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Environmental Protection Technology Series

Infrared Dry Caustic Vs. Wet Caustic Peeling of White Potatoes

National Environmental Research Center
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JUNE 1975

INFRARED DRY CAUSTIC VS. WET CAUSTIC PEELING OF WHITE POTATOES

by

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Grant 12060 EIG
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ABSTRACT

The infrared dry caustic peeling system has been evaluated through plant scale comparisons with the conventional wet caustic system. The following significant differences were noted when the dry peel system was compared to the wet process:

(a) decreased peel loss by 13.1 percent.

(b) decreased caustic consumption by 26 percent.

(c) decreased wastewater from peeling by 73 percent.

(d) decreased BOD_5 in the peeler wastewater by 78 percent.

(e) decreased suspended solids in the peeler wastewater by 77 percent.

(f) decreased alkalinity in the peeler wastewater by 61 percent.

(g) increased operating costs of peeling by 39 percent but decreased total annual cost of peeling and primary treatment through lower peel loss by 10 percent.

(h) decreased total plant raw waste load: water use by 18 percent, BOD_5 by 47 percent, and suspended solids by 57 percent.

No significant differences were noted in the efficiency of primary sedimentation of the raw wastes nor in the mud clarifier results. Primary sludges and their dewatering characteristics were found to be similar.

This report was submitted in fulfillment of Project 12060 EIG by Western Potato Service, Inc. of Grand Forks, North Dakota, and Potato Service, Inc. of Presque Isle, Maine under the partial sponsorship of the Environmental Protection Agency. Work was completed as of December 31, 1971.

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ACKNOWLEDGMENTS

This project was financed in part by the Office of Research and Development, U. S. Environmental Protection Agency under Project 12060 EIG, and by Western Potato Service, Inc.(WPSI), Grand Forks, North Dakota and Potato Service, Inc. (PSI), Presque Isle, Maine where the studies were carried out. The support and help provided by Mr. Kenneth A. Dostal, the Grant Project Officer, are acknowledged with sincere thanks. The assistance of Pradeep Safaya, Environmental Control Manager at WPSI, with the statistical evaluations and the stenographic labors of Suzette Olmstead are also acknowledged with sincere thanks.

SECTION I

CONCLUSIONS

Peel loss (using fall and early winter results when the system operated most successfully), as shown in Table 1, decreased by 13.1 percent; caustic usage decreased by 26 percent; peeling water usage decreased by 73 percent; 5-day biochemical oxygen demand (BOD) decreased by 78 percent; suspended solids decreased by 77 percent; alkalinity decreased by 61 percent; and capital and operating costs increased by 39 percent but decreased total annual costs through lower peel losses by 10 percent.

Table 1. COMPARISON OF PEELING SYSTEMS

Items Compared	Wet Caustic	IR-Dry Caustic
Peel Loss (%)		
Late Winter & Spring	20.50	20.32
Fall & Early Winter	18.83	16.36
All Seasons	19.22	18.58
Caustic Usage (lbs/100 lbs)(lbs/ton)		
All Seasons	1.020 20.4	.753 15.1
Wastewater Characteristics		
Volume (gal/ton)	1302	346
BOD_5 (lbs/ton)	64	19
Suspended Solids (lbs/ton)	103	29
Alkalinity (lbs/ton)	28	10
Capital and Operating Costs $/ton	1.869	2.593
Credit for Reduced Peel Costs $/ton		-.91
Overall Capital and Operating Costs $/ton	1.869	1.683

Capital cost was $47,245 for each conventional wet caustic line rated at 20,000 pounds per hour and $110,775 per infrared dry caustic line (same rating). Capital costs for primary treatment at Western Potato Service, Inc. (WPSI) (3 peel lines) was $165,304 and at Potato Service, Inc. (PSI) (4 peel lines) $212,100. Total annual cost of peeling and primary treatment per ton processed was $2.126 at PSI and $2.017 at WPSI based on actual production. At potential production, these figures would be $1.993 and $1.537, respectively.

The overall plant raw waste BOD for PSI was 62.8 pounds per ton; at WPSI, 33.5 pounds per ton. The primary clarifier BOD removal was 33.5 percent for PSI vs 31.7 percent for WPSI. Primary sludge in pounds of total solids per ton of raw potatoes was 34.6 for PSI vs 33.3 for WPSI. The primary clarifier effluent at PSI contained 46.0 pounds of BOD and 16.9 pounds of suspended solids per ton vs 23.1 and 8.80 pounds, respectively, at WPSI.

At PSI, the total solids content of the filter cake averaged 12.6 percent and a recovery of total solids in the cake of 12.7 pounds per ton; at WPSI, 39.3 percent and 40.3 pounds per ton, respectively. Filter loadings were 0.75 of total solids per square foot per hour at PSI and 4.6 pounds at WPSI.

There were no expectations that the dry caustic peel system would have any effect on the finished product and none was observed. It would be extremely unlikely that a change in peeling procedures would affect the finished product since peeling variables are altered as required to keep the finished product in grade.

SECTION II

INTRODUCTION

The increased demand for processed potatoes in the form of dehydrated or frozen products has occurred concomitantly with an increased demand for treatment of the processing wastes. Responsibility for treatment of the wastes produced has become the obligation of the industry or, in some cases, the industry and the municipality.

Although biologic decomposition and stabilization of the conventional caustic peel effluent can be accomplished by several well-established practices, a system of peeling which yields wastes of lower concentration and less liquid volume has obvious advantages. Additionally, since potato wastes are acceptable as feeds for livestock, the system devised should allow maximum recovery of these utilizable solids.

Development of an infrared (IR) dry caustic peeling method characterized by techniques which allow separation of peel solids from the plant liquid streams along with reduced consumption of water should present the industry with an acceptable alternative to their present system of peeling. However, the acceptance of any new system will depend upon the overall economics.

The development of the IR-dry caustic peel methods by the U. S. Department of Agriculture (USDA) on a pilot plant basis provided the stimulus for investigation of the method on a full scale basis (1). PSI of Presque Isle, Maine and WPSI(redesigned to utilize the IR-dry caustic system) of Grand Forks, North Dakota received support from the EPA to demonstrate the feasibility of the IR-dry caustic method. Both of these plants are subsidiaries of JS Industries, now renamed American Kitchen Foods.

The installation of three IR-dry caustic peeling lines at WPSI along with the primary treatment system was to be contrasted with the conventional wet caustic peeling plant at PSI, also equipped with primary treatment facilities.

The grant objectives were to:

1. Determine total capital expenditures and operational costs of the dry caustic process and the conventional caustic process.

2. Compare the quantity and quality of the waste generated by the two systems.

3. Determine total water consumption, power requirements, and maintenance costs of the two systems.

4. Compare the silt removal systems and primary clarifiers as to quality and quantity of influent and effluent.

5. Determine whether dry caustic sludge would be accepted or rejected for subsequent study as animal feed material.

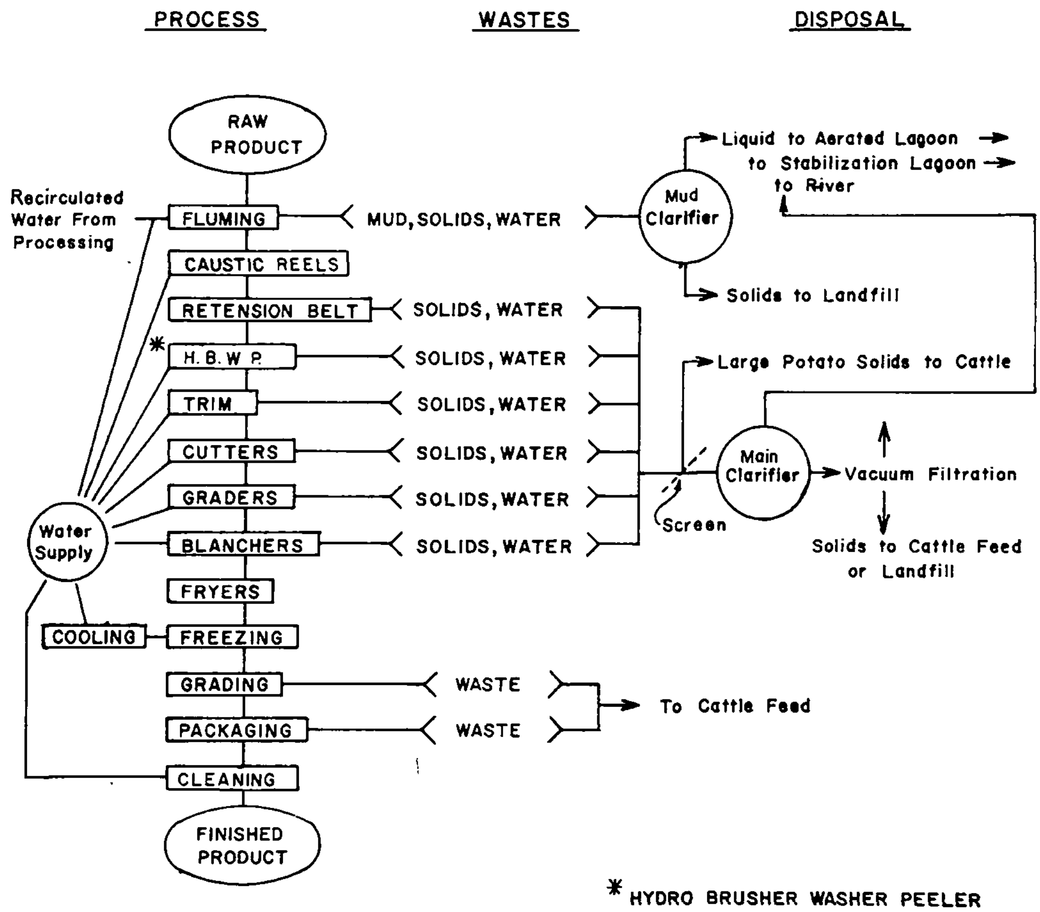
Both PSI (design capacity of 1000 tons per day) and WPSI (design capacity of 600 tons per day) produce primarily frozen french fries (for flow diagrams, see Figures 1 and 2). There are two types of french fries---retail and institutional. Retail products are produced in both straight and crinkle cut in the larger cross section sizes. Institutional products are also produced in straight and crinkle cut; however, in three sizes of straights and two of crinkles. Both plants also produce potato rounds---shredded potato pieces mixed with potato flakes or starch and condiments, then extruded and fried. Other products produced occassionally but not on a daily basis are frozen hash, frozen whole boils, and frozen cottage fries.

PSI has five peel lines (including an automatic steam peeler not used during the grant period) while WPSI has three. All lines at both plants are rated at 20,000 pounds of raw stock per hour. The lines at PSI consist of caustic reels for immersion, retention belts, and hydro-brusher-washer peelers (see Figure 3). At WPSI, the lines consist of caustic reels, retention belts, Shufflo-infrared units (see Figures 4 and 5), Magnuscrubber peeler and Magnuwasher peeler, (see Figures 6, 7, 8 and 9).

There are various types of solids generated by the peeling operation as well as by the waste treatment--- french fry waste, screened solids, filter sludge, peeler waste solids (from the Magnuscrubber peeler), and mud sludge. At PSI the french fry waste and a part of the screened solids and filter sludge are given to a nearby animal food processing company for the trucking; the mud sludge is hauled off for landfill. At WPSI, the french fry waste and some of the screened waste are given to farmers for the hauling; any remaining screened solids, filter sludge, peeler waste solids and mud sludge were trucked to dumping grounds. Recently a drying plant has been placed in operation and it is planned that screened waste solids, filter sludge and peeler waste solids will be taken by this plant.

In-plant treatment systems consist only of effluent screening (4 mesh screens) before discharge to the primary clarifier. Both plants have fat traps to remove waste fat before the primary clarifier.

Process steps at each plant are very similar (see Figures 1 and 2). At PSI, potatoes are flumed from storage to evenflow hoppers from which they are fed into caustic reels (for caustic treatment), then onto retention belts (for additional treatment time), then over the hydro-brusher-washer peelers (to remove the skin) and finally to surge tanks for controlled flow to the trim tables. Once the potatoes are trimmed,



