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PREDESIGN COST ESTIMATE FOR RE-REFINED LUBE OIL PLANT

By

950 4416 Richard J. Bigda & Associates
Prepared for ERDA Under Contract No. BE-60-P-2688

Date Published—June 1977

Bartlesville Energy Research Center
Energy Research and Development Administration
Bartlesville, Oklahoma

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By

Richard J. Bigda & Associates
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Engineering and design studies
Prepared for the Energy Research and
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Technical Project Officer
Marvin L. Whisman
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Bartlesville, Oklahoma

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ENERGY RESEARCH AND DEVELOPMENT ADMINSTRATION
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EXECUTIVE SUMMARY

The first estimates for a predesign of the BERC re-refining process are contained in this report. Although many process equipment variables are yet to be resolved, this first estimate indicates the probable viability of the process. Based upon a plant which could process 10 million gallons of waste lube oil a year, the following preliminary conclusions were made:

Capital costs would approximate $2 million.

Waste oil purchased at 15 cents/gal could be re-refined into blendable lube oils for 39 cents/gal.

Considering a selling price of 47 cents/gal in bulk, the return on investment before taxes would approach 45 percent.

The operation is very sensitive to the cost of the used oil.

The plant capacity could be doubled or tripled with only a modest increase in cost.

These findings and the predesign analysis show areas where more intensive R&D is required. More effort is also apparent to demonstrate the feasibility of economically gathering the waste oil. A larger plant would be more economical, but this must be balanced with the cost of collecting the used oil. In general, the project offers promise as a means of economically and profitably conserving millions of gallons of valuable lube oils.

PREDESIGN COST ESTIMATE FOR RE-REFINED LUBE OIL PLANT

In the predesign stages of any plant design there are many variables which have not been resolved. Because of this, predesign cost estimates have many limitations. Until an actual engineering design is made, which would include a plant layout, elevations, distances between units, and until other physical characteristics have been determined, it is not practical to determine exact equipment costs. However, predesign cost estimates have value in that they point out important cost elements and places where R & D should be focused. Because of the nature of this situation, predesign cost estimates are probably accurate to within only plus or minus 20 percent.

In this evaluation, the method used involved first a rough calculation of the various unit sizes and the particular service which might be expected of these units. For example, the amount of heat that must be transferred from a hot oil to a cold oil or from steam to oil can be estimated; and by knowing the temperature ranges, one can calculate the heat-exchanger duty and thereby its expected surface area. The surface area plus the design of the exchanger will determine its cost. In general, the exchangers must be designed for greater than their calculated capacity because over a period of time the exchangers foul and their heat-transfer efficiency is greatly decreased. In this design, an average heat-exchanger fouling factor was used which would reflect normal operation. Pumps are sized by determining the flow rates from one unit to another, and the volume or sizes of vessels can be calculated for the particular service. Employing these estimated equipment specifications, costs were first obtained from publications containing cost curves relative to equipment size and complexity. Finally these costs were verified in a preliminary way with manufacturer's representatives to at least make sure that the particular equipment approximately matched the 1976 selling price and installation costs.

Even though the equipment was sized, cost-estimated and verified, the exact cost of any piece of equipment will depend on the location where it is to be erected and the particular time that it is to be erected, and inflationary factors must be considered along with local labor costs. In addition, much will depend on the final selection of a particular manufacturer's piece of equipment. Similar equipment may vary in cost because of quality or unusual or important features. Further, various safety and materials standards codes will have to be adhered.

For this particular plant, with a nominal capacity of 10 million gallons of waste oil re-refinement per year, it was found that it is relatively small, and the costs are somewhat size-insensitive. This means that to manufacture much larger equipment would not cost particularly more than it would for a smaller unit. For example, a 50-gpm pump costs about the same as a 100-gpm pump. Tanks, for example, could double in size, and their price would only increase by about 30 percent. Small heat exchangers cost as much, if not more, than some larger heat exchangers because most of the cost of the unit is in labor for fabrication and installation, rather than for materials. In particular, the installation cost for small units is as large as that for a considerably larger unit, providing no additional special erection equipment is necessary. Based upon the cost estimates that were made, it would appear that a plant which could be capable of processing 20 million gallons per year would only cost about

30 percent more than the 10 million gallon processing unit. Because of this, considerable attention should be paid to the economic problems of collecting waste oil. It may be that higher prices could be paid for waste oil, thereby larger quantities could be processed for much less capital investment per barrel of oil processed.

