ENICO-1079

Distribution Category:
UC-15
Safeguards -- Nuclear
Materials Security

FINAL REPORT FOR FISCAL YEAR 1980

Advanced-Safeguards Systems Development for Chemical-Processing Plants

by

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April 1981

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PREPARED FOR THE
DEPARTMENT OF ENERGY
IDAHO OPERATIONS OFFICE
UNDER CONTRACT DE-AC07-79ID01675

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I. SUMMARY

The ENICO Safeguards Development Program at the Idaho National Engineering Laboratory has the objective of providing improved safeguards concepts for chemical processing plants. The program is installing a computer system to test and evaluate process monitoring as a new Safeguards function to supplement the usual physical security and accountability functions.

Safeguards development sensors and instruments installed in the Idaho chemical Processing Plant (ICPP) provide information via a data acquisition system to a Safeguards analysis computer. The objective of the system is to collect data from process and Safeguards sensors and to show how this data can be used to detect diversion operations, improper plant operations, or equipment failures. The system also tests the performance of the monitoring sensors to verify the accuracy and reliability of the sensor data under realistic plant operating conditions.

The system is expected to provide specific advantages including:

* Increased accuracy in measurement of process tank levels and densities.

* Automated cross checks of volumes and weights on transfers, checks between instruments, automated calibration of plant instrumentation outputs, and comparison of plant activities with expected procedures and flowsheet operations.

* Monitoring of certain diversion paths, detection of equipment leaks and accountability measurements evasion.

* Estimates of plant material balances using data from the analytical lab and on-line analytical instrumentation as it becomes available.

* Processing of the data to support Safeguards analyses and to automatically maintain records of plant history and analysis results.

This monitoring function can significantly enhance current material control (accountability) and containment surveillance capabilities for domestic and international Safeguards uses. Installation in modern processing plants should be cost effective since most of the instrumentation needed will already exist as part of plant computer systems.

The installation of sensors and instruments in the ICPP was more than 75% complete in FY-1980. Installation work was halted at the request of ICPP operations near the end of the year to eliminate possible conflict with instrument calibrations prior to plant startup. Seven of the eleven work packages were installed before the halt including 1st-cycle sensors, sensor interfaces, and most wiring runs. The remaining part of the installation was scheduled for completion in FY-1981 in time to collect data from plant runs.

Some improvements to the computer hardware were made during FY-1980. New CRT terminals and an additional tape drive were installed on the analysis computer to support data analysis. The basic software for the data acquisition system and for the collection of the plant data base was written. Software testing was scheduled for plant runs during FY-1981.

Sensor and instrument development during FY-1980 emphasised device testing for ICPP monitoring applications. Pressure transducers, pressure switches, a bubble flowmeter, and load cells were tested; an ultrasonic liquid-in-line sensor was developed and tested.

Work on the portable, isotope-ratio mass spectrometer led to the comparison of the HP quadrupole instrument with a small magnetic instrument and to the selection of the quadrupole. The HP instrument was subsequently prepared for field tests.

The Safeguards development program was slowed by changes in installation scheduling due to competing priorities, software programming problems and reduced funding. The Safeguards computer system startup and data collection is expected in FY-1981.

II. MASS SPECTROMETER DEVELOPMENT

Background

Effective safeguarding or inspection of nuclear materials in a processing plant requires rapid and accurate measurement of the isotopic composition of the SNM (Special Nuclear Material). Current laboratory mass spectrometers used for isotope ratio measurements are bulky, expensive, must be located in controlled environments, and must be operated by specially trained personnel.

The objective of this part of the program is to develop a moderately priced, portable, isotope-ratio mass spectrometer. This instrument would be used for rapid isotopic analysis of materials in plants and eventually for timely detection of attempts to conceal diversion of SNM by isotopic substitution in the plant. For inspection or auditing of SNM plant operations, independent verification by the inspecting agency would be facilitated by a portable instrument that could be operated and controlled by the inspector.

