1989

A study of current computer technology in plant operations and the integration of expert systems /

Karen A. Trubela
Lehigh University

A STUDY OF
CURRENT COMPUTER TECHNOLOGY IN PLANT OPERATIONS
AND THE INTEGRATION OF EXPERT SYSTEMS

by

Karen A. Trubela

A Thesis

Presented to the Graduate Committee

of Lehigh University

in Candidacy for the Degree of
Master of Science

in

Industrial Engineering

Lehigh University

1988

This thesis is accepted and approved in partial fulfillment of the requirements for the degree of Master of Science.

December 13, 1988

(date)

Professor in Charge

Chairman of the Department

Acknowledgements

I would like to express my appreciation to those individuals at the Pennsylvania Power and Light Company for their efforts in helping me obtain the needed information and resources, to my husband John, for giving his time and undivided attention, and to my advisor, Dr. John C. Wiginton for helping me in the development and completion of this thesis.

Table of Contents

List of Figures

List of Attachments

Abstract

Over 100 commercial nuclear power plants currently operate in the United States. Complex technology and intense regulation has mandated a fast-paced evolution of process control and myriad use of computer systems to properly govern operation of these plants.

Of all the computer systems in use at the Susquehanna Steam Electric Station (SSES), a Pennsylvania Power & Light facility, two of the most important are the Advanced Control Room (ACR), which governs plant process control, and GETARS, a system that monitors operational transient activity.

To keep these computer systems operating at peak efficiency, to serve the plant and the company most effectively, these systems must be kept current. Computer technology continues to evolve rapidly, and these systems, from a cost standpoint, and most importantly, from a safety standpoint, should be periodically examined to see if a retrofit, an upgrade, or replacement based upon the latest state-of-the-art enhancements is justified.

Key among these enhancements is expert system technology. In order for a utility to hold the leading edge in a competitive industry, a hard look should be given to the applicability of this technology. Expert system versatility makes it attractive for decision making applications, as well as, for any tedious logic that is currently executed in a cumbersome manual format,

using hardcopy procedures, or equivalent media.

Computer systems are used to monitor the heartbeat of the nuclear industry. Similarly, the nuclear industry should be checking the pulse of computer evolution. The most successful and the most efficient commercial nuclear power plants are those that contain the latest, most judiciously chosen computer hardware and software. Prudent retrofit of computer technology inevitably results in a payback, by creating cost-effective, safely-run energy generation for the public.

I. Introduction

Nuclear power has been a growth industry in the United States from its advent in the 1940's until the Three Mile Island accident in 1979. Since then negative public opinion has led to a decline in its status to where there are no existing orders for any future commercial nuclear power plants in the United States; meanwhile, nuclear power still flourishes in other countries such as France, Canada, and Japan. This negative public opinion has been created by the news media and by public unfamiliarity with this technology. Nuclear power to many people is confused with the destructive force of nuclear war and weapons, and not with the energy efficient power that it is. The public does not realize that the latest generation of sophisticated controls and technologies from private industry, and government regulations in the use of these technologies, are used to provide safe commercial nuclear generation; computer technology in the nuclear industry is no exception.

Nuclear power should be looked at again as a prime source of energy for our nation, especially since environmentally devastating phenomena such as 'acid rain' and the 'greenhouse' effect have become top concerns among the media and government. The 'greenhouse' effect is believed to be caused largely by fossil fuel production and its heat-trapping gases that raise average ambient temperatures around the world. Throughout the summer of 1988, Senate hearings explored the greenhouse phenomenon where several experts gave their options on the future of energy production in the United States. During the hearing, comments such as "reviving nuclear power program using passively safe economical reactors" and "it's time for America to get rid of it's 'nuclear measles'" were stated by two senators. DOE Associate Undersecretary D. Fitzpatrick stated that the development of advanced nuclear technologies is underway and the way of the future.[1]

Nuclear Power has been providing efficient and safe nuclear power, and providing the U.S. with 20% of its power from only 104 reactors. This thesis will address these aspects of computer technology and applications which provide information to plant control operators and engineers. Following is a brief explanation of the Susquehanna Steam Electric Station (SSES), and the theory behind nuclear power generation, to familiarize the reader with the application systems that are the basis for the computer systems addressed in this thesis.

SSES consists of two commercial units which have a common control room, diesel generators and refueling floor, turbine operating deck, radioactive waste system, and other auxiliary systems. SSES is located on a 1075 acre plant site in Salem Township, Luzerne County, Pennsylvania, approximately 20 miles southwest of Wilkes-Barre, 50 miles northwest of Allentown and 70 miles northeast of Harrisburg.

---

[1] "The Greenhouse: New Climate,Same Old Target", <u>Electrical World</u>, September 1988,pp.13-18.

The Nuclear Steam Supply System (NSSS) for each unit consists of a General Electric Boiling Water Reactor (BWR/4 product line). The containment is a pressure suppression type, designated as Mark II. The drywell is a steel-lined concrete cone located above the steel-lined concrete cylindrical pressure suppression chamber. The drywell and suppression chamber are separated by a concrete diaphragm slab which also serves to strengthen the entire system. The design core thermal power for each unit is 3439 MWt with a corresponding net electrical output of 1100 MWe.[2] The difference between the thermal megawatts (MWt) and the electrical megawatts (MWe) is attributed to plant losses from the heat generated in the core to the actual electricity produced. This translates to an overall 30% efficiency.

A simplified drawing of the steam cycle in a BWR is illustrated in Attachment A. Instead of developing heat by burning fuels in a boiler, the Nuclear Power Plant generates heat by the fissioning of Uranium nuclei in the fuel within the reactor. As stated earlier, the reactor at SSES is a Boiling Water Reactor (BWR). The water is boiled and steam is produced in the reactor vessel. The water used serves three purposes;

1. To slow down (moderate) neutrons needed to increase the nuclear reaction.
2. To cool the 'core' from overheating in nuclear reaction.
3. To become the steam or "thermal power" generated after

---

[2] "Final Safety Analysis Report", <u>Pennsylvania Power and Light Company</u>.

the boiling process in the core.

An illustration of a simplified nuclear reaction is given in Attachment B.

Because the reactor releases energy from the atomic structure of the atom, rather than a simple rearrangement of the atoms as is done in burning fuel, a far greater amount of energy can be developed. The conventional coal fired plant produces 1.5 kilowatt-hours per pound of coal verses the nuclear power plant which produces about 70,000 kilowatt-hours per pound of fuel.

The remainder of the steam cycle at SSES is similar to a fossil fuel plant where the thermal energy from the boiling process is transmitted to the turbines to be transformed into mechanical energy. At SSES the steam from the reactor enters the main turbine through four steam lines to the high pressure turbine and the three low pressure turbines. The turbines share the same shaft as the main generator to convert the mechanical energy from the turbines to electrical power to be transmitted to the PP&L's power grid for distribution. The steam is returned to the reactor in the form of water via the condenser. The feedwater system then reheats the water, and feeds it back to the reactor to complete the primary and main steam cycles.

In addition to this cycle, hundreds of main and auxiliary systems are needed so that the plant may run continuously and smoothly. Many automatic controls through instrumentation provide the plant with automatic responses in normal operating conditions. But, it is the prompt and correct operator response to process conditions that is needed for unusual plant conditions in any power plant.

Because of the complexity of the regulatory environment of nuclear plants, control room technology, including instrumentation, computer controlled equipment, computer systems and semi-conductor technology, have been combined to create the Advanced Control Room (ACR).

II. Advanced Control Room (ACR) - Present Scope

The Advanced Control Room (ACR) provides the operator with centralized and integrated front panel displays, annunciators, and control devices necessary for efficient, coordinated operation of the boiling water reactor (BWR) plant during all operating conditions. Minimization of the quantity of data which the operator must continuously survey, analyze, and comprehend reduces the operator response time, and the probability for operator error.

The Plant Process Computer (PPC) aids in improving this operator-process interface by continuously monitoring plant process variables and displaying various plant process systems on cathode ray tubes (CRT's) located on the Unit Monitoring Consoles (UMC). The UMC's are activated by the PPC's appropriate warning or alarm indications if any parameter reaches a predetermined limiting value.

Attachment C illustrates a simplified version of the SSES ACR. Operator controls are arranged in panels in logical sequence and groups. Briefly, these panels are the most important:

- o Unit Operating Benchboard
- o Reactor Core Cooling Benchboard
- o Plant Operator Benchboard
- o Unit Services Benchboard
- o Standby Information Panel

o **Unit Monitoring Console**

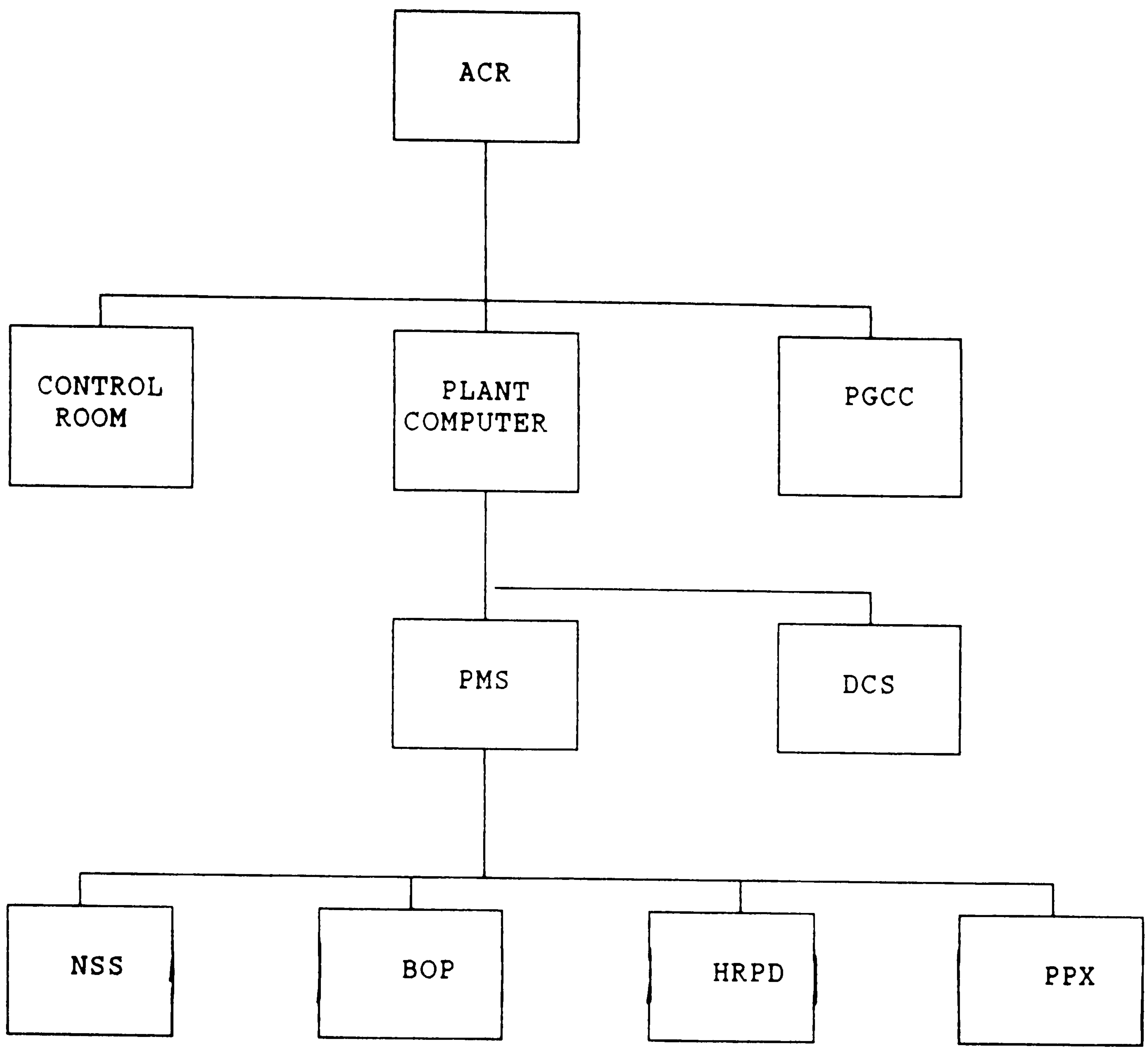
The ACR meets the following design requirements:

1. Improve the operator-process interface in order to simplify planned operations without sacrificing reliability or safety.
2. Optimize the quantity of data the operator must observe and analyze, thereby decreasing operator response time while minimizing operator errors.
3. Centralize and integrate the control devices which the operator must routinely manipulate.
4. Provide efficient hardware and software display techniques to present timely, useful information to the operator.
5. Accurately calculate the core power distribution to verify proper reactor operation within thermal safety limits.
6. Provide automatic initiation of the periodic logs and special event logs for printout in the control room.
7. Initiate control rod withdrawal or insertion blocks if the prescribed rod movement sequence is not adhered to while operating at low power levels, known as the Rod Worth Minimizer Program.[3]

---

[3] "Design Specification for the Advanced Control Room", Pennsylvania Power and Light Company.

Three major elements compose the ACR, these are the control room configuration, the Power Generation Control Complex (PGCC) and the Plant Process Computer (PPC), which are illustrated in Figure 1.



Advanced Control Room Block Diagram

FIGURE 1

The control room, which is composed of front and back panels with CRT's, instrumentation and alarm control systems (known as the UOB), is the central location for operation and control of the unit. The control room is the physical basis of the ACR. The PGCC receives electrical signals from the plant and PPC and conditions the signal so that it can be used to efficiently control the unit. The PPC provides on-line monitoring of thousands of input points representing significant process variables. The system scans digital and analog input signals at specified intervals and activates appropriate alarms and indications if monitored analog values exceed predetermined limits, or if digital trip signals occur. The PPC performs calculations with selected input data to provide the operator with essential plant performance information through a variety of logs, trends, summaries and other typewritten data arrays. Computer output signals also include various displays to color CRT's for monitoring system status and parameters.

The PPC consists of two major systems, the Display Control System (DCS) and the Performance Monitoring System (PMS), which perform the required functions to achieve more efficient and reliable operation of the plant.

The Display Control System (DCS) scans 625 remote digital and analog signals from the process instrumentation, adjusts the collected data, and error checks it. It formats the data in accordance with the layouts selected for each video monitor on the UOB. Nine standard systems are displayed on the front panels in the control room. They are:

1. RWCU - Reactor Water Clean-Up
2. Condensate Systems
3. Feedwater Systems
4. Recirculation System
5. Control Rod Drive System
6. Neutron Monitoring
7. Nuclear Steam Supply Shutoff
8. Turbine Controls
9. Generators and Transformers

Separate "formats" may be selected for each system screen, based on plant operations. Each plant operation requires display of certain variables. Switching of formats helps select the optimum predefined display for the operating condition. This display can be switched locally at each screen by a master display control panel for all nine screens. Attachments D and E shows the individual CRT selection and the master display control panels, respectively. The operator can request a display of any system or format on any of the nine CRT's on the Unit Operating Benchboard (UOB) within one second in case of any CRT failure. Rotary switches and pushbuttons are used to select which of the various DCS formats are to be displayed on the CRT.

The Performance Monitoring System (PMS) performs the functions and calculations defined as being necessary for efficient operation of the reactor. These functions include monitoring of analog and digital inputs, validations, conversion and combination of collected data, and conducting performance calculations to determine the actual plant performance. Four subsystems provide these functions. They are:

1. Nuclear Steam Supply Subsystem (NSSS) - uses collected data to calculate reactor performance. It provides output to peripherals and to permanent storage for later retrieval.
2. Balance of Plant (BOP) subsystem - uses collected data to complete balance of plant performance calculations and to provide CRT displays and alarms.
3. Historical Record and Program Development (HRPD) - receives input from common core unit and processes the data for permanent storage. Development, maintenance and updating of programs and formats are also performed by this subsystem.
4. Powerplex (PPX) Subsystem - is used with Exxon Fuel and replaces General Electric NSS computer functions. Data is received from the NSS processor via fiber optic links to the Remote Data Analysis System located in a separate building at SSES. This data is used to perform in-core monitoring, predictions of future core operating conditions and other fuel management calculations.

On the Unit Operating Benchboard, the unit supervisor can access a keyboard and CRT display for either DCS and PMS. Several display services are incorporated into PMS. These services can be called from the keyboards on the UOB. These services include alarm, single point, group point, and video display services and logging and trend pen services. Single, group and video services are used to create and redefine variables and their display format. Logging and trend pen services help troubleshoot problems within the plant. Alarm services are divided into 3 categories:

1. Equipment Trips, displayed in Red.
2. Pre-equipment Trips, displayed in yellow.
3. Trouble or local alarms, displayed in white.

