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APPLYING NEW SAFEGUARDS TECHNOLOGY TO EXISTING NUCLEAR FACILITIES

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Abstract

The application and operation of safeguards instrumentation in a facility containing special nuclear material is most successful when the installation is designed for the operation of the specific facility. Experience at the Idaho National Engineering Laboratory demonstrates that installation designs must consider both safeguards and production requirements of specific facilities. Equipment selection and installation design influenced by the training and experience of production operations and safeguards personnel at a specific facility help assure successful installation, reliable operation, and minimal operator training. This minimizes impacts on existing plant production activities while maximizing utility of the safeguards information obtained.

1. Introduction

The primary goal of the safeguards development program at the Idaho Chemical Processing Plant (ICPP) is to design and install an integrated safeguards system to test and evaluate safeguards concepts in an operating nuclear facility. The ICPP was designed to recover uranium from a wide variety of highly enriched uranium fuels and has been operational since 1952.

The safeguards development program is also contributing to the Tokai Advanced Safeguards Technology Exercise (TASTEX) Program. Within this program, the Safeguards Development Program is preparing to install a material monitoring system in the plutonium product area of the Power Reactor and Nuclear Fuel Development Corporation (PNC) plant at Tokai-Mura, Japan. This nuclear pilot facility processes low-enriched uranium fuels.

The objectives of a modern safeguards system can be classified as physical protection, accountability, and material control. International safeguards recognizes accountability and containment/surveillance as primary safeguards functions. National safeguards physical protection subsystems control access to special nuclear material (SNM) by physical barriers, alarms, and guards. Accountability subsystems precisely measure and record physical inventory of special nuclear material. Containment and surveillance or material control subsystems use data from several sources to maintain a constant automated surveillance of SNM. These classifications are not mutually exclusive and a single device may provide inputs to more than one subsystem.

The systems being installed at ICPP and PNC are containment and surveillance systems. Both employ process monitoring techniques to assure approved safeguards procedures are followed and to provide estimates of nuclear material distribution throughout the processing systems. These capabilities complement other safeguards functions of accountability and physical protection of special nuclear material.

ICPP has developed and tested several safeguards monitoring concepts. These concepts maximize use of existing plant instruments to minimize equipment and installation costs.

A. Precision instruments measure tank solution volumes and weights. A real-time estimate of the material balance of the processing plant can be derived from these measurements and nuclear material solution assay information.

B. Process valve sensing provides plant operational data to assure appropriate nuclear material transfer routes are opened and other routes are closed. This status information provides both operating procedure verification and direct indications of solution containment.

C. Transfer monitoring provides a capability for watching material movement between parts of the process . Solution volume changes between parts of the process can be compared and the material balance updated accordingly.

D. Diversion path monitoring includes detectors for liquid in normally empty lines, low threshold flow detectors to detect movement of solution in lines that should be stationary, and nuclear material detectors to verify solution concentrations within process flowsheet limits.

E. Verification and tamper-indicating capabilities are included in the system to assure the monitoring is not compromised.

The operational test and evaluation of the developed concepts requires computerized monitoring of sensors and instruments in the operating plant. In many cases, these signals can be acquired from existing plant instrumentation. Other devices are selected from commercial process monitoring and instrument manufacturers. Sensors and instruments for the ICPP and PNC systems include: valve positions, tank levels, liquid densities and concentrations, flow rates, temperatures, pressures, voltages, and sequences of operations.

Specific plants significantly influence the design of the safeguards system. Both the ICPP and PNC are built as a series of shielded cells to facilitate direct maintenance. Access in many cells is limited only by radiation levels. Both plants were designed for flexible operation so there are many possible flow paths for SNM. In both cases, many plant operations are controlled manually.

Product load out and storage areas rely on direct manual control which inhibits effective remote surveillance. To solve this problem at ICPP, manual valves are being replaced with remote valves, and a new control panel designed for installation in the uranium product area. Other equipment such as pumps and pressure gauges are being upgraded to provide reliable remote operation. These changes allow remote process monitoring and decrease access to SNM.

2. Conceptual Design

The installed systems will demonstrate an automated surveillance system retrofit in existing reprocessing plants without adversely affecting production.

Past Development at ICPP has defined design criteria which significantly enhance the acceptability of system retrofits.

A. The safeguards data collection equipment must be simple to operate.

1. Interactive BASIC language has been effective for data collection programming and analysis support.

2. The IEEE-488 data bus structure for instrument control and data collection has successfully supported safeguards development work. These concepts are used in systems at ICPP and PNC.

