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STACK MONITOR FOR THE PROOF-OF-BREEDING PROJECT

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ABSTRACT

This stack monitor system is a coordinated arrangement of hardware and software to monitor four hot cells (8 stacks) during the fuel dissection for the Proof-of-Breeding Project. The cell monitors, which are located in fan lofts, contain a microprocessor, radiation detectors, air flow sensors, and air flow control equipment. Design criteria included maximizing microprocessor control while minimizing the hardware complexity. The monitors have been programmed to produce concentration and total activity release data based on several detector measurements and flow rates. Although each monitor can function independently, a microcomputer can also be used to control each cell monitor including reprogramming if necessary. All programming is software, as opposed to firmware, with machine language for compactness in the cell monitors and Basic language for adaptability in the microcomputer controller.

INTRODUCTION

The Proof-of-Breeding Project has been developed to determine the breeding efficiency of the Shippingport Reactor. To determine this efficiency, a number of fuel elements will be destructively analyzed. As the elements are dissected, chemically diffused, etc., a considerable amount of radioactive gas will be released and eventually vented to the atomsphere. This gas must be monitored, not only to account for the releases but also to supply data for project calculations. An instrumentation system will be described which monitors the eight exhaust systems from the four shielded hot cells and generates the gas concentrations and release information.

During a project of this scope, all instrumentation needs cannot be predicted, therefore ease of system modification was considered a necessity. The data manipulations required to generate release information from the various radiation detectors and air flow sensors dictated that a microprocessor based system be used. In addition, various control functions were required to select sample stack, change filter media, etc. To fulfill the needs of this project and develop a base for future stack monitor applications, a microprocessor based system was designed which maximized program control. Generally, the hardware circuitry can be simplified and modularized when operational functions are shifted to software control. This can lead to greater standardization between monitors where the final performance is more a function of the software program than the hardware circuitry.

DESCRIPTION

The system consists of four field processors and one query-and-control unit (fig. 1). Each field processor is located in a fan loft near the stack sampling location.

The field processors have several configurations from a single detector sampling two stacks to a five

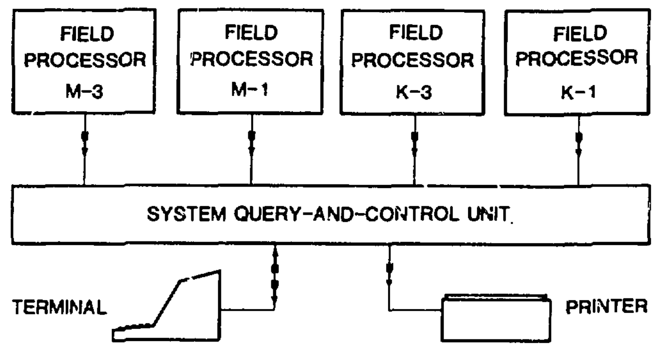

Fig. 1 SYSTEM COMPONENTS

detector unit with two air systems sampling two stacks. The most complex processor (fig. 2) will be the subject of the following discussion. All processors contain one or more radiation detectors, air pumps, air flow controls, air flow sensors, and a microprocessor. The microprocessor programs are designed to generate concentration and release data (in standard units) from the various detector outputs and air flow measurements. The program also controls sample stack selection, filter media movement and isokinetic probe flow. Each field processor is a self-contained unit capable of independent operation. An internal battery maintains accumulated data and program during power interruptions.

A microcomputer query-and-control unit is used to coordinate the data and provide a central control location for the system. System data is periodically printed and can be displayed continously on the system terminal.

Field Processor Hardware

Air flow control by motor driven valves allow sampling of one of two stack at each processor location. Optical sensors provide valve position signals for stack selection control. One processor also includes a moving filter sampler which has a seperate air flow system. The moving filter air flow is controlled to maintain isokinetic air flow at the sampling probe. Heated thermistors in the air streams are used to sense air flow in all stacks and sampling lines. All air flow control; stack selection, isokinetic flow, and filter media, is maintained by the microprocessor program. The microprocessor also generates stack and sampling air flow data from the thermistors signals.