The hardware configuration for the plant computer is illustrated in Attachment F for the PMS and Attachment G for the DCS. DCS consists of remote analog and remote digital units which provide data from instruments located throughout the plant to switching units which transmit the data to the appropriate Data Acquisition Processor (DAP). The DAPs consist of two Honeywell 4400 processors, each scanning half of the inputs (at 4 scans/sec for accurate processing). The variable data is then sent to two Honeywell processors called the Display Control Processors (DCP). Each is capable of sending all CRT data to 4 Display Generators. A common memory allows data communication and data sharing between DCS and PMS. In addition, PMS consists of four Honeywell 4400 processors. Each performs one of the following functions:

1. Data Acquisition Processor for Balance Of Plant Data.

2. **NSS Processing, including data retrieval from PowerPlex.**

3. **HRPD, Historical Data processing.**

4. **BOP I/O operations with peripheral devices.**

A status display of the DCS processors is provided on the Standby Information Panel (SIP), referred to as the test reconfiguration unit (see Attachment H). In "AUTO" mode, it provides self-checks from any hardware problems, sending a signal to display any problems. A manual check can also be completed by operators or engineers if data integrity is questioned.

Each variable contained in the PPC has a preset value (precoded internally) to change the display CRT when the increment is reached. Each CRT is split into a 80/20 format. The top 80% displays the screen and the bottom 20% displays any Alarm Initiated Display (AID). Information on the display is either background or dynamic information. Background information consists of display formats, labels and units of measure. Dynamic information consists of graphs, plots, and numeric values. Where applicable, a diagram of the piping of the system is displayed (background), with the changing data from the process variables (dynamic). The CRT screens also use a system of color-based visual hues intended to aid the operator in locating specific information. The color schemes and their intended use are:

1. Green - Used for Lines and symbols in process diagrams to represent system components.

2. Cyan - Used as a supporting hue and applied to alpha numeric identification, scales and borders.

3. Yellow - Applied to all process variable display elements such as bar graphs and digital data.

4. Red - Restricted to use as a visual cue from emergency or abnormal conditions.

5. White - Used as a reference mark on scales adjacent to bar graphs to indicate process limits and to present low confidence data on instrumentation reliability.

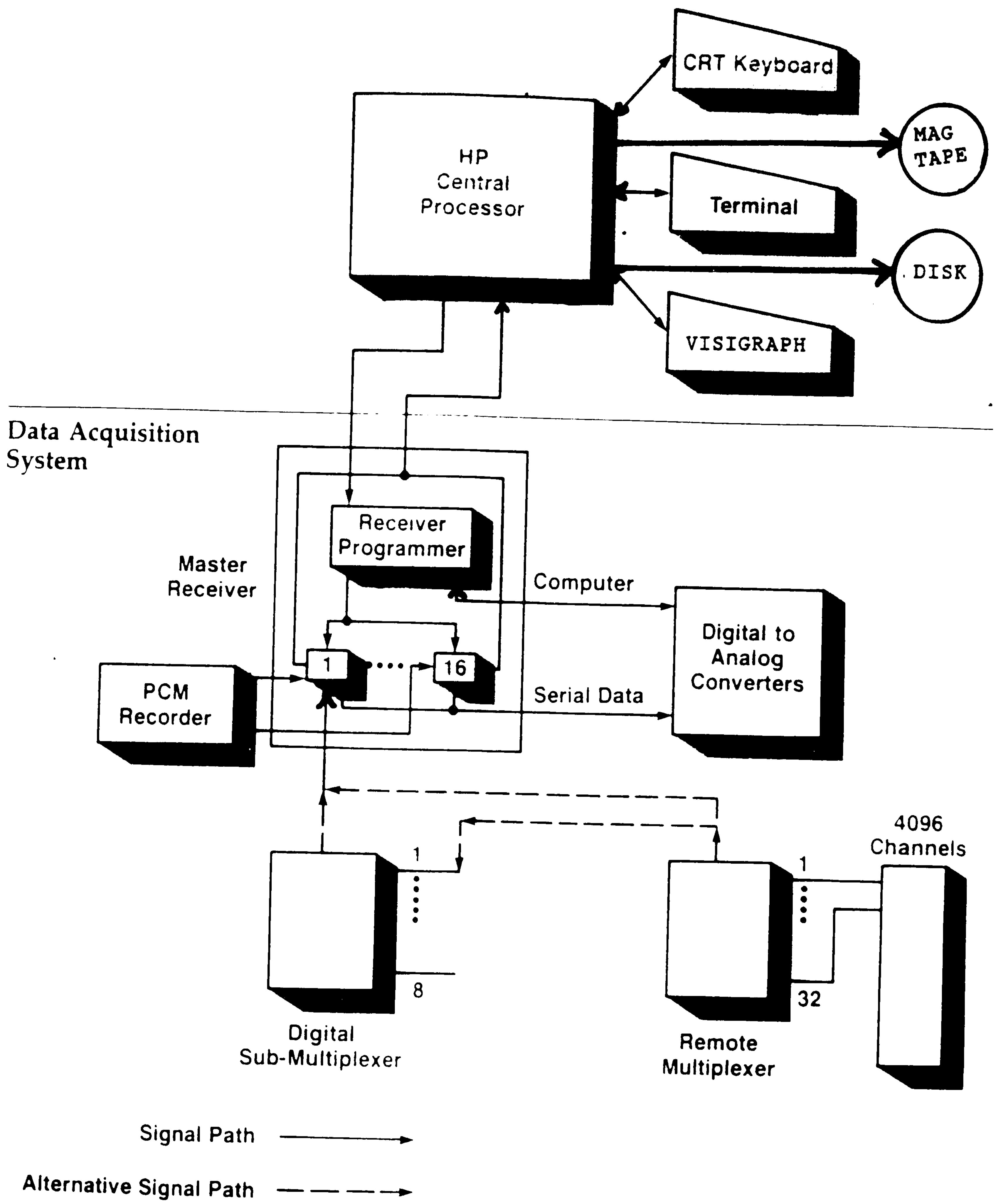
III. GETARS - Present Scope

GETARS is an acronym for General Electric Transient Analysis Recording System. GETARS is a third-generation system used initially for start-up testing at Power Water Reactors (PWR) and Boiling Water Reactors (BWR) power plants. Its popularity in nuclear plants is not a result of mandatory regulations, but from its unique ability to capture real-time data in a format engineering groups can use for such activities as surveillance tests, maintenance diagnostics, scram timing, and transient identification. It is used mainly by Shift Technical Advisors (STAs) and Engineering personnel.

GETARS has a Data Acquisition System (DAS) designed to record and display plant and system operating data, which can then be used to document and analyze their performance. DAS can be interfaced to any available process instrument such as accelerometers, tachometers, level, radiation, displacement, pressure and flow instruments or, more generally, any signal that can be converted into an electrical output. It can record up to 500 process signals, plus piping motion and rod scram time tests. The system monitors the reactor's response to planned transients, such as scram timing (which monitors the time it takes to insert a control rod into the reactor core to stop reactivity - see Attachment I for a sample run), Main Steam Isolation Valves (MSIV) closure times, and other surveillance and maintenance activities. However, its use is invaluable when the plant experiences unplanned transients, such as turbine trips, level transients, and other events.

GETARS has the capability to continuously check 50 setpoints for preset limits. The standard setpoint list includes parameters such as flux, pressure, flow and level. In a planned transient, the engineer usually inputs a step change while monitoring the controlled process variables in question. In an unplanned transient, i.e. any exceeded preset limit on any of the 50 monitored points, GETARS immediately saves the previous minute of data and 10-15 minutes of data following that event. The data that is saved involves 614 channels (from a possible 4096 channels) of data from various operating variables. This data must be collected to identify any problems throughout the plant, and to monitor certain safety systems as to how they operated during a transient versus how they were designed to operate. In the event of a reactor scram, this data is vital to support restart of power generation.

The basic hardware setup of GETARS involves a Hewlett Packard computer with 128K words of memory, a 50 M byte moving head disk for permanent and temporary storage, a 1600 bits/inch magnetic tape drive for permanent offline storage and backups, a terminal with 24 by 80 character monochrome video display and a Honeywell Visigraph printer/plotter for hard copies of data and graphs. Figure 2 shows a simplified diagram of this hardware configuration.



GETARS system Block Diagram

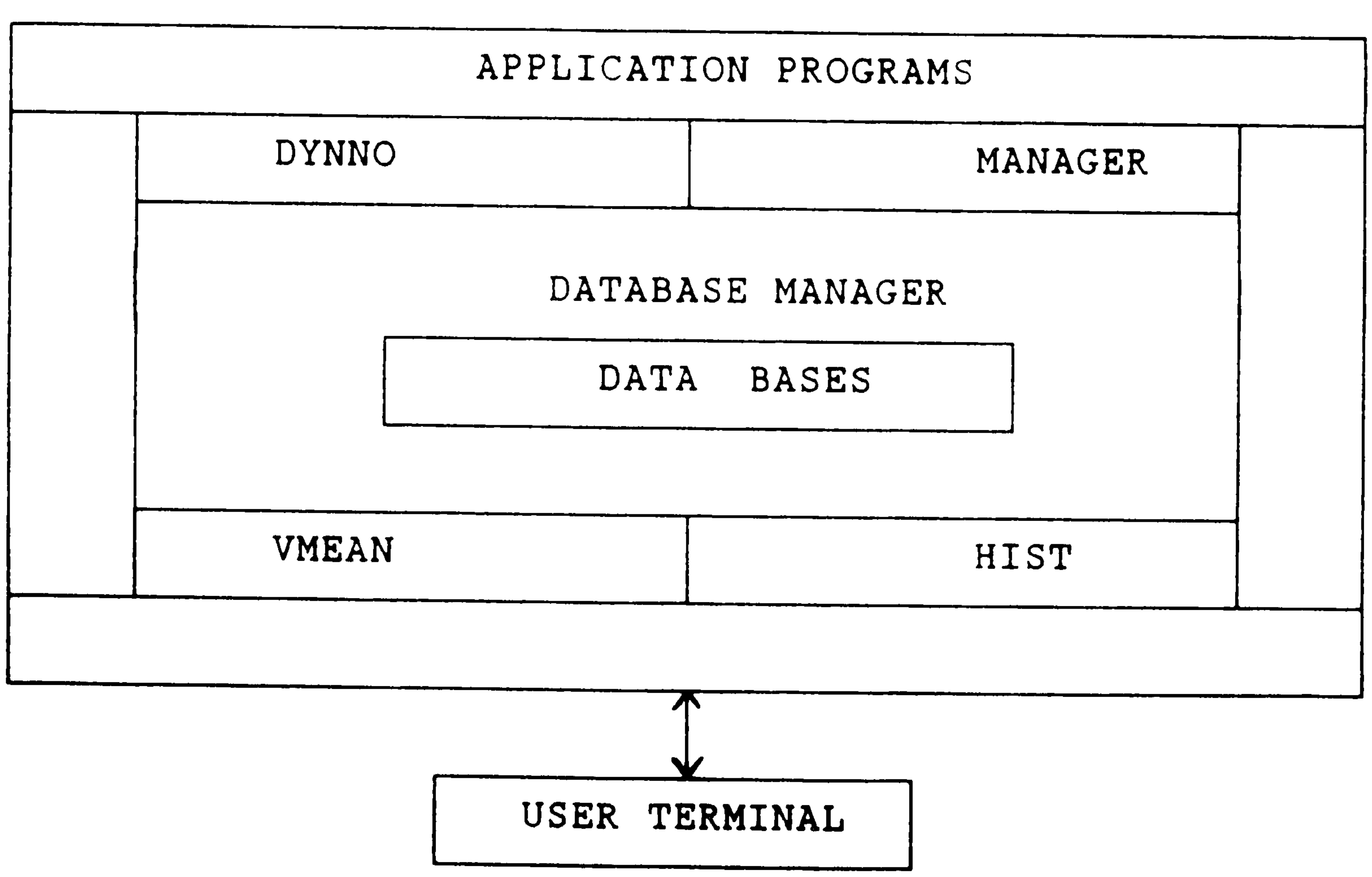
Figure 2

DAS consists of a master receiver, submultiplexer and remote multiplexers. The remote multiplexers receive the sensor signals from -10 to 10 volts (0 - 100% scale). The signal is sent at a 1 MHz bit rate to the submultiplexer and the master receiver where the data can then be processed by GETARS. A total of 4096 digital or analog signals can be interfaced. A Pulse Code Modulation (PCM) recorder can be used for high speed recording for tasks such as vibration analysis. This is currently not used at SSES. (See Attachment J for a simplified diagram of its DAS hardware configuration.) One system setup per unit is provided at SSES.

The GETARS computer is capable of sampling rates ranging from 1 to 1,000 times per second, and can capture a maximum of 1,000 samples per second, with a maximum throughput of 125,000 samples per second. The DAS used with GETARS can sample at rates greater than 23,000 samples per second per channel. It captures and records any selected 614 channels of signals (from 4096 channels available in the DAS), and at rates fast enough to permit resolution and analysis of almost instantaneous occurrences.

Both memory-based and disk-based supervisory software is used at SSES. The memory-based software is a real time executive program that operates with very low overhead. It provides a controlled environment for the high-speed DAS programs, including SENTINEL and RECORD (Attachments K & L respectively). SENTINEL is a network of real-time programs which scans signals from both analog and digital channel inputs. This system use was described earlier for planned and unplanned transients. It is similar in concept to an aircraft's flight recorder or switch yard oscillograph recorder. RECORD is a network of real-time programs which scans and records analog signals on magnetic tape or disk and provides a real-time strip chart plot of signals during data acquisition. Data can be plotted in real-time from any of the 614 channels but only 10 at a time can be plotted. The engineer has complete control of signal gain (engineering units), signal offset (where the plot is to begin), and the time axis. (See Attachment M.)

The disc-based software is a real-time executive system that provides data entry, data reduction, utility programs and program preparation functions. Figure 3 illustrates their relations.



GETARS DISC-BASED Software

FIGURE 3

The program preparation environment provides language processors, a source editor (EDIX), a relocating loader, and a file management package. These programs are primarily non-real-time data reduction and utility type programs. The following is a partial list of programs:

- HIST Displays selected signal data in engineering units or millivolts. It also provides statistical data.
- CALIB is an off-line program that will calculate slopes and intercepts in engineering units for user-selected analog channels. These can be used to update a point identification file automatically.
- EXPAND is used to calculate the expansion or contraction of a pipe and can compare it to design limits.
- FOREGROUND SENTINEL is the set of real-time programs that provides the same function as SENTINEL but allows concurrent program development and use.
- Other Off-line programs include DISPLY, V MEAN and DYNNO which can be used to analyze data from previously recorded tapes.

IV. Analysis

A. General

Analysis of computer systems is directly tied to the SSES modifications prioritization process. Computer modifications are not just analyzed and rated against each other. They are also ranked and their benefits are weighted along with plant modifications such as new pump installations, improvements to safety systems (e.g.- reducing water hammer in Emergency Service Water System.) Analysis of the computer systems is accomplished by answering the following questions:

1. Are the hardware and software configurations in full compliance with government regulations and requirements?

2. Are there any safety concerns or requirements? (Examples: any electrical or physical constraints or any probability of increasing an accident analyzed in the FSAR or creating the probability for an accident not defined in the FSAR.)

3. Is the system reliable?

4. Is the system outdated? Does it no longer meet the needs and requirements of the users of the system? Are there human factors issues that should be examined?

5. Are there any other non-tangibles? Can

improvements be made to provide functions not previously intended for the system, but will improve the plant operations and engineering support?

6. a. Can the changes be completed as minor modifications, where costs of implementing all changes and supporting documentation/training do not exceed $100,000; or

   b. Would it be a project requiring changes exceeding $100,000 with major change requirments in hardware and software changes, training requirements, new documentation and procedures?

7. Will the changes result in any financial savings? (Cost/Benefit Analysis).

Answers to these questions result in regulatory, safety requirements, and reliability factors being top priorities at SSES. Any other parameters (such as obsolete systems and new improvements) are secondary, but not ignored, especially if a change could be implemented as a minor project where limited resources will be needed and training requirements don't have to be implemented on a wide scale. The following portions of this section will analyze the Advanced Control Room (ACR) and General Electric Transient Analysis Recording System (GETARS) for all of the above issues.

