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Steam Generator Group Project

Progress Report on
Data Acquisition/Statistical Analysis

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ABSTRACT

A major task of the Steam Generator Group Project (SGGP) is to establish the reliability of the eddy current inservice inspections of PWR steam generator tubing, by comparing the eddy current data to the actual physical condition of the tubes via destructive analyses. This report describes the plans for the computer systems needed to acquire, store and analyze the diverse data to be collected during the project. The real-time acquisition of the baseline eddy current inspection data will be handled using a specially designed data acquisition computer system based on a Digital Equipment Corporation (DEC) PDP-11/44. The data will be archived in digital form for use after the project is completed. Data base management and statistical analyses will be done on a DEC VAX-11/780. Color graphics will be heavily used to summarize the data and the results of the analyses. The report describes the data that will be taken during the project and the statistical methods that will be used to analyze the data.

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The assistance of the Virginia Electric and Power Company (VEPCO) in obtaining the use of the research generator removed from service at their Surry Nuclear Station Unit 2 is hereby acknowledged. VEPCO has also provided valuable assistance with historical information on the generator's operation inspection and maintenance.

CHAPTER I

INTRODUCTION

The scope of the Steam Generator Group Project (SGGP) creates a multi-disciplinary and data intensive environment in which a generator retired from service at the Surry Nuclear Station will be used as a vehicle for research into problem areas that are generalizable to all or most PWR systems. Major research objectives are to:

1. Establish the reliability of detection and the accuracy and precision of sizing defects for nondestructive inspections of generator tubing.
2. Establish the remaining mechanical integrity of generator components, primarily the steam generator tubing, subjected to different forms of service degradation.
3. Assess the accuracy of the estimation of the number and distribution of defects in the generator based on a sample of tubes.
4. Establish the effects of cleaning/decontamination on the non-destructive evaluation (NDE) characterization of the tubes.

Therefore, the necessity for an overall plan to organize and analyze the data was recognized. This is the purpose of Task 4, Data Acquisition and Analysis. Specific task objectives are to:

1. Design and implement a data acquisition/retrieval system that is optimized for ease of access to data and analyses.
2. Utilize statistical principles to design valid sampling plans for various identified task/specimen requirements.
3. Utilize statistics to establish confidence levels for current and developmental nondestructive evaluation (NDE) techniques.
4. Develop automated signal processing and pattern recognition methods to enhance the accuracy and precision of NDE signal interpretation.

During the project, data will be collected in the following chronological order:

1. Historical data on the generator including in-service inspection (ISI) results, tube plugging history, blowdown water chemistry, and general plant operation information.
2. Monitoring inputs of radiation exposures to workers on the generator. Also, determination of total exposures for particular tasks, for example, decontamination of the channel head and various sectioning operations.

3. Baseline single and multifrequency eddy current (EC) inspection along 100% of all accessible tubes.
4. Radiologic species mapping of the generator.
5. Data from other NDE technologies yet to be specified.
6. Geometry information on tube flaws. This includes location, and qualitative descriptions from visual inspections and physical measurements from other NDE technologies.
7. Secondary-side measurements and observations on the generator tubes, support plates, and general structure.
8. Data on the location appearance and chemical composition of corrosion products.
9. Results of the destructive assay of tube and support plate specimens.

The EC and radiation data are analog, necessitating a conversion to digital form before being analyzed in a standard digital computer. The other data are discrete and can be entered directly into the computer.

The data handling system consists of two overlapping phases; data collection and management, and statistical analysis. Each phase will be discussed in turn.

DATA COLLECTION AND MANAGEMENT

Data collection can be as simple as using a terminal to interactively enter a series of numbers into a computer. The researchers performing the chemical and destructive analyses should input the data directly into the computer. Some training will be necessary, but there will be a substantial pay-off of faster data entry and more efficient error detection and correction. The data will be maintained by a data base management system for easy retrieval.

This is a unique project which is likely to generate interest in the data that is collected after the project is completed. Technological advances in digital electronics are making the digital recording of traditionally analog data, such as eddy current, increasingly routine. The digital storage of the analog data collected during the project will facilitate access to it in the future.

Real-time recording of analog data and the subsequent conversion to a digital form is defined as data acquisition. The data acquisition system should be as automated as justified by a cost-benefit analysis of staff time versus hardware costs. Our analysis showed that realtime digitization using a digital computer would be the only alternative that would minimize the total cost of the data acquisition process.

DATA ANALYSIS

Data analysis is an exploratory process that is best performed using a variety of interactive statistical tools. Graphical representation of analysis results is an effective way of facilitating its understanding. It should be an integral part of the analysis process as well as a means of communicating the results to others. For example, the tubes with EC indications of a certain flaw type or size can be displayed on cross-section maps of the generator, thereby showing the flaw distribution.

Our approach to the Data Acquisition and Analysis Task is to have a flexible user-oriented system. This will provide the researchers with tools to allow them to easily interact with their data at all stages of the process, from data collection through analysis. We have done this in a cost effective manner by automating data acquisition based on an existing computer system, and by using existing data base management and statistical software as much as possible.

Data base management and statistical software are found on most digital data analysis computer systems. However, the real-time analog data collection and its subsequent digital conversion requires a digital computer to be interfaced to the analog instruments. This type of system tends to be custom designed for the particular type of data being collected. The development of virtual memory minicomputer technology has made data collection, management and analysis possible on a single computer. The ideal approach would be the acquisition of a computer such as the Digital Equipment Corporation (DEC) VAX 11/750. However, for the project to continue on schedule, the difficulties in obtaining the approval for such a computer nullify this option. In addition, technically adequate, cost effective alternatives existed at the research site.

In view of this, we have decided to use a small computer for real-time analog data acquisition and a larger computer for data base management and statistical analysis. For data acquisition, we have acquired a long-term commitment for the use of an existing DEC PDP 11/44 with a NEFF analog-to-digital converter (ADC). The acquired data will be transferred to a DEC VAX 11/780 computer for analysis. This latter computer is part of the DOE Analysis of Large Data Sets (ALDS) Project.

The rest of the report describes the Data Acquisition and Analysis Task in more detail. Chapter II describes, in depth, the different types of data to be collected. Chapter III describes the analog-to-digital data acquisition system that has been configured. Chapter IV describes the ALDS data analysis computer. Chapter V describes the statistical analyses planned for the project.

