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PLANT PROCESS SURVEILLANCE SYSTEM FOR N REACTOR
SYSTEMS STUDY

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Instrument & Automation TechnologyPLANT PROCESS SURVEILLANCE SYSTEM FOR N REACTORSYSTEMS STUDY

by

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and Automation
Technology

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RICHLAND, WASHINGTON

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iii. NOMENCLATURE

ALPHANUMERIC

Characters normally represented by letters of the alphabet and numbers.

ANALOG-TO-DIGITAL CONVERTER

A device for converting a continuous analog signal into digital form before entering the computer.

ANALOG INPUTS

Continuous (as opposed to discrete) inputs.

ARITHMETIC UNIT

Part of computer where arithmetic and logical operations are performed.

ASSEMBLER

An assembler translates numeric programs into machine language.

AVAILABILITY

The fraction of time the system performs its function in the designated mission time.

BINARY NUMBER SYSTEM

The number system to the base 2.

BIT

A contraction for binary digit.

BOOTSTRAP PROGRAM

A program entered into the computer through the console to operate an input device so that larger programs, like the executive monitor, can be entered into the core memory.

CENTRAL PROCESSING UNIT

That portion of the computer consisting of core storage, arithmetic and logic elements, and control elements.

CHANGE DETECT

An independent subsystem in the digital data acquisition system that detects a change in status of digital inputs and "informs" the computer of the change. The changed value or values are then read by the computer

CODE

A set of computer instructions for performing a given function or task.

COMPILER

A program that translates arithmetic or higher level language into machine language.

CORE STORAGE

The random access memory, consisting of magnetic cores, in the central processing unit.

CRITICAL "Y"

An unscheduled abnormal condition on the 230KV or the 13.8KV system.

CYCLE TIME

The time required to fetch a word from memory and write it back into the memory.

DIAGNOSTIC PROGRAMS

Computer programs used to test surveillance system components including the scanners, peripherals, bulk and core storage, and arithmetic unit.

DIGITAL INPUTS

Discrete (as opposed to continuous) inputs.

DISK MEMORY

A bulk storage device with information stored on one or both sides of a disk.

DOUBLE WORD MODE

The capability to use two word lengths as one word. Also referred to as double word length or double precision.

DRUM MEMORY

A bulk storage device with information stored on a rotating cylinder.

DUPLEX, HALF-TRANSMISSION

Electrical transmission in one direction at any given time. Full duplex is transmission in both directions simultaneously.

EXTENDED ARITHMETIC UNIT

The EAU offers a means of rapidly and easily performing the double precision and floating point calculations associated with on-line calculations.

HARD COPY

Any form of computer-produced printed document.

INTERRUPT LEVELS

Levels of importance assigned to inputs which will allow the most important requirements to be processed first, and then continuing with lower levels.

I/O TYPEWRITER

Allows for communication to the computer via entries on the typewriter keyboard and from the computer by providing hard copy output.

MAPS

The printout of process tube heat generation rates, coolant flow rates, and coolant outlet temperatures in a format of the actual matrix of the tubes.

MEMORY PROTECT

The capability to inhibit erasure of specific core memory contents or addresses.

MULTIPROCESSING MODE

The time sharing of computer by various programs with operation of foreground (real-time) and background programs.

OCTAL NUMBER SYSTEM

The number system to the base 8.

OFF-LINE COMPUTER

A computer not connected directly to the process under surveillance.

ON-LINE COMPUTER

A computer connected directly to the process for monitoring and/or controlling.

PARITY BIT

An additional bit put in a word to make the sum of the bits always even or odd.

PROCESS STANDARDS MANUAL

A manual in which are specified the normal limitations governing operation of the N Reactor complex as required for reasons of nuclear safety, conservation of service life of critical facilities, and maintenance of product quality.

REAL-TIME PROGRAMS

Those programs initiated and terminated in real process time.

REAL-TIME MONITOR SYSTEM

- Vendor-supplied software in the operating system which controls other programs based on priorities and time. It establishes the communication between input and output devices, and provides for multiprogramming capability.

REGISTER

A semi-conductor circuit capable of containing one or more computer bits or words.

RELIABILITY

The probability that a device or system will perform without failure of its specific function within a mission time.

ROUTINE

A series of computer instructions; a computer code.

SCANNER

A matrix of controlled relays or switches each connected to a specific process input, used for selection of inputs.

SOFTWARE

All the computer programs for a system directing the operation of the hardware.

STORE

Another term for core or bulk storage (memory).

TIME DISTRIBUTION REPORTS

Douglas United Nuclear generated reports giving the man-hours performed on each assigned task.

TRANSDUCER

A device for converting a process measurement, such as temperature, flow, or pressure, into an electrical signal.

WORD

A set of bits comprising the basic addressable unit of information in a programmable memory.

WORD LENGTH

The number of binary digits (bits) in a word. The particular word length varies with different computers.

iv. ABBREVIATIONS

A.C.	- Alternating current
ADC	- Analog-to-digital converter
Annunc.	- Annunciator
Amp.	- Amplifier
Avail.	- Availability
BPA	- Bonneville Power Administration
CDL 609	- Central Data Logger Model 609
CE	- Combustion Engineering
Cond.	- Condensate
CPU	- Central Processing Unit
CRT	- Cathode ray tube
CRW	- Circulating raw water
D.C.	- Direct current
ECB	- Electrical control board
ECS	- Emergency coolant supply
ECW	- Emergency coolant water
Eq.	- Equipment
FW	- Filtered water
GC	- Graphite coolant
GCP	- Graphite coolant pump
HPV - 201	- High Pressure Valve No. 201
HX	- Heat exchanger
I/O	- Input/output
ISI-609	- Information Systems Incorporated Model #609 Computer
LOG 309	- Data Logger Model #309

LOG 409	- Data Logger Model #409
LOG 509	- Data Logger Model #509
MCB	- Mechanical control board
MG	- Motor-generator
MW	- Mercury-wetted
MWd	- Megawatt-day
N ₂	- Nitrogen gas
NPR	- New Production Reactor
PCL	- Primary coolant loop
PCP	- Primary coolant pump
PCSV-203-1	- Primary coolant suction valve No. 203-1
PCRV-204-1	- Primary coolant return valve No. 204-1
Pt.	- Point
Rm.	- Room
RPM	- Revolutions/minute
S.G.	- Steam generator
Temp.	- Temperature
T.G.	- Turbine-generator
UNIVAC 1108	- UNIVAC - registered trademark for Sperry Rand Corporation's computer model No. 1108.
V (without number)	- Volts
V-20 (with numbers)	- Valve and its respective number

v. SUMMARY

This Systems Study is submitted in accordance with the requirements of AEC Manual Chapter 1801, and proposes the procurement and implementation of a Plant Process Surveillance System for N Reactor. The envisioned system consists of instrumentation, data acquisition equipment, a digital computer, and input/output equipment. It is intended that the system will be a tool for reliable administration of safety limits and standards, simplification of plant operation, and reduction of operating costs by replacing the tasks of shift operations personnel, an instrument technician, and a process engineer.

Background

N Reactor is a dual purpose, graphite moderated reactor which produces plutonium and electrical power, using pressurized light water coolant and zirconium alloy-clad metallic uranium fuel. It is operated at 4000 megawatts (thermal), and produces low pressure steam for an adjoining electrical generating plant which is rated at 800 megawatts (electrical). With this plant rating, N Reactor is the largest operating nuclear power plant in the world. In addition to its large size, N Reactor has the other characteristics which are measures of successful application of automatic data processing equipment to industrial plants. These include complexity, frequent disturbances, good availability of instrumentation, and good availability of process knowledge.

The main control center for the reactor complex is located in the reactor building (105-N Building) with satellite control centers being located in the heat exchanger building (109-N Building), the demineralization plant (163-N Building), the high lift pump house (182-N Building), and the stand-by powerhouse (184-N Building). Shift operating personnel work 24 hours per day, seven days per week, engaged in plant operation, plant surveillance and check-out, material handling, and housekeeping.

Functions performed depend in large part on the status of the plant; i.e., the reactor is shutdown (outage), it is in the process of being started-up (start-up and power ascension), or it is operating at or near full

power (equilibrium operation). Surveillance of the plant is important during all of these modes of operation, but is most complex during pre-start-up checkout, start-up, and power ascension.

In addition to operations personnel, process engineers are required to audit the plant status, see that safety limits are administered adequately, and perform technical analyses in support of plant operation. The safety and operational quality assurance are administered by means of the Process Standards, the Process Audit Checklist, the Start-Up Checklists, and Standard Operating Procedures. The standards are exacting, and the checks and procedures are complex, giving high potential for error and room for improvement in operating reliability, simplicity, and efficiency.

A small process computer (ISI-609) has been utilized since 1963 as a tool for some surveillance and recently for some modest calculations. It is demonstrating unreliability due to aging, however, and requires replacement.

Scope of Application

The Plant Process Surveillance System will be utilized as a tool to do the following:

- a. Centralize and simplify administration of operating limits and standards.
- b. Simplify plant operation by means of automated surveillance and check-out.
- c. Increase the inherent reliability of N Reactor by means of the above simplifications, by supplying a reliable system for reactor surveillance, and allowing thorough, disciplined check-out.
- d. Reduce operating costs by replacement of labor and routine tasks.

Surveillance of the following plant critical systems is planned:

- a. Electrical System
- b. Primary Cooling System
- c. Secondary Cooling System

- d. Reactor Instrumentation Systems
- e. Safety Circuits
- f. Confinement System
- g. Auxiliary Steam Systems
- h. Horizontal Control Rod System
- i. Ball System
- j. Emergency Cooling System

Signals which will be monitored and processed include the following:

<u>Signal Source (Building)</u>	<u>Types of Signals</u>	
	<u>Analog</u>	<u>Digital</u>
105-N	2583	696
109-N	225	0
181-N - 182-N	131	227
184-N	147	286
TOTAL	3086	1209

which gives a total of 4295 signals from important reactor systems and processes which will be available at a digital computer in the main control center. The system will be largely passive in nature; however, direct control actions are planned in the form of automatic actuation of the electrical switch gear which are now actuated manually from an electrical control board in the 184-N Building.

The envisioned system with centralization of control and surveillance will allow simplification of plant administration and operation as follows:

- a. Administration of limits and standards - The system will perform routine calculations which are now performed off-site, eliminating the series steps and complex procedure necessary to perform and utilize these calculations. Also, the system will employ management by exception techniques to give clear, simple out-of-limit statements to the control room operators. Partial automation of the Process Standards audit will also be included, giving status

(exceptions) of such things as flow monitor trip spans, process tube outlet temperatures, confinement door positions, and critical valve positions.

- b. Check-out operation - The signals which will be processed will be available automatically for check-out of systems and processes during pre-start-up checks, start-up, and power ascension. These will be available at one location with automatic or demand access to operations personnel in the main control room. Also the complicated manual electrical switching procedure will be done automatically. With reduction of staff, there will also be net simplification.

Inherent reliability of N Reactor will increase as follows:

- a. The simplifications discussed will reduce the probability of error.
- b. Check-out of the plant will be more thorough as well as more simple. Discipline in check-out and in recheck after correction of problems will be a natural product of the system.
- c. The central system will be the principal data logging system. The probability that the reactor will be held down because of failures in special purpose equipment will be reduced importantly.

Cost reduction will be achieved by replacing the functions of 21 shift operations personnel and one equivalent process engineer. In addition, savings will occur due to the elimination of manual data logging of control rod coolant temperatures.

Description of the Surveillance System

The system will consist of inputs and outputs, software, data acquisition equipment, a digital process computer and peripheral equipment, and instrumentation. Inputs will consist of the following:

- a. The 4295 analog and digital signals described in "Scope of Applications"
- b. Programming inputs via a computer control console and/or input-output typewriter

- c. Alphanumeric codes and demand signals from operators for information and control

Outputs to operations in the central control room will consist of the following:

- a. Summary reports of plant operating data
- b. Process limit reports giving calculated operating boundaries
- c. Exception reports, and displays via a cathode ray tube of process parameters approaching or exceeding their limits
- d. Equipment status exception reports, showing which switches, breakers, valves, and confinement doors are in off-normal position
- e. Sequence of events reports such as the logging of control rod positions and motion sequences during the start-up and power ascension of the reactor

Software will consist of the following programs shown with their requirements:

<u>Program</u>	<u>Requirement</u>
Tube powers, fuel exposures, conditions summary	Administration of limits, standards audit
Tube flows	Administration of limits, standards audit
Zone Temperature Monitor limits	Administration of limits, standards audit
Moderator temperatures	Administration of limits, standards audit
Coolant systems monitoring	Administration of limits, standards audit, critical systems surveillance
Horizontal control rods	Standards audit, critical system surveillance
Panel and console status	Standards audit, critical system surveillance
Control center D.C. breakers	Critical systems surveillance
Auxiliary building monitoring	Standards audit, centralization of control
Actuation and monitoring of ECB breakers	Standards audit, centralization of control

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Hardware will include the data acquisition equipment, the computer and peripheral equipment, and instrumentation. These are summarized in Figure S-1, Table S-1, Table S-2, and Figure S-2.

The hardware components and subsystems will be developed, proven items; prototypes or "first-of-a-kind" items will not be acceptable. Also, an experienced, reliable vendor will be required to supply and maintain the equipment throughout its useful life. This approach will preclude the risk of component and subsystem development, and will also minimize the risk of early system obsolescence.

Technical Approach

Emphasis was placed in the important areas of data point selection criteria, system sizing, and system reliability and availability. Criteria used for selections of data points were based on the following:

- a. Process Standards
- b. System critical to safety, Category 1
- c. Process Audit Checklist (and within this emphasis was given to identified problems)
- d. Centralization of control (staff reduction)

It was not practical to include every system point contained in the Start-Up Checklists, since the consequent system complexity would have compromised its reliability and would not have given adequate return for the additional expenditure.

Analyses were performed to determine the memory requirements of the computer core memory, which gave the requirement for a 32 thousand word memory with word length of 2^4 bits plus parity. Also analyses were performed to determine the bulk memory storage requirements. Results of these analyses are given in Tables S-3 and S-4.

Reliability and availability analyses were performed in support of selection of the configuration. Some of the important results showed that a mean-time-to-failure of 5800 hours or more for the computer main frame is required and realizable. Also requirements for redundancies in input/output

TABLE S-1

COMPUTER PERIPHERALS REQUIRED AND NORMAL CHARACTERISTICS105-N Computer Room

<u>No.</u>	<u>Type</u>	<u>Characteristics</u>
1	Card reader	200 cards/min.
1	Paper tape reader/punch	300 characters/sec.-read 110 characters/sec.-punch
1	Line printer	300 lines/min. 120 characters/line
1	Magnetic tape unit	45 in./sec. 200, 550, 800 bits/in. (selectable)
1	Programmers I/O typer	10 characters/sec.
1	Bulk Memory Unit	500K words

105-N Control Room

<u>No.</u>	<u>Type</u>	<u>Characteristics</u>
2	Logging typewriters	15 characters/sec.
1	Alarm typewriter	15 characters/sec.
1	Operator's console	Manual point selection
1	CRT display	Alphanumeric and vector generation 100 in. ² display

184-N Control Room

<u>No.</u>	<u>Type</u>	<u>Characteristics</u>
1	Communications and alarm typewriter	15 characters/sec.

REMOTE SITES

FIGURE 8-1

PROPOSED DATA ACQUISITION
EQUIPMENT FOR H AREA

TABLE 8-2

CENTRAL PROCESSING UNIT REQUIREMENTS

<u>Description</u>	<u>Requirement</u>	<u>Basis</u>
<u>Instruction Speed</u>		
Add Time (μ sec.)	≤ 4	Meets requirements for control rod monitoring and display for 1" resolution
Cycle Time (μ sec.)	≤ 2	
<u>Core Memory</u>		
Word Length (bits)	24 + parity	Instruction repertoire, inherent accuracy, data packing
Size (words)	32K	Heavy load case indicates 2000 word margin (see Table 5-5)
Memory Parity	Yes	Detect data transfer malfunctions in computer
Memory Protect	Yes	Protect critical core resident codes from destruction
<u>Bulk Memory Size (words)</u>	> 500K *	Satisfy initial real and free time applications plus margin (see Table 5-6)
<u>Other Hardware Features</u>		
Extended Arithmetic Unit	Yes	Floating point will save 10-20% in programming man-hours (24)
Priority Interrupts	Yes	Necessary in real-time systems to acknowledge process needs (see Appendix B)
Block Transfer Channels	6	Large amount of inputs requires cycle steal technique for efficient use of CPU and ease of programming.

*Disks are available in sizes of 151, 303, and 606K words and drums in sizes of 96, 128, and 256K words. One 606K word disk or two 256K word drums are required.