The principal technique competing with direct mass spectrometry is gamma spectrometry. As compared to gamma spectrometry, mass spectrometry responds directly to the number of atoms rather than to their radioactivity. Mass spectrometry requires a very small sample, on the order of a microgram, and does not require self absorption or matrix corrections.

Three portable mass spectrometer types are being evaluated for this safeguards use: two quadrupole instruments and a small conventional magnetic deflection instrument. Two quadrupole mass spectrometers, one made by ExtraNuclear Laboratories Inc.[a] and the other made by Hewlett-Packard[b] were evaluated. A small magnetic instrument made by Ion Instruments, Inc.[c] was also purchased for testing.

In general, the desired instrument should be light weight, easily moved about, rugged, require a minimum of utilities, and be usable by an operator with a minimum of training. The more suitable instrument was to be chosen by laboratory tests after necessary modification and checkout were done. The chosen instrument will be field tested and used for a NBS comparative study using "resin bead" samples.

A. ExtraNuclear Laboratories Inc. Quadrupole (M. W. Echo)

Following verification of the superior performance of the HP instrument, the ExtraNuclear Laboratories instrument was dropped from consideration and transferred to the analytical laboratories.

B. Hewlett Packard Quadrupole Mass Spectrometer (M. W. Echo)

The Hewlett Packard mass spectrometer was totally disassembled for modifications. The frame was shortened by about 9 inches and a base plate was added to mount the vacuum lock mechanism for the thermal ionization source. A new end panel was fabricated and a controllable power supply installed. A vacuum gauge was installed on the panel. Figure 1 shows the modified mass spectrometer. Figure 2 shows a filament source being loaded.