B. ACR

1. Regulations governing design and operation of the ACR and Plant Process Computer (PPC) include:

a. 10 CFR Part 50 "Licensing of Production and Utilization Facilities, Appendix A, General Design Criteria for Nuclear Power Plants."

b. IEEE 279, 308, 323, 336, 338, 344

2. Existing design considerations present no safety concerns.

3. Reliability is 99% which is not only acceptable from a regulatory standpoint, it is a commendable record.

4. Human factors are an important consideration in a control room because the ease of identifying problems and the ability to react quickly are paramount concerns. This is accomplished by following the human factors guidelines set up by the NRC as NUREGs. References from the Human Factors Manual at SSES for control rooms include:

- "Process Computers" includes guides on computer access, CRT displays and printer response times.
- "Panel Layouts" includes control room panel layouts, which address topics such as panels used most frequently and required separation criteria for reliability.

Although the ACR was developed over 15 years ago with GE and implemented over 7 years ago, the concept of this control room was the state of the art, and still exceeds most control room designs in the nuclear industry. The latest development of control room technology by General Electric, one of the leaders in this industry, is presented in a product called "NUCLENET 1000". It implements the same control room configuration as the ACR, with the only major difference seen by the operator being the streamlined alarm panels provided above the CRTs for human factors improvements (see Attachment N). Of course, a new system would also provide the latest in hardware such as the faster and expanded memory, more options at the control of plant operations, and better software development tools. These are non-tangibles, and will not weigh heavily when any decision is made to implement changes.

5. Improvements to the ACR in two forms:

   a. Through GETARS and

   b. The Safety Parameter Display System (SPDS).

The implementation of SPDS supplements the ACR with improvements that go beyond the original design and intent of the ACR. Briefly, this system provides the operators and Shift Technical Advisors (STAs) with concise and easy-to-understand data relating to plant safety. It does not replace the ACR but it does focus on broad safety functions, determines which instrumentation is providing reliable information by synthesizing the data into a final form useful for diagnosis and decisions, and relieves both parties from tedious calculations that are needed quickly during emergency scenarios. SPDS was a product of the requirements mandated by the NRC through the following NUREG's:

1. NUREG-0737 "Clarification of the TMI Action Plan Requirements".

2. NUREG-0696 "Functional Criteria for Emergency Response Facilities".

3. NUREG-0654 "Requirements for Emergency Response Capability".

These regulations were not intended to preclude the design and intent of the ACR but to supplement the ACR with improvements recognized by the industry as an extension needed for plant operations to maintain the safety of the public. The most important aspects of SPDS is the primary display that includes reactor power, reactor water level, reactor pressure, drywell pressure and total noble gas effluent.

6/7. The current capabilities of the ACR are satisfactory in meeting the operators' needs in a control room environment. Many of these capabilities go beyond the requirements set by the NRC and other governing agencies. Other items such as the NUCLENET are 'nice to have' and would only be feasible if the changes were on a minor modification scale requiring small monetary resources and limited manpower. A preliminary cost/benefit analysis would indicate that the scope of a new hardware and software system would be extremely costly, and training requirements for the new alarm panels would require retraining of the six shifts of 7 operators each shift. For what is envisioned as returns of mostly a non-tangible nature, it would not appear to currently benefit SSES to invest in a large scale replacement and/or upgrade of the existing ACR.

C. GETARS

1/2. GETARS has been accepted in the nuclear industry as not only a start-up test program, but also as an answer to the NRC Generic Letter 83-28. This letter set the precedent for all nuclear power plants to evaluate control room instrumentation against scram analysis criteria to determine the level of instrumentation needed to conduct a scram analysis. This analysis includes:

a. showing proper safety system functioning per their design and

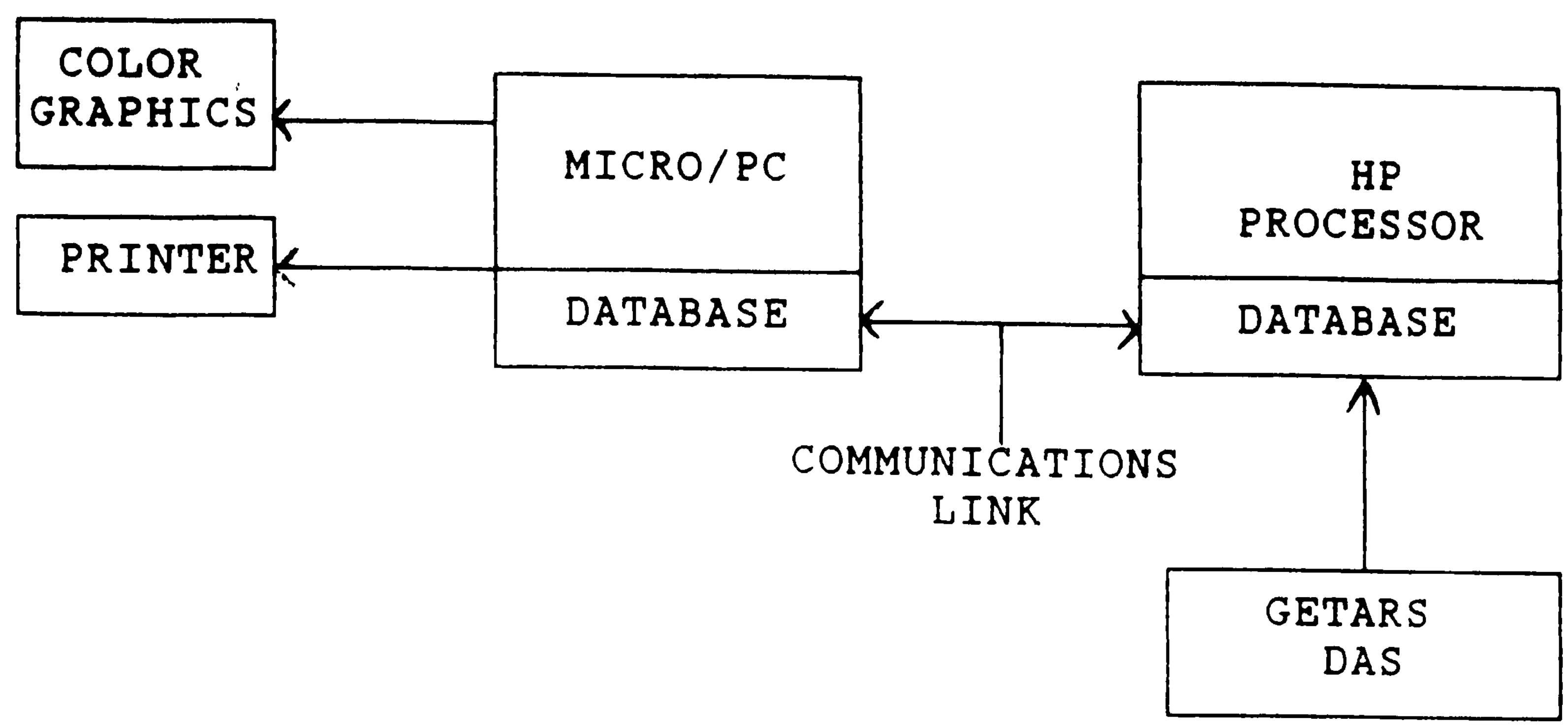
b. finding the cause of the scram prior to any re-start of a nuclear power plant.

Many plants use a transient recording system to determine or assist in determining how the plant functions versus depending on operation observation and on the slower plant process computers of the ACR. It is important to keep GETARS performing as well as the process computers of the ACR and adhering to the criteria followed for the ACR. Currently, GETARS meets all regulatory requirements and does not present a safety issue at SSES.

3. GETARS' reliability record runs close to 100% for being available during transients and capturing 180 out of 185 scram timings at each transient. This meets PP&L's standard for reliability. Reliability has an outstanding record because of the precautions that are taken to prevent any misuse of this system. However, the problems with this environment are addressed next.

4. During any user interaction with the available programs, such as VMEAN, the scanning rate of GETARS is reduced and may cause the transient recording system to fail to respond as quickly as it does while in SENTINEL mode. This raises some questions as to how such a useful system can be made available to all engineers who need data for various analysis. One approach which could be implemented to update this aspect of GETARS is the use of minicomputers or personal computers (PC) for optional accessing. Two concepts could be incorporated into the existing GETARS. They are:

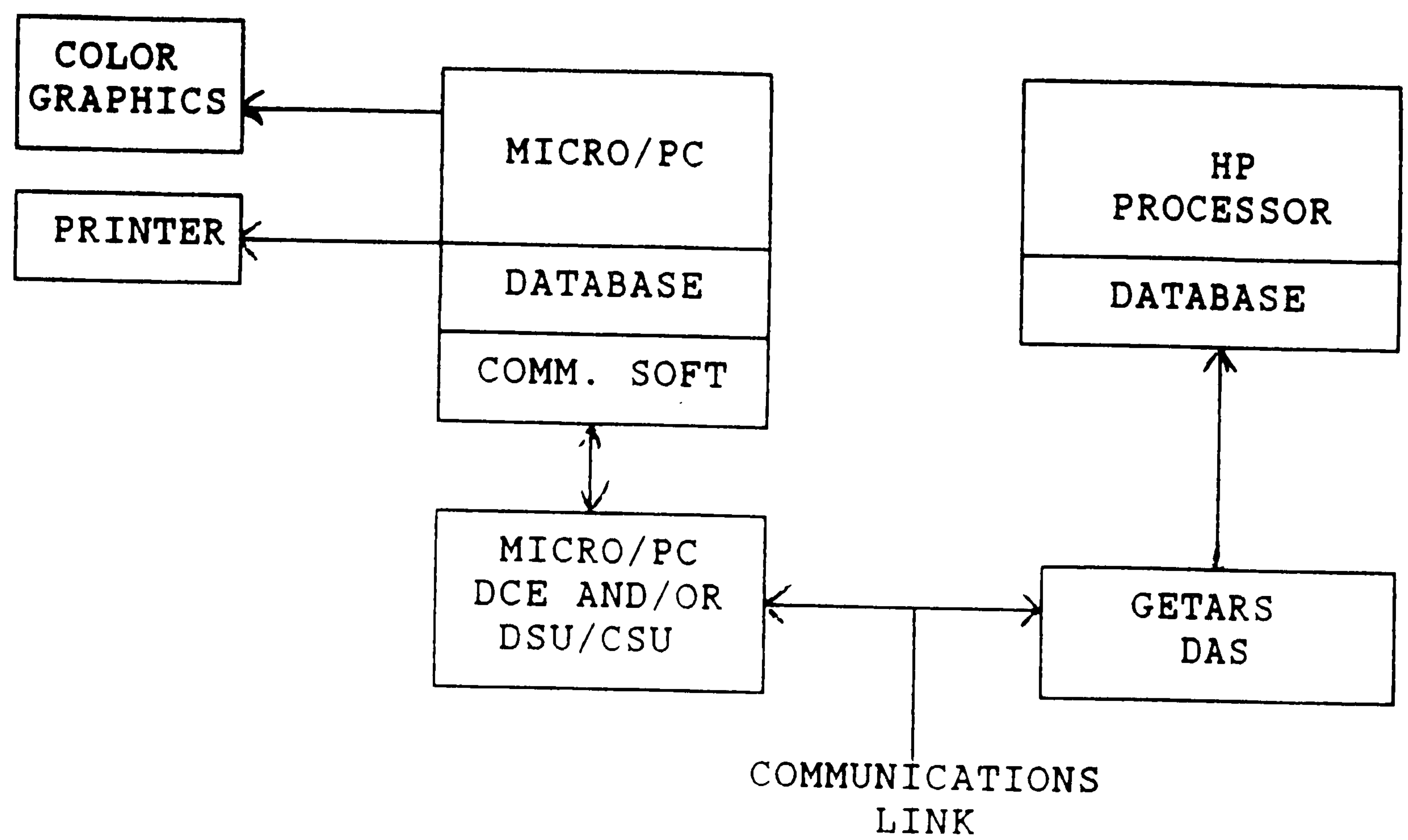
a) To utilize GETARS DAS and incorporate logic where a PC would interface with the HP central processor for needed information. The PC would share a common database with the HP. The interface between the two would be via a commercial software communications package and a communications port. Other commercial packages such as operating systems, full screen editors, language compilers and menu driven screen formats can be used to support this interface. The latest in PCs and color graphic displays can be used to create a responsive real-time and user friendly environment. Figure 4 represents this concept.



GETARS/PC Block Diagram

FIGURE 4

b) Another possible configuration, available to access the various data points read in GETARS, would be to have a separate DAS imbedded in the PC. This would require an additional hardware interface to the existing Validyne Data Communications Equipment (DCEs). A separate program could be developed to access data at a different rate than what GETARS currently does. This option provides a little more flexibility and separation from the HP processor. This method has also been successfully demonstrated in various plants on projects such as monitoring thermal losses in the primary cycle. Figure 5 illustrates this concept.



GETARS/PC with Separate DAS Block Diagram

FIGURE 5

Additionally, there are human factors issues which are ignored in GETARS. In its initial application, it was intended for temporary use. Thus, many unfriendly interactive screen sessions still exist in the version of GETARS that SSES uses. Attachment O shows that GETARS is not consistent in many areas with SSES policies outlined from the SSES Human Factors manual. Most of these items have been corrected in the newer versions of GETARS because they include a full menu format for data input and program queries by the user. However, better use of graphics could be implemented if a micro-computer and a work station were used to replace some of the functions of the plant process computer.

5. What improvements could GETARS make that go beyond the original definition of its use? Already GETARS has lived an extended life from plant start-ups and has demonstrated its usefulness for scram recoveries and surveillance tests.

Improvements could be made to eliminate a time consuming task that the Shift Technical Advisors (STAs) must do to obtain facts from GETARS to compile data needed in the scram analysis. This can be accomplished through pre-formatted reports programmed into a PC. If a PC was physically connected to GETARS as explained earlier for optional data retrieval, a floppy disk can be written by GETARS containing the transient data to be analyzed using a stand-alone PC for pre-formatted processing and future networking capabilities. This pre-formatted data would include safety parameter responses, valve closure times, all of which is normally obtained from GETARS. This step would help eliminate any errors created by human intervention in data re-entry.

6/7. The human factors issues should be implemented by upgrading to the next generation of GETARS provided by GE. This would create a more user-friendly interactive session with the use of menus and better error identification. Also, a PC/work-station connection should be made and available for use by all interested engineering groups. This would provide better access to GETARS without jeopardizing reliability. The cost of the equipment and available commercial software would place this item in the category of a minor modification, with savings to be recouped from more efficient engineering analyses.

V. Introduction of Expert Systems

A. General

"Expert Systems", computer programs that incorporate the sophisticated knowledge and thought processes of experts, are no longer science fiction but rather the newest form of the computer science and industrial engineering fields. Applications of expert systems can be split into three areas:

1. Applications where tasks involve diagnostics, analysis and / or troubleshooting.
2. Applications that deal with subjects for which limited experts are available.
3. Applications involving analysis in which some facts exist, but only imprecisely.[4]

Expert systems are best applied to solving problems in which the subject is highly detailed, but not tightly defined. Expert systems are not suited for solving problems in which the causes of a problem are diverse and unrelated.

At SSES, many applications are potential candidates, these include but not limited to, the following areas:

1. ACR-related;

a. Implementation of Control Room Procedures-

---

[4] Dickey, Samuel, "Expert Systems: Distilling Business Savvy", Today's Office, June 1986.

including Operating Procedures (OPs), Off Normal Procedures (ONs), and Emergency Operating Procedures.

b. Any application involving memorization by operators.

