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DATA ACQUISITION FOR THE SODIUM LOOP SAFETY FACILITY EXPERIMENT P4

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ABSTRACT

Data acquisition for the Sodium Loop Safety Facility (SLSF) experiment P4 used three computers for the continuous collection of data and two computers for the routing and displaying of data. Four of these computer systems were located at the Engineering Test Reactor (ETR) site, in Idaho, to access sensor signals from the analog to digital interfaces. The fifth system was located at Argonne National Laboratory (ANL), in Illinois, and was used mainly for display and storage of data. All display computers were connected together using the DECNET software package. The transmission of data was managed over a dedicated phone line using 9600 baud long distance modems. A stand-alone high speed data acquisition system was also used to record data during planned reactor transients.

DATA ACQUISITION SYSTEMS

The main purposes of the Data Acquisition Systems (DAS) were to provide a reliable system for collecting and storing data for long periods of time and for transmitting this data to operators and experimenters.

Primary and Secondary Data Acquisition Computers

Two systems, the primary DAS and secondary DAS, were used to collect data, from loop sensors, during the experiment. The computer in the primary DAS was a Digital Equipment Corporation (DEC) PDP-11/34 with 32k words of memory. The devices connected to the primary included a console terminal (LA120 Decwriter III), a 40 megabyte disk (AMPEX DM9400), two 800 bits per inch (BPI) magnetic tape drives (Kennedy 9300), a programmable multiplexer analog to digital subsystem (Neff S400, S500), and an interface (DEC DMC-11) to a display computer system. Software in the primary DAS was the DEC RT-11 real time operating system. The computer in the secondary DAS was a DEC PDP-15/78 with 40k words of memory. Devices connected to the secondary included a system console terminal (LA36 Decwriter II), a 5 megabyte disk (CDC 9247), two 800 BPI magnetic tape drives (Wang 1145), a multiplexer analog to digital subsystem (Xerox MD40), a paper tape reader/punch (DEC PC05), an interface (DR-11B) to the display computer system, and a 24 channel digital multiplexer connected to various reactor monitoring functions. Interfaced to the 24 channel multiplexer were 12 digital function generators, two data loggers (Doric), four 64 channel Unidrivers, an IRIG clock, and the reactor scram signal. Software in the secondary DAS was an in-house operating system supporting data acquisition, FOCAL, and a selection of operator commands.

The primary and secondary systems collected data from 256 and 128 loop sensors, respectively. The 128 channels on the secondary were backup records of the most critical test section sensors. The channel to channel sampling frequency of the multiplexers was approximately 100 microseconds. Data rates for individual channels of 450, 150, 50, and 10 samples per second were obtained by using the programmable multiplexers and a sequence control program (SCP). A sequence control program contains a list of channels that determines the order in which the multiplexer will sample each channel. A data record consisted of one scan of the SCP. The primary and secondary systems could generate ten data records per second. If a channel were specified 45 times in the record, it would be sampled 45 times per data record or 450 times per second. Sampling rates of 10 times per second were obtained by specifying a channel only once in the data record. The system had the ability to handle the 256 channels in any combination to produce a total through-put of 50k samples per second, consequently, there was a large flexibility available in setting sampling rates. The secondary SCP was similar to the primary SCP but contained specifications on only the first 128 channels.

The primary and secondary systems recorded data on the magnetic tapes in either a continuous (fast) or an intermittent (slow) mode. In the fast mode, each scan of the SCP was recorded. In the slow mode, scan(s) of SCP data were transferred to magnetic tape under operator control by specifying a period parameter (the time in seconds between data transfers). When an end-of-tape was sensed on the current tape being recorded, a logical end-of-file was written and data recording proceeded on the alternate tape unit. The full tape unit was rewound to its load point for dismounting and replacement by the operator. In addition, the secondary system also saved data on disk in a circular file. In the event of a reactor scram, that disk file was saved and the recording mode automatically changed to fast. With this feature about 15 seconds of high speed data before a major unplanned event could be saved.

On Line Cover Gas Data Acquisition Computer

The third computer used in collecting data for this experiment, the On Line Cover Gas System (OLCS) DAS, was a DEC PDP-11/34 with 128k words of memory. The devices connected to this computer included a system console terminal (LA36 Decwriter II), a graphics display terminal (Tektronix 4014) and hard copy unit (Tektronix 4610), four 5 megabyte disks (DEC RK05), an 800 BPI magnetic tape drive (Kennedy 9100), a dial-up phone modem (Vadic 1601), two 4096 channel gamma spectrum counters (Tracor Northern 1213), a 32 channel analog to digital interface (Camac 1500), an interface (Camac) for relay activation, and an interface (DEC

DMC-11) to the auxiliary computer. The operating system in the OLCS DAS was RSX-11M. It was possible for the computer to change the scale of spectra being collected by dynamically changing the gas sample chamber size and collimator position. The DECNET communications package linking the OLCS DAS to other display computers made it possible to operate the OLCS locally or from any display computer.

