

FILTRATION PROCESS AND
EQUIPMENT STUDIES FOR
COAL LIQUEFACTION PROCESSES

QUARTERLY REPORT FOR MARCH-MAY 1977

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QUARTERLY TECHNICAL PROGRESS

TASK II - LABORATORY FILTRATION TESTS

SUMMARY AND CONCLUSIONS

Filtration rates in excess of 700 pounds/hour/square foot were obtained at 100 psid differential pressure (600°F, 100 psid, 4 and 2 mil/cycle, 2 second immersions).

Filtration rate dependence upon differential pressures up to 100 psid has been studied. Rates in excess of 450 pounds/hour/square foot (600°F, 100 psid, 5 second immersions, 4 mils/cycle) were obtained.

A timing device has been installed on the test leaf allowing more accurate rate calculations, particularly for short immersion times. Rates obtained for two second immersions, simulating a 12 rpm drum speed, were above 650 pounds/hour/square foot (600°F, 70 psid, 4 mils/cycle blade advance).

Filter aid usage under these conditions would be high, but can be lowered by reducing the knife advance rate. Filtration rates near 600 pounds/hour/square foot (600°F, 70 psid, 2 mils/cycle) were obtained at the same immersion times. Filter aid consumption was reduced

about 40 to 45 percent with only a 10 percent reduction in filtration rate, as the knife advance rate was successively cut in half from 4 mil/cycle to 2 mil/cycle to 1 mil/cycle.

Initial use of a non-asbestos filled pre-precoat of CELITE 550 resulted in a 12 percent increase in filtration rate with acceptable filtrate ash content. Additional evaluation of a non-asbestos pre-precoat indicates slightly higher ash contents of 0.07 percent ash. Improper precoating technique falsely indicates a significant reduction in filtration rate. Future tests will properly evaluate the effect of the use of non-asbestos pre-precoats upon filtration rate.

EXPERIMENTAL DETAILS AND DISCUSSION

During the Quarter, March 1977 through May 1977, filtration runs on unfiltered solvent refined coal (SRC) from Fort Lewis were performed on the rotary pressure precoat filter test leaf.

The results of runs performed during March 1977 and April 1977 are summarized in Table 1. The results of experiments performed during May 1977 will be treated separately. Each run consists of 15 to 25 immersions of the filter leaf under controlled conditions of temperature and differential pressure. Usually six

data points on filtration rate are obtained during the course of each run. Each data point is based on 1 to 4 immersions. The rates entered in Table 1 are the average of 2 or more data points or the last observation of a sequence if a trend is evident.

As introduced in February 1977, Report No. FE-2007-28, the filter aid usage is included in Table 1. Note that the usage data are expressed as pounds of filter aid per 1000 pounds of filtrate.

TABLE 1. DATA FROM FILTRATION RUNS - MARCH 1977
ALL RUNS ON TFF 216 AT 600F USING AF5 PRECOATS

RUN NO.	PRESSURE DIFFERENTIAL psid	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	3 second	5 second	10 second	20 second	2 second	3 second	5 second	10 second	20 second
D15	40	4			>139	> 90					<17.3	<13.3	
D17	60	4			370	255					6.5	4.7	
D19	80	4			447	257					5.4	4.7	
D21	100	4			459	261					5.2	4.6	
D23	100	2			376						3.2		
		4			451						5.3		
		7			468						9.0		
		10			472						12.7		
D27	70	4			>347						< 6.9		
D29	70	4					244					4.9	
D31	70	4	658							9.1			3.8
D33	70	4						158					
D35	70	2	485		332	209				6.2		3.6	2.9
D39	70	4			350							6.9	
D41	70	4						148					4.1
D43	70	2	590							5.1			
D45	70	2			331							3.6	
D47	70	2				205	127						2.9
D47	70	2								127			2.4
D51	70	4	675							8.9			
D53	70	2	607							4.9			
D55	70	4			526						7.6		
D57	70	2			464						4.3		
D61	100	4			>352						< 6.8		
D63	100	2			303						4.0		
D65	100	4					268					4.5	
D67	100	2					199					3.0	
D69	100	4						138					4.3
D71	100	2						126					2.4

TABLE 1. DATA FROM FILTRATION RUNS - APRIL 1977
 Runs on TFF 216 at 600F, 70 psid Differential Pressure Using AF5 Precoats

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

A device to time the immersions of the test leaf has been installed allowing more accurate rate determinations. Previously, five second immersions were assumed to be exactly 5.0 seconds as timed with a handheld stopwatch subject to human reaction time variations. If the actual immersions were biased by a uniform amount, for example, 4.7 seconds, an error of 6 percent in the rate calculation results. With the new timing device, the immersion time is obtained as 4.7 seconds which is then used in the filtration rate calculation eliminating the bias.