CHAPTER II

THE DATA

All of the data, except the blowdown chemistry, plant operating information and personnel dosimetry, are a function of location within the generator. Position within the generator is customarily determined by reference to the nearest tube. Each tube has a row and column coordinate derived from the generator cross-section diagram. Vertical position on the tube is referenced by distance from the tube sheet, a support plate, or the U-bend region.

HISTORICAL DATA

Records of various types were kept on the generator during its service life. The project has acquired as much of this information as possible in order to more efficiently plan the work of the project. This data includes the EC analog tapes of all of the ISI's, the interpretation of the EC signals for each tube inspected, the reason for plugging for each plugged tube, the secondary side operating water chemistry, and the plant operating history such as the power levels and outage times.

The analog tapes have been digitized in order to compare them to the signals obtained during the baseline inspection of the generator and to design the signal processing and pattern recognition algorithms. The interpretation of the EC signal is needed to develop a history of the condition of each tube to compare to its present condition. The interpretation data was obtained from two sources: a Westinghouse computerized data base and the ISI records from VEPCo. The Westinghouse data base contains the interpretation of the regulatory guide inspection for each tube with an indication, and the results of special tests, such as sludge height and denting measurements, during the time they performed the ISI's (1974-1976). The complete set of interpretation results were obtained from the VEPCo ISI records, which were not in computer form, but they have been computerized and added to the Westinghouse data.

The reason and date that individual tubes were plugged is important for designing the sample of tubes to be unplugged for the baseline inspection. The plugging criteria changed over time. Initially tubes were plugged if there was an EC indication of 40% through wall or larger. After a leaker was discovered in the row 1 U-bend region, nine tubes were removed for examination, and subsequently all of the tubes in row 1 were plugged. At various times up until March, 1977, tubes were plugged on the advice of Westinghouse, which was based on experience at other plants and the predictions of stress analysis studies. After the denting of the tubes became severe, the plugging criteria of the ISI's in 1977 and 1978 was based on the size of the probe that the tube would pass. A tube was plugged if it would not pass a .610 probe and adjacent tubes were also plugged if it would not pass a .540 probe. The plugging

date for each plugged tube is contained in the Westinghouse data base, but the reason for the plugging had to be obtained from VEPCo and added to the data base.

The secondary side water chemistry data obtained during reactor operation is part of the Westinghouse data base. This blowdown chemistry data will be used to attempt correlation with chemical compositions of corrosion products at different layered depths.

The plant operation information was obtained from the VEPCo monthly and semiannual reports to the NRC. This data, of course, was not in computer form, and had to be computerized as part of the project.

PERSONNEL EXPOSURES

There are two reasons for collecting personnel exposure data: first, to meet radiation protection requirements for workers in a radiation zone, and second, to determine radiation exposure estimates associated with the performance of various tasks. The latter will provide referential information for similar inspection or maintenance operations in commercial units. The exposure received during decontamination of the steam generator is a particular example.

The personnel exposure data will be maintained by the data acquisition computer because of its proximity to the generator. The system will allow the radiation monitor to simply query the computer to ascertain whether a particular person should be admitted to the generator facility. The decision will be based upon information stored on the individual's prior radiation training and dosimetry history record.

BASELINE EDDY CURRENT INSPECTION DATA

A single frequency EC instrument (Zetec EM-3300) was used for the ISI's. It will be used to reinspect the tubes which were inspected during the ISI's. However, in the past few years, more advanced EC instruments have come into accepted use. Therefore, several baseline inspections utilizing different EC instruments are under consideration. The most demanding from a data base standpoint is use of an absolute coil, multifrequency EC instrument. This provides a maximum of four frequencies (eight channels) of analog data. The sheer volume of data that will be generated from inspecting in excess of 3000 tubes dictates real-time collection with a data acquisition computer. Automated data acquisition, however, requires some special instrumentation. A computer-operated intelligent controller will be used to drive a DC motor that operates the EC probe pusher-puller. This, in conjunction with a digital incremental encoder attached to the probe cable between the inspection system probe guide conduit and the EC probe, will automatically provide probe location information as EC or other NDT data is acquired. The data acquisition system will be described in more detail in Chapter III.

The EC signal and the location on the tube where the signal is measured will be transmitted to the computer for archiving on digital tape. Since most of the signal will be background, simple signal processing for the recognition of anomalous signals will also be performed at a later time. These signals and their location will be stored on a removable disk pack for physical transfer to the analysis computer for storage and further processing.

As a second back-up, the data will simultaneously be archived on analog tape as is done in a conventional ISI.

TUBE RADIATION MEASUREMENTS

A radiation detector probe will be inserted in a sample of tubes to obtain dose and species measurements. The probe is interfaced to a radioactive species analyzer that supplies digital output on a "floppy" diskette which can be read by the analysis computer. Since the analyzer will not be interfaced to the data acquisition computer, the probe encoder positions cannot be supplied directly to the analyzer. However, the encoder position associated with each measurement can be determined if the measurements are taken at fixed distance intervals within a tube.

OTHER NDE MEASUREMENTS

Data from other NDE techniques have not been specified. The program is seeking to identify and demonstrate the use of a variety of NDE techniques for characterizing the generator. Some of these techniques may be new or innovative. Not all instrument specifications are known at this time, consequently, it is difficult to determine whether or not the instruments will be compatible with the existing data acquisition system. Some data may have to be recorded as analog signals on tape and digitized later. The digitization of this data can be accomplished on the data acquisition computer and then added to the data base on the analysis computer.

PHYSICAL, MATERIAL AND CHEMICAL PROPERTY MEASUREMENTS

The remaining types of data provide discrete information on the physical and chemical status of the corrosion products and sludge located within the generator. The researchers, through the use of a computer terminal, will input these data into the analysis computer.

CHAPTER III

III.1 THE DIGITAL DATA ACQUISITION COMPUTER SYSTEM

The need for an automated data acquisition system for the baseline EC data was recognized because of the size of the data set involved. Because samples of degraded tube sections are to be removed for destructive analysis, there was also the need to have a more accurate location of the degradation than could be obtained from the conventional method of locating flaws from the distance from a support plate indication measured from the strip chart recording of the EC signal. A data acquisition system that also provided location information with the EC signal was feasible since a similar system had been built at Battelle. Once it was decided to use a data acquisition system that would also provide location information, it was realized that a system could not be designed to be flexible enough to accommodate every type of analog instrument for which location information was needed that might be used during the project. Because of time and cost constraints, we were restricted to use as much existing or off-the-shelf equipment as possible.

