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PROCESS AUTOMATION

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ABSTRACT

Process automation technology has been pursued in the chemical processing industries and to a very limited extent in nuclear fuel reprocessing. Its effective use has been restricted in the past by the lack of diverse and reliable process instrumentation and the unavailability of sophisticated software designed for process control. The Integrated Equipment Test (IET) facility was developed by the Consolidated Fuel Reprocessing Program (CFRP) in part to demonstrate new concepts for control of advanced nuclear fuel reprocessing plants. A demonstration of fuel reprocessing equipment automation using advanced instrumentation and a modern, microprocessor-based control system is nearing completion in the facility. This facility provides for the synergistic testing of all chemical process features of a prototypical fuel reprocessing plant that can be attained with unirradiated uranium-bearing feed materials. The unique equipment and mission of the IET facility make it an ideal test bed for automation studies. This effort will provide for the demonstration of the plant automation concept and for the development of techniques for similar applications in a full-scale plant.

The primary driving force for automating the operation of processing equipment is economics. Augmenting the basic point-by-point control system with automation is expected to reduce the operating cost of a reprocessing plant significantly but to require only a relatively small incremental capital cost increase. Automation provides smoother plant operation with less operator error and consequently yields less unsuitable product that must be reworked. Automation promises to dramatically reduce the operating and analytical staffs required to satisfactorily operate a plant. The availability of enhanced safeguards opportunities is another important benefit of automation.

Automation has not always been possible or practical. In the 1950s and 1960s, suitably powerful computers and satisfactory in-line instrumentation had not yet been deployed in industry. In the 1970s, microprocessor technology expanded tremendously, and better in-line instrumentation, which was often dependent on microprocessors, became available. The IET facility is equipped with a microprocessor-based Distributed Data Acquisition and Control System (DDACS), which contains all the features needed for

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both standard process control, and sophisticated automation. Proven electronic instrumentation has also been supplemented with advanced instrumentation such as the multiwave photometer. The DDACS also has powerful data acquisition and manipulation capabilities.

The automation of individual IET process system components such as steam-jet gang valves began in 1983 and was completed concurrently with equipment checkout testing. The primary objective of this phase of automation was to relieve the operators of tedious jobs; however, it also provided the initial opportunity to plan, implement, and actually use automation. The experience gained in this work was applied in 1984 to automation of routine filling, sparging prior to sampling, and jetting of the two high-activity waste (HAW) surge tanks. A high-level (English language) DDACS/operator interface was implemented for the first time as a part of this demonstration. This effort was successful; however, a subsequent automated start-up test of the HAW evaporator startup was not totally satisfactory. The automation effort was slowed in 1985 because of higher priority work; however, this year the priority of the automation work was raised, and the scope was broadened. In the first half of 1986, automation of the solvent extraction feed makeup tank and the remote sampling vehicle were successfully demonstrated. Work on automating the routine operations of the solvent extraction system and four supporting systems is expected to be completed later this year. When completed, this will be the first automated control of multiple IET processing systems operating in an integrated manner.

Experience has shown that to successfully combine the capabilities of a control system with the demanding requirements of process equipment in a timely manner, precise communication between the programmers, process engineers, and operators must be maintained. In the IET, a system using logic flow diagrams supplemented with explanatory text has met this communication need during all phases of planning, preparing, and testing automation software.

It is also apparent that the successful automation team will have the proper mixture of experienced people with the appropriate backgrounds. In the IET, this consists of selected members of the group who prepared the piping and instrument diagrams, experienced operations engineers, IET operators, and instrumentation and controls applied-software engineers.

Automation of the solvent extraction and supporting systems will be completed this year. The results of this and previous work will be documented in early 1987. Assistance to the CFRP safeguards groups will be provided to demonstrate the benefits derived from automation. Automation of the dissolution system will be completed next year along with a demonstration of higher level process monitoring.