* HYDRO BRUSHER WASHER PEELER

FIGURE I – FLOW DIAGRAM OF POTATO SERVICE, INC. (PSI) WET CAUSTIC METHOD OF PEELING

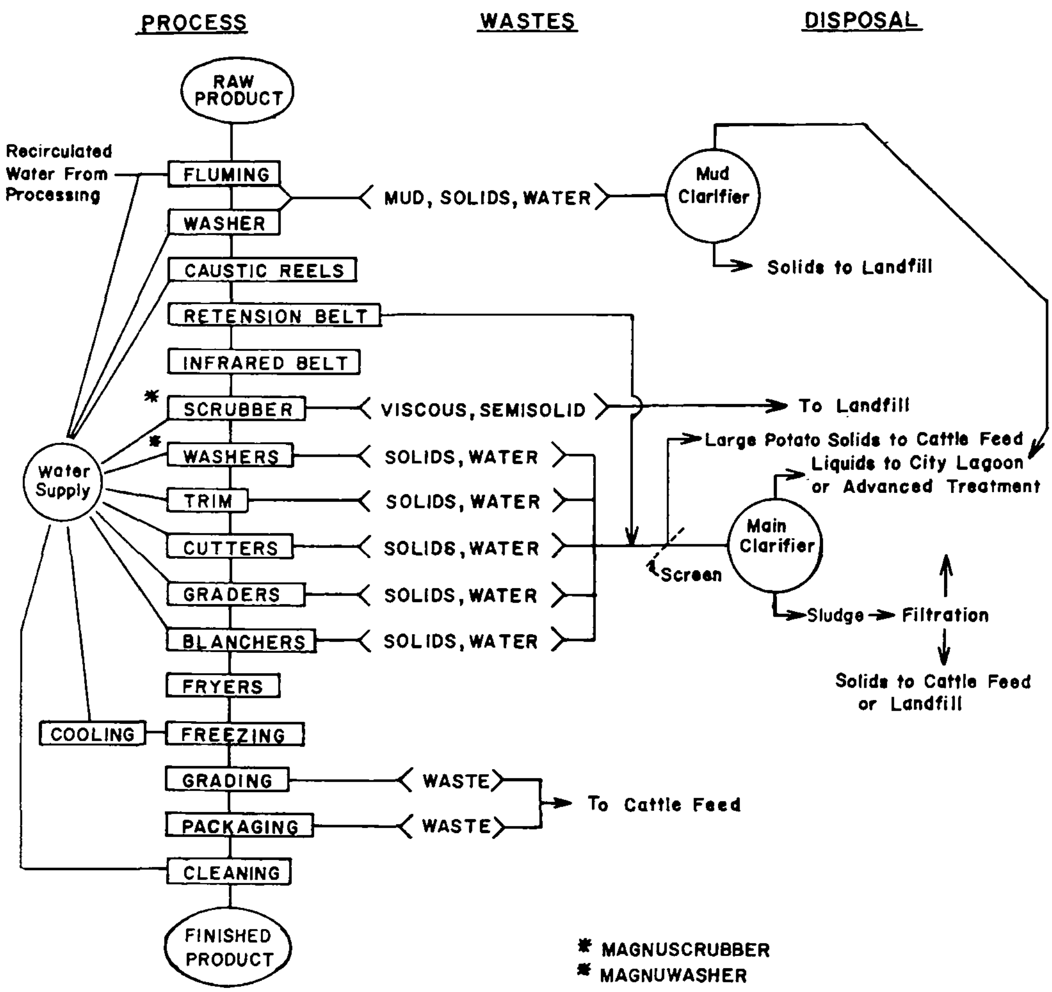


FIGURE 2 FLOW DIAGRAM OF WESTERN POTATO SERVICE, INC. (WPSI) DRY CAUSTIC METHOD OF PEELING

Figure 3. Hydro-brusher-washer peeler

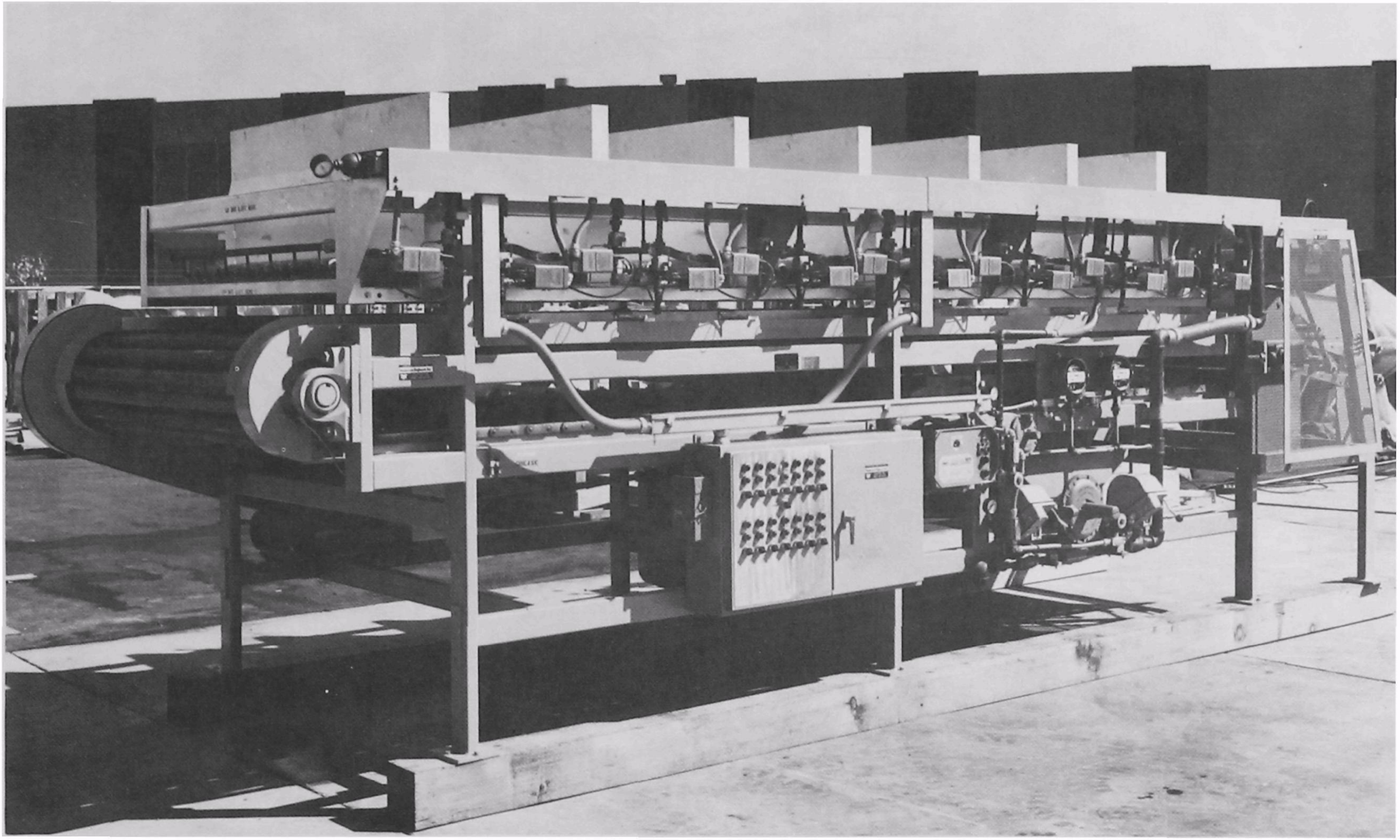


Figure 4. Model D-14 Shufflo infrared unit

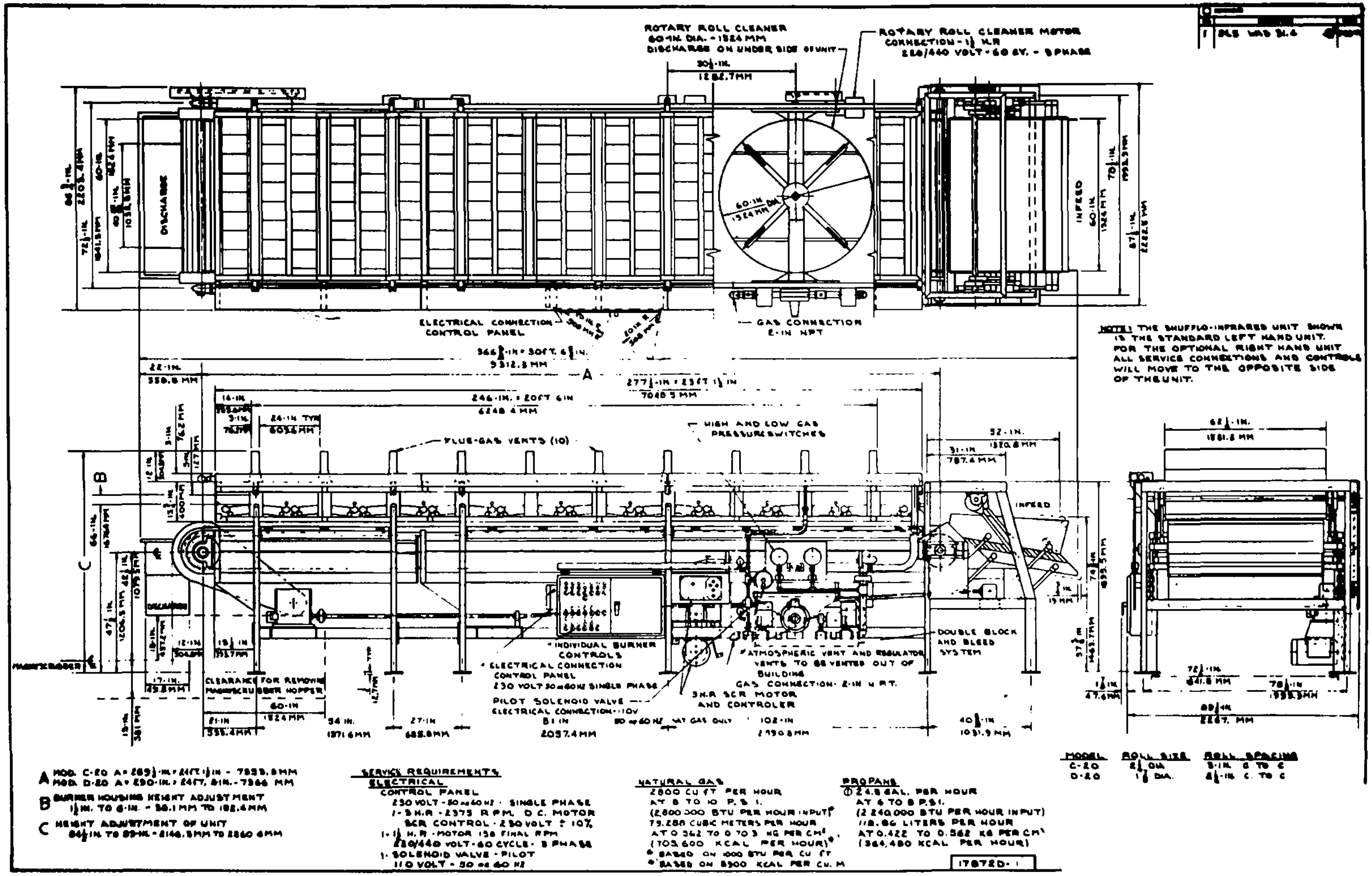


Figure 5. Pictorial drawing of model D-14 Shufflo infrared unit

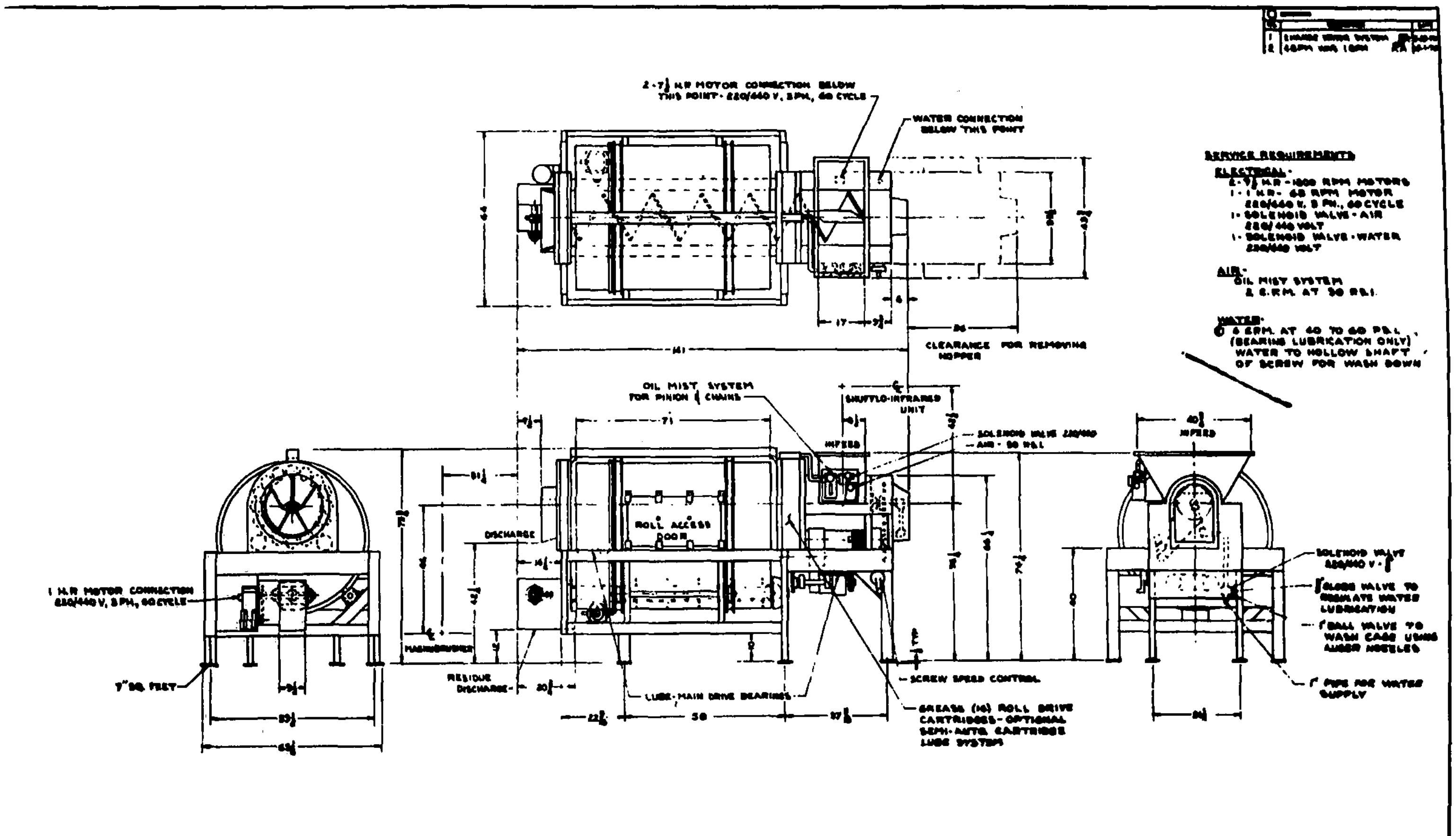


Figure 6. Magnuscrubber peeler

Figure 7. Manguscrubber peeler - with roll removed to show coupling and water jets

