline{d}_P/\overline{d}_I$ and S is shown by the data presented in Figure 7; the backwash pressure associated with each datum is also indicated. Two general trends can be observed from the data:

(1) $\overline{d}_P/\overline{d}_I$ decreases with increasing S.

(2) The backwash pressures associated with each datum increased with increasing drum speed.

On the basis of these trends a best-fit curve has been developed as shown in Figure 7, the lower bound of the curve being defined as $\overline{d}_P/\overline{d}_I$ = I at S = 0, and $\overline{d}_P/\overline{d}_I$ = 0.75 at S = 8 sq m/min. The limited available data precluded an examination of the impact of S on $\overline{d}_P/\overline{d}_I$ at constant P_B, and P_B on $\overline{d}_P/\overline{d}_I$ at constant S, but given the foregoing context, it appears that the date set represents a situation in which the negative effects of shear on $\overline{d}_P/\overline{d}_I$ were countered over the range of 0<S<4 sq m/min by the positive effect of optimization of the backwash subprocess in exporting particles from the system.

In order to incorporate a transform between $\overline{d}_P$ and $\overline{d}_I$ in the subprogram model (Appendix C), the best-fit curve in Figure 7 was described in terms of a two-component linear relation as follows:

(1) for 0<S<5 sq m/min; $\overline{d}_P/\overline{d}_I$ = 1.00-0.0123 S (7)

(2) for 5<S<8 sq m/min; $\overline{d}_P/\overline{d}_I$ = 0.94-(0.05) (S-5) (8)

The relationship between ($\sigma_{LOG-P} - \sigma_{LOG-I}$), S, and P_B is illustrated by the data presented in Figure 8; the backwash pressures for each of the data are also reported. The general trend of the data can be described as one of slightly increasing $\Delta\sigma_{LOG}$ with increasing S to a level of S $\simeq$ 4 sq m/min, after which $\Delta\sigma_{LOG}$ decreases about 0.3 unit as S increases from 4 to 8 sq m/min; it is also noted the P_B tends to increase with increasing S. Thus, relative to the PSD of the influent suspension, the PSD of the drum pool suspension became less uniform as drum speed increased from 0 to 4 sq m/min, and then became more uniform as drum speed increased from 4 to 8 sq m/min. This trend is more pronounced than was observed from the date in Figure 7 for $\overline{d}_P/\overline{d}_I$, and can also be explained in terms of the negative effect of shear with increasing S, and the positive effect of optimizing backwash efficiency up to a maximal level of P_B and S on the parameter ($\sigma_{LOG-P} - \sigma_{LOG-I}$).

The best-fit curve in Figure 8 was described in terms of a three-component linear relation which is used as a transform in the subprogram model. The relation is as follows:

(1) for 0≤S≤4.5 sq m/min; $\sigma_{LOG-P} - \sigma_{LOG-I}$ = 0.011S (9)

(2) for 4.5≤S≤6; $\sigma_{LOG-P} - \sigma_{LOG-I}$ = 0.05 - 0.033(S-4.5) (10)

(3) For S≤6; $\sigma_{LOG-P} - \sigma_{LOG-I}$ = -0.15(S-6) (11)

RELATIONSHIP BETWEEN DRUM POOL AND INFLUENT MEAN PARTICLE SIZES AND DRUM SPEED AND BACKWASH PRESSURE

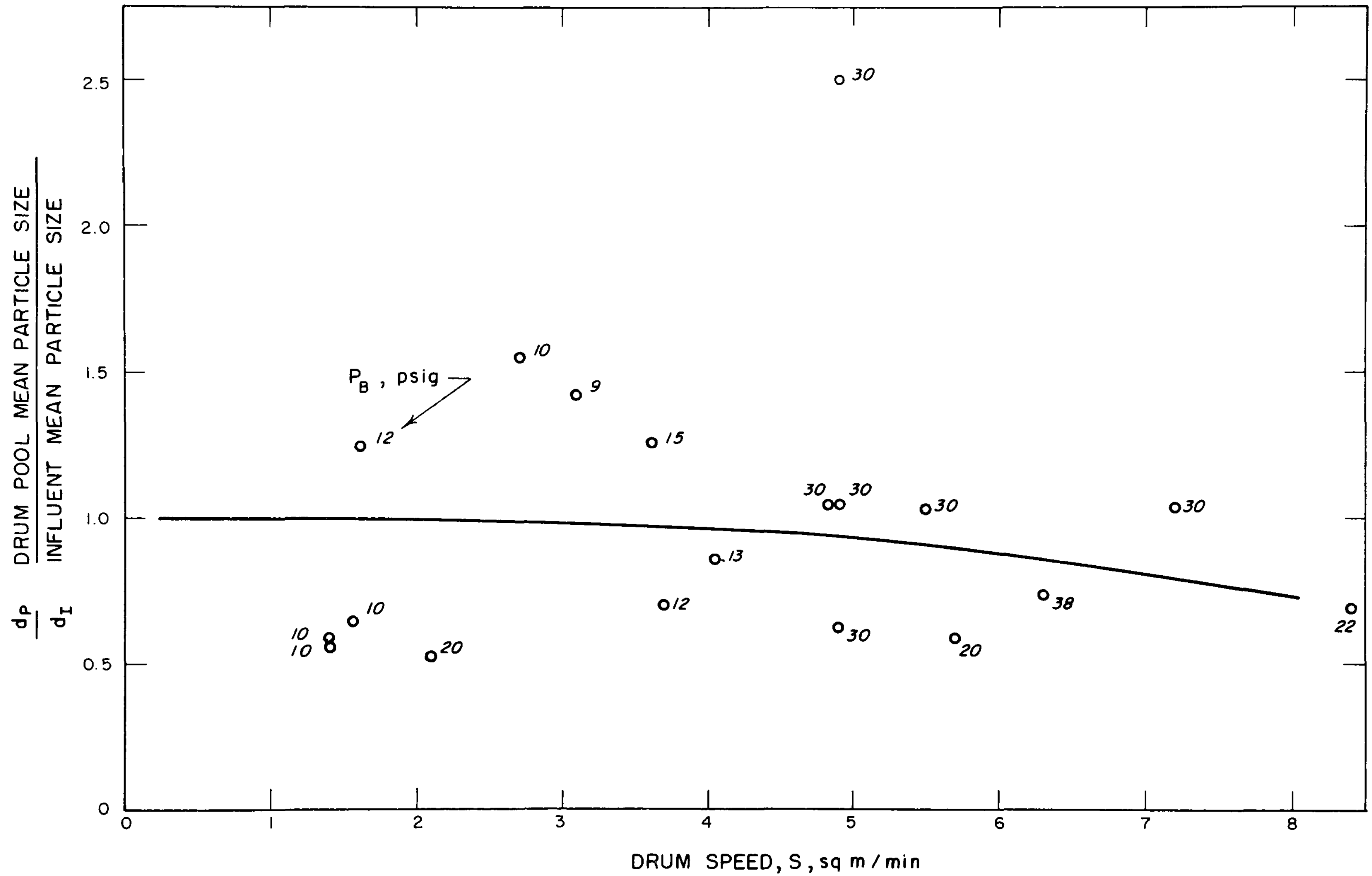


FIGURE 7

RELATIONSHIP BETWEEN ($\sigma_{LOG-P} - \sigma_{LOG-I}$) AND DRUM SPEED AND BACKWASH PRESSURE

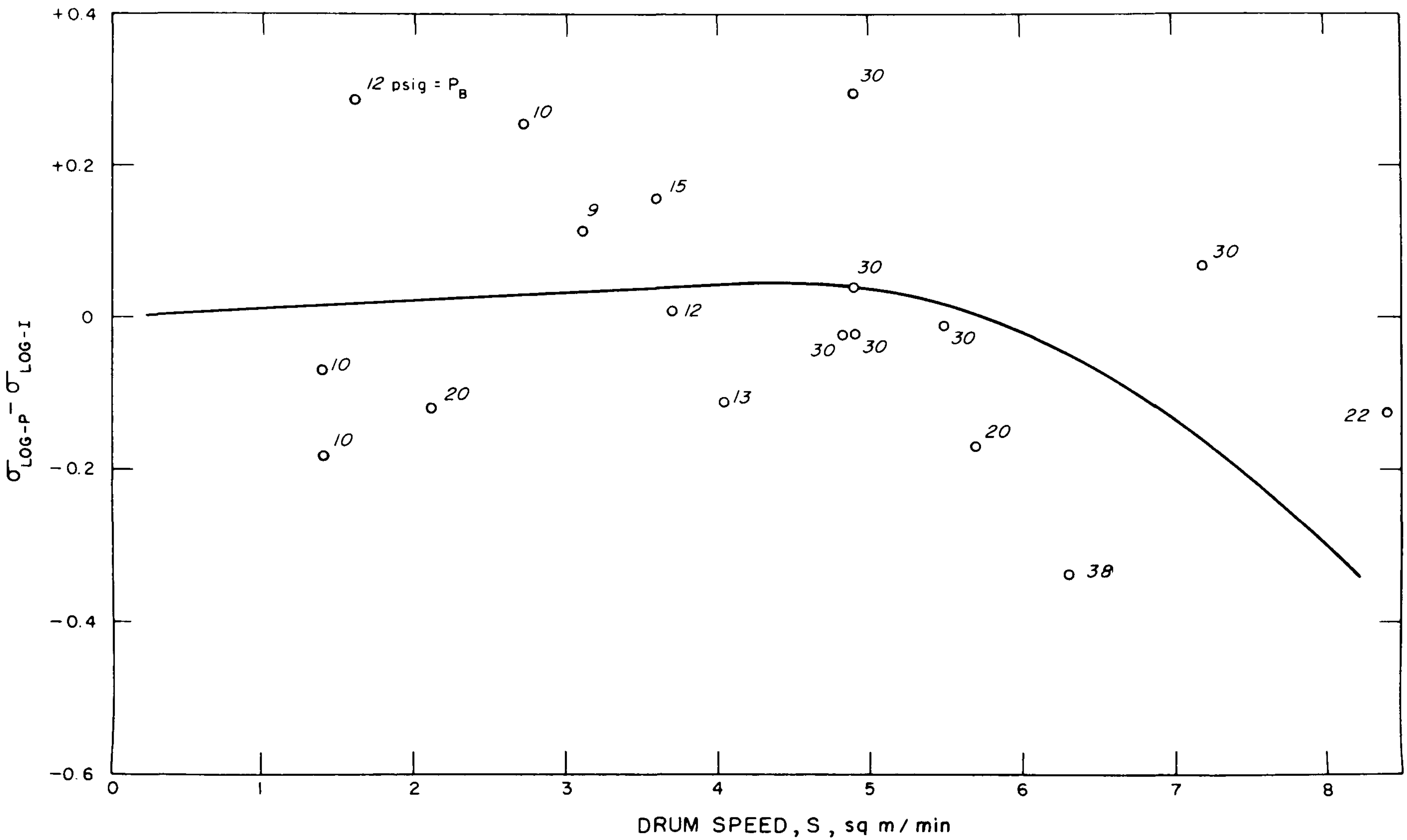


FIGURE 8

Trapping Efficiency

The trapping efficiency of the microscreen process has been viewed previously from two perspectives in the present study, the anticipated response surfaces from the simulation model, and the updated physical model (Section IV).

Given, in the present study, that trapping efficiency was measured on a drum pool → effluent basis, the measured efficiency data obtained in the field program constitute observations of the net removal achieved by the interactions of all three subprocesses (separation, transfer, and backwash), rather than by the separation subprocess alone.

In consideration of the above and the observations in Section IV, it was possible to examine the effect of the critical parameters of initial trapping diameter, $\bar{d}_P$, and σ_{LOG} only on an *overall run* basis. Thus, in approaching the data analysis and presentation, each datum was classified in terms of: the nominal pore size (NPS) of the fabric used during each run, as a measure of the initial trapping diameter; $\bar{d}_P$; and σ_{LOG-P}. The date were arrayed to permit the mapping and examination of specific planes across a response surface relating process efficiency (measured as MC/MI), solids loading (MI), NPS/$\bar{d}_P$ (a normalized parameter assumed to relate initial trapping diameter and mean drum pool particle size), and σ_{LOG}.

In accomplishing the above, it was originally intended that the data be viewed insofar as possible as being independent of wastewater source. The premise of this original concept was that, within certain constraints, a suspension could be described in terms of PSD character and suspended solids concentration independent of solids source and history. It is recognized in this approach that many factors may obviate this position, the foremost being the manifestations of the different types of chemical, electrical, and concentration forces operative in the various types of suspensions examined, resulting in different levels of water-particle interactions and behavior when cakes are formed from the suspensions (e.g., porosity). Initial attempts at data analysis within the original concept did not bear positive results, the range of sensitivity of the data being a major factor precluding this. As a result, an additional variable added to the response surface analysis as described subsequently was wastewater source.

The steady-state results on trapping efficiency have been classified in terms of:

(1) Four ranges of NPS/$\bar{d}_P$ (<2; 2 to 4; 4 to 6; >6)

(2) Three ranges of σ_{LOG-P} (<1.00; 1.01 to 1.20; >1.21)

(3) Five types of influent wastewater sources

- (a) AS (clarified activated sludge effluents)
- (b) TF (clarified trickling filter effluents)
- (c) UTF (unclarified trickling filter effluents)
- (d) PE (primary effluents)
- (e) OP (oxidation pond effluents)

An overview of the data set can be obtained from a review of the data summary in Table 5. The greatest diversity of information in terms of ranges of NPS/$\overline{d}_P$ and σ_{LOG-P}, was obtained for AS and TF sources. The least information was obtained for PE and OP sources. The foremost trends that can be observed from examination of the data are as follows:

(1) Independent of efforts made in the field program to maximize the range of observation, most of the steady-state points fall into one of two ranges of solids loadings on the basis of waste type; 0<MI<10 gm/sqm for AS, PE, and UTF streams; and MI>6 gm/sqm for TF streams.

(2) For any given range of solids loading (MI), and for each wastewater source, a decreasing trend in efficiency occurs with increasing values of σ_{LOG-P} and NPS/$\overline{d}_P$ ratio.

To explore the latter trend in more detail, the individual overall run data have been plotted in Figures 9 and 10. The data presented in Figure 9 are identified in terms of efficiency, MI, and σ_{LOG-P}, independent of NPS/$\overline{d}_P$ and waste type, and the data presented in Figure 10 are identified by efficiency, MI, and NPS/$\overline{d}_P$ independent of waste type or σ_{LOG-P} designations. These plots were developed in the above formats to identify the trends in efficiency over the range of MI associated with each of the PSD characteristics.

Three trend lines (one for each range of σ_{LOG-P}) have been drawn in Figure 9 as best-fit curves relating efficiency and solids loading. The best-fit curves of Figure 9 indicate the following:

(1) For any given range of σ_{LOG-P}, overall suspended solids removal efficiency decreases at a decreasing rate with increasing MI; a doubling of the solids loading from 2 to 4 gm/sq m resulted in 12 to 15 percent reduction in efficiency, and a doubling in solids loading from 4 to 8 gm/sq m resulted in a 35 to 40 percent reduction in efficiency.

(2) The more uniform the PSD (ie., the lower the value of σ_{LOG-P}), the more efficient was the overall efficiency of suspended solids removal; for example, at a solids loading of 2 gm/sq m, the efficiency decreased from 71 percent for $\sigma_{LOG-P} < 1.00$ to 57 percent at $1.00 \leq \sigma_{LOG-P} \leq 1.20$ and 38 percent at $\sigma_{LOG-P} \geq 1.21$.

Four trend lines have been drawn in Figure 10 as best-fit curves, one per range of NPS/$\overline{d}_P$, relating efficiency and solids loading. The following trends are indicated by the best-fit curves:

(1) For any given range of NPS/$\overline{d}_P$, efficiency decreases at a decreasing rate with increasing MI.

(2) Efficiency at any given MI is a function of the NPS/$\overline{d}_P$ ratio, i.e., a direct function of the fabric pore size and an inverse function of the mean particle size.

The trend lines of the data presented in Figures 9 and 10 are confirming

TABLE 5

SUMMARY OF OVERALL RUN SUSPENDED SOLIDS REMOVAL OBSERVATIONS

Wastewater Source	NPS $\bar{d}_P$	σ_{LOG-P}	Average MI (gm/sq m)	Average MC/MI (Overall Run) (%)
Clarified Activated Sludge Effluent	<2	<1.00	2.4	13.2[a]
	<2	1.01-1.20	2.4	65.2
	<2	>1.21	3.3	56.4
	2-4	<1.00	3.1	59.5
	2-4	1.01-1.20	2.4	22.2
	4-6	<1.00	4.9	54.0
	6-10	<1.00	4.5	66.7
Trickling Filter Effluent (Clarified)	<2	<1.00	14.0	34.4[a]
	2-4	<1.00	11.5	40.3
	4-6	<1.00	16.7	31.8
	4-6	1.01-1.20	12.7	24.4
	6-10	<1.00	9.5	47.7
	6-10	1.01-1.20	11.6	12.8[a]
	6-10	>1.21	34.9	9.9
Trickling Filter Effluent (Unclarified)	2-4	<1.00	5.6	33.3
	4-6	<1.00	2.4	61.2
	6-10	<1.00	3.4	43.3[a]
	6-10	1.01-1.20	6.8	68.7[a]
	6-10	>1.21	2.5	28.0[a]
Primary Effluent	2-4	>1.21	1.0	51.1[a]
	4-6	<1.00	3.6	21.8[a]
	4-6	>1.21	1.4	37.8[a]
Oxidation Pond Effluent	>100	-	2.9	5.1[a]
	>100	-	8.2	8.7[a]

Note: [a] Single observation

RELATIONSHIP BETWEEN OVERALL SUSPENDED SOLIDS REMOVAL EFFICIENCY AND SOLIDS LOADING VS σ_{LOG-P}

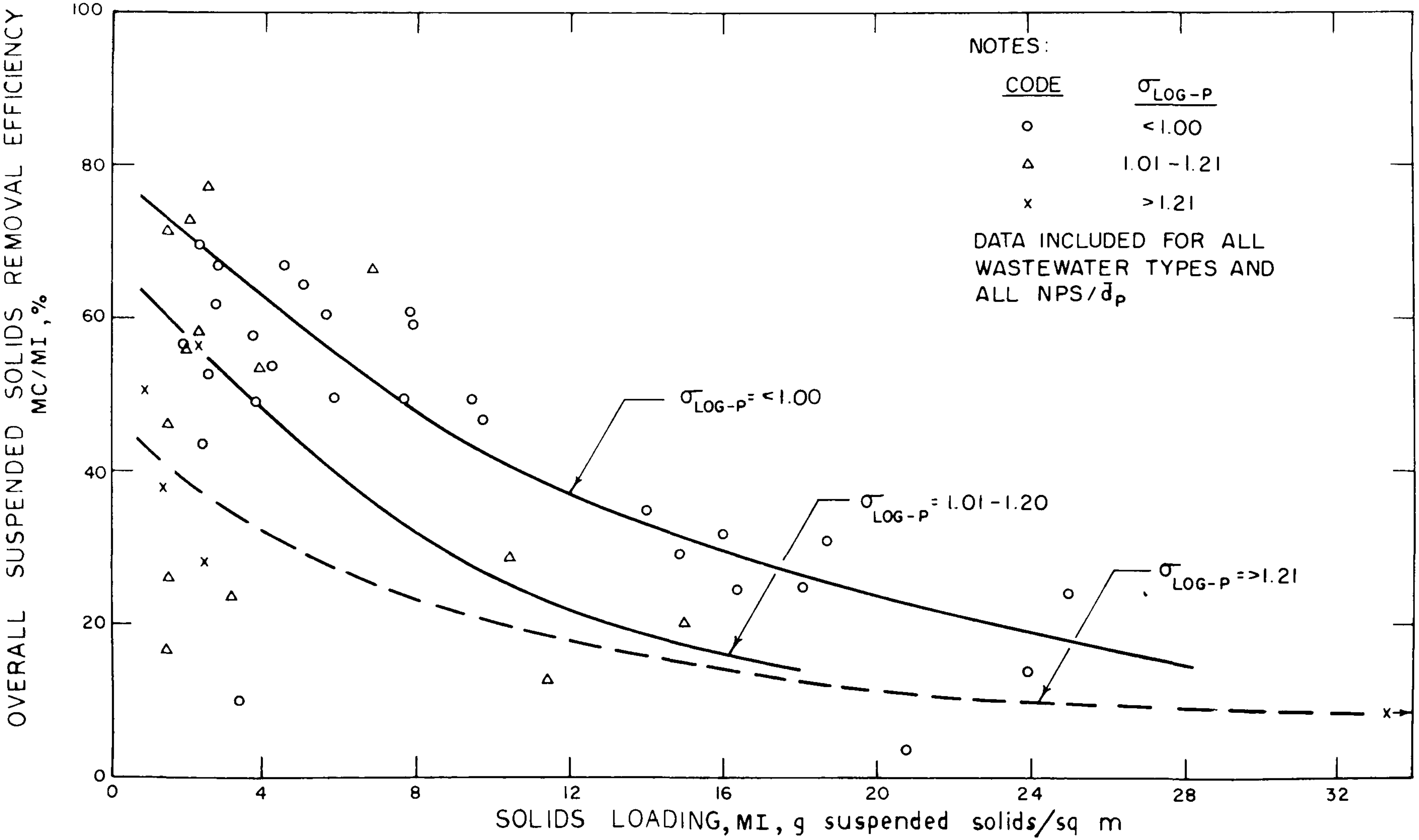


FIGURE 9

RELATIONSHIP BETWEEN OVERALL SUSPENDED SOLIDS REMOVAL EFFICIENCY AND SOLIDS LOADING VS NPS / $\bar{d}_P$

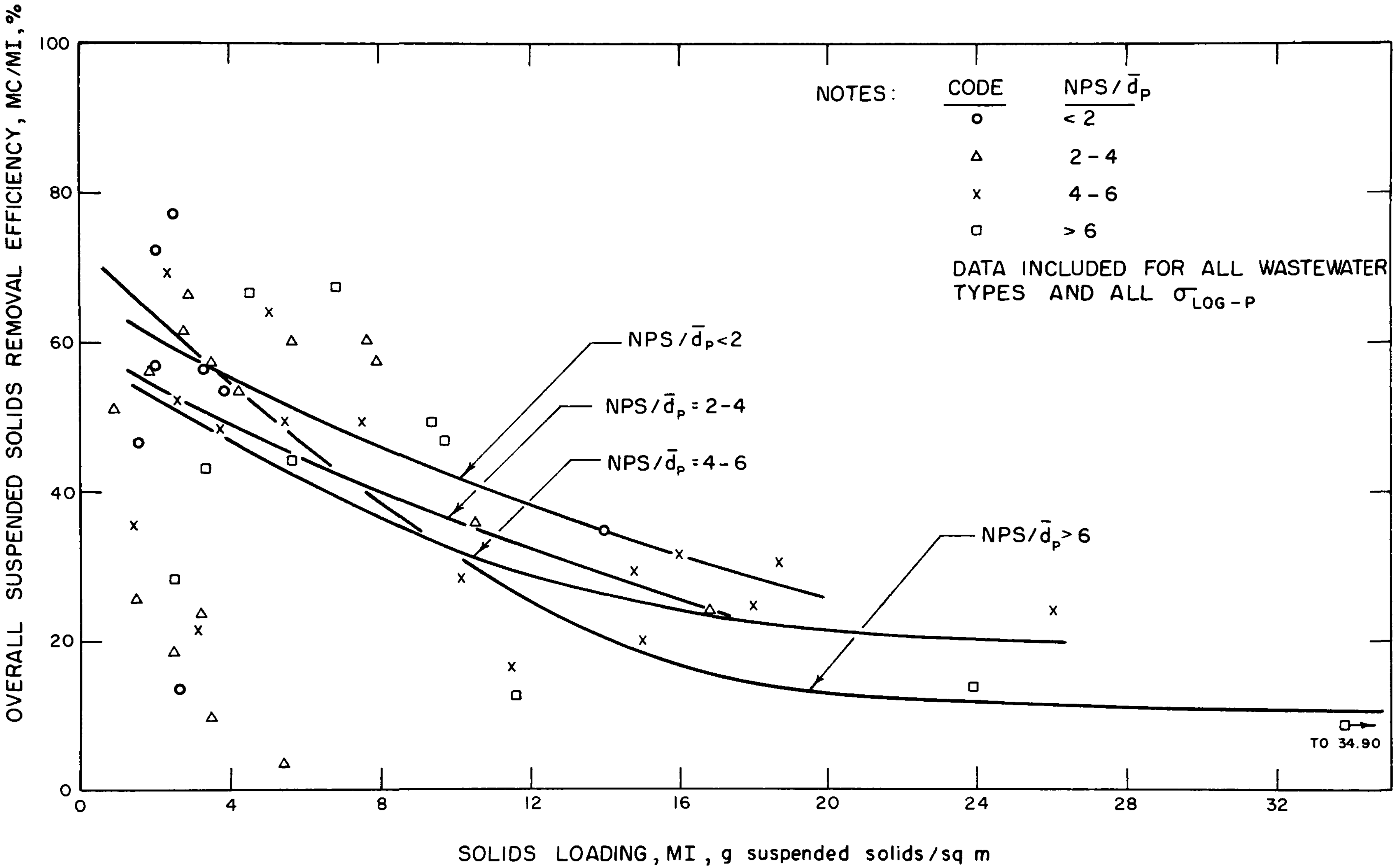


FIGURE 10

evidence of the validity of the trends predicted with the simulation model (Section IV) and of the trapping mechanism incorporated therin. Additionally, it is apparent that the specification of wastewater source was tantamount to specifying a range of MI values in which the process would be operative. It is presently unknown if yet another waste type would result in the microscreen process operating over a yet-undefined range of MI values. Two factors that may be associated with specification of wastewater source, and which could not be examined within the scope of the study, are the drainability and porosity of the water-solids complex itself.

When it is considered that the process efficiency as described in Figures 9 and 10 is defined on a drum pool → effluent basis, and that the drum pool itself acts as an influent solids concentrator, it is apparent that there exists a combination of operating conditions and solids loadings at which the concentration effect in the drum pool will preclude the microscreening process from achieving any solids removal whatsoever on an influent → effluent basis. That is, there exists a combination of operating conditions and solids loadings at which the product of the drum pool concentration ratio (X_P^S/X_I^S) and the ratio of effluent: drum pool solids concentrations (X_E^S/X_P^S) is equal to, or greater than, unity. The condition for which the product of the ratio (X_P^S/X_I^S) and (X_E^S/X_P^S) is equal to unity can be designated as a *zero performance* boundary for the process. This boundary condition for the microscreen process can be defined with the information developed in the field program. For example, if it is assumed that σ_{LOG-P} for a microscreen influent is <1.00, and the desired drum speed is 2 sq m/min, then:

(1) From Figure 6, $X_P^S/X_I^S = 1.4$

(2) For $X_P^S/X_I^S = 1.4$, the ratio of X_E^S/X_P^S must be less than (1/1.4), or 71.4 percent simply for process efficiency on an influent → effluent basis to exceed zero; that is the trapping efficiency (MC/MI) across the screen must exceed 100-71.4, or 28.6 percent

(3) From Figure 9, for σ_{LOG-P} <1.00 and MC/MI @ 28.6 percent, the *zero performance* boundary occurs at MI∿16 gm/sq m.

Needless to say, the zero boundary condition in the process resulting from the concentration effect in the drum pool precludes the technical feasibility of operating microscreen units (configured in a manner permitting this effect) in certain ranges of drum speeds, and solids loadings. Moreover the set of operating variables (solids loading, drum speed, screen size, etc.) at which the boundary conditions occur cannot be defined without a knowledge of the PSD characteristics of the wastewater to be treated.

Based on the foregoing observations, the following *caveat* is offered to the designer contemplating a microscreen application: *At no time should a microscreen unit be specified for a specific application in the absence of pilot-scale microscreen performance data developed with the actual stream under consideration.*

The trends indicated by the data in Figures 9 and 10 conflict with reports in the literature that microscreen suspended solids removal efficiency remained constant (effluent solids concentration proportional to influent solids concentration) or increased with increased solids loadings (eg., Reference 5). It is impossible to compare the results of the present study with those of previous investigations, the foremost of which are as follows:

(1) Prior researchers without exception have not normalized their solids loading and removal data with respect to drum speed, S. That is, the drum speed parameter was not assumed to have an impact on the suspended solids removal performance of the microscreen.

(2) Neither the particle size distribution of the influent stream nor the ratio of fabric NPS to a particle size parameter has been identified and evaluated as a situation-specific variable affecting microscreen performance.

(3) As noted in Section IV, very few microscreen investigations have been documented with a sufficiency of information to permit the calculation of liquid and solids balances and screen loading rates.

(4) The microscreen process has not been viewed by previous researchers as in fact a system comprised of three basic subprocesses as done herein.

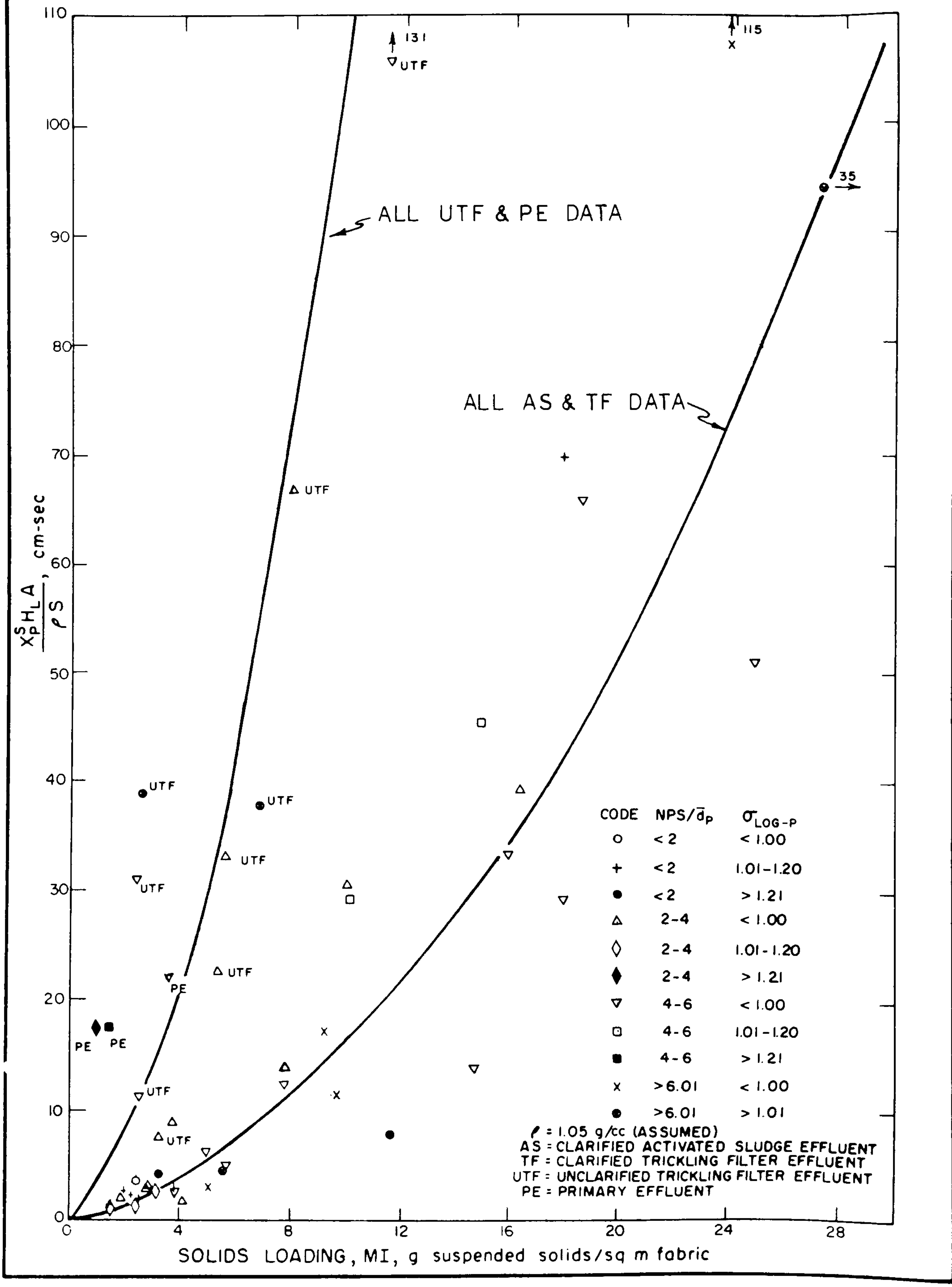
Hydraulic Resistance

Hydraulic resistance characterized by the hydraulic parameter (X_P^S $H_L A/\rho S$) as described previously, has been viewed from the perspectives of the simulation as well as the physical model in the present study (Section IV). It was observed in sensitivity tests with the simulation model that changes in the defined porosity of the formed cake had a significant impact on this parameter, the rate of change of hydraulic resistance over the screening cycle decreasing with increasing solids loading as the porosity increased. A variation of the magnitude of the standard deviation of the PSD was found to have only a nominal effect on the hydraulic parameter, the effect being one of decreasing the rate of change of the hydraulic resistance over the screening cycle with increasing solids loading as the standard deviation increased.

A major limitation of the pilot microscreen units utilized in the present study was that headloss could be measured only on an average basis for an averaged flow through the submerged screen rather than at discrete points across the screen, for flow at the discrete points. Thus, the calculation of the hydraulic parameter from the field effort could be based only on the total headloss between drum pool and clear well, and the solids loading parameter was based on the overall run MI.

The hydraulic resistance data were analyzed in the same manner as were the trapping efficiency data; all of the data were classified in terms of NPS/d_P, σ_{LOG-P}, and waste source, and then examined at this level to ascertain what relationships existed in each classification with respect to solids loading. The entire data set is presented in Figure 11, and a

RELATIONSHIPS BETWEEN OVERALL RUN HYDRAULIC PARAMETER AND SOLIDS LOADING - ALL WASTEWATER TYPES



consideration of the data set relative to the above classifications shows that:

(1) A wide range of variation in both the hydraulic resistance parameter and solids loading was observed in the field;

(2) Two discrete best-fit curves can be defined, within the range of sensitivity of the data, as follows:

(a) All AS and TF data independent of σ_{LOG-P}.

