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U.S. Department of Energy Mixed Waste Integrated Program Performance Systems Analysis

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1. INTRODUCTION

The primary goal of this project is to support decision making for the U.S. Department of Energy (DOE)/EM-50 Mixed Waste Integrated Program (MWIP) and the Mixed Low-Level Waste Program. A systems approach to the assessment of enhanced waste form(s) production will be employed including, coordination and configuration management of activities in specific technology development tasks.

The purpose of this paper is to describe the development and application of a methodology for implementing a performance systems analysis on mixed waste treatment process technologies. The second section describes a conventional approach to process systems analysis followed by a methodology to estimate uncertainties when analyzing innovative technologies. Principles from these methodologies have been used to develop a performance systems analysis for MWIP. The third section describes the systems analysis tools. The fourth section explains how the performance systems analysis will be used to analyze MWIP process alternatives. The fifth and sixth sections summarize this paper and describe future work for this project.

Baseline treatment process technologies (i.e., commercially available technologies) and waste management strategies are evaluated systematically using the ASPEN PLUS program applications developed by the DOE Mixed Waste Treatment Project (MWTP). Alternatives to the baseline (i.e., technologies developed by DOE's Office of Technology Development) are analyzed using FLOW, a user-friendly program developed at Oak Ridge National Laboratory (ORNL).[1] Currently, this program is capable of calculating rough order-of-magnitude mass and energy balances to assess the performance of the alternative technologies as compared to the baseline process. In the future, FLOW will be capable of communicating information to the ASPEN PLUS program. It is expected during fiscal year 1993, that alternatives to the baseline process will be developed as technology subsystems and analyzed with respect to various factors, such as performance, risk, and life-cycle cost.

The overall systems analysis, of which this task is one component, includes performance assessment, risk assessment, and life-cycle cost calculations for alternative technologies. The overall analysis will indicate whether the production of enhanced waste form(s) for low-level mixed waste makes sense and whether improvements to the baseline treatment scheme are recommended to waste management for implementation.

2. GENERAL FRAMEWORK FOR SYSTEMS ANALYSIS

This section describes a conventional systems analysis approach and a methodology that estimates uncertainties in innovative technologies. Elements of these two approaches are used to develop a methodology for the study of MWIP process alternatives analysis.

Methodologies for systems analysis are concerned with the interactions among units within a larger system and how the units should be established and organized so that the whole system operates in the best possible manner. Systems analysis is a formal awareness of the interactions among the parts of the system. The interconnections, the compatibility, the effect of one component upon the other, the objectives of the whole, the relationship of the system to the users, and the economic feasibility must receive even more attention than the parts if the final result is to be successful.

2.1 Conventional Systems Analysis

To apply a systems analysis approach to a process the defined system should have an objective. Figure 1 establishes that the system should be designed and operate in such a way that it will achieve its overall objective. For the system under study, efforts must be made to build mathematical models of the separate components using the results of experimentation for this purpose. The interactions among the units and the overall effects of adjustments are then studied by using the unit models for simulation of the whole system, usually on a computer. Once the unit models are adequately established, the effects of variations and the optimum settings can be determined through the computer simulation, thus reducing the need for expensive experimentation. It is important to make an initial assessment of which subunits of the system must be modeled accurately and which need only to be represented crudely.

There is a great need for model builders and development of general techniques of model simplification. The level of detail for the model should reflect the level of detail needed by the study system. The crucial question is how to simplify the model while retaining characteristics of each subsystem that are significant to the current problem. The model must be chosen to suit the criterion with which it is employed. Similarly, when experiments are carried out to test the model, they must be designed so that the correct information is obtained.

It is sometimes possible to make immediate recommendations for improved operating conditions after an initial appraisal. In addition, the most sensitive points of the system—where the rewards of further investigation are likely to be greatest—will be identified.

Conventional systems analysis methodologies have been proposed elsewhere.[2] One of these methodologies suggests following a sequence of steps to perform systems analysis.[1] An investigation is typically organized by considering different stages in the analysis as illustrated in Fig. 1. This analysis normally starts by formulating an economic objective function from which an extreme value will be sought within the permitted operating limits by taking the value of the product, cost of the feed, cost of utilities, cost of makeup materials, and power of compressors, pumps, or other machines into account. Then, in a qualitative analysis, the components of the objective function are examined to eliminate insignificant items. A very simplified model of the plant will probably be formulated at this stage to aid in the assessment.

The analysis would be followed by an examination of the plant flow sheet. Sections of the flow sheet that are derived from the previous analysis stage may be excluded from further consideration or deferred in favor of more important matters. In addition, it should be determined whether any section of the plant can be isolated (for purpose of analysis) so that its contribution to the overall performance can be assessed independently.

The next stage in the analysis illustrated in Fig. 2 would be to examine the plant instrumentation and controls to determine whether the significant components of the objective function are recorded during normal operations. In addition, the performance record of the individual units should be examined in order to determine whether values are adequate to make comparisons with the predictions of the models of the units. The type of controls exercised over the performance of individual units should also be evaluated.

The next phase of analysis to be considered is plant experimentation. The objective of experimentation is to improve plant performance. All model building supports this requirement. The results of the experiments can be used for both intermediate improvement of plant performance data generation for model improvement. An analysis of the data produced may indicate that the project should be terminated at this stage or, if there is room for improvement, that a more detailed model building exercise should be undertaken.

The factors affecting performance for individual units must also be assessed. For significant units where performance is not well understood, a program of experimentation and model building should be developed for the plant and/or in the laboratory.

At this point, models for the separate units should be assembled so that overall performance can be predicted as a function of operating conditions. The purpose of the evaluation phase is to take full advantage of any possible simplification by independent treatment of the plant sections.

After the separate models are assembled, operational improvements within the existing plant should be proposed using the overall plant model to predict the sensitivity of the objective function to variations in operating conditions. Finally, the economics of replacement and/or modifications of various components of the plant should be considered using the overall plant model.

2.2 Framework Addressing Uncertainties in Analysis Involving Innovative Technologies

As mentioned earlier, a baseline process for treating mixed waste has been established by MWTP. The individual units for the baseline system are generally comprised of conventional process operations that have been demonstrated in industrial scale. However, there have been several promising technologies developed recently that may improve the baseline system performance. These innovative technologies should be analyzed as prospective alternatives to the MWTP baseline processes for treatment of DOE mixed wastes. An innovative technology is defined as a technology that departs in some fundamental way from the existing technology and holds the promise of significant performance or cost improvement.