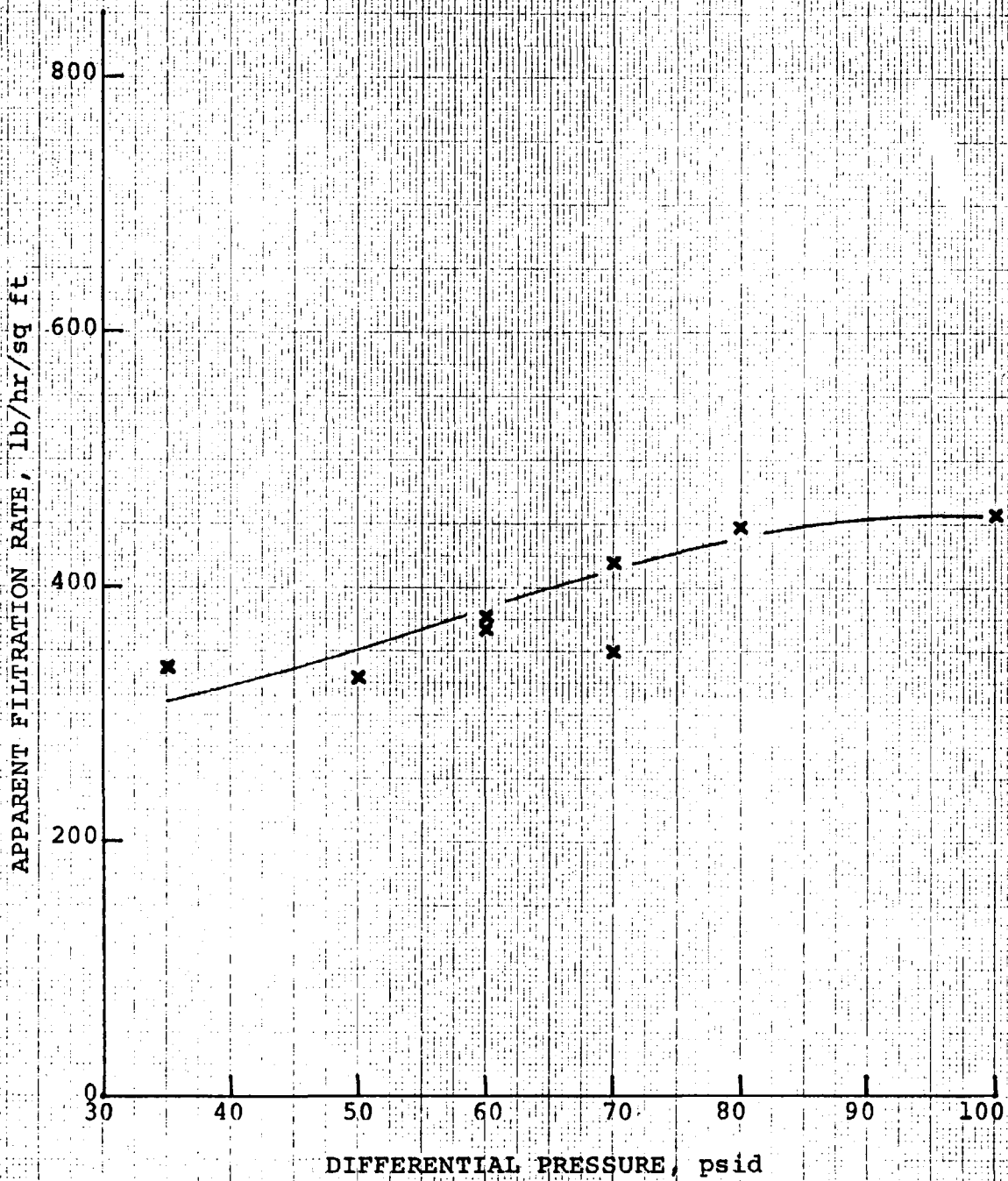
The majority of measured immersion times have been found to be within 0.2 seconds of the planned immersion times, regardless of the length of immersion. Thus, very short immersion times around 2 seconds vary by as much as 10 percent, while longer immersion times around 20 seconds vary by at most 1 percent. Since timing errors exist around the planned immersion times, the immersion times reported in Table 1 and the corresponding drum speeds based on such planned immersion times are, therefore, nominal times and drum speeds, not exact values.

