

FILTRATION PROCESS & EQUIPMENT STUDIES
FOR COAL LIQUEFACTION PROCESSES

FINAL REPORT

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EXECUTIVE SUMMARY

Precoat filtration has been used as the liquid/solid separation process at both the Pittsburg & Midway Coal Mining Company, Fort Lewis, Washington, SRC I Pilot Plant and the SRC Pilot Plant at Wilsonville, Alabama. Johns-Manville's experience from other precoat filtration operations indicated that major improvements in filtration rate and operating costs should be possible.

A Rotary Pressure Precoat Filter Test Leaf was designed and constructed which makes it possible to simulate the operation of a full scale rotary pressure precoat filter. Variables affecting the operation of the rotary pressure precoat filter were investigated in detail. At optimized operating conditions, the filtration rates were three to four times those achieved at Fort Lewis and almost an order of magnitude higher than those obtained at Wilsonville on another type of filter. It now appears possible to markedly reduce the filtration cost in coal liquefaction plants.

This Report includes a review of precoat filtration principles, a description of the test equipment used, and a

presentation of the effect of filtration variables as determined
by studies with the Rotary Pressure Precoat Filter Test Leaf.

PROGRAM OBJECTIVES

The primary objective of the program is to achieve major improvements in the filtration process and equipment used in coal liquefaction processes. Reproducible doubling of the filtration rate and reduction of filter aid usage are ultimate goals. A secondary objective is the development of operating conditions for the startup in June 1978 of a 50 Square Foot Pilot Filter at Fort Lewis.

IMPORTANCE TO FOSSIL ENERGY TECHNOLOGY

Efficient solid/liquid separation is a "must" in coal liquefaction processes now under consideration. While other means of solid/liquid separation are being investigated, it would appear that filtration is most likely to succeed because of its inherent ability to produce a solids-free filtrate with product losses of less than five percent.

Since coal liquefaction processes constitute a large segment of the Fossil Energy Technology program, it is likely that filtration will be very important to the total Fossil Energy Technology effort.

Section 2

SUMMARY AND CONCLUSIONS

After completion of construction of a laboratory scale filter test leaf system, designed to operate at high temperatures and pressures, its operation proceeded for the purpose of studying the primary filtering variables. This Phase of the Program/Management Plan has been identified as "Task II". The variables studied were temperature, pressure drop, knife (or blade) advance rate (cycle), drum rotation rate, CELITE grade, and filter feed materials. The main objectives of this work were:

- To simulate operations of a plant scale Rotary Drum Pressure Precoat Filter
- To attain more than double the rates being obtained in existing plant operations
- To reduce current energy usage.

These objectives have been exceeded operating at the following maximum or minimum conditions.

- Minimum immersion time of 2 seconds, equivalent to 12 rpm drum speed.
- Maximum temperature of 600^oF (minimum viscosity) representing the stability limit of the feed material.
- Differential pressures up to 100 psid.

·Knife advance rates down to 1/2 mil per revolution.

·Use of fine particle size precoat grade.

For initial work with Wilsonville Filter Feed (WFF), these principle parameters were visualized cubically to show an augmented full factorial experimental design with center point. The augmentation includes insertion of immersion time levels in every set of conditions. The cube in isometric position, left plane, represents all data taken at maximum temperature; the right plane, all data taken at maximum rate of knife advance; and the upper plane, the maximum differential pressure. Thus, highest filtration rates are obtained at maximum conditions of temperature, differential pressure, and blade advance plus minimum immersion times. While rates of over 700 pounds per hour per square foot of filter area were obtained, rates in the range of 400 to 500 pounds per hour per square foot have been obtained on a consistent basis (with AF5 precoat, 100 psid, 600°F, 2 mils per cycle, and 2 seconds immersion) for both Wilsonville and Tacoma feeds.

The significant data contributing to the completion of Task II and included in the accompanying data sheets were obtained during the span of a year starting in September 1976 and ending in August 1977. During this period, 192 separate runs were made, grouped according to basecoat, precoat, and feed materials in the following tabulation:

<u>FEED</u>	<u>BASECOAT</u>	<u>PRECOAT</u>	<u>NO. OF RUNS</u>
Synthoil (FB451)	FIBRA-FLO 7C	AF7	9
*Wilsonville (SN15719)	FIBRA-FLO 7C	AF7	5
*Wilsonville (SN15719)	FIBRA-FLO 7C	AF6	5
**Wilsonville (SN25260)	FIBRA-FLO 7C	AF5	21
Tacoma (TFF-216)	FIBRA-FLO 7C	AF7	34
Tacoma (TFF-216)	FIBRA-FLO 7C	AF6	12
Tacoma (TFF-216)	FIBRA-FLO 7C	AF5	72
Tacoma (TFF-216)	CELITE AF13	AF5	34
			192 TOTAL

*Wilsonville SN15719: Kentucky No. 9 & No. 14 Coal

**Wilsonville SN25260: Utah-Emery Coal

The feed samples evaluated were identified as Synthoil, Tacoma, and Wilsonville, listed in order of increasing filtration rates when run at the same immersion time, temperature, pressure, and blade advance rates. At high immersion times (20 seconds) and with the other variables in the medium or mild range, the filtration rates of these materials tend to come together. These results show the effects of poor cake cutting at low differential pressures resulting from the milder conditions and to a lesser extent, at low blade advance rates. In addition, the resistance of the filter cake plays a greater role in determining filtration rate at longer immersion times.

Various grades of precoat filter aids were evaluated in selecting the optimum for both basecoating and precoating. FIBRA-FLO 7C, containing asbestos, was used as the pre-precoat for most runs. CELITE AF13, however, proved to be satisfactory also, with no sacrifice in filtration rate or ash removal. CELITE AF13 is a relatively coarse, non-asbestos filled diatomite filter aid.

Application must be applied with care and any significant compression must be avoided.

The use of CELITE AF13 as a basecoat when filtering Tacoma Filter Feed (TFF) displayed no appreciable difference in filtration rate or filtrate ash content as compared with previous testing under similar conditions with an asbestos containing FIBRA-FLO 7C pre-precoat.

Precoating data were obtained with precoat grades CELITE AF2, AF5, AF6, and AF7. Most runs were made with CELITE AF5. CELITE AF2 is a finer diatomite with smaller pore openings and thus is less permeable than CELITE AF5.

Using TFF, filtration rates with CELITE AF2 precoat were similar to or slightly lower than rates with CELITE AF5.

The "AF" precoat grades are special filter aids treated with an anti-flocculation agent and were used for the early runs. With CELITE AF7, precoats were more dense and cracked less than with the standard grades of CELITE. A toluene/xylene mixture was found to be the most satisfactory precoating liquid of those evaluated.

Minimum filter aid usage involves precoating and operating techniques that will improve cutting characteristics of the cake and limit penetration of the solids. For minimum precoat usage, the

knife advance rate was lowered successfully to 1/2 mil per revolution. Data, however, at 1/2 mil and 1 mil per revolution were more erratic than at higher advance rates. With TFF, a 1/2 mil per revolution knife advance (at 100 psid) resulted in rates in excess of 325 pounds per hour per square foot.

2.1 RATE VERSUS TEMPERATURE

All data show an increase in rate with temperature.

2.2 RATE VERSUS PRESSURE

Data which show increasing filtration rate with increasing differential pressure from 70 to 100 psi are indicated below for both WFF (SN25260, Emery Coal) and TFF. Conditions in both cases were: 600°F, 2 seconds immersion, 2 mils per revolution knife advance, and CELITE AF5 precoat.

<u>FILTRATION RATE - lb/hr/sq ft</u>	<u>FEED</u>	<u>70 psid</u>	<u>100 psid</u>	<u>PERCENT INCREASE</u>
TFF	600	704		17
WFF	601	766		27

Earlier runs compared the effect of pressures from 35 to 70 psid on rate with both CELITE AF6 and AF5 precoats.

2.3 RATE VERSUS KNIFE ADVANCE

Filtration rates for WFF (SN25260, Emery Coal) were about the same for both 1 and 2 mils per revolution knife advances indicating that 1 mil per revolution was sufficient to remove the solid particles which penetrate and tend to blind the precoat. With TFF, definite decreases in filtration rates occurred when reducing the knife advance from 4 to 1/2 mil per revolution. The largest reduction occurred when reducing from 1 to 1/2 mil knife advance. Rate comparisons at 35, 70, and 100 psid all indicated partial precoat blinding between 2 and 4 mils per revolution knife advance and the same conclusion was made for CELITE AF5, AF6, and AF7 precoats when filtering at 35 psid.

2.4 RATE VERSUS DRUM SPEED

At increased drum speeds, filtration rates increased appreciably. For example, at 2 mils per revolution knife advance as immersion times decreased from 10 to 2 seconds (a drum speed increase from 2.4 to 12.0 rpm), the filtration rate increased from about 200 to 600 pounds per hour per square foot. Also, in one series of runs, it was observed that rate increased four times while precoat consumption only doubled.

In general, the curves of filtration rate versus leaf immersion time show a marked decrease in rate as the immersion time increases.

Major differences between results with WFF (SN25260, Emery Coal) and TFF materials were as follows:

- Filtration rates for WFF at both 1 mil per revolution and 2 mils per revolution knife advances were about the same. This indicated that 1 mil per revolution was sufficient to remove the solid particles which penetrated and tended to blind the CELITE AF5 precoat.
- Filter aid usage when filtering WFF material was nearly constant for each knife advance over a range of drum speeds; whereas, the TFF material has exhibited a greater increase of filter aid consumption with increased drum speeds.

Section 3

REVIEW OF PRECOAT FILTRATION PRINCIPLES

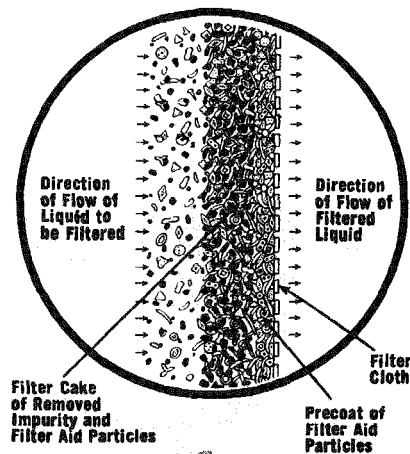
Two basic types of filtration are used for solid/liquid separation at coal liquefaction pilot plants. These processes both use filter aids and differ only in how the filter aids are used. These basic filters are stationary element pressure and rotary drum precoat pressure filters.

3.1 STATIONARY ELEMENT PRESSURE FILTER

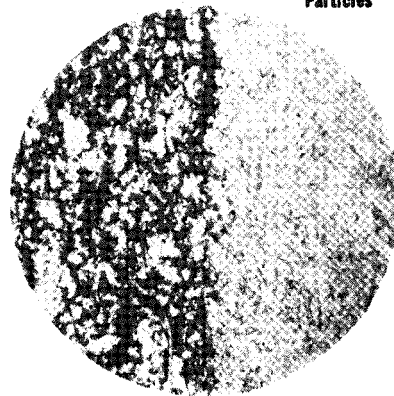
There is a wide variety of stationary element filters, depending on whether the element is in the form of a leaf, tube, or plate (as in the plate and frame filter). To increase throughput and improve clarity, diatomite filter aid may be used.

Filtration on a stationary element filter using diatomite filter aids is a two step operation. First, a thin protective layer of filter aid (the precoat) is built up on the filter medium by recirculating a filter aid slurry. The precoat serves to prevent suspended solids from fouling the medium, to give immediate clarity and to facilitate cake removal at the end of the filtration cycle. After precoating, small amounts of filter aid (body feed) are

normally added continuously to the liquid to be filtered. As filtering progresses, the filter aid, mixed with the suspended solids in the liquid, is deposited on the precoat. Thus, a new open filtering surface is continuously formed as the minute filter aid particles provide countless microscopic channels which entrap suspended impurities, but allow clear liquid to pass through without clogging. This procedure is shown in Figure 3-1.



Schematic Diagram
of Filter Cake



Actual Photograph
of Filter Cake

Figure 3-1

Filtration continues until either maximum pressure, minimum flow, or maximum filter cake volume has been reached. At this point, filter cake is removed from the filter by backwashing (for tubular filter elements only), sluicing, or drying the cake by blowing with gas followed by vibrating or spinning the cake off the leaves.

An efficient economical filter aid must:

- Have strong, intricately shaped, porous, individual particles.
- Form a highly permeable, but rigid and incompressible filter cake.
- Remove even the finest solids at high rates of flow.
- Be inert to the liquid being filtered.

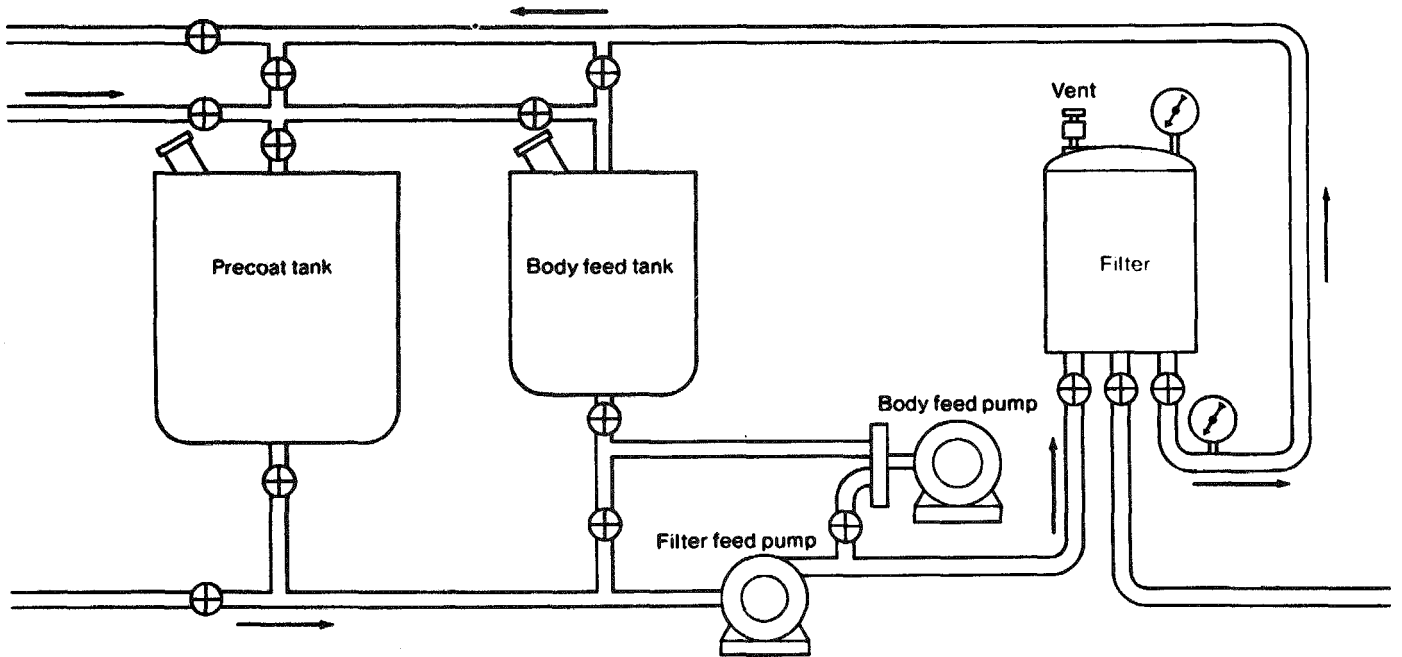
The essentials of a stationary element filter aid filtration system are shown in Figure 3-2. These consist of the filter, the filter feed pump, tanks containing filter aid for precoating and body feed addition, and the body feed pump for continuous addition of filter aid. Note also the lines for filling the body feed tank and the precoat tank with filtered liquid and for circulating clear or filtered liquid containing filter aid between the precoat tank and the filter. The system may also include a precoat circulating pump and auxiliary lines for blowing back the filter heel to the feed tank and for filling and recirculating wash

liquid. It may also include vent lines and lines for blowing the filter cake dry with air, inert gas, or steam.

Continuous addition of filter aid (body feeding) is usually done by feeding the filter aid as a slurry using either a plunger or diaphragm pump. If filtration is a batch process, the filter aid can be added directly to the batch.

FIGURE 3-2

Typical diatomite filtration system



The total cost of filtration is dependent upon a number of factors, including:

- The amount and type of filter aid used
- The energy needed to heat and pump the liquid being filtered
- The filtration rate and cycle length
- Amortization of the filter station
- Maintenance
- Labor
- The amount of valuables left in the cake.

All these factors are interrelated. The first two items are direct charges and are related to throughput. The third factor has a major effect on labor requirements and on filter station cost. Filtration cycle length also affects filter aid cost since the cost of the precoat must be amortized over the volume of liquid filtered. The relative effects of these factors in one hypothetical case are shown in Figures 3-3 and 3-4. The assumptions used were that an automatic filter station was used (so labor costs can be neglected) and that one hour of downtime was required for each filtration cycle. The effect of short cycles on costs is very marked.

The amount of body feed added is dependent on the type and amount of undissolved solids being removed. For incompressible solids, the ratio of body feed to solids, by weight, may be 1/2 to 1, but for compressible solids, the ratio may be as high as 7 on

8 pounds of filter aid per pound of solids.

When hazardous liquids such as liquefied coal in solvent are being filtered, operation of the pressure stationary element system becomes quite involved and time consuming. Each time the filter is precoated there is an opportunity for solids not completely removed from the filter to gradually blind the filter element, necessitating removal and cleaning.

FIGURE 3-3

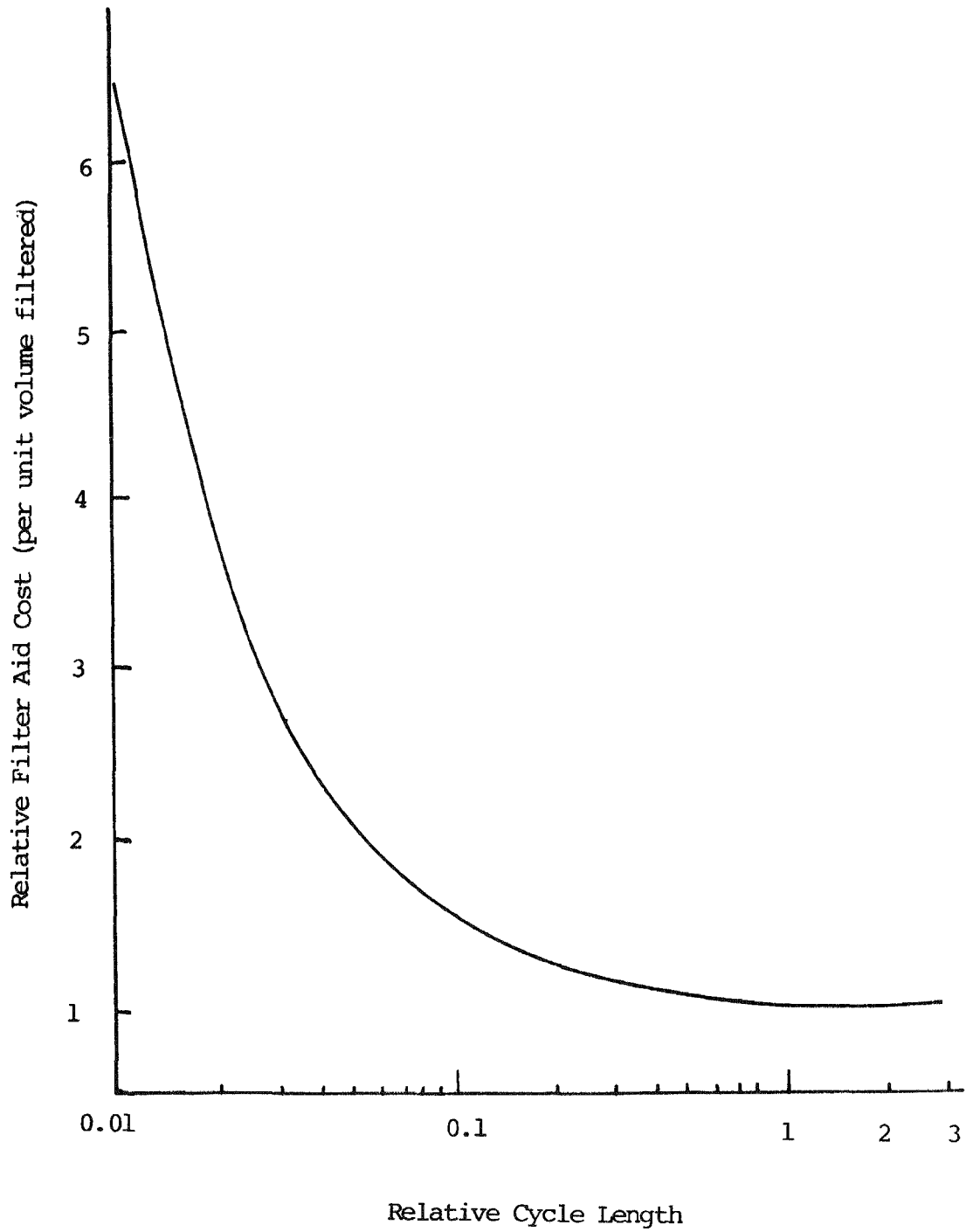
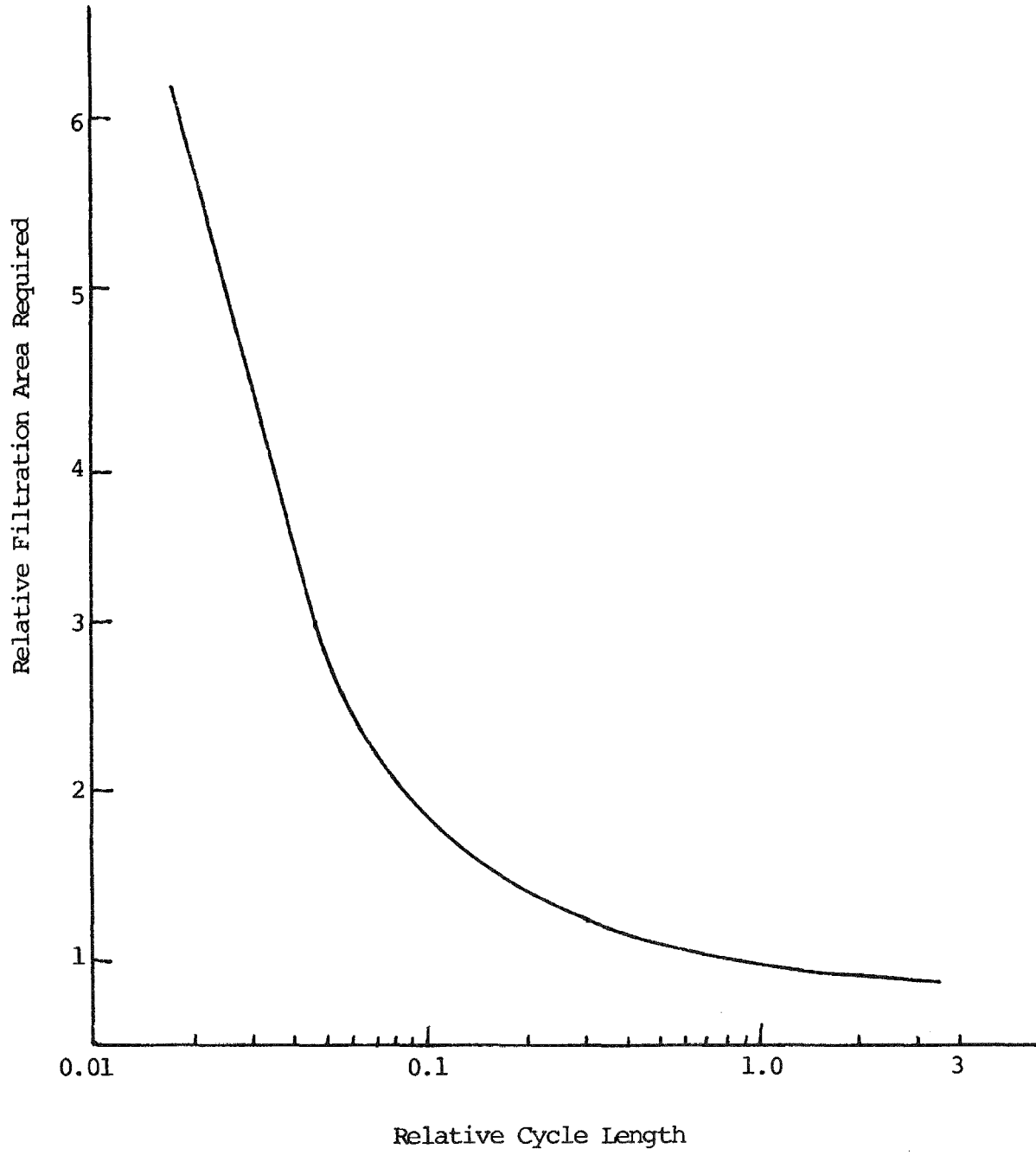


FIGURE 3-4



3.2 VACUUM ROTARY DRUM PRECOAT FILTER

For liquids with high volumes of solids, the rotary drum precoat filter is indicated.

The rotary drum precoat filter, Figure 3-5, is a modification of the continuous rotary vacuum drum filter. The drum serves as a support for the precoat which is the actual filtration medium. This precoat is supported on a drainage structure of stainless steel wire cloth on top of a series of coarser wire meshes. The drum surface is divided longitudinally into a series of panels (or sectors). Each sector has a drainage line, or lines, going from the sector toward the center of the filter drum and then out through the end of the drum into a valve. The filtrate with its entrained gas flows through the precoat and drain lines into the filtrate receiver where the filtrate and gas are separated. The vast majority of these filters currently being used in many different industries, including the petroleum industry, are vacuum rotary drum precoat filters.

In operation, a precoat of filter aid up to 6 inches thick is built up on the drum by pumping a slurry of filter aid and clear liquid from a precoat tank to the filter. The filter aid remains on the drum (where it forms the precoat) and the liquid passes through the drum and either back to the precoat tank or on to the process. After the precoat is built up, unfiltered liquid is introduced into the filter. As the drum rotates, unfiltered solids are removed on

the surface of the precoat. A blade (or knife) along the face of the drum and above the liquid level continually advances toward the drum, peeling off the collected cake of filtered solids plus a very small amount of precoat. This continues until the knife is within 1/4 to 3/8-inch of the drum, at which time the drum is cleaned and reprecated.

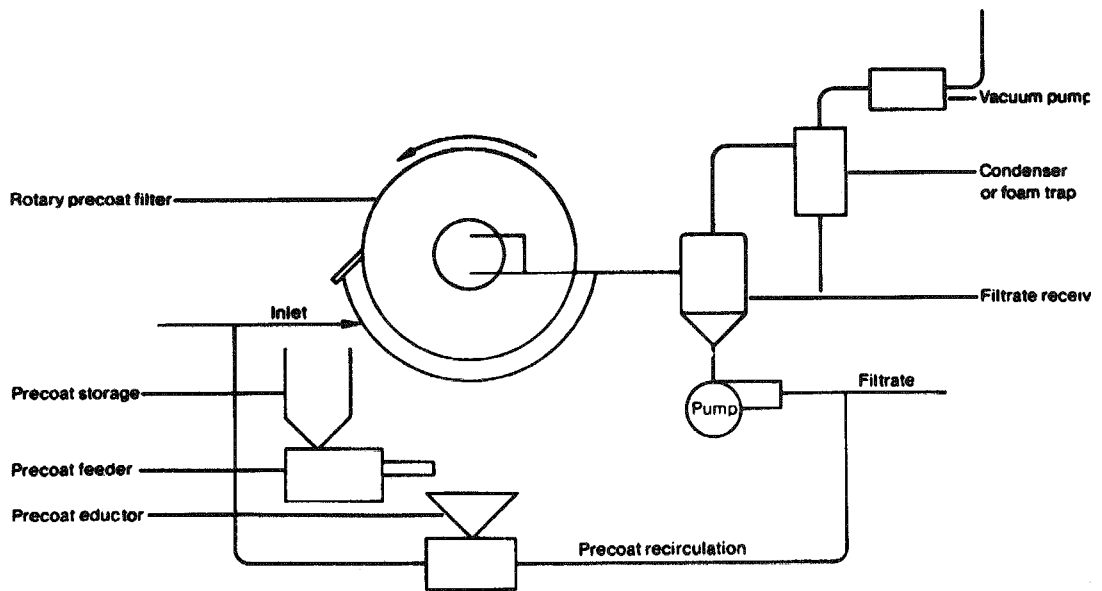
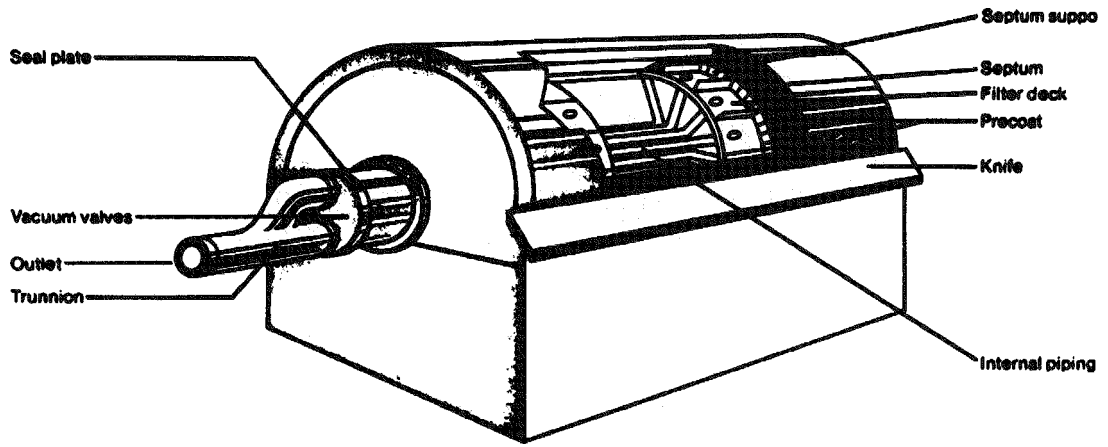


FIGURE 3-5

3.2.1 Key Operating Factors for Rotary Precoat Filters

For the most economical operation of a rotary precoat filter, several factors as listed below must be considered:

- Drum Speed
- Drum Submergence
- Cake Drying Time
- Differential Pressure
- Knife Advance Rate
- Filter Aid Grade
- Cake Filterability
- Liquid Viscosity

Drum Speed, Drum Submergence, and Drying Time are closely related and are generally optimized as a group.

During filtration, as some types of solids build up on the precoat, their permeability approaches zero. Additional submergence (filtering time) after this point will decrease efficiency. This is shown in Figure 3-6, where the throughput essentially stops after 30 seconds of submergence. The time required to dry the "dewatered" cake to an acceptable level for disposal can also be found by observation or moisture analysis of the filter cake. Optimum drum

submergence, rotational speed, and drying time will be partially determined by the desired rate and cake drying time.

The optimum differential pressure must also be determined by experimentation. Generally, the highest usable differential pressure yields the highest flow rate and driest cake. Within limits, higher pressures also result in higher precoat efficiency due to improved cake cutting.

Knife advance rate has a direct effect on precoat consumption and is a large factor in operating costs. If, for example, the knife advance rate can be halved without significantly affecting the flow rate, precoat consumption will be halved and the filtration cycle length (precoat life) will be doubled. To achieve maximum flow rate, knife advance must be greater than the depth of solids penetration into the precoat. Figure 3-7 shows typical knife advance versus flow rate curves for various filter aid grades. In Curve A, until the knife advance is greater than penetration of solids into the precoat (about 2 mils, in this case), flow rate is controlled by the permeability of the penetrated solids, rather than the precoat. A knife advance greater than 2 mils per revolution does not increase flow rate, however, but only shortens the filter cycle.

Figure 3-7 also shows that filter aid grade selection is related to knife advance rate. Filter aid grades differ by their permeability and, therefore, pore size. A filter aid must be matched

with the solids being filtered so that solids penetration is kept to a minimum and flow rate kept at a maximum for the smallest reasonable knife advance. If a filter aid grade is too porous, as is the case with Curve B in Figure 3-7, a large knife advance will be needed to remove the penetrated solids. Even then, increasing penetration during the filter cycle will eventually diminish the flow to a rate lower than that obtained on Curve A. On the other hand, if the filter aid has too low a permeability (Curve C), penetration will not be a problem, but flow rate will be low due to the hydraulic resistance of the precoat.

The above variables are interrelated and optimum conditions can best be established through actual laboratory and pilot scale test work on the specific liquid. After these conditions are established, changes in solids concentration do not change the filtrate quality, but only result in a flow rate change, as shown in Figure 3-8.

FIGURE 3-6
FILTRATE VOLUME VERSUS SUBMERGENCE TIME

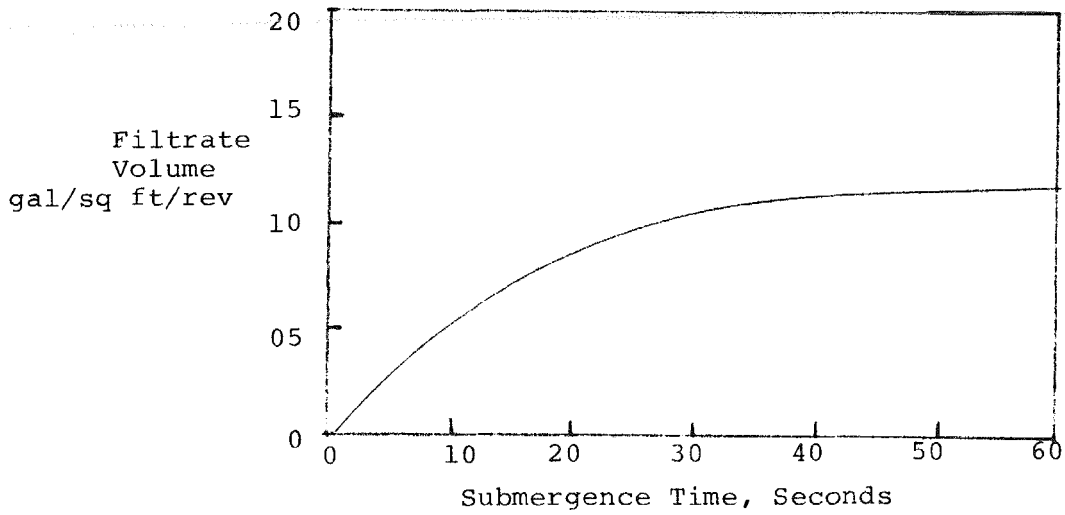


FIGURE 3-7
TYPICAL FLOW RATE VERSUS KNIFE ADVANCE CURVES

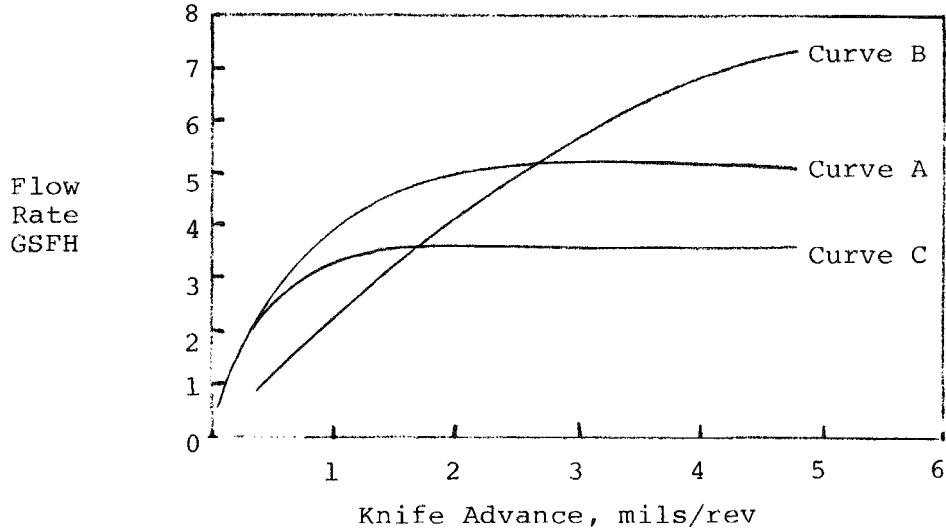
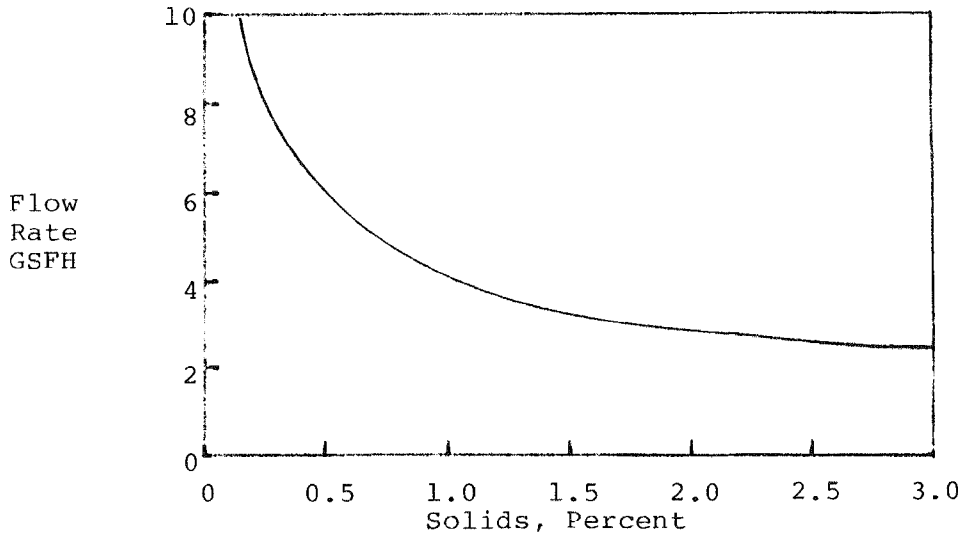


FIGURE 3-8
FLOW RATE VERSUS ALUM SLUDGE CONCENTRATION



When a rotary drum filter is used as a rotary drum precoat filter, the piece of hardware commonly referred to as the filter no longer does the filtering, but merely serves as a holder for the "filter aid", which now becomes the filter medium. The efficiency of the filtration then becomes entirely dependent on the way in which the filter aid is applied to the filter as a precoat, the grade of filter aid selected, and the manner in which the precoat plus cake is removed by the knife. Unfortunately, both manufacturers and users of rotary drum filters (the vast majority of which are used without a precoat) fail to recognize many of the details which make for the efficient use of filter aids as a precoat. These problems have been observed on vacuum rotary drum filters for many years and it has repeatedly been possible to significantly increase rates through these filters by changing operating techniques, selection of the correct grade of filter aid, and making equipment modifications.

Solutions for these problems have been the result of either changes in operating techniques, filter design, or both.

The cutting of the cake is a critical factor. It is often possible to markedly improve the operating efficiency of the rotary precoat vacuum filter by operating at higher drum speeds. Higher drum speeds take advantage of the more rapid filtration achieved during the first 2 to 10 seconds of submergence (see Figure 3-6). To achieve economical utilization of the precoat at these higher drum speeds, it is necessary to take as small a knife cut per revolution

as possible. These thin cuts often have not been achievable because the knife support mechanism lacked sufficient rigidity to achieve a small, uniform cut completely across the face of the filter. As a result, knife chatter is a common occurrence at higher drum speeds causing very uneven cuts. More rigid knife supports and mechanisms have been designed, resulting in higher filtration rates and better filter aid economy.

The following are typical cake cutting problems:

- Precoat gouging due to a thick, sticky cake of suspended solids and a viscous liquid.
- Precoat chipping due to formation of a dry cake on the precoat.
- Uneven precoat cutting due to vibrations which may be caused by outside forces.
- Smearing of cake solids over the surface of the precoat due to a dull knife.

3.3 COMPARISON OF ROTARY PRESSURE TO ROTARY VACUUM PRECOAT FILTERS

The rotary pressure precoat filter performance obtained in coal liquefaction pilot plants has been inferior to what we would expect based on our experience with rotary vacuum precoat filters. For instance, a 6-inch thick precoat can be applied to a rotary vacuum drum precoat filter within an hour; yet, when using a rotary pressure precoat filter up to 3 hours have been required to apply a 1 1/2 to 2-inch precoat. We believe this is due to incorrect internal piping in the filter drum plus poor suspension of filter aid around the

drum.

Filtration results have frequently been inconsistent, with relatively few filter cycles being completed before the filter must be opened for maintenance and screen cleaning. Opening of the pressure vessel to gain access to the filter drum for these purposes was a time consuming and tedious job. Proper precoating and screen cleaning techniques should greatly reduce this type of maintenance. In addition, observation of the precoat and cutting by the filter knife were almost non-existent. Observation of the cutting area is essential on this type of filter to determine how the cake is being removed from the precoat (i.e., whether the knife is cutting smoothly or whether it is causing chipping or gouging of the precoat) and to take corrective measures.

