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# DATA HANDLING AT EBR-II FOR ADVANCED DIAGNOSTICS AND CONTROL WORK

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## ABSTRACT

Improved control and diagnostics systems are being developed for nuclear and other applications. The Experimental Breeder Reactor II (EBR-II) Division of Argonne National Laboratory has embarked on a project to upgrade the EBR-II control and data handling systems. The nature of the work at EBR-II requires that reactor plant data be readily available for experimenters, and that the plant control systems be flexible to accommodate testing and development needs. In addition, operational concerns require that improved operator interfaces and computerized diagnostics be included in the reactor plant control system. The EBR-II systems have been upgraded to incorporate new data handling computers, new digital plant process controllers, and new displays and diagnostics are being developed and tested for permanent use. In addition, improved engineering surveillance will be possible with the new systems.

## INTRODUCTION

Since 1964 the Experimental Breeder Reactor II (EBR-II) has served as a facility for the development and testing of new concepts ranging from fuels and materials irradiations, safety tests, operational strategies development, through improved plant control, diagnostics and toward full plant automation. At the same time, the EBR-II is a full power plant system rated at 20 Mwe (62.5 Mwt) with an operating plant capacity factor of over 70% for the past 10 years. The facility has been upgraded continuously in order to accommodate the many experimenters who use the facility.



The experimental load at EBR-II has required special plant data handling capability with enough flexibility to provide data for numerous types of experiments. The plant Data Acquisition System (DAS) allows flexible usage for streaming real-time data as well as for archival purposes. Recently, the DAS computer has been replaced and an additional network of computers installed which have permitted significant work to be done in the area of plant monitoring for engineering surveillance and for operator use. Concurrently, digital controllers have been phased into operation for the main plant control tasks. The controllers are networkable and will ultimately provide the base for full plant automation when coupled with the information presentation capability through the DAS and other display computers.

## DATA ACQUISITION

The current data acquisition system (DAS) at EBR-II is the result of a complete hardware-software conversion that was completed in 1986. The goal was to evaluate the needs of operations, experimenters and analysts, and then optimize the DAS resources to fit those needs.

The new system is designed to log up to 1024 channels of data with a time stamp of .5 second each. At this time 788 analog and 143 calculated channels are logged which include channels received from 4 mini stand-alone computers located in the plant. This makes a total of 931 channels of data.

The data comes from three multiplexors and 4 mini computers. The multiplexors receive the analog signals and convert them to digital signals for processing. The digital data from the multiplexors is processed through a controller which loads the data into the Concurrent 3210 processor for conversion to engineering units and distribution. The data coming from the mini computers are processed directly into the computer's primary data buffer.

The calculated channels are made from two or more analog channels. The CALC program reads these values from the data buffer each .5 second, does the composite calculation and stores the values back into the data buffer.

The LOGGER program averages the data and logs the data into the various data files. There are three continuous circular data files, one file set up for frozen and scram data, and one file that is built from archived data to provide a 30 or 90 day display for all channels of data. The frozen log can be initiated at any time to save a frame of data that may be of special interest. The scram log is automatically recorded if the reactor scrams for any reason. The DAS data flow is graphed on Figure 1.

There are three 80 mb disc drives on the DAS. One drive is dedicated to system software. One drive is dedicated to acquisition and user software and the other drive is dedicated to the data store.

All data in the data store is in engineering units and uses 8 bytes per data sample. Each record for 1024 channels of data plus a time stamp uses 4096 bytes of storage. The organization of the data store on the disc is shown in Figure 2. The 80 mb unformatted disc converts to a 67 mb formatted storage area. The following information provides a detailed tabulation of the disc storage allocation.

| File | Records | Megabytes | Percent of Disc | Display |
|---|---|---|---|---|
| Frozen | 720 | 2.9 | 4.4 | Scram |
| .5 sec. | 720 | 2.9 | 4.4 | 2 min. |
| 5 sec. | 720 | 2.9 | 4.4 | 20 min. |
| 1 min. | 11520 | 47.1 | 70.0 | 4-8 hr 4-8 day |
| 3 hour | 720 | 2.9 | 4.4 | 30-90 day |
| 5 time selections | 14400 | 58.7 | 87.6 | 9 displays available |

The data can be viewed either graphically or numerically by using the various applications shown on the DAS menu (Figure 3).