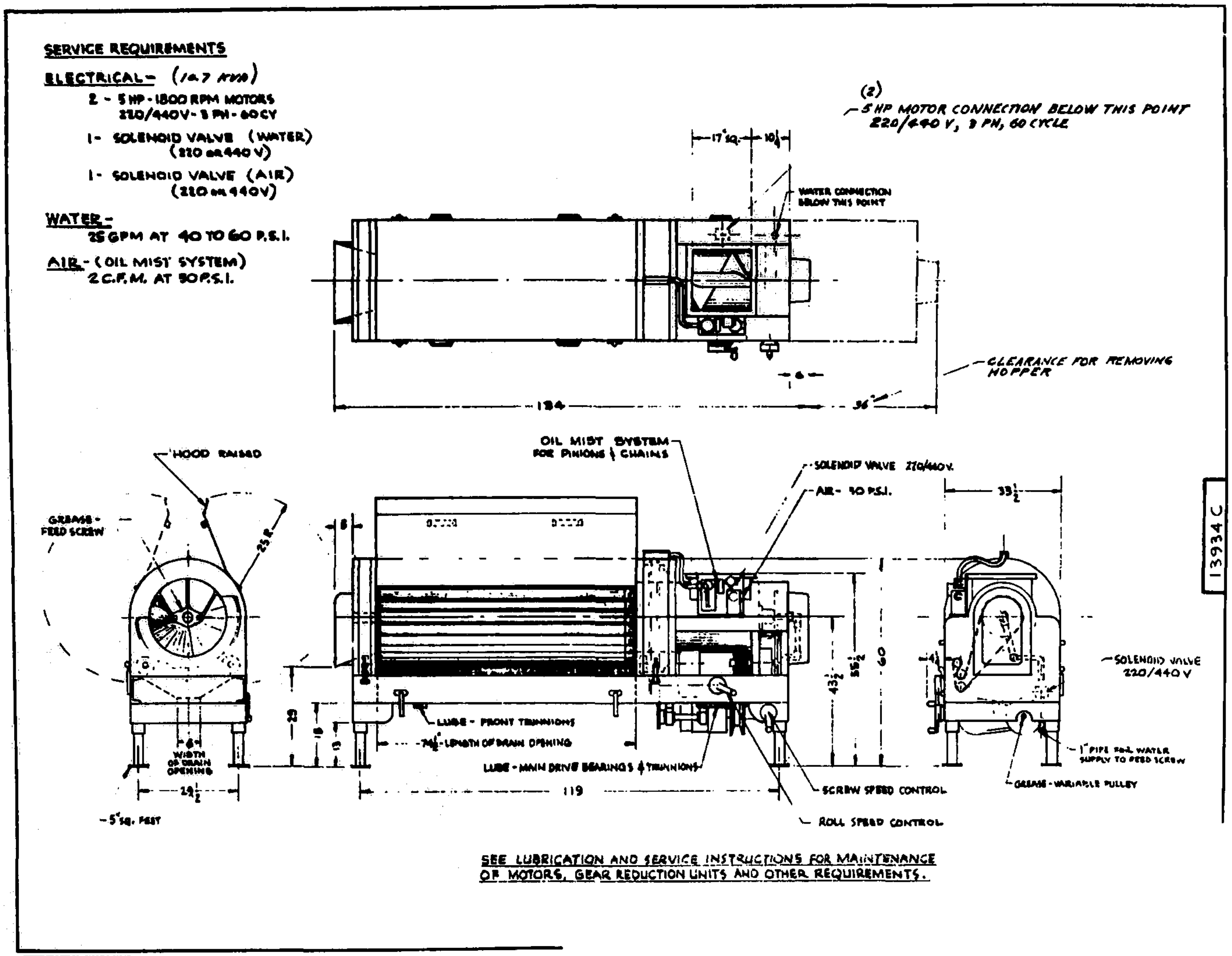


Figure 8. Magnuwasher peeler, pictorial drawing

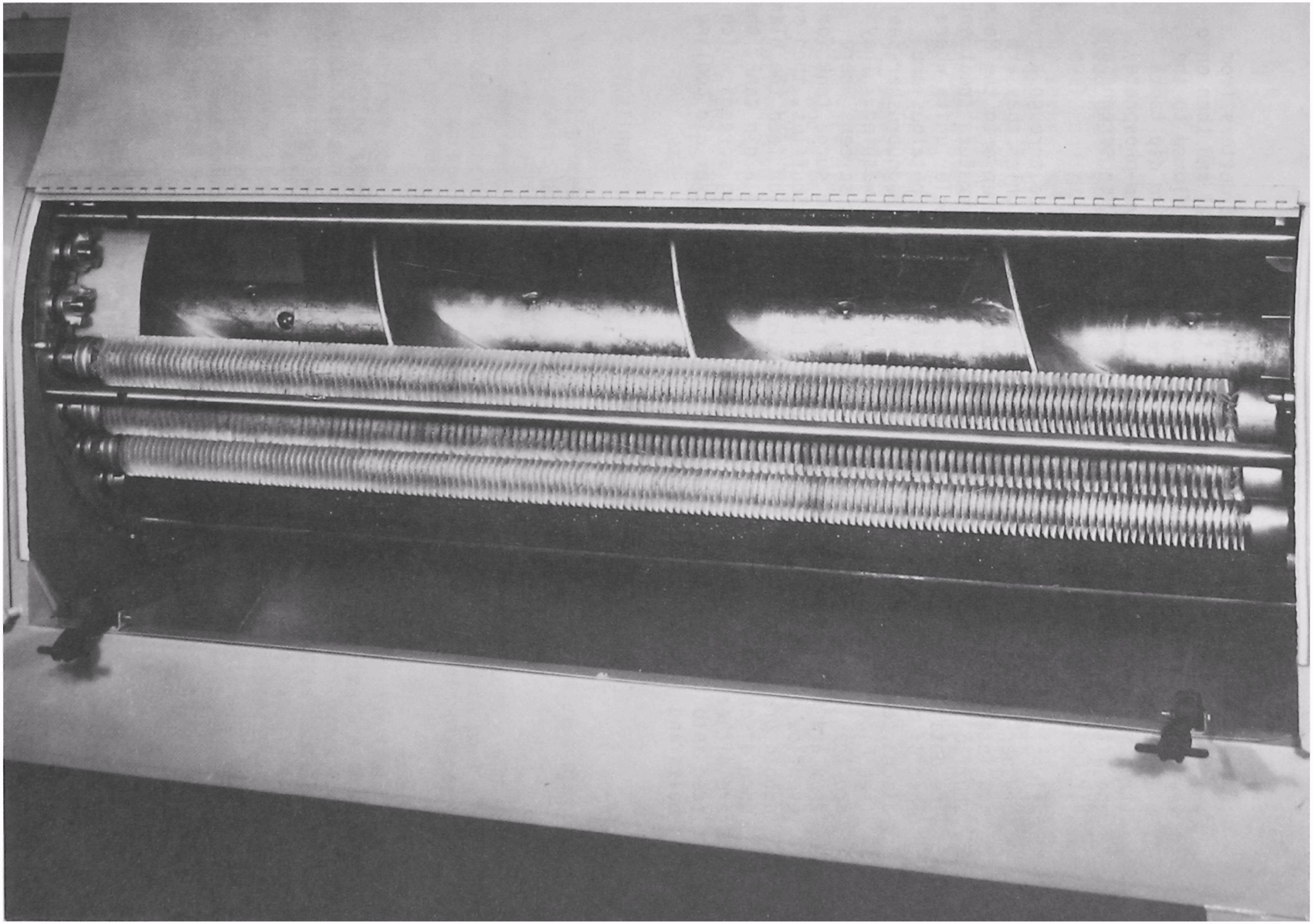


Figure 9. Magnuwasher peeler with two rolls removed to show auger and water jets

they are hydro pumped to Gilkie shakers to feed the cutters from which they are flumed onto Shufflos (sliver removal) and then onto key graders (nubbin and short piece removal), then flumed to the blanchers. From the blanchers, they are dropped into dip tanks (treatment with dextrose and disodium dihydrogen pyro-phosphate); and after dewatering, to the fryers; then to defatting screens and onto air cooling belts and into the freezer tunnels.

At WPSI, the potatoes are flumed from storage, passed through a hydro-brusher-washer and then to an evenflow hopper from which they are fed into caustic reels, over retention belts, and then onto the Magnu-shufflo Infrared units (for increased time and temperature treatment). The potatoes are then fed into the Magnuscrubber-peeler units where most of the peel is removed as a thick sludge. The potatoes are discharged from the Magnuscrubber-peelers into the Magnubrusher-peelers (see Figures 8 and 9) for complete peel removal and washing. They are then screw lifted to a shaker feeder to grading screens where they are sized, then trimmed and screw lifted to the surge tank for evenflow over a Gilkie shaker to the cutters, over Shufflos, then over nubbin graders to flumes feeding the hydro-pumps which feed the blanchers. Upon discharge from the blanchers, they are fed into a dip tank, then are either hydro-pumped or belt removed to dewatering screens which feed into the fryers, then over defatting screens, over air cooling belts and into the freezers.

SECTION III

DESCRIPTION OF PEELING SYSTEMS

Good peel removal is a pre-requisite to maintaining defects at the level required by U. S. Grade Standards. Peeling may be accomplished by several methods - caustic treatment to soften the skin and immediate underlying tissue followed by skin removal by brushes; steam treatment followed by skin removal; and abrasive treatment. Although steam peeling will give a lower peel loss in the fall, caustic is preferable in the winter and spring. In theory, the caustic treatment should be kept to a minimum consistent with the required peeling (determined by minor defect count). Peeling should never be used as a method of removal of major defects. Theoretically, potatoes could be heated in water until the skins could be removed. However, this would result in a very high peel loss as much of the potato immediately under the skin would be lost. Thus a caustic treatment to soften a minimum amount of potato along with softening the skin is required to give optimum results. In fact, it is this reasoning that led to the trial use of the infrared treatment. By increasing the temperatures of the skin and caustic, the softening would take place sooner and less of the potato immediately under the skin would be lost.

CONVENTIONAL WET CAUSTIC---POTATO SERVICE, INC.

The PSI processing plant described herein is an example of a conventional wet-caustic peel system.

Potatoes reach the peel line via a water flume from storage (no raw potato washer is included in this line as at WPSI). Each peel line has a storage hopper for continuous and uniform feed of potatoes to the remainder of the peel line.

The four peel lines utilize a common large caustic storage tank. Each peel line consists of four ferris-wheel type caustic-reels each equipped with its own vari-speed drive, temperature controllers, black-iron circulation tank and pump and overflows to return excess caustic to the circulation tank. Following the reels, each line has its own rubber-belt retention-conveyor on which the caustic-dipped tubers are held for several minutes. As the tubers leave the retention belts, they are dropped onto a hydro-brusher-washer peeler which consists of cylindrical brushes into which water spray nozzles direct wash water over the moving tubers (see Figure 3).

Water usage is 5 gpm per nozzle (there are 80 nozzles divided among six headers with a total water usage of 400 gpm). Each of these are rated at 10 tons of unpeeled potatoes per hour. Potatoes emerging from the hydro-brusher-washer peeler are dropped onto an evenflow surge tank from which they are transferred to the trim table. Variables on the peel lines are caustic dip time (1/2 to 6 minutes), caustic concentration (7 to 25 percent), caustic temperature (130°F to 210°F), and retention belt time (1 to 8 minutes).

INFRARED DRY CAUSTIC---WESTERN POTATO SERVICE, INC.

Potatoes reach the peel line via a water flume from storage, two basket elevators, then a washer consisting of brush rolls and water sprays, and finally a storage hopper to control flow to the peel lines.

The three peel lines utilize one large black-iron caustic storage tank where caustic (50 percent NaOH) is diluted to the desired concentration of 10 to 20 percent. Each line consists of a ferris-wheel type caustic reel, each equipped with its own vari-speed drive, temperature controller, black-iron circulation tank and pump and overflow to return excess caustic to the storage tank. Following the reels, each line has its own cleat-type retention conveyor on which the caustic-dipped tubers are held for various times (controlled through sprocket changes) ranging from 1-1/2 to 8 minutes. As the tubers leave the retention belts, they are aligned in rows on the Model D-14 Shufflo infrared units (see Figures 4 and 5), which are equipped with 60 inch long roller-conveyors that rotate the tubers as they are conveyed beneath the gas fired infrared source. To provide the infrared irradiation, seven porous ceramic heads per assembly row (total of 14 rows present) are used. These burners provide a temperature of approximately 1650°F on the ceramic surface with an output of approximately 50 percent infrared radiation. The IR section is not necessary insofar as keeping the peel waste sludge out of the waste system, but does contribute to a lower peel loss by increasing the temperature of the tuber-caustic interface to provide increased reaction over shorter contact time with less penetration.

From the Shufflo infrared units, the tubers drop onto the infrared units and then into the Magnuscrubber peeler units which allow controlled scrubbing for minimum waste. The tubers are moved through the scrubber at a uniform rate by an auger with speed adjustable (700-920 rpm) for controlling exposure time. Sixteen stud-rubber rolls are arranged in a circular cage around the auger and rotate at a common fixed speed. A residue wiper-conveyor inside the drum discharges the peel residue out of the waste chute. A minimum amount of water is added to prevent the peel residue from building up inside the scrubber---this is discharged with the peel residue.

From the scrubber, the tubers are fed into the Magnubrusher peeler (see Figures 6 and 7), and are continuously augered through the brusher at a uniform rate (see Figures 8 and 9). This rate may be adjusted to control and minimize exposure time as it is only necessary to wash off any treated tissue and caustic. Twenty-three abrading rolls, each with coated surfaces of preselected grit size, are arranged in a circular cage around the auger. The roll cage rotates at a fixed speed about the auger to mix and turn the product to expose all surfaces uniformly, while the abrasive rolls rotate to regulate the applied abrasiveness. A centralized water system, with jets located on the shaft of the auger, provides a constant water spray to the product and the abrasive rolls. The desired water flow is 20 gpm at 40 to 60 psi for each 10 ton per hour unit.

Wastewater from the unit is transported through a chute to a nearby flume and then to primary treatment. As shown in Figures 6, 7, 8 and 9, the Magnuscrubber and Magnuwasher are of similar design except for type and number of rolls, water use, and equipment speed.

A pilot study suggested that the peeling wastes (approximately 75 percent of the total plant waste load in the wet caustic system) could be removed from the liquid waste stream (2). In addition, it was also expected that the peel loss could be reduced by as much as 25 percent.

SECTION IV

DESCRIPTION OF PRETREATMENT AND PRIMARY TREATMENT SYSTEMS

POTATO SERVICE, INC.

Pretreatment of liquid wastes at PSI consisted of sliver and nubbin removal by Shufflos and grader screens, respectively, and of screening white waste through two 4 mesh screens in advance of the primary clarifier. Waste fat removal is accomplished through flume baffles which allow the liquid waste to flow underneath them but retain the floating fat which is cleaned out manually. Finished product wastes were removed as solids rather than allowing them to enter the waste stream.

Primary treatment of wastewater is accomplished by utilizing two clarifiers; a 60-foot diameter process water clarifier (main clarifier) and a 24-foot diameter fluming water clarifier (mud clarifier).

The process water passes through two 4 mesh shaker screens (process water does not include fluming water) prior to entering the main clarifier, 60 feet in diameter with a 9 foot side wall depth and an approximate volume of 225,000 gallons. This clarifier is equipped with a surface skimming device to remove floating solids, such as frying shortening, and a pair of rake arms on the bottom of the tank. These arms move the settleable solids on the conical bottom surface to the center of the clarifier where they are drawn off for dewatering on a continuous belt vacuum filter. The filtrate is discharged into the primary clarifier effluent prior to discharge into lagoons.

WESTERN POTATO SERVICE, INC.

Pretreatment of waste from WPSI consists of three separate operations: peel solids (peel taken off the potato by the Magnuscrubber peeler) removal, white waste (trim waste, unusable potatoes, etc.) removal, and finished product waste (french fries) removal. The peeler solids are conveyed from the Magnuscrubber peeler to a small pumping pit from which they are pumped by a concrete pump to a waste hopper for ultimate disposal by truck to land fill. Removal of white waste is accomplished by passing the waste stream through a 4 mesh link belt vibrating screen. These solids are collected in a waste hopper for trucking to cattle feeders; the remaining wastewater is pumped to primary treatment. The third operation, finished product removal, is "dry handled" for ultimate trucking off for cattle feed.

Primary treatment of the wastewater is accomplished by utilizing two clarifiers: a 60 foot diameter process wastewater clarifier (main clarifier) and a 24 foot fluming water clarifier (mud clarifier).

The process water passes through a 4 mesh vibrating screen (process water not including fluming water) prior to entering the main clarifier, 60 feet in diameter with a 9 foot sidewall depth and having an approximate volume of 225,000 gallons. This clarifier is equipped with a surface skimming device to remove floating solids, such a frying fat, and a pair of rake arms on the bottom of the tank. These arms move the settleable solids on the conical bottom surface to the center of the clarifier where they are thickened and drawn off for dewatering on a continuous belt vacuum filter (see Figure 10). The effluent from the main clarifier can be sent either directly to the city sewer or to secondary treatment consisting of a five million gallon aerated activated sludge basin and a 100 foot diameter secondary clarifier. Following the secondary process, the waste can again be directed to the city sewer or to a tertiary plant where flocculating chemicals are added prior to filtration through sand filters. At this point the water can be wasted to the city sewer or chlorinated and pumped back to the processing plant for reuse in various areas.

The fluming wastewater flows to the mud clarifier, 24 feet in diameter with a sidewall depth of 8 feet. The mud clarifier is provided with a set of rake arms, similar to those mentioned above, but has no surface skimmer. The "mud sludge" accumulated in the bottom of the clarifier is pumped to a hopper for trucking to land fill. The clarifier overflow is pumped to the secondary process.

The sludge collected from the process clarifier (main primary clarifier) is pumped to an 8' X 10' continuous vacuum belt filter for dewatering. The filter "cake" thus obtained is either fed to cattle or used as land fill. The filtrate is returned to the center well of the main clarifier.

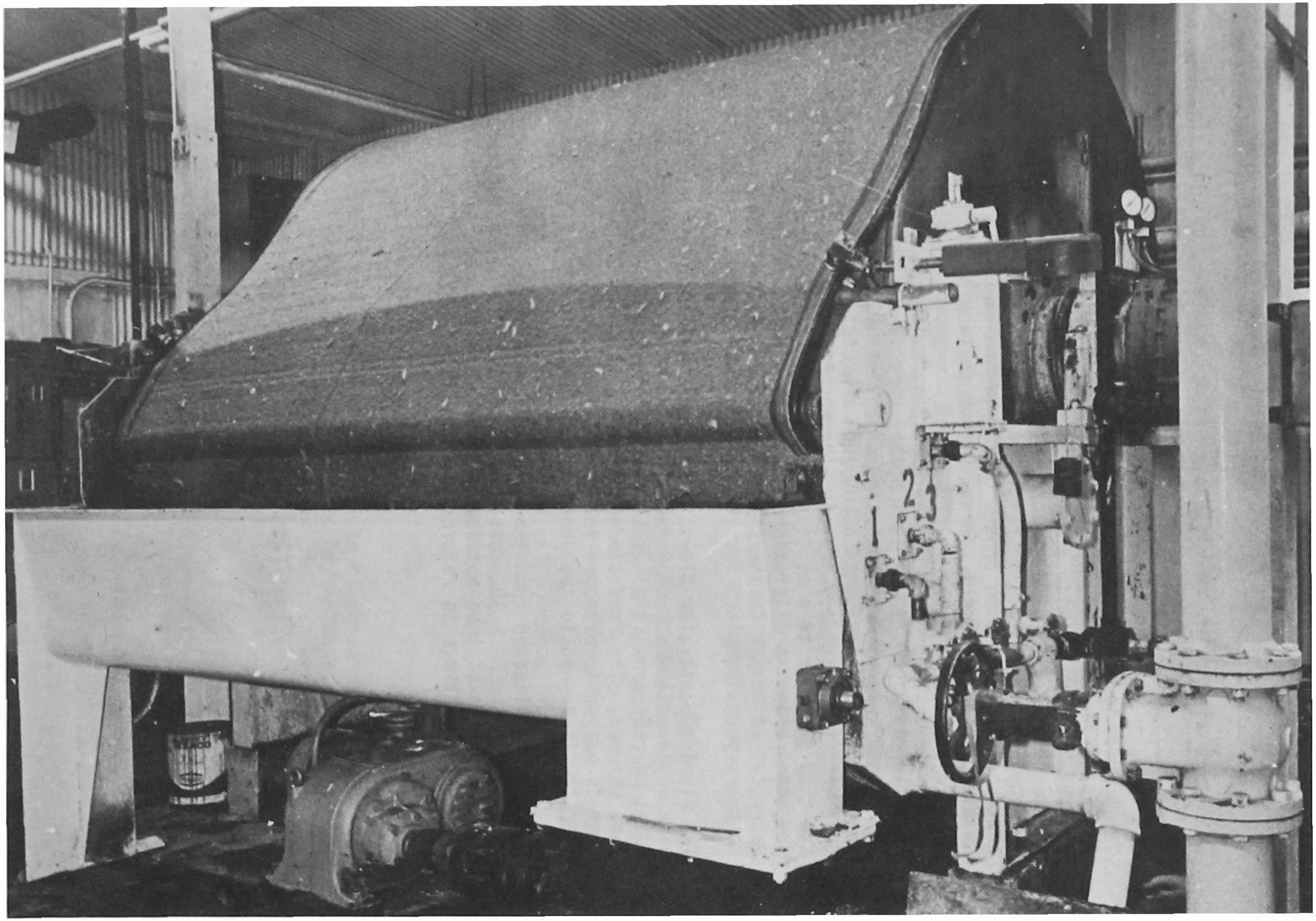


Figure 10. EIMCO continuous filter at WPSI (Produces filter cake from main clarifier sludge).