The series of Runs D15 through D21 was a differential pressure study from 40 psid to 100 psid (600^oF, 4 mils/cycle, 5 and 10 second immersions, CELITE AF5 precoat) in 20 psid increments. The results of these runs are shown in

Figure 1 along with data from previous runs at the same conditions. The apparent filtration rate increased to about 450 pounds/hour/square foot at 80 and 100 psid from about 350 pounds/hour/square foot at 35 psid as previously reported. The low rates at 40 psid for Run D15 are attributed to little or no knife cutting of the initially compressed precoat. This situation was discussed at length in Report No. FE-2007-28 for February 1977.

FIGURE 1
FILTRATION VERSUS DIFFERENTIAL PRESSURE

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



Run D23 was a knife blade advance study at 100 psid, 600°F, and 5 second immersions. The results are shown in Figure 2 along with previously reported results at the same conditions for 35 psid and 70 psid. The rate versus knife advance results show fine solids penetration and partial precoat blinding between 2 and 4 mils/cycle blade advance. Future runs will be performed using the next grade finer precoat material to see if smaller precoat cuts can be made without sacrificing filtration rate.

The filter aid usage for the results shown in Figure 2 are plotted in Figure 3. The lowest filter aid usage obtained was at the smallest knife cuts, even though the filtration rates were lower than at larger knife cuts.

