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AN INDUSTRIAL APPLICATION OF THE JPL ACTS WITH ENERGY RECOVERY

Prepared By

Marshall F. Humphrey
California Institute of Technology
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103

George E. Wilson
Terry W. Schroepfer
Eutek, Inc.
1828 Tribute Road
Sacramento, California 91103

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INDUSTRIAL APPLICATION OF JPL ACTS WITH ENERGY RECOVERY

INTRODUCTION

Some of the earliest reported studies of the application of powdered activated carbons (PAC) to wastewater were conducted by West Virginia Pulp and Paper Company (1). These studies involved the development of PAC adsorption isotherms in terms of COD removals. The studies concluded that an intermediate quality PAC, Aqua Nuchar, might be a cost effective adsorbent for COD removal from municipal wastewater.

Subsequent PAC studies have concerned themselves with alternatives for dewatering and handling spent PAC, regeneration, and, advanced wastewater treatment with more sophosticated carbon contacting and separation systems (2, 3, 4).

Use of solid waste as an alternative source of raw material for production of PAC was investigated at Stanford University (5). Lignite was suggested as a supplemental raw material for the PAC when the waste solids were insufficient to meet the JPL ACTS process demand (6).

The JPL Activated Carbon Treatment System (ACTS) was the first to make use of sewage solids derived from the municipal wastewater treatment system as a source of organic material for PAC. This PAC would then be utilized for COD removal from the wastewater and as a filter aid in the recovery of additional sewage solids. The process was first described in 1974 (7). Figure 1 is a schematic illustration of the proposed system. A 10,000 gpd trailer mounted pilot facility was constructed at JPL and applied at the Orange County Sanitation District's Wastewater Treatment Facility, Plant number 1. The results of the pilot studies were sufficiently promising to warrant construction of a 1 MGD system at the plant (8, 9). A schematic of the 1 MGD JPL ACTS

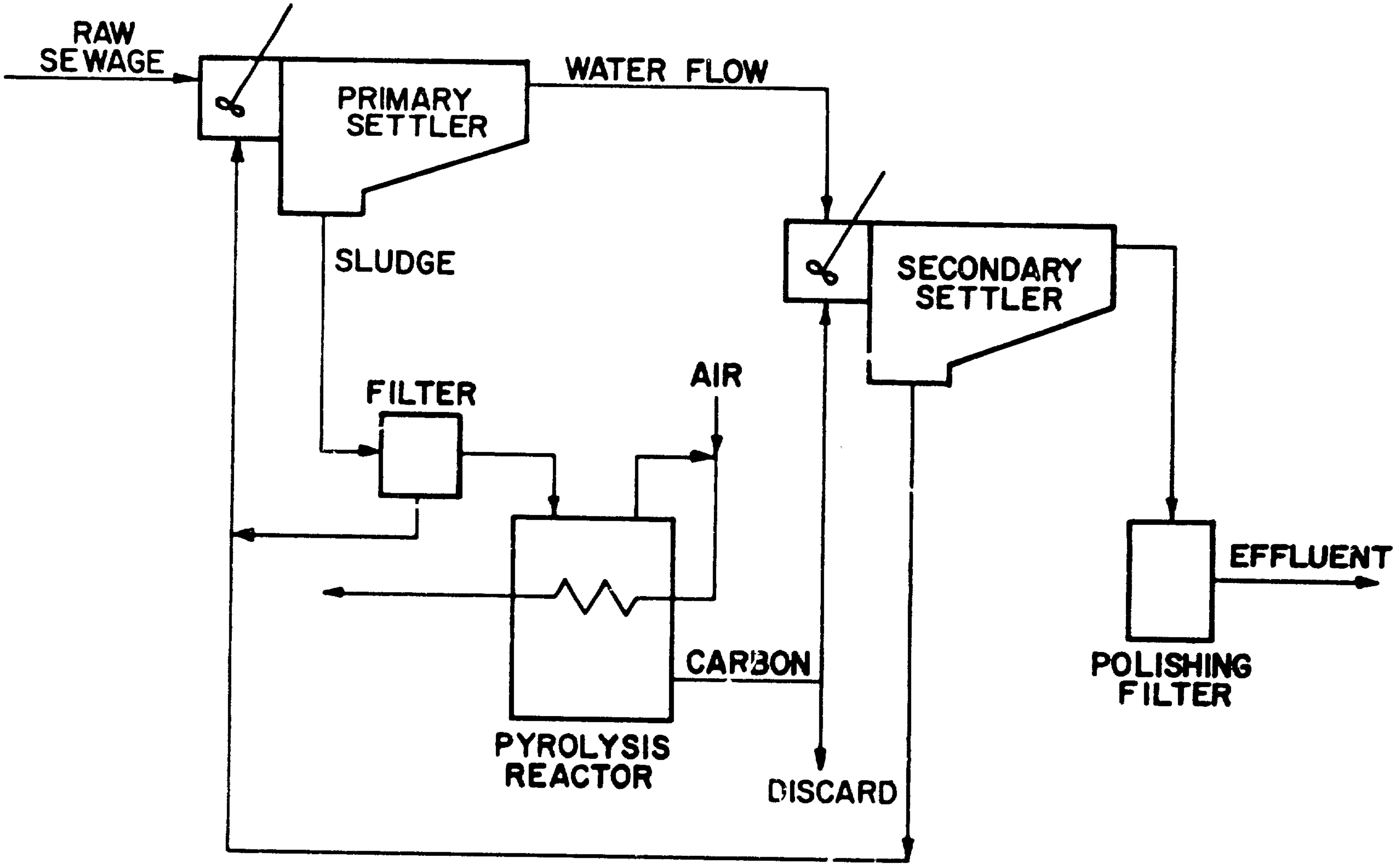


FIG. I JPL ACTIVATED CARBON TREATMENT SYSTEM (ACTS)

OCSD pilot plant is shown on Figure 2. Results of the 1 MGD pilot facility operation have been reported by the Resources Management Center of the County Sanitation Districts of Orange County (10). Recently, Humphrey has provided a critique of the work performed to date on the application of JPL ACTS to municipal wastewater treatment (11).

In April 1980 JPL contracted with EUTEK, INC. to:

> "Provide a definitive demonstration of JPL's Activated Carbon Treatment System (ACTS) for the purification of a selected industrial wastewater. This demonstration shall be performed with the existing trailer mounted pilot facility, modified and updated to adapt the ACTS process to a particular selected wastewater. Accomplishment of this program will first require that the contractor survey the potential commercial application of ACTS and determine the proper candidate industries. Since the objective of this work is to demonstrate the effectivity of the ACTS, the industry selected for the demonstration will be based on selection criteria of potential impact and reasonable measure of success."

This paper will describe the results of this work.

STUDY OBJECTIVES

An early investigation of the potential of JPL ACTS for industrial application was undertaken by Koebig and Koebig Inc. under contract to JPL (12). The final report was submitted on 18 April 1975. This study was with the application of the ACTS process as illustrated on Figures 1 and 2 to several industrial applications. JPL ACTS was compared with alternative activated carbon systems and the activated sludge wastewater treatment system. It was concluded that for the best practicable control technology currently available (BPCTCA), JPL ACTS would not provide as economical a

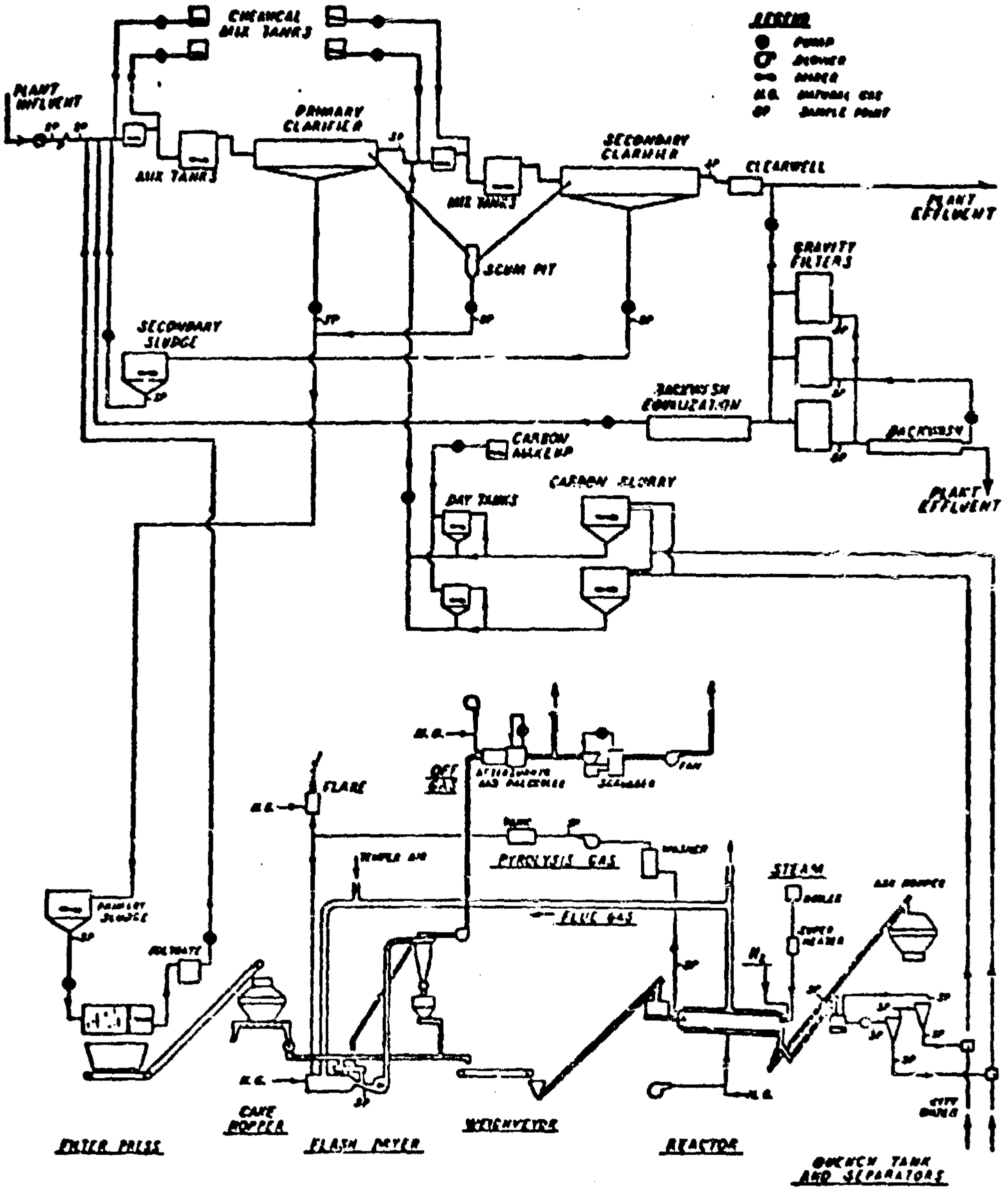


FIG. 2 JPL-ACTS OCSD PILOT PLANT SCHEMATIC

wastewater treatment alternative as the conventional activated sludge treatment system.

In the present study, it was intended that a different approach be taken in evaluating the potential of JPL ACTS for industrial applications. Allowance was made for modification of JPL ACTS, as applied to municipal wastewater treatment, in order to assure the highest degree of success in an industrial application. A survey of industries would be made in order to select industries for which JPL ACTS would have the greatest potential of success. The survey results were to be confirmed through pilot scale demonstration of the feasibility of the modified JPL ACTS process.

The established basis for successful industrial application of JPL ACTS has been summarized on Table 1. The study results will be discussed in terms of the following objectives.:

1. Required JPL ACTS modifications for profitability and integrability in industrial applications.
2. Industrial survey of need and profitability of a modified JPL ACTS.
3. Pilot scale demonstration of feasibility of modified JPL ACTS.