Knife design has a significant effect on filter efficiency. We find the knife design to be inadequate in many currently available rotary pressure precoat filters. (This is also the case for most rotary vacuum filters now in use.) These have a knife that is not sufficiently rigid to remove only 0.0005-inch to 0.001-inch of precoat per drum revolution, a figure which we have attained on rotary vacuum precoat filters with properly designed knife support structures. We believe that these small cuts are attainable with a rotary pressure precoat filter. Cutting in excess of this minimum is necessitated by such things as flexing of the knife support mechanism, irregularity of the knife drive device, dull knives, angle

of knife in relation to precoat causing skipping of the knife over the precoat, gouging of precoat due to nature of cake being removed, and chattering due to external vibrations. All of these problems have been overcome on rotary vacuum precoat filters and we see no reason to believe that they cannot be overcome on the pressure rotary drum precoat filter.

3.4 COMPARISON OF THE ROTARY PRESSURE PRECOAT FILTER & STATIONARY LEAF PRESSURE PRECOAT FILTER

While there are more variables in the operation of the rotary pressure precoat filter as compared to the stationary pressure leaf filter, once optimum conditions have been obtained, the operation is in many ways an easier one.

Each time a stationary pressure leaf filter must be turned around, the following general steps must be taken:

- Unfiltered liquid removal from filter
- Filter filled with solvent for washing the filter cake
- Solvent recirculation
- Solvent blown from filter cake with heated gas.

- Cake removed from filter leaves by vibration, sluicing, leaf rotation, or other methods
- If leaf rotation or vibration are used in the above step, remainder of cake must be sluiced from filter leaves and washed from filter shell
- Filter filled with precoat slurry and slurry recirculated until precoat is formed
- Precoat liquid blown from filter to prevent dilution of liquefied coal (not done in all cases)
- Filter filled with liquefied coal and filtration started

The above series of steps is very time consuming (taking up to 1-1/2 hours) and results in a high percentage of filter downtime. In addition, because of the involved nature of these steps, every time they are carried out presents an opportunity for gummy solids to come in contact with filter screens risking blinding and reduced throughput.

In operating a rotary precoat pressure filter, the filter is filled with precoat slurry and the slurry is recirculated through the filter system until the desired thickness of precoat is applied. This procedure should take approximately one hour and could very well take less time considering the higher differential pressures available. When the precoat is in place and trimmed, the liquid to be filtered is introduced and continued to the end of the cycle, when the drum is washed down for the next precoat. A much larger amount of liquefied coal can be filtered, (at much higher rates) on a rotary

pressure precoat filter before removing the precoat heel and reprecating than on a pressure leaf filter.

3.5 ROTARY DRUM PRECOAT FILTER TEST LEAVES

3.5.1 A Rotary Vacuum Precoat Filter Test Leaf

Many of the operating factors outlined above for the rotary vacuum precoat filter can be determined with a test leaf designed by Johns-Manville. This type of test unit has been used for over twenty years.

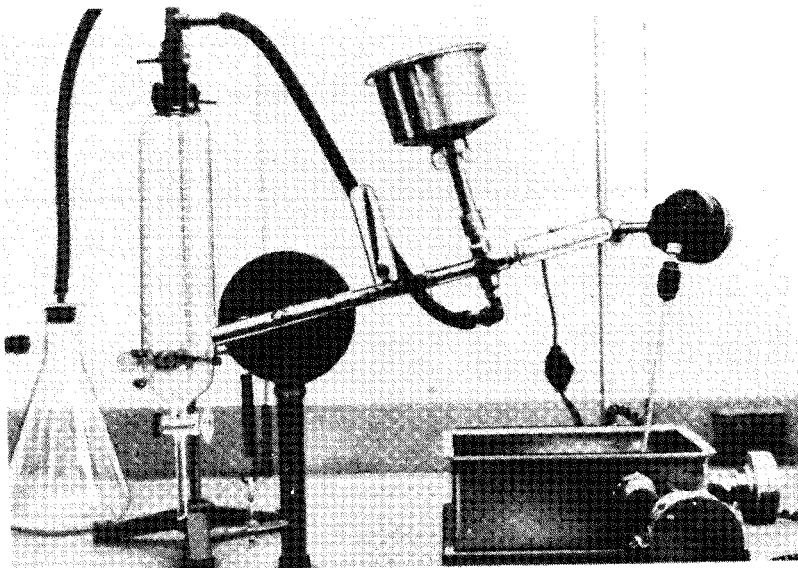
In use, the 0.1 square foot test leaf simulates the function of an equal area on the surface of a full sized rotary vacuum precoat filter drum. Since such a filter drum in the course of each revolution passes through filtration, drying (and washing if required), and cake removal phases, the test equipment must be capable of such sequential operation on a carefully timed basis. This equipment was developed specifically for this purpose and in practice has been found reliable.

The leaf is a maximum of 2-inches deep and is attached to a clutch, so that it can be left in any position without being held by an operator. Crossover valves send filtrate to alternative receivers for venting and draining unused receivers. The leaf

with agitated temperature controlled test liquid tank, vacuum gage, lines and receivers is shown in Figure 3-9.

In operation, a precoat is formed on the leaf by submerging it repeatedly in the test liquid. The leaf, with precoat, is then immersed in the test liquid for a period of time equal to the submergence time of a similar spot on a filter drum. The leaf is then removed and the cake and precoat extruded axially out the end of the leaf, (which has a machined surface) an amount equal to the knife advance rate to be simulated. The cake and precoat are then cut from the leaf, the precoat allowed to dry, and the cycle repeated as many times as needed.

These same principles have been applied to the design and operation of a rotary pressure precoat filter test leaf.



TEST LEAF

Figure 3-9

Section 4

EXPERIMENTAL DESIGN

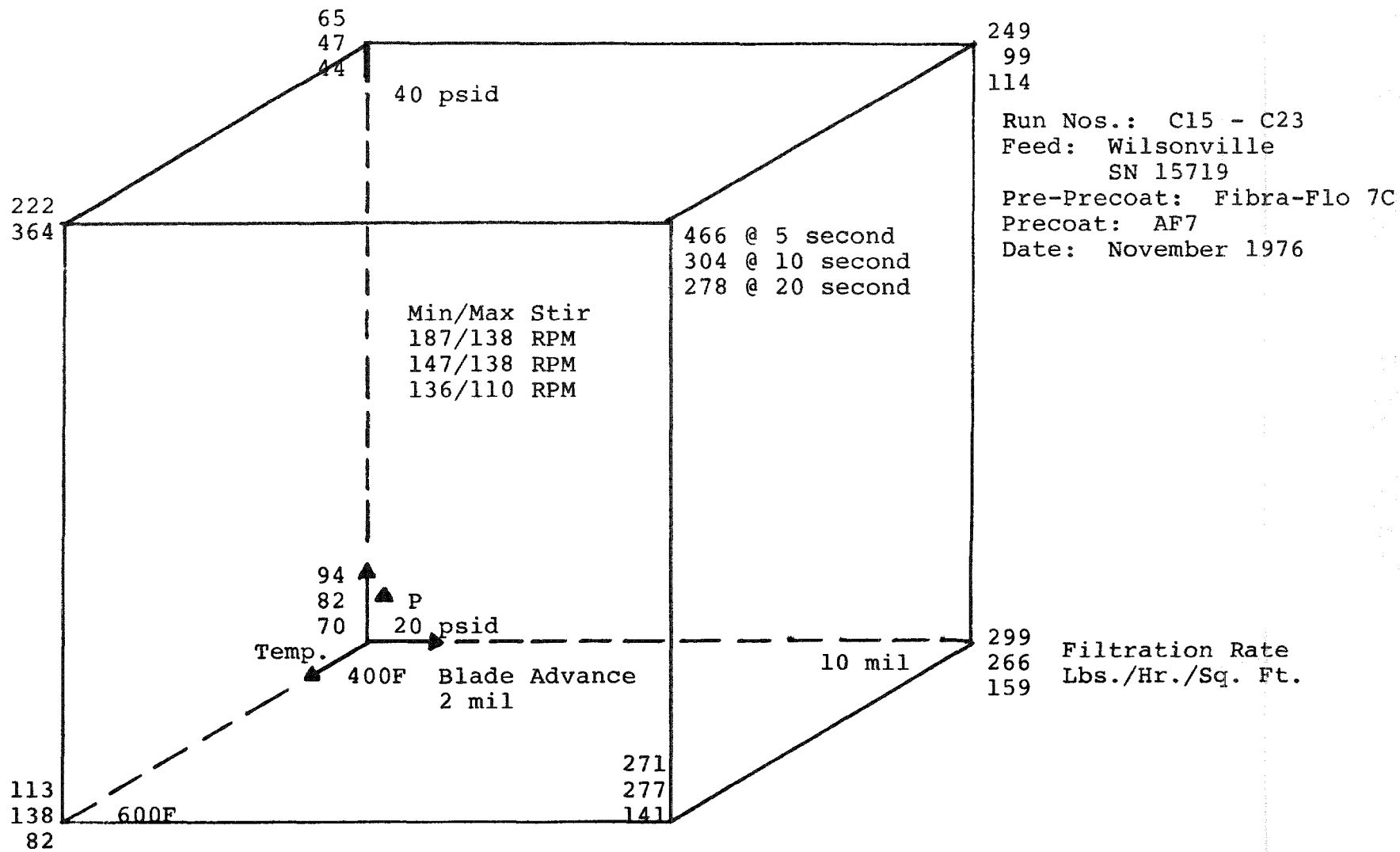
A series of tests were run to gain filtration information based on an augmented full factorial design (2^3), with center point. The principle variables (temperature, pressure differential, and knife advance) are treated at two principle levels each. The augmentation includes insertion of (1) immersion time [three levels] as a rider in every set of conditions, and (2) agitation [minimum and maximum feasible] as a second rider in the center point.

An example of the data gathered from this type of experimental design is shown on the cube in Figure 4-1. The three vertical data points at each apex of the cube and at the center are the result of the augmentation of three immersion times of the test leaf in the test liquid, the numbers from top to bottom representing immersion times of 5, 10, and 20 seconds respectively. The immersion time can then be translated into drum speed based on the assumption of a specific drum submergence. Thus, a submergence time of 5 seconds can be translated into a drum speed of 4.8 rpm at a drum submergence of

40 percent. Each datum refers to pounds of SRC and solvent filtered per square foot of total filter area (submerged and open) per hour.

The cube, front plane, represents all data taken at maximum temperature (600°F); the right hand plane, all data at maximum rate of blade advance (mils per cut or drum revolution); and the upper plane, the maximum differential pressure.

FIGURE 4-1 AUGMENTED FULL FACTORIAL DESIGN WITH CENTER POINT



Experience and filtration theory show that maximum filtration rates are obtained at maximum differential pressure, maximum temperature (minimum viscosity), and, up to a point, maximum knife advance. While temperature in these processes is "free", temperatures above 600°F are not considered practical because of degradation of liquefied coal and increased equipment costs. Early tests on the Rotary Pressure Precoat Filter Test Leaf show no significant rate advantage in going from a differential pressure of 35 psi to one of 45 psi. Pressure bomb leaf tests, however, show increased rates up to 160 psi differential pressure. Rate increases with higher pressures were demonstrated on the leaf in later tests.

As knife advance rate directly affects filter aid consumption, it is naturally desirable to work toward the minimum knife advance that will give reasonable rates.

Considering the three variables outlined above, work should be carried out along the front line of the cube representing the intersection of the maximum differential pressure and temperature planes and extending up the differential pressure plane to maximum pressures permitted by the filter system. At the same time, tests should be toward lower knife advance rates including the use of finer precoat filter aids to reduce penetration.

For maximum filtration rates, it is desirable to run at the maximum drum speed that will still permit the filter knife advance mechanism to advance into the precoat at an even rate. This rate must also be high enough to remove essentially all the precoat into which solids from the liquefied coal have penetrated. Knives on many filters in use today are not capable of maintaining an even cut at much less than 3 to 5 mils per drum revolution without smearing the cake solids into the precoat, partially blinding it, and reducing its effectiveness.

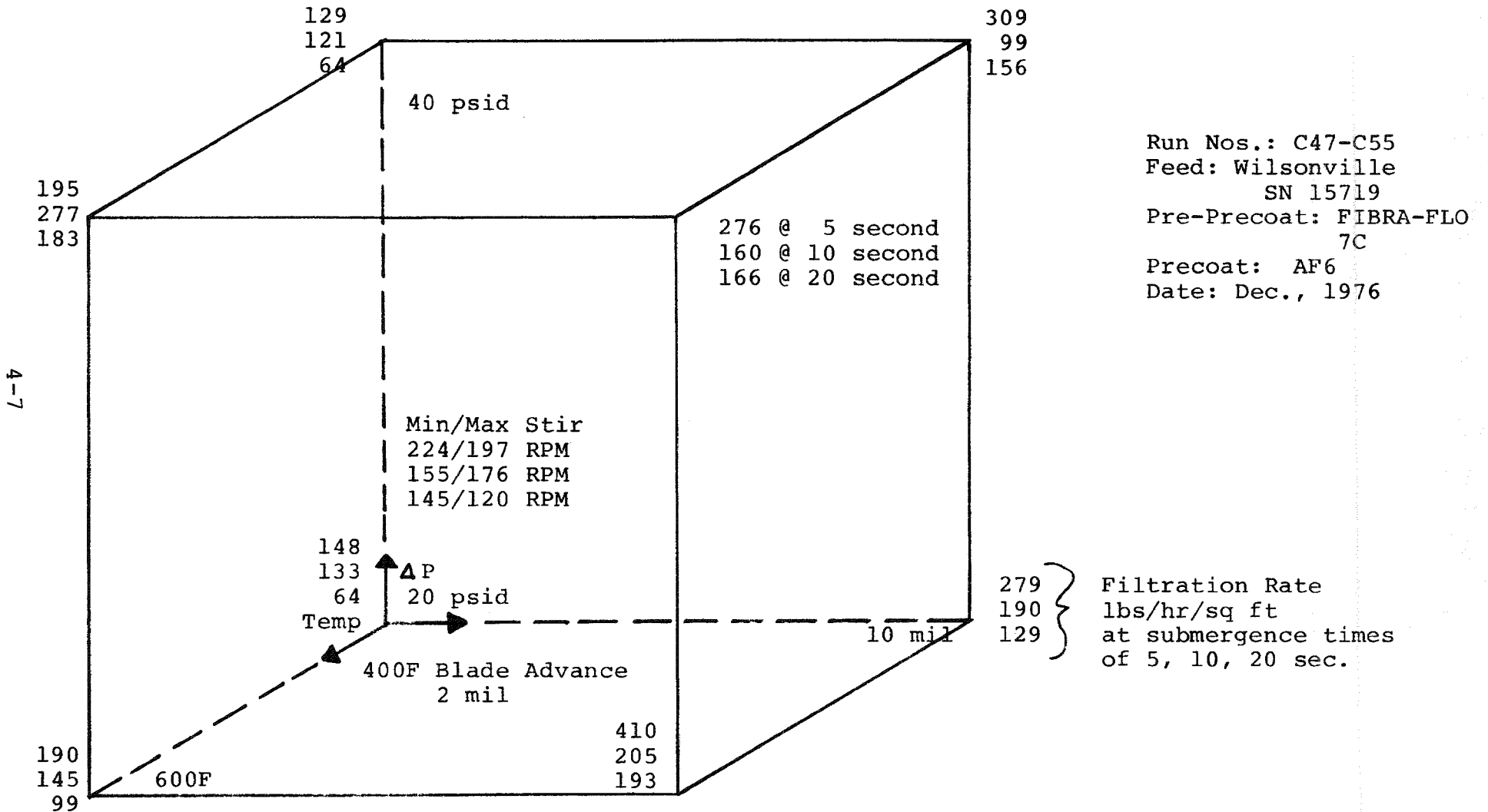
Many filters are operated at knife advance rates lower than this, but in actual fact the instantaneous rate may range from 0 to 10 mils per revolution with the knife alternately smearing cake into the precoat or taking excessive cuts beyond the rates which produce any increase in flow through the filter. Experience has shown that a 0.5 mil cut can be evenly maintained and is a practical rate of knife advance for filters with special knife support designs. Maximum drum speed will be that limited by the ability of the knife advance mechanism to advance the knife at an even rate and the precoat material to reduce penetration of solids to below that rate.

No consideration has been given to ash and sulphur removal in the experiment design because, with the coals tested to date, both pressure bomb leaf and rotary pressure precoat leaf precoat filtration have had no difficulty in meeting removal goals. Indeed, for the precoat on the rotary drum filter to perform efficiently, it

must remove essentially all suspended solids within about 1 mil of its surface or become plugged with solids to the extent that it ceases to function at all.

While the "cube" is a good way of visualizing the major parameters affecting filtration, the relationships, pairs of parameters, are better shown on two dimensional graphs. Such a graph including data taken from the "cube", Figure 4-1, along an internal diagonal on which center point data is included is shown in Figure 4.2.

FIGURE 4-2
 AUGMENTED FULL FACTORIAL DESIGN WITH CENTER POINT



The data shown on the cube of Figure 4-2 were from WFF Runs C47 through C55. These runs were designed to duplicate and confirm the previous data from Runs C15 through C23 except for use of CELITE AF6 instead of AF7 for the precoat. The results, presented, however, are not entirely consistent with expectations. For example, the 10 second rate in Run C49 (400°F, 40 psid, 10 mil cut) was less than the 20 second rate; the 10 second rate in Run C55 (600°F, 40 psid, 2 mil cut) was greater than the 5 second rate; and the rates in Run C55 (600°F, 40 psid) were not significantly higher than the rates in Run C53 (600°F, 20 psid) even though the differential pressure was doubled. Post run examination of the filter indicated some significant reduction (approximately 15 to 20 percent) of the effective filtration area due to precoat breakout. The loss of filtration area could account for some of the unexpected results.

General conclusions from the data at the time of these runs were that:

- The filtration rate increased about two-fold upon increasing the knife advance from 2 mils per revolution to 10 mils per revolution.
- The filtration rate did not increase significantly upon increasing the differential pressure from 20 to 40 psid. (This lack of rate increase with increased pressure was shown later in the program to be due to precoat shrinkage.)

Section 5

EQUIPMENT DESCRIPTION

The Rotary Pressure Precoat Filter Test Leaf designed and built for this contract work is based on the same technology developed for the Rotary Vacuum Precoat Filter Test Leaf. It differs in that the leaf must operate under high temperature and pressure. To be able to achieve operation at this condition has required some special design considerations which are subsequently described.

This apparatus is basically a pressure precoat leaf filter system in which the operation of a 0.1 square foot segment of the drum surface of a rotary pressure precoat filter may be simulated by a 0.1 square foot test leaf. The full sequence of events, which occur at a segment of the rotating drum, may be executed with this apparatus. This includes filtering, cake washing, cake drying, and cake removal in a typical filtration cycle. It is recognized that precise spacing of events along the time axis may not be duplicated; time duplication has not been found necessary in the vacuum dip leaf filter.

The apparatus, designed to operate at temperatures up to 750°F (400°C) and pressures up to 400 psig, is schematically illustrated in Figure 5-1. The main pressure vessel, A, (Figures 5-2 and 5-3) is supported on trunnions on which it may be rotated (e.g., 90° counterclockwise) in the course of an experiment. The filter leaf, B, has a cylindrical face, concentric with its support arm and the vessel. The support arm, which serves also as filtrate delivery pipe, extends through a packing gland on the top head to a swivel union. Thus, the leaf may be rotated 180°F from the position shown for cake washing and cutting in the course of an experiment. The outline of a can in which to collect cuttings and excess wash fluid is shown in the schematic. Omitted, in the interest of clarity of the figure, are:

- The adjustable doctor blade for cutting the filter cake
- The stirring mechanism which enters through a packing gland at the bottom of the vessel.

Above the swivel union is a "Christmas Tree" consisting of a receiver manifold and condensers, and supported by a framework attached to the upper head. In an experiment, pressurizing nitrogen may be introduced via Tube C to suppress evolution of light fractions from the coal oil contained in Vessel A (vertical position) during heatup. The gas will be bled through the precoat and filter leaf to Condenser D, where any condensibles picked up in Vessel A will be trapped. (The gas flow must be maintained to hold the precoat in

place.) Nitrogen is bled to the atmosphere through Relief Valve E which is set to control pressure in the downstream portion of the system and thus gas flow rate at the desired level. Provision is made for periodic return of condensate to Vessel A. Vessel A and all receivers are held at desired temperatures by use of electrically controlled heating mantles.

To initiate filtration, the apparatus is tilted 90° on the trunnions, bringing the trunk of the "Christmas Tree" to a horizontal position, heated Receiver E to a vertical position below the trunk, and the fluid under study into position to cover the filter leaf. Valving to Condenser D having been closed, filtrate is collected in Receiver E and condensibles (which will tend to flash off when liquid reaches the reduced pressure region downstream of the filter leaf) are collected in Cool Trap F. Pressure in the downstream portion of the apparatus, thus the differential pressure driving the filtration, is controlled in this step by Relief Valve G. The receiver-trap system shown in the schematic represents one of seven such systems which are manifolded in such a manner that filtrate may be directed to a given receiver at any time and for any time chosen in the course of an experiment.

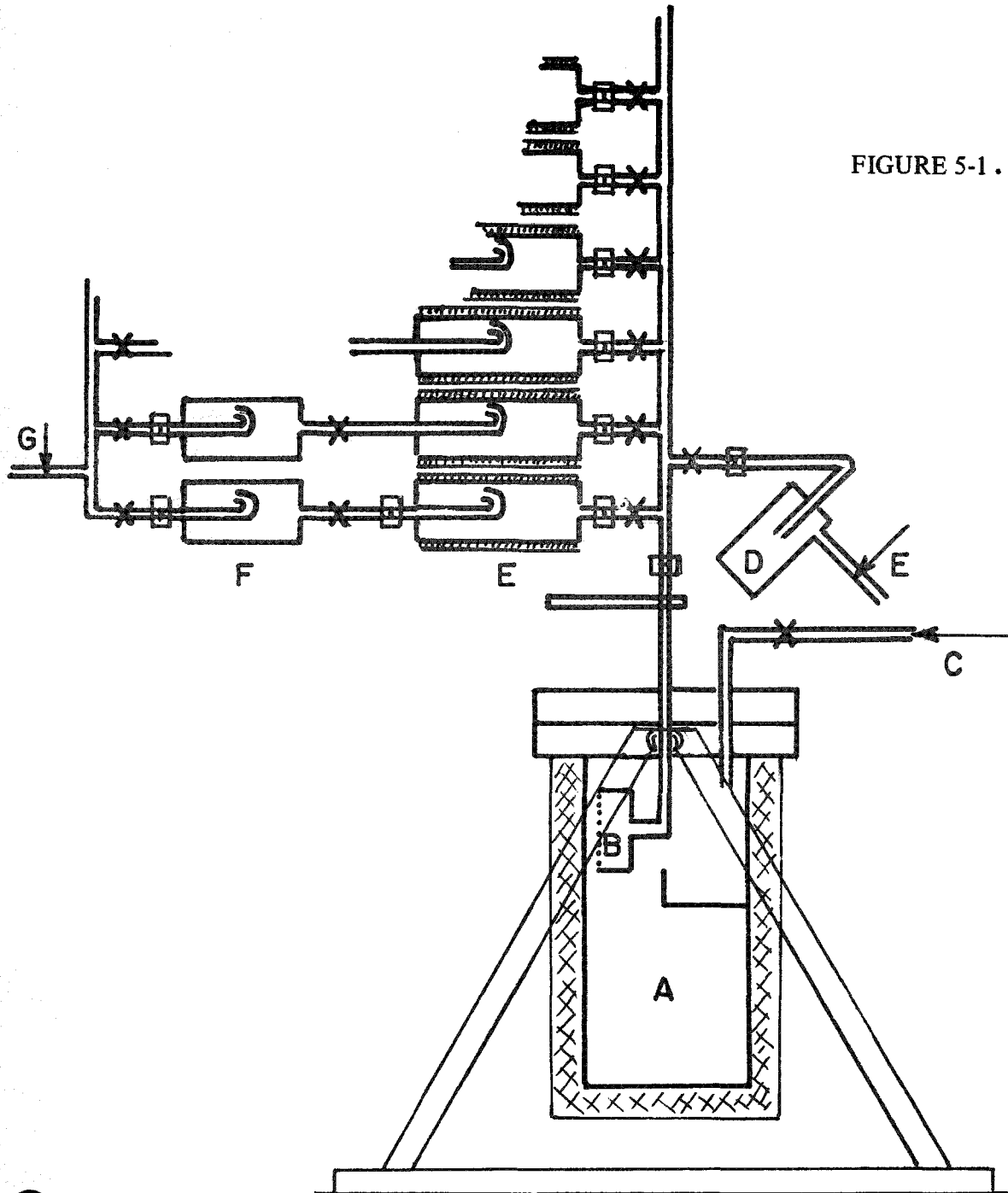
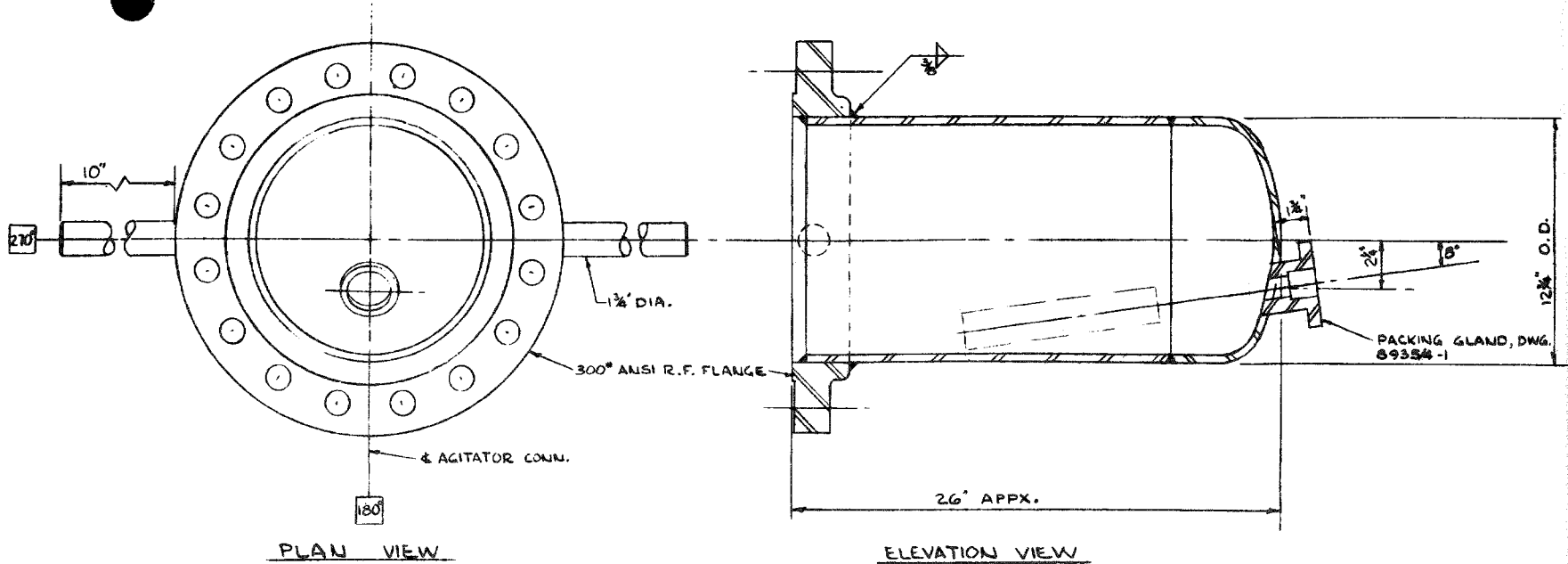
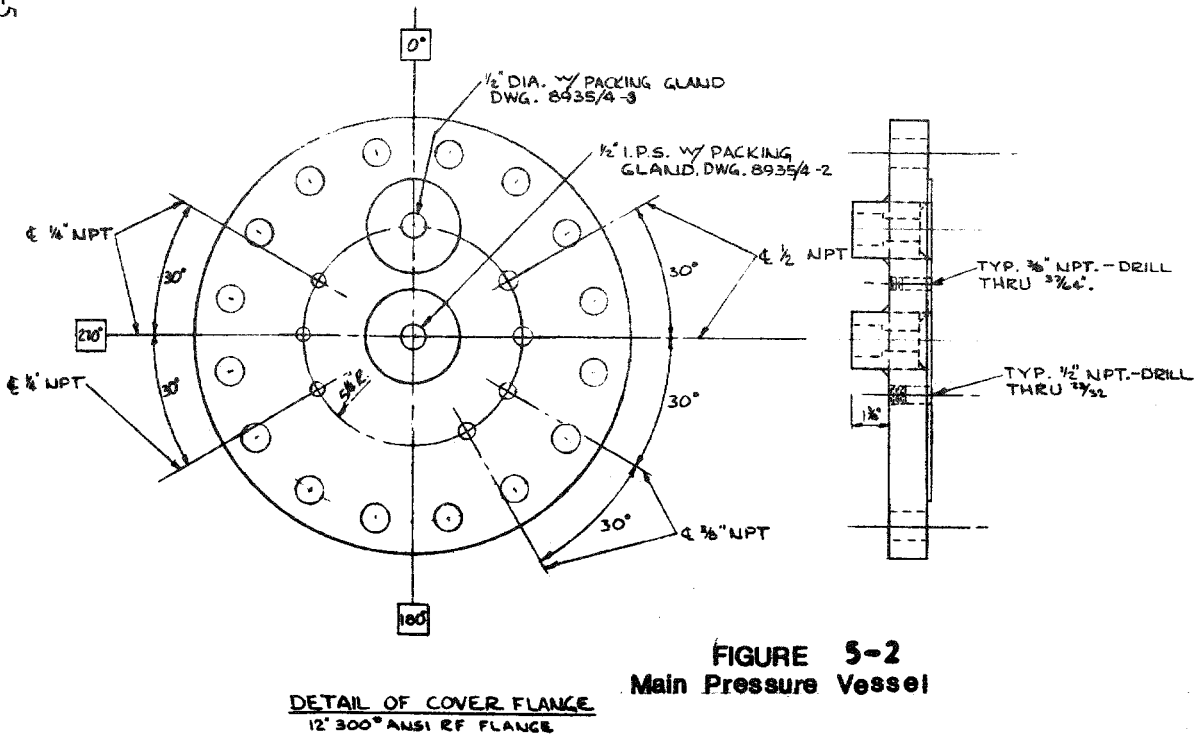


FIGURE 5-1. Schematic of
Laboratory Scale
Filtration Apparatus



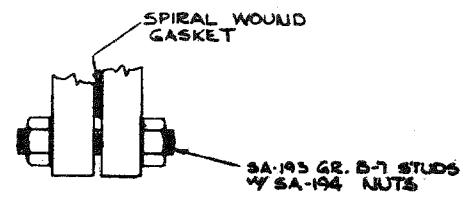
S-5



- GEN. NOTES-
1. DESIGN PRESS 400 psi @ 750° F
 2. MAT'L.-ALL 316 SS
 3. FLANGES, ANSI 300° R F
 4. STAMP ASME SECT VIII, DIV. I. LATEST ED.
 5. STAMP NATIONAL B.D.

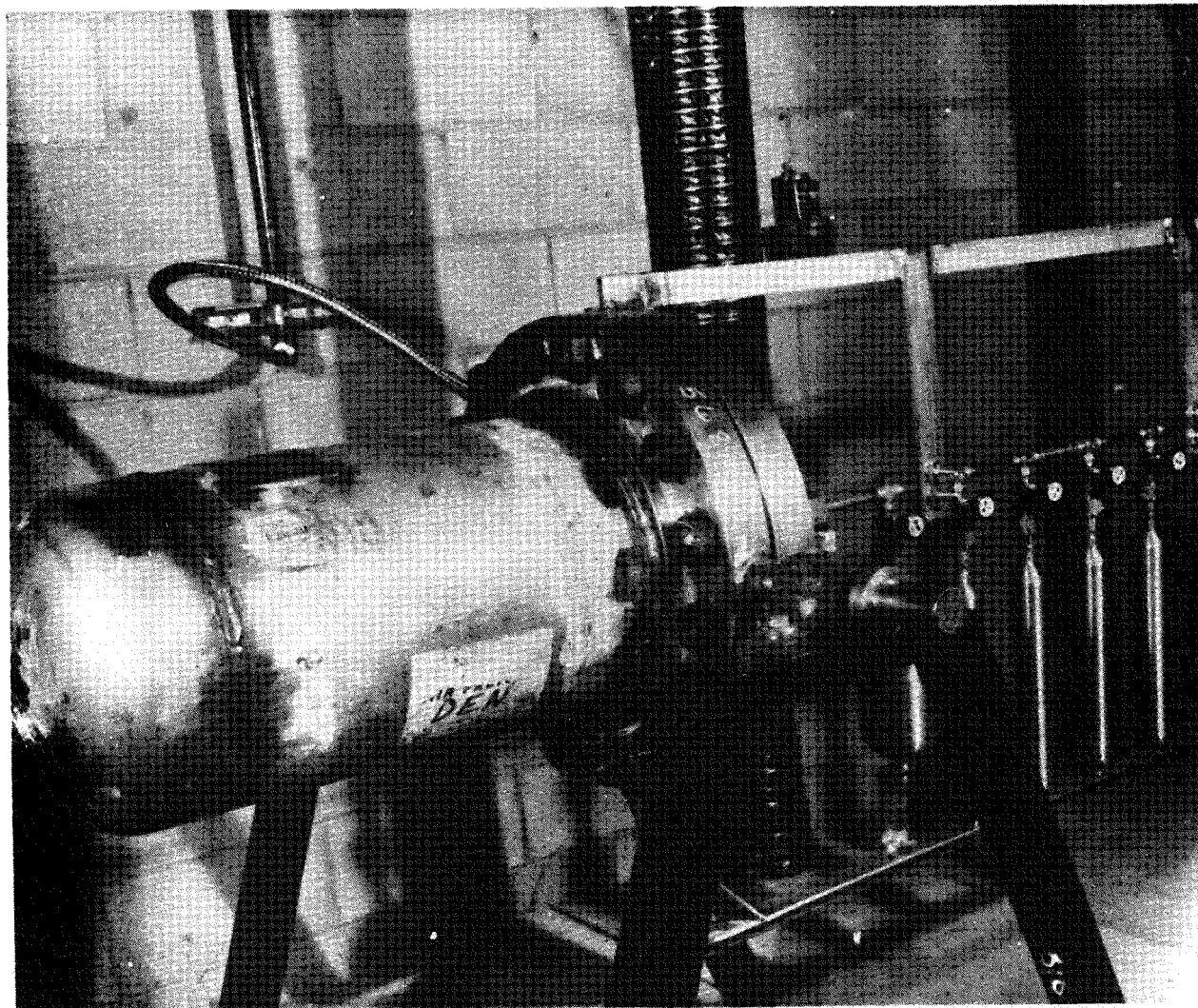
APPX WTS

SHELL	90#
HEAD	30#
SO. FLG.	113#
BLIND FLG.	183#
STUDS & NUTS	44
1 1/2" BARS	14
TOTAL	491# + PACKING GLANDS



FLANGE BOLTING

FIGURE 5-2
Main Pressure Vessel



MAIN PRESSURE VESSEL AND RECEIVER
ASSEMBLY IN PLACE

FIGURE 5-3

Figures 5-4 and 5-5 are updated photographs which show additional features and details of the present overall test leaf system. Major elements have been identified in the photographs and are described below.

- Pressure Vessel with insulation and metal covering over an exterior heating blanket for containing the feed sample, test leaf, cake cutting knife, cake catching box, and a bottom inlet agitator.
- Test Leaf
- Test Leaf after Precoating
- Vent Condenser
- Seven preweighed receivers with individual heating blankets in an air purged box closed during operation. Process flow is through the precoat, the leaf, and the leaf stem and header into one of the receivers.

Other items were shown in Figure 5-5. This photograph shows the leaf closed and tilted on its side for filtering.

- Shielded Vent Bubbler and Flow Meter
- Condensate Receiver
- Pressure Transmitters to Differential Pressure Recorder
- Electric Power Junction Boxes
- Thermocouple Junctions
- Wash Spray Supply Container, Heating Blanket, and Insulation in Air Purged Box
- Leaf Rotating Handle
- Temperature Gauge
- Agitator Drive

•Diaphragm Pressure Gages, One for Each Side
of Leaf

•Electric Heated Receiving Header

Thus, in operation temperatures are controlled by electric current control to the heating mantles and nitrogen is used to pressurize the system. The upper condenser is used for the recirculation of light ends from venting and the lower condenser is used for collection of the light ends of filtrate.

Filtration takes place in the horizontal position with the leaf being rotated into the test liquid for a desired number of seconds. After the leaf has emerged from the test liquid, liquid is purged from the cake and precoat with nitrogen, and the unit is rotated to an upright position. In this position the knife is advanced toward the leaf a specified amount and the leaf rotated past the knife for cutting the cake and a small amount of precoat from the leaf. Cake and precoat drop into a catch box and the unit is ready for another cycle. This continues until either the precoat or the sample is completely used. Blade advance is controlled by a micrometer located outside the vessel.

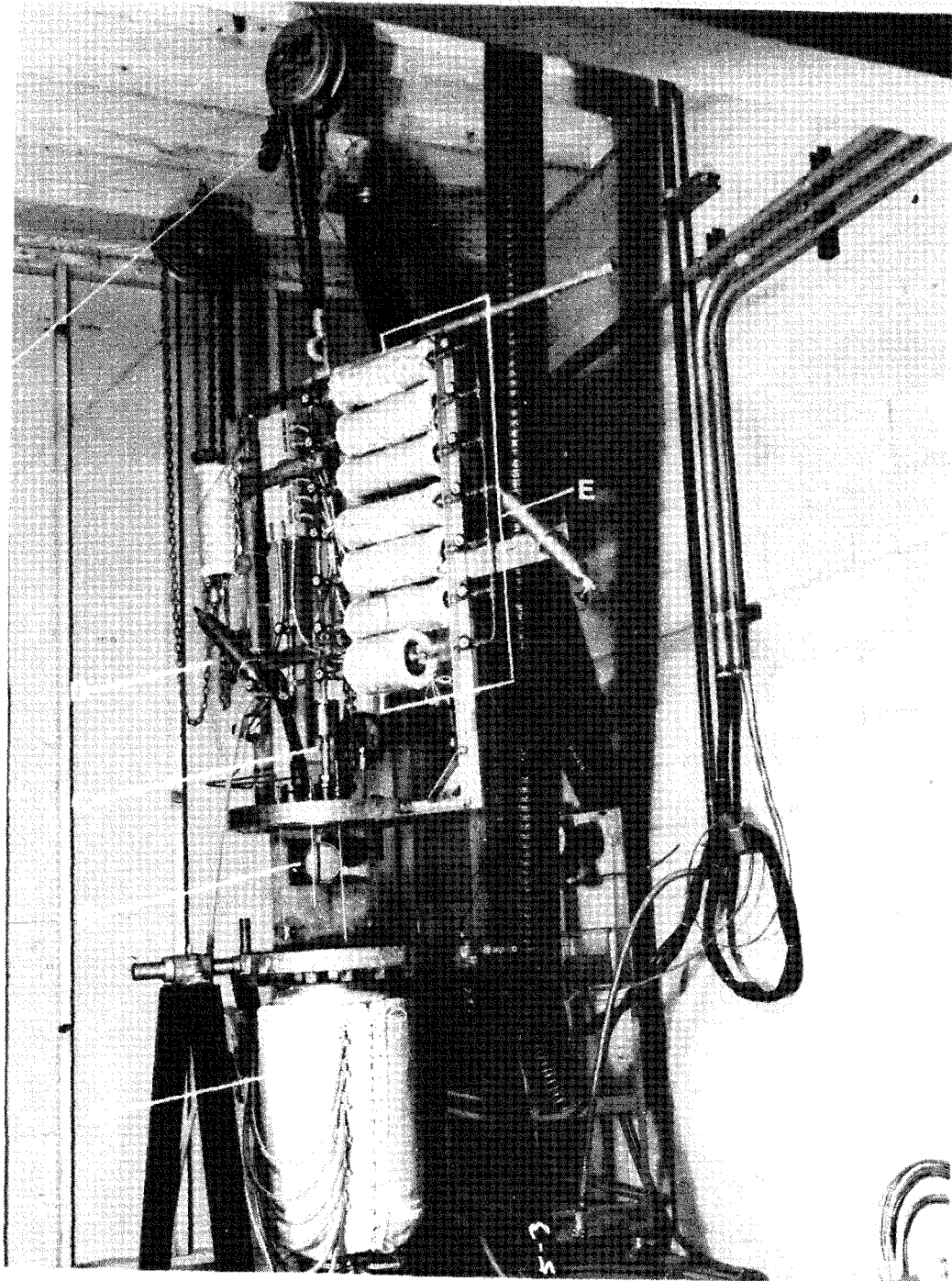


Figure 5-4

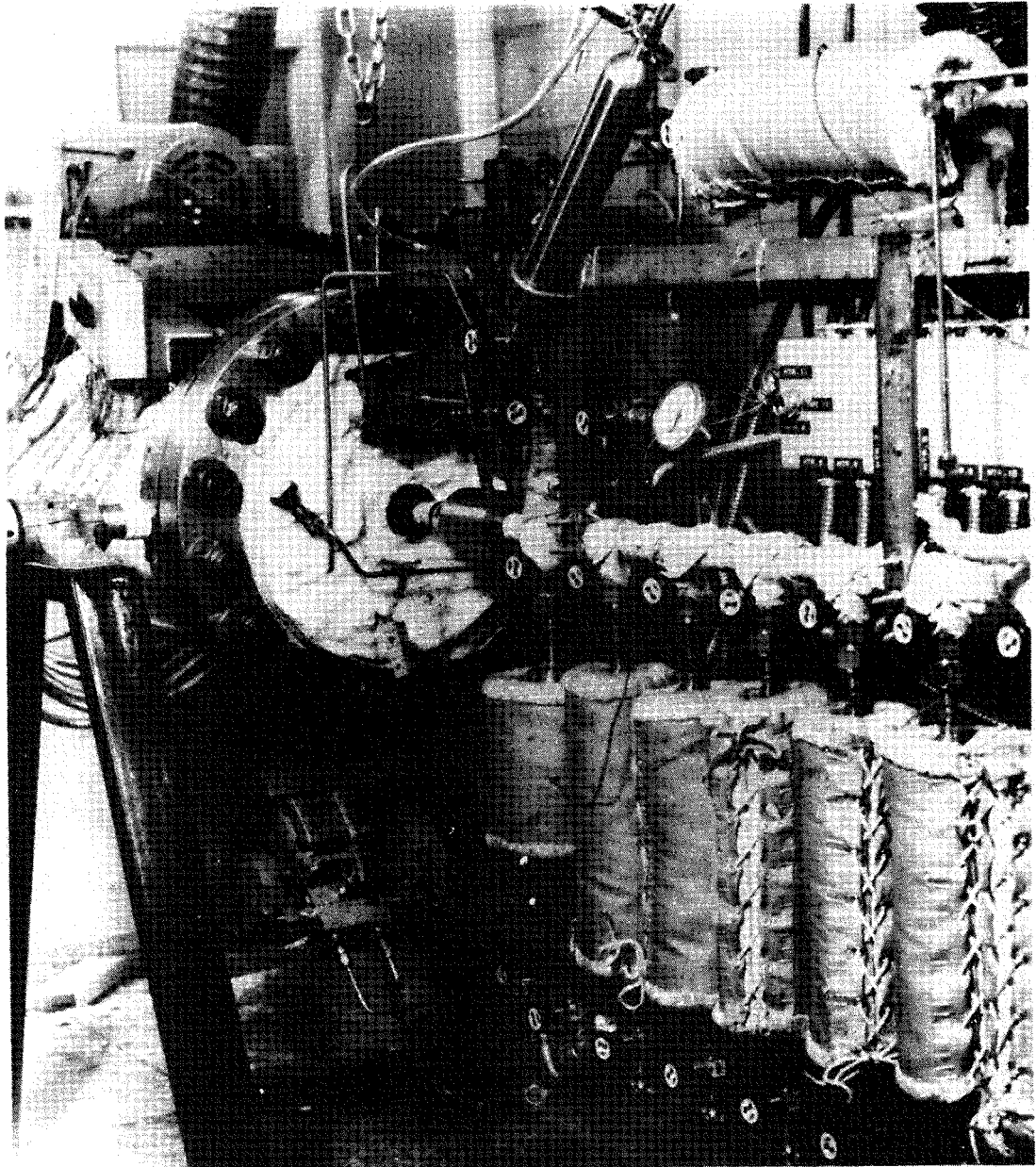


FIGURE 5-5

Section 6
OPERATING PROCEDURES
(Vacuum Applied Precoat)

The techniques for pre-precoating, precoating, filtering, and washing are described below. First the leaf screen must be thoroughly cleaned with solvent to eliminate blinding or plugging.