Systems analysis for innovative technologies has been addressed by other authors, one author will be discussed in this section.[3] Important decisions made during research, development and demonstration (RD&D) include whether a new technology should be developed or rejected, where the process development should be focused, and what improvements should be made to optimize the process. The uncertainties inherent in these types of evaluations and decisions, however, are not often properly characterized. Results of improper characterization could include the use of misleading estimates of performance and cost to justify research on new technologies that might not have been otherwise pursued, or research focused on the wrong areas of potentially promising technologies.

Uncertainties in key performance parameters of an innovative technology consequently yield uncertainties in key output characteristics, such as plant efficiency, costs, or pollutants emissions. The sources of these uncertainties in process evaluation are typically derived from the following areas: (1) process performance variables; (2) equipment sizing parameters; (3) process-area capital costs; (4) requirements for initial catalyst and chemicals; (5) indirect capital costs; (6) process maintenance costs; (7) consumable needed during plant operation; and (8) unit costs of consumable by products, waste, and fuel. Hence, performance and cost figures developed in early stages of technology development could easily prove incorrect.

Problems are frequently encountered while calculating the performance and cost estimates of innovative technologies. These include bias and uncertainty in performance and cost estimates resulting from inadequate process and project understanding, widespread underestmates of the cost (which is systematically related to low levels of project definition), and overestimates of performance.

Some companies are beginning to use probabilistic modeling approaches to explicitly characterize uncertainties in new process technologies. This specification of uncertainties, however, has only occurred for cost-related parameters. The potential losses associated with poorly informed RD&D decisions and the shortcomings associated with traditional approach to handling uncertainties suggest a strong need for quantitative uncertainty analysis in the evaluation of both the performance and cost of advanced process technologies.

The questions for uncertainty analysis are enumerated below.

1. What is the expected commercial performance and cost based on what is currently known?
2. How reliable are these estimates for mature commercial plants?
3. What are the key factors driving uncertainty in performance and cost?
4. Which of these factors can be the focus of targeted research to reduce the risks or increase the payoff of the technology?
5. What are the risks and payoffs of the new technology compared to the conventional technology?

Predictions about the performance and cost of innovative technologies should reflect the degree of confidence that engineers have in the input assumptions used to generate the predictions. Using probabilistic simulation techniques, the effects of uncertainties in simultaneous input parameters can be propagated through the model to yield an explicit indication of the uncertainty in output values.

In order to estimate uncertainties, there are a few steps that need to be followed.

1. Review the technical basis for uncertainty.
2. Identify candidate parameters that should be treated as uncertain.
3. Determine the source of information regarding uncertainty for each parameter.
4. Develop estimates of uncertainty based on available information.

The estimates of uncertainty can be based on published judgements in the literature, which are rarely available; published information, both quantitative and qualitative, that can be used to infer a judgement about uncertainty; statistical analysis of data; and/or judgement elicited from technical experts. Consequently, the probability distribution may be based on empirical data or other considerations, such as technically informed judgements. The approach to developing a probability distribution for model parameters is similar in many ways to the approach taken to pick a single "best guess" number for deterministic analysis or to select a range of values to use in a sensitivity analysis.

An expert may specify a judgement using different types of probability distributions. Some of the probability distributions include:

- a uniform distribution that presents the probability of obtaining a value between upper and lower limits;
- a triangle distribution that presents the willingness of an expert to specify both a finite range of possible values and "a most likely" value;
- a normal distribution that is often assumed as the basis of unbiased measurements errors; and
- a fractile distribution, where a finite range of possible values is divided into subintervals in which the values are sampled uniformly according to a specified frequency for each interval.

In order to analyze uncertainties in innovative process technologies using probability distributions, a probabilistic modeling environment is required. Monte Carlo simulation provides this environment by repeatedly running the model using different values for each of the uncertain input parameters each time. The values of each of the uncertain input parameters are generated based on the probability distribution for the parameters. Over the course of a simulation 20-100 or more repetitions are made. The sample size is selected based on the desired precision of the estimate of the output distribution. The result, then, is a set of values for each of the model output variables that can be treated statistically as if it were an experimentally or empirically observed set of data.

Using the Monte Carlo simulation, it is possible to represent uncertainty in a model of a process technology by generating sample values for uncertain variables and running the model repeatedly. Instead of obtaining a single number for model output, as in deterministic simulation, a set of samples is obtained. These values can be represented as cumulative distribution functions and summarized using typical statistical analysis techniques, such as calculations of mean and variance.

Furthermore, the input uncertainties that are the most significant contributors to key results can be identified and ranked using a variety of statistical analysis techniques, such as sample correlation coefficients or multivariate regression. Thus, probabilistic modeling gives a decision maker both explicit measures of uncertainty in key decision variables (i.e., levelized cost or process efficiency) and a listing of key input parameters and their uncertainties.

2.3 Proposed methodology for the MWIP Performance Systems Analysis

The conventional methodology for systems analysis has elements that address systems analysis in a very straightforward manner. However, when a new technology or a new application for a known technology is proposed, uncertainties arise during the analysis that must be considered when evaluating performance. Additional data is required to aid in defining those parameters that are most uncertain and require further laboratory or pilot-scale studies.

The two methodologies mentioned in Sec. 2.1 and 2.2 provide the basis for developing a tool to analyze systems that include innovative technologies. The steps to transform an innovative technology from an idea to a commercial application are dictated by a set of sequential procedures, similar to the methodological stages introduced in Sec. 2.1 and 2.2. Figure 2 shows that five primary stages comprise the suggested methodology. The first stage involves the determination of viable alternatives for further research where screening, R&D, and cost estimates are the issues of concern. Typically, a new concept may be evaluated theoretically and/or tested in bench scale. Promising results may indicate the need to develop a preliminary cost estimate of a commercial-scale design. If the cost of this endeavor seems prohibitive, then the project may be dropped or additional research may be considered to find variations to the technology. If cost estimates are considered reasonable, more financial resources should be used to better define the scope of the project.

The second stage involves project definition. Formulation of an economic objective function may include the cost of processing initial waste, cost of the final waste, etc. For initial assessment, a simple form of this function can be used, but, as the investigation proceeds, this function should be refined to take effects (such as variations in the process parameters) into account. Interactions among the process and the surrounding processes should be considered to avoid the new technology affecting other subsystems in a way that makes the final results less than optimal. Relevant criteria including economic and technical issues, must be established to measure the efficiency with which the system can achieve its objectives. Significant criteria may be difficult to precisely define or determine in early stages of the project. An obvious criterion to use for a project is the life-cycle cost. Other issues that may be considered in waste management operations include volume reduction, contamination control, waste generation, implementability, applicability, operability, etc. Estimates of the order-of-magnitude of feasible improvements should indicate those aspects worth pursuing further. A very simplified model of the plant will probably be formulated at this stage to aid in the assessment.