REQUIRED JPL ACTS MODIFICATIONS FOR PROFITABILITY AND INTEGRABILITY

PAC User Markets

During the mid 1970's no increase in activated carbon production was occurring and the prospects for alternative sources were not optimistic (13). However, since 1976, the growth in the activated carbon market has been impressive as illustrated on Figure 3. New plants have recently come on-line for production of activated carbon (14). Approximately half of the total activated carbon production is PAC and the remainder granular activated carbon (GAC).

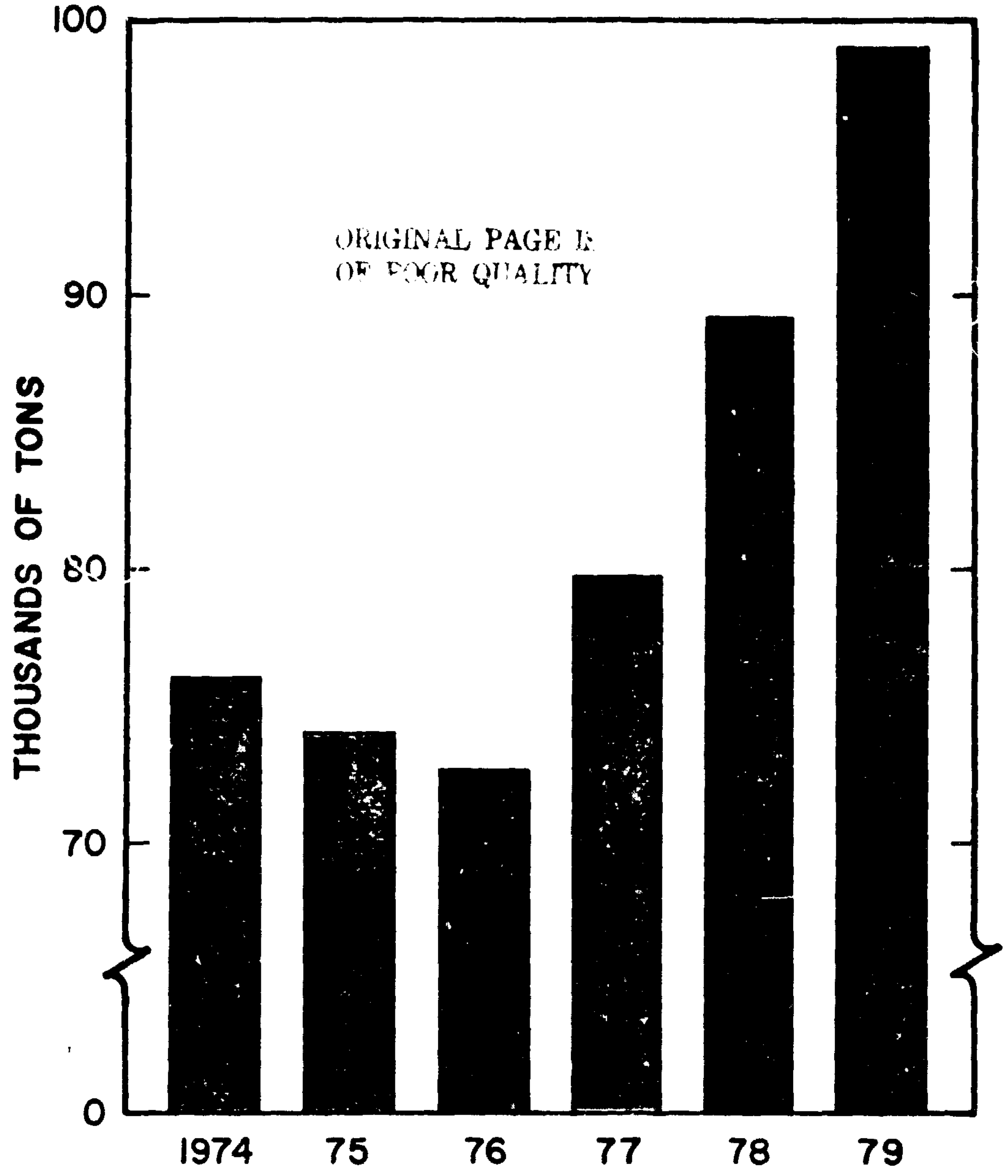
TABLE 1

BASIS FOR SUCCESSFUL INDUSTRIAL APPLICATION

1. NEED
   a. Current wastewater and/or solid waste disposal problems resolvable by JPL ACTS.

2. ECONOMIC ADVANTAGE (PROFIT)
   a. JPL ACTS approach must be decidedly less costly by industry standards than other available alternatives for resolving wastewater and/or solid waste disposal problems.

3. MANAGEMENT FEASIBILITY (INTEGRABLE)
   a. Application of JPL ACTS must be integrable within existing industry management policies and structures.



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FOR DECOLORIZING AND WATER PURIFICATION GRADES. SOURCES: DEPARTMENT OF COMMERCE, BUREAU OF THE CENSUS.

FIG. 3 ACTIVATED CARBON MARKET GROWTH

In wastewater treatment there will be new markets generated for PAC in certain industries due to the mandated requirement for industry to implement best available technology economically achievable (BATEA) by 1984. In addition to effluent standards for conventional pollutants such as COD and BOD, standards will be implemented as well for 65 classes of priority (toxic) pollutants.

In upgrading BPCTA activated sludge treatment facilities to BATEA facilities there is a growing interest in the addition of PAC directly into the aeration tank. Benefits of this treatment have been demonstrated by the DuPont PACT process as well as several oil refining industries (15, 16). Of particular interest to the oil refining industry is control of phenols through the use of PAC.

The use of significant quantities of PAC on a "throw away" basis through addition to BPCTCA activated sludge systems appears to be a cost effective means of achieving BATEA effluent standards. Many studies have established that this approach is more cost effective than utilization of granular activated carbons (GAC). JPL ACTS, with careful selection of source material, has the potential of providing an economical source of pollutant-specific PAC which should represent a viable alternative to commerically produced PAC in supplying this coming market.

PAC Source Material

The JPL ACTS process as illustrated on Figures 1 and 2 cannot be easily adapted to upgrading BPCTCA activated sludge treatment facilities to BATEA facilities. Waste activated sludge represents an extremely difficult material to dewater. The ash content of the resultant char would be impratically high for efficient carbon utilization. The cost of producing such a low grade

PAC from waste activated sludge would make the process uneconomical in comparison with commercially available PAC.

Those industries for which addition of PAC to activated sludge represents a feasible means of upgrading to BATEA are generally industries having few available organic solids to utilize as source material for PAC. Alternatively, those industries having significant quantities of organic solids as source material for PAC are generally industries which have no need to upgrade with PAC. These latter industries are primarily those involved with food products and food processing. Thus, the most practical source of material for PAC is to be found in a different class of industries than those in which its application will soon have most advantage.

There are other benefits as well which may result from the utilization of food product waste solids as PAC source material. On the one hand, there is a wide range of such materials which might potentially be utilized as a source material. It is known that both the surface groups on activated carbon and the initial pore structure of the material have a strong influence on the affinity of the activated carbon for specific pollutants (17, 18). By carefully screening alternative source materials, it should be possible to obtain organic source material for specific priority pollutants (pollutant-specific PAC).

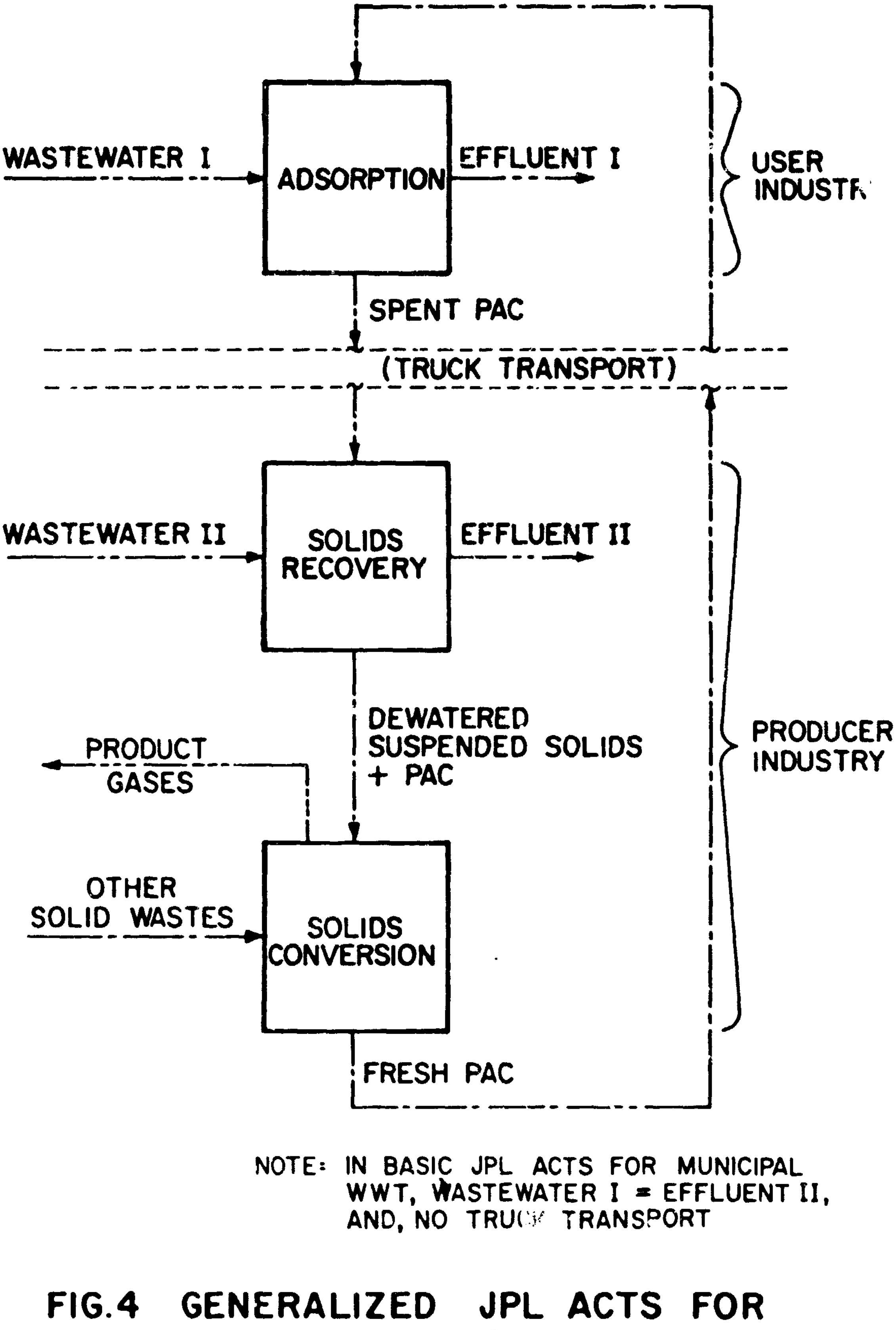
Producer vs. User Industries

Due to the practical necessity of separating PAC industrial user markets and JPL ACTS PAC source material industries it was apparent that municipal wastewater treatment JPL ACTS as illustrated on Figures 1 and 2 would have to be generalized for a profitable and integrable industrial application. Dr. William Spuck of JPL concieved the more generalized scheme illustrated on

Figure 4. Figures 5 and 6 illustrate elements of the generalized JPL ACTS. User industries of the JPL ACTS PAC would be those in which PAC added to existing activated sludge systems could upgrade such systems to meet BATEA standards. Producer industries on the other hand, would be food product handling or food processing industries in which specific types of organic solids are currently disposed of either as solid waste or wastewater suspended solids. These specific solids would be identified in terms of the specificity of the resultant PAC for priority pollutants. The adsorption stage of JPL ACTS would be utilized in the user industry. Solids recovery and solids conversion stages would be utilized by producer industries.