It is recommended that research and development effort be directed toward resolving certain design elements which utilize expensive units or processes. Thought should be given to the solvent-mixing operation with equipment costs approaching $100,000. Perhaps it is possible to get by with fewer mixing units or larger ones, thereby making more efficient use of capital or labor. The solvent stripping units may cost about $150,000, but it is doubtful that much could be done to improve this operation if any solvent at all is used. The same is true of the vacuum distillation unit which costs a total of $450,000, including a furnace for supplying the very high temperature hot oil for the distillation. Alternative heating methods should be explored. Another item of considerable expense is the filtration of the clay which is added in the clay contacting unit. A rotary vacuum drum filtration unit will cost approximately $200,000 and will be utilized only to a small extent. A less automated system may require more workers. Other design problems such as the size and shape of the solvent settlers should be reviewed. Problems which have not been addressed as yet, but will need attention, are involved with sludge and oily clay disposal. Further, waste water treatment may be necessary if oil or other contaminants get into the coooling or process water.

The process does seem to be sensitive mainly to the cost of the waste oil. The cost of waste oil affects the economics of the process in two ways: first, obviously as a raw material of which about a third is lost during processing; secondly, as the price of the waste oil increases, its working capital charges increase because of the large inventory of the crude waste oil and in process oil. Considering raw material inventory, product inventory, and extended credit amounting to the equivalent of 1 month's sale of the oil, the amount of capital tied up is considerable. If the waste oil price reaches 50¢ a gallon, these inventories and credit will be worth approximately $1 million, a not inconsiderable sum if one is paying high interest rates. Inventory control, in this case, will be an important part of management's function.

The following sections present comments and calculations relating to various design variables which require resolution, predesign equipment cost estimates, and specifications. In addition to fixed capital, the amount of working capital had to be estimated based upon such factors as inventories, credits, and available cash for manufacturing expenses. To estimate manufacturing costs on a 350-day-per-year basis, material costs were estimated along with the minimum labor and supervision needed. Other overhead factors were considered along with depreciation and other direct, indirect, and general expense items. The appendix contains additional information to support some of the cost estimates and vendor contacts relative to sources of cost information.