Optimizing DAS resources to provide information to operations, analysts, and experimenters in a meaningful and timely way is based on historical data requests. Data can be provided in time slices of from .1 second to three hours and this data can be viewed over several time frames. This scheme satisfies most of the users most of the time.

A high speed data system that will gather data at a 100 samples per second is now being installed. The high speed DAS is a dedicated Concurrent 3210 processor interfaced with a NEFF Multiplexor. Up to 64 data channels can be connected and recorded on a dedicated 67 mb hard disc.

The communications protocols and networks are being upgraded to distribute real-data more efficiently to other systems for on-line analysis and display.

## DEVELOPMENT COMPUTER NETWORK

To serve both the needs of developers from within the Laboratory and those outside the laboratory for real-time data, a network of computers was purchased and installed. The computers have access to plant signals from the DAS as previously described. The configuration of the system is shown on Figure 4.

The network consists of six SUN Microsystems computers and a VAX 11/750 on an ethernet. Three of the SUN computers are color machines, two are monochrome, and the other is a file server. The VAX incorporates the DEC ULTRIX operating system and the SUN computers use the SUN operating system which is a derivative of UNIX. Transfer of information between computers is straightforward due to the similar operating systems and the support of NFS protocol (as supported by both DEC and SUN).

Plant signals that are transferred to the development network may be used, for example, to provide real-time displays of the plant processes. They may also be used in software programs running "under" the graphics for diagnostic purposes including system state analysis, alarm handling, etc. As many as 25-30 signals may be used in a single display.

The plant signals are transmitted to the SUN file server on the ethernet and the server, in turn, provides signals to the other computers on the system as needed. Each computer on the network is a "client" to the server and, as a particular display or program is run on one of the computers, the channels of plant data required for the display or program are sent to the client on the network. An example of the use of data is the display for the secondary sodium system (Figure 5) which is the sodium side of the steam generator. The display includes a temperature scale on the left of the computer screen, with outline mimics of the intermediate heat exchanger, superheaters, and evaporators on the display. Within the outline are "bar" graphs which move according to the temperatures of both the inlets and the outlets of the component. This approach allows the operator or engineer an immediate comparison of the performance of the system both with respect to the optimal full-power values and between the components. Flow signals for the system are also provided.

With the present system configuration, there is a great deal of flexibility as to the location where plant information may be made available. This is especially important when considering the needs of engineering surveillance activities which should not necessarily clutter the control room. For example, the DAS is in the Power Plant building of EBR-II and serves the control room as well as many users on a multiplexed data network. The SUN network is based in the engineering building but the ethernet is extended through the engineering building, power plant, and another office building adjacent to the engineering building. There are two computers attached to the ethernet in the EBR-II control room, and three in the engineering building in addition to the server. The placement of computers requires only that the ethernet cable be in place.

The DAS and the development computer network are connected, at present, by an RS 232 hard-wired link running at 19.2 Kb. Full error correction is employed to insure data integrity.

## DEVELOPMENTAL ACTIVITIES

The development network has enabled EBR-II Engineering to work on improving plant systems surveillance by considering the needs of engineering, operations, and outside experimenters who may wish to test their ideas on a real plant environment. Several approaches have been made which are demonstrating the potential for significant advances in plant monitoring.

EBR-II personnel were involved in the early development activities in the Man-Machine Integration (MMI) work sponsored by the Department of Energy. Work at EBR-II included interaction with other organizations on such projects as the DISYS diagnostic program, developed by Westinghouse Advanced Energy Systems Division (W-AESD). This software package was taken to EBR-II and converted for use on the SUN computers and was tested with real-time plant signals. The status of DISYS is that there are some software "bugs" in the program that are being worked on as time permits.

