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ARCTIC EVALUATION
OF A
SMALL PHYSICAL-CHEMICAL SEWAGE TREATMENT PLANT

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SMALL PHYSICAL-CHEMICAL SEWAGE TREATMENT PLANT

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A Working Paper presents results of investigations which are to some extent limited or incomplete. Therefore, conclusions or recommendations--expressed or implied--are tentative. Mention of commercial products and/or trade names does not constitute indorsement.

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INTRODUCTION

In Arctic Alaska there are many transient industrial camps of 10-60 men each. Oil well drilling camps on the Arctic North Slope are usually set up at one site for no more than one to two months. These camps contain about 30 men each. The extended aeration package plant process is the most common form of secondary waste treatment used. The major disadvantage of such units is that they require skilled operators and from two to ten weeks to build up an operating biomass before efficiency can be achieved.

The more concerned camp managers in the Arctic recognize the problems with the extended aeration units and have been seeking other means of providing secondary or higher level sewage treatment for their temporary camps. Physical-chemical treatment is one method being considered to guarantee secondary and in some cases achieve tertiary treatment. The physical-chemical process involves chemical clarification followed by carbon adsorption.

One such plant, a prototype installation, was operated consecutively at two different sites near Prudhoe Bay in April and in May of 1972. This paper will discuss the operation and performance of the unit. Initially, this 7,000 gpd physical-chemical (P-C) unit was set up in late March at the Nabors Drilling Co. #1-3 Drill Site east of the Deadhorse airport and operated for approximately one month. Three sets of samples from April 12 to 17 were obtained from this site. The unit was then set up at the Arco #1 Drill Site (approximately one mile from the Arco Prudhoe Bay base camp) and operated during the month of May. Seven sets of samples were obtained from that site.