3. Standard commercial components distribute the system data acquisition functions to different areas of the plants. Past work in plant environments have identified techniques for protecting sensitive development instrumentation.

4. Computer interrupt techniques decrease data acquisition rates to seconds or minutes, allowing more process inputs.

5. Safeguards studies at ICPP have identified over 800 process inputs to test and evaluate the safeguards concepts at ICPP. The system assembled for TASTEX Task I, Plutonium Product Area Monitoring, requires approximately 200 process inputs for concept test and evaluation. The computer monitoring system must efficiently handle these large volumes of data at relatively fast data rates. The system must also have a suffiently fast processing capability to scale process values to engineering units and store the values for efficient recall or analysis support. The system at ICPP uses a DEC VAX-11/780 computer with Hewlett-Packard and Computer Products data acquisition control components. The system assembled for PNC uses a Hewlett-Packard 9845 computer for data acquisition control and analysis support.

B. All components must be highly reliable to maintain system integrity and to minimize maintenance demands. The past work at ICPP has been invaluable for the operational testing of data acquisition components and process sensors and instruments. The development program also has a parallel sensor and instrument development activity which evaluates state-of-the-art process devices for general safeguards applications.

C. Failures of any part of the system must not interrupt plant operations. This requirement is met by careful selection of devices in the sensor and instrument development work, quick detection of system failures, and rapid isolation of failed components. Most nuclear fuel reprocessing plants use pneumatic plant instrumentation. Several techniques for multiplexing pnuematic information have been tested at ICPP to minimize impacts on plant instruments.

Intimate knowledge of plant operating procedures and physical construction is required for the efficient design and operation of an effective safeguards system. Information on the physical configuration of existing plants can be obtained by a thorough study of blue prints and flow sheets followed by physical verification. Basic understanding of plant procedures can be obtained from formal documents such as Standard Operating Procedures, but much valuable information can only be obtained from candid discussions with operating and maintenance personnel. This knowledge is necessary to identify locations of sensors to define plant status during all possible conditions including plant cleanout, recycle, and possible intentional misuse of operating equipment.

3. Sensor Selection Criteria

Detailed knowledge of how the plant functions is required to ensure that sensor selection will satisfy the design criteria. Once the need and location of a sensor have been identified, five questions must be answered in order to choose among candidate devices:

- What is the range of normal and abnormal operating conditions for the device?
- What effect would instrument failure have on the process, and how can adverse effects be eliminated or isolated?
- Will the presence of the instrument cause physical or procedural changes for plant operations?
- Does the device require special maintenance or calibration?
- Will the device create a new diversion route?

Sensor selection is often determined by the conditions under which it must function. Few standard industrial components can withstand the highly corrosive environment in a reprocessing plant such as the ICPP. Equipment in process cells is subjected to spray decontamination with corrosive fluids, and corrosive vapor is found in many plant areas. All in-cell devices have stainless steel wetted parts and stainless steel or epoxy coated external surfaces. Where feasible, electrical components and precision instruments have been placed in air purged enclosures. Certain procedures, such as steam cleaning or overpressurization for removing blockages, may compromise the integrity of some devices. Precision instruments are protected by system controlled solenoid valves and differential pressure relief valves. No reliance is placed on operating or maintenance personnel to protect safeguards instrumentation. In many instances, trade-offs of accuracy for physical ruggedness have been made. Resistance to radiation damage is important in process cells. Teflon, for example, is avoided in high radiation areas. Where a failure could affect plant operations, devices have been selected which are overdesigned so that failure is extremely unlikely. If a satisfactory device could not be found, then isolation from the process such as valving is provided.

Crowded instrument and control galleries and crowded process piping may not permit ideal equipment locations for retrofitting safeguards to existing facilities. New devices must not cause unnecessary inconveniences or hazards for the operating and maintenance personnel. In general, the greater the precision demanded of a device, the more frequent will be the demands for calibration and maintenance. Experience and qualification testing aids in selection of devices that minimize these requirements. Automated calibration, self-checking, and comparative verification are used wherever feasible.

Devices which require new penetrations into process lines or through process cell walls may cause new diversion pathways. In the ICPP system, it was necessary to install the high precision pressure transducers for the liquid product storage banks inside the process cell to prevent this problem.

