EXPERT SYSTEM APPLICATIONS TO RADWASTE PROCESSING FACILITIES

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ABSTRACT

Recently, Artificial Intelligence (AI)technology has been applied to a broad spectrum of processing fields. Expert Systems, or "knowledge based" systems are becoming one of the most popular and active areas in the AI field. The Expert System concept uses the computer, after programming, to act as the "expert" in some specialized domain. The applications to the process system including radwaste processing appears endless.

Expert Systems have been developed for plant diagnostics and support operations for petroleum refineries, chemical plants, food processing plants, etc. Development of an Expert System requires the input of "expert" knowledge of plant operations and of facility and equipment design. With an Expert System active, diagnosis and operational support activities previously performed by the expert workers can efficiently be performed by the computer. Currently, most computer control systems are designed to control various physical functions in a plant. They are not designed to diagnose problems, or to interpret data from a global plant perspective. The ability of Expert System technology to deal with such items presents a clear opportunity for augmenting existing control systems with Expert Systems.

INTRODUCTION

Artificial Intelligence (AI) is a modern technology which consists of several disciplines including intelligent robotics, intelligent computer aided interaction (CAI), computer vision systems, and expert systems. This paper is directed toward the application of expert systems to the field of radwaste processing. Expert Systems or "knowledge based" systems could be used to supplement facility operation by supplying the equivalent of an "expert" to the facility operation staff. This paper addresses three (3) applications of expert systems. Two are directed at monitoring process equipment. The third applies an Expert System to maintenance planning and activities. Implementation of an AI system such as an Expert System can be added (backfit) to any system's capabilities at any time.

BACKGROUND

Expert System applications have become popular in the industrial field due to several reasons:

- Increase of facilities complexity,
- Need for increased reliability,
- Rapidly developing technology,
- Turnover of experience operators, and
- Demands for flexible (off-normal) operations.

Stable design basis operation of any process system is desirable due to the inherent efficiency of such operation. But real world conditions dictate otherwise. Constantly changing input conditions in many types of process systems, such as radwaste, require operational variations. Few operational variations are independent of the other process parameters, therefore, the overall process is quite often in a complex state of change. It can be very difficult or impossible to manually observe, evaluate and interrelate all the changing parameters of a complex system. In addition, operators must also monitor and maintain compliance with strict environmental regulations on process effluents. All these knowledge requirements on the operator suggest that an Expert System could significantly enhance the operator's control of a radwaste processing system.

TOOLS/METHODS

Traditional software technologies are fit to generally well structured, logic based problems and are not easily adaptable to the complex multi-variable, un-restrained interaction systems. Expert System software by itself does not replace traditional software but applies itself to the software/process system to sort out, prioritize and manage the vast information available in much the same way as an "expert" would.

Hardware technologies has dramatically improved in CPU power and peripheral technologies. Computer "work stations" have become compact, powerful, and ease-to-use. Several high performance systems such as DEC's VAX, SUN, HP, SONY's NEWS are user-friendly and can easily connect to process control systems as a means to apply an Expert System to a facility process system.

There are two ways of developing an expert system. The first uses program languages such as LISP or PROLOG to program the Expert System. These languages are difficult to learn and take a long time to master. The second method uses an approach called an "Expert Shell". Shells provide the framework of the Expert System and the programmer simply provides the "expert knowledge" necessary for the Expert System to function.

The knowledge contained within the Expert System is based on numerical calculations and heuristic methods interrelated by the experience of the operators. For example, the "knowledge" regarding a control valve which is crucial to the successful operation of a component, is based on the relation between a process parameter and the valve manipulation parameters. Also, diagnostics of a component (e.g. drum heat exchanger) would be done based on material and heat balance parameters which affect the unit operation.

Expert Shells consist of 4 basic parts: 1) inference engine, 2) knowledge base, 3) explanation of inference results and 4) additional knowledge acquisition. The input knowledge based on experiences and/or theory are utilized by the inference engine. Knowledge must, however, be presented in a usable form or expression.(1) An example of a typical expression, called the production rule, is as follows:

If A then B

This simply and obviously means if A is true then B should be true. This type of expression is applicable to a diagnostic system as shown in the example given later in the radwaste process application section. Other such expressions could examine process or equipment conditions to see if conditions account for the off-normal response or if the information in fact verifies a problem.