2. GETARS-related;

   a. Diagnostics

   b. CRD Timing

   c. Surveillance Testing

   d. Scram Recovery

3. Other Applications;

   a. Technical Specifications (TS)

   b. Emergency Plans

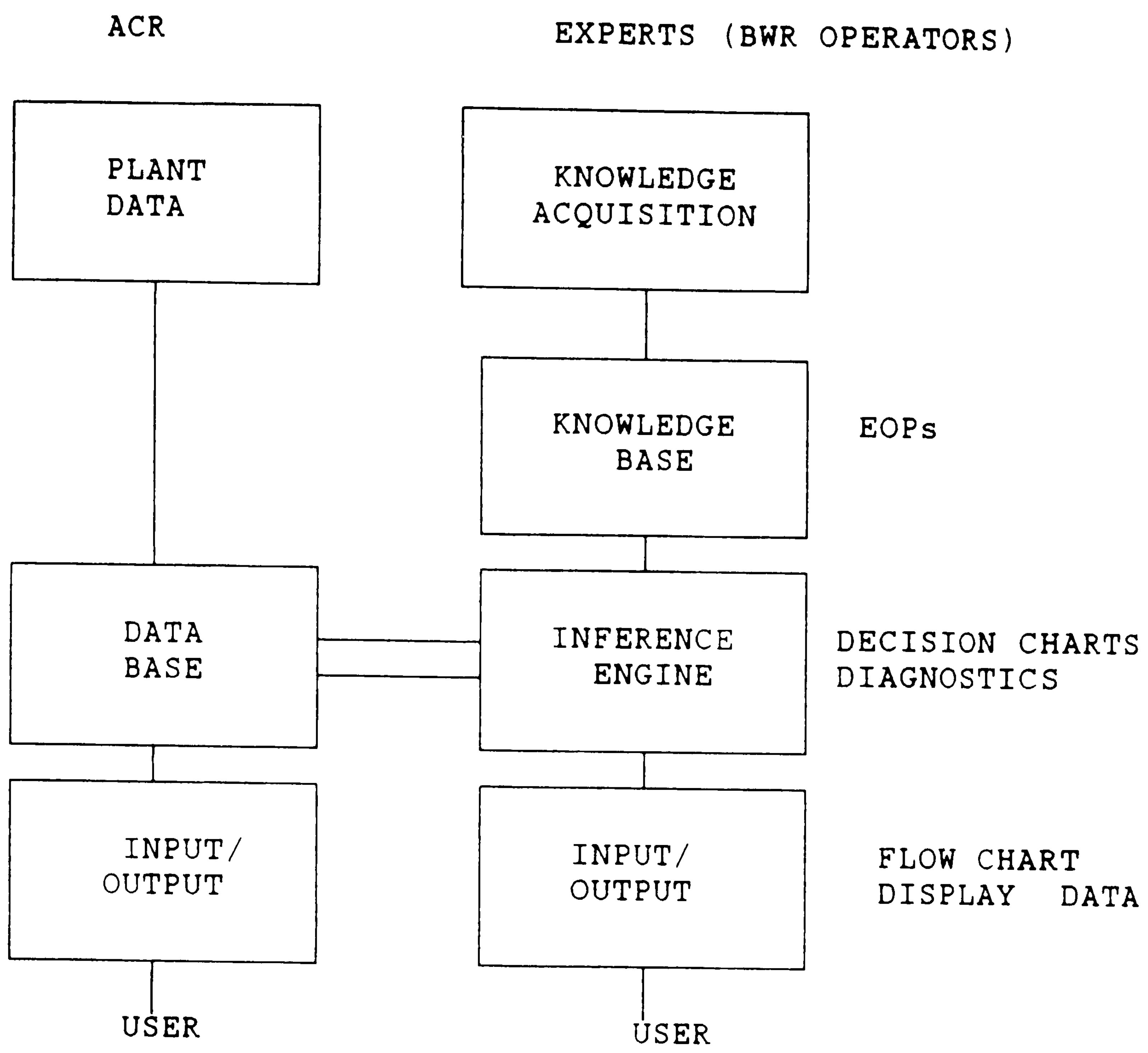
B. Advanced Control Room (ACR)

During the analysis of the ACR it was mentioned that applications do exist which go beyond the original design and intent of the ACR. In the control room, procedures are developed for all operating conditions. Current reference to these procedures is through manual research of the hardcopy procedures. These procedures appear to a prime candidate for expert system applications. The most promising of the procedures mentioned above would be the Emergency Operating Procedures (EOPs). These procedures have a series of conditions that must be addressed quickly in a decision-making process. The tests for the conditions are predefined, but the path which is followed depends on the results of the test. Hence, they appear to be a suitable candidate for an expert system application.

The EOPs are only used during an abnormal event where an operating parameter exceeds one of its predefined limits. These parameters, known as 'entry' conditions, are plant parameters that are available from both the ACR and the Safety Parameter Display System (SPDS). During these scenarios, operators utilize specially designed 3'x3' laminated boards containing the detailed information from the procedures. These boards are helpful in that they do what a expert system does - they prompt the users for information, and guide them to the next logical step. Depending on the abnormal event, entry is made into one of the ten EOPs. Different paths can be followed, depending on plant parameters and on decisions that are made by the operators, assisted by prompts from the board. Exit from the EOP is made once the entry condition and, ultimately, the plant, is stabilized. The main disadvantage over use of these boards is that they are numerous (at least one per EOP), cumbersome, and generally difficult to manage. The entries and guidelines of these boards and the EOPs make an optimal knowledge-base for an expert system.

To better explain the methodology of incorporating EOPs into expert systems, the Reactor Pressure Vessel (RPV) Control (EOP 102), will be referenced. Attachment P shows a simplified version for easier reference.

The following figure 6 gives a simplified block diagram of the components required to make this expert system function.



ACR Expert Operating System

Figure 6

The right side shows the interrelations between the components of an typical expert system, including; 1). the knowledge-base which contains the guides and rules detailed in the EOPs; 2). an inference engine that contains inference rules and user interfaces to gain the desired input/output that the user needs to help make a decision; 3). the inference shell that could help simplify the development of the EOP knowledge-base and inference engine. The left side of the figure contains a simplified block diagram of the existing process computer containing the needed information and the database. The inference engine must obtain the plant parameters that are needed to complete the expert system.

Since the knowledge-base is already predefined in the EOPs, the knowledge acquisition is 80% complete. The knowledge-base would contain the five entry conditions and other entries from other EOPs to start the inference process of the expert system. In this EOP, three paths must be executed simultaneously, with each section containing an If-Then-Else sequence. When an entry condition exists for an EOP, an alarm should be provided to the operator, as well as a signal to the inference engine to begin processing the applicable EOP. Plant parameters that are reliable as indicated by the process computer can be fed into the inference engine and can be shown to the operator on the EOP. Any needed information can be prompted to the operator so the next decision can be made until the entry condition stabilizes and an exit out of the procedure is reached.

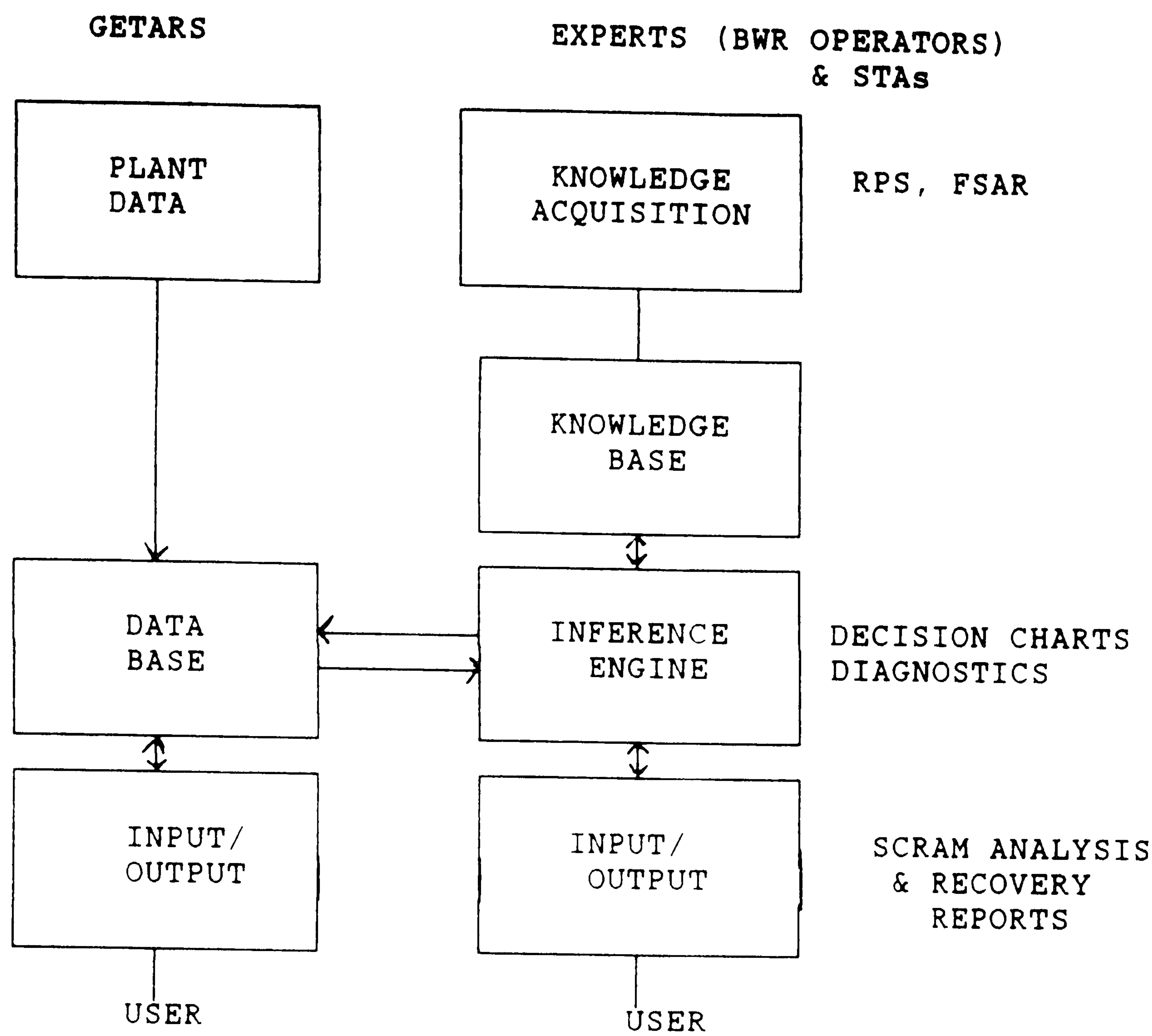
C. G.E. Transient Analysis and Recording System (GETARS)

Four of the eight expert applications mentioned earlier in this section can be developed through the GETARS system. These are:

1. Scram Recovery
2. Surveillance Testing
3. Diagnostics
4. CRD Timing

Currently the Shift Technical Advisor compiles information from several sources and determine what caused the scram. This 'Scram Recovery' is necessary prior to restarting the affected reactor. Since GETARS is used for all this information (unless the GETARS system was not running), it would be appropriate to have GETARS determine the cause of the scram. The knowledge-base would consist of both the Operator's and STA's background on transient analysis as defined in the FSAR and the scram trip signals from the Reactor Protection System (RPS). (See Attachment Q for all the possible signals from RPS that will cause a reactor scram and Attachment R for a list of the most common analyzed transients in the FSAR.) Operators and STAs are trained on the possible causes and the reactor's corrective response for all transients analyzed in the FSAR. If the reactor's response does not correct the transient, the RPS initiates a scram from the various built-in protections designed to stop the transient. The instruments that measure the parameters in these transients, such as reactor pressure and reactor temperature, have two separate channels that are wired into the DAS portion of GETARS. This gives GETARS added redundancy in case of a failed instrument and thus would make the expert system accurate in its analysis. Figure 7 on the next page shows the relationship of the expert system to GETARS. The right side represents the expert system components and the left side represents GETARS' components; this representation will be easier to implement if GETARS utilized a separate mini-computer for this activity. Either forward-chaining or backward-chaining methods can be used to determine the cause of the scram. In the backward-chaining method, the user (STA) can guess at what caused the scram. The expert system can then chain backwards to determine if various parameters responded to that type of accident, thus confirming the STAs guess. In the forward-chaining method, the expert system reviews any parameters that were out of a predefined range at the time of the scram. It can then follow possible paths to determine the accident type that caused the scram. The forward-chaining method is the best method, since it does not require an expert (the STA) to be present for prompting.

This allows the STA to complete other work duties.



GETARS Expert SCRAM Recovery

Figure 7

Surveillance testing is another expert application that can be applied to GETARS. Experts in both GETARS and the system expert for the surveillance must be involved in the test. When a test is run, normally the expert would review certain parameters for the proper predefined responses. These parameters must be analyzed for response times and for the proper response actions (such as a valve closure). The experience of the system expert can be captured in the knowledge-base so the test can be run without the expert present. An expert system can systematically review all parameters and determine if the test was a success.

The CRD timing and diagnostic applications operate on the same principles as surveillance testing. These applications can be implemented in-house (as described above) or they can be purchased from various companies that have already developed expert systems in these two areas. GE is the manufacturer of the CRD's and Hydraulic Control Units (HCUS) and have serviced this equipment over the last 20 years. They have developed this knowledge-base into an expert system called 'DRIVEX'. DRIVEX diagnoses both CRD and HCU problems like one of their veteran CRD diagnostic engineers, without the high cost of calling in the engineer each time a problem occurs. The system runs on any PC or PC-Compatible computer, and interfaces with the existing GETARS DAS and graphics systems. Problems such any CRD insertion and withdrawal timing errors are handled, as well as variations of hundreds of possible malfunctions. Since the development of a new computer system is costly, the use of this 'off-the-shelf' type package would presumably be the best cost effective path to take.

D. Other Applications

Other applications include:

1. Technical Specifications - which are NRC required and company created specifications that each nuclear plant must adhere to. Any deviation from the specifications causes a Limiting Condition for Operations (LCO). The company has a predefined time frame allowed to resolve the discrepency causing the LCO and thus bringing the company into compliance with the TS and avoiding a forced shutdown of the affected unit. Each time frame is based on the type of problems causing the LCO. The current TSs are located in a hardcopy manual layout in a cumbersome format. References are difficult to find if one is not familiar with this layout. This might also be suited to hypertext.

2. Emergency Plans - where an optimum evacuation plan can be developed, depending on the direction of the wind and topography.

Applications to Technical Specifications and to Emergency Planning were briefly mentioned to show the need for improvements in these areas. This was also done to demonstrate the potential for versatility and the wide-ranging capabilities that exist for future implementation of expert systems.

VI. The Integration of Expert Systems

The computerization of knowledge and decision-making in expert systems represents a fundamental change in plant operation technology. Certain management acceptance and organizational adaptation are needed for expert systems to be successfully integrated. There are basic industry principles to be followed when introducing a new technology. Certain principles can be remembered when deciding which expert system to present first:

1. New technologies are usually expensive and crude when first introduced. The first introduction of expert systems were developed in languages such as COBOL, PL/1, LOTUS on machines that were used for other corporate purposes. These systems had limitations that probably are not forgotten by some managers.
2. Technologies have their limitations. Expert systems should not be considered where the domain has not been developed yet. A more common application should be used first when the success rate is high. (ACR is high risk, where applications such as DRIVEX are low risk because expert diagnostic packages have been developed and used.)
3. Both new and old technology can grow together until finally the new technology is accepted. The old methods do not have to disappear. Again, GETARS would be an ideal environment in which to have the old and new co-exist.

Decisions can be made based upon experience and research. Once properly tested in an operating environment, the expert system can be run to determine the cause of a SCRAM. The old and new can be compared. As the new GETARS gains a good track record, the old one can be phased out.

4. Unsuccessful organizations will usually marginally recognize the value of a new technology. PP&L is one of the leading plants in the nuclear industry and is recognized as a successful organization. They are positively grounded in innovation, and at the same time plant operations are not jeopardized.

5. Successful integration of new technology almost always requires an internal champion. Internal in the organization, the expert systems must be presented in a persistent manner to upper level management. Proposals and backup capability are essential for success. (DRIVEX presents a problem not having an expert internal to the organization.)

6. Acceptance and integration of new technologies are always under fire. Again, the old concept "It's better to start small and be successful" definitely applies to new technology. Implementation, slow, small, and safe also leaves a lasting positive impression on management when it comes time for future implementation.

7. Social acceptance of new technology must not intimidate those experts that must be relied on to make the expert

system a success. Care must be taken to ensure that expert system introduction does not supplant existing employees (STA's and engineering employees). Company politics could kill a system propsal in a hurry.

8. It is preferable to maximize return at minimum risk. Usually, one will incur a larger risk (increased investment) proportional to the size and function (closer to a central, primary process) of the unit. The safest investment to go with is a pre-developed package that has demonstrated potential, along with support expertise to guarantee its service and availability.

9. A system that has no recognized problems, and is performing well in the eyes of management, is not the system to go after with proposed improvements (expert application). It is easier to obtain approval for a system that has a history of trouble, one that is perceived as an important system, and one that can be converted with a maximum of improvement and a minimum of cost.

10. An additional consideration, particularly for nuclear power plants, is safety. If the margin of safety is demonstrated to be improved substantially by implementation of an expert system, even at a significant cost, a prudent management may embrace the package. In some circles, improved safety is considered priceless.

These rules must be kept in mind while selecting and presenting the first potential expert system to management. The reason for implementing any project is directly tied to payoff or rate of return. In general, the simpler the scope of the project, the fewer unknowns, the lower the perceived risk, the higher the chances are of management approving the project. The old cost/benefit analysis may be more difficult to apply in determining the relative merit of new technologies. Things such as developmental cost (engineering and programmer development) and initial hardware and software purchases to support expert system development must be examined. A higher risk venture may bear merit in certain cases because competition is very keen and the very existence of a business may depend upon how "state of the art" its operations are.

