REPLACEMENT OF THE ADVANCED TEST REACTOR CONTROL ROOM

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ABSTRACT

The control room for the Advanced Test Reactor has been replaced to provide modern equipment utilizing current standards and meeting the current human factors requirements. The control room was designed in the early 1960 era and had not been significantly upgraded since the initial installation. The replacement did not change any of the safety circuits or equipment but did result in replacement of some of the recorders that display information from the safety systems. The replacement was completed in concert with the replacement of the control room simulator which provided important feedback on the design. The design successfully incorporates computer-based systems into the display of the plant variables. This improved design provides the operator with more information in a more usable form than was provided by the original design. The replacement was successfully completed within the scheduled time thereby minimizing the down time for the reactor.

1. INTRODUCTION

The Advanced Test Reactor (ATR) is a 250 MWt research reactor located at the Idaho National Engineering Laboratory (INEL). The reactor provides high neutron fluxes for material testing in support of the U.S. Department of Energy programs. The reactor has been in operation since 1969 and until recently retained the original control room design. Although safety circuits and associated instrumentation have been upgraded to maintain modern standards, most of the operator-machine interface remained the same as the original installation until early 1989. A modern control room has recently been installed to provide an improved operator-machine interface and to provide easier access to more operating information. This paper describes the changes made, the reasons for them, the approach to control the modification, and the experience resulting from the modification.

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2. FACILITY DESCRIPTION

The ATR is designed for irradiation of a number of experiments simultaneously in flux traps formed by fuel elements arranged in the serpentine geometry shown in Fig. 1. The reactor is operated at relatively low temperature and moderate pressure. It is fueled with highly-enriched U-235 contained in plate-type fuel elements constructed of aluminum. It is water moderated and utilizes beryllium as the reflector. The control of the reactor is accomplished by adjustment of hafnium absorbers located in the central cruciform housing and in the reflector. The safety rods are hafnium absorbers located in six of the flux traps that also include irradiation facilities.

The reactor is controlled from two separate control rooms. One is the process control room which contains the controls to adjust the primary coolant system parameters such as pressure, flow, and temperature. The second is the main control room which contains the reactivity controls. The main control room contains indications and alarms that are available in the process control room, but it contains no active controls for those parameters. The plant operation is directed from this room by the shift manager and appropriate staff. It necessarily contains the appropriate communication facilities to assure that all needed interfaces within the plant and the control areas are established. The control of experiment parameters is accomplished at control consoles located in basement areas of the building in the vicinity of the supporting equipment for the experiments.

The design of the control room was completed around 1960 and has remained basically unchanged since that time. A significant upgrade of the plant protective system (PPS) was completed in 1978, but the upgrade did not change the appearance of the control room or the manner in which the data is displayed to the operator.

A computer-based data acquisition system is included to provide operating history and some manipulation of data for the use of the operator. Several modifications to this system have been completed since the original design to take advantage of the changing capability of computers. The current system uses the VAX-11/750 and includes two machines for reliability.

There has been a simulator facility for the reactor control room since the beginning of operation. This facility provided adequate simulation of the system response, but it did not duplicate all features of the control room.

3. CONSIDERATIONS FOR THE DESIGN CHANGE

The experience of the failure at the Three Mile Island nuclear plant indicated that the operator-machine interface has considerable importance to the performance of operators in control of accident sequences. This experience resulted in industry activities to improve the interface and provide the operator with added tools to follow the

