CONF-910852--5

DE91 015613

POTENTIAL APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN COMPUTER-BASED MANAGEMENT SYSTEMS FOR MIXED WASTE INCINERATOR FACILITY OPERATION

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Submitted for presentation at the 1991 Summer National Meeting of the
American Institute of Chemical Engineers
Pittsburgh, Pennsylvania
August 18-21, 1991

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The Department of Energy/Oak Ridge Field Office (DOE/OR) operates a mixed waste incinerator facility at the Oak Ridge K-25 Site. It is designed for the thermal treatment of incinerable liquid, sludge, and solid waste regulated under the Toxic Substances Control Act (TSCA) and the Resource Conservation and Recovery Act (RCRA). This facility, known as the TSCA Incinerator, services seven DOE/OR installations. This incinerator was recently authorized for production operation, becoming the first regulator-approved facility in the United States for the processing of mixed (radioactively contaminated chemically hazardous) waste as regulated under TSCA and RCRA. Operation of the TSCA Incinerator is highly constrained as a result of the regulatory, institutional, technical, and resource availability requirements. These requirements impact the disposition of incinerator residues, limit the characteristics of waste feeds and operating conditions, and restrict the handling of the waste feed inventories. This incinerator facility presents an opportunity for applying computer technology as a technical resource for mixed waste incinerator operation to facilitate promoting and sustaining a continuous performance improvement process while demonstrating compliance. Demonstrated computer technology applications could be transferred to future mixed waste incinerator facilities.

To identify areas of computer technology application, a computer-based management system is being developed as a technical resource to support operation of the TSCA Incinerator using a life-cycle capacity utilization performance optimization model as a design framework. The objective of the computer-based management system is to integrate timely and reliable data, expertise, and experience of multiple disciplines applied to the constrained nature of the mixed waste incineration operation. A portfolio of models will be needed to meet the data processing needs of the various users. This portfolio of data processing models could include linear programming, multiple regression analysis, and deterministic and probabilistic simulation models, supplemented by artificial intelligence (AI) algorithms. One function of these models is to assist performance oriented decision-making tasks such as performance planning, scheduling, tracking, and control. This paper describes mixed waste incinerator facility performance oriented tasks that could be assisted by AI and the requirements for AI tools that would implement these algorithms in a computer-based system.

1. INTRODUCTION

The U. S. Department of Energy (DOE) has an operating incinerator located at the K-25 Site in Oak Ridge, Tennessee. This incinerator is known as the Toxic Substances Control Act (TSCA) Incinerator. This incinerator was designed and constructed by International Waste Energy Systems and Alberici Construction Company, both of St. Louis, Missouri, under contract with Martin Marietta Energy Systems, Inc. (which is responsible for operating the incinerator under a contract with DOE). The incinerator is a 30 million Btu/h unit. It is a rotary-kiln type incinerator designed and operated to thermally destroy mixed wastes (i.e., wastes that are hazardous and/or toxic and contain radionuclides) in compliance with all applicable federal and state environmental regulations and DOE orders. The incinerator is to be used to destroy mixed wastes from the DOE's Feed Materials Production Center in Fernald, Ohio; the Paducah Gaseous Diffusion Plant (PGDP) in Paducah, Kentucky; the Portsmouth Gaseous Diffusion Plant (PORTS) in Piketon, Ohio; the RMI Titanium Company Extrusion Plant in Ashtabulah, Ohio; and the three DOE facilities in Oak Ridge, Tennessee — namely, the Y-12 Plant, the K-25 Site, and the Oak Ridge National Laboratory (ORNL).

A line sketch of the incinerator is given in Fig. 1. Briefly, the TSCA Incinerator consists of a refractory-lined rotary kiln (7.5-ft OD by 25-ft long) primary combustion chamber followed by a vertical refractory-lined secondary combustion chamber (9-ft ID by 40-ft tall) and a complete off-gas treatment train. The off-gas treatment train consists of a quench tower, a venturi scrubber, a packed-bed scrubber, and two ionizing wet scrubbers (all in series). The effluent gases from the destruction of the wastes are thoroughly scrubbed with an aqueous caustic solution as they traverse through the off-gas treatment train before being discharged to the atmosphere. The aqueous effluent from the incinerator is treated at the nearby Central Neutralization Facility (CNF) prior to discharge to West Poplar Creek, which ultimately flows into the Clinch River.