FIGURE S-2

INSTRUMENTATION REQUIRED

TABLE 8-3CORE MEMORY BUDGET ESTIMATE

	<u>WORDS (thousands)</u>
<u>Real-Time Requirements</u>	
Real-time monitor system	7 - 11
Application programs	
digital control	.5 - 1
calculational	1.5 - 5
monitor and alarm	3
I/O Buffer (25,26,27)	.5 - 2
	<hr/>
	12.5 - 22
 <u>Free-Time Requirements</u>	
Language processing, program testing, and library main- tenance (25,26,27)	8
	<hr/>
TOTAL	20.5 - 30

TABLE 8-4BULK MEMORY BUDGET ESTIMATE

<u>REQUIREMENTS</u>	<u>WORDS (thousands)</u>
Real-time monitor system (25, 26,27)	7 - 11
Application programs	50 - 100
Current Data Tables	10 - 20
Backup Data Tables	10 - 20
Message Tables	16
Library (25,26,27)	50
Scratch Pad (25,26,27)	150
	<hr/>
TOTAL	293 - 367

equipment evolved from these analyses. In addition it was determined that the mean-time-to-repair of the system should be two hours or less in order to assure inherent availability above 0.99. A maintenance program was derived which will give the means for achieving this availability, and the program is described in the report with estimates of maintenance costs. Reliability and availability estimates were derived for both the passive (monitoring) and active (control) parts of the Surveillance System.

Cost, Schedule, and Program Interactions

A capital expenditure of \$983,700 is forecast for the system. Table S-5 gives details of this estimate. Milestones include the following, dependent upon an approval to proceed by the Atomic Energy Commission on or before January 15, 1970.

<u>Milestone</u>	<u>Date</u>
Approval to proceed	January 15, 1970
Selection of vendor	January, 1971
System testing complete	December, 1972

A task plan is given in Table S-6, which shows the relationship between the program to implement the Surveillance System and the envisioned dates for completion of the licensability effort for the dual purpose N Reactor, and the beginning of conversion to power-only operation. Delay in schedule of greater than six months would interfere with the envisioned transfer date.

Benefits

The estimated capital expenditure for the system is \$983,700. Also, the estimate for replacement of aging equipment which the system will displace is \$370,000, giving a net cost difference of \$613,700. Reduction in operating cost is expected to be \$254,900 per year, giving a pay-out period of 2.4 years.

The above figures are based upon 1969 material costs and wage rates. Historically, the costs of process computers and data acquisition equipment have decreased over the last decade. If the current inflationary spiral continues, it is reasonable to expect that the total system cost may increase

TABLE S-5

ESTIMATES OF CAPITAL EXPENDITURE,
PLANT PROCESS SURVEILLANCE SYSTEM

<u>Item</u>	<u>Cost (thousand dollars)</u>
Materials and Installation	
Computer and peripheral equipment	356.0
Computer room	36.2
Data acquisition equipment	
105-N Building	88.9
109-N Building	33.5
184-N Building	55.6
181/182-N Buildings	41.1
Total	219.1
Instrumentation	
105-N Building	84.7
109-N Building	57.0
184-N Building	47.2
181/182-N Buildings	27.4
Total	<u>216.3</u>
Total, Materials and Installation	827.6
Contingency	81.1
Engineering and Drafting	<u>75.0</u>
TOTAL	<u>983.7</u>

TABLE S-6

TASK PLAN

N REACTOR SURVEILLANCE SYSTEM

TABLE S-7

COST REDUCTION, PLANT PROCESS

SURVEILLANCE SYSTEM

<u>Staff Reduction</u>	<u>Annual Cost Savings (thousand dollars)</u>
Twenty-one shift operating personnel	269.2
One equivalent process engineer	17.2
Data monitoring and logging	<u>25.0</u>
TOTAL	311.4
<u>Additions</u>	<u>Annual Cost Increase (thousand dollars)</u>
Two technicians	26.2
One equivalent programmer-engineer	15.3
Contract maintenance	<u>15.0</u>
TOTAL	56.5
<u>Net Annual Savings</u>	<u>254.9</u>

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up to five to ten percent per year. Also, it is reasonable to expect that labor costs will increase, giving more reduction in annual operating costs.

The basis for the estimates of net annual savings are shown in Table S-7.

Identified benefits to be derived from the system are as follows:

- a. Replacement of aging equipment with a reliable system
- b. Enhancement of safety and the posture for licensability by the following means:
 1. Simplification of the administration of operating limits and standards
 2. Automatic surveillance of critical systems
 3. Centralization of control
- c. Increase in reliability of the reactor by providing the following:
 1. Back-up for special purpose data logging equipment
 2. A tool for application to thorough, disciplined check-out
- d. Reduction in operating cost of \$254,900 per year by reducing manpower requirements.

As N Reactor continues to mature, and application of the Surveillance System becomes routine, other benefits will be identified.

Alternatives

Consideration was given to three alternatives, as follows:

- a. One-year deferral of the system as proposed

Funding has already been deferred two years. The central data logger is giving age-related problems, and future problems are expected. Further delays will hamper the N Reactor operability effort, and will be out of phase with other programs such as licensability and conversion to power-only operation.

In addition, successful implementation of the system is dependent upon competent technical staff now in place. Deferral of this project will result in some erosion of this capability.

b. Replacement of the ISI-609 process computer functions only

This alternative would serve only as a replacement for equipment which is now showing age-related problems. It would not give the capability for an automated process audit nor the means for reduction of staff in the auxiliary buildings.

c. Surveillance of processes in 163-N and 183-N Buildings

This alternative was reviewed in some detail for purposes of staff reduction. Monitoring of the pertinent variables by means of a remote scanning system and actuation required to displace tasks would give a materials and installation cost of approximately \$200,000. While this type of automation might relieve the operators of some tasks, no true economic or reactor life incentives are evident at this time. It is believed that special purpose automation of the water processes would have better potential for benefits than consolidation of control.

Conclusions and Recommendations

In accordance with the requirements set forth in AEC Manual Chapter 1801, this study provides the description of and justification for a Plant Process Surveillance System for N Reactor. It is concluded that the system will contribute importantly to safe, reliable operation of the plant, and will provide a means for important reduction in operating cost.

The schedule for implementation of the system shows first routine application of the system by Operations personnel in mid-fiscal year 1973. This schedule is compatible with the envisioned dates for licensability of N Reactor as a dual purpose reactor and for the beginning of conversion to power-only operation. In order to achieve this schedule, funding for the system will be required in fiscal year 1971.

Therefore, it is recommended that the system proposed herein be authorized and funded in fiscal year 1971.

PLANT PROCESS SURVEILLANCE SYSTEM FOR N REACTOR
SYSTEMS STUDY

1.0 INTRODUCTION

In accordance with the requirements of AEC Manual Chapter 1801 (1)¹, this Systems Study is submitted to give the description of and justification for a Plant Process Surveillance System for N Reactor. The study represents the second step in the acquisition procedure, the first step being the Feasibility Study (2), which was approved July 18, 1968 (3).

N Reactor is a dual purpose, graphite moderated reactor which produces plutonium and electrical power with pressurized light water coolant and zirconium alloy-clad metallic uranium fuel. It is operated at 4,000 megawatts (thermal), and produces low pressure steam for an adjoining electrical generating plant which is rated at 800 megawatts (electrical). With this plant rating, N Reactor is the largest operating nuclear power plant in the world (4). In addition to its large size, N Reactor has the other characteristics which are measures of successful application of automatic data processing equipment to industrial plants. These include complexity, frequent disturbances, good availability of instrumentation, and good availability of process knowledge (5).

The Systems Study contains results of engineering and economic analyses as well as the functional requirements of the proposed system. Emphasis is placed on the technical approach to formulation and application of the Plant Process Surveillance System. In particular, knowledge gained from experience with the N Reactor central data logger (ISI-609 process computer) was useful.

This in turn highlighted the need for analysis directed toward development of a system configuration which has the inherent reliability (reliable hardware and software) required for dependable data acquisition and data processing. The system which evolved is almost entirely a passive system;

¹Numbers in parentheses denote references in Section 11.0 of this report.

i.e., it observes and reports the status of critical process variables and operational actions. One small set of direct digital control actions are included, however, because of the resulting operational simplification.

Included in the system are proposed data acquisition hardware and instrumentation, as well as the process computer and peripheral equipment which are defined as automatic data processing equipment in reference 1. It was found necessary to consider the system as a whole, principally because of additional and replacement instrumentation subsystems required for centralization of control.

It is intended that the Plant Process Surveillance System be applied as a tool for centralized administration of operating safety limits. In addition, it is intended as a replacement for the aging central data logger and as a replacement for performance of certain routine and operational tasks. Complete installation of the proposed system is scheduled for first quarter fiscal year 1973. Conclusions and recommendations are based upon the projected operating conditions and requirements during and subsequent to that time period.

2.0 PURPOSE OF THE SURVEILLANCE SYSTEM

The purposes of the system are as follows:

- a. to replace aging monitoring and data acquisition equipment with a reliable system
- b. to provide a tool for centralized administration of operating limits and standards
- c. to provide a tool which will simplify reactor check-out and control by providing centralization of control and replacement of manual tasks.

The Plant Process Surveillance System is a part of the Basic Production Program, with applications to Nuclear Safety and Licensability. Applications are categorized as follows:

- a. Basic Production - increase in reactor reliability and simplification of plant operation
- b. Nuclear Safety - automatic surveillance of critical processes
- c. Licensability - redundant cross-checking of critical plant functions to upgrade the position for licensability.

The following sections describe the approach to achieving the above objectives, and give results of analyses which demonstrate the need for and benefits to be derived from the Plant Process Surveillance System for N Reactor.

3.0 APPROACH

The general approach taken to the acquisition and development of the proposed Surveillance System is as required by AEC Manual Chapter 1801 (1). The four steps required are as follows:

- a. Feasibility Study (2)
- b. Systems Study
- c. Equipment Specifications and Selection Study
- d. Acquisition Proposal

The Feasibility Study (2) outlined general areas in which the proposed system would be attractive in terms of cost reduction and nuclear safety.

The steps taken in the evaluation of the Systems Study were as follows:

- a. Analysis of current methods and procedures of operation
- b. Determination of tangible and intangible benefits
- c. Development of the proposed system
- d. Detailed cost and reliability analysis of the system

In the analysis of current methods and procedures, staffing requirements, personnel work loads, frequency of monitoring data, type of data logged, and use of data were analyzed both from an operational and nuclear safety point-of-view. In addition, pre-startup and safety audit checklists were examined in detail as well as Standard Operating Procedures, control room operating logs, time distribution reports, process standards, and licensability requirements for power reactors.

From the above analysis, the information and instrumentation requirements to allow staff reduction and further strengthen the safety and licensability posture of the N Reactor complex evolved. These requirements in turn formed a basis for structuring the hardware systems.

The separation of the 100-N Area buildings as well as the information requirements influenced the data acquisition requirements. The separation of the buildings gives requirements for remote scanners with transmitter-

receivers capable of inputting data to the Main Control Center in 105-N Building. Consequently the distances involved, the cable runs, and the noise levels in the auxiliary buildings were measured. Concurrently computer vendors were contacted to inquire as to the general capability of their data acquisition equipment in terms of scanning rates, noise rejection, reliability, cost, and current applications in the field.

With the above data, an extensive cost and reliability analysis was initiated. Estimates of required resources were made for the following:

- a. Training, programming, and maintenance
- b. Instrumentation and data acquisition equipment
- c. Computer and peripherals
- d. Engineering and drafting
- e. Site preparation including air conditioning and fire protection equipment.

Using reliability data supplied by manufacturers as a base, a detailed fault tree was constructed of the proposed Surveillance System. Extensive parametric case studies were made to determine the system's reliability, availability, and average mission time before encountering a failure.

The effects of the proposed system on manpower reduction, improved reliability of the reactor systems, licensability, and nuclear safety in general were then determined.

4.0 OPERATIONAL BACKGROUND AND SCOPE

Current and expected problems exist at N Reactor in the central data logging system (ISI-609 Process Computer), complexity of the equipment and procedures used for administration of operating limits, and complexity due to decentralization of control. These are considered serious but tractable problems in application of the large, dual purpose N Reactor, and are addressed along with proposed solutions in this section.

4.1 Replacement of the ISI-609 Process Computer Functions

4.1.1 Background

The central data logger (ISI-609) is a small process computer which was installed at N-Reactor in 1963. With the interfacing data acquisition equipment and later additions, the cost of hardware and installation was approximately \$500,000 (6). It was intended as a tool for administration of operating limits by means of printing out automatically and on-demand values of selected process parameters. A summary of parameters and systems monitored by the ISI-609 is shown in Table 4-1. Also shown are the numbers for applicable Process Standards (7).

The central data logger was intended as backup for the smaller data logging systems, and as the result of a program to update it, to give some modest process computing capability. Because of poor availability of the system over the past three years, however, the system has not served these functions adequately, leading to an increase in operational complexity and, in some cases, an increase in reactor down time.

Figure 4-1 gives a summary of the availability history of the ISI-609 system for calendar years 1964 through 1968 and for calendar year 1969 through July, 1969. Also, Figure 4-2 depicts performance by month for the first seven months of 1969, and shows that recent performance has been better than that during 1968, because of special actions taken to increase availability of the system. However, it is believed that the performance will not increase importantly in the future even with reasonable application of effort to keep the ISI-609 system on-line,

TABLE 4-1
SURVEILLANCE OF CRITICAL PROCESSES

<u>ISI-609 Monitoring Function</u>	<u>Process Standard (7)</u>
Process Tube Thermal Power	B-265
Tube Flows	B-245
Tube Temperatures	B-250
Rod Safety System	B-240
Primary Coolant System	B-200
Secondary Coolant System	B-205
Oil Fired Boiler System	B-206
Circulating Raw Water System	B-210
Graphite Cooling System	B-220
Shield Cooling System	B-225

*Through July, 1969

LEGEND:

△ Availability
○ Reliability

AVAILABILITY DATA

CALENDAR YEAR	TOTAL			MAIN FRAME		OUTPUT EQ.		INPUT EQ.	
	Days Down	% Avail.	% Reliability	Days Down	% Avail.	Days Down	% Avail.	Days Down	% Avail.
1964	8	97.8	93.9	1	99.7	4	98.9	3	99.2
1965	12	96.7	93.9	3	99.2	6	98.4	3	99.2
1966	13	96.4	93.9	2	99.5	6	98.4	5	98.6
1967	96	73.7	11.1	85	76.7	6	98.4	5	98.6
1968	151	58.6	5.0	142	61.1	6	98.4	3	99.2

FIGURE 4-1

IST-609 AVAILABILITY AND RELIABILITY HISTORY

FIGURE 4-2

ISI-609 DOWNTIME, JAN.-JULY, 1969

because the system is nearly seven years old, it is composed of out-dated and hard-to-get circuit components, and it has operated for long periods of time in an incompatible environment.

4.1.2 Problems and Proposed Solutions

Availability of Equipment

Table 4-2 gives a list of the problems which have been experienced with the ISI-609 system, and solutions to these which will be provided by the Plant Process Surveillance System. Of the five problems listed, of special interest is the component problem.

A large fraction of the components in the computer are of British origin (the ISI-609 was made in England by Elliot Brothers Limited); therefore, replacement parts have excessively long procurement lead times. Many of these components (read amplifiers, write amplifiers, logic devices) are unique. In addition, a skilled electronics system designer was hired to evaluate problems and direct corrective action in December, 1968. He gave the evaluation ". . . the combination of thermal stress, age, and design techniques used in this vintage computer have resulted in reduced circuit margins giving rise to a high degree of sensitivity to various environmental disturbances." (8)

Figure 4-3 compares the dependability of the ISI-609 for January through July, 1969, with that inherent to the system which is intended to replace it. The predictions for the proposed system are based on results of the analyses described in Section 6.0 of this report.

In conclusion, a replacement computer system is required to perform the functions intended for the now-obsolete ISI-609 system.

Nuclear Safety and Operational Complexity

In order to operate the reactor with continuous nuclear safety assurance, observation and recording of the critical processes is required continuously. Basic requirements are contained in Process Standards - NPR (7).

TABLE 4-2

AVAILABILITY OF SURVEILLANCE EQUIPMENT,
PROBLEMS AND SOLUTIONS

<u>ISI-609 Problems</u>	<u>Proposed Solutions (New System)</u>
Reliance on rare and obsolete spare parts	Application of modern equipment with spare parts planning.
Susceptible to power transients	Isolation and desensitizing design approach
Susceptible to ground-induced noise	Centralized ground, and grounding isolation
Environment induced failures	Preplanned environmental control
Turnover in skilled maintenance personnel	Thorough training program, maintenance contract

FIGURE 4-3

DEPENDABILITY COMPARISON
ISI-609 vs. REPLACEMENT SYSTEM

The intent for recorded surveillance is shown in the lists of parameters and variables given in Table 4-3; i.e., a central system (ISI-609) with various other devices such as dials, strip charts, and special-purpose data loggers distributed throughout the Main Control Room in the 105-N Building. Also, some of the information (process tube power, process tube coolant flow trip spans) requires calculation off-site, and some data can be collected manually.