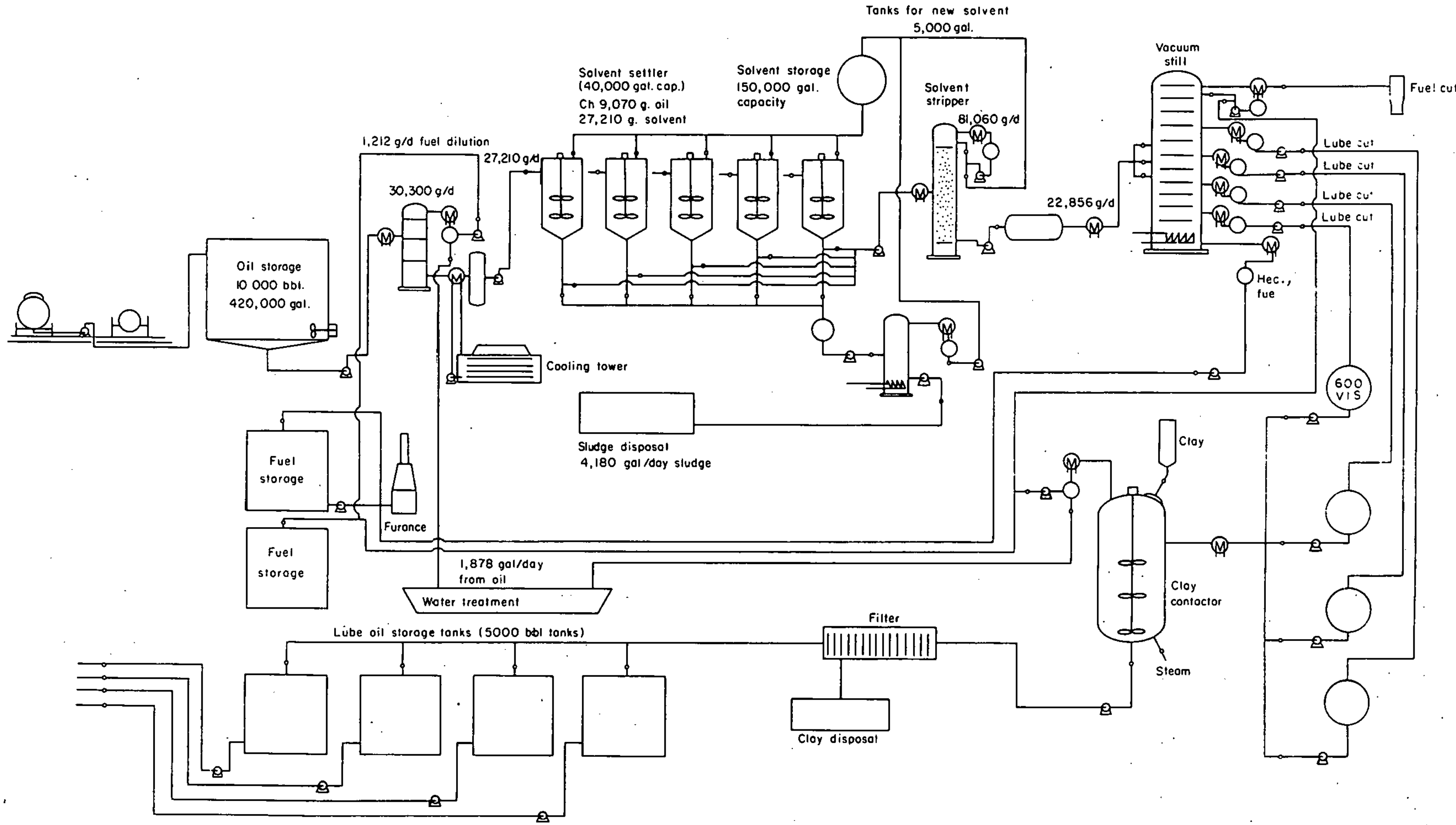

Figure 1. - *Re-refining process.*

TABLE 1. - *Predesign process equipment costs*

Item of equipment	Specifications	Estimated erected cost, each	Total cost
Oil unloading:			
Oil storage tank, two . . .	200,000	$ 45,000	$ 90,000
Side mixers, two	5 hp	3,000	6,000
Unloading pump	100 gpm, 1.5 hp	2,600	2,600
Total			$ 98,600
Fuel flash:			
Oil feed pump.	25 gpm	1,900	$ 1,900
Fuel flash heat exchanger.	330 ft^2	15,800	15,800
Fuel flash drum.	3 ft by 5 ft	5,000	5,000
Condenser	40 ft^2	2,500	2,500
Accumulator.	100 g	1,000	1,000
Lt. fuel pump	3 gpm	800	800
Crude lube cooler	511	21,300	21,300
Total			$ 48,300
Solvent treatment:			
Oil to treater pump	20 gpm	1,900	$ 1,900
Solvent pump to treater.	60 gpm	2,500	2,500
Solvent settler, four. . . .	40,000 g	20,000	80,000
Agitators	3 hp	3,200	16,000
Total			$ 100,400
Solvent stripper:			
Pump solvent stripper. . .	80 gpm	2,600	$ 2,600
Feed heater—sol. st.	790 ft^2	30,300	30,300
Solvent stripper.	4 ft dia. by 30 ft packed Berl saddles	30,000	30,000
Reflux condenser	400 ft^2	16,500	16,500
Accumulator	100 g	1,000	1,000
Reboiler	2700 ft^2	70,000	70,000
Pump reflux	90 gpm	2,600	2,600
Pump stripper bottoms. .	20 gpm	1,900	1,900
Total			$ 154,900