On Figure 6 has been illustrated the modifications proposed for the trailer mounted pilot facilities for demonstration of feasibility of the JPL ACTS for such an industrial application. It will be noted in comparing Figure 6 and Figure 1 that the settling basins for recovery of municipal sewage organic solids have been replaced with continuous filter belts(CFB)as would be more appropriate for the higher solids concentration encountered in food processing wastewaters. The solids dewatering plate and frame filter and flash dryer serviced by an off-gas scrubbing system illustrated on Figure 2 have been replaced by an indirect dryer. The adsorption step is essentially a duplication of the solids recovery step in the event that large quantities of PAC required for removal of priority pollutants would be recovered and regenerated.

The PAC requirements of a typical oil refinery activated sludge system might range from 1500 to 2500 annual tons of PAC as carbon. The market value of commercial PAC in these quantities would be approximately $700



NOTE: IN BASIC JPL ACTS FOR MUNICIPAL WWT, WASTEWATER I = EFFLUENT II, AND, NO TRUCK TRANSPORT

FIG.4 GENERALIZED JPL ACTS FOR INDUSTRIAL APPLICATION

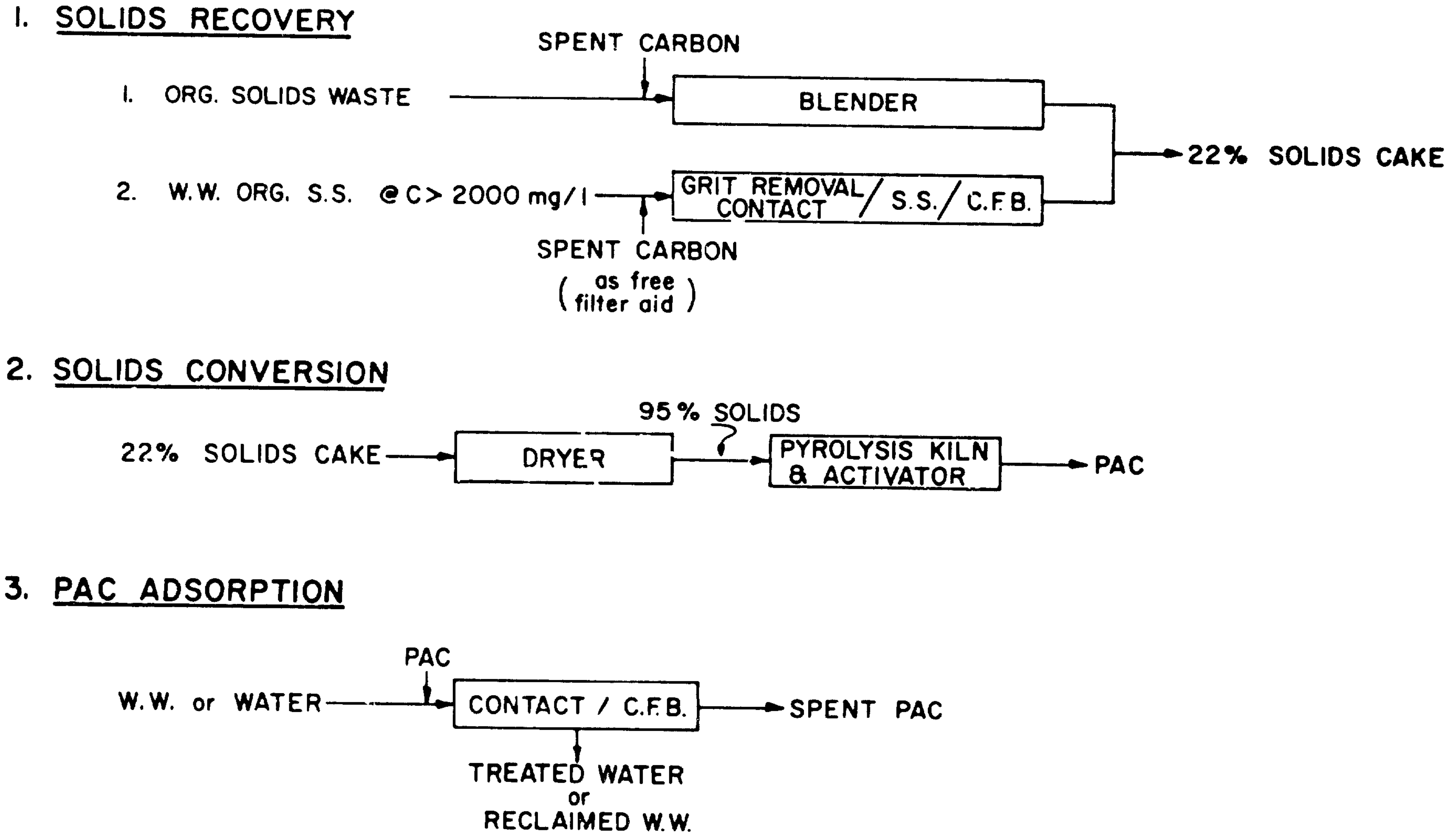


FIG. 5 ELEMENTS OF JPL ACTS

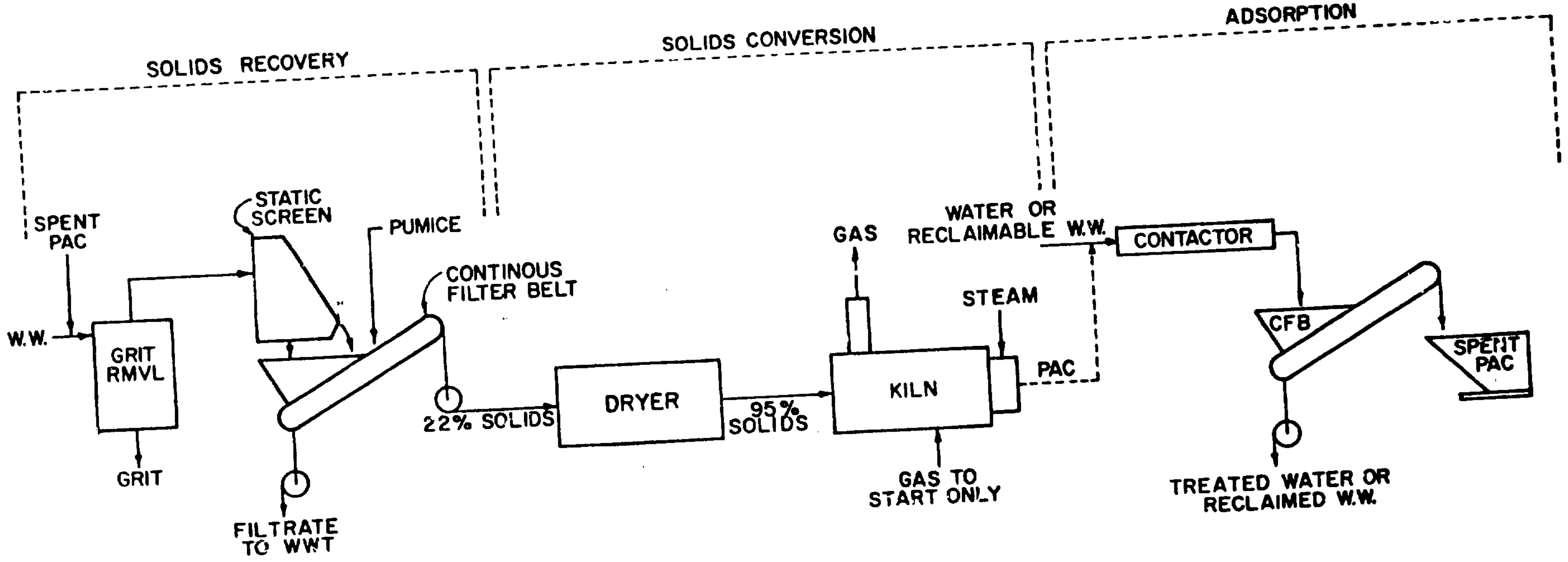


FIG. 6 PROPOSED PILOT FACILITY MODIFICATIONS

per ton. JPL ACTS PAC would have to meet this scale of demand for each oil refinery wastewater treatment plant served. For economical production the producer industry should have pollutant-specific organic solids containing less than 10% ash in quantities of 6,000 to 10,000 or more annual tons derivable from waste solids and/or recovered wastewater suspended solids in streams with suspended solids concentration in excess of 2500 milligrams per liter. These quantities have been summarized on Table 2.

INDUSTRIAL SURVEY OF NEED AND PROFITABILITY

User Industry

Numerous industries were contacted during the industrial survey to determine their potential need for JPL ACTS PAC in meeting the 1984 BATEA standards. Surveyed industries having a need to upgrade for priority pollutants removal included oil refineries, petro-chemical and chemical processing industries. Of these industries, the significant wastewater volumes are associated with major oil refinery operations. Furthermore, phenols are a PAC adsorpable priority pollutant which occur in varying amounts in these wastewaters and are anticipated to require greater removal in the 1984 BATEA standards.

Grieves et al (15) have recently reported on successful application of PAC to upgrading oil refinery BPCTCA activated sludge treatment facilities to BATEA through addition of PAC to the activated sludge aeration basins. Table 3 summarizes their conclusions. In the industrial survey, it was found that oil refineries are most interested in those treatment alternatives involving modifications of existing biological wastewater treatment systems in order to meet BATEA standards. Addition of PAC to activated sludge units or aerated lagoons represents one such alternative. This industry is now

TABLE 2

BASIS FOR INDUSTRIAL ECONOMIC JPL ACTS PROCESS

---

1. User industry requiring 1500-2500 annual tons of PAC @ 35¢/lb of carbon.

2. Producer industry organic solids (less than 10% ash) of 6,000-10,000 tons annually derivable from waste solids and/or recovered wastewater suspended solids in streams with SS concentrations in excess of 2500 mg/l.

TABLE 3

PAC ADDITION TO OIL REFINERY ACTIVATED SLUDGE SYSTEMS (REF. 15)

- Powdered-carbon-enhanced activated sludge systems can be successfully operated for extended periods at very high sludge ages (100 days), provided optimum pretreatment is used.
- Such systems can produce effluents with quality comparable to that of tertiary treatment by granular carbon adsorption.
- Except at the very highest effluent qualities, the powdered carbon activated sludge system is many times more cost-effective than granular carbon adsorption.
- The experimental high-surface-area powdered carbon evaluated, if commercially available, would improve the cost-effectiveness of the powdered carbon enhanced activated sludge system.

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involved in investigation of a number of alternatives of reducing priority pollutant concentrations in treated wastewater streams.

Producer Industries

There is generally no economic advantage for the food processing industry to utilize PAC in wastewater treatment. However, the industry does produce significant quantities and varieties of organic solid waste materials which are disposed of as either solid waste or are discharged with wastewaters as suspended solids.

On Table 4 has been summarized the nature of organic solids contained in wastewaters discharged by this industry. If these suspended solids are discharged to industrial wastewater treatment facilities, the cost for total aerobic digestion would amount to approximately $45. per thousand pounds of suspended solids discharged. Discharge of the same amount to a typical municipal treatment system would cost the industry approximately $41. Should these suspended solids be recovered as in JPL ACTS, care must be taken not to "squeeze" intracellular COD-containing juices from the organic solids into the filtrate stream. Much of what can be gained by JPL ACTS solids recovery would be lost should this occur.

Costs for disposal of organic solid wastes are typically less. Reported costs generally range from $5 to $15 per ton of wet solids. In some cases, solid wastes can be sold as animal feed. However, reported values as animal feed were minimal, generally less than $5 per wet ton.

