FLOW Analyses: Substituting Plasma Hearth Technology (PHP) in a Conventional Baseline Mixed Waste Treatment Facility

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Executive Summary

This analysis shows a benefit to substituting the fixed hearth plasma arc technology (PHP) for incineration in a mixed waste treatment facility designed to treat a wide variety of waste streams. The evaluation process concluded that using plasma hearth technology instead of incineration results in significant improvement in lowering facility cost and increasing operability.

A FLOW model of the fixed hearth plasma arc unit was developed and validated by an ORNL team using experimental and design data supplied by SAIC and Retch, Inc. The FLOW model is able to predict the final concentrations of hazardous contaminants that would be found in slag resulting from the treatment of a representative Idaho site mixed waste stream.

By developing a baseline FLOWsheet of a mixed waste facility, FLOW was able to compare two cases of the PHP technology to the baseline technology for their performance, costs and risks. The baseline facility uses a conventional incinerator to destroy organics. Case 1 of the PHP substitutes a fixed hearth plasma arc unit for the incinerator that treats only those waste streams that it has been proven it can handle. The remaining waste streams in this case are processed in the same manner as the baseline facility. In Case 2, the FLOW model team optimized the entire facility to use the full capability of the fixed hearth plasma unit, assigning all waste stream to this treatment and eliminating redundant treatments. This resulted in a streamlined integrated FLOWsheet that reduced costs and increased operability of the baseline facility.

FLOW has been demonstrated by ORNL in both EM-30 and EM-50 studies as a fast and effective tool for comparing the relative benefits of emerging technologies for conventional treatments. In the case of the PHP, the results of the analysis show that this technology can improve the costs and operations of facilities which may be considering incineration. This study confirms the value and importance of current PHP demonstrations that will increase the relative evaluation indices of the PHP technology by resolving risk and schedule issues.

1. DESCRIPTION OF PLASMA ARC PROCESSES

A series of treatment alternatives have been considered for low level radioactive waste from the operations of nuclear power plants, medicine, industry, and research. Incineration, solidification, and conditioning appear to be preferred options. However, in this country there is an increasing public concern about installing additional incinerators. Consequently, the focus has shifted to thermal treatment alternatives that can replace the incineration. One viable thermal alternative is plasma arc technology. It is forecasted that this technology will simplify treatment of mixed waste.

1.1 Fixed Hearth Plasma Arc Process

The fixed hearth plasma arc process (PHP) is a thermal treatment process using an electric arc plasma to melt non-combustible wastes and vaporize/oxidize combustibles. Vaporized organics partially combust in the primary process chamber, and completely combust in the secondary combustion chamber. The PHP contains an air pollution control system consisting of a partial water quench and a high temperature pulse-jet baghouse. The system was primarily designed for particulate removal.

Noncombustible materials melted into the hearth are removed as slag and metal melts. the hearth is drained, the melted material is separated into slag, and metal which can be recycled. A simplified version of the PHP is show in Figure 1. Figure 2 displays the complete PHP as simulated in FLOW.

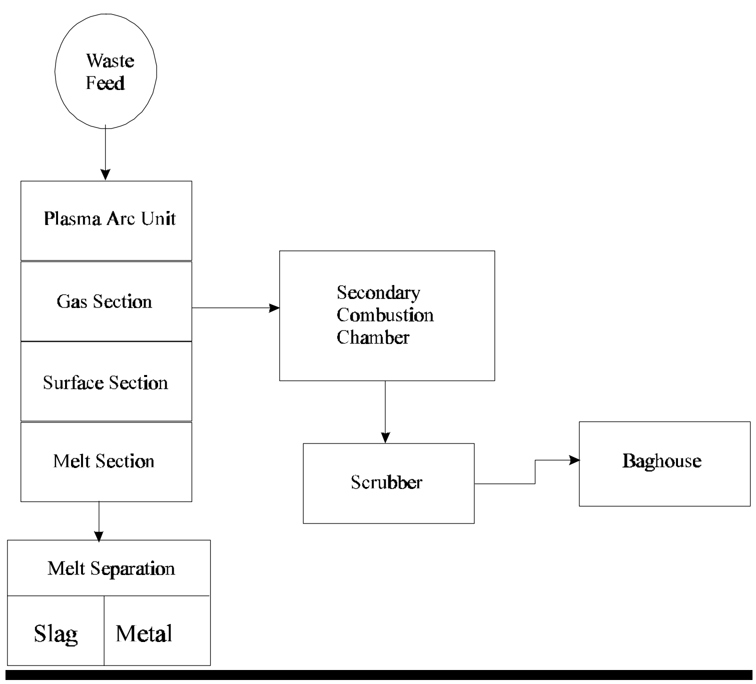

Figure 1. Simple map of the PHP.