4. Design Reviews

Operations, Maintenance, Engineering, Safety, Safeguards and Security, Technical Support and Quality Assurance organizations reviewed the ICPP system design. These reviews assured that all installations met or exceeded applicable plant standards and that all operational and procedural changes were coordinated and incorporated. They also assured adequate documentation for updating plant drawings and for maintenance troubleshooting. Inputs from plant operations groups helped select devices compatible with existing facilities and familiar to plant personnel.

The installed instruments significantly expand the capability of the existing plant instrumentation, thereby benefiting operations. Maximizing the benefits of the new safeguards instruments, while minimizing the impact on plant operations helped overcome the natural resistance to change. Retraining of operations personnel has not been required at ICPP. A minimal training session of one week is planned for PNC personnel.

5. Specific Sensors

Information such as tank levels and densities, fluid flow rates, and temperatures can be obtained from normal electrical or pneumatic plant instruments. Neither ICPP nor PNC had this information available at a central location. The distributed data acquisition system is adding this capability. In several instances, sensors were installed in parallel with an existing plant instrument. Many pneumatic signals could be monitored through the installation of a tee in the signal line and a suitable transducer. A Scanivalve[1] using a rotary switch to multiplex up to 64 signals (0.2-1.0 Kg/cm^2) was selected for this application. This instrument is designed for remote digital control and data acquisition.

In higher radiation areas, fluid transfers can be accomplished with steam jets or air lifts. Flow direction is controlled with pneumatically operated valves. Pressure switches were installed in the supply lines to monitor valve and steam jet actuation. Static-O-Ring "Omni"[2] pressure switches rated at more than ten times normal operating pressure have provided the physical durability and corrosion resistance required for this application. Valving on certain transfer jets may create ambiguous pressure signals. These jets are also monitored by mounting stainless steel clad thermocouples on the discharge pipes inside the process cell. The thermocouple output identifies the start and end points of a transfer, and may aid plant operators who currently must rely on level variations to follow the transfer.

High precision level and density measurements on selected tanks provide an independent check on input accountability volume measurements and allow estimation of a material balance in areas where no other accountability information is available. In a static tank, 1 mm level changes can be rapidly detected by the high precision electromanometers.

Previous studies at ICPP identified two suitable precision pressure transducers, the RUSKA[3]"DDR-6000" and the Paroscientific[4]"Digiquartz". Both instruments are capable of .015% accuracy measurements under laboratory conditions. Pneumatic noise in the plant vessel off-gas system will reduce the practically attainable measurement accuracy. In the ICPP, the lower cost and space requirements favor application of the Digiquartz transducer.

Precision pressure transducers systems are expensive (approximately $4,000 to $5,000), so signals are being multiplexed. Two pneumatic mulitplexing schemes are being compared, one based on solenoid valves, and the other on pneumatic rotary switches. The results of these comparisons identified several criteria for consideration before pneumatic multiplexing, these are:

A. Minimize transient effects by using small switching dead volumes.

B. Use instruments (such as pressure transducers) having fast time response for plant signal analysis.

C. Use logic circuitry such that plant instruments cannot be inadvertently cross connected.

D. Test and provide ability to isolate instruments from the plant.

E. Use corrosion resistant materials.

F. Do not vent pneumatic instruments to undesired areas and filter pneumatic lines when necessary.

G. Provide on-line, programmable signal sources for value checking and calibrations for crucial instruments.

6, Summary

The Safeguards Development Program designed safeguards instrument systems for the ICPP and PNC nuclear fuel reprocessing plants. These designs will test and evaluate safeguards monitoring techniques applied to an existing facility without adversely affecting plant production.

Improving safeguards at an operating nuclear facility often requires adding to or replacing existing instruments. The disruptive effects can be reduced by careful selection of system equipment and considering the capabilities and experience of safeguards, plant support, and operations personnel at specific plants.

The design installation and operation of these safeguards devices enhance safeguards information and minimize the impact on plant operations.

Footnotes

1 Tradename of an instrument manufactured by the Scanivalve Corporation.

2 Tradename of device manufactured by SOR, Incorporated.

3 Ruska Instrument Corporation

4 Paroscientific, Incorporated

REFERENCES

1. "Instrument Installation Design Criteria, Safeguards Test and Evaluation System", E. P. Wagner et al, ACI-381, dated June 1979.

2. "Program Plan, Advanced Safeguards Systems Development for Chemical Processing Plants", ACI-346, revised January, 1979.