6.1 PRE-PRECOATING

The required pre-precoat is applied to the leaf from a slurry with use of vacuum and with the leaf outside the vessel. Most pre-precoats have been CELITE AF13 diatomite applied from a 2 percent slurry in toluene/xylene. Dipping of the leaf into the slurry is repeated as many times as necessary for the required thickness (usually about 1/4-inch).

6.2 PRECOATING

Vacuum precoating is accomplished in the same manner and with the same equipment as for pre-precoating. An exception is that

the slurry is about 7 percent instead of 2 percent diatomite in toluene/xylene.

Precoats on the filter leaf are rather conveniently made by suspending the top flange assembly in the horizontal position with the filter leaf facing down while applying vacuum to the filter leaf and rotating it into and out of the slurry. In the initial stages of such precoat deposition, a vacuum of 3 to 5 inches of mercury is employed and the vacuum increased as the coat thickens until it reaches approximately 15 inches of mercury. The precoat thus formed has more or less the shape of an inverted mushroom. It is then trimmed to the desired shape (intersection of two cylindrical surfaces) by use of a free knife blade and the doctor blade of the apparatus. The shaped precoat is held in place by the same vacuum system while the equipment is set up for filtration.

6.3 FILTERING

After completion of precoating, including any required hand trimming and repair, liquefied coal filter feed at 150 to 200°F is poured into the vessel. In-situ filtering then proceeds according to the following steps:

- Close the vessel by bolting on the main flange with assembly in a vertical position.

- Heat the feed liquid in the vessel to the desired filtration temperature of either 500 or 600°F.
- Flush system thoroughly with nitrogen with the main axis in the horizontal position and filter leaf rotated up out of the oil, maintaining an appropriate pressure differential across the precoat at all times.
- Bring pressure to a preselected value for experiment.
- Adjust Relief Valve No. 1 to attain proper pressure differential (70 or 100 psid) for maintenance of gas flow during tilting and cutting operations.
- Adjust Relief Valve No. 2 to proper pressure differential (70 or 100 psid) desired for filtration.
- With assembly in the horizontal position and gas flow through Relief Valve, open selected receiver.
- Rotate leaf into liquid for a predetermined period.
- Rotate leaf from liquid.
- Flush leaf and assembly trunk of liquid. (Complete flushing indicated by increase of bubbling rate of gas from Relief Valve No. 2.)
- Close receiver.
- When gas flows from Relief Valve No. 1, tilt trunk (main axis) to vertical position.
- Cut cake by rotating leaf past preset doctor blade.
- Return trunk to horizontal position.
- Repeat procedure, employing a fresh receiver.

A mercury position switch connected to a digital timer is used to indicate the time for use in rate calculations. This device allows more accurate rate determinations than possible with a handheld stopwatch subject to human reaction time variations. Measured immersion times are in the range of about 0.2 seconds from the planned immersion times, regardless of the length of immersion.

Thus, very short immersion times around 2 seconds vary by as much as 10 percent; while longer immersion times around 20 seconds vary by at most 1 percent. Since timing errors exist around the planned immersion times, the immersion times and the corresponding drum speeds are nominal rather than exact values.

In all runs reported, methods of analyzing data were the same. Each run included 15 to 20 filtering immersions of the test leaf with the feed temperature controlled to either 500 or 600°F and the differential pressure controlled to either 70 or 100 psid. The objective during the course of all runs was to obtain six filtration data points.

Each data point obtained represented the total filtrate collected in a single receiver from one to four immersions with the same depth of knife cut for each immersion and all other conditions constant. The filtration rates reported in the tabulations for graphical presentation and conclusions are the average of two or more of these data points or the last point if a trend was evident. Those points which did not correlate were eliminated from the averaging or other consideration.

Section 7

PRECOATING AT ELEVATED TEMPERATURES & PRESSURES

7.1 INTRODUCTION

The previous section describes the construction and operation of the equipment where all precoating has been done under vacuum with the precoat then trimmed and transferred to the pressure vessel. As temperature and pressure are brought up to operating ranges, some additional compaction of the precoat undoubtedly takes place during filtration. This situation is unlike that of a plant scale operation where precoating takes place at temperatures and pressures of up to 500°F and 60 psid respectively. A precoat formed in-situ under these operating temperatures and pressures should be more compact and less subject to expansion and contraction as it revolves through the filtering, drying, and cutting cycles in the filter. Also, because the precoat is laid down at greater differential pressures, it is expected that the size of the openings in the precoat will be somewhat reduced. Both the above factors should result in improved cake cutting characteristics and reduced penetration of solids into the precoat with resultant reduction in knife advance and improved filter aid economy at little or no sacrifice in filtration rate. At the higher temperatures, it is also probable that it will not be

necessary to use an anti-flocculant filter aid, thus reducing filter aid costs.

Part of the program to develop an in-situ precoating procedure was to develop a retaining ring around the leaf so that the precoat forms with straight walls rather than as a mushroom as it would without the retaining ring. This ring in turn must be retractable to permit cutting of the precoat. Gradual retraction of the ring, will make it possible to reduce the area of precoat that currently sloughs off the back of the leaf during cutting, resulting in substantial reductions, on occasion, of effective filtering area.

While shutting the leaf down for installation of the in-situ precoating system, it was also moved to a different more permanent location. At the same time, ventilation was improved and other safety features were added.

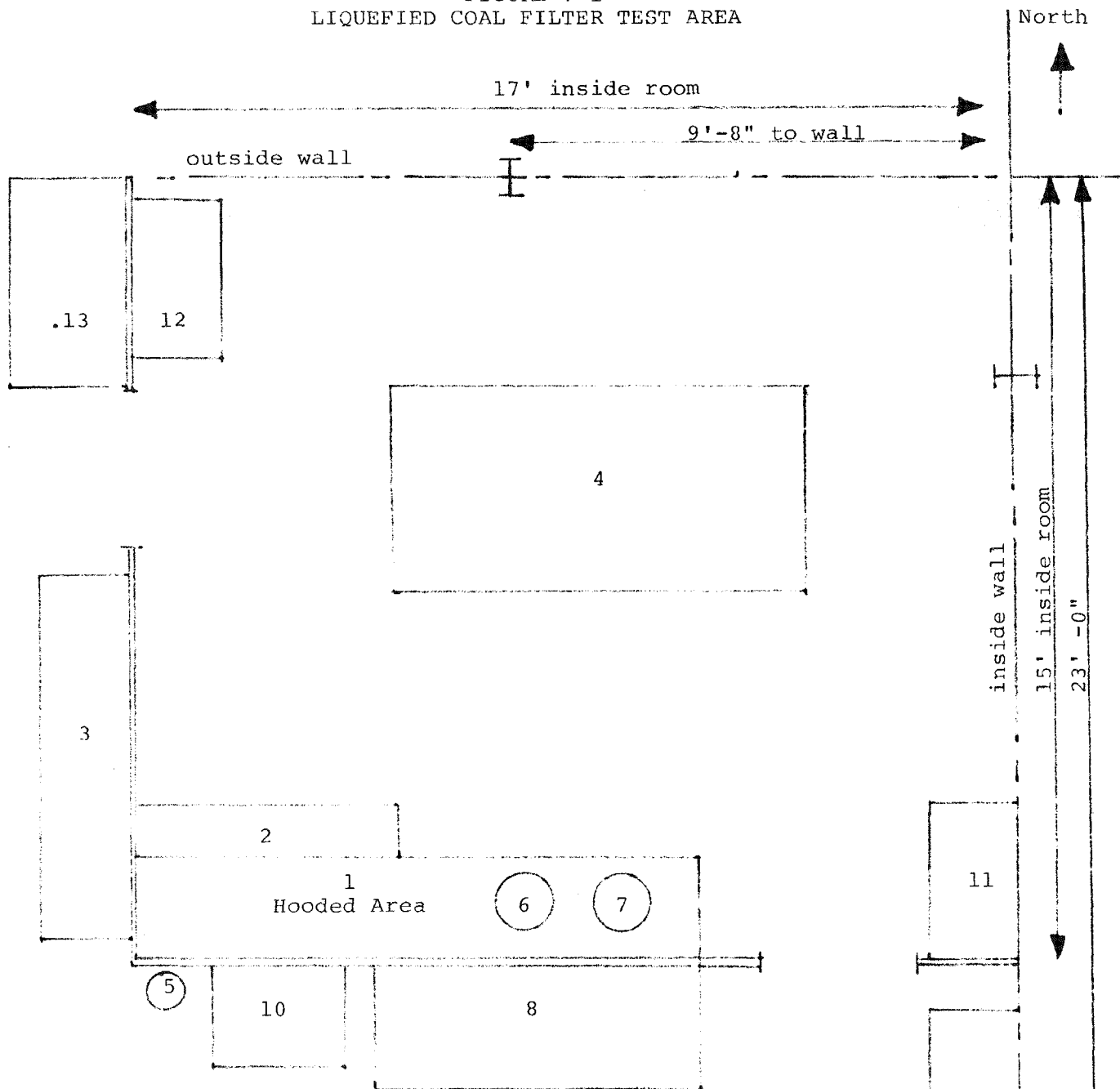
7.2 BUILDING MODIFICATIONS

All equipment was moved and rearranged in an outside wall area of the main Johns-Manville Research Center as shown in Figure 7-1. The operations portion of the area was enclosed in an explosion proof room. Minimum dimensions of the room were 15 by

17 feet as compared to the previous 11 by 15-foot room. The larger room is required because of space needed for:

- Installation of additional vessels for in-situ operation.
- Operating space completely around the filtering area.
- Location of oven and drum rolling (mixing) operations within the room. (This resulted in all open or vented solvent handling operations occurring under hoods in a ventilated room.)

FIGURE 7-1
LIQUEFIED COAL FILTER TEST AREA



- 1 2' Deep Hooded Area
- 2 3' x 5' Table Under Hood
- 3 1'-9" x 7'-0" Table
- 4 4' x 8' Filter Area
- 5 Nitrogen Cylinder
- 6 Feed Vessel
- 7 Solvent Vessel

- 8 28" x 6' Solvent Table
- 9 20" x 6' Drum Roller
- 10 2' x 2'-6" Control Box
- 11 20" x 35" Equipment Cart
- 12 Tool Cart
- 13 28" x 4' Table

SCALE: 3/8" = 1'-0"

7.3 ELECTRICAL MODIFICATIONS

The items which were corrected to make the area safe from an electrical standpoint are listed below:

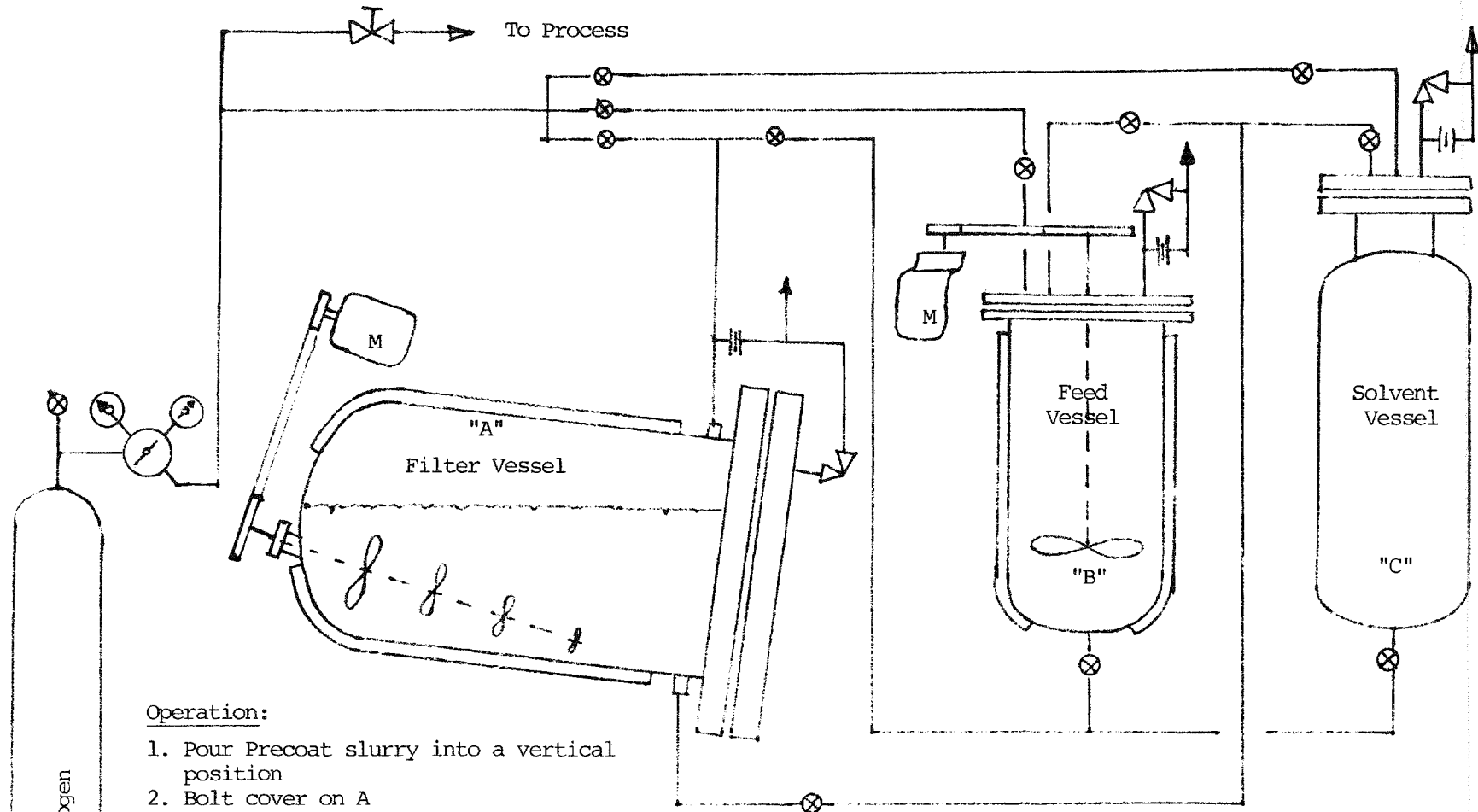
- Installation of explosion proof junction boxes with suitable sealing for all connections.
- Replacement of all 110 volt wiring in operating room with non-hazardous type.
- Installation of new 110 volt disconnect switches outside of room to replace arcing plug.
- Replacement of heating tapes with silicon impregnated type to avoid sparking from open connections.
- Provision for air pressurized box(s) for digital instruments (existing filtering timer, new vessel temperature, and new differential pressure).
- Properly grounded all items including use of grounded battery clips where applicable.
- Installation of explosion proof hot plate under hood.
- Install individual indicating heater fuses on the control console.
- Replacement of all thermocouple wiring.
- Installation of sheet metal enclosures with air purging around all heating blanket arrangements.

7.4 MECHANICAL & PIPING MODIFICATIONS

The following mechanical additions and revisions include the additional vessels and piping required for in-situ precoating and washing. Originally, it was proposed that the transfer of liquids required for in-situ precoating would all be done under elevated

temperatures and pressures. Figure 7-2 describes the required in-situ transfer at elevated temperature and pressure with use of nitrogen. The operation of this system is described on the diagram. After reviewing this operation, it became evident that it was too costly and complicated in view of the benefits to be obtained. The system was not installed. As an alternative, it was decided that after the precoat had been formed in-situ, the vessel would be cooled, depressurized, and opened. The unused precoat slurry would then be poured from the vessel, the vessel cleaned, and the test sample added. The vessel would then be closed, heated, and pressurized for the filtration tests.

7-7



Operation:

1. Pour Precoat slurry into a vertical position
2. Bolt cover on A
3. Apply precoat to leaf
4. Transfer A into C
5. Pour feed into B
6. Bolt cover on B
7. Rinse A from B to A to C
8. Transfer from B to A
9. Filter
10. Transfer from A to B
11. Empty C
12. Pour wash solvent in C
13. Transfer from C to A

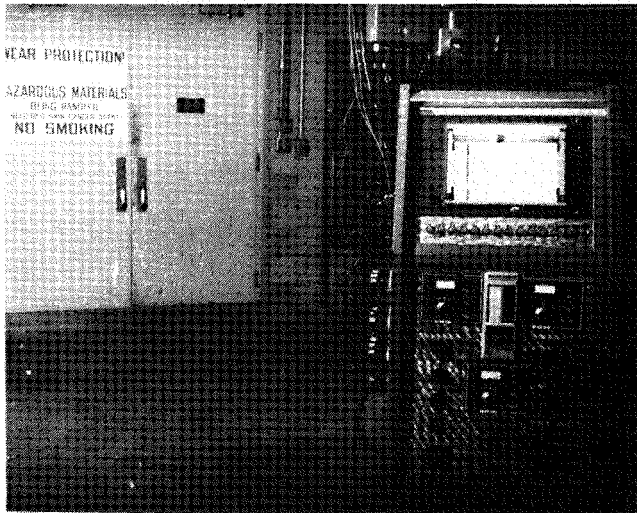
LIQUEFIED COAL "IN SITU" TEST FILTER TRANSFER SYSTEM

FIGURE 7-2

Other mechanical changes are shown below:

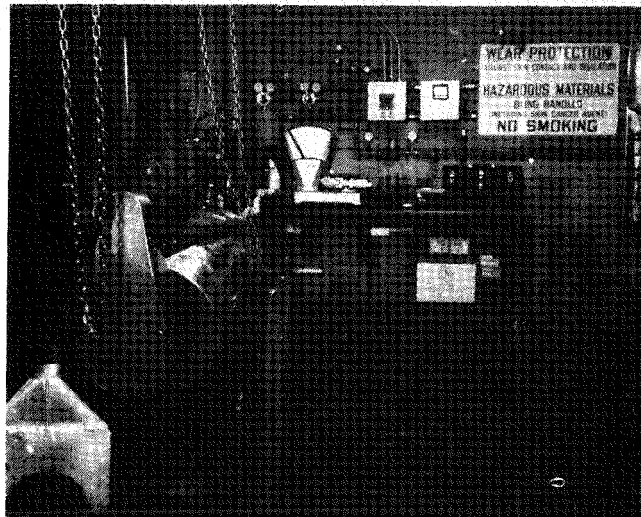
- Installation of permanent insulation over heating blanket and removable insulation panels around the flanges of the filter vessel.
- Provision for nitrogen cylinder station outside the operating room with regulating valve at the cylinder plus an additional regulating valve in each of two branch lines.
- Provision for suction from a 1-inch air syphon instead of using a vacuum pump.
- Provision for plastic guard around each glass venting assembly.
- Separation of operations from rest of room with two 1/4-inch thick by 6-foot by 8-foot Lexan plastic sheets hung from roof beams.
- Increase filter vessel agitator speed from 220 to 350 rpm to improve heat transfer when heating and avoid supplemental manual rocking. Replace packing and improve alignment.
- Replacement of mechanical relief valve with rupture disc.
- Installation of spray nozzle and revise piping for injection of wash solvent.
- Relocation of sprinkler piping and install three additional nozzles.
- Increase interior height of existing hood and provide arrangement so as to pour from a supported 5 gallon solvent container into a 2000 cc plastic graduate under the hood.
- Provision for portable hoods for floor and vessel, each connected to flexible ventilating ducts.

Photographs of the modified test leaf and operating area are shown in Figure 7-3.



Entrance to Operating Area

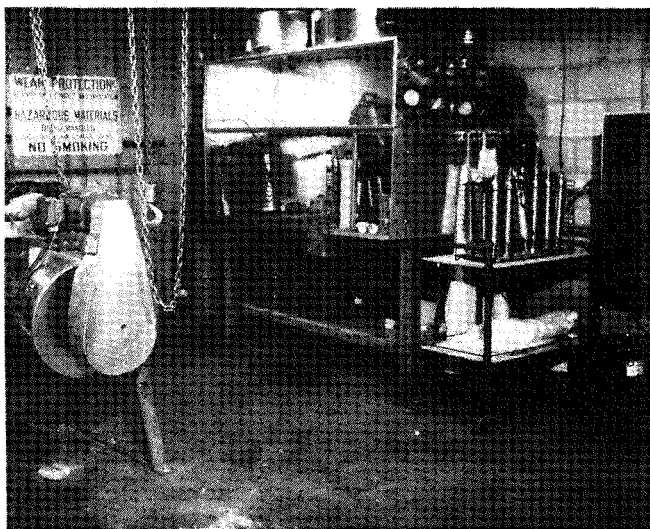
Left: Nitrogen Supply Cylinder, Master Switches
 Right: Temperature Control and Recording Console



Operating Area

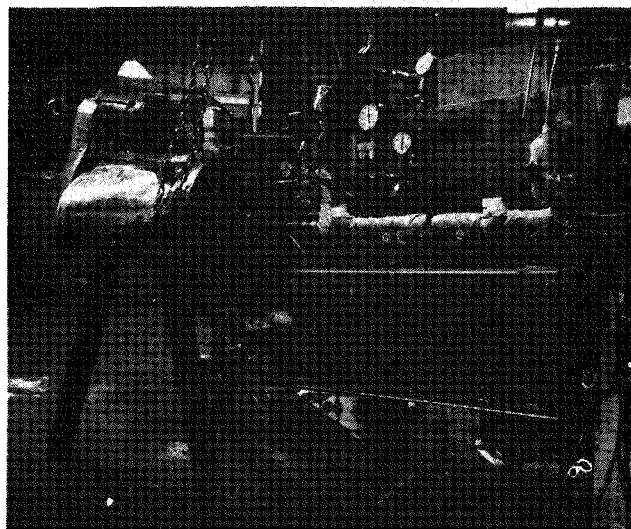
Left: Insulated & Agitated Pressure Vessel Containing Test Leaf. Portable ventilation receivers. Exit doors in back

Right: Nitrogen and Air Piping Dip Time Indicator, Feed Temperature Indicator



Operating Area

Left: Filtering System
 Right: Large Hood for Pouring, with Small Hood on each side for Cleaning



Filtering System

Pressure Vessel, Piping, and Receivers

7.5 TEST LEAF DESIGN & OPERATION

A retractable sleeve and method of moving it from outside the filtering vessel was added around the previously used 0.1 square foot test leaf. Figures 7-4, 7-5, and 7-6 describe this design as now installed. As shown, a cam arrangement provides the sleeve motion back and forth around the outside of the leaf holder. The vessel opening for outside extension of the operating shafts is sealed with Viton O-Rings. The cam arrangement replaced an originally installed miter gear transmission and threaded disc arrangement.

The original concept as illustrated in Figure 7-7 was to operate as follows:

- Turn miter gears with exterior extension of connecting tube shaft.
- This turned a connected disc whose exterior was threaded to the sleeve interior.
- This allowed movement of the sleeve back and forth along the filter leaf holder and extension beyond the leaf for supporting precoat.

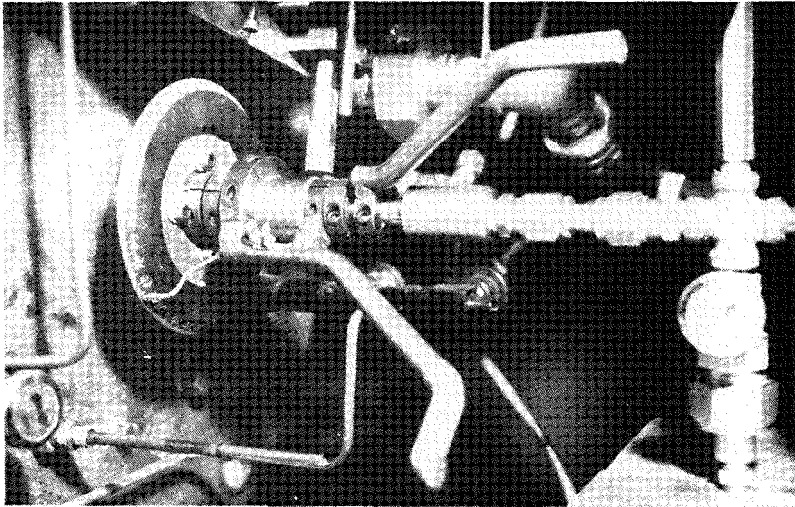
The main problem with the gear/thread arrangement was the inability to turn the threaded disc in the sleeve freely, if at all, after applying precoat to the leaf. This was due to lack of lubrication by the solvent or plugging of the threads with filter aid or restriction from filter aid in the sleeve slots or all three. Any turning was hard and jerky, resulting in the precoat cracking or falling off. Light oil on the threads was used successfully to

regain ease of motion. The following revisions were evaluated with very little improvement in results:

- Increasing gears from two to three for improving smoothness of transmission.
- Changing sleeve threading from 16 threads per inch to 10 threads per inch and lapping the threads to smooth and loosen the motion.
- Removing metal from the threaded disc to result in 3/4-inch long contact of five threads at four equally spaced points around the circumference. The ends of threads were at 90° to the radius for giving a plowing effect.
- Lightening the overall weight by reducing the sleeve thickness to 3/32-inch over the non-threaded area.
- Use of high temperature non-seizing compound on the threads.

Loosening the nut for independently moving the sleeve, when at the filtering conditions of 600°F and 200 psig, was not done because of the potential hazard of a release of hot fumes and solvent. Also, any mechanical tubing connection tended to slip when in contact with the heated solvent.

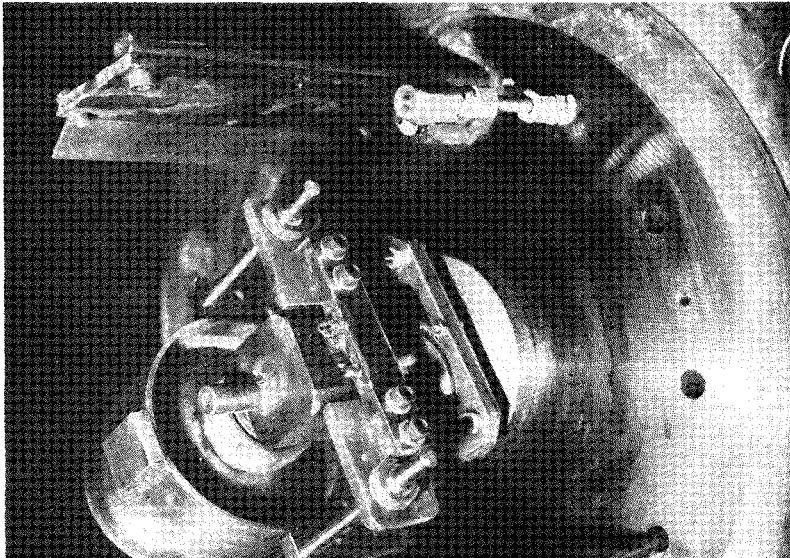
Figure 7-4 FILTER TEST LEAF ASSEMBLY
WITH RETRACTABLE SLEEVE AND WASH SPRAY



OUTSIDE VESSEL

showing:

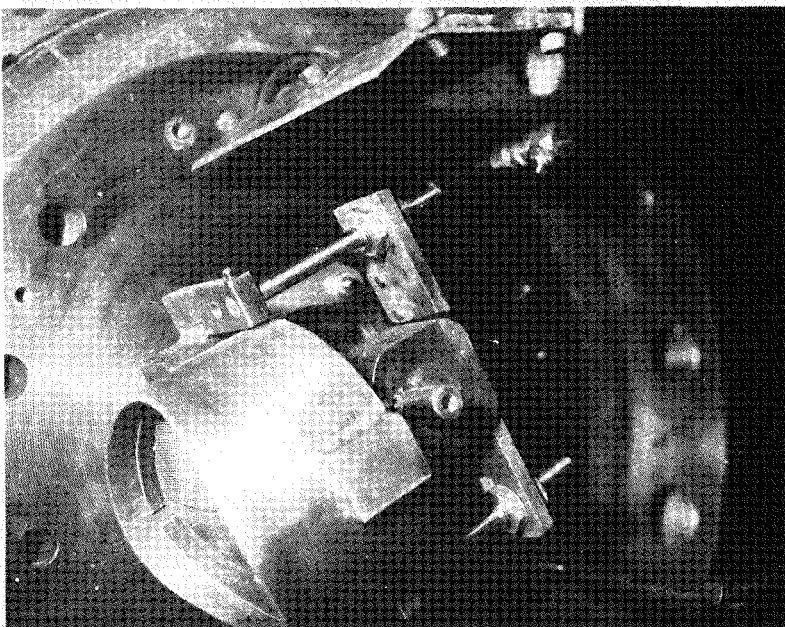
Dial and Pointer
O-Ring Housings
Operating Handles
Outer and Inner Shafts



INSIDE VESSEL

showing:

Wash Spray Nozzle
Cake Cutting Blade
Cam and Bearing
Sleeve and Guides



INSIDE VESSEL

showing:

Sleeve and Screen
at Inlet

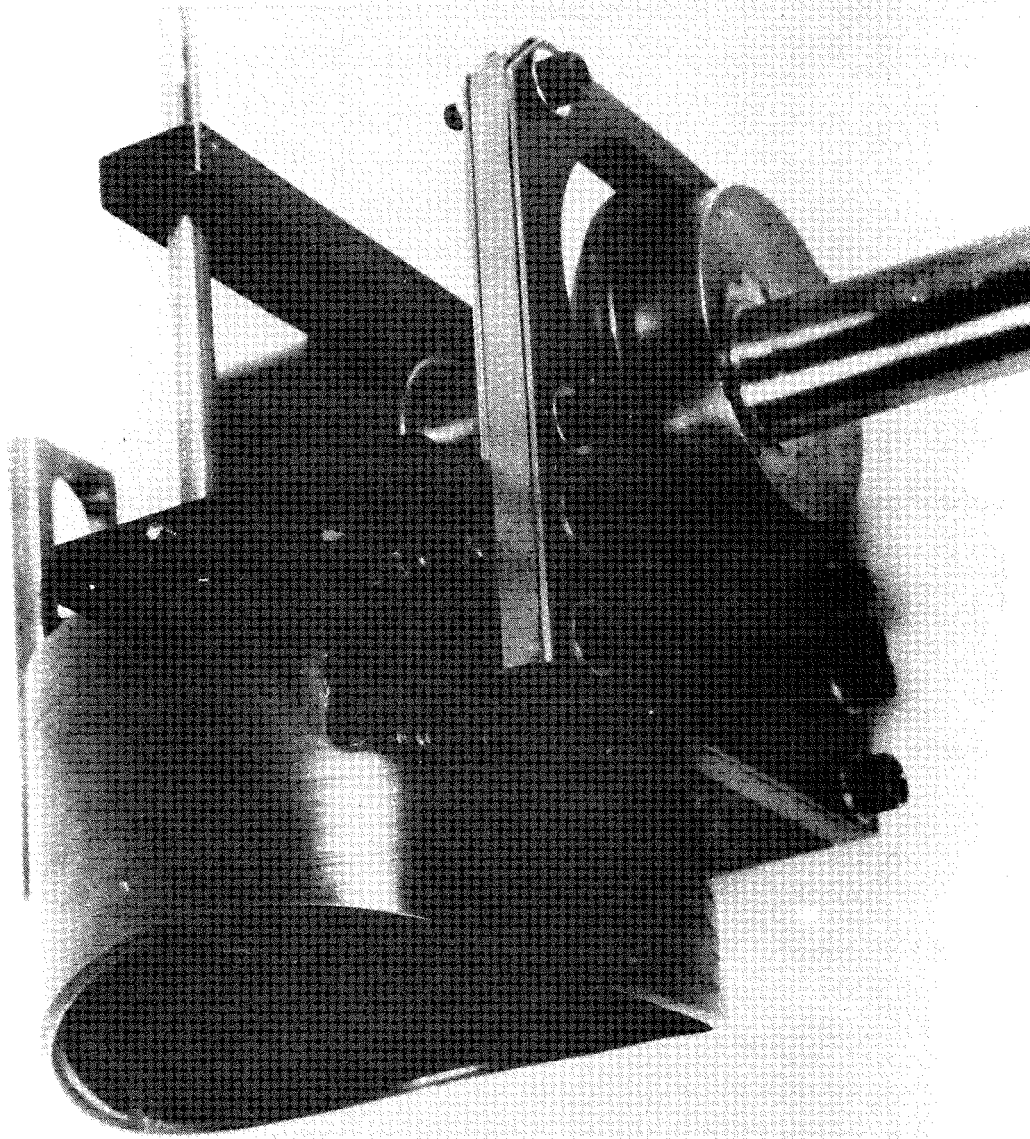
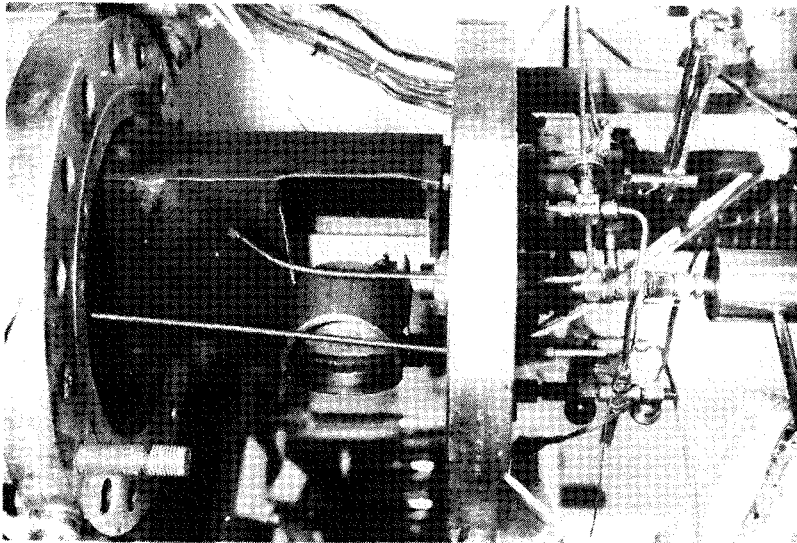


FIGURE 7-5

Figure 7-7 IN SITU DESIGN

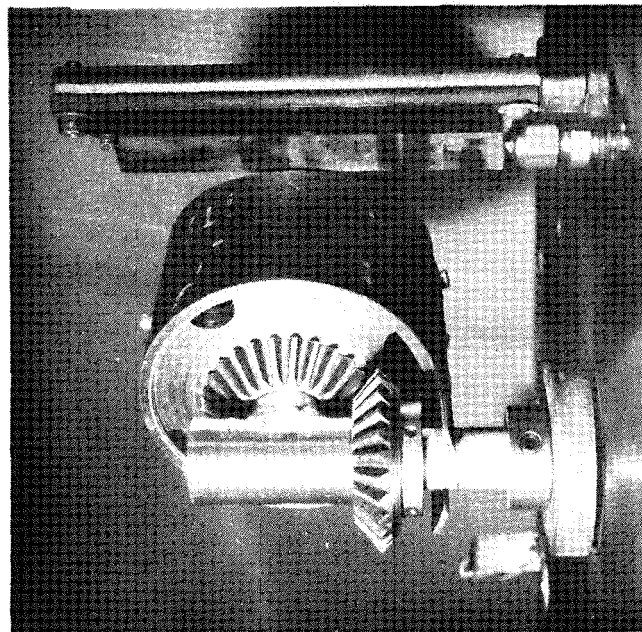
0.1 square foot filter test leaf
in horizontal position



- Left of cover flange:
- (1) cut catching chamber
 - (2) stationary blade inside chamber
 - (3) leaf in filtering position with sleeve extended

- Right of cover flange in center:
- (1) packing gland
 - (2) outer shaft connection and seal with pointer
 - (3) inner shaft connection and seal
 - (4) packing gland with circular scale for pointer and turning handle

Leaf in cutting position showing method of moving sleeve back and forth in relation to leaf. Outer shaft turns gears and threaded disc on ends of stationary tee.



7.6 FILTER SYSTEM REVISIONS

Figure 7-8 shows the final overall test leaf system. The general operating principles are described below:

7.6.1 Pre-Precoating

The required pre-precoat is applied with use of suction and with the leaf outside the vessel as for previous data. Although this procedure is not in-situ, it is felt that any effects on subsequent in-situ operations during the overall run will be negligible. At the beginning of the run, the retractable sleeve around the leaf is extended to a maximum distance beyond the leaf. This allows at least 3/4-inch precoat thickness after applying 1/4-inch of pre-precoat. The pre-precoat is CELITE AF13 diatomite applied to the leaf from a 2 percent slurry in toluene/xylene.

7.6.2 Precoating

A technique for applying the precoat in-situ was developed. Application is from a slurry contained in the closed filter vessel. This slurry is composed of about 7 percent CELITE AF5 diatomite in liquefied coal process solvent. Temperature and pressure are controlled at about 275°F and 35 psid.

Application may require several dozen cycles of dipping the leaf into the slurry and drying to obtain the desired overall precoat thickness of at least 1-inch. Filtrate is collected in any or all of the seven filtrate receivers as required. After application, excess thickness may be trimmed off while the vessel is still closed using a knife setting previously determined with the vessel open.

The vessel is cooled and suction applied to relieve the pressure and maintain the precoat. The vessel is opened, the condition of the precoat is observed, and unused slurry is poured out of the vessel.