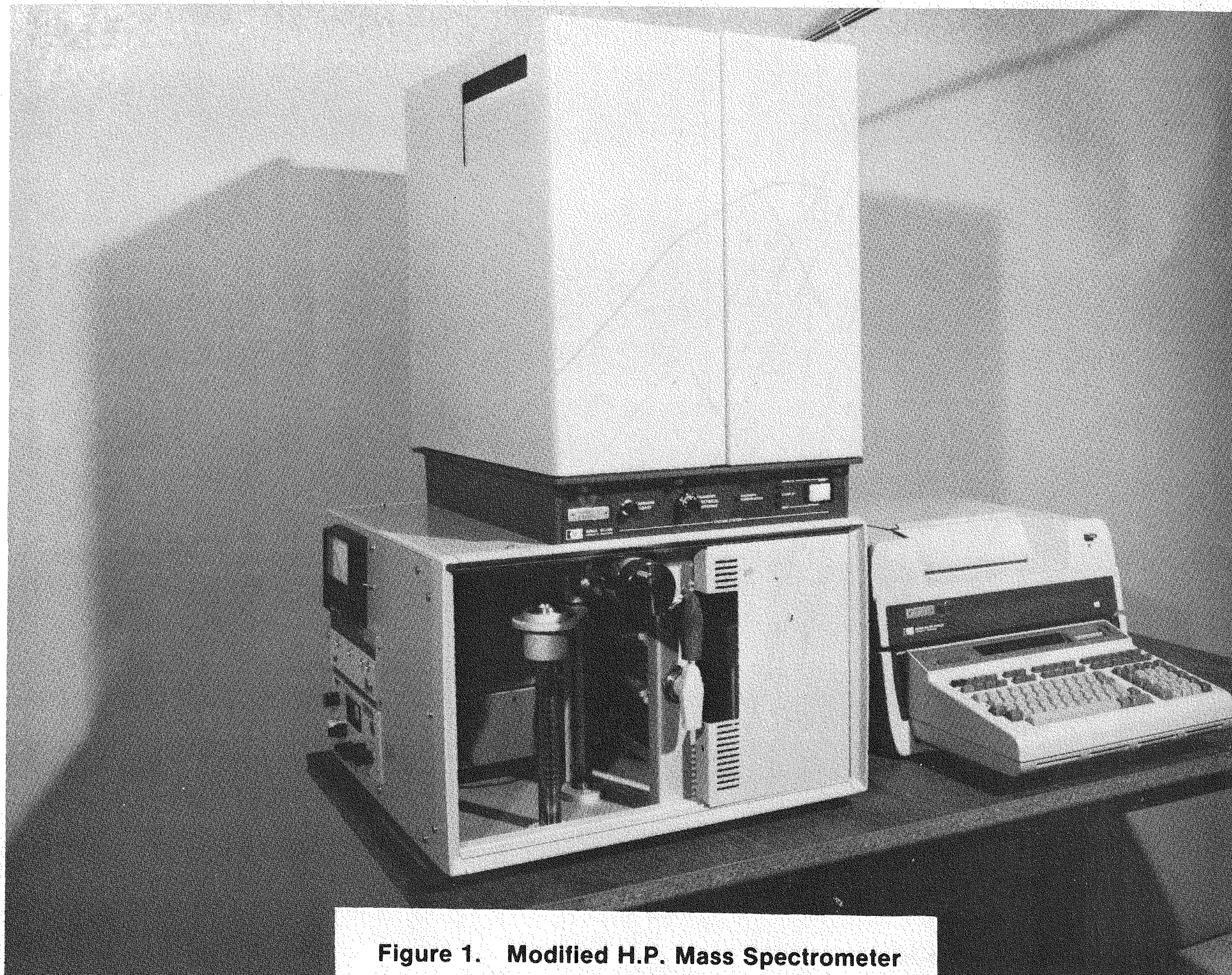


Figure 1. Modified H.P. Mass Spectrometer

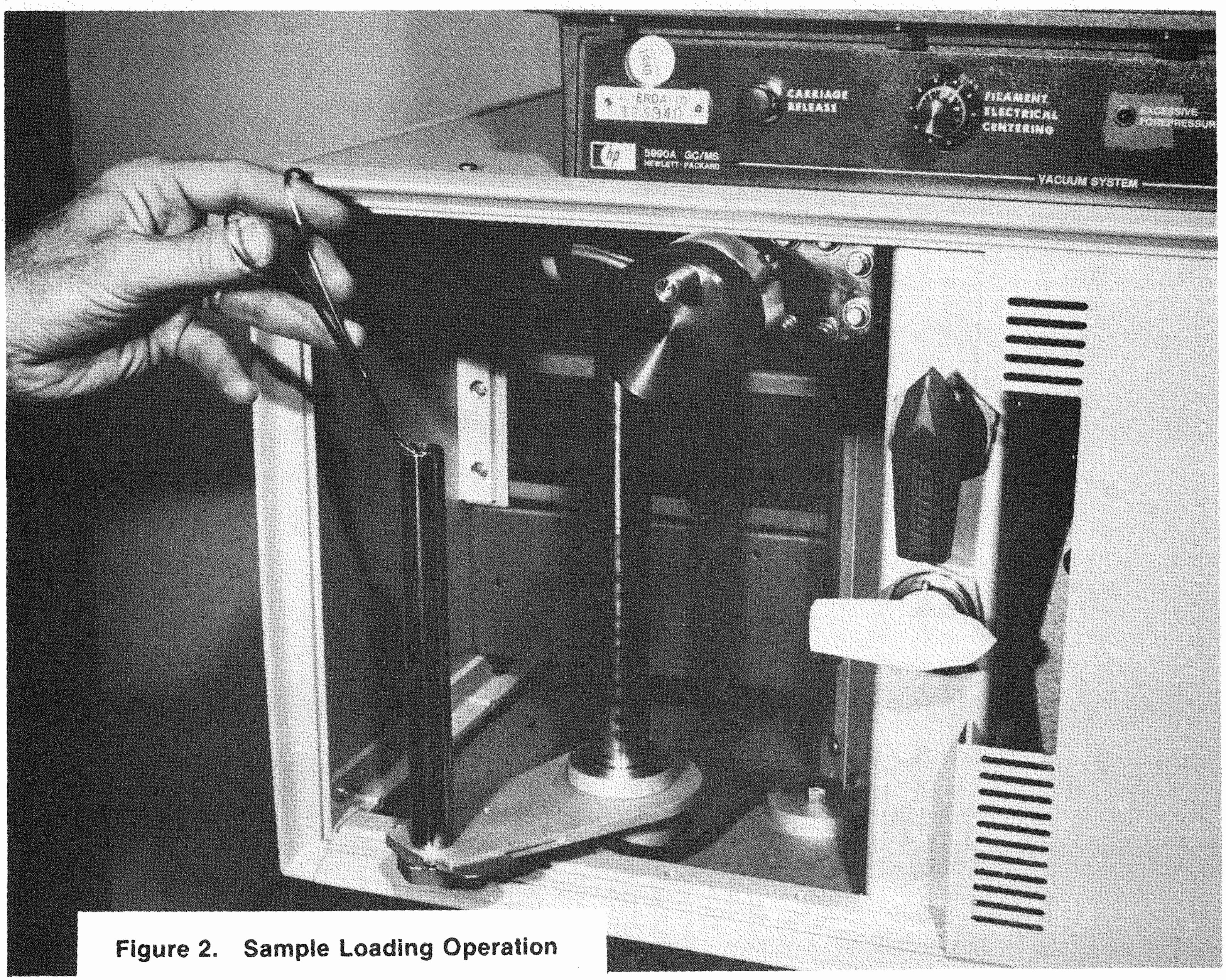


Figure 2. Sample Loading Operation

Operating software for the HP-9825 controller was rewritten and tested. The operator need only load the sample and push a button. The controller will then wait until the necessary vacuum is attained, and make the measurement automatically, and print out the results. A sample of one microgram or less is needed. Successive measurements require about 7 minutes. Relative accuracies of 1% or better are achievable for peaks of 5% abundance or greater. Figure 3 is a plot of counting rate against mass for a uranium standard showing the instrument's resolution.

The modified instrument is 50 cm wide, 89 cm high, 55 cm deep, and weighs 88 kilograms exclusive of the HP-9825 controller. It requires approximately 10 amperes at 110 VAC, and 1 liter/minute cooling water. It will fit in the rear compartment of a Volkswagen Rabbit subcompact car.

The instrument was scheduled for field testing at Richland, WA. These tests were postponed until early FY-1981.

C. Ion Instrument Inc. Magnetic Mass Spectrometer (M. W. Echo)

The Ion Instruments[c] spectrometer was received on November 27, 1980. It had sustained minor damage to the cover panels caused by screws and bolts loosened in transit. The instrument was set up and good vacuum obtained by mid December. At this point, the first of a number of problems occurred: A power transformer failed; a magnet power supply failed; several wiring and connector failures occurred; a fan failed, and the electromagnet shorted. These repairs used much of the available test and evaluation time. The instrument did produce rhenium spectra, but the indicated resolution was no better than that of the HP instrument.

D. Comparison of Instruments and Proposed Program

Because of funding limitations, it was necessary to select one instrument for subsequent test and evaluation. The HP quadrupole was selected. Compared to the HP instrument, the Ion Instruments spectrometer is heavier (214 to 88 kg), larger (roughly a 1 meter cube), and less convenient to operate. The vacuum lock is larger and the filament source is more difficult to position. Additionally, a longer time is required to make a measurement.