A set of preliminary recommendations for implementing process automation has been compiled. Some of these concepts are not generally recognized or accepted. The automation work now under way in the IET facility should be useful to others in helping avoid costly mistakes because of the underutilization or misapplication of process automation.

ORNL–WS 46630

PROCESS AUTOMATION

- DEFINITION OF AUTOMATION
- POTENTIAL BENEFITS OF AUTOMATION
- HISTORY OF U.S. REPROCESSING I&C CAPABILITY
- INTEGRATED EQUIPMENT TEST FACILITY CONTROL SYSTEM
- AUTOMATION IMPLEMENTED IN IET
  - WHAT
  - HOW
- FUTURE WORK
- PRELIMINARY RECOMMENDATIONS

ORNL–WS 46631

DIFFERENT ASPECTS OF PROCESS CONTROL AND AUTOMATION

- PROCESS CONTROL
  - MAINTAINS STEADY STATE
  - ACCOMMODATES SOME TRANSIENTS
  - USES MANUAL OR AUTOMATIC FEEDBACK CONTROL
- AUTOMATION
  - EXECUTES DISCRETE SEQUENTIAL OPERATIONS
  - HANDLES TRANSIENTS CONTINUOUSLY
  - UTILIZES EXISTING AUTOMATIC CONTROL LOOPS WHENEVER POSSIBLE
  - DIFFERENT LEVELS OF IMPLEMENTATION

ORNL–WS 46632

POTENTIAL BENEFITS OF AUTOMATION

- SMOOTHER OPERATION GIVING LESS OFF–SPECIFICATION PRODUCT
- IMPROVED REFERENCE DATA BASE FOR SAFEGUARDS MONITORING
- REDUCED OPERATING STAFF (POSSIBLY BY 25%)
- REDUCED ANALYTICAL STAFF (POSSIBLY BY 30%)

ORNL-WS 46633

U.S. FUEL REPROCESSING INSTRUMENTATION AND CONTROL HISTORY

- 1950s
  - SOPHISTICATED PNEUMATIC SENSORS
  - MANY MANUAL ACTUATORS
  - SOME CLOSED LOOP CONTROL WITH PNEUMATIC CONTROLLERS
  - NONGRAPHIC PANEL BOARDS
- 1960s
  - ELECTRONIC SENSORS/TRANSMITTERS
  - ELECTRICALLY DRIVEN ACTUATORS
  - CLOSED LOOP CONTROL WITH ELECTRONIC CONTROLLERS
  - GRAPHIC PANEL BOARDS
  - BASIC DATA ACQUISITION