(b) All UTF and PE data independent of $MPS/\overline{d}_P$ and σ_{LOG-P}.

(3) The general trend defined by the best-fit curves is one of the hydraulic parameter increasing at an increasing rate with increasing MI.

Based on the relative locations of the two best-fit curves in Figure 11, it is apparent that the hydraulic resistance of the screen solids complexes forming in the microscreening of UTF and PE streams is significantly greater than that of the complexes derived from AS and TF streams. For example, at an MI level of 4 gm/sq m, a hydraulic resistance of 30 cm-sec is indicated for the UTF/PE streams as compared with 3 to 5 cm-sec for the AS/TF streams. Because of the overlap of the two groups of streams in terms of $NPS/\overline{d}_P$ and σ_{LOG-P} classifications it is likely that the difference is associated with parameters other than the PSD characteristics, particularly with factors associated with/manifested by the manner in which the screen-solids complex is formed and passage of water through the interstices of the complex occurs. Porosity is the only factor that has been evaluated on a simulation basis, although it is recognized that other factors may also be involved.

If it is assumed that porosity is a dominant factor in the relative differences manifested by the data sets in Figure 11, then it is possible to estimate the relative difference in the porosity of the cakes formed by the two groups of streams, using the relationship $H_L \sim n^{-3}$ as developed from the Carmen-Kozeny relationship and described in Reference 4. On the basis that the relative difference in hydraulic resistances are associated totally with a difference in the porosities of the formed cakes at a given MI, then the magnitude of the porosity of UTF/PE cakes is from $(\sqrt[3]{10})^{-1}$ to $(\sqrt[3]{6})^{-1}$, or about one-half that of the AS/TF cakes.

In the calibration of the sub-program model to pilot scale data, it was deemed inadvisable to attempt to fit this variation in porosity, due to the paucity of UTF/PE data for steady-state points. Accordingly, the heuristically-fit porosity in the subprogram model is probably somewhat low for AS/TF effluents, and high for UTF/PE effluents.

TRANSFER AND BACKWASH SUBPROCESSES

Although the transfer and backwash subprocesses have been properly viewed as discrete subprocesses in the update of the physical model presented earlier in this chapter, each component subprocess could not be documented separately as to its behavior in the field investigations due to the physical configuration of the pilot plants. The major data analysis effort was directed to examining the input/output and cleaning efficiency characteristics of the backwash subprocess and to describing the response surfaces relating the cleaning efficiency of the backwash subprocess with the operating variables P_B and S.

Backwash System Characteristics

Initial tests were directed to ascertaining how applied washwater flow (Q_B) was distributed as a function of the operating variables, the alternate points of distribution being as throughput backwash flow captured in the washwater collector (Q_W), or as splash-back or splash-over not recovered in the collector. The distribution of applied washwater was examined independent of the separation subprocess by operating the drum and backwash sprays with no influent entering the drum pool. This approach was taken in recognition of the possibility that the absence of particles in a screen-solids complex and/or particles jammed into the pores of the fabric could result in not simulating the normal operating behavior of the backwash system. However, the advantages in the approach were that the behavior of the physical components in the backwash subprocess could be examined independent of interferences from the separation and transfer subprocesses. A single fabric type (30µ stainless steel) was used in the evaluation.

The results of the experiment are presented in Figure 12, in which the data are presented in the format of a relationship between recovery of applied backwash flow as throughput washwater vs. backwash pressure at varying levels of drum speed. The region of the response surface relating these variables can readily be envisioned as having the following characteristics:

(1) Recovery decreasing with increasing drum speed and increasing with decreasing pressure.

(2) For a given level of drum speed, the recovery tends to saturate at a maximal level with increasing pressure, the maximal level being a function of drum speed. For example, maximum recovery was 52 percent at S = 3.2 sq m/min, whereas maximum recovery was 48 percent at S = 8.2 sq m/min.

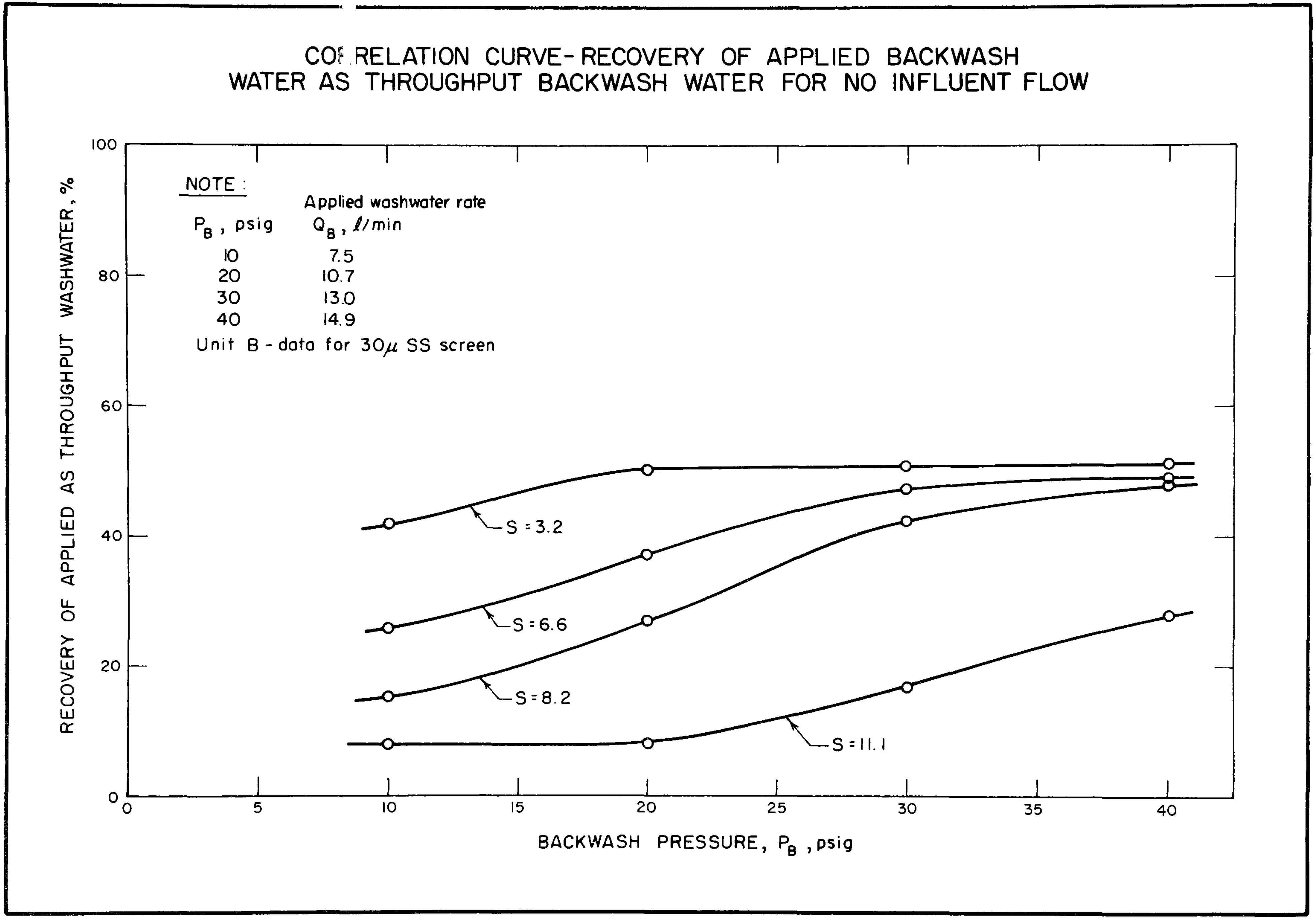
(3) The backwash pressure required to achieve a saturation of recovery at a maximum level increases with increasing drum speed.

Based on the foregoing, the shape of a response surface can be speculated upon over the entire range of variation of the operating variables S and P_B, that shape being:

(1) Recovery decreasing with increasing S from a global maximum recovery (undefined in the experiment) at S = 0 and maximum pressure.

(2) Recovery increasing at any speed with increasing pressure to a saturation level that can be defined, relatively, as occurring at:

(a) P_B >20 psig for S = 3.2 sq m/min



COFRELATION CURVE-RECOVERY OF APPLIED BACKWASH
WATER AS THROUGHPUT BACKWASH WATER FOR NO INFLUENT FLOW
NOTE:
Applied washwater rate
P_B, psig
Q_B, ℓ/min
10 7.5
20 10.7
30 13.0
40 14.9
Unit B - data for 30μ SS screen
S = 3.2
S = 6.6
S = 8.2
S = 11.1
RECOVERY OF APPLIED AS THROUGHPUT WASHWATER, %
BACKWASH PRESSURE, P_B, psig
0
20
40
60
80
100
0
5
10
15
20
25
30
35
40

FIGURE 12

(b) P_B >35 psig for S = 6.6 sq m/min

(c) P_B >40 psig for S = 8.2 sq m/min

The above response surface shape demonstrates vividly several of the hypotheses presented in Section IV, viz:

(1) That, as evidenced by the saturation of recovery, there exists for any given combination of type and size of nozzle, backwash pressure, and screen size a speed of rotation at which the synchronization of the various components of the subprocess attains a maximal level.

(2) That the efficiency of the backwash subprocess is reduced with increasing speed in part due to the increased tangential velocity imparted to the impinging drops by the rotating drum, the result being that the time available for the drops to traverse the screen and fall into the collection trough is decreased.

It is readily evident from the foregoing that the variables S and P_B are important factors to be considered in optimizing the utilization of the applied backwash flow independent of considerations such as resultant cleaning efficiency, type and size of nozzle, screen indentation, etc.

Fabric Acclimatization

A factor of concern in the experimental program was to ensure that the microscreen fabrics had been appropriately acclimatized or pre-conditioned with the suspension to be microscreened prior to starting a formal experimental run. In this context, fabric acclimatization was defined conceptually as the accumulation of a stable level of residual solids carryover on an initially virgin fabric as a result of preconditioning of the fabric with the physical model. Inasmuch as acclimatization has not been a documented concern in previous studies, a criterion was needed to define the magnitude of pre-conditioning required to achieve the desired stability, and to evaluate this factor as a variable in the experimental program.

The approach used in developing an acclimatization criterion was to track the rate of change of hydraulic resistance of a panel of backwash medium removed from the microscreen drum at discrete time intervals over a day-long test period. Only one of the two microscreens was operated, using clarified activated sludge effluent as the feed stream, and holding the operating variables S and P_B constant insofar as possible throughout the test period. The hydraulic resistance was measured as K, the slope of the headloss vs. superficial velocity curve (units of cm per cm/sec @ 15°C), using the MTA methodology (Appendix B). The hydraulic resistance of the backwashed panel of fabric/solids was then compared with the hydraulic resistance (K°) of the virgin fabric to assess the rate and relative impact of operation on the medium over time.

The results of the acclimatization test are presented in Table 6 and illustrated in Figure 13. The rate of change of K with respect to time, cumulative liquid loading, and cumulative solids loading is apparent from a consideration of the best-fit curves presented in Figure 13. As

TABLE 6

RUN 0 - FABRIC ACCLIMATIZATION EXPERIMENT

SUMMARY OF OBSERVATIONS

Run Time (hr)	K ($\Delta H_L/\Delta \bar{V}$) (cm/cm/sec) @ T=15°C	Cumulative Liquid Flow-Through (1,000 ℓ/sq m)	Cumulative Solids Loading (1,000 g/sq m)	Specific Backwash Rate (ℓ/sq m)	Average H_L during Subrun (cm)
0	1.35	0	0	0	0
1.50	6.45	18.8	1.47	1.1	12
3.02	7.40	43.7	2.75	1.2	17
3.75	11.50	53.7	3.23	1.4	16
4.90	9.05	69.8	4.02	1.8	18
5.90	9.50	78.6	5.08	1.6	16
6.75	6.25	87.4	6.05	1.5	18

Notes: (1) Screen: 21μ Stainless Steel 200x630 mesh

(2) Run date: 16 and 17 February 1971

(3) Waste source: San Leandro clarified activated sludge process effluent

(4) Screen area: ~0.8 sq m

RELATIONSHIPS BETWEEN BACKWASH SCREEN HYDRAULIC CHARACTER AND RUN TIME AND SCREEN LOADING PARAMETERS, FABRIC ACCLIMATIZATION-RUN O

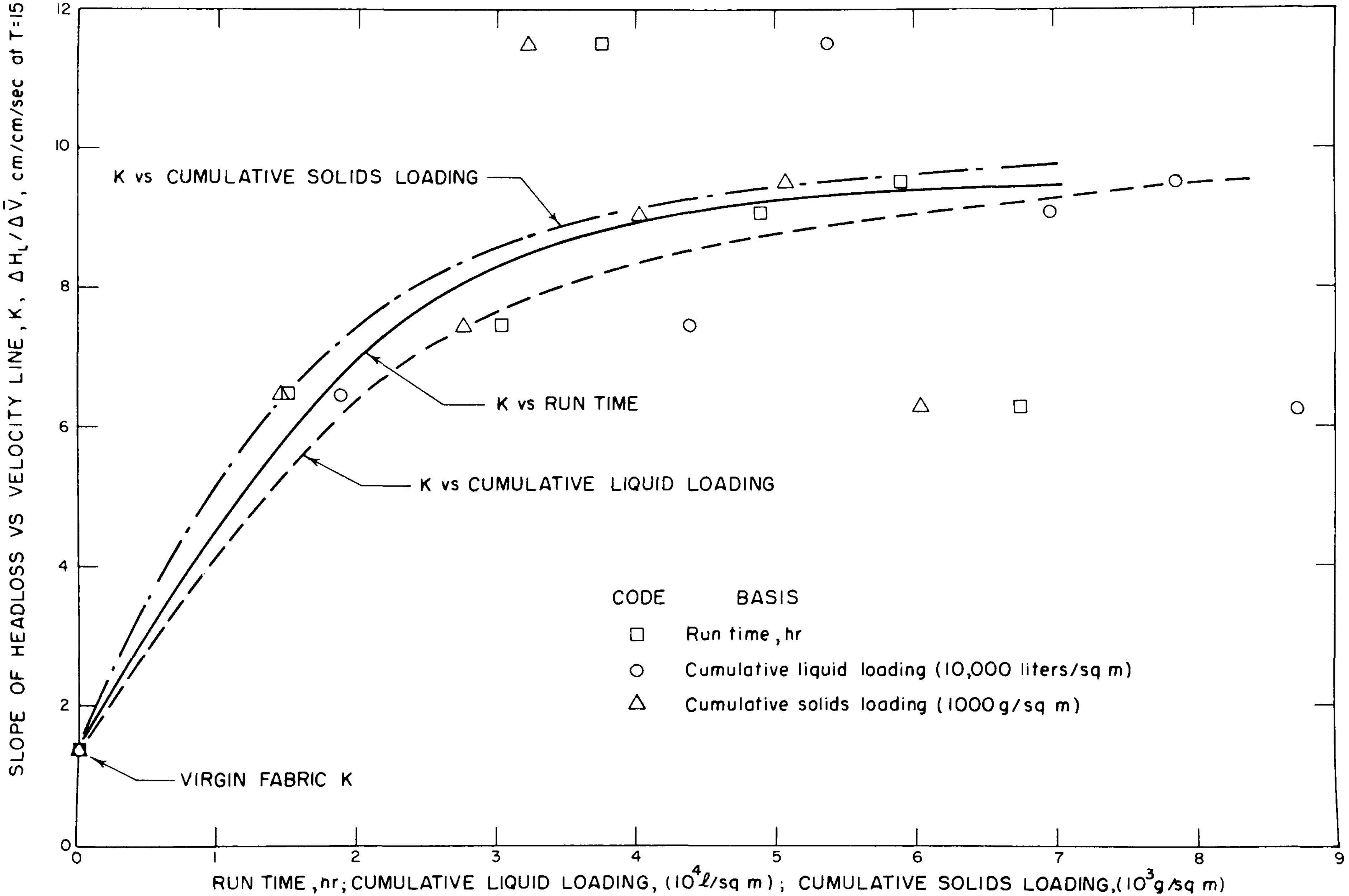


FIGURE 13

a general trend, K tended to saturate in a pattern of harmonic variation about a mean value of K of 10 cm/cm/sec, a value which, for the selected experimental/operational conditions, was over seven times greater than the hydraulic resistance (K°) of the virgin fabric. The parameter values at which the saturation level of K was approached was within: eight hours operating time; 60,000 l/sq m of liquid loading; and 6,000 gm/sq m of solids loading.

Based on the above results, all subsequent test runs in the experimental program were done after a prior overnight acclimatization of the fabric in the wastewater to be test-microscreened.

Response Surface for Backwash Subprocess

With the preliminary definition of the behavior of the backwash subprocess obtained from the response surface for backwash flow recovery, a search was made with the available data to map out the relationships between cleaning efficiency, fabric pore size, drum speed, and backwash pressure. In the case of each experimental or operating variable, the mapping effort was approached in a single dimension using data selected from runs where the parameters in the other dimensions were held constant. In this manner (assuming superposition) the multidimensional response surface could be sketched out across each dimension, and from this, constructed in all dimensions within the totality permitted by the data. Cleaning efficiency was evaluated as the degree of recovery of the hydraulic capacity virgin fabric upon backwashing of the medium, and was defined in terms of the ratio K°/K where K° and K are as defined above. For a ratio value of 1.0, it was assumed that a cleaning efficiency of 100 percent was obtained.

Effect of Fabric Nominal Pore Size

The hypothesis presented in Section IV for the effect of fabric pore on cleaning efficiency was that, for any given type and size of nozzle and water pressure, there should exist a threshold pore size below which cleaning effectiveness declines rapidly and above which cleaning efficiency is independent of pore size. In order to examine the validity of this hypothesis, data were selected for all runs where P_B was 15 psig (the backwash pressure most commonly used) and speed was held within the range of 1.3 to 2.4 sq m/min (the latter being the range of speeds in which optimal cleaning efficiency was observed, as discussed subsequently). Excluded from this data set were results obtained when nylon fabric (NPS of 10μ) was used because of the deformation characteristics of this fabric.

The resultant data set is presented in Figure 14, and the relationship between cleaning efficiency and fabric NPS is illustrated by the best-fit curve. As a general trend, the least effectiveness was obtained with fabrics having the smallest NPS, and the cleaning efficiency tended to increase toward a maximal level of 0.90 to 0.95 at an NPS value of 16.5μ, and then to decrease slightly with increasing values of NPS. It is tentatively concluded from these results that the cleaning efficiency relationship exhibits a saturation with respect to NPS at a level of NPS equal to or exceeding about 16μ. On the basis of these observations,

RESPONSE SURFACE RELATIONSHIP FOR BACKWASH EFFICIENCY AND FABRIC NOMINAL PORE SIZE

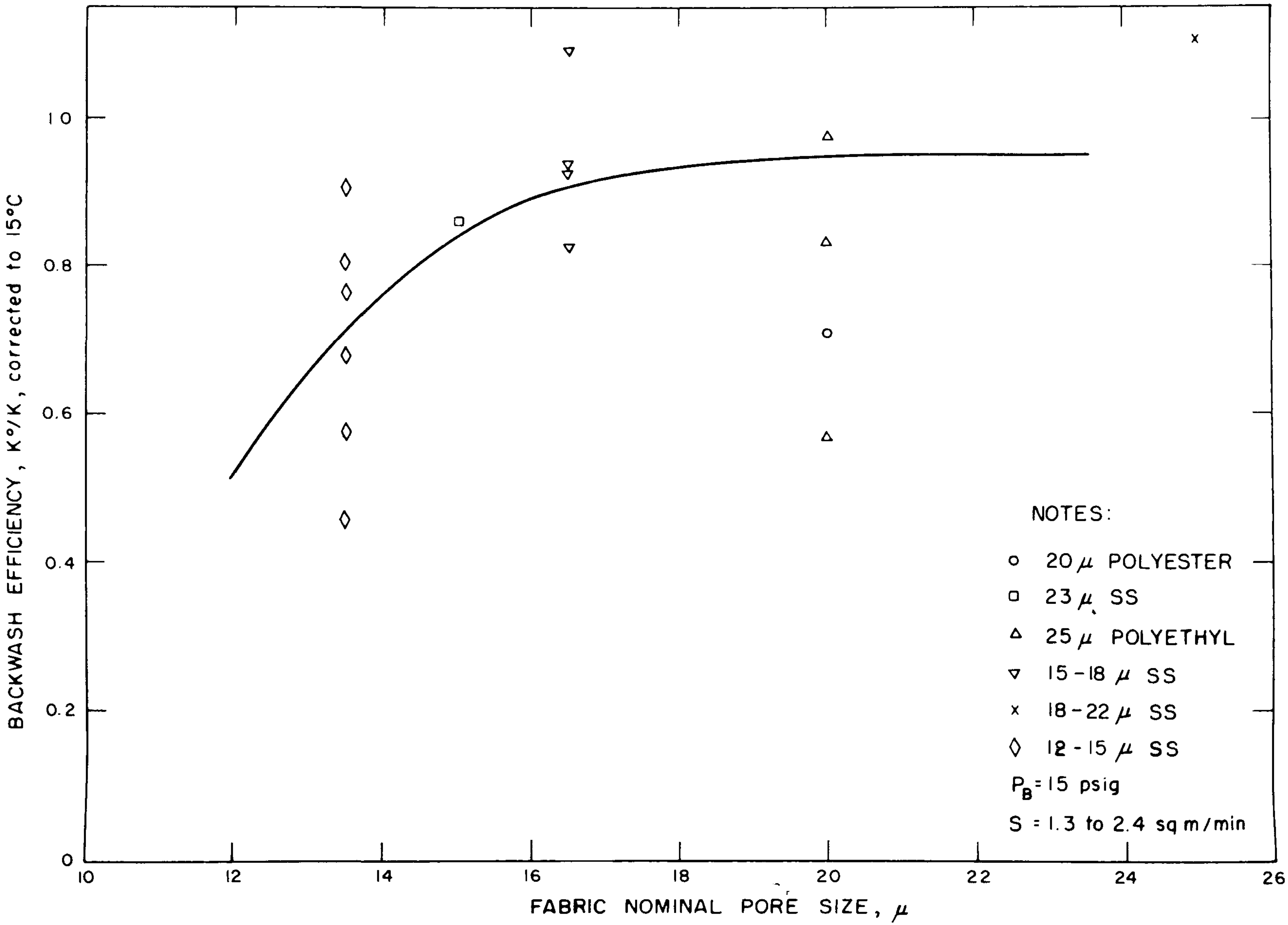


FIGURE 14

only data obtained in runs with fabrics having an NPS greater the 16μ were used in the subsequent unidimensional response surface analysis.

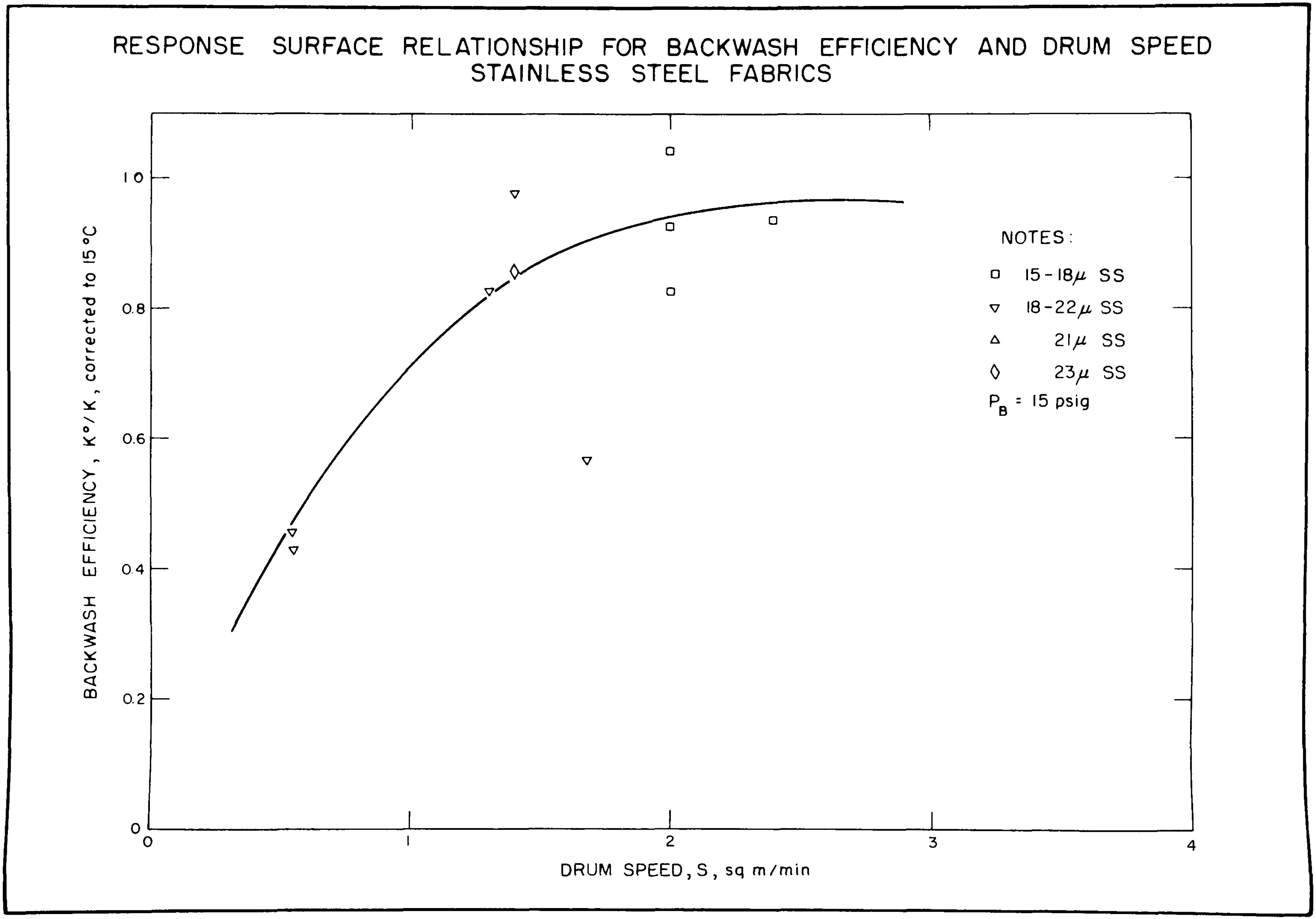
Effect of Drum Speed

The hypothesis developed previously for the effect of drum speed on the cleaning efficiency was that, for any given combination of type and size of nozzle, water pressure, and fabric NPS, there should be a speed of rotation which optimizes the synchronization of the intersection of pores and droplets, above or below which cleaning efficiency should decline rapidly. Because it was observed during the field program that some of the fabrics, particularly nylon, flexed much more than the stainless steel fabrics, two discrete response surface relationships were mapped, one for runs with stainless steel fabrics only, and the second only for runs with nylon.

The cleaning efficiency vs. drum speed data for runs with stainless steel fabrics and a constant operating pressure of 15 psig are shown in Figure 15. Data in this set were available for a range of speeds varying from 0.5 to 2.4 sq m/min. Based on the trend of the best-fit curve, the data indicate that the cleaning efficiency increased at a decreasing rate from a level of 0.4 at S of 0.5 sq m/min to a maximal value of about 0.95 at S of 2.4 sq m/min. The data generally indicate that the cleaning efficiency was in excess of 0.85 over the range of speeds from 1.3 to 2.4 sq m/min. Given the range of sensitivity of the data, it has been assumed from the results that 0.85, or 85 percent restoration of the hydraulic capacity of the virgin fabric represents an optimal level of cleaning efficiency for stainless steel fabrics as measured by the MTA technique. Additionally, in terms of the previously discussed response surface relating drum speed, backwash pressure, and recovery of applied as throughput backwash flow, the drum speed range and operating pressure at which optimal cleaning efficiency was observed with the stainless steel fabrics represent conditions at which a saturation level of recovery is expected to occur.

The available data on cleaning efficiency vs. drum speed for runs with the nylon fabrics are presented in Figure 16. The range of operating pressures for the data set is 20 to 25 psig and the range of drum speeds is from 1 to 4 sq m/min. Because of discontinuities in the data set in the range of speeds from 1 to 2 sq m/min, it has been necessary to speculate on the best-fit curve of the data defining the cleaning efficiency vs. drum speed in this speed range. A pronounced peak can be observed in the relationship at a speed of 2.2 sq m/min, for which the cleaning efficiency was 2.05, or 205 percent; i.e., at this point the hydraulic resistance of the backwashed nylon fabric was about 49 percent of that of the same fabric in a virgin state.

From observations of the behavior of nylon fabrics both in the physical model and when assayed in the MTA apparatus, it was found that the nylon fabric deformed into a catenary shape as flow passed through it, particularly as the solids-laden fabric passed through the zone of influence of the backwash spray. The net effect of the flexure, as documented in Reference 4, was to decrease the hydraulic resistance of the fabric. What is unknown about the nylon fabric is whether or not its deforming



RESPONSE SURFACE RELATIONSHIP FOR BACKWASH EFFICIENCY AND DRUM SPEED
STAINLESS STEEL FABRICS
BACKWASH EFFICIENCY, K°/K, corrected to 15 °C
DRUM SPEED, S, sq m/min
0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
NOTES:
15-18μ SS
18-22μ SS
21μ SS
23μ SS
P_B = 15 psig

FIGURE 15

RESPONSE SURFACE RELATIONSHIP FOR BACKWASH EFFICIENCY AND DRUM SPEED
10 μ NYLON FABRIC

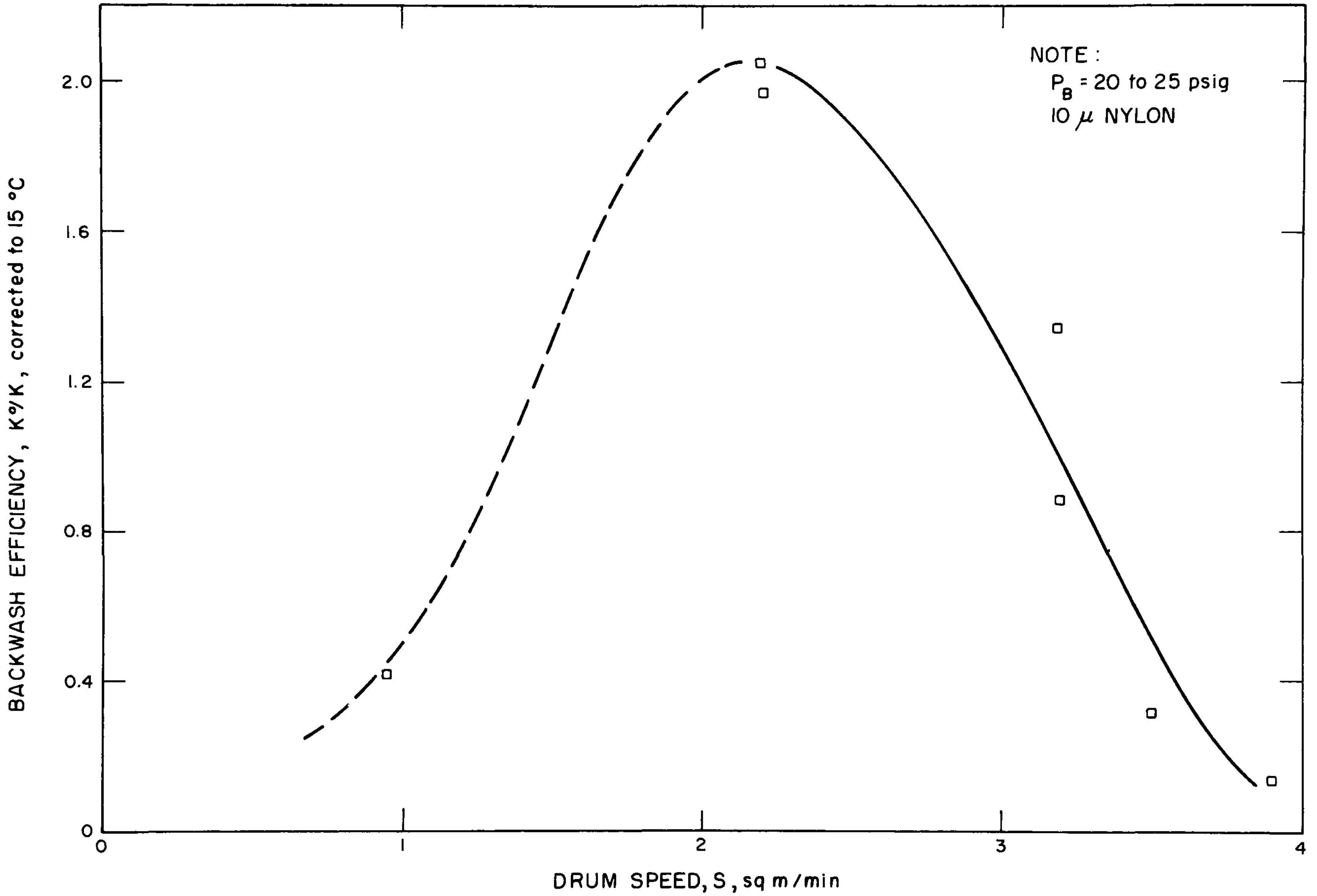


FIGURE 16

characteristics changed with time of usage, exposure in wastewaters, etc., so that hydraulic resistance of the fabric decreased with use. Otherwise stated, did or did not the nylon fabric stretch irreversibly with use, the net result being that its resistance was reduced relative to that of the fabric in its virgin state? If such were the case, then K° would be greater than K, as was observed. Because of the improbability that the hydraulic resistance of a backwashed fabric subjected to considerable use would be less than that of a virgin fabric unless some form of irreversible flexure/stretching/aging did occur, it has been assumed from the results with the nylon fabric that this fabric did deteriorate with usage. Additionally, on the basis of this assumption, physical model runs made with nylon fabrics were not used in subprogram model calibration.