Reasons other than financial savings may be very significant in weighing the importance of a proposed expert system. Non-tangibles often have to be "quantified", such as viability of a proposed system in solving a prevailing corporate problem that cannot be solved otherwise. Determination may also have to be made whether or not the problem is solved partially or entirely, and whether the problem reoccur in the future.

One example of a desirable system to upgrade is one that may undergo a relatively modest installation to implement an expert system status, and by doing so, may relieve the company of a cadre of highly-paid "required" consultants to maintain, support, and supplement the current system. The installation proposal, in this case, may result in a high rate of return for the company.

Based upon the attached assessment (Attachment S) and the above discussion, DRIVEX is the most suitable expert system application to supplement the diagnostic capabilities of the GETARS. At a relatively low cost, and with guaranteed support personnel, implementation of this system would increase the level of safety at SSES. And, at the same time, DRIVEX implementation can create a financial rate of return by reducing ongoing engineering costs which would be incurred in hydraulic control unit (HCU) and control rod drive (CRD) diagnostics.

Upon the demonstrated success of the DRIVEX system, company management awareness of the capabilities of expert system technology would be greatly enhanced. At this point, a secondary system may be proposed for installation in the GETARS. This system could then be developed by in-house personnel to perform some of the tedious decision-making involved in post-scram or post-accident analysis. There is an obvious financial rate of return here in saved technical costs and an increased factor of safety by having the expert system aid in the decision-making process. Additional costs are eliminated by having the down unit return to service much more quickly with the aid of the expert system.

The third area of substantial improvement at minimum cost would be the "expertization" of Technical Specifications. Available PC packages (such as VP Expert, Guide 2.0 or Level 5) could be obtained and adapted in-house at a minimal investment to the company. Recouped engineering costs would be immediate and substantial, because technical specification analyses are performed constantly. Many of the cumbersome logic pathways can be expertized (relatively easily), eliminating the need for tedious, and repetitive, and redundant work.

Ultimately, expert systems applications will inevitably be made in the ACR (EOP expertization in the near future), and in perhaps all other systems involving decision-making processes that have not been discussed. Many of these, however, will involve future technology improvements and simplification that will correspondingly reduce the associated risks and costs of expert system application.

VII. Future Developments

Over the next several years changes will become visible as modern managers are challenged by this new technology. Almost all organizations of the future, in order to maintain a competitive edge, will need to find ways to incorporate expert systems into their day-to-day operations. This force, driven by intense competition, will create increasing demands for higher software productivity and reliability, better identification of true expertise, establishing more knowledge bases, developing systems capable of addressing more complex problems, and inventing faster processors. Management information systems, computer sciences, and industrial engineering departments at universities and colleges across the nation are continuously adding research programs, courses, and specialties addressing these issues. Most estimates of the combined size of the AI market in 1990 range from two to three billion dollars; expert systems will account for 20-30% of this total. These above actions and statistics will help SSES address the issues of using expert systems with the ACR, including the EOPs and even more decision-making processes that the operators must address in every day operations.

A key to the commercial success of any innovation is how the leading companies respond to it. With expert systems the response has been tremendous. Major companies, such as Ford, Sperry, Texas Instruments, and the Department of Defense, have been actively developing million dollar projects involving expert systems applications.

As future expert systems become more complex and integrated, severe demands will be placed on current hardware technology. Current technology must be improved, or new technology must be developed, to accommodate these demands. These developments have already been taking place in companies such as Texas Instruments in their development of the Compact Lisp Machine, and Bell Laboratories with their development of parallel processing which has enabled them to create an expert system on a single chip.

Eventually, expert systems will affect almost every area of operations of an organization and could become the most integral part of an organization's normal operations of the future. Potential applications range from management to production. With the increased application use of expert systems, more powerful systems will be demanded. This demand will pull the economic forces of research to develop more sophisticated hardware, which is already been seen with Bell Lab's expert chip and parallel processing. We will be at the point where the limitations to an expert system will be the human knowledge and understanding - not the hardware and software. This will make almost any application with decision-making at SSES, a solvable expert system.

VIII. Conclusions

At SSES, computer technologies have been an aggressive area of development. Two of the current computer systems that support plant operations and engineering personal, the Advanced Control Room (ACR) and GE's Transient Analysis and Recording System (GETARS), are definite signs of this progressive attitude in the past years. To keep this progressive and competitive edge, management must assess these systems and propose improvements. Minor improvements to these existing computer systems include; 1). provide easier access to both the ACR and GETARS for engineering personnel, 2) upgrade GETARS' operating and software systems and most importantly, 3) to integrate the new technologies in the computer and industrial fields. "Expert" systems is the one of the newer technologies that can enhance plant operations and help support engineering activities. Many applications are good candidates for expert systems; however, the following applications should be introduced to management, in the listed order, for a greater acceptance and success rate:

1. Install DRIVEX with GETARS for "expert" diagnostics.
2. Develop and install an expert system on GETARS for scram recovery.
3. Develop and install an expert system on a PC for easier access and retrieval of Technical Specifications.
4. Develop and install an expert system to address the Emergency Operating Procedures on the ACR.

Bibliography

-----., "Control Room Technology", Control Engineering, June (1988).

Carter, R., "Management Accountability and Corporate Security", Administration Management, June (1986).

Correll, John T., " Machines That Think", Air Force Magazine, July (1986).

Dickey, Samuel, "Expert Systems: Distilling Business Savvy", Today's Office, June (1986).

Electrical World, "The Greenhouse Effect: New Climate, Same Old Target", Electrical World, Sept. (1988).

Emmett, Arielle, "Do Managers Believe What They See?", Computer Graphics World, September (1986).

Faltermayer, Edmund, "Taking Fear Out of Nuclear Power", Fortune, August 1, 1988.

Frost, Robert A., Introduction to Knowledge Based Systems, New York, MacMillan, 1986.

IBM Technology Educational Group, "Telecommunications and You", Morehead and Company, Los Anageles, California, Feb. 1987.

General Electric Company, GETARS User Guide, 1988.

Keller, Robert, Expert System Technology: Developments and Applications, N.J., Yourdon Press, 1987.

Landry, John B., "Examining Expert Systems", Computerworld (Focus), July (1986).

Martin, James, Design of Real-Time Computer Systems , Englewood Cliffs, N.J., Prentice-Hall, 1967.

Penna. Power and Light Co., Advanced Control Room Design Document, 1980.

Penna. Power and Light Co., Safety Parameter Display System (SPDS) Design Documents, 1982.

Penna. Power and Light Co., SSES Human Factors Guidelines, 1988.

Penna. Power and Light Co., PP&L Final Safety Analysis Report, 1974.

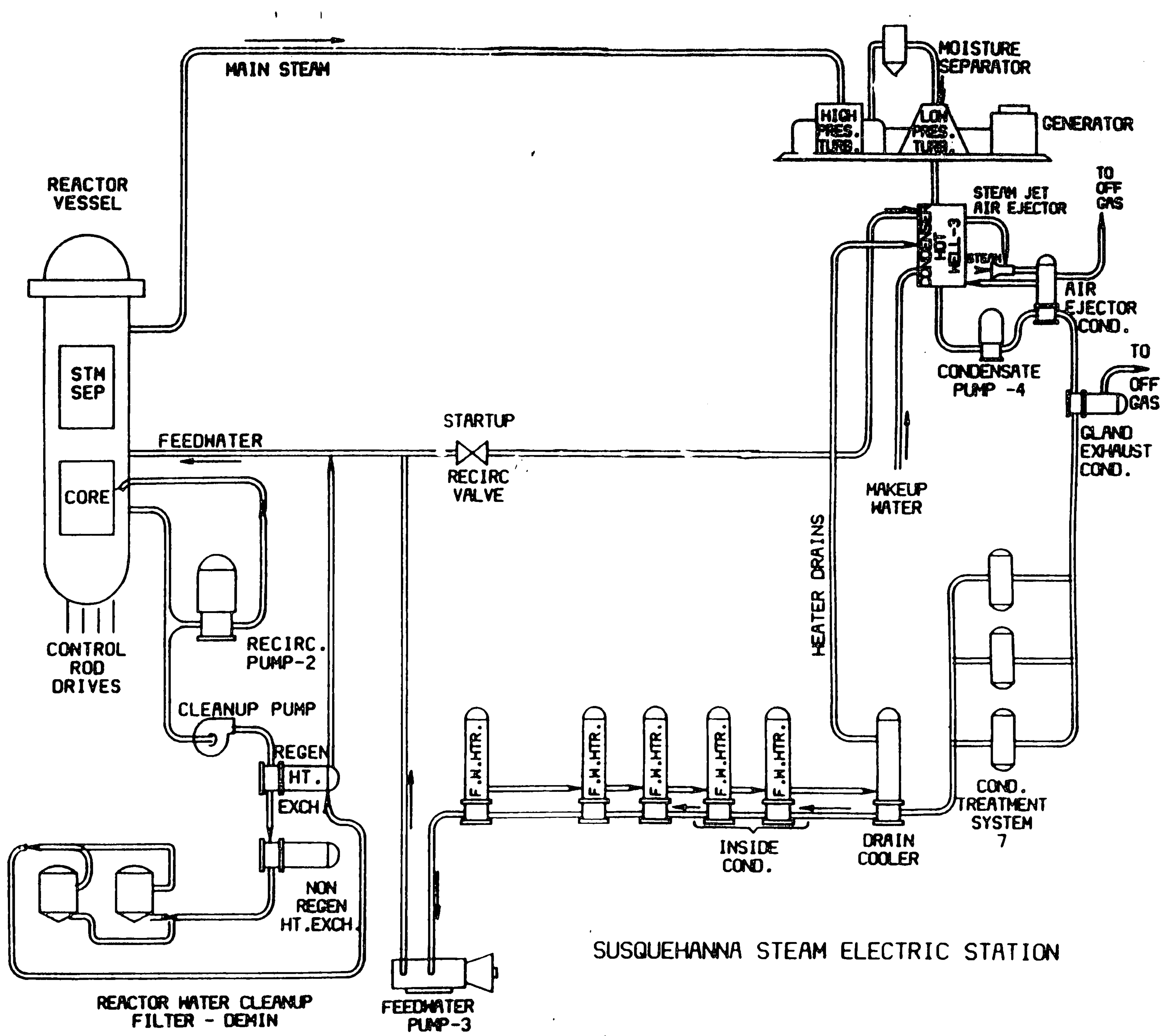
Plasket, Richard L., "Project Management: New Technology Enhances Old Concepts", Journal of Systems Management, June (1986).

Rowe, Stanford, Business Telecommunications, N.Y., Science Business Research Associates, Inc., 1988.

Simons, G>L>, Expert Systems and Micros, England, The National Computing Centre Limited, 1985.

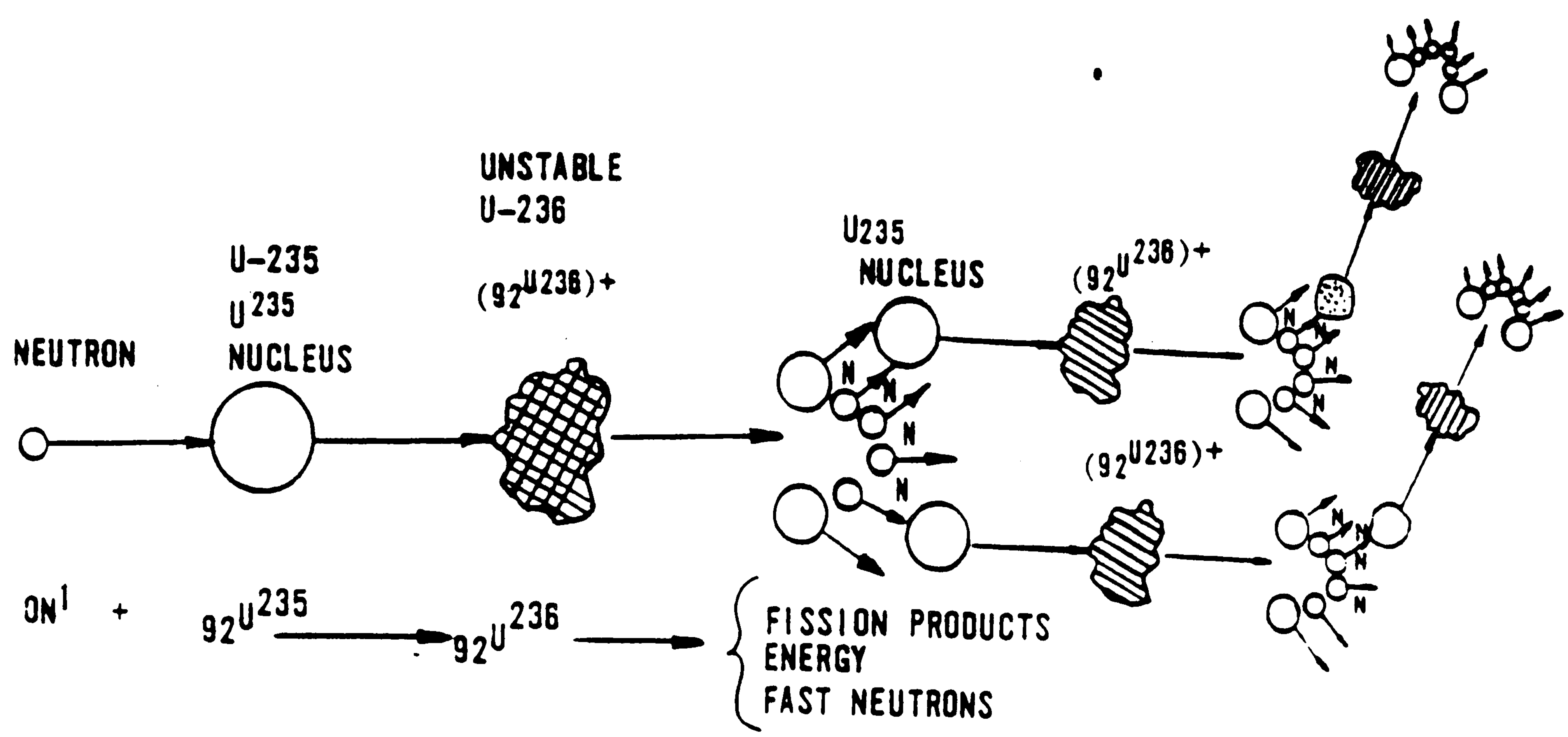
Wolfgram, T.S., Dear, C.S., Galbraith, Expert Systems for the Technical Professional, N.Y., John Wiley and Sons, 1987.

United States Regulatory Commission, United States Code of Federal Regulations, 1988.