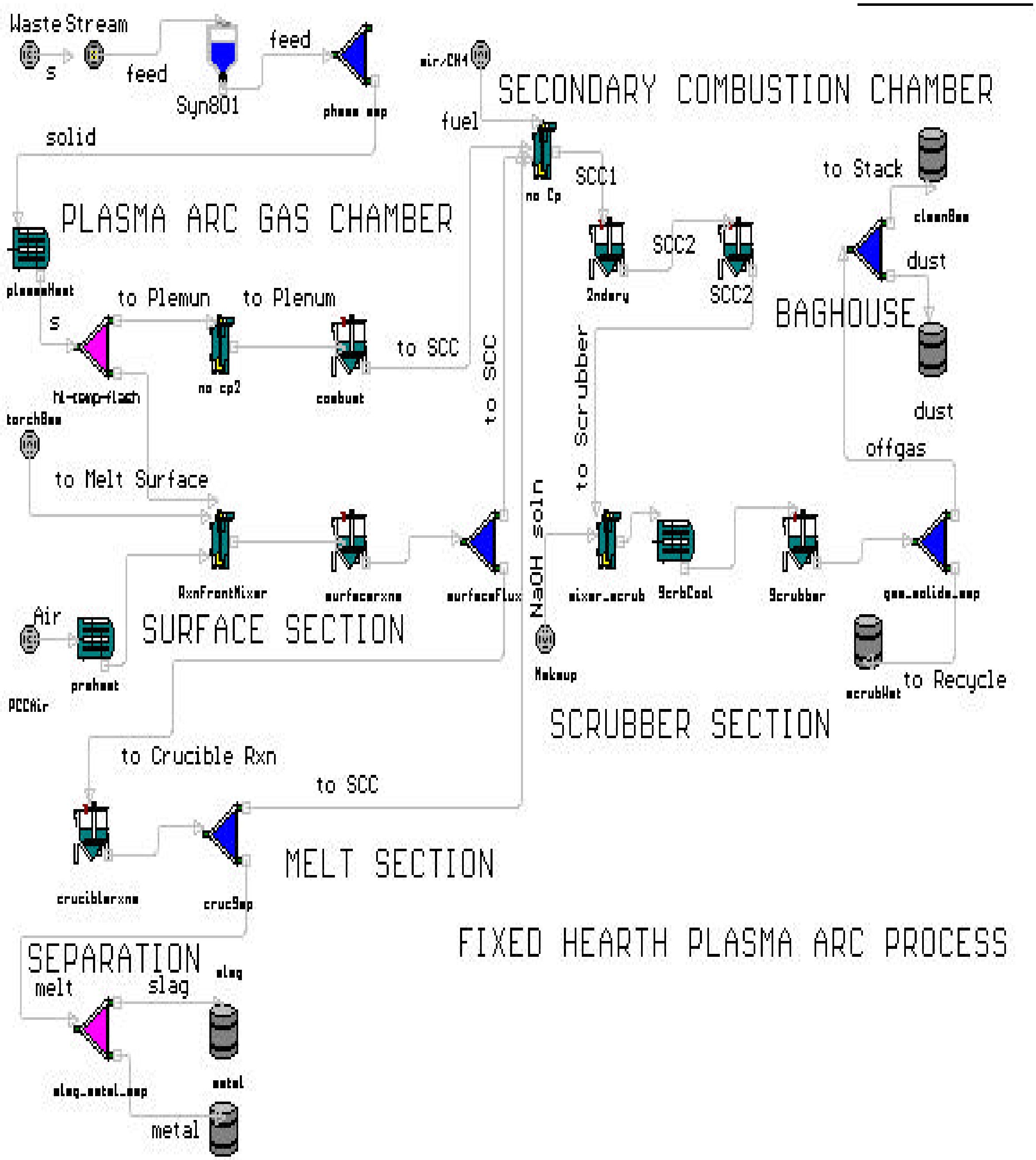

Figure 2. The complete PHP illustrated in the FLOWsheet from the FLOW simulation of the process. This simulation is based on the plasma arc unit built in Ukiah, California.

1.1.1 Waste Feed

Drums are placed in a feed chamber where a hydraulic ram pushes the drums into the primary process chamber. Drums may contain various wastes as shown in Table 1.

Table 1. Waste steams that can be treated using a fixed hearth plasma arc furnace.

Combustibles	yes	Organic Liquids	yes
Aqueous Liquids	yes	Organic Sludges	yes
Inorganic Sludges	yes	Soils	yes
Debris	yes	Lab Packs	yes
Reactive	no	Inherent Hazardous	yes
Metals	yes	Solidified Sludges	Special Capability

1.1.2 Status of development

A non-radiological pilot scale system (approximately 500 lbs/hr) has been constructed at Retech, Inc. in Ukiah, California. The system was tested demonstrate the ability of PHP technology to treat three different DOE wastes: organic sludge, inorganic sludge, and heterogeneous debris[1] . The tests were performed with DOE waste surrogates. Two test cases were run for each waste type for a total of six cases. The test wastes were put into DOT 17H 30 gallon steel drums. The feed rate was about one drum per hour.

Test results show the PHP process has the required destruction and removal efficiency (DRE) for organics of 99.99%. Particulate emissions from the off-gas system ranged from 0.0018 g/dscf to 0.0044 g/dscf for the six tests. This is less than the RCRA requirement of 0.08 g/dscf. The metal concentrations in the leachates from the slag were at least two orders of magnitude below the RCRA limits. Comparing the metal leachate concentrations in the slag to the new Phase Two Land Disposal Restrictions Universal Treatment Standards shows that the leachate concentrations are well below the limits of the standard by a factor of four to forty. The amount of chlorine in the off-gas was measured. It ranged from 0.0012 lb/hr for the inorganic sludge, to 0.9 lb/hr for the organic sludge. Cadmium, cesium, and lead were recovered primarily in the baghouse dust. Less than ten percent of these metals were found in the slag or metal phases. Cerium and chromium consistently remained in the slag. The process produced a homogeneous final product and had an overall volume reduction for all waste types ranging from 5:1 to 11:1

[1] SAIC, Evaluation of the Test Results From the Plasma Hearth Process Mixed Waste Treatment Applications Demonstrations. Draft final report SAIC-94/1095 June 14, 1994.

1.1.3 Advantages of the Plasma Hearth Process

- Accepts whole drums of widely varying composition
- May minimize characterization
- Facilitates steel recycling
- Complete thermal destruction of organics
- Non-leachable slag produced
- High volume reduction
- Additives are not needed to achieve vitrification
- Low off gas flow reduce capital investment in off gas treatment system.
- Anticipated stakeholder acceptance due to interest of the Western Governors' Association Mixed Waste Working Group

1.1.4 Disadvantages of the Plasma Hearth Process

- NO_x formation greater than conventional thermal process
- Materials of construction problems with hearth
- Small scale operations are not cost effective
- Volatilization of mercury, cesium and cadmium might cause problems
- Requires an enhanced off-gas system design to remove particulates and NO_x

1.1.5 Schedule

The PHP schedule for a field scale design shows availability in August, 1996.

2. SIMULATION OF A 500 KG/HR FIXED HEARTH PLASMA ARC UNIT

2.1 Model development and validation

The FLOW simulation used experimental data from the SAIC report[2]. Empirical equations used in the simulation were formulated from information included in the report and chemical and engineering handbooks[3]. The model was developed and the results were compared with the SAIC experimental data for validation. The FLOW simulation and SAIC experimental data compare favorably as shown in Table 2.

Table 2. FLOW simulation and SAIC experimental results on output mass flowrates of the PHP.

PHP Output Mass Flowrates (kg/hr)						
Waste Stream	Slag & Metal		Flyash		Stack gas	
	FLOW Simulation	SAIC Exp. Data	FLOW Simulation	SAIC Exp. Data	FLOW Simulation	SAIC Exp. Data
Inorganic Sludge	47	51	1.6	2	527	1115
Heterogeneous Debris	40	40	2.2	2	658	1421
Organic Sludge	44	42	2.6	4	1258	1991

In this FLOW simulation, the stack gas results did not match the experimental values reported by SAIC. This PHP model validation was based on only one experimental campaign consisting of three tests. Reports indicated that the experimentalists had difficulty with their stack gas monitoring during this campaign. Since the parameters currently used in FLOW have proven consistently accurate in other studies, they were not adjusted in these cases. If Retech's experimental stack gas data were accurate, the predicted concentrations of contaminants in the scrubber solids will be conservatively high in the simulation, and the FLOW estimates of costs for sizing and operating the off-gas treatment system and the scrubber-solids grouting system will be low and should be adjusted by a factor of approximately 2.

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[2] SAIC, "Evaluation of the Test Results from the Plasma Hearth Mixed Waste Treatment Applications Demonstrations." Draft final report, SAIC-94/1095, June 14, 1994.

[3] Perry's Chemical Engineers' Handbook, Sixth Edition. Lang's Handbook of Chemistry, Eleventh Edition. CRC Handbook of Chemistry and Physics, Sixtieth Edition.

The accuracy of the model will be improved when the PHP demonstration produces new data. If the new data confirms the higher stack gas flow, the ORNL team will modify this portion of the model to match the predicted stack flows with the data. Otherwise, this FLOW simulation accurately represents the behavior of the PHP.