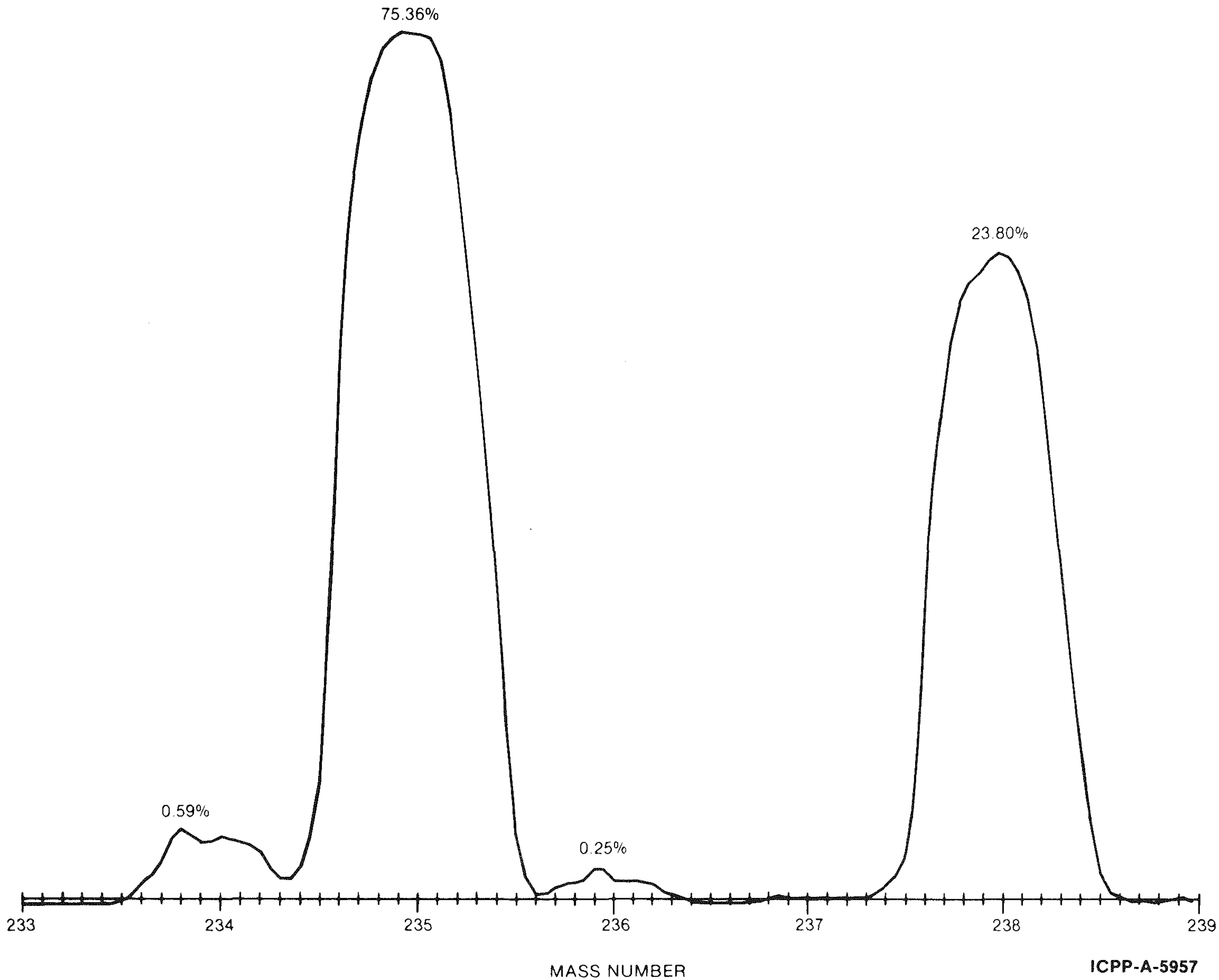


Figure 3. Log Plot of NBS 750 Uranium Standard - H.P. Instrument

III. SENSOR AND INSTRUMENT DEVELOPMENT

Background

Because of the requirements for reliable and effective sensors in a Safeguards monitoring sytem, the development and testing of candidate sensors is part of the Safeguards development program. Safeguards device development includes surveys of the latest sensor and instrument technology to identify candidates for specific safeguards applications. These "off the shelf" candidates and other modified or developed devices are tested in the laboratory for potential safeguards application.

Sensors investigated during FY-1980 included load cells, precision pressure transducers, pressure and vacuum switches, ultrasonic liquid-in-line sensors, and a bubble flowmeter.