Given the above qualifications, it is apparent that the response surface relationship for cleaning efficiency vs. drum speed with the nylon fabrics defines an optimal range of drum speeds (2 to 2.5 sq m/min) in terms of backwash efficiency. The shape of the response surface is as was predicted in the original hypothesis, and the range of speeds (2 to 2.5 sq m/min) and backwash pressures (20 to 25 psig) are within the region at which the recovery of applied as throughput backwash flow is expected to saturate (Figure 12).

Effect of Pressure

The hypothesis for the effect of pressure on the cleaning efficiency was that, given any combination of nozzle type and size, speed of rotation, and NPS, there should be a backwash pressure at which cleaning efficiency is optimal (Section IV). This hypothesis can be modified in view of the observations presented above that recovery of applied as throughput backwash flow at any given speed saturates at a maximal level with respect to pressure, the modified hypothesis being that for the given conditions it is also expected that cleaning efficiency will saturate with respect to pressure.

The data set used for examining the effect of backwash pressure was selected on the basis that only data from runs with stainless steel fabrics and drum speeds in the range of 1.3 to 2.4 sq m/min should be used for the evaluation. These constraints on developing an appropriate data set were accepted as necessary in view of the relationships/observations on the backwash subprocess presented above. The resulting, limited, data set is presented in Figure 17, and on the basis of the best-fit curve of the data, there is no apparent trend defined other than a slight increase in cleaning efficiency with increasing backwash pressure over the pressure range of 15 to 35 psig. That is, within the range of backwash pressures in the available data set, cleaning efficiency was found to be essentially independent of backwash pressure. Relative to the modified hypothesis for the response surface, it can be reasoned that the cleaning efficiency saturated with respect to backwash pressure at a P_B at or less than 15 psig for the range of drum speeds from 1.3 to 2.4 sq m/min.

Generalized Response Surface

The following statements can be made about a generalized response surface for the backwash subprocess on the basis of the above findings and qualifications:

RESPONSE SURFACE RELATIONSHIP FOR BACKWASH EFFICIENCY AND BACKWASH PRESSURE

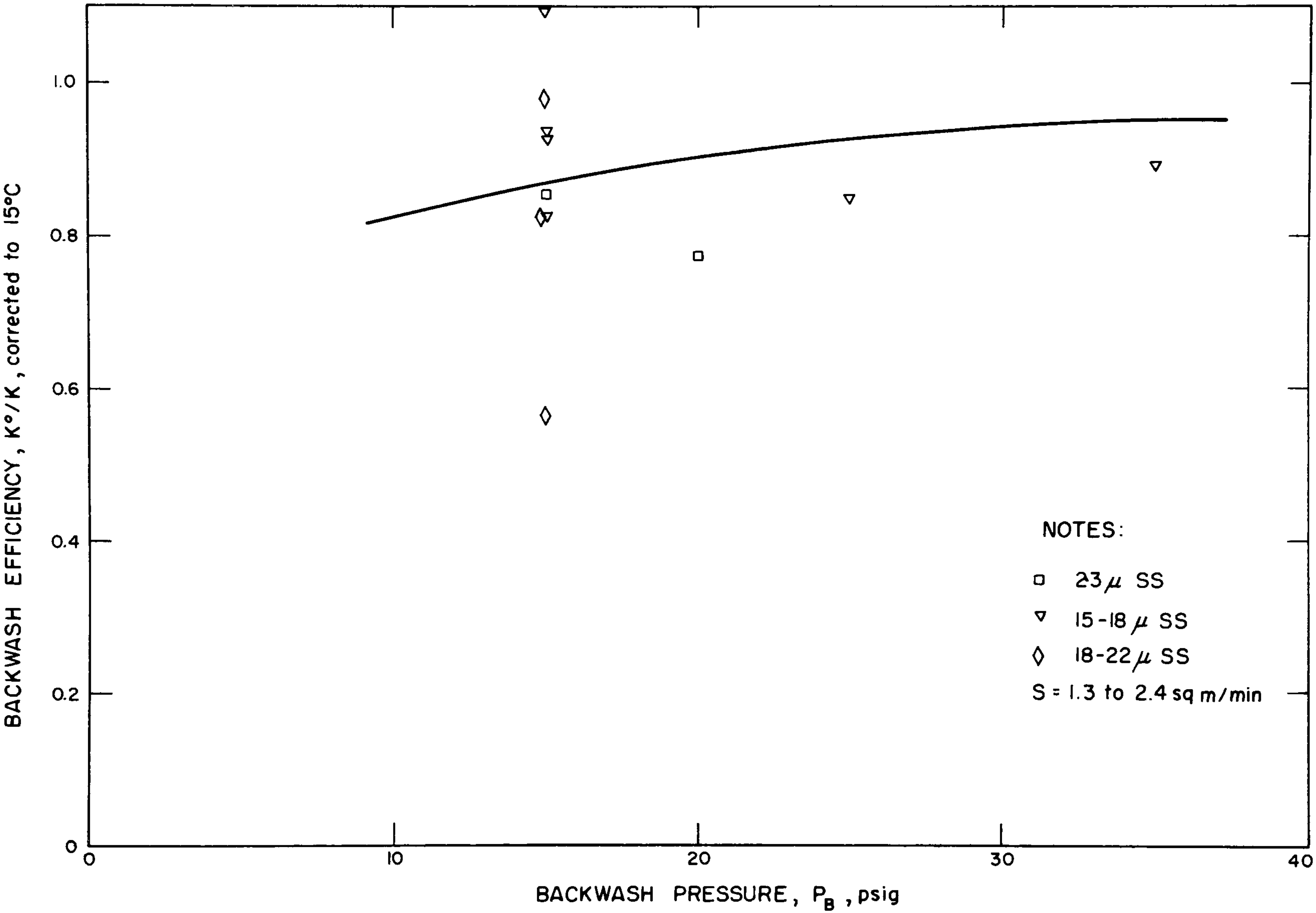


FIGURE 17

(1) With other than the nylon fabric of 10μ NPS, cleaning efficiency was found to increase with increasing NPS to a maximal value of 0.90 to 0.95 at an NPS of 16.5 μ, and then to decrease slightly with increasing NPS.

(2) With stainless steel fabrics, cleaning effeciency was found to increase with increasing speed to a maximal level at or in excess of 0.85 over a range of speeds from 1.3 to 2.4 sq m/min. The lack of data precluded examining the response surface for speeds in excess of 2.4 sq m/min.

(3) With other than the 10μ nylon fabric, cleaning efficiency was found to be independent of backwash pressures in the range of 15 to 35 psig and for a speed range of 1.3 to 2.4 sq m/min.

Relative to the third statement above, the implications of the response surface for recovery of applied as throughput backwash flow are that a saturation with respect to recovery is expected to occur for the pressure range (15 to 35 psig) and speed range (1.3 to 2.4 sq m/min) in which the response surface relating cleaning efficiency and backwash pressure was mapped. If it is assumed that a direct relationship exists between cleaning efficiency and recovery in terms of the variables S and P_B, then it is anticipated that the cleaning efficiency response surface will saturate at a maximal efficiency at increasingly greater backwash pressures as drum speed is increased.

It can be concluded from the foregoing analysis of the backwash subprocess that the efficiency of the subprocess can be described in terms of a multi-dimensional response surface which could be defined in terms of two variables, P_B and S, in the present study. It is apparent from these findings that the region of operation of the backwash subprocess must be selected in consideration of at least these two variables if the performance of the subprocess is to approcah an optimal level.

Yield

Based on the constraints of the physical system used in the investigation, the yield of raw influent wastewater as effluent product water was computed as:

$$Y = \frac{Q_E - Q_W}{Q_E} \qquad (12)$$

where: Q_E = Effluent flow rate, l/min

Q_W = Throughput washwater flow rate, l/min

An empirical correlation curve was developed between Y and Q_E (specific effluent flow rate, l/min - sq m) and is illustrated in Figure 18. The trend of the empirical correlation indicates that the yield increases at a decreasing rate with increasing Q_E from a minimum of 87 percent at Q_E of 90 l/min - sq m to over 98 percent at Q_E of 700 l/min - sq m, and to a saturation value of about 99 percent. About 80 percent of the observations (data points) used in developing the correlation were at yields

RELATIONSHIP BETWEEN YIELD (EFFLUENT BASIS) AND SPECIFIC EFFLUENT FLOW RATE

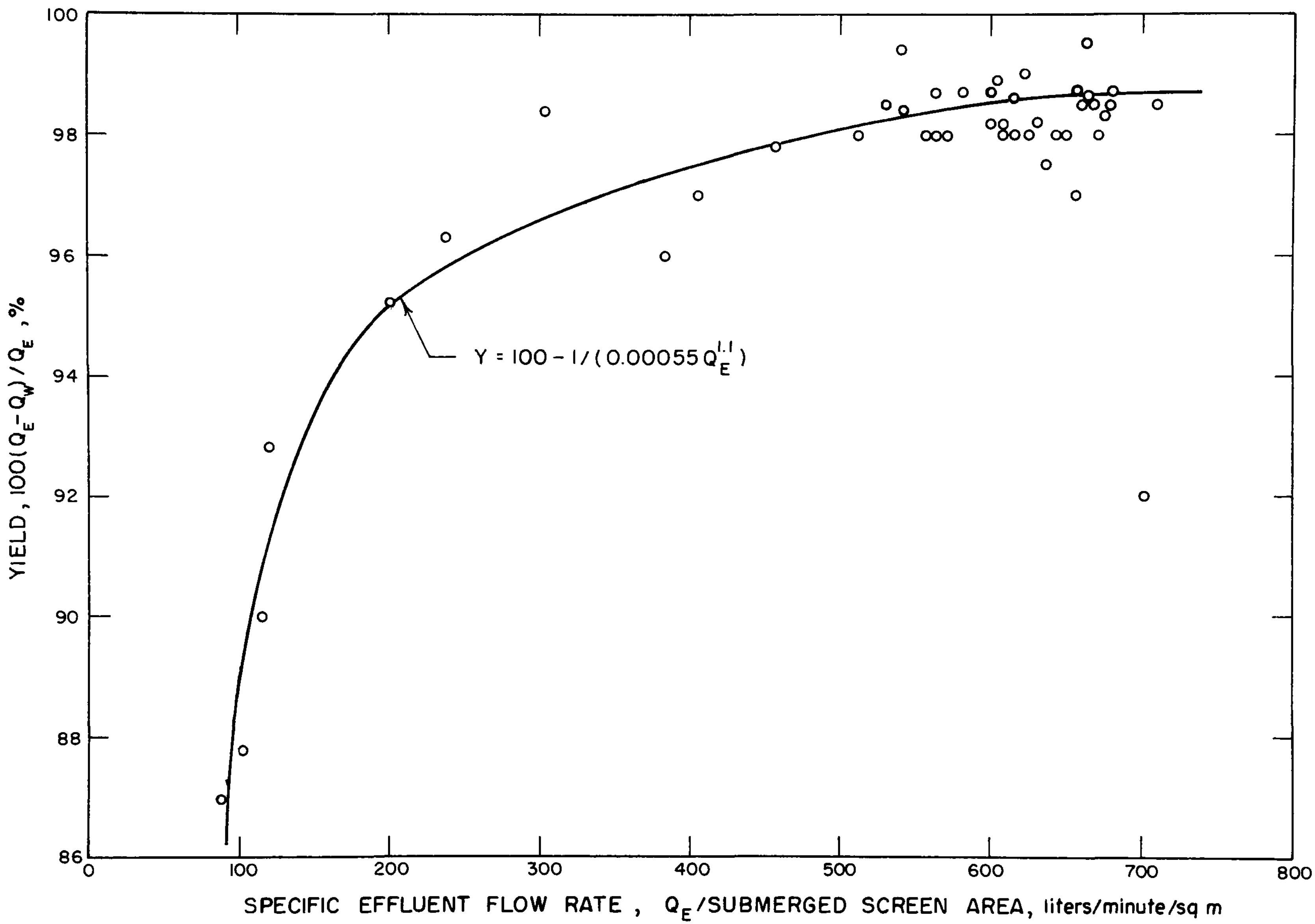


FIGURE 18

equal to or greater than 97 percent. The empirical correlation curve of the yield data can be described by the equation:

$$Y = 100 - 1/_{(0.00055Q_E{}^{1.1})} \qquad (13)$$

Equation 13 was incorporated into the subprogram model as described in Appendix D.

SUMMARY-RESPONSE SURFACES FOR MICROSCREEN PROCESS AS DETERMINED IN THE FIELD STUDY

The response surface relationships describing the field program results were developed in consideration of the implications of the response surfaces developed with the simulation model and an ongoing evaluation of the realities imposed on the study by the physical model (i.e., the pilot plant system). The basic data requirements for development and evolution of the mathematical model required that process behavior be viewed on a steady-state basis. To this end criteria were established for defining quasi-steady-state data. With these criteria and the collected data, over 50 quasi-steady-state data points were defined which were used to analyze process behavior and which, in the analysis, have been treated as representative of microscreen process behavior in the quasi-steady-state mode.

Steady-state data points were obtained for 21 runs with clarified activated sludge effluents, 18 runs with clarified trickling filter effluents, 7 runs with unclarified trickling filter effluents, three runs with primary effluents, and two runs with oxidation pond effluents. Each data point was classified as to influent and drum pool solids concentration and PSD characteristics, and operating variables. The data points were then analyzed within the contexts established for evaluation of the implication of the simulation model and physical/conceptual models of the process. Individual data points were selected from the set of steady-state data points to formulate (map out) the response surface relationships needed for completing model development and implementing model calibration.

The ramifications of these relationships were discussed in Section VI and are summarized below.

Separation Subprocess

The role of the drum pool as a solids concentrator (reservoir) in the microscreen process was defined quantitatively by relating observations on the influent stream solids concentration and PSD characteristics (d and σ_{LOG}) with the corresponding parameters for the drum pool suspension. Within the range of sensitivity of the data it was found that:

(1) The ratio X_P^S/X_I^S (drum pool suspended solids concentration: influent suspended solids concentration) varied independently of backwash pressure variation, but that it increased at an increasing rate in the range 0<S<2 sq m/min, and increased linearly with increasing speed in the range 2<S<4 sq m/min.

(2) The ratio $\bar{d}_P/\bar{d}_I$ mean drum pool particle size: mean influent particle size, in a log-normal PSD) was independent of speed in the range 0<S<4 sq m/min, and decreased by 25 percent as speed was varied from 4 to 8 sq m/min.

(3) The parameter $(\sigma_{LOG-P} - \sigma_{LOG-I})$ (log standard deviation of drum pool PSD - log standard deviation of influent PSD) increased from zero to 0.05 as speed varied from zero to 5 sq m/min, and decreased from 0.05 to 0.30 as speed was varied from 5 to 8 sq m/min.

The evaluation of the trapping efficiency of the separation subprocess was done on a drum pool → effluent basis rather than on an influent → effluent basis in order to view the behavior of mechanisms operative in the separation subprocess across the screen. The field measurements of trapping efficiency were developed on a drum pool → effluent basis. Response surface relationships were mapped from the data set relating trapping efficiency (suspended solids removal efficiency between the drum pool and the effluent) and the PSD characteristics of the suspensions at any given level of solids loading (MI). The shape of these surfaces can be described as:

(1) Trapping efficiency decreasing from maximal levels for σ_{LOG-P} increasing from 1.00 and for NPS/$\bar{d}_P$ (ratio of fabric nominal pore size: mean drum pool particle diameter) increasing from 2 (this portion of the response surface correlating with the predictions of the simulation model).

(2) Trapping efficiency varying inconsistently in the region of the response surface where σ_{LOG-P} was less than 1 and NPS/$\bar{d}_P$ less than 2.

(3) Trapping efficiency decreased at a decreasing rate with increasing solids loading for any given level of NPS/$\bar{d}_P$ and σ_{LOG-P}. The design is that the relationships can be used, in conjunction with the relationship for X_P^S/X_I^S defining the degree of concentration of influent solids in the drum pool, to identify regions of the trapping efficiency relationship in which a microscreen will approach a *zero performance* boundary in any application. That is, it is possible using the above relationships for trapping efficiency to define the combinations of operating variables and solids loading in which the microscreen process has zero performance capability in terms of suspended solids removal on an influent → effluent basis for a given application, given a definition of the PSD characteristics of the solids to be microscreen.

The hydraulic resistance of the solids-screen complex could be measured only on an average (overall-run) basis on the entire screening cycle in the field program. It was not possible, with the information base developed in the study, to characterize the headloss and flow rate profiles at any point across the drum. The data analysis indicated that four discrete response surface relationships could be defined relating the overall-run hydraulic resistance, solids loading, and PSD characteristics, the general trend of the curves being that overall-run hydraulic resistance increased at an increasing rate with increasing MI, and as a function primarily of the wastewater source of the suspension being screened and secondarily of

The PSD characteristics of the suspension. At a solids loading (MI) of 4 gm/sq m, it was found that the hydraulic resistance of screen-solids complexes formed from microscreening of primary effluents and unclarified trickling filter effluents was six to ten-fold greater than the hydraulic resistance of clarified activated sludge and trickling filter effluents, the difference being associated with and manifested by the manner in which the screen-solids complex is formed and passage of water through the interstices occurs.

Transfer and Backwash Subprocesses

The transfer and backwash subprocesses could not be examined discretely in the present study because of constraints imposed by the physical model. Consequently, the major effort was devoted to examining the input/output and cleaning efficiency of the backwash subprocess.

As a result of the data analysis, a generalized response surface was formulated for the backwash subprocess relating cleaning efficiency and operating and experimental variables. Cleaning efficiency was defined as K°/K, or the ratio of the hydraulic resistance of the virgin fabric (head-loss/unit velocity) to that for a panel of backwashed medium removed from the drum; it was assumed that a cleaning efficiency of 100 percent was obtained for a K°/K ratio of 1.0. The generalized response surface can be described as follows:

(1) Cleaning efficiency was found to increase with increasing fabric NPS to a maximal level of 0.90 to 0.95 at an NPS of 16.5, and then to decrease slightly with increasing NPS.

(2) Cleaning efficiency was found to increase with increasing speed to a maximal level at or in excess of 0.85 over a range of speeds from 1.3 to 2.4 sq m/min. The lack of data precluded examining the response surface for speeds in excess of 2.4 sq m/min.

(3) Cleaning efficiency was found to be independent of backwash pressure in the range of 15 to 35 psig and for a speed range of 1.3 to 2.4 sq m/min.

(4) The implication of information acquired on the recovery of applied as throughput backwash flow is that the cleaning efficiency response surface will saturate at a maximal efficiency at increasingly greater backwash pressures as drum speed is increased.

It was concluded from the above findings on the backwash subprocess that the region of operation of the backwash system of a microscreen unit must be selected in consideration of backwash pressure and speed of drum rotation if the performance of the system is to approach an optimal level.

Yield

An empirical correlation was developed between the yield (defined as ratio of effluent product water to influent raw water) and the specific effluent flow rate (q_E, l/min - sq cm). The trend of the correlation was that yield was found to increase at a decreasing rate with increasing specific effluent flow rate, from a minimum observed yield of 87 percent at q_E of 700 l/min - sq cm. About 80 percent of the observations used in developing the correlation curve were at yields equal to or exceeding 97 percent.

Additionally, it was concluded from observation of the physical model that the transfer and backwash subprocesses are the weakest links in the microscreen process. Because microscreen units are designed traditionally as package systems rather than on a situtation-specific basis, both of the above conclusions relate to how microscreen units should be designed, an area of concern presently being dealt with only by the limited number of firms presently manufacturing microscreening equipment.

SECTION VII

DEVELOPMENT OF SUBPROGRAM MODEL

TRADE OFFS AND ASSUMPTIONS OF THE SUBPROGRAM MODEL

Theoretical Structure

A number of decisions were made in extracting a final model version from the complex of constraints and realities. The foremost among these decisions was that of maintaining a theoretical structure as the basis for the model, rather than going to a wholly empirical formulation. The field investigative program results have shown the microscreen to be a process which is variable in nature and very situation-specific; the development of an empirical model formulation from results with these indications would yield no more than an additional small territory on the overall map of process performance. Rather, the maintenance of a theoretical framework and the interpretation of field program results in the light of the theoretical framework are consistent with the investigative context of developing broad delineations of the process maps and providing methodology for transferability of process-related information from one specific context to another.

Steady-State

A further decision in developing the subprogram model was related to the mode of achieving a steady-state model. The "best" model formulation as presently conceived would be time-variant, expressing the feedback relationships in the process; steady-state behavior would be determined by time-averaging. The achievement of such a model formulation, however, was well beyond the scope and intent of the present study. Accordingly, steady-state behavior was modeled by aggregating the transient character of the process to quasi-steady-state behavior at the field program/data base level, rather than by postponing this aggregation and modeling the transient behavior.

Drum Pool Solids Concentration Effect

The phenomenon of drum pool concentration of solids is a composite result of many causes. The resultant composition and concentration of solids in the drum pool is expected to be a result of the mechanisms operative in the turbulent shear of particles, the fall-back of cake, and the splash-over of applied backwash water. A detailed model of such a process, with the purpose of determining solids character and concentration in the drum pool as a function of external gross parameters, would require the time-variant, feedback-type model noted above. The approach taken to quantitatively define the phenomenon of solids concentration in the drum pool was to correlate, empirically, the drum pool solids concentration and PSD characteristics with the corresponging characteristics for the influent suspension and with the drum rotational speed. The rationale associated with this effort was that drum rotational speed was assumed to be a measure of the turbulence, and resultant particle shear occurring in the drum pool, and a measure of the rate of cake erosion and splash-over in the transfer and backwash subprocess. The model, as formulated, thus requires that an influent mean particle size ($\bar{d}_I$) and σ_{LOG-I} be included in DMATX.

The use of an empirical correlation between influent and drum pool solids concentration and characteristics and the drum speed variable integrates, in one step, a number of mechanisms and sub-processes which are operative in the overall microscreen process; in particular, the effects of particle shear and flocculation are thus assumed to have balanced out to a quasi-steady state between the influent character, turbulent shear, splash-over, and fall-back. Having eliminated all these effects in terms of the model, it became possible to maintain the mechanism of the solids separation subprocess as used in the operational model (viz., geometric trapping). Thus, the basic concept of filtration across the drum pool from the theoretic/simulation formulation was retained in the subprogram model formulation, but the identity of influent and drum pool character that was present in the operational model could no longer be held in the subprogram model.

Microscreen performance was found to be sensitive to the parameters $\bar{d}$ and σ_{LOG}, both as predicted in the model and as observed in the field. Given that a good predictive model will be only as good as the input values for these parameters, and that the range of variation of the PSD characteristics for the types of effluent was found to be significant, it is apparent that gross correlations of the PSD characteristics as a function of type of influent source represents a tenuous, if not totally unsatisfactory, approach. Accordingly, no such correlation is included in the subprogram.

Backwash Subprocess

The backwash function is more stochastic than deterministic and appears to be highly situation-specific. Backwash throughput and cleaning efficiency are affected by a number of variables which are inherently undefinable, e.g., the manner of installing the microscreen fabric, which will affect the flexing and stretching behavior of the fabric. Further, the magnitudes of splash-back and splash-over, which are prime determinants in the recovery of applied as throughput backwash flow, will be dependent on the specific design features of the components of the backwash system, etc. Accordingly, a simple, empirical formulation was selected which, though inadequate to model the backwash process at a high level of sophistication, provides the needed input to the overall model at a level of sophistication commensurate with its intended utilization. This choice was made with the recognition that the backwash model used in the subprogram is not to be considered as a definitive statement of the behavior of the backwash process.

Costs of Microscreen Installations and Operation

Ideally, a process performance-cost model should be capable of generating response surfaces relating process performance levels and the least costs necessary to achieve the levels of performance; this type of response surface implies an optimal design procedure has been pursued so that the least cost performance is in fact being obtained. Design flexibility for most sanitary engineering processes, however, is limited by tradition and equipment availability, so that, in general, cost-optimizing choices are possible only within a narrow range, if at all. For the case of the microscreen process, the problem is further compounded by the fact that both design and equipment manufacture rest in the same hands; there is no generally accepted process of microscreen design and cost-estimating, thus the design decision, as noted previously, is generally of a binary (yes or no) type in regards to utilization of a given microscreen at a given cost, all information on design and cost being supplied by the manufacturer. Further, the number of manufacturers of microscreening equipment is presently less than ten, additionally limiting the region of choice and, hence, the potential for optimization of the design of a microscreen installation.

Microscreen units, as supplied, are available only in a discrete number of sizes from the manufacturers. The units built by the different manufacturers are not mutually overlapping as to size, screen-mounting equipment, backwash systems, nominal submerged screen area, and in the manner in which the hydraulic capacity of the units are designated. Thus, the costing problem is further exacerbated by the availability of only discrete cost information for defined types and sizes of microscreen units where, properly, (for modeling purposes) it should be possible to define a continuous cost function (itself optimized for any given microscreen size). Inasmuch as the microscreen manufacturers hold as proprietary the information used for cost-estimating of microscreens, it is not possible to develop such a cost curve independently, except by speculating as to the probable nature of costs incurred. In light of the above, the only course available in the present investigation was to obtain empirical data from manufacturers and generate continuous cost curves as a function of gross parameters. It is recognized that this approach is far from optimizing.

One particular problem which is apparently unique to the microscreen process is that there is a high capital cost associated with material whose expected life is significantly less than that of most other process facilities; i.e., the screening fabric. There is at present no field experience in tertiary treatment applications of sufficiently long duration to give adequate estimates of actual screen life; available information from the manufacturers indicated that a useful life of nine to ten years could be obtained, but these estimates were given without substantiation of actual field observations. The nature of the fabric is such that it is quite susceptible to being rendered useless through mechanical accident, while the chemical characteristics of secondary effluents in some instances will cause continual degradation of the fabric. It was necessary to include cost of fabric replacement as an amortized capital cost; the capital cost of fabric is typically upwards of 50 percent of microscreen capital cost, hence the amortized cost of fabric is a significant part of the total cost of a microscreen, and is sensitive to the assumed screen life.

SUBPROGRAM MODEL ELEMENTS

The above considerations represent the basic trade-offs and assumptions used in developing the various model elements and the over-all structure of the subprogram model. The program is comprised of five basic elements: concentration, trapping, hydraulics, backwash, and cost, each of which is described below.

Concentration

The concentration element is designed to yield drum pool suspended solids concentration and PSD characteristics as a function of influent solids concentration, PSD characteristics, and drum rotational speed. The ratio of drum pool solids concentration to influent solids concentration was derived empirically as a function of drum rotational speed, as were the ratios of mean particle size and standard deviation.

The distribution of particles within the drum pool is assumed to be log-normal by number of particles, and unimodal, and is generated by the computer subprogram as the number of particles in each size class, utilizing the drum pool PSD characteristics and solids concentration for each influent. In terms of the stream vector, it is assumed that the suspended solids parameter and all other parameters associated with suspended solids are concentrated similarly, whereas the concentration of dissolved components remain unchanged as the liquid stream is transferred both into the drum pool and subsequently through the medium into the clear well.

Trapping

The trapping mechanism of the subprogram model is geometric, and is governed by a continuously diminishing "effective trapping diameter". The particles retained upon the cake are those particles whose diameters are greater than the effective trapping diameter. The effective trapping diameter is initially some fraction of the fabric nominal pore size; as the cake is built, the trapping diameter is taken as one-fifth of the 15th percentile diameter of particles in the retained cake layer. This number is assumed to be representative of the pore size of the cake. Mathematically, a variable number of iterations (layers) of cake are used to describe the trapping process; the number of layers utilized depends upon the quantity of particles impinging upon the cake, and is reduced as this quantity increases, so that at each iteration, a layer not more than 50 d_{15} in thickness is built, in order to insure an accurate integration. Continuity between retained, approaching, and passing particles in each size class is used to determine the number of particles in each size class that pass through the cake and screen to the effluent. At each step, the velocity of approach of particles to the cake is determined by the hydraulic mechanism, described below.

Hydraulics

For both trapping and hydraulic consideration, the submerged arc of the drum is treated as being composed of eight radial segments; all calculations are on a unit width basis, and constant head over each segment of the drum arc is assumed. Thus, the throughput will be largest for the entering segment, and lowest at the emerging segment. Inasmuch as the subprogram determines the requisite width of drum as a function of head, rotational speed, and influent flow calculations of throughput are based on an arc of unit width; the total throughput for this arc is then divided into the total required flow capacity, to determine the required number of such arcs of unit width. The throughput for each segment is calculated, and is integrated around the drum to obtain the unit-arc throughput.

The methodology for calculating throughput is based on the calculation of the hydraulic resistance coefficient for the combination of cake and screen. Laboratory experiments early in the project indicated that the assumption of laminar flow through the cake and screen was not wholly justified, hence a quadratic expression of pressure as a function of velocity was utilized. The coefficients are defined by the structure of the cake, and are calculated utilizing a form of the Carmen-Kozeny Relationship for calculating head-loss through mixed beds of particles. As each incremental layer of cake is built in the trapping iteration, the coefficients of the quadratic expression are calculated as functions of the then-current cake particle composition, and the quadratic equation is solved for velocity as a function of the externally defined head on the drum. Thus, both the throughput and the rate at which particles approach the cake are determined for each iteration and for each segment. A running total of the incremental throughput is maintained, and in this manner the total throughput is determined as the sum of the throughput through each segment.

Backwash

A simple, empirical backwash model was selected for use in the subprogram. The parameters which must be determined by the backwash model are the flow rate in the backwash waste stream, and the condition of the fabric at entrance to the drum pool (i.e., at submergence). The concentration of solids in the backwash waste stream is obtained by assuming that all residual solids on the fabric (retained solids less fall-off) are "captured" by the throughput backwash flow (that portion of the applied backwash flow that is transferred to the collection trough). The screen condition at entrance is described by two parameters: The effective trapping diameter, and the hydraulic resistance. The phenomenon of fabric acclimatization has been described previously; it is assumed that any reduction in initial effective pore diameter is due to this acclimatization process, and is independent of backwash. Thus, backwash is assumed to affect only the hydraulic resistance of the screen. Based on an analysis of the backwash process, a typical ratio between clean screen and post-backwashed hydraulic resistance coefficient is 0.85, and this coefficient is taken as constant for all conditions of backwash. An empirical correlation of yield (Y) with specific throughput rate (Q_E) was developed and has been utilized in the backwash model to determine the quantity of backwash flow by back-figuring from the yield, rather than by calculating yield as a function of throughput and backwash.

Cost

Five components of cost were utilized in the subprogram. Capital cost is calculated from manufacturer's data, organized on a cost/submerged screen area basis inasmuch as the required submerged area to pass the flow rate is calculated within the subprogram, and capital cost is based upon this parameter assuming a continuous cost function. Operating, replacement, and maintenance costs are assigned to four areas; fixed cost of operation, variable cost of operation, energy costs, and cost of amortizing fabric replacement. The fixed cost of operation is assumed to be one hour/day, independent of size, on the basis of information provided by manufacturers; a wage cost (CWAGE) of $3.64/hr (Reference 6, 1971) was assumed. The variable cost of operation was assumed to be a function of flow rate, using the relationship as follows:

$$COSTO(N,2) = (38.*(SMATX(2,ISI)**.19))-35.*(CCOST(N,I)*(10^{-3}) \quad (1)$$

Energy cost in kwh were obtained from information provided by manufacturers, and were correlated with submerged area, assuming an average rotational speed of 5 rev/min. This cost was adjusted proportionally for microscreens operating at other rotational speeds. The screen replacement costs were derived assuming an average fabric cost of $60/sq ft, with an optimistic fabric life of nine years at an interest rate of 4.5 percent.

The relationship between cost/unit area and submerged area is illustrated by the data in Figure 19 and Table 7. The curve-fit equation for the model was taken as:

CCOST(N,1) = EFFA*300, dollars/yr (for EFFA greater than 150) (2)

CCOST(N,1) = (3860./SQRT(EFFA)*EFFA, dollars/yr (for EFFA less than or equal to 150) (3)

where: EFFA is the submerged screen area in square feet.

The fixed cost of operation is expressed as:

COSTO (N,1) = 365.*CWAGE, dollars/yr (4)

A relationship for energy costs was obtained from an analysis of data presented in Figure 20, and is expressed as follows:

COSTO(N,3) = 365.*CKWH*(EFFA*.4+12.5)*AFAC, dollars/yr (5)

where: CKWH = the cost in dollars of a kilowatt-hour.

AFAC = the ratio of design rotational speed to 5 rpm.

The screen replacement costs are expressed as:

COSTO(N,4) = 60.*EFFA*.1376/DMATX(3,N), dollars/yr (6)

where DMATX(3,N) is the design submergence factor.