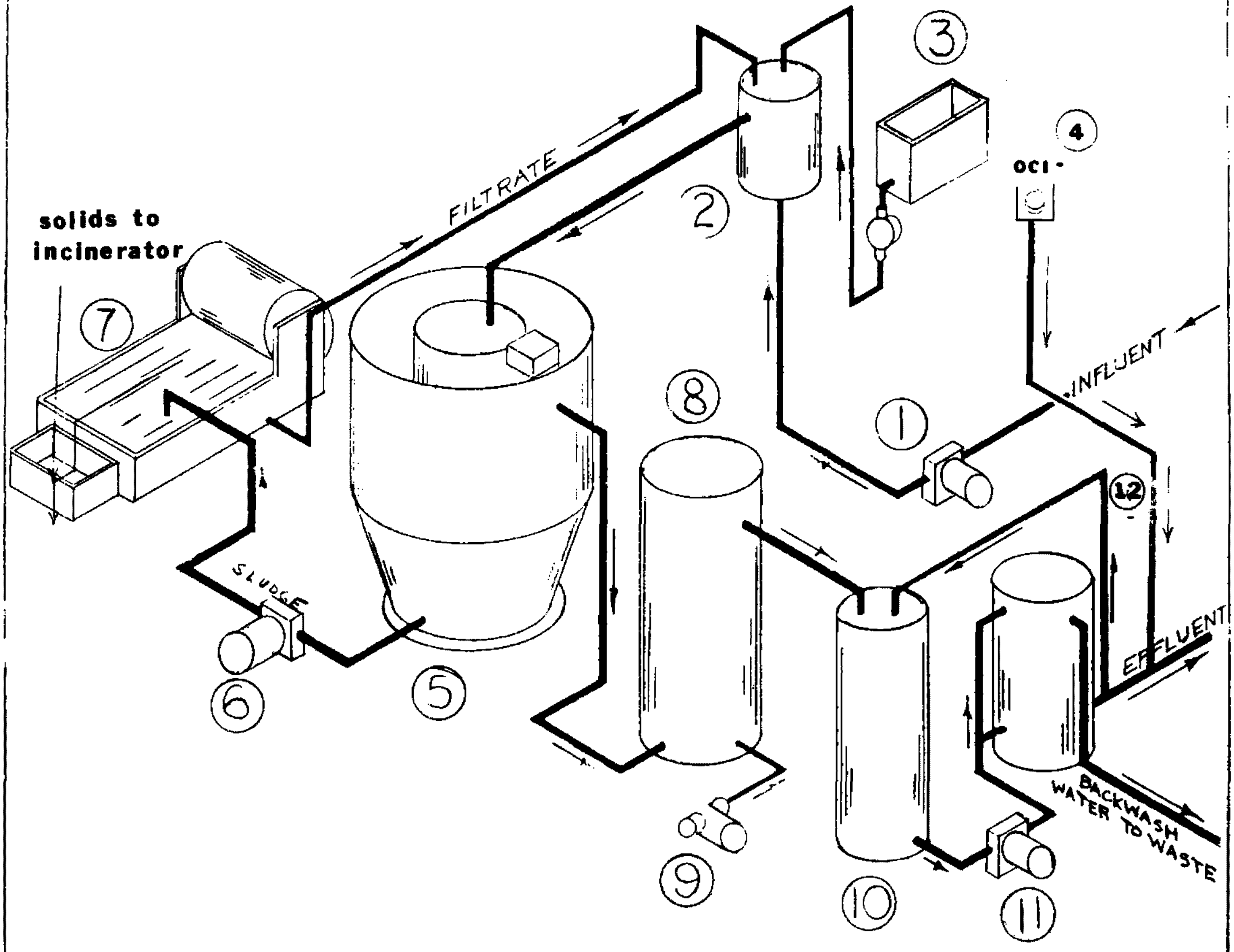
OPERATING EXPERIENCES

The block flow diagram of the unit is shown in Figure 1 (Met-Pro Drawing Number 0003902): raw sewage is collected and pumped from a sump below the housing trailer floor into an approximately 3500 gallon aerated equalization tank. From the equalization tank the sewage and coagulant are separately pumped into a flash mixer. From the flash mixer flow is by gravity into the flocculation (center) section of an upflow clarifier. Effluent (supernatant) from the clarifier then flows along with a small airstream (for fluidization and to prevent anaerobiosis) up through a carbon adsorption column (upflow) and into an 80 gallon surge tank. Liquid from the surge tank is pumped through a pressure sand filter. Effluent from this filter is chlorinated by use of hypochlorite tablets and intermittently siphoned onto the tundra.

The chlorinator consisted of a small dissolution box into which four 3-inch slotted pipes (hypochlorite tablet containers) are standing. Effluent flowing around and through the slots leaches hypochlorite from the tablets. The baffled chlorine chamber has a theoretical design detention of 1/2 hour.

Sludge from the bottom of the clarifier is pumped onto a moving paper filter. Filtrate is pumped to the flash mixer. Sludge solids collected on the filter paper are incinerated with the paper.

When activated by the high liquid level switch in the feed equalizer tank the unit operates continuously at about 5 gpm design capacity until shut off by a low level switch. This P-C process operated only at 100 percent of design capacity; the equalization tank absorbed sewage flow fluctuations.



1 RAW WASTE PUMP
2 FLASH MIX TANK
3 COAGULANT FEEDER
4 DISINFECTANT FEEDER
5 FLOCCULATOR CLARIFIER
6 SLUDGE PUMP
7 DISPOSABLE MEDIA FILTER (OPT)
8 ADSORBER
9 ADSORBER AERATOR
10 SURGE TANK
11 FILTER/BACKWASH PUMP
12 PRESSURE FILTER

Figure 1

Process Flow Isometric

MET-PRO WATER TREATMENT CORP.
LANSDALE, PA. 19446

TITLE SERIES 14000
IPC WASTEWATER TREATMENT

0003902

Some process design parameters were:

Flash mix tank: ∿3 gallon tank with a 1750 rpm propeller mixer.

Clarifier: Circular upflow with conical bottom and center-mounted flocculator.
Overflow rate: 0.45 gpm/sq ft.
Sludge drawoff: Continuous at ∿1/2 gpm.

Carbon Column: 24 inch diameter upflow - air fluidized.
Charge: 300 lb hard (coal base) granular activated carbon.
Contact time: 20± minutes.

Sand filter: Pressure downflow, single media.
Flow rate: 6 gpm/sq ft.

Paper filter: Adjusted to renew paper at ∿6 inch water head.