The ISI-609 provides monitoring from a centrally located console in the Control Room of the 105-N Building on a fixed time schedule, and presents the process values to the operator in digital form, with out-of-limit values printed in red (a form of management by exception). Human errors, generated in reading non-centralized instrumentation, are substantially reduced by presenting the data in digital form on a documented log sheet.

As a particular case, recording of the control rod coolant temperatures is required once each eight-hour shift, in order to assure that the coolant is below 150°F (9). When the ISI-609 system is available, the rod coolant temperatures are recorded for observation every two hours. However, when the system is not available, the rod coolant temperatures are recorded by a technician, who must obtain the data outside of the control room, record it, and deliver it to the control room supervisor once each eight-hour shift. Table 4-4 gives results of this particular case study (10).

In conclusion, close surveillance of critical processes is required for nuclear safety assurance. The operational complexity which results (as shown by Table 4-3 and the example summarized in Table 4-4) gives need for a reliable central surveillance system.

Dependability of Reactor Start-Up

Lack of central data logging has contributed to reactor down-time. As an example, problems with the flow data logger kept the reactor from starting up for 24 hours in March, 1969 (11), and again for 19 hours in September, 1969 (12).

TABLE 4-3

CRITICAL DATA MONITORING IN 105-N CONTROL ROOM

MONITORING FUNCTION	ISI EQUIPMENT					CONTROL PM.EQ.BY PANEL LOCATION				OTHER			
	CDL	Rod Flow		Temp.	Temp.	Strip	Multi Pt.	Chart	Recorder	Gauges	Annunc.	Off-Site Calculations	Manual
	609	Log	Log	Log	Scan								
		509	409	309	209								
<u>Thermal Power</u>													
Process Tube Power	X											X	X
<u>Tube Flow</u>													
Process Tube Coolant Flow													
Trip Spans	X											X	X
Process Tube Coolant Flows	X		X										X
<u>Tube Temperature</u>													
Reactor Inlet Temps.	X			X									X
Process Tube Outlet Temps.	X			X	X								X
<u>Rod Safety</u>													
Rod Coolant Temps.	X												X
Rod Positions		X											X
<u>Primary Coolant (P.C.)</u>													
P.C.P. Seal Water Diff.													
Pressure	X									B+G	6+11		X
P.C.P. Seal Flow	X									BB+GG			X
										B+G			
Pressurizer Flow	X					A				AA	5		X
Pressurizer Pressure	X					A				AA	5		X

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MONITORING FUNCTION	ISI EQUIPMENT					CONTROL RM. EQ. BY PANEL LOCATION				OTHER	
	CDL 609	Log 509	Log 409	Log 309	Temp. Scan 209	Strip Chart	Multi Recorder	Pt. Gauges	Annunc.	Off-Site Calculations	Manual
Pressurizer Level	X					A		AA	5		X
P.C. Cell Flow	X					B+G		BB+GG	6+11		X
P.C. Suction Temp.	X					B+G		BB+GG			X
P.C.P. Suction Pressures	X							BB+GG			X
P.C.P. Discharge Pressure	X					B+G		BB+GG			X
<u>Secondary Coolant</u>											
Steam Flow from S.G.	X						P				X
Ccnd. FW Temp. to S.G.	X							B+G BB+GG	6+11		X
S. G. Inlet Pressure	X										
S. G. Level	X							B+G BB+GG	6+11		X
Ccnd. Return Flow from 184-M	X							JJ			X
Main Steam Header Pressure	X					J		JJ	13		X
Main Steam Header Flow	X					GPR B+G		GPC BB+GG			X
Drive Turbine Steam Header Pressure	X							GPC JJ			X
Dump Condenser Level	X							BN K+N	14+17		X
<u>Oilfired Boiler</u>											
Boiler Steam Drum Pressure	X							JJ			X

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MONITORING FUNCTION	ISI EQUIPMENT					CONTROL RM. EQ. BY PANEL LOCATION				OTHER	
	CDL 609	Log 509	Log 409	Log 309	Temp. Scan 209	Strip Chart	Multi Recorder	Pt. Gauges	Annunc.	Off-Site Calculations	Manual
<u>Circulating Raw Water</u>											
CRW Outlet Temp. from Dump Condenser	X						P	K-N	14+17		X
<u>Graphite Cooling</u>											
GC 205 Bulk Dump Temp.	X						33		0		X
GC HXs Pressure	X					32		32	0		X
GCP Suction Header Pressure	X						32				X
GCP Discharge Pressure	X						32		0		X
GC Surge Tank Level	X					32		32			X
GC Coolant Tube Temp.	X										X
<u>Shield Cooling</u>											
Shield Test Stringer Temp.	X							11			X
Permanent Stringers Temp.	X							11			X
Reflector Temp.	X							11			X

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TABLE 4-4SURVEILLANCE OF 86 ROD COOLANT TEMPERATURESISI-609 vs. MANUAL COLLECTION

<u>ITEM</u>	<u>ISI-609</u>	<u>MANUAL COLLECTION</u>	(10)
Logging frequency	12 logs per day	3 logs per day	
Alarm scanning frequency	4 per hour	none	
Error fraction	1 per 10,000 readings	estimated at 5 per 86 readings	
Labor per log	negligible	4 manhours	
Labor cost	negligible	\$23 per log \$69 per day \$25,000 per year*	

*Central Data Logger not available.

Periodic flow maps are required for safe start-up and operation of the reactor. If the ISI-609 system had been applied as intended (Table 4-3, Tube Flow Monitoring) flow maps would have been available for support of reactor operation, and the hold-downs reported would not have occurred.

Again the solution is a dependable, centralized surveillance system.

4.1.3 Conclusions and Recommendations

The ISI-609 system has performed poorly in recent years. Current performance is still marginal, and the outlook for future improvement is dim. The need for its surveillance capability and operations assistance is still present.

In seeking a solution to this problem, three alternatives are available. These are as follows:

- a. Repair the ISI-609
- b. Replace the ISI-609 with a modern surveillance system
- c. Retire the ISI-609 and hire additional manpower to fulfill its monitoring and data logging functions

The first alternative, repair the system, has been tried several times during the last three years. A certain degree of success was achieved, but not enough to compensate for the continuing decay of the system. Efforts in this area are of a continuing nature, and are not providing a permanent or satisfactory solution to the problem.

The third alternative, manual surveillance, would inherently cost considerable dollars to execute and would provide only minimum process surveillance capability. This is evidenced by the example presented on the rod coolant temperatures. Also the start-up dependability problem would not be resolved.

The second alternative, installation of a replacement system, remains the most logical choice. The replacement system would be able to satisfy all of the current surveillance requirements intended for the ISI-609

and provide a reliable instrumentation system which could be applied to reactor operation.

Since the replacement system would consist of modern equipment, would be operated in a controlled environment, and would be supported by an effective maintenance program, a reasonable availability would be attainable.

Therefore, it is recommended that a system for replacement of the functions intended for the ISI-609 system be authorized, as a part of the expanded Plant Process Surveillance System.

4.2 Surveillance of Systems and Processes Throughout the Plant

In Section 4.1 the case was made for a system which replaces the intended functions of the ISI-609 Process Computer. This section gives the background analysis, with problems and proposed solutions, leading to recommendations for additional automation of data acquisition and data processing.

4.2.1 Current Control and Monitoring Practices

Because of the complexity of N Reactor and the great amount of associated process equipment, extensive procedures and checklists are used with the instrumentation systems to insure that the reactor is maintained and operated within reactor safety standards (7). Currently, reactor operating personnel check out about 5,000 parameters in the Main Control Center alone during a startup and power ascension (13). A summary of the startup checklist is given in Table 4-5. During the pre-startup checkout, operations personnel go to each graphic panel and console in the control room and visually check the status of each switch position and/or valve position via indicating lights; proper adjustments are made as required. In electrical switch gear rooms near the main control room, instrumentation and electrical technicians examine hundreds of electrical circuit breakers as well as power supplies for their proper state. For the many steps in this checkout procedure, the countdown is sequential with the startup procedure, being held up until specific items meet operational and safety criteria (7).

In addition to the requirements shown in Table 4-5, control room operating personnel take frequent flow and temperature maps in order to keep abreast of the locations of the process tubes with the highest coolant temperatures, highest heat generation rates, and flows closest to limits. This monitoring becomes more important as the reactor approaches its equilibrium power level, and the process tube operating parameters approach their mandatory limits. To give a more indepth analysis of the state-of-the-reactor at 3300-3400 megawatts before going to a higher power level, neutron flux measurements (traveling wire system) are taken to determine the axial incore flux profile in nine sectors of the reactor. These flux profiles,

TABLE 4-5START-UP CHECKLIST SUMMARY

- I. Console "AA"
 - A. PCL Leak Check
 - B. Primary Graphic Panel Check
 - C. Cell Graphic Panel Check
 - D. Turbine Trip Check
 - E. Scram Action Functions
 - F. Primary Control Systems
- II. Console "BN"
 - A. Secondary Coolant System
 - B. Other Items
- III. "Nuclear" Console
- IV. Miscellaneous
 - A. Heating, Ventilating, and Confinement
 - B. Reactor Shield Cooling
 - C. Space Monitor System
 - D. Housekeeping
 - E. Pre-Startup Instrument Checklist
- V. "Control Rod" Check-Out
 - A. Rod Room Checks (Right & Left)
 - B. Room 2 Rod Checks
 - C. Control Room Rod Checks
 - D. Transducer Room Rod Checks
- VI. Safety Circuit
 - A. Rod Safety Circuit
 - 1. Rod Scram Manual Trip 1 of 2
 - 2. Intermediate Range Fast Period 2 of 3
 - 3. Intermediate Range Excess Flux 2 of 3
 - 4. High Range Excess Flux 2 of 12
 - 5. High Range Rate of Rise 2 of 3
 - 6. High Range High Average Level 2 of 3
 - 7. Process Tube High or Low Flow
 - 8. Outlet Header Boiling 2 of 4
 - 9. Zone Monitor High Temperature 3 of 109
 - 10. Rod Cooling Water Low Flow 1 of 86
 - 11. BPA or TG Power Failure 1 of 2
 - 12. CRW Low Pressure 1 of 4
 - 13. Pressurizer Extreme Low Level 1 of 3
 - 14. Surge Tank Low Level 1 of 3
 - 15. Primary Loop Very Low Pressure 2 of 4

- B. Ball Safety Circuit
 - 1. Ball Drop Manual Trip 1 of 1
 - 2. Seismoscope 2 of 3
 - 3. High Flux Level After Scram 2 of 3
 - 4. Reactor Critical After Scram 2 of 3
 - C. Emergency Cooling Water Circuit
- VII. Graphite Cooling System
- A. Graphite Cooling System
 - B. Other
- VIII. Gas System
- IX. Electrical
- A. DC Voltage - 105 and 109
 - B. Flow Monitor System
 - C. Instruments Power Supply
 - D. Circuit Breakers Room 6
- X. Auxiliary
- A. 181/182-N
 - 1. Tank Levels
 - 2. Pumps in Service
 - B. 163/183-N
 - 1. Demineralization Plant Ready for Startup
 - 2. Filter Plant Ready for Startup
 - C. 184-N
 - 1. Instrument Power on "B" Bus with Auto Transfer to "A" Bus
 - 2. Panel E on "B" Bus
 - 3. Flame Failure MG Set Transfer Switch on "B" Bus
 - 4. Boiler in Service
 - 5. TG Set Warming Up
- XI. Flow Monitor
- A. Low en masse Trip Check
 - B. High en masse Trip Check
 - C. Process Tube Flow Monitor Trip Circuit Check
- XII. Safety Circuit Bypass Panel

along with the process tube powers, temperatures, and flows, and their respective limits, are calculated either on an off-line UNIVAC 1108 computer 36 miles from the reactor, or manually. Because of the distance, the output from the off-line program is available, as a minimum, to the reactor operators eight to twelve hours after the initial submission of data.

Additional back-up to reactor operation is provided by reactor process engineers who perform audits of the reactor processes to insure compliance with the Process Standards (7). Their check-out procedure (14) is well-considered but is lengthy and arduous.

In conclusion, the check-out and surveillance of N Reactor are complicated and unwieldy. Consequently they lead to errors, increased risks due to these errors, and loss of operational efficiency. Specific considerations are given in the next section.

4.2.2 Problems and Proposed Solutions

A summary of problems and solutions is given in Table 4-6.

.1 Nuclear Safety and Operational Complexity

In addition to simplifications recommended in Section 4.1, reductions in operational complexity are proposed by deletion of the need for manual and off-site calculations of operating limits and automation of portions of the process auditing.

Manual and Off-Site Routine Calculation

Calculation of operating limits is now conducted off-site with some manual calculation to support start-up, power ascension, and routine operation. In Figure 4-4, the steps required for calculating a set of limits are compared to one routine approach which would be applied with a new process computer as part of the Surveillance System. The reduction in the series steps and in the interface of this procedure will give an increase in inherent reliability to the calculation and application of operating limits. Also, changed limits due to changed operating conditions will be available on demand, as

TABLE 4-6OPERATIONAL PROBLEMS AND
SURVEILLANCE SYSTEM SOLUTIONS

<u>PROBLEM</u>	<u>SOLUTION</u>
Operational complexity due to exacting standards	Simplification - integrated system, automated routine calculations, replacement of routine tasks
Limited number of key personnel	Automatic process audit, where practical
Reactor dependability	Integrated system with back-up, tool for operational check-out
Operating costs	Replacement of routine tasks, centralization of control

FIGURE 4-4

SIMPLIFICATION OF OPERATING LIMITS COMPUTATION

opposed to waiting for up to twelve hours for them. As N Reactor continues to mature, it will be a natural step to conduct routine, required calculations for assurance of day-to-day safety standards automatically and on-site.

As a by-product of application of a process computer, some increase in production efficiency will occur. One example will be capability for a more efficient power ascension, as depicted in Figure 4-5. Two observed power ascensions (15) are compared with one which will be practical with application of the Surveillance System. Also, some increase in the efficiency of the pre-start-up checks will be possible (16).

Process Audit Checklist

A checklist (14) has been developed over the last several years which represents a list of items which deserve special attention. Because of the depth of experience behind the list, it was adopted as a guide for selection of parameters to be audited automatically. Examples of potential violations of standards prevented by this audit are given in Table 4-7. These will be subject to automatic surveillance. Application of the Surveillance System will simplify the current audit procedure, and will release key safety engineering personnel to monitor more thoroughly parameters not adaptable to automatic check-out. A more complete description of this application is given in Section 4.2.3.

.2 Reactor Reliability and Dependability

A means for prevention of outage extensions was given in Section 4.1. Also application of the Surveillance System will lead to prevention of forced shutdowns. Currently, effort at Douglas United Nuclear is being applied to quantitative identification of problems at N Reactor and long-term solutions. One candidate solution is routine operational check-out of the primary system before start-up (17). The Surveillance System will be an essential tool for support of this operational check-out.

FIGURE 4-5

REACTOR POWER ASCENSION

TABLE 4-7

EXAMPLES OF POTENTIAL VIOLATIONS PREVENTED
BY PROCESS AUDIT

<u>ITEM</u>	<u>DESCRIPTION</u>	<u>AUTOMATIC EXCEPTION REPORTS VIA SURVEILLANCE SYSTEM</u>
Secondary loop make-up pumps	Needed another pump on-line	Pump status
Flow monitor	High/low checks not completed	Trip setting status
Confinement doors	Cells 1 and 2 open to access corridor	Confinement door limit switches
Process tube outlet temperatures	Consistent bias error of 4 to 5°F	Calibration channel status
Primary coolant pump	Counted as on-line when disconnected	Pump and cell status
Graphite coolant system dump valve	Not on "Auto" control	Valve control status
Zone V ventilation dampers	Not on "Auto" control	Damper control status
B bus paralleled with D tie line	Critical "Y" condition but not communicated to control room (105-N) by 184-N operator	Electrical control board status

A specific example of a recent forced shutdown is one which occurred on May 29, 1969. The flow monitor, the safety system which responds to out-of-limit flows in the individual process tubes, caused a shutdown because the low trip limit on tube number 0458 was inadvertently set too high (18). When the en masse low trip limits were adjusted normally during power ascension, this error in the individual trip limit caused an automatic reactor full scram. With a reliable, efficient process computer which will calculate proper limits and trip spans, and track these through power ascension, this type of shutdown will be much less probable.