On Table 5 has been summarized the required solids concentrations which must be fed to the JPL ACTS pyrolysis kiln and the resultant energy yield for a producer industry as a function of the feed solids composition and the kiln thermal efficiency. Kiln efficiencies have been reported to range from

TABLE 4

THE NATURE OF FOOD WASTEWATER

ORGANIC SOLIDS DISPOSAL COSTS

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1. COD/SS ratio ∿ 2
2. lbs O_2/lb COD for total oxidation ∿ 2
3. Oxidation efficiency 2 lbs O_2/hp-hr
4. For total destruction with Mechanical Aeration, energy cost $45/1000 lbs SS @ 3¢/kwh
5. Municipal treatment costs at $25/1000 lbs SS + $8/1000 lbs COD would be 25 + 2(8) = $41/1000 lbs SS
6. Organic solids cannot be "squeezed" without significant loss of COD content

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TABLE 5

ENERGY YIELD VS. FEED COMPOSITION (1)

Feed Solids Composition	35% Kiln Efficiency		65% Kiln Efficiency	
	Breakeven % Solids	Energy Yield BTU/lb PAC	Breakeven % Solids	Energy Yield BTU/lb PAC
100% Organic Waste Solids	40	1200	67	9600
50% Organic Waste Solids & 50% Spent PAC	47	< 900 >	75	2400
100% Spent PAC	44	< 3100 >	73	< 800 >

(1) Assumes: 2000 BTU/lb H_2O evaporated using kiln waste heat
25% conversion of organic solids to PAC
80% recovery of spent PAC

35 to 65% for indirect fired systems as are required in the production of PAC in JPL ACTS (19). The heat contained in the exhaust gases from the kiln can be utilized for indirect solids drying as illustrated on Figure 7. Drying efficiency has been assumed to be that of a conventional dryer. Higher efficiencies should be achievable through development of mechanical vapor recompression (MVR) in conjunction with dehydration step (20).

As illustrated on Figure 7, product gases from the kiln would be recycled as required for maintenance of the kiln operating temperature. Excess product gases would represent energy yield. If product gases are not sufficient to meet the kiln energy requirements, additional gas would have to be provided as required.

If solids are supplied to the dryer at solids concentrations above the breakeven percentages shown on Table 5, the process as shown on Figure 7 would operate with the energy yield (or gas required) as shown on Table 5. If solids concentrations are less than those breakeven percentages, additional fuel would be required to dry to the breakeven solids concentrations in order that the remainder of the process could operate as illustrated on Figure 7.

The most energy efficient operation for the producer industry would involve a feed solids composition consisting entirely of a selected organic solid waste. Under these circumstances the producer industry should realize a net energy yield of approximately 10,000 BTU per pound of PAC produced. Solids would have to be provided at reasonably high solids concentrations (67%).

Solids recovery of waste organic solids utilizing spent PAC as a filter aid and supplied as a very dry solids to an efficient kiln would represent

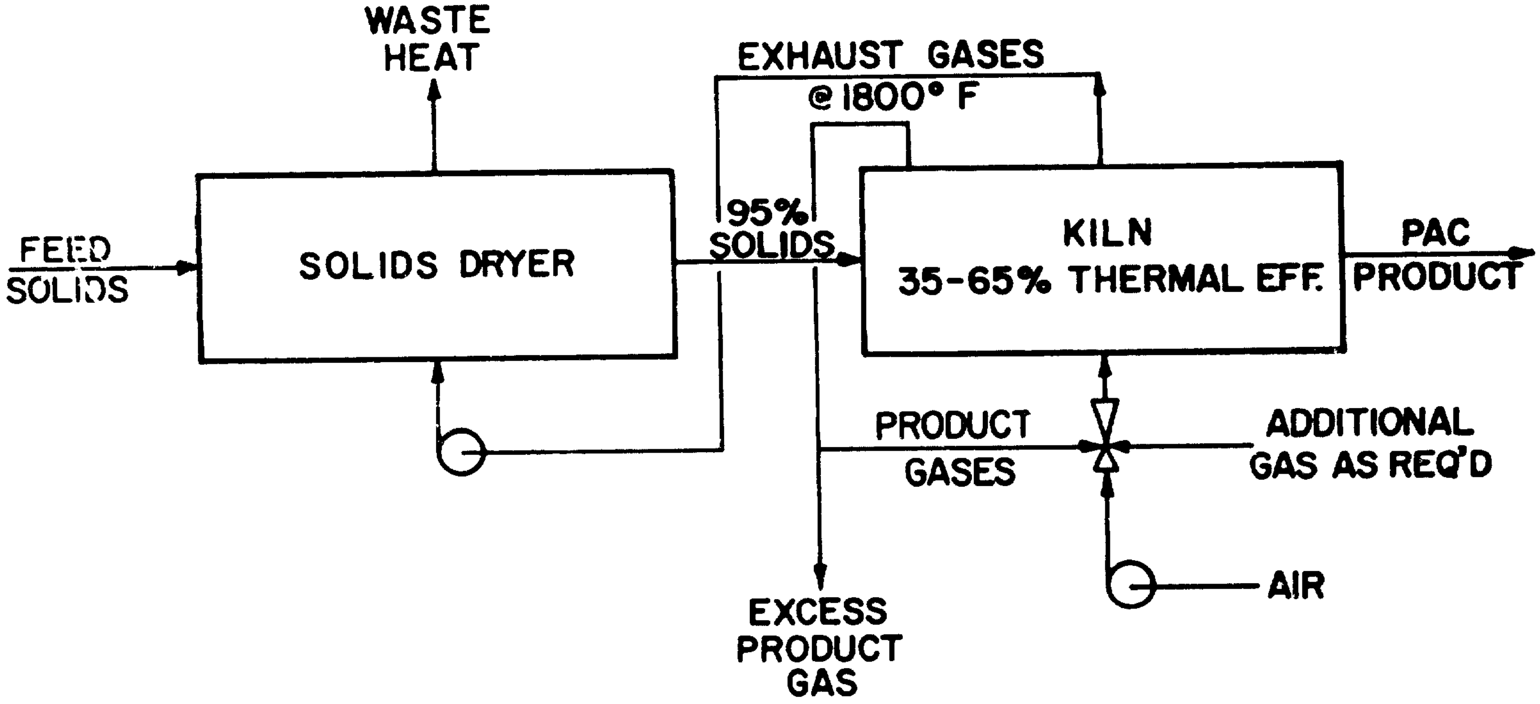

FIG. 7 SOLIDS CONVERSION WITH ENERGY PRODUCTION

the next most energy efficient configuration yielding approximately 2500 BTU per pound of PAC produced. However, achievement of a dewatered 75% solids feed to the solids dryer is probably not practical and would make this configuration of doubtful feasibility.

The only remaining configuration listed on Table 5 which would continue to yield energy would be the supply of selected 100% organic solid waste to a relatively inefficient kiln. In this case, the waste heat from the kiln exhaust gases would be able to accomplish a higher degree of drying and therefore a much lower breakeven feed solids concentration could supply the system (40%). Energy yield would be correspondingly low at 1200 BTU per pound of PAC produced.

If it were desired to regenerate a 100% spent PAC solids feed such a configuration would not be energy yielding, but would require a net amount of additional fuel.

The insoluble ash content of the resultant char is an additional consideration of importance for the producer industry in selecting the type of feed solids composition. With 25% conversion of organic solids to carbon, organic waste solids containing 20% insoluble ash would result in a product carbon containing 50% insoluble ash. If this high ash content char were to be regenerated, the ash content of the resultant product would be extremely high. There would be a corresponding reduction in adsorption capacity per unit weight of char.

In order that the capacity of the product PAC be commensurate with that of commercial carbons, ash content of the organic waste solids should be less than 10% and desirably less than 5%. Utilization of this material on a "throw away" basis would insure that the ash content of the JPL ACTS would remain comparable with that of commercial PAC.

In carbonizing organic solids, care should be taken to keep gasification to a minimum. As summarized on Table 6, the heat of combustion value of carbon as a fuel is significantly less than the value of the product PAC.

PILOT SCALE DEMONSTRATION

Solids Conversion

The solids conversion portion of JPL ACTS was evaluated utilizing dried apple pumice, the product of apple juice production. The solids concentration of the pumice ranges from 40 to 60%. Solids consist primarily of rice hulls which are supplied on a one-to-one basis with pulverized apples to the juice press. The JPL ACTS solids conversion scheme originally considered is illustrated on Figure 8. While MVR dehydration of apple solids was found to be feasible on a laboratory scale, and may be a much more efficient drying process, it was not possible to incorporate a pilot scale MVR dehydrator in the demonstration. Instead, hot-stack gases from the kiln were pressed through storage bins containing the solids for dehydration as illustrated on Figure 9.

Good energy and mass balances had not been possible in previous studies with the pilot scale kiln (11). In the present demonstration, attention was given to monitoring and sampling at all essential points in the system to obtain mass and energy balances. The sampling points and monitoring program utilized in the solids conversion demonstration have been illustrated on Figure 10 and tabulated on Table 7.

The solids conversion stage operated smoothly with a 100% organic solid waste feed. Consistent and steady gas production was achieved with a consistent and steady solids feed. Product gas quality was of reasonably consistent composition (Table 8). Gas composition was different from that reported for

TABLE 6

CARBON VALUES

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1. FUEL

    14,087 Btu/lb

    $\$5/10^{6}$ Btu

    $14{,}087 \times 5 \times 10^{-6}$ = 7¢/lb as fuel

2. PAC

    Valued at 35¢/lb (quantity)