Except for one solid state detector, the radiation detectors are photomultiplier-scintillator assemblies. The beta gas flow assemblies use a thin (3 mm) plastic scintillator on the photomultiplier which is mounted at the end of a cylinder 73 mm dia. and 100 mm long. A similiar cylinder (50 mm dia. and 60 mm long) has the interior surfaces lined with zinc sulfide scintillation material for alpha gas detection. A charcoal filter is

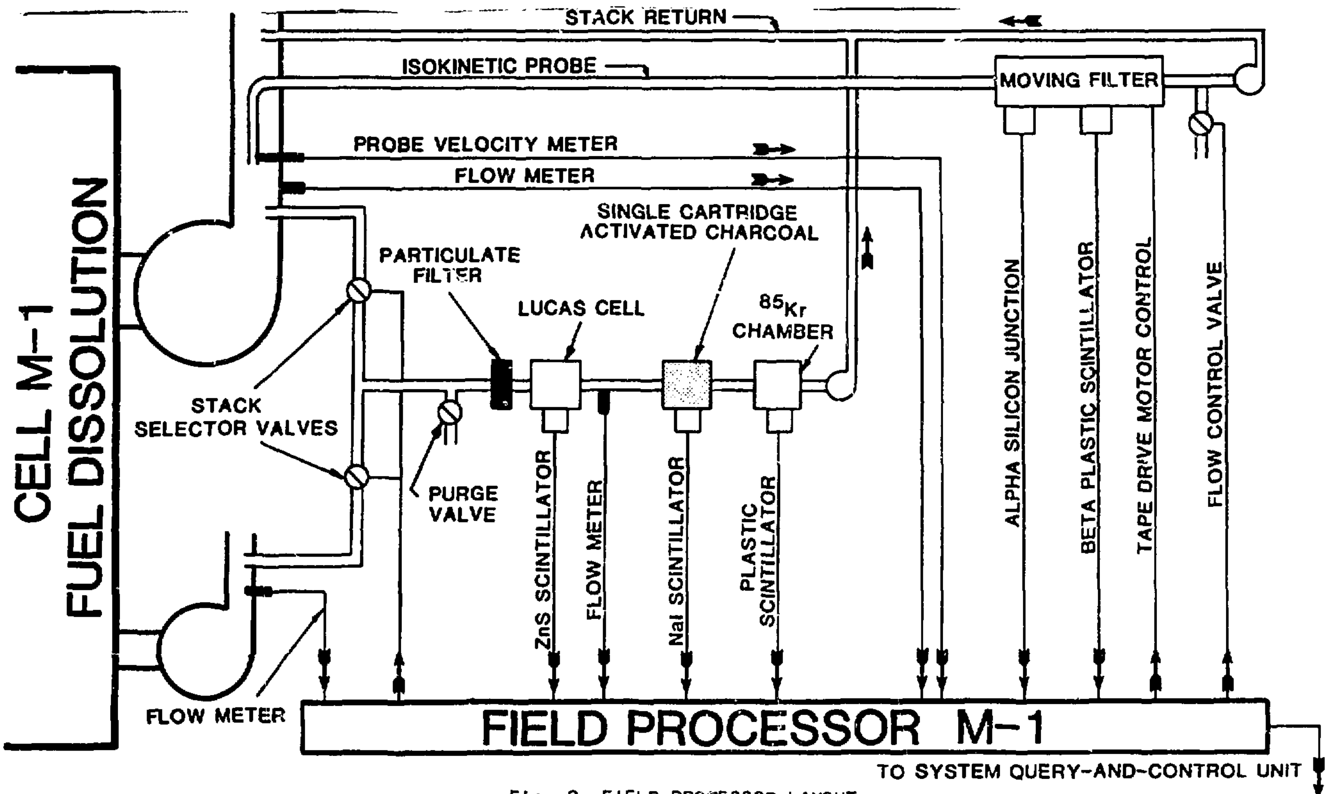

Fig. 2 FIELD PROCESSOR LAYOUT

monitored with a 2 mm by 50 mm sodium iodide scintillator. A standard electronic package is used for the photomultiplier assemblies which incorporates light stabilized electronic circuitry.[1]

The moving filter components; detectors, drive motors, flow controls, etc., are mounted in a separate box. The air is exhausted from the box through the filter media which slides on a media guide plate. The air flows through the media and a hole in the guide plate. An air seal is maintained between the media and the guide plate by the pressure drop across the media. Since the box is sealed, the air source must be from the box inlet which is piped near the upstream side of the media guide hole. Isokinetic probe flow is attained by bleeding room air into the flow downsteam of the filter media with a motor driven valve. Two detectors are used for the moving filter sampler. One detector is a thin plastic scintillator for beta particulate mounted near the down stream side of the filter media guide. A solid state detector for alpha particulate is located near the up steam side of the guide.

A RCA 1802 microprocessor and 6 kilobyte RAM supply the basic computer function. Query-and-control unit communication and initial program loading are provided with a standard RS232 I/O port which operates at 300 baud. Although this system has direct cabling between units, the field processor can be operated through the telephone system since the port is modem compatible.