The third stage suggests a thorough examination of the flow sheet. Possibilities of excluding plant sections from further considerations based on the relative importance they will represent in the plant must be addressed. Analyses can reveal sections of the plant that can be split off so that these sections' contributions to the overall performance can be assessed independently. Examination of the plant instrumentation and controls is required at this stage, to determine whether the significant components of the objective function are recorded appropriately. One of the important issues that needs to be addressed here is the examination of the types of control that will be exercised over the performance of individual units and the components of the objective function.

The fourth stage refers to the necessity for quantitative uncertainty analysis in the evaluation of both performance and cost of innovative process technologies. In this manner, losses due to poorly informed R&D decisions will be diminished. Predictions about the performance and cost of innovative technologies should reflect the degree of confidence the engineers have put on their predictions. Candidate parameters that should be treated as uncertain must be identified as well as the sources of information for estimating uncertainties.

Analysis of uncertainty for innovative technologies requires a probabilistic modeling environment. Typically, Monte Carlo simulation, in which a model is run several times using different values for each of the uncertain parameters each time has been used for this purpose. The result is a set of values for each of the model output variables. These variables can be treated statistically. Instead of obtaining a single number for model outputs, as in deterministic simulation, a set of samples is obtained that can be represented as a cumulative distribution function and summarized using typical statistics, such as mean and variance. The cumulative distribution represents the probability distribution for any variable X. This function gives the probability that X will be less than or equal to each possible value x. It is called cumulative because it represents the cumulative probability that X will have any value less than or equal to x.[4] The obvious benefit of probabilistic analysis is the ability to identify key sources of uncertainty when many parameters are varying simultaneously. These key uncertainties can then be prioritized for further research.

The fifth stage indicates that, once the major uncertainties have been spotted on the previous stage, R&D or pilot-plant research should proceed. If more R&D is required, then the entire cycle should start again, unless uncertainties indicate that proceeding further would be counterproductive. If pilot-plant data are necessary, then experimentation should be directed at resolving these uncertainties. The results of pilot-plant studies should indicate whether an improvement in the model as well as a definite improvement in performance has been obtained. If not, then the project must be reconsidered for R&D or abandoned.

This type of analysis always uses a reference point for comparisons. Normally, a conventional technology is compared to the innovative technology. Benefits of the innovative technology must be evident in order justify further development. If the comparative analysis indicates that the new technology is better than the conventional one for most of the criteria, this technology must be aggressively promoted as a replacement for the conventional process. This new technology should be seriously considered, and industrial-scale implementation should be analyzed.

3. SYSTEMS ANALYSIS TOOLS

Over the last decade, a variety of computerized tools have been used to simplify modeling of waste processes and chemical treatments process systems. ASPEN™, CHEMCAD™, and other simulation packages perform very well with traditional chemical unit operations. Such packages normally contain user-friendly interfaces even though considerable chemical engineering knowledge is required to prepare a consultation session. Almost all of the commercially available computer programs also provide a library of process unit operations. However, there are unit operations widely used in waste management that are not explicitly included in the available packages (reverse osmosis, carbon adsorption, incineration, etc.) that have to be simulated by adding new code or adapting the existing models in order to include such unit operations in the system model. Some processes in the conventional chemical industry must be coded in, but the need to create code is more noticeable in radioactive waste management.

FLOW, an ORNL simulation tool that is in the initial stages of implementation, is a computer software package that facilitates the analysis of process flow sheets. FLOW is a graphical interface with icons representing a different units operation. These unit operation models have to be developed. During the early stages of system analysis, is a good idea to go through the exercise of modeling these unit operations because it gives the system analysis a better control over the innovative processes parameters. In the later (more developed) stages of analysis, this process can be modeled on commercial programs (e.g., ASPEN™) for more accurate results. Consequently, FLOW will be used to model the innovative processes during the early stages of development where rough order-of-magnitude data are required (and where ASPEN™ may not be able to deliver information). The information obtained during this simulation may be useful for further improvement and implementation of more refined subroutines of the innovative processes in ASPEN™.

Other tools required for the systems analysis study are statistical simulation programs such as the Monte Carlo methodology. The development of a computerized Monte Carlo simulation for uncertainty analysis is in progress.

4. ANALYSIS OF THE FIRST ALTERNATIVE TO THE BASELINE METHODOLOGY

The systems analysis methodology described above will be used in the performance systems analysis for the DOE MWIP. The mission and goals of MWIP are to develop, for deployment, complete and appropriate technologies for the treatment of DOE mixed low-level wastes.[5] The two main goals of MWIP are assessing whether production of enhanced waste form(s) for low-level mixed waste makes sense, and improving upon the baseline treatment scheme, which consists of commercially available technologies as defined by the DOE MWTP.

4.1 Application of Stage 1 of the Methodology

Alternatives to the baseline technology are the main concern of this analysis. The MWTP baseline technology is in the preliminary stages of development. MWTP has conceptualized a process that is divided into different processing areas. Each processing area will treat a specific waste type (inorganic liquids, organic liquids, homogeneous solids, heterogeneous solids, etc.)[6] as illustrated in Fig. 3. The representation of the baseline flow sheet indicates that several process technologies will be used to treat the wastes, producing a complex process system. The alternatives to this baseline technology will attempt to reduce the complexity of the global process as well as produce an enhanced waste form(s) that is economically and environmentally appropriate.

4.2 Application of Stage 2 of the Methodology

The innovative subsystems developed as part of the MWIP tasks will be analyzed for performance, risk, and life-cycle cost. The performance systems analysis includes material and energy balance and assessments of operability, effectiveness, and reliability. At this stage, the material and energy balance of innovative processes will be analyzed using FLOW rather than ASPEN. (ASPEN does not have subroutines for most of these nonconventional waste treatment technologies.) The preliminary models developed for FLOW will produce rough order-of-magnitude calculations indicating sensitive areas within the technology. The control gained over the modeling of these technologies will allow an easier implementation of these models in ASPEN when a more accurate analysis of the global project is required by MWTP. FLOW will also aid in the development of a very simple model of the alternative technology to initiate the preliminary analysis.

Operability, effectiveness, and reliability should be evaluated qualitatively or quantitatively. An assessment of operability should address the difficulties of maintaining the technology, degree of automation, training requirements, demonstration time, and implementation risks. Effectiveness evaluation revolves around such factors as volume reduction, waste generation, flexibility of design, robustness, expected lifetime, destruction removal and efficiency. Finally, when assessing reliability, simplicity, regulatory compliance, safety of the process, and the consistent availability of the process during operations, should be considered.