Since the largest set of analog data that will be collected was the baseline EC, the design of the data acquisition system was based on the assumption of using the EC equipment most commonly used in the U.S. today, which is the Zetec MIZ-12 multifrequency (8-channel) unit and SM-4 probe motion unit (probe positioner and pusher-puller). The system was designed so that other instruments besides the MIZ-12 could be used as long as the SM-4 equipment was used. For that reason, EM-3300 data can be collected with the system. Other analog instruments which will be used during the project for which tube location information is appropriate will have to be evaluated on an individual basis as to whether it is practical to modify the system or the instrument to acquire the data. If not, then that data would have to be digitized using the data acquisition system at a later date, without location information.

The functions of the data acquisition system are:

1. Probe positioning within a tube without data collection
2. Data acquisition with distance information using equal distance intervals for digitization of the EC signal
3. Data acquisition with distance information using equal time intervals for digitization of the EC signal
4. Digitization of analog data (probably from tape), without location information, using equal time intervals for digitization
5. Conventional EC data collection using a manual controller in case of a computer malfunction.

A major requirement of the data acquisition system was that it should mimic as much as possible the way EC inspections are done in the field. There are several reasons for that. First, the system should be acceptable, with some training, to the people doing the EC inspections. Second, a major research objective is to establish the reliability of the EC inservice inspections of steam generators, so the data collection procedure should be as realistic as possible.

Briefly, the data acquisition process using the data acquisition system is as follows. The probe fixture is located at the tube to be inspected using the SM-4 probe positioner (conventional method). The operator then interacts with the computer which provides instructions to an intelligent controller (discussed in a later section). The intelligent controller (rather than a manual controller) drives a DC motor on the eddy current probe pusher-puller and receives probe position information from an encoder located on the pusher-puller. The computer then appends the location information to the digitized EC signal received from an Analog to Digital Converter (ADC) and stores them together in interim storage for later transfer to digital tape. Analog tapes of the complete EC inspection will also be recorded as a back-up. Since most of the tube degradation is expected near the support plates, tube sheet, and the U-bend region, there will be lengths of tubing with a background signal only. This is estimated to be 80% of the signal for a tube. Simple signal processing will be performed after the inspection has been completed to select anomalous parts of the signal for transmittal to disk storage and transfer to the analysis computer for further processing.

Because of the radiation exposures involved, the inspection of the generator tubes is done remotely with as little equipment in the radiation zone as possible. Of necessity, the pusher-puller and encoder are located near the generator. Because of cable requirements, the intelligent controller is located in an instrument enclosure (called a NEMA box) on the east outside wall of the Steam Generator Examination Facility (SGEF). The computer and all other EC equipment are housed in a trailer, which has been modified to properly support computer equipment, located north of the SGEF. A diagram of the location of the various components of the data acquisition system is shown in Figure 1.

The two major components of the digital data acquisition system as it is configured for eddy current baseline data are the computer itself (which includes the ADC) and the intelligent controller. Specific details of the configurations of the computer and the intelligent controller are given in Sections III.2 and III.3, respectively. The data acquisition software and system operation are described in detail in Section III.4. Section III.5 describes other uses of the data acquisition computer for the project.

CONCEPTUAL STEAM GENERATOR INSPECTION SYSTEM

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FIGURE 1.

III.2 COMPUTER SYSTEM

The real-time data acquisition system is based on a DEC PDP 11/44 computer system with NEFF ADC subsystem hardware. The computer and ADC subsystem are owned by Battelle-Northwest (BNW) and the Steam Generator Group Project has acquired an exclusive use commitment of this equipment for the duration of the data acquisition phase of the project. The NEFF ADC sub-system will perform 8 channel EC data acquisition satisfactorily. However, it may not handle other NDE data acquisition such as ultrasonic, due to the 20 KHz sampling rate limit. To complete the NEFF hardware for EC data acquisition, two high level differential preamplifier/filter cards, eight gain modules, four filter modules, and a NEFF service kit to calibrate the NEFF hardware were purchased.

The two RL02 disk cartridge drives which are part of the PDP 11/44 have replaceable cartridges that are capable of storing 10 megabytes (MB) each. One drive will store the system software while the other drive can be used for software development and storage of personnel exposure data. Five additional RL02 disk cartridges have been obtained for backing up the system, and for storage of other software and data. The disk cartridges are not large enough to store the digitized EC data. To meet this need the program has purchased a Systems Industries 300 MB disk drive, controller, and three disk packs that have become a peripheral component of the BNW PDP 11/44 system. This disk drive is also compatible with those on the analysis computer to make data transfer easy. Although a tape drive was included in the PDP 11/44 system, it was not considered to be capable of handling the magnitude of the data to be archived. Therefore a 6250 BPI (bytes per inch) tape drive and controller were acquired from Systems Industries. This high speed, high density tape drive will be used to archive all digitized EC inspection data to minimize the number of tapes. The analysis computer has an identical tape drive, thereby providing another data transfer medium.

There are two computer terminals on this system. One is a LA120 (132 column hardcopy) terminal and the other is an ADM-42 intelligent CRT terminal. The LA120 is used primarily as a system console but it can be used to print listings of programs and data. The ADM terminal with 32 programmable keys can store/recall four pages of text. However, its probable use is that of a "dumb" terminal (such as the LA120). Neither terminal will display simple graphical representations. This need was met by the purchase of a DEC VT100 graphics retrofit terminal and software. This additional terminal will enable the operator to monitor the digitized data after it has been received and processed during the EC data acquisition, and will also serve as the primary terminal for operating the data acquisition system.

A high resolution digital clock also had to be purchased for the time-based digitization. The complete list of components for the computer and ADC system are listed in Table 1, and Figure 2 is a conceptual diagram of the system. Figure 3 shows the installed system in the trailer outside the SGEF.