In conclusion, the Surveillance System will contribute to reliability of N Reactor by serving as a tool for operational check-out and as a tool for simplification of operational procedures.

.3 Operating Costs

By centralization of control and displacement of routine operations and engineering tasks, some reduction in operating costs will occur. These are discussed in detail in Section 4.3.

4.2.3 Functional Scope of Application

Figure 4-6 gives a simplified block diagram which shows acquisition of data from the reactor plant outlying buildings and from 105-N Building. A more complete description of the system is given in Section 5.0

.1 Services Provided by the System

The system will do the following:

- a. Serve as a tool for a partially automated process audit and as an operational start-up aid.
- b. Release key personnel to monitor more thoroughly parameters not easily adaptable to automation.
- c. Present the status of critical systems and processes in one location - the Main Control Room, 105-N Building.
- d. Serve as the principal data logger.

FIGURE 4-6

SURVEILLANCE SYSTEM SIMPLIFIED BLOCK DIAGRAM

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- e. Provide routine calculations required for engineering and physics support of safety and operability.
- f. Serve as an operational aid during power ascension.

.2 Scope of Surveillance

Table 4-8 gives a summary of additional systems which will be monitored by the Plant Process Surveillance System. These are given in addition to those which are shown in Table 4-3. The categories given in Table 4-8 are as follows:

- a. Critical to reactor safety, Category 1 (19)
- b. Process Audit Checklist (14)
- c. Problems listed on Table 4-7
- d. Centralization of control (Section 4.3 of this report)

With one exception, all critical data points covered by this system are also available for direct manual observation in the event of a computer system failure. The exception is the rod coolant temperatures which are available indirectly for manual observation (instrument set up required) as in current practice.

4.2.4 Programmatic Applications

The Plant Process Surveillance System is a part of the Basic Production Program, with applications to Nuclear Safety and Licensability. Applications are categorized as follows:

- a. Basic Production - increase in reactor reliability and dependability, simplification of plant operation, and reduction in operational cost. The approaches to these benefits are discussed in detail in this report, as follows:
 - 1) Reactor reliability and dependability - Sections 4.1.2 and 4.2.2
 - 2) Simplification of plant operation - Sections 4.1.2, 4.2.2, and 4.3
 - 3) Cost reduction - Section 4.3

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TABLE 4-8

CRITICAL SYSTEMS PROPOSED FOR AUTOMATIC SURVEILLANCE

<u>SYSTEM</u>	<u>CURRENT MONITORING TECHNIQUE</u>	<u>PROPOSED VIA SURVEILLANCE SYSTEM</u>
<u>Electrical System</u>		
A/B Bus and D Tie Line	Visual monitoring from ECB at 184-N Control Room	Monitor and actuate circuit breakers. Monitor analog readings on ECB. Output in 105-N Control Room ^{1,2,3,4}
24V D.C. Batteries	Visual monitoring (1/shift) at 105-N Room 6	Monitor 0-50V D.C. on battery banks ^{1,4}
125V D.C. Batteries	Visual monitoring (1/shift) at 109-N	Monitor 0-300V D.C. on battery banks ^{1,4}
125V D.C. Breakers	Visual monitoring (1/month) at 105-N Room 6	Monitor circuit breaker positions (125V D.C.) ^{1,4}
24 and 28V D.C. Breakers	Visual monitoring (1/month) at 105-N Room 6	Monitor circuit breaker positions (24 and 28V D.C.) ^{1,4}
<u>Primary Cooling System</u>		
Primary Pumps and Drives	Visual monitoring of all parameters at 105 and 109-N	Monitor primary pumps, turbines, and pony motors at 105-N for flows, RPM, bearing temperatures, and switch positions via remote scanner in 109-N ^{1,2,3,4}
Primary System Valves	Visual monitoring at 105-N for critical valves	Monitor valves PCSV 206-1, PCRV 205-1, V-20, 23, 30, 33, 38 ^{1,2,3}

¹Critical to reactor safety, Category 1²Process audit checklist³Problems, Table 4-7⁴Centralization of control

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SYSTEM	CURRENT MONITORING TECHNIQUE	PROPOSED VIA SURVEILLANCE SYSTEM
High Pressure Injection	Visually monitored at 182-N and at 105-N	Monitor switch positions, flow, temperature, and pressure ^{1,2,4}
ECS Tank	Monitor tank level and temperature via C.D.L.	Monitor same automatically ^{1,2,4}
ECS Diesels (Hi and Low Lift)	Monitor lube oil and starting air pressures, fuel supply pressure, jacket water cooling, RPMs at 181/182-N, RPMs at 105-N	Monitor RPMs, starting air and lube oil pressures, fuel supply pressure, jacket water temperature via remote scanner in 182-N ^{1,2,4}
ECW Fanel	Visually monitored every two hours at 105-N Control Room	Monitor same automatically ^{1,2}
Air Supply for V-3, 4, and 23 Pressure	Monitored remotely on startup (at Gas Storage)	Monitor pressure gauges at 105-N ^{1,2}
Graphite Coolant System (GCS)	Visually monitored every two hours at 105-N Control Room	Monitor graphite bulk flow, GCS temp. switch positions for heat exchanger in service, raw water pumps in service, and recirculation pumps in service; GCS surge tank level ^{1,2,3}
<u>Secondary Loop Systems</u>		
Standby Boilers	Visual monitoring at 184-N	Monitor status of switches and process parameters on consoles and local panels ^{1,2,4}
Afterheat Removal System	Visual at 105-N; level on C.D.L. at 105-N	Monitor for pump status and bus selection, level of storage tank at 105-N automatically ^{2,4}
Secondary Loop Makeup	Visual at 182-N; Controlled at 182-N	Monitor automatically pump status, suction and discharge pressures on headers at 182-N ^{2,3,4}
Demineralized Storage Tank	Monitored by C.D.L. at 105-N	Monitor same automatically ^{2,4}
Circulating Raw Water System	Monitored by C.D.L. and on panels at 105-N Control Panels	Monitor pump motor status (3-out-of-4 running) ^{1,2,3}

<u>SYSTEM</u>	<u>CURRENT MONITORING TECHNIQUE</u>	<u>PROPOSED VIA SURVEILLANCE SYSTEM</u>
Raw Water System	Fog Spray System monitored at 105-N; Raw Water System at 182-N every two hours	Monitor automatically pressures, temperatures, and switch positions for Fog Spray diesels via remote scanner in 182-N ^{1,2,4}
Fire Prevention System	Visual at 182-N every two hours	Monitor pressure alarm on fire system header via remote scanner in 182-N ^{1,4}
Bailey Instrumentation	Monitored every two hours via Central Data Logger	Monitor same automatically ¹
<u>Instrumentation</u>		
Reactor Moderator	Monitor permanent and removable stringers (thermocouples)	Monitor removable stringers automatically ¹
Zone Temperature Monitor	Monitored at 105-N Control Room - visual	Monitor power supply voltages ^{1,2}
Flow Monitor	Monitored at 105-N Control Room - visual; also flow logger and intended for C.D.L.	Automatic surveillance of flows, trips, and trip spans ^{1,2,3}
Power Calculator	Monitored in 105-N Control Room - visual	Monitor switch position (in "Run" position) ^{1,2}
Confinement Doors	Monitored every two hours at 105-N Control Room	Monitor switch positions for open or closed ^{1,2,3}
Safety Circuit Panel	Monitor once every two hours at 105-N Control Room	Monitor via change detect technique ^{1,2}
<u>Confinement System</u>		
Zone I Cylinder Supply Pressure	Monitored visually	Monitor same automatically ^{1,2}
Confinement Panel	Monitored visually 105-N every two hours	Monitor filters in service, drain valves open, fog spray by-pass valve, steam vents (auto position,) dampers on auto, steam vents closed, supply fans status, fog sprays in cells and pipe gallery normal, and ground detector switch in test position ^{1,2,3}

<u>SYSTEM</u>	<u>CURRENT MONITORING TECHNIQUE</u>	<u>PROPOSED VIA SURVEILLANCE SYSTEM</u>
Fog Spray Supply Pressure	Monitored visually every two hours	Monitor same automatically ^{1,2}
<u>Instrumentation and Miscellaneous</u>		
Instrument and Control System Air	Monitored every two hours - visual at 184-N	Monitor same automatically ^{1,2}
Ball System	Monitored every two hours	Monitor ball backup system at 105-N for "Normal" switch position automatically ^{1,2}
<u>Rod Systems</u>		
Oil Systems	Visual at 105-N Outer Rod Rooms of temperature (analog signals) N ₂ pressure, accumulator oil leaks and oil pressure	Monitor same automatically ^{1,2}
All Rod Components Except Cooling	Visual rod position, selector switch positions at 105-N Control Room	Monitor for "Safety Rod" and "OFF" position on Rod Selector Panel ^{1,2}
Rod Positions	Monitored and logged by rod data logging system	Monitor same automatically ^{1,2}

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- b. Nuclear Safety - automatic surveillance of critical processes and systems; partial automation of the process audit.
 - 1) Automatic surveillance of critical processes and systems - Sections 4.1.2, 4.2.2, and 4.2.3
 - 2) Partial automation of the process audit - Sections 4.2.2 and 4.2.3
- c. Licensability - centralization of control and surveillance of critical processes; Design Criterion 11 - Control Room (20) and Design Criterion 12 - Instrumentation and Control Systems (20).
 - 1) Centralization of control (Design Criterion 11) - Sections 4.2.3 and 4.3
 - 2) Surveillance of critical processes (Design Criterion 12) - Sections 4.1.2, 4.2.2, and 4.2.3

4.2.5 Conclusions

The proposed additional surveillance capability will give important simplification of the operation of N Reactor. The current methods in the areas of data acquisition, data utilization, and control are complex and require simplification. The approach to selection of parameters for surveillance is based on critical system definitions, the process audit, and the need for centralization of control. Consequently, the nuclear safety and licensability posture of N Reactor will be enhanced.

Centralization of control aspects were mentioned briefly in this section. The next section will give the background, scope of application, and benefits to be derived from consolidation of auxiliary building controls.

4.3 Consolidation of Auxiliary Building Controls

The overall site plan for the N Reactor complex is shown in Figure 4-7. The main control center for the reactor complex is located in the 105-N Building, with four other satellite control centers being located in the 109-N, 163-N, 182-N, and 184-N auxiliary buildings, respectively.

The further consolidation of the auxiliary building controls is attractive for many reasons:

- a. Important information would be collected at one location instead of three or four sites.
- b. Manpower reduction will be possible.
- c. Many of the monitoring and control functions performed in the auxiliary buildings are routine and repetitive, and lend themselves well to automation.
- d. The depth of monitoring will improve because of the increased speed and frequency at which the process parameters will be monitored.
- e. Certain critical parameters, given in Table 4-8, presently monitored manually and locally will be available in the 105-N control room.

The simplified block diagram of the surveillance system is illustrated in Figure 4-6. Such a system will provide the capability of scanning analog inputs with scanning frequency under computer program control with variations for each auxiliary building as required. For example, the parameters in the 182-N Building can be scanned every 15 minutes, whereas parameters requiring closer surveillance, such as boiler drum level and pressure, every five minutes. The remote scanners will be located in the 109-N, 182-N, and 184-N auxiliary buildings along with their respective transmitters because of the relatively long distances between the auxiliary buildings and the 105-N Building.

The data will be transmitted from the scanners to a process computer located in the 105-N control room. Consequently, overall plant information

100-N PLOT PLAN

109-N	REACTOR
108-N	CHEMICAL UNLOADING
107-N	HEAT EXCHANGER
116-N	AIR STACK
117-N	AIR FILTERS
151-N	250 KV ELECTRICAL SUBSTATION
153-N	4, 160 KV ELECTRICAL SUBSTATION
163-N	DEMINEZATION PLANT
168-N	FUEL OIL STORAGE TANKS
181-N	RIVER WATER PUMP HOUSE
182-N	HIGH LIFT PUMP HOUSE
183-N	WATER FILTER PLANT
184-N	STAND-BY POWERHOUSE
1303-N	RADIOACTIVE DUNNY BURIAL FACILITY
1310-N	RADIOACTIVE CHEMICAL WASTE TREATMENT
1614-N	RADIATION MONITORING BUILDING
1704-N	ADMINISTRATION BLDG.
1716-N	GARAGE FACILITY
1734-N	STORAGE BUILDING
1908-N	OUTFALL STRUCTURE

FIGURE 4-7

will be available to the reactor control center supervisory personnel at pre-determined intervals or on demand. In addition to the faster and more frequent monitoring of parameters as well as the additional coverage of critical parameters discussed in Section 4.2, the installed remote scanning system provides a means for manpower reduction as indicated in Table 4-9.

In the following paragraphs a brief description of the process equipment, the current data logging and control practices, and the proposed system configuration are discussed for each auxiliary building. Additional bases for manpower reduction are given to complete the section on the Consolidation of Auxiliary Building Controls.

4.3.1 181 and 182-N Buildings

.1 Current Control and Data Logging Practices

The system and process equipment located in the River Pump House (181-N) and the High Lift Pump House (182-N) are described briefly in Tables 4-10 and 4-11, respectively. As noted in the tables these buildings contain a wide assortment of pumping systems required for both normal and emergency operation of the reactor complex.

A number of the systems in the 181/182-N Buildings currently can be manually actuated from the 105-N Control Room and/or are started automatically without intervention from the 182-N Control Room operation; these are as follows:

- a. Circulating raw water pumps
- b. Fog spray pumps
- c. Afterheat removal pumps
- d. High pressure injection pumps
- e. Low lift emergency diesel driven pumps
- f. High lift emergency diesel driven pumps
- g. Fire pumps
- h. High pressure air compressors

TABLE 4-9

PROPOSED MANPOWER REDUCTION
IN AUXILIARY BUILDINGS

<u>BUILDING NO.</u>	<u>TOTAL NUMBER OF OPERATORS REQUIRED</u>	
	<u>Current</u>	<u>Proposed</u>
181-182	8	4
163-183	8	8
184	16	8
109	12	4
Relief	4	4
Day Shift	3	6
	<hr/>	<hr/>
TOTAL	51	34
	<hr/> <hr/>	<hr/> <hr/>

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TABLE 4-10181-N BUILDING SYSTEMS AND FUNCTIONS

<u>System or Process Equipment</u>	<u>Function</u>
Traveling Water Screens	Six screens remove debris from the water supply to circulating raw water pumps and low lift emergency diesel system.
Circulating Raw Water System	Four CRW pumps supply water to the dump condensers, turbine surface condenser, 182-N Building, the filter plant, and various plant heat exchangers.
Low Lift Emergency Diesel System	Two pumps provide emergency water to the fog spray and five pumps, and if required to the high lift emergency diesel pumps.

TABLE 4-11182-N BUILDING SYSTEMS AND FUNCTIONS

<u>System</u>	<u>Function</u>
Secondary Loop Makeup	Two pumps provide normal make-up to the 184-N Building deaerators before makeup water is supplied to boiler.
Afterheat Removal Fill	Three pumps provide water to 163-N Building for polishing and to the secondary system during water-to-water operation. They also provide emergency makeup to boiler plant deaerators and to secondary loop low level makeup.
Low Pressure Injection	Three pumps supply makeup water and seal water to graphite coolant system.
High Pressure Injection	Normally four of five pumps supply demineralized water to the primary coolant system and seal water to the primary coolant pumps.
High Lift Emergency	Three diesel-driven pumps supply tempered water for emergency once-through cooling to the reactor.
Fog Spray	Two diesel-driven pumps supply water to the confinement fog spray nozzles in the reactor and heat dissipation buildings, control rod backup cooling, thermal shield backup, and reactor building fire protection.
Fire Pump	Two pumps, one diesel-driven, the other electrically-driven, supply river water for fire fighting in the N Reactor area.

<u>System</u>	<u>Function</u>
Low Pressure Filtered Water	Four pumps supply water to reactor shield, subcritical monitor chambers, normal suction to high pressure filtered water system, and if required, once-through coolant to reactor process tubes.
High Pressure Filtered Water	Three pumps supply cooling water to the control rods.
High Pressure Raw Water	Three electrically-driven pumps serve as backup to the control rod and graphite cooling system; they supply the fog spray system, the rupture monitor heat exchangers, and the fire main.
Low Pressure Raw Water	Three pumps supply cooling water to high lift and fog spray diesel jacket and oil coolers, the high pressure injection pump oil coolers, primary loop spill coolers, confinement system oil coolers, air compressors after-coolers.
Compressed Air	Two compressors supply air for diesel startup, instrument air, and service air.
Diesel Generator	Supply 480 volts A.C. to the ventilation and emergency lighting equipment.