SECTION V

SAMPLING AND ANALYSES

Samples were collected at PSI from the cutter deck effluent; caustic reel dump; hydro-brusher-washer peelers; caustic reel intake; raw effluent prior to screening; screened solids; main clarifier influent, effluent and sludge; mud clarifier influent, effluent and sludge; filter filtrate and sludge; potable water and raw material. Specific analyses for each sampling point are listed in Table 2. See Figure 11 for sampling and instrumentation at PSI.

Samples were collected at WPSI from the Magnuscrubber peeler; caustic-peel dump; Magnubrusher peelers; caustic reel intake; screened solids; main clarifier influent, effluent and sludge; filter filtrate and sludge; potable water and raw material. See Figure 12 for sampling points and instrumentation at WPSI.

Twenty-four hour composited samples were collected and analyzed approximately once a week at PSI and twice weekly at WPSI (see Table 3).

Table 3. SEASONS, DATES, AND NUMBER OF SAMPLE SETS

SEASON	DATES	NO.	DATES	NO.
	WET CAUSTIC - PSI		IR-DRY CAUSTIC - WPSI	
Winter	03-24-71 to 03-31-71	2	02-09-71 to 04-01-71	14
Spring	04-22-71 to 06-30-71	8	04-06-71 to 06-19-71	19
Fall	09-06-71 to 11-31-71	12	09-02-71 to 12-02-71	21
Winter	12-02-71 to 12-14-71	2	12-02-71 to 12-30-71	7

All samples were collected on the hour with liquid samples being taken proportional to flow and solid samples collected on the hour in predetermined quantities. The samples were analyzed in accordance with Table 2.

Valid data were not obtained for every sampling day due to experimental, sampling and analysis error, frozen sampling lines, and plant shutdowns.

TABLE 2

SAMPLING POINT DESIGNATION AND ANALYSES PERFORMED AT WPSI AND PSI

Sampling Point	Letter Code WPSI Fig. 6	Letter Code PSI Fig. 7	Turbidity	Vol. - Wt.	TPO4	TKN	COD	BOD_5	Sett. Solids	SS	VSS	TS	TVS	Alkalinity	pH	Specific Gravity
Cutter Deck Effluent	-	A		X	X	X	X	X	X	X	X	X	X	X	X	X
Peeler Solids	A	-		X	X	X						X	X	X	X	X
Caustic Peel Dump	B	N		X	X	X	X	X	X	X	X	X	X	X	X	X
Washers	C	B		X	X	X	X	X	X	X	X	X	X	X	X	X
Caustic Peel Intake	D	O		X												X
Raw Effluent before Screening	-	C		X	X	X	X	X	X	X	X	X	X	X	X	X
Screen Solids	E	D		X								X	X			X
Main Clarifier Influent	F	E		X	X	X	X	X	X	X	X	X	X	X	X	X
Main Clarifier Effluent	G	F	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Mud Clarifier Influent	H	G		X	X	X	X	X	X	X	X	X	X	X	X	X
Mud Clarifier Effluent	I	H		X	X	X	X	X	X	X	X	X	X	X	X	X
Mud Pump Sludge	J	I		X								X	X	X	X	X
Main Clarifier Sludge	K	J		X								X	X	X	X	X
Filter Filtrate	N	K		X					X	X	X	X	X		X	X
Filter Sludge	L	L		X	X	X						X	X		X	X
Potable Water	M	M		X	X	X	X	X	X	X	X	X	X	X	X	X
Water to Flume	-	P														
Raw Material	Q	Q		X												X

Twenty-four hour samples composited on flow basis twice weekly at WPSI and weekly at PSI at all locations.

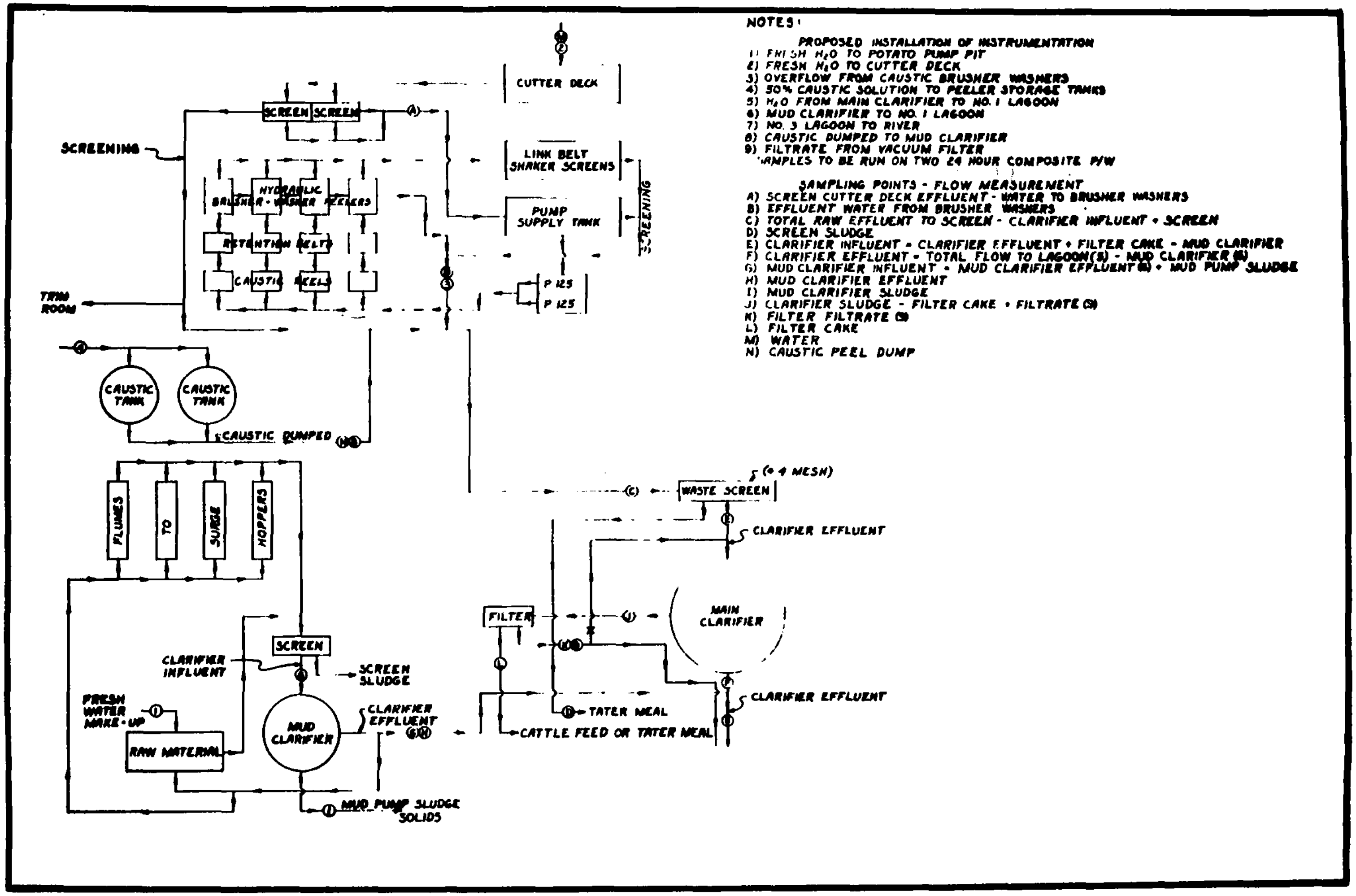


Figure 11. Sampling points and instrumentation (PSI)

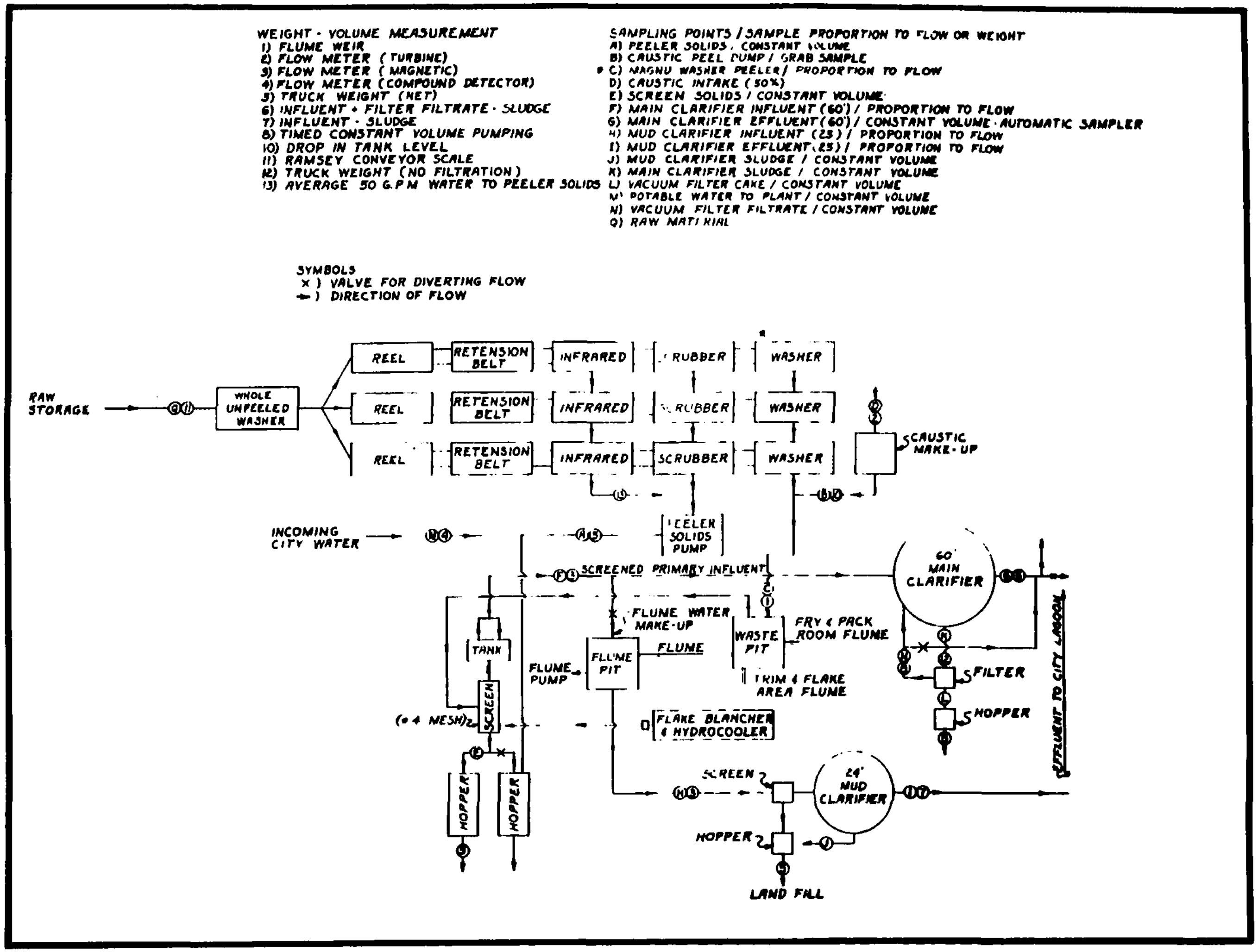


Figure 12. Sampling points and instrumentation (WPSI)

Analyses were performed according to Standard Methods (3) for total solids, total volatile solids, suspended solids, volatile suspended solids, settleable solids, alkalinity, pH, BOD, and specific gravity.

A Technicon Auto Analyzer was used to determine total Kjeldahl nitrogen, chemical oxygen demand, and total phosphate (4).

SECTION VI

RESULTS AND DISCUSSION

The analytical data from the two plants will be presented by separating the results into winter, spring, and fall sections. The winter data are for February, March, and December, 1971; the spring data for April, May and June, 1971, and the fall data are for September, October and November, 1971. The potatoes used for the late winter (February and March) and spring data were from the 1970 growing season, while the fall and early winter (December) 1971 data were from the 1971 growing season. This separation of data has been made since there may be a difference in the waste characteristics, especially from the peeling process, since a deeper peel of the potato is usually necessary on those held longer in storage. Also the early and late winter data have been grouped due to the small number of sample sets for these two periods from PSI.

Although the design tonnage for the PSI plant is 1000 tons of raw potatoes per day it only processed 810 tons per day during this evaluation. Comparable tonnages for WPSI are 600 and 425, respectively. There was a significant difference in the average quantity of potatoes processed between seasons at the WPSI plant; however, this was not so at the PSI plant. This contrast was probably due to the fact that the PSI plant had been in operation for more years and thus had more experienced help than the WPSI plant.

A summary of some of the data collected during this evaluation at the PSI and WPSI plants is shown in Tables 4 and 5, respectively. A copy of all the raw data is available upon request from the Waste Treatment Research Program, Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon.

The main clarifier influent is made up of the waste loads from the peel system and all following operations within the plant except for the potato flumes used to convey the potatoes from storage to the peel lines. The waste characteristics of these other processes can be obtained by substracting the peel system data from the main clarifier influent data. The data for the mud clarifier influent are for water used to flume the potatoes from storage to the unpeeled potato washer located before the peel lines.

The main clarifier influent at both PSI and WPSI passed through 4 mesh screens in advance of the sampling point. In correlating certain data, such as suspended solids entering the main clarifier with that leaving the Magnuwasher peeler, it may be noted that the values may be less entering the clarifier than they are leaving the Magnuwasher peeler. This has been caused by solids removal at the screen and/or additions of water with lower solids content. In cases where the values entering the clarifier are higher than those leaving the washer, the other parts of the plant have contributed a large load of solids which passed through the 4 mesh screen.

A perusal of the Magnuwasher peeler data at WPSI for the three seasons shows that each of the various waste characteristics were lower for the spring season than for the fall and winter seasons. This was caused in major part by the decreased by-passing of the Magnuscrubber peeler waste solids to the Magnuwasher peeler wastewater line during the spring months. Discharge of this material to this line occurred on certain sampling days because of peeler solids handling equipment breakdown and/or increased plant production in the fall and winter resulting in increased peeler scrubber solids at a rate which exceeded the capacity of the solids handling equipment. Therefore, bypassing of the solids on some of these days to the washer wastewater line was inevitable.

The data have been analyzed for significant differences with a two way variance test and by a t test. (These results will be presented at appropriate points in the discussion.)

PEEL LOSS

The data for comparison of the peel loss are presented in Table 6. It has been expected that the IR-dry caustic system would lessen the peel loss, and this proved to be true to a degree during the fall and early winter, but not so in the late winter and spring. The following factors were thought to be the cause of the low differential between the plants during the late winter and spring:

1. Water spray use over Shufflos---whenever the caustic treatment became too harsh, some of the affected potato tissue would build up on the Shufflos. One remedy for this was to continually wash the Shufflos with a water spray. This treatment would, of course, lower the tuber temperature which in turn resulted in less efficient treatment by the infrared necessitating more caustic treatment to effect the desired result. This difficulty was not discovered and corrected until early fall.

2. Infrared units too small for load.

3. Operation of the Magnuscrubber peeler and Magnuwasher peeler with insufficient load to operate efficiently---with low loads, the potatoes tended to spend more time bouncing than in contact with the rolls.