The P-C unit was installed (by Steel Fabricators, Anchorage, Alaska) along with the chlorine contact tank, the feed equilizer tank, sewage sump and incinerator in a skid-mounted trailer, approximately 10x40 feet, so that the whole waste handling system could be loaded into a C-130 aircraft (Herc) and flown to the North Slope. Placement of the unit in the trailer is as shown in Figure 2 and Figure 3 (Modified Met-Pro Drawing Number 0003815). The disadvantage to such a compact enclosure was that there was too little access room for easy operation and maintenance. The only access to the unit with more than one foot clearance from any wall was the side with the control panel. Clearance on that side was limited to less than two feet.

As noted on Figure 3 access to the surface of the clarifier was severely limited by the domed trailer roof; so limited, in fact, that there was not enough room for the mixer to be installed on the flash-mix tank.

The following problems were observed with the units during the inspection trips. This listing is not meant to be a criticism but should

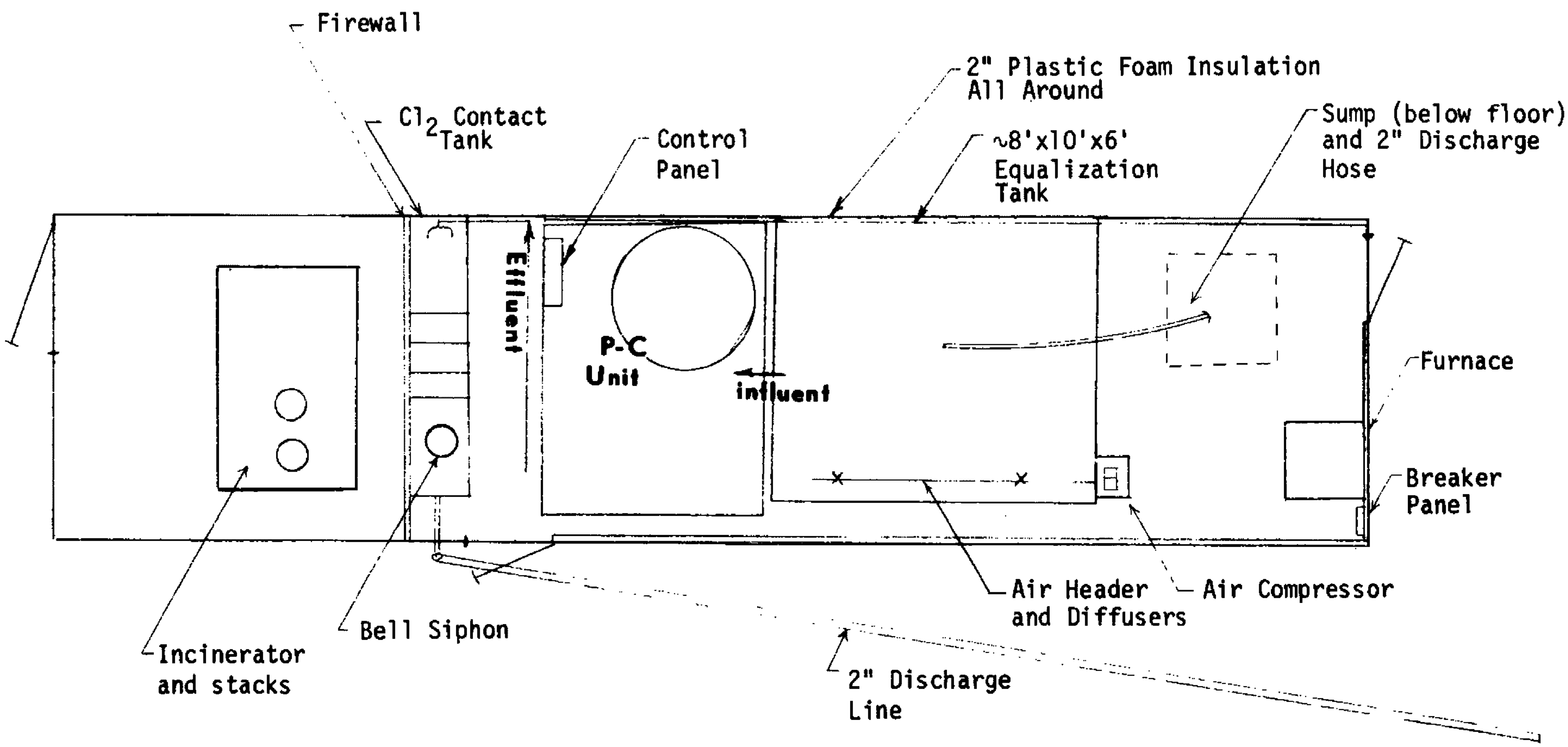


Figure 2

WASTE TREATING SYSTEM LAYOUT

Skid Mounted Trailer Approx. 10'x40'