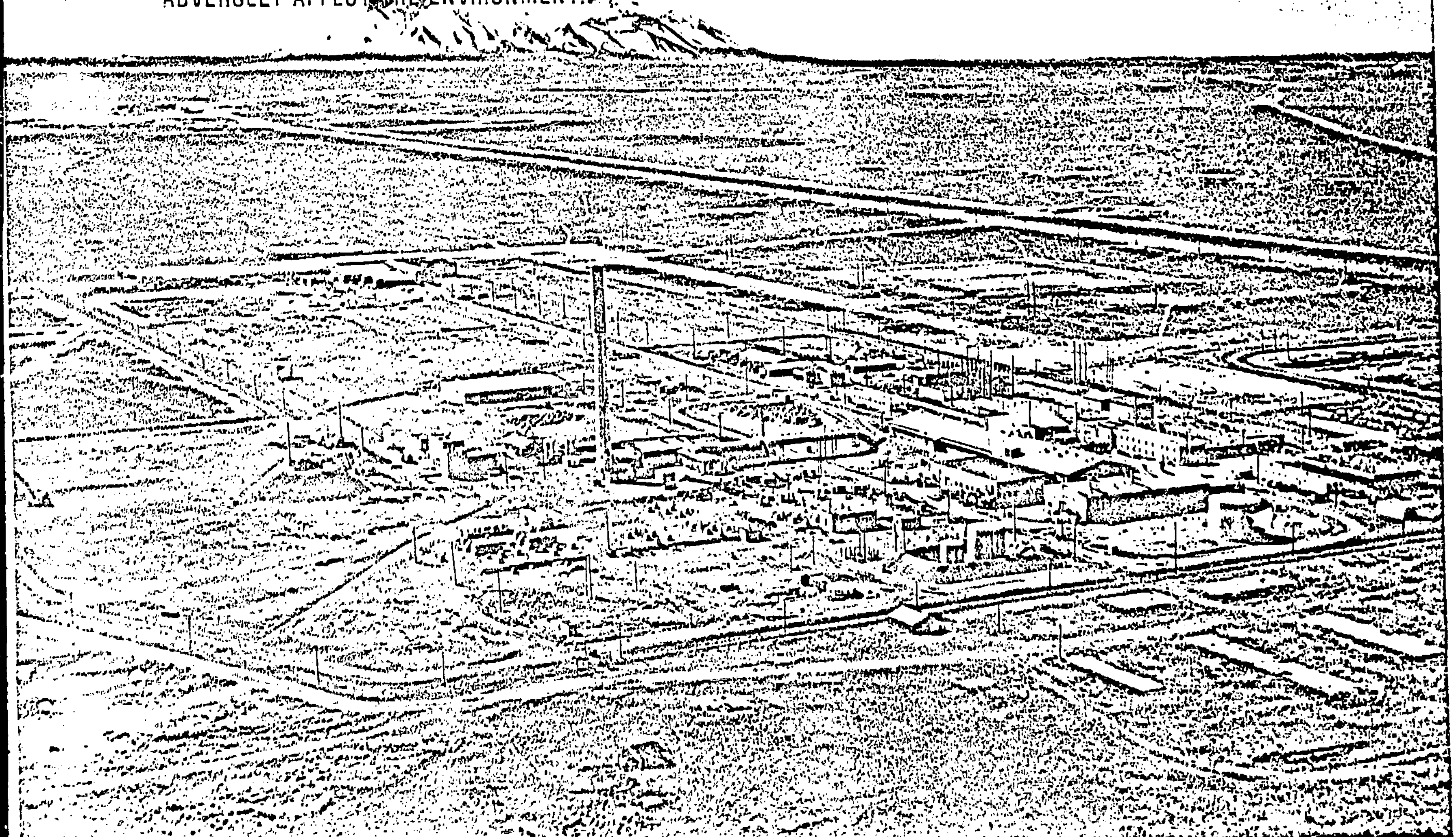
3. "Tokai Advanced Safeguards Technology Exercise, Program Plan", International Safeguards Project Office, Brookhaven National Laboratory, revised January 15, 1979.

Viewgraphs for Presentation

These are possible viewgraphs for illustrating points during the presentation. Some, or all, viewgraphs may be used if approved for release. Additional information or photographic originals may be requested from C. E. Johnson, 6-2281.