TABLE 4

WASTE ANALYSES
WET- CAUSTIC - PSI

SEASON		FLOW	BOD	COD	SS*	TS	TVS	TKN	TPO	ALK	pH	SETT SLDS	SP GR
		Gal/ton				Lbs/Ton						ml/L	
WINTER													
B. Hydro brusher-peeler	Avg	1117	64.6	116	98.0	153	72	1.47	0.60	32.8	12.3	251	1.000
	s	736	37.4	83	74.7	117	85	1.76	0.14	26.1	0.8	54	1.002
	n	4	4	4	4	4	4	3	2	4	4	4	4
E. Main Clarifier Influent	Avg	2591	90.7	147	96.8	152	111	3.60	2.93	28.3	11.6	78	0.999
	s	517	28.2	24	23.8	37	25	0.44	1.94	8.88	0.8	11	0.001
	n	3	4	4	4	4	4	3	3	4	4	4	4
F. Main Clarifier Effluent	Avg	2404	62.1	101	16.9	.0	72	1.90	1.50	22.8	7.4	51	0.998
	s	497	20.6	32	8.99	.3	19	0.57	1.25	3.20	2.3	77	0.001
	n	3	4	4	4	4	4	2	3	4	4	4	4
REMOVAL (%)		---	31.4	31	82.8	40	35	49.5	55.2	16.1	---	35	---
G. Mud Clarifier Influent	Avg	1315	3.90	10	13.5	17	9.8	0.20	0.60	0.5	11.6	25	0.998
	s	1429	2.87	0.8	2.69	4.0	9.0	0.14	0	0.2	0.5	13	0.001
	n	4	3	3	2	3	3	2	1	3	3	3	4
H. Mud Clarifier Effluent	Avg	557	1.83	3.9	4.05	11	3.8	0.15	0.3	0.3	11.2	1.2	0.997
	s	239	0.29	1.1	0.21	2.7	3.3	0.07		0	0.4	0.7	0.001
	n	4	3	3	2	3	3	2	1	3	3	3	4
REMOVAL (%)		---	39.1	61	68.8	35	61	0.0	.0	40	---	95	---
SPRING													
B. Hydro Brusher-peeler	Avg	1224	50.1	114	90.8	142	94	.77	1.50	32.0	11.9	294	0.999
	s	1033	23.8	73	53.7	8.4	59	.39	.65	20.8	0.3	150	0.001
	n	8	7	8	8	8	8	6	6	8	8	8	8
E. Main Clarifier Influent	Avg	3794	94.1	172	134	210	158	4.56	4.53	42.0	10.8	63	0.998
	s	828	17.4	50	36.4	57	36	1.16	1.29	5.66	0.7	24	0.001
	n	8	7	8	8	8	7	8	8	2	8	8	8
F. Main Clarifier Effluent	Avg	3777	65.1	113	28.9	156	94	3.00	3.03	40.5	9.0	7.0	0.998
	s	817	19.9	38	7.50	40.3	30	1.04	0.97	4.95	2.2	11	0.001
	n	8	7	8	7	7	8	4	8	2	8	8	8
REMOVAL (%)		---	31.5	35	78.1	26	41	33.6	32.4	3.5	---	89	---

G. Mud Clarifier Influent	Avg	728	9.68	15	13.5	22	10	0.13	0.54	0.2	8.4	19	0.998
	s	415	7.88	8.9	5.89	15	6.3	0.06	0.24	0.2	1.8	13	0.001
	n	8	8	8	7	8	8	3	7	8	8	8	8
H. Mud Clarifier Effluent	Avg	723	2.33	5.3	4.96	11	3.7	0.13	0.31	0.2	8.5	2.8	0.997
	s	411	1.66	4.8	1.61	5.0	2.0	0.14	0.14	0.1	1.7	2.2	0.001
	n	8	7	8	7	8	8	3	7	8	8	8	8
REMOVAL (%)		---	67.3	65	66.6	51	80	0.00	42.6	0.0	---	85	---
FALL													
B. Hydro brusher-peeler	Avg	1425	78.2	148	110	160	115	---	---	25.6	10.8	264	1.000
	s	160	20.8	43	24.6	55	40	---	---	5.91	0.8	91	.001
	n	11	10	12	11	12	12	---	---	10	12	12	12
E. Main Clarifier Influent	Avg	2121	58.4	115	716	192	157	---	---	17.4	10.2	72	0.999
	s	197	18.4	47	24.4	280	278	---	---	3.42	1.0	20	0.001
	n	11	11	12	11	12	12	---	---	8	12	12	12
F. Main Clarifier Effluent	Avg	1790	28.0	51	9.19	49.4	30	---	---	10.0	8.2	26	0.998
	s	726	14.5	26	6.38	34.3	25	---	---	6.10	1.8	40	.002
	n	12	11	11	11	11	12	---	---	9	12	12	12
REMOVAL (%)		---	42.8	51	85.5	74.2	76	---	---	37.5	---	64	---
G. Mud Clarifier Influent	Avg	810	3.51	11	13.0	8.8	3.0	---	---	0.3	9.6	5.8	0.998
	s	414	1.93	9.8	4.89	27	10	---	---	0.2	1.3	2.5	0.001
	n	12	9	11	9	11	11	---	---	11	11	11	11
H. Mud Clarifier Effluent	Avg	661	1.57	3.3	4.03	8.8	3.4	---	---	0.2	9.3	0.9	0.997
	s	192	0.99	1.8	2.42	5.3	3.3	---	---	0.1	1.3	0.4	0.001
	n	12	9	11	11	11	11	---	---	11	11	11	11
REMOVAL (%)		---	48.1	56	60.2	58	58	---	---	33	---	85	---

Note: The letters, preceding the sampling points above, indicate the "letter code" for those points. (See Table 2).

s. Standard deviations - see Glossary
n. Number of samples - see Glossary

TABLE 5

WASTE ANALYSES
IR - DRY - CAUSTIC - WPSI

SEASON		FLOW	BOD	COD	SS	VSS	TS	TVS	TKN	TPO	ALK	pH	SETT SLDS	TURB	SP GR
		Gal/Ton					Lbs/Ton						ml/L	JTU	
WINTER															
C. Magnuwasher-peeler	Avg	272	18.2	35	24.6	23	41	29	0.49	0.20	5.81	11.5	451		1.002
	s	83.0	10.1	9.9	14.8	15	18	13	0.21	0.09	3.57	0.4	261		0.003
	n	19	18	13	19	20	16	16	12	12	18	19	21		21
F. Main Clairfier Influent	Avg	1716	35.1	68	47.6	37	81	53	1.36	2.67	14.3	10.7	38		0.999
	s	366	8.56	21	12.7	11	17	15	0.37	1.13	3.05	0.9	11		0.002
	n	20	18	13	19	20	16	16	10	9	19	19	21		21
G. Main Clarifier Effluent	Avg	1815	23.8	37	8.11	6.1	45.0	26	1.26	1.79	9.11	7.92	12	560	0.998
	s	581	6.39	11	1.81	1.8	10.8	8.7	0.47	0.54	1.75	1.61	15	194	0.002
	n	21	19	13	19	20	16	16	11	9	18	19	21	19	21
REMOVAL (%)			33.6	45	80.5	84	44	51	15.4	29	30.9	--	69	---	---
H. Mud Clarifier Influent	Avg	280	5.11	12	12.7	7.7	22	12	0.27	0.34	2.8	10.8	37.71		1.000
	s	221	3.60	6.4	10.1	5.9	14	9.8	0.13	0.31	2.0	0.6	14.8		0.002
	n	15	9	9	10	14	10	10	9	9	13	13	13		15
I. Mud Clarifier Effluent	Avg	274	4.72	8.3	4.21	3.7	11	7.2	0.18	0.26	1.9	9.5	32	1000	0.999
	s	223	3.61	4.0	2.26	4.1	7.0	5.0	0.10	0.23	1.8	1.6	46	529	0.008
	n	15	9	8	12	14	10	10	8	9	13	13	13	12	15
REMOVAL (%)		---	26.2	33	71.8	52	50	39	.0	23.5	32	---	28	---	---
SPRING															
C. Magnuwasher-peeler	Avg	392	7.38	15	11.6	12	18	12	1.33	0.13	4.33	11.0	95.3		1.001
	s	96	2.33	11	7.39	9.0	7.2	5.5	.19	0.05	1.44	0.5	94.8		0.003
	n	19	10	13	17	18	19	19	6	9	16	17	16		19
F. Main Clarifier Influent	Avg	2613	25.9	35	39.3	30	65	40	1.52	1.58	18.0	10.5	21		1.000
	s	453	7.12	9.4	17.0	14	19	16	0.21	.58	4.22	0.5	14		0.003
	n	18	11	12	17	18	19	19	6	6	16	18	17		19
G. Main Clarifier Effluent	Avg	2536	17.8	26	10.0	7	46.1	27	1.43	1.05	11.3	7.65	13	653	1.000
	s	545	3.96	9.2	4.45	3.1	8.60	9	0.27	0.56	3.86	1.37	29	199	0.002
	n	19	10	9	18	18	16	18	6	6	17	18	17	16	19
REMOVAL (%)		---	29.1	25	70.2	77	29	34	6.0	34.2	35.5	---	37	---	---

H. Mud Clarifier	Avg	356	6.3	---	7.3	5.6	12	8.2	---	---	2.4	11.3	37	---	1.003
Influent	s	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	n	1	1	---	1	1	1	1	---	---	1	1	1	---	1
I. Mud Clarifier	Avg	351	4.3	---	6.4	1.9	6.9	4.4	---	---	1.3	8.8	7.5	850	1.001
Effluent	s	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	n	1	1	---	1	1	1	1	---	---	1	1	1	1	1
REMOVAL (%)		---	32	---	12	66	43	46	---	---	46	---	80	---	---
FALL															
C. Magnuwasher-peeler	Avg	378	14.9	43	32.8	38	52	38	.67	0.20	7.22	11.5	531		1.001
	s	93.0	9.52	24	15.8	27	42	24	.26	0.06	3.64	0.3	252		0.008
	n	17	9	18	16	18	18	18	15	14	17	18	18		18
F. Main Clarifier	Avg	2294	38.4	64	38.5	34	77	59	1.64	2.21	14.3	10.0	36		0.998
Influent	s	626	13.1	21	14.9	12	23	29	0.41	0.75	3.35	1.1	55		0.002
	n	19	11	21	20	17	21	21	17	10	17	21	21		21
G. Main Clarifier	Avg	2624	26.3	43	8.27	7.5	49.4	32	1.33	1.63	9.72	7.7	4.2	428	0.999
Effluent	s	1220	7.51	14	2.57	3.3	9.63	10	0.23	0.37	2.51	1.4	6.4	81	0.001
	n	21	12	20	20	18	20	21	16	11	17	21	21	21	21
REMOVAL (%)		---	30.0	33	79.1	78	31	46	16.2	26.7	30.8	---	88	---	---
H. Mud Clarifier	Avg	255	3.63	8.4	11.0	9.3	21	8.6	0.19	0.18	3.2	10.7	53.8		1.003
Influent	s	142	2.22	4.7	4.31	5.4	8.6	3.8	0.08	0.11	1.3	1.5	21.6		0.023
	n	21	11	21	5	21	21	21	17	18	21	21	19		21
I. Mud Clarifier	Avg	248	2.88	5.9	3.58	2.3	9.5	5.1	0.14	0.11	2.0	9.7	20	1380	0.999
Effluent	s	153	2.13	3.7	2.42	1.9	5.9	2.9	0.09	0.09	1.0	1.8	25	619	0.003
	n	20	13	20	19	20	20	20	18	18	20	20	19	20	20
REMOVAL (%)		---	24.6	30	83.5	75	55	41	50	50	38	---	65	---	---

Note: The letters, preceding the sampling points above, indicate the "letter code" for those points (See Table 2).

s. Standard deviation - see Glossary
n. Number os Samples - see Glossary

TABLE 6

COMPARISON OF PEEL LOSS DATA

WET CAUSTIC - PSI		DRY CAUSTIC - WPSI	
Season	% of Raw Potato	Season	% of Raw Potato
Winter 3-24 to 3-31		2-16 to 3-31	
Avg	19.53		19.69
s	3.31		1.71
n	45		148
Spring 4-22 to 6-30		4-6 to 6-19	
Avg	21.00		20.81
s	2.31		1.97
n	86		191
Fall 9-1 to 11-31		9-2 to 12-2	
Avg	18.05		16.26
s	3.11		1.00
n	367		239
Winter 12-2- to 12-14		12-2 to 12-30	
Avg	23.63		17.23
s	4.42		1.32
n	60		26
Late Winter & Spring Avg*	20.50		20.32
Fall Early Winter Avg*	18.83		16.36
All Seasons Avg*	19.22		18.58

s Standard Deviation - see glossary
n Number of samples - see glossary
* Weighted averages throughout

The above effects appeared to peak during the late winter and spring when the degree of peeling required was at the maximum. In the fall, the Magnuscrubber peelers and Magnuwasher peelers were reset to carry more load---1/3 to 1/2 full. Once this was accomplished and the caustic treatment cut back to the point at which the potatoes were reaching the Shufflos essentially intact, the need for water sprays over the Shufflos was essentially eliminated. With these conditions and with caustic concentration at 9.5 to 10.5 percent, caustic temperature at 190°F, and caustic immersion time at 2 to 2-1/4 minutes, the retention belt set for approximately 2 minutes residence time, and the infrared burners set for 1-1/2 minutes, peel losses as low as 15.0 percent were obtained.

The peel loss results during the last week in November and the first two weeks of December are not included due to a breakdown of one scrubber which necessitated extremely heavy loading of the other two peel lines.

Using the peel losses for fall and early winter (9-2 to 12-30) when the IR-dry caustic system was operating most successfully and there was a significant difference at the 0.05 level, the peel loss was 2.5 percent less than the wet system which calculates to a 13.1 percent decrease in peel loss when compared to the wet caustic system. There was a statistical difference at the 0.05 level between the four periods at each of the plants, and between plants during the fall and early winter but not during late winter and spring.

COMPARISON OF CAUSTIC USAGE

The caustic consumption data is presented in Table 7 below. It may be noted that weighted averages were consistently lower at WPSI.

Standard deviations are not shown due to the effect of the caustic make-up tank. Once this tank was charged, it required an indeterminate number of hours before recharging was necessary. Thus the daily usage did not necessarily reflect actual usage, but merely the amount of 50 percent caustic added to the caustic peeling solution. However, over a period of one or several weeks, this did represent very nearly the actual usage ("n" indicates the actual number of "daily caustic usages" represented).

The WPSI caustic consumption was only 73.8 percent of the PSI results, indicating a significant reduction in caustic usage by the dry caustic method. The IR-dry caustic peeling system decreased caustic usage by an average of 0.262 lbs per 100 lbs peeled and thus would decrease the costs of peeling by $0.42 per ton of potatoes.

Table 7. COMPARISON OF CAUSTIC USAGE

SEASON	WET CAUSTIC-PSI lbs/100 lbs Peeled	IR-DRY CAUSTIC - WPSI lbs/100 lbs Peeled
WINTER		
Avg	1.131	.759
n	60	64
SPRING		
Avg	1.412	.900
n	54	59
FALL		
Avg	.643	.608
n	74	63
OVERALL AVERAGE*	1.020	.753

n Number of samples - see glossary
* Weighted averages

Caustic peeling conditions at each plant ranged as follows:

	PSI WET CAUSTIC	WPSI IR-DRY CAUSTIC
Temperature range	170°F to 200°F	145°F to 200°F
Concentration range	7.5 to 23 percent	8.6 to 20 percent
Immersion time range	3 to 7 minutes	1 to 5 minutes

INFRARED DRY CAUSTIC MAGNUSCRUBBER PEEL WASTES

The IR-dry caustic peeler solids data are shown in Table 8. The recovery of total solids were 53, 81 and 41 pounds per ton of potatoes processed during winter, spring and fall respectively.

The increased recovery in the spring was caused by more actual peel loss due to deeper peeling of the potatoes and also to a diminished bypassing of the solids to the Magnuwasher peeler wastewater line. The low dry solids content of the peeler solids---9.8 to 8.6 percent---was due to the water added to keep the material in a condition that could be pumped. A dry solid content of 14 to 15 percent might be expected if the water had not been needed.

Table 8. PEELER SOLIDS DATA---DRY CAUSTIC - WPSI

SEASON	Dry Solids	TS	TVS	Alk	TPO_4	TKN	pH	Sp. Gr.
	percent	pounds/ton						
WINTER								
Avg	9.8	53	35	9.6	0.2	0.5	12.6	1.004
s	1.1	30	19	5.0	0.1	0.2	0.3	0.009
n	16	16	16	19	13	13	19	16
SPRING								
Avg	9.4	81	57	14	0.4	0.9	12.6	1.022
s	1.1	17	11	4.0	0.1	0.2	0.2	0.025
n	18	18	18	15	8	6	16	18
FALL								
Avg	8.6	41	28	11	0.2	0.6	12.4	1.000
s	2.3	22	14	16	0.1	0.3	0.2	0.025
n	12	12	12	12	12	11	12	12
ALL SEASONS								
Avg*	9.3	61	42	11	.25	.62	12.6	1.010

s Standard Deviation - see glossary
n Number of samples - see glossary
* Weighted average

Occassionally, a whole potato entered the peeler solids line and plugged the pump. This necessitated reversal of the pump flow to dislodge the potato. Future installations should consider the addition of a food chopper prior to the pump to grind whole potatoes to a pumpable consistency thereby reducing pump maintenance problems.

SCREEN SOLIDS CHARACTERISTICS

The data for the sludge from the vibrating 4 mesh screens located in advance of the main clarifier are shown in Table 9. The total solids averaged over the year was 15.7 pounds per ton at PSI and 33.0 pounds per ton at WPSI. This difference was significant at the 0.05 level for all three seasons between plants as well as at WPSI between seasons. However, there was no significant difference between seasons at PSI at this same level.