TABLE 1. Components of SGGP Data Acquisition Computer

PDP 11/44 computer with the following:

- 256 KB memory
- TU58 tape cartridge drive
- LA120 hard copy terminal
- Dual RL02 disk cartridges (10 MB each)
- RSX-11M operating system
- FP11-F floating point processor
- FORTRAN IV-PLUS language
- Documentation for RSX
- DZ11E 16-port terminal interface board
- HP 4-color pen plotter with graphics software
- LEAR SIEGLER ADM 42 CRT terminal with 4 pages of memory and 32 programmable keys
- 1600 BPI 9-track tape drive and controller
- Cabinet, rack and backplane
- Systems Industries 300 MB disk drive
- Systems Industries tri-density tape drive
- DEC VT100 graphics terminal
- Plessey KWIIP real time clock
- TEKTRONIX PLOT 10 Easy Graphing software

NEFF data acquisition system with the following components:

- 64-channel capacity control input assembly
- Programmable gain amplifier with gains of 1, 2, 4, 10, 20, and 40
- 14 bit binary, 20 KHz throughput, 16 channel ADC
- Two amplifier/filter cards each with 4 channels and gains from 10-1000
- 16 gain modules with gains from 10-1000
- Filter modules with filters ranging from 1-1000 Hz
- Five foot, 16 channel analog input cable set
- 64 channel mounting assembly
- Two 4-channel input conditioning cards
- Input assembly (local)
- Peripheral device buffer card
- 16 point form "C" relay output
- 8 channel DAC card
- DMA interface to PDP 11/44
- RSX-11M software driver
- Two RDT/potentiometer mode cards
- Six strain gauge mode cards
- Eight 4-channel input termination cards
- Two 4-channel high level differential preamplifier/filter cards
- Eight gain modules
- Four 100 Hz filter modules
- NEFF service kit

SURRY GENERATOR DATA ACQUISITION COMPUTER SYSTEM

FIGURE 2.

FIGURE 3.

III.3 INTELLIGENT CONTROLLER

The probe pusher-puller intelligent controller, which was designed and fabricated at Battelle, is responsible for inspection probe motion control, local indication of probe position, probe status information and for synchronizing position of the probe with data acquisition. To accomplish these objectives, an STD bus architecture was utilized. A high speed Z80A microcomputer controls all activity. Data collection synchronization is accomplished through a dedicated optically isolated link to generate interrupts at the PDP 11/44 data collection system. The line receiver is located at the PDP 11/44. All commands and status are passed on separate serial communication lines via Beldon bit drivers (see Figure 1). One bit driver is located at the PDP 11/44. The other is located at the intelligent controller (installed in the NEMA enclosure). Probe motion is controlled by an EG&G Torque Systems pulse width modulated DC motor driver. Position information is displayed on the Zetec manual control unit whenever it is plugged into the intelligent controller. DC power for the position encoder and the local display are supplied by the intelligent controller.

A keylock switch located at the PDP 11/44 allows control over the manual and computer modes of probe positioning. In the 'manual' position, computer commands are not accepted. A separate Zetec motor driver is used in this mode of operation.

One of the cards inside the intelligent controller contains a toggle switch labeled OFFLINE/ONLINE. In the OFFLINE position, the controlling PDP 11/44 computer can be emulated by connecting a CRT terminal into the serial input-output (SIO) card instead of the bit driver. The terminal must be set up in the data terminal equipment (DTE) mode with a baud rate of 9600. Debugging is facilitated by echoing characters typed each time a carriage return (CR) is received. The switch must be in the ONLINE position for computer control. In this position the received characters are not echoed back.

THEORY OF OPERATION

Six STD bus compatible cards make up the controlling electronics inside the intelligent controller. The cards are labeled for identification (see Figure 4). A brief description of the functions of each card follows. The firmware listings are self documenting as to how each card accomplishes the required tasks.

CPU

The Mostek MDX-CPU2 card contains the Z80A microprocessor, program memory, data memory, and a quad timer/counter. One counter is utilized for sending synchronous information to the data collection system based on the number of encoder pulses between synchronous pulses. Two additional timers are utilized for generating 10 millisecond timing information for updating the encoder display and other timing functions.

FIGURE 4. Innards of the Intelligent Controller

SID	The Mostek MDX-SID2 serial input/output card contains two universal asynchronous receiver transmitters (USARTs). Channel A is utilized for communication with the data collection system through the Beldon bid drivers. The serial input/output (SIO) card is set up for DTE asynchronous mode of operation.
BCD	The Ziatech ZT 7399 card provides two 4-digit BCD counters that are cascaded to provide one 8-digit BCD counter. The incremental encoder output is input to this register through a signal conditioner for storage of the current absolute probe position as established by the operator.
ESC	The PROLOG 7902 card is a prototyping card with no STD bus backplane connection. The sine/cosine outputs from the incremental encoder are decoded and signal conditioned on this card to provide transistor-transistor logic (TTL) compatible increasing/decreasing pulses and an up/down control line.
SERVOCONTROL	The Applied Control Technology STD-15 STD BUS/SERVO Control Card provides an analog output signal (+ 10 volts full scale) to the Torque Systems servo feedback controlled motor driver also located in the NEMA enclosure. The STD-15 accepts displacement and velocity information from the microprocessor. Several potentiometers on the card provide control over deceleration rate, zero displacement torque and other servo feedback control. Once these potentiometers are adjusted for optimum operation, they should not be changed.
EDD	The PROLOG 7904 decoded input/output utility card contains Battelle designed logic to provide (1) signal drivers for updating the manual control unit encoder display utilizing RS-232-C line drivers binary coded digit (BCD) (digit parallel with strobe), (2) buffered output to the PDP 11/44 through an optically isolated line receiver for data collection synchronous information and (3) the ONLINE/OFFLINE toggle switch for control over echo feedback when emulating the data collection system with a CRT terminal.

The complete list of components for the intelligent controller is given in Table 2.

TABLE 2. Components of Intelligent Controller

- 1 Power-One 12-volt, 3.4 ampere Model C15-3 linear power supply
- 1 Applied Control Technology STD-15 STD BUS/SERVO control card
- 1 Datricon STD bus extender board
- 2 Zilog Z80A CPU with extended temperature range
- 2 RS-232-C metallic Belden bit drivers
- 2 Intel EPROM, type D2732
- 1 Intel 8-bit microprocessor unit, type ID8085A
- 1 Pro-Log STD bus decoded input/output utility card
- 1 Mostek MD series STD bus, Z80A CPU board, designator MDX-CPU2-4
- 1 Mostek MD series STD bus, Dual UART function, designator MDX-S10-4
- 1 Mostek MD series STD bus, 6-slot card cage, designator MD-CC6
- 1 Mostek MD series cable, RS-232 DCE to S10, designator MD-232 DCE-C
- 2 Mostek Static RAM, 1Kx8 with 250 nsec cycle time
- 1 Ziatech STD bus compatible dual BCD counter/timer card
- 2 Bud utility box, type CU-347
- 1 Oak anti-static keylock switch, type 5-5111-501
- 2 IMC Super Boxer fan, type BS2107F-110
- 2 IMC Boxer filter kit, type 531001
- 2 IMC plug and cord set, type 432000
- 1 Lambda switching triple output power supply for +5 and $\pm$ volts
- 1 Lambda EMI suppression cover
- 2 Lambda monolithic voltage regulator (5 volts, 2 amperes)
- 1 Zero VIP 6-way enclosure system
- 1 EG&G Torque Systems Model C0701 controller
- 1 Power supply, Model PS-210, for above controller

COMMAND/STATUS SUMMARY

All components and status indicators are American Standard Code for Information Interchange (ASCII) characters which are sent over a serial link. The commands and status indicators are a single character followed by numeric parameter information, when required, and terminated with a carriage return (CR). All numeric information passed in either direction is ASCII decimal digits with the most significant digit first.