Input counts from the detector units are accumulated in 32 bit counters (LSI LS7060) which interface directly with the microprocessor buss lines. Likewise, buss compatible analog-to-digital converters are used; National ADC0808 for air flow and RCA CA3300 for pulse height. Additional digital input-outputs sense stack valve positions, media advance, etc., and send control signals to the drive motors. Timing data is supplied by a real-time clock component (RCA CDP1879). Each field processor has a battery for back-up power which can maintain program and data for several hours.

Except for basic detector and air flow sensor adjustments, there are no controls available at the field processor location. All set-up and operational functions are under the microprocessor software control and can be selected with a standard terminal or the system query-and-control unit. In addition to several function selections, a field processor has up to 36 numerical parameters that can be set. These parameters include fault and alarm levels for all counting and air flow channels, calibration factors, backgrounds constants, and readout time periods.

Query-and-Control Unit Hardware

The query-and-control unit consists of a video display terminal, printer and microcomputer (Gimix® 6809 with FLEX® operating system, dual disk drives, and four additional RS232 ports). Battery power has not been provided for the query-and-control unit since the data and running programs are maintained in the field processors.

Field Processor Program

The field processors have been designed for stand-alone operation with complete control through a RS232 interface port. A break-break-break sequence on a line enables the program to be loaded and run. Data accumulation and control functions are accomplished with microprocessor interrupt routines and direct memory access (DMA). With interrupt routines and DMA, correct data collection timing is maintained during control requests and data calculations. All processor programs have been written in assembly language.

Several control functions have been provided including; sample stack selection, filter media advance, and automatic isokinetic air flow adjustment. All counting and data channels have associated fault and alarm level parameters. The multichannel pulse height data between selected upper and lower channels can be summed to provide a window function. As appropriate, background and calibrations factors can be also be set.

Two command formats are available to the operator. These formats have been designed to accomodate both the experienced and inexperienced operator. The first format level will step thru various command tables by displaying the commands as a keypress is repeated. When the desired command has been displayed, another key can be used to execute the command. The second level, which is also used by the query-and-control program, will select and execute a command with a single keypress.

In the run mode, the processor program waits for either an input command or a flag which indicates new data is available for analysis. The data accumulation and control function timing are controlled by the program interrupt sequence which occur at 62.5 millisecond intervals. At this time, the control sensors (stack selection, paper advance, etc.) are compared with control status and the approriate motor power is maintained until there is agreement. Between interrupts, multichannel events from the flash A/D converters are recorded directly with the microprocessor DMA function. At interrupt time, this data is summed in a memory area as a function of channel number or pulse height. After 1440 interrupts (one minute), a readout cycle is initiated which include checking motor power to control functions. Since all control functions require less than one minute for completion, a fault is noted if motor power is still applied. The count data is moved from the channel counters to a memory storage location. When a multichannel accumulation period is complete, the summed data is move to a second buffer area which is available for analysis. In this manner, the last minute data is always available for analysis until the next minute data has accumulated. After new data is moved to the buffer areas, a flag is set which signals the main program that new data is available for analysis.

The calculation routine generates data from the raw counts and checks all channels for high and low alarm levels. A data readout message is always formatted but may not be sent as determined by a command function. It can be automatically sent at one hour (one minute if abnormal conditions) or one minute intervals. The data generated by the processor program is in final form scaled with appropriate units and corrected for various factors. This data is available to the query-and-control unit (or a terminal) until updated at the end of the minute. The message is a single line which includes numerical and graphical representations of the data as calculated. If appropriate, alarm flags are inserted to indicate abnormal conditions.

All changes to the field processor operation are syncronized with the once-a-minute analysis cycle. If a control function has been requested by keyboard command, it will be initiated at this time. The interrupt routine will maintain the function until completed. During the anaylsis cycle, the isokinetic air flow can be adjusted by pulsing the motor driven air bleed value. Each minute the motor will be pulsed until the probe and stack velocities agree within preset limits.

A 32 bit interger number format has been used for all data storage and calculations. Although the 32 bit numbers provides sufficient range (> 4E9) for intermediate calculations and total accumulations, the display scheme for concentrations consists of a decimal point and three digits (.001 to 999.). With a 1K scale factor, this represents one to 999,000. When the scaling factor is absorbed in the unit prefix, the format becomes very readable. Total accumulations are displayed and printed in scientific notation.