IDAHO CHEMICAL PROCESSING PLANT
IDAHO NATIONAL ENGINEERING LABORATORY

- THE PRIMARY MISSION OF THE IDAHO CHEMICAL PROCESSING PLANT IS TO RECOVER URANIUM FROM SPENT RESEARCH REACTOR AND SHIP PROPULSION FUELS FOR RE-USE IN REACTORS.
- ANOTHER KEY ACTIVITY IS TO MANAGE AND DISPOSE OF NUCLEAR WASTES IN A MANNER THAT WILL NOT ADVERSELY AFFECT THE ENVIRONMENT.



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SAFEGUARDS

NATIONAL

Accountability

Material Control

Physical Protection

INTERNATIONAL

Accountability

Containment/Survcillance

SAFEGUARDS MONITORING CONCEPTS

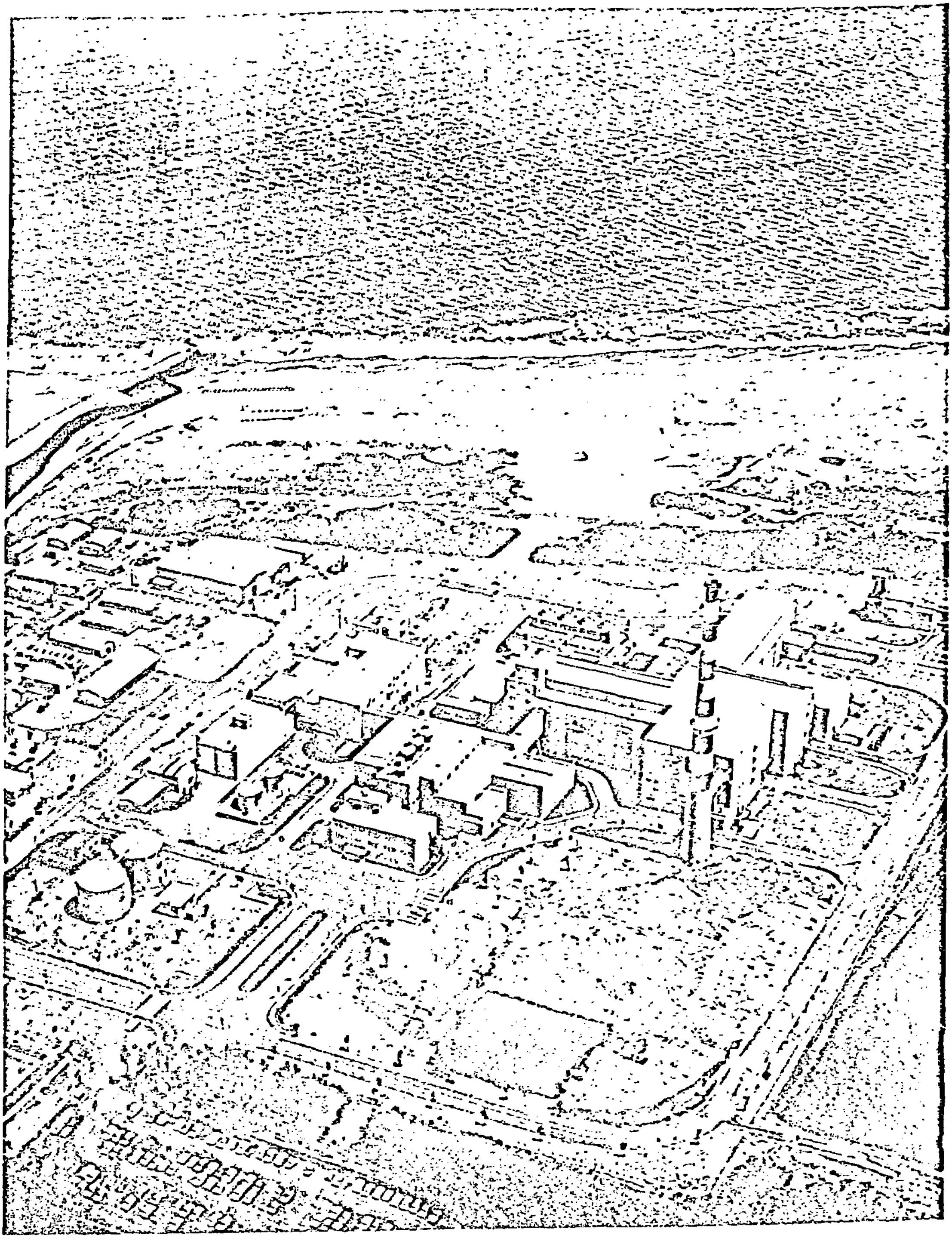