Analog data on the OLCS DAS was sampled on one second intervals and saved in reserved memory locations. Every minute the data for the prior 60 seconds was copied to a disk file and then averaged, to obtain minute average values. The latter was transmitted to the DEC PDP-11/60 at ANL by DECNET. If the system was in standby mode, the system recorded, each hour, the previous hour's data on magnetic tape from the disk files. If the system was in experimental mode, the operator had control of the recording of the data. Every time the operator saved a spectrum on magnetic tape all files not previously recorded were saved. During standby mode, the spectrum counters were also recorded and zeroed once an hour. There were 120 locations for each data sample and 120 disk files for each minute's survey, therefore up to two minutes of data could be saved in memory and two hours of data could be saved on the disk.

The Delayed Neutron Detector (DND) data was collected by scaler counters attached to the 32 channel analog to digital interface. At one second time intervals, the counter values were transferred to a memory buffer and the counters zeroed. This data was saved on disk files once a minute with the analog data and recorded to magnetic tape once an hour.

Online displays included a schematic plot of the OLCS, plots and listings of the last two minutes of data saved in memory, and plots of the gamma spectrum data stored in memory or from magnetic tape. A calibration routine was also available to obtain the necessary coefficients for converting spectrum channel number to energy. These coefficients were stored on a disk file for easy access to any plotting or listing program. Other utility programs were available to rewind the magnetic tape, initialize the spectrum counters, activate relays to change the volume of the gas being sampled, and set alarms to warn operators of high counting rates. A block diagram showing how these computers were connected in shown in Figure 1.