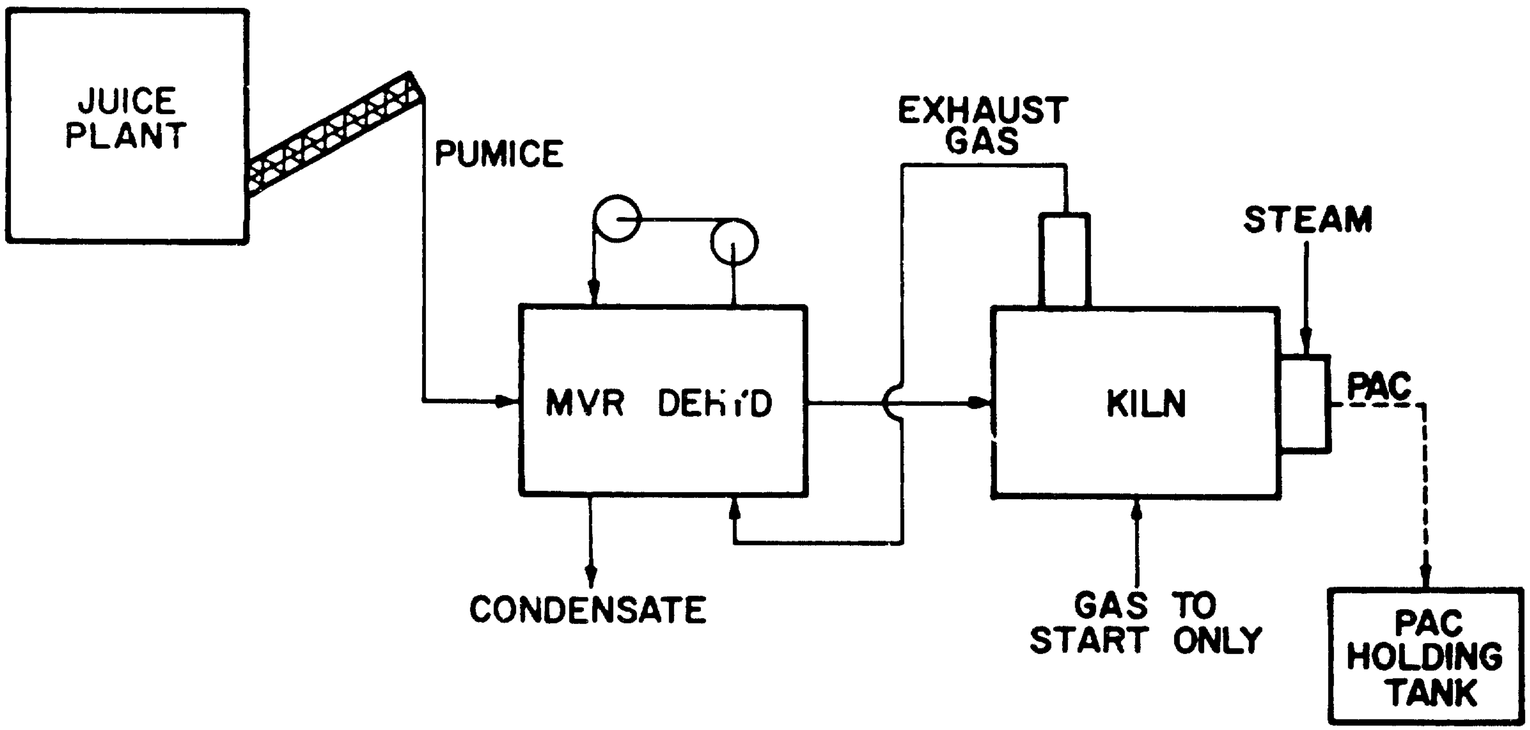


FIG. 8 JPL ACTS APPLIED TO APPLE JUICE SOLID WASTES

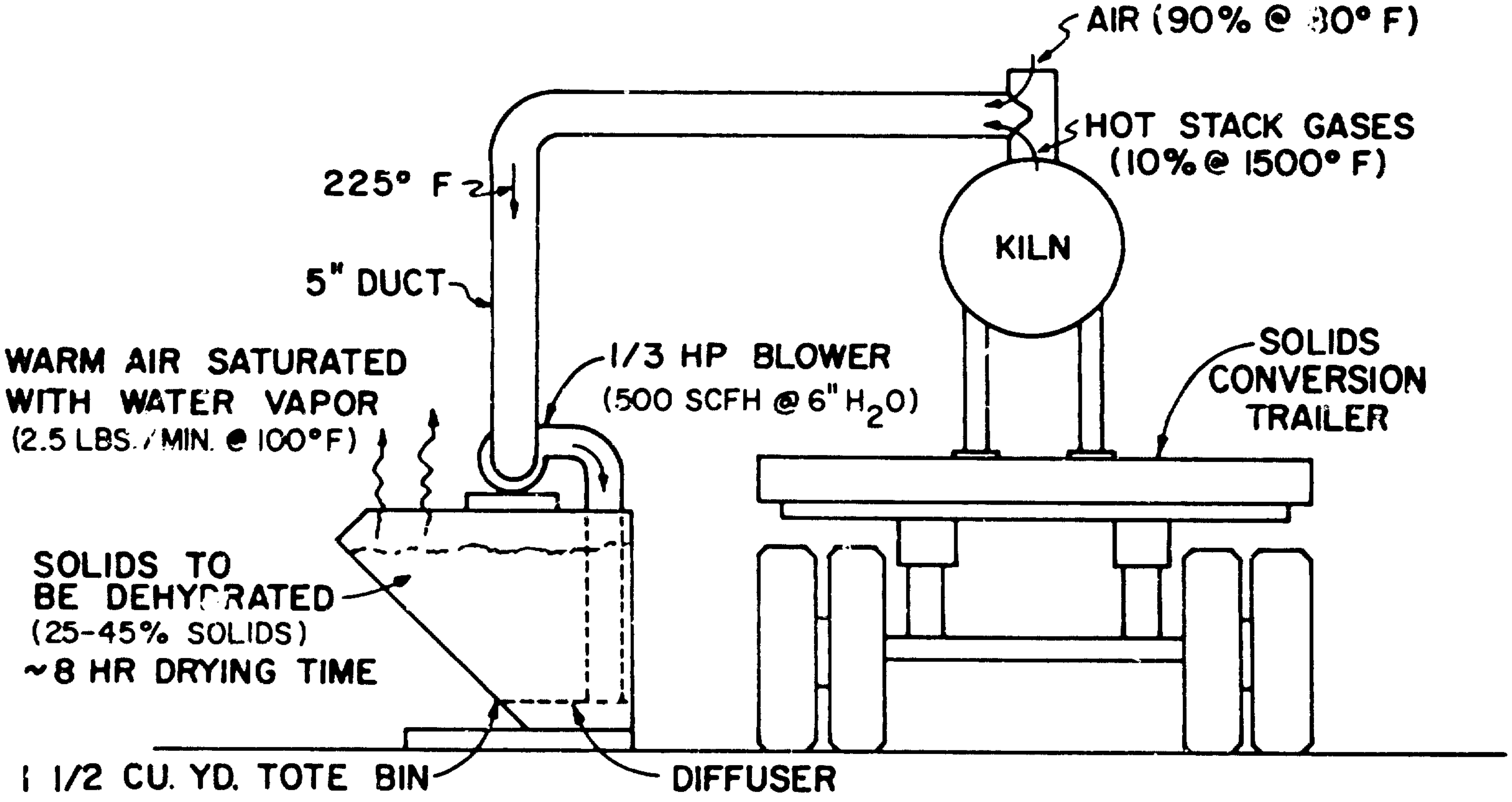


FIG. 9 APPLE PUMICE DEHYDRATION SYSTEM

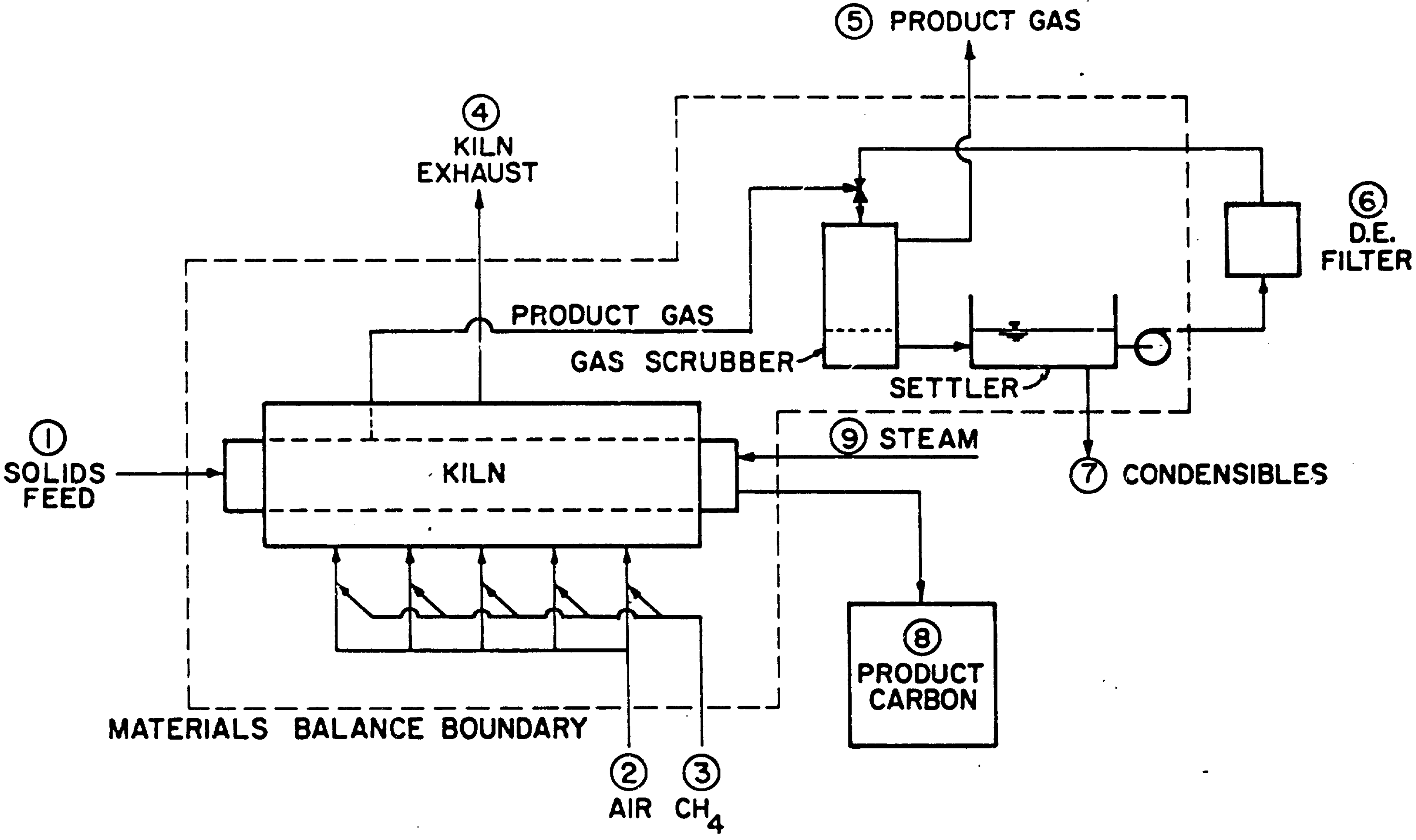


FIG. 10 SOLIDS CONVERSION MATERIALS AND ENERGY BALANCE BOUNDARY WITH SAMPLE POINTS

TABLE 7

JPL ACTS DEMONSTRATION

SOLIDS CONVERSION MONITORING PROGRAM

Sample Point	Items to be Monitored	Frequency
Solids Feed	1. Mass (lbs)	As Fed
	2. % solids	Daily Composite
	3. % volatile matter	Daily Composite
	4. Feed rate (lbs/hr)	Hourly
	5. Feed screw rotation (rpm)	Hourly
	6. Temperature	Hourly
	7. Kiln rotation (rpm)	Hourly
Kiln Air Supply	1. Flow rate (cfh)	As Needed
	2. Temperature	As Needed
Kiln Fuel Supply	1. Flow rate (cfh) and total accumulated flow	Hourly/Daily
	2. Temperature	Hourly
Kiln Exhaust	1. Temperature	Hourly
Product Gas	1. Flow rate and total accumulated flow	Hourly/Daily
	2. Temperature	Hourly
	3. Gas composition (CO_2, CO, H_2, CH_4)	5 Per Day
	4. Gas heat content (BTU/scf)	5 Per Day
D.E. Filter	1. Accumulated mass gain or change in volatile matter	Daily
Condensibles	1. Accumulated volume (mass)	Hourly
	2. Total and volatile solids concentration	Daily
Product Carbon	1. Temperature	Hourly
	2. Mass (lbs)	Daily
	3. Iodine number	Daily
	4. % Ash	Daily
Steam Injection	1. Temperature	Hourly
	2. Mass	Daily

TABLE 8

KILN OFF-GAS COMPOSITION

GAS	UNIT	SAMPLE BAG NO. 1	BAG NO. 2	BAG NO. 3	BAG NO. 4	PREVIOUS STUDIES REF. (9)
Hydrogen(1)	(%)	43	42	45	41	32.5
Carbon Monoxide(2)	(%)	27.4	27.4	27.4	27.2	35.3
Carbon Monoxide(2)	(%)	10.6	10.8	10.1	10.9	18.3
Methane (2)	(%)	5.1	5.4	5.1	5.4	10.5
C_1 (3)	(%)	5.6	5.9	5.6	5.5	
C_2 (3)	(%)	1.4	2.5	1.1	1.1	3.5
C_3 (3)	(ppm)	581	542	315	322	--
C_4 (3)	(ppm)	243	215	132	141	--
C_5 (3)	(ppm)	17	19	13	29	--
Total Amines(4)	(%)	1.8	1.9	1.7	1.6	--
H_2S(5)	(ppm)	--	30-40	--	--	--
NH_3(5)	(ppm)	--	<50	--	--	--
$NO-NO_2$(5)	(ppm)	--	< 1	--	--	--
TOTAL ACCOUNTING (%)		89.8	90.5	90.9	87.2	100.1

All units are v/v.