Another program worked on at EBR-II is the Component Impact Analysis System (CIAS). This program was devised at EBR-II and includes the features of providing a "validation" of system line-up against control documents such as operating instructions, technical specifications, tagging logs, etc. It allows the operators to investigate alternate line-up scenarios etc. The status of the CIAS is that the inference engine is complete but the program has only been checked out in the simulation mode.

## Graphics Development

As work progressed on the projects mentioned above and on some other related work, it became obvious that there should be an integrating framework that would include the diagnostics and similar work and integrate those efforts into a system that would enhance surveillance and operations. This led to a real-time display concept that includes significant "intelligence" in the display. It provides focus for the diagnostics programs that are being developed. The method of displaying plant signals was developed from the pioneering work of Leo Beltracchi(1) and recently further elucidated by Jens Rasmussen(2). The displays are based on the thermodynamic cycle of the EBR-II facility.

The heat-flow of the plant is directly depicted in a thermodynamic model (Figure 6) as the heat is generated in the reactor, transported to the secondary sodium system, and finally to the steam system and the energy utilized to generate electric power. The real-time plant signals are converted to graphical position on the computer screen such that as temperatures change, the model is precisely changed (based on a temperature scale on the computer screen) to reflect the thermodynamic changes in the plant. This display requires the use of two bit-planes to allow the display of stationary objects such as temperature scales, the temperature-entrophy curve (for water) etc., and the display of dynamic data such as the polygons, that depict the thermal properties of the primary, secondary and steam systems.

Other displays have also been developed that are related to the main display but which show greater detail of a particular system. An example is the display of the secondary system

(Figure 5) which shows the delta temperatures of the secondary side of the Intermediate Heat Exchanger, the Superheaters, and the Evaporators, along with system flow.

The graphical displays are serving as the focus for including diagnostics, alarm handling, etc. in a structured and logical fashion. Interesting insights as to plant operation and performance have already resulted from the displays.

As part of the mission of EBR-II, tests have been and are being conducted to determine the feedback characteristics of all the plant systems. Investigation into the inherent characteristics that relate to plant safety issues is the reason for such work. The graphical displays as described above are used in real-time on the network for monitoring of plant performance. They are very useful as the plant is subjected to various transients which may originate from a change of primary system flow, or perhaps a variation in the steam drum pressure etc.

During November, 1987, special tests were conducted on EBR-II over a wide range of power. Feedback to the reactor was measured using most of the main plant parameters as the initiators for the tests. The test results led to power changes in the plant from feedbacks such as thermal expansion/contraction etc. As the power changed, the entire thermodynamic cycle was easily monitored using the new graphical presentations.

Another display has also been made available to experimenters and operations. The display consists of up to four real-time inputs which are then graphed as the event takes place. The computer screen is divided into quadrants and the signals are traced over a set period. This feature is useful for comparisons of parameters that are of major concern in tests.

## System State Analyzer

A proprietary (commercial product) diagnostic and surveillance method has been developed and tested at EBR-II by Energy Incorporated. The System State Analyzer (SSA) is a software package that incorporates pattern recognition, learn modes, and analysis modes that permit detailed analysis of plant performance and/or performance of individual systems or components. The SSA is structured so that it can be used off-line or on-line with either steady-state or transient operation. The SSA utilizes the DAS as the primary computer for both the learn and analysis modes for the real-time version. Other versions exist that can be used on PC computers by streaming the information from the DAS and doing off-line analysis with the PC class machine.

The SSA has demonstrated the ability to closely identify the plant state, based on previous learned and validated states, and to further detect individual signals or processes that have drifted. The SSA was originally developed for steady state operation, but was recently demonstrated to provide high quality output during plant transient tests.

Further development of the SSA will include moving the output to the SUN computer system to allow the use of a common protocol to access the information by the plant operators and engineers. The SUN system graphics will then include not only the model based real-time plant displays, but also the diagnostic and analysis capability of the SSA as a part of the display package.