The only commands which are permissible while executing a probe motion command are the 'Q' and 'S' commands (described below). Any other commands will not be accepted. A negative acknowledge 'N' will be returned.

While the keylock switch is in the MANUAL position no commands from the data collection system are accepted. 'M' is returned, indicating manual mode operation only. While in the COMPUTER position, computer commands are accepted as appropriate.

The controller supports three types of parameters which affect the probe motion. The first is a default direction, the second is a distance parameter, and the third is a motion rate.

1. The default direction is the direction the probe moves when collecting data. This direction must be consistent throughout a test because of discrepancies in determining coordinates when changing directions. The cable has a tendency to be coiled like a cork screw or stretched when pushing or pulling, respectively. To insure a consistent state, the controller will always take data and position to a given coordinate in the default direction. In some cases, the controller will be required to overshoot a position and come back from the opposite direction. In this way, the cable will always have the same forces being exerted when positional data is expected. The default may be either direction (see the '+' and '-' commands) but the operator must be consistent to expect consistent data.
2. Distances are established by the 'D' and 'd' commands. These values are specified in 100ths of an inch and represent distances and measurement points.
3. The velocity of probe motion is established by the 'R' and 'r' commands. One velocity is established for measurement rate. The other velocity is established for non-measurement traverse rate. This allows the operator to move the probe faster when positioning the probe than when collecting data.

The commands accepted by the controller are as follows:

- An Assign: Defines the current probe location coordinates as 'n' where 'n' is up to 6 digits. It indicates that the current encoder position is 'n' 100ths of an inch away from the zero position. This logical assignment can be made whether or not the probe is in a valid state for data collection (see 'default direction' description).
- C Continuous: Starts the probe moving in the opposite direction of the default direction. The probe will move until physically stopped or until a 'Q' command is received or until location 0 is reached (when reeling in).
- Dn Distance (measurement): Sets the distance between measurement points. Parameter 'n' is up to 3 digits not to exceed 255 (2.55 inches). The minimum value of 'n' is 1 at measurement rates less than or equal to 12 inches/second. The minimum value for 'n' is 4 for higher measurement rates.
- dn Distance (index): Sets the index 'distance' parameter to 'n' where 'n' is up to 5 digits. The minimum value for 'n' is 10 (0.1 inches).
- I Index motion: Moves the probe in the default direction. The distance moved is determined by the distance parameter specified by the 'd' command. The probe will be in a position ready to take measurements after the motion is complete (see 'default direction' description).

- Mn Measure: Controls the motion so that data measurements can be taken starting at absolute location 'n' in the default direction with measurement interval as specified by the 'D' command. This action will continue until physically stopped or until the 'Q' command is received or until location 0 is passed (when reeling in). The value 'n' is up to 6 digits indicating the distance in 100ths of an inch from location 0. The default direction is specified by the '+' and '-' commands.
- P Position: Returns the current probe position in 6 digits without leading zero suppression. If the probe is not ready for data collection (see 'default direction' description), the probe will be positioned to the same encoder position in a way which will make the position a valid data collection position.
- Q Quit: Stops probe motion within 20 inches of the position where the probe is located when the command is requested. If an error flag is already set or if a 'quit' command is currently in progress, then a faster abort is executed.
- Rn Rate (measurement): Sets the rate of travel for the probe motion during data collection (during execution of the 'M' command). The rate 'n' is specified as a number from 1 to 255. The resolution is 1/6 inch/second/unit when reeling out and 1/18 inch/second/unit when reeling in. This allows a rate ranging from 1/18 ips when reeling in, to 42.5 ips when reeling out.
- rn Rate (non-measurement): Sets the rate of travel for non-data-collecting probe motion. The rate specification is the same as for the 'R' command.
- S Status: Returns the controller status indication. The following status indicators are currently defined. They are listed in the order of precedence each status has.
- M Manual mode - the controller will not execute computer commands. Commands generated by the computer will be given a negative acknowledgement. This mode is entered by turning the keylock switch to the MANUAL position. While using the manual control (with a different motor driver) the current probe position can be defined as zero by depressing the manual encoder display push-button. Power must be removed from both motor drivers while switching between MANUAL and COMPUTER modes of operation.
- X Executing - the probe is in motion.
- B Bandwidth exceeded - the combination of the 'D' and 'R' commands have set up a data collection rate which exceeds the bandwidth capability of the data collection system.
- E Error - last motion request could not be completed correctly. This status is cleared after a status request only.

I Idle - the controller is idle (not executing a command).

Tn Turn around distance: Specifies the distance 'n' required to 'turn around' and insure the probe is in a valid position for taking data in the default direction. The parameter 'n' is up to 5 digits (327.67 inches maximum). The default turn-around distance is 1000 (10.00 inches). This distance is temporarily overridden if the previous motion request failed and motion in the opposite direction is requested. In this case, the turn around distance is 0.

+ Positive direction: The default direction is moving into the tubes (letting out cable). The default direction is the direction traveled when collecting data.

- Negative direction: The default direction is moving out of the tubes (pulling in cable). The default direction is the direction traveled when collecting data.

The following conventions are followed when passing back status information (also, see 'S' and 'P' commands):

A Acknowledge - returned after every successfully completed (or initiated) command except the 'P' command which returns a position indication when successful. This status is returned after the completion of a command if it is self-terminating (most commands). This status is returned after motion has started on commands which do not have a predetermined completion ('M' and 'C' commands).

N Negative acknowledgement - returned when an invalid command is requested or when a command could not be completed as requested. This can happen when the probe is stuck, the controller is on manual override, or the command syntax was not received correctly. Checking the status with the 'S' command after a negative acknowledgement will help determine the cause of the failure. If an error flag was set, asking for the status using the 'S' command will clear the error flag.