TABLE 1. - *Predesign process equipment costs—Continued*

Item of equipment	Specifications	Estimated erected cost, each	Total cost
Sludge stripper:			
Sludge accumulator	5,000 g	$ 3,000	$ 3,000
Sludge pump to stripper .	80 gpm	3,000	3,000
Sludge pump	80 gpm	3,000	3,000
Sludge overhead condenser.	6 ft^2	500	500
Accumulator	100 g	1,000	1,000
Sludge-solvent pump . . .	3 gpm	800	800
Reboiler	107 ft^2	6,800	6,800
Sludge cooler		7,300	7,300
Sludge stripper	2 ft by 5 ft packed	2,900	2,900
Total			$ 28,300
Vacuum distillation:			
Vac. still feed HX	75 ft^2	4,800	$ 4,800
Vacuum ejector.	1 lb/hr, 5.0 mm	3,500	3,500
Feed pump.	20 gpm	1,900	1,900
Vac. still	4 ft dia. by 40 ft + 24 trays	82,000	82,000
Reboiler	2,000 ft^2	51,000	51,000
Reflux cond., lt. oil	26 ft^2	1,500	1,500
Accumulator	100 g	1,000	1,000
Reflux pump	2 gpm	800	800
Lube condenser, 100 V. .	55	3,500	3,500
Accumulator.	100 g	1,000	1,000
Pump	5 gpm	800	800
Lube condenser, 150 V. .	53 ft^2	3,500	3,500
Accumulator.	100 g	1,000	1,000
Pump	5 gpm	800	800
Condenser, 250 V	73 ft^2	4,800	4,800
Accumulator.	100 g	1,000	1,000
Pump	6 gpm	800	800
Condenser, 600 V	22 ft^2	1,500	1,500
Accumulator.	100 g	1,000	1,000
Pump	2 gpm	1,000	1,000
Hvy gas oil condenser. . .	14 ft^2	700	700
Accumulator.	100 g	1,000	1,000
Pump	2 gpm	1,200	1,200
Total			$ 170,100

TABLE 1. - *Predesign process equipment costs—Continued*

Item of equipment	Specifications	Estimated erected cost, each	Total cost
Intermediate lube storage:			
Storage tank, 100 V. . . .	25,000 g	$ 8,000	$ 8,000
Pump	90 gpm	2,600	2,600
Storage tank, 150 V. . . .	25,000 g	8,000	8,000
Pump	90 gpm	2,800	2,800
Storage tank, 250 V. . . .	25,000	8,000	8,000
Pump	90 gpm	2,800	2,800
Storage tank, 600 V. . . .	25,000 g	8,000	8,000
Pump	90 gpm	2,800	2,800
Total			$ 43,000
Clay contactor:			
Clay contactor.	20,000 g	15,000	$ 15,000
Agitator.	3 hp	3,200	3,200
Clay hopper	50 ft^2	800	800
Lube heater	788 ft^2	30,000	30,000
Condenser		500	500
Pump, water	2 gpm	600	600
Product pump.	90	2,600	2,600
Total			$ 52,700
Filter:			
Filter, rotary vacuum drum.	10 ft dia. by 16 ft + aux. equipment	200,000	$ 200,000
Total			$ 200,000
Finished lube and solvent storage:			
Lube storage tanks, four .	200,000 g	39,000	$ 156,000
Pumps, four	100 gpm	2,600	10,400
Fuel storage, three.	40,000 g	9,000	27,000
Pump loading	100 gpm	2,600	2,600
Solvent storage	150,000 g	28,000	28,000
Separate solvents, three .	10,000 g	3,500	10,500
Pump	60 gpm	2,400	2,400
Total			$ 236,900
Each separate:			
Boiler, complete	200 psi, 22,000 lb/hr	134,000	$ 134,000
Hot oil furnace, complete direct (Dow therm x 1.3). . . .	20 M Btu/hr, 700° F	277,000	277,000
Cooling water, complete	1,400 gpm, 14,000,000 BTU/hr	221,000	221,000
TOTAL EQUIPMENT COST			$1,765,200

TABLE 2. - *Capital investment*

Installed equipment	$1,765,200	
Piping		
Buildings, $20/ft^2 x 1,000 ft^2	20,000	
Land and improvements (incl. in cost	Unknown	
Utilities	Unknown	
Total	$1,785,200	
Engineering and construction, 10 pct (Part incl. in equip.)	178,000	
Total fixed cost	$1,963,200	
Working capital:	10 cents	50 cents
Raw material inventory, one month @ $0.10/g	$ 90,000	$ 450,000
Solvent inventory, full tanks	215,800	215,800
Product inventory, one mo. (at cost) @ $0.30/g	180,000	300,000
Extended credit, one mo. sales @ cost	180,000	300,000
Available cash, one mo. mfg. expense	60,000	60,000
Total working capital	$ 725,800	$1,325,800
Total capital required	$2,689,000	$3,289,000

TABLE 3. - *Labor requirements*

	Men
Day:	
Shipping, receiving and utilities	1
Operator: solvent settlers + stills	1
Operator: clay contactor + filter	1
Maintenance	2
Supervisor	1
Total	6
Night:	
Operators, two	
Three shifts	6
Administration:	
Manager	1
Clerk	1
Sales	1
Total	3
Total personnel:	
12 Hourly x 40 hr/week x $5 x 52 weeks	$124,800/year
3 Salary x $20,000/y	$ 60,000
Total payroll	$184,800/year