7.6.3 Filtering

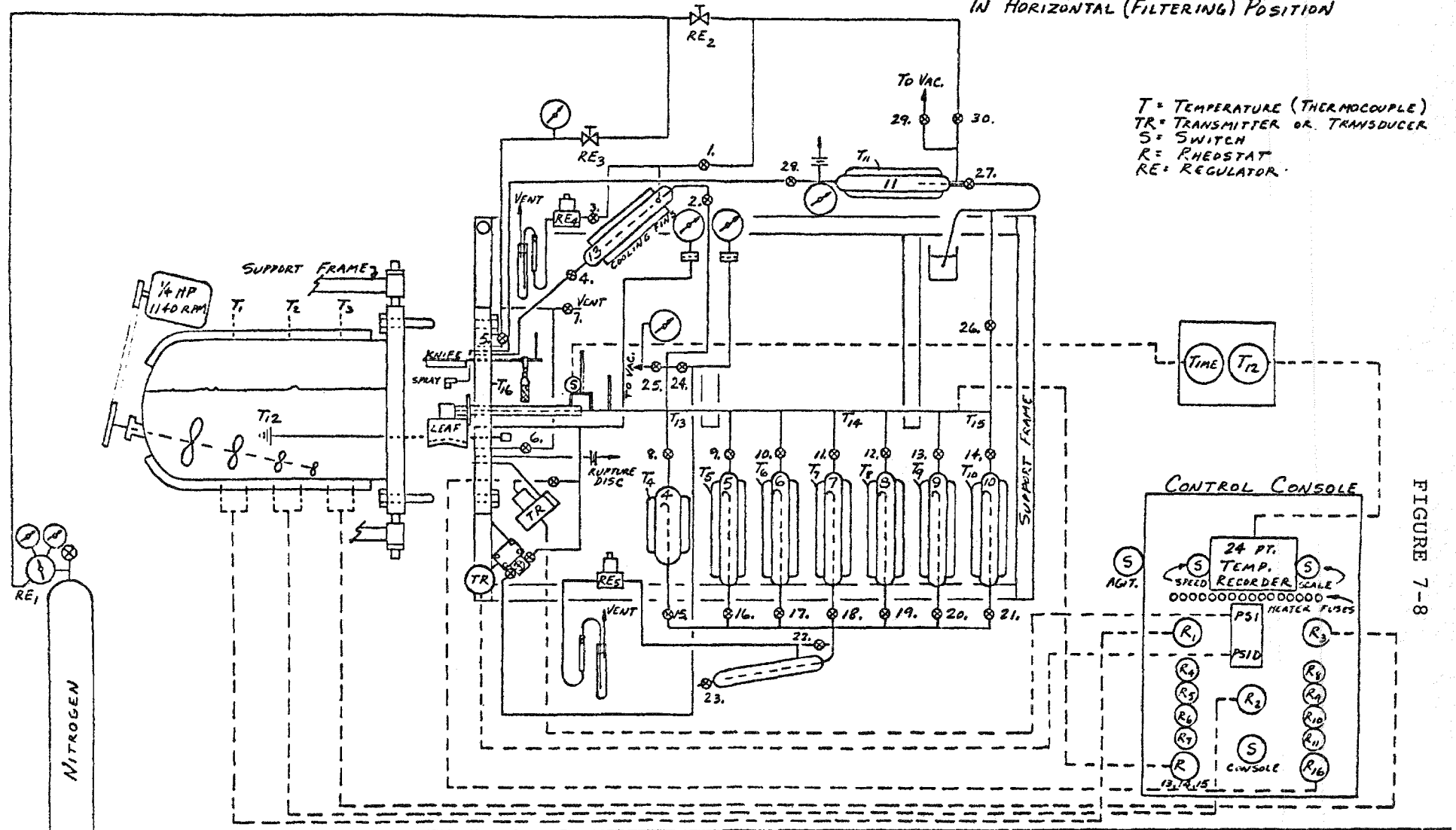
As soon as possible after removing unused precoat slurry, liquefied coal filter feed is poured into the filter vessel. The vessel is closed and controlled at 600°F and 70 to 100 psid for in-situ filtering and comparison with previous runs. The leaf sleeve is kept retracted slightly from the precoat surface as cutting progresses. This is per the exterior degree dial and for the purpose of preventing the knife blade from touching the sleeve.

7.6.4 Washing

A small cone spray type nozzle has been installed in the area between leaf and knife for cake washing tests. With the use of suction and nitrogen pressure, process solvent is introduced into Vessel No. 11, heated to 600°F, and injected through the spray nozzle. Pressure differential is the same as for filtering and wash filtrate is collected in the receivers. Time limitations, however, prevented any cake washing tests from being run.

FLOW DIAGRAM -- ROTARY PRESSURE PRECOAT TEST LEAF

IN HORIZONTAL (FILTERING) POSITION



7-19

FIGURE 7-8

7.7 OPERATING PROCEDURES

After several runs, the following operating procedures for precoating and filtering were developed.

- Thoroughly clean the leaf screen with solvent to eliminate all possible blinding or plugging.
- Fully extend the leaf sleeve and apply 1/4-inch thickness of CELITE AF13 pre-precoat. With the leaf outside the vessel and using suction, dip it into a 2 percent slurry in toluene/xylene as many times as necessary.
- Retract the sleeve 5/32-inch (about 1/8-inch and representing about 50° on a degree dial) from the fully extended position. This will avoid interference between sleeve and blade.
- Prepare a 7 percent slurry of CELITE (AF5 or Standard SUPER-CEL) and liquefied coal process solvent in the vessel.
- Close the vessel with the leaf in it.
- Heat the slurry to 275°F (for decreasing viscosity of the solvent to about 1 cp).
- Adjust pressures to 35 psid for precoat application.
- Apply precoat by successive dips of 5 seconds each with about 10 seconds drying between dips (equivalent to 4.8 rpm drum speed on the 50 Square Foot Pilot Filter).
- Collect filtrate into one receiver at a time and use as many receivers as required.
- Dip and collect filtrate 12 times without attempting to cut it with the knife.
- Turn on agitator for about 1 minute between dips.
- After 12 dips and with the blade set at about 13/64-inch from the sleeve, pass the leaf by the blade after each dip until a total of 20 dips has occurred.

- Retract the sleeve $3/64$ -inch (5° on degree dial) for a total retraction of $13/64$ -inch. This results in about $1/4$ -inch from the end of the sleeve to the surface of the precoat for initial filtering and cutting.
- During filtering and cutting, retract the sleeve 5° (as per degree dial) at a time as often as required to keep the blade from touching the sleeve and still give maximum side support to the precoat.

Section 8

EVALUATION OF PRECOAT GRADES WITH VARIOUS APPLIED PRECOATS

8.1 PRECOAT PREPARATION

Laboratory tests were made to assess a flocculation problem which was recognized early in the program. Tests, in which 1 gram samples of various diatomite filter aids were dispersed in 40 cc of various organic fluids and of water and allowed to settle for at least 18 hours, clearly defined the flocculation problem. Final volumes of settled solids were from two to three times as great for all cases with the organic solvents (50:50 toluene/xylene mixture, tetralin, and various solvent fractions from the Wilsonville Coal Liquefaction Plant) as for the case of the water based slurries. Subsequently, tests were made with the toluene/xylene mixture (the most satisfactory solvent system available in suitable quantity) as the suspending fluid for various diatomite filter aids, including a special filter aid, CELITE AF7, treated with an anti-flocculation agent. The CELITE AF7 yielded precoats approximately 20 percent more dense than the others and did not present the cracking problem associated with the floc-like precoats obtained with the untreated

diatomite products. Accordingly, the CELITE AF7 filter aid was chosen for initial experimentation in the filtration apparatus.

Precoats on the filter leaf of the high pressure-high temperature apparatus are conveniently made by suspending the top flange Christmas Tree assembly in the horizontal position with the filter leaf facing down, applying vacuum to the filter leaf through attachments on the Christmas Tree, and rotating the leaf into and out of a slurry consisting of approximately 125 grams of CELITE AF7 in 1000 cc of the mixed toluene/xylene solvent. In the initial stages of precoat deposition, a vacuum of 3 to 5-inches of mercury is employed and the vacuum is increased as the precoat thickens until it reaches approximately 15-inches of mercury. The precoat thus formed has more or less the shape of an inverted mushroom. It is then trimmed to the desired shape (intersection of two cylindrical surfaces) by use of a free knife blade and the doctor blade of the apparatus. The shaped precoat is held in place by the same vacuum system while the equipment is set up for filtration.

8.2 PRE-PRECOATING

Pre-precoating materials evaluated were CELITE AF13 made from CELITE 550 and FIBRA-FLO 7C with asbestos.

CELITE AF13 material made from CELITE 550 is a relatively coarse, non-asbestos diatomite filter aid. It should prevent precoat bleeding through the leaf screen into the filtrate with minimum flow resistance at the screen.

Precoating in both cases was with CELITE AF5 as shown in Table 8-1. There was very little difference in apparent filtration rates and essentially no change in the filtrate ash content were observed. The variations when using CELITE AF13 pre-precoat may be due to compression of the precoat and pre-precoat with resulting reduction in the accuracy of small blade advances. Apparently, extreme care must be taken to assure that the coating is properly and uniformly applied. For valid and most favorable results, any significant amount of compression must be avoided.

Some difficulties occurred in retaining precoats on the leaf when formed over a CELITE AF13 pre-precoat. Probably, this happened due to precoat shrinkage causing a separation between pre-precoat and precoat. This might have been due to thicker layers of CELITE AF13 having been applied than in the case of FIBRA-FLO 7C rather than CELITE AF13 shrinking differently than the FIBRA-FLO 7C. The reasoning behind this increase in thickness for CELITE AF13 was to more closely simulate the conditions expected on the 50 Square Foot Pilot Filter to be operated at Fort Lewis.

TABLE 8-1
COMPARISON OF FILTRATION RATES
WITH DIFFERENT PRE-PRECOATS

CONDITIONS: 70 psid
600°F
CELITE AF5 Precoat
TFF 216 Feed

BLADE ADVANCE mils/cycle	DRUM SPEED rpm	RATE (lb/hr/sq ft)	RATE (lb/hr/sq ft)	RUN	DIFFERENCE PERCENT
		WITH FIBRA-FLO 7C PRE-PRECOAT	WITH CELITE AF13 PRE-PRECOAT		
2	12	600	592	E51	- 1
2	8	465	506	E49	+ 9
2	6	375	369	E63	- 2
2	4.8	325	286	E61	-12
1	12	495	>410	E65	-17
1	8	385	466	E53	+21
1	6	310	358	E55	+15
1	4.8	265	293	E67	<u>+11</u>
					+ 3 Avg.

8.3 PRECOATING

Runs E146 through F4 and F9 through F19 used CELITE AF2 precoat for comparison with those using CELITE AF5 precoat. Comparisons at a pressure differential of 70 psid and at 1 and 2 mils per revolution knife advances in Table 8-2 indicate some reduction (15 to 20 percent) in rate with CELITE AF2. The CELITE AF2 is a finer diatomite with smaller pore openings than CELITE AF5 and thus less permeable (2/3) than CELITE AF5. Higher rates (in excess of 500 pounds per hour per square foot) were obtained at the higher pressure of 100 psid. However, this also represented a reduction from the filtration rates in the range of 700 pounds per hour per square foot with CELITE AF5 precoat and FIBRA-FLO 7C pre-precoat (at 100 psid, 600°F, 4 and 2 mils per revolution, and 2 second immersions). Less knife advance resulted in less rate, but a smaller ratio of filter aid usage to amount of filtrate.

The use of CELITE AF2 might be practical on a large scale in the interest of filter aid economy. Due to its fineness and low permeability, it would have to be proven on a large scale with the precoat thickness up to 6-inch.

TABLE 8-2
 COMPARISON OF FILTRATION RATES WITH
 AF5 AND AF2 PRECOATS

BLADE ADVANCE mils/rev	DRUM SPEED rpm	RATE (lb/hr/sq ft)		RATE (lb/hr/sq ft)		DIFFERENCE PERCENT
		WITH AF5 PRECOAT	(RUN)	WITH AF2 PRECOAT	(RUN)	
2	8	506	(E49)	388	(F19)	-23
2	6	303 & 369	(E47 & 63)	288	(F9)	-14
1	6	346 & 358	(E55 & 137)	198	(F11)	-15

8.4 RATE LIMITING EFFECT OF PRECOAT

In attempting to increase filtration rates significantly, the viscous drag of the precoat on the filtered liquefied coal must be considered. To determine this, the following experiment was carried out.

A sample of liquefied coal filtrate (Sample No. 465) was obtained from the Tacoma SRC Plant, together with Sample No. 466 of the simultaneous filter feed. These were employed as feed in equivalent runs using the same precoat. The "filtration" rate of 1150 pounds per hour per square foot observed for the liquefied coal filtrate was so high that 10 second immersions were the maximum that could be accommodated without overflowing the receivers. For the five immersions for which measurements could be made, rates were quite uniform and showed no trend toward increase or decrease. In companion runs with unfiltered material, rates measured were in the range typically observed with other TFF samples (i.e., 178 pounds per hour, 605°F, 25 psi, 10 mil, 20 second submergence). From these runs, it is concluded that for filtration under the conditions imposed, the rate limiting resistance to flow resides in the filter cake formed by the SRC solids on or near the surface of the precoat.

Section 9
FILTRATION DATA
(Vacuum Precoating)

9.1 EFFECT OF TEMPERATURE ON RATE

The effect of temperature on filtration rate is shown for various immersion times in Figure 9-1 at 10 mils per revolution knife advance and 40 psi differential pressure. These conditions gave consistent results. Increased temperatures result in lower viscosities which in turn positively affect filtration rates. (Viscosity data for TFF are shown in the Appendix.) As the viscosity of TFF at 500°F is less than 1 cps and not measurable by the techniques used here, no quantitative predictions based on filtration theory were made. All data show, however, an increase in rate with temperature for all conditions recorded. All the data are also in the expected direction related to immersion times.

In tests on WFF (SN25260, Emery Coal), a decrease in temperature from 600 to 500°F at 100 psid pressure reduced the filtration rate from about 760 to 550 pounds per hour per square foot for 2 second immersions, but inconsistent results were

obtained for 3 and 4 second immersions (Runs E73 to E119,
Appendix I).

TABLE 9-1
 APPARENT FILTRATION RATES AT 100 and 70 PSID
 (lb/hr/sq ft)

FEED	Immersion Time seconds	Knife Advance 2 mils/rev			Knife Advance 4 mils/rev		
		Differential Pressure		RUN	Differential Pressure		RUN
		70 psid	100 psid		70 psid	100 psid	
TFF	2	600	704	D81a	665	725	D79a
TFF	3	465	495	D81a	563	511	D79a
TFF	5	375	298	D77a	440	456	
Wilsonville (Emery Coal)	2	601*	766	E105			

*Run No. E79

9.2 EFFECT OF DIFFERENTIAL PRESSURE ON RATE & USAGE

Figure 9-2 shows a comparison of apparent flow rates at 40 and 20 psi differential pressure for different immersion times (inverse of drum speed) for WFF, TFF, and Synthoil (SYN) materials at various immersion times. Three points were obtained for all curves, except Curve No. 4, although the points were not always consistent with theory. For instance, as submergence time decreases (drum speed increases) filtration rates should increase due to the lower resistance of the cakes formed at these shorter submergence times. All curves were so drawn even though, as in the case of Curve No. 4, not all the points showed an increase in rate with decrease submergence time.

There are also some additional inconsistencies that it is felt are not worth discussing considering accuracy of the data. For all feed materials and submergence times, however, higher rates were obtained at 40 psid versus 20 psid.

TABLE 9-2

TFF 216, 600F, 35 psid, 5 second

Filtration Rate
lb/hr/sq.ft

KNIFE ADVANCE mils/rev.	AF5 PRECOAT	AF6 PRECOAT	AF7 PRECOAT
10	365	345	345
7	354	341	330
4	338	319	289
2	260	264	259

The effect of differential pressure in increasing rate is shown in Figure 9-3 for various knife advance rates. As can be seen, increasing differential pressure increases flow rate for all blade advance rates.

The data in Figure 9-3 is recalculated to show precoat usage versus knife advance for three differential pressures in Figure 9-4. At all knife advance rates, precoat usage declines with increasing differential pressure.

Figure 9-5 shows plots under the same conditions as Figure 9-2 except at a knife advance rate of 2 mils per revolution instead of 10 mils per revolution. As in Figure 9-2, Curves 5 and 6 (Synthoil) are quite consistent. Data points in the other curves representing runs made on TFF and WFF all exhibit various degrees of inconsistency, but do indicate higher rates at higher differential pressures. We believe that the main cause of these inconsistencies is the poor cake cutting properties of these other materials at low knife advance rates. Other techniques need to be investigated to improve cake cutting at low knife advance rates. The higher peripheral speeds of larger filters will have a beneficial effect on cake cutting which should overcome much of this problem.

Synthoil (Curves 5 and 6) seems to have a better cutting cake that gives more consistent results under all filtration conditions.

FIGURE 9-3

APPARENT FILTRATION RATE VERSUS KNIFE ADVANCE

TFF 216, 600F, AF5 Precoat
5 second Immersions, 40% Submergence

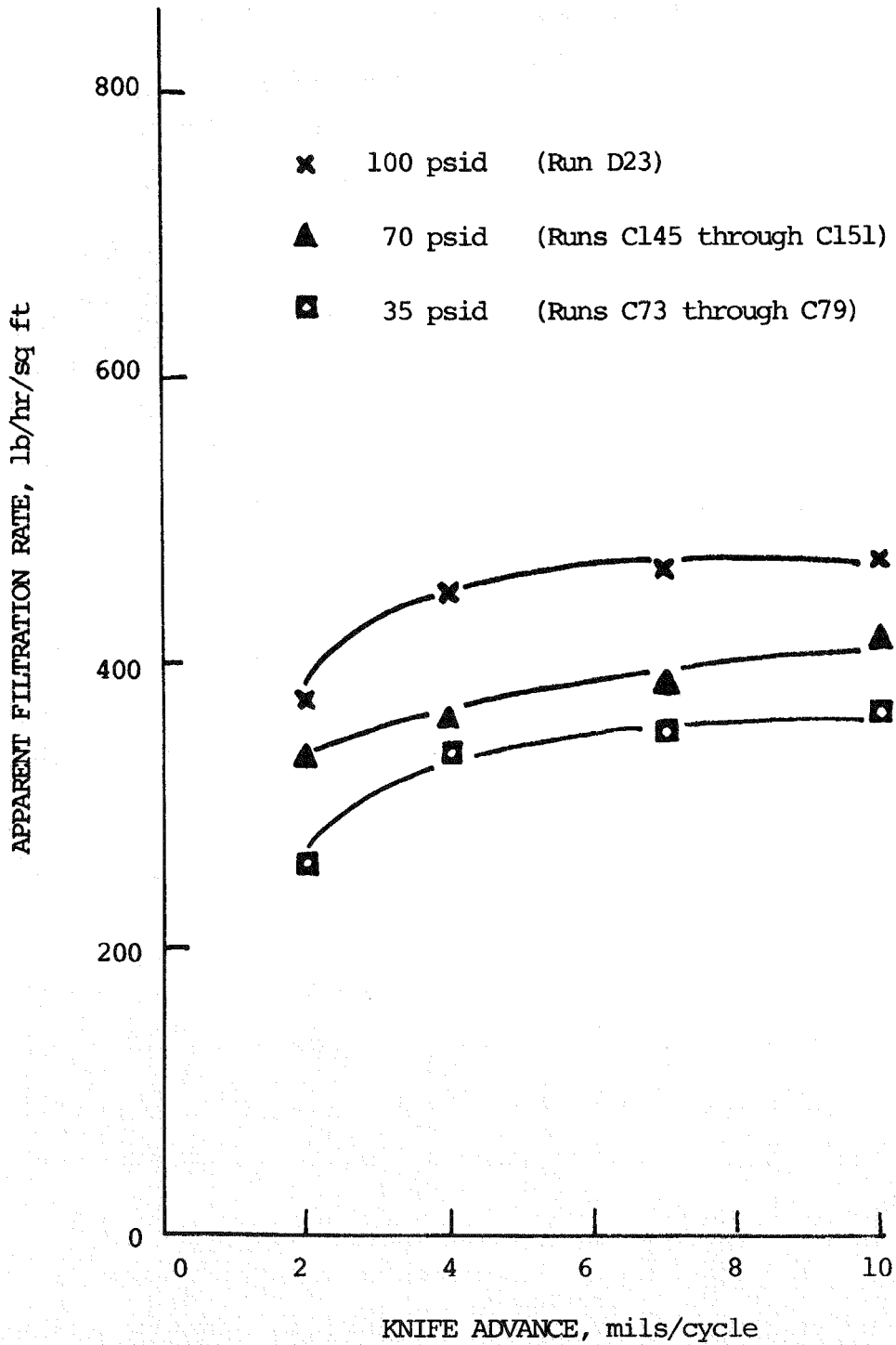


FIGURE 9-4

PRECOAT USAGE VERSUS KNIFE ADVANCE

TFF 216, 600F, AF5 Precoat
5 second Immersions, 40% Submergence

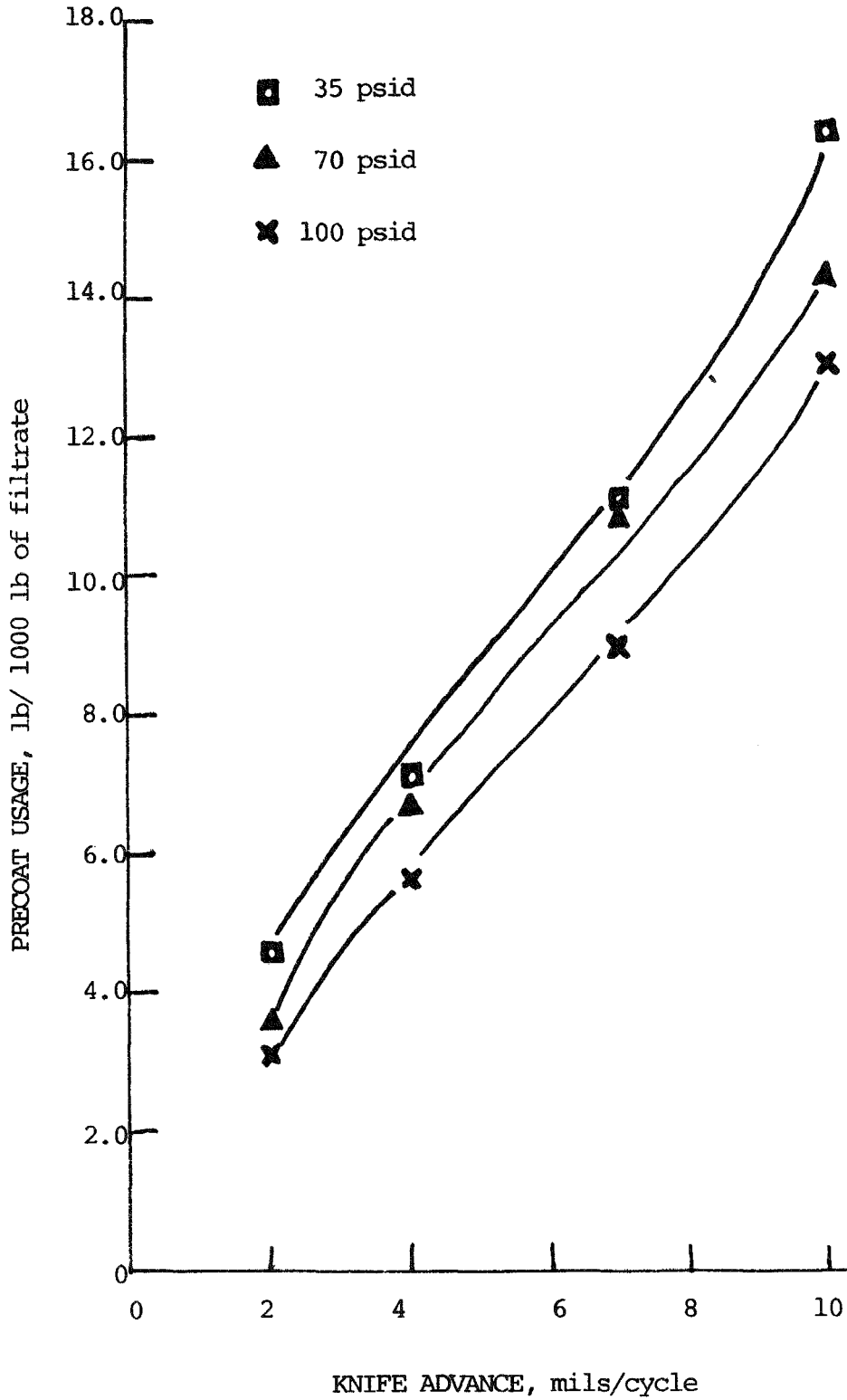
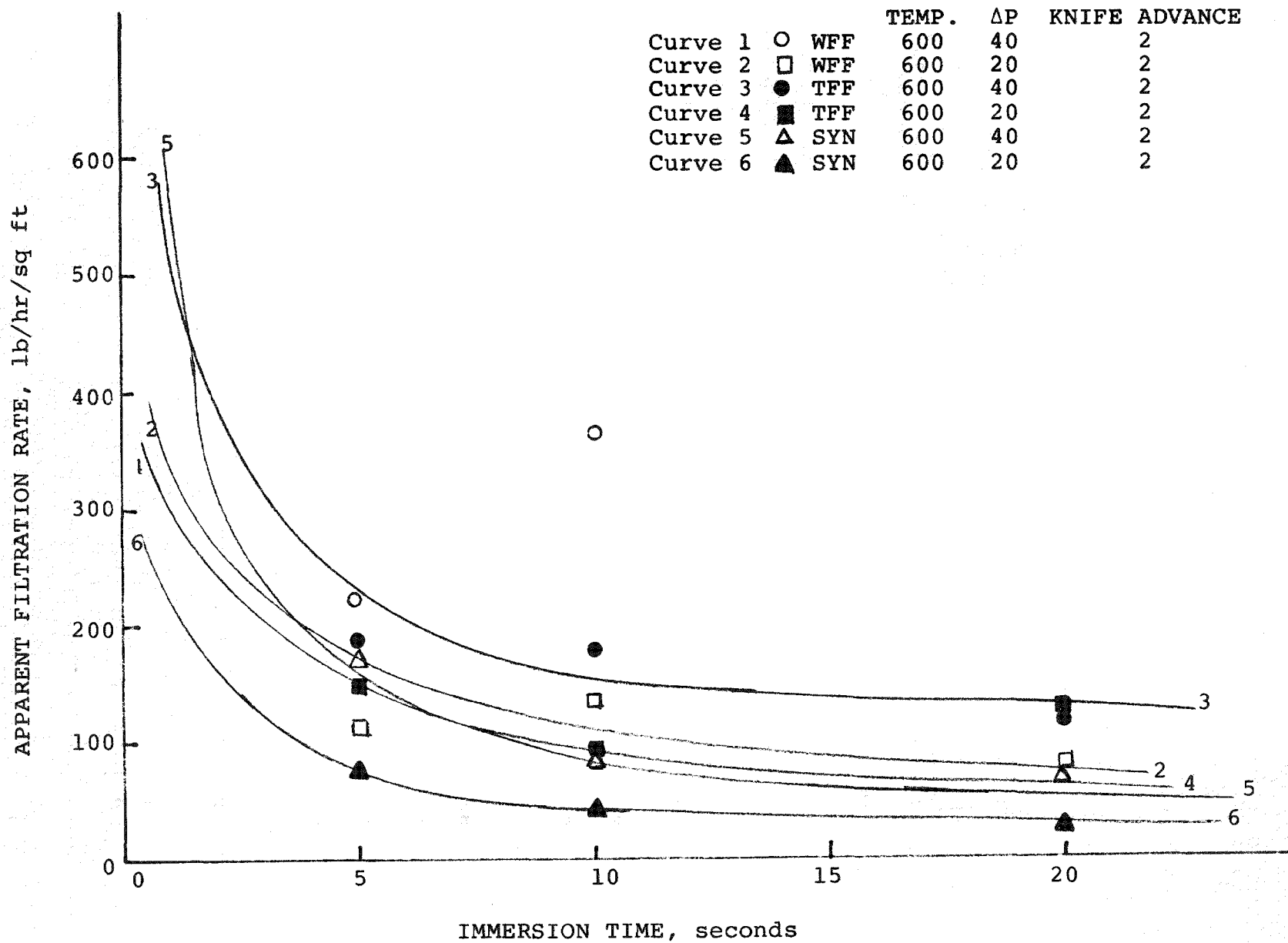


FIGURE 9-5 ΔP DEPENDENCE



01-6

The two series of Runs C82 through C89 and C117 through C125, Figure 9-6 (also shown in Appendix I), with TFF 216 were intended to clarify the dependence of the filtration rate upon differential pressure. Runs C83 through C89 used CELITE AF6 (medium pore diameter 4 microns) as the precoat. During the course of these runs, the differential pressure was increased from 35 psid to 70 psid in increments of 5 psi. The temperature of the filter feed was maintained at 600°F. Four mils per revolution knife advance and 5 second immersions were used for these runs.

The reasons for the lack of increased rate with increased pressure for CELITE AF6 can be explained as follows. The first immersions in Runs C83 through C89 appear to have significantly compressed the precoat causing it to recede from the knife, resulting in essentially no precoat cutting and, therefore, lowered filtration rates. The filtration rate remained essentially constant even though increasing the differential pressure from 35 psid to 70 psid should theoretically result in an increase in filtration rate. When the knife advance rate was increased to 10 mils per revolution in Run C89, the rate increased substantially indicating that the knife had caught up to the precoat or that a 10 mil cut was required to prevent penetration of solids into the CELITE AF6 precoat. Evidence that fine solids penetration into the precoat may have been an important rate determining factor is indicated by the dramatically increased rate

of Run C89 at 10 mils per revolution knife advance at 70 psid. This rate is also shown in Figure 9-6 as "10 mil".

The rates when using the 40 percent smaller pore size precoat of CELITE AF5 did not indicate severe fine solids penetration at 4 mils per revolution. The filtration rate increased nearly 30 percent when the differential pressure was increased from 50 psid to 70 psid. Additionally, the rate at 70 psid and 7 mils per revolution knife advance (Run C125) was the same as at 70 psid and 4 mils per revolution (Run C123).

In Runs D15 through D21, differential pressure was increased from 40 psid to 100 psid with other filtration conditions as follows: 600°F, 4 mils per revolution, 10 and 5 second immersions, CELITE AF5 precoat. The results of these runs are shown in Figure 9-7 along with data from previous runs at the same conditions. The apparent filtration rate increased to about 450 pounds per hour per square foot at 80 and 100 psid from about 350 pounds per hour per square foot at 35 psid. The low rates at 40 psid for Run D15 are attributed to little or no knife cutting of the initially compressed precoat.

Table 9-1 compares filtration rates at 70 and 100 psid using TFF at 600°F with CELITE AF5 precoat. Increasing the differential pressure from 70 to 100 psid resulted in a marginal increase in filtration rate for runs on Tacoma Filter Feed at 2 seconds

submergence and the Wilsonville Filter Feed. The other two runs at 3 and 5 seconds submergence showed either an insignificant increase or even a decrease in rate for, it is assumed, the same reasons as described above.

FIGURE 9-6

TFF 216, 600F, 4 mils/cycle, 5 second

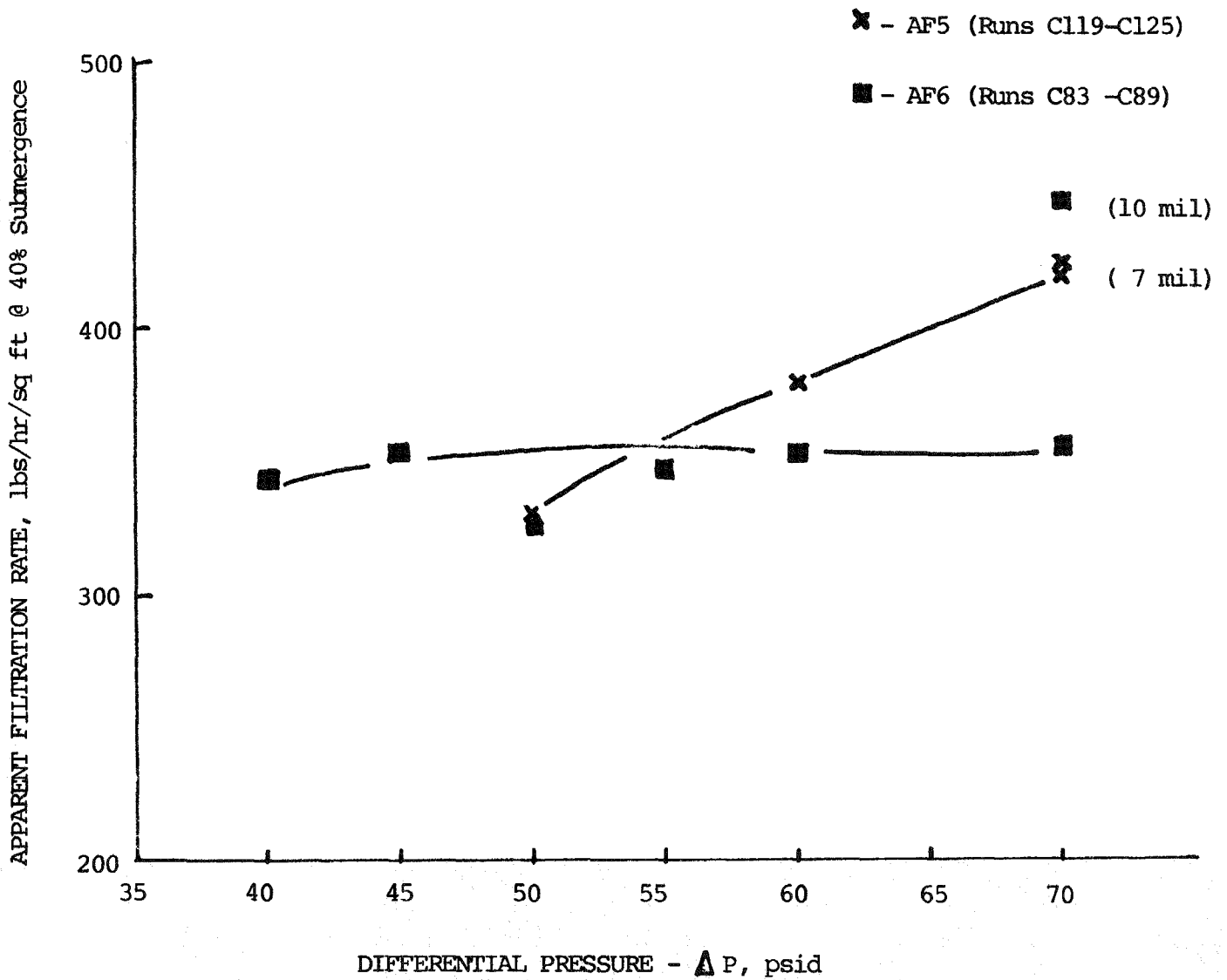


FIGURE 9-7

APPARENT FILTRATION RATE VERSUS DIFFERENTIAL PRESSURE

TFF 216, 600F, 4 mils/cycle, AF5 Precoat
5 second Immersions, 40% Submergence
Runs D15 through D21

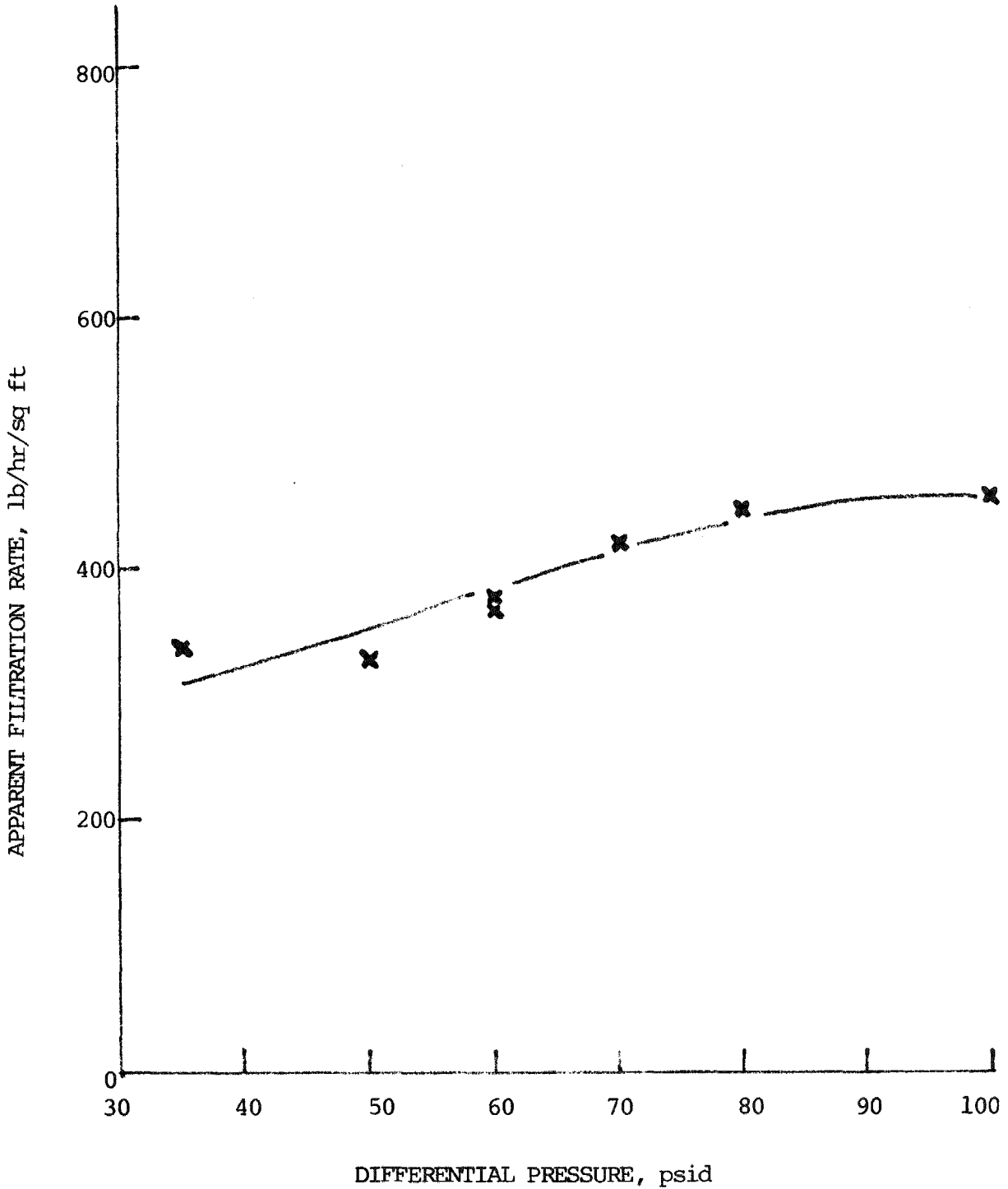
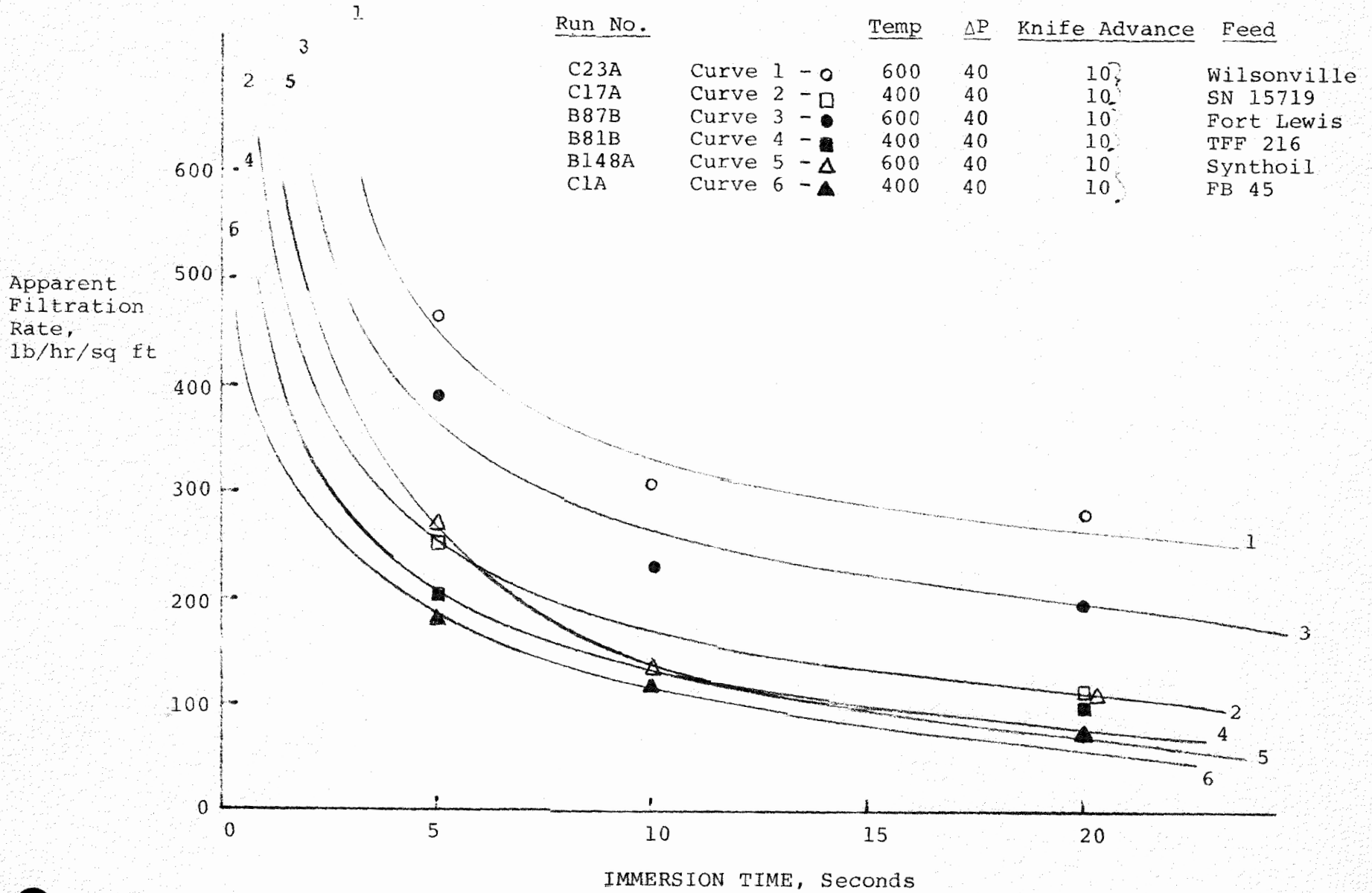


FIGURE 9-1
TEMPERATURE DEPENDENCE



9.3 EFFECT OF DRUM SPEED ON RATE & PRECOAT USAGE

Every test comparing filtration rates with drum speed shows an increase in flow rate with increasing drum speed. Conversely, flow rate decreases with increased immersion time as the immersion time is inversely related to drum speed. This relationship can be seen in all curves in Figures 9-1, 9-2, and 9-5. At the time of completion of graphs in these figures and Figure 9-12, it became apparent that in order to obtain the highest rates possible, immersion times of 5 seconds and less (corresponding to drum speeds of 4.8 rpm and up) must be used. The temperature and pressure differential tests also indicated that these should be kept at the maximum of 600°F and 100 psid respectively. As a result, all subsequent testing was done at immersion times equivalent to a minimum drum speed of 4.8 rpm, 600°F, and 70 and 100 psid. The reason for the continued use of 70 psid was for comparison purposes with previous data and ease of equipment operation.