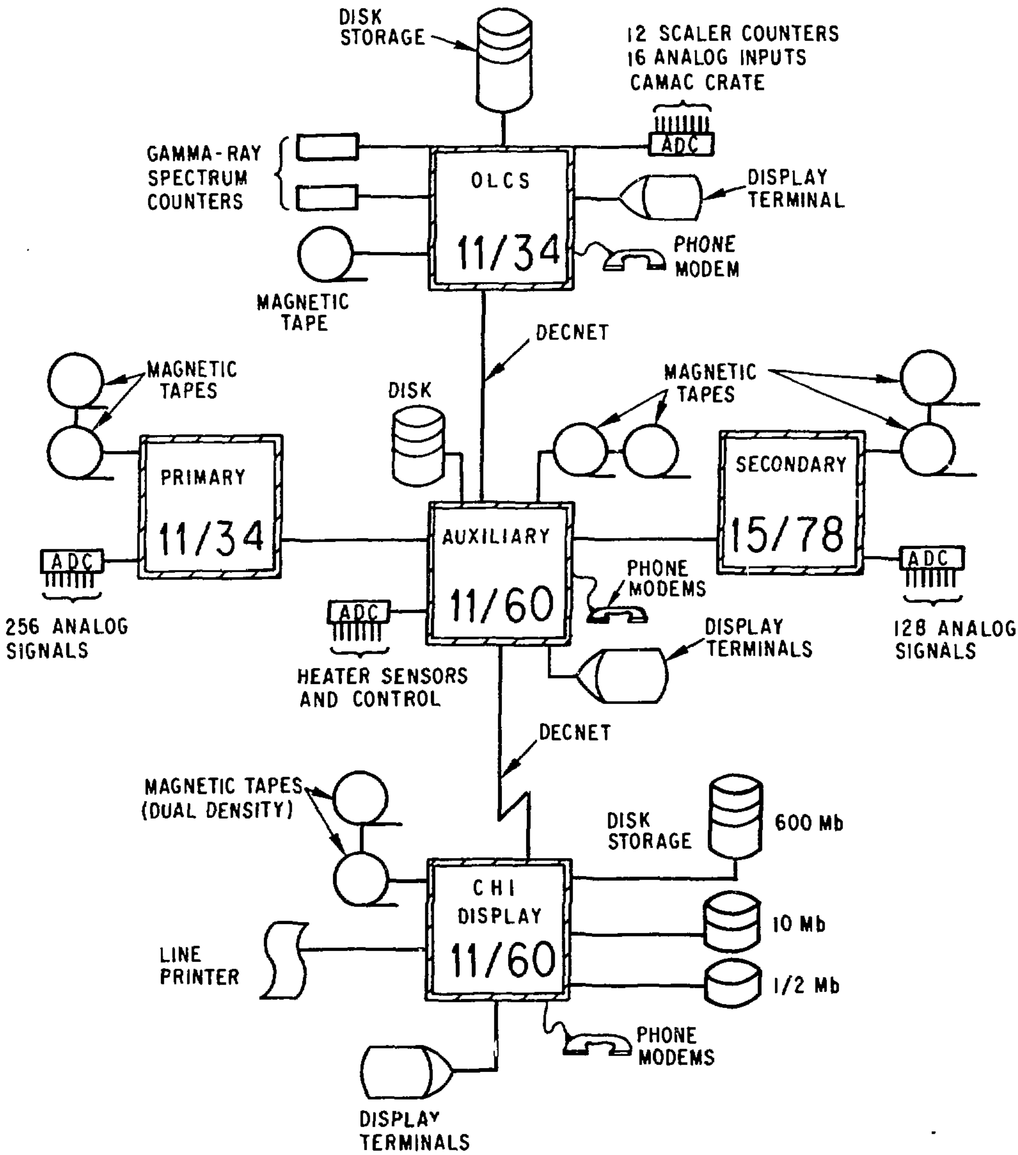
DISPLAY SYSTEMS

The data for the P4 experiment needed to be displayed at the reactor site and at ANL. Display systems were used to show operators and experimenters the up to the minute values of various parameters. Two separate systems were used, one at the reactor site and one at ANL offices in Chicago, to provide better coordination of the experiment.

Auxiliary Display Computer

The computer used to provide a display at the reactor site was called the auxiliary computer. The auxiliary display computer was a DEC PDP-11/30 with 128k words of memory. Devices connected to the auxiliary

Fig. 1 Schematic of P4 Data Acquisition System



computer included a 256 channel analog to digital multiplexer (Neff S400), two 800 BPI magnetic tape drives (Wang 1145), an 80 megabyte disk drive (DEC RM02), four console terminals (2-LA120 Decwriter III's and 2-LA36 Decwriter II's), three graphic display color terminals (ISC 8001H), a graphic display terminal with a hardcopy unit (Imlac PDS-1G and A. B. Dick 675), a line printer/plotter (Versatec 1100), two call-in phone modems (Vadic 3467), a paper tape reader/punch (DEC PC05), a link to three Power Transient Controllers (LSI-11), and interfaces to the primary DAS (DEC DMC-11), secondary DAS (DR11-B), OLCS DAS (DMC-11), and a display and storage computer located at ANL (DEC DMC-11). Software in the auxiliary display computer consisted of the RSX-11M operating system. This is a multi-user, multi-programming system which makes program development and system resources available to many users at the same time. The 256 channel data multiplexer was used for the control of loop and sodium sampling system heaters.

The high speed links to the primary DAS and secondary DAS provided data in the auxiliary display computer several times per second. The data was stored in memory to make it possible for several programs to simultaneously access and display the data in either graphic or tabular form. Software provided for a disk save of approximately two minutes of data, a list of current data, comparison of primary DAS with secondary DAS data, display of a loop schematic, and two-hour time history plots of selected heater control sensors. Other utility programs provided for the copying of magnetic tapes, listing of data from magnetic tape, and the compressing of data.

The auxiliary display computer also routed data from the OLCS DAS to the ANL computer and sent one minute averages of data collected from the primary DAS or secondary DAS to ANL. This was accomplished by using the DECNET software package and the links to these computers. The averaged data was mainly from the primary DAS, but if the primary DAS did not update its buffer in the auxiliary computer, the secondary DAS data stored in the auxiliary computer was transmitted to ANL. The use of this mode usually was an indication of a primary DAS hardware failure.

ANL Display Computer

The display computer used to provide a display at ANL was a DEC PDP-11/60 with 128k words of memory. Devices connected to this computer included a system console (LA36 Decwriter II), two 800 BPI magnetic tape units (Kennedy 9100), two 10 megabyte disks (DEC RL01), two floppy disk units (DEC RX02), two 300 megabyte disks (Trident 302), a line printer/plotter (Versatec 900A), a graphics display terminal (Tektronix 4014) with a hard copy unit attached (Tektronix 4610), and 8 multiplex terminal ports (DEC DZ-11) for display terminals (Mime I's and Mime II's) and dial-up modems (Vadic 355's and 3455's). The operating system was RSX-11M. DECNET was used for computer to computer communications and transfer of data. For brevity, this display computer will be called CHI (Chicago).

CHI was used for the storage and display of data collected from the three DAS computers located at the reactor site. The data was available in a standard format for programs to display, in engineering units, any operating parameters used in the experiment. Data was stored in daily files for easy access by listing and plotting programs. Data was also stored into real time files for easy access by programs needing the most current information.