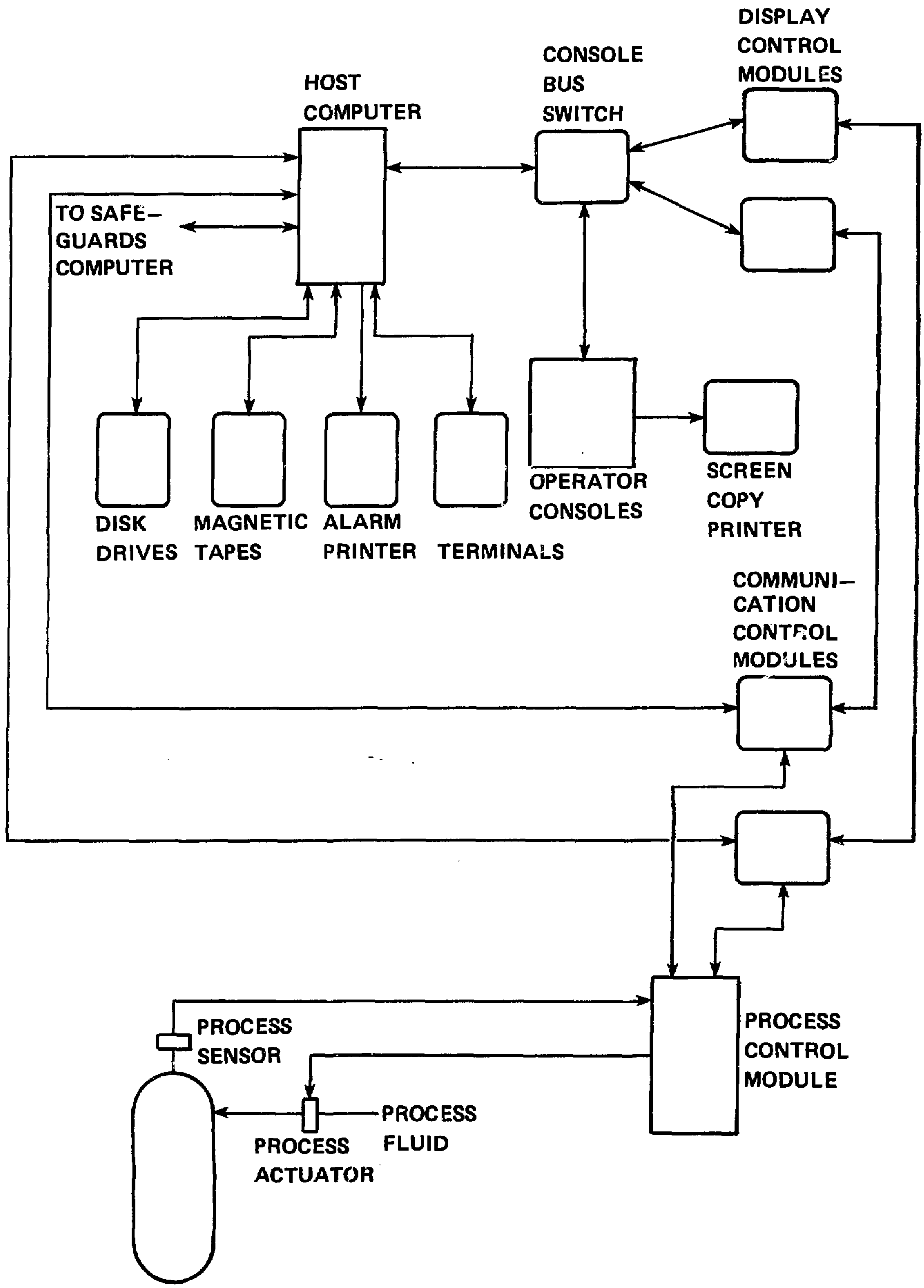
ORNL–WS 46633A

U.S. FUEL REPROCESSING INSTRUMENTATION AND CONTROL HISTORY (CONTINUED)