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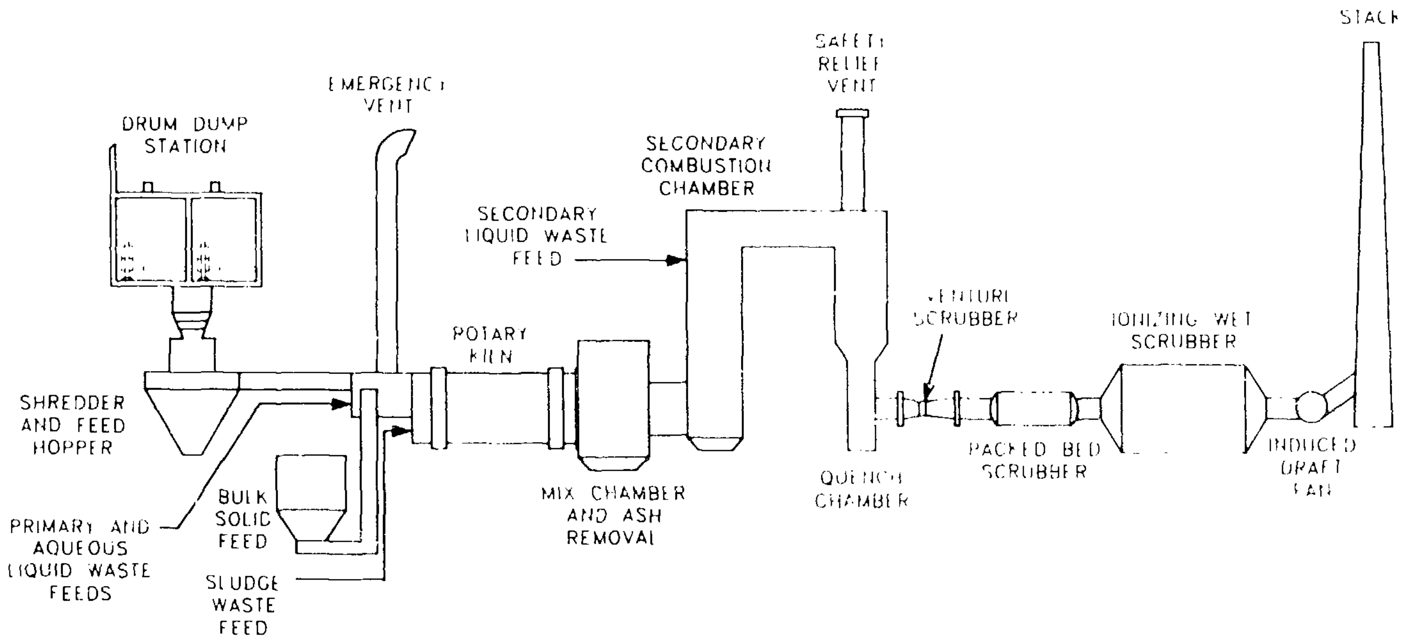

Fig. 1. Schematic diagram of the TSCA Incinerator.

The solid residue from the incinerator is presently drummed and stored at the K-25 Site awaiting decisions regarding its disposal.

The K-25 Site TSCA Incinerator will be used to incinerate principally organic wastes contaminated with radionuclides (mainly uranium and technetium-99). Following are some of the wastes proposed to be incinerated:

- PCB-containing liquids from transformers and capacitors;
- waste oils such as lubricating, hydraulic, and synthetic oils;
- waste chemicals and solvents such as trichloroethane, perchloroethane, acetone, methyl ethyl ketone, methanol, various other alcohols, paints, toluene, and scintillation fluids;
- aqueous wastes (namely, wastes containing more than 50% water) such as machine coolants, contaminated aqueous solvents, and synthetic fuel wastes);
- sludges such as paint sludges, degreaser residues, greases, oils, and bio-denitrification sludges; and
- solids including such items as contaminated rags, trash, rubber parts, adsorbents, used high efficiency particulate air filters and ion-exchange resins, discarded animal bedding, spent carbon, contaminated boxes and crates, and glass bottles and vials.

The K-25 Site TSCA Incinerator has successfully completed the performance tests required by regulations. The incinerator operations are governed by several federal and state regulations and DOE Orders. The principal federal regulations are the TSCA, Resource Conservation and Recovery Act (RCRA), Clean Air Act [including the National Emission Standards for Hazardous Air Pollutants (NESHAP) related to radionuclides emissions], and the Clean Water Act. The state regulations are the State of Tennessee Air Permit, which regulates the air emissions from the incinerator, and the National Pollutant Discharge Elimination System (NPDES) permit, which regulates the aqueous effluents from CNF. CNF receives and treats the wastewater from the incinerator to comply with the NPDES permit requirements. In addition, DOE Order 5400.5 regulates the radionuclides releases from the facility.

All the new land disposal restrictions (LDR) developed by the Environmental Protection Agency (EPA) have provided a tremendous opportunity for incineration technology. The basic philosophy being adopted relies on incineration as the preferred treatment technology for most organic wastes. However, there is a complication in mixing treatment standards when wastes with different hazardous waste codes are incinerated together. The situation is even more complicated when waste feeds are contaminated with different radionuclides. Incinerator operations are required to invest in waste-feed management techniques with the objectives of determining optimum waste feed rates and mixtures to the incinerator. The waste feed decisions are driven by:

- treatment standards assigned to different hazardous waste codes;
- feed limitations on metals;
- feed limitations on radionuclides;
- feed limitations on flow rates;
- feed limitations on heating value (Btu/lb), chlorine content, etc.; and
- feed limits by limitation on disposal of the ash.