4.3 Application of Stage 3 of the Methodology

The flow sheet proposed as the first alternative has been developed by the MWIP support group.[7] This process flow sheet is illustrated in Fig. 4. A noticeable reduction in process operations is observed as compared to the baseline process. A plasma arc melter capable of accepting a wide variety of waste streams as direct inputs (without sorting or preprocessing) has been added to the system. This innovative process for treating mixed waste has replaced several units from the baseline process and, thus, promises an economic advantage. The concentrated organics stream will be fed to a conventional secondary chamber together with the off-gas from the plasma arc and gases from the mercury condenser. Gases from the conventional secondary chamber will be fed to the off-gas treatment system. A roaster bakeout is considered for those cases where mercury, and/or lead-contaminated wastes are fed into the plant.

The most involved section in this alternative flow sheet is the plasma arc section. There will be a great deal of material handling as well as gas production and final wastes that may negatively affect the global performance of the plant. The plasma arc furnace will produce solid waste as glass/ceramic and metal final forms that will be sent directly to a disposal site. Gases produced in the plasma arc furnace may carry over some metallic emissions to the off-gas treatment plant as well as other gases that may require high efficiency treatment processes. The indicators that will rate the performance of any of these vital units include the degree of automation; implementation risk; flexibility of design; robustness; destruction, removal, and efficiency; simplicity; regulatory compliance; safety, and life-cycle cost. The analysis of these indicators will provide an accurate indication of the performance of vital individual units.

Information required in the calculation of performance indicators can be obtained by executing the simple models that simulate the behavior of the process(es) using FLOW. Figure 5(a) illustrates the graphical interface used by FLOW to develop a flow sheet. Figure 5(b) illustrates a mass-balance result in one of the streams of the process. Obviously, every single unit operation is represented by a model. Mass and energy models for plasma arc are nonexistent furthermore, a great deal of effort has to be spent establishing an appropriate model to represent the operational behavior of the process. The basis for modeling the plasma arc are illustrated in Fig. 6. Five zones have been defined within the plasma arc. In zone 1, the waste drum fed into the furnace is assumed to go to a separation process (gas and solid). In zone 2, the melt zone is represented by a separator that is divided in two streams—one that mixes gases and one that considers a mixer where oxygen and gases coming from the plasma torch are mixed, reacted, and separated into gases and molten material. In zone 3, the slag formation is represented by a separator that separates gases from the stream where reactions are produced. In zone 4, the molten metal is obtained. Zone 5 is essentially the conjunction of gases and volatile particles formed in the interior of the chamber. This zone is represented by a mixer, and reactions are assumed to occur in the gaseous phase.

4.4 Application of Stage 4 of the Methodology

Prior experience with plasma arc units points to several important issues. Based on information obtained from previous runs of a semi-pilot plasma arc unit, it is known that particle formation may be an issue in the unit operation. Any particles formed will join the gaseous stream, consequently adding complexity to the off-gas treatment process(es). Further, the production of gases that could potentially affect the environment may be an issue in the off-gas treatment. Finally the glass or ceramic final forms require some research on phase diagrams and final form stability in order to comply with the U.S. Environmental Protection Agency (EPA) regulations of disposal.

The performance in the plasma arc furnace will directly affect the performance of the off-gas treatment units. The ultimate objective of MWIP is to minimize the amount of final waste produced to the lowest possible cost and environmental impact. Consequently, it is imperative to analyze operational variables, such as plasma torch temperature, furnace chamber configuration, gas flow, etc., that may affect the performance of the furnace in terms of solid particle or harmful gas emissions that will affect the performance of the off-gas treatment plant, ultimately affecting the final cost of treating the waste. It is believed that there will be significant uncertainties in these performance and also cost estimates for commercial-scale systems. To explicitly characterize such uncertainties and evaluate the overall uncertainty, a probabilistic modeling framework should be implemented. The uncertainties for the process parameters will be characterized using a variety of user-specified distribution functions. For example, the solid particle retention efficiency displayed by an off-gas treatment may have a normal probability distribution with the value falling within one standard deviation according to previous experience.

In summary, all of the uncertain parameters that will affect the objective function must be given probability distribution functions that, in conjunction with the performance model using Monte Carlo simulation, will produce an output (e.g., production cost). In a Monte Carlo simulation, a model is run repeatedly using different values for each of the uncertain input parameters each time. The values of each of the uncertain input parameters are generated based on the probability distribution for the parameter. If there are two or more uncertain input parameters, one value from each is sampled simultaneously in each repetition of the simulation. Over the course of a simulation, 20-100 or more repetitions are made depending on the desired precision of the estimate of the output distribution.[2] The output can be represented as cumulative distribution functions and summarized using typical statistics such as mean and variance. Furthermore, the input uncertainties that are most significant contributors to key results can be identified and ranked.

4.5 Application of Stage 5 of the Methodology

Stage five of the methodology essentially will give the user explicit measures of uncertainty in key decision variables (e.g., levelized cost or solid capture efficiency) and a listing of key input uncertainties. The former can be used to understand the risks and payoffs of the new technology, while the la**er can be used to focus research on reducing the specific input parameter uncertainties that contribute most to the risk of technology failure. Some of these items may represent capital costs for the furnace, furnace maintenance costs, waste throughput, etc. These key uncertainties can be prioritized for further research using statistical techniques, such as correlation or regression analysis.

Pilot-plant studies are then determined based on key input uncertainties. Results from pilot-plant experiments will improve the uncertainty level and the basis for models that represent the process. This new information will allow new global estimates of the plant performance or an indication that more R&D is required to improve the performance models. Ultimately, a comparison with the baseline process on identical items of the objective function will determine whether this innovative technology will be able to replace total/partial process(es) of the baseline technology. The next logical step will be to proceed with the analysis of a definite industrial-scale plant.

5. DISCUSSION

A methodology has been developed to assist MWIP in the performance systems analysis task. This approach uses elements of conventional systems analysis, in which a deterministic sensitivity analysis is applied to one variable at a time, and incorporates a methodology to determine uncertainties for innovative technologies. This methodology uses a probabilistic evaluation method that permits explicit characterization of the uncertainties in performance, emissions, and costs of developing technologies. Quantitative techniques will allow the identification of key measures of plant performance and cost for the purpose of targeting additional research. Certainly, probabilistic modeling is not a trivial exercise for obtaining appropriate foresight as it can represent an important technique for developing more realistic estimates and insights needed for research planning and technology selection.

Modeling a plasma arc furnace is of high importance because of the many thermodynamic and kinetic mechanisms that occur simultaneously in the plasma chamber. Possible reaction mechanisms have been postulated and are being tested by FLOW.