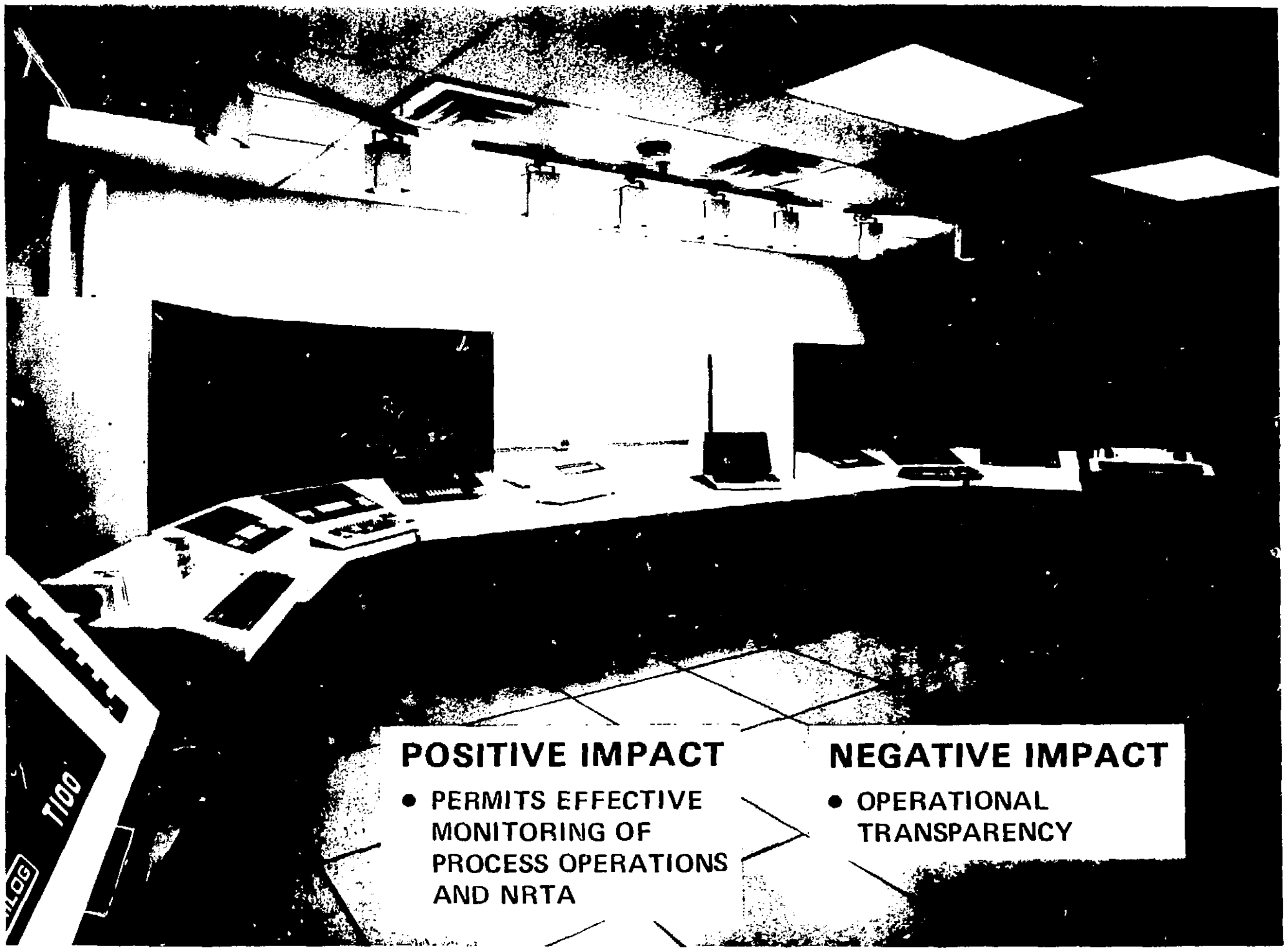
- 1970s
  - PROGRAMMABLE CONTROLLERS
  - SOPHISTICATED COMPUTERIZED DATA ACQUISITION
  - EMERGING MICROPROCESSOR TECHNOLOGY
- 1980s
  - IN–LINE CONCENTRATION MEASUREMENTS
  - EXPANDING MICROPROCESSOR TECHNOLOGY