TABLE 4. - *Solvent inventory and costs*

Butyl alcohol, 50 pct (150,000 gal)	75,000 g	
100 pct storage	10,000 g	
@ $1.36/g	85,000 g	$115,600
Isopropyl alcohol, 25 pct (150,000 gal)	37,500 g	
100 pct storage	10,000 g	
@ $0.83/gal	47,500 g	$ 39,425
Methyl ethyl ketone, 25 pct (150,000 gal)	37,500 g	
100 pct storage	10,000 g	
@ $1.28/g	47,500 g	$ 60,800
Total solvent inventory		$215,825
Solvent loss:		
82,000 g/d @ 0.5 pct	410 g/d	
Cost of solvent:		
$1.21/g x 410 g/d	$496/d	
@ 350 d/yr x $496		$173,600/yr

TABLE 5. - *Manufacturing cost per day (350 days per year)*

	10 cents	50 cents
Used oil, 30,000 g	$3,000	$15,000
Solvent	496	496
Clay @ $50/ton dlvd. @ 10 lb/B x 500 B	125	125
Supplies, 15 pct of main costs	45	45
Labor	357	357
Supervision: (see administration)	—	—
Utilities, est. $0.30/B x 500 B	150	150
Maintenance, 5 pct of fixed capital	300	300
Direct manufacturing cost	$4,473	$16,473
Overhead, 50 pct of labor	178	178
Laboratory, 10 pct of labor cost.	36	36
Shipping, incl. in other costs	—	—
Indirect manufacturing cost.	$ 214	$ 214
Depreciation, 10 pct of fixed capital	600	600
Property taxes, 2 pct of fixed capital.	120	120
Insurance, 1 pct of fixed capital	60	60
Fixed manufacturing cost	$ 780	$ 780
Administration and salesman	171	171
Expense: (see overhead)	—	—
Finance, 10 pct total capital	800	980
General expense	$ 971	$ 1,151
Total manufacturing cost/day	$6,438	$18,618
20,570 g/D: Cost/g:	$ 0.31	$ 0.91

Sales of Re-refined Products

The present market price of virgin lube oil stocks is 57 cents/g. For the purpose of this estimate, a selling price of 47 cents/g is assumed. The actual selling price could vary, but as the price of crude oil increases the value of the reclaimed oil will increase.

Fuel oils recovered from the waste oil are tagged with a sale price of $10/B. Depending upon the grade, the value of this oil may vary upward to $12/B. This estimate then is conservative.

	Per year
Re-refined lube oils	
20,500 g/d x 350 d	7,175,000 g
Fuel oils	
3,500 g/d x 350 d	1,225,000 g
Sales value:	
Re-refined lube oils @ $0.47/g	$3,372,250
Fuel oils @ $10/B	$ 291,666
Total sales	$3,663,916

Profitability—Percent Return on Investment

Considering the sales price of the lube oils at 47 cents/g and the fuel oils at 23.8 cents/g, profitability before taxes becomes a function of the manufacturing cost with the principal variable being the cost of the waste oil.

Profit = sales, minus manufacturing cost

Waste oil cost, cents/g . .	10	15	20
Profit, $/year	1,444,000	877,000	364,000

$$\text{Pct, return on investment} = \frac{\text{profit}}{\text{fixed investment}}$$

Waste oil cost, cents/gal .	10	15	20
Profit, pct	74	45	19

Payout Time

Payout time in years is a function of the fixed capital invested relative to the profit plus depreciation. Depreciation is money returned at the usual rate of 10 pct each year and is included in the manufacturing cost.

$$\text{Payout time} = \frac{\text{Fixed investment}}{\text{Profit + 10 pct fixed investment}}$$

Waste oil cost, cents/g . .	10	15	20
Payout time, years.	1.2	1.8	3.5

Please note that these values could vary considerably with the fixed investment. The $1,963,000 used here could be modified by land costs, equipment costs, and labor costs. More complete design work would be necessary to firm these profit figures, but this preliminary work does indicate that the project is positively worthwhile.

As can be seen, the profitability is very dependent upon the cost of the waste oil. Much attention should be devoted to a study of the gathering of waste oil and its probable cost. Since the plant capacity could be increased at little additional cost, manufacturing costs may be minimized, and profits could be maximized by doubling or tripling the throughput.