Precision Volume and Weight Measurement

Process Valve Monitoring

Transfer Monitoring

Diversion Path Surveillance

Verification and Tamper-Indicating



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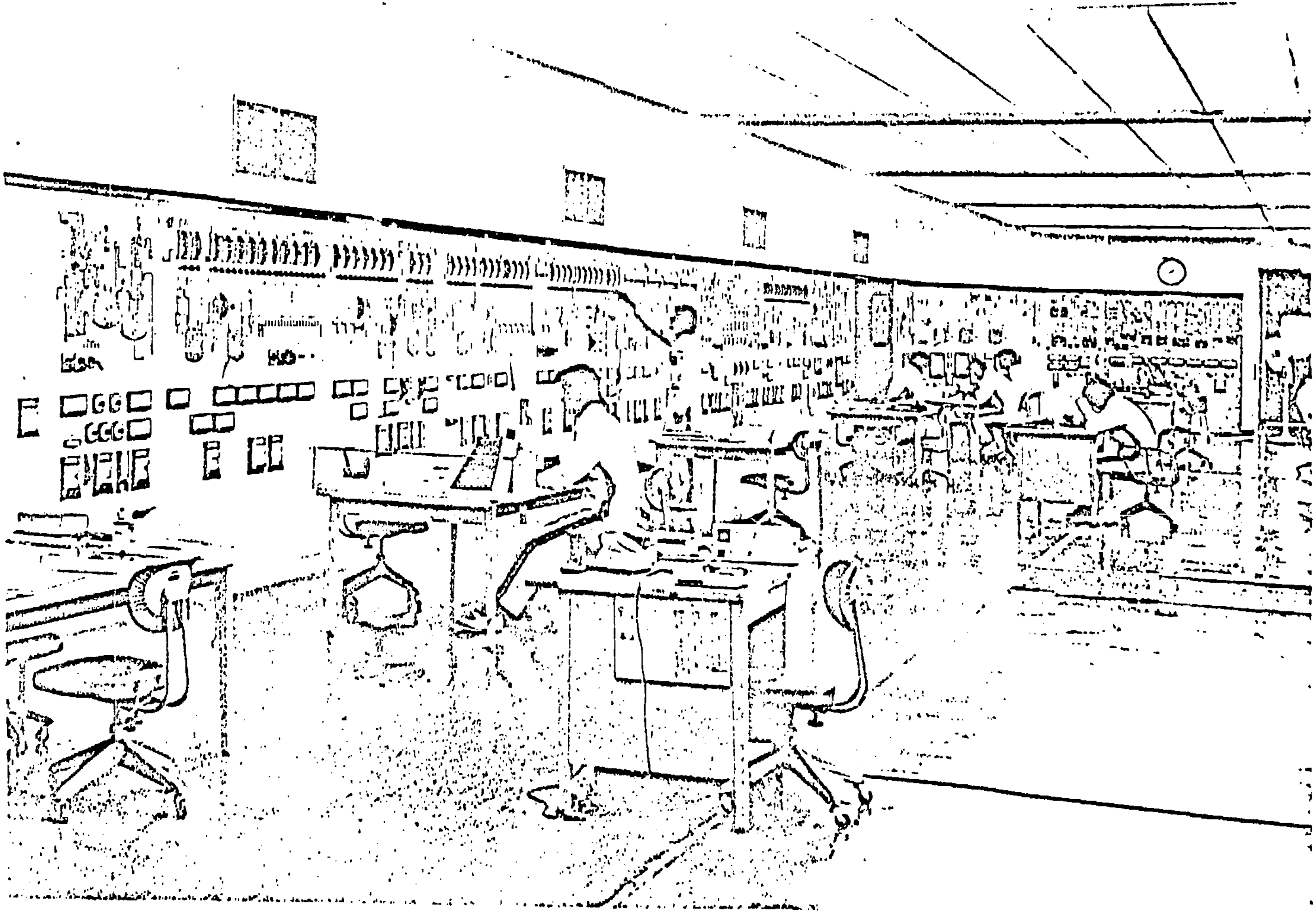
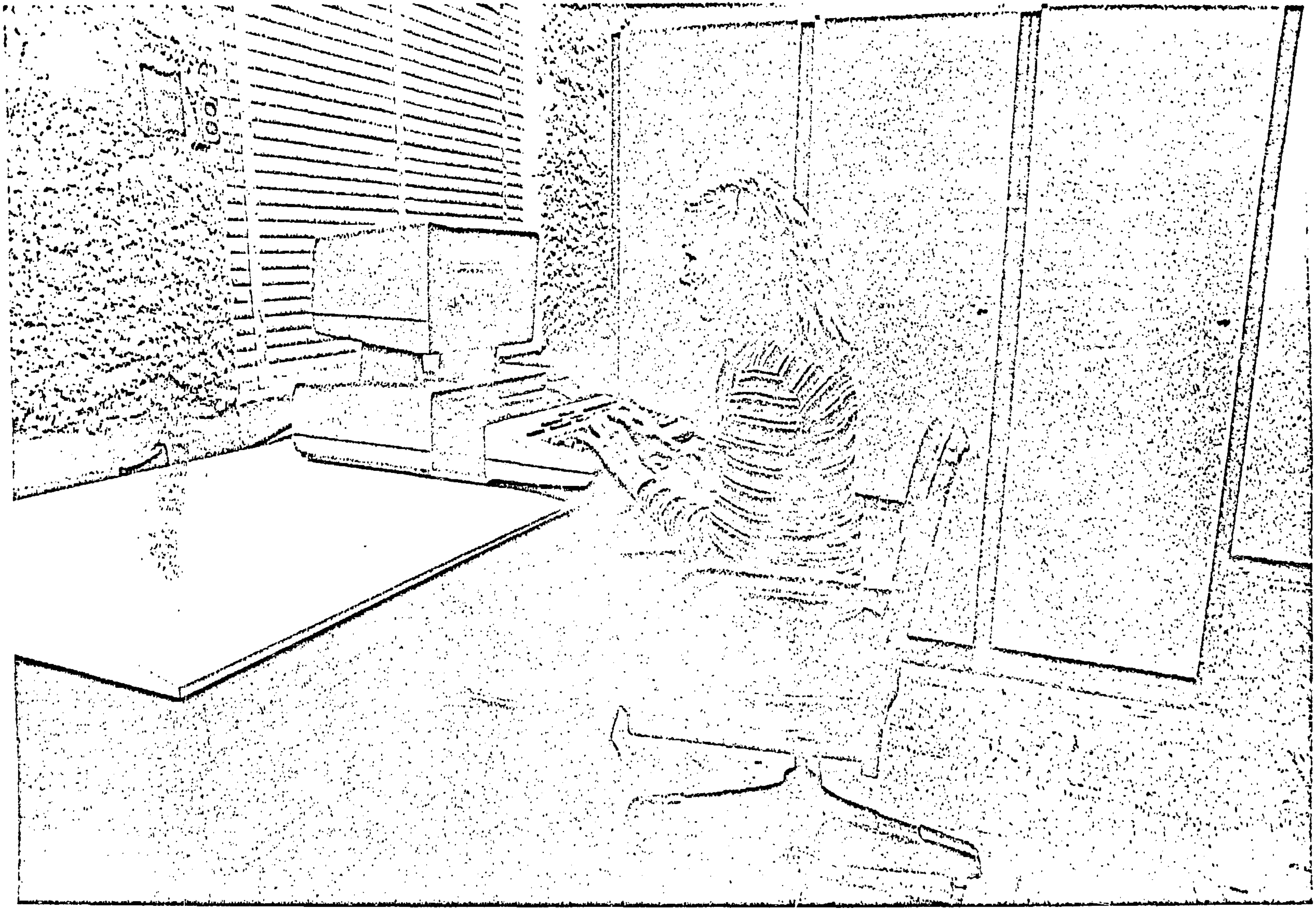
(Reprinted from Japanese Magazine)