To comply with all of these requirements, waste generators are required to submit waste analysis data on every request for incineration and waste shipment. These data facilitate acceptance and scheduling of the waste shipment and will help in the daily operation of the incinerator facility.

2. COMPUTER-ASSISTED INCINERATOR FACILITY OPERATIONS MANAGEMENT

The TSCA Incinerator represents a strategic asset for the DOE/Oak Ridge Field Office (OR) in the management of incinerable low-level radioactive mixed waste (LLRMW). Incineration is considered to be the best demonstrated available technology (BDAT) for the removal, by destruction, of the hazardous organic component of LLRMW. In response to the anticipated increase in performance requirements for the TSCA Incinerator operations during the production operations phase, a computer-based management system is being designed and implemented to facilitate the development of burn plans and schedules and the timely reporting of waste incineration and incinerator operations. This system is called the TSCA Incinerator Management Information System (TIMIS) and will consist of a centralized and integrated data base, data management for tracking and reporting applications, and data processing for decision-support applications.

The TIMIS Program was initiated in January 1990, and the initial efforts were focused on providing an understanding of the DOE/OR incinerable waste system as shown in Fig. 2, where the TSCA Incinerator is a key component. Initial performance testing for the incinerator has focused on establishing operating conditions for incineration, operability of the system, and emissions control. Additional performance requirements are anticipated with the incineration of solid and sludge waste as a result of disposition requirements for waste residuals.

The objective of TIMIS is to support TSCA Incinerator operations in achieving and sustaining the following set of life-cycle performance goals:

1. produce a disposable ash by-product;
2. defensibly demonstrate compliance with all regulatory requirements;
3. minimize the generation of secondary LLRMW residuals from waste processing activities; and
4. optimize waste incineration capacity utilization subject to:
   - resource availability,
   - waste incineration needs and priorities, and
   - goals 1, 2, and 3, above.