ORNL–DWG 86–11794

DISTRIBUTED DATA ACQUISITION AND CONTROL SYSTEM HARDWARE ARCHITECTURE



IET PROCESS CONTROL ROOM

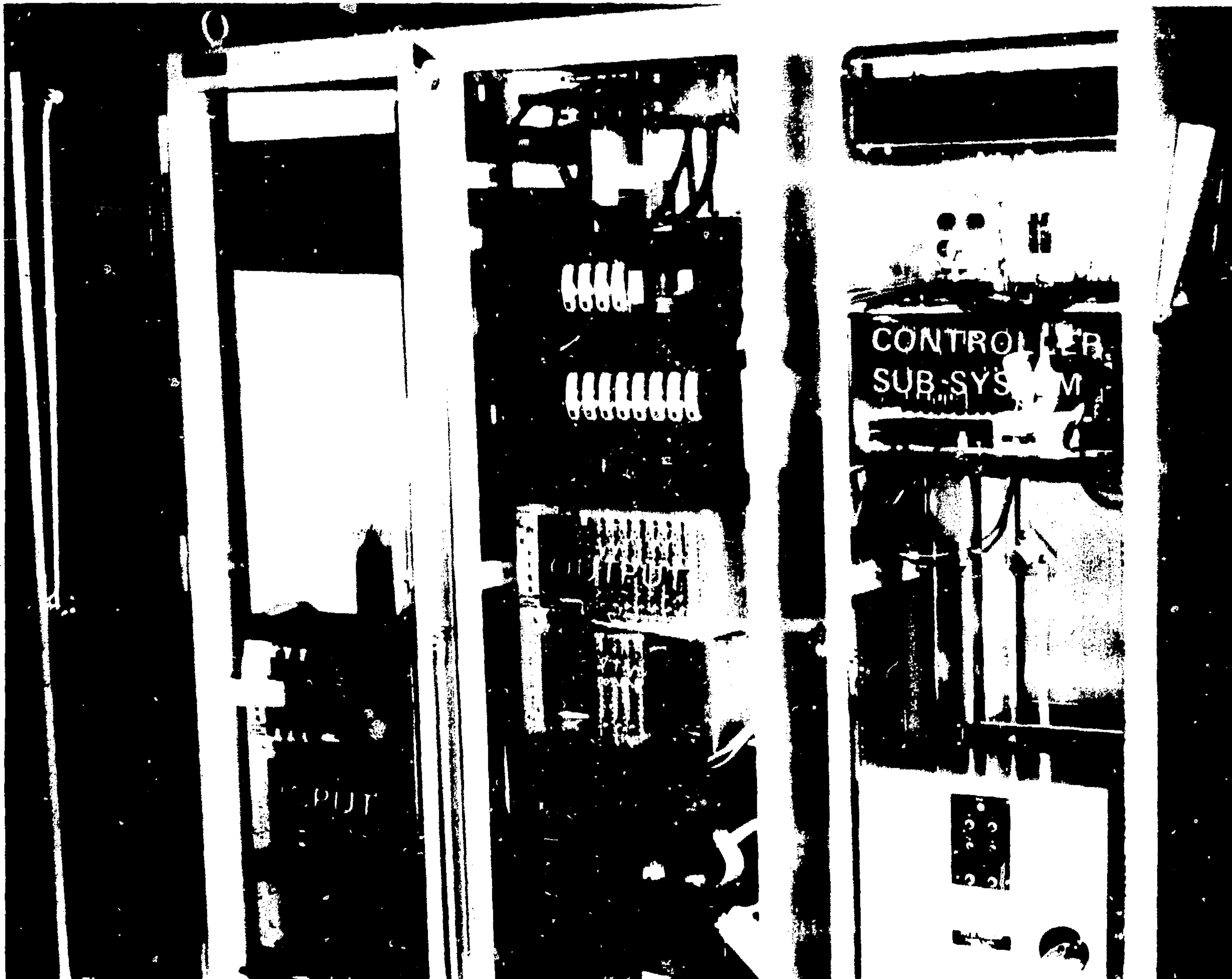


ORNL–PHOTO 3551–86A

IET PROCESS CONTROL SYSTEM

ORNL–PHOTO 3577–86A

IET PROCESS CONTROL MODULE



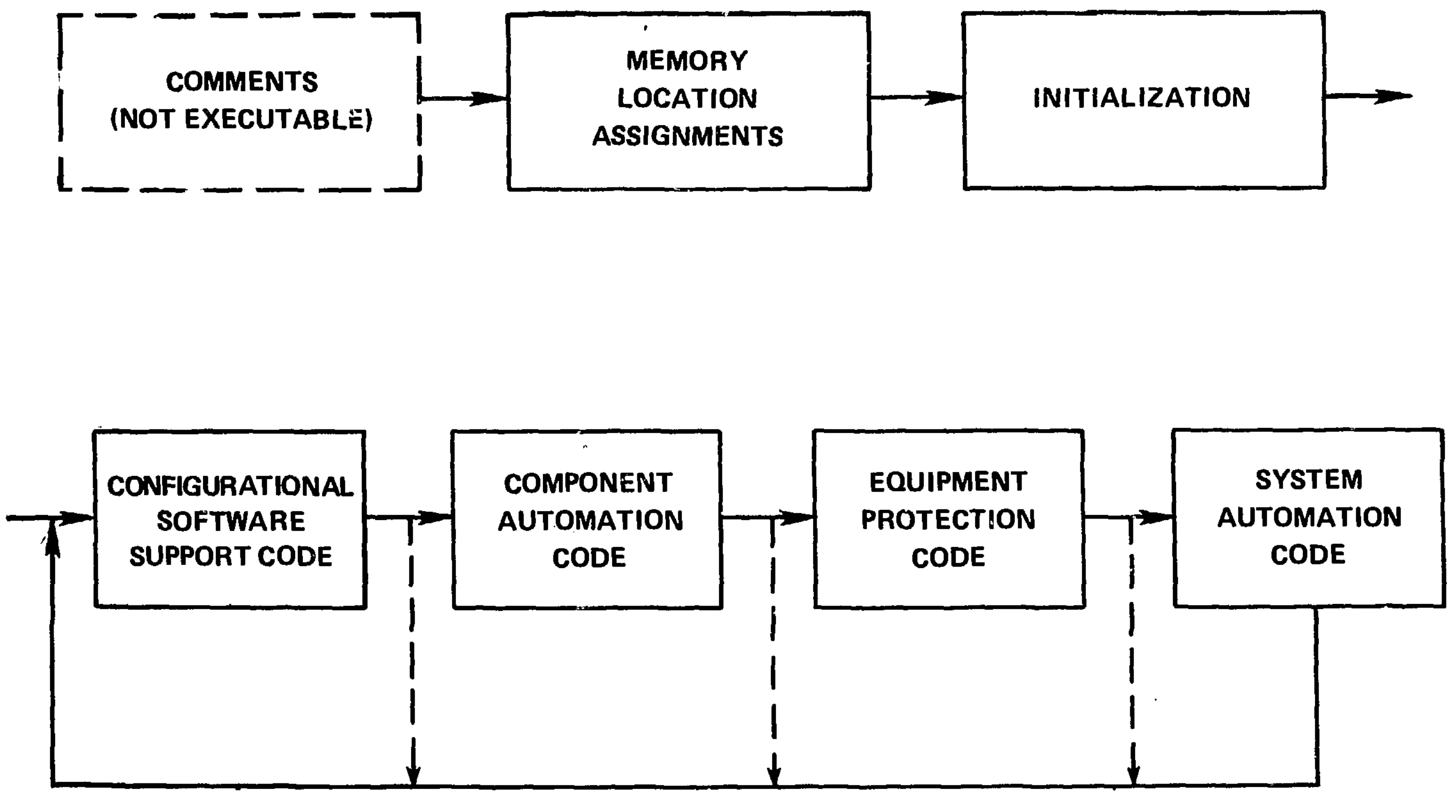
ORNL–WS 46634

FUNCTIONS OF THE IET HOST AND PROCESS CONTROL MODULES

- HOST
  - IS GENERAL INTERFACE TO SYSTEM
  - PROVIDES SOFTWARE DEVELOPMENT
  - DRIVES OPERATOR DISPLAYS
  - PROVIDES DATA ARCHIVAL
  - SUPPLIES DATA TO OTHER COMPUTERS
- PROCESS CONTROL MODULE SOFTWARE
  - CONTROL BLOCK CONFIGURATION
  - SEQUENTIAL CONTROL
  - INTER–PCM MESSAGES
  - PCM OPERATING SYSTEM

ORNL–DWG 86–11795

FLOW DIAGRAM FOR SEQUENTIAL LOGIC EXECUTION



ORNL–WS 46635

AUTOMATED EQUIPMENT IN THE INTEGRATED EQUIPMENT FACILITY

- COMPONENTS
  - STEAM JETS
  - MOTORS (PUMPS AND AGITATORS)
  - FLUIDIC PUMP
  - ROTARY DISSOLVER DRUM
  - FEED CHUTE ISOLATION VALVES
  - FEED STATION