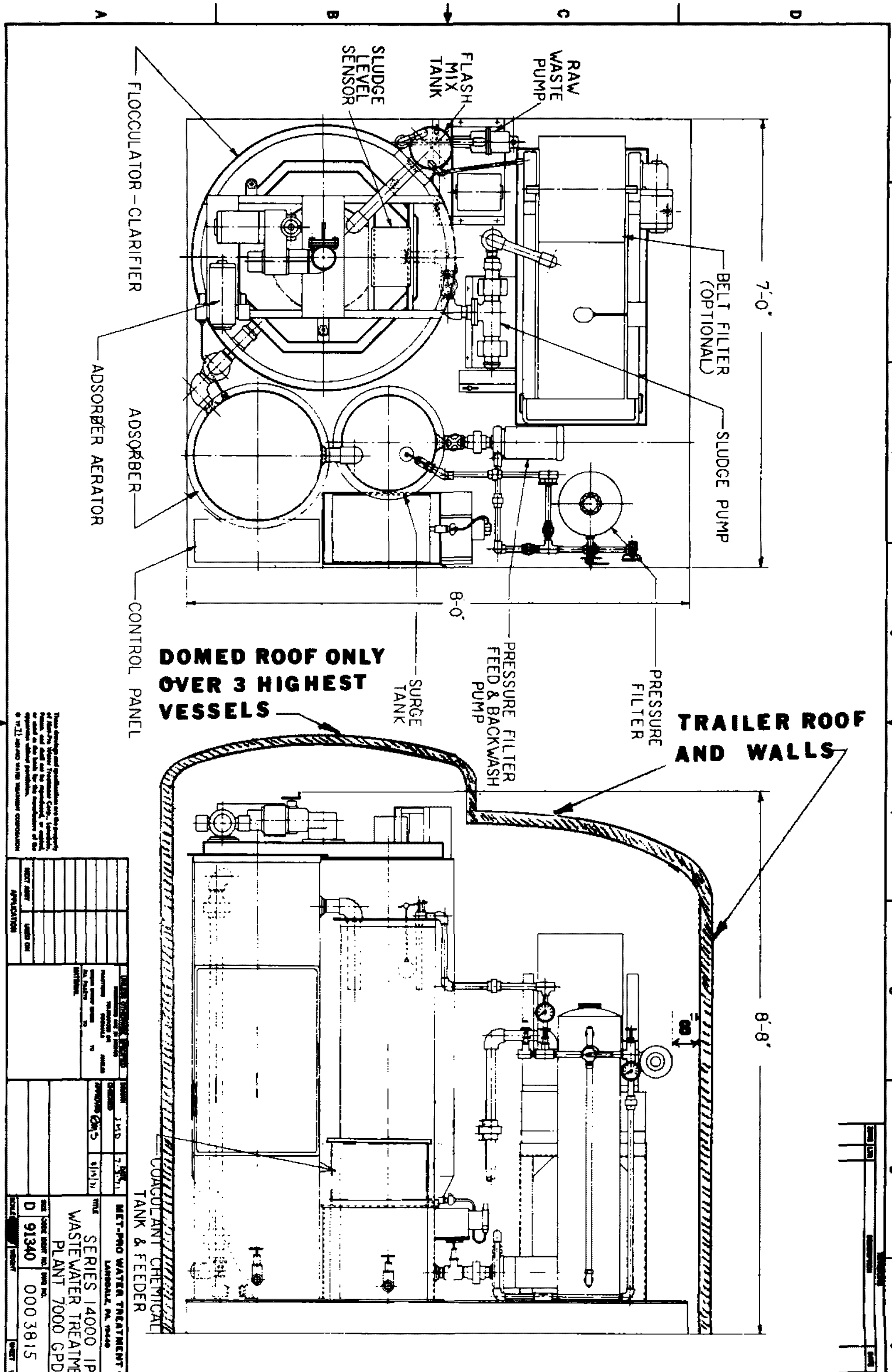


FIGURE 3

P-C UNIT EQUIPT. LAYOUT

be used as a guide to avoid the problems in future installations involving package P-C sewage treatment systems.