When knowledge is expressed by the various rules, the order in which they are input or executed is not important. The speed of the computer can compensate for the human thought pattern which prioritizes, selects and/or excludes "rules" from consideration.

EXPERIENCE

Chemical Process Application

JGC implemented an Expert System for diagnostics of a phosphoric acid manufacturing process operated by RHONE-POLANC in Belgium. The process consisted of four basis parts as follows:

1. Feed Process: crushed phosphoric rock
2. Reaction Process: crushed rock and H_2SO_4 mixed in Rx vessel
3. Filter Process: separation of Gypsum from phosphoric acid.
4. Concentration Process: adjust concentration of acid.

Refer to Fig. 1 for reaction vessel and filter system Process Flow descriptions.

In the reaction process at the reaction vessel, the temperature, pressure and acid concentration needs to be carefully controlled to maintain product quality and to prevent sludge and scale from forming in the reaction vessels. In the filter process section the pressure drop must be monitored closely to determine filter backwashing or renewal requirements.(2) The implemented Expert System provides process supervision and operations by 1) monitoring the process, 2) adjusting parameters on vessel and 3) anticipating potential or diagnosing actual failures.

The Expert System for the RHONE-POLANC facility was developed using the G2 code which is a product of Gensym Corp.(3) G2 is a domain shell and specializes in on-line, real time systems. The expert System was developed and runs on a UNIX SUN-3/60 system and was connected to the existing CENTUM (4) Distributed Control System (DCS). The DCS was used as the tool to gather all the needed process data for the Expert System automatically. Operator feedback on the Expert System has been good. After some initial skepticism, and after installation, the operators were quite pleased and commented that routine work was made much easier. An assessment was made that very experienced operators could often diagnose a routine problem quicker than the Expert System but that for newer operators or for non-routine problems, the Expert System was far superior.

Prototype Radwaste Process Application

JGC has developed a prototype Expert System for diagnostics of a drum mixing unit for a radwaste bitumen solidification facility. The system solidifies low level liquid and laundry radwaste. The water in the waste is evaporated and recovered. The process is shown in Fig. 2. The equipment of significance is the drum mixer, the condenser, control valves and instruments. The Expert System was developed to 1) monitor the mixer, 2) monitor and diagnose instruments and 3) make predictions of mixer performance.

There are two operation modes of this system. The first is an on-line, real time mode for monitoring and diagnosis. The system checks and indicates whether abnormal conditions exist or if some malfunctions have occurred by monitoring process data which is automatically measured and transmitted from instruments in the system.

The diagnosis rules are based on calculations and operators experience. An examples of rules related to the pressure control of the drum mixer are as follows:

If ΔP of vapor dome is large and position of PCV is fully open then vapor dome is plugged.

or

If ΔP of vapor dome is large and position of PCV is normal then ΔP meter has malfunctioned.

In the case of the first situation, a message would be displayed on the CRT such as:

Asphalt product is plugged in the vapor dome.

RECOMMENDED ACTION: Change operation mode to washing mode yand measure surface dose