The remaining process equipments are manually actuated from the motor control centers and mechanical control board located in the 182-N Building Control Room.

The manual control; i.e., the starting and stopping of pumps, is the responsibility of the chief operator, whose main responsibility is the High Lift Pump House (182-N). He also records data every two hours and, when roving through the building, checks for leaks, feels pump casings for excessive vibrations, and listens to engine sounds that may give warnings of an incipient failure.

The chief operator has a journeyman helper (a roving operator) who checks the River Pump House (181-N) about every two hours. He likewise, through sight, sound, and feel, monitors the operation of the process equipment for any abnormal operation.

The data recorded by the two operators are used primarily for trend analysis rather than any immediate corrective action for an historical log that can be used by the follow-on shift to give a picture of past operation.

.2 Proposed System Configuration

A remote scanning system in the 182-N Building will monitor the analog and digital parameters summarized in Table 4-12. The monitoring of switch positions will ensure that the proper pumps are on or off-stream, and that they are on the proper electrical supply (A or B bus).

With the annunciator points under surveillance, any point approaching an out-of-limit condition would be specifically identified in the 105-N Control Room (a capability not presently available).

The monitoring and logging capability provided by the surveillance system would relieve in-part the work loads of the 181-182-N operators. The essential duties remaining would be the first-hand monitoring of equipment for oil and water leaks, excessive equipment vibrations, and general housekeeping.

TABLE 4-12

SUMMARY OF INPUTS
FROM
181-N and 182-N BUILDINGS

<u>Description</u>	<u>Types of Inputs</u>	
	<u>Analog Signals</u>	<u>Digital Signals</u>
<u>181-N Building</u>		
CRW pump flows	4	---
Diesel annunciators	---	14
<u>182-N Building</u>		
Header and pump pressures	31	---
Header temperatures	4	---
Tachometers (D.C.)	7	---
Tachometers (A.C.)	5	---
Bearing temperatures	80	---
Switch positions	---	117
Annunciators	---	96
TOTAL		227

The need for two operators per shift diminishes. With the proposed data system, one operator can be assigned to the 181-182-N Buildings. While the assigned 181-182-N operator is on his roving assignment, monitoring of the 182-N Control Room as previously indicated is provided by the scanning system. If required, an operator could be dispatched from the 163-183-N Buildings for temporary coverage of 182-N.

4.3.2 184-N Building

.1 Current Control and Data Logging Practices

The major systems within the 184-N Building include the following:

- a. Three oil-fired boilers that supply steam to primary pump drive turbines and a turbo-generator during the startup and shutdown of the reactor. The boilers also supply steam to the 109-N emergency seal water pump, steam jet air injectors, and fuel oil heating facilities.
- b. A 15 megawatt turbo-generator that utilizes low pressure steam from the reactor or boilers to generate sufficient electrical power to "B" bus loads.
- c. Breathing, instrument, and service air compressor systems
- d. Hydrazine and morphaline mixing and feed distribution system for the Secondary Coolant System.

The two main control consoles in the 184-N Control Room are the electrical and mechanical control boards. The electrical control board (ECB) has the meters and switches for setting up "A" and "B" bus breakers at the 13.8 and 4.160 kilovolt levels, and for turbo-generator operation. Electrical power in turn is fed to all locations for 100-N Area. The mechanical control board (MCB) contains the indicators and recorders for monitoring the operation of the plant boilers and the switches and controllers for activation of control pump, fans, valves, and air compressors. Both control boards have annunciators for signaling impending out-of-limit conditions of

process variables. There are also local annunciator and temperature monitoring panels mounted in the proximity of the process equipment being monitored.

The 184-N Building is staffed by four operators per eight-hour shift, one chief and two journeymen operators for boiler operation and one operator for the electrical control board. The mechanical control board is manned by the chief operator. The journeymen operators rove through the 184-N Building, about every two hours monitoring equipment and logging data on the chemical feed system, turbine generator, boiler feed pumps, air compressors, and forced draft and purge fans; and when required, they clean the boilers' burners.

.2 Proposed System Configuration

Electrical Control Board

Presented in Table 4-13 is the percentage breakdown of the tasks executed by an electrical control board operator. As shown, only about eight percent of the operator's time is useful. The requirement for an operator can be eliminated by installing data acquisition equipment for logging and monitoring process variables and control switch positions on the electrical control board, supplemented by automatic switching with manual override. The installation of a remote scanning system with automatic switching of the ECB functions will absorb about 6.5 percent of the 8.0 percent work load of the ECB operator. The remaining task of visually checking the turbo-generator brushes can be done by a roving or chief operator and/or electrician on his routine checking. The switching function accounting for 0.4 percent of an operator's time is usually routine and procedurally well-defined, with the majority of switch operations occurring during the startup and shutdown phases of the reactor operation. A flow chart of the current startup operation is illustrated in Figure 4-8, and that proposed in Figure 4-9.

Improved monitoring of the electrical system will also be provided by a status board mounted in the 105-N Control Room. The board will be

TABLE 4-13ELECTRICAL CONTROL BOARD OPERATOR'S*
TIME DISTRIBUTION

<u>Task</u>	<u>Time (Percent)</u>
Switching	0.4
Data Logging and Monitoring	5.9
Communications to Electrical Distribution	0.07
Observe Brush Action	1.7
Inactivity	91.9
TOTAL	<u>100.0 %</u>

*Personal Notes, "184-N ECB Switching," T. M. Hall, Specialist,
January 3, 1967.

FIGURE 4-8

"A" BUS STARTUP MANUAL ACTION FLOW DIAGRAM

FIGURE 4-9

PROPOSED "A" BUS STARTUP AUTOMATIC
FLOW DIAGRAM

a direct mimic of a one-line diagram of the electrical complex circuit breakers at the 13.8 and 4.160 kilovolt levels with selected mimics of the 480 and 120-208 volt breakers. Each breaker status will be indicated by lights (green for open and red for closed).

Mechanical Control Board

Extending the monitoring and logging function of the surveillance system to the boilers' operating parameters on the mechanical control board and the local panels, gives a potential for the reduction of one journeyman operator and provides for a cross-check of the boiler operation by supervisory personnel in the main control center. Again, the process variables and switch positions would be monitored periodically and compared against high-low limits or, in the case of switches, the proper position for a given mode of operation. Any off-standard value or position would be displayed in both the 105-N and 184-N Control Rooms via output typewriters. Corrective action would be by the Chief Operator in the 184-N Control Room; automatic actuation will not be provided on the boiler controls. The reduction of one journeyman operator assumes the interchange of operators among other buildings in periods of heavy work loads.

The summary of inputs required to support the above described functions are given in Table 4-14.

4.3.3 109-N Building

.1 Current Control and Data Logging Practices

The major process equipment in the Heat Dissipation Plant (109-N) monitored by the 109-N operators are as follows:

- a. Six primary coolant system drive turbines, pony motors, and supporting equipment which supply power to the primary pumps that furnish coolant to the reactor; the pony motors provide backup to the drive turbines.

TABLE 4-14SUMMARY OF INPUTS
FROM
184-N BUILDING

<u>Description</u>	<u>Types of Input</u>	
	<u>Analog Signals</u>	<u>Digital Signals</u>
Electrical Control Board	24	104
Mechanical Control Board	50	75
CE Control Board	42	39
FW Boiler Feedwater Pumps, Forced Draft Fan Panels, Air Compressors	23	37
Turbine Panel	8	31
	<hr/>	<hr/>
TOTAL	147	286
	<hr/>	<hr/>

- b. Drive turbine oil conditioning system that filters and maintains the proper oil temperature before being returned to the primary pumps and drive turbines.
- c. Sixteen dump condenser condensate pumps which supply steam condensate from the dump condensers or from the Washington Public Power Supply System plant to the twelve steam generators at N Reactor.
- d. Sixteen hydraulic control systems that modulate the positions of the dump condenser steam admittance valves (HPV-201's).
- e. Heat and ventilation system for the 109-N Building.

The 109-N Building is manned by one chief and two journeymen operators. Their duties are much the same as the operators in the other auxiliary buildings in that they log and monitor the operating parameters about every two hours. They patrol the 109-N Building looking for water and oil leaks in the process equipment, observe the level of oil reservoirs, and perform general housekeeping chores. During the reactor startup period, they are responsible for manually starting-up the primary pump drive turbines to 900 RPM before turning control over to the Main Plant Center (105-N) operations.

.2 Proposed System Configuration

As with the other auxiliary buildings, installation of a remote scanner-transmitter in the 109-N Building will enable the logging and monitoring of the six drive turbines' operating parameters plus selected parameters on the heat and ventilation system. The total number of points as summarized in Table 4-15 is 225. The number includes such critical parameters as shaft bearing oil temperatures and pressures, oil pump pressures, control oil pressures, bearing temperatures, and condenser valve positions.

The proposed system will reduce importantly the need for manual data monitoring and logging, and at the same time give more frequent intervals of data checking. The means will exist for the reduction of two operators per shift from the 109-N Building with additional assistance from relief operators as required.

TABLE 4-15SUMMARY OF INPUTS
FROM
109-N BUILDING

<u>Description</u>	<u>Analog Signals</u>
Pressures	85
Resistant temperature detectors	120
Tachometers	6
Valve positions	6
Battery voltages	2
Annunciators	6
TOTAL	<u>225</u>

4.3.4 Additional Staff Reduction

The current ratio of operators to supervisory personnel in the 105-N Building and auxiliary buildings is five to one. With reduction of 17 operators, there is the added potential for reduction of one supervisor per shift, giving a total staff reduction of 21 shift operations personnel.

4.3.5 Conclusions

Consolidation of surveillance and control of systems and processes in the 181-N, 182-N, 184-N, and 109-N Buildings is the means for allowing important staff reduction, which in turn will give a reduction in operating cost. In addition, automation of routine tasks by means of automatic control of electrical switch gear, and programmed communication to the central control room will give reduction in complexity of plant operation.

4.4 Summary and Conclusion

In this section (4.0) operational background and scope of application were treated in the following areas:

- a. ISI-609 Process Computer functions
- b. Surveillance and control of critical systems and processes
- c. Consolidation of control

Problems and proposed solutions in each of the above areas were discussed in detail, and it was shown how an automated surveillance system will provide each solution. Benefits to be derived include the following:

- a. Reduction in operational complexity
- b. Increase in reactor dependability
- c. Enhancement of safety and licensability postures
- d. A means for reducing operating costs

In conclusion, application of the envisioned system will provide the desired solutions and benefits. The next section gives a detailed description of the envisioned inputs/outputs, hardware, and software which will be required for implementation of the system.

5.0 DESCRIPTION OF THE SURVEILLANCE SYSTEM

The proposed surveillance system will be comprised of a number of hardware devices supported by extensive computer programs. The sizing of the hardware is dependent upon the number of inputs, the computations required, and the form of the output; i.e., actuation, logging, or display.

5.1 System Inputs and Outputs

During routine operation, inputs into the system will come from two main sources, the plant process equipment via data acquisition equipment, and control room operators through a console located in the Main Plant Control Center. Occasionally, inputs will come from programmers via the computer console and/or input-output typewriter in the control room.

The total number of plant inputs required to support the previously described functions are summarized on the next page. Of the total analog inputs, eighty-two percent (2544) are already logged semi-automatically by the current data loggers. None of the 1200 digital inputs (switch, valve, breaker positions, etc.) are presently monitored automatically.

The inputs into the system from a control operator will be alpha-numeric codes inserted on the control room console that will call upon programs to display or print a current value of a process variable(s), high or low limit, or last calibration date. The operator will be restricted to requesting information only; changing or updating programs and/or coefficients of equations will be the responsibility of designated programmer-engineers.

Examples of inputs, other than codes themselves entrusted with the engineer-programmers, are as follows:

- a. enthalpy unbalance factors for the fuel channels
- b. ranges of flow transducers on the fuel channels
- c. riser and connector pressure corrections used in computing temperature limits
- d. tables containing process limits such as specific powers, low trip margins, steam generator levels, primary and secondary system operating pressures.

TABLE 5-1SUMMARY OF SURVEILLANCE SYSTEM INPUTS

	<u>TYPES OF INPUTS</u>	
	<u>Analog Signals</u>	<u>Digital Signals</u>
<u>105-N Building</u>		
<u>Process Tube Coolant</u>		
Outlet Temperatures	1003	---
Inlet Temperatures	32	---
Flow Rates	1003	---
<u>Pile and Coolant Systems</u>	420	---
<u>Horizontal Control Rods</u>		
Positions	86	---
Control Rod Mode	---	172
Nitrogen Pressure	---	86
Accumulator Oil Leaks	---	86
Oil Temp. & Press.	3	6
<u>Panels and Consoles</u>		
Safety Circuit Panel	---	150
Emergency Coolant Panel	5	28
Confinement, Fog Spray, Doors, Supply Press.	6	76
Other	19	85
<u>Electrical Inputs</u>		
105-N Battery Voltages	6	---
Room 6 Circuit Breaker Panels	---	7
<u>109-N Building</u>		
<u>Primary Pumps & Turbine Drives</u>	225	---
<u>181-182-N Buildings</u>		
	131	227
<u>184-N Building (With Actuation)</u>		
	147	286
TOTAL	3086	1209

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Outputs to Operations personnel will consist of the following:

- a. summary reports of plant operating data
- b. process limit reports giving calculated operating boundaries such as coolant temperature limits for each process tube
- c. exception reports, and displays via a cathode ray tube of process parameters approaching or exceeding their operating limits
- d. equipment status reports and displays showing which switches, breakers, and valves are in an off-normal position
- e. sequence of events reports such as the logging of position and sequence of movement of horizontal control rods as functions of time during the start-up and power ascension of the reactor.

5.2 Software Description

A summary of the real-time computation and monitoring programs for implementation on the Surveillance System appear in Table 5-2 with a brief description given below. The real-time computational programs will provide values of operating parameters not directly measurable, such as process tube heat generation rates, and fuel channel exposures, and will determine the margins of these parameters with their respective limits. Likewise, monitoring codes will command the data acquisition hardware to screen all input signals, and check for actual or incipient off-normal conditions. Any value found to be off-normal will be logged or displayed as previously discussed.

5.2.1 Tube Powers, Fuel Exposures, Conditions Summaries, and Tube Flows

Values of the inlet riser coolant temperatures and process tube coolant flows and outlet temperatures will be automatically read by the on-line system. The most recent values will be stored and used in computing individual process tube powers. An individual tube power margin will be calculated as the difference between the tube power limit and the current power. Maps of tube powers and margins will be provided as required. In addition, the program will select exceptional tubes based on high and low power margins.

Each time a new value of tube power is calculated, it will be combined with the previous value for that tube to get an average power for the last time interval. This average power will be used to calculate an incremental fuel exposure, and hence the updated accumulated exposure. Upon a reactor shutdown, a fuel exposure map will be available on demand.

The individual process tube flow rates will be compared with their low trip limit and both a margin and a flow map as required per Process Standards requirements. In addition, the equivalent process tube outlet temperature limits based on the low trip flow limits will be computed and logged in map-form along with a temperature margin map.

TABLE 5-2

SUMMARY OF REAL-TIME COMPUTATIONS AND MONITORING PROGRAMS

PROGRAM	REQUIREMENT	FUNCTION	REPLACES	SUPPLEMENTS	SALIENT FEATURES
Tube Powers, Fuel Exposures, Conditions Summary	Administration of limits and standards audit	Display and log power distribution and proximity to limit	Off-line code and ISI-609 intended function	Temperature and flow maps	Exception reports and display Summary reports
Tube Flows	Administration of limits and standards audit	Display and log flow distribution and proximity to limits	Off-line code and ISI-609 intended function	Temperature and flow maps	Exception reports and display
ZTM Limits	Administration of limits and audit	Display and log coolant temperature in relation to limit	Off-line code and manual computations	Manual cross-checks	Detailed coverage, exception reports, and display
Moderator Temperatures	Administration of limits and audit	Monitor graphite temperatures	ISI-609 function	Recorder	Exception reports and display
Coolant Systems Monitoring	Administer limits, standards audit	Display and log primary and secondary process parameters	ISI-609 function	Labor	Exception reports and display
Horizontal Control Rods	Critical systems surveillance, process standards audit	Sequence of events of rod withdrawal. Monitor hydraulic system	Rod Logger function	Checklist for rod withdrawal sequence. Labor pre-startup check	Exception reports and display
Panel, Console, and Equipment Maintenance Status	Standards audit, critical systems surveillance, equipment maintenance standards	Display off-normal equipment and maintenance standards status		Labor, pre-startup check	High speed check-out, hardcopy report of off-normal status

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PROGRAM	REQUIREMENT	FUNCTION	REPLACES	SUPPLEMENTS	SALIENT FEATURES
Control Center DC Breakers	Critical systems surveillance	Ensure electrical power to critical systems		Labor, pre-start- up check	High speed check- out, hardcopy report of off- normal status
Auxiliary Bldg. Monitoring	Centralization of control, standards audit	Display and log 109, 184, 182, 181 Bldgs. operating parameters	Labor	Labor	Exception report- ing in Main Control Center
Actuation of Circuit Breakers	Centralization of control, standards audit	Monitors and actuates 13.8 and 4.16 KV circuit breakers	Labor	Labor	Automated switch- ing

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Summary of Power Conditions by Fuel Type

A typical fuel loading for N Reactor consists of several types of fuel. For each type, the on-line system will provide: total flow, total power, number of fuel columns, average flow, and average power. This information will be given on demand.