2.2 Flow simulation of the PHP

A fixed hearth plasma arc unit was simulated using FLOW (See Figure 2). The waste stream used in the simulation was specified in the draft PHP test plan as representative of mixed waste, heterogeneous debris, at the Idaho site.

2.2.1 Operation Conditions of the FLOW simulation

Table 3. Operation conditions of the PHP

Parameter	Operation Conditions
Waste Flow Rate (Feed rate)	500 kg/hr
Torch Gas (Air) Flowrate	526 kg/hr
Oxygen Lance Flowrate	0 kg/hr
Aux Torch Gas Flowrate	114 (N_2) kg/hr
Secondary Combustion Chamber Natural Gas Flowrate	914 kg/hr*
Scrubber Liquor	528 kg/hr

* natural gas and combustion air

Table 4 shows the composition of the waste stream used in the FLOW model. The waste stream is representative of DOE heterogeneous debris from the Idaho site. The waste stream was initially given as a list of materials and not as chemical components. The waste stream was spiked with RCRA metal components such as $Cr(NO_3)_3 \bullet 9H_2O$, $Ni(NO_3)_2 \bullet 6H_2O$, $Pb(NO_3)_2$, and $Cd(NO_3)_2 \bullet 4H_2O$.

Table 4. Waste stream composition used in the FLOW model before conversion to chemical components:

Components	Wt %	Components	Wt %
Aqueous Organics	2	PVC	1
Cardboard	1	Rubber	2
Aluminum Ceramic	1	Sheetrock	8
Concrete	10	Steel	43
Dirt	4	Wood	4
Glass	17	$Cr(NO_3)_3 \bullet 9H_2O$*	0.1
Oil	1	$Ni(NO_3)_2 \bullet 6H_2O$*	0.1
Metal	0.6	$Pb(NO_3)_2$*	0.1
Paper	2	$Cd(NO_3)_2 \bullet 4H_2O$*	0.1
Polyethylene	3	*spiked metal	

The materials in the waste stream were converted into chemical components prior to modeling (See Table 5). FLOW contains a catalog of common materials and their elemental composition for the conversion process.

Table 5. Waste stream composition used in the FLOW simulation following conversion into chemical components.

Components	Wt %	Components	Wt %	Components	Wt %
C	3.3322	Mn	0 .1308	C_6H_5Cl	0.004
H	0.4422	P	0.01744	$C_{10}H_8$	0.004
O	1.7464	SiO_2	22.55	MgO	1.15
N	0.029	B_2O_3	0.85	C_2H_4	3
S	0.0683	Al_2O_3	2.63	Fe_2O_3	2
Ash	0.4475	Na_2O	1.7	$Cr(NO_3)_3 \bullet 9H_2O$	0.1
$C_6H_{10}O_5$	3.6	CaO	5.52	$Ni(NO_3)_2 \bullet 6H_2O$	0.1
H_2O	3.28	PbO	1.7	$Pb(NO_3)_2$	0.1

C_2H_3Cl	1	CH_4	0.006	$Cd(NO_3)_2 \bullet 4H_2O$	0.1
Fe	44.3864	C_3H_8	0.006		
Subtotal	58.33	Subtotal	34.98	Subtotal	6.56
				Total	**99.87**

2.2.2 FLOW simulation output flowrates

The output mass flowrates for the slag and metal, baghouse dust, and stack gas, of the heterogeneous debris waste stream used in the FLOW simulation are shown in Table 6.

Table 6. FLOW simulation output mass flowrates

Output	Flowrate kg/hr
Slag and Metal	428
Baghouse Dust	5
Stack Gas	1449

The FLOW model provides a detailed composition analysis of the slag material. Table 7 shows the detailed composition analysis of the slag material that resulted from the processing of the heterogeneous debris waste stream used in the FLOW simulation.

Table 7. Composition analysis of slag material produced in the FLOW simulated PHP.

Element	Wt %	Spiked Metals	Wt %
Aluminum	1.0	Cadmium	0.038
Boron	0.3	Chromium	0.014
Calcium	4.1	Lead	1.718
Iron	49.0	Nickel	0.021
Magnesium	0.7	**Subtotal**	1.791
Oxygen	29.0		
Silicon	12.0		
Sodium	1.3		
Carbon	0.0004		
Manganese	0.00005		

Nitrogen	0.012	
Phosphorus	0.000006	
Sulfur	0.08	
Subtotal	97.492456	
TOTAL	99.283456	

Spiked metal concentration data is valuable for determining final waste acceptance and emission quality. The partitioning factors used in the FLOW model were taken from the SAIC report. Table 8 shows the results of the FLOW simulation for the partitioning of the spiked metals introduced with the feed stream. The values are expressed as the percentage of the feed that goes into the different output streams.

Table 8. Spiked metal concentration data from the FLOW simulation is helpful for determining emission quality and final waste acceptance.

Spiked Metal	**Feed Rate**	**Baghouse Dust**		**Stack Gas**	
	kg/hr	**Output kg/hr**	**% of feed**	**Output kg/hr**	**% of feed**
Pb	1.64069	0.007996	0.487356	1.20E-05	0.000731
Cr	0.012995	0.000064	0.492497	9.54E-08	0.000734
Ni	0.020189	0.000097	0.48046	1.47E-07	0.000729
Cd	0.036439	0.000178	0.488488	2.66E-07	0.000731

2.2.3 Performance

The following values represent the model estimate for the Idaho site heterogeneous debris waste stream used in the FLOW simulation. It should be noted that the volume reduction factor is directly related to the constituents of the waste stream. For this particular waste stream the volume reduction factor was not high since the amount of steel in the waste stream was 43 %.

Volume Reduction

The PHP will produce an effective volume reduction, but it is dependent on the feed composition. The **volume reduction factor of 2.2** was calculated for the waste stream used in this model. The waste stream used for this analysis was heterogeneous debris that was 43% steel (see Table 4). With the high metal content in the waste stream, it was not surprising that the volume reduction factor was low.

The volume reduction factor is calculated by dividing the feed volume by the output volume:

$$\text{Volume Reduction Factor} = \frac{\text{Feed Volume}}{\text{Output Volume}}$$

Assumptions were made for the material densities in the feed volumes and output volumes. Table 9 displays the data used to calculate the feed volume, Table 10 displays the data used to calculate the output volume. The feed rate of the system is 500 kg/hr (see table 3). The slag and metal output stream was 428 kg/hr (see table 6). The percent of metal in the output stream was approximately 49% (see Table 7).

Table 9. Feed volume data used in the calculations of the volume reduction factor.

Feed Material	**% of feed**	**Feed Rate**	**Density**	**Feed Volume**
		kg/hr	**g/cm^3**	**m^3/hr**
Metal	43	215	8	0.027
Other	57	285	1.5	0.19
Total Volume of Feed				0.217

Table 10. Output volume data used in the calculations of the volume reduction factor.