FIGURE 2
FILTRATION VERSUS KNIFE ADVANCE

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

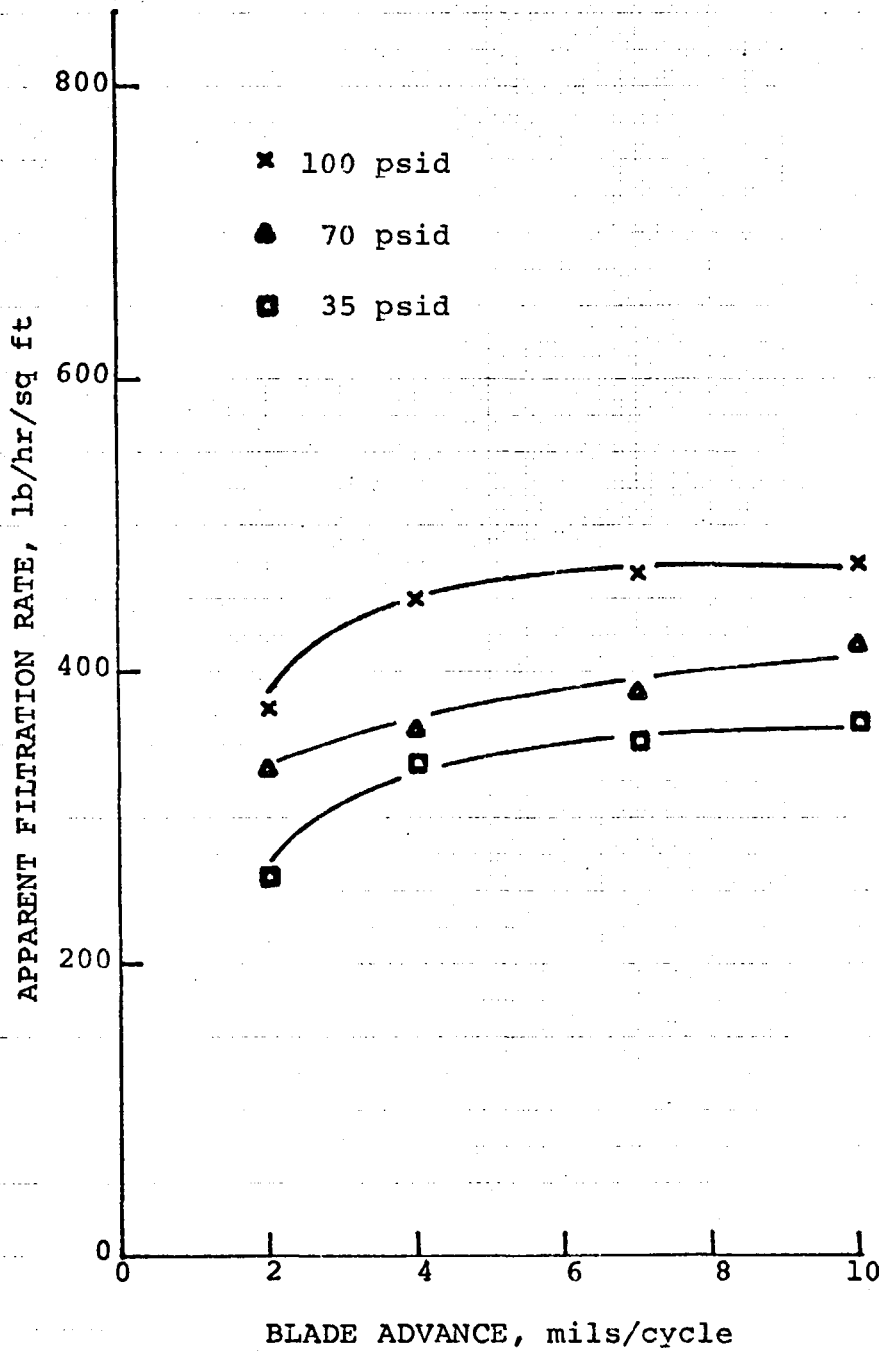
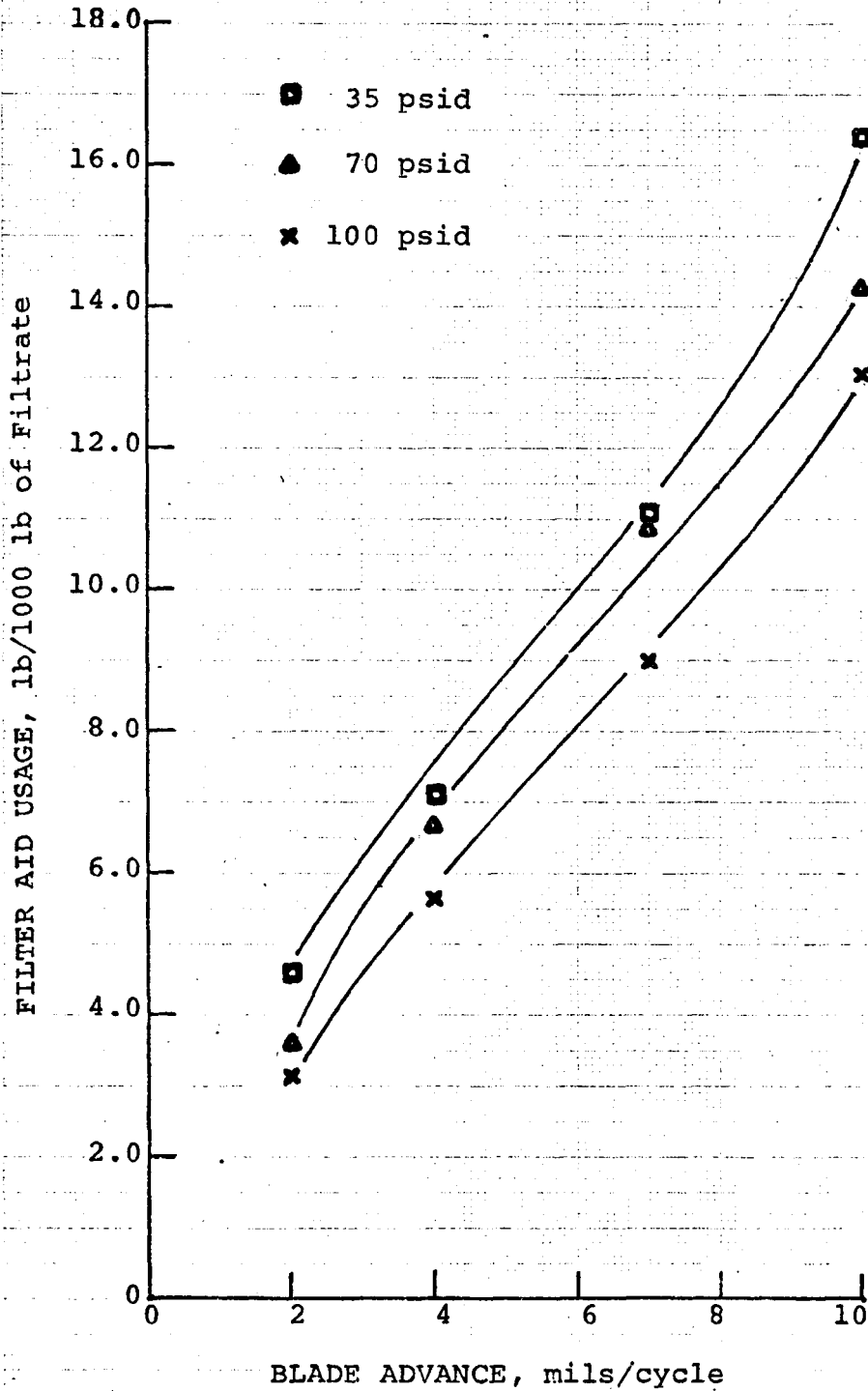