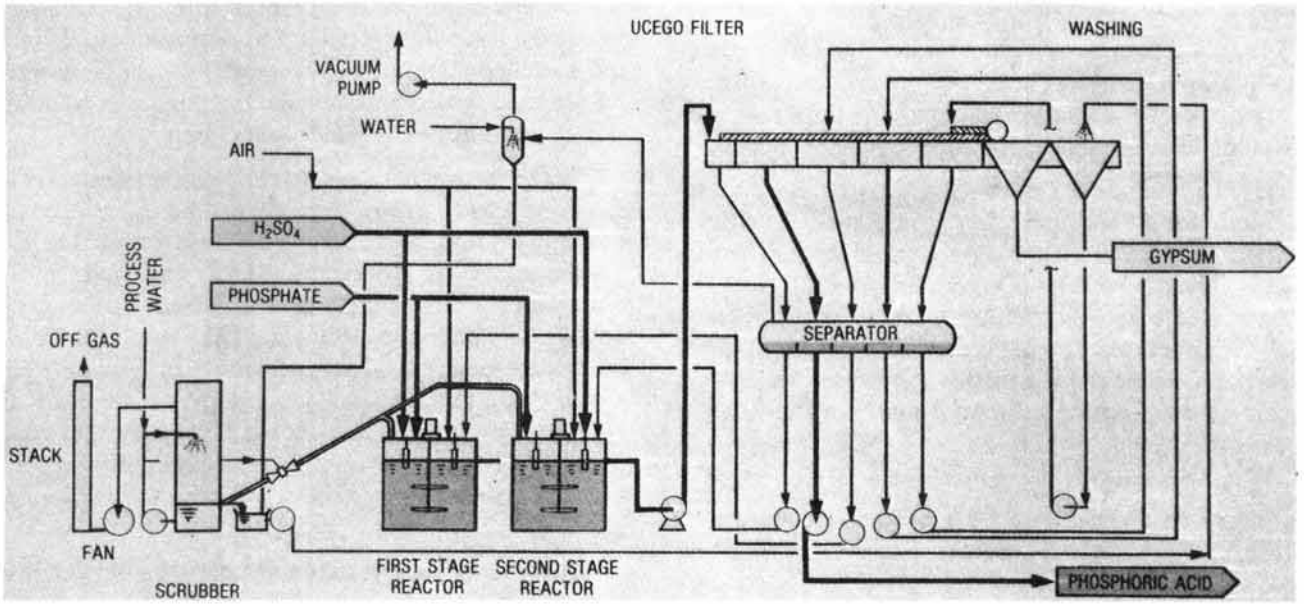

Fig. 1. RHONE-POLANC phosphoric acid process.