FLOW is a tool that performs mass balance and can perform energy balance. Although it is still developing and requires accuracy in the external thermodynamic libraries, the use of FLOW is appropriate as a rough order-of-magnitude calculation tool. Once more data are available, then an improved subroutine that models the operational behavior (e.g, the plasma arc model) can be implemented in ASPEN for a more accurate simulation of the mixed waste treatment plant, probably in the late stages of analyzing the industrial-scale operation.

6. FUTURE WORK

Future work has been scheduled in different areas. Pilot-plant studies to gain knowledge about uncertain parameters will be performed. Other alternatives to the baseline process will be analyzed as well. The objective of this analysis work is to aid in determining the most appropriate way of treating mixed waste produced in DOE facilities with minimal environmental and economic impact.

7. ACKNOWLEDGEMENTS

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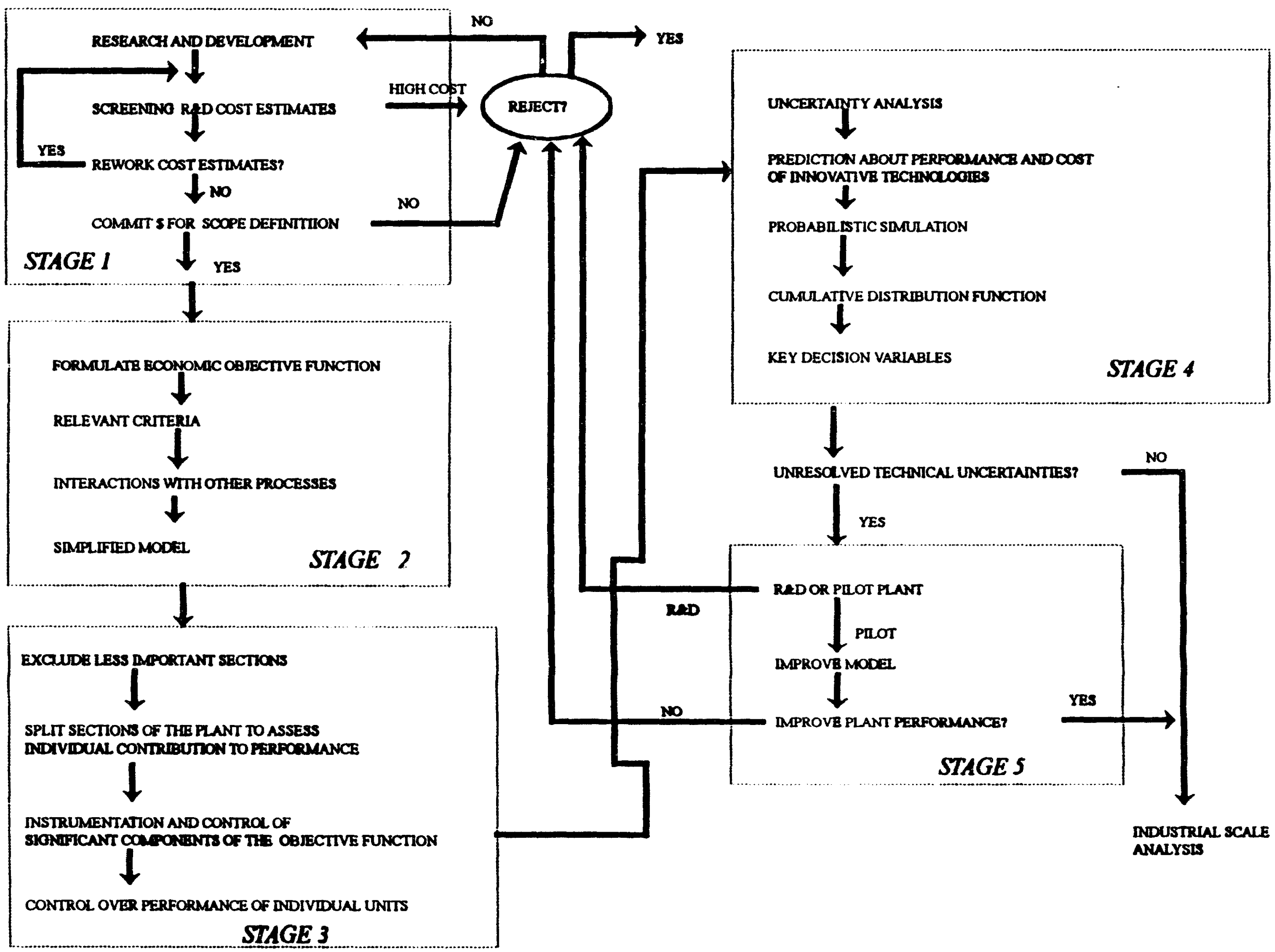

Fig. 2. Systems analysis methodology suggested to MWIP.