April 1972

Operational Problems	Probable Cause--Suggested Cure
Excess coagulant (ferric sulfate) in effluent.	Operator not familiar with jar test. Instruction manual should direct the operator to observe the clarifier overflow for coagulant color and/or clarity.
High pressure drop through the carbon adsorption column.	Initial carbon charge too soft. Use manufacturer specified carbon.
Air-fluidizing line clogged with carbon particles.	Carbon particles too fine? Maintain integrity of diffuser screen over air outlet.
Filter paper supply exhausted.	Lack of adequate supplies. Innovative operator had to use rolls of paper towels.
Contaminated air in trailer; chlorine, smoke, and aerosols.	Solid tablet dissolution system effervescing chlorine gas. Use fewer tablets and cover contact chamber.
	Incinerator smoke coming through firewall leak. Seal firewall.
	Aerosols from aerated equalization tank. Reduce aeration rate and/or cover tank.
Excess noise in housing trailer.	Install inlet filter silencer on air compressors.
Sludge level sensor activated by surface scum rather than sludge blanket.	Operator did not realize existance of dimmer switch which would reduce sensitivity. This was not discussed in the instruction manual.

May 1972

Operational Problems	Probable Cause--Suggested Cure
Copper and plastic process line breakage.	Moving units from Nabors to Arco pad. Provide 100 percent spare for vulnerable lines or fittings or change piping materials to eliminate vulnerability.

Operational Problems	Probable Cause--Suggested Cure
Sludge filtrate return pump burned out.	Unknown.
Relay switches in control panel tripping (overheating).	Electrical. Unknown. Feed pump line clogging?
Sewage solids clogging 3/4 inch (suction) feed line.	Use comminuter or easily cleaned suction cage, or larger size pipe.
Low voltage turbidity sensing light had been removed.	Short in light transformer? Transformer replaced.
Chemical feeder pump, head needed rebuilding (diaphragm).	Grit in ferric sulfate. Premix ferric sulfate and decant into chemical feeder supply tank.
Excessive foam over-flowing equalizer tank.	Too much aeration. Cycle air compressor or reduce aeration rate. Install foam control spray header.
Loss of media in the sand filter.	Lost when thawing and removing ice from unit. Drain all lines and tanks during shutdown.

It should be noted that almost any new piece of process equipment usually has a considerable number of operational problems during its start-up and initial operational phases. Untrained and inexperienced operators usually compound the problem. These problems were listed only as a guide for considerations of future installations of similar units. It should be remembered that this P-C unit was hastily installed in the trailer. A less rushed job of preparation may have eliminated many of the problems which were encountered. Many of the problems were minor (none were unsurmountable) and the unit was operable at design capacity after recharging with the proper activated carbon before operation at the Arco site (May). The manufacturer-specified activated carbon (hard coal base) was not available at Anchorage when the unit was to be shipped to the site so the only available activated carbon (lignite base) was substituted. Attrition of this charcoal during handling and operation decreased its mesh size to the extent that it severely reduced capactiy.

Operators of P-C units in the Arctic seem to prefer ferric sulfate as coagulant. The advantages of ferric salts as compared to lime and alum are that: it operates over a wide concentration range, it dissolves easier, effluent neutralization is usually not required, and a rust clouded effluent may indicate its use in excess.

One disadvantage of P-C units is that they contain much intricate machinery and it takes the operator a while before he can become familiar with all the equipment; but he does not have to understand a biological process as a good operator of an extended aeration unit must.

PROCESS PERFORMANCE

At the Nabor's camp (April 1972) the unit treated an estimated 1,000 to 2,000 gpd of bathroom and personal laundry wastewater from about 33 men. Linens and towels were sent out for laundry. Kitchen wastes were separately sewered and discharged into a lagoon.

After recharging with the proper size carbon (Calgon Filtrasorb 300) the unit was set up at the Arco site on approximately May 2. All domestic wastewater including kitchen wastes from the 33-man camp was treated in the unit.