OVER-ALL PROGRAM STRUCTURE

General Features

The subprogram has been developed to be compatible with the EPA Executive Program as a sub-routine, but certain additional options are present so that the subprogram also acts as a simulation model, yielding additional output data on particle size, mass loadings, and parameters for construction of design curves, as an aid to microscreen design and performance description. This option is activated through common argument IS2, the

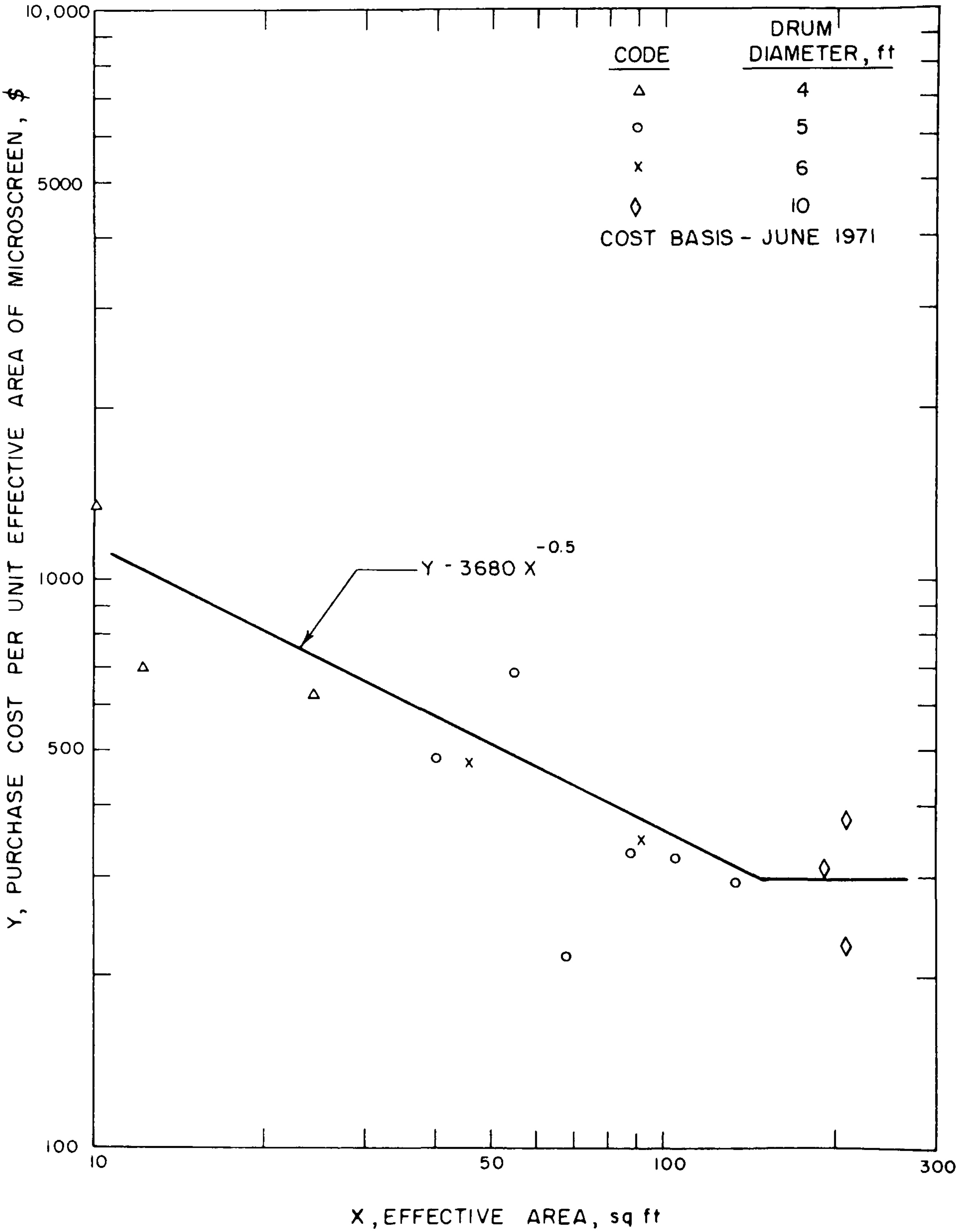
TABLE 7

SUMMARY OF COST DATA

MICROSCREEN MANUFACTURER

Manufac-turer	Size Dia.xWidth	Effective Area (sq ft)	Capital Cost (Feb.1970)	Capital Cost (June 1971) (est.)
A	5x1	13.3	14,000	15,100
	5x3	40	18,000	19,400
	5x5	55	35,000	37,800
	10x10	210	75,000	81,000
B	4x1	9	11,000	11,900
C	5x6	66	13,200	14,300
	5x8	88	28,100	30,400
	5x10	105	31,900	34,500
	5x12	133	36,400	39,300
D	10x10	210	41,600	47,000
E	10x10	190		60,000
	4x4	24		15,000
	6x8	92		35,000
	6x4	46		22,000
	4x2	12		8,500

RELATIONSHIP BETWEEN PURCHASE COST/UNIT EFFECTIVE AREA OF MICROSCREENS AND EFFECTIVE AREA OF MICROSCREEN



DAILY POWER REQUIREMENT PER EFFECTIVE AREA, MICROSCREENS WITH HIGH-PRESSURE SPRAY BACKWASH SYSTEMS

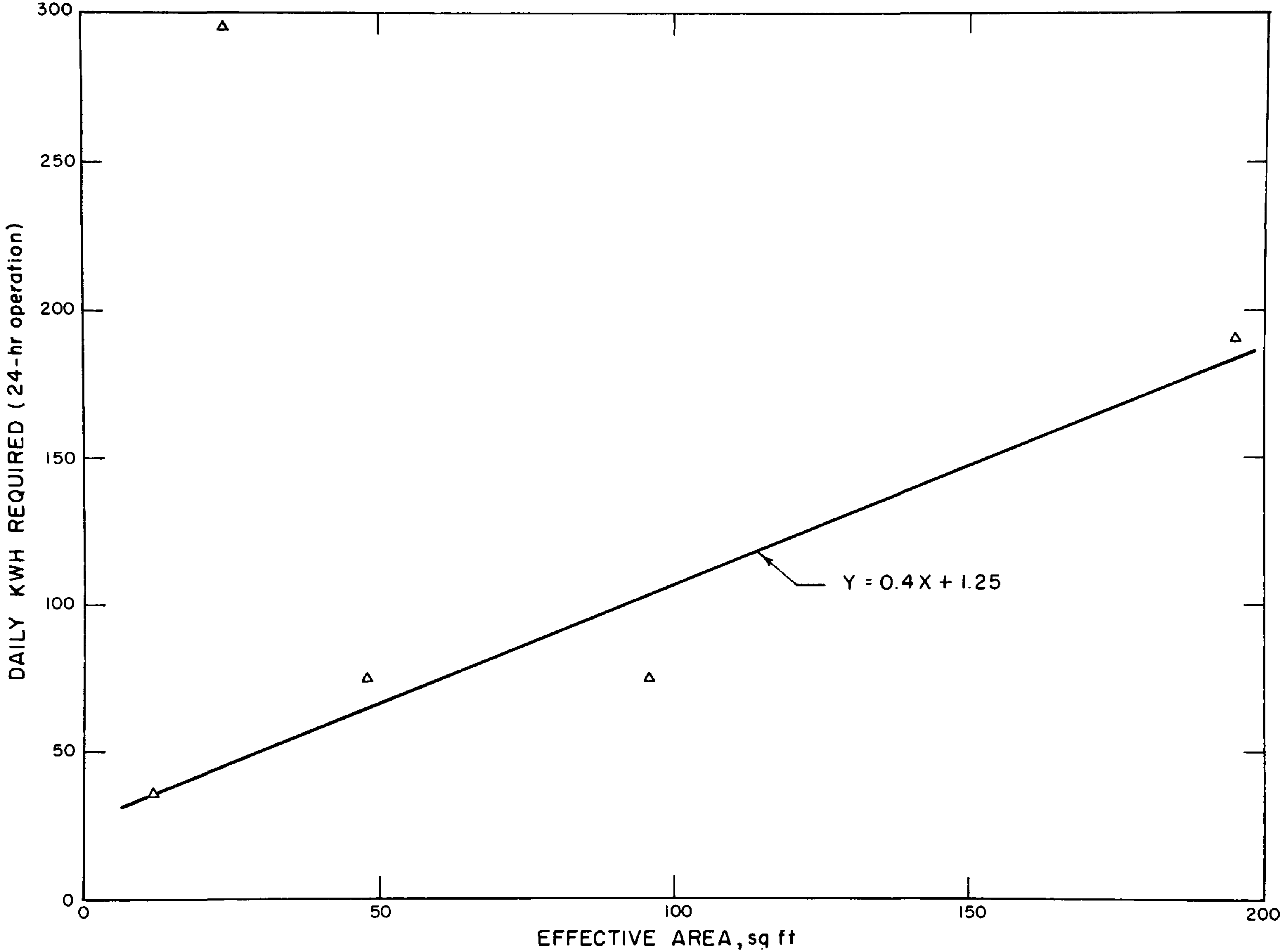


FIGURE 20

stream number of a second input stream, which is not used by the microscreen subprogram. Setting this number to zero produces the additional output printing.

The behavior of the concentration element in the program is such that it can appear that the microscreen is actually generating solids - such behavior was, in fact, observed on an influent/effluent basis in the field in transient behavior. This is a result of the explicit specification of drum pool solids concentration rather than influent concentration in the subprogram model, in lieu of the calculation of drum pool solids concentration through evaluation of the various solids transfers in the process. Thus, a check was placed in the program which automatically sets the effluent solids mass flow rate equal to the influent solids mass flow rate, resulting in zero suspended solids removal efficiency, whenever the combination of input and operating variables and predicted process efficiency is such as to result in a predicted greater effluent mass flow rate relative to influent mass flow rate.

Overall process performance is computed in the subprogram model on the basis of the influent/effluent solids removal efficiency, which is calculated as the ratio of the respective mass flow rates in the influent and effluent streams. After this parameter is calculated, the effluent stream vector is calculated from the influent stream vector by multiplying all particulate species concentrations by this ratio; as noted above, the concentration of dissolved components in the influent stream vector is assumed to remain unchanged by the process and is transferred directly through the process to the effluent stream vector.

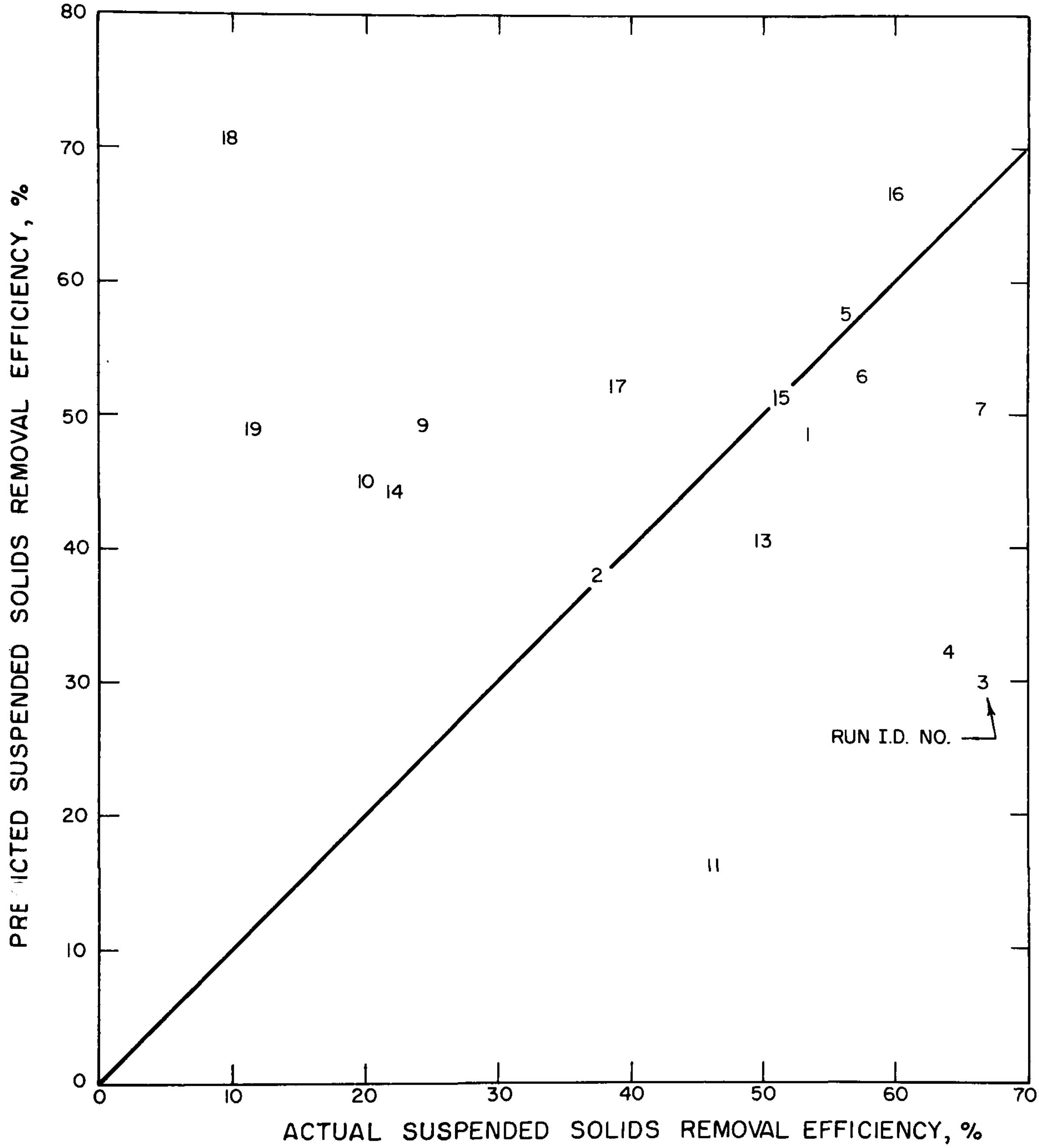
Variable Coefficients

The variable coefficients in the model formulation (eight in number) were originally determined from laboratory experiments with Pelaspan particles (References 3 and 4); for the final formulation, twenty-one steady-state points were utilized and the variable coefficients were modified heuristically until a satisfactory fit of predicted and observed (field) trapping and hydraulic data was obtained.

The results of this process are presented in Figures 21 and 22. In the heuristic fitting process, no distinction was made as to the provenance of the individual test runs, i.e.,the same values of the eight coefficients were applied to all sample points, rather than varying them individually or by groups to obtain "better" fit by"placing each point on the line". With eight variable coefficients, it is possible, by sufficient dissection expostulation, and finagling, with regard to the data points, to put any point anywhere on a given line. In the present case this was not done. The correlation coefficient for the data presented in Figure 21 is 0.192; it is not known whether this is significant for a steady-state predictor of a dynamic process.

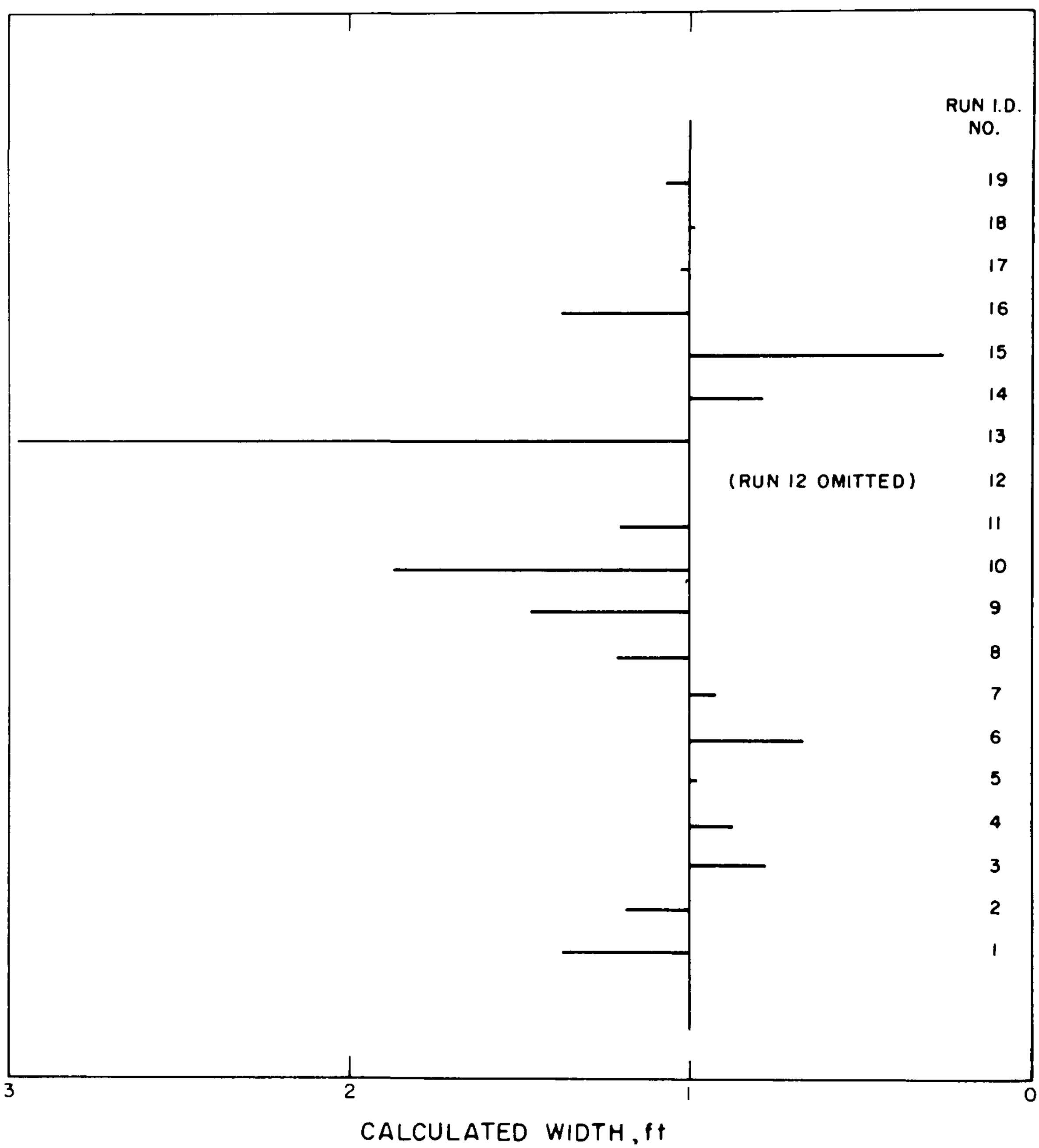
A comparison of predicted vs. actual trapping efficiency across the drum can be made from the data shown in Figure 21. The predicted values were

PREDICTED VS ACTUAL MICROSCREEN SUSPENDED SOLIDS REMOVAL EFFICIENCY ACROSS DRUM POOL TEST RUNS



CORRELATION COEFFICIENT = 0.192

CALCULATE WIDTH OF MICROSCREEN FABRIC
REQUIRED IN TEST RUNS
(ACTUAL WIDTH = 1')



derived on the basis of the actual measured drum pool concentration and PSD characteristics, rather than from the available empirical correlations with the influent concentration and PSD characteristics and drum speed. Test Run No. 12 is not included in the comparison on Figure 21 inasmuch as the solids loading resulted in the computer program exceeding its maximum permissible number of iterations; Test Runs No. 20 and 21, representing oxidation pond effluents, could not be modeled since the particle size as calculated from a log-normal distribution was too small to provide any trapping whatsoever.

A comparison of hydraulic performance of the model relative to the prototype can be made from the data presented in Figure 22, where in the calculated required microscreen width is plotted for each run by identification number. A perfect prediction of hydraulic performance would be a width of one foot, the actual width of the pilot plant drum.

The results of a sensitivity analysis of model predicted performance for variation in drum pool characteristics are shown in Figure 23. In each rosette (constructed for the first seven test run points), each arm represents a 100 percent variation; the vertical axis represents standard deviation. The values shown at the end of each arm represent the percent deviation of the predicted values for the modified condition(s) relative to those predicted for the original condition(s). The upper value at each arm corresponds to percent deviation in trapping efficiency while the lower value indicates the percent deviation in the hydraulics. The results of this sensitivity analysis indicate that the process is largely sensitive to the average drum particle size, a 10 percent variation producing as much as a 20 percent variation in trapping performance. Further,the variations are asymmetrical and depend upon the local position on the response surface; i.e., the sensitivity is dependent on specific local conditions of trapping. An inspection of the original values of $\bar{d}_P$ and σ_{LOG-P} for the seven test points shows that, with the exception ot Test Run No. 1, sensitivity to changes in $\bar{d}_P$ increases with decreasing $\bar{d}_P$, as would be expected. The exception for Test Run No. 1, with its high sensitivity, may be ascribed to the low value σ_{LOG-P} to implying high uniformity of particle sizes and associated higher efficiencies and sensitivities of trapping.

Program Listing

The contents of DMATX and OMATX for the microscreening subprogram are presented in Table 8. The program listing for the sub-program model is presented in Appendix D.

FIGURE 23

SENSITIVITY OF PERFORMANCE TO DRUM POOL CHARACTERISTICS

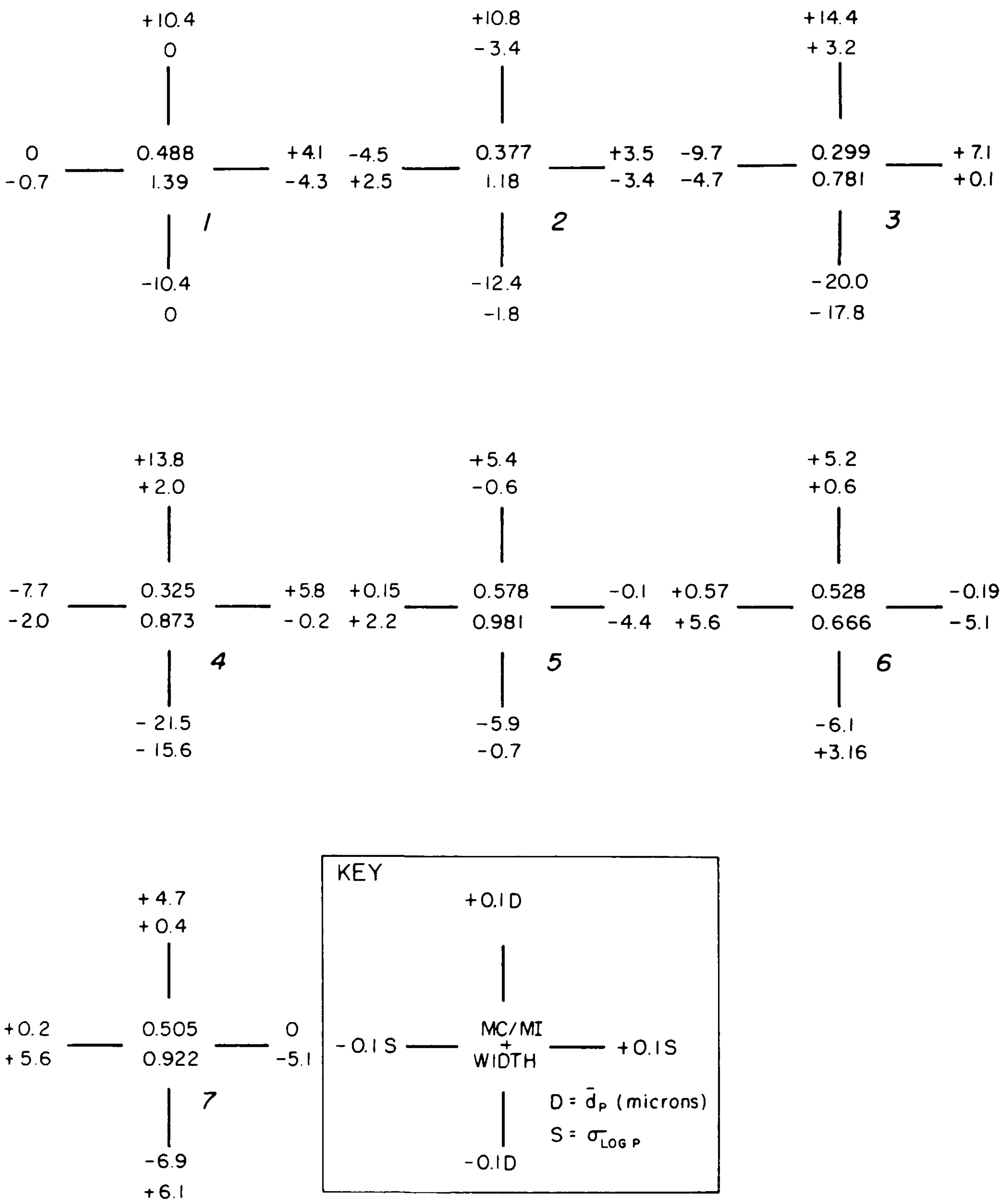


TABLE 8

PROGRAM PARAMETERS

DMATX(1,N) = 1. activated sludge effluent
2. trickling filter effluent
3. primary clarifier effluent
4. oxidation pond effluent

DMATX (2,N) = drum diameter. ft
DMATX (3,N) = submergence %/100
DMATX (4,N) = operating head, inches
DMATX (5,N) = drum speed, rpm
DMATX (6,N) = average nominal fabric pore diameter, microns
DMATX (7,N) = hydraulic resistance coefficient inches of head/gallon per min
DMATX (8,N) = influent mean particle size, microns
DMATX (9,N) = influent σ_{LOG}

OMATX (1,N) = DMATX (2,N)
OMATX (2,N) = DMATX (3,N)
OMATX (3,N) = DMATX (4,N)
OMATX (4,N) = DMATX (5,N)
OMATX (5,N) = DMATX (6,N)
OMATX (6,N) = DMATX (7,N)
OMATX (7,N) = drum width, ft
OMATX (8,N) = solids removed efficiency %/100
OMATX (9,N) = yield, percent
OMATX (10,N) = submerged screen area, sq ft
OMATX (11,N) = efficiency of screening between drum pool and effluent

SECTION VIII

ACKNOWLEDGMENTS

A number of people contributed their efforts to the conduct of the project. Dr. T. G. Shea served as the project manager. Dr. R. M. Males and Mr. M. A. Aaronson developed the mathematical/computer models and assisted in the formulation of the conceptual models. Mr. J. D. Stockton and Mr. J. McGill served as project engineers for the field program and design of the microscreen units respectively. Mrs. Lillian Cors edited and typed the final draft of the project report, which was authored by Drs. Shea and Males. During the course of the study Mr. John Convery and Mr. Joseph Roesler provided valuable input to the project as project officers for the Environmental Protection Agency.

SECTION IX

REFERENCES

1 "State of the Art of the Microscreen Process" report prepared by Engineering-Science, Inc. for Federal Water Quality Administration. July 1970. (Contract 14-12-819).

2 "Theoretical Formulation of Operational Model for Simulation of Microscreen Behavior, Report B-1", prepared by Engineering-Science, Inc. for Federal Water Quality Administration, September 1970. (Contract 14-12-819).

3 "Current State of Operational Model for Simulation of Microscreen Behavior", prepared by Engineering-Science, Inc. for Federal Water Quality Administration, November 1970 (Contract 14-12-819).

4 "Development of Field Data Acquisition Program for Pilot-Scale Microscreens", prepared by Engineering-Science, Inc. for Federal Water Quality Administration, January 1971 (Contract 14-12-819).

5 Lynam, B., Ettelt, G., McAloon, T., "Tertiary Treatment at Metro Chicago by Means of Rapid Sand Filtration and Microstrainers", JWPCF, 41,2, pp 247-279 (February 1969).

6 "Employment and Earning Statistics for United States, 1901-1967. Bulletin 1312-5," prepared by Bureau of Labor Statistics, United States Department of Labor.

Note: References 1 to 4 have been submitted to: Clearinghouse for Federal Scientific and Technologic Information, United States Department of Commerce, Springfield, Virginia 22151.

SECTION X

PUBLICATIONS AND PATENTS

No publications or patents associated with the project have been produced or are pending as of the date of this report.

SECTION XI

GLOSSARY

Symbol	Description	Units
A	Submerged area of screen	Area
BEF	Backwash energy flux	Force/length
$\bar{d}$	Mean particle size of log normal PSD	Length
f	Suspended solids removal efficiency	Unitless
K	Hydraulic resistance of backwashed medium	Length/length/time
K°	Hydraulic resistance of virgin fabric	Length/length/time
MC	Mass of solids retained per unit area over the screening cycle	Mass/area
mi	Cumulative mass loading of solids per unit area periphery	Mass/area
MI	Mass of solids loaded per unit area over the screening cycle	Mass/area
n	Porosity	Dimensionless
NPS	Norminal pore size of fabric	Length
P	Pressure	Force/area
PSD	Particle-size distribution	
q	Unit flow rate	Volume/area-time
Q	Volumetric flow rate	Volume/time
S	Rate of screen presentation	Area/time
$\bar{v}$	Average superficial velocity	Length/time
vc	Cumulative volume of retained solids per unit area	Volume/area
vi	Cumulative volume of influent solids per unit area	Volume/area
X^S	Suspended solids concentration	Mass/volume
Y	Yield	

Symbol	Description	Units
ω	Drum rotational speed	Rev./time
ρ	Mass density of suspended solids in drum pool	Mass/volume
σ	Standard deviation of log-normal PSD	Dimensionless

Subscript	Description
B	Backwash; applied backwash flow
E	Process effluent
E1,E2..E7	Segregated-flow effluent channel
I	Process influent
P	Drum pool
W	Throughput backwash flow

APPENDIX A

DESCRIPTION OF SEWAGE TREATMENT FACILITIES

The pilot microscreen studies were conducted from January to April 1971, at two wastewater treatment facilities located in the San Francisco Bay Area. The San Leandro Water Pollution Control Plant utilizes a dual biological waste treatment system. The facility is equipped with a standard rate activated sludge plant and a high-rate trickling filter facility both used for the treatment of about 8 mgd domestic and industrial wastes. The Concord Water Pollution Control Plant is equipped with a high-rate trickling filter system followed by aerobic ponds, and is used for the treatment of about 5 mgd of domestic and light industrial wastes. Descriptions of each of these facilities are presented in the following sections.

SAN LEANDRO, CALIFORNIA WATER POLLUTION CONTROL PLANT

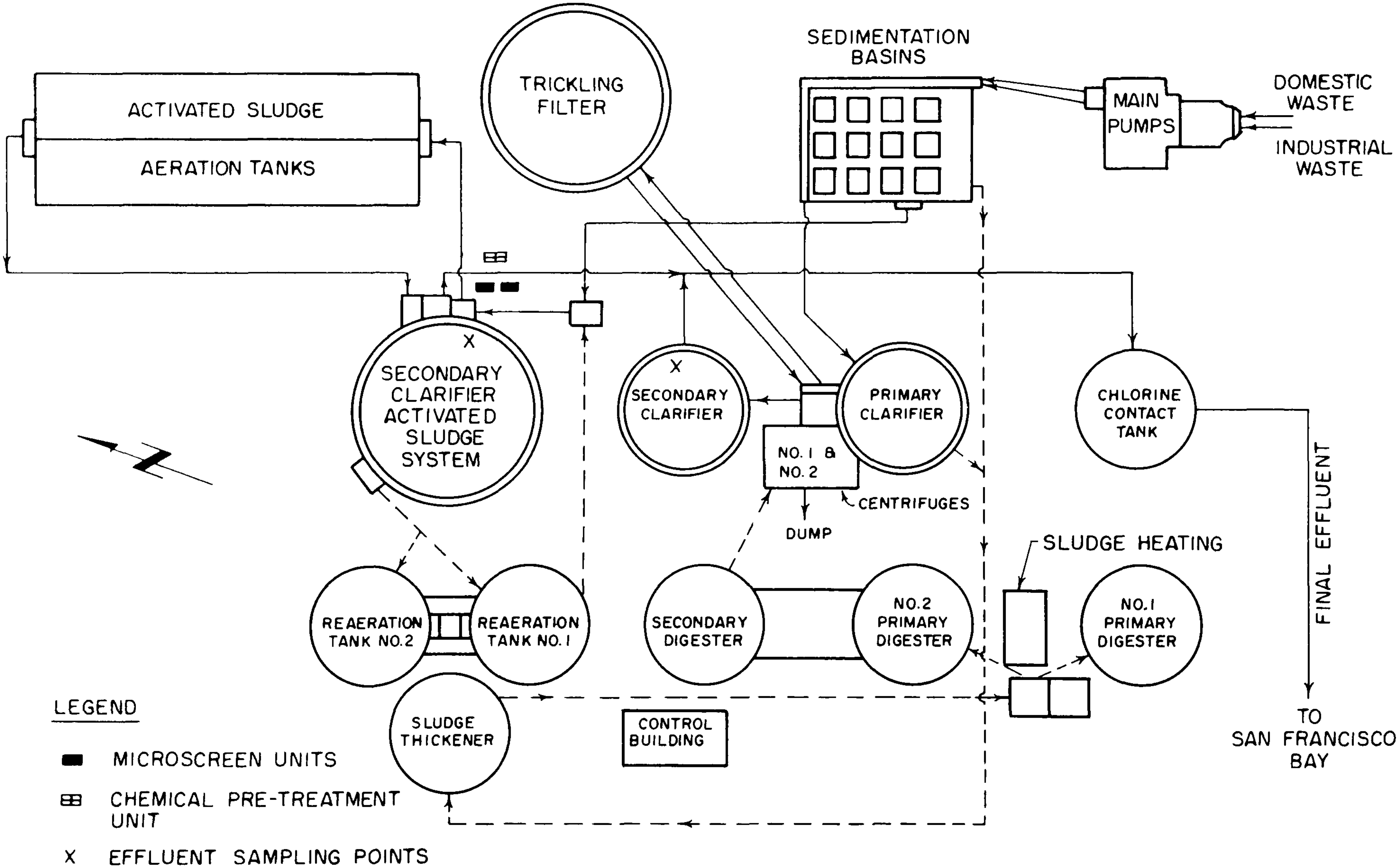
Facility Description

A layout of the treatment facilities at the San Leandro facility is shown in Figure 24. Both domestic and industrial wastes are routed through the sedimentation basins or the primary clarifier before distribution to the activated sludge or trickling filter systems. The microscreen units were located midway between the secondary clarifiers of the activated sludge and trickling filter systems (Figure 24). Clarified effluent was withdrawn alternatively from the clear well of the clarifier of either system, and transferred to the CPU (chemical pretreatment unit) of the pilot microscreen system. The approximate locations of the points of intake of microscreen effluent from either clarifier are also shown in Figure 24.

Performance Characteristics

Because of the small size of the San Leandro facility (8 mgd), the routine monitoring program conducted at the facility is very limited in nature. Influent and clarified effluent suspended solids, BOD_5, settleable solids, and pH characteristics are monitored weekly for both the activated sludge and trickling filter processes. Sludge volume index (SVI) and sludge density index (SDI) are monitored on a daily basis in the activated sludge process. The results of the weekly and daily monitoring programs developed during the six week period of testing are summarized in Tables 9 and 10 respectively. No additional information was available to describe other characteristics of the biological processes at the San Leandro facility; particularly lacking were data on solids concentrations maintained in the aeration tanks and on sludge wastage and recycle rates and concentrations.