III.4 REALTIME DATA ACQUISITION SOFTWARE

The implementation of the realtime data acquisition system required an extensive software development effort. The purpose of the software is to tie the various components of the system together into a functioning unit that is easy for an operator to use. The software provides the interface to the operator by prompting for the information needed to conduct the inspection and then automatically sets up the data files and converts the inspection parameters into commands to the intelligent controller to position the probe for taking data. The software constantly monitors the position and movement status of the probe as it is returned from the intelligent controller, and if it is moving satisfactorily, associates the probe position with the digitized signal that is being received from the ADC and transfers them to the data file.

The maximum sampling rate for the digitization is 800 Hz per channel for either time or distance based sampling, which is the upper limit of the disk transfer rate. At moments when realtime data acquisition is not in progress, such as when the probe positioner is being moved between tubes, the disk files will be transferred to high density tape for archiving. The data file for a finished inspection will contain the information needed to identify the tube and the inspection parameters.

The data acquisition system was designed to enable a non-computer-oriented operator to run the system after a short learning period. To reduce human error, the software was designed to query the operator for all of the information needed to identify an inspected tube, describe the pertinent parameters of the inspection, such as the type of instrument used, and will not allow the inspection to proceed until all of the information is properly entered.

The information that is required to identify the inspection is:

- date
- operator identification
- instrument name
- probe type
- channel assignments (maximum of 8)
- row number
- column number
- side of generator being inspected (inlet or outlet)

The parameters that are needed to execute the inspection are:

- data file name
- type of sampling (equal time or distance intervals)
- sample interval (time or distance)
- probe start position
- probe stop position
- probe position at the start of data collection
- speed of probe to position
- speed of probe during data collection

To save time, the inspection parameters that do not change between tubes can be put into data files which the computer reads, instead of the operator having to reenter them for each tube. The only thing the operator would have to enter would be the row and column number of the tube to be inspected. This should minimize the errors in parameter specification unless there was a mistake in the initial parameter files.

The control statements that the operator can give the computer once all the parameters have been entered are:

- Initialize (open files, set probe speeds and digitization rates)
- Start (commence data collection)
- Suspend (temporarily halt data collection)
- Continue (resume data collection)
- Stop (premature termination)

These five commands are much easier for the operator to use than the intelligent controller commands that are given in Section III.3.

While data acquisition is in progress, the status of the process is updated on the VT100 terminal screen as shown in Figure 5.

III.5 OTHER USES OF THE DATA ACQUISITION COMPUTER

Although its main purpose is realtime data acquisition, the computer system will not be used for this purpose continuously. The PDP 11/44 is a stand-alone computer that has many capabilities that are not used for realtime data acquisition.

Its proximity to the SGEF makes it convenient for use in record-keeping for the project. Data base management software (RMS and DATATRIEVE) were purchased for maintaining several sets of records. The computer will be used to maintain the personnel training and exposure records of the researchers and contractors involved in the various project tasks. The radiation monitor will be able to obtain the complete exposure record of any individual requesting access to the SGEF from a CRT in his office.

The computer will also be used to maintain the bookkeeping records on the type, status and location of all specimens removed from the generator and the associated lab books. This should make the location of specimens as they are analyzed easier than in the past.

The PDP 11/44 will be used for as much preprocessing of data as possible. This includes data entry for researchers located near the SGEF and the preliminary signal processing done on the archived EC tapes. Software has been written to identify anomalous signals for further analysis and the pattern recognition analysis described in Chapter 5. The graphics capability of both the VT100 terminal and the HP plotter will be heavily used to plot signals for visual interpretation in much the same way as an oscilloscope. Editing and graphics software has been obtained that permits the writing of reports and the drawing of view-graphs on the HP plotter. Additional software will be added as the need arises.

SDR System

Status Report

06-OCT-82 10:18:26

-----Data ID----- Tube IO-----

Operator:	SSE-JOS-PJH	Row:	0
Calibrate:	off	Column:	1
Dataset:	SURRY	ICB:	INIT1
Input Tape:		SCB:	SURRY
		Leg:	hot

-----Collection Parameters/Status-----

State:	initialized	Mode:	time
Start:		Index:	0.010 sec.
Duration:	00:00:00	Speed:	12.0/36.0 in. per sec.

	Selected	Current
	-----	-----
Position:	1000.000/ 100.000	0.000 in.
Travel:	-900.000	0.000 in.
Frames:	7500	0

Status: ok

FIGURE 5. Example of Computer Controlled ISI Data Sheet

CHAPTER IV

DATA ANALYSIS COMPUTER SYSTEM

The Analysis of Large Data Sets (ALDS) computer was selected for the data analysis task because the hardware features and software tools, developed for large data sets, are directly applicable to the large complex data set to be generated on this project. The use of the ALDS computer is cost effective because it eliminates the need to acquire hardware and develop software. Also, the ALDS project benefits from our use of their computer because we will be testing their software/hardware to determine its performance in handling large data sets. The following is a brief ALDS system overview paraphrased from Nicholson et al, 1980. A description of the software interfacing tools that are available is also included.

ALDS DATA ANALYSIS SYSTEM

The purpose of the ALDS project is to develop a statistical laboratory designed for efficient analysis of large data sets. This involves the implementation of new data handling, analysis, and display techniques specifically designed to handle large amounts of data.

COMPUTING HARDWARE

The central computing resource for the ALDS Statistical Computing Laboratory is a DEC VAX-11/780 minicomputer with 2 megabytes of memory (see Figure 6). This is a high-performance 32-bit virtual memory machine. There are currently 900 megabytes of disk storage available for data and program storage. As well as a conventional 45 ips dual-density tape drive, the system has a 125 ips tri-density tape drive for processing large amounts of data. In addition to software developed specifically for the VAX, previously developed software on the well-established PDP-11 series of computers can also be used. Thus, a wealth of proven system and application software is available. To facilitate resource sharing, the ALDS VAX will join a minicomputer network of VAX-class computers that are at other Department of Energy laboratories and several universities.

The statistical laboratory relies heavily upon graphical display of data and analysis results. In addition to several alphanumeric CRT terminals, a RAMTEK 9400 color raster graphics system is interfaced to the VAX. It offers high resolution (1280 x 1024 pixels) and internal microprocessor control. The unit allows the investigation of the value of color and shading in identifying and highlighting important data relationships from large data set analysis. A graphics hardcopy unit, a letter quality, and a desk-top pen plotter are among the other I/O devices available. Figure 7 is a diagram of the major components of the ALDS computer system.

FIGURE 6.

ANALYSIS OF LARGE DATA SETS COMPUTER SYSTEM

FIGURE 7.