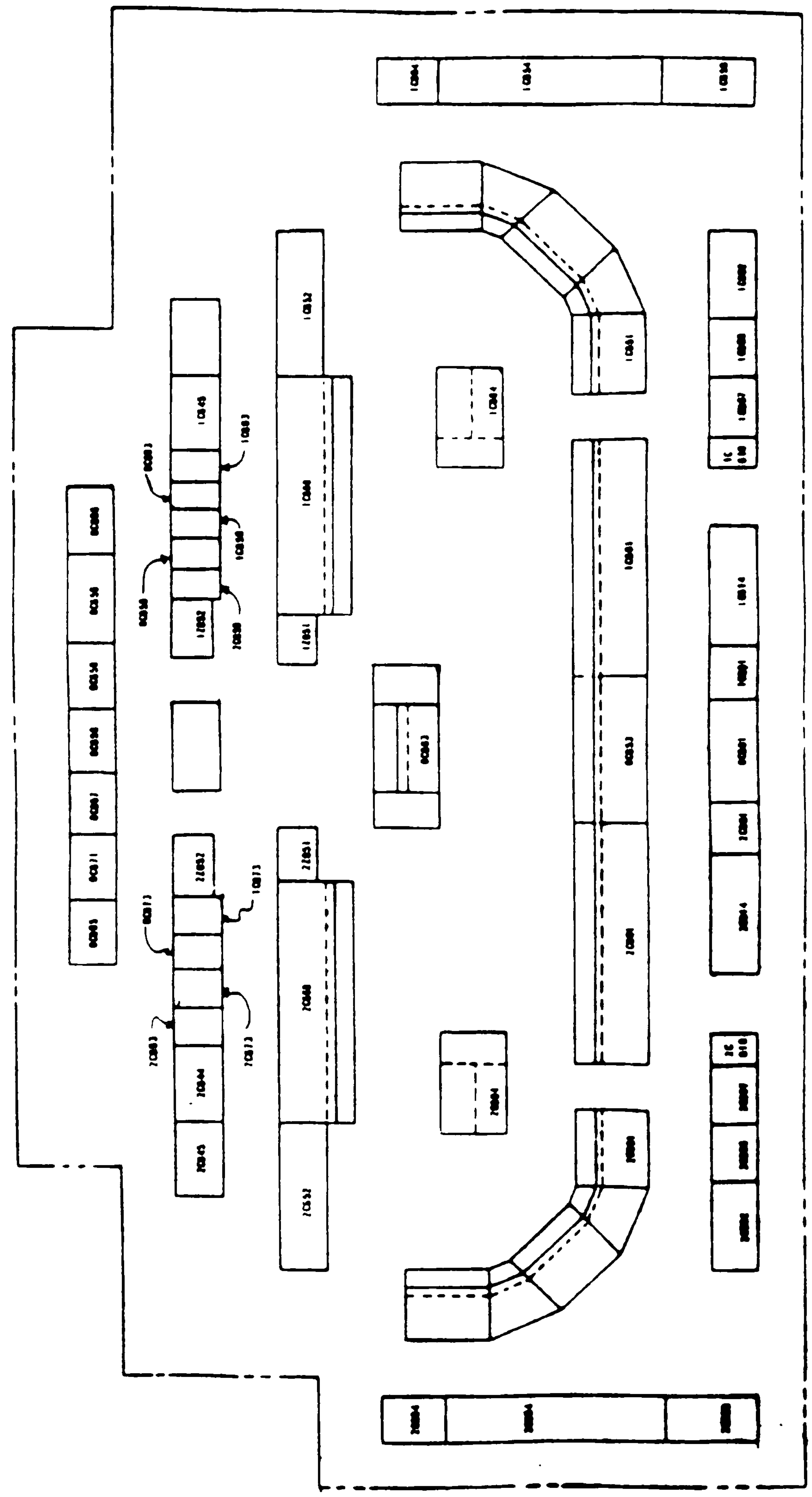
Susquehanna Steam Electric Station Primary Cycle