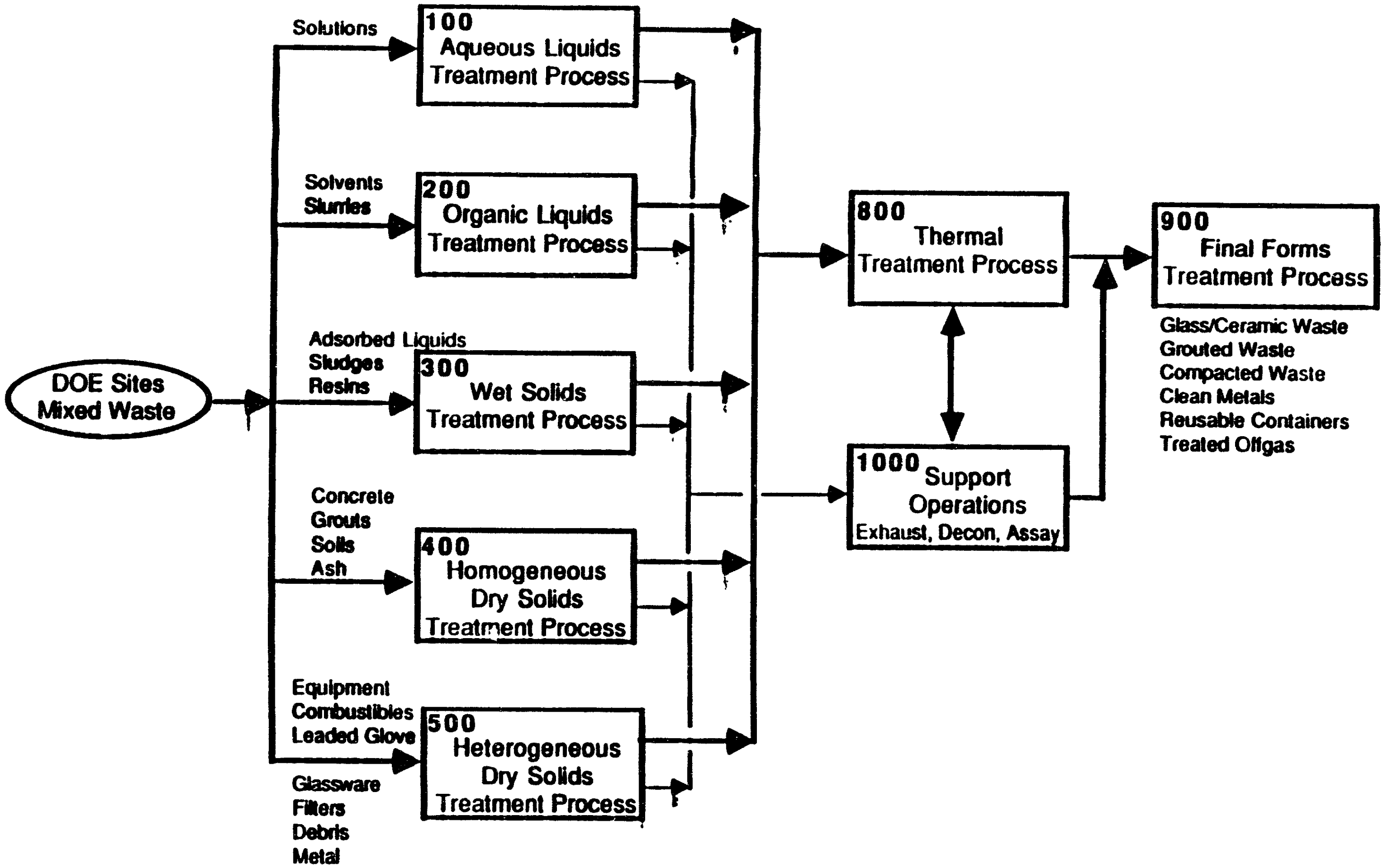

Fig. 3. The MWTP baseline technology.

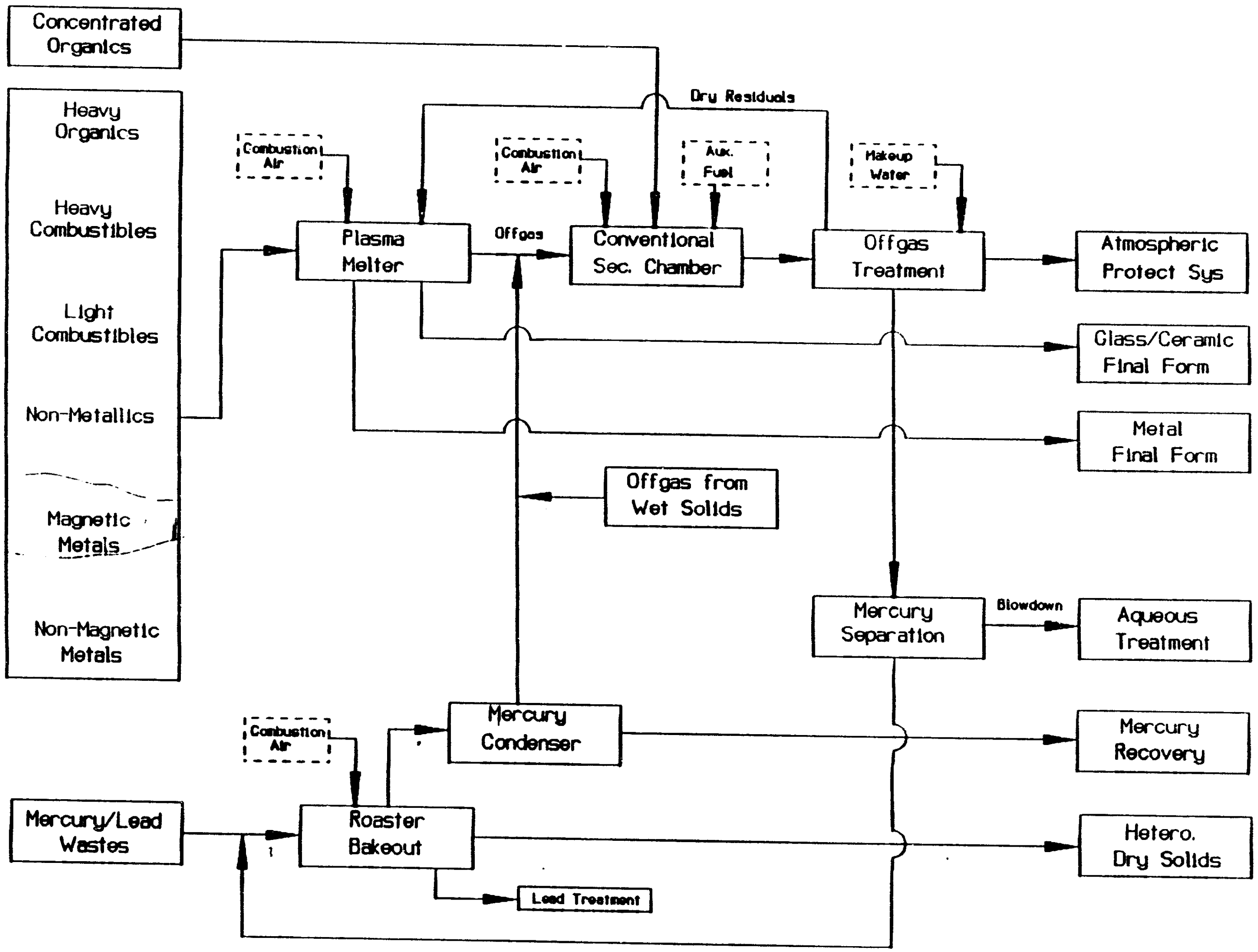

Fig. 4. MWIP first alternative to the MWTP baseline technology.