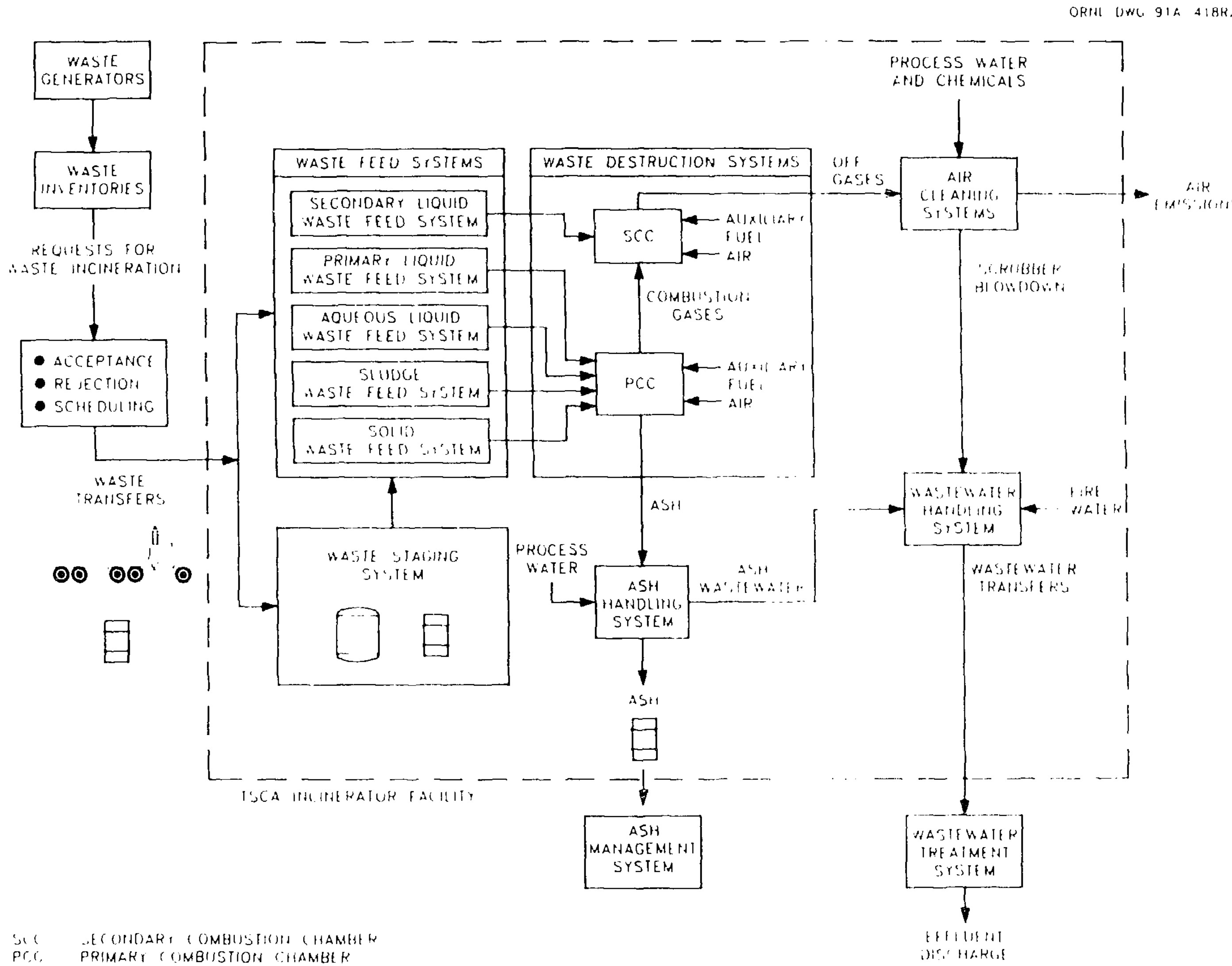

Fig. 2. Process diagram of mixed waste incineration system.

Optimization of waste incineration capacity utilization requires (1) adequate capacity availability as determined by preventive and corrective maintenance requirements and operational schedules, (2) allocation of projected available capacity among waste inventories and generators, (3) integration between the waste feedstocks availability and schedules and incineration capacity availability and schedules, and (4) utilization of available capacity in compliance with appropriate regulatory requirements.

TIMIS will maintain a centralized and integrated data base to provide reporting capabilities including, but not limited to, waste incineration needs and priorities, burn schedules, requests for incineration, waste transfers, waste receiving, waste inventories at Building K-1435, waste blends, waste characterization, sampling and analysis, waste feedstocks, waste burn campaigns, waste feed rates, waste incineration, emissions, generation and characterization of secondary waste streams, maintenance logs, process performance data, and certificate of destruction (COD). Reports are to be prepared on demand and will include a daily summary of operations and plans and reports to the Central Waste Management Division (CWMD), other organizations within Energy Systems, DOE/OR, and the regulatory agencies.

The design of TIMIS is oriented toward minimization of keyboard data entry and on-line availability of all requirements from operating procedures, conduct of operations, operating limits, emission limits, management controls, and performance indicators. TIMIS will provide interfaces for data transfer with the TSCA Incinerator Data Acquisition System (DAS), Analytical Chemistry Data Systems, and waste generators inventory systems.

Waste incineration capacity utilization optimization can be expressed as a series of waste burn campaigns during a given performance period as shown in Fig. 3.

$$Max\ C_{u\tau} = Max \left[\sum_{\beta=1}^{\beta=\beta_\tau} \theta_\beta \sum_{i=1}^{i=5} X_{i\beta} F_{i\beta} \Phi_{i\beta} \right]_\tau , \qquad (1)$$