Daily Summary of Reactor Conditions and Production

Reactor physics calculations involve the tube power factor; i.e., the ratio of the individual tube power to the reactor average tube power, and the square and cube of this factor. The tube power factor information will be combined with other data to provide a daily report of reactor conditions which lists the following data for every tube: tube number, fuel type, accumulated exposure, average power for the past 24 hours, exposure accumulated during the past 24 hours, plus the latest values of coolant inlet temperature, outlet temperature, pressure drop across the process tube, coolant flow rate, and tube power. Also, the total MWD production and excess reactivity held in control rods, which are required to be reported each day, will be included in the daily report.

5.2.2 Zone Temperature Limits Program

Utilizing the data from the above codes, the temperature limits for each of the 109 immersion temperature detectors will be calculated for both four and five lattice spacings. Exception reports on temperature margins will be provided on the logging typers.

5.2.3 Moderator and Coolant Systems Monitoring Program

Moderator temperatures and coolant systems' parameters currently monitored and logged by the ISI-609 Computer will be implemented on the Surveillance System. The permanent graphite temperature detectors will be deleted from monitoring because they cannot be replaced when they malfunction.

5.2.4 Horizontal Control Rods Program

This routine will provide for monitoring of control rod positions and hydraulic system parameters such as oil temperatures and pressures. Positions of active rods will be displayed on a cathode ray tube in alphanumeric form.

5.2.5 Check-Out Program

The status switches, power supply voltages, and DC circuit breakers, as indicated in Table 5-1, located in the Main Plant Control Center, will be monitored for off-normal conditions for each mode of operation; i.e., shutdown, start-up, and equilibrium operation. In addition, the status of equipment maintenance standards will be provided. Exception reports will be provided automatically.

5.2.6 Auxiliary Building Monitoring Programs

Operating parameters for the auxiliary buildings discussed in Section 4.0 will be monitored for limits surveillance with summary logs provided as required in the Main Plant Control Center and the 184-N Control Room.

5.2.7 Electrical Switch Gear Program

A routine will be written for both monitoring the status and the automatic actuation of circuit breakers currently controlled manually from the 184-N Electrical Control Board.

5.3 Hardware System Description

The N Reactor Surveillance System will be composed of two main subsystems:

- a. data acquisition and transmission systems
- b. the central processing unit (CPU) or computer, and its peripherals

5.3.1 Data Acquisition Systems

The data acquisition sub-systems installed in the various locations, as shown in the diagrams on Figure 5-1, generally have the function of acquiring data and transmitting it to the CPU for action. Because all surveillance system equipment must be internally compatible, an integrated system consisting of the central processing, data acquisition, and peripheral units will be specified and procured as a package. A detailed description of the functional operation of the data acquisition equipment is given in Appendix A.

5.3.2 Computer Peripherals

The N Surveillance System will process more than 3000 analog and 1200 digital inputs and is thus significantly larger than the typical process computer system. In order to provide for the efficient implementation, assembling, testing, and processing of computer programs, the input/output peripheral equipment presented in Table 5-3 are required.

.1 Computer Room I/O Devices

The card reader, paper tape reader/punch, line printer, magnetic tape units, and I/O typewriter will be the tools used by the programmer to implement and assemble new monitoring and control system on-line programs.

Programs will be initially coded on specially formatted paper and then punched on cards which will be manipulated by the programmer in making preliminary corrections and additions. When a program card deck is completed, it will be read into the computer via the card reader. With the program in the computer, logical checks or program verifications will be made by use of the I/O typewriter. The

REMOTE SITES

FIGURE 5-1

PROPOSED DATA ACQUISITION
EQUIPMENT FOR N AREA

TABLE 5-3COMPUTER PERIPHERALS REQUIRED AND NORMAL CHARACTERISTICS105-N Computer Room

<u>No.</u>	<u>Type</u>	<u>Characteristics</u>
1	Card reader	200 cards/min.
1	Paper tape reader/punch	300 characters/sec.-read 110 characters/sec.-punch
1	Line printer	300 lines/min. 120 characters/line
1	Magnetic tape unit	45 in./sec. 200, 550, 800 bits/in. (selectable)
1	Programmers I/O typer	10 characters/sec.
1	Bulk Memory Unit	500K words

105-N Control Room

<u>No.</u>	<u>Type</u>	<u>Characteristics</u>
2	Logging typewriters	15 characters/sec.
1	Alarm typewriter	15 characters/sec.
1	Operator's console	Manual point selection
1	CRT display	Alphanumeric and vector generation 100 in. ² display

184-N Control Room

<u>No.</u>	<u>Type</u>	<u>Characteristics</u>
1	Communications and alarm typewriter	15 characters/sec.

typewriter with its interpreter program will allow the programmer to talk to the computer in a higher level (assembly) language instead of octal, binary, or hexadecimal machine language. Thus, time will be saved in debugging the previously untested program. Once the program is satisfactorily tested, or a difficult program error is encountered, the source program, as it exists in core memory, will be printed out on the line printer. This provides a hard copy of the program for permanent record and gives a means of visually checking for programming errors. A line printer will be essential for this job function due to its rapid output speed as compared to a typewriter which performs the same function but increases manpower costs. The printer will also be used for large output summary reports.

To quickly recreate the programs in the event of a power failure or hardware malfunction, the paper tape reader/punch unit, backed-up by the card reader, will be used to read-in a bootstrap program. The bootstrap program will allow the programmer to activate the magnetic tape unit which has a complete source program ready to read-in. Thus, the paper tape reader/punch unit along with the magnetic tape unit provides an efficient way of recreating the on-line system program once it has been destroyed. System maintenance or diagnostic programs will be contained on paper tape since the paper tape reader requires the least amount of software control.

Besides satisfying program development and hardware maintenance needs, these equipment pieces will be useful in providing alternate output media in the event of 105-N Control Room peripheral malfunctions. The line printer and I/O typewriter will provide temporary data logging, alarm message, and calculational outputs to the process operators. Operator input requests for critical process parameters will be prepunched on paper tape and read-in through the paper tape reader if the operator's console fails.

.2 105-N Control Room I/O Devices

The two logging typewriters, one alarm typewriter, operator's console, and cathode ray tube (CRT) display will make up the man-machine

communication medium between the surveillance system and the reactor operators. They will provide the link which allows operations personnel to interrogate the system for immediate process information and, in turn, allows the surveillance system to keep them informed, automatically, of process parameters approaching their respective limits. An example of a CRT acting as a link between the process and the control room operators is shown in Figure 5-2 where selected drive turbine parameters are displayed. This device will also be used to display the dynamically changing control rod positions during startup and the margins of the process tube temperatures and power at equilibrium reactor power. In addition, the two logging typewriters will provide exception reports and messages to the operators and will be used for the smaller logging requirements imposed by the auxiliary building inputs and general Process Standards audit logs.

By having separate output devices (alarm typewriters and CRT) to provide out-of-limit surveillance, the operators will not have to rely on one device for immediate process corrective action information. Use of a separate typewriter avoids confusion on the part of the operator, who must interpret this information before he can take corrective action.

The operator's console will allow interaction with the surveillance system in acquiring process information between or during logging, monitoring, and alarm scan intervals. He can request continuous readout of any process input which is desired. While working with a particular input, such as making a manual adjustment to a pump flow, he can home-in on the actual value desired by looking at the surveillance system output and whatever analog control room measurement may be available. In the event of an alarm output, he can quickly verify the alarm by selecting that particular process input and demanding its readout. The operator can also request specific on-line calculations by selecting previously determined pushbuttons which will enable a program in the computer to process the information.

FIGURE 5-2
CRT DISPLAY OF PROCESS PARAMETERS

.3 184-N Control Room Requirements

An input/output typewriter is required in the 184-N Control Room for communicating the surveillance system monitoring results and any digital control actions taken. It will provide the link between the 184-N operator and the surveillance system which allows him to request monitoring and control information and automatically receive alarm messages.

5.3.3 Central Processing Unit

In Table 5-4 are detailed basic central processing unit (CPU) characteristics which will meet the surveillance system requirements and objectives. These features, in addition to satisfying technical requirements, will permit DUN engineers to write computer programs in a straight forward manner without reliance on "optimum" techniques.

.1 Instruction Execution Speed

Standard 24-bit word length process computers currently marketed meet the speed requirements given in Table 5-4 (21,22). With this speed capability, a number of monitoring and calculational functions can be accomplished in a multi-processing mode of operation as illustrated in Figure 5-3. For example, a horizontal control rod position can be read into the computer, converted to engineering units, and displayed on a cathode ray tube in a fraction of the time interval between rod position readings. During this same time interval, a fuel channel coolant temperature and its venturi pressure drop can be processed. Once all of the process tube flow and temperature data are in store, the computer speed is sufficient to allow the process tube heat generation rates and operating limits to be calculated within a five-minute time span which will allow scheduled and on-demand requests without sacrificing other system functions (23).

.2 Core and Bulk Memory Storage Requirements

The estimated memory requirements for the core and bulk are given in Tables 5-5 and 5-6, respectively. The store requirements of programs

TABLE 5-4CENTRAL PROCESSING UNIT REQUIREMENTS

<u>Description</u>	<u>Requirement</u>	<u>Basis</u>
<u>Instruction Speed</u>		
Add Time (μ sec.)	≤ 4	Meets requirements for control rod monitoring and display for 1" resolution
Cycle Time (μ sec.)	≤ 2	
<u>Core Memory</u>		
Word Length (bits)	24 + parity	Instruction repertoire, inherent accuracy, data packing
Size (words)	32K	Heavy load case indicates 2000 word margin (see Table 5-5)
Memory Parity	Yes	Detect data transfer malfunctions in computer
Memory Protect	Yes	Protect critical core resident codes from destruction
<u>Bulk Memory Size (words)</u>	> 500K *	Satisfy initial real and free time applications plus margin (see Table 5-6)
<u>Other Hardware Features</u>		
Extended Arithmetic Unit	Yes	Floating point will save 10-20% in programming man-hours (24)
Priority Interrupts	Yes	Necessary in real-time systems to acknowledge process needs (see Appendix B)
Block Transfer Channels	6	Large amount of inputs requires cycle steal technique for efficient use of CPU and ease of programming.

*Disks are available in sizes of 151, 303, and 606K words and drums in sizes of 96, 128, and 256K words. One 606K word disk or two 256K word drums are required.

FIGURE 5-3

TYPICAL DATA ACQUISITION
AND COMPUTATION CYCLE

TABLE 5-5CORE MEMORY BUDGET ESTIMATE

	<u>WORDS (thousands)</u>
<u>Real-Time Requirements</u>	
Real-time monitor system	7 - 11
Application programs	
digital control	.5 - 1
calculational	1.5 - 5
monitor and alarm	3
I/O Buffer (25,26,27)	.5 - 2
	<hr/>
	12.5 - 22
 <u>Free-Time Requirements</u>	
Language processing, program testing, and library main- tenance (25,26,27)	8
	<hr/>
TOTAL	20.5 - 30

TABLE 5-6BULK MEMORY BUDGET ESTIMATE

<u>REQUIREMENTS</u>	<u>WORDS (thousands)</u>
Real-time monitor system (25, 26,27)	7 - 11
Application programs	50 - 100
Current Data Tables	10 - 20
Backup Data Tables	10 - 20
Message Tables	16
Library (25,26,27)	50
Scratch Pad (25,26,27)	150
	<hr/>
TOTAL	293 - 367

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supplied with the computers were provided by prospective vendors (25, 26,27) whereas, the storage requirements of the application codes were estimated by DUN engineers, based on experience with the ISI-609 computer. Real-time codes relate to those programs operating under various levels of priority interrupt in real process time, and free-time codes relate to those programs executed during the "idle" time of the computer.

Based upon the estimates in Tables 5-5 and 5-6 and with both real and free-time monitor systems in effect (maximum duty cycle), a 2000 word core memory margin exists.

.3 Word Length

The single length word mode of the 24-bit word provides five decimal digit precision which is adequate for the Surveillance System applications such as the process tube heat generation computations. The precision available from larger word length computers is not required and does not warrant the additional expense. With smaller word length computing machines, the same resolution as provided by the 24-bit word requires a double word mode. Consequently, core storage is not utilized as efficiently.

Further efficiency is gained with a 24-bit over a 16-bit machine by data packing. Each analog input will be represented by 12 bits which will allow the packing of two analog parameters per computer word. With smaller word sizes, such as a 16-bit word, only one process parameter can be stored in one computer word. Thus, for a given amount of data to be stored in the computer memory, the storage requirements will double for the smaller word length computer. Ease of programming results because of the larger instruction repertoire provided by the 24-bit word lengths which vary between 90-120 instructions depending upon the manufacturer. By contrast, computing machines with 16-bit word lengths possessing hardware memory protection and memory parity features vary between 34 and 100 instructions with the majority falling in the range of 50 to 75 (23,25).

.4 Programming Language

The vendor supplied assembler and Fortran IV languages (28) will be used as required. In line mixing of assembler and Fortran statements will be specified to take advantage of the efficiency provided by the assembly language and the ease of programming complicated expressions or routines using the Fortran.

5.3.4 New Instrumentation

Besides the data acquisition and computer equipment, additional primary instrumentation will be needed. This includes, for example, analog transducers for temperature, pressure, and flow measurements and digital sensors (relays) for monitoring various switch positions on consoles and panels. The instrumentation required is illustrated in Figure 5-4.

FIGURE 5-4INSTRUMENTATION REQUIRED

6.0 SYSTEM RELIABILITY ANALYSIS, AND INSTALLATION AND MAINTENANCE REQUIREMENTS

The dependability of the Plant Process Surveillance System is a function of the inherent reliability of the equipment and of the installation and maintenance practices applied. This section presents the results of a reliability analysis of and the installation and maintenance requirements for the proposed surveillance system.

6.1 Reliability Analysis

The reliability technique referred to as fault tree analysis (29) was used in evaluating the inherent performance of the proposed surveillance system. The major steps in utilizing this method are as follows:

- a. Define what a system failure is.
- b. Construct a system fault tree model according to the failure definition.
- c. Determine MTTF (mean time to fail) and MTTR (mean time to repair) values for each component in the fault tree model.
- d. Determine a representative mission time or system run time.
- e. Process fault tree inputs on the Univac 1108, using the fault tree analysis program (29).
- f. Evaluate results.

These considerations are addressed in the following discussions.

6.1.1 System Failure Definition

The surveillance system will provide an extensive amount of data monitoring along with a limited amount of off-reactor digital control as described in Sections 4.2 and 4.3. In view of this, system failures were defined in two ways:

- a. Those failures which interfere with each required monitoring function as specified by the specific input subsystem analyzed.

- b. Those failures which interfere with the intended control functions.

A further discussion on the system failure definition is presented in Appendix C.

6.1.2 System Fault Tree Models Developed

Due to the two system failure definitions just presented, two distinct system fault trees are required: a monitoring fault tree and a control fault tree. The two models are presented in the following text.

.1 Monitoring System

The monitoring fault tree model describes the logic used in determining the expected performance of the surveillance system when providing data logging and plant status monitoring functions. Figure 6-1 illustrates a simplified version of the model where the system components are weighted with "AND" and "OR" logic gates according to their degree of interaction within the entire monitoring system. The following logical relationships define a monitoring system failure:

Equation (1) Monitoring failure = (computer system failure)
.OR. (power supply system failure) .OR. (input
system failure) .OR. (logging and alarm output
failure)

Equation (2) Computer system failure = (computer mainframe
failure) .OR. (bulk memory and direct memory
access failure)

Equation (3) Input system failure = (program input failure)
.OR. (human error in modeling and program
development) .OR. (process input failure)

FIGURE 6-1

SURVEILLANCE SYSTEM
MONITORING FAULT TREE

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.2 Control System

The control system fault tree model describes the logic used in determining the expected performance of the N Surveillance System when performing limited digital control actions on the process. From the simplified control fault tree in Figure 6-2, logical failure relationships may be defined.