## SUMMARY

Data handling at EBR-II has taken on far greater importance than at the beginning of plant life over 20 years ago. The plant data handling system has been structured such that it provides great flexibility in the methods of data display. From the multiplexing and isolation of plant signals through the DAS to the provision of those signals to networks for further use, the system is proving that using the more up-to-date tools that are now available for information presentation will pay great dividends. Early detection of instrumentation anomalies, plant systems degradation, or system failures will provide immediate payoff. Instrument failures have already been seen and repaired at EBR-II that were not readily detected with the normal plant instrumentation. As plants age, it is expected that better information will be available to assist in decisions that may need to be made for plant refurbishment and further operation.

## ACKNOWLEDGMENTS

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REFERENCES


1. L. Beltracchi. "A Direct Manipulation Interface for Heat Engines Based Upon the Rankine Cycle." IEEE Transactions on Systems, Man, and Cybernetics, Vol. SMC-17, No. 3, May/June 1987, pp. 478-487.

2. J. Rasmussen and K. J. Vicente. "Cognitive Control of Human Activities and Errors: Implications for Ecological Interface Design." Paper given at: The Fourth International Conference on Event Perception and Action. Trieste, Italy, August 24-28, 1987.

Figure 1

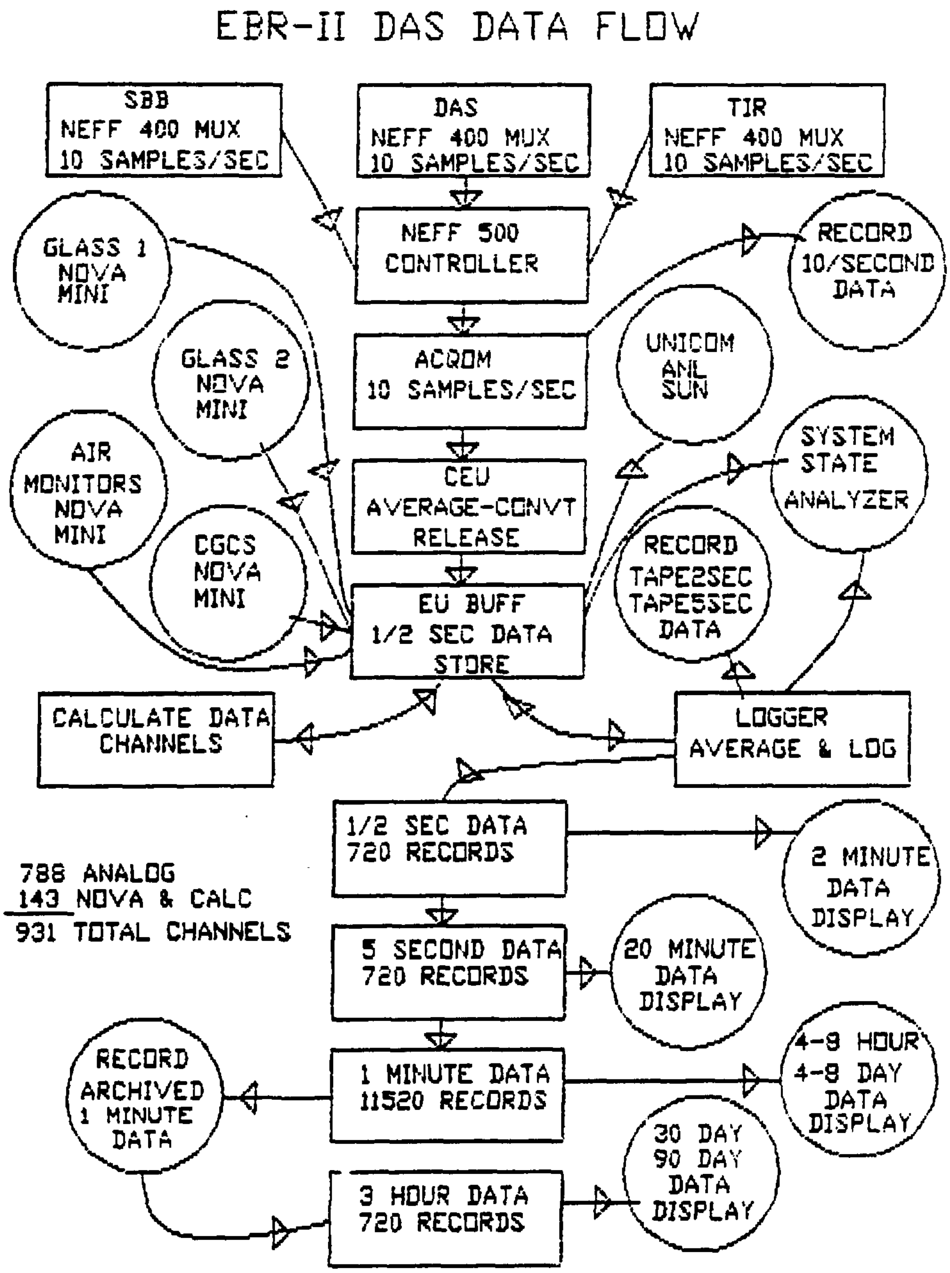
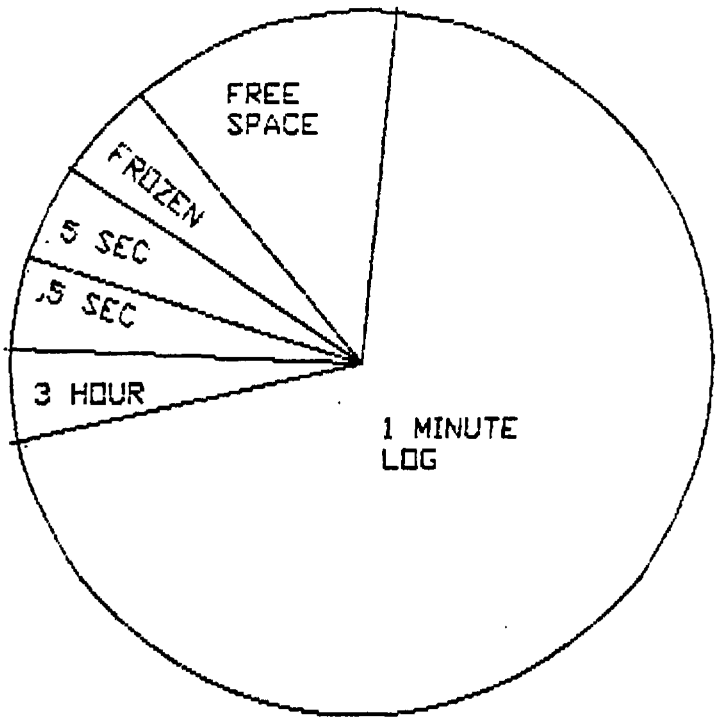