A. Load Cell Tests (T. C. Piper)

Plant level and density measurements are normally made with bubbler probes. These devices are simple and reliable, but are subject to probe plugging in concentrated liquids; in addition, the instrument lines are potential diversion routes. An alternate method of tank content measurement, with accuracy as good or better than attainable with bubbler probes, would be useful. Direct weighing of plant tanks would be an acceptable alternative if sufficient accuracy was attainable. For this reason, a series of strain gauge load cells was tested to determine their suitability for measurement of the weight of plant vessel contents.

The requirements for plant load cells are severe. Usable load cells should have a good zero stability since plant tanks are infrequently emptied, making the job of resetting the zero nearly impossible. Temperatures in some parts of chemical processing plants are not easily controlled, making good temperature stability a useful property. In addition, some vessels are in high radiation fields, making good radiation stability essential.

A number of commercial strain gauge type load cells with suitable vendor-claimed properties were obtained for testing (See Table I). Measurements of stability with and without a load were made and measurements of temperature stability were made.

The Celesco[d] load-cell was returned to the factory for repair of a lead-to-bridge connection. The first test run on it after its return showed a temperature sensitivity of 0.027% of f.s./deg.F. occurring primarily in the form of a zero shift versus temperature. Since the zero shift was warranted to be under 0.0025% of f.s./deg.F., it was returned to the factory.

Tests of output shift versus time for the four HBM[e] load cells showed consistent results one to the other. The output of the 100 pound (45.5 kg) full scale drifts about 0.08% f.s. in the first 10 hours of loading with nearly 1/2 of the drift occurring in the first two hours. Upon unloading, 0.08% of f.s. shift occurs (in the opposite sense - towards lower indicated load) within 16 hours. One half of this shift occurs in the first two hours. No temperature sensitivity is evident.

TABLE I

LOAD CELL - MANUFACTURER SPECIFICATIONS

	Celesco[d] 150-P-1-300-AZ	HBM[e] C3H2	Lebow[f] 3397	Sensotec[g] Series W, Precision
Accuracy Class, %fs	0.03	0.03	0.1	0.05
Load Range, pounds	300	110	300	300
Output, mv/V at fs	3	2	2	3
Temp. Coef. of Sensor, ±% nd/10°K	0.09	0.010	0.036	0.014
Temp. Coef. of Zero, %fs/10°K	0.045	0.013	0.036	0.018
Temp. Compensation Range, °F	15 to 115	-14 to 150	30 to 150	50 to 150
Hysteresis, ±%fs/time	0.03	0.025	0.05	0.03
Repeatability, ±%fs	no data	0.01	0.02	no data
Serial # of Units Tested	0495981	13341 9283 13351 13327	2655 2666 2667	42651

The Lebow Inc.[f] 300 pound (136.4 kg) load cell was returned to the factory because its zero drift was out of specification. On return from the factory, the temperature variation of the load cell was 0.046% f.s./deg.F, twenty times worse than the specification. Because the zero drift of the other Lebow units were irregular with time, they were not tested for variation or sensitivity with temperature.

It had been hoped that extensive calibration of load cells could produce measurements of better accuracy than that stated in the factory specifications. However, these limited tests suggest that the accuracy of most load cells is worse than reported in their specifications. For those load cells that are within their specifications, zero drifts and temperature variations were such that there was no reasonable chance of obtaining load data any better than their specified accuracy class, whatever calibration or characterization was used. There appeared little chance of obtaining better than 0.1% accuracy using the load cells tested. Because of large drift characteristics, applications requiring high precision would need some reference point, as provided by a zeroing (unloading) capability.