Output Material	**% of output**	**Output Rate**	**Density**	**Output Volume**
		kg/hr	**g/cm^3**	**m^3/hr**
Metal	49	209.7	8	0.026
Slag	51	218.3	3	0.073
Total Volume of Output				0.099

The expected volume reduction factor of 1 was calculated for the metal contained in the waste stream. The volume reduction factor for the other material contained in the waste stream was calculated to be 2.6. The total volume reduction factor for the heterogeneous debris waste stream was 2.2.

2.2.4 Cost Analysis

Cost analysis of the PHP includes a capital cost estimate, operating cost estimate, and pre-operational cost, resulting in a total life cycle cost estimate. The FLOW model life cycle cost analysis of the PHP was based on cost estimates from previous reports[4], and other plasma arc process data.[5] The cost equations in the FLOW simulation are regression analyses applying the models used by Barnes-Smith and Booth.

Capital Cost Estimate

Table 11 shows the capital cost for a 500 kg/hr PHP. An estimated cost break-down of individual process equipment items is contained in right hand side of the table.

Table 11. Estimated capital cost breakdown of the PHP produced in the FLOW model.

Cost Item	$ Million	*Process Equipment	$ Million
Building & Facilities	49.1	Drum Feed System	0.51
Process Equipment*	6.804	Primary Combustible Chamber	2.2
Trial Burn	0.285	Secondary Combustible Chamber	0.404
Start Up	3.0	Off-gas treatment	0.113
Total	**59.19**	Process control	0.74
		Indirect field cost	0.53
		Contractor field	0.338
		Construction management	0.529
		Engineering, design, and inspection	1.44
		Total	6.804

[4]Peter Barnes-Smith and Steven Booth. "Life Cycle Cost Analysis for the Plasma Arc Furnace." Los Alamos, October, 1993.

[5]Personal communication with SAIC/Retech technical staff.

Operating Cost Estimate

The operating cost estimate from the FLOW model was based on a process plant comprised of one plasma arc unit, operating 360 day per year. Each day would be comprised of four shifts, with three laborers per shift at a rate of sixty dollars per laborer per hour. Two supervisors would work one shift per day at a rate of 70 dollars per supervisor per hour. Energy costs are based on 1.5 kW hr/kg at 8 cents per kilowatt hour. The operating costs are broken down in table 12.

Table 12. Operating cost based on the FLOW analysis for a process plant comprised of one plasma arc furnace unit.

Operating Cost Item	$ Million/year
Labor	2.07
Energy	0.346
Maintenance	0.375
Supervisor	0.202
Materials	0.06
Oxygen & Fuel	0.12
TOTAL	**3.173**

Pre-operational Cost

Pre-operational costs assumes additional development work that has been estimated at three million dollars[6].

Decontamination and Decommissioning (D&D) Cost

The D&D costs have been assumed to be 30% of the capital cost or eighteen million dollars.[7]

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6 Personal communication with SAIC staff.

7 INEL report, "Waste Management Facilities Cost Information For Mixed Low Level Waste., EGG-WM-10962, March, 1994

Total Life Cycle cost

The total life cycle cost assumes the PHP will operate for ten years, two hundred and forty days per year, and twenty-four hours per day. Table 13 shows the composition of the estimated total life cycle cost.

Table 13. Estimated total life cycle cost from the FLOW simulation

Cost Item	**$ Million**
Capital cost	59.5
Operating Cost (28 million kilograms of waste fed into the system over 10 years)	31.73
Pre-operational cost	3.0
D&D cost	18.0
Total	**111.93**

3. USING FLOW TO COMPARE THE IMPACT OF SUBSTITUTING THE PHP TO A BASELINE TREATMENT TECHNOLOGY

A system analysis including cost, risk, and performance was conducted at ORNL for the Mixed Waste Treatment Facility (EM-30). It included the PHP as a viable alternative technology. The method for analysis consisted of defining a baseline, and comparing the baseline to the PHP.

3.1 Baseline Treatment Scenario

The baseline design was based on the Mixed Waste Treatment Facility design information report[8]. The design consists of a receiving and handling facility for waste classification, a pretreatment facility for de-watering, sizing, shredding, crushing, and four treatment operations including: incineration, surface decontamination, thermal desorption, and stabilization (includes vitrification and grouting). Liquids produced in the process are treated in the secondary pre-treatment facility. A simplified flow diagram illustrated the baseline technology in Figure 3. The baseline technology FLOWsheet is shown in Figure 4.

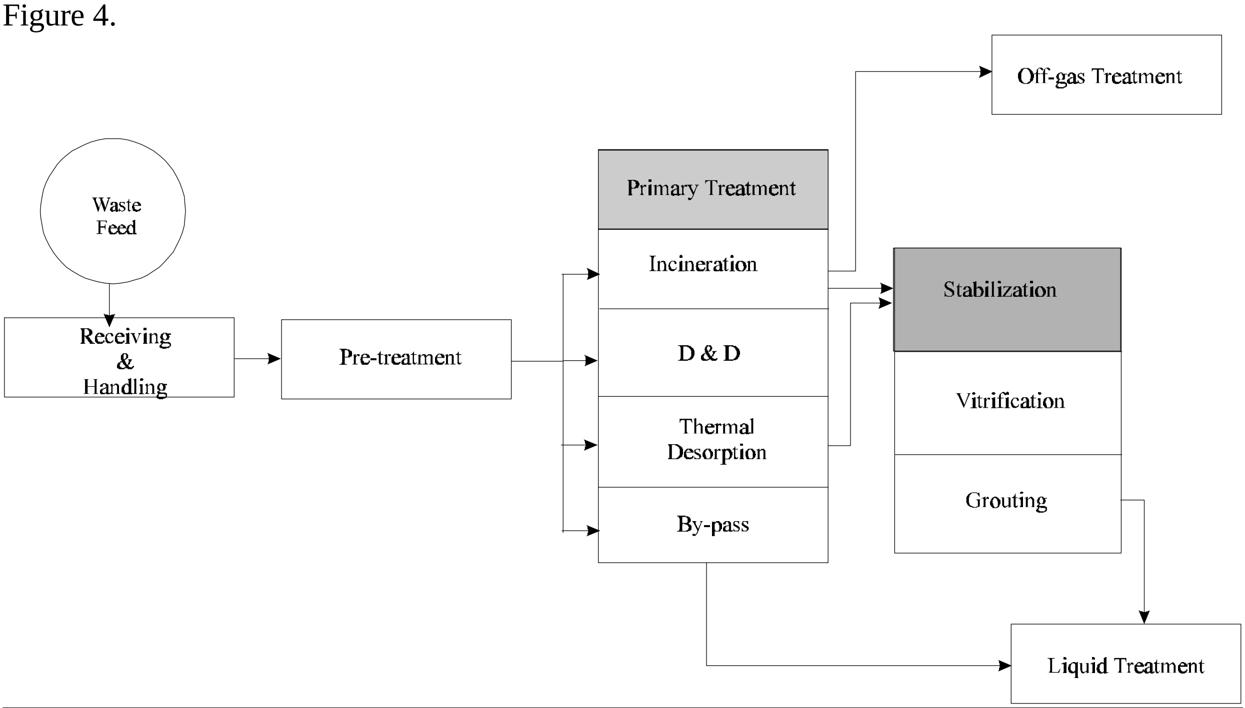

Figure 3. Simple map of the baseline treatment technology.