Central Control Room

79-5034
(Reprinted from Japanese Magazine)



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SYSTEM DESIGN CRITERIA

Simple to Operate

- Higher-Level Computer Language
- Standard Instrument Bus
- Commercial Components
- Computer Interrupts for Efficient Data Collection
- Large Data Base

Reliable

- Maintain Integrity of Data
- Minimize Maintenance Support

Isolation and "Transparency"

EQUIPMENT SELECTION AND REVIEWS

Plant Environment

Failure Isolation

Installation Impact

Support Requirements

Safeguards Acceptability

SAFEGUARDS SURVEILLANCE SENSORS

Pressure Switches

Flow Monitor

Pneumatic Instrument Signal (3-15 psi) monitor

Liquid-in-Line Detector

Jet Temperature Detector

Electrical Current Detector

Precision Differential Pressure Transducer

Manual Valve Position Indicator

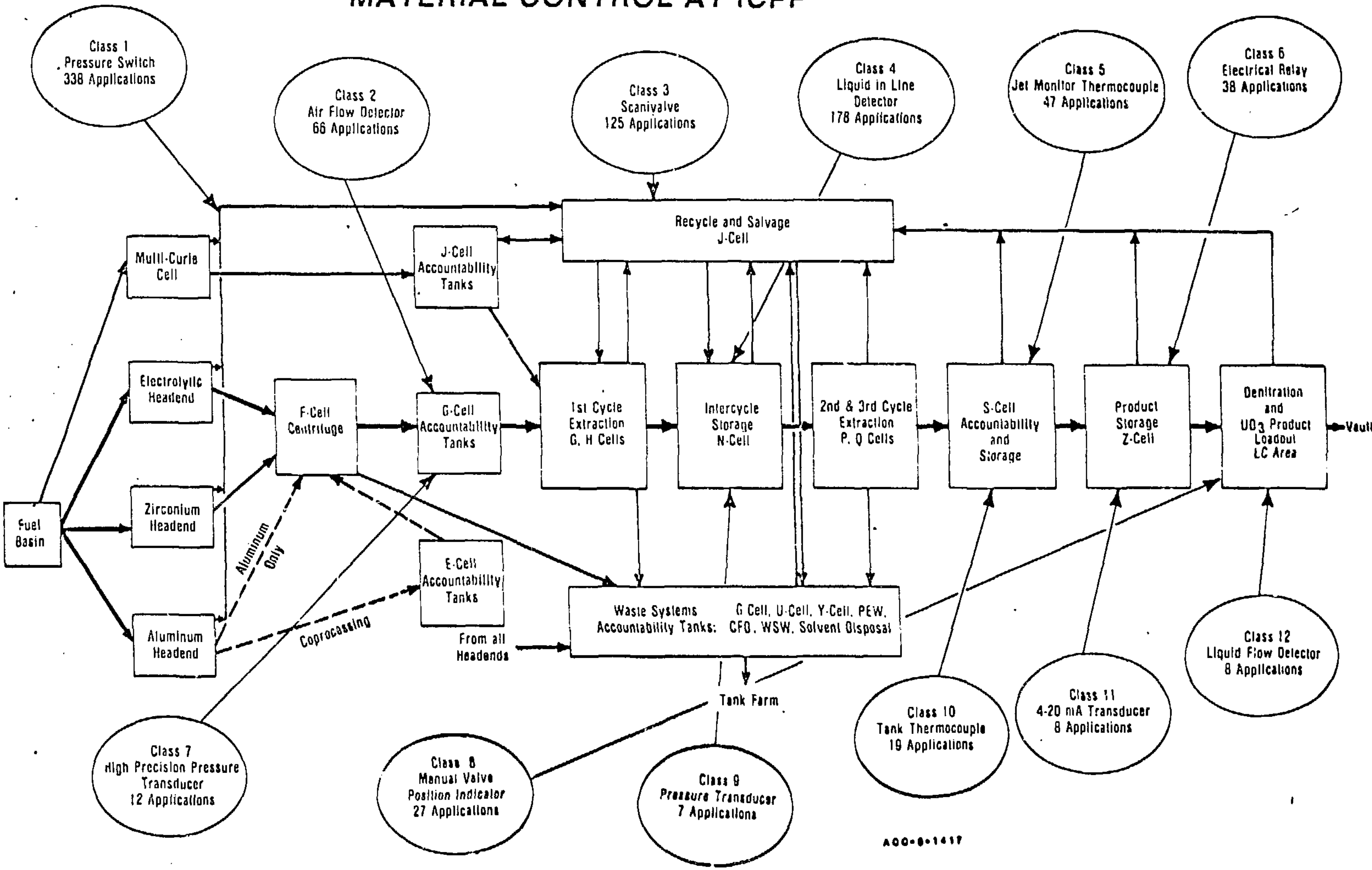
Pressure Transducer

Tank Temperature Transducer

Electrical Instrument Signal (4-20 ma) Monitor

Process Liquid flow monitor

SAFEGUARDS DEVELOPMENT
MATERIAL CONTROL AT ICPP



Previously Reviewed and Approved for Presentation