Concentration and accumulation calculations vary between the channels. Gaseous channels have a background count subtracted from the gross count before multiplying by the calibration factor. A small error occurs from the background subtraction since negative results are discarded. In the channels with filter media, the calculated "particulate activity" from the last minute is subtracted from the current minute data. A positive difference is considered to be the concentration for that time interval. Particulate concentration calculation includes a calibration factor without a background adjustment since background is included in both activities. The calibration factors are chosen to provide concentrations in reasonable units, e.g., microcuries/cubic meter. Each minute, the concentrations are multiplied by the measured stack air flow and added to the previous accumulation. The accumulation continues until reset by a command function.

Query-and-Control Program

The query-and-control unit coordinates the control functions and data display from the field processors. The main program is written in Basic with machine language subroutines for communication with the field processors.

When in the normal operating mode, data is requested from each field processor once each minute. This data is combined and formatted with units, titles, etc. for display on the terminal. A single line (132 characters) is also generated which contains both numerical and graphical representations of the data. This line will be printed on the hour and each minute that a fault condition is present.

The general operating commands; stack sample change, readout period, accumulator readout, etc., are accessed with a menu format which requires minimal system knowledge. To change alarm-fault limits, calibration factors, etc., the operator is provided direct access to the field processor. Some functions have been purposely made more awkard to use in an effort to separate set-up and calibrations from normal running functions. Generally, the functions which do not affect the data collection or alarm conditions have been given easy accessibility.

At least one record of concentrations and other system data is printed each hour. If an alarm or fault occurs, one minute readouts will be printed until 3 minutes after normal conditions return. The minute-hourly printouts combine numerical and graphical data in a single line. The graphical data is represented in a logarithmic format by different characters for each channel which are printed at the appropriate line positions. The collective picture of several readouts resembles a multichannel strip chart recording and can be used to indicate long term trends. Alarm levels are flagged with an asterisk (faults with a minus sign) beside the numerical data for the channel.

Figure 3 illustrates the printed format. Each midnight, the date and header descriptors are printed.

```
20-SEP-84
TIME DATE  THR  ION  KRY BPAR AGAS PARA GGAM -BPR  S                                 ION  KRY GGAM S   1AGS S   3AGS S
0000 09/20 .056 .000 .005 .000 .890 .186 32.7 .532  2  T  P    A            G        .000 .001 11.2 2   .006 1   3.75 1    I                3  G
0023 09/20 .000 .091 .146*.042 .772 .168 33.1 .583  2 8 1 K    A             G       .000 .002 11.3 2   .000 1   4.29 1    I                 3 G
0024 09/20 .000 .208 .579*.000 .765 .160 33.4 .569  2     PI  K              G       .000 .001 11.2 2   .006 1   3.56 1    I                3  G
0025 09/20 .026 .000 .019 .127 .821 .167 33.1 .602  2    BP    A             G       .257 .001 11.5 2   .000 1   3.80 1    K        I       3  G
0026 09/20 .037 .000 .005 .403 .703 .183 32.6 .707  2 T   P  BA             G        .000 .002 11.1 2   .013 1   3.77 1    I                3  G
0027 09/20 .000 .139 .005 .000 .793 .197 33.0 .578  2     IP   A             G       .164 .001 11.4 2   .013 1   3.60 1    K      I         3  G
0100 09/20 .000 .000 .006 .000 .669 .176 32.9 .551  2     P   A              G       .000 .001 11.2 2   .000 1   3.90 1    I                3  G
0200 09/20 .023 .000 .004 .177 .814 .196 32.7 .593  2     BP   A            G        .000 .001 11.4 2   .006 1   3.22 1    I                3  G
0236 09/20 0936 09/04 22,579 [M1-2] THR-4.05E+06 ION-1.95E+07 KRY-2.93E+06 BPAR-1.35E+07 AGS-2.05E+08 [M3-2] ION-8.70E+06 KRY-2.49E+05 [K1] AGS-3.15E+06 [K3] AGS-8.16E+08
0237 09/20 .000 .000 .005 .199 .890 .171 32.4 .619  2     PB   A            G        .161 .001 11.5 2   .006 1   3.85 1    K      I         3  G
0238 09/20 .046 .129 .005 .000 .917 .168 32.5 .562  2 T   I    A            G        .000 .002 11.2 2   .000 1   3.21 1    I                3  G
0239 09/20 .000 .095 .004 .076 .986 .164 32.6 .582  2   I P    A            G        .001 .001 11.2 2   .000 1   3.74 1    I                3  G
0240 09/20 .072 .000 .005 .030 .910 .176 32.5 .538  2   T P    A            G        .188 .002 11.5 2   .006 1   3.38 1    K      I         3  G
0241 09/20 .013 .115 .005 .000 .834 .199 32.5 .519  2    I P   A            G        .000 .002 11.4 2   .090 1   3.63 1    I                3  G
0242 09/20 .000 .000 .005 .158 .841 .172 32.6 .560  2     B    A            G        .000 .002 11.4 2   .013 1   3.22 1    I                3  G
0243 09/20 .013 .000 .004 .088 .890 .192 32.2 .583  2   B  P   A            G        .000 .001 11.4 2   .006 1   3.60 1    I                3  G
0244 09/20 .000 .120 .005 .000 .883 .172 32.4 .565  2    IP    A            G        .644 .001 11.3 2   .000 1   3.34 1    K I              3  G
0245 09/20 .006 .078 .004 .092 .821 .181 32.5 .589  2   I P    A            G        .010 .002 11.3 2   .013 1   3.97 1    I                3  G
0246 09/20 .000 .000 .005 .008 .862 .178 32.5 .591  2     P    A            G        .065 .002 11.3 2   .006 1   3.44 1    K   I            3  G
0247 09/20 .020 .000 .005 .084 .841 .181 32.4 .613  2   B P    A            G        .000 .002 11.4 2   .006 1   3.39 1    I                3  G
0248 09/20 .013 .170 .005 .016 .703 .188 32.4 .617  2     I   A             G        .142 .001 11.4 2   .013 1   3.36 1    K      I         3  G
0249 09/20 .000 .544 1.32*.000 .890 .160 33.2 .559  2     P   IAK            G       .000 .001 11.3 2   .006 1   3.99 1    I                3  G
0250 09/20 .000 .074 2.20*.000 .821 .160 33.7 .509  2   I P    A  K          G       .003 .001 11.3 2   .013 1   2.83 1    I               3   G
0251 09/20 .040 .000 .497*.265 .841 .160 32.7 .578  2 T   P BK A            G        .124 .001 11.4 2   .020 1   3.08 1    K     I          3  G
0252 09/20 .026 .886 3.27*.000 .827 .194 34.4 .559  2      P   I   K         G       .000 .001 11.4 2   .000 1   3.90 1    I                3  G
```