[8] Parsons Main, Inc. "Supplemental Process Studies for Mixed Waste Treatment Facility", August 1994.

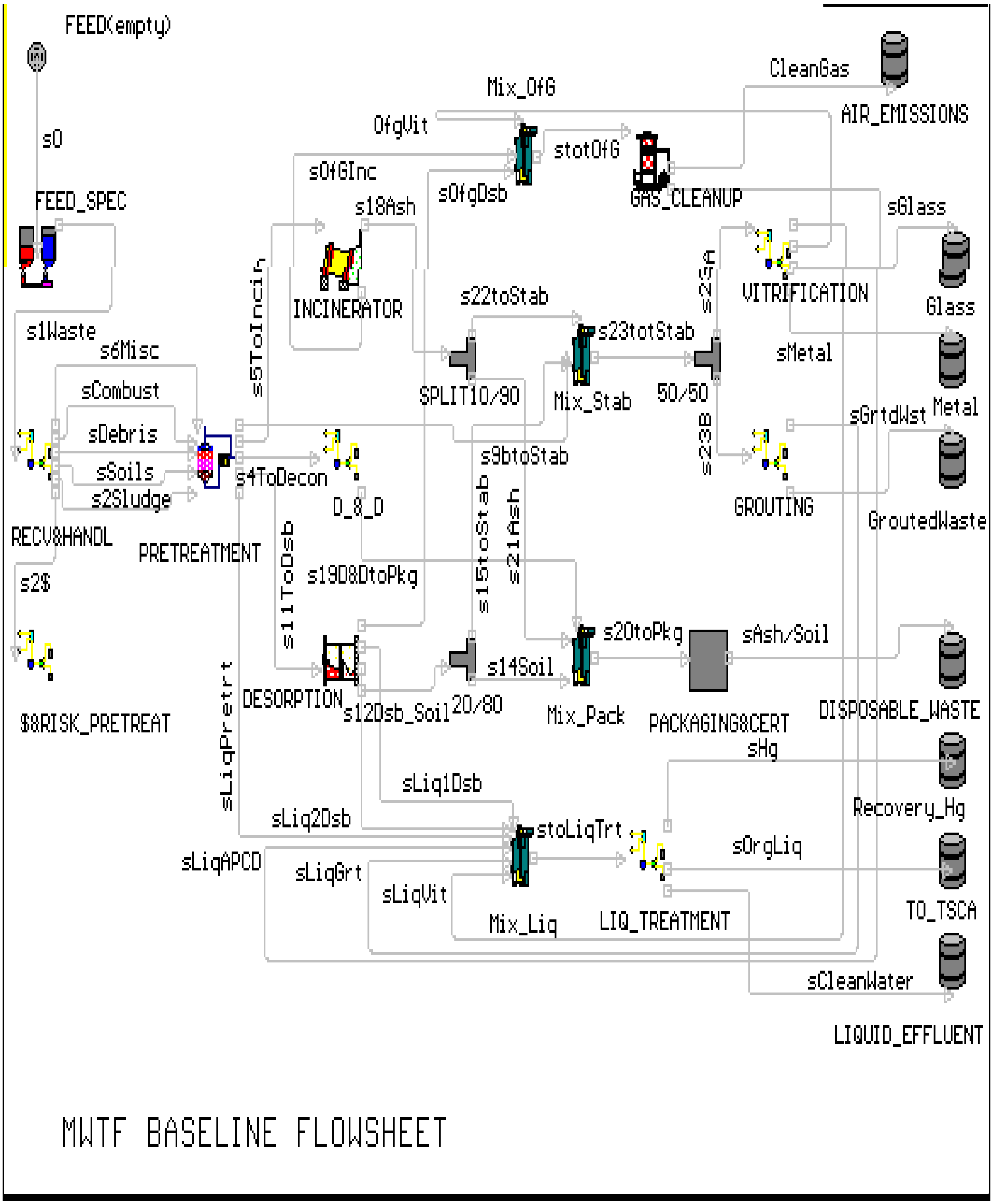

Figure 4. FLOWsheet of the baseline design used in the comparison of alternative technologies.

Mixed wastes will be sent to the central receiving and segregation area, where it will be sorted and categorized as either soil, sludge, combustible, debris, or miscellaneous. Once sorted, these wastes will be sent to the appropriate facility for treatment.

First, the sludges will be filtered and de-watered. Soils and de-watered sludges will be sent to the thermal desorption facility. Following thermal desorption, wastes will be checked against landfill waste acceptance criteria (WAC) and sent directly to the landfill, or stabilized before disposal.

The debris stream will be sorted to remove all items less than 60 mm in size. If the small debris stream meets the WAC, it will be sent to the landfill. If not, the stream will be sent to thermal desorption for treatment before disposal. The larger debris stream will be sorted into porous and non-porous fractions. The porous stream will be sent to a crusher and then combined with the small debris stream being sent to thermal desorption. The non-porous fraction will be sent to surface decontamination.

Combustibles will consist of liquid and solids. Liquid combustibles will be sent directly to the incinerator. Combustible solids will be sent to a shredder before being sent to the incinerator. The remaining ash will be sent to stabilization.

Miscellaneous waste that does not fall into one of the other four categories will consist of both solids and liquids. Liquid wastes will be sent to a secondary liquid pre-treatment facility. The solids that do not meet the WAC for stabilization will be handled like the debris stream with a size separation step, and then treated by thermal desorption.

3.2 Replacement of the incinerator with the PHP

The treatment of wastes will be based on one of two cases if the incinerator in the baseline design is replaced by the PHP.

3.2.1 Case One

In the first scenario, the PHP will treat only waste streams that it has previously handled successfully. In this case, the PHP would replace the incinerator in the baseline technology, but the treatment process would still include: decontamination, thermal desorption, and stabilization. Debris and soils would be sorted, size reduced, and treated in the same manner as the baseline case. Sludges will be dewatered and sent with the combustible and miscellaneous wastes to the PHP for treatment. Figure 5 is a simplified diagram of Case One. The FLOWsheet of Case One produced during the technology comparison is shown in Figure 6.