SOFTWARE ARCHITECTURE

The software system for the ALDS Statistical Computing Laboratory is being designed as an integrated set of statistical analysis tools. These tools are versatile and easy to use, yet they offer the user powerful data processing capabilities. They are being tailored to provide efficient loading, manipulation, analysis and visualization of large collections of data. The software also provides many convenient bookkeeping services to relieve the data analyst of many tedious tasks heretofore performed manually during the data analysis process.

The ALDS system is designed around two existing interactive statistical analysis packages, MINITAB and RUMMAGE. A control monitor allows the user to initialize either or both packages as a dormant process (a state in which a process is inactive but known to the system with all of its current status). The user may then perform other tasks external to the package such as data editing, file manipulation, graphical display, or the execution of a special application program. All of these external tasks are initiated, upon user request, by the control monitor software. When the user has completed these tasks (e.g., preparation of a data file to be merged with other data previously generated in MINITAB), he may reactivate a dormant data analysis package (MINITAB or RUMMAGE) and resume the initial analysis process. All data previously generated and left in the package's internal data storage area are preserved.

In addition to MINITAB and RUMMAGE, a pattern recognition package, ARTHUR, has been interfaced with the ALDS system. A data editor has been implemented to provide basic editing, sampling, and subsetting capabilities. It operates on special self-describing binary (SDB) data files. "Self-describing" is a coined term to denote data descriptors being stored in the same file as the data being described. Binary (or machine) representation of data results when formatted data is transformed into unformatted data. This methodology provides a means for efficiently handling large data files as well as establishing a common interface to facilitate data transfer among existing software packages. It also serves as the standard data file format for all ALDS application and utility software modules. MINITAB and RUMMAGE interfaces have been developed to allow these software packages to read and write SDB files directly.

The ALDS system contains a collection of user interface tools to provide a common method of processing user/computer interactions. All system prompts and user responses are logged in a history (transaction) file assigned to the user.

Some enhanced RAMTEK 9400 graphical display routines have also been developed. These routines operate directly on data stored in SDB files and are designed for efficient processing and display of large numbers of data points. Data transformation capabilities exist within these routines.

CHAPTER V

STATISTICAL ANALYSES

Statistical analysis, as stated in the Research Program Plan, will be a major task during the entire life of the project. Due to the expense involved in obtaining data, the same data should be used to answer questions raised by several of the research objectives. A major role of statistics will be to help design sampling techniques and experiments to minimize conflict between the data needs of various tasks. Early statistical input into the project planning will ensure that the work is approached in an organized manner. This way the experiments that are conducted and the data collected can answer the questions in a cost effective manner. Also it will guarantee that enough samples are taken, and that the test matrices for the materials work reflect the necessary conditions, to allow the relationships of interest to be quantified.

The types of statistical analyses that we foresee being employed during the project include:

- Sampling Methodology
- Experimental Design
- Signal Processing/Pattern Recognition
- Reliability Analysis
- Modeling

Each technique will be discussed briefly including an outline of its respective role in the project. We must emphasize that this is our concept of the statistical methodology that may be useful to fulfill the project objectives. All analyses will be performed with close collaboration between the researchers and statisticians.

SAMPLING METHODOLOGY

Sampling is an important aspect of the work since it is not feasible to obtain physical measurements for every EC indication, nor to destructively analyze the entire generator. This methodology will initially be employed to design an NDE round robin sample plan with a distribution of indications based on analysis of the baseline EC data from both the never-plugged and unplugged tubes as well as consideration of the historical data. This distribution, representing the population from which a stratified sample (Cochran, 1968) can be designed, will determine the locations to take physical measurements in order to obtain the flaw type and dimension of the indication. The size and composition of the stratified sample will be selected so that the reliability of EC inspections can be established for:

1. the detection of flaws
2. the categorization of flaw type

3. the size of the flaw.

Based on EC results and visual inspection of the secondary side, a stratified sample will be designed for removal of tubing specimens from the generator. Sampling will also be employed to select a set of tube sections that represent a statistically meaningful spectrum of flaw types for destructive analyses. Metallographic analysis of defects will provide quantitative data on the accuracy and precision of various NDT techniques and instrumentation. Other samples will be used to determine remaining tube integrity of the defected tubing by burst and collapse tests. (A detailed description of sampling methodology and how it will be used in the project will be the subject of a later document.) Because the physical measurements must be related to the EC data, experimental design concepts become quite important.

EXPERIMENTAL DESIGN

As stated previously, the data to be collected during the project are costly to obtain and must be used for a variety of purposes. For example, the materials testing work will be used to establish mechanical properties related to the baseline inspection data, and to verify tube failure models.

The purpose of an experimental design is to maximize the amount of information obtained at an optimized cost. The use of statistical sampling and design methodology will accomplish this by preventing the objectives of one experiment from compromising the outcome of the others. To do this efficiently, the requirements of each study will be detailed with respect to the objectives. An experimental design will be developed for each study and then the data requirements from each study will be compared with respect to the sample sizes needed to produce precise estimates of, for example, tube mechanical properties and the ability to detect differences between groups, such as different defect types.

Experimental design methodology will be employed as an aid in determining test matrices for the materials research aspects of the project. Mechanical testing will be performed to generate data for use in evaluating tube failure models developed by the NRC Steam Generator Tube Integrity Program. Leak rate test results on different defect types will be used to provide inputs to NRC's tube-plugging criteria.

The test matrix design is also needed for determining the composition of a mock-up tube bundle to be fabricated from components removed from the Surry generator for future NDE inspection or validation of new NDE instruments.

SIGNAL PROCESSING/PATTERN RECOGNITION

Digital signal processing methods have been recently applied to improve the reliability of NDE data interpretation. The skill, experience, and fatigue level of the operator are the principal components governing the quality of NDE inspections.

Adaptronics (Shankar et al, 1978) has used a pattern recognition technique known as Adaptive Learning Networks. It was used to classify and size laboratory induced flaws from eddy current data. Babcock and Wilcox (Flora et al, 1980) have also initiated activity in this area. At PNL, we (Doctor et al, 1981) have classified and sized artificially induced flaws in PWR Inconel 600 steam generator tubing using general pattern recognition techniques.

After physical measurements have been obtained to provide information on the type and size of service induced flaws, we will develop a pattern recognition algorithm for ISI's. Using the multifrequency baseline data we can ascertain the feasibility of performing automatic interpretation in the reactor environment. For specific flaws, we may also compare the baseline eddy current signals to those obtained during the historic ISI's. This will enable us to learn the effects of defect growth upon the EC signals.