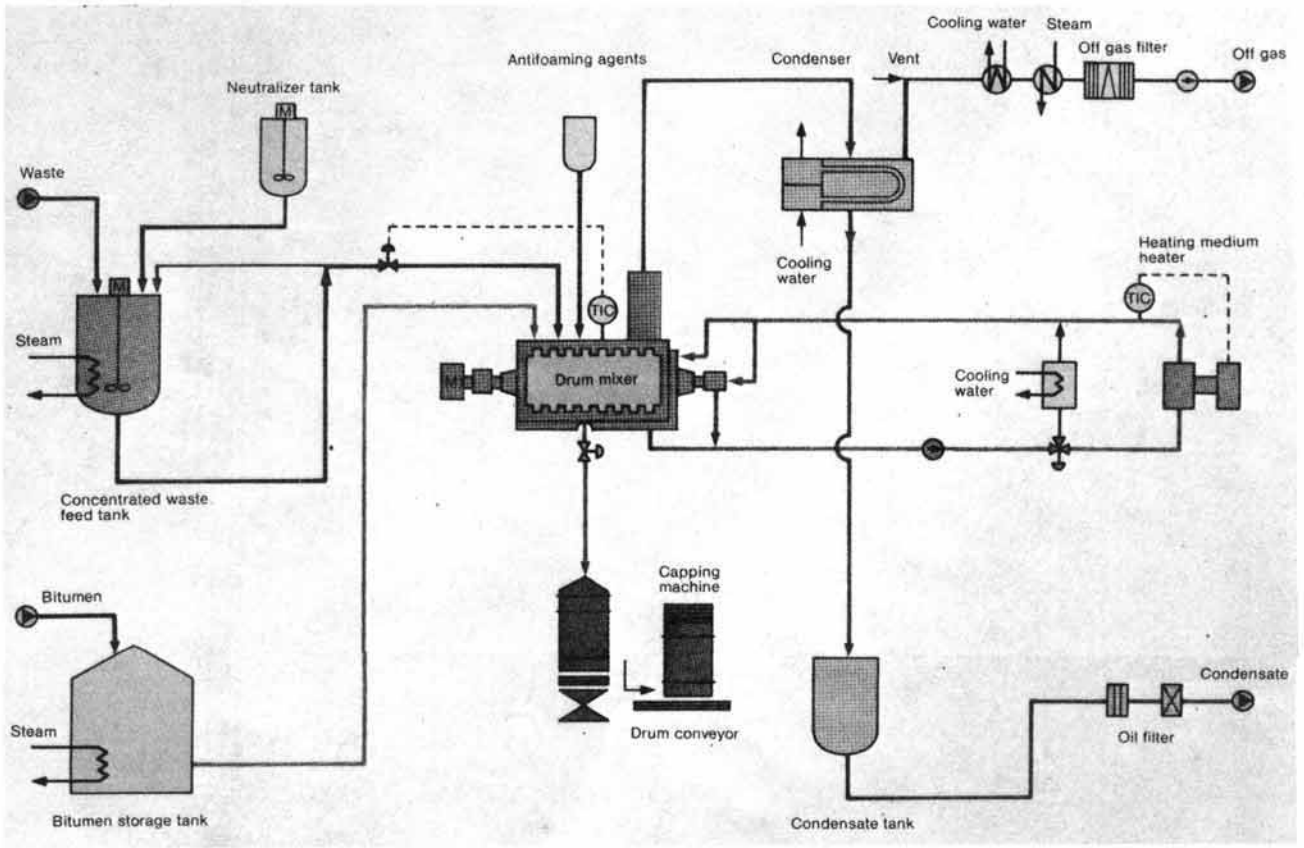

Fig. 2. JGC drum mixer process (bitumen solidification).

rate of the dome to check whether product material was completely removed.

A system computer screen mimic for the Drum Mixer Expert System is given in Fig. 3. Mimics and messages are to be used together as part of the operator Expert System user-friendly interface.

The second mode of this prototype system is a conversation mode for gathering diagnostic information. After a trip of the mixer, the system asks some questions to the operator. The operator obtains the information from the field, such as rotary joint condition, lubricating oil level, and so on. The system infers what is the cause of the trip from the data based on the inquiry. In this application, the Expert System is functioning as a knowledgeable fault tree analyst.

Radwaste Maintenance Support Application

In order to avoid unnecessary radiation exposure to radiation workers, the maintenance activities in radiation work areas must be planned very carefully. This presents another potential application of an Expert System. Such a system would consist of a knowledge base for equipment and system maintenance, a database consisting of the facilities design basis and as-built information, and exposure, training and qualification files for all the workers. The operational history of all facility equipment including malfunctions, temporary repairs, and periodic inspections and maintenance would be in the Expert System's memory. This information would be available for diagnosis, trending, or simply periodic maintenance scheduling.

Maintenance manuals would be incorporated into the Expert System. Upon request, maintenance procedures could be printed, reviewed or used for training. The Expert System could list all necessary tools and spare parts required for a job. Needed drawings, tables or other graphics could easily be made available. This would minimize job time by starting with all needed materials. This information would come initially from the equipment manuals. However, as experience is gained, the Expert System could be "trained". This technique makes the cumulative experience of many maintenance activities available to first time workers.

Another capability that an Expert System can provide is ALARA planning. By being updated with the latest radiological surveys in a planned maintenance area, an Expert System can determine the best approach path to a work area, identify any additional shielding requirements,