Fig 1

Figure 2

# EBR-2 DATA ACQUISITION MANAGEMENT

## 67 MB DISC




EACH RECORD IS 4096 BYTES

| FILE | RECORDS | MEGABYTES | PERCENT OF DISC | DISPLAY |
|---|---|---|---|---|
| FROZEN | 720 | 2.9 | 4.4 | SCRAM |
| .5 SEC | 720 | 2.9 | 4.4 | 2 MIN |
| 5 SEC | 720 | 2.9 | 4.4 | 20 MIN |
| 1 MIN | 11520 | 47.1 | 70.0 | 4-8 HR 4-8 DAY |
| 3 HOUR | 720 | 2.9 | 4.4 | 30-90 DAY |

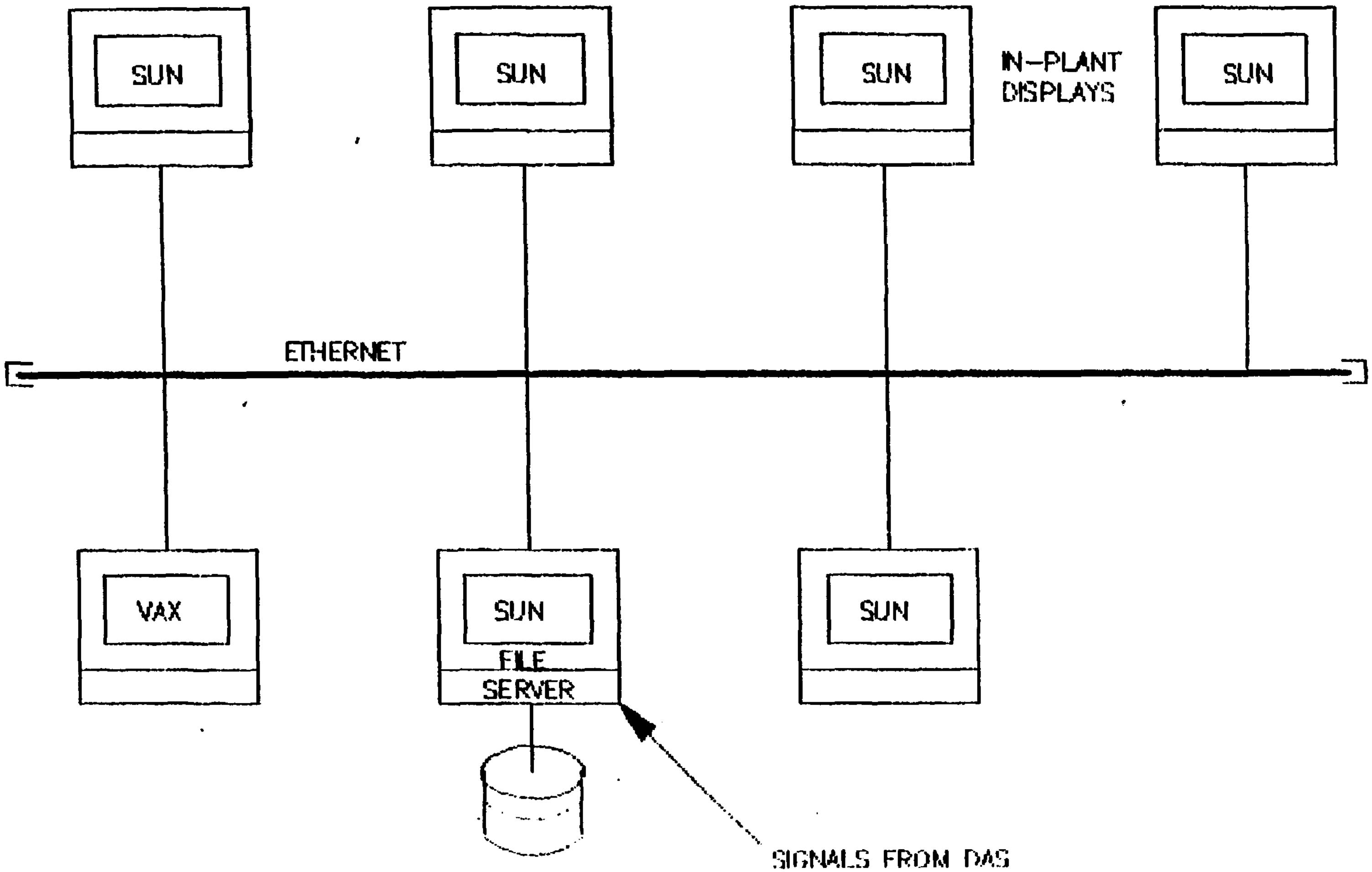
Fig 2

# EBR-II DAS MAIN MENU

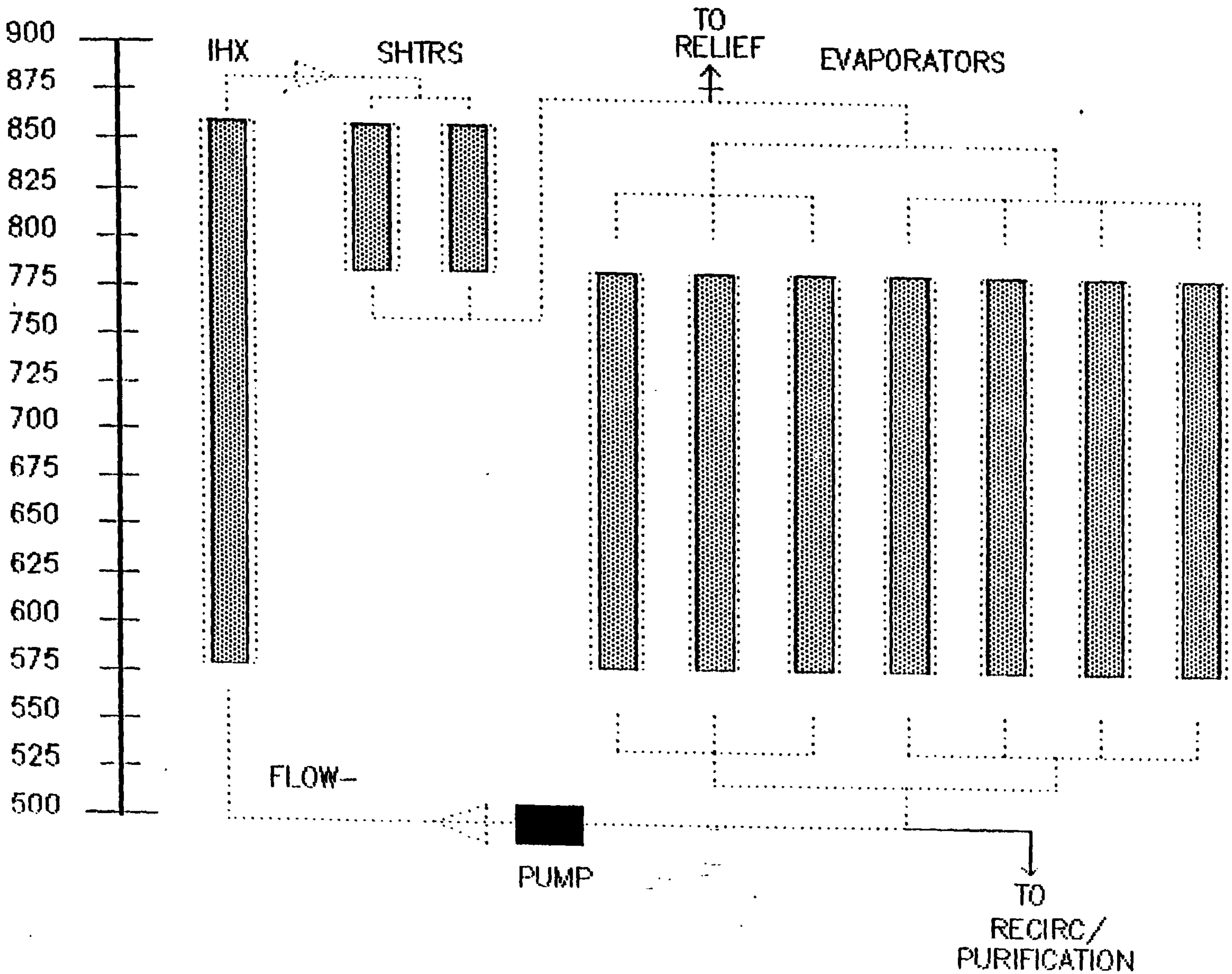
| | | | |
|---|---|---|---|
| ALRM | DAS ALARM SCOPE | MENU | DISPLAY THIS MENU |
| DATA | DISPLAY DAS DATA | MISC | MISCELLANEOUS OPERATIONS |
| FIND | FIND DAS CHANNELS | NOVA | CONTROL NOVA COMPUTERS |
| GLAS | GLASS 1 & 2 CONTROL | PLOT | PLOT PLANT DATA |
| GRAF | GRAPHICS MENU | RCAL | CONTROL ROD CALIBRATION |
| HELP | DISPLAY INFORMATION | SDAT | SPECIAL DATA DISPLAY |
| HIST | DISPLAY DAS DATA HISTORY | SETL | SET DAS ALARM LIMITS |
| | | TSE | TIME SEQUENCE OF EVENTS |