ATTACHMENT A



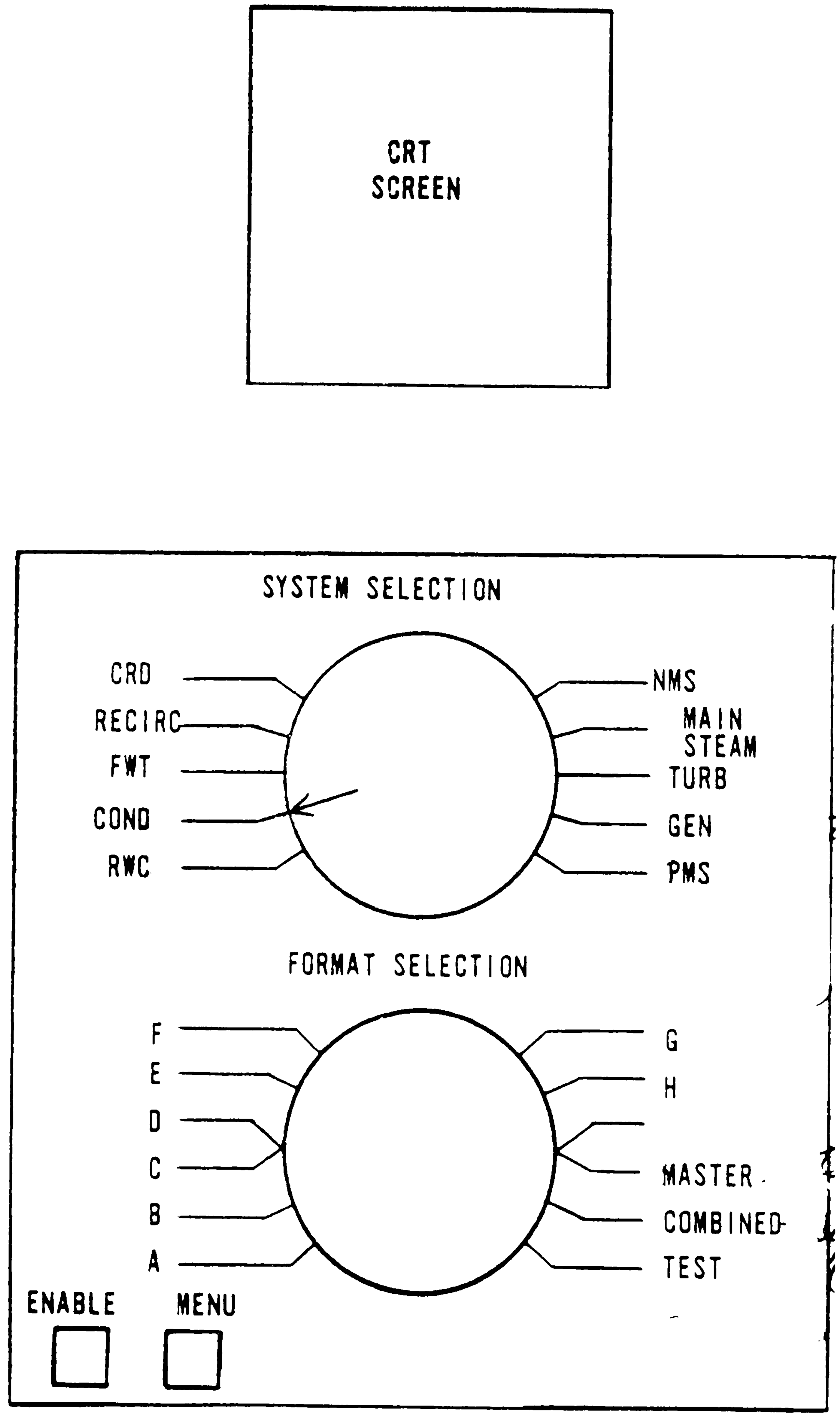
Typical Chain Reaction

ATTACHMENT B



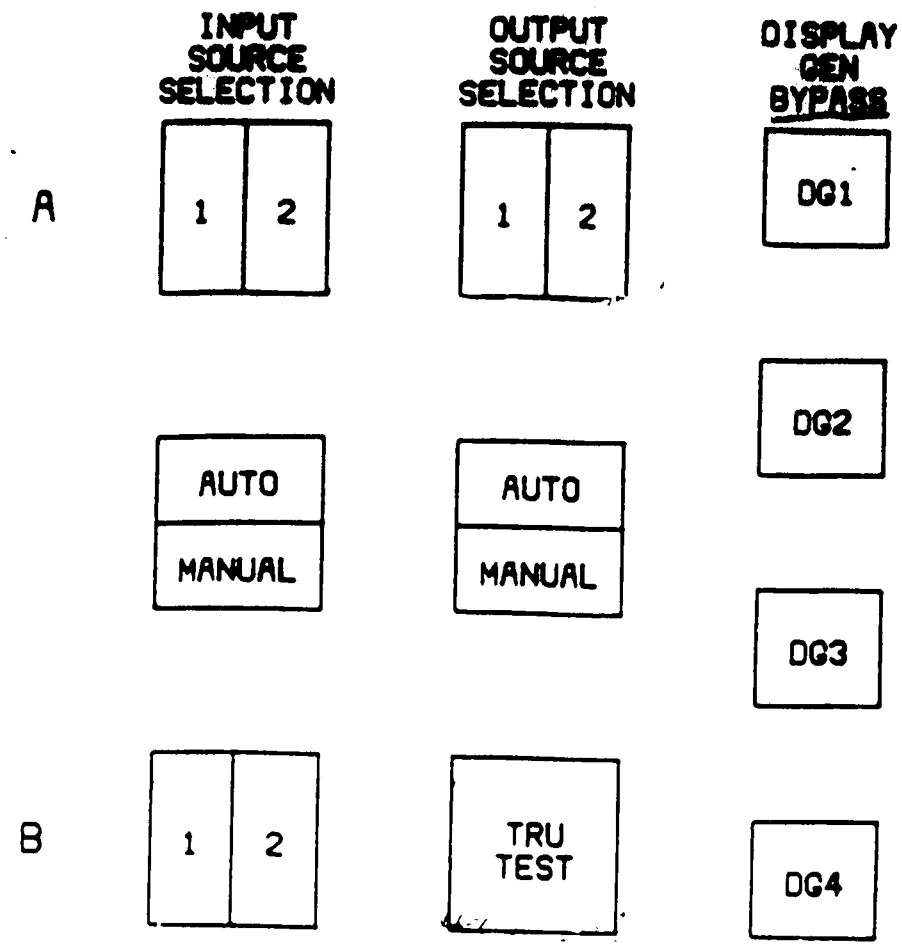
Advanced Control Room Layout

ATTACHMENT C

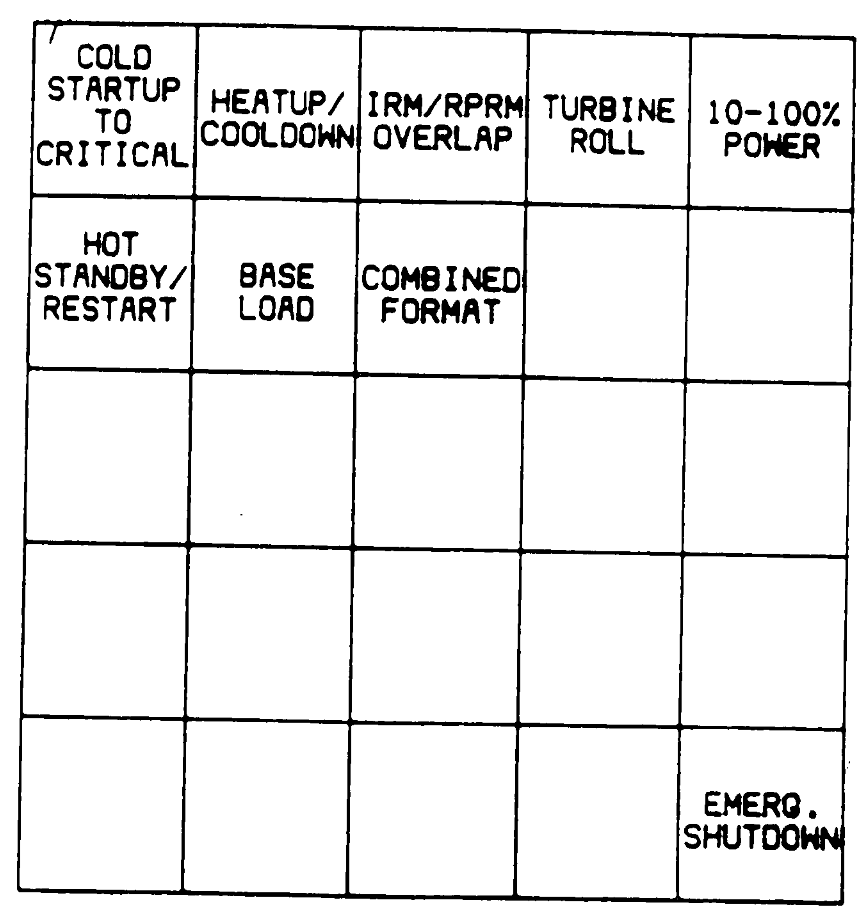


DCS Operator Interface

ATTACHMENT D



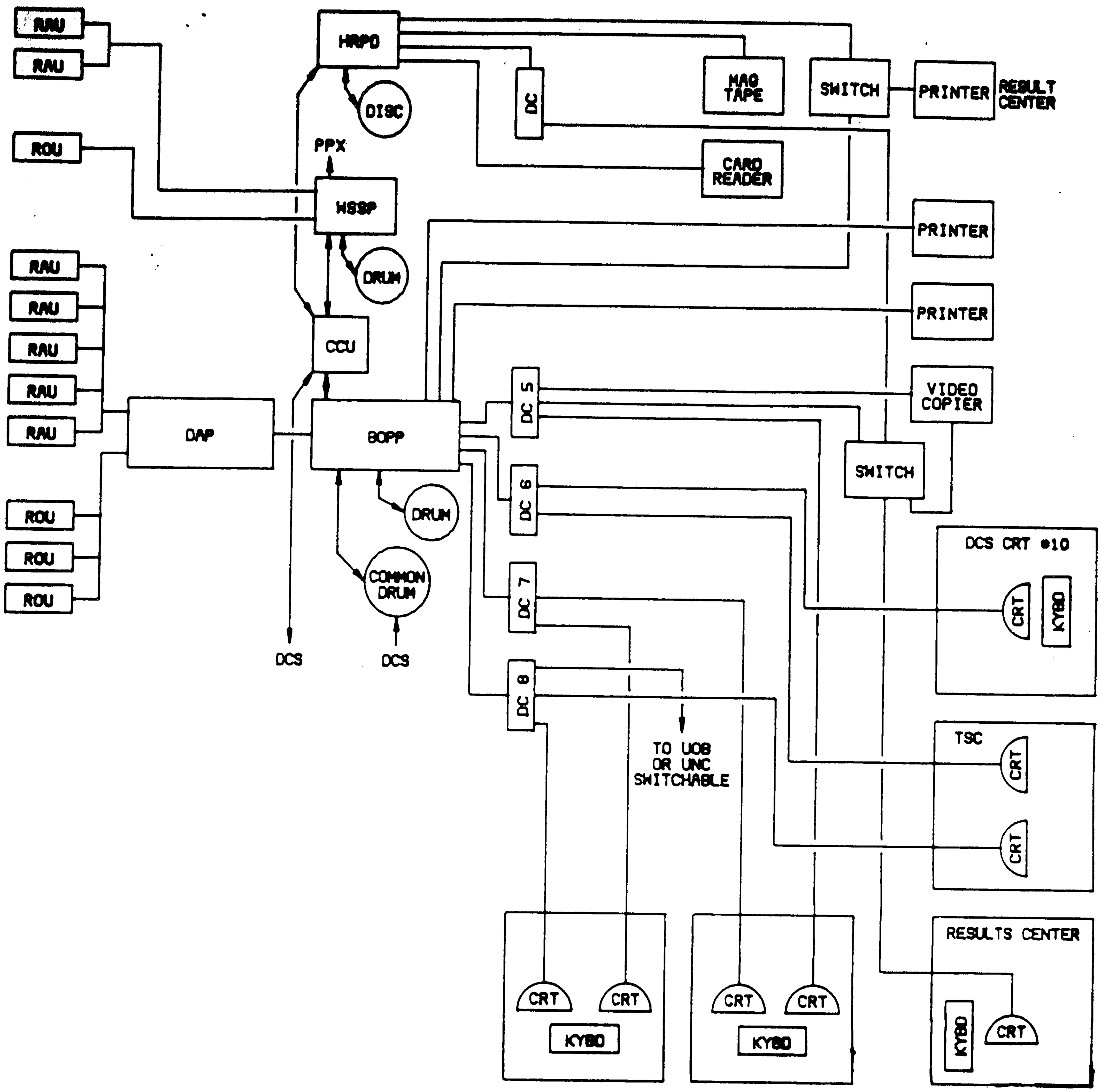
DCS CONFIGURATION CONTROL



MASTER DISPLAY CONTROL PANEL

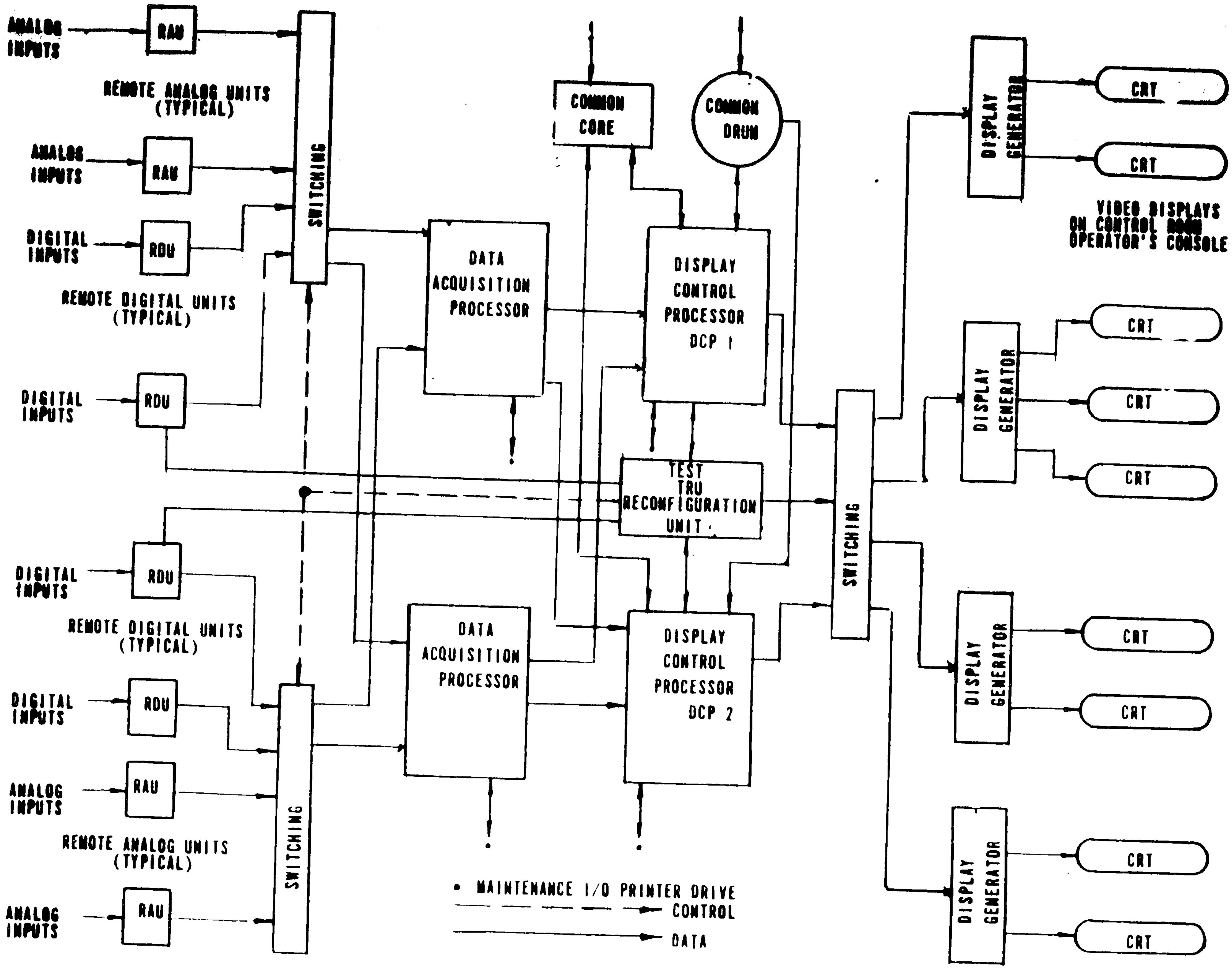
DCS Master Display Select Matrix

ATTACHMENT E



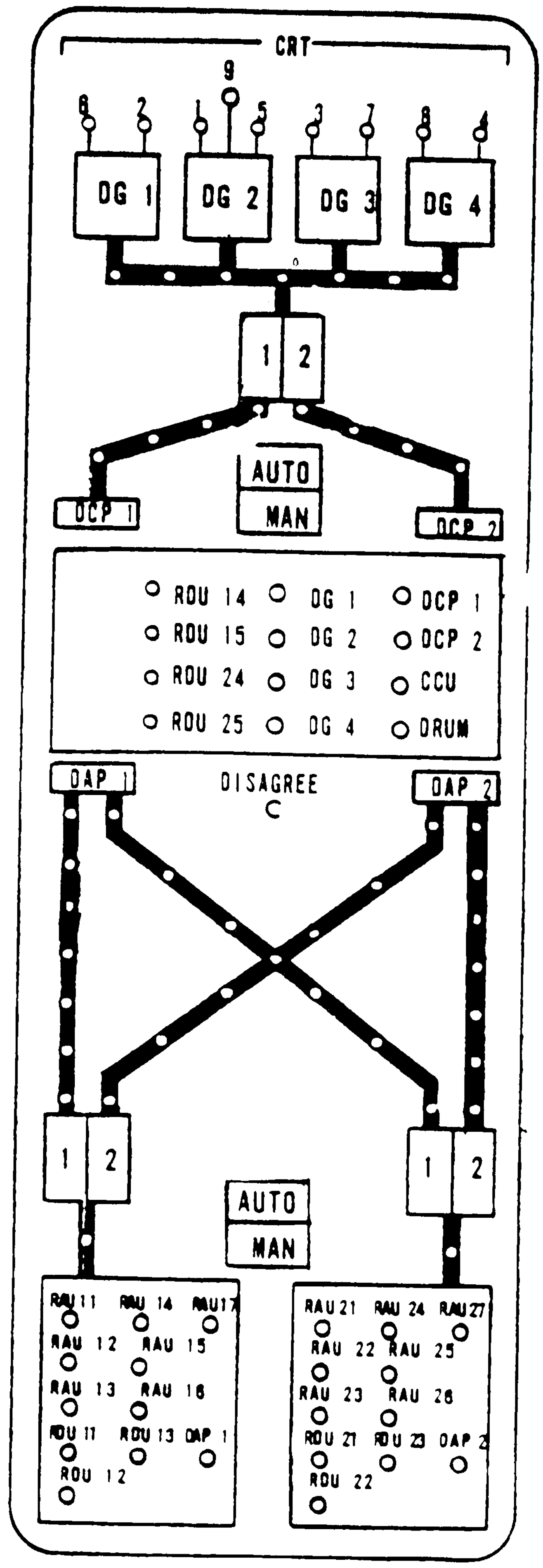
Performance Monitoring System Block Diagram

ATTACHMENT F



Display Control System Block Diagram

ATTACHMENT G



Test Reconfiguration Unit Status Display

ATTACHMENT H

Sample Output - Timing Analysis

CONTROL TIMING ANALYSIS PERFORMED AT 2:00 PM TUE., 29 JAN., 1985

RUN NUMBER 1071 SNTNL& U2 CAL FILE 2/28/84

CRD I.D. STATUS OF ALL CRD'S

J	2	6	10	14	18	22	26	30	34	38	42	46	50	54	58
59					0	0	0	0	0	0	0				
55				0	0	0	0	0	0	0	0	0			
51			0	0	0	0	0	0	0	0	0	0	0		
47		0	0	0	2	0	0	0	0	0	0	0	0	0	
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
31	0	0	0	0	0	0	0	99	0	0	0	0	2	0	0
27	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0
15		0	0	0	0	0	0	0	0	0	0	0	0	0	
11			0	0	0	0	0	0	0	0	0	0	0		
7				0	0	0	0	0	0	0	0	0			
3					0	0	0	0	0	0	0				
I															

0 => NO DATA, 2 => NORMAL ROD, 4 => FAILED ROD, 99 => INOPERATIVE ROD

Sample GETARS Output - Timing Analysis

ATTACHMENT I-1

Sample Output - Maximum, Minimum and Averaged Scram Times

CORE AVERAGED SCRAM TIMES.

NOTCH	45	39	25	5
TIME	.2630	.5554	1.2824	2.3864

MAXIMUM SCRAM TIMES.

NOTCH	45	39	25	5
ROD ID	27,34	35,42	27,26	27,26
TIME	.2710	.5840	1.3590	2.5430

MINIMUM SCRAM TIMES.

NOTCH	45	39	25	5
ROD ID	19,10	19,10	19,10	19,10
TIME	.2550	.5360	1.1830	2.1910

Sample Output - Scram Times Update

LIST OF RODS FOR WHICH SCRAM TIMES HAVE BEEN UPDATED

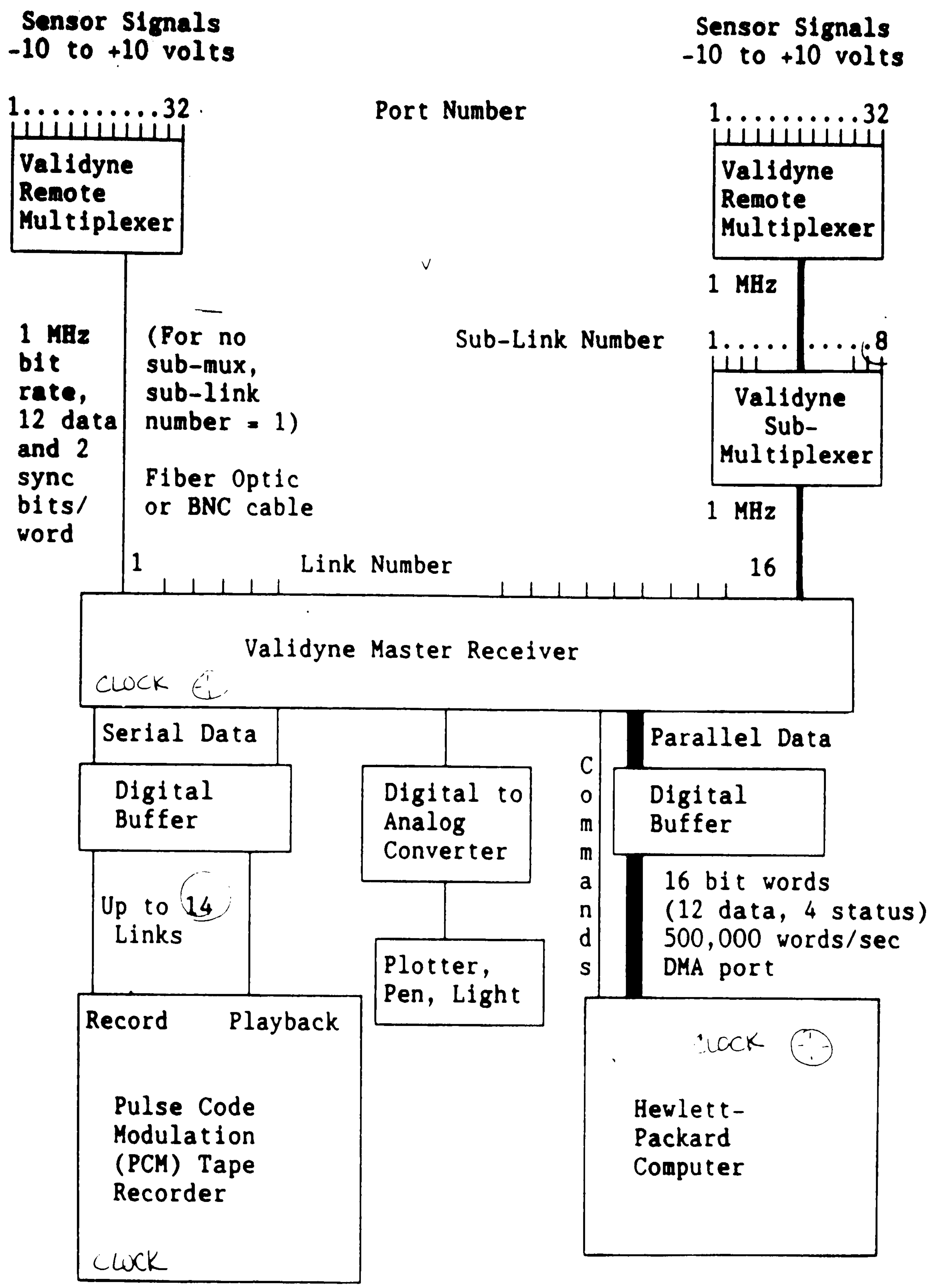
ROD ID	DATE	TIME	TIME TO NOTCH # 45	39	25	05	STATUS
47,18	3/ 2/84	23:16	.263	.552	1.271	2.359	2
39,22	3/ 2/84	23:16	.255	.544	1.271	2.383	2
35,42	3/ 2/84	23:16	.271	.584	1.319	2.423	2
31,50	3/ 2/84	23:16	.263	.544	1.247	2.327	2
27,26	3/ 2/84	23:16	.263	.560	1.359	2.543	2
27,34	3/ 2/84	23:16	.271	.568	1.327	2.479	2
19,10	3/ 2/84	23:16	.255	.536	1.183	2.191	2
AVERAGE TIMES			.263	.555	1.282	2.386	

NUMBER OF RODS UPDATED: 7

Sample GETARS Output - Min.,Max., and Scram Times

ATTACHMENT I-2

GETARS-I Data Acquisition System (DAS) Block Diagram



DAS Hardware Overview

ATTACHMENT J

SENTINEL - SIGNAL SURVELILLANCE AND RECORDING

SENTINEL Sample Input

```
:RU,RTEM,SNTNL

 ENTER THE WORK FILE# (OR -1 TO ABORT)...                              1

 RUN # 1
 NEW RUN # ('CR' INCREMENT RUN #)
 DESCRIPTION ....RTEM SNTNL  RUN # 1                                   1
 CHANGE DESCRIPTION   [YES,NO]
 RUN #          DESCRIPTION                                            NO
     1        RTEM SNTNL  RUN # 1
 PLAY BACK PCM DATA?  [YES,NO]
                                                                       NO

 SAMPLE PLAN    1ØØ  CHANNELS    1  THROUGH  1ØØ



    S E N T I N E L    S Y S T E M    B O O T I N G

SET TIME

*TM,1984,74,12,3Ø


*RU,ROP
????

GO


RU,ROP

????

TI

1984,74,12,3Ø,45,19Ø

*RU,ROP
????

STOP
```

GETARS Sentinel Sample Output

ATTACHMENT K

RECORD - DATA ACQUISITION SUBSYSTEM ONE

RECORD Sample Input

```
ENTER THE WORK FILE# (OR -1 TO ABORT)...                        1

RUN # 1
NEW RUN # ('CR' INCREMENT RUN #)                                1
DESCRIPTION ....RTEM RECORD RUN # 1
CHANGE DESCRIPTION   [YES,NO]                                   NO
RUN #           DESCRIPTION
   1        RTEM RECORD RUN # 1
PLAY BACK PCM DATA?  [YES,NO]                                   NO

SAMPLE PLAN    1ØØ  CHANNELS    1  THROUGH  1ØØ


   R E C O R D    S Y S T E M    B O O T I N G

SET TIME

*TM,1984,74,12,3Ø


*RU,ROP
????

GO


AUTO CUTOFF :

YES

*RU,ROP
????

PLOT

*RU,ROP
????

STOP
```

GETARS RECORD Sample Output

ATTACHMENT L-1

RECORD Sample Output

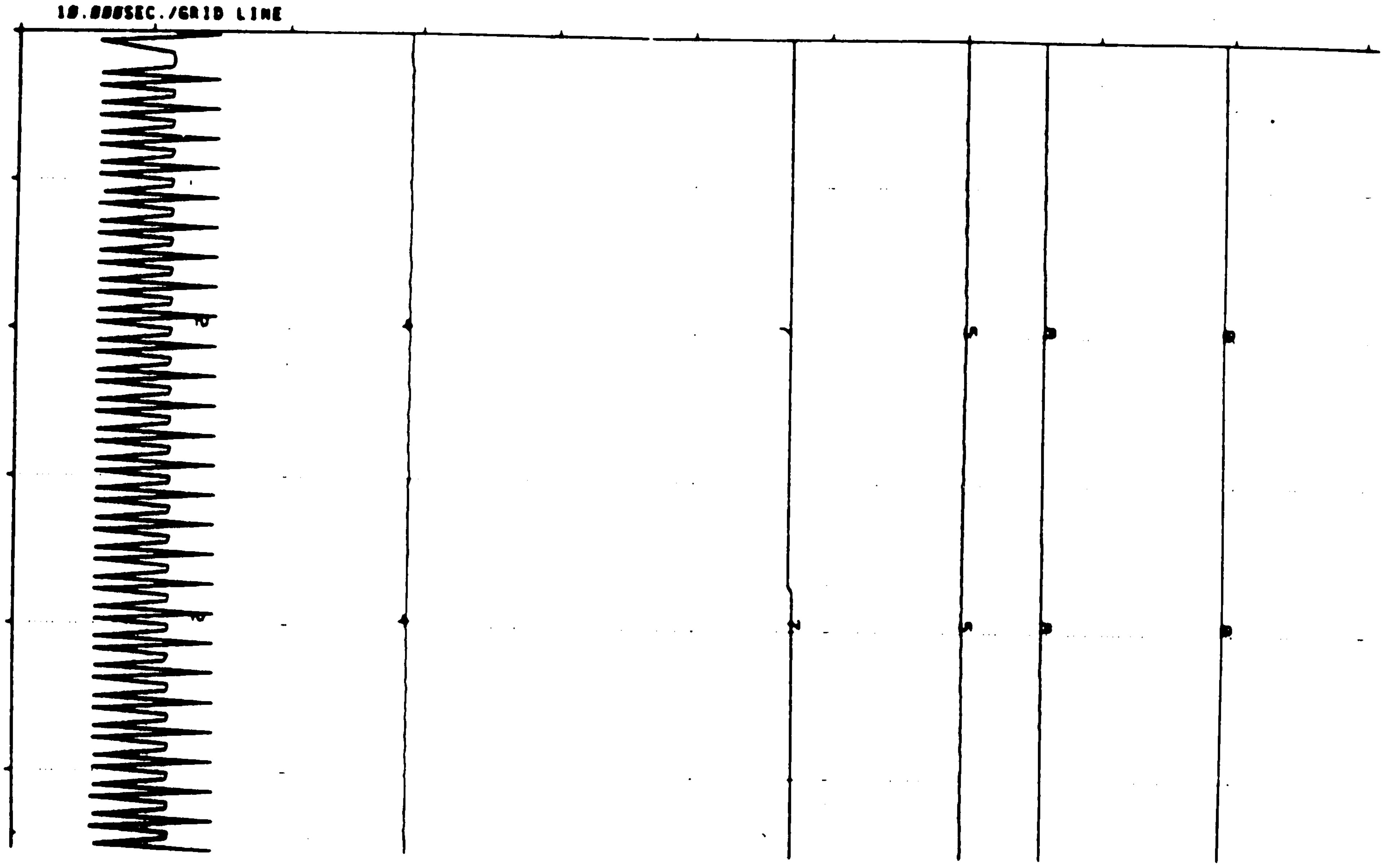
REAL TIME PLOT

WARNING PLOT TRACES ARE ONLY APPROXIMATIONS AND SHOULD NOT BE USED FOR FREQUENCY ANALYSIS

RUN # 1 HOPE CREEK DEMO
DATE 1984-339
TIME 17: 6: 7:050

CHAN# 3	CHAN# 8	CHAN# 5	CHAN# 6	CHAN# 4	CHAN# 7
CHAN 003	CHAN 008	CHAN 005	CHAN 006	CHAN 004	CHAN 007
MV	MV	INCH	DEGF	MV	INCH
EU 2500.0	EU 1000.0	EU 1.0	EU 20.0	EU 10000.0	EU 2.0
OFF 0.0	OFF 0.0	OFF 0.0	OFF 70.0	OFF 0.0	OFF 0.0
ORG. 2.	ORG. 4.	ORG. 5.	ORG. 7.	ORG. 8.	ORG. 10.