Equation (4) Control system failure = (computer system failure)
.OR. (power supply system failure) .OR. (input
system failure) .OR. (actuation output failure)

Equation (5) Computer system failure = (computer mainframe
failure) .OR. (bulk memory and direct memory
access failure)

Equation (6) Input system failure = (program input failure)
.OR. (human error in modeling and program
development) .OR. (process input failure)

They are very similar to the equations defined for the monitoring system, except that the data logging and monitoring output components have been replaced with digital output control components.

With the logical relationships defined, each component was assigned an MTTF and an MTTR value. Table 6-1 presents the MTTF and MTTR values for the more critical system components.

The logical relationships, along with their component failure and repair data, were processed by the fault tree analysis program to determine quantitative system performance measurements. The results of these analyses are presented in 6.1.3 for both fault tree models.

6.1.3 System Analysis Results

The following text describes the results of both the monitoring and control fault tree analyses. For all analyses, a mission time of

LEGEND

OR Gate

Failure Source

FIGURE 6-2

SURVEILLANCE SYSTEM
CONTROL FAULT TREE

TABLE 6-1AVAILABILITY INPUT VALUES FOR
CRITICAL SYSTEM COMPONENTS

<u>COMPONENT</u>	<u>MTTF</u>	<u>MTTR</u>	<u>Source</u>
Main Frame	5,800 hrs.	2.0 hrs.	Reference*
Power Supplies	100,000 hrs.	2.0 hrs.	
BPA Power (A Bus)	18,800 hrs.	13.0 hrs.	
A to B Bus Transfer	570,000 hrs.	18.0 hrs.	
B Bus Power	8,760 hrs.	10.0 min.	
Digital Multiplexers	100,000 hrs.	2.0 hrs.	
Analog Multiplexers	10,000 hrs.	2.0 hrs.	
MW Relays	1,000,000 hrs.	2.0 hrs.	
Fixed Head Disc	10,000 hrs.	4.0 hrs.	
Direct Memory Access Channel	83,000 hrs.	2.0 hrs.	
Typewriters	1,000 hrs.	10.0 min.	

* Sources include manufacturers' data (30,31), equipment performance handbook (32,33), and experience at Hanford (34,35).

22.1 days (16) was selected. Figure 6-3 illustrates the importance of mission time with respect to monitoring system performance.

Analyses were made to determine the effect of certain surveillance system component failures on the reliability and availability of the system. After numerous cases were analyzed, it was concluded that the component most influential on system reliability/availability was the computer mainframe. Other components, such as power supplies and multiplexers, were also contributors to system failure, but were minor compared to the mainframe failure contributions. Figures 6-4 through 6-5 illustrate the reliability and availability of the monitoring system while Figures 6-6 through 6-7 illustrate the performance of the control system when performing their intended functions. The figures show performance measurements as functions of the computer mainframe MTTF, while the remaining critical system components were held constant at the values presented in Table 6-1. Table 6-2 summarizes the inherent surveillance system performance measurements, using a computer mainframe MTTF of 7,800 hours (30).

6.1.4 Conclusion

The results of this study show an inherent availability in excess of 99 percent while satisfying the N Plant monitoring, data logging, and control functions proposed herein.

TABLE 6-2SURVEILLANCE SYSTEM PERFORMANCE ESTIMATES

<u>System Mode of Operation</u>	<u>Reliability</u>	<u>Availability</u>
Monitor system	0.9135	0.99966
Control system	0.8726	0.99950

FIGURE 6-3

SURVEILLANCE SYSTEM MONITORING RELIABILITY
vs.
MISSION TIME

FIGURE 6-5

SURVEILLANCE SYSTEM MONITORING AVAILABILITY

vs.

COMPUTER MAIN FRAME MTTF

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FIGURE 6-6

SURVEILLANCE SYSTEM CONTROL RELIABILITY

vs.

COMPUTER MAIN FRAME MTF

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6.2 Computer Installation and Maintenance Requirements

The method of attaining acceptable performance levels and safe operating conditions for the N-Surveillance system will consist of three major elements:

- a. Well defined physical and environmental installation requirements.
- b. An adequate equipment and software maintenance program.
- c. Adequate spare parts inventory and test equipment array.

6.2.1 Installation Requirements (36,37)

Table 6-3 summarizes briefly the key computer installation requirements, both physical and environmental, and their associated costs. A modification cost of \$23,000 is anticipated, based on the cost of modifying Rooms 146, 147, 148 and 149 at the south end of the 105-N Control Room and on electrical power and environmental system costs.

6.2.2 Maintenance Requirements (38)

In acquiring the maintenance capability required, the following choices are present:

- a. Attract qualified personnel in the open market.
- b. Train selected DUN maintenance employees.
- c. Purchase maintenance service from the manufacturer.
- d. Do any portion or all of that mentioned in a, b, and c.

The combination of choices b and c, in-plant trained maintenance personnel and a maintenance contract, will provide first line¹ maintenance coupled with more specialized second line² maintenance.

¹ First line maintenance - Includes immediate surveillance of machine problems, initial troubleshooting and repair. If the problem cannot be resolved within approximately two hours, it becomes a second line maintenance problem.

² Second line maintenance - Under the maintenance contract, the vendor must respond within approximately four hours after he is called and stay until the machine is running. This would be the case if a serious machine problem had occurred, at which time contract maintenance personnel would be required. The vendor would also provide periodic preventive maintenance of the entire system.

TABLE 6-3COMPUTER INSTALLATION REQUIREMENTS AND COSTS

<u>Category</u>	<u>Requirement (40)</u>	<u>Initial Cost</u>
Room size	500 ft ² , 100% enclosed	\$ 5,000
Floor load limit	200 lb/ft ²	--
Light intensity	60 ft candles at 30 inches from floor	--
Light source	Diffused fluorescent light	--
Fire protection	One detection sensor/500 ft ² 25 lb capacity CO ₂ extinguisher	4,000 (1)
Door width	4 ft wide equipment passageway	200
Raised floor	2 ft ² , vinyl, steel back, seal tight edge tiles Locking type jacks for support	13,000
Power	115/230 volt AC ±10% 30 KVA, 60 HZ ±1 HZ Voltage transfer between A&B Bus	3,000
Air conditioning	Completely independent environmental control system	11,000
Ground	Less than .05 ohms between equipment ground and earth	--
Total Cost		<u>\$36,200</u>

The two sources constitute a strong maintenance program, both ensuring high availability figures. Figure 6-8 illustrates the importance of competent maintenance by showing the relative effect of computer main frame repair time on the surveillance system monitoring availability. The dashed line represents a repair time of two hours, and its intersection with the curve yields an inherent surveillance system availability of greater than 0.99 with this maintenance program. The availability of the system decreases as a function of the increased repair time incurred, which reflects any decreases in maintenance capability.

Table 6-4 summarizes the manpower and contract maintenance costs incurred under this maintenance program. A cost of \$56,500 per year is anticipated for the first three years of system operation.

6.2.3 Spare Parts and Test Equipment Requirements (38)

Recommended spare parts inventories will be supplied by the selected vendor and purchased as a part of the system.

Estimated costs are \$55,000 for the parts inventory and \$5,000 for test equipment.

MTTR = 2 hrs.
Monitor System Availability = 0.99966
Mission Time = 22.1 days

Computer Main Frame - MTTR-Hrs.

FIGURE 6-8
SURVEILLANCE SYSTEM MONITORING AVAILABILITY
vs.
COMPUTER MAIN FRAME MTTR

TABLE 6-4MAINTENANCE REQUIREMENTS AND COSTS

<u>Category</u>	<u>Requirement</u>	<u>Cost \$/Year</u>
First line maintenance (in house)	Two instrument men One engineer	\$26,200 15,300
Second line maintenance (computer vendor)	Contract maintenance	15,000
	Total maintenance cost	\$56,500 /year

7.0 ALTERNATIVES

Consideration was given to three alternatives, as follows:

- a. One-year deferral of the system as proposed
- b. Replacement of the ISI-609 system intended functions only
- c. Surveillance of the processes in 163-N Building (demineralization plant) and 183-N Building (water filter plant) in addition to the surveillance proposed.

7.1 One-Year Deferral of the Proposed System

Funding has already been deferred two years. The central data logger is giving age-related problems, and future problems are expected. Further delays will hamper the N Reactor operability effort, and will be out of phase with other programs such as licensability and conversion to power-only operation.

In addition, successful implementation of the system is dependent upon competent technical staff now in place. Deferral of this project will result in some erosion of this capability.

7.2 Replacement of the ISI-609 Process Computer Functions Only

This alternative would serve only as a replacement for equipment which is now showing age-related problems. It would not give the capability for an automated process audit nor the means for reduction of staff in the auxiliary buildings.

7.3 Surveillance of Processes in 163-N and 183-N Buildings

This alternative was reviewed in some detail for purposes of staff reduction. Monitoring of the pertinent variables by means of a remote scanning system and actuation required to displace tasks would give a materials and installation cost of approximately \$200,000. While this type of automation might relieve the operators of some tasks, no true economic or reactor life incentives are evident at this time. It is believed that special purpose automation of the water processes would have better potential for benefits than consolidation of control.

8.0 CAPITAL EXPENDITURE FORECAST AND SUMMARY OF BENEFITS

The estimated capital expenditure for the system, consisting of materials, installations, engineering, drafting, and contingency is \$983,700. Also, the estimate for replacement of aging equipment which the system will displace is \$370,000, giving an incremental cost difference of \$613,700. Reduction in operating cost is expected to be \$254,900 per year, giving a pay-out period of 2.4 years.

The above figures are based upon 1969 material costs and wage rates. Historically, the costs of process computers and data acquisition equipment have decreased over the last decade. If the current inflationary spiral continues, it is reasonable to expect that the total system cost may increase up to five to ten percent per year. Also, it is reasonable to expect that labor costs will increase, giving more reduction in annual operating costs.

8.1 Capital Expenditures

A summary of capital expenditure estimates is given in Table 8-1. Bases for costs of materials and installations are as follows:

- a. Computer and peripheral equipment - based on prospective vendor quotations contained in catalogs
- b. Computer room - based on information given in Table 6-3
- c. Data acquisition equipment - based on prospective vendor quotations contained in catalogs
- d. Instrumentation - based on estimates made by DUN specialists

8.2 Reductions in Operating Cost

As shown in Section 4.3 of this report, the Surveillance System will give the means for reduction of 21 shift operating personnel. Also, by simplifying administration of operating limits and standards, tasks equivalent to those performed by one process engineer will be eliminated. In addition there will also be savings due to replacement of manual surveillance of the rod coolant temperatures as shown in Section 4.1.

TABLE 8-1

ESTIMATES OF CAPITAL EXPENDITURE,
PLANT PROCESS SURVEILLANCE SYSTEM

<u>Item</u>	<u>Cost (thousand dollars)</u>
Materials and Installation	
Computer and peripheral equipment	356.0
Computer room	36.2
Data acquisition equipment	
105-N Building	88.9
109-N Building	33.5
184-N Building	55.6
181/182-N Buildings	41.1
Total	219.1
Instrumentation	
105-N Building	84.7
109-N Building	57.0
184-N Building	47.2
181/182-N Buildings	27.4
Total	<u>216.3</u>
Total, Materials and Installation	827.6
Contingency	81.1
Engineering and Drafting	<u>75.0</u>
TOTAL	<u>983.7</u>

TABLE 8-2COST REDUCTION, PLANT PROCESSSURVEILLANCE SYSTEM

<u>Staff Reduction</u>	<u>Annual Cost Savings (thousand dollars)</u>
Twenty-one shift operating personnel	269.2
One equivalent process engineer	17.2
Data monitoring and logging	<u>25.0</u>
TOTAL	311.4
<u>Additions</u>	<u>Annual Cost Increase (thousand dollars)</u>
Two technicians	26.2
One equivalent programmer-engineer	15.3
Contract maintenance	<u>15.0</u>
TOTAL	56.5
<u>Net Annual Savings</u>	<u>254.9</u>

Some increase in staff will be required for maintenance of the system, as discussed in Section 6.2. The summary of cost reductions and cost increases is given in Table 8-2, with a net reduction in operating cost of \$254,900 per year.

The money attributed to manpower reduction and manpower increase include the following (39,40):

- a. base salary expense
- b. isolation pay and shift differential
- c. continuity of service factor applied to a and b (current rate is 15.5 percent)
- d. a factor to include such items as radiation records, transportation, supplies, office equipment rental, and business taxes (estimated as 10 percent).

8.3 Summary of Benefits

Identified benefits to be derived from the system are as follows:

- a. Replacement of aging equipment with a reliable system
- b. Enhancement of safety and the posture for licensability by the following means:
 1. Simplification of the administration of operating limits and standards
 2. Automatic surveillance of critical systems
 3. Centralization of control
- c. Increase in reliability of the reactor by providing the following:
 1. Back-up for special purpose data logging equipment
 2. A tool for application to thorough, disciplined check-out
- d. Reduction in operating cost of \$254,900 per year by reducing manpower requirements.

As N Reactor continues to mature, and application of the Surveillance System becomes routine, other benefits will be identified. The potential for production efficiency was discussed in Section 4.2. Others have not been identified at this early date.

9.0 PROGRAM PLAN

The task of implementing the program for achieving the ultimate goals of the Plant Process Surveillance System may be divided into the following six phases:

- a. Development of detailed hardware and software requirements and specifications
- b. Preparation and submittal of the acquisition proposal and project proposal
- c. Procurement and installation of the system
- d. Training of programmers, maintenance personnel, and operations personnel
- e. System and software development
- f. Routine application of the system

9.1 Program Milestones

Figure 9-1 depicts the planned schedule for procurement, development, and initial application of the system. The schedule is based on the assumption that approval to proceed is granted on or before January 15, 1970.

9.1.1 Hardware and Vendor Supplied Software Specifications

Specifications will be prepared and submitted through the AEC to prospective vendors for the preparation of system and equipment proposals and price quotations. The proposals will be evaluated for adherence to specified requirements and exceptions to the requirements.

9.1.2 Acquisition Proposal and Project Proposal

An acquisition proposal which will cover the data acquisition equipment, computer peripherals, and digital output equipment will be prepared and submitted for AEC approval.

TABLE 9-1

TASK PLAN

N REACTOR SURVEILLANCE SYSTEM

FISCAL YEAR	1970				1971				1972				1973			
QUARTER	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
<u>MILESTONES</u>																
Authority to proceed																
Selection of vendor																
System testing complete																
Envisioned Phase III start (N Reactor)																
Envisioned dual purpose licensability (N Reactor)																
<u>PROCURED HARDWARE AND SOFTWARE</u>																
Specifications and selection study																
Project proposal for instrumentation																
Acquisition Proposal (ADP)																
Procurement and installation																
Detailed design																
Installation of instrumentation																
<u>INTERNAL SOFTWARE</u>																
Model development and specifications																
Development of computer programs																
<u>OPERATIONAL TESTING</u>																
Hardware system testing																
Software testing and refinements																
Central processing unit (CPU) acceptance																
Overall system testing and acceptance																
<u>TRAINING</u>																
Maintenance																
Software																
Applications																

UNCLASSIFIED

9-2

DUM-6356 REV1

UNCLASSIFIED

Concurrently, the project proposal will be submitted for AEC approval for the entire project, including procurement and installation of instrumentation. This project will entail the preparation of specifications for transducers, relays, power supplies, wire and cable, and enclosures.

9.1.3 Procurement and Installation of the System

Liaison will be maintained with the computer system's vendor to ensure the proper interfacing of data acquisition equipment with plant instrumentation, the suitable scheduling of hardware installation, and the performance of the vendor-supplied hardware and software specifications. The detailed design procurement and installation of instrumentation will be coordinated closely with data acquisition equipment installation and scheduled reactor outages.

9.1.4 Training

Both hardware and software training sessions will be conducted for maintenance and computer programming personnel, respectively. The selected engineers and craftsmen will be sent to the computer vendor's manufacturing site for detailed formal training sessions on hardware maintenance and software programming. Additional training will be conducted at N Reactor as required.

As the installation and checkout of the Surveillance System nears completion, on-the-job training will be given to operations personnel on the function, application, and operation of the system.

9.1.5 Systems and Software Development

After the formal programming course, intensive coding, testing, and refining of applications computer routines will begin. This phase of development will continue through the installation and checkout of the overall system. Modifications to the vendor supplied software will be made as required. The software development phase is estimated to require 16.5 man-years of effort.

9.1.6 Routine Application

Following the acceptance test of the Surveillance System, it will be turned over to N Operations for routine application. To insure that the availability objectives of the system are met, emphasis will be placed on running diagnostic computer programs for both the CPU and data acquisition equipment, as well as sustaining a competent contract and in-house maintenance staff.