FIGURE 3
FILTER AID USAGE VERSUS KNIFE BLADE ADVANCE

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



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

For example:

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

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 4 and 5. 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/hour/square foot and higher. In Figures 4 and 5, the curvature above 6 rpm is attributed to test equipment limitations. 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 dynamic differential pressure change is a larger proportion of the immersion time. The actual rates would be slightly higher than those shown for 8 and 12 rpm.

FIGURE 4
FILTRATION VERSUS DRUM SPEED
TFF 216, 600F, 70 psid, AF5 Precoat, 40% Submergence

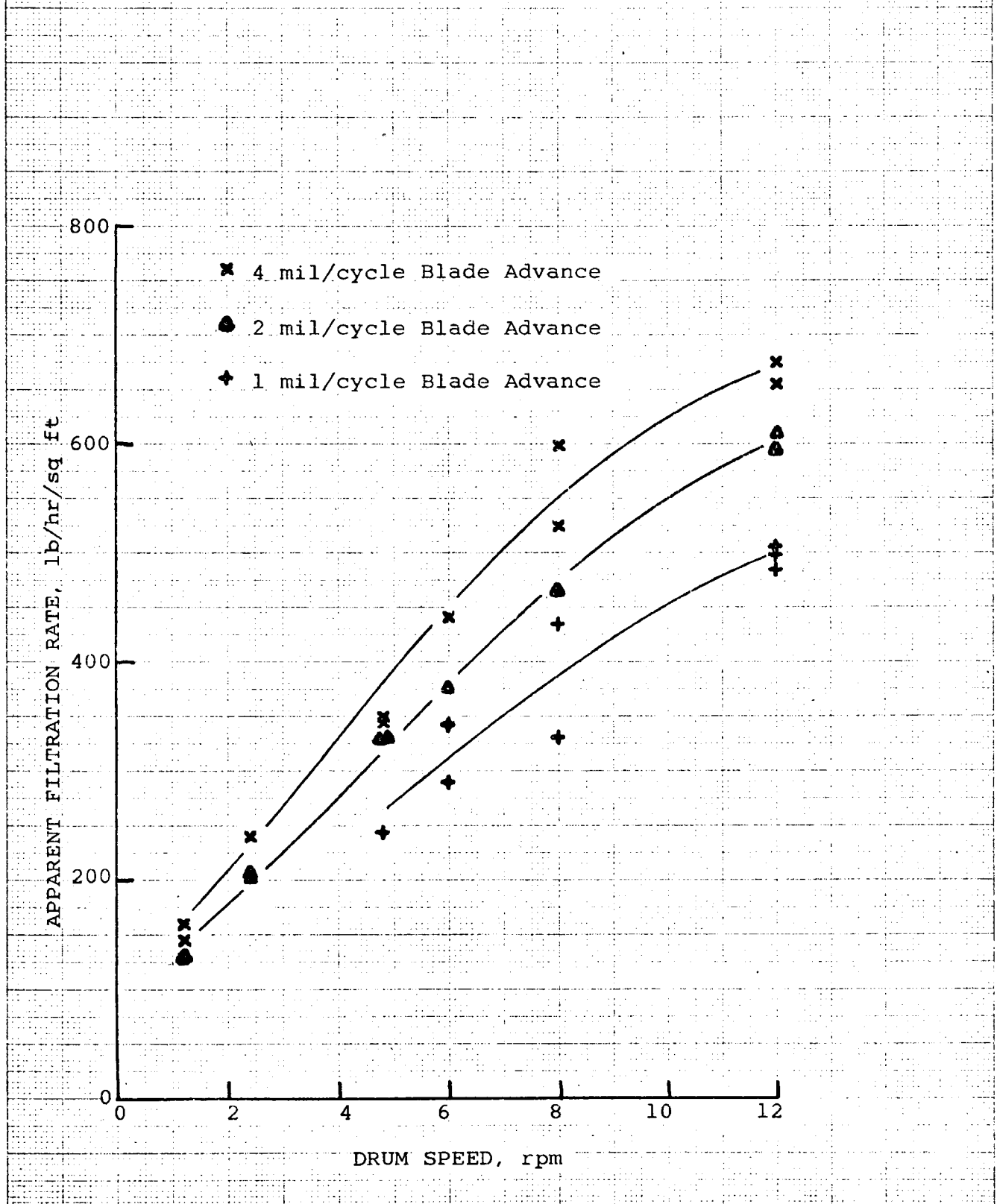
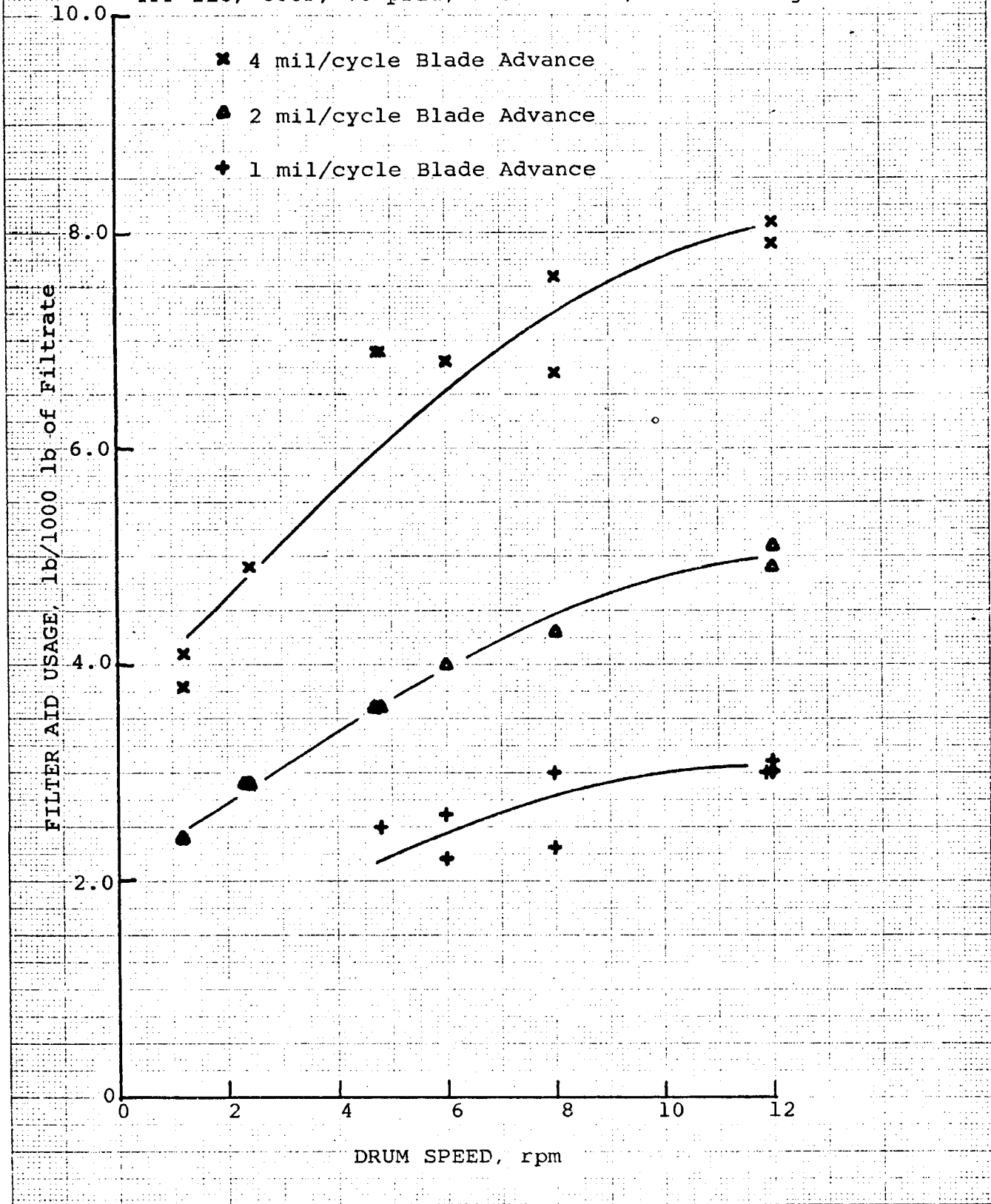