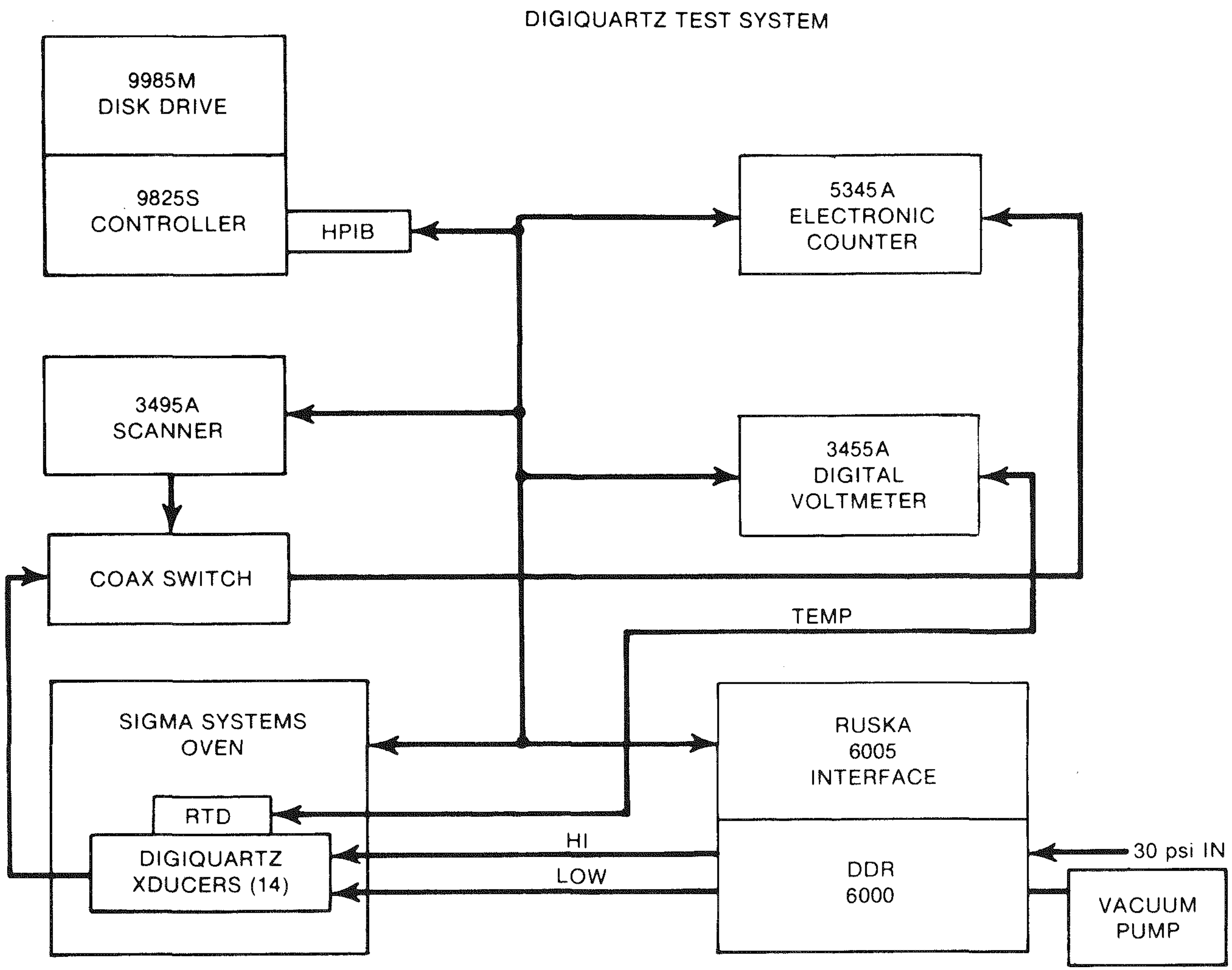
Further work was temporarily stopped since the demonstrated capabilities would not provide better results than conventional bubbler probe measurements.