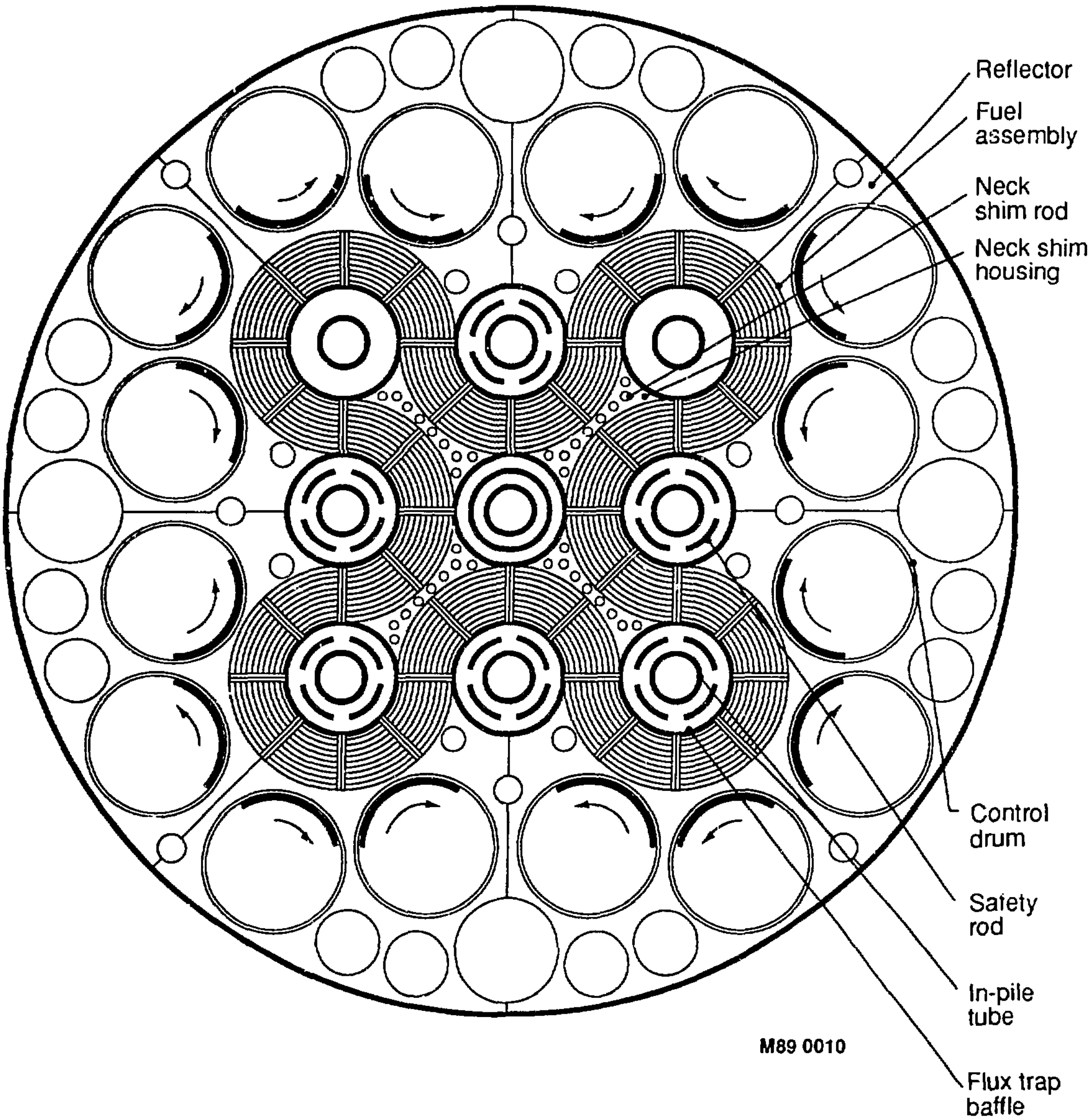

Fig. 1. Horizontal cross section of ATR core.

progression of both normal operation and accident sequences. This experience was a factor in initiating an updated design for the ATR control room. The features of the ATR control room did not include any serious deficiencies requiring immediate changes; however, the evaluations as a result of the industry concerns indicated that improvements could be obtained. Improvements in grouping of displays and controls to provide better conformance to established Human Factors Engineering were design requirements.