At both sites the feed (raw sewage) samples were collected as a small slip stream from the sewage pump that discharges into the feed equalization tank. A pipe Tee was attached to the end of this pump's 2-inch discharge hose, and from that Tee a 3/8 inch sample hose was run into a 15 gallon collection barrel. For a 24-hour composite the barrel was sampled and emptied daily. When the 3/8 inch line plugged, grab samples were taken from the equalization tank. The clarifier overflow samples were dipped (all were grab samples) from the surface adjacent to the overflow weir. Effluent samples were collected (in a 15 gallon barrel) as a slip stream from the sand filter; but before chlorination. Both 15 gallon collection barrels were set on the cold trailer floor in lieu of refrigeration.

An hour meter was attached to the positive displacement feed pump and measurements taken from May 16 to May 23. The unit ran at 81 percent of design capacity during one eleven-hour period (0800 to 1900) on May 17. The average flow rate was 4,100 gpd; 58 percent of design capacity. The per capita daily consumption averaged 120 gallons.

Apparently in thawing the unit (before moving to Arco pad) the operators inadvertently removed most of the media from the sand filter. The effect of insufficient effluent filtration shows in the data for May (Appendix). The most important parameters are summarized in Table 1.

TABLE 1

Data Summary
Physical-Chemical Unit on the North Slope, 1972

	April Average Nabors Site	May Average Arco Site
FEED: Waste Water Source	Bathroom and Personal Laundry	All Domestic Camp Sewage
Rate	Est. 1000-2000 gpd	4100 gpd
COD mg/l	1257	846
Total Nitrogen mg/l	127	48
Total Phosphorus mg/l	9.3	15
(Number of samples)	(3)	(7)
Clarifier Overflow:		
COD mg/l	178	439
Suspended Solids mg/l	40	119
(Number of samples)	(3)	(4)
Effluent:		
COD mg/l	61	312
Suspended Solids mg/l	26	155
Total Nitrogen mg/l	127	32
Total Phosphorus mg/l	0.7	3.4
(Number of samples)	(3)	(7)

The April data for the chemical precipitation-clarification step had a COD removal ranging from 79 to 89 percent. The carbon adsorption-sand filtration steps had a removal range from 61 to 71 percent. Average overall COD removal was above 95 percent. This is much higher than one could expect with conventional extended aeration practice where the upper limit is about 80 percent. The only BOD data point for April (Appendix) shows a removal approaching 99 percent.

The lack of effluent filtration shows in the data for May, but the chemical precipitation-clarification step also had a very poor COD removal, averaging about 48 percent. The inclusion of kitchen wastewaters, raising grease and detergent levels, may account for a minor part of the reduction in coagulation-clarification performance. The sludge level sensor light was out of service (see operational problems) during the May sample collection period. Without the sensor light there is no control of clarifier effluent turbidity which is suspected as being the major cause of poor clarifier and carbon column performance. The carbon adsorption-sand filtration steps had a low average COD removal of 29 percent. It should be recognized that computations based on clarifier surface grab samples are not as reliable as those based on composite samples. The average overall COD removal for the May samples is about 63 percent. Average BOD (Appendix) removal is about 71 percent which is about the performance to be expected for an extended aeration process under similar conditions.

For total solids the April data (Appendix) shows about 650 mg/l removed. For May, only about 400 mg/l was removed. Again for April the effluent suspended solids averaged about 26 mg/l, whereas for May the average was about 155 mg/l. Turbidity data (appendix) follow the same trend.

This physical-chemical process had an inconsistent effect upon the removal of total and ammoniacal nitrogens. Average removals varied from 0 to 33 percent. P-C processes usually remove only organic nitrogen. The effluent total phosphorus concentration could be kept below 1 mg/l independent of feed concentration when enough coagulant is used and suspended solids removal is effective. May data shows an average removal of 77 percent.

There was excellent total coliform removal (Appendix) before chlorination. With all four tablet dispensers in the chlorinator the effluent total chlorine (O-tolidine method) concentration exceeded 5 ppm after a theoretical contact time of 1/2 hour. The pH ranged from 6.3 to 7.9 which indicates that in this case effluent neutralization was not required.