Table 9. SCREENINGS DATA

SEASON	WET CAUSTIC - PSI (4 Mesh Screenings) TS lbs/ton	TVS lbs/ton	Dry Solids %	IR-DRY CAUSTIC - WPSI (4 Mesh Screenings) TS lbs/ton	TVS lbs/ton	Dry Solids %
WINTER						
Avg	12.7	12.0	16.6	28.8	27.0	17.6
s	5.87	5.8	1.81	17.20	17	4.32
n	4	4	4	16.0	16	15
SPRING						
Avg	14.4	13.4	15.6	35.3	27.5	18.3
s	5.12	7.7	1.58	8.55	8.34	1.71
n	7	8	7	15	15	17
FALL						
Avg	19.0	17.6	15.1	40.7	39.7	21.6
s	8.75	8.8	2.61	6.38	9	1.56
n	12	11	11	20.0	21	20.0
ALL SEASONS						
Avg*	15.7	15	14.8	33.0	34	19.4

s Standard Deviation - see glossary
n Number of samples - see glossary
* Weighted average

This was probably caused by more internal screening at PSI for potato recovery for specialty products.

PLANT MASS BALANCES

Mass balances were performed on both the WPSI and the PSI plants. The purpose of the balances was to ascertain the degree of control each plant had over its raw materials, finished product and waste products.

The balances for six (6) days at WPSI were determined by accounting for (1) all the dry solids and water entering the plant in the form of raw material, chemicals, and water, and (2) the dry solids and water in the finished products and wastes. Table 10 presents the difference between the material leaving the plant as a percentage of the material entering the plant. The balances for WPSI were good with a mean of 95.3 percent for dry solids and 107.3 percent for water. These percentages are reasonable considering the difficulty encountered in obtaining representative samples from such a large volume operation.

Table 10. PLANT MASS BALANCES

WET CAUSTIC - PSI		IR-DRY CAUSTIC - WPSI	
Day	Dry Solids %	Dry Solids %	Water %
1	85.4	94.3	95.4
2	88.4	88.7	110.1
3	112.1	88.3	107.4
4	86.1	100.0	106.3
5	94.8	103.3	110.5
6	91.4	97.5	114.3
Avg	93.1	95.3	107.3
s	10.0	6.1	6.5

s Standard Deviation - see glossary

Solids balances were calculated for six (6) days at PSI by accounting for all the solids entering and leaving the plant in the form of raw material, chemicals, finished product, and waste products. Only the solids balance could be obtained from PSI because the plant fresh water was not metered. The dry solids recovery for PSI was determined in the same manner as for WPSI. The solids leaving the plant were expressed as a percentage of the solids entering the plant. The solids balance for PSI was also quite good (93.1 percent) considering the problems encountered in sampling.

WASTEWATER CHARACTERISTICS

Biochemical Oxygen Demand

The PSI plant main clarifier influent BOD values of 90.7, 94.1, 58.4 pounds per ton of raw potatoes processed for the winter, spring, and fall seasons, respectively, were considerably larger than the corresponding values of 35.1, 25.9, 38.4 pounds per ton at the WPSI plant.

The weighted average for the year (all three seasons) was 33.5 pounds at WPSI and 62.8 at PSI - a difference of 29.3 pounds per ton. The results during the winter and spring seasons between plants were significantly different at the 0.05 level as were those between seasons at each plant. However, there was no significant difference between the plants during the fall season.

The BOD values for the washer wastewater at WPSI were about one-third that of the hydro-brusher peeler at PSI. The values at PSI for winter, spring and fall were 64.6, 50.1, and 78.2 pounds per ton while the corresponding values at WPSI were 18.2, 7.4 and 14.9 pounds per ton. The weighted average for the year was 66.2 pounds per ton at PSI and only 14.5 at WPSI - a difference of 52 pounds per ton. The results were significantly different between plants during the spring and fall seasons and between seasons at WPSI but not during the winter between plants nor between seasons at PSI (0.05 level). A very marked BOD reduction was obtained by the IR-dry caustic peeling system over the wet caustic system. The removal of the peeler solids in the Magnuscrubber peeler prior to the Magnubrusher peeler effected a significant reduction in the BOD reaching the wastewater from the potato peeling operation as shown by the above mentioned significant difference at 0.05 level between the plants during the spring and fall. The BOD value of 7.4 pounds per ton in the spring at WPSI was caused partially by decreased production but largely by better handling of the peeler solids.

The mud clarifier influent from the potato fluming lines had about the same BOD values at each plant with no significant difference between plants or between seasons at the plants. The BOD did show some increase from fall to spring indicating increased leaching of solubles from stored potatoes which had broken down over the storage season.

Suspended Solids

The suspended solids data at the PSI plant have been computed from the reported total solids data, using a ratio of 0.639 pounds of suspended solids per pound of total solids for the main influents, 0.6413 for the peeler wash water, and 0.1859 for the main clarifier effluent. These ratios were established from all the usable data for winter, spring and fall at the WPSI plant because the analytical method for the suspended solids at the PSI plant was not used correctly. The analysis of the suspended solids data at PSI must be cautiously reviewed considering the method used to obtain it.

The main clarifier influent suspended solids of 47.6, 39.3 and 38.5 pounds per ton for the winter, spring and fall seasons at WPSI were significantly smaller than the 96.8, 133.9 and 71.6 pounds per ton obtained at the PSI plant, even with the additional screening at PSI and the bypassing at times of the peeler sludge disposal system at WPSI. The differences in these data between plants by seasons were significant at the 0.05 level and also between seasons at PSI (but not at WPSI).

The average Magnubrusher peeler suspended solids in the wash water at WPSI was only 22.9 pounds per ton for the three seasons but was 101.2 pounds per ton for the hydro brusher washer peeler at PSI. This difference of 78.3 pounds per ton accounted for most of the difference in the main clarifier influent suspended solids between the two plants. As discussed earlier, the Magnubrusher peeler suspended solids of only 11.6 pounds per ton at WPSI in the Spring were significantly smaller than the winter and fall figures of 24.6 and 32.8, respectively. This was caused in part by changes in the plant production rate. Increased production during the fall and early winter overtaxed the peeler's solids handling capacity, causing equipment breakdown at WPSI, and thus requiring that part of these solids be discharged to the Magnubrusher peeler wastewater line. There was a significant difference at the 0.05 level between seasons at WPSI and during the spring and fall seasons at the two plants. However, no significant difference at the 0.05 level occurred during the winter season nor between seasons at PSI.

The mud clarifier influent suspended solids to total solids ratio at WPSI was 0.737, and the suspended solids at PSI were calculated using this ratio. Clarifier influent suspended solids differed significantly at the 0.05 level between plants during the three seasons and within PSI (but not WPSI) by seasons.

Total And Total Volatile, Volatile Suspended, And Settleable Solids

The remaining solids data show that the peeler solids (except the fall and winter settleable solids) from the dry caustic peeling process at WPSI were less than from the wet caustic process at PSI. The settleable solids at PSI of 250 and 272 ml/liter for the winter and fall were lower than the 451 and 531 ml/liter at WPSI. This was caused by the occasional bypassing of some of the peeler scrubber waste solids to the washer wastewater line during the fall and winter months. The difference between plants also is magnified somewhat since the settleable solids measurement is a sludge per unit volume of sludge and water. The lower volume of water used at WPSI in the washers gives an exaggerated estimate of the differences between the two peeling processes.

Peeling Water Use

The water use for the hydro-brusher-washer peelers at PSI was three and one-half times the use by Magnubrusher peelers at WPSI. The difference by weighted average was 955 gallons per ton of raw potatoes processed. The water usage per ton of potatoes reflects the tonnage of potatoes processed. That is, when the plant is started, all plant valves including peeler water valves are turned on and generally left on throughout the day. Therefore, during those seasons such as winter when more potatoes are processed than at other seasons, the water volume used per ton goes down. This occurred during the winter season, reflected in the data by the smaller values of 1117 gallons per ton at PSI and 272 gallons per ton at WPSI (see Tables 4 and 5). The results showed a significant difference between plants for all three seasons, as well as between seasons at WPSI (but not at PSI).

Main Plant And Fluming Use

The yearly average main clarifier influent was 2672 gallons per ton at PSI and 2192 gallons per ton at WPSI. At WPSI, where the fresh water was metered into the plant, a total of 2593 gallons per ton were used. Thus, 401 gallons were lost in boiler usage, condenser usage, and evaporation. By estimation, PSI's equivalent losses should be about 490 gallons, making a total usage of approximately 3162 gallons and a difference between plants of 568 gallons (less than the 955 gallons per ton decrease in the peeling systems usage). These differences between total plant use and between peeler washer use---955 gallons per ton vs 568, respectively---are probably due to blanching and leaching procedures to remove excess sugar. Whenever high sugar raw material is encountered, increasing the overflow from the blanchers to leach out the necessary amount of sugar is necessary in order to produce material within the acceptable color range.

The yearly average fluming water use was 665 gallons per ton at PSI but only 265 gallons at WPSI. This difference, while significant, is not related to the peeling methods but simply to the efficiency of the two fluming systems.

Nitrogen and Phosphate

The total Kjeldahl nitrogen for the main clarifier influent at PSI for the two seasons (when tests were taken) averaged 4.30 pounds as elemental N per ton of potatoes processed versus 1.53 pounds per ton at WPSI. The results were significantly different at the 0.05 level during the winter and spring seasons between plants and between seasons at PSI but not at WPSI. This difference was not caused by the difference in the peeling systems since the hydro-brusher-washer peeler waste at PSI for the three seasons averaged 1.00 pound of total nitrogen per ton of potatoes while the corresponding value at WPSI was 0.72 pounds.

Differences were noted in the peeling system liquid effluent total phosphate of the two plants. The PSI hydro-brusher-washer peeler wastes averaged 1.28 pounds of PO_4 per ton processed for the three seasons while the WPSI plant had only 0.18 pounds per ton in its Magnubrusher peeler wastes. The results were significantly different at the 0.05 level during the winter and spring seasons between plants and also between seasons at WPSI (but not at PSI). The weighted average for the main clarifier influent total phosphate was 4.50 pounds per ton at PSI and 2.22 pounds per ton at WPSI. The results were not significantly different at the 0.05 level during the winter season between the plants nor between seasons at each of the plants. There was, however, a significant difference during the spring between plants.

The weighted average for phosphate as PO_4 in the mud clarifier influent was 0.55 and 0.23 pound per ton at PSI and WPSI, respectively. Results between seasons at WPSI were significantly different at the 0.05 level. Sufficient data were not available at either plant for further comparison. The mud clarifier influent total Kjeldahl nitrogen as N was 0.16 pound per ton at PSI and 0.22 pound per ton at WPSI. Results were not significantly different at the 0.05 level within plants by seasons nor between plants during the winter or spring; sufficient fall data was not available for comparison between plants.

BOD:N:P Ratio

The proper BOD:N:P ratio is necessary to maintain a satisfactory bacterial population. The best ratio is 100:5:1. Table 11 gives the main clarifier BOD:N:P ratios.

Table 11. MAIN CLARIFIER BOD:N:P *RATIOS

	WET CAUSTIC - PSI		IR-DRY CAUSTIC - WPSI	
SEASON	Influent	Effluent	Influent	Effluent
Winter	100: 3.97:1.06	100:3.06:0.79	100:3.87:2.48	100:5.30:2.44
Spring	100: 4.84:1.57	100:4.61:1.52	100:5.87:2.01	100:8.03:1.91
Fall	------	-----	100:4.28:1.88	100:5.06:2.01

*Weighted averages

No fall results for PSI nor spring results for WPSI are shown because nitrogen and phosphorus determinations were not made during those periods. These data indicate that adequate phosphorus will be available for secondary treatment but that nitrogen may be a limiting nutrient in the wet caustic waste after primary sedimentation. Supplementation of nitrogen may be necessary to achieve satisfactory biological treatment if short term (2 to 4 days) aerated lagoons are used. Longer aeration periods would allow more biological recycling of nitrogen and could decrease the amount of supplementation required.

Table 12 gives the mud clarifier BOD:TKN:P ratios.

Table 12. MUD CLARIFIER BOD:N:P *RATIOS

	WET CAUSTIC - PSI		IR-DRY CAUSTIC - WPSI	
SEASON	Influent	Effluent	Influent	Effluent
Winter	100:5.13:5.13	100:8.20:5.46	100: -- :2.17	100:3.71:1.69
Spring	100:1.34:1.86	100:8.58:4.29	100:4.29:---	--------
Fall	-------	-------	100:5.23:1.65	100:5.76:1.39

* Weighted average

The mud clarifier effluent data show that the phosphorus is present in satisfactory quantities in the effluent from each plant. The nitrogen level appears satisfactory at PSI, but supplementation might be required at the WPSI plant.

Alkalinity and pH

The average alkalinity over the three seasons in the main clarifier influent at PSI was 24.0 pounds per ton, while WPSI had a much lower value of 14.9 pounds per ton. Alkalinity for the three seasons averaged 29.2 pounds per ton of potatoes for the hydro-brusher-washer peeler at PSI versus 5.8 pounds per ton for the Magnubrusher-peeler at WPSI. Due to a misprint in the method cited in the EPA Manual (6), the analysis figures from PSI showed the alkalinity as 1/10 of its actual strength. This has been corrected in the text. This difference between the two peeler systems resulted because most of the caustic at WPSI was taken out with the peeler solids and did not gain access to the washer wastewater. Alkalinity in the peel system wastes at PSI also increased from 25.6 pounds per ton in the fall to 32.3 pounds per ton in the winter and spring. This is attributed to the increased caustic penetration required to effectively peel potatoes in storage from the fall season. The results showed a significant difference between plants during the winter, spring and fall, as well as between seasons at the individual plant.

PRIMARY SEDIMENTATION AND SLUDGE FILTRATION

Overflow And Solids Loading Rates

The data for the waste analyses in and out of the primary clarifier are shown in Tables 4 and 5. The efficiency of removal of suspended solids is a function of the hydraulic and solids loadings. The hydraulic loading data are presented in Table 13. The data show that the overflow rates in the main clarifiers were not significantly different during winter and spring months; however, the 221 gallons per day per square foot (gpd/ft^2) at PSI during the fall was significantly lower at the 0.05 level than the 412 gpd/ft^2 at WPSI. There was also a significant difference at the same level between seasons at each of the plants.

Excessive detention times in primary clarifiers with readily fermentable wastes such as potato solids are undesirable. The suspended solids, if retained for excessive periods, will be fermented by anaerobic bacteria. This fermentation may result in a sludge that floats due to gasification in the sludge zone. The sludge may be altered so it will not dewater well and the BOD in the clarifier overflow may be increased as a result of the solubilization of the sludge during the anaerobic fermentation. Since the equipment was designed for acid conditions, practically no maintenance problems were caused by the acid resulting from excessive detention times. Table 13 shows that the average detention time at PSI during the fall months was 12.9 hours, compared to 4.7 hours during the winter and 6.4 hours during the spring. These high detention times permitted excessive fermentation of the sludge. The weighted average pH of the main clarifier effluent at PSI was 8.3 versus the average of 7.7 at WPSI. The results showed no significant difference (at the 0.05 level) between either plants or seasons at the individual plants. The higher pH at PSI, even though more acid production occurred, was caused by the much higher initial alkalinity present in its waste than in that at WPSI. This additional buffering prevented the pH from dropping to lower levels in the effluent.

BOD Removal

The BOD removal by primary clarification at each plant was nearly the same, averaging 33.5 and 31.7 percent for the year at PSI and WPSI, respectively. There was no significant difference at the 0.05 level between seasons at each plant nor between plants during the winter and spring; however, there was a significant difference at this level in the fall, the result of a low main clarifier influent at PSI. The difference in the peeling method between the two plants did not, therefore, appear to affect the efficiency of BOD removal through primary clarification. It should be noted that the PSI plant had a higher BOD in the main clarifier effluent, 46.0 pounds per ton averaged over the three seasons, versus the corresponding 23.1 pounds per ton at WPSI. The results were significantly different at the 0.05 level between seasons at the individual plants and between plants during the winter and spring but not during the fall. This represents 22.9 pounds per ton more BOD from the wet caustic peeling process for treatment by the secondary treatment system. This 99 percent increase in the BOD to be treated in the secondary system is a conservative figure since the sludge bypass did at times increase the plant effluent BOD level at WPSI.