In addition to the improvements considered for the reactivity control interface, other features of the control room were evaluated for improvement at the same time. The recorders in use in the control room were designed and built in the 1960's and were becoming difficult to maintain. Replacement parts often were not being manufactured and had to be specially fabricated or salvaged from out of service recorders from other facilities. Rather than replace the equipment in a piecemeal fashion, replacement of all recorders with available modern recorder systems was chosen.

4. DESCRIPTION OF THE CHANGES

The change of the control room design takes advantage of the power of computer-based systems that can provide flexibility to display data in several forms and to manipulate it to provide more information than the original design. However, such designs are a considerable departure from the original design. Therefore, to assure a successful transition to a new design, most features of the original display were maintained. The original design displayed essentially all of the system parameters and alarms on an upright panel immediately in front of the operator console. The upright panel and the displays were maintained by installing modern recorders. The recorders were relocated to establish appropriate grouping of parameters.

The major change to the control room is in the operating console. The control switches and position indicators for the reactivity control elements are replaced with modern equivalents. Rotary switches have been replaced with matrixed push button switches for control element selection with rotary switches retained for actual element motion control, and all switches have been relocated for better access. The location of the position indications are also changed to provide easier viewing consistent with the recommendations of human factors studies. Additionally, the modified console contains five video displays for the operators use. A sixth video display is installed at the shift managers station which is away from the operating console but still within the control room. These displays have the capability to show current status and recent history of several categories of parameters.

The currently available information from these video displays is listed in Table I. As more experience is obtained with the system, others will be developed. As may be noted from the table, there are displays that provide the operator with information on the control logic (interlocks and controls) including the current logic status. The system has the potential to provide listings of procedures and drawings that may be of use for particular operational evolutions or particular accident sequences. This application remains to be developed.

TABLE I. Data Display Available at Console

DISPLAY NAME	DESCRIPTION
Reactor Quadrants	Reactor process parameters by core quadrant (flow, pressure, temperature, and others for the primary coolant)
Reactor Total	Power from the thermal monitors for reactor total and each core quadrant
Water Power	Recorder icons for the thermal power system
Fission Break	Recorder icons for the fission break monitors in the primary coolant system
Wide Range	Recorder icons for the rate of change monitors (neutron flux)
PPS Part I	Recorder icons for pressure, temperature, neutron level, and radiation level (Plant Protective System)
Log CR and Log N	Recorder icons for the log count rate and the log N systems (neutron flux parameters)
Power Distribution	Block diagram of the fraction of full power for the N-16 recorders (power distribution)
Neutron Level	Recorder icons for the neutron level system
Power Split	Relative and absolute power generation for each lobe of core
Rod Panel	Position of reactivity control elements and safety rods
Procedure Panel	Diagrams of control system logic and status (control elements and safety rods)
Message Window	Status of selected items that are soft alarms (notification)
TTY Window	Allows request of data not a part of a particular display
Building Alarms	Provides indication of building door status
SER Report	Sequence of Event Report (sequence for multiple alarm conditions)
History Menu	History of selected parameters at requested frequency (trending)
DAC/DAN	Selection of the data network to provide the data (two available)

The video displays are driven by six standard Hewlett Packard series 9000 work stations. These work stations receive plant parameter information from the plant data system which accumulates the information. The work stations are programed to arrange the parameters into the desired displays for the operators use. The displays utilize colors to provide the operator with information about the status of variables to ensure that they are maintained within the required ranges. Variables within normal ranges are displayed in green, if an alarm level is reached, the display of the variable becomes orange, and if a trip level is reached, red is displayed. The displays also provide trend data for selected parameters, such as outlet temperature, neutron level, and primary coolant flow to assist in the interpretation of both normal operation and off-normal conditions.

In addition to the changes to the operating console and the replacement of the existing recorders, the annunciator panels and the communications systems between the control rooms and the experiment console areas were replaced. These replacements are essentially like for like in function, but current technology is used in the new panels and the communications system. The annunciator panels utilize fiber optic technology and are computer based allowing additional flexibility.