9.2 Resources for Software Development

The major implementation of applications programs will be accomplished within Douglas United Nuclear, Inc. As many as seven engineers will be devoted to development of the control laws and computer programs. In addition, the selected vendor will be utilized for correction or modification of the vendor-supplied systems software, as required.

Additional expertise exists for consultation from the parent company (McDonnell Douglas Astronautics Company). Also, the computing facilities at both Computer Sciences Corporation and Pacific Northwest Laboratories are available for simulation studies, control systems analysis, and check-out of process computer programs.

9.3 Principal Management Considerations

In order to assure an orderly, successful program, sound engineering management will be applied. The following brief list gives salient considerations:

- a. The data acquisition equipment, computer, and peripherals will be procured from one vendor in order to assure compatibility among these subsystems.
- b. Hardware components and subsystems will be proven items; prototypes or "first-of-a-kind" items will not be acceptable. Also, an experienced, reliable vendor will be required. This approach will preclude the risk of component and subsystem development, and will also minimize the risk of early system obsolescence.

10.0 CONCLUSIONS AND RECOMMENDATIONS

In accordance with the requirements set forth in AEC Manual Chapter 1801 (1), this study provides the description of and justification for a Plant Process Surveillance System for N Reactor. It is concluded that the system will contribute importantly to safe, reliable operation of the plant, and will provide a means for important reduction in operating cost.

The schedule for implementation of the system shows first routine application of the system by Operations personnel in mid-fiscal year 1973. This schedule is compatible with the envisioned dates for licensability of N Reactor as a dual purpose reactor and for the beginning of conversion to power-only operation. In order to achieve this schedule, funding for the system will be required in fiscal year 1971.

Therefore, it is recommended that the system proposed herein be authorized and funded in fiscal year 1971.

11.0 REFERENCES

1. AEC Manual Appendix 1801, "Data Processing Equipment and Services (Handbook)," January 13, 1969.
2. DUN-3551, "Automatic Data Processing Equipment Feasibility Study #6802, Process Computer System for N Reactor," C. F. Poor, June 7, 1968.
3. Approval Letter, C. D. Harrington to U. S. Atomic Energy Commission, "Process Computer, N Reactor," ATD-162, June 19, 1968 (approval dated July 18, 1968).
4. Douglas United Nuclear, Inc., "Hanford's N Reactor," Richland, Washington, April, 1968.
5. T. M. Stout, "Estimating Plant Profits for Process Computer Control," Instrumentation Technology, June, 1969.
6. DUN Property Custodian Listing - Fixed, Report 4004, April 30, 1969.
7. HW-76500, "Process Standards - NPR," Hanford Atomic Products Department, General Electric Company, Richland, Washington, February, 1967 (Confidential).
8. Letter, L. G. Meares to W. E. Bounds, "Trip Report, Douglas United Nuclear, Inc.," December 6, 1968.
9. Letter, H. H. Wrantham to R. G. Lauer, "Rod Coolant Temperature Manual Monitoring," October 22, 1969.
10. Letter, R. G. Lauer to T. H. Young, "Rod Coolant Temperature Manual Monitoring Costs," October 21, 1969.
11. DUN-2664 Vol. 10, "Control Room Supervisor's Log Book," March, 1969, pp. 18-20 (Secret).
12. DUN-2664 Vol. 13, "Control Room Supervisor's Log Book," September, 1969, pp. 51, 52 (Secret).
13. Startup Checklist for Extended Outage, October 17, 1968.
14. N Reactor Process Standards Auditor's Checklist, J. T. Long - Custodian.
15. DUN-2569 RD, "Console Data Log - 105-N," D. S. Lewis (Confidential).
16. Letter, T. H. Young to J. W. Riches, "Time Operating Efficiency Goal Allocation, N Reactor," May 16, 1969.
17. Letter, T. H. Young to Distribution, "N Reactor Problem Identification Meeting - October 23, 1969," October 24, 1969.
18. Letter, A. A. Leventis to T. H. Young, "Causes of Outages - Calendar Year 1969 - Summary," June 5, 1969 (Confidential).

19. DUN-5276 REV2, "N Reactor Critical System Definition," April 28, 1969.
20. Part 50 - Licensing of Production and Utilization Facilities, General Design Criteria for Nuclear Power Plant Construction Permits, Federal Register, p. 10213, July 11, 1967.
21. Computer Industry Annual 1967-1968, Fawcett-Haynes Printing Corp., Chicago, Illinois.
22. Bhushan, A. K., "Selecting a Small Computer for Your Application," Computer Design, September, 1969.
23. Letter to File, "General Recommendations for Computing Configuration and Speed Requirements of N Reactor Surveillance System," George Meister, McDonnell Douglas Astronautics Company, Huntington Beach, California, June 27, 1969.
24. DUN-2751, "Savannah River Trip Report," P. D. Gross and G. C. Clodius, June 26, 1967 (Confidential).
25. GE-PAC 4020, Standard Software Directory, March 6, 1969.
26. Personal communication, R. Jusenius, Systems Engineering Laboratory, to R. G. Lauer, "SEL 840 MP Standard Software Core Requirements," September 8, 1969.
27. Personal communication, C. L. Pleasance, General Electric Company, to R. G. Lauer, "GE-4020 Core and Bulk Storage Requirements," September 10, 1969.
28. ASA-X3.9-1966, "American Standard FORTRAN," American Standards Association, March 7, 1966.
29. DUN-5508, "Computer Program for Fault Tree Analysis," P. A. Crosetti, April, 1969.
30. Letter, C. L. Pleasance to C. F. Poor, "General Reliability and Cost Information," May 15, 1969.
31. Letter, D. T. Rozak, Philco-Ford Corporation, to C. F. Poor, DUN, "Computer System Failure Data," September, 1969.
32. FARADA, Failure Rate Data Handbook - Volume 1A, U. S. Naval Fleet Missile Systems Analysis and Evaluation Group, September, 1967.
33. Tech Report, RADC-TR-68-114, "Data Collection for Non-Electronic Reliability Handbook (NEDCO 11), Volume II, Section I, Failure Rate Data," Hughes Aircraft Co., June, 1968.
34. Personal communication, R. Furrer to R. G. Lauer, "Component Failure Information," August 1, 1969.

35. Personal communication, R. Sherrard to R. G. Lauer, "Reactor Plant Failure Data," August, 1969.
36. Letter, R. G. Lauer to C. F. Poor, "N Computer System Installation Requirements and Costs," October 28, 1969.
37. H-1-27602, "Architectural Floor Plan at El. 0'-0' Area 1," Mar, 1959.
38. Letter, R. G. Lauer to C. F. Poor, "N Computer System Maintenance Requirements and Costs," October 28, 1969.
39. Letter, R. G. Lauer to T. H. Young, "Labor Costs," October 22, 1969.
40. Letter, L. B. Brown to T. H. Young, "Manpower Reduction Cost Savings," October 28, 1969.

APPENDIX ADESCRIPTION OF DATA ACQUISITION
AND TRANSMISSION SYSTEMSDIGITAL DATA ACQUISITION

A typical digital channel is shown in Figure A-1. Digital data are on-off data, and will represent the status of limit switches, control switches, power breakers closed or open and other devices of an on-off nature. Digital inputs can also be on-off voltages as well as contacts or switches. Plug-in signal conditioning equipment is used to convert the various types of digital signals to a common logic level recognized by the computer. By examining the voltage logic levels or bits, the computer can determine if a device is on or off, and can further compare the state of each bit with a required pattern stored in memory to determine if the status of each device monitored digitally is correct.

In addition to the ability of monitoring status, the computer can also, through devices very similar to digital data acquisition devices, output bits of information that can change the status of on-off devices such as breakers. In this case each bit would control a contact-making device such as a relay, either energizing it or de-energizing it so that the contact would operate and close or open the control circuits of a breaker.

In addition to monitoring the status of equipment periodically, there are two cases, the safety circuit bypass and the electrical control board switch positions, where their status will be monitored continuously.

To provide the equivalent of continuous monitoring without the actual inconvenience of continuous monitoring, a technique called change detection will be employed. The change detection hardware will monitor the special digital inputs on a continuous basis at the digital input level rather than the CPU level. Whenever a digital input changes, the change detect hardware will detect the fact that a change has occurred and will generate a priority interrupt of the CPU. The priority interrupt will then interrupt the CPU,

FIGURE A-1

DIGITAL INPUT/OUTPUT

stopping any task in process, and the CPU will request a read in of the digital data of interest. The CPU will then determine what has changed, and take action on the change as dictated by an internal CPU program.

Data acquisition of digital information will be programmed by two methods, random access and block transfer control or direct memory access. These modes of operation are essentially the same for digital and analog data acquisition and will be explained below in the section on analog data acquisition.

ANALOG DATA ACQUISITION

An analog signal is a continuous direct current signal representing a measurement of a process parameter such as pressure, temperature, flow, voltage, or current. An electrical transducer is used to measure the process quantity and convert it to a D.C. voltage proportional to the quantity measured; an example is the main steam header pressure which is first converted to a $\pm 25V$ D.C. signal by a movable core transformer (MCT) and is then converted to ± 25 milli-volts D.C. by a converter and divider. In the analog data channel as illustrated in Figure A-2, the D.C. voltages proportional to a measured quantity are commutated (multiplexed) by means of switches (mercury wetted relays, reed switches, or semi-conductor switches) to an amplifier and analog-to-digital converter (ADC).

The ADC will convert the amplified analog signal to a binary word recognizable by the CPU. In the CPU, the binary word will be examined for limits and converted to engineering units. If an analog input is out of limits, an appropriate message to the process operator will be outputted from the CPU to one of the several output devices such as an alarm typewriter.

The operation of the three main components of analog data acquisition, input switches, amplifier, and ADC are internally timed by hardware in the analog data acquisition system. Analog data acquisition can be either sequential or random. In the sequential mode, the input switches sequence through the inputs in a fixed order until the sequence or scan is complete. In the random mode, the CPU instructs the data acquisition equipment to seek a particular input, which is digitized and presented to the CPU by a data

FIGURE A-2

ANALOG DATA ACQUISITION SYSTEMS

ready signal. Random access requires a computer instruction for each analog data point to be acquired, and the computer must then wait until the data is ready. This method of operation ties up the CPU, therefore, slowing it down to the data acquisition rate and requires more program instructions which must be stored in memory. Because of the wasted time and excessive memory requirements, this mode of data acquisition will not be used except in special cases. If the block transfer control described below malfunctions, the data will be read-in via the random access technique. Also, upon detection of a process upset (usually indicated by priority interrupts which will be explained later), the CPU will designate data on particular parameters to be acquired immediately. Random access will be used to get the required data and all other CPU functions will be stopped while the data is randomly acquired and processed by the CPU.

Sequential data acquisition will be used with block transfer control or direct memory access for nominal data acquisition. In the block transfer mode of operation, one set of instructions is given by the CPU to acquire data in blocks. The CPU will instruct each individual data acquisition system to start reading data. It will also instruct and store in the block transfer control (BTC) equipment, the total number of points to be acquired and the memory address of the first data word. The BTC equipment in conjunction with the data acquisition equipment will then start acquiring data. The total number of points will be de-incremented as each point is acquired and the memory location for storing the data will be incremented. Data and memory location are transmitted to the CPU in parallel time over separate cables. The BTC equipment will also request a memory read-in transfer on a priority basis for each data point when it is digitized and ready.

When the transfer request is granted, the data will be transferred into memory on a memory cycle steal basis. This method of data acquisition is very efficient. Each transfer to memory will require only one memory cycle (approximately 2 micro-seconds) and any other task being fulfilled by the CPU will be delayed only one memory cycle while the data is being loaded into memory. In addition, none of the registers in the CPU will be affected, obviating the necessity of clearing registers, storing register contents, and then reading back into the CPU the stored information to continue the interrupted program (after storing the acquired data).

DATA ACQUISITION SYSTEMS, REMOTE TRANSMITTERS, AND RECEIVERS

Except for the data acquisition gear located in the 105-N Building, all inputs, digital and analog, will have to be transmitted to 105-N from the building where they originate. This technique is required because of the relatively long distances (up to 2,000 feet) between the 109, 181-182, and 184-N Buildings from 105-N. The inputs will be acquired with normal data acquisition equipment, and the data acquisition equipment will be coupled to remote transmitters to transmit digital data to receivers in the 105-N Building.

Since the normal output of digitizers for analog signals and digital signal outputs are relatively high impedance, low level signals, an interference-proof transmission system must be provided. Two types of equipment are available:

- a. Telephone line modulator-demodulator (modem) techniques
- b. Parallel current mode transmission over multiple cable paths

The modem technique is not desirable. It requires serial transmission of data, resulting in a maximum rate of 40 computer words per second and is subject to interference.

Current mode transmission is resistant to interference, transmission is parallel and transmission rates of up to 10,000 computer words per second are available. This transmission rate is very compatible with the analog and digital multiplexer acquisition rates.

A half duplex system in which data can be transmitted or received, but not simultaneously, is deemed adequate.

APPENDIX BDESCRIPTION OF PRIORITY INTERRUPTS

In real-time systems one of the primary means for directing the facilities of the computer to a problem or problems is by priority interrupts. Higher priority interrupts are serviced before lower priority interrupts; lower priority interrupts being processed are interruptible by a higher priority interrupt. In addition, any priority interrupt can be enabled or disabled under program control as conditions dictate. For example, a primary loop low pressure is normal for N Reactor during a shutdown and its corresponding interrupt should be disabled. The same condition at equilibrium is very important and action should be taken as soon as it is discovered. Therefore, the program would enable the interrupt during equilibrium operation and disable it during shutdown.

Upon recognizing a priority interrupt, the interrupt hardware directs the CPU to a particular dedicated memory location which contains instructions which command that all important registers be stored and cleared, and then goes to a special program in memory to handle the particular situation. The CPU then follows the instructions until they are completed or interrupted by a higher priority interrupt. Upon interruption by a higher interrupt, the same procedure of storing and clearing is carried out, and the higher priority interrupt is serviced. When completed the CPU then goes back to the lower priority interrupt and finishes the instructions. If no other priority interrupts are present, the CPU then goes back to the first interrupted program, and starts again where it was first interrupted.

In the specific case where an interrupt is generated by a change in status of digital inputs, the CPU goes through the same initial steps of storing important registers and the interrupt program commands it to read in the digital inputs from which the change detector acted. The CPU then examines the digital data against a standard stored in memory to identify the particular contact or input that changed status, and branches to other programs which give specific messages or commands to alert control room operators via the alarm typewriter and CRT display.

APPENDIX CSYSTEM FAILURE DEFINITION

For the monitoring system analysis, a system failure is defined as the loss of process information required by the reactor operator to fulfill each monitoring function. Each monitoring function is related to a specific digital or analog multiplexer subsystem from which the function is dependent on for its input datum. Thus, a system failure is defined in relation to an individual multiplexer input subsystem from its input level through the computer processing and output mediums. The lowest level of equipment interaction with the process, which is included in the fault tree descriptions, consist of the sensor and multiplexer subsystem power supplies along with the multiplexer instrumentation. The input sensors, either proposed or existing, are not included in the analysis. Thus, a true system failure excludes the input sensor, but incorporates equipment pieces which are required to process a particular subsystem's datum from its input to an operator output device. Since the proposed N Surveillance System requires a large number of system inputs and thus a number of separate input subsystems, this method of analyzing the system by each independent input subsystem offers the best means of determining system performance measurements. Models that include all input subsystems would not represent the true performance of the system since a failure in any one subsystem (analog or digital multiplexer) would affect the performance of the other subsystems, which is not true. Thus, in defining a system failure, it has been limited to the effect of a failure on individual input subsystems which contain related or dependent reactor operating information. The monitoring system figures presented in Section 6.0 illustrate the performance of one input subsystem (digital or analog multiplexer) in conjunction with the complete data processing, main power, and output systems.

For the control system, a system failure is defined as any failure which interferes with the control functions of the surveillance system. In this model all input and output multiplexer subsystems containing control related information (digital and analog) were included. This is necessary since the loss of one subsystem does affect the control function of the entire system. For example, the loss of a digital input subsystem, upon which output control

decisions are made, prohibits the energizing of the digital output or actuation subsystem. Again, as in the monitor system, the lowest level of input system equipment in the fault tree descriptions consist of input and output sensor and multiplexer power supplies, and multiplexer instrumentation. However, in the output actuation subsystem, the actuation or energizing relays required by the system are included in the fault tree description. The existing ECB relays are not modeled since their failure is independent of the control system actuating relays. The control system performance curves, resulting from this analysis, are presented in Section 6.0, where a computer main frame MTTF of 5,800 hours is used to represent the proposed system.