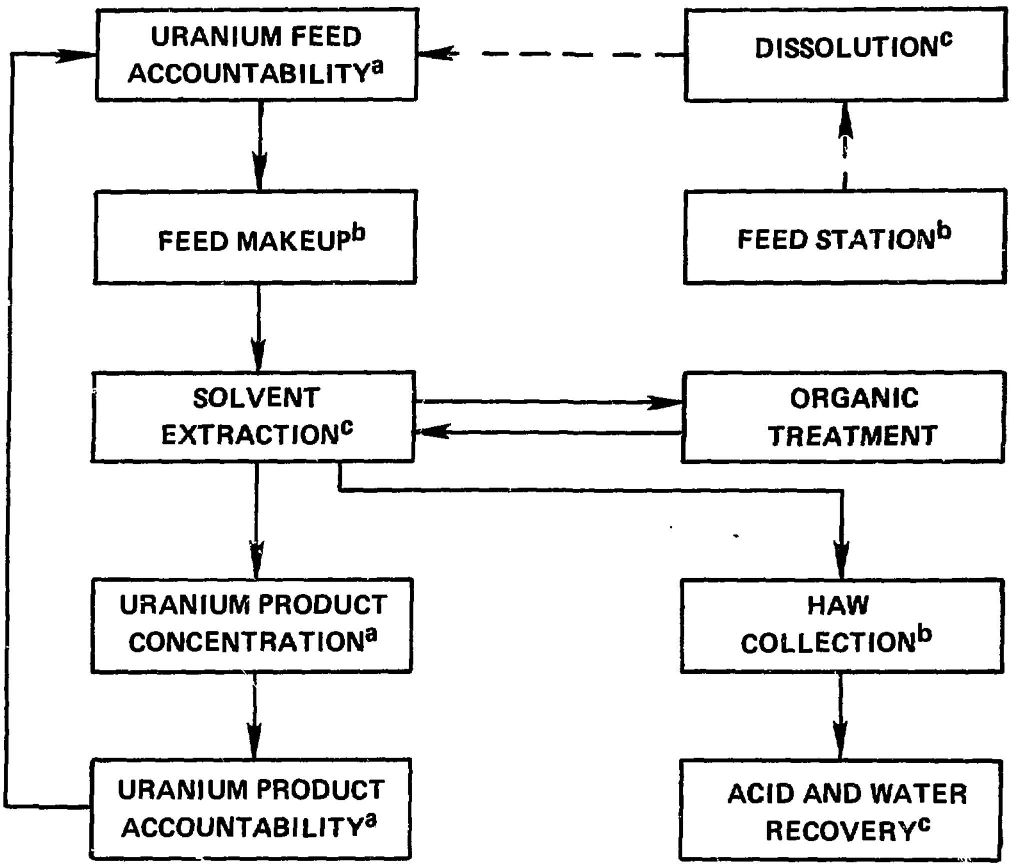
ORNL–WS 46635A

AUTOMATED EQUIPMENT IN THE INTEGRATED EQUIPMENT FACILITY (CONTINUED)

- EQUIPMENT PROTECTION
  - COMPLETED
- SYSTEMS
  - HAW SURGE TANKS
  - HAW EVAPORATOR STARTUP (SEMISUCCESSFUL)
  - SOLVENT EXTRACTION FEED MAKEUP TANK
  - AUTOMATED SAMPLING VEHICLE