(1) Analysis by gas chromatography: Molecular Sieve 5A and Porapak Q columns in series with thermistor detector. Dilution technique used.

(2) Analysis by gas chromatography: Molecular Sieve 5A plus Porapak Q columns with thermistor detector.

(3) Analysis by gas chromatography: Porapak Q column with flam ionization detector.

(4) Analysis by gas chromatography: Carbowax 20M (KOH-treated) column with flame ionization detector.

(5) Analysis by detector tubes.

Analysis by LFE, San Rafael, California

gas composition from sewage sludge (9). Product carbon Iodine number was also reasonably consistent.

Operation of the solids conversion step with a blend of organic solids and PAC as would result from the solids recovery process represented a very difficult operation. The fine PAC was readily released with the produced gas in the kiln or attached to the surface of the product gas lines, ultimately plugging them. In the runs with a blend of PAC and organic solids, it was difficult to achieve a good material and energy balance around the system.

A summary of the industrial JPL ACTS solids conversion results is contained on Tables 9A, B, C. The pilot scale kiln was found to be thermally inefficient (10%). The yield of PAC from organic solids was approximately 11%. less than the desired 25%. Activation based on Iodine number was comparable to that of commercial PAC.

PAC Adsorption

The feasibility of the JPL ACTS PAC for application to removal of pollutants was done with isotherm evaluations. In reducing phenols from 150 to 10 ppb, the apple pumice PAC had approximately one half the capacity for phenol as did the commercial carbon. The affinity of apple pumice PAC for parathion was similar to that of commercial PAC. In all cases, comparisons were based on the carbon mass of char.

On Table 9C has been summarized the standardized adsorption characteristics of the PAC produced from apple pumice. In all cases, the characteristics of the JPL ACTS PAC produced from apple pumice was compared with commercial PAC removals.

TABLE 9A

MATERIALS BALANCE (lbs)

	NEW ORGANIC MATERIAL FEED			SPENT PAC AND NEW ORGANIC MATERIAL FEED		
	FIXED SOLIDS	VOLATILE SOLIDS/CARBON	WATER	FIXED SOLIDS	VOLATILE SOLIDS/CARBON	WATER
INPUTS						
PRODUCT	4.51	31.66 VS	17.74	4.10	11.62 VS 31.81 C	21.83
STEAM	-	-	16.10	-	-	16.83
SUB-TOTALS	4.51	31.66	33.84	4.10	43.43	38.66
OUTPUTS						
PRODUCT	4.56	3.61	-	5.15	27.47	-
SCRUBBER	0.09	0.03	0	0.15	1.01	7.05
METERED GAS (.049 lb/cf)	-	17.96	-	-	4.65	-
SUB-TOTALS	4.65	21.60	0	5.30	33.13	7.05
RECOVERY (%)	103	68	0	129	76	18

TABLE 9B

ENERGY BALANCE (10^3 BTU)

	NEW ORGANIC MATERIAL FEED	SPENT PAC AND NEW ORGANIC MATERIAL FEED
PRODUCT INPUT		
Volatile Solids	- 243	- 89
Carbon	-	- 448
Sub-Total	- 243	- 537
HEAT TO 1700°F		
Solids	+ 29	+ 38
Water @ 80°F	+ 62	+ 72
Sub-Total	- 152	- 427
PRODUCT OUTPUT		
Carbon	+ 51	+ 401
Gas(a)	+ 190	+ 94
Net	+ 89	+ 68
ENERGY INPUT	1030	618
WASTE STACK HEAT(b)	- 376	- 222
Net	654	396
OVERALL EFFICIENCY (%)	9	11
FUEL UTILIZATION EFFICIENCY (%)	14	17

(a) Assumes 100% volatile solids and carbon balance.

(b) Assumes stoichiometric and complete combustion.

TABLE 9C

PRODUCT PAC QUALITY

Paramenter	Units	Apple Carbon	Aqua Nuchar
Ash Content	%	56	6-10
Iodine No.	mg I/g/ C	625 - 890	1150
Phenol No.			

PAC as a Settling and Filter Aid

The PAC product from the solids conversion stage was evaluated as a settling and filter aid for both activated sludge and apple processing wastewater.

Activated Sludge. The potential benefits of addition of PAC to the aeration basin of an activated sludge system have been discussed previously. In addition to these priority pollutant removal benefits, the product PAC also enhanced the settleability of mixed liquor suspended solids (MLSS) of the activated sludge process. On Figure 11 has been plotted the results of a settling test of MLSS alone at 2,000 mg/1 and MLSS blended with PAC for a total concentration of 4,000 mg/1. The settleability of the PAC:MLSS was approximately 70% greater than that of the MLSS alone. This improvement in settleability in spite of higher solids concentrations can provide for greater sludge ages (15).

The product PAC improved filterability of activated sludge. On Figure 12 has been plotted the results of a standard filterability test for a blend of MLSS and PAC. The solids concentrations of activated sludge alone was 1.6%. With PAC, the total solids concentration was 3.2%. The filter cloth employed was selected because of its ability to provide a clear filtrate with PAC alone.

The measured specific resistence of activated sludge is typically in excess of 10^{10} sec^2/g without conditioning. In the filterability test, the activated sludge alone blinded the filter cloth and no measureable filtrate was obtained.

The specific resistence of the blended MLSS:PAC was measured to be $9x10^8$ sec^2/g. Thus, the blended material had a specific resistence approximately

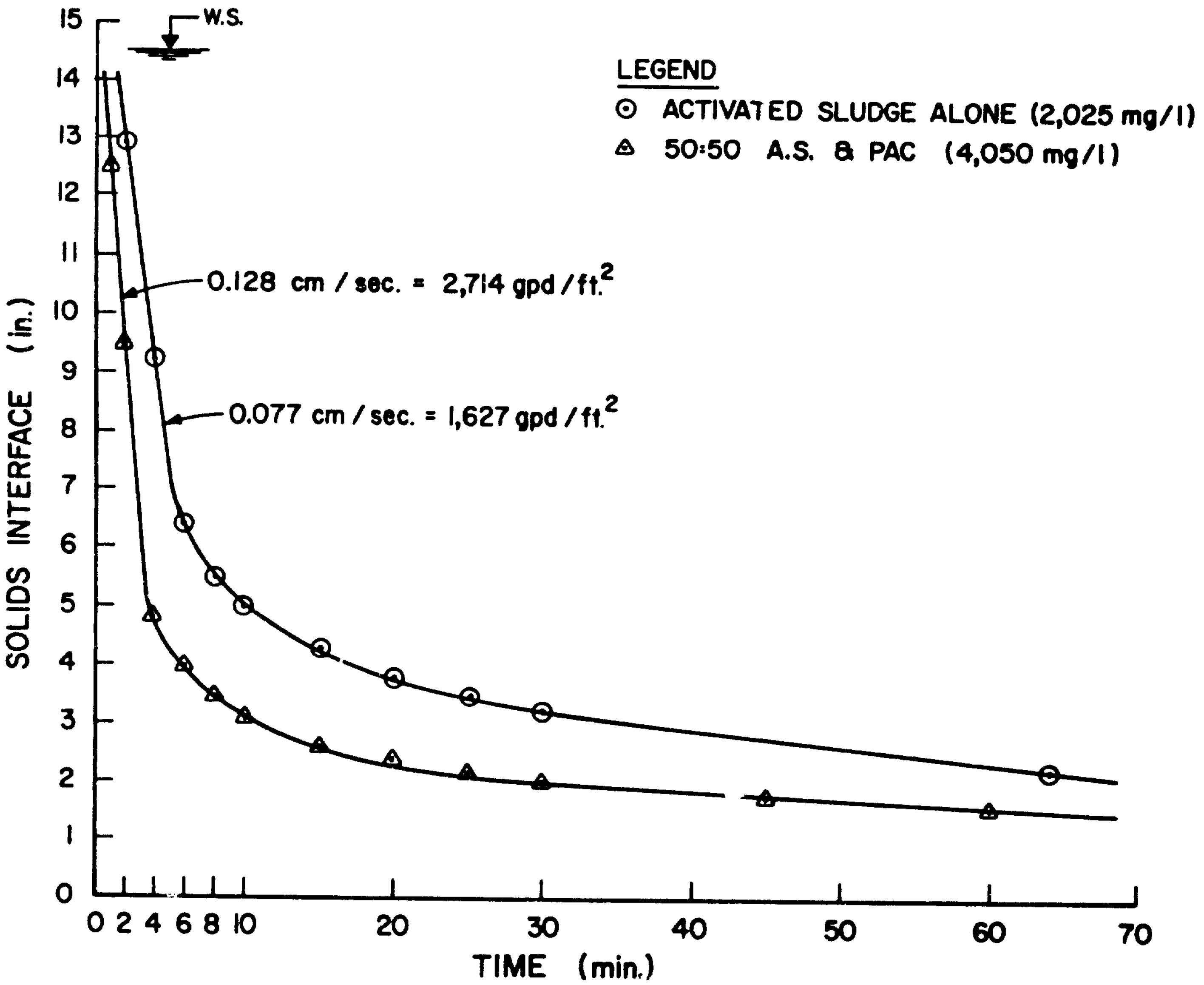
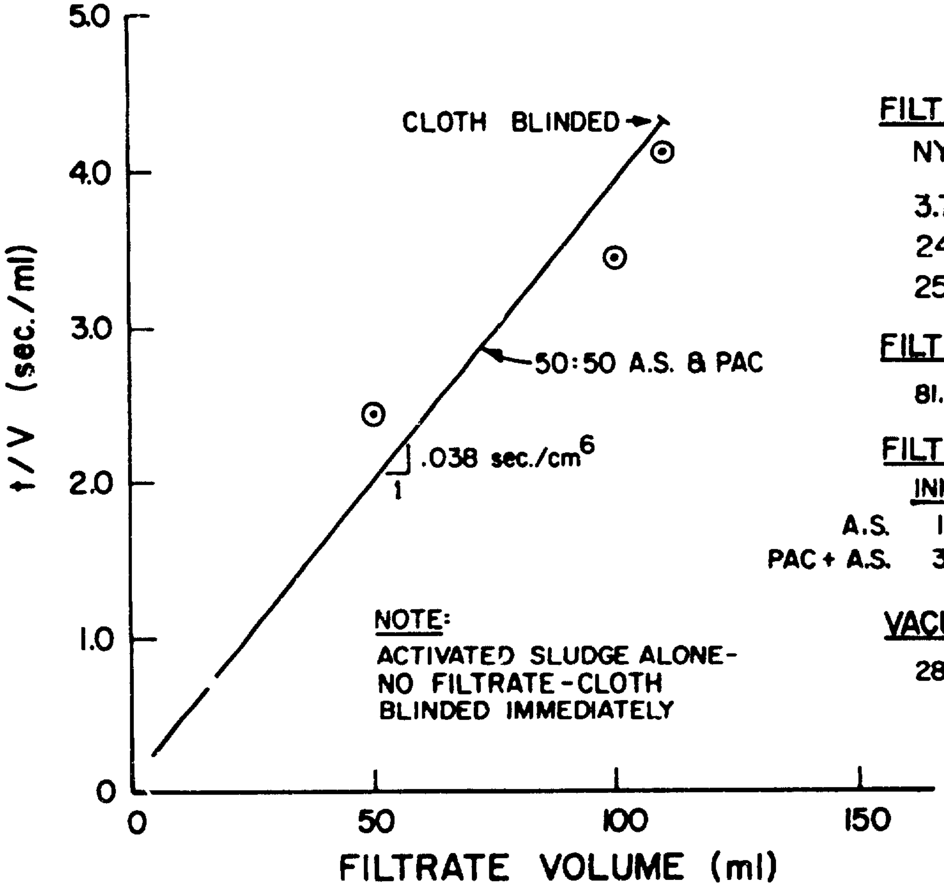


FIG. 11 PAC: ACTIVATED SLUDGE SETTLEABILITY



NOTE:
ACTIVATED SLUDGE ALONE-
NO FILTRATE-CLOTH
BLINDED IMMEDIATELY

FILTER CLOTH
NYLON CONT. FIL. SATEEN
3.78 oz./yd.^{2}
247 x 120 COUNT
25.6 cfm

FILTER AREA
81.1 cm^2

FILTER SOLIDS

	INITIAL (%)	FINAL (%)	CAKE THICKNESS (in.)
A.S.	1.62	7.4	1/16
PAC + A.S.	3.24	8.2	3/16

VACUUM
28.5" Hg

FIG. 12 PAC: ACTIVATED SLUDGE FILTERABILITY one order of magnitude less than that of the MLSS alone.