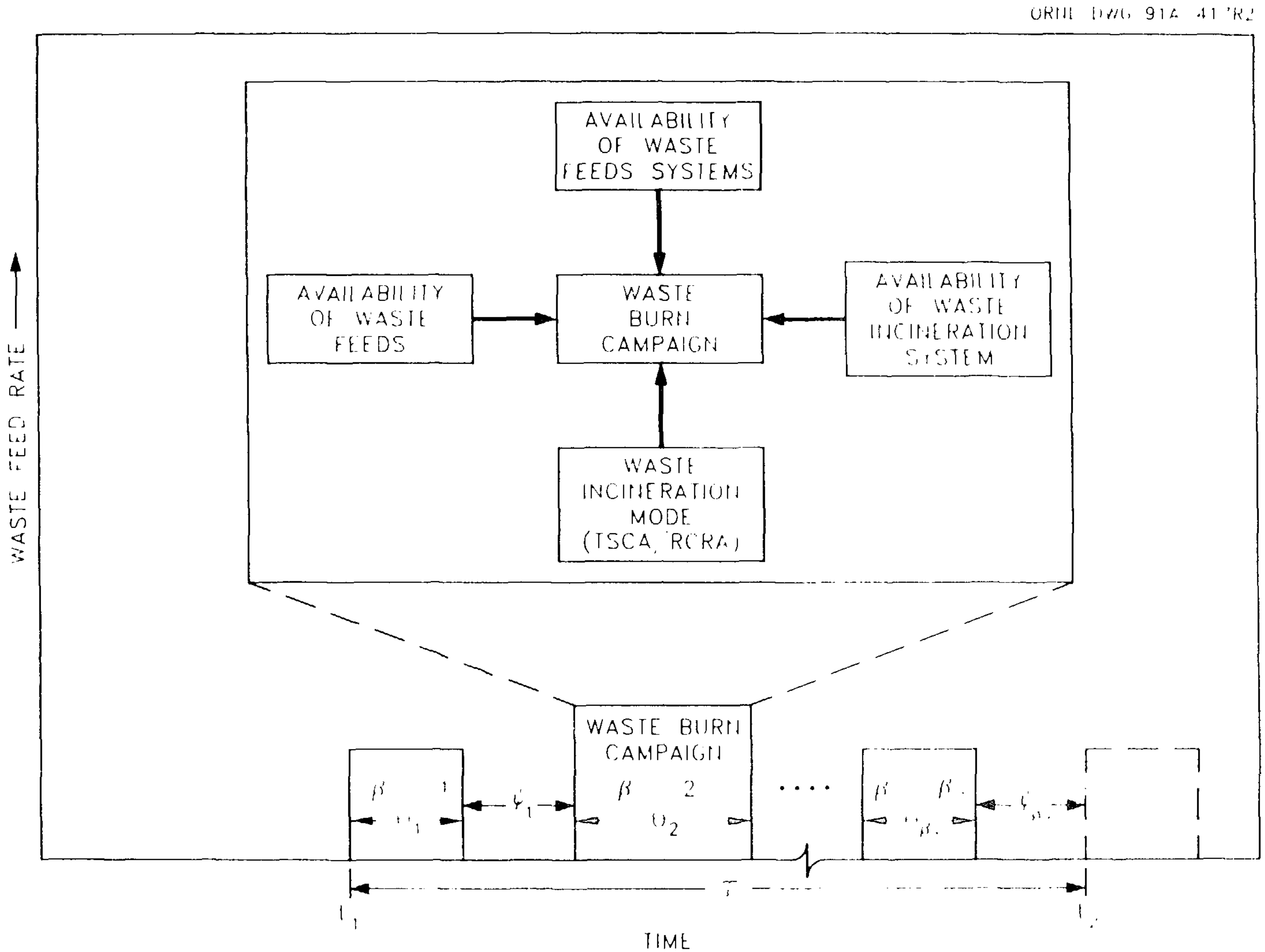

Fig. 3. Conceptual model of waste burn campaigns for waste incineration capacity utilization optimization.

where

$C_{u\tau}$ = capacity utilization in lbs for the performance period τ,

θ_β = duration, in hours, of waste burn campaign β,

β_τ = total number of waste burn campaigns during performance period τ,

$F_{i\beta}$ = flow rate in lbs/h for waste feed i during waste burn campaign β,

i = waste feed, i = 1, 2, ... 5, where

i = 1 primary liquid waste feed,

i = 2 secondary liquid waste feed,

i = 3 aqueous liquid waste feed,

i = 4 sludge waste feed, and

i = 5 solid waste feed.

$X_{i\beta}$ = availability of waste feed system i during waste burn campaign β, $0 \leq X_{i\beta} \leq 1$, and

$\phi_{i\beta}$ = availability of waste for waste feed system i during waste burn campaign β, $0 \leq \phi_{i\beta} \leq 1$.

The waste incineration time θ is related to the down-time ψ as follows:

$$\Delta t_\tau = \sum_{\beta=1}^{\beta=\beta_\tau} \theta_\beta + \sum_{\beta=1}^{\beta=\beta_\tau} \psi_\beta \qquad (2)$$

where

ψ_β = the time between waste burn campaigns β and $\beta+1$.

There are two upper limits to capacity utilization:

Limit 1. Maximum Capacity Utilization

$$C_T = \Delta t_\tau \sum_{i=1}^{i=5} F_{i\tau}^* = 3000\,\Delta t_\tau\,, \tag{3}$$

where

C_T = maximum theoretical capacity utilization in lbs,

Δt = duration of performance period $\tau = t_2 - t_1$ in hours,

t_1 = beginning schedule of performance period τ,

t_2 = ending schedule of performance period τ, and

$\sum_{i=1}^{i=5} F_{i\tau}^*$ = maximum total waste feed rate = 3000 lbs/h, which is the regulatory limit for the TSCA Incinerator.

Limit 2. Maximum Potential Capacity Utilization

$$C_P = \Delta t_\tau A_\tau \sum_{i-1}^{i=5} X_{i\tau} F_{i\tau}^*\,, \tag{4}$$

where

C_P = maximum potential capacity utilization as defined by the incinerator availability during performance period τ,

A_τ = incinerator availability for performance period τ, $0 \le A_\tau \le 1$ and

$X_{i\tau}$ = availability of waste feed system i during performance period τ, $0 \le X_{i\tau} \le 1$.

3. POTENTIAL OPPORTUNITIES FOR AI APPLICATION

The objective of TIMIS is to provide computer assistance by integrating the functions of planning, scheduling, and "status" tracking and reporting. The main opportunities for AI applications are integration of data from multiple sources, including input data and providing timely and defensible recommendations as shown in Fig. 4.

The opportunities that have been visualized for the application of AI in TIMIS have been encountered in two main areas: (1) decision support and (2) tracking and reporting systems. In general terms, the systems have to answer the following questions:

- What decisions need to be made?

  Examples: approve, reject, yes, no, when, where, what, how much, etc.

- What data is needed to make the decisions?
- How fast, reliable, and defensible do we need the decisions?
- How reliable should the data be to make the decisions?

3.1 DECISION SUPPORT SYSTEMS

The expert systems in the decision-support area should address the resources for burn plans and help in the decision-making process of the incinerator activities.