FIGURE 5
 FILTER AID USAGE VERSUS DRUM SPEED
 TFF 216, 600F, 70 psid, AF5 Precoat, 40% Submergence



The second significant result is the large reduction in filter aid usage upon going from 4 mil/cycle to 2 mil/cycle to 1 mil/cycle knife blade advance with only a minor reduction in filtration rate. Overall, filter aid usage appears to be reduced about 40 to 45 percent for about a 10 percent loss in filtration rate as the knife blade advance is progressively cut in half. For example, Run C71 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/hour/square foot. These rates are typical for long submergence times of 20 seconds.

The third significant result concerns the reproducibility of the experimental results. The close correspondence of most runs at similar conditions is evident in Figures 4 and 5. The multiple points at a given drum speed and knife blade advance represent runs performed at different times on different samples of the same filter feed. The results indicate that a good degree of confidence in the validity of the results of most experiments can be assumed. Occasionally, a data point will be grossly out of line with an obvious trend in the results and usually some cause for the irregularity such as a change in the differential pressure or a precoat

breakout has been identified, justifying the elimination of such a data point from the overall result.

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 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 this may also reduce filtration rate.

Knife advances of less than 2 mils/cycle on the test leaf may not be extremely reliable as indicated by the greater degree of scatter in the results at 1 mil/cycle. Therefore, such experiments should be approached with some caution. In contrast, the Electric Power Research Institute sponsored 50 Square Foot Pilot Filter presently being constructed for PAMCO at Fort Lewis has been designed to allow very accurate knife blade advance rates permitting more precise control of filtering conditions. More valid conclusions regarding filtration economy should be available from the operation of the pilot filter at PAMCO in Fort Lewis.

The series of Runs D75 through D81 were performed at 100 psid differential pressure. The results at 100 psid are compared with results at 70 psid in Table 2.

TABLE 2
 APPARENT FILTRATION RATE
 lb/hr/sq ft

Immersion Time, seconds	100 psid		70 psid	
	4 mil/ cycle	2 mil/ cycle	4 mil/ cycle	2 mil/ cycle
2	725	704	665	600
3	511	495	563	465
5	456	298	440	375

There appears to be a marginal increase in filtration rate of about 5 to 10 percent obtained by increasing the differential pressure from 70 psid to 100 psid. Further work will be required to arrive at an absolute conclusion.

The last series D113 through D121 was the start of tests to investigate the use of a non-asbestos pre-precoat. A 1/4-inch thick pre-precoat of CELITE 550 was applied to the test leaf prior to precoating with CELITE AF5. CELITE 550 is a coarse grade filter aid which should prevent CELITE AF5 bleeding through the leaf screen into the filtrate while actually causing

less flow resistance at the leaf screen. Results with CELITE 550 are compared with results using the asbestos filled pre-precoat in Table 3.

Filtration rates with the CELITE 550 pre-precoat were about 12 percent higher than for the asbestos filled pre-precoat. The filtrate ash analyses averaged 0.7 percent ash with the CELITE 550 pre-precoat, which is not quite twice the ash analyses obtained with the asbestos filled pre-precoats. The ash contents were within the specified limits of 0.15 percent ash.

Subsequent tests performed in May 1977 and discussed below indicate that the above filtration rates should be considered with some caution.

TABLE 3

APPARENT FILTRATION RATE
 pound/hour/square foot; 600F, 70 psid, AF5 Precoat
 2 second Immersions, 40% Submergence

<u>mil/cycle</u>	<u>CELITE 550</u>	<u>Asbestos Filled</u>
4	766	665
2	660	600
1	551	495

The major portion of the experimental work performed on the test leaf filter during May 1977 was devoted to the evaluation of the effect of filtration rate of blowdown time and further evaluation of non-asbestos pre-precoat materials.