| | |
|---|---|
| EXIT | EXIT FROM REMOTE PORT |
| MTM | MULTI-TERMINAL MONITOR |

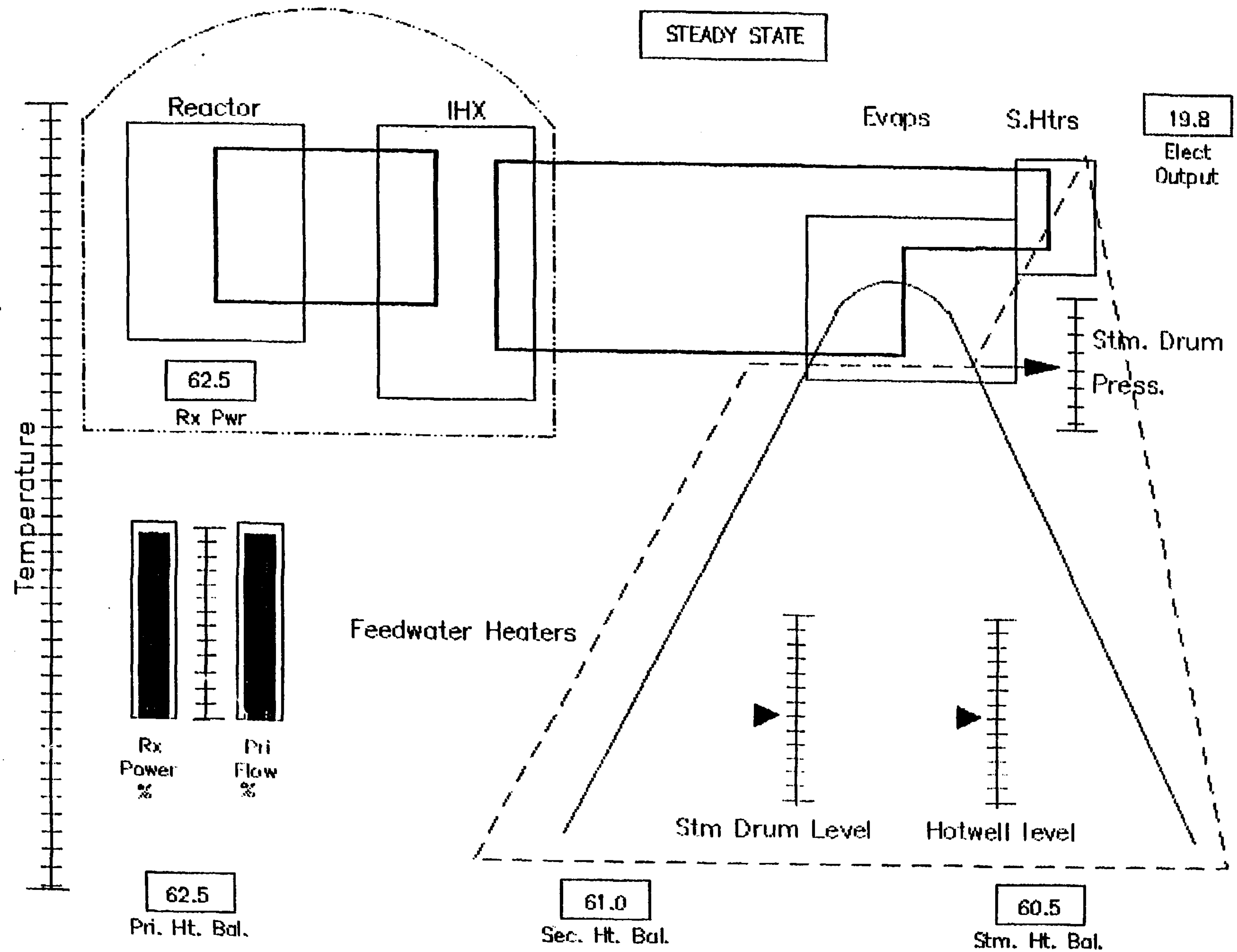
ENTER NAME AT LEFT TO SELECT OPTION




DEVELOPMENT COMPUTER NETWORK




SECONDARY SODIUM SYSTEM




MAIN DISPLAY

Fig 6