The sets of Runs D27 through D35, D39 through D47, D51 through D57, D85 through D95, and D99 through D109 were made to determine the filtration rate and filter aid usage dependence on knife advance and immersion time (or equivalent drum speed) of a rotary drum filter at 40 percent submergence.

Drum speed may be calculated from submergence time. The following example is for 40 percent drum submergence.

$$\frac{10 \text{ seconds}}{\text{immersion}} \times \frac{\text{immersion}}{0.40 \text{ revolution}} = \frac{25 \text{ seconds}}{\text{revolution}}$$

which is:

$$\frac{1 \text{ revolution}}{25 \text{ seconds}} \times \frac{60 \text{ seconds}}{\text{minute}} = 2.4 \text{ rpm}$$

The results are shown in Figures 9-8 and 9-9. Several significant results of these experiments should be noted. First, as drum speed increases, filtration rate increases dramatically. At 12 rpm or 2 second immersions, the filtration rates were 600 pounds per hour per square foot and higher. In Figure 9-8, the downward curvature above 6 rpm is attributed to test equipment limitations. For example, the differential pressure of the test leaf during the immersion starts out low and increases rapidly to the desired differential pressure. For short immersions, the duration of this differential pressure change is a larger proportion of the immersion time.

A major conclusion which may be discussed further is that as the drum speed increases, the filtration rate increases dramatically, but unfortunately the filter aid consumption as shown in Figure 9-9 also increases significantly. At higher drum speeds, the total filter area required for a given filter throughput decreases at the expense of filter aid usage and shortened filter cycles. Filter aid consumption can be reduced by making smaller knife cuts per revolution, but at a reduction in filtration rate.

Knife advances of less than 2 mils per revolution on the test leaf may not be extremely reliable as indicated by the greater degree of scatter in the results at 1 mil per revolution. This should not be the case on a plant sized filter as operating conditions are much more stable. Also, it is possible to design knife assemblies that will advance at these low rates.

TFF data for 1, 2, and 4 mils per revolution knife advances have been plotted in Figure 9-9 to show the relationship between the ratio of filter aid consumption per 1000 pounds of filtrate (or the ratio of filter aid consumption per pound of ash) to drum speed. From the 2 mil per revolution knife advance curve, it may be observed that filter aid consumption ranges from:

•About 2.5 pounds per 1000 pounds filtrate at a filtration rate of slightly less than 150 pounds per hour per square foot (from Figure 9-8) to:

·About 5 pounds per 1000 pounds filtrate at a filtration rate of 600 pounds per hour per square foot (from Figure 9-8).

Thus, in this case rate increased four times while the filter aid consumption doubled. It is obvious that filter aid consumption is directly proportional to drum speed at a given knife advance rate per revolution for filter aid usage per unit of throughput to remain constant, therefore, the filtration rate increase must be directly proportional to increases in drum speed.

Figure 9-10 shows the relationship of drum speed to filtration rate for WFF. The rates obtained were comparable to those under similar conditions with TFF-216. The flat curves in Figure 9-11 exhibit that filter aid usage when filtering WFF material is nearly constant for each knife advance over a range of drum speeds; whereas, TFF has exhibited a much greater increase of filter aid consumption with increased drum speeds. These differences are due to the different filterabilities of the solid materials in the two liquids.

FIGURE 9-8

APPARENT FILTRATION RATE VERSUS DRUM SPEED

TFF 216, 600°F, 70 psid, AF5 Precoat, 40% Submergence

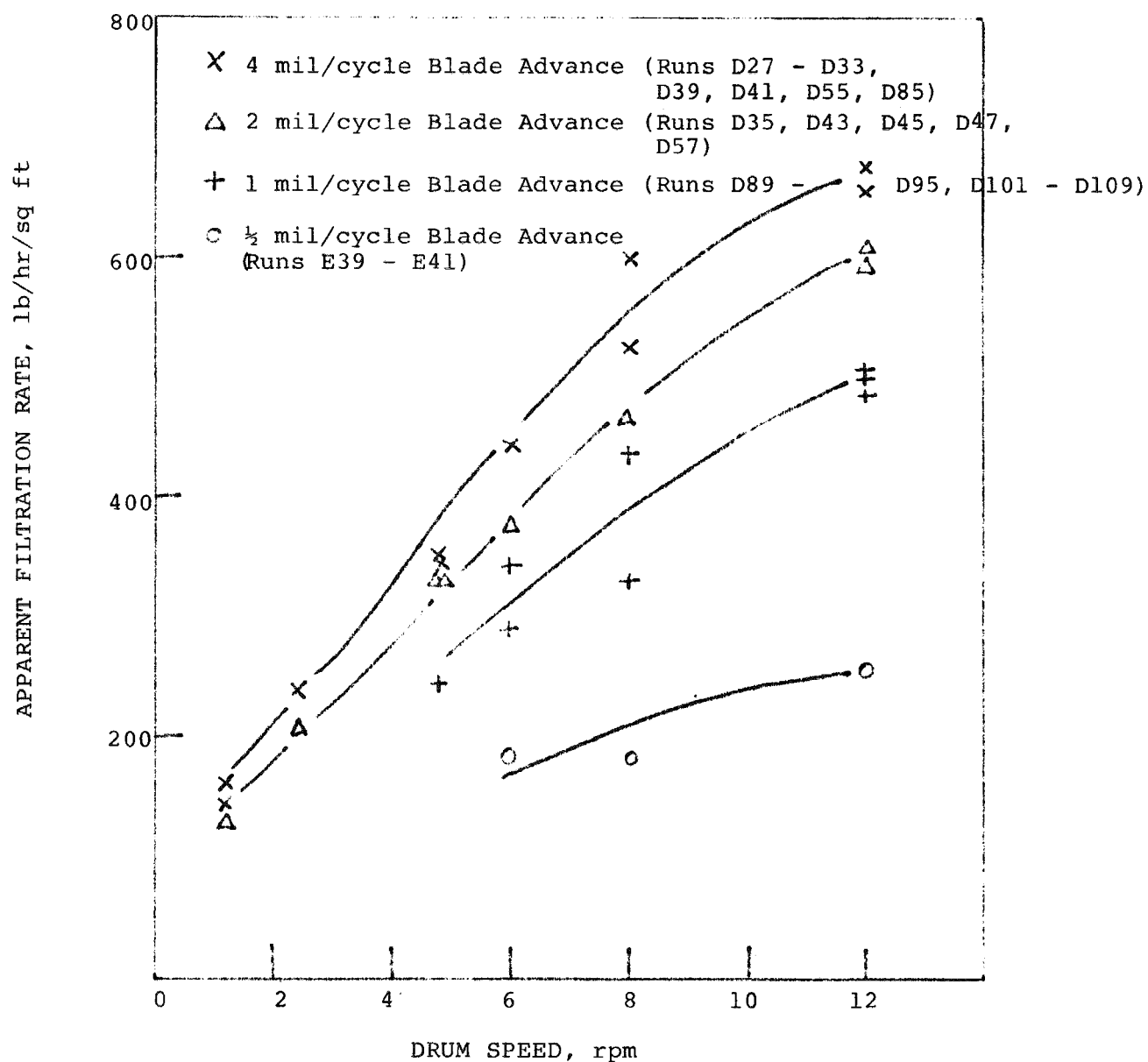


FIGURE 9-9

PRECOAT USAGE VERSUS DRUM SPEED

TFF 216, 600F, 70 psid, AF5 Precoat, 40% Submergence

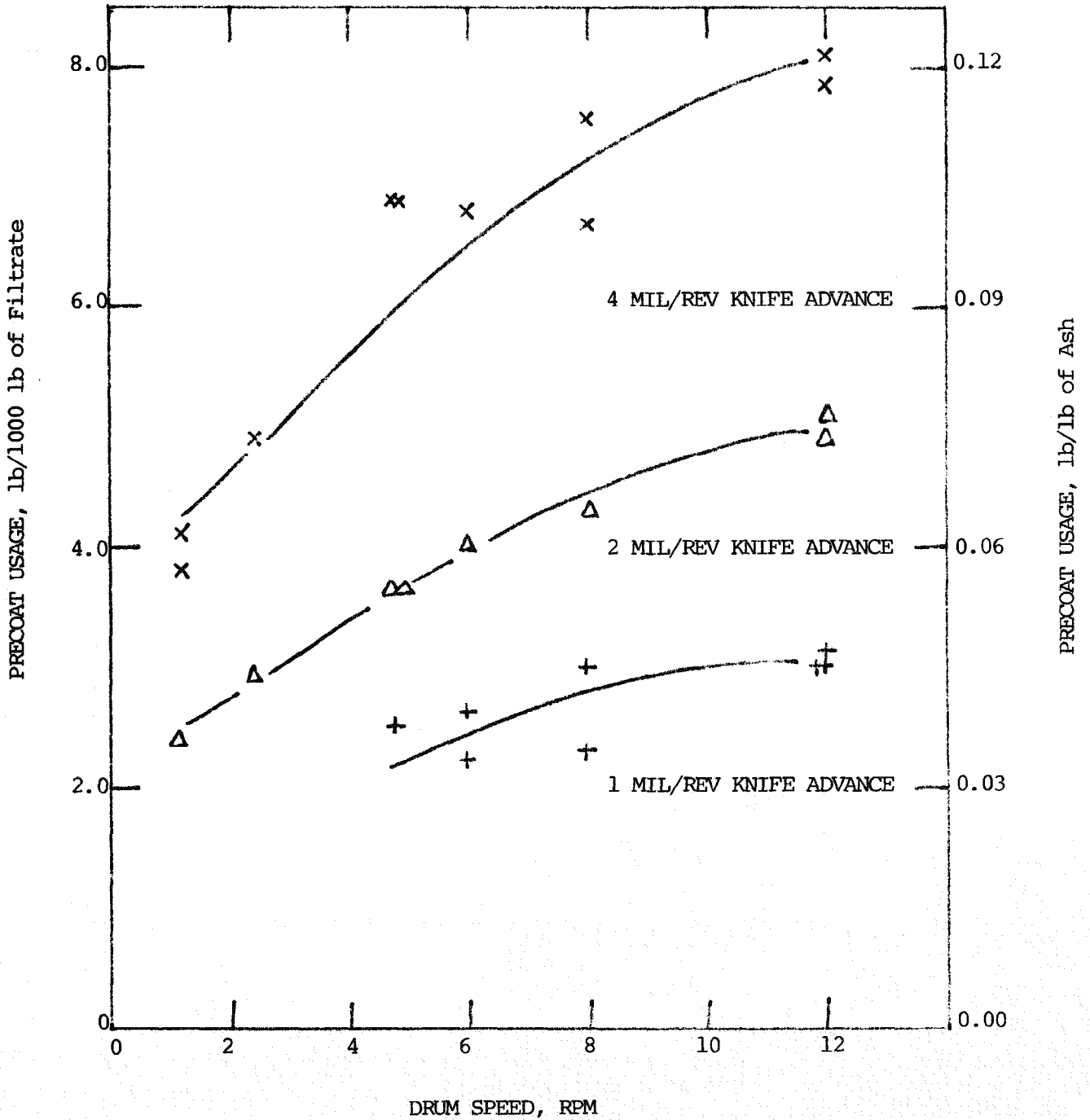


FIGURE 9-10

FILTRATION VERSUS DRUM SPEED
Wilsonville SN25260, 600F, 70 psid, AF5 Precoat, 40% Submergence

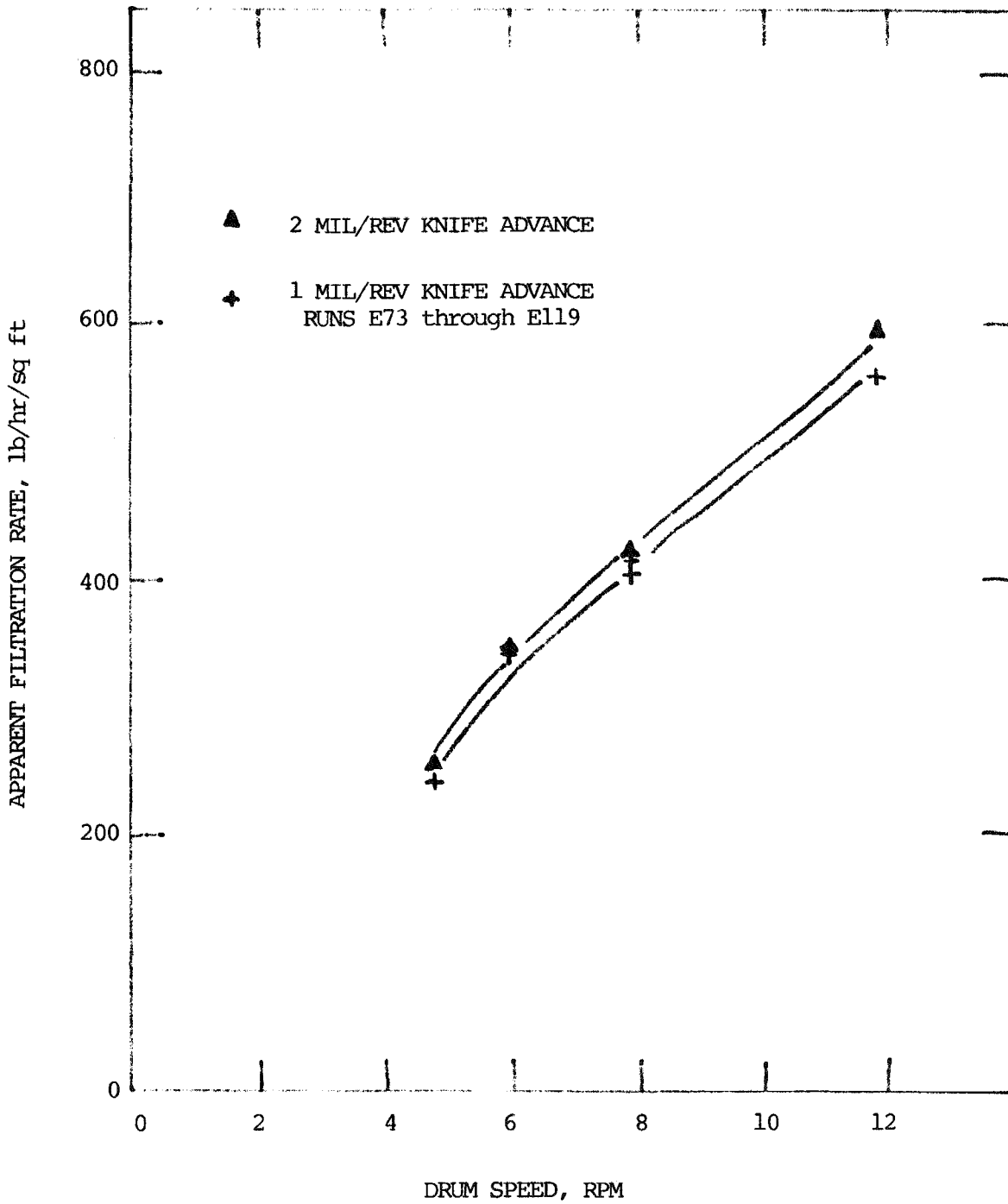
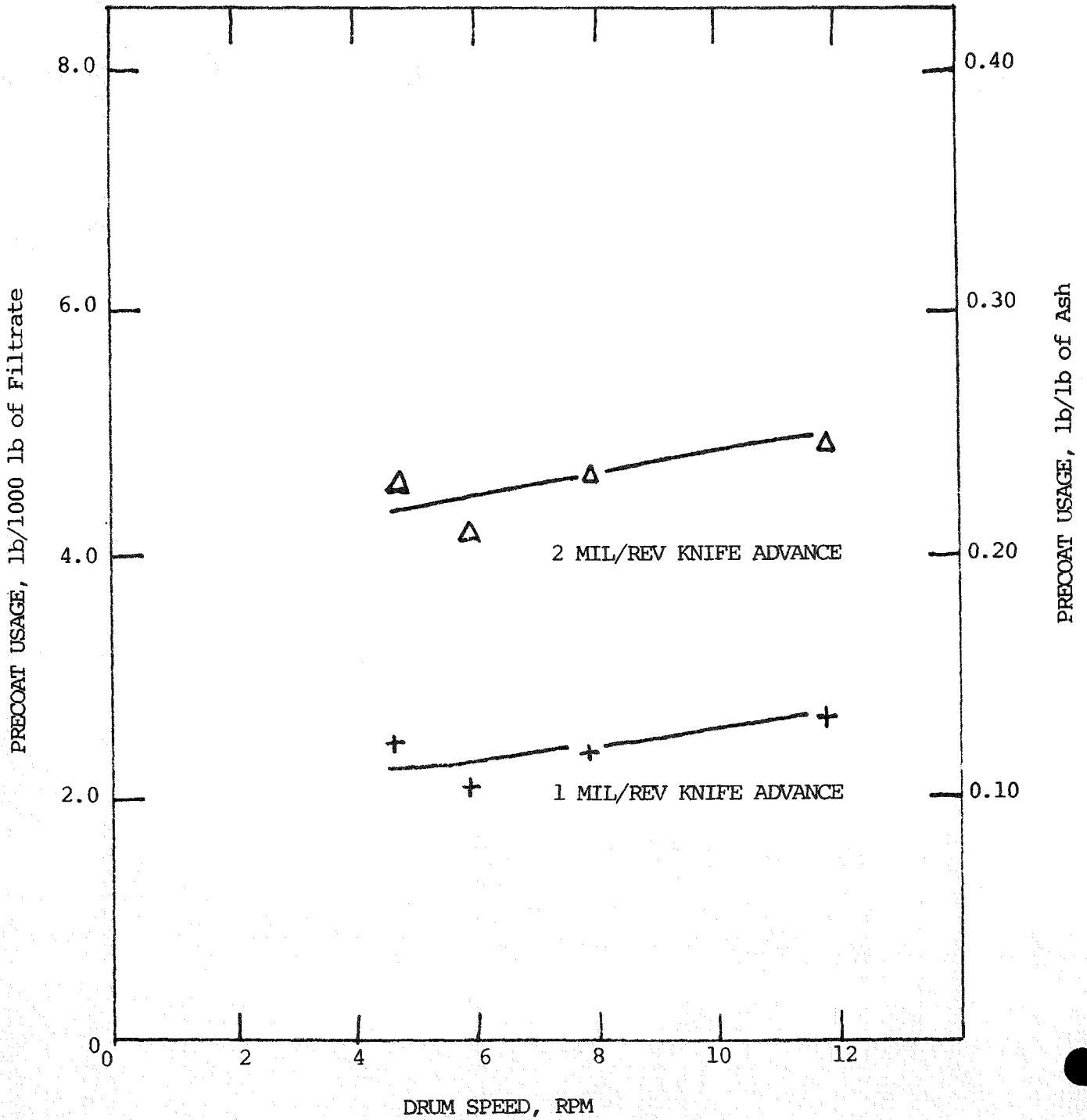


FIGURE 9-11

PRECOAT USAGE VERSUS DRUM SPEED
Wilsonville SN25260, 600F, 70 psid, AF5 Precoat, 40% Submergence



9.4 EFFECT OF KNIFE ADVANCE ON RATE & PRECOAT USAGE

As discussed in the section on the operation of the rotary vacuum precoat filter, the grade of precoat material can have a large effect on both filtration rate and precoat consumption. Note Figures 9-2 and 9-5 which were run under the same conditions except for knife advance rates which were 10 to 2 mils per revolution respectively. The shapes of the curves (see Section 8.2 for a more detailed discussion) are similar for both graphs, but those run at 2 mils per revolution knife advance were all displaced downward showing the lower rates resulting from the lower knife advance rate. This lower advance rate aggravated the problems of solids penetration into the precoat and quality of cake cutting further reducing flow rates.

Run D23 was a knife advance study at 100 psid, 600°F, and 5 second immersions. The results are shown in Figure 9-3 along with previously reported results at the same conditions for 35 psid and 70 psid. The rate versus knife advance results show the greatest degree of solids penetration and resultant partial precoat blinding between 2 and 4 mils per revolution knife advance.

The precoat usage for the results shown in Figure 9-3 is plotted in Figure 9-4. The lowest precoat usage (and lowest rates) were obtained was at the smallest knife cuts.

The sets of Runs D27 through D35, D39 through D47, D51 through D57, D85 through D95, and D99 through D109 (referred to in Section 9.3 Figure 9-8) were run to show rates versus drum speed at different levels of knife advance ranging from 1/2 mil per revolution to 4 mils per revolution. The curves show increased filtration rates for all knife advance rates, the greatest increase being between 1/2 and 1 mil per revolution.

The curves (with the exception of the 1/2 mil per revolution curve) are replotted in Figure 9-9 to show precoat usage. Note at the 12 rpm drum speed, the large reduction in precoat usage upon going from 4 mil to 2 mil to 1 mil per revolution knife advance with much smaller reductions in filtration rates. For instance at 12 rpm, filter aid usage is reduced from about 0.12 percent to 0.075 percent percent for a loss in filtration rate from 700 to 600 lb/hr/sq ft (Figure 9-8) Run D71 indicated 2.4 pounds of filter aid per 1000 pounds of filtrate, a reduction of 44 percent from the 4.3 pounds per 1000 pounds of filtrate calculated for Run D69 at the same conditions, with only a 9 percent reduction in filtration rate from 138 to 126 pounds per hour per square foot at 1 rpm drum speed. These low rates are typical for long submergence times of 20 seconds.

Similar curves to those in Figures 9-8 and 9-9 were developed for WFF material, Sample SN25260 (Figures 9-10 and 9-11).

The WFF material differed from TFF material in that rates (at 70 psid and 600°F) for 1 mil per revolution knife advance were about the same both for 1 and 2 mils per revolution knife advance (see Figure 9-10). This indicates that the solid particles which penetrate and tend to blind the CELITE AF5 precoat are sufficiently large to be removed by a knife advance of 1 mil per revolution. The improved filterability of the solids in the WFF material also resulted in a filtration rate increase almost directly proportional to drum speed.

The flat curves in Figure 9-11 show that filter aid usage when filtering WFF material is nearly constant for each blade advance over a wide range of drum speeds; whereas, the TFF material has exhibited a much greater increase of filter aid consumption with increased drum speeds. This, of course, is the result of the large increase in rate with drum speed mentioned above.

Additional filtration rates versus drum speed for TFF are tabulated below for 1 mil per revolution blade advance and CELITE AF5 precoat.

<u>DRUM SPEED</u> (rpm)	<u>FILTRATION RATE</u> (lbs/hr/sq ft)		
	<u>JUNE 1977</u>	<u>AUGUST 1977</u>	<u>AVERAGE</u>
8	466 (E53)	414 (E135)	440
6	358 (E55)	346 (E137)	352
4.8	293 (E67)	284 (E139)	289

Such a comparison also serves to prove the accuracy and reproducibility of the data being collected.

9.5 EFFECT OF PRECOAT GRADES ON RATE

Figure 9-12 shows curves of rate versus knife advance for TFF indicating that most of the cutting problems shown in Figure 9-5 have been overcome. These curves are particularly interesting for several reasons. First, they indicate quite consistent data. Second, nearly equal rates are shown for two precoat materials with different permeabilities (CELITE AF6 has a permeability approximately 65 percent of CELITE AF7) at the same submergence times. Submergence time (drum speed), therefore, has a much greater influence on rate than the different properties of the two precoat grades.

Figure 9-13 and Table 9-2 show the effects of knife advance on filtration rate with TFF using precoat materials of different pore sizes and permeabilities. The curves show the effects on filtration rate of solids penetration into the precoat. Maximum rates were obtained with all filter aids at a knife advance rate of approximately 10 mils. The rate dropped off at once for all advance rates under 10 mils for the most permeable of the precoat materials, CELITE AF7. The rate for the finest of the precoat grades held up pretty well until the knife advance rate dropped below 4 mils per revolution. Obviously, the lower the knife advance rate that will permit high filtration rates the lower the amount of precoat material consumed.

FIGURE 9-12

APPARENT FILTRATION RATE VERSUS KNIFE ADVANCE
TFF 216, 600F, 35 psid

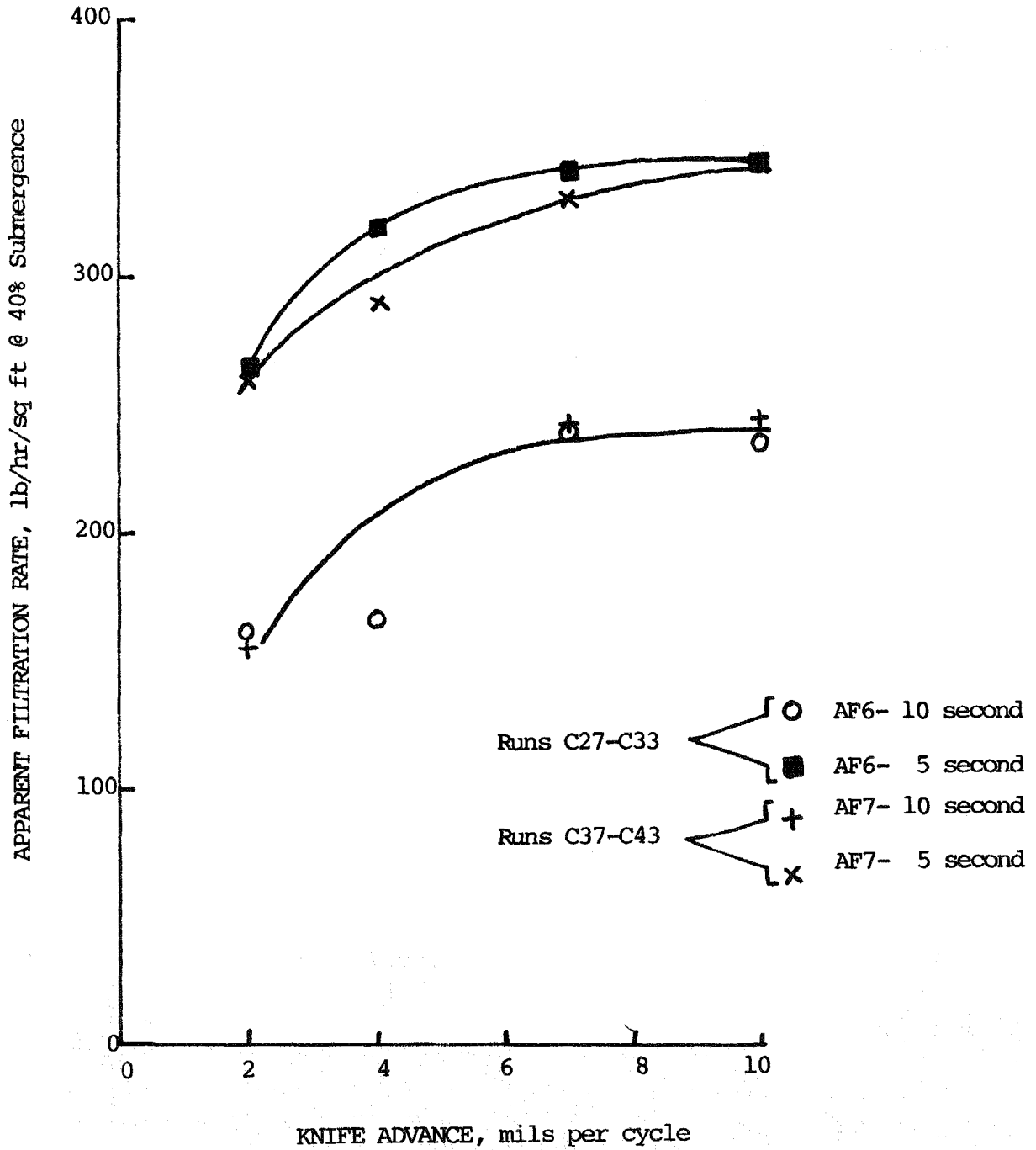


FIGURE 9-13

APPARENT FILTRATION RATE VERSUS KNIFE ADVANCE
TFF 216, 600F, 35 psid

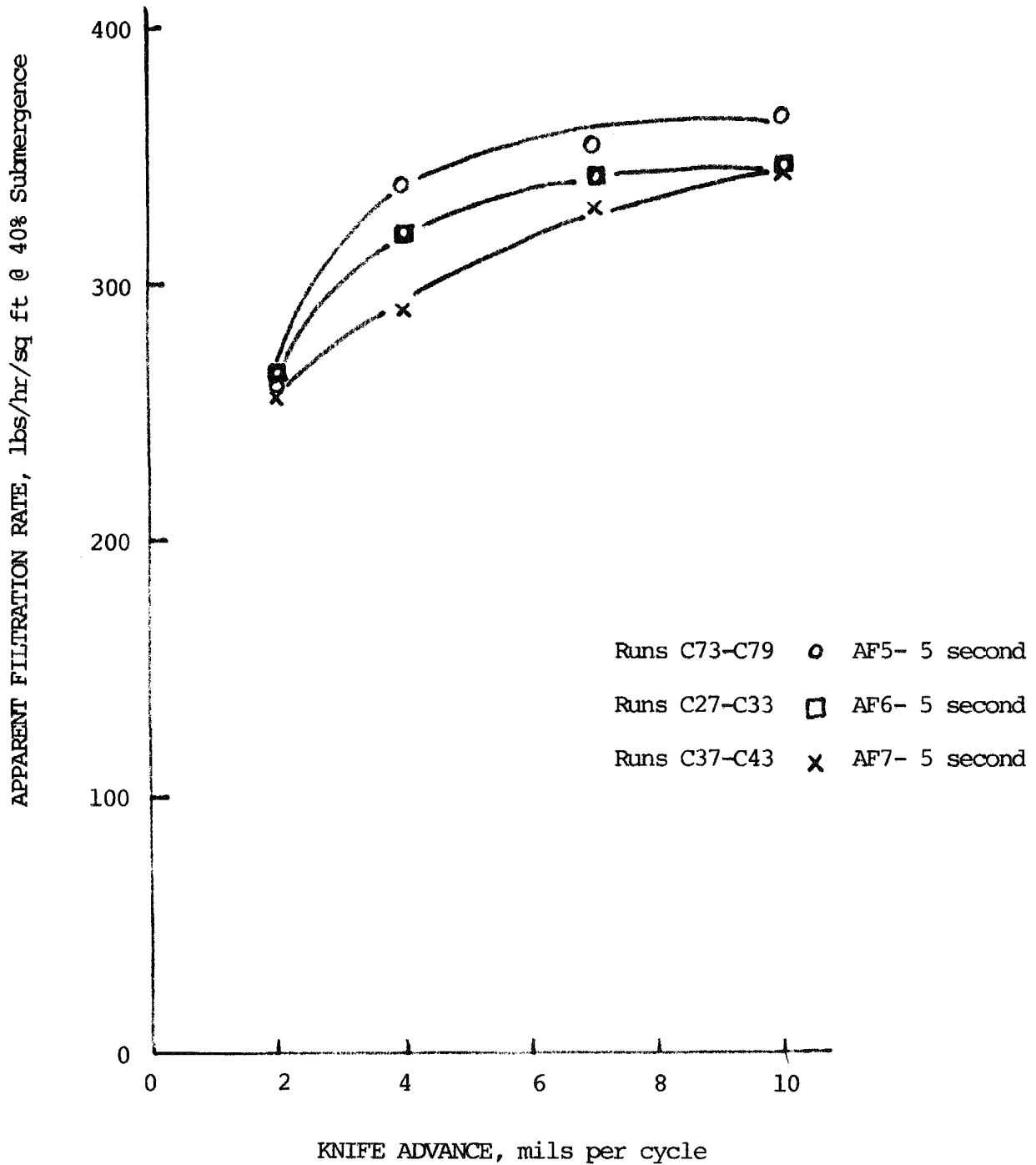
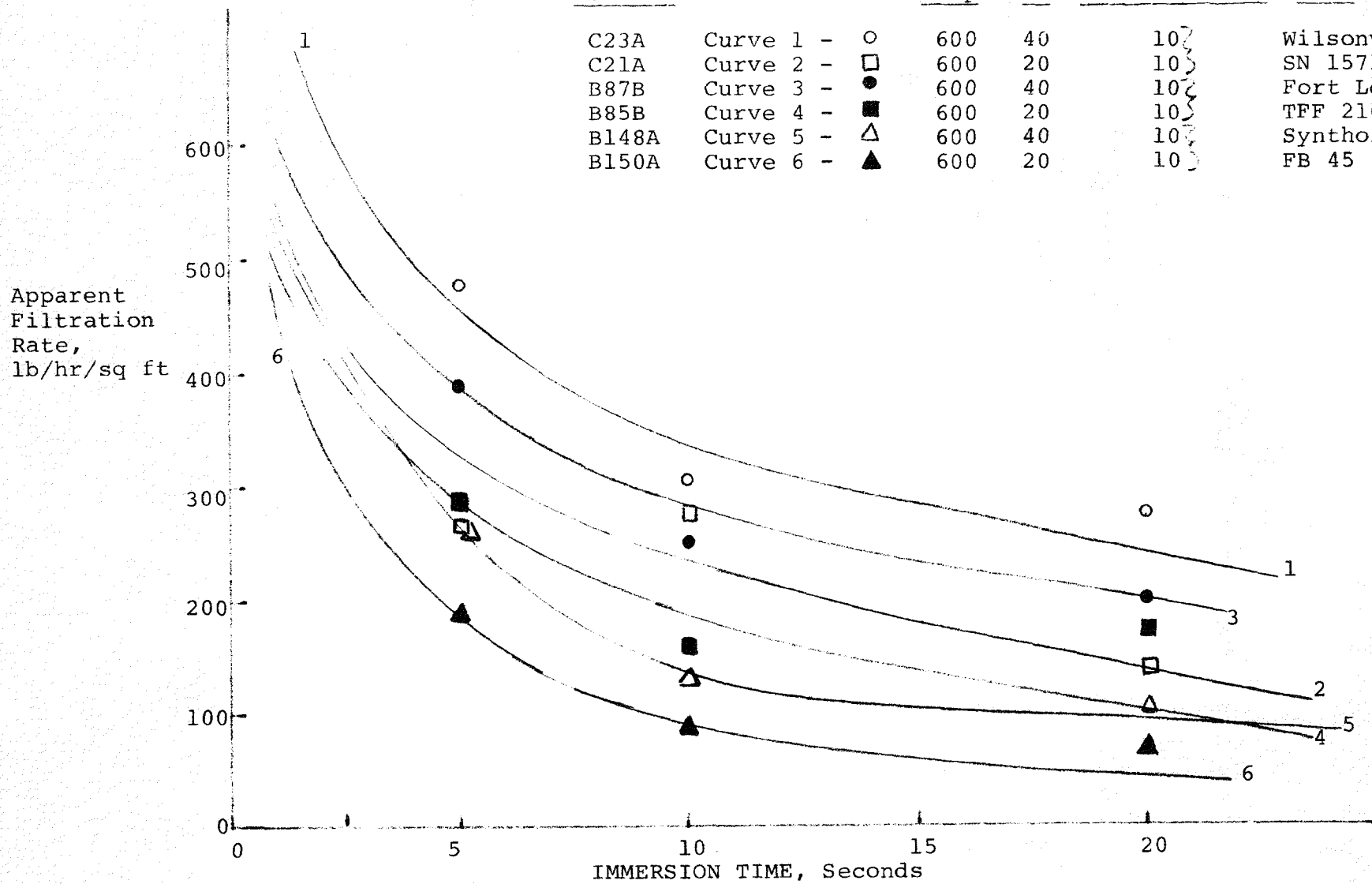


FIGURE 9-2
 ΔP DEPENDENCE

Run No.		Temp	ΔP	Knife Advance	Feed
C23A	Curve 1 - ○	600	40	10	Wilsonville
C21A	Curve 2 - □	600	20	10	SN 15719
B87B	Curve 3 - ●	600	40	10	Fort Lewis
B85B	Curve 4 - ■	600	20	10	TFF 216
B148A	Curve 5 - △	600	40	10	Synthoil
B150A	Curve 6 - ▲	600	20	10	FB 45



9.6 EFFECT OF FILTER FEED MATERIALS ON RATE & PRECOAT USAGE

While most of the tests were run on TFF samples in preparation for starting up a 50 square foot pilot filter at Tacoma, tests were also run on two samples of filter feed from Wilsonville and one Synthoil sample.

Data from the first comparative tests are shown in Figures 9-1, 9-2, 9-5, and 9-14. The origin of Figure 9-14 is the experimental design cube shown in Section 4, Figure 4-1. As this data may be considered as a summary of that in the other figures, it will be used as a basis for this discussion. Each of the through feed materials was run at 5, 10, and 20 seconds immersion times, temperatures of 400, 500 and 600°F and knife advance rates of 2, 5, and 10 mils per revolution, with the exceptions of synthoil feed which was run at only two different temperatures, pressures and knife advance rates. Judging from the shapes of the curves, the most reasonable data was that obtained at 600°F, 40 psid and 10 mils per revolution knife advance (curves 1, 4, and 7). This, again, we believe, is due to the better knife cuts obtained under the more extreme operating conditions. Decreasing filtration rates, however, are shown for WFF, TFF, and synthoil filter feeds under all conditions.