TABLE 2
Filter Paper Performance

Sample Date	% Water in Captured Sludge	Dry Solids Capture gm/in^2 paper	Dry Solids % Volatile	$Fe_2(SO_4)_3$ Feed Conc. mg/l
4/12/72	∿90	0.1±	49	∿300
5/17/72	91	0.36	49	∿380
5/19/72	95	0.04	49	∿380
5/23/72	98	0.02	49	∿380

The performance of the paper filter is shown in Table 2. Only the clarifier sludge was filtered. The filter system was set to operate (expose fresh filter paper) when the pressure head on the paper exceeded about 6 inches of water. The mass of the solids captured on the paper varied over one order of magnitude.

The instruction manual stated that a scale (coagulant pump stroke setting) of approximately 25 percent represented a feed strength of approximately 250 ppm if coagulant was mixed 16 oz per gal. of water. At the Arco site ferric sulfate was mixed 12 oz per gal. of water and the scale set at 50 percent. The bulk density of the ferric sulfate is about 70 lb/cubic ft; for the above calculations it was assumed to be the same as water. The usage rate averaged 15 lbs per day since there appeared to be considerable grit left after decanting the concentrated ferric sulfate into the chemical feeder tank.

OPERATING COSTS

Based upon flow and supplies information obtained at the Arco site (except for carbon usage) the following cost estimates (materials: FOB Anchorage) are made:

1. Manpower. The unit required about 6 ± 3 hours per day to operate. This would represent in the order of about 1.0 cent per gallon but this cost should not be directly attributed to the treatment since the operators were untrained and unfamiliar with some of the equipment. After the equipment was completely shaken down, adjusted and properly maintained, the manpower requirement should be less than 3 hours per day.

2. The ferric sulfate cost at the dosages used was about 0.06 cents per gallon of wastewater.

3. The filter paper usage varied from about 50 to 100+ yards per day. Using an average of about 80 yards per day the filter paper charge would then be about 0.15 cents per gallon wastewater treated.

4. A 300 lb charge of activated carbon was used. Assuming a capacity of 1 lb of COD per lb of activated carbon and an average clarifier overflow COD of 180 mg/l (Nabors site) the charge for replacing the activated carbon would then be 0.07 cents per gallon of wastewater treated. Under conditions as they were at the Arco site the carbon charge should last about 1 to 2 months.

5. Since the hypochlorite tablets were at times used in excess, consumption figures were not recorded. The chlorination charge should be less than 0.02 cents per gallon and was therefore neglected.

Excluding manpower or equipment amortization the total operating expense has been in the order of about 0.3 cents per gallon. Substitution of an economical solids concentrator along with other equipment improvements and operator training could substantially reduce operating costs.

CONCLUSIONS

The performance characterizing this plant is based on sampling periods when the process was not operating as intended. Therefore the data does not show the actual capability of the process.

The process performed well attaining an overall COD removal above 95 percent in April, in spite of many operational problems. In May the unit attained a secondary treatment level.

Considerable effort, for isolated arctic installations, needs to be devoted towards proper design, set up, hardware selection and operation if P-C units are to consistently provide a tertiary treatment level.

APPENDIX

GLOSSARY

Unless otherwise noted all analyses were performed in accordance with EPA Methods for Chemical Analysis of Water and Wastes, 1971, and/or Standard Methods - Water and Wastewater, 13th Edition, 1971.

BOD - Biochemical oxygen demand expressed as elemental oxygen.

COD - Chemical oxygen demand expressed as elemental oxygen.

FILT COD - COD of filtrate through Gelman #61633 glass fiber filter.

TOC - Total organic carbon expressed as elemental carbon.

TS - Total solids.

TVS - Total volatile solids.

SS - Suspended solids.

VSS - Volatile suspended solids.

T. coli/100 ml - coliform bacteria enumeration using membrane filter technique - counts per 100 milliliters.

TKN-N - Total Kjeldahl nitrogen expressed as elemental nitrogen.

NH_3-N - Ammonical nitrogen expressed as elemental nitrogen.

T-PO_4-P - Total phosphate expressed as elemental phosphorus.

Fe - Iron.

Grease - grease and oil liquid-liquid extraction with chloroform.

mg/l - milligrams per liter.

gpd - gallons per day.

pH - indicates acid <7.0 or base >7.0; 7.0 is neutral.

COLOR - True, absorbance at 380 millimicron wavelength.

TURBIDITY - Jackson turbidity units, Hach #2100 Turbidimeter.