Whereas no cake thickness was achieved with MLSS alone, a good cake was formed on the filter leaf with the blended solids. No significant difference in filter cake solids concentration was noted.

Apple Processing Wastewater Solids. Addition of PAC to apple processing wastewater to improve solids settleability was not considered since most apple solids float. Instead, the trailer mounted continuous filter belt (CFB) was evaluated for simultaneous solids removal and solids dewatering. These results will be discussed subsequently.

Apple solids do occur in relatively high concentrations throughout an apple processing plant. Further dewatering of these solids would be required should this material be considered for subsequent production of PAC. Therefore, filterability tests were conducted on these solids alone and with the product PAC.

The results of filterability tests have been plotted on Figure 13. It will be noted that more filtrate per unit time was obtained with the blended solids mixture than with the apple solids alone. There was not the dramatic difference in filtration rates, however, as had been observed in the case of activated sludge.

The specific resistence of a solids mixture under a given vacuum is a function both the rate of filtrate removal and of the final solids concentration. A somewhat dryer cake was obtained in filtering apple solids alone than was obtained in filtering apple solids with PAC. As a consequence of this effect, the specific resistence of the apple solids alone was somewhat lower (2.5 x 10^5 sec^2/g) than that measured for the blended apple solids with PAC (3.6 x 10^5sec^2/g). However, a much thicker filter cake was formed

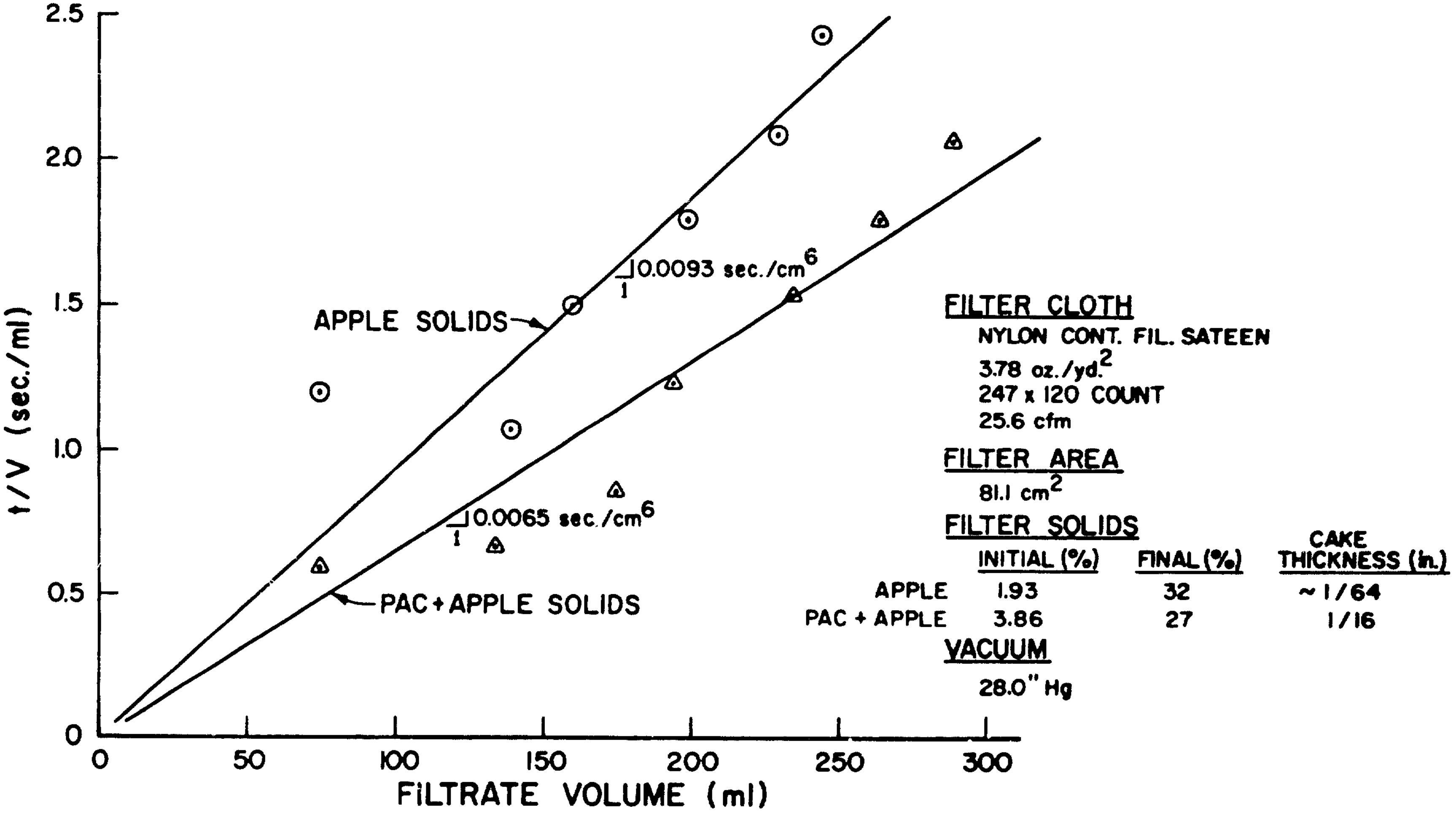


FIG. 13 PAC: APPLE SOLIDS FILTERABILITY

with the blended solids than with apple solids alone.

Addition of product PAC to apple processing wastewater for enhanced solids removal did not result in the dramatic improvements in filterability as had been observed in the case of activated sludge. A somewhat greater filter cake thickness was obtained and slightly greater rate of filtrate removal was measured. A reasonably dry cake was obtained for both conditions: 32% solids for apple solids alone and 27% solids for the blended mixture. Tests with the CFB yielded blended solids filter cake solids concentrations of similar magnitude.

CFB Solids Recovery

The pilot industrial solids recovery system was mounted on a 6' by 8' trailer as illustrated on Figures 14A and 14B. The concentrated carbon slurry was per-flocculated with non-ionic polymer before mixing with the wastewater. This greatly improved PAC solids recovery efficiency at negligible additional costs. The slurry was added to the industrial wastewater to achieve a one-to-one blend of PAC with organic suspended solids. The blended stream was first passed through a grit removal device (Teacup). The degritted wastewater was then passed through a tube contacter to achieve a five minute plug flow contact time following which the mixture was discharged to a continuous filter belt (CFB) for dewatering and recovery of the organic solids and PAC. The materials balance boundary and sampling points have been shown in Figure 15 and the monitoring program summarized on Table 9.

On Table 10 has been summarized the solids recovery study results. A reasonably high solids cake was achieved by the CFB (20 - 30% solids).

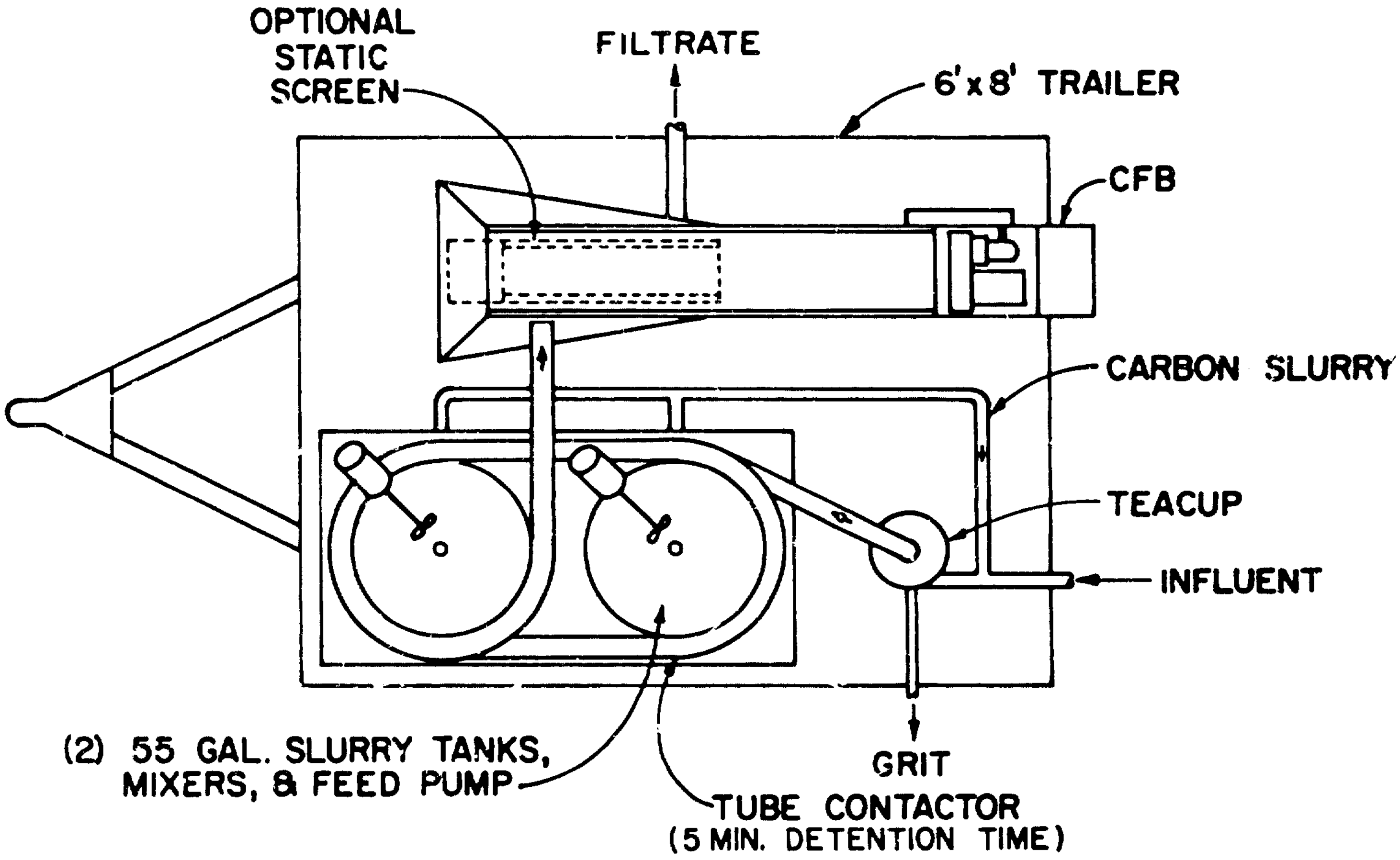


FIG. 14a SOLIDS RECOVERY AND PAC ADSORPTION TRAILER
(PLAN)