3.1.1 Expert Systems for Maintenance/Operating Plans/Schedules

This system will support an efficient incineration operation system. Based on a provided operation plan schedule, it will check the current incinerator plan schedule. Based on that information, it will develop a plan, if nothing has been scheduled, taking into consideration restrictions imposed by preventive maintenance and availability of inventory and operating policy (holidays and shifts). If a plan has been scheduled, it may be used as such or changes may be introduced due to the addition of incineration cycles or sudden changes in the maintenance process.

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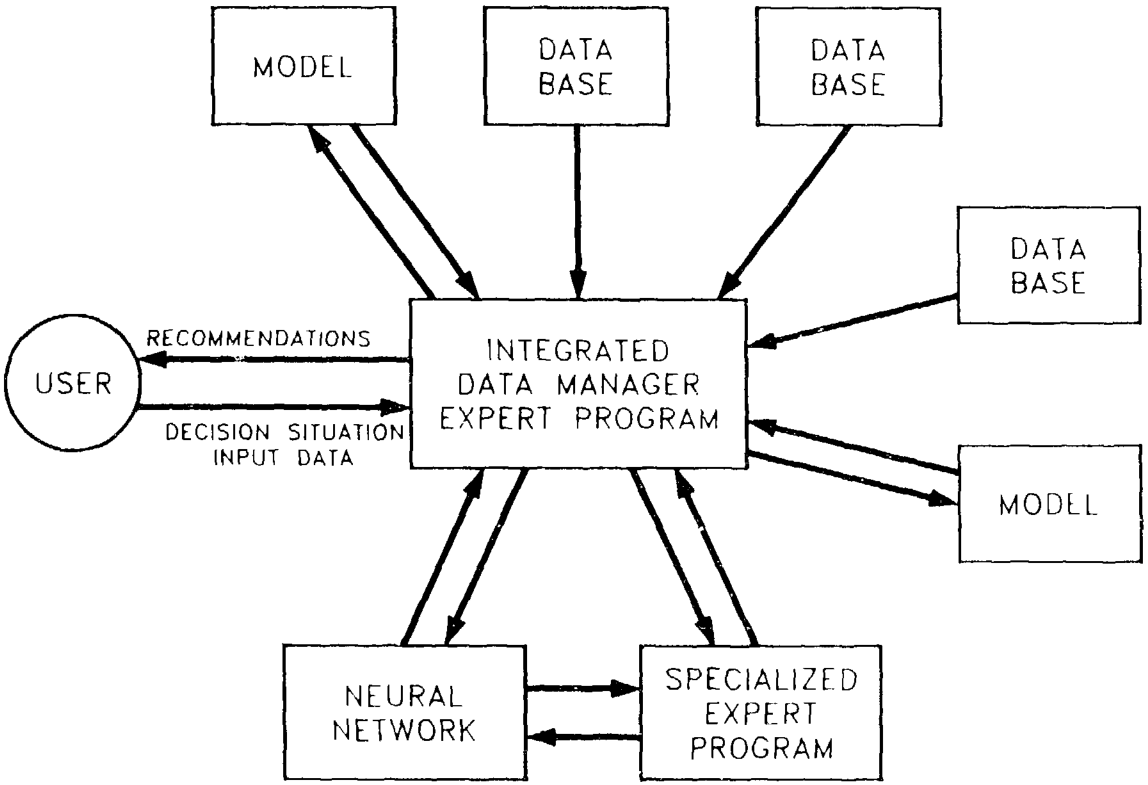

Fig. 4. An intelligent user interface is a significant application of AI in support of mixed waste incinerator facility operations.

Operation of the incinerator in a manner that efficiently reduces waste inventories is of primary importance. One of the major aspects that contributes to having a smooth and fault-free operation is an adequate maintenance system. A sound maintenance system will hold operation and maintenance costs in line while insuring safety and reliability. This principle brings another support system to smooth the incinerator operations. This program combines the Important-To-Reliability, Predictive Maintenance, Preventive Maintenance, Preventive Maintenance Review, and System Engineering programs into one system, which also aims to reduce "scrams," minimize regulatory surveillance, and help engineers become more cognizant of their system's status. In principle, the system should recommend a maintenance program, provide trend data for operation and maintenance of the different equipment, provide a fault diagnosis and trouble-shooting package, and recommend a spare-part purchase system.

Information about vibrational structural analysis, oil analysis, and thermography is essential for the predictive maintenance. Maintenance history information is mandatory to determine trends in operation and maintenance. Spare-part inventory is a requirement to establish an appropriate maintenance schedule consistent with the regulatory requirements for preventive maintenance.

3.1.2 Expert System for Development and Scheduling Blends

A preliminary analysis of the feed preparation system has established the possibility of developing one expert system to work as a short-term blend advisor that will utilize wastes on-hand to determine when to blend, how to blend, and what to blend, based on criteria that will include chemical compatibility, regulatory issues, optimization for process efficiency, etc. In addition, the prototype works as a feed preparation advisor that will determine how to develop a burn plan that guides the user regarding efficient feed preparation.