RESULTS OF ANALYSIS OF SAMPLES FROM NABORS SITE

Date Location	Feed	4/12/72 Clarif. Surface	Eff.	Feed	4/14/72 Clarif. Surface	Eff.	Feed	4/17/72 Clarif. Surface	Eff.
24-hr Composite?	Yes	No	Yes	Yes	No	No	No	No	Yes
COD mg/l	1050	223	65	1450	158	62	1270	153	55
Filt. COD mg/l	-	-	-	-	-	-	-	138	52
TOC mg/l	375	93	26	-	-	-	-	-	-
BOD mg/l	-	-	-	-	-	-	490	-	6
TS mg/l	2000	1300	1200	-	-	-	1700	1300	1200
TVS mg/l	940	270	220	-	-	-	900	310	210
SS mg/l	840	49	8	-	-	-	830	31	43
VSS mg/l	470	27	5	-	-	-	560	13	13
TKN mg/l N	110	-	113	-	-	-	144	-	140
NH_3 mg/l N	38	-	92	-	-	-	99	-	107
T-PO_4 mg/l P	13	-	0.8	-	-	-	5.6	-	0.6
T. coli/100 ml	-	-	-	-	-	-	$4x10^8$	-	<18
pH	7.5	6.8	7.5	-	-	-	8.1	-	7.9
Color	-	-	108	-	-	-	-	-	-
Turbidity	-	52	13	-	-	-	160	-	43

RESULTS OF ANALYSIS OF SAMPLES FROM ARCO SITE

Date	5/17/72			5/18/72			5/19/72		
Location	Feed	Clarif. Surface	Eff.	Feed	Clarif. Surface	Eff.	Feed	Clarif. Surface	Eff.
24-hr Composite?	No	No	Yes	Yes	No	Yes	Yes	No	Yes
COD mg/l	838	399	134	925	179	306	701	554	408
Filt. COD mg/l	479	-	60	470	-	155	498	416	318
TOC mg/l	-	-	-	-	-	-	-	-	-
BOD mg/l	180	-	33	505	-	105	227	-	138
TS mg/l	1800	1500	1600	1900	1500	1400	1600	1500	1400
TVS mg/l	710	330	210	760	230	330	590	520	420
SS mg/l	370	190	150	530	46	270	110	110	48
VSS mg/l	220	100	67	290	26	130	77	70	31
TKN mg/l N	53	36	28	19	21	39	63	58	51
NH_3 mg/l N	45	30	31	17	20	32	54	44	36
T-PO_4 mg/l P	25	3	0.7	5.5	0.1	2.5	25	20	14
T. coli/100 ml	$5x10^8$	$9x10^7$	<20	$5x10^9$	-	<10	$1.5x10^8$	-	<20
pH	7.6	-	6.3	7.3	-	6.5	7.0	-	7.0
Color	283	252	139	307	66	114	138	236	171
Turbidity	-	125	130	-	51	125	79	94	70
Fe mg/l	7	25	52	-	17	48	3	11	9

Date	5/20/72		5/21/72		5/22/72		5/23/72		
Location	Feed	Eff.	Feed	Eff.	Feed	Eff.	Feed	Clarif. Surface	Eff.
24-hr Composite?	No	No	No	No	No	No	No	No	Yes
COD mg/l	700	159	848	459	925	465	986	622	250
Filt. COD mg/l	463	95	-	-	115	116	311	-	169
TOC mg/l	172	49	238	136	326	118	313	-	76
BOD mg/l	-	-	-	-	-	-	360	-	78
TS mg/l	-	-	-	-	-	-	2200	1600	1500
TVS mg/l	-	-	-	-	-	-	790	530	260
SS mg/l	-	-	-	-	-	-	780	130	150
VSS mg/l	-	-	-	-	-	-	420	68	76
TKN mg/l N	60	14	-	-	29	24	61	-	41
NH_3 mg/l N	41	11	-	-	9.1	8.1	40	-	22
T-PO_4 mg/l P	25	0.7	-	-	0.2	2.3	7.6	-	0.4
T. coli/100 ml	-	-	-	-	-	-	$3x10^9$	-	<10
pH	7.7	6.8	-	-	8.0	7.0	7.0	6.4	6.3
Color	-	-	-	-	-	-	282	265	65
Turbidity	-	-	-	-	-	100	140	110	110
Fe mg/l	-	-	-	-	54	207	48	-	41

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