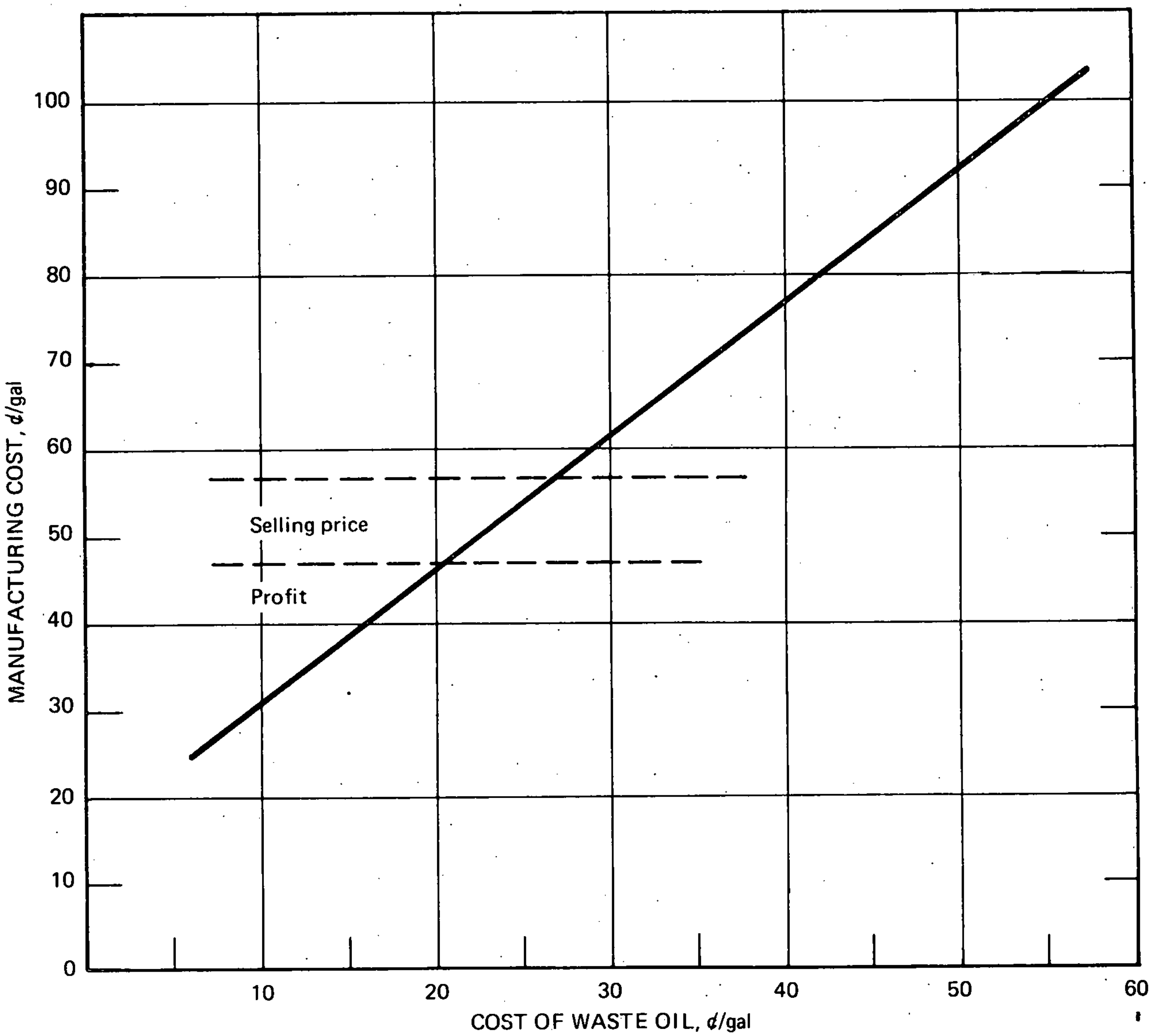

Figure 2. - *Sensitivity of manufacturing costs and profits to feedstocks.*

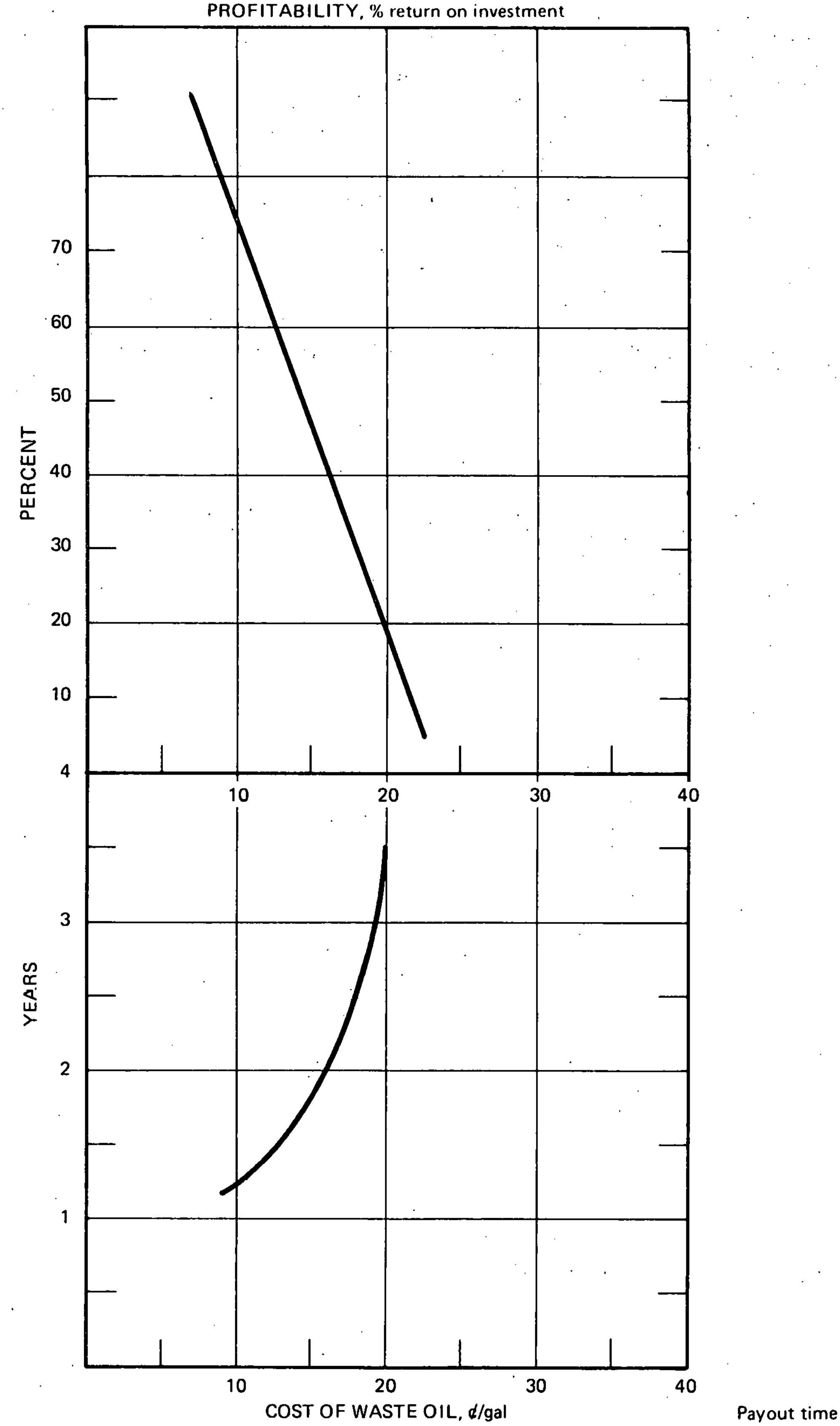

Figure 3. - *Impact of feedstock costs on profits and payout time.*

DESIGN VARIATIONS

Waste oil storage:

Two 200,000 g tanks are included, would one 400,000 g tank be better?

What about bottom, sludge settling?

Is agitation necessary?

Fuel flash:

Is accumulation necessary or could cooled oil be pumped directly to solvent treater?

Solvent settler:

How many are really needed at $23,200 each?

What is best shape—tall and small diameter or short and large diameter?

What is best angle for conical bottom?

Clay contacting:

Determine precise quantity of clay necessary.

Determine quantity of steam added.

Filter design is dependent upon clay present.

Water disposal:

Consider problems of sludge disposal either by burning or reclaiming.

Consider problems of oily clay disposal—can it be burned or regenerated?

Determine any problems of water treatment.