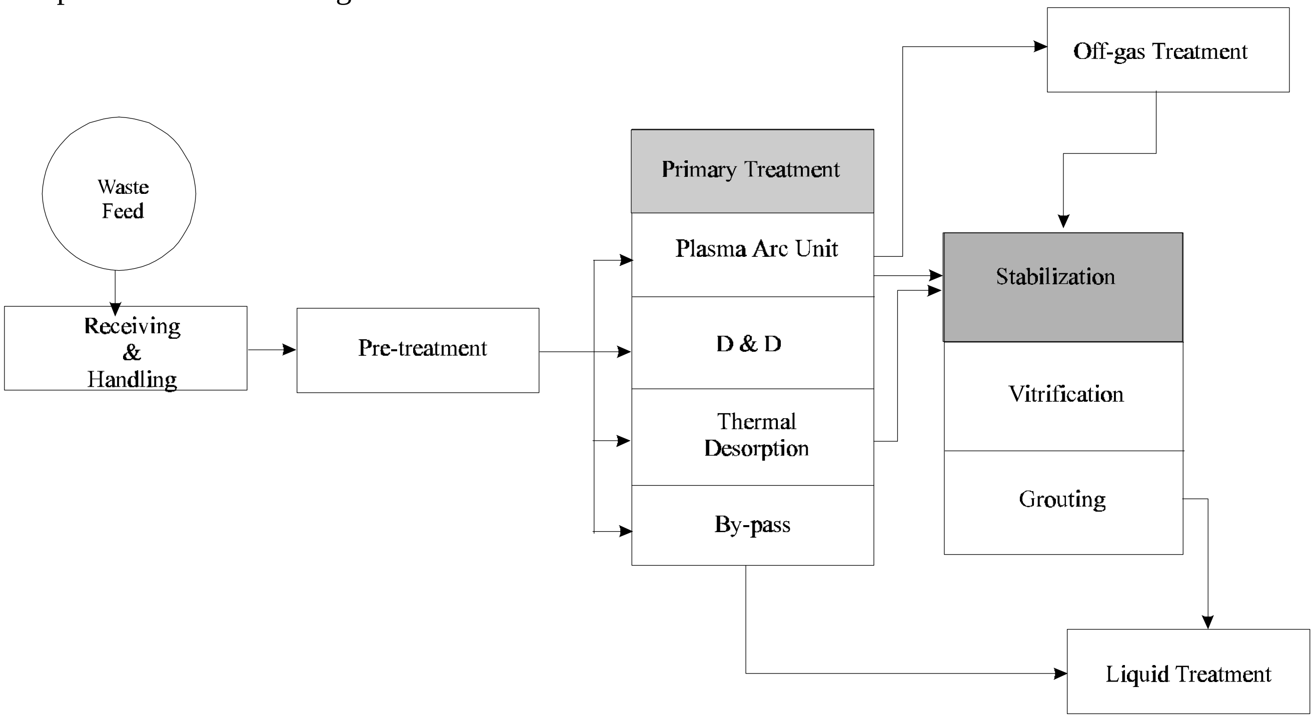

Figure 5. Simplified diagram of Case One.

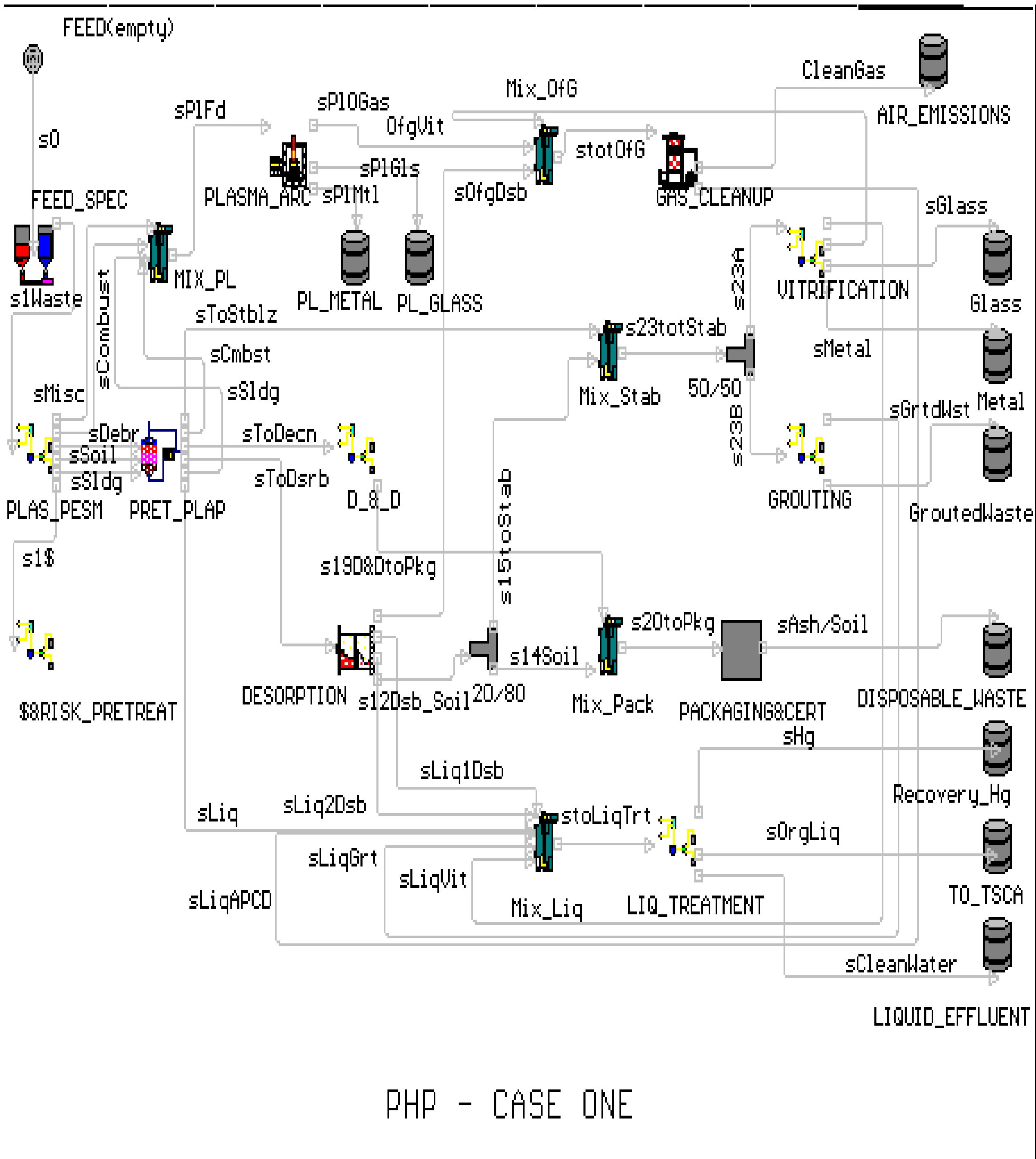

Figure 6. The FLOWsheet of Case One assumes that only the incinerator would be replaced by the PHP. Other treatment operations would remain in place.

3.2.2 Case Two

In the second scenario, the PHP handles wastes that it can theoretically process. All wastes, including soil and debris will be sent to the PHP for treatment. In this case, no other treatment process would be required. Figures 7 is a simplified diagram of Case Two. Figure 8 is the FLOWsheet of Case Two produced during the comparison.