Curves 3 and 6 (WFF and TFF) were run at the mildest conditions of temperature, differential pressure, and knife advance (400°F, 20

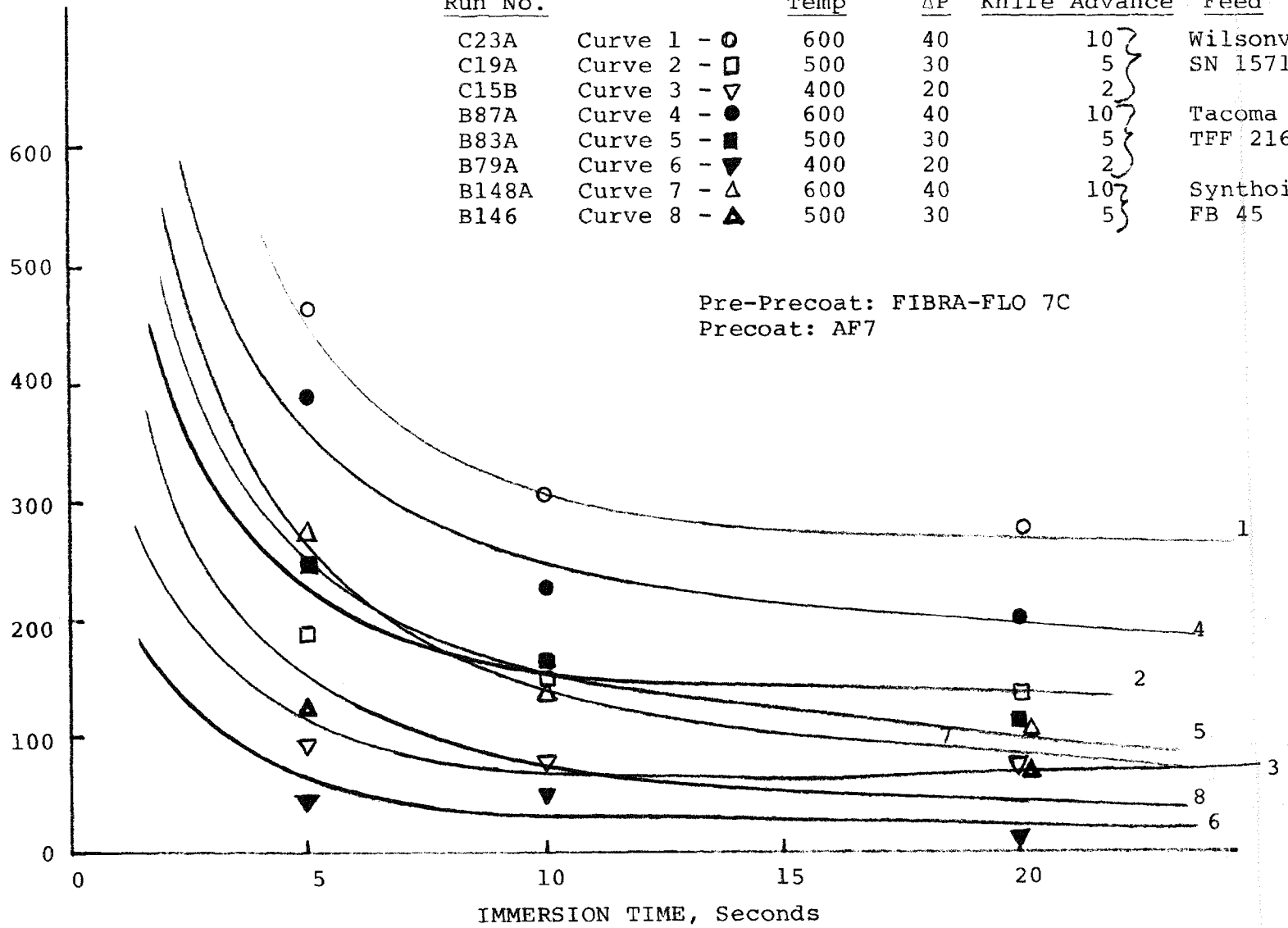
psi, and 2 mils per revolution) and show the least increase in rate with decreasing immersion times as well as some reversals of rate.

At high immersion times (20 seconds) and medium to low knife advance rates, rates for all materials run at medium or mild conditions tend to come together (Curves 2, 3, 5, 6, 8). This shows the effect of poor cake cutting at lower differential pressures and to a lesser extent at lower knife advance rates. In addition, the resistance of the filter cake plays a greater role in flow rate toward the end of an immersion than at the start of an immersion.

Differences between the TFF sample and the WFF sample show up strongly in Figures 9-8, 9-9, 9-10, and 9-11. In these figures, the WFF material flow rate increases more rapidly with increased drum speed than the TFF material. This results in a much lower increase in precoat consumption for the former material. In addition, the change in filtration rates at 1 and 2 mils per revolution blade advance is much less for the WFF material indicating much lower penetration of coal solids into the precoat.

FIGURE 9-14
CUBE DIAGONAL DEPENDENCE

Run No.	Temp	ΔP	Knife Advance	Feed
C23A	600	40	10	Wilsonville
C19A	500	30	5	SN 15719
C15B	400	20	2	
B87A	600	40	10	Tacoma
B83A	500	30	5	TFF 216
B79A	400	20	2	
B148A	600	40	10	Synthoil
B146	500	30	5	FB 45



9-35

9.7 PRECOAT COMPRESSION

Runs C129 through C137 were intended to validate results of an earlier differential pressure study. The results of these runs indicated several things. The rotary test leaf precoat experienced significant compression during the first few immersions at high differential pressures. There appears to have been no knife cutting of the precoat for about 0.170-inch of blade advance as indicated by the low rates of Runs C129 and C131. In Runs C133 through C137, the rates approached those reported previously for these conditions.

This initial precoat compression during the first immersions of a series of runs would occur to a greatly reduced degree on a filter which is precoated at operating differential pressures. The capability to precoat the test leaf at operating differential pressures was developed as one phase of the program and is discussed in Sections 7 and 10 and Appendix VI.

A second result noted during these five runs was an unusually high ash content in the filtrate. Ash contents as high as 0.29 percent were found indicating unusual operating conditions. An ash content five to ten times those normally found can be explained only by a large scale disturbance of a precoat. Apparently, the malfunctioning pressure regulator, which resulted in a subsequent dropped precoat, caused some rapidly fluctuating pressures in the test equipment which were sufficient to disrupt the precoat, but not

to drop the precoat from the test leaf support. Therefore, the results of Runs C129 through C137 are not considered valid, but do show the magnitude of the precoat compression which has been observed at higher initial differential pressures.

9.8 POST RUN EXAMINATIONS

Examinations of the filter leaf and remaining precoat were performed after each series of runs. Post run measurements indicated precoat densities of 25 to 27 pounds per cubic foot. The precoats were compressed during the runs from 20 to 24 pounds per cubic foot densities as initially precoated before the runs. The filtered solids which built up on the sidewall of the precoat attained a thickness of about 1/8-inch, three to four times as thick as the filter cake solids. These sidewall solids built up rapidly during the first few immersions. Thus, the filtration rate through the sidewall should have been very small during subsequent immersions.

Section 10

OPERATION WITH PRECOATS APPLIED AT HIGH TEMPERATURES & PRESSURES

10.1 INTRODUCTION

All filtration data described previously have been obtained with precoats applied under vacuum. As temperature and pressure are brought up to operating ranges some additional compaction of the precoat undoubtedly takes place. To the extent that compaction takes place, properties of the precoat may be changed.

In plant operation, it is anticipated that the precoat will be applied at temperatures of 300 to 400°F and differential pressures up to 60 psid. A precoat formed under these conditions should be more compact and less subject to expansion and compression as it revolves through the filtering, drying, and cutting cycles in the filter. Also, because the precoat is laid down at greater differential pressures, it is expected that the size of the openings in the precoat will be somewhat reduced. Both the above factors should result in improved cake cutting characteristics and reduced penetration of solids into the precoat with resultant reduction in knife advance rates and improved filter aid economy at little or no sacrifice in filtration rate. At the higher temperatures, it is also

possible that it will not be necessary to use an anti-flocculant filter aid, thus reducing filter aid costs. For these reasons, an in-situ precoating method was developed. The equipment development is described in Section 7.

10.2 FILTRATION RESULTS

The modification of the test leaf to permit in-situ precoating resulted in numerous mechanical and operational problems. As a result, very little data were obtained, most of the time having been taken up with solving problems. By the end of the program, however, solutions were found to practically all the problems. Details of test run problems and solutions are contained in Appendix VI. Filtration results, problems, and solutions will be outlined in this section. A description of the in-situ precoating and filtering operation is described in Section 7.6.

A summary of the data that were obtained is shown in Tables 10-1 and 10-2 for sample TFF-216 at 70 psid differential pressure and 600°F. Differences in rates for the two precoat application methods were not consistent. For instance, at 4 mils per revolution knife advance and 4 seconds immersion, the rates for vacuum and pressure applied precoat were 295 and 424 pounds per hour per square foot respectively. At 2 mils per revolution, the rates were 303 and

374 pounds per hour per square foot but decreased from 506 to 446 pounds per hour per square foot at 3 seconds immersion times.

Table 10-2 shows wide rate inconsistencies due to mechanical and operational problems. This data indicates that the inconsistencies in Table 10-1 lie with the pressure applied precoat.

TABLE 10-1

RUN NUMBER	WEEK OF	PRECOAT APPLICATION METHOD	BLADE ADVANCE (Mils/rev)	FILTRATION RATE (pounds/hour/square foot)	
				3 SECONDS IMMERSION (8 rpm)	4SECONDS IMMERSION (6 rpm)
E-45	6-13-77	Vacuum	4		295
E-47	6-13-77	Vacuum	2		303
E-49	6-13-77	Vacuum	2	506	
E-53	6-13-77	Vacuum	1	466	
E-55	6-13-77	Vacuum	1		358
E-63	6-20-77	Vacuum	2		369
E-135	8--1-77	Vacuum	1	414	
E-137	8--1-77	Vacuum	1		346
F-34	1--9-78	Pressure	4		424
F-36	1--9-78	Pressure	2		374
F-54	1-30-78	Pressure	2	446	

10-4

TABLE 10-2

RUN NO.	KNIFE ADVANCE mils/dip	FILTRATION RATE lbs/sq.ft/hr average
F99	1	343
F105	1	780
F117	1	370
F97	2	1093
F101	2	547
F101	2	1066
F103	2	515
F115	2	388
F119	4	382

10.3 MECHANICAL & OPERATIONAL PROBLEMS

The poor filtration results have been due primarily to two causes, both related to the application of the precoat and precoat leaf.

The first of the causes is primarily mechanical in nature and resulted in cracks forming in the precoat with occasional partial loss of precoat. After observing a number of precoats in which the cracks all had the same pattern, it was evident they were due at least in large part to a loose screen on the leaf. Therefore, a new leaf was constructed. Precoats formed on the new leaf showed much less cracking.

An aluminum foil lip or baffle applied to the inner rim of the new leaf appeared to give improved ash removal by reducing bypassing of unfiltered material.

During one month, there were repeated failures of the rupture disc on the main pressure vessel. These were remedied by a change from a Monel to an Inconel rupture disc and addition of a disc vacuum support.

The second problem area was evidenced by holes 1/8-inch to 1/2-inch appearing in the precoat and basecoat primarily during filtration, but on occasion during precoating. It was hypothesized

that these holes were caused by flashing of the precoat solvent. A number of tests were made to explore this hypothesis.

- A precoat applied entirely under vacuum using a toluene/xylene mixture showed no holes.
- Precoating with pentane resulted in a precoat with holes. The pentane boiling point was such that it would flash under precoating conditions indicating that flashing was a cause of the holes.
- Light ends of the precoat solvent were allowed to flash off by holding the solvent at 345°F and atmospheric pressure. The precoat formed from this solvent, while partially lost as a result of operational procedures, showed no holes. The basecoat did, however, show some holes possibly as a result of flashing of the basecoat toluene/xylene solvent during heating up to precoat temperature of approximately 300°F.
- A precoat applied with process solvent from which solids had been removed, using a Buchner Funnel, under vacuum showed no holes.

Apparently, the use of vacuum for filtering caused a loss of some of the light ends resulting in less flashing of solvent during precoating. This explanation is consistent with the previous three experiments. (An additional test to confirm this explanation whereby the solvent was merely exposed to a vacuum without filtering proved positive.) Increasing the back pressure during precoating would also very likely reduce hole formation.

An additional area of investigation concerning the optimum grade of basecoat material has resulted from the precoat formation problems discovered above. At those times where because of precoat cracking or hole formation the coal solids reached the basecoat, it was noted that a significant amount of solids were able to partially pass through the basecoat. This has been evidenced by the high ash contents of those filtrate samples where precoat problems existed and by post run observation of the precoat.

The basecoat, in the projected operation of the pilot filter at Fort Lewis, serves both to reduce overall precoat resistance as well as to permit reprecating over a basecoat heel. The basecoat should also, however, be fine enough to prevent coal solids which have gotten past the precoat from reaching the filter screen and blinding it or passing through the screen and contaminating the filtrate. The CELITE AF13 pre-precoat was shown in Buchner Funnel tests to allow substantial quantities of coal solids to pass through it (Appendix VI). As a result, a change was made to CELITE AF9 both on the test leaf and at Fort Lewis with successful results.

Section 11

CONFIRMATION OF LEAF TESTS USING FRESH SAMPLES

11.1 INTRODUCTION

The series of Runs C62 through C70 (Appendix I) reported in Table 1 cover the filtration tests performed on a sample of TFF (8 to 10 gallons) obtained fresh at Tacoma on December 13, 1976 (1100 MST) and immediately shipped to Denver. This sample was obtained at 245°F and was not allowed to cool below 200°F. Discussions with Tacoma personnel indicated that the sample should not be allowed to cool below 150°F nor should it be held at temperatures near 600°F. Apparently, the SRC and solvent mixture undergoes some chemical-physical changes when held at elevated temperatures.

The rotary pressure precoat filter in Denver was precoated with CELITE AF7 and preheated before charging with the sample which has been designated "Hot TFF December 13, 1976". The sample was agitated before charging the filter by rolling the sample container for 1/2 hour. The first run (Run C62) was performed on December 14, 1976 at 1400 MST. The filtration rates for all runs are shown in Table 1 and Figures 11-1 and 11-2. Figure 11-1 shows the apparent filtration rates plotted versus the number of immersions of the filter leaf.

Run C62 was intended to simulate the average operating conditions of the filter at Tacoma (450 to 500°F, 150 psig, 30 psid differential pressure, 2 mils per revolution knife advance, 12 second immersion time or 1.75 rpm, and 36 percent submergence). The filtration rates obtained in Run C62 were calculated to be approximately one-third the apparent rates reported at Tacoma. (Refer to comments below on precoat filter aid density.)

Run C64 was performed at nearly the same filtration conditions, but with 7 mil per revolution knife advance. The filtration rates were approximately the same as the apparent rates reported at Tacoma. There is apparently a significant amount fine solids penetration into the precoat.

Runs C66 and C68 were conducted to compare the filtration of "Hot TFF" with TFF as obtained previously. The results of a knife advance study are presented in Figure 11-2 where they are compared with the knife advance results shown in Figure 9-12 for CELITE AF7-5 seconds. The filtration rates were more dependent upon knife advance than previous tests with TFF-216, indicating a finer particle size and more significant penetration of the fine solids into the precoat.

Runs C93 through C101 and C105 through C113 were performed using the two companion samples obtained at the same time as the fresh Hot TFF on December 13, 1976. The filtration rate data are shown in Figures 11-2, 11-3, and 11-4.

Figure 11-3 shows the results of filtration of the sample which was not allowed to cool below 150°F for one month and will be referred to as "Old Hot TFF 12/13/76". Figure 11-4 shows the results of filtration of the sample which was allowed to cool and was treated as were previous samples of TFF. This sample is referred to as "Cold TFF 12/13/76". Figure 11-2 shows the results of a blade advance series for all three samples. All three samples were tested at five different conditions. Runs C62, C105, and C93 approximated the conditions of normal filter operation at Fort Lewis (450°F, 30 psid, 2 mil per cycle, 12 second immersion or 1.75 rpm, and 36 percent submergence). All three samples filtered at approximately one-third the average rate reported at Fort Lewis. Runs C64, C107, and C95 were at the same conditions, but with 7 mil per cycle blade advance. Filtration rates were then all about equivalent to the rates reported at Fort Lewis.

We hypothesize that the reason for the higher rates at Fort Lewis at the lower blade advance rates is due to a reduction in filter aid particle size resulting from their precoat slurry handling system. This particle size reduction results in less penetration of coal solids into the precoat, thus giving the higher rates at the lower knife advances.

The other three runs were a knife advance series performed at conditions at which previous samples of TFF have been tested (600°F, 35 psid, 5 second immersions or 4.8 rpm, and 40 percent

submergence). Recall that the fresh hot sample, Figures 11-1 and 11-2, was characterized as subject to fine solids penetration. The evidence of fine solids penetration is most obvious in Figures 1-2. The two other samples are characterized by filtration rates reduced after a number of cycles due to fine solids penetration into the precoat even at 7 mils per revolution knife advance. These results are most obvious in Figures 11-3 and 11-4. Recalling the comments made earlier concerning fine solids penetration into precoats of CELITE AF5, the filtration characteristics of these three samples using the coarser CELITE AF7 precoat are not at all surprising.

The series of Runs D3 through D11 was intended to duplicate the conditions of the confirmation tests reported above, but with CELITE AF5 rather than CELITE AF7 as the precoat material. The rates found in Runs D3 and D5 were the same as the rates found in previous runs at the processing conditions, indicating that either fine solids penetration is still suppressing the rate at 2 mils per revolution knife advance or the initial precoat compression discussed above is a problem area to be considered even at 30 psid differential pressure.

FIGURE 11-1

TACOMA FILTER FEED - HOT SAMPLE 12/13/76 AF7 PRECOAT

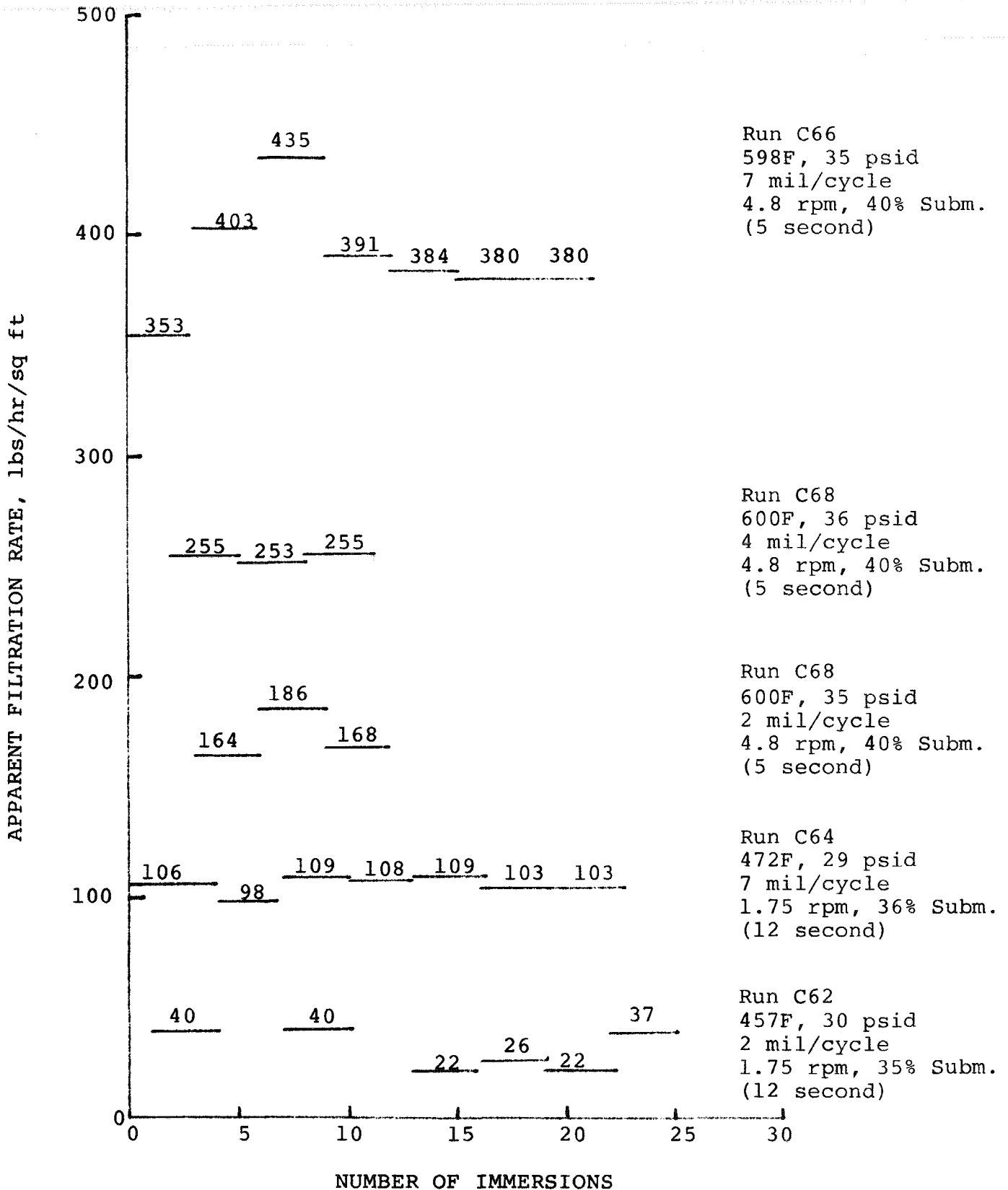


FIGURE 11-2

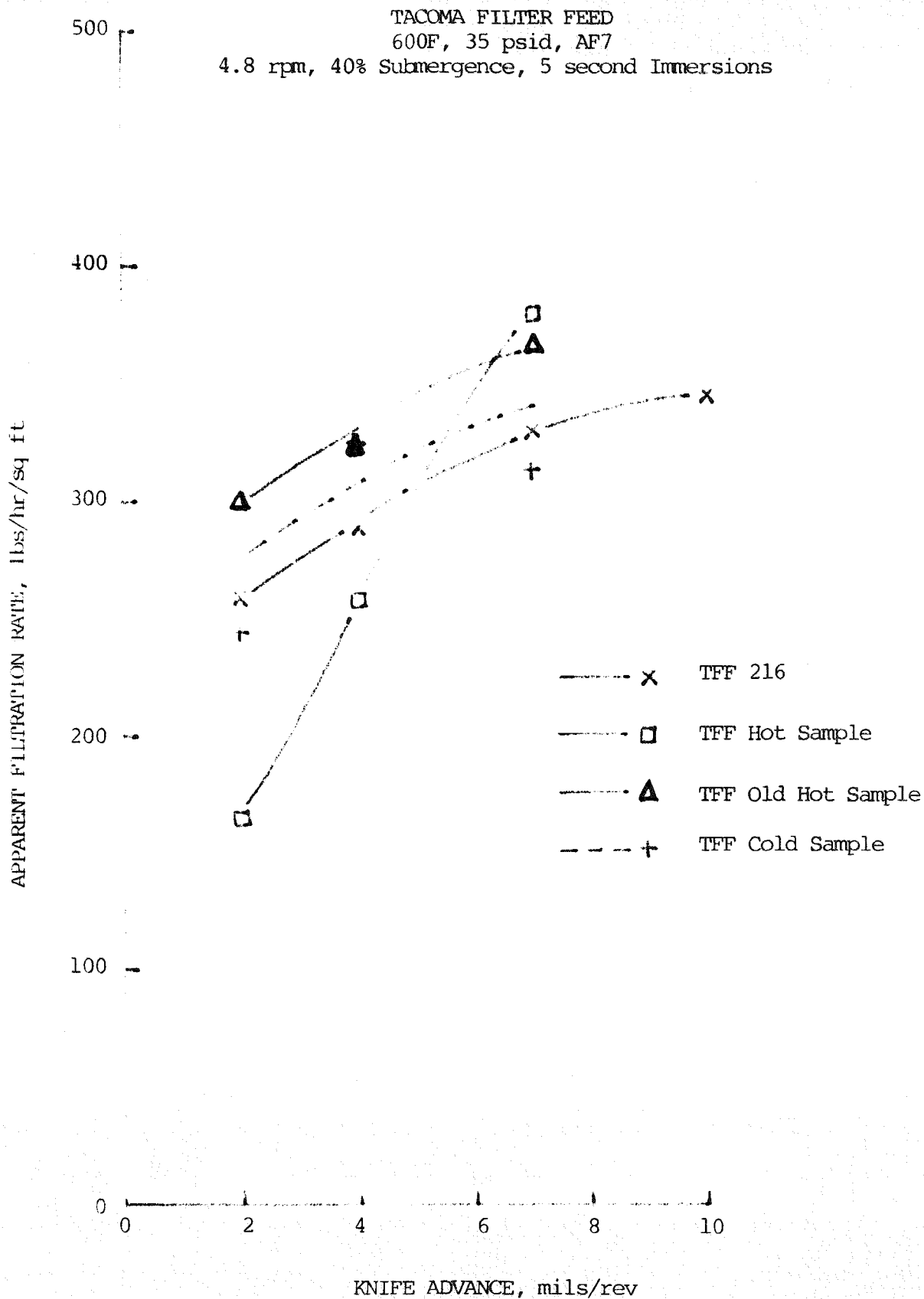
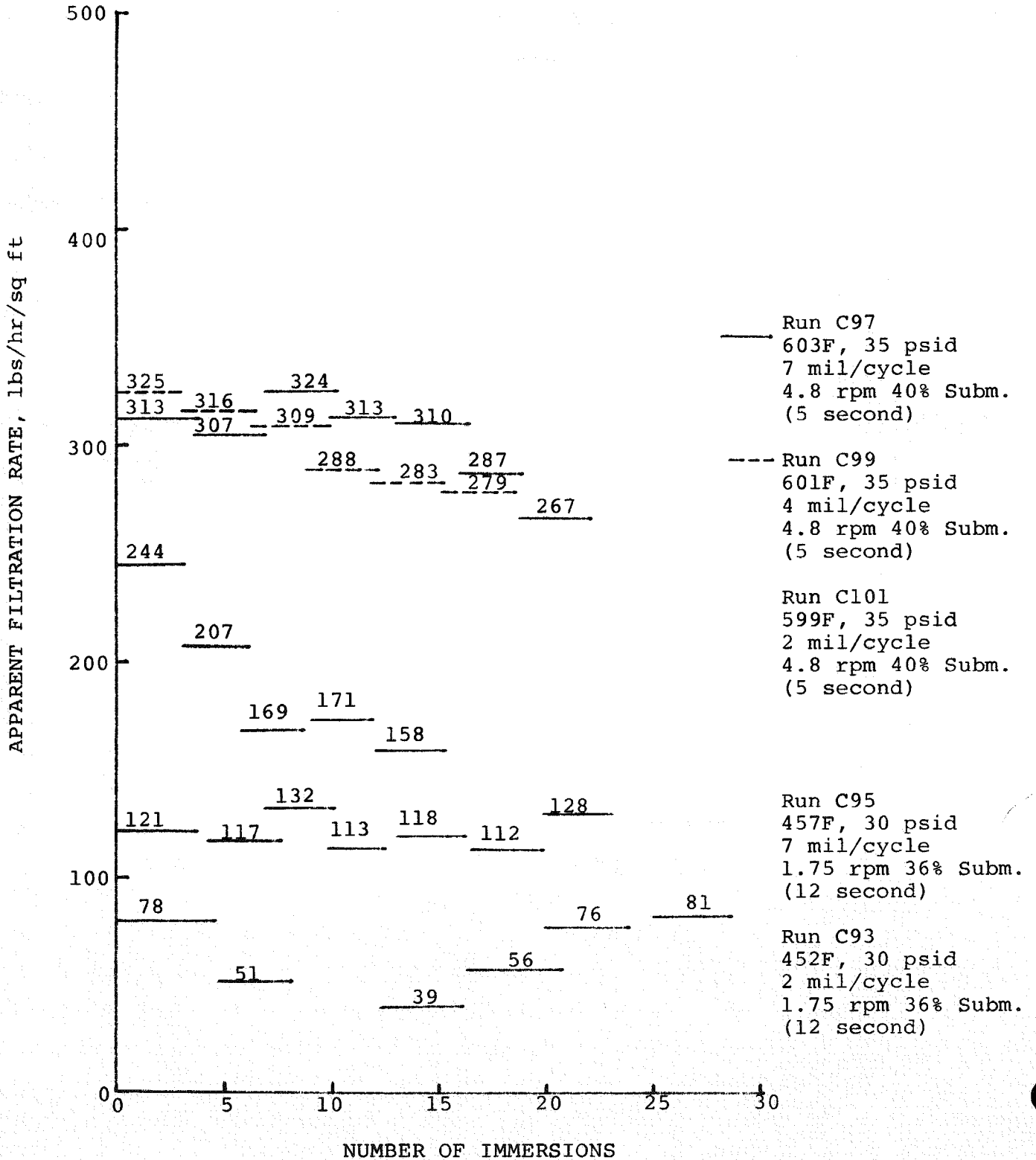


FIGURE 11-4

TACOMA FILTER FEED
Cold TFF 12/13/76, AF7 Precoat



11.2 PRECOAT FILTER AID DENSITY AT FORT LEWIS

Current practice at the Pittsburgh & Midway Coal Mining Company, Fort Lewis, Washington is to precoat the 40 square foot and 80 square foot rotary pressure precoat filters using 500 and 1000 pounds precoat filter aid respectively to build up 4-inch precoats. The volume of these precoats based on area and thickness is approximately 13 cubic feet and 26 cubic feet. The additional precoat that builds out from the edge of the filter might add another 3 to 4 cubic feet per filter to the above precoat volumes giving total volumes of 17 to 30 cubic feet for the two filters. Densities of diatomite filter aid precoats are typically 20 to 24 pounds per cubic foot of precoat. Densities of precoats on the rotary pressure precoat test leaf at Johns-Manville range from 23 to 25 pounds per cubic foot. Assuming a precoat density of 23 pounds per cubic foot and an additional 4 cubic feet of precoat at the edge of the filter drum giving respective precoat volumes of 17 and 30 cubic feet, precoat requirements are only 390 and 690 pounds for each of the two filters. These amounts are substantially below the amounts actually being used. Actual precoat densities, assuming all precoat gets onto the filter drums, would be 29 and 33 pounds for the 40 and 80 square foot filters.

These higher densities could be caused by the Fort Lewis procedure of bringing the precoat slurries up to temperature by recirculating through a heat exchanger using a 3600 rpm centrifugal

pump. Experience has shown us that repeated passes through such a pump will degrade filter aids (and the pump).

Accordingly, samples of precoat slurries were obtained at various stages and times during a precoating cycle, the filter aid was extracted, and density and relative flow rate tests performed.

The following samples were tested:

<u>NO.</u>	<u>SAMPLE</u>
679	Dry Filter Aid as Received at the SRC Plant
680	This is the same Filter Aid as Sample 679, but mixed at Denver with a sample of Process Solvent also sent from Tacoma
673	Precoat Slurry from the Precoat Atmospheric Mix Tank after agitation
677	Precoat Slurry from Precoat Slurry Pressure Vessel after recirculation through heat exchanger to raise temperature
672	Same as Sample No. 677, but taken 1/2 hour after start of precoating

The results of the evaluation tests are shown in Table 11-1.

The test results confirm that serious degradation of precoat material has taken place in the Precoat Slurry Pressure Vessel. This is indicated by a greater than 50 percent reduction in relative flow rate and an increase in precoat density of approximately 25 percent. The relative flow rate of Sample No. 672 is in the range of some of those materials used on the Rotary Pressure Precoat Test Leaf at

Denver, but the densities of 31 and 32 pcf must be compared with those of approximately 22 to 24 pcf observed on the Test Leaf in Denver. This increase in density indicates, based on our experience with similar problems in other applications, a reduction in precoat filter aid efficiency several times greater than indicated by the figures in Table 11-1. Note also that the density of the dry material is higher than expected.

Based on the above analysis, corrective procedures and/or design changes will be recommended (some have already been proposed during discussions with Fort Lewis personnel on the installation of the Electric Power Research Institute - Johns-Manville pilot filter) followed by evaluations of the changes.

The problem of obtaining actual density of the precoat as it is on the filter was recognized during the conceptual design stage of the Electric Power Research Institute 50 Square Foot Pilot Filter. As a result, provision for a "coring" device has been included in the design, which will enable the extraction of a core of precoat from the filter at or near operating temperatures and pressures.

TESTS ON FILTER AID EXTRACTED FROM
 SAMPLES SENT FROM FORT LEWIS

SAMPLE IDENTIFICATION	RELATIVE FLOW RATE	PRECOAT DENSITY, pcf
No. 679 Dry Filter Aid	84	25
No. 679, 680 Dry Filter Aid Mixed in Process Solvent	80	26
No. 673 Precoat Slurry from Precoat Atmospheric Mix Tank	80	26
No. 677 Precoat Slurry from Precoat Slurry Pressure Vessels	55	32
No. 672 Precoat Slurry from Precoat Slurry Pressure Vessel $\frac{1}{2}$ hour after precoating	36	31

APPENDIX I
TEST LEAF FILTRATION DATA

APPENDIX I - TABLE 1

0.1 SQ. FT. TEST LEAF FILTRATION DATA SEPTEMBER, 1976

FEED: FT. LEWIS TFF 216 OR SYNTHOIL FB 45

PRE-PRECOAT: FIBRA-FLO 7C PRECOAT: AF6 OR AF7

A-2

RUN NO.	PRECOAT	FEED	TEMPERATURE °F	PRESSURE DIFFERENTIAL psid	BLADE ADVANCE mils	APPARENT FILTRATION RATE			FILTRATE ANALYSIS	
						5 second	10 second	20 second	PERCENT ASH	PERCENT SULFUR
B79A	AF7	TFF 216	383	20	2	44	50	12	0.06	0.45
B79B	AF7	TFF 216	383	20	10	39		24		
B81A	AF7	TFF 216	409	40	2	55	44	13	0.07	0.42
B81B	AF7	TFF 216	409	40	10	208		106		
B83A	AF7	TFF 216	497	30	5	249	162	113	0.04	0.43
B83B	AF7	TFF 216	497	30	5	239	158	108		
B85A	AF7	TFF 216	604	20	2	148	96	124	0.02	0.39
B85B	AF7	TFF 216	604	20	10	282	158	176		
B87A	AF7	TFF 216	607	40	2	187	180	119	0.06	0.39
B87B	AF7	TFF 216	607	40	10	388	229	195		
B91A	AF7	TFF 216	605	35	3	124	101	108	0.04	0.40
B91B	AF7	TFF 216	605	35	5	229	132	138		
B94A	AF7	TFF 216	610	35	7	271	127	164	0.05	
B94B	AF7	TFF 216	610	35	10	338	205	163		
B97A	AF7	FB 45	399	20	2	18	8	13		0.28
B97B	AF7	FB 45	399	20	10	20	3	3		
B100A	AF7	FB 45	402	40	2	29	22	3	0.09	0.48
B100B	AF7	FB 45	402	40	10	13	3	22		
B102A	AF7	FB 45	508	30	5	104	65	46	0.04	0.49
B102B	AF7	FB 45	508	30	5	86	57	34		
B104A	AF7	FB 45	603	20	2	72	84	27	0.04	
B104B	AF7	FB 45	603	20	10	152	59	62		
B106A	AF7	FB 45	601	38	2	177	87	61	0.05	0.80
B106B	AF7	FB 45	601	38	10	195	113	86		
B109	AF6	TFF 216	610	34	3	55	62	48		
B112	AF6	TFF 216	595	35	5	63	27	19		
B114	AF6	TFF 216	595	35	7	52	39	45		
B116	AF6	TFF 216	596	34	10	307	197	171		

APPENDIX I - TABLE 1

0.1 SQ. FT. TEST LEAF FILTRATION DATA

OCTOBER, 1976

FEED: FT. LEWIS TFF 216 OR SYNTHOIL FB 45

PRE-PRECOAT: FIBRA-FLO 7C PRECOAT: AF7

RUN NO.	PRECOAT	FEED	TEMPERATURE °F	PRESSURE DIFFERENTIAL psid	BLADE ADVANCE mils	APPARENT FILTRATION RATE			FILTRATE ANALYSIS	
						5 second	10 second	20 second	PERCENT ASH	PERCENT SULFUR
B120	AF7	TFF 216	598	34	10	370	251		0.05	0.38
B123	AF7	TFF 216	598	35	7	244	228			
B125	AF7	TFF 216	600	35	5	210	118			
B127	AF7	TFF 216	600	35	3					
B135	AF7	TFF 216	609	35	3	225	150		0.07	0.41
B138A	AF7	TFF 216	608	34	10	437			0.03	
B138B	AF7	TFF 216	608	40	10	438				
B141	AF7	TFF 216	606	40	0	112	96		0.03	
B143	AF7	TFF 216	600	40	-	45		32	0.03	
B146	AF7	FB 45	508	30	5	128		70	0.02	0.44
B148A	AF7	FB 45	603	40	10	269	133	105	0.10	0.46
B148B	AF7	FB 45	603	40	2	171	91	~70		
B150A	AF7	FB 45	606	20	10	185	90	71	0.08	
B150B	AF7	FB 45	606	20	2	76	37	24		
C1A	AF7	FB 45	508	40	10	171	121	76	0.08	
C1B	AF7	FB 45		40	10	198	~110	77		

APPENDIX I - TABLE 1

0.1 SQ. FT. TEST LEAF FILTRATION DATA NOVEMBER, 1976
 FEED: WILSONVILLE SN 15719 OR FT. LEWIS TFF 216
 PRE-PRECOAT: FIBRA-FLO 7C PRECOAT: AF6 OR AF7

RUN NO.	PRECOAT	FEED	TEMPERATURE °F	PRESSURE DIFFERENTIAL psid	BLADE ADVANCE mils	APPARENT FILTRATION RATE			FILTRATE ANALYSIS	
						5 second	10 second	20 second	PERCENT ASH	PERCENT SULFUR
C15A	AF7	SN 15719(WFF)	399	20	10	299	266	159	0.04	0.53
C15B	AF7	SN 15719(WFF)	399	20	2	94	82	70	0.04	0.54
C17A	AF7	SN 15719(WFF)	406	40	10	249	99	114	0.05	0.49
C17B	AF7	SN 15719(WFF)	406	40	2	65	47	44	0.04	
C19A	AF7	SN 15719(WFF)	501	30	5	187	147	136	0.04	0.55
C19B	AF7	SN 15719(WFF)	501	30	5	138	138	110	0.03	0.44
C21A	AF7	SN 15719(WFF)	600	21	10	271	277	141	0.02	0.47
C21B	AF7	SN 15719(WFF)	600	21	2	113	138	82	0.01	
C23A	AF7	SN 15719(WFF)	605	39	10	466	304	278	0.03	0.51
C23B	AF7	SN 15719(WFF)	605	39	2	222	364		0.04	
C27	AF6	TFF 216	619	35	10	345	235		0.04	0.51
C29	AF6	TFF 216	613	35	2	264	161		0.04	0.34
C31	AF6	TFF 216	624	35	7	341	238		0.04	0.37
C33	AF6	TFF 216	615	35	4	319	166		0.04	
C37	AF7	TFF 216	615	35	10		250		0.12	0.27
C39	AF7	TFF 216	608	36	2	259	154		0.12	0.40
C41	AF7	TFF 216	613	35	10	345	244		0.10	
					7	330	241		0.09	0.38
C43	AF7	TFF 216	610	35	4	289	164		0.12	0.43

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APPENDIX I - TABLE 1

0.1 SQ. FT. TEST LEAF FILTRATION DATA DECEMBER, 1976
 FEED: WILSONVILLE SN 15719 OR FT. LEWIS TFF 216
 PRE-PRECOAT: FIBRA-FLO 7C PRECOAT: AF5, AF6, OR AF7

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RUN NO.	PRECOAT	CHARGE	TEMPERATURE °F	PRESSURE DIFFERENTIAL ΔP, psid	BLADE ADVANCE mils	APPARENT FILTRATION RATE lb/hr/sq ft*				FILTER AID USAGE* lb/lb of FILTRATE			
						5 sec.	10 sec.	12 sec.	20 sec.	5 second	10 second	12 second	20 second
C47A	AF6	SN 15719	398	20	10	279	190		129	0.0215	0.0158		0.0116
C47B	AF6	SN 15719	398	20	2	148	133		64	0.0081	0.0045		0.0047
C49A	AF6	SN 15719	403	40	10	309	99		156	0.0194	0.0303		0.0096
C49B	AF6	SN 15719	403	40	2	129	121		64	0.0093	0.0050		0.0047
C51A	AF6	SN 15719	506	29	5	224	155		145	0.0134	0.0097		0.0052
C51B	AF6	SN 15719	506	30	5	197	176		120	0.0152	0.0085		0.0063
C53A	AF6	SN 15719	604	19	10	410	205		193	0.0146	0.0146		0.0078
C53B	AF6	SN 15719	604	20	2	190	145		99	0.0063	0.0041		0.0030
C55A	AF6	SN 15719	600	37	10	276	160		166	0.0217	0.0188		0.0090
C55B	AF6	SN 15719	600	39	2	195	277		183	0.0062	0.0022		0.0016
C62	AF7	Hot TFF	457	30	2				31				0.0145
C64	AF7	Hot TFF	472	29	7				105				0.0150
C66	AF7	Hot TFF	598	35	7	380				0.0111			
C68A	AF7	Hot TFF	600	36	4	254				0.0094			
C68B	AF7	Hot TFF	600	35	2	166				0.0072			
C70A	AF7	Hot TFF	599	35	10	288				0.0208			
C70B	AF7	Hot TFF	599	35	0	< 86							
C73	AF5	TFF 216	606	35	10	365	256			0.0164	0.0117		
C75	AF5	TFF 216	603	35	2	273	155			0.0044	0.0039		
C77	AF5	TFF 216	610	35	4	338				0.0071			
C79A	AF5	TFF 216	608	35	7	354				0.0119			
C79B	AF5	TFF 216	608	35	0	<215							

*The 5, 10, and 20 second immersions were run at 40 percent submergence; the 12 second immersion was run at 36 percent submergence.