10.000SEC./GRID LINE

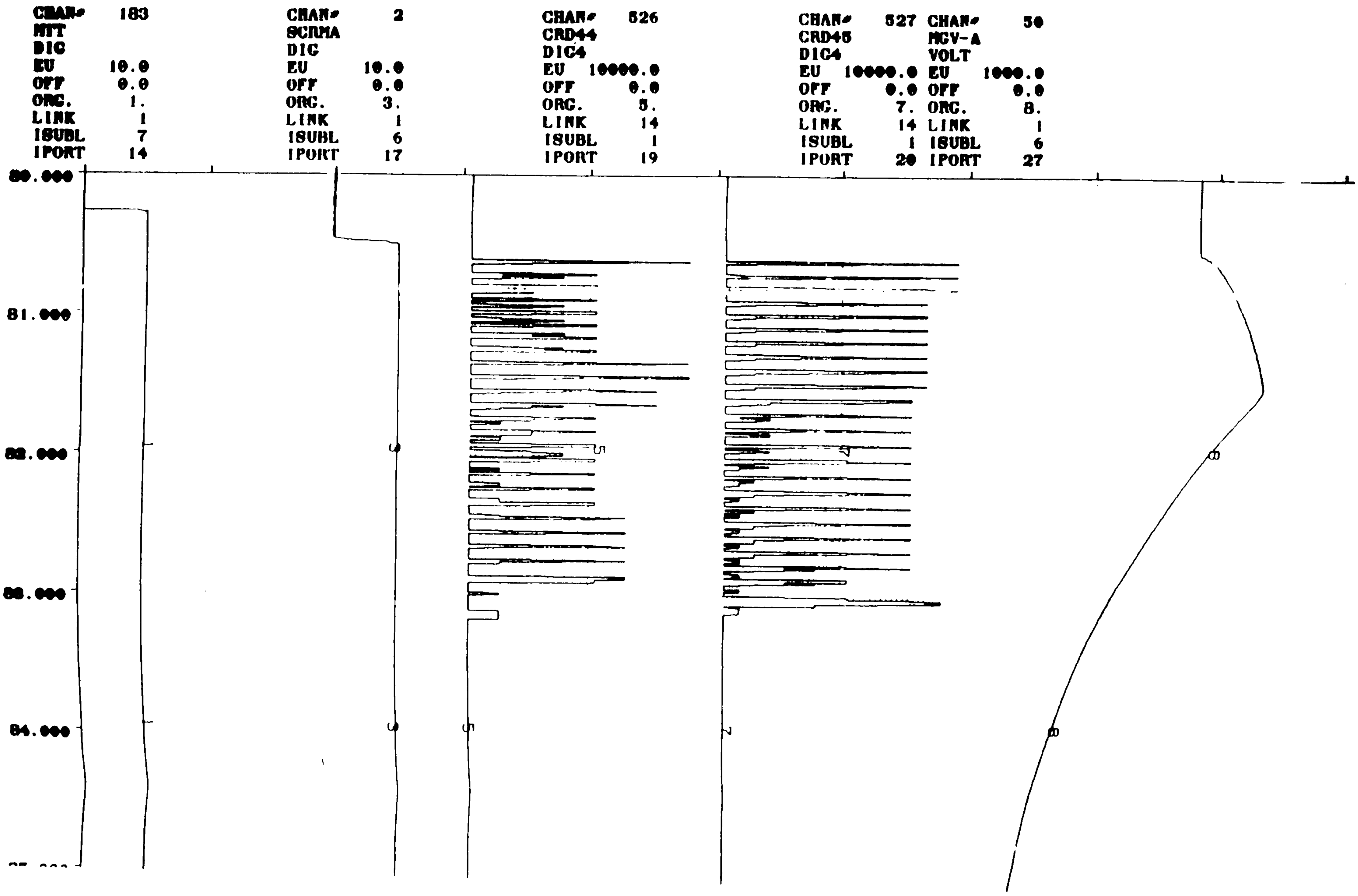


GETARS RECORD Sample Output (Continued)

ATTACHMENT L-2

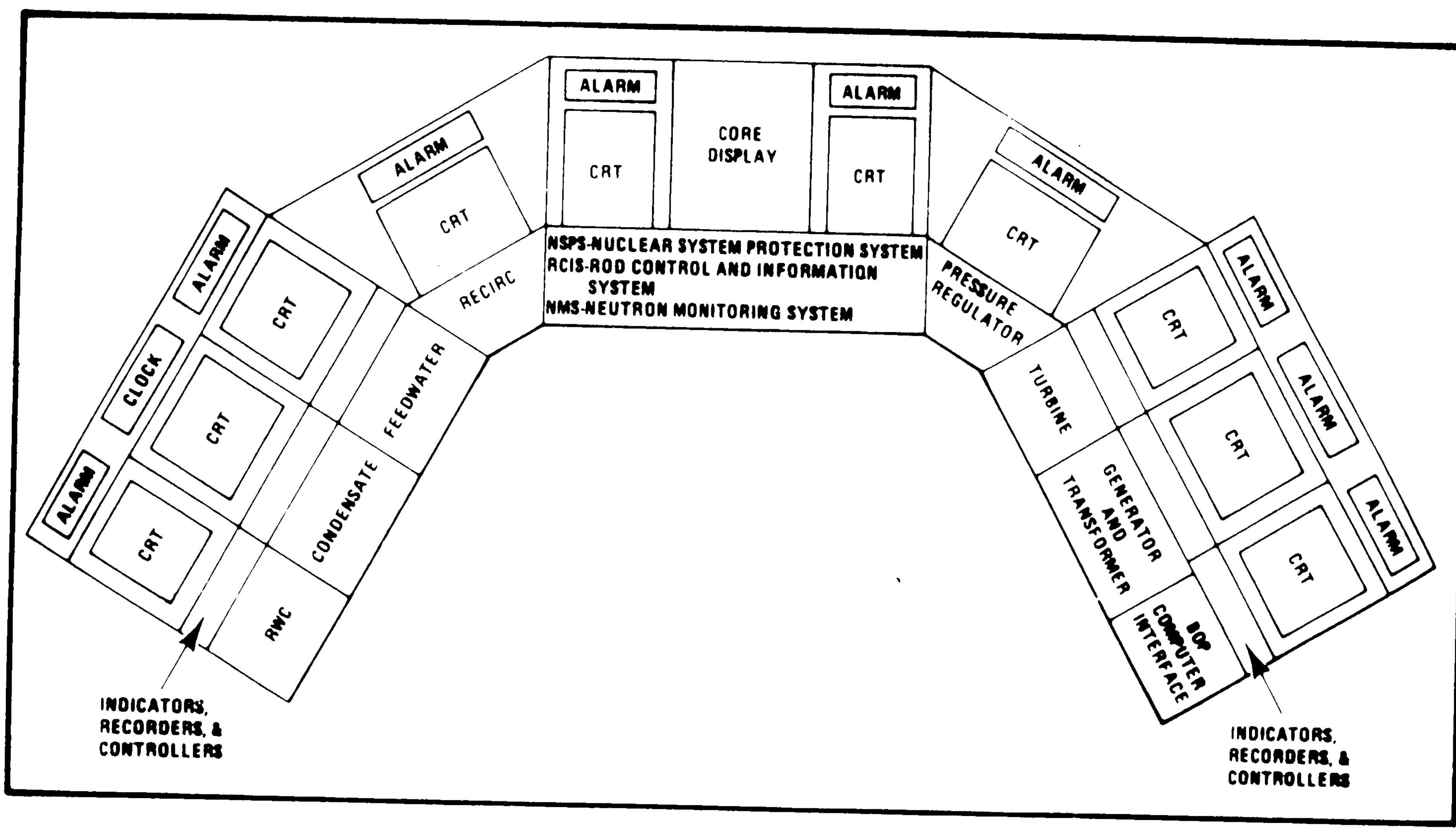
OFF-LINE PLOT
SNTNLS U2 CAL FILE 2/28/84 *
FILE # 1
RUN #1071
DATE 2/28/84
TIME @ START OF RUN 1: 2:18:116
SENTINEL TRIP CH# 183 AT 1: 3:38: 404
BEGINNING AT 80.00 SECS. FROM START OF RUN

1.000SEC./GRID LINE



GETARS Sample of Plotter Format

ATTACHMENT M

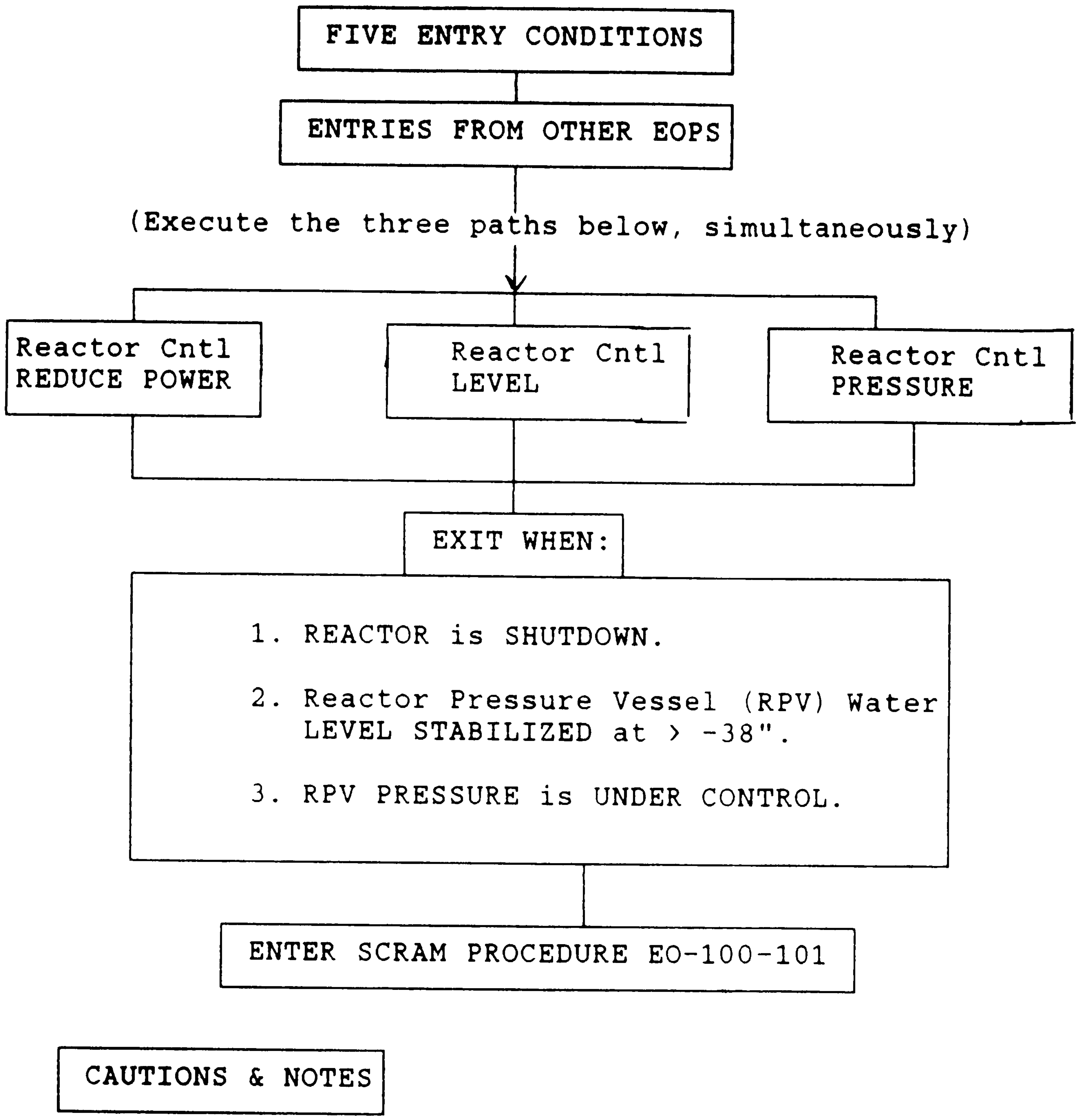


NUCLENET Operator Control Console

ATTACHMENT N

SECTION	DESCRIPTION	EVALUATION
6.7.1.4	Data Entry Keyboards	Keyboard not the req'd spacing
6.7.2.4	Data Presentation Format	
sec.(f)	menus	Currently line by line entry
sec.(g)	lists	Currently difficult to view
sec.(p)	Labels	Needs highlighting
6.7.2.5	Screen Layout and Structuring	Needs general improvements
6.7.2.6	Messages	Needs User Friendly error messages
6.7.2.7	Graphics Capability	Use of color graphics can provide easier screen viewing
6.7.3.1	Screen to printer capability	Currently not available

SIMPLIFIED RPV CONTROL 102



Simplified RPV Control 102

ATTACHMENT P

Reactor Protection System (RPS) Parameters

1. Intermediate Range Monitors - High Flux
2. Average Power Range Monitors - High Flux, etc.
3. Reactor Pressure Steam Dome Pressure - High
4. Reactor Vessel Water Level - Low
5. Main Steam Line Isolation Value - Closure
6. Main Steam Line Radiation - High
7. Drywell Pressure - High
8. Scram Discharge Volume Level - High
9. Turbine Stop Valve - Closure
10. Turbine Control Value Fast Closure
11. Reactor Mode Switch to Shutdown
12. Manual Scram

RPS Parameters

ATTACHMENT Q

Transients Analyzed in the FSAR

1. Decrease in Reactor Pressure
2. Increase in Reactor Pressure
3. Decrease in Reactor Coolant Temperature
4. Decrease in Reactor Coolant Flow Rate
5. Reactivity and Power Distribution Anomalies
6. Electric Distribution Malfunctions
7. Loss of Coolant Accidents
8. Containment Response to a LOCA

FSAR Transients

ATTACHMENT R

ISSUE	ACR (EOP)	GETARS DRIVEX	GETARS SCRAM	GETARS OTHER
Past Experience	no	YES	no	no
Internal Expert	YES	no	YES	YES
Manageable Size	no	YES	?	YES
Minimize Risk	no	YES	no	no
Current Problems	no	YES	YES	YES
Cost Savings	?	YES	YES	?
Safety Range	?	YES	YES	?
# YES	1	6	4	3

Prioritization of EXPERT System Development

ATTACHMENT S

Candidates Biography

BIRTH LOCATION: Wilkes-Barre, Pennsylvania

BIRTH DATE: July 12, 1956

PARENTS' NAMES: Alex and Joan Trubela

INSTITUTIONS ATTENDED: Millersville State University

B.S. in Computer Science - 1977

PROFESSIONAL EXPERIENCE:

1977-1985: Programmer/Analyst at Penna.Power & Light Co. in the Systems and Computer Services Department.

1985-1987: Project Digital Control Analyst at Penna. Power & Light Co. in the Nuclear Plant Engineering - Computer Engineering Department.

1987: Completed Penna. Power & Light Co. nine month Nuclear Training Program.

1987-Present: Senior Nuclear Plant Specialist at Penna. Power & Light Co. in the Technical Engineering Department.