During the testing period at San Leandro, the average flow rates to the trickling filter and activated sludge processes were 4.3 mgd and 3.0 mgd, respectively. The hydraulic loading to the trickling filter averaged



FACILITY LAYOUT, SAN LEANDRO, CALIFORNIA, WATER POLLUTION CONTROL PLANT

FIGURE 24

TABLE 9

SUMMARY OF WEEKLY MONITORING DATA DURING PILOT

MICROSCREEN PROGRAM, SAN LEANDRO, CALIFORNIA

LOCATION	WEEKLY SAMPLING DATE	CHARACTERISTICS				
		FLOW, mgd	pH	SETTLEABLE SOLIDS, ml/l	SUSPENDED SOLIDS, mg/l	BOD_5 mg/l
A.S. Infl.	18 February 71	3.8	7.3	8.0	240	363
A.S. Cl. Effl.		-	7.4	0.0	40	15
T.F. Infl		4.1	7.5	3.5	120	255
T.F. Cl. Effl		-	7.4	0.0	48	77
A.S. Infl.	23 February 71	3.2	7.1	10.0	252	420
A.S. Cl. Effl.		-	7.3	0.0	32	58
T.F. Infl.		4.1	6.9	2.6	672	518
T.F. Cl. Effl		-	7.1	0.0	64	165
A.S. Infl.	3 March 71	2.2	6.7	5.0	156	230
A.S. Cl. Effl.		-	6.9	0.0	16	22
T.F. Infl.		4.5	6.8	0.0	188	230
T.F. Cl. Effl		-	6.9	0.0	48	97
A.S. Infl.	11 March 71	2.8	6.8	4.0	244	368
A.S. Cl. Effl.		-	6.9	0.0	16	22
T.F. Infl.		4.4	6.8	8.0	130	350
T.F. Cl. Effl.		-	6.8	0.0	24	106

Notes:
(1) A.S. - Activated sludge
(2) T.F. - Trickling filter
(3) Infl. - Influent
(4) Cl. Effl. - Clarified effluent

TABLE 10

SUMMARY OF DAILY SVI AND SDI DATA

DURING PILOT MICROSCREEN PROGRAM,

ACTIVATED SLUDGE PROCESS

SAN LEANDRO, CALIFORNIA

Date	Characteristics SVI	SDI	Date	Characteristics SVI	SDI
2-14-71	171	0.58	3-1-71	154	0.7
2-15-71	64	1.20	3-2-71	161	0.6
2-16-71	115	0.87	3-3-71	145	0.7
2-17-71	78	1.30	3-4-71	158	0.6
2-18-71	118	0.60	3-5-71	-	-
2-19-71	83	1.20	3-6-71	-	-
2-20-71	121	0.83	3-7-71	-	-
2-21-71	-	-	3-8-71	168	0.6
2-22-71	82	1.20	3-9-71	134	0.7
2-23-71	182	0.5	3-10-71	188	0.5
2-24-71	81	1.2	3-11-71	177	0.6
2-25-71	96	1.0	3-12-71	172	0.6
2-26-71	155	0.6	3-13-71	-	-
2-27-71	96	1.0	3-14-71	156	0.6
2-28-71	132	0.7	3-15-71	182	0.5
			3-16-71	92	1.1
			3-17-71	89	1.1
			3-18-71	181	0.6
			3-19-71	80	1.3

21.6 mgad (million gallons per acre per day) and the BOD_5 loading to the filter averaged 239,000 lb/acre-day, or about 30,000 lb/acre-day/ft of filter depth. The average solids loading to the trickling filter was 198,000 lb/acre-day, or about 25,000 lb/acre-day/ft of filter depth. The BOD_5 removal efficiency averaged 67 percent and the suspended solids removal efficiency averaged 83 percent in the trickling filter system (relative to plant influent) during the test period.

The volume of the activated sludge aeration tank is 84,000 cu ft, which provides a detention time of five hours at a flow rate of 3.0 mgd. The BOD_5 loading to the aeration tank averaged 35,600 lb/day or 420 lb BOD_5/day/1,000 cu ft aeration tank, and the BOD_5 removal efficiency averaged 92 percent relative to plant influent during the test period. The suspended solids loading to the aerator averaged 22,900 lb/day and the suspended solids removal averaged 88 percent during the test period. The SVI of the mixed liquor solids varied from 78 to 182.

The range of suspended solids concentrations in the clarified trickling effluent varied from 34 to 55 mg/l and the suspended solids concentration in the clarified activated sludge effluent varied from 10 to 33 mg/l in the observations made during the test period.

Set-up of Pilot Microscreen System

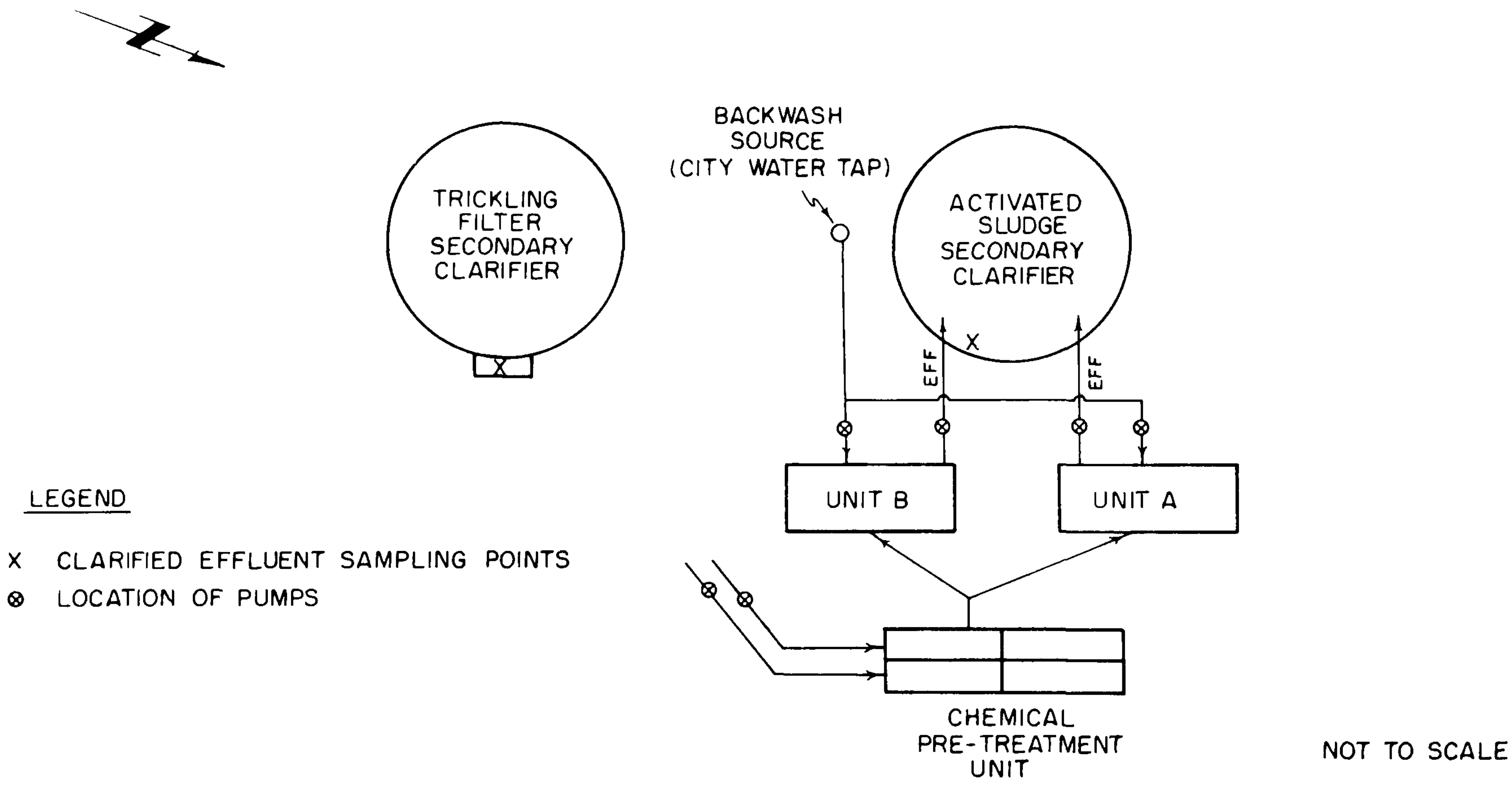
A flow sheet illustrating the set-up of the pilot microscreen system at San Leandro is shown in Figure 25. The chemical pretreatment unit was deployed as a head tank to which either clarified activated sludge or trickling filter effluent was transferred by means of two pumps (each 1 HP Marlow Centrifugal pumps), and from which the wastewaters flowed by gravity to the microscreen units. The flow rate from the head tank to each microscreen unit was regulated independent of that to the other tank by adjusting the height of free discharge from the transfer pipe into the feed well of each microscreen unit. Tap water was used for the backwashing operations in each unit, and the effluents from the microscreens were disposed to the activated sludge secondary clarifier.

CONCORD, CALIFORNIA WATER POLLUTION CONTROL PLANT

Facility Description

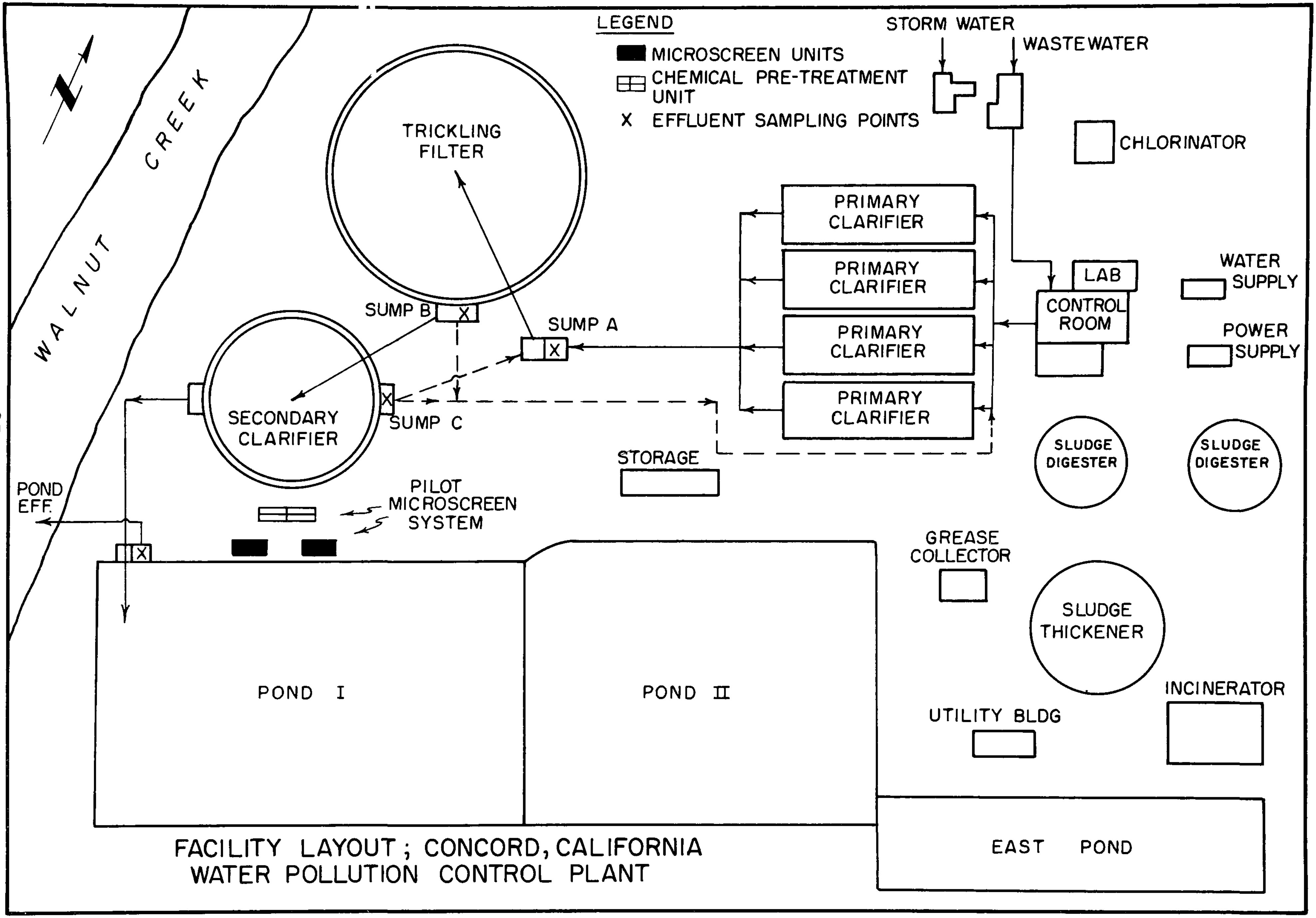
A layout of the treatment facilities at the Concord facility is shown in Figure 26. Raw wastewater entering the plant is passed through the primary sedimentation system (consisting of four clarifiers in parallel) from which it is transferred through a two-section sump (Sump A) into the trickling filter. Primary effluent was withdrawn from the first section of Sump A for use in the microscreen testing.

Clarified trickling filter effluent is recycled to the second section of Sump A, where it is mixed with the primary effluent prior to transfer to the trickling filter. Trickling filter effluent (unclarified) was withdrawn from Sump C for microscreen testing. Effluent from the secondary clarifier is transferred to the oxidation pond system, and oxidation pond



SET-UP OF PILOT MICROSCREEN SYSTEM
SAN LEANDRO, CALIFORNIA, WATER POLLUTION CONTROL PLANT

FIGURE 25



FACILITY LAYOUT; CONCORD, CALIFORNIA WATER POLLUTION CONTROL PLANT

FIGURE 26

effluent was withdrawn for microscreen testing from the outlet sump of the oxidation pond system.

Performance characteristics

The average flow rate to the Concord facility was 5.2 mgd during the March-April testing period, and the daily flow rate during this period varied from 4.9 to 5.6 mgd. Because of the size of the Concord facility, the monitoring programs conducted at the plant are limited in nature. Yearly averaged data (from a monthly sampling program) are presented for BOD_5, suspended solids, settleable solids, and pH in Table 11. On an annual basis, the BOD removal in the trickling filter system averaged in excess of 87 percent and suspended solids removal averaged 85 percent.

Each of the five streams used in the microscreen testing were grab-sampled on 24 March 1971, and the results of analyses of these samples are reported in Table 12. The TSS (suspended solids) concentration at the time of sampling varied from 193 mg/l in the primary effluent to a minimum of 30 mg/l in the clarified trickling filter effluent.

The surface area of the trickling filter is 0.374 acres and the average loading to the filter during the study period was 5.2 mgd, equivalent to 13.9 mgad, or about 3.5 mgd/acre-ft of filter depth. The average BOD_5 loading to the filter was 44,000 lb/day, or 115,000 lb/acre-day. The average suspended solids loading to the trickling filter was 37,000 lb/day, or 100,000 lb/acre-day. During this period, the monthly monitoring data indicated that an average of 82 percent suspended solids removal and 78 percent BOD_5 removal was obtained in the clarified trickling filter effluent relative to that in the plant influent.

Set-up of Pilot Microscreen System

A flow sheet illustrating the set-up of the pilot microscreen system at Concord is shown in Figure 27. The set-up used at Concord was similar to that used at San Leandro in all aspects as described above. The effluents from the microscreen units were disposed to the oxidation pond.

TABLE 11

ANNUAL AVERAGE CHARACTERISTICS OF WASTEWATER STREAMS

CONCORD, CALIFORNIA WATER POLLUTION CONTROL PLANT

Source	Characteristics			
	BOD mg/l	Suspended Solids mg/l	Settleable Solids ml/l	pH
Plant Influent	200-300	235	15-20	7.6
Primary Clarifier	80-100	85	2-10	7.6
Trickling Filter Effluent	47	53	1.5-10	7.9
Clarified Trickling Filter Effluent	27	30	0	7.9
Final Effluent to Creek				
(a) Filtered	9	-	-	-
(b) Unfiltered	13	31	-	10.1

TABLE 12

CHARACTERISTICS OF WASTEWATER STREAMS

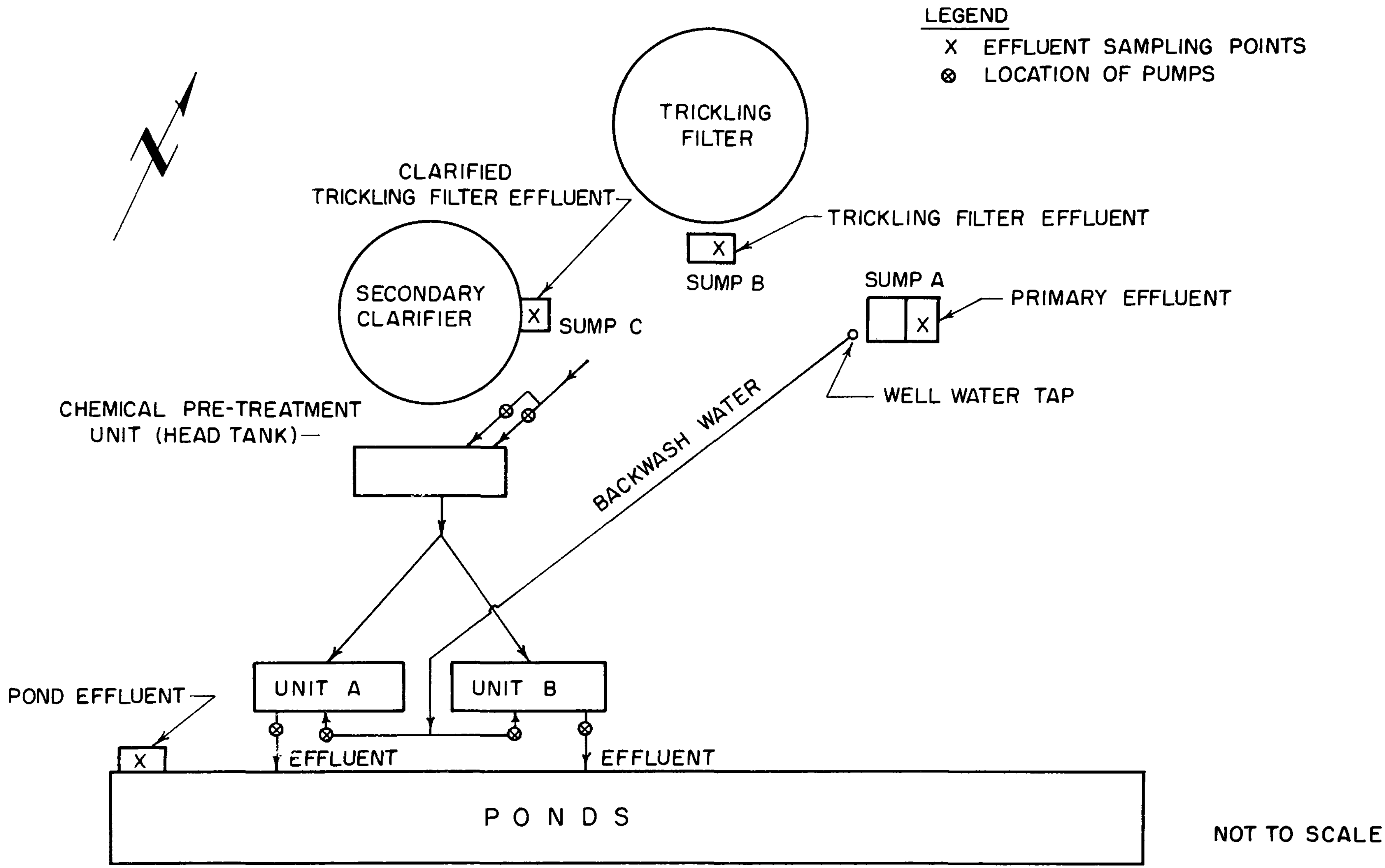
USED AS MICROSCREEN INFLUENTS

CONCORD, CALIFORNIA WATER POLLUTION CONTROL PLANT

(Sampled 24 March 1971)

Source	Characteristics			
	Suspended Solids mg/l	Turbidity JTU	Equivalent Turbidity JTU	pH
Primary Effluent	193	44	47.5	8.2
Trickling Filter Effluent	65	20	27	8.4
Clarified Trickling Filter Effluent	41	14	15	8.5
Oxidation Pond Effluent	57	11	13	10.1
Final Treatment Plant Effluent	65	13	15	10.3

Note: Equivalent turbidity: sample homogenized prior to measurement of turbidity.



SET-UP OF PILOT MICROSCREEN SYSTEM
CONCORD, CALIFORNIA, WATER POLLUTION CONTROL PLANT

FIGURE 27

APPENDIX B

OPERATING AND ANALYTICAL PROCEDURES

An overview of the experimental program was presented in Table 4 (Section V). The operating objectives and procedures and analytical procedures used in the experimental program are described below, using the run designations of Table 4.

OPERATING OBJECTIVES

Fabric Acclimatization (Run 0)

The general objective of the fabric acclimatization run was to establish a time criterion for accomplishing the "break-in" of a microscreen fabric, i.e., to establish the time period required for development of a stable residual solids carryover (after backwash) on an initially virgin fabric. The basic premises of the experiment were that:

(1) Over a period of operating time, there will result an accumulation of debris on the pores of the backwashed fabric.

(2) The level of accumulation will approach stability for a condition of constant drum speed and backwash energy.

(3) The impact of accumulation of solids on the backwashed screen can be assessed by comparing the hydraulic resistance (K) of the backwashed fabric relative to that of the virgin fabric (K^o).

In order to develop a fabric acclimatization criterion, the two microscreen units were operated over an eight-hour time period in a fixed range of headloss values and process flow rates, varying P_B (backwash pressure) and S (drum speed) only as necessary to maintain the headloss in the fixed range. The flow rates and solids transfers in the units were tracked over time. The MTA analysis (described subsequently) was conducted on backwashed screen panels removed from the drum at bi-hourly intervals to determine the hydraulic resistance of the screen on a point-in-time basis.

Long-Term Runs (Runs 1 and 3)

The objective of Runs 1 and 3 was to determine, on a continuous, 24-hour basis, how the microscreen process behaved and how transient variation in .nfluent quality and selected variation of the operating parameters on P_B,S, and total headloss affected process performance (as measured by efficiency of suspended solids removal across the screen). The fundamental understanding of how the variables interacted in the process, to be derived from an analysis of data from these runs, was to be used in the design of specific experimentation in subsequent runs.

The operating protocol for Run 1 was analogous to that of Run 0. During the initial 24-hour run, it was found (because of the combination of fabrics and wastewater sources selected) that it was not possible to achieve a six-inch headloss during the run. For this reason, the operating protocol of Run 3 was revised as follows, in order that a headloss equal to, or greater than, six inches was maintained at all times:

(1) As an initial step, the drum speed was adjusted to increase or decrease H_L, using a drum speed control setting range varying from 20 to 75 percent.

(2) If the above step did not result in maintaining H_L at a level equal to or exceeding six inches, then the backwash pressure (P_B) was adjusted downward as necessary within an operating range of 15 to 30 psig.

(3) As a third measure, the influent flow rate (Q_I) was adjusted as necessary to maintain the desired headloss.

Run 1 was conducted over the 24-hour operating period as originally planned. However, it was necessary to terminate Run 3 after 12 hours of running time due to failure of a facility pump supplying the influent stream to the head tank unit (HTU).

Backwash Subprocess Run (Run 2)

The overall objectiv e of Run 2 was to describe the effect of varying the drum speed and the backwash pressure P_B alternatively on the hydraulic resistance of a panel of the backwashed medium (fabric-residual solids complex) as removed from the drum. A specific objective of the run was to document the response surfaces relating each parameter with the cleaning efficiency as measured by the ratio of the virgin fabric hydraulic resistance (K^o) and the backwashed medium hydraulic resistance (K), i.e., defining cleaning efficiency as equal to K^o/K.

The operating approach entailed the following steps:

(1) A headloss range of six to eight inches was maintained for both units; Unit A was operated at a constant backwash pressure of 25 psig and Unit B at a constant specific backwash rate of two liters/min per sq m/min of drum speed.

(2) In Unit A, process performance and the hydraulic resistance of a panel of backwashed medium was assessed after operation for one or two-hour time periods at drum speeds of 3.9, 7.3, 10.2, and 12.7 rev/min.

(3) In Unit B, process performance and the hydraulic resistance of the backwashed screen panel was assessed after operation for one or two-hour periods of operation at backwash pressures and drum speeds as follows:

(a) P_B, 10 psig (main header; drum speed, 4.0 rev/min
(b) P_B, 20 psig (main header); drum speed, 6.1 rev/min
(c) P_B, 20 psig (main and auxiliary headers; 10.3 rev/min
(d) P_B, 35 psig (main header); drum speed, 8.8 rev/min

Runs 5 to 15

The overall objective of these runs was to extend the applicability of the response surface relationships developed in Runs 0 to 4 by operations with a diversity of process influents and the available selection of microscreen fabrics. The operating approach used in these runs was developed as a result of experience acquired in Runs 0 to 4, and consisted of the following:

(1) The basic operating objective of the approach was to maintain a constant P_B (backwash pressure), during the entirety of a 2-hour subrun (three subruns per run).

(2) In order to maintain a constant P_B level, the initial subrun values of Q_I and S (drum speed) were selected to provide a headloss equal to, or greater than, six inches throughout the subrun.

(3) A different value of P_B was used during each of the three subruns in the run, and S was adjusted as necessary to maintain a headloss equal to, or greater then, six inches.

Runs 16 and 17

The overall objective of Runs 16 and 17 was to investigate process performance in either of two ways:

(1) Run 16 (using Mode A) to assess the relationship between process efficiency and MI (solids loading, mass suspended solids loaded on the fabric/unit area of fabric) at a constant $\bar{d}_p$ (median particle size of the suspended solids concentration in the drum pool).

(2) Run 17 (using Mode B) to assess the relationship between process efficiency and $\bar{d}_p$ at a constant value of MI.

The operating approach for Run 16 was to conduct a sequence of microscreen subruns, each using a successive dilution of HTU effluent as an influent stream. The HTU effluent was diluted with tap water and the solids concentration in the diluted stream was maintained constant during each subrun by continuously adjusting (as necessary) the flow rate of tap water into the HTU effluent. The solids concentration of the diluted stream was measured on a real-time basis using the homogenized-sample optical density analysis discussed below. The control variables P_B, S, and Q_I were maintained constant during the run.

The operating approach used in the conduct of Run 17 was based on using Unit A to generate a throughput washwater stream in which the particle size distribution of the suspended solids could be controlled, and to use this stream to adjust the particle size characteristics of the influent stream to Unit B. The median particle size of the throughput backwash stream from Unit A was adjusted from subrun to subrun by varying the fabric used in the microscreen in each subrun. The solids concentration of the combined stream (which comprised the influent to Unit B) was held constant throughout all of the subruns by continuously adjusting the flow rate of the HTU effluent. The solids concentration of the combined stream was measured on a real-time basis using the homogenized-sample optical density analysis. The control variables P_B, S, and Q_I were maintained constant during the run.

Operating Procedures

The operating protocols for the experimental program were based on the subrun, or unit of work in which all control variables were held constant for a defined time period while process performance was being monitored. As a general rule a run was comprised of three two-hour subruns, during which the monitoring and analytical activities outlined in Table 13 were conducted. The activities conducted in each subrun included the following:

(1) Development of two-hour composite samples of influent, effluent, and throughput washwater, to permit an assessment of the process efficiency.

(2) Measurement of the optical density (OD) of homogenized samples of influent, drum pool, and effluent, and the throughput washwater streams at hourly intervals.

(3) Measurement of the particle size distribution (PSD) of samples from the drum pool at hourly intervals and from the effluent collector at bi-hourly intervals. The optical density data were converted to values of total suspended solids using correlation curves relating OD and TSS as developed on an ongoing basis during the field program. Upon completion of the subrun, a panel of backwashed medium was removed from the drum and subjected to the MTA analysis for measurement of the hydraulic resistance (K) of the backwashed medium.

Analytical Techniques

The analytical techniques used in the experimental program were, with exception of the MTA, PSD, and homogenized optical density analyses, performed as described in *"Standard Methods for Analysis of Water and Wastewater", 13th Edition.*

MTA Analysis

The MTA (Medium Testing Apparatus) analysis was developed to permit measurement of the hydraulic resistance of panels of microscreen fabric under steady flow conditions. The MTA is shown in Figures 28 and 29, and is designed to permit the continuous flow of filtered water from a head tank into a test head and through the fabric panel. The MTA was used in the experimental program both with virgin fabrics and backwashed fabrics removed from the microscreen unit during experimentation. The hydraulic resistance was measured as the slope of the headloss vs. superficial velocity curve (units of cm per cm/sec at 15° C), and was designated by the symbols K° for virgin fabrics and K for backwashed fabrics.

In the MTA test procedure, the panel of fabric to be tested was loaded into the pilot-scale MTA by clamping the panel to the support bar shown in Figure 28. The test head could be moved laterally and the support

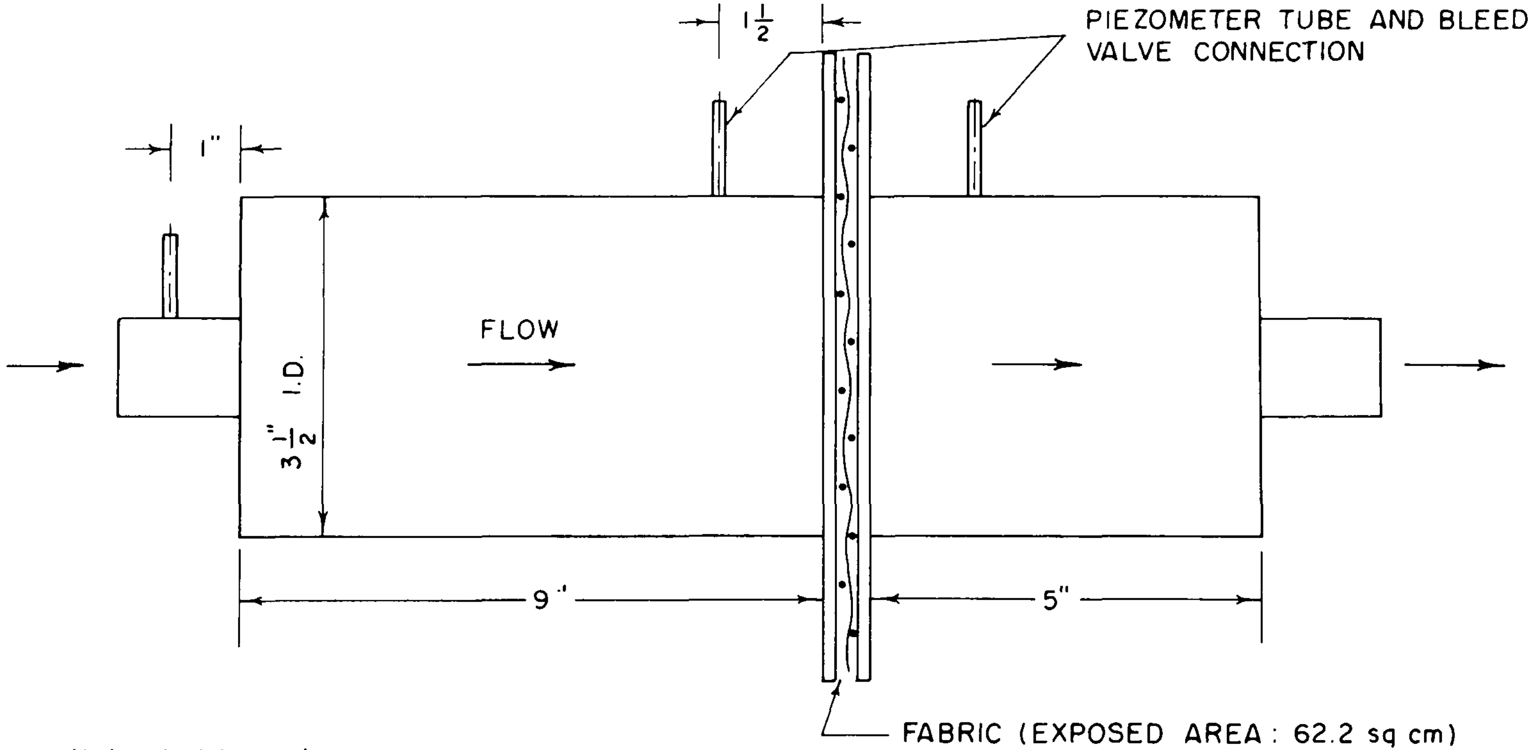
TABLE 13

SUBRUN OPERATING SCHEDULE

SUBRUN TIME (minutes)	SAMPLING POINT AND ANALYSES			ACTIVITY
	PSD	OD	TSS (2-hr comp)	
0	-	-	I, E, W	Start subrun
30	P, E	I, P, E, W	I, E, W	-
60	-	-	I, E, W	Monitor headlosses, P_B, and S at half-hourly intervals
90	P, E	I, P, E, W	I, E, W	-
120	-	-	I, E, W	Stop subrun; remove screen panel and start MTA analysis

Symbols: I = Influent
P = Drum pool
E = Effluent
W = Throughput backwash flow
PSD = Particle size distribution
OD = Optical density
TSS = Total suspended solids concentration

MTA TEST HEAD

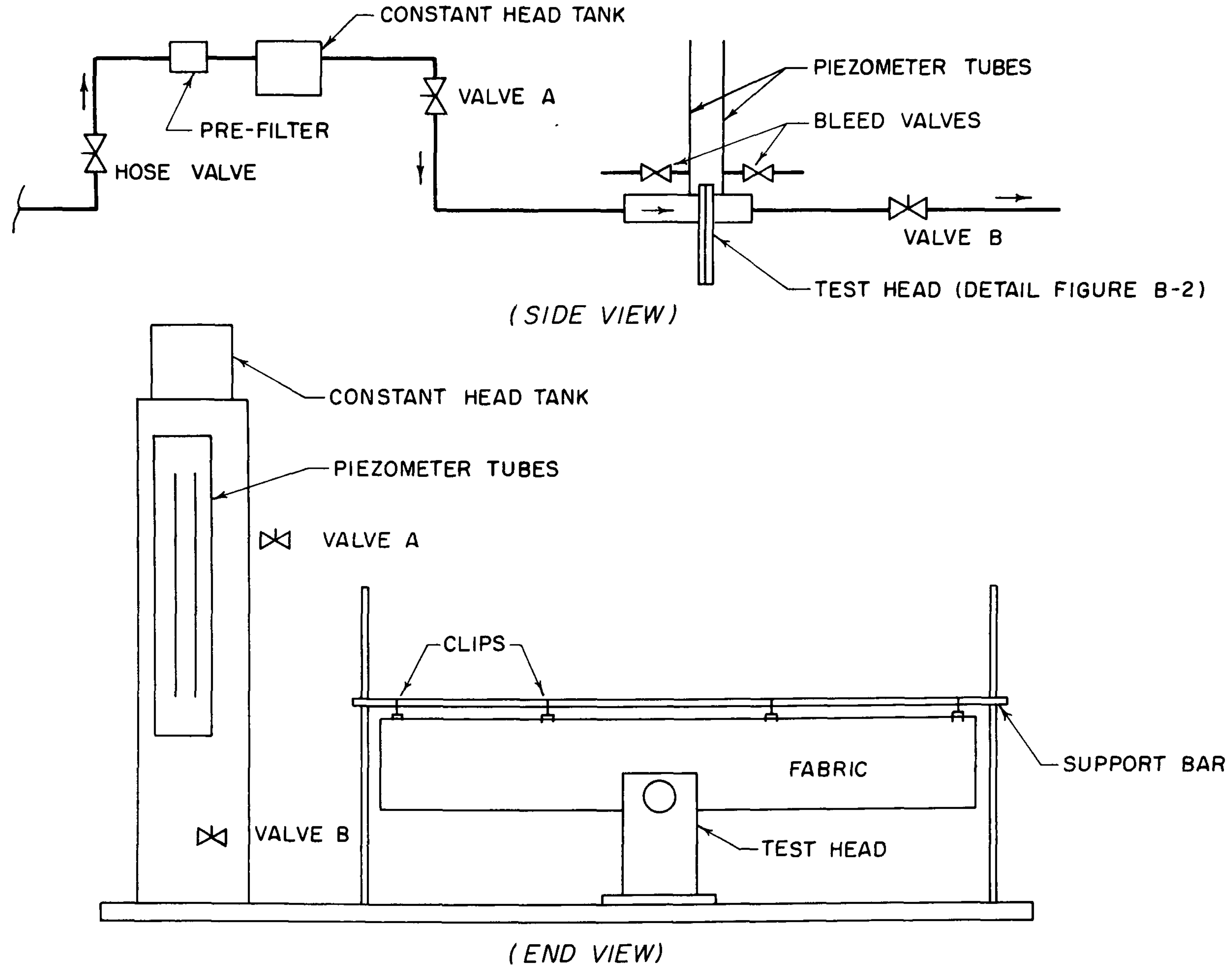


Note: Not to scale

FIGURE 28

FIGURE 29

P .OT-SCALE MEDIUM TESTING APPARATUS (MTA)



bar vertically so that the test head could be located at any point on the attached panel. After the test head had been located, the fabric was pulled taut and the test head clamped over the fabric using C-clamps.