APPENDIX I - TABLE 1

0.1 SQ. FT. TEST LEAF FILTRATION DATA JANUARY 1977

FEED: FT. LEWIS TFF 216

PRE-COAT: FIBRA-FLOW 7C PRECOAT: AF5, AF6, OR AF7

RUN NO.	PRECOAT	CHARGE	TEMPERATURE °F	PRESSURE DIFFERENTIAL ΔP, psid	BLADE ADVANCE mils	APPARENT FILTRATION RATE lb/hr/sq ft*		FILTER AID USAGE* lb/lb of FILTRATE	
						5 second	12 second	5 second	12 second
C83A	AF6	TFF 216	601	35	4	211		0.0114	
C83B	AF6	TFF 216	601	40	4	343		0.0070	
C85A	AF6	TFF 216	600	45	4	353		0.0068	
C85B	AF6	TFF 216	600	50	4	327		0.0073	
C87A	AF6	TFF 216	603	55	4	348		0.0069	
C87B	AF6	TFF 216	603	60	4	353		0.0068	
C89A	AF6	TFF 216	600	70	10	447		0.0134	
C89B	AF6	TFF 216	600	70	4	355		0.0068	
C93A	AF7	Cold TFF	452	30	2		71		0.0063
C93B	AF7	Cold TFF	452	30	10		118		0.0191
C95A	AF7	Cold TFF	457	30	7		118		0.0134
C95B	AF7	Cold TFF	457	30	10		121		0.0186
C97	AF7	Cold TFF	603	35	7	277		0.0152	
C99A	AF7	Cold TFF	601	35	4	279		0.0086	
C99B	AF7	Cold TFF	601	35	10	434		0.0138	
C101A	AF7	Cold TFF	599	35	2	165		0.0073	
C101B	AF7	Cold TFF	599	35	10	387		0.0155	
C105	AF7	Old Hot TFF	454	30	2		40		0.0113
C107A	AF7	Old Hot TFF	448	30	7		113		0.0140
C107B	AF7	Old Hot TFF	448	30	10		100		0.0225
C109	AF7	Old Hot TFF	601	35	7	250		0.0168	
C111	AF7	Old Hot TFF	599	35	4	246		0.0098	
C113A	AF7	Old Hot TFF	597	35	2	203		0.0059	
C113B	AF7	Old Hot TFF	597	35	10	362		0.0166	
C117A	AF5	TFF 216	605	35	4	122		0.0197	
C117B	AF5	TFF 216	605	35	10	285		0.0211	
C119	AF5	TFF 216	604	49	4	331		0.0073	
C121	AF5	TFF 216	599	60	4	379		0.0063	
C123	AF5	TFF 216	600	70	4	420		0.0057	
C125	AF5	TFF 216	600	70	7	424		0.0099	

*The 5 second immersion was run at 40 percent submergence;
the 12 second immersion was run at 36 percent submergence.

APPENDIX I - TABLE 1

0.1 SQ. FT. TEST LEAF FILTRATION DATA FEBRUARY 1977

FEED: FT. LEWIS TFF 216

PRE-PRECOAT: FIBRA FLO 7C PRECOAT: AF5

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RUN NO.	PRECOAT CHARGE	TEMPERATURE °F	PRESSURE DIFFERENTIAL psid	BLADE ADVANCE mils	APPARENT FILTRATION RATE, lb/hr/sq ft			FILTER AID USAGE lb/lb of FILTRATE		
					5 second	10 second	12 second	5 second	10 second	12 second
*C129A	AF5 TFF 216	603	70	10	408			0.0147		
C129B	AF5 TFF 216	603	70	7	120			0.0350		
*C131	AF5 TFF 216	600	71	4	319			0.0075		
*C133A	AF5 TFF 216	600	60	4	343			0.0070		
C133B	AF5 TFF 216	600	60	10	491			0.0122		
*C135A	AF5 TFF 216	598	50	4	336			0.0071		
C135B	AF5 TFF 216	598	50	10	349			0.0172		
*C137A	AF5 TFF 216	598	35	4	277			0.0087		
C137B	AF5 TFF 216	598	35	10	324			0.0185		
C143	AF5 TFF 216	600	70	10	143	225		0.0420	0.0133	
C145	AF5 TFF 216	600	70	7	388	277		0.0108	0.0176	
C147	AF5 TFF 216	595	70	4	343	233		0.0070	0.0052	
C149A	AF5 TFF 216	600	70	2	346	188		0.0035	0.0032	
C149B	AF5 TFF 216	600	70	10	402			0.0149		
C151A	AF5 TFF 216	597	70	10	417			0.0144		
C151B	AF5 TFF 216	597	70	7	382			0.0110		
C151C	AF5 TFF 216	597	70	4	360			0.0067		
C151D	AF5 TFF 216	597	70	2	347			0.0035		
D3	AF5 TFF 216	450	30	2			46			0.0098
D5	AF5 TFF 216	458	30	7			113			0.0140
D7A	AF5 TFF 216	603	35	7	342	235		0.0123	0.0089	
D7B	AF5 TFF 216	603	35	10	361			0.0166		
D9A	AF5 TFF 216	600	35	4	320	212		0.0075	0.0057	
D9B	AF5 TFF 216	600	35	10	379			0.0158		
D11	AF5 TFF 216	600	35	2	305			0.0039		

* Filtrate analysis indicates some irregularities, rate data validity suspect.

TABLE I-7
0.1 SQUARE FOOT TEST LEAF FILTRATION DATA

Feed: Fort Lewis TFF 216
Pre-Precoat: FIBRA-FLO 7C
Precoat: AF5

RUN NO.	PRESSURE DIFFERENTIAL psid	BLADE ADVANCE mils/cycle	TEMP °F	APPARENT FILTRATION RATE lb/hr/sq ft					FILTER AID USAGE (25 pcf Precoat Density) lb/1000 lb of Filtrate						
				IMMERSION TIME					2	3	5	10	20		
				2	3	5	10	20						2	3
sec.	sec.	sec.	sec.	sec.	sec.	sec.	sec.	sec.	sec.	sec.	sec.	sec.	sec.		
D15	40	4	600												
D17	60	4	600			>139	> 90								
D19	80	4	600			370	255						<17.3	<13.3	
D21	100	4	600			447	257						6.5	4.7	
D23A	100	2	600			459	261						5.4	4.7	
D23B	100	4	600			376							5.2	4.6	
D23C	100	7	600			451							3.2		
D23D	100	10	600			468							5.3		
													9.0		
D27	70	4	600			>347							12.7		
D29	70	4	600										<6.9		
D31	70	4	600	658				244						4.9	
D33	70	4	600							9.1				3.8	
D35	70	2	600	485		332	209		158						
										6.2			3.6	2.9	
D39	70	4	600			350							6.9		
D41	70	4	600											4.1	
D43	70	2	600	590					148						
D45	770	2	600							5.1					
D47	70	2	600			331							3.6		
								205	127					2.9	2.4
D51	70	4	600	675											
D53	70	2	600	607						8.9					
D55	70	4	600							4.9					
D57	70	2	600			526							7.6		
						464							4.3		
D61	100	4	600										<6.8		
D63	100	2	600			>352							4.0		
D65	100	4	600			303								4.5	
D67	100	2	600					268						3.0	
D69	100	4	600					199							
D71	100	2	600						138					4.3	
									126					2.4	

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TABLE I-8
0.1 SQUARE FOOT TEST LEAF FILTRATION DATA - APRIL 1977

Conditions: 600F and 70 psid differential pressure
 Feed: Fort Lewis TFF 216
 Pre-Precoat: FIBRA-FLO 7C or 550
 Precoat: AF5

RUN NO.	BLADE ADVANCE mils/cycle	APPARENT FILTRATION RATE lb/hr/sq ft				FILTER AID USAGE (25 pcf PRECOAT DENSITY) lb/1000 lb of Filtrate			
		IMMERSION TIME, seconds				IMMERSION TIME, seconds			
		2	3	4	5	2	3	4	5
D75a	4				>380				6.3
D77a	2				298				4.0
D79a	4	725	511			8.3	7.8		
D81a	2	704	495			4.3	4.0		
D85	4			441				6.8	
D87	2			376				4.0	
D89	1			341				2.2	
D91	1	505				3.0			
D93	1		330				3.0		
D95	1				<351				>1.7
D99	4		599				6.7		
D101	1		434				2.3		
D103	1	497				3.0			
D105	1			289				2.6	
D107	1	484				3.1			
D109	1				243				2.5
D113b	4				>255				<9.4
D115b	4	766				7.8			
D117b	2	660				4.5			
D119b	2		441				4.5		
D121b	1	551				2.7			

a - Runs D75 through D81: 100 psid Differential Pressure

b - Runs D113 through D121: Non-Asbestos Pre-Precoat of CELITE 550, other pre-precoats 7C.

TABLE I-9
0.1 SQUARE FOOT TEST LEAF FILTRATION DATA - JUNE 1977

FEED: Fort Lewis (TFF 216)
 PRE-PRECOAT: FIBRA-FLO 7C
 SCREEN: 24 x 110 Plain Dutch Weave
 NOTE: Number in Parenthesis = Data Points Averaged

RUN NO.	DATE (WEEK OF)	PRECOAT	PRESSURE DIFFERENTIAL psid	TEMPERATURE °F	BLADE ADVANCE mils/cycle	APPARENT FILTRATION RATE lb/hr/sq ft				FILTER AID USAGE (25 pcf Precoat Density) lb/1000 lb of Filtrate			
						IMMERSION TIME 2 second (12rpm)	3 second (8rpm)	4 second (6rpm)	5 second (4.8rpm)	IMMERSION TIME 2 second	3 second	4 second	5 second
E29	6/6/77	AF5	70	600	4			343(4)					8.7
E31	6/6/77	AF5	70	600	½			185(3)					2.0
E33	6/6/77	AF5	70	600	½			181(3)				2.8	
E35	6/6/77	AF5	70	600	½	254(4)				3.0			
E37	6/6/77	AF5	100	600	½	>314(4)				<2.4			
E39	6/6/77	AF5	100	600	½			344(4)				1.5	
E41	6/6/77	AF5	100	600	½			326(4)					1.2

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0.1 SQUARE FOOT TEST LEAF FILTRATION DATA - JUNE AND AUGUST 1977

FEED: Fort Lewis (TFF 216)

PRE-PRECOAT: CELITE AF13 (Without Asbestos & Made from CELITE 550)

SCREEN: 24 x 110 Plain Dutch Weave

NOTE: Number in Parenthesis = Data Points Averaged * = Poor Correlation with Other Data

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RUN NO.	DATE (WEEK OF)	PRECOAT	PRESSURE DIFFERENTIAL psid	TEMPERATURE °F	BLADE ADVANCE mils/cycle	APPARENT FILTRATION RATE lb/hr/sq ft IMMERSION TIME				FILTER AID USAGE (25 pcf Precoat Density) lb/1000 lb of Filtrate IMMERSION TIME			
						2 second (12rpm)	3 second (8rpm)	4 second (6rpm)	5 second (4.8rpm)	2 second	3 second	4 second	5 second
E45	6/13/77	AF5	70	600	4			> 295(3)					<10.2
E47	6/13/77	AF5	70	600	2			> 303(4)					<5.0
E49	6/13/77	AF5	70	600	2							4.0	
E51	6/13/77	AF5	70	600	2	592(4)	506(3)			5.1			
E53	6/13/77	AF5	70	600	1		466(3)				2.1		
E55	6/13/77	AF5	70	600	1			358(5)					2.1
E59	6/20/77	AF5	70	600	4			> 304(2)					<9.2
E61	6/20/77	AF5	70	600	2			286(4)					4.2
E63	6/20/77	AF5	70	600	2			369(4)					4.1
E65	6/20/77	AF5	70	600	1	> 410(3)				<3.7			
E67	6/20/77	AF5	70	600	1				293(3)				2.0
E69	6/20/77	AF5	70	600	1			> 286(3)				<3.5	
E73	6/27/77	AF5	70	600	4			356(2)					8.4
E75	6/27/77	AF5	70	600	2			348(4)					4.3
E77	6/27/77	AF5	70	600	2			425(4)				4.7	
E79	6/27/77	AF5	70	600	2	601(4)				5.0			
E81	6/27/77	AF5	70	600	1			418(5)			2.4		
E85	7/04/77	AF5	70	600	4			685(4)				5.8	
E87	7/04/77	AF5	70	600	2								4.7
E89	7/04/77	AF5	70	600	1				255(4)				2.5
E91	7/04/77	AF5	70	600	1				241(3)				
E93	7/04/77	AF5	70	600	1			351(2)					2.1
E95	7/04/77	AF5	70	600	1	563(5)				2.7			
E99	7/11/77	AF5	100	600	4								2.4
E101	7/11/77	AF5	100	600	2			445(5)					6.7
E103	7/11/77	AF5	100	600	2			375(4)					4.0
E105	7/11/77	AF5	100	600	2			410(4)				4.9	
E107	7/11/77	AF5	100	600	1	766(3)				3.9			
						648(5)				2.3			

0.1 SQUARE FOOT TEST LEAF FILTRATION DATA - JUNE AND JULY, 1977

FEED: Wilsonville (SN 25260)
 PRE-PRECOAT: FIBRA-FLO 7C
 SCREEN: 24 x 110 Plain Dutch Weave
 NOTE: Number in Parenthesis = Data Points Averaged

RUN NO.	DATE (WEEK OF)	PRECOAT	PRESSURE DIFFERENTIAL psid	TEMPERATURE °F	BLADE ADVANCE mils/cycle	APPARENT FILTRATION RATE lb/hr/sq ft				FILTER AID USAGE (25 pcf Precoat Density) lb/1000 lb of Filtrate			
						IMMERSION TIME				IMMERSION TIME			
						2 second (12rpm)	3 second (8rpm)	4 second (6rpm)	5 second (4.8rpm)	2 second	3 second	4 second	5 second
E111	7/18/77	AF5	100	500	4			475(5)					6.3
E113	7/18/77	AF5	100	500	2			299(4)					5.0
E115	7/18/77	AF5	100	500	2		466(4)				4.3		
E117	7/18/77	AF5	100	500	2	550(5)				5.5			
E119	7/18/77	AF5	100	500	1	569(5)				2.6			
E131	8/01/77	AF5	70	600	4				323(5)				8.9
E133	8/01/77	AF5	70	600	1	*326(3)				4.6			
E135	8/01/77	AF5	70	600	1		414(3)				2.4		
E137	8/01/77	AF5	70	600	1			346(3)				2.2	
E139	8/01/77	AF5	70	600	1				284(3)				2.1
E146	8/08/77	AF2	100	600	4			*309(5)			12.9		
E148	8/08/77	AF2	100	600	2			509(4)			3.9		
E150	8/08/77	AF2	100	600	1				373(3)			2.0	
E152	8/08/77	AF2	100	600	1	*473(4)				3.2			
F2	8/08/77	AF2	100	600	1/2				308(3)			1.2	
F4	8/08/77	AF2	100	600	1/2	504(4)				1.4			
F9	8/15/77	AF2	70	600	2				288(3)			5.2	
F11	8/15/77	AF2	70	600	1				298(4)			2.5	
F13	8/15/77	AF2	70	600	1	*516(3)				2.9			
F17	8/15/77	AF2	70	600	1/2				224(3)			1.7	
F15	8/15/77	AF2	70	600	1/2	395(4)				1.9			
F19	8/15/77	AF2	70	600	2			388(3)			5.2		

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APPENDIX II

APPARENT FILTRATION RATE

Apparent filtration rate terminology has been used in the discussions and some explanation of its meaning is desirable.

Rate is calculated in pounds per hour per square foot on the basis of total area of a rotary precoat filter. Apparent rates are calculated on the assumption that full area of filter leaf was active. Since this is not true in many cases, true rates are generally higher than apparent rates.

The term "Apparent Filtration Rate" as defined above is used to denote rates calculated from observed rates under the assumption that the entire precoat area as defined by the face of the filter leaf is presented unencumbered (not blinded) to the filter cake at the beginning of each immersion. Inspection of the cake/precoat after a series of runs typically reveals some degree of encumbrance which developed at some unidentifiable point in the series. Thus, "apparent" rates are in every case equal to or smaller than true rates in effect at the time of the measurement. From post run inspections, it is estimated that apparent rates may be from 1 or 2 percent to 40 percent low. The 40 percent

represents an extreme case; typically, apparent rates are less than 25 percent low. The following represents a sample filtering rate calculation for all runs in this report:

Pounds per hour per square foot =

Sample Weight (grams) X 3600 Seconds per Hour X
453.6 (grams/pound) Time (seconds)

144 (square inch/square foot) =
13.6 square inch (O.D. of pipe)

Sample Weight (grams) X 84.03
Time (seconds)

APPENDIX III
 FILTER AID USAGE

With few exceptions, which have been noted previously, the
 grate analyses tabulated in previous reports have been 0.01 to
 6 percent ash and 0.3 to 0.5 percent sulphur. Therefore, the
 grate analyses will not be specifically reported to allow
 inclusion of the filter aid usage or consumption in the tabulated
 a. Filter aid usage has been calculated based on an average
 coat density of 24 pounds per cubic foot (pcf) on a rotary drum
 filter at 40 percent submergence. For example, consider Run C133
 second immersion, 4 mils per revolution, 343 pounds per hour per
 square foot filtrate rate):

5 second @ 40% submergence is 4.8 rpm = 288 revolutions/hour

$$\frac{288 \text{ revolutions}}{\text{hour}} \times \frac{4 \times 10^{-3} \text{ inches}}{\text{revolution}} \times \frac{1 \text{ foot}}{12 \text{ inches}} \times \frac{25 \text{ lbs Filter Aid}}{\text{cubic foot}} = 0.0070$$

$$\frac{343 \text{ lbs Filtrate}}{\text{hour sq ft}} \frac{\text{lb Filter}}{\text{lb Filtrate}}$$

A lower number indicates increased efficiency of filter aid
 usage. These data were useful in evaluation of overall filtration
 economy and establishing the optimum filtration conditions at the
 Mt. Sturgis & Midway Coal Mining Company Solvent Refined Coal Plant at
 Mt. Lewis, Washington.

APPENDIX IV

PRECOAT DENSITY DETERMINATION

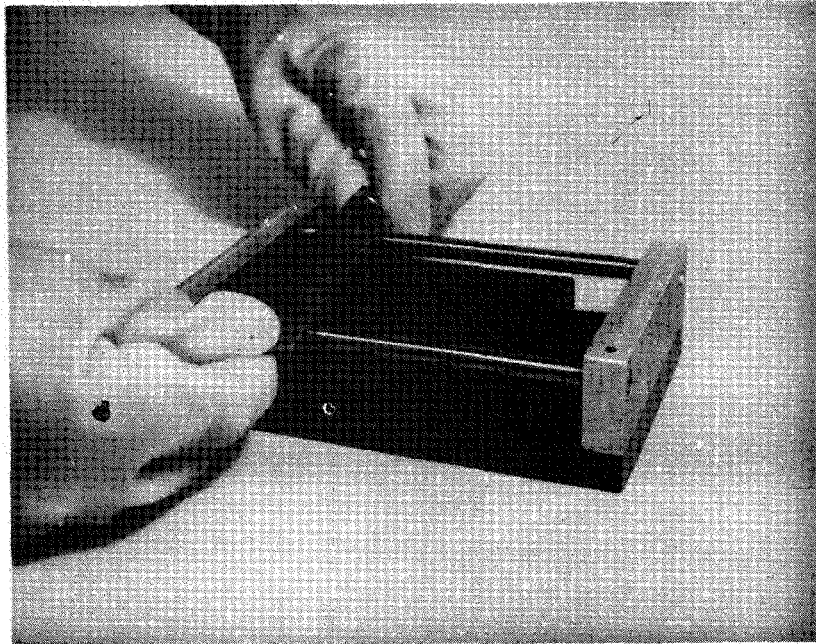
The following work was done to improve accuracy of measuring a volume of the residual precoat for determining density. The method illustrated in the following photographs uses a sharp knife guided by two rods to accurately trim each side for obtaining a uniform thickness. Different thicknesses and combinations of shims are used to support the precoat, depending on its initial thickness. Then, a borer is used to gain a sample of exact diameter for calculation of volume and burning for determining the inorganic weight. This trimming and boring should be done as soon as possible after running while the precoat is still moist and easy to handle without breaking. A water displacement method was used for measuring the volume of an irregular piece without trimming or boring. Comparison of results for recent CELITE AF5 precoats are as follows. These results indicate a good degree of accuracy and reproducibility.

LABORATORY PRECOAT DENSITIES

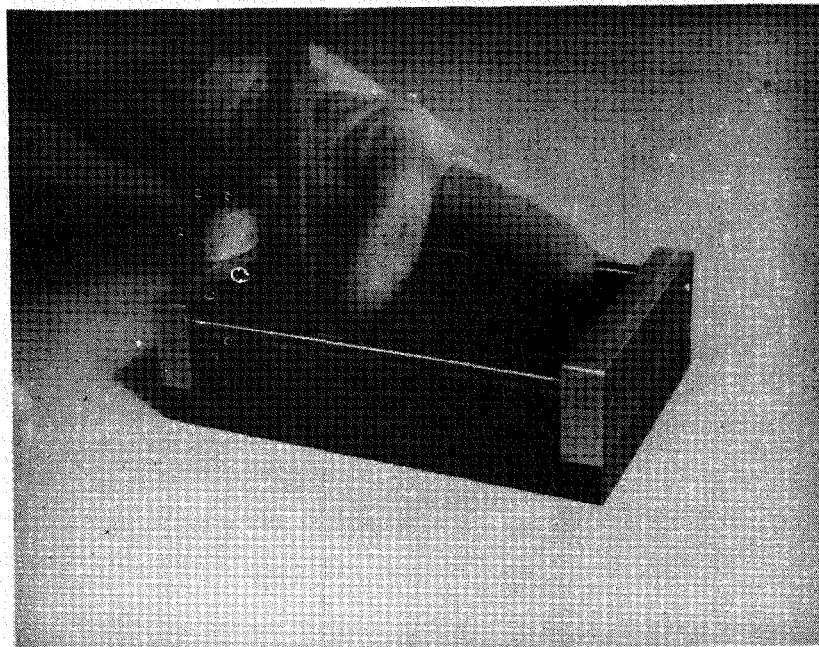
SAMPLE NUMBER	SAMPLE OBTAINED	SAMPLE PREPARED	METHOD	CUBIC FEET	POUNDS	POUNDS/CUBIC FOOT
1	12/22/77	1/06/78	Trim & Bore	6.56×10^{-5}	1.4×10^{-3}	21.3
	12/22/77	12/29/77	Displacement	1.82×10^{-3}	0.0404	22.2
2	1/13/78	1/17/78	Trim & Bore	5.12×10^{-5}	1.36×10^{-3}	26.7
	1/13/78	1/17/78	Trim & Bore	4.61×10^{-5}	1.25×10^{-3}	27.1
3	2/9/78	2/9/78	Trim & Bore	6.70×10^{-5}	1.68×10^{-3}	25.1
	2/9/78	2/9/78	Trim & Bore	5.20×10^{-5}	1.31×10^{-3}	25.1

Figure A-1

PREPARATION OF SAMPLE FOR DENSITY DETERMINATION
OF LIQUEFIED COAL FILTER CAKE



Trimming to Uniform Thickness



Boring to Exact Diameter

APPENDIX V

CHARACTERISTICS OF PROCESS FLUIDS

The data in this section are from the Electric Power Research Institute AF-614 Project 459-1 Final Report, December 1977.

Three samples of process fluids received from the Pittsburg & Midway Coal Mining Company at Fort Lewis, Washington were analyzed in some detail. They are:

Sample No. 149 of Filter Feed Stock (TFF-149)

Sample No. 216 of Filter Feed Stock (TFF-216)

Sample No. 309 of Process Solvent (TPS-309)

SULPHUR & ASH ANALYSIS

Sulphur analyses of filtrate samples from runs on TFF-149 reveal sulphur contents uniformly near 0.6 percent, regardless of ash content. This indicates that most of the sulphur in the filtrate samples, even those containing up to 0.3 percent ash, is in the liquefied organic components and thus is not removed by filtration.

The few sulphur analyses obtained on samples of filtrate from TFF-216 have rather uniform sulphur contents of about 0.4 percent; again, apparently independent of ash content in the low ash range treated. The low sulphur contents here, relative to those found in TFF-149 filtrates, are especially interesting in light of the somewhat higher sulphur content found for TFF-216, relative to that of TFF-149. These differences suggest different chemical organization of the sulphur in the two feed stock samples.

EFFECTS OF AGING ON DENSITY & VISCOSITY

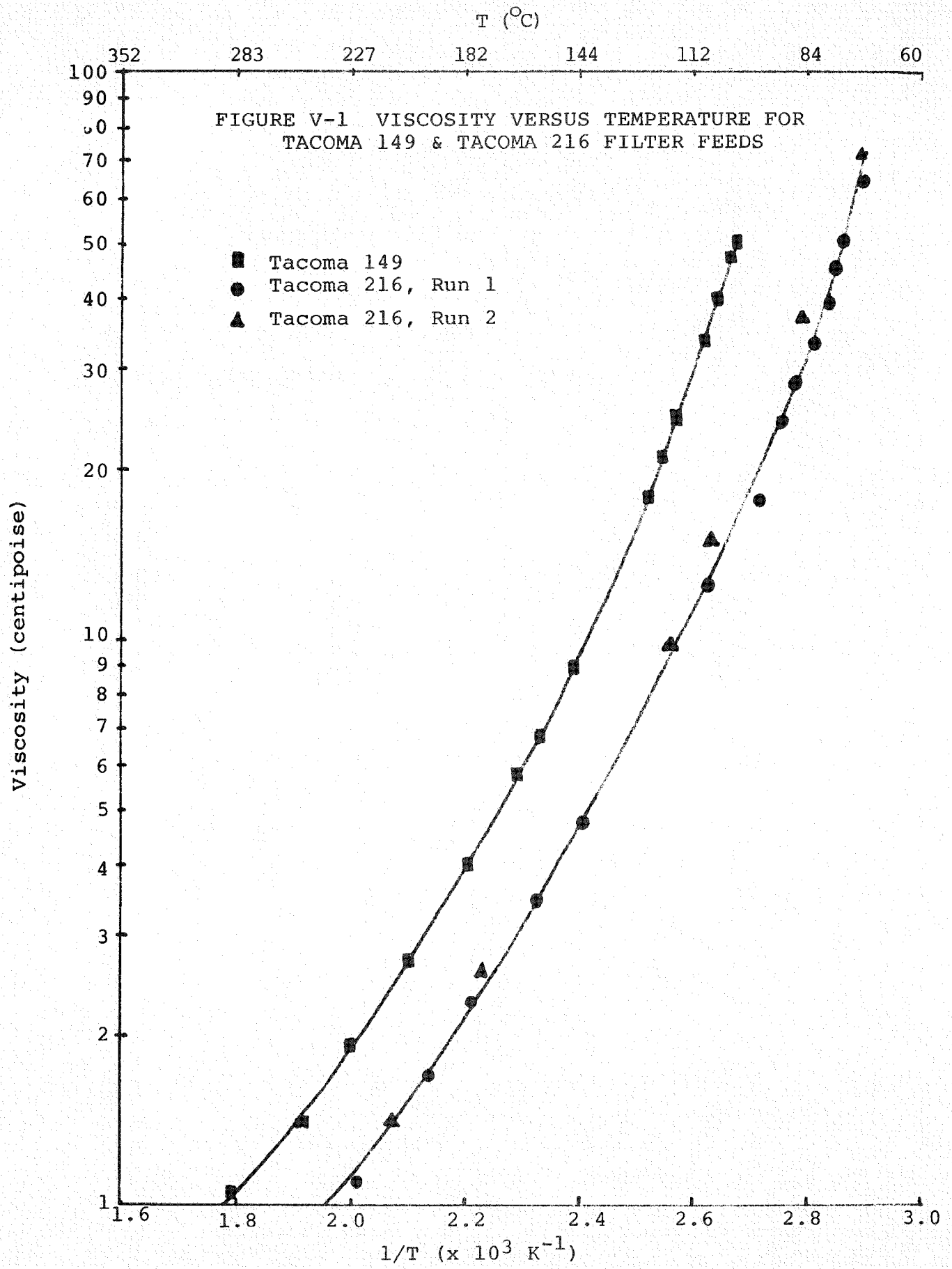
Brief examination was made of physical properties of a sample of residual TFF-149 in the main vessel after a series of runs and of a sample of "as received" TFF-149. The former sample had been heated in the apparatus, under a blanket of N₂ of 150 psig to temperatures near 330°F (165°C) for about 30 hours and to temperatures near 430°F (220°C) for about 10 hours. Results are shown in the table below:

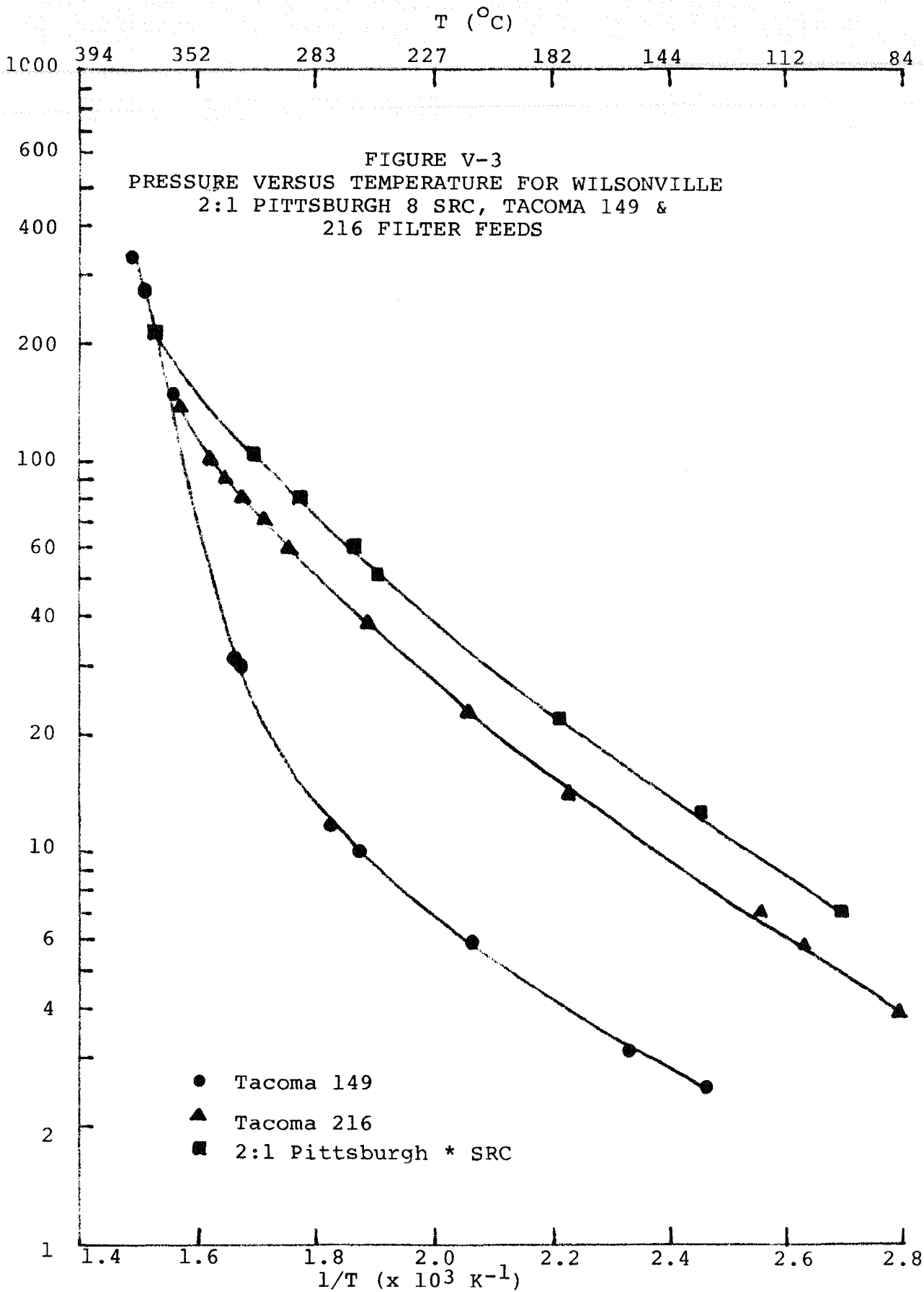
TFF-149 AGING TESTS

	<u>AS RECEIVED</u>	<u>AGED</u>
Density (grams per cc)	1.10	0.82
Viscosity (cps, ambient)	20.0	40.0

VISCOSITY

Viscosity-temperature curves for the three fluids have been generated empirically by use of a Dynatrol High Temperature Viscometer (Model CL-10 DVT-2). Data are presented together with the corresponding curve for TFF-149 let down with 23 percent TPS-309. While the viscosity curve for TFF-216 is quite similar to that for the let down TFF-149 at lower temperatures, the curves diverge significantly at the temperatures of greatest interest for this filtration study.





VAPOR PRESSURE¹

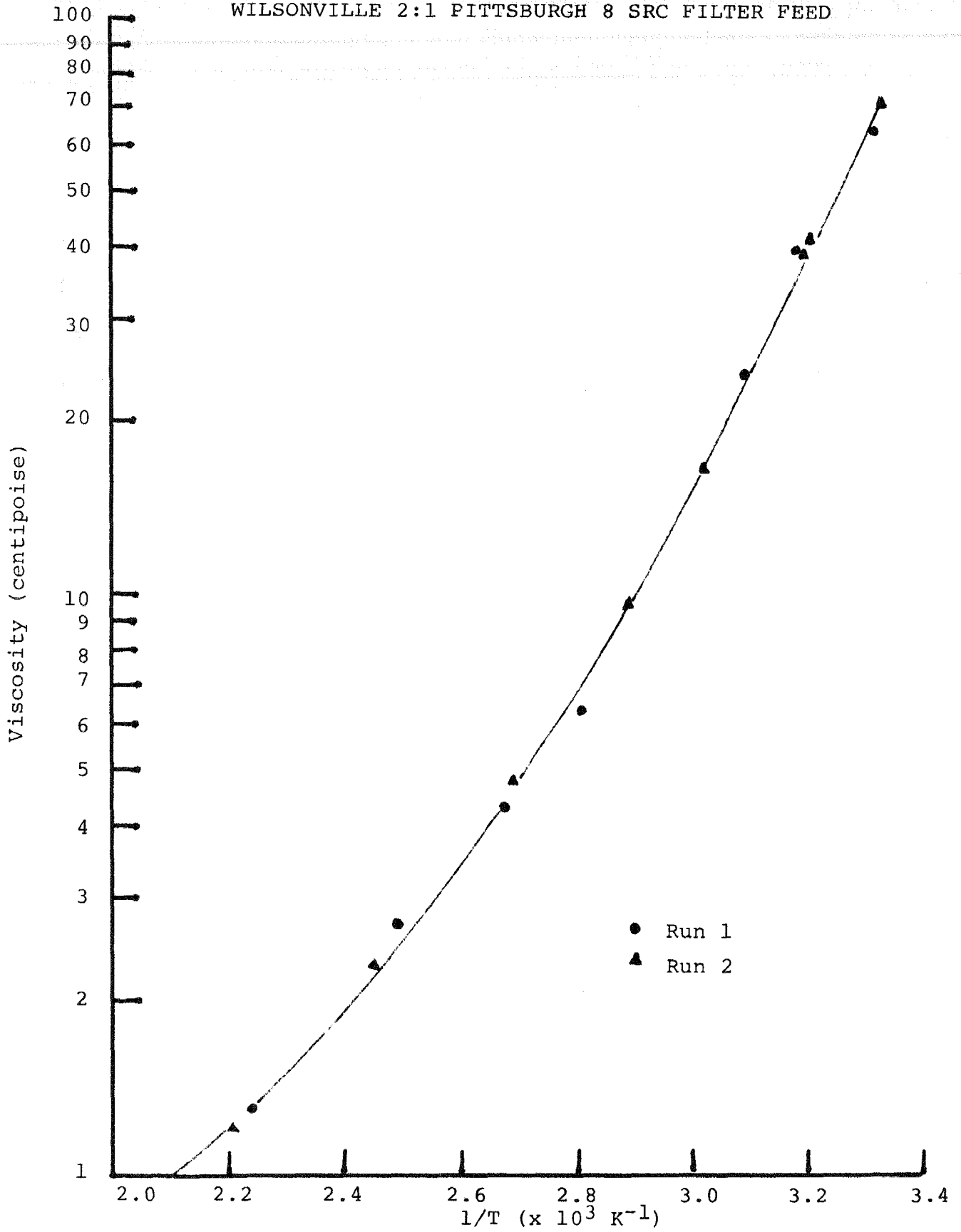
Vapor pressure-temperature curves are presented in Figure V-3. Note that in accordance with these data the normal boiling point of TPS-309 is 132°C (269°F), that of TFF-216 is 177°C (351°F), and that of TFF-149 is 292°C (557°F). Some decomposition of both of the TFF materials has been noted at temperatures above 350°C (662°F). While no such decomposition was detected in the case of the process solvent, it might be noted that the time above 350°C in the one run made was very short.

TYPICAL RESULTS OF SAMPLE ANALYSES

The properties described above are summarized below:

	<u>TFF-149</u>	<u>TFF-216</u>	<u>TPS-309</u>
<u>Synthoil</u>			
Ash (Percent)	3.7	7.5	0.15
Sulphur (Percent)	0.8	1.0	0.8
Density (grams/cc)	1.10		1.02
Viscosity (cps)			
400°F (204°C)	2.2	1.25	1
500°F (260°C)	1.3	1.00	1
Vapor Pressure (psig)			
400°F (204°C)	5.4	20	48
500°F (260°C)	9.5	37	85
600°F (316°C)	22.0	72	140

FIGURE V-2
VISCOSITY VERSUS TEMPERATURE FOR THE
WILSONVILLE 2:1 PITTSBURGH 8 SRC FILTER FEED



APPENDIX VI

MINERAL AND CHEMICAL ANALYSIS OF SOLIDS IN FILTER FEEDS

	WILSONVILLE 2:1 Pittsburgh 8 SRC	HRI LO-93A	TACOMA 149	TACOMA 216
Pyridine Insolubles, Weight Percent	5.0	4.6	5.8	N.D.**
Analysis of Pyridine Insolubles, Weight Percent				
Sulphur	3.3	6.0	5.9	N.D.**
Nitrogen	0.4	1.2*	0.4	N.D.**
Loss on Ignition at 1800°F (982°C)	45.9	40.9	38.8	N.D.**
1800°F (982°C) Ash from Filter Feed, Weight %	2.3	2.9	3.8	7.8
Analysis of 1800°F (982°C) Ash, Weight Percent				
Sulphur	1.9	0.06	0.07	0.24
Nitrogen	N.D.**	0.01	0.01	N.D.**
Iron	11.9	>10	>10	>10
Silicon	69	>10	>10	>10
Aluminum	10.6	5-10	5-10	5-10
Calcium	5.7	1-5	0.1-1	1-5
Magnesium	1.2	0.1-1	0.1-1	0.1-1
Sodium	1.1	0.1-1	0.1-1	--
Titanium	0.3	0.1-1	0.1-1	0.1-1
Boron	--	0.1-1	0.01-1	0.1-1
Manganese	--	0.01-1	0.01-1	<0.01
Copper	--	<0.01	0.01-1	<0.01
X-Ray Diffraction Analysis of 1800°F (982°C) Ash				
Hematite	Major	Major	Major	Major
Quartz	Minor	Minor	Minor	Minor
Anhydrite	Trace	--	--	--
Cristobalite	--	--	--	Trace
Feldspar	--	Poss. Trace	Poss. Trace	Poss. Trace
Mullite	--	Poss. Trace	Poss. Trace	--
Barytes	--	--	--	Poss. Trace

*May be high due to traces of pyridine

**N.D. - Not Determined

FLASH POINT DETERMINATION

Cleveland Open Cup Flash Points were determined on several materials as shown in the following table. Autoignition temperature would probably be more important to know, but equipment was not available for running this test. Based on relative values for other materials, however, it may be safely assumed that the filter feed autoignition temperature is 1000°F or greater.

<u>MATERIAL</u>	<u>FLASH POINT, °F</u>
Wilsonville Filter Feed Sample 8010	215
Wilsonville Recycle Solvent Sample 10140	198
Wilsonville Light Organic Product Sample 10139	Below Room Temp.
Tacoma Filter Feed	280

APPENDIX VI

OPERATING DETAILS OF TESTS WITH IN-SITU PRECOATS

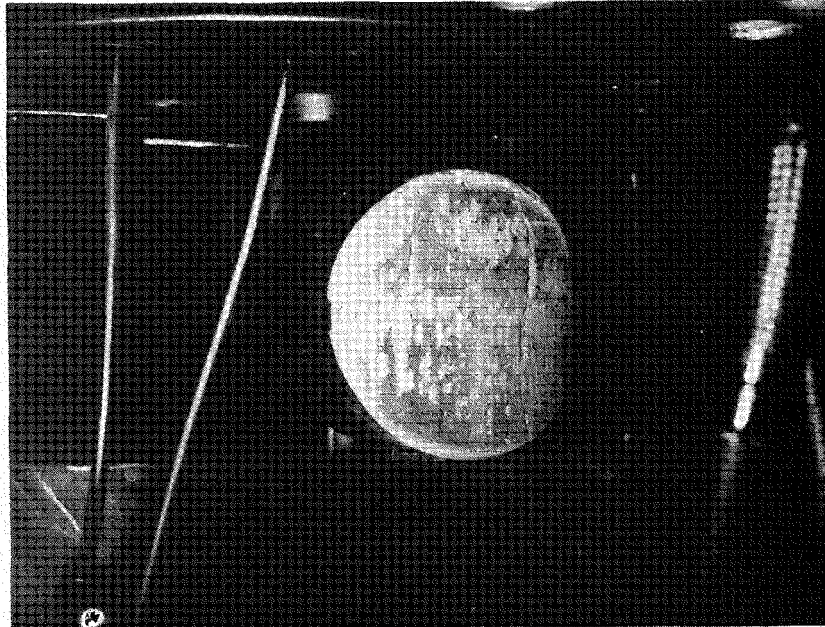
Run F34, Table VI-1 was the first since revising and moving the equipment. It presents the first filter rate data using a precoat applied in-situ. The rate of 424 pounds per hour per square foot for this run was higher than for previous comparable runs made with vacuum applied precoats. Run F36 was the second and final run of this series and exhibited a rate of 374 pounds per hour per square foot. This rate was also in the same range as previous data with vacuum precoats. Run F36 was shortened and the series discontinued due to precoat failure. The failure was represented by a single fairly uniform hole (approximately 1/2-inch in diameter) completely through the center of the precoat.