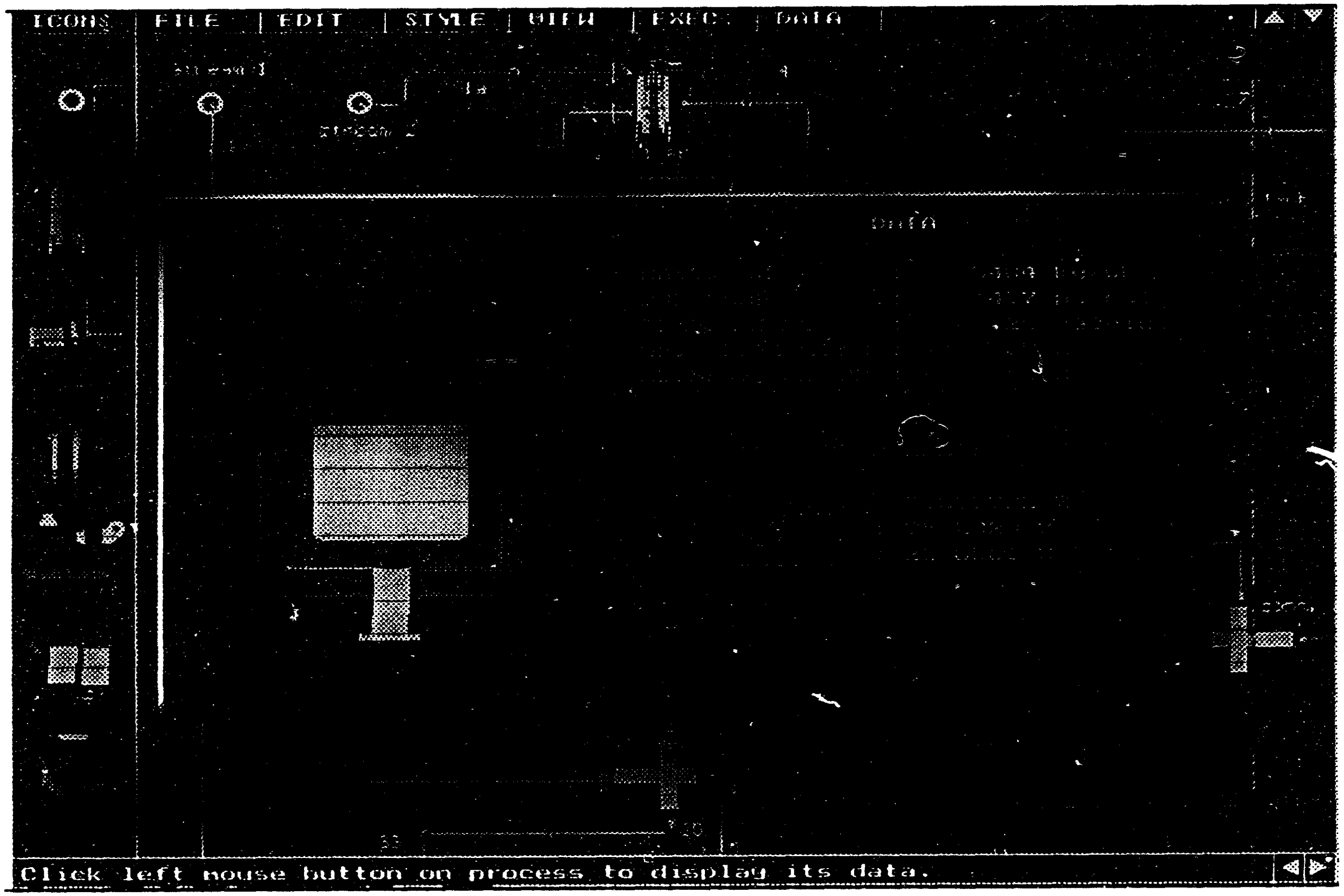

Fig. 5b. Mass balance results given by FLOW.

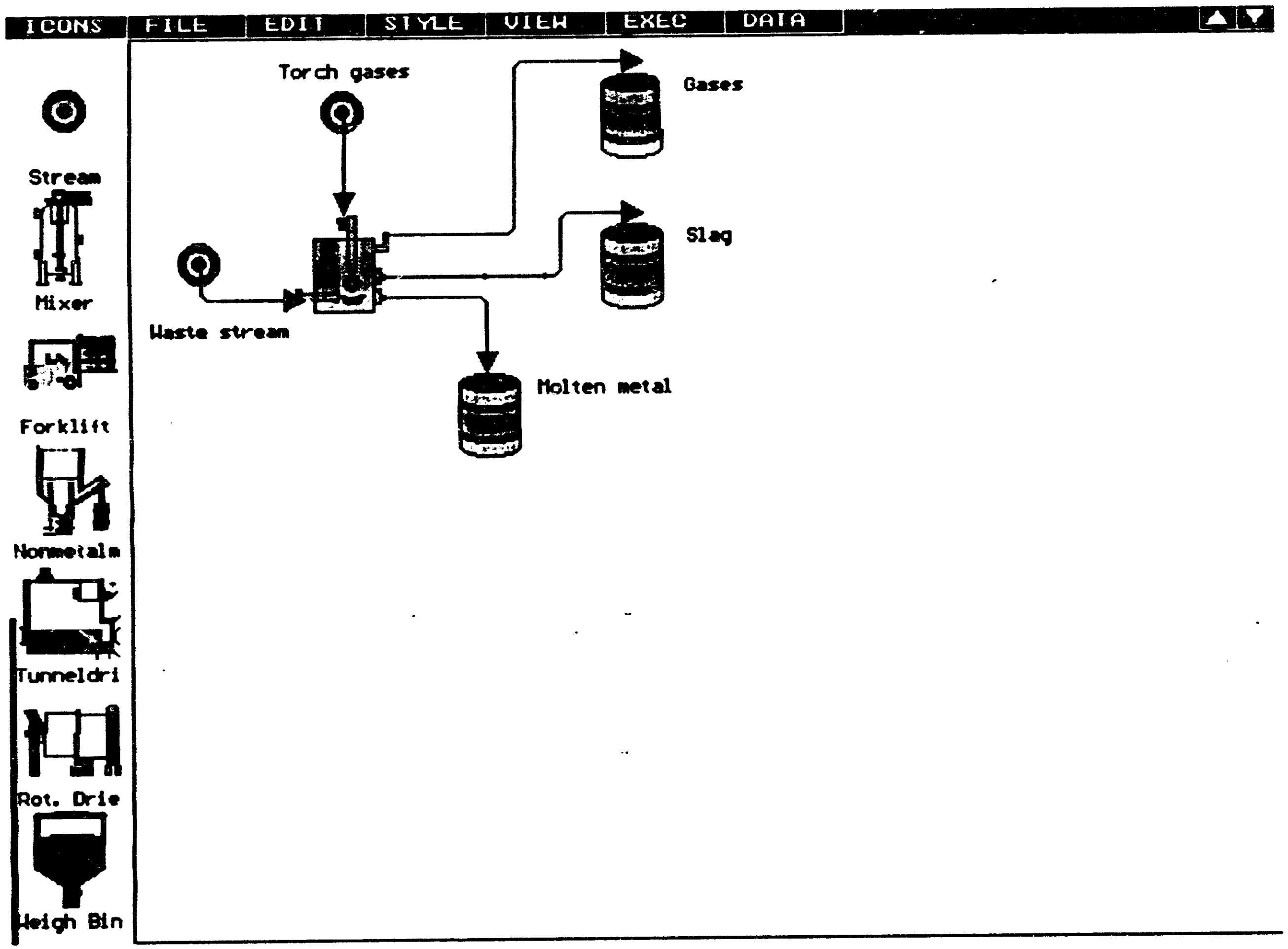

Fig. 5a. Graphical interface utilized by FLOW.