The test head is the key element in the MTA and consists of a 3-1/2 inch ID (internal diameter) lucite column with a cross-sectional area of 62.2 sq cm. The 3-1/2 inch ID span across the test head was similar to the span between the peripheral bands on the drums of the pilot microscreen units; as was the case in the pilot units, no fabric supports were used to minimize deflection or stretching of the fabric caused by the movement of water through the test head.

The hydraulic components of the MTA include; a pre-filter, constant head tank, valves, and piezometer tubes as shown in Figures 28 and 29. Water was introduced to the MTA by filling the head tank through the hose valve with all other valves closed. The test head was then filled by opening the bleed valves and Valve A slowly, releasing all trapped air from the system between the head tank and the test head. At this point, the bleed valves were closed and air was purged from the piezometer tubes to complete preparation of the unit for a test run.

A test run was conducted by adjusting the flow rate through the test head with Valves A and B to attain a desired differential head-loss across the fabric. The discharge rate through the test head was measured with a bucket-stopwatch procedure, and the superficial velocity was determined by dividing the average flow rate by the exposed fabric area. The MTA was shut down by reversal of the above procedure.

Particle Size Distribution

The particle size distribution (PSD) analysis was conducted using the techniques of photomicroscopy to record the presence of microscopic-sized particles on slides, and statistical counting and plotting techniques to develop and describe the particle size distribution characteristics of the sample suspension. The photomicroscopic technique (using a Polaroid Camera) was adapted after several alternatives were explored for the following reasons:

(1) The technique permitted the direct observation of the particles being recorded.

(2) Microphotography precluded the necessity of measuring individual particle size and count at the time of observation, reducing the time of direct observation.

(3) The quality of photography could be checked immediately after the particles were photographed.

A statistical analysis was conducted with sets of photomicrographs of several samples to assess the minimum number of particles that should be counted to ensure that a representative particle size distribution was obtained. It was observed that counts in excess of 300 particles per individual sample did not increase the precision of the analysis as measured by the coefficient of variation of the median particle size of the PSD (which was found to be log-normal for all suspensions observed in the present study). On this basis the criterion was established that a minimum of 300 particles should be counted per individual sample, requiring that from three to ten individual photomicrographs be taken of each sample.

The basic equipment and materials used in the PSD analysis consisted of:

(1) Tiyoda R Microscope

(2) Tiyoda Microscope Light Source

(3) Polaroid Camera and Olympus PN-P camera/microscope attachment

(4) No. 10F/3,000 speed Polaroid film (black and white)

It was found that the best photomicrographs were obtained at a shutter speed of 1/100 second, a microscope light setting of 5 to 6 volts, and a lens adjustment of 40x or 100x.

The photomicroscopic procedure entailed the following basic steps:

(1) Mount sample of suspension on glass slide and cover with cover slip.

(2) Scan sample at 40x lens adjustment to define the distribution of particles on the slide.

(3) Conduct photomicrography sequence to record a minimum of 300 particles; prepare a log identifying each photomicrograph, and identify on the Polaroid print all particles seen in the microscope.

The number and size of individual particles on each photomicrograph were observed using a scaled circle template and magnifying glass. The particle size was taken as the maximum particle dimension, and the particle counts were arranged into a frequency-particle size data set from which probability plots could be made and the parameters of the PSD (median particle size and standard deviation) ascertained.

Homogenized-Sample Optical Density

The homogenized-sample optical density analysis was done to provide a real time method for tracking the concentration of particulate matter in the influent and effluent streams of the microscreen during a subrun. The sample was first homogenized over a standard two-minute time interval to normalize the particle-size distribution of the suspension, after which the sample was allowed to stand for five minutes to release air entrained during the homogenization. After completion of these steps the optical density of the sample was determined and, by means of a correlation curve relating the optical density and total suspended solids (TSS) concentration, the TSS concentration of the individual sample was estimated.

APPENDIX C

FIELD PROGRAM BASIC DATA

TABLE 14

INDIVIDUAL MICROSCREEN RUN DATA

(Run 1 Unit A)

Time	X_P^S (mg/ℓ)	Q_I (ℓ/min)	X_E^S (mg/ℓ)	Q_E (ℓ/min)	S (sq m/min)	MI (mg/sq m)	MC (mg/sq m)	MC/MI (%)	$\bar{d}_P$ (μ)	P_B (psig)	K (sec)
0930	52	232	22	236	2.72	4,430	2,530	56.9	8.6	10	
1000	45	236	19	240	2.72	3,910	2,230	57.0		10	
1100	169	221	18	225	2.72	13,750	12,250	89.2		10	
1200	44	216	20	220	2.72	3,500	1,880	53.7		10	
1300	59	244	30	248	2.72	5,250	2,510	47.8		10	
1400	106	102	43	108	3.1	3,480	2.000	57.4		12	
1510	97	90	-	102	6.3		-	-		35	
1530	-	-	-	-	-	-		-	8.1	30	
1600	153	110	65	119	4.8	3,510	1,900	54.0		24	
1700	59	195	30	204	4.8	2,380	1,130	47.5		16	
1800	93	167	24	180	8.8	1,750	1,270	72.2		30	
1900	79	167	20	181	6.65	1,990	1,450	73.0		17	2.21
2000	-	-	-	-	-	-	-	-			
2100	45	216	20	221	2.32	4,180	2,620	62.6		10	
2130	38	223	18	228	1.36	6,230	3,220	51.7	5.5	10	
2220	33	233	18	237	1.36	5,670	2,520	44.5		10	
2300	34	227	16	231	1.36	5,680	2,950	51.9		10	
2400	32	222	14	226	1.36	5,150	2,820	54.8		10	
0100	33	220	14	224	1.36	5,340	3,030	56.7		10	
0200	32	239	14	243	1.36	5,540	3,040	54.8		10	
0300	37	239	18	243	1.36	6,500	3,280	50.0		10	
0330	55	186	20	201	3.84	3,940	2,890	73.3	4.3	23	
0400	47	221	18	225	2.08	5,000	3,050	61.0		19	
0500	43	216	13	221	1.76	5,270	3,060	58.2		16	
0600	46	226	20	233	2.96	3,510	1,930	55.0		32	
0700	50	215	18	220	2.08	5,100	3,200	62.7		20	3.36
0800	50	202	20	208	2.08	4,800	2,800	58.2		20	
0900	33	218	13	224	2.08	3,460	2,060	59.5		20	
0930	32	214	12	220	2.08	3,240	1,970	60.8		20	

TIME AVERAGES

Time	MI	MC	MC/MI	
0930 - 1510	5,720	3,900	67.9	6-hourly
1530 - 2100	2,760	1,670	60.3	6-hourly
2130 - 0300	5,730	2,980	51.9	6-hourly
0330 0930	4,290	2,620	61.2	6-hourly
0930 0930	4,910	2,830	57.6	

Notes:

1. Clarified Activated Sludge Effluent (San Leandro)
2. Date: 19 and 20 February 1971
3. Screen: 30μ SS
4. K° = 0.59 sec.
5. Total Screen Area: 0.8 sq.m.

TABLE 15

INDIVIDUAL MICROSCREEN RUN DATA

(Run 1 - Unit B)

Time	X_P^S (mg/ℓ)	Q_I (ℓ/min)	X_E^S (mg/ℓ)	QE (ℓ/min)	S (sq m/ min)	MI (mg/ sq m)	MC (mg/ sq m)	MC/MI (%)	$\bar{d}_P$ (μ)	P_B (psig)	K (sec)
0930											
1030	41	167	12	171	3.13	2,180	1,520	70.2		9	
1130	46	162	16	166	3.13	1,465	625	42.6		9	
1230	45	162	16	166	3.13	2,340	1,495	64.1		9	
1330	124	107	30	122	7.84	1,695	1,230	72.7		19	
1430	522	54	57	70	7.84	3,590	3,085	85.8		19	
1530	858	34	73	51	8.44	3,470	3,028	87.1	6.0	21	
1630	167	87	49	95	6.58	2,200	1,490	67.8		33	
1730	76.5	175	22	185	4.90	2,740	1,900	69.2		20	
1830	45	227	16	232	3.87	2,650	1,690	63.9		18	3.59
1930	-	-	-		-	-	-	-			
2030	43	250	16	254	3.87	2,775	1,720	61.9		14	
2130	-		-		-	-	-	-			
2230	38	-	15	-		-	-	-		10	
2330	34	252	12	256	2.17	3,910	2,480	63.4		10	
0030	32	239	12	244	2.17	3,530	2,180	61.8		10	
0130	34	250	12	256	2.49	3,360	2,120	63.2		13	
0230	32	309	11	320	3.69	2,700	1,740	64.2		24	
0330	54	217	16	225	3.69	3,200	1,960	61.3	5.1	24	
0430	47	227	11	234	3.69	2,920	1,930	66.1		24	
0530	50	212	16	219	3.69	2,860	1,890	66.1		24	
0630	59	230	15	243	5.73	2,340	1,710	73.2		20	
0730	50	233	12	246	5.73	2,000	1,490	74.5		20	5.30
0830	59	234	15	248	5.73	2,380	1,740	73.1		20	
0930	38	247	10	260	5.73	1,650	1,210	75.3	5.7	20	

TIME AVERAGES

Time	MI	MC	MC/MI	
0930 - 1530	2,460	1,830	74.6	6-hourly
1630 - 2130	2,590	1,700	65.6	6-hourly
2230 0330	3,340	2,100	62.9	6-hourly
0430 - 0930	2,360	1,660	70.4	6-hourly
0930 - 0930	2,660	1,820	68.3	24-hourly

Notes:

1. Clarified Activated Sludge Effluent (San Leandro)
2. Date: 19 and 20 February 1971
3. Screen: 21μ SS
4. K° = 1.35 sec
5. Total screen area: 0.8 sq m

TABLE 16

INDIVIDUAL MICROSCREEN RUN DATA

(Run 3 - Unit A)

Time	X_P^S (mg/ℓ)	Q_I (ℓ/min)	X_E^S (mg/ℓ)	Q_E (ℓ/min)	S (sq m/ min)	MI (mg/ sq m)	MC (mg/ sq m)	MC/MI (%)			
1200	108	159	63	163	1.6	10,720	4,370	41.0			
1230	113	227	77	231	1.6	15,900	4,750	29.9			
1300	110	234	73	238	1.6	16,000	5,170	32.4			
1330	110	211	75	214	1.6	14,500	4,460	30.8			
1400	113	230	84	233	1.6	16,200	3,900	24.0			
1430	122	231	91	236	1.6	17,600	4,180	23.7			
1500	119	230	91	235	1.4	19,500	4,200	21.5			
1530	126	222	93	226	1.4	20,000	5,060	25.3			
1600	129	229	98	233	1.4	21,000	4,780	22.8			
1630	144	229	113	232	1.6	20,600	3,630	17.6			
1700	187	228	153	232	1.6	26,600	4,400	16.5			
1730	260	214	218	216	1.4	39,800	6,150	15.4			
1800	450	208	260	212	1.4	67,000	26,400	38.0			
1830	314	234	260	239	1.4	52,500	8,150	15.5			
1900	290	213	183	218	1.4	44,000	15,750	35.8			
1930	270	197	215	201	1.4	38,000	7,050	18.5			
2000	167	213	135	217	1.4	26,100	4,500	17.2			
2030	153	237	125	241	1.4	26,000	4,360	16.8			
2100	151	223	123	228	1.4	24,000	3,500	14.6			
2130	144	-	114	-	-	-	-	-			
2200	158	223	130	227	1.2	29,400	4,660	15.9			
2230	173	385	148	391	1.4	47,600	6,150	12.9			

TIME AVERAGES

Time	MI	MC	MC/MI
1200 --1530	16,300	4,510	27.6
1600 - 2230	33,900	6,900	20.3
1200 - 2230	28,100	6,410	22.8

Notes:

1. Trickling Filter Effluent (Clarified, San Leandro)
2. Date: 19 and 20 February 1971
3. Screen: 30μ SS
4. K° 0.59 sec.
5. Total screen area: 0.8 sq.m.

TABLE 17

INDIVIDUAL MICROSCREEN RUN DATA

(Run 3 - Unit B)

Time	Screen	X_P^S (mg/ℓ)	Q_I (ℓ/min)	X_E^S (mg/ℓ)	Q_E (ℓ/min)	S (sq m/ min)	MI (mg/ sq m)	MC (mg/ sq m)	MC/MI (%)
1200	40μ SS	101	121	71	124	2.28	5,360	1,490	27.9
1230	"	115	159	77	162	"	8,000	2,360	32.8
1300	"	108	227	83	231	"	10,860	2,460	22.8
1330	"	110	212	81	216	"	10,600	2,540	24.0
1400	"	117	236	89	240	"	12,200	2,720	22.5
1430	"	124	224	92	248	"	12,400	2,190	17.7
1500	"	108	292	94	246	"	11,600	1,490	12.8
1630	21μ SS	138		-		-	-	-	-
1700	"	169	237	150	242	3.19	12,550	1,190	9.5
1730	"	280	242	210	248	3.40	20,000	4,650	23.2
1800	"	406	245	254	251	4.05	24,600	8,900	31.2
1830	"	340	220	254	226	4.81	15,600	3,630	23.3
1900	"	280	244	187	251	"	14,200	4,450	31.4
1930	"	213	247	197	254	"	10,900	520	4.8
2000	"	167	204	134	211	"	7,000	1,200	17.2
2030	"	164	239	123	246	"	8,140	1,870	23.0
2100	"	162	245	118	252	"	8,250	2,080	25.2
2130	"	138	245	114	252	"	6,660	980	14.3
2200	"	147		123		"	-	-	-
2230	"	202	253	140	260	"	10,400	2,990	28.8
2300	"	194	250	146	256	"	9,900	2,260	22.8

TIME AVERAGES

Time	MI	MC	MC/MI
1200 - 1500	10,145	2,217	21.8
1630 - 2300	12,320	2,877	23.5

Notes:

1. Trickling Filter Effluent (Clarified San Leandro)
2. Date: 25 February 1971

TABLE 18

INDIVIDUAL MICROSCREEN RUN DATA

(Run 5 Units A and B)

PARAMETERS			UNIT A SUBRUNS A	UNIT A SUBRUNS B	UNIT A SUBRUNS C		UNIT B SUBRUNS A	UNIT B SUBRUNS B	UNIT B SUBRUNS C
P_B	(psig)	Control Variables	15	33	30		15	33	35
S	(sq m/min)		3.7	4.8	1.0		4.0	2.3	2.3
Q_I	(ℓ/min)	Process Efficiency	225	196	244		234	212	213
Q_E	(ℓ/min)		231	301	250		240	220	222
Q_B	(ℓ/min)		8.7	11.6	14.2		9.2	12.6	14.0
Q_W	(ℓ/min)		2.7	3.7	6.5		2.8	4.8	5.0
X_I^S	(mg/ℓ)		8.0	15	9.3		29	13	10
X_P^S	(mg/ℓ)		26	66	20		29	17	26
X_E^S	(mg/ℓ)		25	17	5.3		18	29	5.3
X_{EI}^S	(mg/ℓ)		6.0	10	8.6		8.5	9.3	7.0
X_W^S	(mg/ℓ)		475	386	132		515	180	144
MI	(mg/sq m)		1,590	2,860	4,580		1,600	2,480	2,470
MC	(mg/sq m)		19	2,120	3,340		1,050	28.2	1,970
MC/MI	(%)		1.2	74.0	72.3		64.5	--	79.3
$\bar{d}_P$	(μ)	P.S.D	9.7	12.7	8.6		9.0	10.8	10.5
σ_{LOG-P}			1.06	1.09	1.08		1.10	1.15	1.15
$\bar{d}_E$	(μ)		3.3	4.5	3.6		1.3	4.7	5.6
$\bar{d}_{EI}$	(μ)		4.6	5.1	4.4		6.6	6.0	5.7
K°	(sec^{+1})	MTA	2.12	2.12	2.12		2.53	2.53	2.53
K	(sec^{+1})		2.18	2.16	2.14		2.78	2.34	2.36
K°/K			0.971	0.982	0.990		0.910	1.08	1.07
BEF(10^{-3})	(dyne/cm)	Backwash	6.3	11.3	18.4		7.1	13.2	16.5
Yield	$(Q_E-Q_W)/Q_E$,%		89.0	98.4	97.0		98.2	98.0	98.0

Notes:
1. Type of waste: Clarified Activated Sludge Effluent
2. Date: 3 March 1971
3. Screen size: Unit A - 12-15μ SS
   Unit B - 20μ Polyester
4. BEF Backwash energy flux
   I Influent
   E = Composite effluent
   EI = Channel one effluent
   P Drum pool
   B = Backwash (applied)
   W = Backwash (throughput)

TABLE 19

INDIVIDUAL MICROSCREEN RUN DATA

(Run 6 - Unit A and B)

PARAMETERS			UNIT A SUBRUNS A	B	C		UNIT B SUBRUNS A	B	C
P_B	(psig)	Control Variables	15	20	25		15	20	25
S	(sq m/min)		1.4	2.1	4.5		2.3	1.5	2.3
Q_I	(ℓ/min)	Process Efficiency	235	187	140		25	235	215
Q_E	(ℓ/min)		241	193	150		252	241	224
Q_B	(ℓ/min)		9.6	11.3	12.8		9.2	10.7	11.9
Q_W	(ℓ/min)		4.0	4.6	4.6		2.0	4.8	5.3
X_I^S	(mg/ℓ)		12	64	11		9.0	12.5	30.6
X_P^S	(mg/ℓ)		22	29	67		13	55	26
X_E^S	(mg/ℓ)		7.0	14	2.0		2.0	14	6.8
X_{EI}^S	(mg/ℓ)		4.0	14	15		8.0	19	11.5
X_W^S	(mg/ℓ)		208	652	492		44	52	750
MI	(mg/sq m)		3,670	2,610	2,080		1,340	8,850	2,430
MC	(mg/sq m)		2,480	1,300	2,010		1,120	6,600	1,770
MC/MI	(%)		67.5	50.2	96.5		83.8	74.1	72.8
$\bar{d}_P$	(μ)	P.S.D	9.1	7.6	13.2		7.0	9.4	12.5
σ_{LOG-P}			1.09	1.03	1.32		1.11	1.30	1.0
$\bar{d}_E$	(μ)		3.4	5.6	4.2		5.3	1.4	7.0
$\bar{d}_{EI}$	(μ)		6.3	6.2	5.5		8.8	7.6	7.6
K°	(sec^{+1})	MTA	1.70	1.70	1.70		1.20	1.20	1.20
K	(sec^{+1})		1.98	2.20	2.22		1.08	1.48	0.985
K°/K			0.858	0.775	0.768		1.11	0.812	1.22
BEF(10^{-3})	(dyne/cm)	Backwash	7.2	10.8	13.2		7.1	9.6	11.3
Yield	$(Q_E-Q_W)/Q_E$,%		98.5	98.0	97.0		99.5	98.0	98.0

Notes:
1. Type of waste: Clarified Activated Sludge Effluent
2. Date: 4 March 1971
3. Screen size: Unit A Unit A - 23μ SS
   Unit B - Unit B - 25μ Polyethylene
4. BEF = Backwash energy flux
   I = Influent
   E = Composite effluent
   EI = Channel one effluent
   P = Drum pool
   B = Backwash (applied)
   W - Backwash (throughput)

TABLE 2u

INDIVIDUAL MICROSCREEN RUN DATA

(Run 7 - Unit A and B)

PARAMETERS			UNIT A SUBRUNS				UNIT B SUBRUNS		
			A	B	C		A	B	C
P_B	(psig)	Control Variables	15	25	35		15	25	35
S	(sq m/min)		2.4	2.4	2.4		3.2	3.2	3.2
Q_I	(ℓ/min)	Process Efficiency	241	243	250		201	246	115
Q_E	(ℓ/min)		247	252	257		206	254	124
Q_B	(ℓ/min)		9.6	12.8	14.6		9.2	11.9	14
Q_W	(ℓ/min)		4.2	5.3	7.5		2.9	4.1	5.8
X_I^S	(mg/ℓ)		9.5	41	20.5		9.5	20	32.5
X_P^S	(mg/ℓ)		24	61	40		28	43	78
X_E^S	(mg/ℓ)		7.5	26	17		11	14	27
X_{EI}^S	(mg/ℓ)		21	33	21		7.0	25	27
X_W^S	(mg/ℓ)		218	690	96		436	294	280
MI	(mg/sq m)		2,380	6,190	4,180		1,800	3,330	2,860
MC	(mg/sq m)		1,610	3.470	2,350		1,080	2,210	1,810
MC/MI	(%)		67.5	56.2	56.3		60.3	66.5	63.2
$\bar{d}_P$	(μ)	P.S.D	9.5	6.9	3.1		9.3	9.4	11.4
σ_{LOG-P}			1.11	1.01	0.91		1.17	1.11	1.15
$\bar{d}_E$	(μ)		9.6	7.4	3.0		3.1	4.7	1.2
$\bar{d}_{EI}$	(μ)		9.8	8.4	1.7		4.4	4.4	10.3
K°	(sec^{+1})	MTA	1.53	1.53	1.53		3.45	3.45	3.45
K	(sec^{+1})		1.64	1.79	1.72		2.67	2.58	2.00
K°/K			0.934	0.850	0.890		1.29	1.34	1.73
$BEF(10^{-3})$	(dyne/cm)	Backwash	7.1	13.2	17.5		7.1	11.3	16.3
Yield	$(Q_E-Q_W)/Q_E$,%		98.5	98.0	92.0		98.5	98.5	96.0

Notes:
1. Type of waste: Clarified Activated Sludge Effluent.
2. Date: 5 March 1971
3. Screen size: Unit A - 15-18μ SS
   Unit B - 10μ Nylon
4. BEF = Backwash energy flux
   I = Influent
   E = Composite effluent
   EI = Channel one effluent
   P = Drum pool
   B = Backwash (applied)
   W = Backwash (throughput)

TABLE 21

INDIVIDUAL MICROSCREEN RUN DATA

(Run 8 - Unit B)

PARAMETERS			Unit A Subruns A	Unit A Subruns B	Unit A Subruns C		Unit B Subruns A	Unit B Subruns B	Unit B Subruns C
P_B	(psig)	Control Variables					25	25	
S	(sq m/min)						3.2	3.2	
Q_I	(ℓ/min)	Process Efficiency					255	242	
Q_E	(ℓ/min)						263	251	
Q_B	(ℓ/min)						11.9	14	
Q_W	(ℓ/min)						4.0	5.0	
X_I^S	(mg/ℓ)						54	72	
X_P^S	(mg/ℓ)						92	95	
X_E^S	(mg/ℓ)						38	48	
X_{EI}^S	(mg/ℓ)						36	47	
X_W^S	(mg/ℓ)						1,060	1,020	
MI	(mg/sq m)						7,380	7,230	
MC	(mg/sq m)						4,220	3,410	
MC/MI	(%)						57.3	46.9	
$\bar{d}_P$	(μ)	P.S.D					2.0	2.7	
σ_{LOG-P}							0.91	0.90	
$\bar{d}_E$	(μ)						3.5	3.5	
$\bar{d}_{EI}$	(μ)						2.6	3.1	
K°	(sec^{+1})	MTA					3.45	3.45	
K	(sec^{+1})						3.88	4.04	
K°/K							0.890	0.853	
BEF(10^{-3})	(dyne/cm)	Backwash					11.3	16.3	
Yield	$(Q_E-Q_W)/Q_E$,%						98.5	98.0	

Notes:
1. Type of waste: Clarified Trickling Filter Effluent4.
2. Date: 9 March 1971
3. Screen size: Unit A -
   Unit B - 10μ Nylon

BEF = Backwash energy flux
I = Influent
E = Composite effluent
EI = Channel one effluent
P Drum pool
B Backwash (applied)
W Backwash (throughput)

TABLE 22

INDIVIDUAL MICROSCREEN RUN DATA

(Run 9 - Unit B)

PARAMETERS			UNIT A SUBRUNS				UNIT B SUBRUNS		
			A	B	C		A	B	C
P_B	(psig)	Control Variables					15	20	25
S	(sq m/min)	Control Variables					3.2	2.2	2.2
Q_I	(ℓ/min)	Process Efficiency					257	236	238
Q_E	(ℓ/min)	Process Efficiency					262	242	245
Q_B	(ℓ/min)	Process Efficiency					9.3	7.7	11.9
Q_W	(ℓ/min)	Process Efficiency					4.3	4.6	5.2
X_I^S	(mg/ℓ)	Process Efficiency					34.7	55.5	102
X_P^S	(mg/ℓ)	Process Efficiency					68	89	199
X_E^S	(mg/ℓ)	Process Efficiency					30	46	55.5
X_{EI}^S	(mg/ℓ)	Process Efficiency					27	45	57
X_W^S	(mg/ℓ)	Process Efficiency					547	544	622
MI	(mg/sq m)	Process Efficiency					5,530	9,630	16,300
MC	(mg/sq m)	Process Efficiency					3,060	4,480	10,070
MC/MI	(%)	Process Efficiency					55.2	46.5	61.8
$\bar{d}_P$	(μ)	P.S.D					4.4	2.8	3.6
σ_{LOG-P}		P.S.D					0.9est	0.9est	0.9est
$\bar{d}_E$	(μ)	P.S.D					3.3	2.6	3.6
$\bar{d}_{EI}$	(μ)	P.S.D					5.9	4.9	5.7
K°	(sec^{+1})	MTA					3.45	3.45	3.45
K	(sec^{+1})	MTA					1.65	1.75	1.68
[illegible]		MTA					2.09	1.97	2.05
BEF(10^{-3})	(dyne/cm)	Backwash					7.2	5.0	11.3
Yield	$(Q_E-Q_W)/Q_E$,%						98.5	97.5	98.0

Notes:
1. Type of waste: Clarified Trickling Filter Effluent
2. Date: 10 March 1971
3. Screen size: Unit A -
   Unit B - 23μ SS
4. BEF = Backwash energy flux
   I = Influent
   E = Composite effluent
   EI = Channel one effluent
   P - Drum pool
   B = Backwash (applied)
   W = Backwash (throughput)

TABLE 23

INDIVIDUAL MICROSCREEN RUN DATA

(Run 10 - unit A and B)

PARAMETERS			UNIT A SUBRUNS A	UNIT A SUBRUNS B	UNIT A SUBRUNS C		UNIT B SUBRUNS A	UNIT B SUBRUNS B	UNIT B SUBRUNS C
P_B	(psig)	Control Variables	15	15	15		15	15	15
S	(sq m/min)		2.0	1.8	1.8		2.3	2.3	2.3
Q_I	(ℓ/min)	Process Efficiency	247	250	242		225	231	225
Q_E	(ℓ/min)		253	255	247		230	237	231
Q_B	(ℓ/min)		9.6	9.6	9.6		9.2	9.2	9.2
Q_W	(ℓ/min)		4.0	3.3	4.2		2.5	3.0	3.0
X_I^S	(mg/ℓ)		100	120	102		92	108	103
X_P^S	(mg/ℓ)		143	110	133		85	114	223
X_E^S	(mg/ℓ)		70	102	125		79	86	84
X_{EI}^S	(mg/ℓ)		76	78	86		61.5	78	89
X_W^S	(mg/ℓ)		990	980	685		490	1165	1015
MI	(mg/sq m)		17,900	14,900	17,500		8,170	11,300	11,850
MC	(mg/sq m)		9,050	800	600		400	2,500	3,490
MC/MI	(%)		50.6	5.3	3.4		4.9	22.1	29.8
$\bar{d}_P$	(μ)	P.S.D	4.2	3.6	4.4		3.9	2.4	4.5
σ_{LOG-P}			0.912	0.805	0.810		0.815	0.832	0.792
$\bar{d}_E$	(μ)		3.2	2.6	4.2		4.8	2.9	4.6
$\bar{d}_{EI}$	(μ)		2.0	2.6	5.0		3.3	3.7	4.0
K°	(sec^{+1})	MTA	1.53	1.53	1.53		2.12	2.12	2.12
K	(sec^{+1})		1.86	1.66	1.41		4.64	2.78	2.65
K°/K			0.822	0.922	1.09		0.457	0.762	0.802
BEF(10^{-3})	(dyne/cm)	Backwash	7.2	7.2	7.2		7.1	7.1	7.1
Yield	$(Q_E-Q_W)/Q_E$,%		98.4	98.7	98.7		98.7	98.7	98.7

Notes:
1. Type of waste: Clarified Trickling Filter Effluent
2. Date: 17 March 1971
3. Screen size: Unit A - 15-18μ SS
   Unit B - 12-15μ SS
4. BEF = Backwash energy flux
   I = Influent
   E = Composite effluent
   EI = Channel one effluent
   P = Drum pool
   B = Backwash (applied)
   W = Backwash (throughput)

TABLE 24

INDIVIDUAL MICROSCREEN RUN DATA

(Run II - Unit A and B)

PARAMETERS			UNIT A SUBRUNS A	UNIT A SUBRUNS B	UNIT A SUBRUNS C		UNIT B SUBRUNS A	UNIT B SUBRUNS B	UNIT B SUBRUNS C
P_B	(psig)	Control Variables	15	15	15		15	15	
S	(sq m/min)		1.6	1.4	1.3		1.1	0.4	
Q_I	(ℓ/min)	Process Efficiency	230	240	237		213	182	
Q_E	(ℓ/min)		236	246	243		218	185	
Q_B	(ℓ/min)		9.6	11.3	9.6		9.3	9.3	
Q_W	(ℓ/min)		4.2	5.0	4.2		4.1	3.8	
X_I^S	(mg/ℓ)		93.5	126	120		102	132	
X_P^S	(mg/ℓ)		111	118	110		115	97	
X_E^S	(mg/ℓ)		64.1	106	118		96	90	
X_{EI}^S	(mg/ℓ)		88	82	99		94	119	
X_W^S	(mg/ℓ)		628	730	700		440	392	
MI	(mg/sq m)		15,970	20,700	22,450		21,450	41,000	
MC	(mg/sq m)		11,830	1,700	--		1,700	2,300	
MC/MI	(%)		74.1	8.2	--		12.7	6.6	
$\bar{d}_P$	(μ)	P.S.D	3.1	4.1	5.2		3.4	2.7	
σ_{LOG-P}			.733	.82	.57		.85	1.44	
$\bar{d}_E$	(μ)		5.5	2.8	2.6		3.8	1.5	
$\bar{d}_{EI}$	(μ)		4.3	3.4	1.9		2.9	1.9	
K°	(sec^{+1})	MTA	1.53	1.53	1.53		1.35	1.35	
[illegible]	(sec^{+1})		2.70	1.58	1.86		0.74	0.89	
K°/K			0.567	0.978	0.823		1.82	1.52	
BEF(10^{-3})	(dyne/cm)	Backwash	7.2	10.5	7.2		7.1	7.1	
Yield	$(Q_E-Q_W)/Q_E$,%		98.2	98.0	98.2		98.0	97.8	