3.1.3 Expert System for Development and Scheduling of Waste Feedstocks

This system will analyze the current existing mix feedstock for the incinerator and will help in the decision-making process of updating the mix, establishing a new feed rate, and examining the current inventory of the elements that constitutes a waste feed mix such as primary waste, secondary waste, aqueous waste, sludge, and solids. In order to update the mix, the system has to address a data base of the existing mixes and confront the updated mix with the changes to be made in the process conditions such as the incinerator temperature, auxiliary fuel, combustion air, etc., as well as the foreseeable emissions produced by the new mixture.

In order to forecast the emissions produced in the incinerator, two approaches have been suggested. One is to develop a model-expert system package which will access an incinerator model that can indicate the characteristics of the emissions from a particular burn. It will suggest recommendations in cases where regulatory requirements are not likely to be met so that alternative waste feed mixes can be examined. The other approach is to apply a hybrid system consisting of a neutral network and rule-based expert system that will replace the model-expert system package. The advantage of this latter approach is that the system could infer an answer from a set of information points where previous results have not been recorded. The disadvantage of this methodology is that a great deal of expertise on the operations of the incinerator needs to be available for the training phase of the hybrid system. The logical solution seems to start with the model-expert system and, when enough expertise on the operations of the incinerator is gathered, then replace the system with the hybrid system. The positive aspect of replacing systems is that the answers of the hybrid package are more accurate because they reflect experience with actual operations. The model-expert system is only accurate insofar as the model is accurate and can serve the purpose of assisting in the short-range while expertise on the incinerator operations is being accumulated.

3.1.4 Expert System for Approval/Rejection of Requests for Incineration

This system will advise in the decision-making process of approving or rejecting a request for incinerating waste.

3.1.5 Expert System for Scheduling Shipments

Once the request for incineration has been approved, the expert system will advise on scheduling or rescheduling a shipment.

3.1.6 Expert System for Inventory Checking

The objective of this package is to check the burn plan for current feed and establish if one or more of the components of the mix is in any danger of being depleted. The system should be able to check the waste inventory data base to determine where the desired elements of the mix may be available. It has to locate the waste and check for the feed preparation steps in order to analyze regulatory compliance, suggest the transfer procedures, and finally develop the burn plan and schedule for that waste.

The data bases used in the prototype development have been created to include information on waste inventories, waste characterization, operating criteria, tank farm configuration, etc. From this experience, it is easier to determine the data bases required to run the expert systems.

3.2 TRACKING AND REPORTING SYSTEM

The objective of the tracking and reporting system is to provide "status tracking" information as well as historical/statistical data and trends. These systems are repositories for data on waste, incinerator, plans/schedules, and performance. The system will track pre-burn waste from inventories to incineration and post-burn secondary wastes. There are several subsystems of the tracking and reporting system that are good opportunities for AI application.

3.2.1 Process Data Analysis and Recommendations Expert System

This package will track and prepare reports on waste inventories, waste generation rates, and waste inventory accumulation rates for incinerable waste with potential for acceptance at the TSCA Incinerator. Analytical data on waste inventories will be maintained under this system and will be used as a decision-support system to generate long-range burn plans. Status reports on inventory levels and changes caused by depletion or accumulation will be maintained by this system.

This system will keep track of incinerator wastewater generation, inventories, locations, characteristics, pretreatment, and transfers to the CNF. In addition, it will track incinerator ash generation, characteristics, containerization, container identification, etc. Also, it will keep track of all residual waste generation and characteristics from waste incineration operations. Another element of this system is the ability to keep track and maintain data and estimates on stack emissions. The data will be obtained from sampling and analysis efforts. For radionuclides, the system will keep track of measured releases, estimated releases, and estimated radiation doses under each scenario. For contaminants such as metals, the system will maintain the amount of metals released, the performance period, and the dates.

3.2.2 Data Quality Control Expert System

This system will keep track of the various data gathering systems and determine any abnormalities on this data. For example, during the waste characterization phase before burning, chemical analytical data may need to be revised based on information from the feedstock history. The history of the feedstock may indicate that there are discrepancies between what is expected from the feedstock and what is reported by the analytical laboratories.

3.2.3 Issuance of Certificates of Destruction

This system will track the waste inventory "as received" during the blending and feed preparation operations and will issue a certificate of destruction the inventory has been incinerated.

3.2.4 Integrated Performance Assessments and Recommendations Expert System

This system will focus on the availability of waste incineration capacity, up-time, downtime, and process data. It will maintain a set of requirements for maintenance activities for the incinerator. The basic objective of this system is to provide historical data on downtime for the incinerator. The system will have a list of systems and equipment for the incinerator and the preventive and corrective maintenance requirements and history for each one.

The system maintain performance summaries of every waste burn campaign. Data include feedstock, incineration conditions, generation of secondary waste, amount of waste incinerated by feed, physical form, generators, and pre- and post-burn estimates. Multiple waste burn campaigns will be analyzed for performance statistics. These statistics will be useful to issue recommendations about the general performance of the incinerator by making comparisons between regulatory requirements and actual performance.