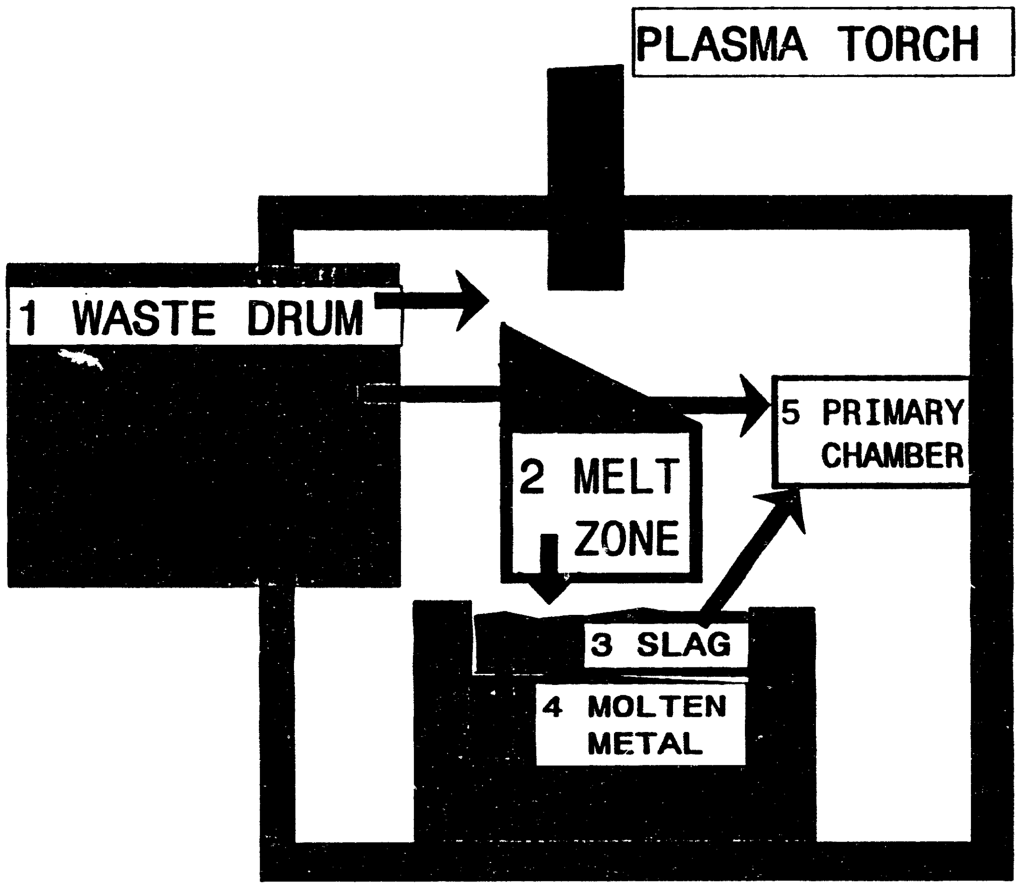

Fig. 6. Plasma arc model.

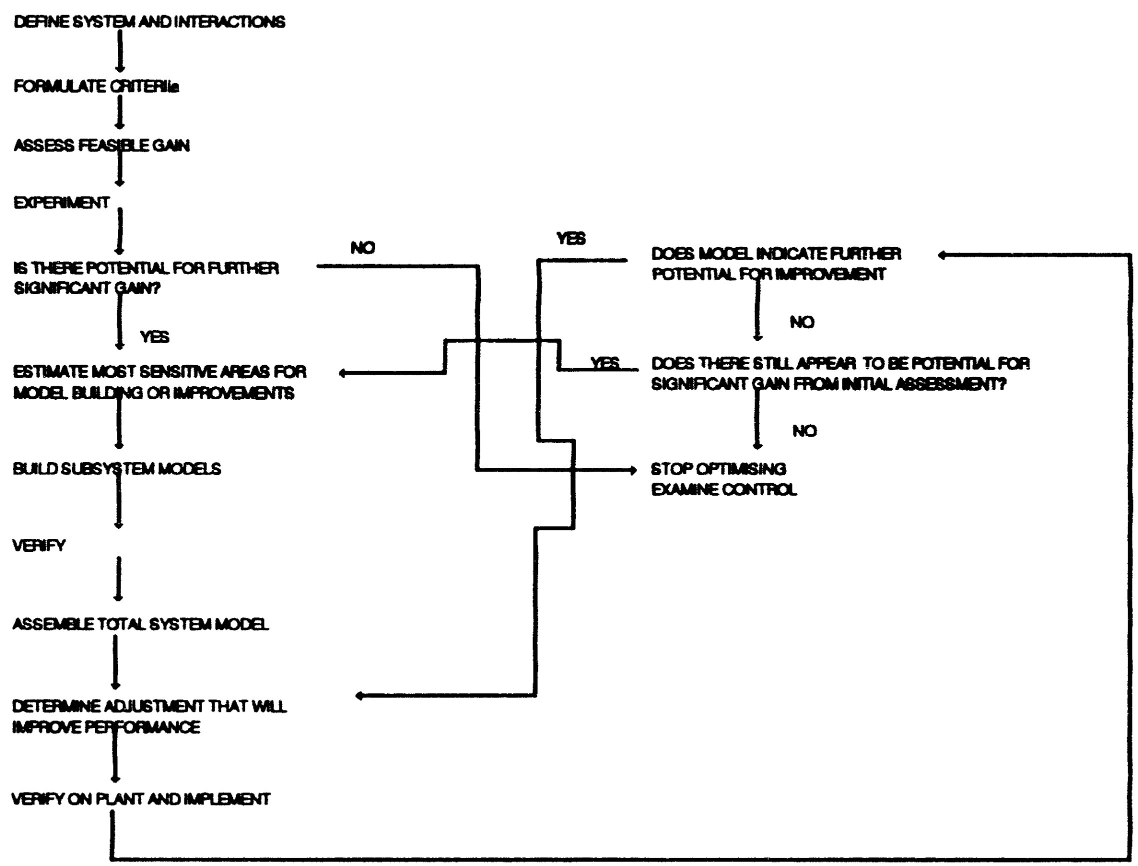

Fig. 1. Conventional systems analysis methodology.

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