Several programs were developed to display and analyze the data. Two of these, ASC and ASK, provided for the on-line display of data from the P4 loop sensors and the OLCS. The ASC program displayed critical loop temperatures, flows, and pressures along with the reactor power. The ASK program displayed the OLCS flowrates and pressures and also the radiation counter's voltages. Experimenters used this information to aid in the comprehension of the significance of the data. These programs would update their displays whenever data was received at ANL, which was usually at one minute intervals. Other programs used were PLT, LST, PWR, CVT, EXT, CPT, and CST. The PLT program plotted data from any of the files created for the P4 experiment and produced high resolution graphs on either the display terminal or the line printer/plotter. These plots could be from any day or series of days that data was recorded and sent to ANL via the dedicated phone line. The LST program was used to display tabular data from any sensor or set of sensors. The PWR program read data from the disk files and calculated test section power and displayed this value along with the average test section temperatures and flows used in the calculation. CVT converted voltage files to engineering unit files. On occasion the calibration factors for some sensors were changed, therefore, the CVT program was developed to update files to current calibration factors. EXT extracted subsets of data from the daily files. The subset could be a subset of the channels and/or times. It could also merge one or more daily files into a single file. The EXT program was developed to create smaller files for multiple access and save a repeated time-consuming search of the larger files. The CPT and CST programs were used to convert the data tapes from the primary DAS and secondary DAS to the same file format used in the daily files, so that other display programs (LST, PLT, PWR) could access these files and provide the experimenter with the needed information. A program was also developed to convert the OLCS DAS data tapes to the CHI file format.

Because there was little time to educate the users of these display programs, standard defaults, self-scaling axis, and help documentation were set up to aid in the orientation of the large number of experimenters who were going to use these programs. A display program could be invoked and, when HELP was typed, all of the commands acceptable to that program were displayed at the terminal.

DATA LINK OPERATION

The display computers were connected together by a software package called DECNET. DECNET is a set of software products that extend the facilities of various DEC operating systems so they can be interconnected to form computer networks. The software package extended the RSX-11M operating systems for the three display computers, i.e., the

OLCS DAS, the auxiliary computer, and the CHI computer. Functions that DECNET provided were device sharing, file sharing, program sharing, and intertask communication. Device sharing allowed a programmer to connect to peripheral devices of a remotely located system. File sharing allowed programmers to open, read, write, and close files on a remote system. Program sharing allowed the transfer of an executable program to a remote system, and load and execute that program on the remote system. Intertask communication allowed two tasks in the same system or in remotely located systems to create a data path for the transfer of information between them.

The structure of DECNET provided for the communication functions of a network to be in four layers. Each layer corresponds to one or more DECNET protocols at that layer. The user layer, the only visible layer to the network user, generated a message to be transmitted to another process. This message could be initiated at a terminal or in a task to gain access to files and devices on other network nodes. The logical link layer provided all the bookkeeping required to allow many users to share a physical link and to make the logical links appear to operate simultaneously over a single physical communications path. The physical link layer maintained the control over a physical communication link in order to provide an error-free data path over the phone line. The hardware layer transmitted and received data from the physical link to the devices on the node and handled synchronization and modem control for the hardware.

The interface between the OLCS DAS and the auxiliary was a direct line communication with two DMC-11 interface boards in the computers. The interface between the auxiliary computer and CHI computer was a dedicated phone line tied to a Gandalf (SM9600) long distance 9600 baud modem at each end and these modems connected to the computers through DMC-11 interfaces.

The system reliability was very good during the time that the data link was in operation. The data link was shut down, for various reasons, for 33% of the time during the three months that the link was in operation. These shut downs were normally at times when the data link was not monitored at ANL. This included set up of communications, hardware maintainance, and computer failures linked to a variety of reasons. While the link was in operation, 74% of the minute averaged data was received by the CHI computer within ten seconds of its transmission from the other computers and 80% of the data was received within 30 seconds of its transmission.

STAND-ALONE DATA ACQUISITION SYSTEM

A stand-alone independent data acquisition system not connected with the system discussed above recorded 52 channels of multiplexed data from the experiment on standard 14-track analog magnetic tape in a Pulse Coded Modulation (PCM) format. This DAS incorporated a DEC PDP-11/05 computer with 16k words of memory. Devices connected this system included a system console (LA36 Decwriter II), two 800 BPI digital magnetic tape units (Wang 1175), a paper tape reader/punch (DEC PC11), a programmable multiplexer encoder (EMR 429), a time code generator/translator (Datum 9310), a PCM decommutator (EMR 711), and a PCM bit synchronizer (EMR 720). This system was turned on only for planned reactor transients and could record for 30 minutes, at a rate of 5000 samples per second for each channel. Other speeds were available by changing the recording speed on the analog tape but were not utilized for the P4 experiment.

After the transient was complete the data on the analog tape could then be played back at a slower speed and digitized and stored on the industry standard digital magnetic tapes. These digital tapes were then shipped to ANL and converted to the CHI data format. This data could then be stored on the 300 megabyte disks and read by the standard data display programs during transient analysis.

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