3.3 SUMMARY OF OPPORTUNITIES

Table 1 illustrates the opportunities for application of AI to the TSCA Incinerator operations. It indicates the opportunities found during the search phase and also the most appropriate AI tools to be applied.

3.4 PRELIMINARY EXPLORATORY DESIGN EFFORTS

3.4.1 Prototype of an Expert System to Assist in Feed Burn Plan Development

An effort is under way to develop a prototype of an expert system that aids in the preparation of a feed burn plan for the TSCA Incinerator. The objectives of this prototype are to determine

Table 1. Opportunities for AI applications in the TSCA Incinerator

AI application	AI tool			
	Expert system	Fuzzy logic	Neutral network	Hybrid neutral network—expert system
Expert systems for maintenance/ operating plans/schedules	X		X	X
Expert system for development and scheduling blends	X			X
Expert system for development and scheduling of waste feedstocks	X			
Expert system for approval/ rejection of request for incineration	X	X		
Expert system for scheduling shipments	X			
Expert system for inventory checking	X			
Process data analysis and recommendations expert system	X			
Data quality control expert system	X	X		X
Issuance of certificate of destruction	X			
Integrated performance assessments and recommendations expert system	X			

the hardware environment where the package is going to be implemented, the data base system that is most appropriate for the expert system, the type of software used for the development stages, the knowledge base for the burn plan, etc.

Currently, the preliminary prototype is in its developmental stages and is implemented in a personal computer (PC)-compatible machine. Four software packages are being used to develop the program. Guru and VP-Expert are two expert shells used to develop the system. A third expert shell, CLIPS, has been installed for evaluation. Finally, the fourth software package is the use of a customized program using the C programming language. The reason for using more than one software package during the developmental stages is to search for various features required by the expert program.

VP-Expert, an expert shell for the PC is the least expensive of the commercial packages, but is limited in the number of available features. Guru is a more powerful package but is also the most expensive. CLIPS is a DOE owned package with several interesting features. The customized program developed in C-language may have more features than any commercial shell, but the code for the entire system has to be developed.

The prototypes are capable of accessing the data bases and determining possible burning schedules. The burn plan determines the date for the incineration of the waste, what type of waste will be incinerated, and the amount of time it will take to transport a waste if it comes from an off-site facility. In addition, a feasibility analysis is in progress for accessing a blending code developed specifically for the TSCA Incinerator during the last fiscal year. It is expected that all of this information will assist the user(s) in establishing an optimum burn plan for the TSCA Incinerator in full compliance with all the regulations.

3.4.2 Expert Program to Estimate the Incinerator Performance

An effort is under way to produce a first prototype of an expert system that will make recommendations about the performance of the incinerator. The system will have a user interface that prompts the user with a customized window for data entry. Each data entry will be checked for validity. After the user has entered the data, the system will access an incinerator modeling program that estimates the production and composition of the gases, liquids, and solids produced during the incineration process. The results will be checked with a data base of regulatory limits to determine if the proposed burn will be within compliance. After this step is achieved, appropriate recommendations will be offered to the user.

The system is being developed using two common languages used in AI applications: Turbo Prolog and Turbo C. The logical capabilities of Prolog are invaluable for the data validation process and for comparison of the computed values with the required regulatory limits. In addition, Prolog is exceptional for issuing recommendations. Turbo C's greatest advantage is being able to produce graphics and implement the modeling program that simulated the incineration process. The link between these two languages has been very fruitful.

CONCLUDING REMARKS

The objective of this paper is to identify selective areas where AI could complement conventional software in increasing the level of assistance from the application of computer technology in support of mixed waste incinerator facility operation. However, the list of potential opportunities are not limited to Table 1.

The new land disposal restrictions developed by EPA have provided a tremendous opportunity for incineration technology. The basic philosophy being adopted relies on incineration as the preferred treatment technology for most organic wastes. To meet all of the performance requirements imposed on mixed waste incinerator facility operations, computer assistance is needed in the integration of waste feed management with incinerator facility management. This paper presents an overview of potential applications of AI in promoting computer assistance. The potential opportunities have been categorized into two groups—namely, general and specialized.

General AI applications refer to an integrated data manager expert program that interacts with the user in several ways. An expert program may interact with the user by:

- helping the user to structure a decision situation and requesting the relevant data input from the user,
- creating an integrated data set relevant to the decision situation,
- processing the data set and presenting a set of recommended approaches to the decision situation, and
- reporting on recommendations or storing the data as official data for future applications.

Specialized AI applications refer to computer programs with a narrow domain for application. Opportunities in this category consist of two main areas—decision support and tracking and reporting systems. Six potential opportunities for AI applications in decision support systems and four potential applications in tracking and reporting systems were presented previously. Preliminary exploratory design efforts for these types of AI applications were also described.

In summary, there are several avenues by which AI could assist in the support of mixed waste incinerator facility operation.