Fig. 3 TYPICAL PRINTOUT

In this example, the krypton (KRY) exceeded the alarm limit at 0023 and one minute printouts continued until 0027. Normal hourly data was printed until 0236 when the operator commanded an accumulation printout and changed the readout period to one minute.

The current accumulations can be printed at any time by keyboard command. All accumulations continue until reset by keyboard command. When accumulators are reset, the accumulations prior to the reset are recorded by the printer along with the time and date.

Multichannel pulse height data can be presented on the terminal in a bar graph display. When a multichannel display is requested, the data is sent from the appropriate field processor and manipulated into a bar graph by the query-and-control program. The display is automatically scaled to the maximum channel count but can be modified by keyboard command.

The programs for all field processors can be loaded by command from the query-and-control unit. Normally, reloading programs is only necessary after extended power outages or equipment failures. Different programs could be loaded to change a field processor function for special applications.

Since the field processors provide the data collection and computation functions, the query-and-control unit does not need to be in the display mode continously. The unit can be used for control functions, data analysis, or other computer applications at any time.

EXPERIENCE

The system has operated without major problems for two years. Most of the problems have been of a mechanical nature, as examples; motor driven valve failure and detector corrosion from exposure to stack air flow.

The program control of operating parameters has proven useful. During the initial calibration, there was some question regarding several calibration factors. It was easy to set the parameters with the keyboard commands, run the system to collect data, and, after several runs, reset the system to the selected parameter value. The access to system parameters has encouraged adaptation to the various project phases. Although not an intended function in the original design, some alarm levels have been reset to force one minute printouts during various steps of the project. After using the system, the operators have become more venturesome to modify the operation for a specific project need.

One problem which was anticipated but has not been answered satisfactorily, is the operator access to the various system parameters and operational functions. Since all system control is available at the keyboard, some supervision is needed to restrict inadvertent or accidental entries which might disrupt normal operations. A password routine could have been used but that was considered both awkard and insulting to the operator. The current program provides two levels of access. The first level has been designed for the occasional operator and allows access to functions which, in general, will not change data collection factors or seriously change operating functions. This level is more "user friendly" than the second level which allows complete access to all operating parameters.

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REFERENCE

1. R. W. Fergus, A Light Stablized Photomultiplier Detector Assembly with Current Mode Operation, IEEE Trans. Nucl. Sc., NS-30, 475 (1983)

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