A brief review of a portion of the experimental procedure will clarify the need for an evaluation of the effect of blowdown time. With the test leaf system at temperature and pressure, receivers in place and heated, an experimental filtration proceeded as follows:

1. Open bottom valve on receiver
2. Open top valve on receiver
3. Immerse test leaf for planned time
4. With test leaf out of liquid, blowdown through receiver for some specified period of time (previously 30 seconds)
5. Close top valve, then bottom valve of receiver

Since the blowdown gas from the main pressure vessel contains some volatile material which might condense in the receivers, the amount of blowdown condensate depends on the length of blowdown time or equivalently the amount of blowdown gas passing through the receivers. Initial tests indicated that 30 second blowdown times could contribute significant quantities of material to the filtrate collected in the receivers. Subsequent tests are summarized in Table 4, comparing

30 second blowdown times with 15 second blowdown times. The 15 second blowdown times more closely simulate the portion of operation of a drum filter between the end of the immersion in the filter feed and the knife cutting portion of the cycle. The results shown in Table 4 indicate that there is little difference in filtration rate between 30 second and 15 second blowdown times.

TABLE 4

COMPARISON OF FILTRATION RATES WITH
30 SECOND BLOWDOWN VERSUS 15 SECOND BLOWDOWN

lb/hr/sq ft at 70 psid, 600°F
CELITE AF5 Precoat, FIBRA-FLO 7C Pre-Precoat

<u>DRUM SPEED</u>	<u>KNIFE CUT</u>	<u>30 SECOND BLOWDOWN</u>	<u>15 SECOND BLOWDOWN</u>	<u>PERCENT DIFFERENCE</u>
12 rpm	4 mil	665	716	+7
12 rpm	2 mil	600	583	-3
8 rpm	2 mil	465	427	-9
6 rpm	2 mil	375	388	+3
4.8 rpm	4 mil	345	328	-5
			AVG.	<u>-1.4</u>

Tests performed in May 1977 using CELITE 550 as a non-asbestos pre-precoat material in place of the previously used FIBRA-FLO 7C indicate a slight increase in ash content from 0.05 to 0.07 percent ash and an apparent reduction in filtration rate as indicated in Table 5, contradicting the results reported in Table 3. Although the rates shown are lower, the overall data appears to indicate that significant compression of the CELITE 550 has occurred. This compression has been attributed to improper precoating technique. The runs reported in Table 3 indicate that precoat was probably applied properly so that less compression occurred resulting in the favorable conclusions indicated. Future runs will avoid the above difficulties so the use of non-asbestos pre-precoats can be properly evaluated.

The test leaf filter is being modified to allow in situ precoating and filter cake washing.

TABLE 5

COMPARISON OF RATES WITH DIFFERENT PRE-PRECOATS

lb/hr/sq ft at 70 psid, 600°F
 CELITE AF5 Precoat, TFF 216

<u>DRUM SPEED</u>	<u>KNIFE CUT</u>	<u>PRE-PRECOAT</u>		<u>PERCENT DIFFERENCE</u>
		<u>FIBRA-FLO 7C</u>	<u>CELITE 550</u>	
4.8 rpm	1 mil	265	314	+16
6 rpm	1 mil	310	320	+ 3
8 rpm	2 mil	465	400	-16
8 rpm	1 mil	385	328	-17
12 rpm	2 mil	600	513	-17
12 rpm	1 mil	495	484	- 2

OTHER ACTIVITIES & COMMENTS

Installation of 50 Square Foot Pilot Filter at Fort Lewis, Washington

Construction of the Pilot Filter remains on schedule with shipment expected in late June.

A technical assistance proposal for installation, startup, testing, and evaluation has been written for Gulf Mineral Resources Company.

Drawings for the Filter plus other information relative to installation have been forwarded to Gulf Mineral Resources Company, Fort Lewis.

Diatomite Ore Reserves

At projected usages, there are ample reserves for the foreseeable future. The total amount of diatomite mined in the United States is approximately 500,000 tons/year.

Diatomite is currently being mined in California, Nevada, and Washington. Western United States reserves are currently estimated by the United States Bureau of Mines at 600,000,000 tons. Approximately 20 percent or 132,000,000 tons of the above reserves are convertible into filter aids of the type projected to be used for liquefied coal filtration. Diatomite growth has been relatively stable, following the Gross National Product.