Clay contacting

Comments:

Clay usage:	2 - 25 lb/B
Loss of oil:	1.5 - 2 pct
Steam usage:	45 - 100 lb/B

For this calculation,

assume 10 lb/B x 500 B = 5,000 lb/D

Clay at $50/ton delivered

Cost = $125/D

Filtration

Rotary vacuum drum filter
coated with diatomaceous earth filter aid 4 inch thick

Capacity = 10 g/ft^2 /hr of finished oil

Therefore 20,570 g/4 hr = requires 500 ft^2 of filter area

Size filter required: 10 ft dia. x 16 ft long

Dorr Oliver cost estimate.	$ 70,000
Auxilliary equipment, i.e., vac. pump, pumps, filter aid, mix tank	30,000
	$100,000
Two times for installation and shipping	
Total cost	$200,000

References on costs

Heat exchangers:
Oscar Castner, Wayner Company, Tulsa

Pumps:
Vince Thompson, Harley Industries, Tulsa

Tanks and vessels:
Charles Purser, C-E NATCO, Tulsa

Filters:
Bob Ullmer, Dorr Oliver, Inc., Houston

TABLE 6. - *Predesign of heat exchangers*

Component	Unit	Gal/day	Gal/hr	Sp. gr.	Lb/gal	Sp. heat Btu/lb °F	Heat of vapor, Btu/lb	TD °F	Heat transfer Q Btu/hr	Btu/hr Ft²/°F U	Lmtd	Ft² = Q/Ulmtd*
	Fuel flash drum											
Waste oil	Feed heater	28,422	1,184	0.80	6.67	0.67		0-350	1,860,241			
Water		1,878	78	1.00	8.34		1,449	0-350	942,603			
Total									2,802,844	25	340	330
Oil	Lt fuel condensing	1,212	50.5		5.89		128		38,073			
Oil	Lt fuel cooling	1,212	50.5		5.89	0.675		350- 80	54,209			
Water	Condensing and cooling	1,878	78		8.34		820		535,136			
Total									627,418	100	160	40
Oil	Crude lube cooler	27,230	1,135	0.8	6.67	0.6		350- 80	1,226,413	15	160	511
	Solvent stripper											
Oil	Feed heater	22,876	956	0.8	6.67	0.6		80-300	841,700			
Solvent	Heating liquid	81,690	3,404		6.75	0.664		80-300	3,356,480			
Solvent	Vaporizing	81,690	3,404		6.75		247		5,675,319			
Total									9,873,499	50	250	790
	Reboiler (0.5 reflux)							300-330	4,771,541	50	35	2,726
Solvent	Condenser (reflux 0.5)											
	Vaporizing	122,535	5,106		6.75		247		5,652,617			
	Liquid	122,535	5,106		6.75	0.664		250- 80	3,890,465			
Total									9,543,082	150	160	397
Sludge + S	Sludge reboiler	4,354	181	0.979	8.16		181	80-300	268,703	10	250	107
Solvent	Solvent condenser	174	7		6.75		247		11,670			
Solvent	Solvent cooler	174	7		6.75	0.664		300- 80	6,902			
Total									18,572	150	220	6
Sludge	Sludge cooler	4,180	174	0.979	8.16	0.8		300- 80	250,131	10	220	114
	Vacuum tower											
Oil	Feed heater	22,876	953		6.672	0.6		300-490	742,986	50	200	75
Hvy oil	Reboiler							630-650	1,202,583	30	20	2,000
Lt oil, V.	Reflux condenser (0.5)	1,151	72		6.9		110		59,600			
		(1.5)										
L.		1,727	72		6.9	0.65		375- 80	95,261			
Total									149,861	20	290	26
	100 Vis. cooler	5,727	239	0.86	7.17	0.62		450- 80	393,106	20	360	55
	150 Vis. cooler	5,727	239	0.865	7.21	0.60		490- 80	424,145	20	400	53
	250 Vis. cooler	6,848	285	0.875	7.3	0.60		550- 80	586,701	20	460	73
	600 Vis. cooler	2,272	97	0.88	7.34	0.615		625- 80	238,638	20	540	22
	Hvy gas oil cooler	1,151	48	0.932	7.77	0.720		650- 80	153,120	20	560	14
Lube	Clay contactor, 4 hr.	20,574	5,144	0.87	7.25	0.60		80-300	4,922,808	25	250	788

**Required size of heat exchanger in* ft^2.