Runs F42, F44, and F46 were made under the same conditions as the last series above. Appearance of the precoat prior to Run F42 filtering on January 19, 1978 is shown in Figure VI-1. The chipped appearance of the precoat is due to much thicker amounts of precoat being cut off during the precoating operation than would be cut off during filtration. Cracks such as the one shown in the upper photograph will usually seal during filtration, preventing the passage of unfiltered liquid into the filtrate. The filter rates

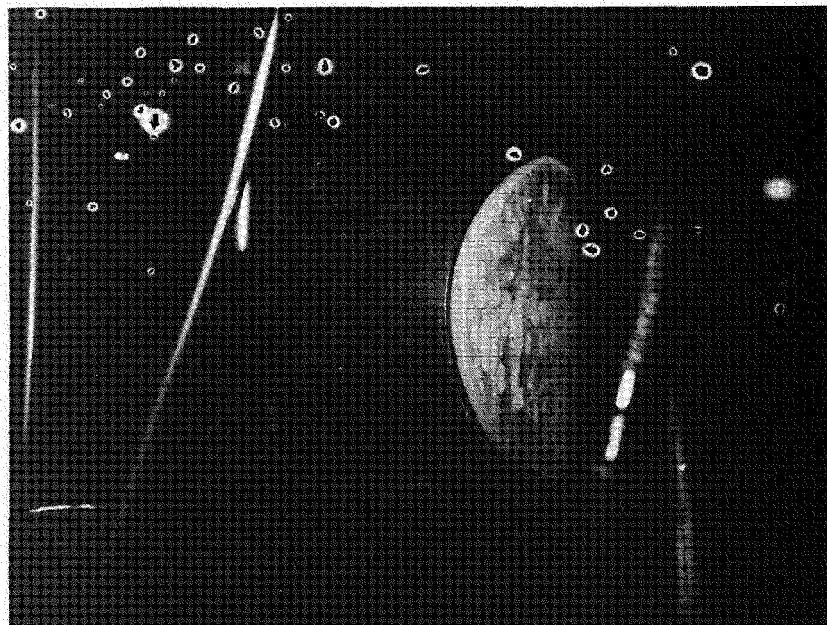
were abnormally low and became progressively less from run to run. After Run F46, it became obvious that the precoat had completely failed and filtration was discontinued. Post run examination showed that the low rates (ranging from 254 to 87 pounds per hour per square foot) were due to a high proportion of the precoat having dropped off (mostly in the center section of the leaf) allowing the progressive plugging. The precoat had cracked, causing pieces to drop off the leaf. This could have resulted from a sudden jar during movement or change in surrounding conditions. Detection of initial failure during filtering was made by observing a sudden increase in quantity and temperature of liquid passing to the receivers, a decrease in differential pressure, and a gushing sound through the receiver inlet header.

Figure VI-1 LIQUEFIED COAL FILTER TEST LEAF
SHOWING PRECOAT APPLIED ON JANUARY 19, 1978
FROM 7% AF5 SLURRY IN PROCESS SOLVENT
AT 275°F and 35 PSID

Thickness = approximately 1-inch,
including $\frac{1}{4}$ -inch AF13 Pre-Precoat



IMMEDIATELY AFTER OPENING VESSEL
WITH NO TRIMMING



TRIMMED EDGE WITH HAND KNIFE
ADDED $\frac{3}{64}$ -INCH SLEEVE RETRACTION FOR FILTERING
INITIAL RETRACTION AND SIDE EXPOSURE OF PRECOAT = APPROXIMATELY $\frac{1}{4}$ -INCH

APPENDIX VI - TABLE 1

0.1 SQUARE FOOT TEST LEAF FILTRATION DATA

(With Precoat Supported by Sleeve & Applied with 35 psid at 275°F)

FEED: Fort Lewis (TFF 216)
 PRE-PRECOAT: CELITE AF13 (From 2 Percent Xylene/Toluene Slurry)
 PRECOAT: CELITE AF5 (From 7 Percent Process Solvent Slurry)
 SCREEN: 24 x 110 Plain Dutch Weave
 NOTE: Number in parenthesis = Data Points Averaged

RUN NUMBER	DATE (WEEK OF)	PSID	OF	BLADE ADVANCE mils/cycle	APPARENT FILTRATION RATE pounds/hour/square foot for				PERCENTAGE ASH IN FILTRATE	REMARKS
					2 sec. (12 rpm)	3 sec. (8 rpm)	4 sec. (6 rpm)	5 sec. (4.8 rpm)		
F-34	1/09/78	70	600	4			424 (3)		0.16	First complete run since Run F-19 on 8/19/77.
F-36	1/09/78	70	600	2			374 (2)		0.18	Run shortened & discontinued due to 1/2-inch hole in precoat possibly caused by pressure surge when vessel vented by mistake.
F-42	1/16/78	70	600	2		254 (3)			0.14	
F-44	1/16/78	70	600	1		108 (6)			0.11	
F-46	1/16/78	70	600	2		87 (4)			0.20	

At start of next run, precoat completely failed. Most of precoat (in center of leaf) had dropped off. Low rates probably due to absence of precoat and resultant plugging.

Average = 0.16

A-31

Runs F54, F56, and F58 were performed under the same general conditions as for the above. The most reliable rate data in this series was the 446 pounds per hour per square foot for Run F54 which was completed before precoat failure as indicated by the ash content in the filtrate. The precoat failure after Run F58 exhibited four holes about 1/32 to 1/16-inch in diameter and extending completely through the cake to the screen. Appearance before filtering had been similar to that shown in Figure VI-1 of the precoat for Runs F42, F44, and F46. The obvious thin surface crack seemed to be consistently related to the system and was repaired for this series with a slurry of 2 percent CELITE AF5 in toluene/xylene. This repair had not seemed related to the hole type failures during filtration as mentioned above.

Runs F72 and F74 were carried out under the same general conditions as stated previously except for use of Standard SUPER-CEL instead of CELITE AF5 for precoating. All filtering was done at either 70 or 100 psid, 600°F, 1 or 2 mils per revolution knife advance, and 3 seconds (8 rpm) immersion time. No appreciable difference between 70 and 100 psid or between 1 and 2 mils per revolution knife advance could be detected. The reason for this is undoubtedly the same as similar situations early in the program using vacuum applied precoats. That is, the increased pressure caused a contraction of the precoat resulting in initial insufficient cutting of the precoat.

No holes through the precoat were apparent, but some cracking and small openings around the periphery were observed. Normally, the filter feed will fill and firmly seal any crack between precoat and holder. The precoat was pried off the screen as a single piece and a definite wet spot was observed on the screen indicating the location of failure. Upon cutting the precoat in half to show a cross-section in the wetted area, it was observed that filter feed had penetrated a section of pre-precoat from one of the periphery openings. Thus, a hole in the pre-precoat had occurred sometime during the operation. Before filtering, the precoat had exhibited the same thin crack as for previous runs and about 1 square inch of precoat had dropped off along one edge. Repair was made by suction application from a 5 percent slurry of Standard SUPER-CEL in process solvent heated to 150°F. The dropped area was near the leak area but away from the surface crack.

APPENDIX VI - TABLE 2

0.1 SQUARE FOOT TEST LEAF FILTRATION DATA

FEED: Fort Lewis (TFF 216)
 PRE-PRECOAT: CELITE AF13 (Vacuum Application from 2 Percent Slurry)
 Run F-53: Xylene/Toluene Solvent at Ambient
 Run F-67: Process Solvent at 150°F
 PRECOAT: CELITE AF 5 or Standard SUPER CEL (Pressure Application from 7 Percent Slurry)
 SCREEN: 24 X 110 Plain Dutch Weave
 NOTE: Number in Parenthesis = Data Points Averaged

A-34

NUMBER	DATE	CELLITE	APPLICATION	PSID °F	PSID °F	FILTRATION CONDITIONS			FILTRATION RATE		PERCENTAGE ASH IN FILTRATE	REMARKS
						BLADE ADVANCE	IMMERSION TIME	3 sec.	4 sec.			
F-53	1/30/78	AF5	PROCESS	35	290							Precoat Conditions
F-54	1/30/78	AF5	PROCESS	35	290	70 69-71	600	2	446 (3)		0.06	
F-56	1/30/78	AF5	PROCESS	35	290	70 64-76	600	1	609 (3)		0.27-1.17	Ash increased during run indicating defective precoat and progressive low rates.
F-58	1/30/78	AF5	PROCESS	35	290	100 93-105	600	1	777 (3)		0.74-2.54	Increased condensate indicating penetration. Cake density = 25.1 pcf
F-67	2/20/78	SSC	PROCESS	35	290							Precoat Conditions
F-72	2/20/78	SSC	PROCESS	35	290	70 67-72	600	1	607 (5)		1.11-1.37	
F-74	2/29/78	SSC	PROCESS	35	290	100 94-103	600	2	522 (2)		0.29-1.11	Run discontinued due to precoat leak. Ash content and cake examination indicated, at least temporary plugging of leak or blinding of screen.

The precoat failures described previously have been attributed to flashing of the solvent used for precoating and/or pre-precoating during filtration at high temperatures of 600°F. Further evidence of this reasoning became apparent during the following two precoating experiments.

- CELITE AF13 pre-precoat and CELITE AF5 precoat applied from 2 percent and 10 percent slurries in toluene/xylene respectively with suction at ambient temperature. Typically, there were small uncoated areas around the periphery of the screen after pre-precoating where welding had blanked the screen. The precoat filled these voids and its overall appearance was smooth without cracks. A few small bubbles were evident on the surface.
- Same as above except using normal pentane instead of toluene/xylene. The application had a good appearance without bubbles or holes. However, after setting overnight at ambient conditions, the precoat became very powdery. Many small cavities (1/16-inch in diameter or less) became evident in the pre-precoat surface as the precoat was shaved off.

The consistent precoat failures during all runs made in January and February 1978 have presented a real problem requiring solution. The failures must be associated with the in-situ precoating procedures and conditions, and might represent a potential problem when operating the 50 Square Foot Pilot Filter. No other conditions which might affect the results have changed. It is felt that the change from ambient/suction application with toluene/xylene to application at elevated temperature and pressure with process solvent is related to the failures. Particularly, volatile materials evaporated during vacuum precoating remained

behind during in-situ precoating. They then volatilized during the heating of the precoat to filtering temperatures of 600°F.

Thus, a likely theory for the failures is that the light fractions of solvent present in the pre-precoat and/or precoat result in the formation of small interior bubbles or voids at elevated temperatures. These open areas may tend to become larger and combine due to refluxing inside such areas during the 600°F filtering temperature.

As a result of the above operating experience, it has been concluded that the retractable sleeve cam motion and the use of Viton O-Ring seals represent satisfactory mechanical methods of operation at 600°F and 200 psig. The mechanism should be completely cleaned between runs and it is recommended that the O-Rings be changed at least every several runs for safety assurance. Alignment and tightness of the mechanism as well as very careful machining are essential for smooth operation.

With the exception of Runs F108 and F112, a 1/4-inch basecoat of CELITE AF13 was applied under each precoat using vacuum and a 50:50 mixture of toluene/xylene. As previously discussed, the "AF" grade was used to prevent the flocculation that occurs with untreated filter aids in solvent at ambient conditions. This flocculation of untreated precoat material is caused by the presence of small amounts of moisture in the precoat solvent. At high precoating temperatures

(290 to 300°F), enough moisture will be driven out of the solvent so that flocculation will be minimal if not nil. The high differential pressures (35 psid) will also help form a compact precoat by overcoming forces present which might be still causing some flocculation. The precoat so formed should be firm and examination of precoat heels (precoat remaining in the leaf at the end of a run) indicates this to be the case.

As stated previously, precoat failure was thought to be due primarily to flashing of light ends in the precoat solvent inside the precoat. Therefore, a precoat was applied after the light ends had been bled off the solvent at a precoating temperature of approximately 345°F (Run F77). After precoating, the precoat liquid was cooled and the vessel containing the precoat slurry and leaf was opened. Part of the precoat had dropped into the catchbox. The remaining precoat on the leaf showed no holes. The basecoat, on the other hand, did contain several holes at the basecoat/precoat interface and near the center of the screen. These holes did not extend down to the screen.

The above test indicates that by bleeding off the light ends of the precoat solvent, a more stable precoat can be formed. The holes in the basecoat may have been formed by flashing of the basecoat solvent as the basecoat was heated up to precoating temperature or by the hot precoat solvent.

To confirm that precoating difficulties were due to the changed conditions of temperature, pressure, and precoat solvent, the next precoat (Run F80) was applied under the same conditions as those used prior to installation of the in-situ precoating device. That is, the basecoat and precoat were both applied under vacuum at ambient temperature using a toluene/xylene solvent.

The precoat showed no signs of holes or cracks associated with flashing of the precoat solvent.

Filtration data obtained using the last precoat is shown in Runs F80 through F86. All tests were run under the same conditions of pressure, temperature, and immersion times. Knife advance rate was varied between 1 and 2 mils per revolution. Average rates for Runs F82 and F84 show the expected decline with decreasing knife advance rate. In Run F86, however, when the knife cut was raised back to 2 mils per revolution from 1 mil per revolution, the rate increase was insignificant. Furthermore, rate data for each individual test show an overall decline throughout Runs F82 and F84 such that the final rate for the 2 mils per revolution test (345 pounds per hour per square foot) is essentially the same as the starting rate for Run F84 (366 pounds per hour per square foot), which was the highest individual rate for Run F86. It would appear that there is a

gradual blinding of the precoat throughout Runs F82 through F86 or that insufficient precoat was removed when returning to the 2 mil cut (Run F86).

In Run F91, light ends were removed from the Tacoma Process Solvent prior to precoating by filtering the solvent on a Buchner Funnel under approximately 17-inches Hg vacuum. Observation of the precoat after precoating but before filtering showed it to have no cracks or holes and to be smooth and uniform. During the heating up of the feed sample in the filter vessel with the precoat, the rupture disc on the vessel blew out and the precoat was lost. All subsequent precoats were applied using filtered solvent.

While data was obtained from only two of the four precoats applied during April 1978, examination of three of the four precoats showed no evidence of the solvent flashing that occurred in earlier runs.

Filtration data in Runs F97 through F103 remained inconsistent with what would be expected from past experience. Eight runs were made. Submergence time (3 seconds), differential pressure (70 psid), and temperature (600°F) were the same for all runs. Knife advance rate was 1 mil per revolution for three runs, 2 mils per revolution for four runs, and 4 mils per revolution for one run. The objective of these runs was to determine the effect of knife advance rate on filtration rate for a precoat applied in-situ and to compare these

rates with vacuum applied precoats. Theoretically, the in-situ precoat should be more compact and on this basis should give equal filtration rates at lower knife advance rates, than would be obtained with vacuum applied precoats. This may, however, be offset by higher resistance of the precoat.

Because of the inconsistency of the data and resultant need for close examination, rate data are shown for each receiver.

Run F97 starts out at rates that are even higher than might be expected for a 2 mil per revolution knife advance. The ash analysis of 0.04 percent indicates that filtration was taking place and that the precoat was intact. The sudden drop in rate is explained by the operator accidentally taking an oversized cut. On subsequent revolutions, therefore, there was no contact between the knife and the precoat. As a result, cake built up on the precoat and the filtration rate dropped to an average of 208 pounds per hour per square foot.

Run F105 was carried out at a knife advance of 1 mil per revolution and resulted in an average rate of 780 pounds per hour per square foot. Compared to an average rate of 1093 pounds per hour per square foot for the first three revolutions of Run F97 at a 2 mil per revolution cut, this rate seems reasonable. The unit was opened after this run as all the unfiltered coal liquid sample had been used up. It is practice at this time to cut one-half of the surface of

the precoat with a 5 mil cut giving an indication of the quality of the precoat. The one-half cut taken at the end of Run F105 showed the precoat to be free of cracks and no noticeable penetration of coal solids into the precoat. Unfiltered coal liquid, however, had entered the space between the leaf wall and the precoat and then flowed through the basecoat into the filtrate receiver. This could account for the exceptionally high initial rate in Run F97.

Run F101 again shows an exceptionally large increase in rate going from an average of 547 pounds per hour per square foot to an average of 1066 pounds per hour per square foot. A third large increase occurs between Runs F103 and F195 where, despite a decrease in knife advance rate from 2 to 1 mil per revolution, the average filtration rate increases from 515 to 780 pounds per hour per square foot.

On all precoats after opening the vessel to change from precoat slurry to filter feed material, a crack was noticed in the precoat in the shape of a "Y". When the leaf was installed 180° from previous runs (Run F108), the crack also appeared in the form of an inverted "Y". There had also been a slight movement of the filter screen in the leaf. Apparently this movement of the screen, as differential pressure across the leaf changes from 0 to 35 psid for precoating or to 70 psid for filtering, is the cause of this crack formation.

Cracks ordinarily are not harmful as they quickly fill in and are sealed off by the solids being filtered out of the liquid. In the case of Run F95, a basecoat of a much coarser grade of precoat material was used. In fact, the basecoat material was coarse enough such that solids in the coal liquid would pass into it and thus would not form a seal.

The combination of crack formation and coarse basecoat material provides a possible explanation of the erratic flow rates described above. Thus, when the precoat is first immersed in the unfiltered coal liquid (Run F97), high rates occur as a result of liquid flowing through cracks in the precoat and then through the basecoat. The drop in rate from an average of 1093 to 208 pounds per hour per square foot is assumed to be coincidental with the extra large knife cut described above. Similar large increases in rates occur in Run F107 where the rate jumps from an average of 547 to 1066 pounds per hour per square foot and between Runs F103 and F105. It is believed that at these points, cracks were opened in the precoat which caused temporary bypassing of the precoat by the unfiltered liquid.

Run F108 was formed with a basecoat of FIBRA-FLO 7C and Standard SUPER-CEL as the precoat. Rates for Runs F115, F117, and F119 were, for all practical purposes, equal even though knife advance rates varied from 1 to 4 mils per revolution. FIBRA-FLO 7C is a much finer material than CELITE AF13 and contains 7-1/2 percent asbestos. The FIBRA-FLO 7C is able to be sealed off by the coal solids and thus

does not allow the high flow rates that occurred with the CELITE AF13 basecoat.

The nearly equal rates for Runs F115, F117, and F119 indicate that the precoat is compacted by the in-situ application to the extent that there is no penetration into the precoat of coal solids beyond a 1 mil depth. Knife advance rates of greater than 1 mil do not result in increased filtration rates.

TABLE VI-3

RUN NO.	DATE (WEEK OF)	PRECOAT GRADE	SOLVENT	PRECOAT		FILTRATION CONDITIONS			FILTRATION RATE lbs/ft ² /hr IMMERSION TIME (3 seconds)	ASH IN FILTRATE (%)
				DIFFERENTIAL PRESSURE psid (nominal)	TEMPERATURE °F (nominal)	DIFFERENTIAL PRESSURE psid	TEMPERATURE °F	BLADE ADVANCE mils/dip (revolution)		
*F80	2/27/78	Standard SUPER CEL	Wash	Vacuum 35	Ambient 300					
F82	3/06/78	AF13 AF5	Xylene/ Toluene	Vacuum 35	Ambient 300	70	600	2	AVG. 484 550 519 545 391 345	NR NR NR NR 0.06 0.06
F84	3/06/78	AF13 AF5	Xylene/ Toluene	Vacuum 35	Ambient 300	70	600	1	AVG. 259 366 304 298 239 172 177	NR NR 0.08 NR 0.09 NR
F86	3/06/78	AF13 AF5	Xylene/ Toluene	Vacuum 35	Ambient 300	70	600	2	AVG. 264 218 287 295 275 263 246	0.07 0.07 NR NR NR NR

*No holes in precoat. Some holes in basecoat.
NR - Not run.

TABLE VI-4. FILTRATION DATA OBTAINED IN APRIL 1978

RUN NO.	DATE (WEEK OF)	PRECOAT		FILTRATION CONDITIONS				FILTRATION RATE lbs/ft ² /hr IMMERSION TIME (3 seconds)	ASH IN FILTRATE (%)	
		PRECOAT GRADE	SOLVENT	DIFFERENTIAL PRESSURE psid (nominal)	TEMPERATURE °F (nominal)	DIFFERENTIAL PRESSURE psid	TEMPERATURE °F			BLADE ADVANCE mils/dip (revolution)
F95	4/03/78	AF13 Standard SUPER-CEL	Xylene/Toluene Tacoma	Vacuum 35	Ambient 290					
F97	4/03/78	AF13 Standard SUPER-CEL	Xylene/Toluene Tacoma	Vacuum 35	Ambient 290	70	600	2 2 2 2 2 2	1014 1197 1069 AVG 1093 251 188 185 AVG 208	0.04
F99	4/03/78	AF13 Standard SUPER-CEL	Xylene/Toluene Tacoma	Vacuum 35	Ambient 290	70	600	1 1 1 1 1 1	419 374 382 288 290 307 AVG 343	0.08
F101	4/03/78	AF13 Standard SUPER-CEL	Xylene/Toluene Tacoma	Vacuum 35	Ambient 290	70	600	2 2 2 2 2 2	581 489 570 AVG 547 1087 1071 1041 AVG 1066	0.53 0.04
F103	4/03/78	AF13 Standard SUPER-CEL	Xylene/Toluene Tacoma	Vacuum 35	Ambient 290	70	600	2 2 2 2 2 2	608 471 461 500 463 589 AVG 515	0.28

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Table VI-5

RUN NO.	DATE (WEEK OF)	PRECOAT		FILTRATION CONDITIONS				FILTRATION RATE lbs/ft ² /hr IMMERSION TIME (3 seconds)	ASH IN FILTRATE (%)	
		PRECOAT GRADE	SOLVENT	DIFFERENTIAL PRESSURE psid (nominal)	TEMPERATURE °F (nominal)	DIFFERENTIAL PRESSURE psid	TEMPERATURE °F			BLADE ADVANCE mils/dip (revolution)
F105	4/03/78	AF13 Standard SUPER-CEL	Xylene/ Toluene Tacoma	Vacuum 35	Ambient 290	70	600	1 1 1 1 1 1	903 853 768 714 722 717 780	0.05
								AVG		

F108 New Precoat; Same Conditions as Run F95 except for a FIBRA-FLO 7C Basecoat. Precoat Lost. No Filtration Results.

F112 Repeat Precoat for Run F108.

F115	4/17/78		Do			70	600	2 2 2 2 2 2	409 411 388 394 369 354 388	0.05
								AVG		
F117	4/17/78		Do			70	600	1 1 1 1 1 1	409 458 389 319 365 283 370	0.04
								AVG		
F119	4/17/78		Do			70	600	4 4 4 4 4 4	400 384 395 387 384 342 382	0.07
								AVG		

TABLE VI-6

RUN NO.	DATE (WEEK OF)	PRECOAT				FILTRATION CONDITIONS				FILTRATION RATE lbs/ft ² /hr IMMERSION TIME (3 seconds)	ASH IN FILTRATE (%)
		PRECOAT GRADE	SOLVENT	DIFFERENTIAL PRESSURE psid (nominal)	TEMPERATURE °F (nominal)	DIFFERENTIAL PRESSURE psid	TEMPERATURE °F	BLADE ADVANCE	DRUM SPEED rpm		
F140	6/12/78	AF13 Standard SUPER-CEL	Toluene Xylene Tacoma	Vacuum 35	Ambient 275	70	600	10-20	8	2400 3532	---- ----
F144	6/19/78	AF13 CELITE 512	Toluene Xylene Tacoma	Vacuum 35	Ambient 275	70	600	4	4	1738 1219 1367 1361 2270 2293 2235 -----	2.9 2.6 --- 3.0 --- --- 3.2 --- 2.9*
F148	6/26/78	AF13 Standard SUPER-CEL	Toluene Xylene Tacoma	Vacuum 35	Ambient 275	70	590	35 4 4 4.2 4.1 4.3	6 6 6 4 4 4	1531 1839 3417 2976 3463 3079	

*Condensate

The rupture disc on the main pressure vessel repeatedly blew out even though it was replaced on each run. Vacuum was thought to be a possible cause of the disc collapsing and that a vacuum support should be used. It is possible that the filter vessel may be under vacuum during the precoating procedure. The basecoat is formed under vacuum. After formation of the basecoat is complete, it continues to be held in place on the leaf as the leaf is inserted in the filter vessel and the flange (with leaf attached) is bolted into the vessel. At this point, the vessel is vented and it remains so until the unit is switched from vacuum to pressure.

Manometer tests showed 1-1/2-inch H_2O vacuum in the filter vessel which does not seem sufficient to collapse a 2-inch disc. Nevertheless, a vacuum support was ordered. Also ordered was an Inconel rupture disc good for temperatures up to 1000°F. This replaces the previous Monel disc. Weakening of the Monel disc by sulphur compounds in the coal liquid is also a possibility. After these changes, no further ruptures of the disc occurred.

Runs F140, F144, and F148 were run on WFF (Sample No. 29717), but produced no data because of precoat failure.

EXAMINATION OF COAL SOLIDS RETENTION BY BASECOATS

The grade of basecoat material should be coarse enough to reduce overall precoat resistance, but fine enough to prevent the passage of significant amounts of coal solids through it.

As a result of problems observed in Runs F97 through F103, the retention of coal solids by different basecoat materials was examined using a Buchner Funnel. Coal solids retention for basecoat grades CELITE AF7, AF9, and AF13 was determined. In these tests, a coarse grade of Watman Filter Paper was wetted with solvent and placed in a 4-inch diameter Buchner Funnel. The funnel was attached to a vacuum system with flasks for collecting precoat and filtrate liquids. A precoat, 1/4-inch thick, was formed on the filter paper by pouring a slurry of filter aid and solvent onto the filter paper under vacuum. This was then followed with unfiltered WFF (No. 29717, Indiana Coal) and flow from the funnel was diverted to the filtrate receiver. Filtrate was filtered through a tared Teflon membrane and weight percent solids were determined. The results are shown in the following table for the different basecoat materials. Relative flow rates of the basecoats are also shown.

BASECOAT		
<u>GRADE</u>	<u>RELATIVE FLOW RATE</u>	<u>FILTRATE WEIGHT PERCENT SOLIDS</u>
CELITE AF7	500	0.35
CELITE AF9	900	0.40
CELITE AF16	1500	2.0

Both CELITE AF7 and AF9 showed a distinct layer of coal solids on their surfaces; whereas the CELITE AF13 precoat showed a much less distinct layer of coal solids and the solids had visibly penetrated into the precoat.

As a result of these tests and observations of precoats in the test leaf, the grade of basecoat material was changed from CELITE AF13 to CELITE AF9. A similar change was successfully made on the 50 Square Foot Pilot Filter at Fort Lewis.

The next two precoats were applied using a 1/4-inch thick basecoat of CELITE AF9. Standard SUPER-CEL was used as the precoat for the first test using standard procedure. After precoating at 275°F and 35 psid, the filter vessel was cooled and opened to exchange precoat slurry for filter feed and for precoat examination. The precoat had shrunk in from the walls of the test leaf and there was one crack in the middle approximately 1/8-inch wide. These were filled with additional precoat by drawing into them under vacuum a slurry of 7 percent CELITE AF5 in process solvent preheated to 180°F. A filtration test run was planned at 600°F and 70 psid using the WFF sample. On the fourth revolution, a very high rate was obtained with

liquid filling up the receiver and flowing into the condenser indicating that the precoat had been dropped. The unit was opened and the precoat examined. The crack in the middle of the precoat was still present and a space between the precoat and the edge of the leaf was filled with coal solids.

The above test was repeated a second time using the WFF sample. Filtration conditions were as follows:

Differential Pressure:	70 psid
Temperature:	600°F
Drum Speed:	7.5 rpm
Knife Advance:	4 mils per revolution

The average filtration rate of runs into six receivers was 1190 pounds per hour per square foot. Filtrate ash analysis in one of the six receivers was 0.49 percent. The rates were consistent with the range being from 1107 to 1258 pounds per hour per square foot. The ash, however, was above specification and indicated a bypassing of coal solids. A second series of tests under the same conditions but at a 2 mils per revolution knife advance produced rates of 1050 pounds per hour per square foot and a filtrate ash of 0.55 percent. The range of rates for the six receivers used was from 1019 to 1110 pounds per hour per square foot. Post examination of the precoat showed it to have a single crack in the middle plus several places around the edge where coal might have bypassed it. There were,

however, no holes and the single crack went only as deep as the basecoat. This indicates that any bypassing of solids must be taking place between the basecoat and the edge of the leaf use of aluminum foil to prevent bypassing of filtrate.

To prevent the bypassing of filtrate described above, a baffle consisting of an annular layer of aluminum foil approximately 1/8-inch wide was cemented to the leaf septum next to the leaf wall which in effect blinded this area. Thus, any flow through the space between the basecoat and the leaf wall was blocked. The seal between the basecoat and baffle is further enhanced as differential pressure across the leaf is increased.

The next precoat was applied to the leaf with baffle. This precoat fell off the leaf due, it is believed, to an expansion of the cement used on the baffle.

The next attempt to construct a baffle consisted of forming the aluminum foil over the leaf wall or cylinder (which is approximately 1/2-inch high) starting at the top of the cylinder and descending down the inner wall and out onto the screen for a distance of approximately 3/16-inch. Thus, if the precoat shrinks and pulls away from the edge of the leaf cylinder, differential pressure will continue to force the precoat against the leaf theoretically preventing bypassing of ash.

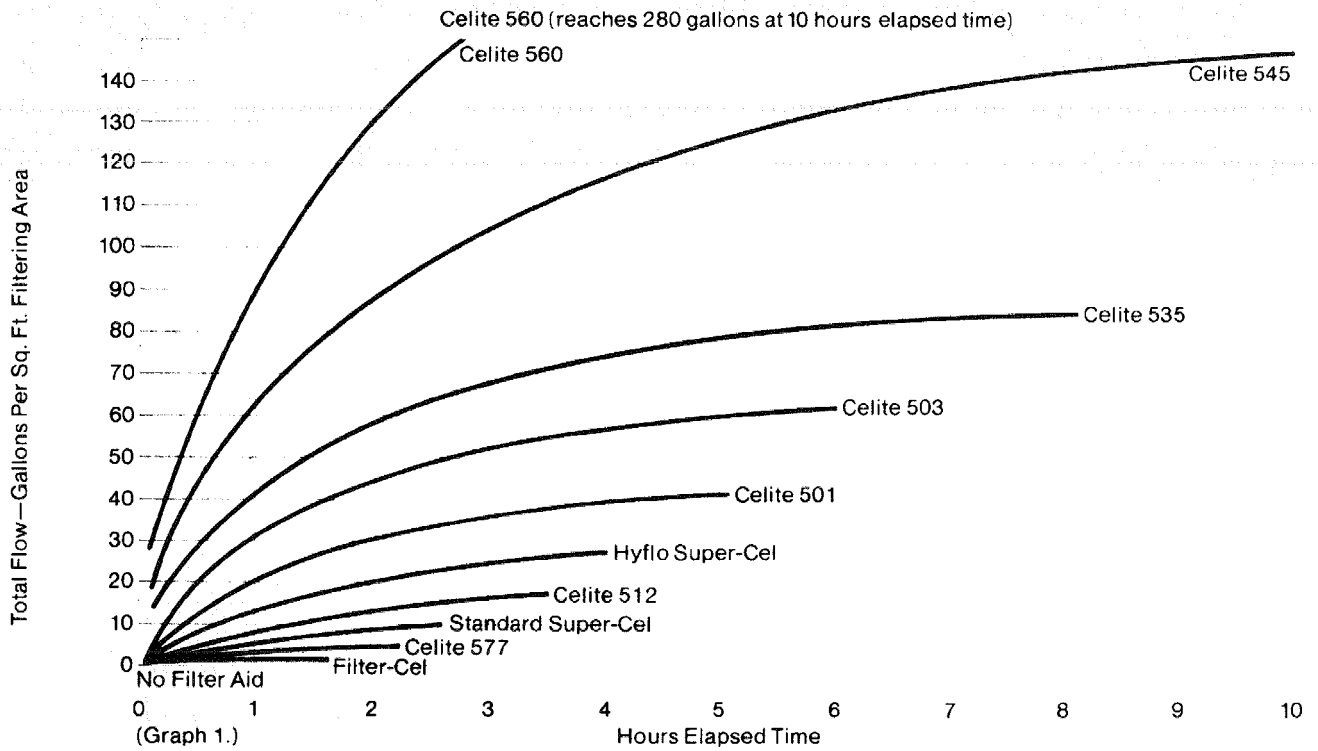
The next precoat was applied in the standard manner for high pressure-temperature application of a CELITE AF9 basecoat and a Standard SUPER-CEL precoat. Filtration was carried out at 70 psid, 600°F, and 2 rpm drum speed using WFF (No. 35834-1). The low drum speed was used because the higher rates obtained at the higher drum speeds overflowed the filtrate receivers. The first set of runs was at 4 mils per revolution knife advance and averaged 833 pounds per hour per square foot. Filtrate ash in Receivers 6 and 9 was 1.03 and 1.95 percent respectively, accounting for the exceptionally high rates.

The second set of runs on this precoat was made at 2 mils per revolution blade advance with no change in the other operating conditions. The average rate into six filtrate receivers was 333 pounds per hour per square foot with ash contents of 0.14 and 0.09 percent respectively in Receivers 4 and 8. The run was stopped at this point.

A partial cut of the precoat was made with the knife before opening the vessel. There was a 1 1/2-inch crack down the middle of the precoat approximately 1/16-inch wide and 1/8-inch deep. There were no signs of holes or erosion. The aluminum baffle was intact. A distinct layer of coal solids remained on the uncut portion of the precoat.

APPENDIX VII
FLOW RATES & PHYSICAL PROPERTIES OF FILTER AIDS

Relative Flow Rates of Celite Grades



Precoat Filter Aids

Used to overcome mechanical and hydraulic deficiencies in the filter to give better clarity and quicker precoat formation.

Name	Composition	Properties and Uses
Fibra-Cel®	Cellulose fiber	Combustible, allowing recovery of suspended solids or where soluble silica is objectionable.
Fibra-Cel Diatomite Blend	Cellulose fiber and diatomite	Widest range of flow rates and clarities. Efficient cake stability.
Acid-Washed Filter Aids Most Celite Filter Aids	Acid washed to reduce iron and calcium content	Used where exceptional purity is needed as in the filtration of distilled spirits and fine chemicals.
Celite Analytical Filter Aid	Maximum acid washing	Used as an aid in filtrations for analytical work.
Adsorptive Materials Sorbo-Cel®	An activated diatomite filter aid	Removes emulsified oil from water.
Micro-Cel®	A synthetic hydrated calcium silicate	Adsorbs free fatty acid and trace amounts of inorganic acids.
Celkate®	A synthetic hydrated magnesium silicate	Removes color and protein hazes from animal and vegetable fats and oils, plus other materials.
Other Filter Aids Celite AF	Process-treated diatomite	Does not flocculate in organic liquids. Provides efficient filtration.
Fibra-Cel AF		Used as a precoat with Celite AF.

Typical Physical Properties ⁽¹⁾

Grades	Color	Fibra-Cel/ Diatomite Blend Equiv- alent(2)	Approx. Median Alpha Rate	Approx. ΔP @ 1 gal./sq. ft./min. with 0.15 lb./ sq. ft. Precoat Filter Aid	Estimated Gal./sq. ft./hr. Water; 6 in. Precoat 24 in. Hg. ΔP	Density lbs./ft. ³		150 Mesh % Retained	% Mois- ture as Shipped	pH Max.	% Solub- les
						Dry	Wet				
Filter-Cel	Gray	1	2	3.2	*	7.0	16	2	3.0	7.0	0.15
505	Pink	3	3	2.0	*	8.0	23		1.0	7.0	0.15
577	Pink	2	5	1.2	*	8.0	18	2	0.5	7.0	0.10
Standard Super-Cel	Pink	5	11	0.7	10	8.0	18	4	0.5	7.0	0.10
512	Pink	6	21	0.4	20	8.0	19	7	0.5	7.0	0.10
Hyflo Super-Cel	White	7	43	0.1	50	9.0	18	6	0.1	10.0	0.15
501	White	8	57	0.07	65	9.5	18	8	0.1	10.0	0.15
503	White	9	80	0.06	130	9.5	18	9	0.1	10.0	0.15
535	White	10	128	0.03	240	12.0	19	10	0.1	10.0	0.15
545	White	11	200	0.02	370	12.0	19	12	0.1	10.0	0.15
550	White	12	322	0.015	600	18.0	21	14	0.1	8.0	0.15
560	White	13	720	0.005	1400	19.5	20	40	0.1	10.0	0.15

(1) As expressed, these are *typical* or estimated physical properties, *not specifications*, and should be used accordingly.

(2) Fibra-Cel grades are designated by a number plus a letter (i.e., Fibra-Cel 7F). The number refers to the equivalent grade of Celite filter aid and the letter to the percent Cellulose in multiples of 2½%; i.e., A=2½%, B=5%, C=7½%, etc.

*Not applicable.

APPENDIX VIII

GLOSSARY

- basecoat A layer of filter aid between the precoat and septum.
- blade Technically the cutting part of the knife. A row of 6-inch long Stellite alloy sections mounted on the leading edge of the knife and used to remove filter cake from the precoat. (In this report blade and knife are used interchangeably.)
- blinding Plugging of a septum by solid material causing the septum to become less permeable.
- chatter A vibration of the knife causing closely spaced axial indentations in the precoat.
- chipping The breaking up into small pieces of a filter cake as it is removed by the knife which in turn lifts up small amounts of precoat leaving irregularly spaced indentations in the precoat.

cycle

A sequence in the operation of a filter.

1. (Most Common) The steps including precoating, filtering, precoat removal, cleaning of the filter and filter system.
2. The steps of filtration, cake washing, cake drying, and cake removal that take place during a single drum revolution. (In this report used interchangeably with drum speed.)

Darcy

A unit of permeability equivalent to the passage of 1 cubic centimeter of fluid of 1 centipoise viscosity flowing in 1 second under a pressure of 1 atmosphere through a porous medium of 1 square centimeter area and 1 centimeter long.

deck

The solid metal surface of the drum on which rests the septum support assembly and septum.

feed

The mixture of particles and fluid that is introduced to the filter.

filter

(verb) To pass a fluid containing particles through a filter medium whereby particles are separated from the fluid.

(noun) A device for carrying out filtration which consists of the combination of the filter medium and suitable hardware for constraining and supporting it in the path of the fluid.

filter cake

The layer of solids, removed in the filtration process, on the surface of the filter medium or precoat.

filter medium

The permeable material that separates particles from a fluid passing through it (in this report, the precoat).

filter system

The combination of a filter with all the associated process hardware required for filtration.

filtrate

The fluid that has passed through the filter.

filtration

The process by which particles are separated from a fluid by passing the fluid through a permeable material.

gouging

The removal of excessive amounts of precoat caused by the buildup of sticky cohesive filter cake at the knife.

heel

The layer of precoat usually 3/8-inch to 1/2-inch thick remaining on the filter drum at the end of a filtration operation. It may either be discarded or a new precoat formed on top of it.

knife

The assembly in which the blade is mounted. (In this report knife and blade are used interchangeably.)

median particle size

That size particle in a group of particles of different sizes such that there are an equal number of particles of greater and lesser sizes.

median pore size

That size pore in a filter cake or precoat such that there are an equal number of pores of greater and lesser sizes.

penetration

The depth to which filtered solids enter a precoat; usually in the order of 1/2 to 4 mils.

permeability

The property of the filter medium or septum that permits a fluid to pass through under the influence of a pressure differential. The reciprocal of resistance.

precoat

The layer of filter aid formed on the drum surface by passing a slurry of filter aid through the filter and which acts as the filter medium.

pore size distribution

Variations in pore sizes in a precoat or filter cake.

porosity

The ratio of void volume to total volume. Usually referring to materials with small connected openings.

pre-precoat

See basecoat.

receiver

The vessel into which the gas and filtrate flow from the filter and are separated.

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