ORNL-DWG 86-11796

STATUS OF AUTOMATION OF THE INTEGRATED EQUIPMENT TEST FACILITY



[a]IN PROGRESS

[b]COMPLETED

[c]PLANNED

ORNL–WS 47274

EXAMPLE OF AN ACTUAL COMPUTER LOG OF AUTOMATED FEED ADJUSTMENT APRIL 1986

- 5 18:48:27 29–APR–86052 SOLVENT EXTRACTION ADJUSTMENT AUTOMATION CODE ENABLED AT TIME SPECIFIED
- 1186.8 L TRANSFERRED TO 11F03 WITH A MASS TRANSFER ERROR OF 2.6%. URANIUM = 214.6 g/L, HNO_3 = 4.1 *M*
- ADJUSTMENT REQUIRES ADDITION OF 65.5 L OF 10.7 *M*/L HNO_3 AND 281.9 L OF WATER
- ACID ADDITION TO 11F03 COMPLETE. VOLUME = 1249.6 L, URANIUM = 200.5 g/L, HNO_3 = 4.6 *M*
- FEED ADJUSTMENT COMPLETE. FINAL 11F03 VOLUME = 1588.3 L, URANIUM = 167.0 g/L, HNO_3 = 3.5 *M*

ORNL–WS 47274A

EXAMPLE OF AN ACTUAL COMPUTER LOG OF AUTOMATED FEED ADJUSTMENT APRIL 1986 (CONTINUED)

- FEED–BATCH TRANSFER FROM 11F03 TO 11F01 AND 11F01 MIXING IN PROGRESS
- 1179.6 L TRANSFERRED TO 11F01 WITH A MASS–TRANSFER ERROR OF 8.8%
- TRANSFER ERROR OUT OF SPECIFICATION: ENTER "C" TO CONTINUE OR "E" TO EXIT FEED ADJUST AUTOMATION.[C/E]   C

ORNL–WS 46636

STEPS TO AUTOMATION IN IET

- PIPING AND INSTRUMENT DIAGRAM
- HIGH-LEVEL COMMUNICATION STRUCTURE
- PROCESS OPERATION DIAGRAM
- SOFTWARE IMPLEMENTATION DIAGRAM
- CODE
- SINGLE-STEP CODE CHECKOUT
- PLANT VERIFICATION
- ROUTINE IMPLEMENTATION

ORNL–WS 47271

MEMBERS OF IET AUTOMATION TEAM

- SELECTED MEMBERS OF P&ID DESIGN TEAM
- EXPERIENCED OPERATIONS ENGINEERS
- I&C APPLIED–SOFTWARE ENGINEERS
- IET OPERATORS
- CODERS (MAY BE SUPPLANTED BY USE OF "EXPERT" SOFTWARE)
- DRAFTING SUPPORT (USED PC DRAFTING AID)

ORNL–WS 47272

PLANNED WORK

- COMPLETE SOLVENT EXTRACTION SYSTEM AUTOMATION (1986)
- ASSIST SAFEGUARDS IN DEVELOPMENT OF SURVEILANCE ROUTINES (CONTINUING)
- ASSESS USEFULNESS OF NEW HARDWARE AND SOFTWARE (CONTINUING)
- PUBLISH PRELIMINARY FINDINGS AND RECOMMENDATIONS (1987)
- COMPLETE DISSOLUTION SYSTEM AUTOMATION (1987)
- DEMONSTRATE HIGHER LEVEL PROCESS MONITORING (1987)
- PROVIDE DEMONSTATIONS TO INTERESTED PARTIES (1987)

ORNL–WS 47273

PRELIMINARY RECOMMENDATIONS FOR IMPLEMENTING PLANT AUTOMATION

- ACQUIRE MANAGEMENT SUPPORT
- DECIDE LEVEL OF IMPLEMENTATION
- ASSESS COST–SAVINGS POTENTIAL
- ASSEMBLE SATISFACTORY AUTOMATION TEAM
- START AUTOMATION WHEN DRAFT P&IDs AVAILABLE
- USE VENDOR SOFTWARE STRUCTURE BUT WRITE AUTOMATION CODE IN–HOUSE
- WRITE AND TEST CODE CONCURRENT WITH PLANT DESIGN/INSTALLATION
- TREAT PROCESS OPERATION DIAGRAMS LIKE OPERATING PROCEDURES