RELIABILITY ANALYSIS

One of the objectives is to establish the reliability of ISI's. Present reliability estimates for ISI's are based on laboratory induced flaws. However, these flaws produce much cleaner eddy current signals than those produced by reactor-operation induced flaws. Some reliability work for ISI's has been performed for NRC at Sandia. Easterling (1978) used modeling techniques to evaluate the ability of various ISI sampling plans to detect flaws. This evaluation utilized flaw samples produced in a laboratory with subsequent laboratory practice NDE. On the basis of the observed variability in EC signal interpretation and of the probability model of the ISI process that he developed, a 100% inspection of the generator was recommended. He used the model on some actual field ISI data, but did not have the actual physical flaw measurements to permit a complete evaluation of the interpretations. This project will supply the physical measurements needed to establish the relationship between the ISI results and the actual flaw conditions for ISI data. In addition to performing conventional reliability studies, we plan to evaluate Easterling's model on the baseline EC data and refine the model if necessary, or develop an alternative model if it appears worthwhile. Also, we will be performing reliability analysis on the pattern recognition interpretation of the EC data.

MODELING

There is potential for developing a model of tube-sheet corrosion. The form of the model is presently unclear. One possibility is a statistical model of degradation based on some physical relationships and a time series analysis. Another possibility is a deterministic model, such as the finite element analysis performed by Westinghouse.

There may be a potential for providing inputs into thermal-hydraulic models of steam generator performance, as affected by tube support plate deformation (flow slot closure), and tube annulus blockage. Secondary side inspections will also potentially provide inputs on regions of steam blanketing within the generator.

SUMMARY

The purpose of the Data Acquisition and Analysis Task is to provide an efficient and cost effective method of collecting and analyzing the different types of data to be collected during the course of the Steam Generator Group Project. To do this we have chosen two computer systems that make use of largely existing hardware and software at Battelle-Northwest. The two computer systems are a data acquisition computer used for collecting analog NDE data, and a data analysis computer with a variety of data management, analysis and graphic tools.

The data acquisition computer is a Digital Equipment Corporation PDP 11/44 system with a NEFF analog-to-digital converter with the basic capability of acquiring and digitizing eddy current data real-time. It is a \$100,000 computer system that is being rented from Battelle for the duration of the project. In order to complete the system so that it can take the EC data in the volume that is needed for the baseline inspection, we have purchased peripheral equipment, the major items being a high density tape drive and a 300 megabyte disk drive, and built an intelligent controller to control probe motion and provide accurate probe position information.

The data analysis computer is a Digital Equipment Corporation VAX 11/780 machine which cost about \$500,000. This computer was purchased by DOE under the ALDS program. We will be charged on a "resource utilization" basis.

The data acquisition and analysis system will perform as follows:

The PDP 11/44 system will be used to control the NDE probe pusher-puller, and will interact with the probe position encoding device to automatically include location information with NDE signals. The raw analog signals will be stored on tape which will be archived for future reference. Concurrently, the signals will be digitized using the NEFF ADC, and archived on digital tape by the PDP 11/44. The reason for storing the data on digital tape, in addition to analog tape, is to provide easy access to the data for analysis purposes. In addition to transferring the data to digital tape, the PDP 11/44 will perform signal processing so that only signals above some discretion limit, indicative of an anomaly such as a flaw, will be transferred to a data disk. The data disk will be physically transferred to the VAX 11/780 system where existing software will provide suitable data base compilation, statistical analysis, and graphical display.

The non-NDE data will be input directly into the VAX 11/780 data base by the research staff using terminals.

In addition to data acquisition, the PDP 11/44 will maintain a personnel dosimetry data base and provide on-line information to the radiation monitoring staff controlling access to the generator.

In summary, the system as described allows for the collection, maintenance and analysis of a potentially very large data set with relative efficiency and cost effectiveness. The archival storage of the largest subset of data, the raw NDE data, will provide a back-up in case data is somehow lost during a system malfunction or questions arise concerning any signal processing step.

System capitalization has been minimized by obtaining use of existing onsite hardware and software, without compromising overall data handling capability, but at some expense to efficiency. Our cost benefit analysis showed the described set-up to be the optimum from both a cost and schedule standpoint.

REFERENCES

Cochran, W. G. 1963. Sampling Techniques, second edition. John Wiley and Sons.

Doctor, P. G., T. P. Harrington, T. J. Davis, C. J. Morris, and D. W. Fraley. 1981. "Pattern Recognition Methods for Classifying and Sizing Flaws Using Eddy Current Data". ASTM Symposium on Eddy-Current Characterization of Materials and Structures, September, 1979, Gaithersburg, MD. ASTM Technical Publication 722, 464-483.

Easterling, R. G. 1979. Exponential Responses with Double Exponential Measurement Error - A Model for Steam Generator Inspection. Proceedings of the 1978 DOE Statistical Symposium, Conf-781108, 90-110.

Flora, J. H., S. Smith, and A. K. Jain. 1980. "Computer Classification of Eddy Current Signals for Automatic Inspection of Steam Generator Tubes". Presented at the IEEE Computer Society and IEEE Systems, Man and Cybernetics Workshop on Digital Signal and Waveform Analysis, Miami, FL.

Nicholson, W. L., D. B. Carr and D. L. Hall. 1980. "The Analysis of Large Data Sets. Proceedings of the 1980 Statistical Computing Section, American Statistical Association.

Shankar, R., C. L. Brown, A. N. Mucciardi and T. J. Davis. 1978. "Feasibility of Using Adaptive Learning Networks for Eddy Current Signal Analysis". Electric Power Research Institute Report NP-723.

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11. ABSTRACT (200 Words or less) A major task of the Steam Generator Group Project (S2GP) is to establish the reliability of the eddy current inspection techniques of PWR steam generator tubing by comparing the eddy current data to the actual physical condition of the tubes via destructive analyses. This report describes the plans for the computer system needed to acquire, store and analyze the diverse data to be collected during the project. The real-time acquisition of the baseline eddy current inspection data will be handled using a specially designed data acquisition computer system based on a Digital Equipment Corporation (DEC) PDP-11/44. The data will be archived in digital form for use after the project is completed. Data base management and statistical analyses will be done on a DEC VAX-11/780. Color graphics will be heavily used to summarize the data and the results of the analyses. The report describes the data that will be taken during the project and the statistical methods that will be used to analyze the data.			
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