Table 13. PRIMARY CLARIFIER OVERFLOW RATES AND DETENTION TIMES

	WET CAUSTIC - PSI					IR DRY CAUSTIC - WPSI				
	Main Clarifier			Mud Clarifier		Main Clarifier			Mud Clarifier	
Season	lbs/ton Solids Loading	gpd/ft.² Overflow	Hours Detention Time	lbs/ton Solids Loading	gpd/ft.² Overflow	lbs/ton Solids Loading	gpd/ft.² Overflow	Hours Detention Time	lbs/ton Solids Loading	gpd/ft.² Overflow
WINTER										
Avg	152	336	7.1	17	720	81	395	5.1	22	353
s	37	126	2.7	4.0	247	17	57.4	1.1	14	284
n	4	4	4	3	4	16	19	21.0	10	15
SPRING										
Avg	210	362	6.4	22	668	65	373	5.4	12	360
s	57	110	2.0	15	112	19	35.2	1.1	--	---
n	8	8	8	8	8	19	18	19	1	1
FALL										
Avg	137	236	12.9	26	824	77	412	4.7	2.1	253
s	89.2	19.0	13.3	27	245	23	39.8	0.5	8.6	140
n	10	10	12	11	12	21	21	21	2.1	20

s Standard Deviation
n Number of Samples

The weighted average BOD removal in the mud clarifier was 54.1 percent at PSI versus 25.6 percent at WPSI. The results were not significantly different at the 0.05 level by seasons at WPSI nor between plants during the winter. However, the results were significantly different at the same level by seasons at PSI and between plants during the fall. Data were insufficient for a comparison between plants during the spring. The higher overflow rate of 755 gpd/ft^2 at PSI may have promoted better settling of the flocculent material in the effluent than the lower overflow rate of 298 gpd/ft^2 at WPSI.

Suspended Solids Removal

The effluent suspended solids data at the PSI plant have been computed from the total solids data. The computation was made using a ratio of 0.186 for the main clarifier effluent and 0.458 for the mud clarifier effluent. These ratios were developed from the WPSI data. As indicated earlier, this procedure was necessary because the original suspended solids data at PSI were determined incorrectly.

The suspended solids removals in the main clarifiers at each of the plants were between 70 and 85 percent for each of the seasons. The difference in these percent removals was significant at the 0.05 level during the fall season between plants and between seasons at WPSI, but not during the spring and winter nor between seasons at PSI. The PSI main clarifier effluent averaged 16.9 pounds of suspended solids per ton of potatoes processed versus 8.8 pounds per ton at WPSI. The results showed a significant difference at the 0.05 level between plants during the winter and spring season, but not during the fall seasons; there was also a significant difference at the same level between seasons at PSI but not at WPSI. The amount of suspended solids in the effluent after primary clarification was significantly less when the dry caustic peeling system was used. These solids would require a larger secondary treatment system and would represent some loss of revenue if the primary sludge solids were being sold. The mud clarifier at PSI removed 63.3 percent of the influent suspended solids versus 76.3 percent at WPSI. The PSI mud clarifier effluent had 4.37 pounds per ton of suspended solids in the effluent, while the WPSI effluent contained 3.82 pounds per ton. The percent removals were not significant at the 0.05 level between seasons at the individual plants nor during the winter season between plants, but were significant during the fall season. Spring could not be compared because of no results at WPSI.

Nitrogen And Phosphate Removal

The total Kjeldahl nitrogen and total phosphate removals in the main clarifier at PSI exceeded those at WPSI. The Kjeldahl nitrogen removal by primary clarification over the three seasons was 36.8 percent and 14.1 percent at PSI and WPSI, respectively, while the phsophate removal was 38.6 percent and 29.2 percent. The lower removals at WPSI may be attributed, in part, to the lower main clarifier influent nitrogen and phosphate values. The influent Kjeldahl nitrogen (as N per ton) at PSI was 4.3 pounds versus 1.5 pounds at WPSI. The corresponding phosphate values (as PO_4) were 4.5 pounds and 2.2 pounds per ton at PSI and WPSI, respectively. The higher influent values at PSI, even though higher percent removals were obtained, resulted in higher concentrations in the effluent. These figures all are from winter-spring results because determinations were not made during the fall at PSI.

pH and Alkalinity Reduction

The pH in and out of the clarifiers at each plant was about the same, though slightly higher at PSI, even though the alkalinity out of the primary clarifier was much higher at PSI. This was especially noted during the winter and spring months when an average of 17.5 pounds per ton of alkalinity was discharged at PSI but only 10.0 pounds per ton at WPSI. Each primary clarifier, during the spring months at PSI, reduced the alkalinity in the influent by producing organic acids in the sludge zone which leached into the overlying water and neutralized part of the alkalinity.

Clarifier Sludge Characteristics

Table 14 shows the solids data in the sludge underflows from the clarifiers. The difference for the percent total solids in main clarifier sludge was not significant at the 0.05 level. Grames and Kueneman (7) have reported that primary sludges from wet caustic peeling systems should be about 5 percent dry solids. The high percent dry solids in the main clarifier sludge at WPSI has resulted from the diminished amount of the peeler washer solids in the sludge. These high dry solids in the sludge are a desirable result of the dry caustic peeling process.

The total solids of 19.7 pounds per ton for the IR-dry caustic mud clarifier sludge was significantly higher (0.05 level) than the 6.9 pounds per ton for the wet caustic at PSI during the winter and fall seasons. The results were significantly different at the 0.05 level between seasons at PSI but not at WPSI. The percent total solids in the sludges were not significantly different at the 0.05 level either during the winter or fall seasons between plants or within plants by seasons.

Vacuum Filtration of Process Clarifier Sludge

Table 15 shows the data for the filter cake at PSI and WPSI. The data for PSI reflect the poor operational characteristics of the primary clarifier. The dry solids in the filter cake averaged 10.4 percent with a filter production rate of less than one pound per square foot per hour. Grames and Kueneman (7) have stated that vacuum filtration of potato sludge solids at pH 6 or less will be very poor unless the sludge is conditioned with chemicals. The pH values of the sludge in this case at PSI were 6.1, 5.1 and 4.8 for the winter, spring and fall months. Excessive fermentation of the sludge in the primary clarifier reduced the pH to these low values. It would be expected that much higher filter production rates could have been achieved if conditioning chemicals had been used.

Table 14. SLUDGE CHARACTERISTICS FROM CLARIFIERS

	WET CAUSTIC - PSI				IR-DRY CAUSTIC - WPSI			
Season	Total Solids lbs/ton	Total Solids %	Total Solids lbs/ton	Total Solids %	Total Solids lbs/ton	Total Solids %	Total Solids lbs/ton	Total Solids %
WINTER	Main Clarifier		Mud Clarifier		Main Clarifier		Mud Clarifier	
Avg	23	2.7	4.3	26	32.9	6.9	19.7	19.6
s[a]	--	--	0.14	4.0	7.91	2.4	8.0	5.5
n[b]	1	1	2	2	15	16	7	7
SPRING								
Avg	53	6.6	13.6	21	32.7	9.3	---	---
s	--	---	11.2	21	13.7	2.9	---	---
n	1	1	5	5	17	18	---	---
FALL								
Avg	34	3.9	4.3	30	34.1	7.9	19.7	29
s	15	1.5	1.66	26	15.7	2.1	14.1	16
n	12	11	11.0	11.0	18	19	15.0	16
AVG[c]	35	4.0	6.9	27	33.3	8.1	19.7	26

a Standard Deviation
b Number of Samples
c Weighted average

The filtration results of WPSI are nearly those which Grames and Kueneman (7) indicated as expected for a wet caustic peeled potato primary sludge. At the WPSI plant the total solids content of the filter cake was about 13 percent and the recovery of total solids in the cake was about 40.3 pounds per ton of potatoes. The results showed a significant difference between plants during the winter and fall and between seasons at PSI but not at WPSI. The filter loading was 4.6 pounds of dry solids per square foot per hour for WPSI.

Table 15. VACUUM FILTER CAKE

WET CAUSTIC - PSI						
Season	wet wt (lbs/ton)	TS (lbs/ton)	TVS (lbs/ton)	pH	Sp. Gr.	ds/ft^2/hr. * (lbs.)
WINTER						
Avg	89	9.5	8.5	5.1	1.013	0.62
s	37	6.3	5.7	0.7	0.005	0.25
n	4	4	4	4	2	4
SPRING						
Avg	210	18	15	4.8	1.020	0.99
s	123	9.5	8.0	0.5	0.021	0.52
n	7	7	7	3	7	7
FALL						
Avg	123	11	8.6	6.1	1.039	0.66
s	47	4.1	3.6	1.9	0.033	0.25
n	12	12	12	10	12	12
Avg **	144	12	11	5.6	1.030	0.75

IR DRY CAUSTIC - WPSI									
Season	wet wt (lbs/ton)	TS (lbs/ton)	TVS (lbs/ton)	AIK (lbs/ton)	TPO_4 (lbs/ton)	TKN (lbs/ton)	pH	Sp.Gr.	ds/ft.^{2}/hr.* (lbs.)
WINTER									
Avg	314	40	37	1.1	0.4	0.2	9.5	1.037	4.6
s	78	9	9.2	0.6	0.2	0.1	2.7	0.011	1.0
n	7	7	7	7	7	7	7	7	7
SPRING	No results due to inoperative vacuum filter.								
FALL									
Avg	390	51	47	1.9	0.4	0.4	7.6	1.046	4.6
s	345	36	34	2.9	0.1	0.3	3.5	0.035	3.3
n	9	8	8	5	2	2	5	8	8
Avg **	557	46	42	1.4	.41	0.2	8.7	1.042	4.6

* Output based on 22 hr. operating day.
s Standard Deviation - see glossary
n Number of samples - see glossary
** Weighted Average

SECTION VII

INFRARED DRY CAUSTIC SLUDGE FOR ANIMAL FEED

Since this work was started, J & R Simplot Co. have made feeding studies of dry caustic peel sludge and have been chopping the "screenings" into the peeler solids, holding the resulting mixture in silos for approximately 24 hours, then feeding the nearly neutral silage to cattle.

Also, the Washington Agricultural Experiment Station at Pullman, Washington has issued its bulletin number 757, entitled "Nutritive Value of Potato Slurry for Steers." Those authors compare feeding studies in which as much as 30 percent of the dry solids have originated from potato peeler solids.

During the spring of 1973, Pillsbury Co. erected and equipped a plant in Grand Forks, North Dakota for drying potato plant wastes. At this writing, only trial runs have been made. However, the company has found that moisture content is the only problem with the waste from the dry caustic system and the sludge from the main clarifier. Sixteen percent solids or better is necessary in order to effect economy in the drying operation. Presently, the solids are low in both the filter cake as well as the peeler solids, and efforts are being directed to increase these levels.

Twenty percent solids primary clarifier sludge is valued at eight to ten dollars per ton on a feed grain basis. This is about 10 percent of the market value of feed grain.

SECTION VIII

CAPITAL AND OPERATING COSTS FOR PEELING AND PRIMARY TREATMENT SYSTEMS

CAPITAL COSTS

The capital costs have been grouped to fit into the categories of the unit cost estimate formula of Peters and Timmerhaus (8). Their equation is:

$$C_n = E + E_L + (f_p M_p + F_{y_p} M_{L_p}) + (f_e M_e + f_{y_e} M_{L_e}) + f_{en} H_{en} + f_d d(1 + f_F)$$

where C_n = new capital investment

E = purchased equipment cost

E_L = purchased equipment installation labor cost

$f_p M_p$ = plumbing materials

f_{y_p} = plumbers rate

M_{L_p} = plumbing man hours

$f_e M_e$ = electrical materials

f_{y_e} = electrician rate

M_{L_e} = electrician man hours

f_{en} = engineer rate

H_{en} engineering man hours

f_d = unit cost per drawing

d = number of drawings

f_F = contractor's fee and contingency This factor was not included since it would be included in the other factors on a completed project

Table 16 shows the costs for these factors with the total capital investment of $332,324 for three lines of the IR-dry caustic system and $188,980 for four lines of the wet caustic system. Table 17 shows the cost for each of the factors with a total capital investment of $212,114 for the PSI primary treatment system and $165,304 for the WPSI primary treatment system. Buildings and yards have not been included since those cost factors are common to both systems and this essentially is a comparison of the two peeling systems.

Purchased equipment includes the items for each peeler system listed in Table 18 and items in Table 19 for each primary treatment system.

Table 16. COMPARISON OF CAPITAL COSTS OF PEELING SYSTEMS

	DRY CAUSTIC WPSI (3 lines)	WET CAUSTIC PSI (4 lines)
Purchased equipment cost (E)	$236900.00	$128300.00
Purchased equipment labor cost (E_L)	38100.00	20500.00
Plumbing materials (f_pM_p)	12000.00	14400.00
Plumber's rate (f_{y_p})	16.00	3.00
Plumbing man hours (M_{L_p})	1270	1440
Electrical materials (f_eM_e)	13376.00	16100.00
Electrician's rate (f_{y_e})	12.00	3.00
Electrician man hours (M_{L_e})	244	300
Engineering rate (f_{en})	6.60	6.60
Engineering man hours (H_{en})	1140	523
Unit cost per drawing (f_d)	168	168
Number of drawings (d)	7	7
Total capital investment (C_n)	$332,324	$188,980

NOTE: Contractor's fee and contingency (f_F) This factor included in other factors, since this is a completed project.

Table 17. COMPARISON OF CAPITAL COSTS OF PRIMARY TREATMENT SYSTEMS

	IR DRY CAUSTIC WPSI (3 lines)	WET CAUSTIC PSI (4 lines)
Purchased equipment cost (E)	$113100.00	$156800.00
Purchased equipment labor cost (E_L)	18200.00	25100.00
Plumbing materials (f_pM_p)	8200.00	8200.00
Plumber's rate (fy_p)	6.00	3.00
Plumbing man hours (M_{L_p})	1160	1300
Electrical Materials (f_eM_e)	11500.00	12300.00
Electrician's rate (f_{ye})	12.00	3.00
Electrician man hours (M_{L_e})	245	250
Engineering rate (f_{en})	6.60	6.60
Engineering man hours (H_{en})	540	640
Unit cost per drawing (f_d)	168.00	168.00
Number of drawings (d)	5	5
Total capital investment (C_n)	$165,304	$212,114

NOTE: Contractor's fee and contingency (f_g) This factor included in other factors since this is a completed project.

Table 18. PEELER EQUIPMENT

	WET CAUSTIC-PSI	IR DRY CAUSTIC-WPSI
Caustic make-up tanks	1	1
Caustic reels with circulation tanks	4	3
Retention belts	4	3
Magnuson shufflos	0	3
Magnuson Infrared units	0	3
Magnuscrubber peelers	0	3
Magnuwasher peelers	0	3
Hydro-brusher-washer-peeler	4	0
Peeler solids pump	0	1

Table 19. PRIMARY TREATMENT EQUIPMENT

	WET CAUSTIC-PSI	IR DRY CAUSTIC-WPSI
Peeler solids storage hopper	0	1
Waste shaker screen	1	1
Primary clarifier	1	1
Vacuum filter	1	1
Filter cake storage hopper	1	1
Mud clarifier	1	1

Single peel line costs for the two systems are $110,800 for the IR-dry caustic system and $47,200 for the wet caustic system. The differences are primarily in the cost of Shufflos, infrared units, scrubbers, washers, and the waste pump.

Primary treatment costs were $212,100 for PSI and $165,300 for WPSI. The differential is due to the smaller clarifiers and vacuum filter but partially offset by the need for a peeler solids storage hopper at WPSI. Sludge disposal costs have not been included in the study since this cost is extremely variable, and both plants are disposing of the waste solids to cattle feed producers willing to do the trucking in return for the waste.

OPERATING AND MAINTENANCE COST - PEELING

The operating and maintenance costs for both plants are presented in Table 20. Actual operating costs for PSI and WPSI are based on 810 and 426 tons per day, respectively, whereas potential operating costs are respectively based on 1000 and 600 tons per day. The actual peeling costs for the IR-dry caustic were $0.276 higher than the wet caustic with potential costs $0.113 per ton higher. Difficulty was encountered in the IR-dry caustic lines which were overloaded when running at their designed rate of 20,000 pounds per hour. Although the lines were designed for this rate, it was learned much later that 90 seconds of infrared treatment were required. The lines were equipped with only 14 IR burners rather than the 20 burners required for 90 seconds of infrared treatment. The lines operated with only 14 burners during the grant period.