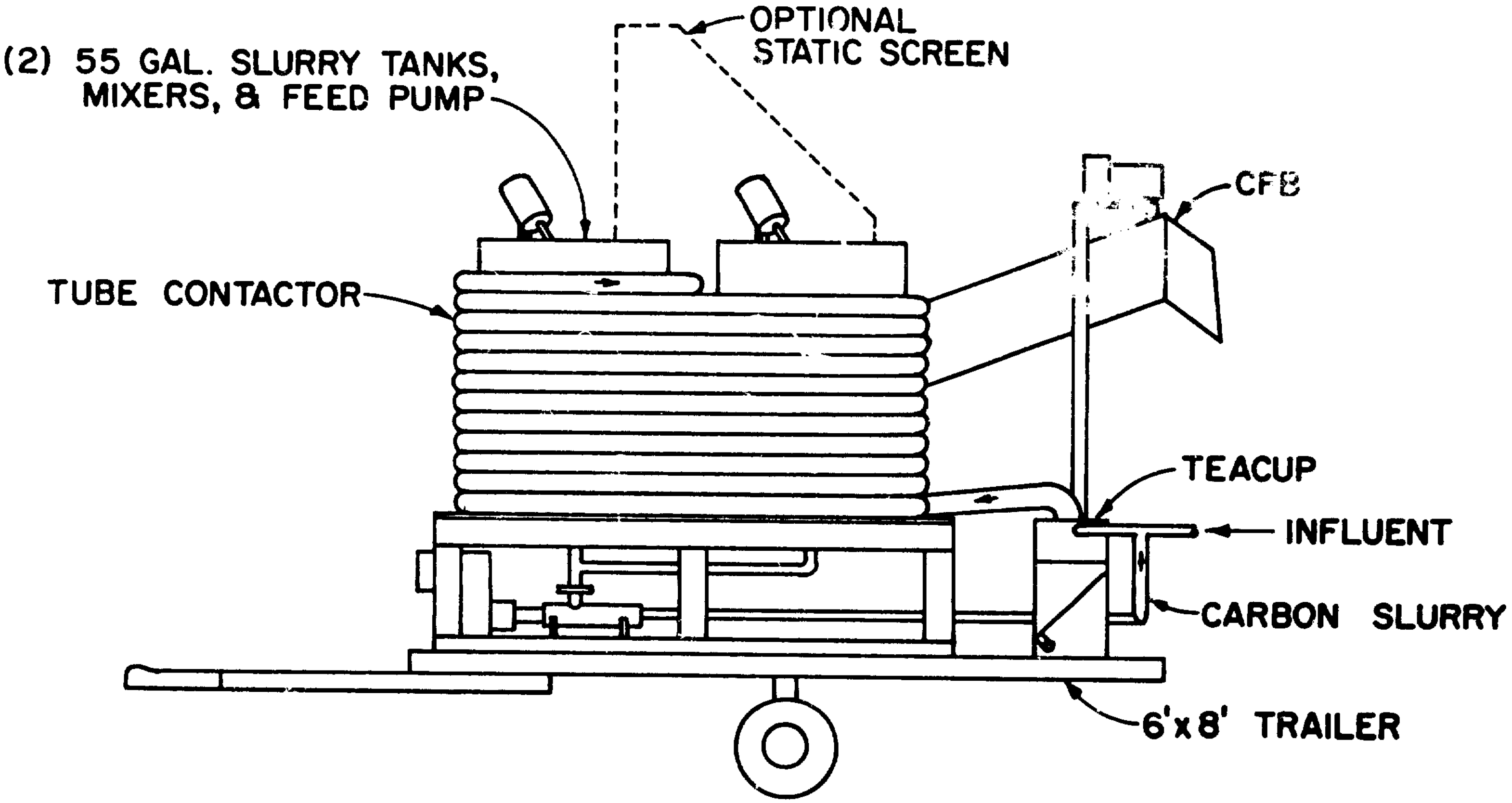


FIG. 14b SOLIDS RECOVERY AND PAC ADSORPTION TRAILER
(PROFILE)

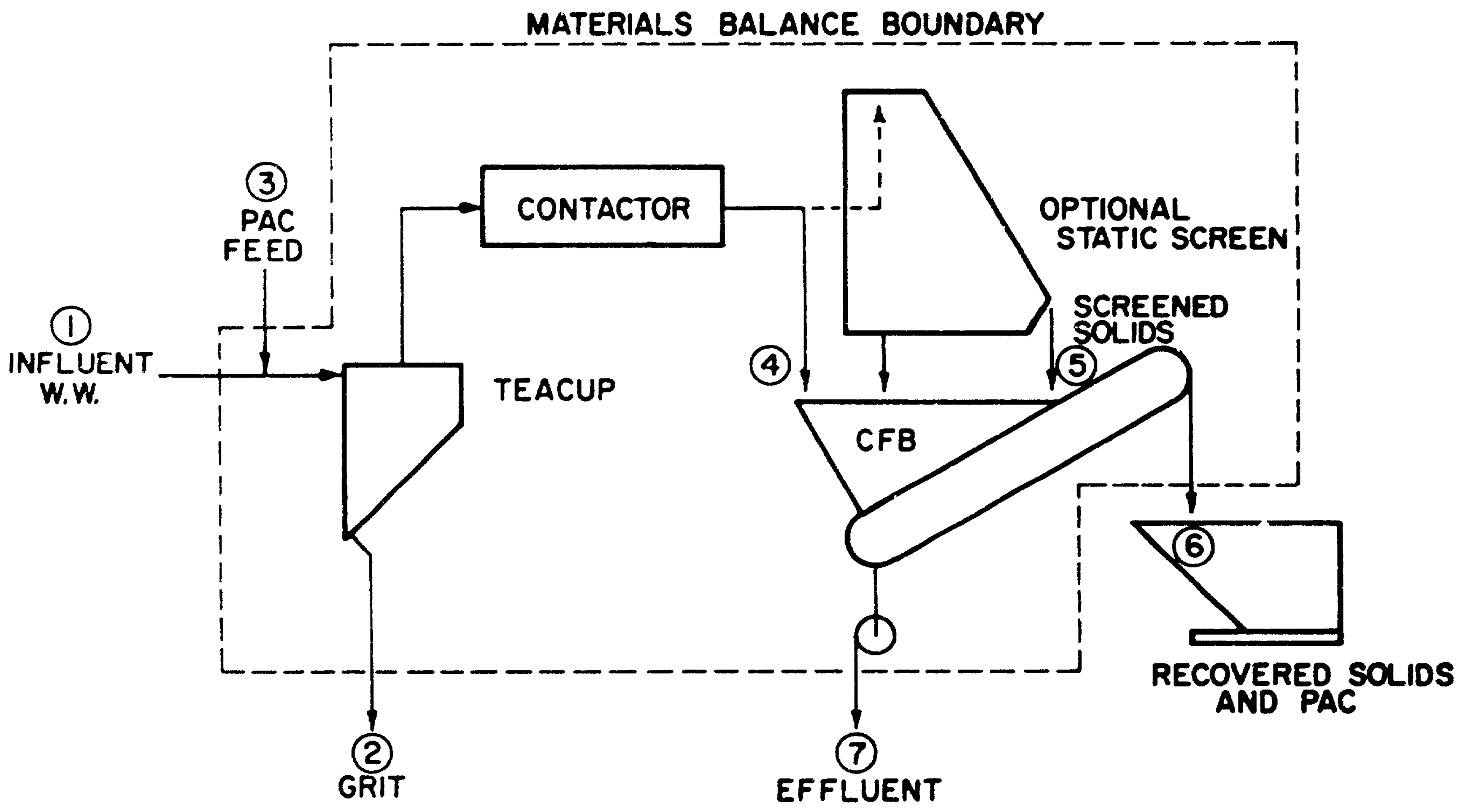


FIG. 15 SOLIDS RECOVERY AND ADSORPTION MONITORING PROGRAM AND MATERIALS BALANCE BOUNDARY

TABLE 9

JPL ACTS DEMONSTRATION

SOLIDS RECOVERY AND ADSORPTION MONITORING PROGRAM

Sample Point		Frequency
Influent Wastewater	1. Flow rate	Hourly
	2. Suspended solids	
	3. % volatile matter	Daily composite
	4. COD	
	5. BOD	
Grit	1. Flow rate	Hourly
	2. Total solids concentration	Daily
	3. Volatile solids concentration	Daily
PAC Feed	1. Slurry concentration	With each batch
	2. Flow rate	Hourly
Contactor Discharge	1. Suspended solids concentration	2 times daily
Screened Solids	1. Mass	Daily
	2. Solids Concentration	Daily
Recovered Solids and PAC	1. Mass	Daily
	2. Solids concentration	Daily
Effluent	1. Flow rate	Hourly
	2. Suspended solids	
	3. % volatile matter	Daily composite
	4. COD	
	5. BOD	

TABLE 10

SUMMARY OF SOLIDS RECOVERY RESULTS

1. Flow rate = 3 gpm

2. PAC feed rate = 1 lb PAC : 1 lb SS in influent

3. Influent Water Quality

SS	1300-2800 mg/l
COD	5200-15800 mg/l

4. Effluent Water Quality with CFB

SS	1900-3400 mg/l
COD	6100-16500 mg/l

5. Effluent Water Quality (batch sedimentation)

SS	1900 (34% removal efficiency)
COD	3100 (55% removal efficiency)

6. CFB Dewatered Solids Concentration = 20.6 to 30.6%

7. Solids Recovery Efficiency: negligible due to short circuiting around CFB

A micron-tight seal between the continuous filter belt and the vacuum pan was not achieved during the course of the solids recovery runs. Belt tracking problems also occurred. Consequently, PAC solids loss in the filtrate was excessive. The seal and tracking problems can be resolved with modifications in the filter belt design.

The use of pre-flocculated PAC and a continuous filter belt makes solids recovery a relatively simple and efficient step. However, there is some question as to the economic feasibility of incorporating such a step in JPL ACTS applied industrially. Solids concentrations in the resulting cake are well below those which must be provided to JPL ACTS solids conversion in order for the process to operate without additional fuel energy. The additional cost of dewatering and drying these solids makes the economics of PAC production from them marginal. Finally, the product PAC ash content from such mixtures will invariably be greater than that of selected 100% organic solid waste feeds. It is probable that a "throw away" application of PAC to BPCTCA activated sludge treatment systems would be a more cost effective approach and would provide a greater energy yield for the producer industry.

CONCLUSIONS

1. Food product and processing solids wastes can be profitably converted to PAC having Iodine numbers comparable to commercially available PAC.
2. An efficient pyrolysis kiln (65%) and greater than 67% solids feed to the JPL ACTS solids conversion process should yield approximately 10,000 BTU of product gas per gross pound of PAC produced.

3. Depending on treatment method, PAC produced from waste apple juice solids has a high ash content (50%), comparable Iodine number, comparable affinity for parathion, and approximately one half the affinity for phenol per pound of carbon when compared with a commercial grade of PAC(Aqua Nuchar).
4. With a careful attention to the source of organic solids for PAC, kiln operational efficiency, and, activation procedures, JPL ACTS PAC should be a cost effective alternative for upgrading BPCTCA activated sludge treatment facilities to BATEA standards through addition of PAC to aeration systems.

RECOMMENDATIONS

1. Screen and evaluate specific 1984 priority pollutant adsorption characterisitcs of JPL ACTS PAC utilizing alternative food product solid wastes.
2. Using product gases, investigate pyrolysis kiln combustion procedures which will maximize kiln efficiency.
3. Investigate alternatives for more efficient solids dehydration so that JPL ACTS could profitably accept lower feed solids concentrations while maintaining good energy yields.

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