Notes:
1. Type of waste: Clarified Trickling Filter Effluent
2. Date: 18 March 1971
3. Screen size: Unit A - 18-22μ SS
   Unit B - 21μ SS
4. BEF = Backwash energy flux
   I = Influent
   E = Composite effluent
   EI = Channel one effluent
   P = Drum pool
   B = Backwash (applied)
   W = Backwash (throughput)

TABLE 25

INDIVIDUAL MICROSCREEN RUN DATA

(Run 12 Unit A and B)

PARAMETERS			UNIT A SUBRUNS A	UNIT A SUBRUNS B	UNIT A SUBRUNS C		UNIT B SUBRUNS A	UNIT B SUBRUNS B	UNIT B SUBRUNS C
P_B	(psig)	Control Variables	15	20			15	20	
S	(sq m/min)		2.3	2.3			1.7	0.9	
Q_I	(ℓ/min)	Process Efficiency	231	245			212	116	
Q_E	(ℓ/min)		248	253			220	125	
Q_B	(ℓ/min)		9.6	11.3			9.3	10.7	
Q_W	(ℓ/min)		2.7	3.5			1.5	2.0	
X_I^S	(mg/ℓ)		82.5	111.6			74	108	
X_P^S	(mg/ℓ)		88.5	136			96.5	95	
X_E^S	(mg/ℓ)		72	77			62	99	
X_{EI}^S	(mg/ℓ)		75.5	128.5			88	90	
X_W^S	(mg/ℓ)		482	770			795	950	
MI	(mg/sq m)		9,100	1,480			12,100	13,640	
MC	(mg/sq m)		1,080	594			2,030	--	
MC/MI	(%)		11.9	33.4			16.8		
$\bar{d}_P$	(μ)	P.S.D	--	--			--	--	
σ_{LOG-P}			--	--			--	--	
$\bar{d}_E$	(μ)		--	--			--	--	
$\bar{d}_{EI}$	(μ)		--	--			--	--	
K°	(sec^{+1})	MTA	2.53	2.53			3.45	3.45	
K	(sec^{+1})		3.58	3.12			5.28	8.48	
K°/K			0.707	0.812			0.653	0.407	
BEF(10^{-3})	(dyne/cm)	Backwash	7.2	10.5			7.2	9.5	
Yield	$(Q_E-Q_W)/Q_E$,%		98.9	98.6			99.4	98.4	

Notes:
1. Type of waste: Clarified Trickling Filter Effluent
2. Date: 19 March 1971
3. Screen size: Unit A - 20μ Polyester
   Unit B - 10μ Nylon
4. BEF - Backwash energy flux
   I = Influent
   E = Composite effluent
   EI = Channel one effluent
   P = Drum pool
   B = Backwash (applied)
   W = Backwash (throughput)

TABLE 26

INDIVIDUAL MICROSCREEN RUN DATA

(Run 13 - Unit and B)

PARAMETERS			Unit A Subruns A	Unit A Subruns B	Unit A Subruns C		Unit B Subruns A	Unit B Subruns B	Unit B Subruns C
P_B	(psig)	Control Variables	15	15	15		15	20	25
S	(sq m/min)		1.3	1.3	1.3		1.9	3.5	3.9
Q_I	(ℓ/min)	Process Efficiency	105	78	78		41	57	53
Q_E	(ℓ/min)		111.4	83.4	84.2		48.7	66.5	64.1
Q_B	(ℓ/min)		9.6	9.6	9.6		9.3	10.7	11.8
Q_W	(ℓ/min)		3.5	3.5	3.5		1.0	1.0	1.0
X_I^S	(mg/ℓ)		26	38.7	68		61.4	55.3	52.7
X_P^S	(mg/ℓ)		43	62.6	67		43.4	100.8	143
X_E^S	(mg/ℓ)		29.3	35.3	42		37.6	33.3	28
X_{EI}^S	(mg/ℓ)		20.8	34.3	36.3		37.5	38.6	35.7
X_W^S	(mg/ℓ)		306	760	330		650	600	1000
MI	(mg/sq m)		3,510	3,760	4,070		960	1,640	1,930
MC	(mg/sq m)		985	1,480	1,330		--	1,010	1,474
MC/MI	(%)		27.3	39.3	32.7		--	61.5	76.6
$\bar{d}_P$	(μ)	P.S.D	--	3.3	3.3		2.5	1.9	2.6
σ_{LOG-P}			--	0.85	0.77		1.57	2.01	1.28
$\bar{d}_E$	(μ)		2.8	1.7	2.0		3.3	2.9	1.9
$\bar{d}_{EI}$	(μ)		3.0	2.3	2.8		3.0	2.6	2.0
K°	(sec^{+1})	MTA	2.12	2.12	2.12		3.45	3.45	3.45
K	(sec^{+1})		3.13	3.69	2.34		6.06	11.5	25.2
			0.678	0.574	0.906		0.570	0.302	0.137
BEF(10^{-3})	(dyne/cm)	Backwash	7.2	7.2	7.2		7.1	9.5	11.4
Yield	$(Q_E-Q_W)/Q_E$,%		94.6	95.8	95.8		97.9	98.5	98.4

Notes:
1. Type of waste: Primary Effluent.
2. Date: 25 March 1971
3. Screen size: Unit A - 12-15μ SS
   Unit B - 10μ Nylon
4. BEF = Backwash energy flux
   I = Influent
   E = Composite effluent
   EI = Channel one effluent
   P = Drum pool
   B = Backwash (applied)
   W = Backwash (throughput)

TABLE 27

INDIVIDUAL MICROSCREEN RUN DATA

(Run 14 Units A and B)

PARAMETERS			Unit A Subruns A	Unit A Subruns B	Unit A Subruns C		Unit B Subruns A	Unit B Subruns B	Unit B Subruns C
P_B	(psig)	Control Variables	15	15	15		15	20	15
S	(sq m/min)	Control Variables	0.67	0.67	0.67		0.55	0.88	0.55
Q_I	(ℓ/min)	Process Efficiency	87.2	38.7	77.3		31	40.2	26.4
Q_E	(ℓ/min)	Process Efficiency	93.2	46	77		35.6	46.4	37.6
Q_B	(ℓ/min)	Process Efficiency	9.6	9.6	9.6		9.3	10.8	9.3
Q_W	(ℓ/min)	Process Efficiency	3.5	3.3	3.7		4.6	4.6	4.0
X_I^S	(mg/ℓ)	Process Efficiency	35.3	47.5	55.5		39	57.5	64
X_P^S	(mg/ℓ)	Process Efficiency	52.5	59	41.9		42.3	68.4	69.8
X_E^S	(mg/ℓ)	Process Efficiency	12	16.5	33.3		14.5	17.5	36
X_{EI}^S	(mg/ℓ)	Process Efficiency	21.5	15.8	29.2		20.2	22.5	37.4
X_W^S	(mg/ℓ)	Process Efficiency	466	418	594		246	268	510
MI	(mg/sq m)	Process Efficiency	6,850	3,410	4,830		2,390	3,120	3,360
MC	(mg/sq m)	Process Efficiency	5,180	2,280	1,000		1,450	2,200	1,220
MC/MI	(%)	Process Efficiency	75.6	66.7	20.7		60.8	70.5	36.2
$\bar{d}_P$	(μ)	P.S.D	4.5	3.1	2.6		1.0	2.6	1.7
σ_{LOG-P}		P.S.D	.76	1.64	1.19		2.52	1.34	2.16
$\bar{d}_E$	(μ)	P.S.D	2.0	1.2	2.2		2.2	2.1	2.1
$\bar{d}_{EI}$	(μ)	P.S.D	1.9	1.8	2.9		2.2	2.4	2.7
K°	(sec^{+1})	MTA	2.12	2.12	2.12		1.41	1.41	1.41
K	(sec^{+1})	MTA	3.59	3.51	3.76		3.28	4.02	3.13
K°/K		MTA	0.592	0.604	0.564		0.429	0.351	0.452
BEF(10^{-3})	(dyne/cm)	Backwash	7.2	7.2	7.2		7.1	9.6	7.1
Yield	$(Q_E-Q_W)/Q_E$,%		96.3	92.8	95.2		87.0	90.1	87.8

Notes:
1. Type of waste: (Unclarified) Trickling Filter Effluent.
2. Date: 26 March 1971
3. Screen size: Unit A - 12-15μ SS
   Unit B - 18-22μ SS
4. BEF = Backwash energy flux
   I = Influent
   E = Composite effluent
   EI = Channel one effluent
   P = Drum pool
   B = Backwash (applied)
   W = Backwash (throughput)

TABLE 28

INDIVIDUAL MICROSCREEN RUN DATA

(Run 15 - Units A and B)

Time	Type of Effluent	X_P^S (mg/ℓ)	Q_I (ℓ/min)	X_E^S (ℓ/min)	Q_E (ℓ/min)	S (sq m/ min)	MI (mg/ sq m)	MC (mg/ sq m)	MC/MI (%)	$\bar{d}_P$ (μ)
UNIT A										
0945	Primary	114	43	80	43	1.06	3,920	705	18.0	2.3
1100	"	123	52	85	52	1.06	5,360	263	4.9	3.2
1145	"	64	47	48	47	1.06	2,480	357	14.4	5.0
1245	"	31	40	18	40	1.06	987	331	33.5	3.0
1400	Clarified Trickling Filter	38	57	21	57	1.06	1,810	719	39.7	2.6
1430		62	35	27	35	1.06	1,650	788	47.8	3.3
1500	"	70	44	41	44	1.06	2,520	826	32.8	3.7
1700	"	61	80	43	80	0.60	7,530	1,830	24.4	3.0
1745	"	28	81	32	81	0.60	3,510	878	25.0	2.6
1815	"	86	106	18	106	0.60	14,340	11,400	79.4	3.5
1845	"	20	55	10	55	0.60	1,590	672	42.2	4.5
UNIT B										
0945	Primary	120	64	74	64	0.57	11,730	3,480	29.6	3.3
1100	"	98	71	90	71	0.57	10,930	(211)	(1.9)	3.9
1145	"	61	62	40	62	0.57	5,870	1,500	25.6	2.1
1230	"	42	44	20	44	0.57	2,950	1,430	48.5	2.3
1400	Clarified Trickling Filter	86	69	47	69	0.57	9,700	4,070	41.9	2.9
1420		48	43	18	43	0.57	3,040	1,690	55.5	2.7
1500	"	78	87	54	87	0.57	10,940	2,740	25.0	3.2
1700	"	63	82	24	82	0.60	7,920	4,630	58.5	3.7
1730	"	53	76	36	76	0.60	6,170	1,640	26.6	2.8
1815	"	48	52	28	52	0.60	3,690	1,270	34.6	3.1
1840	"	31	35	20	35	0.60	1,540	356	23.1	3.8

TIME AVERAGES

Unit	Time	MI	MC	MC/MI	$\bar{d}_P$	Effluent
A	0945 - 1245	3,190	414	13.0	3.4	Primary
A	1400 1845	4,710	2,450	52.1	3.7	Clarified Trickling Filter
B	0945 - 1230	7,860	1,550	19.7	3.9	Primary
B	1400 - 1840	6,140	2,342	38.2	3.2	Clarified Trickling Filter

Notes:

1. Date: 30 March 1971
2. Screen size: Unit A - 12-15μ SS
   Unit B - 18-22μ SS

TABLE 29

INDIVIDUAL MICROSCREEN RUN DATA

(Run 16 and 17 - Units A and B)

Time	Screen	X_P^S (mg/ℓ)	Q_I (ℓ/min)	X_E^S (mg/ℓ)	Q_E (ℓ/min)	S (sq m/min)	MI (mg/sq m)	MC (mg/sq m)	MC/MI (%)	$\bar{d}_P$ (μ)
RUN 16 -	UNIT A									
1420	12-15μ SS	38	107	61	113	0.87	4,660	(3,280)	-	0.19
1450	"		137	38	143	0.87	-	-	-	0.03
1935	"	23	75	-	83	0.96	1,767		-	-
2010	"	23	116	23	123	0.96	3,310	432	13.1	-
RUN 16 -	UNIT B									
1330	18-22μ SS	53	145	58	154	0.70	11,000	(1,730)	-	0.29
1430	"	43	141	43	149	0.70	8.630	(414)	-	0.05
1450	"	43	134	38	140	0.70	8,220	714	8.7	0.09
1530	"		148	-	156	0.70	-	-	-	-
1935	"	28	42	23	50	0.70	1,630	(314)	-	-
2010	"	48	93		102	0.70	-	-	-	-
RUN 17 -	UNIT B									
1110	15-18μ SS	160	9.2	14	15	0.76	1,940	1,550	86.0	2.0
1140	"	118	25	11	31	1.48	1,960	1,740	89.0	2.0
1240	"	127	19	26	25	2.24	2,010	1,740	85.0	3.0
1255	"	128	18	8.9	26	1.10	2,170	1,890	86.0	3.0
1600	"	186	26	24	32	2.40	1,950	1,670	85.0	4.0
1720	"	76	76	20	82	2.80	2,040	1,500	76.0	4.2
1815	"	138	45	33	51	3.12	1,980	1,480	75.0	4.6
1930	"	73	57	47	33	2.14	1,940	1,280	64.0	5.0

Time Averages

Date	Unit	MI	MC	MC/MI	$\bar{d}_P$	Effluent Type
1 Apr.'71	A			-		Oxidation Pond
	B			-		Oxidation Pond
2 Apr.'71	B	2,000	1,610	80.5	3.5	Clarified Trickling Filter

Notes:

1. Run 16 - Oxidation Pond Effluent
   Run 17 - Clarified Trickling Filter Effluent
2. Date: Run 16 - 1 April 1971
   Run 17 - 2 April 1971

TABLE 30

STEADY-STATE MICROSCREEN OPERATIONAL DATA

RUN #.	UNIT	WASTE	MC cm/sq m	MI cm/sq m	MC/MI %	$\bar{d}_P$ μ	σ_{LOG-P}	FABRIC NPS μ	H_L cm	Q_EQ ℓ/min	SUBM. A sq cm	V_E cm/sec	P_B psig	S sq m/min	$\frac{NPS}{d_P}$ μ/μ	$\frac{X_P^S H_L A}{\rho S}$ cm-sec	X_P^S mg/ℓ	TEST RUN #
1	A	AS	2.2	4.1	53.7	8.3	.38	30	6.0	240	3400	.424	10	2.8	3.62	1.91	46	1
1	A	AS	2.8	5.7	49.2	5.5	.67	30	8.7	232	3630	.384	10	1.4	5.47	4.57	33	2
1	A	AS	3.0	4.5	66.7	4.3	.81	30	10.0	212	3650	.348	21	3.0	6.98	3.55	51	3
1	A	AS	3.2	5.0	64.0	5.0	.61	30	13.2	217	3730	.349	20	2.2	6.00	6.38	50	4
1	B	AS	1.07	1.9	56.3	7.3	.52	21	7.8	165	3605	.275	9	3.2	2.88	2.22	44	5
1	B	AS	1.72	2.78	61.7	6.3	.65	21	11.8	250	3680	.408	14	3.8	3.33	2.81	43	
1	B	AS	2.15	3.75	57.3	6.0	.65	21	29.0	225	4070	.332	13	2.5	3.50	8.92	33	6
1	B	AS	1.91	2.88	66.3	5.9	.65	21	12.0	225	3690	.366	24	3.8	3.56	3.27	49	7
3	A	TF	4.5	18.1	24.9	6.2	.63	30	22.0	235	3910	.361	15	1.5	4.84	29.5	90	8
3	A	TF	6.0	25.0	24.0	6.2	.63	30	25.5	235	3930	.359	13	1.4	4.84	51.2	125	9
3	B	TF	1.5	11.6	12.9	3.6	1.05	40	8.0	245	3620	.407	10	2.6	11.1	7.77	108	
3	B	TF	3.0	15.0	20.0	3.6	1.05	21	27.5	255	4010	.382	15	1.96	5.84	45.7	143	10
5	A	AS	.69	1.49	46.3	9.5	1.05	13.5	10.7	240	3660	.393	16	3.6	1.42	1.44	23	
5	A	AS	1.95	2.52	77.3	10.4	1.05	13.5	6.5	205	3570	.345	25	4.7	1.30	1.78	63	
5	A	AS	2.06	3.84	53.7	7.2	1.08	13.5	8.8	245	3620	.407	35	1.1	1.88	2.99	18	
5	B	AS	1.06	1.49	71.2	10.5	1.15	20	11.5	245	3680	.399	15	4.0	1.91	1.52	25	
5	B	AS	.32	2.43	13.2	14.0	.43	20	16.2	232	3790	.367	35	2.3	1.43	3.65	24	
6	A	AS	.76	3.20	23.7	7.2	1.03	23	9.6	245	3670	.401	15	1.5	3.19	2.68	20	
6	A	AS	1.48	2.05	72.2	11.6	1.15	23	6.6	170	3540	.288	25	4.5	1.98	1.61	54	
6	B	AS	.39	1.52	25.6	7.0	1.08	25	9.5	260	3660	.427	15	2.3	3.57	1.21	14	
7	A	AS	.45	2.45		5.0	1.00	16.5	7.5	255	3590	.427	15	2.3	3.30	1.47	22	
7	A	AS	1.87	3.87		3.5	.95	16.5	8.0	255	3600	.426	35	2.3	4.72	2.57	36	
7	B	AS	1.14	2.01		8.8	1.17	10	13.2	208	3715	.336	15	3.1	1.14	2.72	30	
7	B	AS	1.84	3.28		10.0	1.20	10	15.0	255	3755	.408	25	3.2	1.00	4.23	42	
7	B	AS	1.34	2.31		11.2	1.19	10	5.6	120	3545	.203	35	3.2	.89	2.33	66	
9	B	TF	2.50	5.65		3.1	1.00	23	10.5	270	3660	.443	16	3.2	7.42	4.79	70	
9	B	TF	4.5	9.7		2.7	.81	23	14.0	242	3750	.387	20	2.3	8.52	11.60	89	11
9	B	TF	4.61	9.36		3.8	.90	23	19.5	235	3860	.366	25	2.08	6.06	17.30	84	
8	B	TF	4.71	7.81		3.9	.75	10	20.5	270	3880	.418	25	3.2	2.56	13.3	94	12
8	B	TF	3.85	7.75		2.2	.70	10	19.2	255	3860	.396	35	3.2	4.55	12.3	93	13

TABLE 30

STEADY-STATE MICROSCREEN OPERATIONAL DATA

RUN #	UNIT	WASTE	MC gm/sq m	MI gm/sq m	MC/MI %	$\bar{d}_P$ μ	σ_{LOG-P}	FABRIC NPS μ	H_L cm	Q_EQ ℓ/min	SUBM. A sq cm	V_E cm/sec	P_B psig	S sq m/min	$\frac{NPS}{d_P}$ μ/μ	$\frac{X_P^S H_L A}{\rho S}$ cm-sec	X_P^S mg/ℓ	TEST RUN #
10	A	TF	4.3	14.8		3.3	.80	16.5	11.0	250	3740	.402	15	2.2	5.00	14.2	133	
10	B	TF	3.72	10.5		4.6	.93	13.5	30.0	245	4090	.360	15	2.2	3.41	30.6	96	
10	B	TF	4.82	14.0		2.2	.83	13.5	25.5	240	3930	.367	15	2.2	1.63	34.3	132	
11	A	TF	4.00	16.4		5.0	.65	20	21.2	255	3895	.393	20	1.4	4.00	39.5	117	
11	A	TF	5.76	18.7		3.7	.70	20	33.4	232	4170	.333	15	1.4	5.42	66.0	116	
11	B	TF	3.31	23.96	13.8	3.3	.88	21	15.5	217	3770	.346	15	1.0	6.37	38.50	115	
11	B	TF	.30	34.90	8.6	2.3	1.9	21	20	170	3870	.263	15	0.55	9.13	94.00	117	
13	A	PE	.76	3.58	21.8	2.7	.98	13.5	22.4	75	3920	.115	15	1.3	5.00	22.10	57	14
13	B	PE	.50	.98	51.1	2.7	1.40	10	22	38	3910	.058	15	2.4	3.71	10.20	50	15
13	B	PE	.53	1.40	37.8	1.9	2.25	10	33	72	4160	.103	20	4.3	5.27	17.50	96	
14	A	UTF	3.36	5.60	60.0	4.7	.72	13.5	19	88	3840	.138	15	.67	2.87	33.00	53	16
14	A	UTF	1.33	2.54	52.3	2.8	.54	13.5	7	42	3580	.071	15	.67	4.82	11.10	52	17
14	A	UTF	.34	3.44	9.9	5.3	.60	13.5	7	73	3800	.115	15	.67	2.55	7.51	33	18
14	B	UTF	.70	2.50	28.0	1.7	3.10	20	21	37	3890	.057	15	55	11.8	38.90	43	
14	B	UTF	1.63	2.35	69.3	3.4	.90	20	17	35	3800	.055	20	.88	5.88	31.10	74	
14	B	UTF	1.45	3.36	43.2	3.2	1.00	20	6	35	3560	.059	15	.55	6.25	14.70	66	
15	B	UTF	2.11	11.53	18.3	3.5	.68	20	31	68	4030	.102	30	.60	5.71	131.0	110	19
15	B	UTF	4.6	6.8	67.7	3.0	1.15	20	14.5	82	3750	.131	20	.60	6.67	37.8	73	
15	A	UTF	.26	5.36	4.9	3.9	.68	13.5	5	53	3530	.090	20	.55	3.46	22.6	123	
15	A	UTF	4.63	7.92	58.7	3.7	.82	13.5	15.5	82	3660	.136	20	.30	3.65	67.0	62	
16	A	OP	.15	2.93	5.1	.1	d84.3 *	13.5	7.5	108	3590	.181	15	.96	135.	4.02	25	20
16	B	OP	.71	8.21	8.7	.09	d84.3**	16.5	20	142	3880	.220	20	.70	184.	23.4	37	21
3	A	TF	5.2	16.0	31.9	6.2	.63	30	21.5	238	3910	.365	10	1.6	4.84	33.6	112	
3	B	TF	3.0	10.4	28.9	3.6	1.05	21	29.4	262	4090	.384	15	4.8	5.84	29.4	202	

Notes:

AS = Clarified Activated Sludge Effluent

TF = Clarified Trickling Filter Effluent

UTF = Unclarified Trickling Filter Effluent

PE = Primary Effluent

0.8 *

0.79 **

APPENDIX D

SUBPROGRAM MODEL LISTING

```
PAGE   1

// JOB

LOG DRIVE    CART SPEC    CART AVAIL   PHY DRIVE
  0000         0001         0001         0000

V2 M08   ACTUAL 16K  CONFIG 16K

// DUP

*DELETE                  MICRO
CART ID 0001    DB ADDR  3F07    DB CNT    00E7

// FOR
*LIST ALL
      SUBROUTINE MICRO
      INTEGER OS1,OS2
      DIMENSION ZPPOR(3),ZPD2(50),ZPNR(50),ZPD(50),PCT(50),ZPNI(50)
      DIMENSION ZPD1(50),ZPNC(50),ZSP(50),ZST(50),ZPNO(50)
      DIMENSION PCTC(50),PCTI(50),PCTO(50)
      COMMON SMATX(20,25),TMATX(20,25),DMATX(20,20),OMATX(20,20),IP(25),
     * INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),
     * ACOST(20,5),TCOST(20,5)
C     INITIALIZE PARAMETERS FOR SUBPROGRAM
      ZP1=.9
      ZP2=1.
      ZP3=1.
      ZP4=1.
      ZP5=.3
      ZPPOR(1)=.25
      ZPPOR(2)=.15
      ZPPOR(3)=1.5
      RHO=1.
      XMU=.01
      FM=2.
      FT=.5
      LPN=10
      LSN=8
      ZPDNS=1.05
C     CONVERSION FACTORS (PROGRAM OPERATES IN METRIC SYSTEM)
      ZCPI=3.1416
      ZCIN=2.54
      ZCFT=12.*ZCIN
      ZCIN2=ZCIN**2
      ZCFT2=ZCFT**2
      ZCIN3=ZCIN**3
      ZCFT3=ZCFT**3
      ZCLB=1000./2.205
      ZCGAL=ZCFT3/7.481
      ZCMIN=60.
      ZCHR=60.*ZCMIN
      ZCDAY=24.*ZCHR
      ZCGPD=ZCGAL/ZCDAY
      ZCREV=2.*ZCPI
      ZCRPM=ZCREV/ZCMIN
      ZCGRV=32.17*ZCFT
      ZCHIN=ZCIN3*ZCGRV/ZCIN2
C     CONVERT INPUT TO METRIC SYSTEM
```

```
      ZDR=(DMATX(2,N))*ZCFT/2.
      ZDP=(DMATX(4,N))*ZCHIN
      ZDW=1.*ZCFT
      ZDAV=(DMATX(5,N))*ZCRPM
      ZDA=(DMATX(3,N))*ZCREV
      ZDSP=ZDW*ZDR*ZDAV
      ZDT=ZDA/ZDAV
      ZDAR=ZDW*ZDP*ZDA
      ZDRHO=RHO
      ZDMU=XMU
      ZFP=DMATX(6,N)*.0001
      ZFM=FM
      ZFT=FT
      HLC=(DMATX(7,N))*(ZCMIN*ZCFT2*ZCHIN)/ZCGAL
C     TRANSFER DISSOLVED SPECIES TO EFFLUENT STREAM
      DO 666 I=11,17
  666 SMATX(I,US1)=SMATX(I,IS1)
      DI=DMATX(8,N)
      SI=DMATX(9,N)
C     CALCULATE DRUM POOL PARAMETERS
C     CALCULATE CONCENTRATION EFFECT IN DRUM POOL
      IF (DMATX(5,N)-2.5) 21,21,22
   21 XPXSR=1.+(.064)*(DMATX(5,N)**2)
      GO TO 23
   22 XPXSR=1.4+(.58*DMATX(5,N)-1.45)
   23 CO=XPXSR*SMATX(10,IS1)
      WRITE(5,1009) CO
 1009 FORMAT(1H ,24HDRUM POOL CONCENTRATION=,F9.4)
C     CALCULATE DRUM POOL MEAN PARTICLE SIZE
      IF(DMATX(5,N)-6.25) 1000,1000,1001
 1000 DAV=DI*(1.-(.0096)*DMATX(5,N))
      GO TO 1002
 1001 DAV=DI*(1.19-(.04)*DMATX(5,N))
C     CALCULATE DRUM POOL STANDARD DEVIATION
 1002 IF(DMATX(5,N)-5.62) 1003,1003,1004
 1003 XX1=.0088*DMATX(5,N)
      GO TO 1007
 1004 IF(DMATX(5,N)-7.5) 1005,1005,1006
 1005 XX1=.20-.02666*DMATX(5,N)
      GO TO 1007
 1006 XX1=.90-.12*DMATX(5,N)
 1007 S=SI-XX1
      SDL=ALOG(DAV)*S
      CO=CO*1.E-06
5     DAV=DAV*.0001
      SD=EXP(SDL)
      F=1./SQRT(2.*ZCPI)/SDL
      XMIN=DAV*SD**(-4.)
      XMAX=DAV*SD**4.
      XPN=LPN
      DO 9 I=1,LPN
      XI=I
9     ZPD2(I)=XMIN*(XMAX/XMIN)**(XI/XPN)
      ZPD1(1)=XMIN
      DO 92 I=2,LPN
   92 ZPD1(I)=ZPD2(I-1)
      DO 93 I=1,LPN
```

```
   93 ZPD(I)=SQRT(ZPD1(I)*ZPD2( ))
      DDL=ALOG(XMAX/XMIN)/XPN                                    IN
      DO 94 I=1,LPN
      X=ALOG(ZPD(I)/DAV)/SDL
      Y=CO*F*EXP(-1.*X**2/2.)*DDL
   94 ZPNI(I)=Y/(ZCPI*ZPD(I)**3/6.*ZPDNS)
C     BACKWASH FUNCTION
      HLC=HLC/.85
      NN=1
      PV=HLC
      K=0
      IF (IS2) 200,210,200
  210 WRITE (5,900)
  900 FORMAT(1H ,12HSEGMENT DATA)
      WRITE (5,905)
  905 FORMAT(1H ,3HSEG,100H      VI        PV        VIN      VC/VI       D
     EFN      EFFIC      PV2       PVI       POR         VC   )
      VI=0.
      WRITE (5,906) K,VI,PV
  906 FORMAT(1H ,I3,1X,2(E9.3,1X))
  200 CONTINUE
  100 XSN=LSN*NN
      DT=ZDT/XSN
      DO 102 I=1,LPN
  102 ZPNC(I)=0.
      M=LPN
      CALL DISTR(ZPNI,XNI,AVDI,SDI,PCTI,SURFI,VOLI,DISI,ZPD,ZPD1,ZPD2,M)
      X=0.
      Y=0.
      VC=0.
      PSV=0.
      PSV2=0.
      K=0
      DEF=ZFP*ZPS
      PVI=0.
      PV2=0.
      DO 19 K=1,LSN
      DO 18 K1=1,NN
      IF (PV2) 44,44,55
   44 V=ZDP/PV
      GO TO 66
   55 V=(-PV+SQRT(PV**2+4.*PV2*ZDP))/(2.*PV2)
   66 DY=V*DT
      DVI=DY*VOLI
      PVI=PVI+ZDP/V*DVI
C     CALCULATE TRUNCATED PSD
      DO 71 I=1,LPN
      IF (ZPD2(I)-DEF) 71,71,72
   71 ZPNR(I)=0.
      WRITE (5,998) DEF,ZPD2(LPN)
  998 FORMAT(1H ,4HDEF=,E9.3,1X,10HZPD2(LPN)=,E9.3)
      STOP
   72 ZPNR(I)=ZPNI(I)*ALOG(ZPD2(I)/DEF)/ALOG(ZPD2(I)/ZPD1(I))
      IF (ZPNR(I)-ZPNI(I)) 74,74,75
   75 ZPNR(I)=ZPNI(I)
   74 I1=I+1
      DO 73 I=I1,LPN
```

```
 73   ZPNR(I)=ZPNI(I)
      CALL DISTR(ZPNR,XNR,AVDR,SDR,PCT,SURFR,VOLR,D15R,ZPD,ZPD1,ZPD2,M)
      EFFIC=VOLR/VOLI
      DVC=DVI*EFFIC
      IF (DVC-D15R/50.) 12,12,11
 11   NN=NN*2
      IF (LSN*NN-5000) 100,100,51
 51   WRITE(5,446)
446   FORMAT(1H ,4HEXIT)
      CALL EXIT
 12   DEF1=D15R/5.
      DEFL=ALOG(DEF)+ZP1*(DVC/D15R)*(ALOG(DEF1)-ALOG(DEF))
      DEF=EXP(DEFL)
      DO 13 I=1,LPN
      ZPNR(I)=ZPNR(I)*DY
 13   ZPNC(I)=ZPNC(I)+ZPNR(I)
      SURFR=SURFR*DY
      VOLR=VOLR*DY
      VC=VC+DVC
      VCN=VC/AVDI
      VI=VI+DVI
      Y=Y+DY
C     CALCULATE POROSITY
      IF (SDR-ZPPOR(3)) 31,31,32
 31   POR=ZPPOR(1)+ALOG(SDR)/ALOG(ZPPOR(3))*(ZPPOR(2)-ZPPOR(1))
      GO TO 33
 32   POR=ZPPOR(2)
 33   CONTINUE
      X=X+DVC/(1.-POR)
      PSV=PSV+SURFR*(1.-POR)/POR**3
      PSV2=PSV2+SURFR**2/VOLR/POR**3
      IF (VCN-ZFT) 60,60,61
 60   QQQ=VCN
      GO TO 62
 61   QQQ=ZFT
 62   PV=HLC+ZP2*4.2*ZDMU*PSV2+ZP3*HLC*(ZFM-1.)*QQQ
      PV2=ZP4*ZDRHO*PSV
 18   CONTINUE
      ZSP(K)=POR
      ZST(K)=X*1.E04
      VIN=VI/AVDI
      VCVI=VC/VI
      DEFN=DEF/AVDI
      IF (IS2) 225,230,225
230   WRITE (5,910) K,VI,PV,VIN,VCVI,DEFN,EFFIC,PV2,PVI,POR,VC
910   FORMAT(1H ,I3,1X,10(E9.3,1X))
225   CONTINUE
 19   CONTINUE
      ZDQ=(SMATX(2,IS1)*ZCGAL*1.E6)/ZCDAY
      W=ZDQ/(Y*ZDSP)
      DO 883 I=1,LPN
883   ZPNO(I)=ZPNI(I)*ZDQ-ZPNC(I)*ZDSP*W
C     TRANSMIT PARAMETERS TO DMATX
      DMATX(1,N)=DMATX(2,N)
      DMATX(2,N)=DMATX(3,N)
      DMATX(4,N)=DMATX(5,N)
      DMATX(3,N)=DMATX(4,N)
```

```
      OMATX(5,N)=OMATX(6,N)
      OMATX(6,N)=OMATX(7,N)
      OMATX(7,N)=W
C     CALCULATE SUSPENDED SOLIDS REMOVAL
      CALL DISTR(ZPNC,XNC,AVDC,SDC,PCTC,SURFC,VOLC,D15C,ZPD,ZPD1,ZPD2,M)
      CALL DISTR(ZPNO,XNO,AVDO,SDO,PCTO,SURFO,VOLO,D15O,ZPD,ZPD1,ZPD2,M)
      AXI=ZDQ*ZPDNS*VOLI*ZCDAY/ZCLB
      AXB=SMATX(10,IS1)*ZDQ*ZCDAY*1.E-6/ZCLB
      AXC=W*ZDSP*ZPDNS*VOLC*ZCDAY/ZCLB
      AXO=ZPDNS*VOLO*ZCDAY/ZCLB
      OMATX(11,N)=AXC/AXI
      IF (AXO-AXB) 275,275,276
  276 AXO=AXB
  275 SSR=AXO/AXB
      AY=AXB-AXO
      SMATX(10,OS1)=SSR*SMATX(10,IS1)
      OMATX(8,N)=SSR
      EFFA=3.1415*OMATX(2,N)*W*OMATX(3,N)
      QQ=(SMATX(2,IS1)*2646.)/(EFFA*ZCFT2*1.E-4)
      OMATX(9,N)=100.-1./(5.5E-4*QQ**1.1)
      SMATX(2,OS2)=SMATX(2,IS1)*(1.-OMATX(9,N)/100.)
C     ASSUME BACKWASH WATER IS TAKEN FROM PROCESS EFFLUENT
C     CALCULATE WASTE STREAM CHARACTERISTICS
      DO 369 I=11,17
  369 SMATX(I,OS2)=SMATX(I,IS1)
      SMATX(10,OS2)=(AY/SMATX(2,OS2))*.12
      DO 370 I=3,9
  370 SMATX(I,OS2)=(SMATX(10,OS2)/SMATX(10,OS1))*SMATX(I,IS1)
      SMATX(2,OS1)=SMATX(2,IS1)-SMATX(2,OS2)
      DO 101 I=3,9
  101 SMATX(I,OS1)=OMATX(8,N)*SMATX(I,IS1)
C     CALCULATE COSTS
C     COST ELEMENTS
C     CAPITAL COST INSTALLED
C     O+M COSTS OF FIXED WAGES (YEARLY)
C     O+M COSTS OF VARIABLE WAGES (YEARLY)
C     ENERGY COSTS
C     SCREEN REPLACEMENT COSTS (AMORTIZED OVER SCREEN LIFE)
      OMATX(10,N)=EFFA
      IF (EFFA-150.) 841,841,842
  841 CCOST(N,1)=(3860./SQRT(EFFA))*EFFA
      GO TO 843
  842 CCOST(N,1)=EFFA*300.
  843 CWAGE=3.00
      COSTO(N,1)=CWAGE*365.
      COSTO(N,2)=(38.*(SMATX(2,IS1)**.19))-35.*(CCOST(N,1)*1.E-3)
      CKWH=OMATX(1,20)
      AFAC=OMATX(5,N)/5.
      COSTO(N,3)= 365.*CKWH*(EFFA*.4+12.5)*AFAC
      CSCRN=60.
      CCSCR=CSCRN*EFFA/OMATX(3,N)
      AFSCR=.1376
      COSTO(N,4)=CCSCR*AFSCR
C     AFSCR= AMORTIZATION FACTOR FOR 9 YR LIFE AT 4.5 PERCENT
C     OPTIONAL OUTPUT PRINTING
      IF (IS2) 600,610,600
  610 CONTINUE
```

```
      WRITE(5,334)
  334 FORMAT(1H ,//)
      WRITE (5,110)
  110 FORMAT(1H ,11X,'  DRUM POOL   RETAINED  EFFLUENT')
      AVDI=AVDI*1.E04
      AVDC=AVDC*1.E04
      AVDO=AVDO*1.E04
      D15I=D15I*1.E04
      D15C=D15C*1.E04
      D15O=D15O*1.E04
      WRITE (5,111) AVDI,AVDC,AVDO
      WRITE(5,112) SDI,SDC,SDO
      WRITE(5,113) D15I,D15C,D15O
  111 FORMAT(1H ,11H AVG. DIAM.,2X,3F10.2,8H MICRONS)
  112 FORMAT(1H ,11H STD. DEV. ,2X,3F10.2)
  113 FORMAT(1H ,11H D15       ,2X,3F10.2)
  119 FORMAT(1H ,14X,'INFLUENT      DRUM  RESIDUAL  RETAINED  EFFLUENT')
      WRITE(5,334)
      WRITE(5,119)
      WRITE(5,114) AXB,AXI,AY,AXC,AXO
  114 FORMAT(1H ,11H TOTAL MASS,2X,5E10.3,7H LB/DAY)
      WRITE(5,334)
      DO 387 I=1,LPN
  387 ZPD2(I)=ZPD2(I)*1.E04
      INC=LPN/10
      LAST=10*INC
      WRITE(5,120) (ZPD2(I), I=INC,LAST,INC)
      DO 654 I=1,LPN
      PCTI(I)=PCTI(I)*100.
      PCTC(I)=PCTC(I)*100.
  654 PCTO(I)=PCTO(I)*100.
      WRITE(5,121) (PCTI(I), I=INC,LAST,INC)
      WRITE(5,122) (PCTC(I), I=INC,LAST,INC)
      WRITE(5,123) (PCTO(I), I=INC,LAST,INC)
      DO 221 I=1,LPN
  221 PCT(I)=100.*ZPNC(I)*ZDSP*W/(ZPNI(I)*ZDQ)
      WRITE(5,124) (PCT(I), I=INC,LAST,INC)
      INC=LSN/4
      LAST=INC*4
      WRITE(5,334)
      WRITE(5,104) (I,I=INC,LAST,INC)
  104 FORMAT(1H ,7HSEGMENT,8X,7H      1,4I7)
      WRITE(5,105) ZST(1),(ZST(I),I=INC,LAST,INC)
  105 FORMAT(1H ,16H THICK.(MICRONS),1X,5F7.2)
      WRITE(5,106) ZSP(1),(ZSP(I),I=INC,LAST,INC)
  106 FORMAT(1H ,9H POROSITY,7X,5F7.3)
  120 FORMAT(1H ,13H DIAM(MICRON),1X,F5.1,9F6.1)
  121 FORMAT(1H ,13H    DRUM PSD ,1X,F5.1,9F6.1)
  122 FORMAT(1H ,13H RETAINED PSD,1X,F5.1,9F6.1)
  123 FORMAT(1H ,13H EFFLUENT PSD,1X,F5.1,9F6.1)
  124 FORMAT(1H ,13H PCT. REMOVAL,1X,F5.1,9F6.1)
  600 CONTINUE
      RETURN
      END
VARIABLE ALLOCATIONS
 SMATX(RC)=7FFE-7C18 TMATX(RC)=7C16-7830 DMATX(RC)=782E-7510 OMATX(RC)=750E-71F0    IP(IC)=71EE-71BE   INP(IC)=71BC
    IO(IC)=71BA         IS1(IC)=71B8        IS2(IC)=71B6        OS1(IC)=71B4       OS2(IC)=71B2           N(IC)=71B0
```

```
IAERF(IC)=71AE       CCOST(RC)=71AC-70E6 COSTO(RC)=70E4-701E ACOST(RC)=701C-6F56 TCOST(RC)=6F54-6E8E ZPPOR(R )=0004-0000
 ZPD2(R )=0068-0006  ZPNR(R )=00CC-006A   ZPD(R )=0130-00CE   PCT(R )=0194-0132  ZPNI(R )=01F8-0196  ZPD1(R )=025C-01FA
 ZPNC(R )=02C0-025E   ZSP(R )=0324-02C2   ZST(R )=0388-0326  ZPNO(R )=03EC-038A  PCTC(R )=0450-03EE  PCTI(R )=04B4-0452
 PCTO(R )=0518-04B6   ZP1(R )=051A        ZP2(R )=051C        ZP3(R )=051E        ZP4(R )=0520        ZP5(R )=0522
  RHO(R )=0524        XMU(R )=0526         FM(R )=0528         FT(R )=052A       ZPDNS(R )=052C       ZCPI(R )=052E
 ZCIN(R )=0530       ZCFT(R )=0532      ZCIN2(R )=0534      ZCFT2(R )=0536       ZCIN3(R )=0538      ZCFT3(R )=053A
 ZCLB(R )=053C      ZCGAL(R )=053E      ZCMIN(R )=0540       ZCHR(R )=0542       ZCDAY(R )=0544      ZCGPD(R )=0546
ZCREV(R )=0548      ZCRPM(R )=054A      ZCGRV(R )=054C      ZCHIN(R )=054E         ZOR(R )=0550        ZOP(R )=0552
  ZDW(R )=0554       ZDAV(R )=0556        ZDA(R )=0558       ZDSP(R )=055A         ZDT(R )=055C       ZDAR(R )=055E
ZDRHO(R )=0560       ZDMU(R )=0562        ZFP(R )=0564        ZFM(R )=0566         ZFT(R )=0568        HLC(R )=056A
   DI(R )=056C         SI(R )=056E      XPXSR(R )=0570         CO(R )=0572         DAV(R )=0574        XX1(R )=0576
    S(R )=0578        SDL(R )=057A         SD(R )=057C          F(R )=057E        XMIN(R )=0580       XMAX(R )=0582
  XPN(R )=0584         XI(R )=0586        DDL(R )=0588          X(R )=058A           Y(R )=058C         PV(R )=058E
   VI(R )=0590        XSN(R )=0592         DT(R )=0594        XNI(R )=0596        AVDI(R )=0598        SDI(R )=059A
SURFI(R )=059C       VOLI(R )=059E       DISI(R )=05A0         VC(R )=05A2         PSV(R )=05A4       PSV2(R )=05A6
  DEF(R )=05A8        PVI(R )=05AA        PV2(R )=05AC          V(R )=05AE          DY(R )=05B0        DVI(R )=05B2
  XNR(R )=05B4       AVDR(R )=05B6        SDR(R )=05B8      SURFR(R )=05BA        VOLR(R )=05BC       DISR(R )=05BE
EFFIC(R )=05C0        DVC(R )=05C2       DEFI(R )=05C4       DEFL(R )=05C6         VCN(R )=05C8        PUR(R )=05CA
  QCU(R )=05CC        VIN(R )=05CE       VCVI(R )=05D0       DEFN(R )=05D2         ZDQ(R )=05D4          W(R )=05D6
  XNC(R )=05D8       AVDC(R )=05DA        SDC(R )=05DC      SURFC(R )=05DE        VOLC(R )=05E0       DISC(R )=05E2
  XNO(R )=05E4       AVDO(R )=05E6        SDO(R )=05E8      SURFO(R )=05EA        VOLO(R )=05EC       DISO(R )=05EE
  AXI(R )=05F0        AXB(R )=05F2        AXC(R )=05F4        AXO(R )=05F6         SSR(R )=05F8         AY(R )=05FA
 EFFA(R )=05FC         QQ(R )=05FE      CWAGE(R )=0600       CKWH(R )=0602        AFAC(R )=0604      CSCRN(R )=0606
CCSCR(R )=0608      AFSCR(R )=060A        LPN(I )=0616        LSN(I )=0618           I(I )=061A         NN(I )=061C
    K(I )=061E          M(I )=0620         KI(I )=0622         II(I )=0624         INC(I )=0626       LAST(I )=0628

UNREFERENCED STATEMENTS
 5

STATEMENT ALLOCATIONS
 1009 =06CA  900  =06D8  905  =06E5  906  =071E  998  =0727  446  =0736  910  =073C  334  =0745  110  =074A  111  =075F
 112  =0771  113  =077E  119  =078B  114  =07A8  104  =07BA  105  =07CA  106  =07D9  120  =07E5  121  =07F4  122  =0803
 123  =0812  124  =0821  666  =094F  21   =098A  22   =099B  23   =09AA  1000 =09C7  1001 =09D8  1002 =09E7  1003 =09F3
 1004 =0A00  1005 =0A0C  1006 =0A1B  1007 =0A28  5    =0A3B  9    =0A7A  92   =0AA7  93   =0AC4  94   =0B2E  210  =0B5D
 200  =0B73  100  =0B73  102  =0B85  44   =0BDC  55   =0BE4  66   =0C08  71   =0C2E  72   =0C4F  75   =0C8E  74   =0C97
 73   =0CA1  11   =0CD6  51   =0CE6  12   =0CEB  13   =0D22  31   =0D60  32   =0D83  33   =0D89  60   =0DBE  61   =0DC4
 62   =0DC8  18   =0DEE  230  =0E1E  225  =0E38  19   =0E38  883  =0E5C  276  =0F2C  275  =0F30  369  =0FA8  370  =0FE0
 101  =102E  841  =1066  842  =1078  843  =1083  610  =10FF  387  =1167  654  =1189  221  =1219  600  =1282

CALLED SUBPROGRAMS
 FALOG    FEXP     FSQRT    DISTR    FAXB     FADD     FADDX    FSUB     FSUBX    FMPY     FMPYX    FDIV     FDIVX    FLD      FLDX
 FSTO     FSTOX    FSBR     FDVR     FAXI     FLOAT    SWRT     SCOMP    SIOFX    SIOF     SIOI     SUBSC    STOP     SNR

REAL CONSTANTS
  .900000E 00=0634    .100000E 01=0636    .300000E 00=0638    .250000E 00=063A    .150000E 00=063C    .150000E 01=063E
  .100000E-01=0640    .200000E 01=0642    .500000E 00=0644    .105000E 01=0646    .314160E 01=0648    .254000E 01=064A
  .120000E 02=064C    .100000E 04=064E    .220500E 01=0650    .748100E 01=0652    .600000E 02=0654    .240000E 02=0656
  .321700E 02=0658    .100000E-03=065A    .250000E 01=065C    .640000E-01=065E    .140000E 01=0660    .580000E 00=0662
  .145000E 01=0664    .625000E 01=0666    .960000E-02=0668    .119000E 01=066A    .400000E-01=066C    .562000E 01=066E
  .880000E-02=0670    .750000E 01=0672    .200000E 00=0674    .266600E-01=0676    .120000E 00=0678    .100000E-05=067A
  .400000E 01=067C    .600000E 01=067E    .850000E 00=0680    .000000E 00=0682    .500000E 02=0684    .500000E 01=0686
  .420000E 01=0688    .100000E 05=068A    .100000E 07=068C    .314150E 01=068E    .264600E 04=0690    .100000E 03=0692
  .550000E-03=0694    .110000E 01=0696    .150000E 03=0698    .386000E 04=069A    .300000E 03=069C    .300000E 01=069E
  .365000E 03=06A0    .380000E 02=06A2    .190000E 00=06A4    .350000E 02=06A6    .100000E-02=06A8    .400000E 00=06AA
  .125000E 02=06AC    .137600E 00=06AE

INTEGER CONSTANTS
    10=06B0       8=06B1       2=06B2       3=06B3      11=06B4      17=06B5       5=06B6       1=06B7       0=06B8    5000=06B9
```

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     9=06BA      4=06BB      0=06BC

CORE REQUIREMENTS FOR MICRO
 COMMON   4466  VARIABLES   1588  PROGRAM   3200

RELATIVE ENTRY POINT ADDRESS IS 0830 (HEX)

END OF COMPILATION

// DUP

*STORE      WS  UA  MICRO
CART ID 0001   DB ADDR  3F24   DB CNT   00E6

*DELETE              DISTR
CART ID 0001   DB ADDR  3F07   DB CNT   001D

// FOR
*LIST ALL
      SUBROUTINE DISTR(PSD,SUMN,AVG,SD,PCTV,SURF,VOL,D15,ZPD,ZPD1,ZPD2,M
     *)
      DIMENSION PSD(50),PCTV(50),ZPD(50),ZPD1(50),ZPD2(50)
      COMMON SMATX(20,25),TMATX(20,25),DMATX(20,20),OMATX(20,20),IP(25),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),
     . ACOST(20,5),TCOST(20,5)
      LPN=M
      ZCPI=3.141519
      SUMN=0.
      SUMDL=0.
      SUMD2=0.
      SURF=0.
      VOL=0.
      DO 11 I=1,LPN
      XN=PSD(I)
      D=ZPD(I)
      DL=ALOG(D)
      SUMN=SUMN+XN
      VOLUM = XN*D**3*ZCPI/6.
      SUMN=SUMN+XN
      SUMDL=SUMDL+VOLUM*DL
      SUMD2=SUMD2+VOLUM*DL**2
      SURF=SURF+XN*D**2*ZCPI
      VOL=VOL+VOLUM
      PCTV(I)=VOL
   11 CONTINUE
      IF (SUMN) 20,20,30
   20 AVG=0.
      SD=0.
      SURF=0.
      VOL=0.
      D15=0.
      RETURN
   30 AVG=EXP(SUMDL/VOL)
      VARL=SUMD2/VOL-(SUMDL/VOL)**2
      SDL=SQRT(VARL)
      SD=EXP(SDL)
      DO 31 I=1,LPN
```

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   31 PCTV(I)=PCTV(I)/VOL
      DO 32 I=1,LPN
      IF (PCTV(I)-.15) 32,33,33
   32 CONTINUE
   33 DL1=ALOG(ZPD1(I))
      DL2=ALOG(ZPD2(I))
      P1=PCTV(I-1)
      P2=PCTV(I)
      DL15=DL1+(.15-P1)/(P2-P1)*(DL2-DL1)
      D15=EXP(DL15)
      RETURN
      END
 VARIABLE ALLOCATIONS
  SMATX(RC)=7FFE-7C18 THATX(RC)=7C16-7830 DMATX(RC)=782E-7510 OMATX(RC)=750E-71F0    IP(IC)=71EE-718E   INP(IC)=718C
     IO(IC)=71BA          IS1(IC)=7188          IS2(IC)=7186          OS1(RC)=7184          OS2(RC)=71B2         N(IC)=71B0
  IAERF(IC)=71AE      CCOST(RC)=71AC-70E6 COSTO(RC)=70E4-701E ACOST(RC)=701C-6F56 TCOST(RC)=6F54-6E8E  ZCPI(R )=0000
  SUMDL(R )=0002       SUMD2(R )=0004         XN(R )=0006           D(R )=0008          DL(R )=000A      VOLUM(R )=000C
   VARL(R )=000E         SDL(R )=0010        DL1(R )=0012         DL2(R )=0014          P1(R )=0016         P2(R )=0018
   DL15(R )=001A         LPN(I )=0020          I(I )=0022

 STATEMENT ALLOCATIONS
  11    =00E1  20    =00EF  30    =0105  31    =012E  32    =0152  33    =015B

 CALLED SUBPROGRAMS
  FALOG    FEXP     FSQRT    FADD     FSUB     FMPY     FDIV     FLD      FLDX     FSTO     FSTOX    FSBR     FDVR     FAXI     SUBSC
  SUBIN

 REAL CONSTANTS
   .314151E 01=0028    .000000E 00=002A    .600000E 01=002C    .150000E 00=002E

 INTEGER CONSTANTS
      1=0030       3=0031       2=0032

 CORE REQUIREMENTS FOR DISTR
  COMMON    4466  VARIABLES      40  PROGRAM     384

 RELATIVE ENTRY POINT ADDRESS IS 0036 (HEX)

 END OF COMPILATION

// DUP

*STORE      WS  UA  DISTR
CART ID 0001   DB ADDR  3FED   DB CNT   001D

// FOR
*IOCS(CARD, 1403 PRINTER, DISK)
*LIST ALL
      INTEGER OS1,OS2
C     PROGRAM MAIN
C     THIS PROGRAM TESTS THE SUB-PROGRAM AND ACTS AS A SIMULATION MODEL
      DIMENSION NAME(3)
      COMMON SMATX(20,25),TMATX(20,25),DMATX(20,20),OMATX(20,20),IP(25),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(20,5),COSTO(20,5),
     . ACOST(20,5),TCOST(20,5)
C     READ FORMATS FROM EXECUTIVE PROGRAM
C     INITIALIZE TO ZERO
```

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 555  CONTINUE
      DO 5 I=1,20
      DO 5 J=1,25
      SMATX(I,J)=0.
    5 TMATX(I,J)=0.
      DO 10 I=1,20
      DO 10 J=1,20
      DMATX(I,J)=0.
   10 OMATX(I,J)=0.
      DO 15 I=1,20
      DO 15 J=1,5
      CCOST(I,J)=0.
      COSTO(I,J)=0.
      ACOST(I,J)=0.
   15 TCOST(I,J)=0.
C     READ INPUT DATA
      READ(2,60) (SMATX(I,1),I=2,17)
 60   FORMAT (8F10.3/8F10.3)
      READ(2,60) (DMATX(I,20),I=1,16)
      READ(2,120) K,N,IPROC,(NAME(I),I=1,3),IS1,IS2,OS1,OS2,III
  120 FORMAT(I1,1X,I2,2X,I2,1X,3A2,4X,I2,8X,I2,8X,I2,8X,I2,28X,I1)
      SMATX(1,IS1)=IS1
      SMATX(1,OS1)=OS1
      SMATX(1,OS2)=OS2
      READ(2,60) (DMATX(I,N),I=1,16)
      READ(2,70) IPRNT
 70   FORMAT(I2)
C     TRANSMIT IPRNT TO MICRO THROUGH IS2
      IS2=IPRNT
      WRITE(5,300)
 300  FORMAT(1H ,//,1H ,'MICROSCREEN MODEL')
      WRITE(5,804) NAME(1),NAME(2),NAME(3)
 804  FORMAT(1H ,3A2,//)
      IF (IPRNT) 20,25,20
 20   WRITE(5,310)
 310  FORMAT(1H ,27HTRAPPING AND HYDRAULIC DATA)
 25   CONTINUE
      CALL MICRO
      WRITE(5,320)
 320  FORMAT(1H ,//)
      WRITE(5,330) (I,OMATX(I,N), I=1,11)
      WRITE(5,320)
      WRITE(5,326)
 326  FORMAT(1H ,10X,'IS1',6X,'OS1',6X,'OS2')
      WRITE(5,335) (I,SMATX(I,IS1),SMATX(I,OS1),SMATX(I,OS2), I=1,17)
 330  FORMAT(1H ,6HOMATX(,I2,4H,N)=,E10.3)
 335  FORMAT(1H ,3HI= ,I2,2X,F7.3,2X,F7.3,2X,F7.3)
       WRITE(5,336)
 336  FORMAT(1H ,'  CAP. COST   FIX. OP. COST VAR. OP. COST   ENERGY  ',
     +'  SCRN. REP. COST')
      WRITE(5,340) CCOST(N,1),COSTO(N,1),COSTO(N,2),COSTO(N,3),COSTO(N,4
     +)
 340  FORMAT(1H ,5(2X,E11.4))
      GO TO 555
 1111 STOP
      END
```

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VARIABLE ALLOCATIONS
 SMATX(RC)=7FFE-7C18 TMATX(RC)=7C16-7830 DMATX(RC)=782E-7510 OMATX(RC)=750E-71F0    IP(IC)=71EE-71BE   INP(IC)=71BC
    ID(IC)=71BA          IS1(IC)=71B8          IS2(IC)=71B6          OS1(IC)=71B4          OS2(IC)=71B2          N(IC)=71B0
  IAERF(IC)=71AE      CCOST(RC)=71AC-70E6 COSTO(RC)=70E4-701E ACOST(RC)=701C-6F56 TCOST(RC)=6F54-6E8E  NAME(I )=0004-0000
     I(I )=0006           J(I )=0008            K(I )=000A        IPROC(I )=000C         III(I )=000E       IPRNT(I )=0010

UNREFERENCED STATEMENTS
 1111

STATEMENT ALLOCATIONS
 60   =0030  120  =0036  70   =0049  300  =0048  804  =005C  310  =0063  320  =0075  326  =007A  330  =0089  335  =0095
 336  =00A2  340  =00CA  555  =00EA  5    =00FD  10   =0128  15   =015F  20   =0220  25   =0224  1111 =02A2

FEATURES SUPPORTED
 IOCS

CALLED SUBPROGRAMS
 MICRO  FLD    FSTO    FSTOX   FLOAT   CARDZ   SRED    SWRT    SCOMP   SFIO    SIOFX   SIOIX   SIOI    SUBSC   PRNZ
 STOP   SDFIO

REAL CONSTANTS
  .000000E 00=001A

INTEGER CONSTANTS
     1=001C     20=001D     25=001E     5=001F     2=0020     17=0021     16=0022     3=0023     11=0024     0=0025

CORE REQUIREMENTS FOR
 COMMON    4466  VARIABLES     26  PROGRAM    650

END OF COMPILATION

// XEQ


MICROSCREEN MODEL
1A 1


DRUM POOL CONCENTRATION=  57.4199
SEGMENT DATA
SEG      VI         PV         VIN       VC/VI        DEFN       EFFIC        PV2         PV1         POR          VC
  0 0.000E 00 0.690E 03
  1 0.927E-04 0.778E 04 0.177E 00 0.277E 00 0.163E 01 0.290E 00 0.304E 02 0.279E 00 0.150E 00 0.257E-04
  2 0.123E-03 0.105E 05 0.237E 00 0.282E 00 0.160E 01 0.299E 00 0.417E 02 0.558E 00 0.150E 00 0.349E-04
  3 0.147E-03 0.128E 05 0.283E 00 0.285E 00 0.158E 01 0.306E 00 0.509E 02 0.838E 00 0.150E 00 0.422E-04
  4 0.168E-03 0.148E 05 0.322E 00 0.288E 00 0.155E 01 0.312E 00 0.589E 02 0.111E 01 0.150E 00 0.485E-04
  5 0.186E-03 0.166E 05 0.356E 00 0.290E 00 0.153E 01 0.317E 00 0.662E 02 0.139E 01 0.150E 00 0.541E-04
  6 0.202E-03 0.183E 05 0.387E 00 0.293E 00 0.152E 01 0.322E 00 0.728E 02 0.167E 01 0.150E 00 0.593E-04
  7 0.216E-03 0.199E 05 0.415E 00 0.295E 00 0.150E 01 0.326E 00 0.791E 02 0.195E 01 0.150E 00 0.640E-04
  8 0.230E-03 0.214E 05 0.441E 00 0.297E 00 0.149E 01 0.331E 00 0.849E 02 0.223E 01 0.150E 00 0.685E-04


               DRUM POOL   RETAINED   EFFLUENT
 AVG. DIAM.        5.21       13.73       3.46 MICRONS
 STD. DEV.         2.39        1.67       1.89
```

D15	2.02	7.32	1.65

	INFLUENT	DRUM	RESIDUAL	RETAINED	EFFLUENT	
TOTAL MASS	0.215E 02	0.426E 02	0.000E 00	0.126E 02	0.215E 02	LB/DAY

DIAM(MICRON)	0.3	0.6	1.2	2.5	5.2	10.5	21.1	42.5	85.6	172.3
DRUM PSD	0.0	0.6	5.0	20.5	49.9	79.4	94.9	99.3	99.9	100.0
RETAINED PSD	0.0	0.0	0.0	0.0	0.0	30.9	83.1	97.7	99.8	100.0
EFFLUENT PSD	0.0	0.9	7.1	29.2	71.1	100.0	100.0	100.0	100.0	100.0
PCT. REMOVAL	0.0	0.0	0.0	0.0	0.0	31.2	99.9	99.9	99.9	100.0

SEGMENT	1	2	4	6	8
THICK.(MICRONS)	0.30	0.41	0.57	0.69	0.80
POROSITY	0.150	0.150	0.150	0.150	0.150

```
OMATX( 1,N)= 0.400E 01
OMATX( 2,N)= 0.420E 00
OMATX( 3,N)= 0.228E 01
OMATX( 4,N)= 0.350E 01
OMATX( 5,N)= 0.300E 02
OMATX( 6,N)= 0.160E-01
OMATX( 7,N)= 0.135E 01
OMATX( 8,N)= 0.100E 01
OMATX( 9,N)= 0.971E 02
OMATX(10,N)= 0.717E 01
OMATX(11,N)= 0.297E 00
```

	IS1	OS1	OS2
I= 1	1.000	3.000	4.000
I= 2	0.089	0.086	0.002
I= 3	1.000	1.000	0.000
I= 4	2.000	2.000	0.000
I= 5	3.000	3.000	0.000
I= 6	0.000	0.000	0.000
I= 7	0.000	0.000	0.000
I= 8	0.000	0.000	0.000
I= 9	0.000	0.000	0.000
I= 10	29.000	29.000	0.000
I= 11	1.000	1.000	1.000
I= 12	2.000	2.000	2.000
I= 13	3.000	3.000	3.000
I= 14	0.000	0.000	0.000
I= 15	0.000	0.000	0.000
I= 16	0.000	0.000	0.000
I= 17	0.000	0.000	0.000

CAP. COST	FIX. OP. COST	VAR. OP. COST	ENERGY	SCRN. REP. COST
0.1033E 05	0.1095E 04	0.8681E 04	0.3926E 04	0.1409E 03

MICROSCREEN MODEL

DRUM POOL CONCENTRATION= 31.0959

SEGMENT DATA

SEG	VI	PV	VIN	VC/VI	DEFN	EFFIC	PV2	PVI	POR	VC
0	0.000E 00	0.690E 03								
1	0.105E-03	0.930E 04	0.107E 00	0.541E 00	0.858E 00	0.553E 00	0.499E 02	0.486E 00	0.150E 00	0.571E-04
2	0.148E-03	0.133E 05	0.151E 00	0.546E 00	0.834E 00	0.563E 00	0.721E 02	0.972E 00	0.150E 00	0.812E-04
3	0.181E-03	0.165E 05	0.184E 00	0.550E 00	0.816E 00	0.571E 00	0.895E 02	0.145E 01	0.150E 00	0.997E-04
4	0.208E-03	0.193E 05	0.211E 00	0.553E 00	0.800E 00	0.578E 00	0.104E 03	0.194E 01	0.150E 00	0.115E-03
5	0.231E-03	0.219E 05	0.235E 00	0.556E 00	0.787E 00	0.584E 00	0.117E 03	0.243E 01	0.150E 00	0.129E-03
6	0.252E-03	0.243E 05	0.257E 00	0.559E 00	0.775E 00	0.589E 00	0.130E 03	0.291E 01	0.150E 00	0.141E-03
7	0.272E-03	0.265E 05	0.276E 00	0.561E 00	0.764E 00	0.595E 00	0.141E 03	0.340E 01	0.150E 00	0.152E-03
8	0.289E-03	0.286E 05	0.294E 00	0.563E 00	0.753E 00	0.600E 00	0.152E 03	0.389E 01	0.150E 00	0.163E-03

	DRUM POOL	RETAINED	EFFLUENT	
AVG. DIAM.	9.83	19.97	3.93	MICRONS
STD. DEV.	2.82	1.99	1.84	
D15	3.18	10.42	2.02	

	INFLUENT	DRUM	RESIDUAL	RETAINED	EFFLUENT	
TOTAL MASS	0.193E 02	0.230E 02	0.923E 01	0.130E 02	0.100E 02	LB/DAY

DIAM(MICRON)	0.3	0.8	1.8	4.2	9.8	22.5	51.8	119.0	273.3	627.5
DRUM PSD	0.0	0.6	5.0	20.5	49.9	79.4	94.9	99.3	99.9	100.0
RETAINED PSD	0.0	0.0	0.0	0.0	11.3	63.5	91.1	98.7	99.9	100.0
EFFLUENT PSD	0.1	1.5	11.4	47.0	100.0	100.0	100.0	100.0	100.0	100.0
PCT. REMOVAL	0.0	0.0	0.0	0.0	21.6	100.0	100.0	100.0	100.0	100.0

SEGMENT	1	2	4	6	8
THICK.(MICRONS)	0.67	0.95	1.35	1.66	1.92
POROSITY	0.150	0.150	0.150	0.150	0.150

OMATX(1,N)= 0.400E 01
OMATX(2,N)= 0.450E 00
OMATX(3,N)= 0.342E 01
OMATX(4,N)= 0.175E 01
OMATX(5,N)= 0.300E 02
OMATX(6,N)= 0.160E-01
OMATX(7,N)= 0.117E 01
OMATX(8,N)= 0.521E 00
OMATX(9,N)= 0.973E 02
OMATX(10,N)= 0.661E 01
OMATX(11,N)= 0.563E 00

IS1 OS1 OS2

I= 1	1.000	3.000	4.000
I= 2	0.089	0.086	0.002
I= 3	1.000	0.521	35.050
I= 4	2.000	1.043	70.101
I= 5	3.000	1.565	105.152
I= 6	0.000	0.000	0.000
I= 7	0.000	0.000	0.000
I= 8	0.000	0.000	0.000
I= 9	0.000	0.000	0.000
I= 10	26.000	13.564	475.463
I= 11	1.000	1.000	1.000
I= 12	2.000	2.000	2.000
I= 13	3.000	3.000	3.000
I= 14	0.000	0.000	0.000
I= 15	0.000	0.000	0.000
I= 16	0.000	0.000	0.000
I= 17	0.000	0.000	0.000

CAP. COST	FIX. OP. COST	VAR. OP. COST	ENERGY	SCRN. REP. COST
0.9931E 04	0.1095E 04	0.8341E 04	0.1935E 04	0.1214E 03

1 Accession Number	2 Subject Field & Group	SELECTED WATER RESOURCES ABSTRACTS
W	Ø5D	INPUT TRANSACTION FORM

5 Organization

Engineering-Science, Inc., Cincinnati, Ohio 45226

6 Title

Investigation of Response Surfaces of the Microscreen Process

10 Author(s)

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16 Project Designation

EPA, WQO Contract No. 14-12-819

21 Note

22 Citation

23 Descriptors (Starred First)

*Tertiary Treatment, *Filters, Pilot Plants, Computer Models

25 Identifiers (Starred First)

*Microscreens, *Microstrainers, Treatment Process Design

27 Abstract

Field, laboratory, theoretical, and state-of-the-art studies were conducted with regard to utilization of microscreens for tertiary treatment applications. Field studies were conducted with two pilot microscreen units, using a variety of screen sizes and types, for activated sludge, trickling filter, and oxidation pond effluents. Particle size distribution of the effluents (microscreen influents) were found to be the key characterizing parameter in determination of treatment effectiveness. Overall effectiveness of solids removal was low, and is ascribed to deficiencies in microscreen design practice for the transfer of screened solids from the screen to the backwash system and out of the microscreen unit.

A computer model of the process was developed in a format compatible with the EPA Executive Program for Optimization of Treatment Systems.

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