As part of the over all facility upgrade a new reactor control room simulator was provided. The simulated control room is built to provide a high fidelity simulation in physical appearance, operational characteristics, and system response of the reactor control room. This permitted evaluation of all aspects of the operator reactor interface including human factors considerations prior to finalizing design for the reactor control room. All programming for the video display units was developed and tested in the simulator. The total control room simulation was utilized for nearly a year for reactor operator training prior to start up of the reactor with the new control room. Operating concerns identified during this training period were considered and changes made in the design as appropriate. As a result, the design benefitted from the hands-on experience during training.

5. IMPLEMENTING THE CHANGE

Formal procedures for ATR modifications are in place to assure that modifications are carefully reviewed and meet the requirements for a nuclear plant. These procedures include formal reviews of the design requirements and of the design relative to the requirements. Significant changes such as the control room replacement are also accompanied by a readiness review which is conducted by an independent committee to assure that the design has been properly completed and that the necessary training and equipment are available for the modification. The design of the control room replacement was completed well in advance of the actual installation allowing considerable time for planning and review of the activities.

Since the modification would remove normal safety systems from service, it was necessary to evaluate the plant status during the modification to assure safety. The modification was completed without fuel in the reactor which reduced the number of systems required for safety. A temporary panel containing necessary systems such as the area evacuation system, manual control of the confinement isolation with associated heating and ventilating functions, and security communication equipment was installed. This panel provided the required plant protection during the modification.

Prior to beginning the installation, considerable effort was devoted to planning and scheduling the activities to minimize errors and help assure that the modification was completed in a minimum time. This planning also coordinated other plant activities, such as experiment loop modifications and general plant preventive maintenance in progress at the same time. The planning of the work prior to beginning the modification was provided to the craftsmen in the form of work instructions that helped assure the final product.

Following the control room replacement, each system affected by the modifications was tested to assure that the modifications were consistent with the design. Some of the installation required that safety systems were disconnected from certain panels involved in the modification and then connected to new recorders without modification to the function of the safety system. Accurate completion of such activities was clearly important; therefore, quality assurance procedures were utilized extensively in the work activity. The systems were tested using formal procedures that were reviewed by a committee that reviews all ATR procedures. The results of the testing were finally reviewed by a readiness review committee and all control room systems and control room simulator systems were placed under configuration control prior to returning the facility to operational status. The readiness reviews conducted prior to the beginning and at the end of the replacement were completed by independent committees from both the U. S. Department of Energy and the operating contractor.

6. RESULTS OF THE REPLACEMENT

The schedule for the replacement of the control room included 60 days for installation and testing. As a result of the detailed planning and scheduling in advance of the activity, the work was completed consistent with the schedule. The testing detected only a few errors demonstrating the importance of the detailed preparations.

Experience to date indicates that the control room design has been easy for the operating staff to use and has provided a reliable long term supportable facility with no serious operational concerns. Administrative requirements are in place to assure that selection of displays, which is at operator discretion, includes certain parameters that are important to proper operation of the reactor. Administrative requirements are also in place to assure that the information displayed in the upright panels (the original configuration) is appropriately considered in control actions.

The operating experience has indicated that the existing data acquisition system does not update the information transmitted to the work stations as often as is needed in certain circumstances. This delay in the transmission of data is being corrected to provide fast data updates consistent with operational requirements and human factors concerns.

7. SUMMARY

The reactor control room for the ATR has been replaced with modern equipment including an operating console utilizing a computer-based system to provide parameter and procedural information to the operator. The replacement is based on current human factors principles to assure that the information provided to the operator can be utilized with a minimum of concern for errors in interpretation. The displays also provide additional trending information important to operation during normal as well as off-normal conditions. The modification successfully met the design requirements and was completed within the scheduled time which minimized the unavailability of the facility.