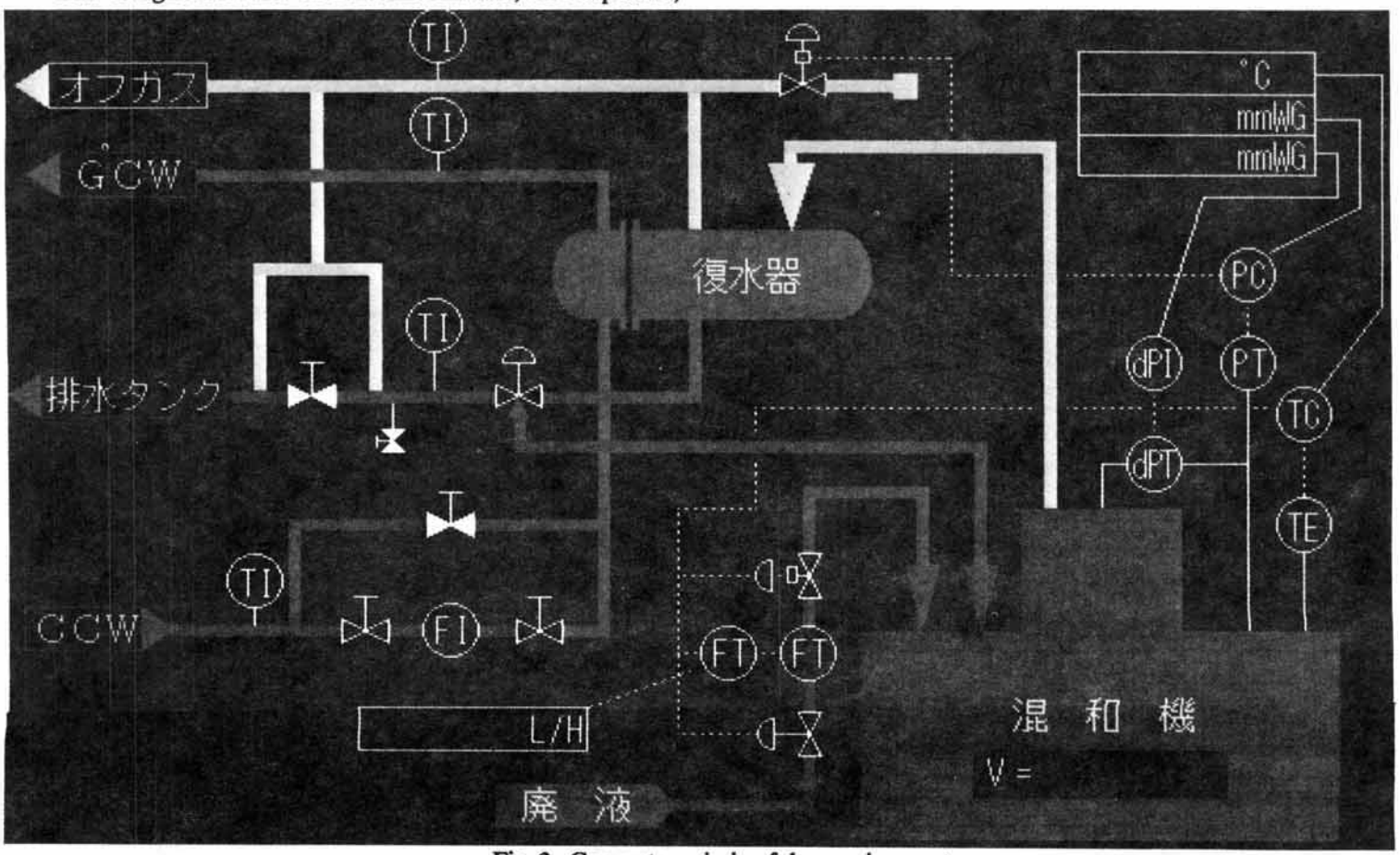

Fig. 3. Computer mimic of drum mixer system.

and make recommendations regarding in-place maintenance or removal. The Expert System may make decisions based on the responses or results of step by step source reduction activities such as flushing or placement of temporary shielding. However, it must be kept in mind that the source reduction actions need to be consistent with the necessary access and handling requirements of maintenance activities. An Expert System would interrelate these requirements and dose data to recommend optimum ALARA planning.

CONCLUSION

Artificial Intelligence technology has made great progress in recent years due to an improved understanding of the concepts and capabilities resulting from the increased use of such items as Expert Systems to industrial applications. The use of "shells" has made the programming of Expert Systems simpler. Work stations have enhanced the speed and capabilities of Expert Systems. The demonstrated acceptance of Expert Systems as an operational tool by operators represents a milestone in any new technology. The applications of Expert Systems are almost endless. Radwaste systems, like any other process system in which hazardous materials are involved, demand a higher level of safety, availability and reliability. Expert Systems can help achieve these goals.

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