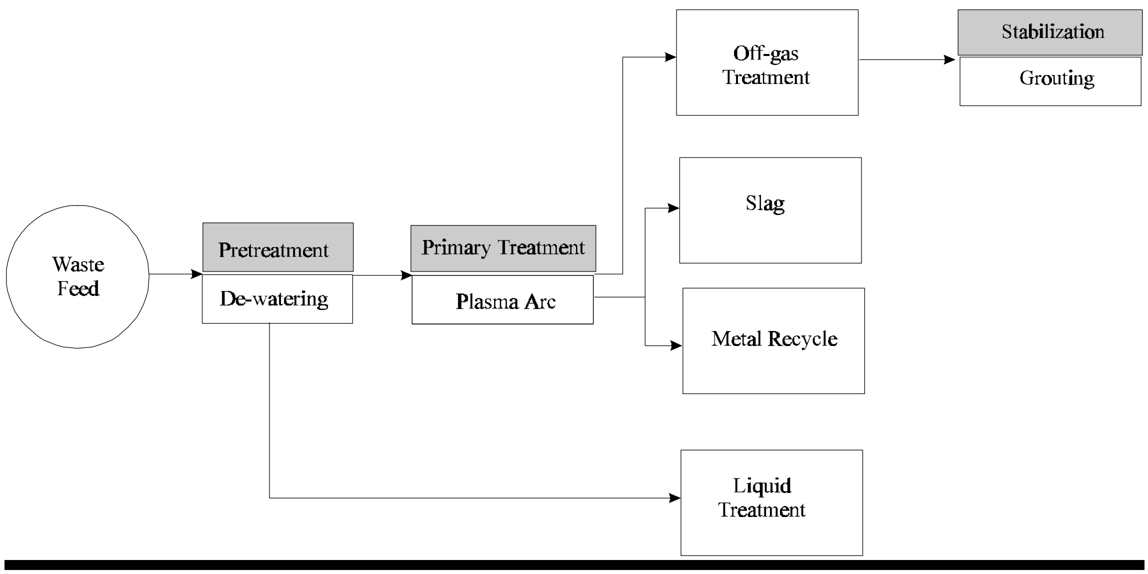

Figure 7. Simplified diagram of Case Two.

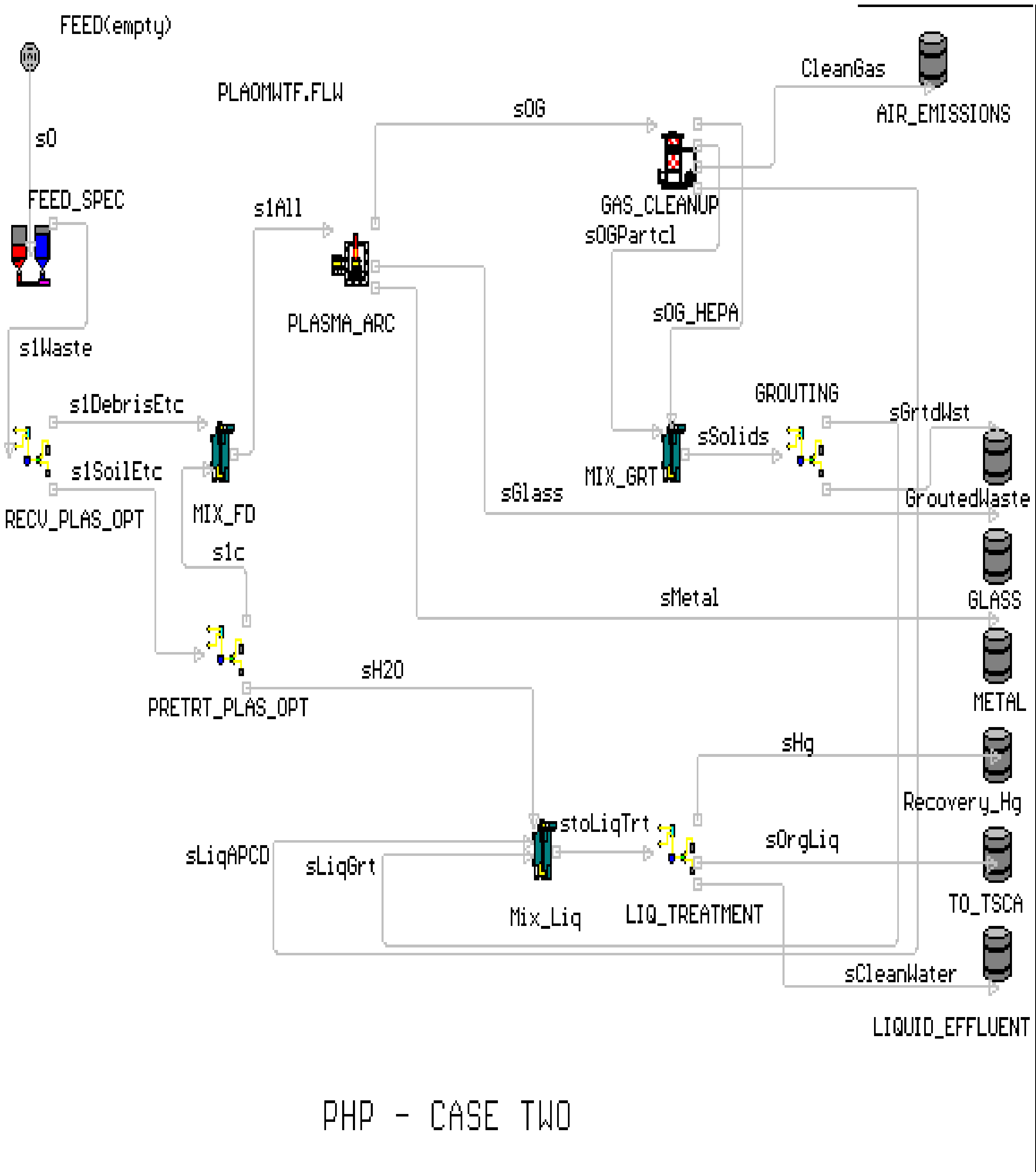

Figure 8. The FLOWsheet of Case Two shows that all treatment operations would be replaced by the PHP. The PHP would treat all waste in this case.

3.3 Comparison of Alternatives

An evaluation methodology was followed to compare and rank the technology alternatives[9]. A set evaluation criteria was established by MWIP and used successfully by the FFCA Options Analysis Team and DOE sites to select technology for specific waste streams. This criteria was applied to the different technology alternatives being evaluated by FLOW. Table 15 shows the criteria elements, the weighting factors assigned to each one and the data for each of the technologies being evaluated.

Table 15. Decision analysis criteria.