Table 20. OPERATION AND MAINTENANCE COSTS - PEELING

	WET CAUSTIC - PSI		IR-DRY CAUSTIC-WPSI	
	Actual/ton	Potential/ton	Actual/ton	Potential/ton
Caustic at $0.0416	$ .523	same	$ .626	same
Water at (0.30/1000 gal.)	.269	same	.110	same
Power at (0.014/KWH)	.127	same	.077	same
Gas at ($0.85/10^6$BTU)	----		.24	.17
Labor $19.79/day/man	.147	.119	.467	.198
Maintenance	.140	.126	.467	.422
Total	$1.523	$1.490	$1.799	$1.603

Diminished infrared treatment resulted in a need for increased caustic treatment. This harsh caustic treatment caused the Shufflo infrared feeders to become loaded with peeler solids causing build-up and sticking. The "cure"---a water spray over the Shufflos---further diminished the infrared effect because of the resulting temperature drop.

Proper caustic treatment and retention belt timing allow the treated tubers to cross the Shufflos with their skins essentially intact without the use of water sprays. Also the Magnuson peeling equipment should be set up to maintain a load occupying approximately 1/3 of the space within the Magnuscrubber peelers. Small loads allow the tubers to pass through with too little actual contact with the abrasive rolls.

OPERATION AND MAINTENANCE COSTS - PRIMARY TREATMENT SYSTEMS

Table 21 shows the operating and maintenance costs of the primary treatment system. The actual per ton costs for the dry caustic were $0.77 higher than the wet caustic, and the potential costs were $0.05 higher per ton.

Table 21. OPERATION AND MAINTENANCE COSTS - PRIMARY TREATMENT SYSTEMS

	WET CAUSTIC - PSI		IR-DRY CAUSTIC-WPSI	
	Actual/ton	Potential/ton	Actual/ton	Potential/ton
Power/ton	$.054	same	$.059	same
Labor 3 men at $19/day/man	.073	$.059	.139	$.099
Maintenance/ton	.130	.117	.136	.122
Total/ton	$.257	$.230	$.334	$.280

TOTAL OPERATION AND MAINTENANCE COSTS

Table 22 shows an evaluation of the overall operation and maintenance costs. The actual costs for the IR-dry caustic were $0.344 per ton higher than for the wet caustic, but only 0.113 per ton higher on a potencial production basis.

Table 22. TOTAL OPERATION AND MAINTENANCE COSTS

	WET CAUSTIC - PSI		IR-DRY CAUSTIC-WPSI	
	Actual/ton	Potential/ton	Actual/ton	Potential/ton
Table 20 - Peeling costs/ton	$1.532	$1.490	$1.799	$1.603
Table 21 - Primary costs/ton	.257	.230	.334	.280
Total net operating cost/ton	$1.789	$1.720	$2.133	$1.833

MAINTENANCE

Maintenance of the IR-dry caustic peel lines was approximately three times that required for the wet caustic peel lines. The thermocouples for the infrared burners were the primary source of trouble in these machines. The infrared conveyors were practically free of breakdowns.

The Magnuscrubbers and Magnuwashers made up the larger portion of maintenance requirements. The problems centered on the bearings for the rolls, variable speed units, and trunions. Undoubtedly, these problems can be corrected in future units.

TOTAL ANNUAL COSTS - PEELING AND PRIMARY TREATMENT

Table 23 shows the actual total annual costs of the peeling and primary treatment systems for both plants including the reduced peel loss savings of $0.91 per ton based on a 250-day operating season. As shown, conventional wet peel and primary treatment costs amount to $2.126 per ton versus $2.017 for the IR-dry caustic peel and primary treatment costs. This is a savings of $0.11 per ton of potatoes processed. The savings on a potential production basis is $0.456 per ton. These savings are conservative since operational difficulties with the infrared equipment necessitated operating conditions which increased the peel loss.

Table 23. TOTAL ANNUAL COSTS - PEELING AND PRIMARY TREATMENT

	WET CAUSTIC -PSI		IR-DRY CAUSTIC-WPSI	
	Actual/ton	Potential/ton	Actual/ton	Potential/ton
Table 20 - Peeling Costs	$1.532	$1.490	$ 1.799	$ 1.603
Table 21 - Primary Costs	.257	.230	.334	.280
Amortization of Capital				
7% interest 10 yr. repayment	.337	.273	.794	.564
Total	2.126	1.993	2.927	2.447
Less Saving - Reduced Peel Loss			0.91	0.91
Total	$2.126	$1.993	$ 2.017	$ 1.537

*250 operating day season

SECTION IX

EFFECT OF PEELING SYSTEM ON COST OF PRIMARY AND SECONDARY SYSTEMS

This section presents an analysis of the effect of a dry lye peeling system on the costs for wastewater treatment.

For these purposes, both plant capacities have been set at 500 tons and the actual percent peel losses of fall and early winter are used for both plants. Since the difference in water usage for peeling between the plants (995 gal/ton) was not reflected in the overall plant water use figures (3162 vs 2593 gal/ton or 570 gal/ton), the total plant effluent at PSI has been increased to remedy this as shown in Table 24. The additional water use in the remainder of the WPSI plant (730 gal/ton) is probably due to the need for increased leaching at WPSI, resulting in more water use as mentioned before. The wet caustic water use has been increased to allow a comparison assuming that potatoes of the same characteristics are being processed at each plant. This table also includes other design criteria from Tables 4, 5 and 6, as well as from other sources as cited below.

Assuming an overflow rate of 600 gallons per day per square foot (7), the areas of the primary clarifier are 2625 square feet for the wet caustic system and 1833 for the IR-dry caustic system. These figures designate primary clarifiers with diameters of 57.8 feet and 48.3 feet, respectively. Using a retention time of 3 hours (9) for each system, the clarifier volumes are 26,320 and 18,380 cubic feet, respectively. Using these areas and volumes, the sidewall depth will be about 10 feet in each clarifier. The clarifiers should be equipped with skimmer, weirs, baffles, and a thickening compartment for the biodegradable solids.

The required vacuum filter for filtration of the four to five percent clarifier underflow solids should be equipped with a removable belt, wash sprays, vacuum pump, filtrate pump, and receiver. The required vacuum filter was a 6' X 10' filter for the wet caustic plant and a 6' X 8' filter for the IR-dry caustic plant(9).

The aeration basin influent with a 32.5 percent BOD reduction (average of both PSI and WPSI) across the primary clarifiers is 24,400 pounds for the wet system and 12,300 pounds for the dry system. Using Greeley's (10) recommendation of 30 pounds of BOD per day per 1000 cubic feet, the aeration basins would be 813,000 cubic feet and 410,000 cubic feet, respectively. These volumes are 6.08 and 3.06 million gallons and include an allowance of 20 percent of the flow

Table 24. DESIGN CRITERIA

Design Criteria	Wet Caustic	IR-Dry Caustic
Production-pounds of raw/day	1,000,000	1,000,000
Peel Loss - percent	18.8	16.3
Peeler System Effluent -gallons/ton	1,300	346
Total Plant Effluent-gallons/ton	2,670	2,190
Total Plant Effluent to reflect peeler system difference gal/ton	3,150	2,200
Primary Clarifier BOD Reduction-%	(33.2)	(31.7)
BOD Reduction for this section	32.5	32.5
Primary Clarifier Capacity-gal/day/sq.ft. (6)*	600	600
Vacuum Filter Capacity-clarifier underflow (8)*	4-5%	4-5%
Aeration Basin Capacity-#BOD/1000 cu.ft. (9)*	30	30
Pounds Oxygen per pound of BOD Removed (8)*	1.25	1.25
Aerators #O_2/HP/hr (8)*	2.2	2.2
Secondary Clarifier Capacity gal/day/sq.ft.(8)*	250	250
Granular Media Filters gal/sq.ft./min. (8)*	2	2
Detention Time for Activated Sludge Digestion(8)*	15	15

*See Indicated Reference

for sludge recycle volume. The retention times with the recycle volume are 3.35 days for the wet system and 2.30 days for the dry. The F/M (food to micro-organism) average ratio is 0.04 using pounds of BOD removed and mixed liquor volatile suspended solid ranges found at the WPSI aeration basin during the current years (fall and winter 1974).

The aeration required---based on 80 percent BOD reduction of BOD, 2.2 pounds oxygen transferred per HP hour (9), 1.25 pounds O_2 per pound of BOD, and influents of 24,400 pounds of BOD per day for the wet system and 12,300 pounds for the dry system---is 462 HP and 233 HP, respectively. This could be supplied by 4-125 HP aerators for the wet system and 2-125 HP for the dry system.

The secondary clarifiers, based on an overflow rate of 250 gallons per day per square foot (7), are 7260 and 5320 square feet, respectively. These areas require 96.1 and 82.3 foot diameter clarifiers. The clarifiers should be of suction type, of steel shell construction, with adjustable weirs, and with baffles.

The granular media filters, with an 80 percent reuse of the total plant effluent and 2 gallons per square foot per minute (9), would require 398 and 321 square feet of filter area, respectively. Two 16 foot and two 14 foot coal and sand media filters are required. These filters would reduce the suspended solids in the filtered effluent to the 5 to 10 ppm range (9).

The waste activated sludge would be processed by aerobic digestion. The sludge produced each day would be approximately 20 percent of the BOD remaining after the primary clarification or 4880 pounds per day and 2460 pounds per day, respectively (9). At 0.7 percent solids in the underflow sludge and with a 15 day detention time in the digester, the volumes to be handled are 168,000 cubic feet for the wet caustic and 85,000 cubic feet for the IR-dry caustic system. Using a 19 foot depth, the digesters required would be 125 feet by 75 feet and 90 feet by 50 feet, respectively. The effluent from the digesters would be returned to the primary clarifier for processing with the main plant effluent. The aeration requirements based on 40 percent bacterial cell destruction and 2 pounds of oxygen per pound of cells destroyed are 3910 pounds per day of oxygen for the wet caustic and 1960 pounds per day for the dry caustic (11). These requirements would be met with 100 horsepower for the wet caustic and 50 horsepower for the dry caustic (11). Table 25 shows the waste treatment equipment required for both the wet and dry peel systems.

Table 26 shows the differential costs between the waste treatment systems as related to the reduced requirements of the IR-dry caustic system. Plumbing and electrical supplies and labor have not been included (except the electrical for the aerators) since the remaining equipment installation and costs would be practically the same for each system.

TABLE 25

TREATMENT SYSTEM PARAMETERS

	Primary Clarifier						Vacuum Filter	Aeration						Secondary Clarifier			Granular Media Filters		Aerobic Digester					
	Influent			Effluent			Size	Basin		Equipment									Basin		Equipment			
	MGD	BOD/day	TS/day	MGD	BOD/day	TS/day		Volume in 1000 cu. ft.	19 ft. deep Length and width	Pounds O_2/day	H P required	No. & Size Aerators	Detention-days	Required square Footage & Depth	Diameter	Detention days	Required Square Footage	Number & Size	Volume in 1000 cu. ft.	19 feet deep Length & Width	Pounds of O_2/day	HP required	Number & Size Aerators	Detention-days
Wet Caustic 18.8% Peel Loss	1.575	36100	95650	1.575	24400	46600	6' X 10'	813	300 x 145	27700	525	4 x 125	3.35	6875 x 9	96	7.83	398	2 x 16	.168	125 x 75	6100	175	2 x 100	15
IR-Dry Caustic 16.3% Peel Loss	1.100	18150	40800	1.100	12300	24200	6' X 8'	410	200 x 110	14300	270	2 x 125	2.30	5555 x 9	82	7.83	332	2 x 14	.085	90 x 50	3075	58	1 x 100	15

TABLE 26
EFFECT OF PEELING SYSTEM ON COST
OF PRIMARY AND SECONDARY SYSTEM*

	WET CAUSTIC	IR-DRY CAUSTIC
Primary Clarifier		
60' C2T X 10' SWD	$50,000	
50' C2T X 10' SWD		$42,000
Vacuum Filter		
8' X 10' E-Belt Eimco	40,000	
6' X 8' E-Belt		36,000
Aeration Basin		
300' X 145' X 19'	47,000	
200' X 110' X 19'		26,000
Aerators		
Four 125 HP LS Fixed Eimco	100,000	
Electrical supplies and labor	6,000	
Two 125 HP LS Fixed Eimco		50,000
Electrical supplies and labor		3,000
Secondary Clarifier		
95' C2D	75,000	
85' C2D		69,000
Granular Media Filter		
Two X 16' Dia. Eimco	70,000	
Two X 14' Dia. Eimco		50,000
Activated Sludge Digester Tank		
125' X 75' X 19'	95,000	
90' X 50' X 19'		40,000
Aerators		
Two X 100 HP LX Fixed Eimco	50,000	
Electrical supplies & labor	3,000	
One & 100 HP LS Fixed Eimco		25,000
Electrical supplies & labor		1,500
	$536,000	$342,500

* Costs are as of March 1974 for this section

SECTION X

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SECTION XI

GLOSSARY

ALKALINITY (ALK) - The capacity of a solution to accept protons usually as the result of the presence of bicarbonate, carbonate and/or hydroxide ions.

BIOCHEMICAL OXYGEN DEMAND (BOD) - A measure of the oxygen necessary to complete the aerobic decomposition of the decomposable organic material in a liquid by bacteria. The standard BOD is five days at 20 degrees C.

CHEMICAL OXYGEN DEMAND (COD) - A measure of the oxygen equivalent of the organic matter in a sample which is subjected to oxidation by a strong chemical oxidant.

CLARIFIER - A basin or tank in which a portion of the material suspended in a wastewater is settled.

COMPOSITE SAMPLE A portion of waste compounded at regular time intervals with the volume taken varying with the waste stream flow.

EFFLUENT - Liquid flowing from an area, basin, tank, or treatment plant.

INFLUENT - Liquid flowing into an area, basin, tank, or treatment plant.

MEAN ($\bar{x}$) - The arithmetic average of the individual sample values.

n - The number of samples or occurrences in given group or population.

pH - The negative logarithm of the hydrogen ion concentration. It indicates the intensity of the acid or alkaline condition of a solution.

PRIMARY TREATMENT - A wastewater treatment process that utilizes sedimentation and/or flotation to remove a portion of the settleable or flotable solids and thus remove some of the BOD_5 of the wastewater.

RANGE (R) - The absolute difference between the highest and the lowest values in a group of values.

SETTLEABLE SOLIDS - Suspended solids which will settle out of a liquid waste in a given period of time.

SLUDGE - The accumulated settled solids from wastewater in clarifiers or basins and having the consistency of a semi-liquid mass.

STANDARD DEVIATION (s) - The square root of the variance which describes the variability within the sampling data on the basis of the deviation of individual sample values from the mean.

$$s \quad \frac{E(x-\bar{x})^2}{n-1}$$

SUSPENDED SOLIDS (SS) - The quantity of material deposited on a filter when a liquid is drawn through a Gooch crucible.

TATER MEAL - Dried potato waste.

TOTAL KJELDAHL NITROGEN (TKN) - The sum of free ammonia nitrogen and organic nitrogen in a sample.

TOTAL PHOSPHATE (TPO_4) - All phosphate present in a sample

TOTAL SOLIDS (TS) - All solids in a liquid, both suspended and dissolved.

TOTAL VOLATILE SOLIDS (TVS) The quantity of residue lost after the ignition of total solids.

TURBIDITY - An expression of the optical property of a sample which causes light to be scattered and absorbed rather than transmitted in straight lines through the sample.

VOLATILE SUSPENDED SOLIDS (VSS) - The quantity of suspended solids lost after the ignition of total suspended solids.

WEIR - A flow measuring device consisting of a barrier across an open channel, causing the liquid to flow over its crest. The height of the liquid above the crest varies with the volume of liquid flow.

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16. ABSTRACT

The infrared dry caustic peeling system has been evaluated through plant scale comparisons with the conventional wet caustic system. The following significant differences were noted when the dry peel system was compared to the wet process:

(a) decreased peel loss by 13.1 percent.
(b) decreased caustic consumption by 26 percent.
(c) decreased wastewater from peeling by 73 percent.
(d) decreased BOD_5 in the peeler wastewater by 78 percent.
(e) decreased suspended solids in the peeler wastewater by 77 percent.
(f) decreased alkalinity in the peeler wastewater by 61 percent.
(g) increased operating costs of peeling by 39 percent but decreased total annual cost of peeling and primary treatment through lower peel loss by 10 percent.
(h) decreased total plant raw waste load: water use by 18 percent, BOD_5 by 47 percent, and suspended solids by 57 percent.

No significant differences were noted in the efficiency of primary sedimentation of the raw wastes nor in the mud clarifier results. Primary sludges and their dewatering characteristics were found to be similar.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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