	Weighing	**Weighted Evaluation Indices**		
Criteria Element	**Factor**	**Baseline**	**Case One**	**Case Two**
Volume reduction	6	0.30	0.54	6.00
Risk (public and environmental)	10	8.10	9.30	0.00
Reliability, availability, and maintainability	8	6.88	6.08	5.76
Schedule	3	3.00	0.00	0.00
Technical risk	9	7.20	6.75	4.50
Construction cost	10	0.20	7.20	10.00
Operation cost	6	4.44	5.46	6.00
Operability	4	0.00	1.92	4.00
Final waste form	2	0.48	0.30	1.88
Total		30.60	37.55	38.14

Information about cost, risk, and performance was obtained from the FLOW simulation of the treatment alternatives. This information was applied to the evaluation criteria, multiplied by the respective weighting factor, and summed for each treatment alternative in the analysis. This resulted in a weighted sum that indicated the ranked position for each treatment alternative. The treatment with the highest total in this evaluation is ranked as the best treatment alternative. Figure 9 illustrates the results of the evaluation.

[9] MWIP report, "Multicriteria Decision Methodology for Selecting Technical Alternatives in the Mixed Waste Integrated Program", October, 1993.

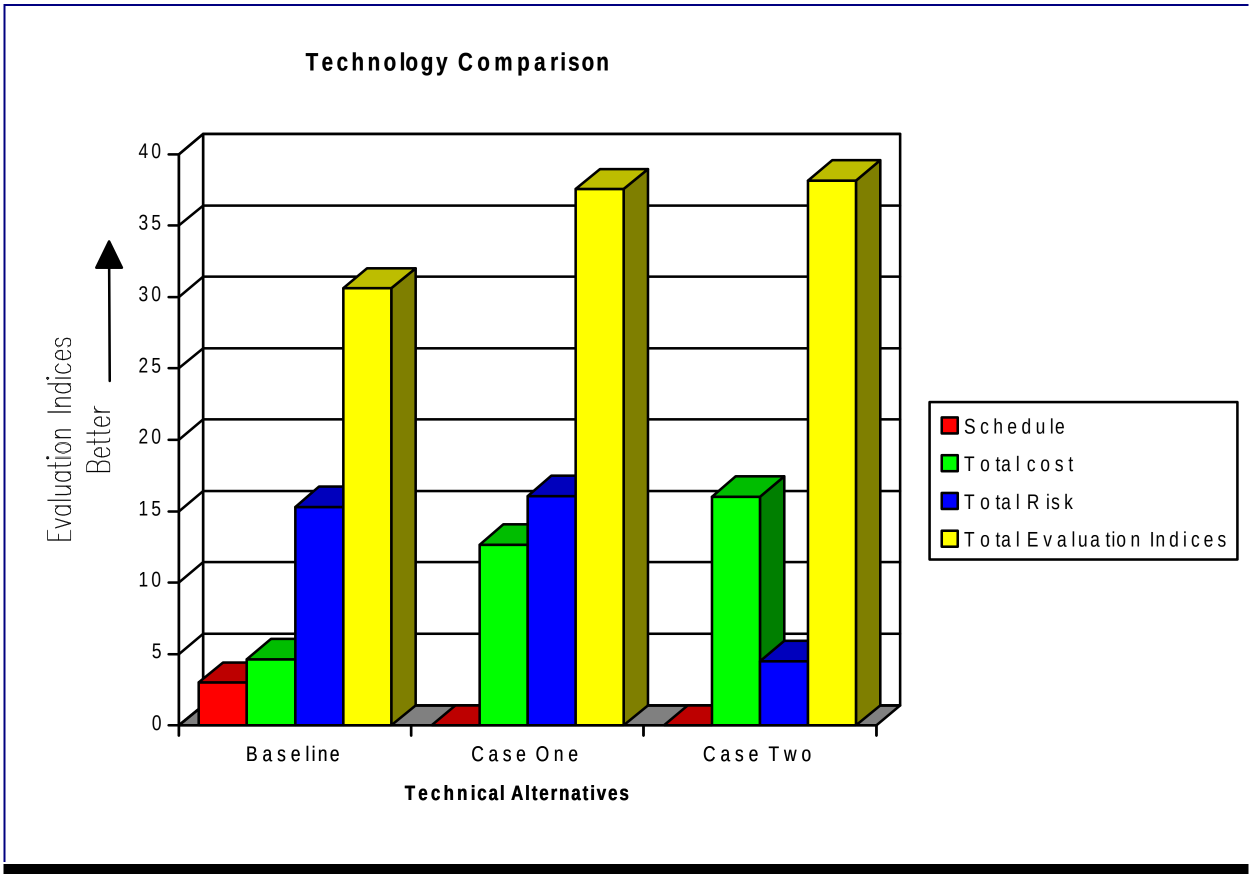

Figure 9. Total evaluation indices of the simulated technologies. A larger indices denotes a better evaluation (e.g. lower costs translates to a higher relative cost index).

3.4 Conclusion

Figure 9 shows that there is considerable benefit to substituting the plasma hearth technology for conventional incineration technologies in this mixed waste treatment facility. Using the PHP, instead of incineration, results in significant improvements in the facilities' costs and operability. The totals of the evaluation indices show the PHP is a credible, effective option when compared to incineration in the baseline FLOWsheet for this proposed facility. Even with conservative assumptions with regard the risks and schedules for the PHP, the plasma hearth technology still comes out on top. The extreme risk and schedule assumptions used in this analysis reflect the reluctance of DOE site design engineers to accept new and emerging technologies because of their unproved operational histories with the assigned mixed wastes.

The conservative risk assumptions in this analysis do not reflect the contrary trend shown by the Programmatic Environmental Impact Statement (PIES). The PIES shows that operator risks are greatly reduced when the number of unit operations in a facility are decreased. The Case 2 (streamlined PHP) FLOWsheet greatly reduces the number of unit operations in the treatment facility. The total risk index or incineration in this analysis is

15.3, compare the Case 2 PHP total risk indices of 4.5. The Case 2 PHP risks are rated high (technical and public risk indices low) because not all of the assigned mixed waste streams have been demonstrated with this technology. Note that the indices used in this analysis were normalized far a comparison of these three cases. To resolve the conservative estimates of risks with the emerging plasma technologies, the on-going EM-30/50 demonstrations will provide data that will raise this technology's relative risk ratings. This will verify the significant advantages of plasma technology over incineration.

The conservative schedule assumptions for the PHP (schedule indices are 0.00) do not reflect that the current plasma demonstrations, and stretched Federal Facility Compliance Act (FFCA) schedules can make PHP technology available when needed by the DOE sites. Current demonstration schedules aim at developing verification and design data in time for PHP technology to be included in the design of DOE mixed waste treatment facilities for site compliance with the FFCA.

FLOW is a fast effective tool for comparing the relative benefits of substituting emerging technologies for conventional treatments in an integrated FLOWsheet of mixed waste treatment facilities. The applications of FLOW by ORNL in both EM-30 and EM-50 studies demonstrate this. In the case of the PHP, this analysis shows that this technology can improve the costs and operations of facilities which may be considering incineration. This study confirms the value and importance of current demonstrations, which will increase the relative evaluation indices of the PHP technology by resolving the risk and schedule issues.