B. Pressure Transducer Tests (F. L. Bentzen, W. J. Harris, T. J. Boland (consultant))

Precision pressure transducers are the critical sensors for Safeguards level and density measurements of plant tank liquids. The test program characterizes the transducers to determine optimum operating conditions. Two transducers were selected for testing: (1) The Paroscientific "Digiquartz" differential pressure transducer[t] uses a quartz crystal oscillator whose operating frequency is changed by the applied pressure difference. (2) The Kavlico[h] transducer uses a ceramic capacitor whose value is changed with applied pressure difference. Zero shift variations with temperature were measured for both transducers during FY-1980.

Initial measurements of zero pressure difference stability were made on 14 Paroscientific transducers purchased for use in the Safeguards Tests and Evaluation system. The measurements showed that for these transducers the standard deviation of the measured oscillator period is less than one part in ten million for tests run over two-hour periods.

An automated data acquisition system was built for the calibration and characterization of precision pressure transducers. Figure 4 is a block diagram of the system, with the system shown as arranged for temperature tests of the Paroscientific "Digiquartz" transducer. The Hewlett-Packard 9825, active through the IEEE 488 bus, sets the oven temperature, adjusts the source pressure from the Ruska[i] calibrator, reads the transducer temperature with the RTD and digital voltmeter, and the frequency output of the transducers through the coaxial switch. The data are stored on the floppy disk for later analysis.



ICPP-A-5958

Figure 4. Block Diagram of Pressure Transducer Calibration System

The output of the "Digiquartz" transducer is non-linear. Paroscientific recommends a calibration equation of the form P = AX + BX2 where P is the pressure, A and B are calibration constants and $X = 1 - \frac{t_0}{t}$, where t_0 is the period of the transducer oscillator at zero pressure and t is the period at the measured pressure. The constants A and B are functions of temperature as shown in Figure 5 for a typical "Digiquartz" transducer. A report on this temperature calibration work was published(1). A review of data taken from Paroscientific transducers installed in the Tokai, Japan reprocessing plant indicated that a third order calibration equation would improve the apparent accuracy of these transducers. These results were documented in an internal technical memo and in the Final Report(2), Task-I, of the TASTEX program, for the International Safeguards Project Office.

The Paroscientific transducer and the Ruska Corp. model DDR-6000 transducer were compared in a calibration exercise at Tokai, Japan (Tokai Advanced Safeguards Technology Exercise (TASTEX) Program). A precision piston gauge was the pressure source. Uncertainties of less than a millimeter of water were found for both transducers.

Four High Precision Level/Density Boxes were designed and built for installation in the ICPP. Each box contains two Paroscientific 0-15 psid (psi differential) transducers used to measure both level and density in 4 separate critical plant tanks. The transducers are switched between tanks using Scanivalve Corp. wafer pneumatic switches(j). The box also provides for on-line calibration of the transducers and the continuation of measurements with one failed transducer. The boxes are designed for remote operation by computer and for operation and maintenance in the difficult environment of a chemical plant. This box is described in a report(3) now in preparation. Preliminary tests were run on a new 15 psid differential pressure transducer made by the Kavlico corporation. This transducer may provide very high, short-term precision at a low unit cost.

C. Pressure/Vacuum Switch Tests (F. L. Bentzen)

Two hundred of the Static-"O"-Ring(k) model 6AB-EDC-M4-C1A pressure switches scheduled for installation in the ICPP were tested for set point (20 psig) and contact resistance. One unit failed and approximately 15 units initially had excessive contact resistance that could be reduced by repeated actuation.

Approximately one hundred Static-"O"-Ring model 54BA-KB-41-M4-C1A pressure/vacuum switches were tested and 15 were returned to the factory for repair. The principal defect found was imprecise actuation when set for a vacuum of three inches of mercury.

D. Liquid-in-Line Sensors (T. C. Piper, F. L. Bentzen)

Liquid-in-line sensors detect the presence of liquids or liquid flows in certain plant air and instrument lines. These lines would only contain liquid or liquid flows during a diversion attempt, an abnormal tank pressurization, or during occasional maintenance operations. The sensors may also be used on sample lines to detect sampling operations. Three types of sensors are being tested: ultrasonic, thermal, and vacuum.

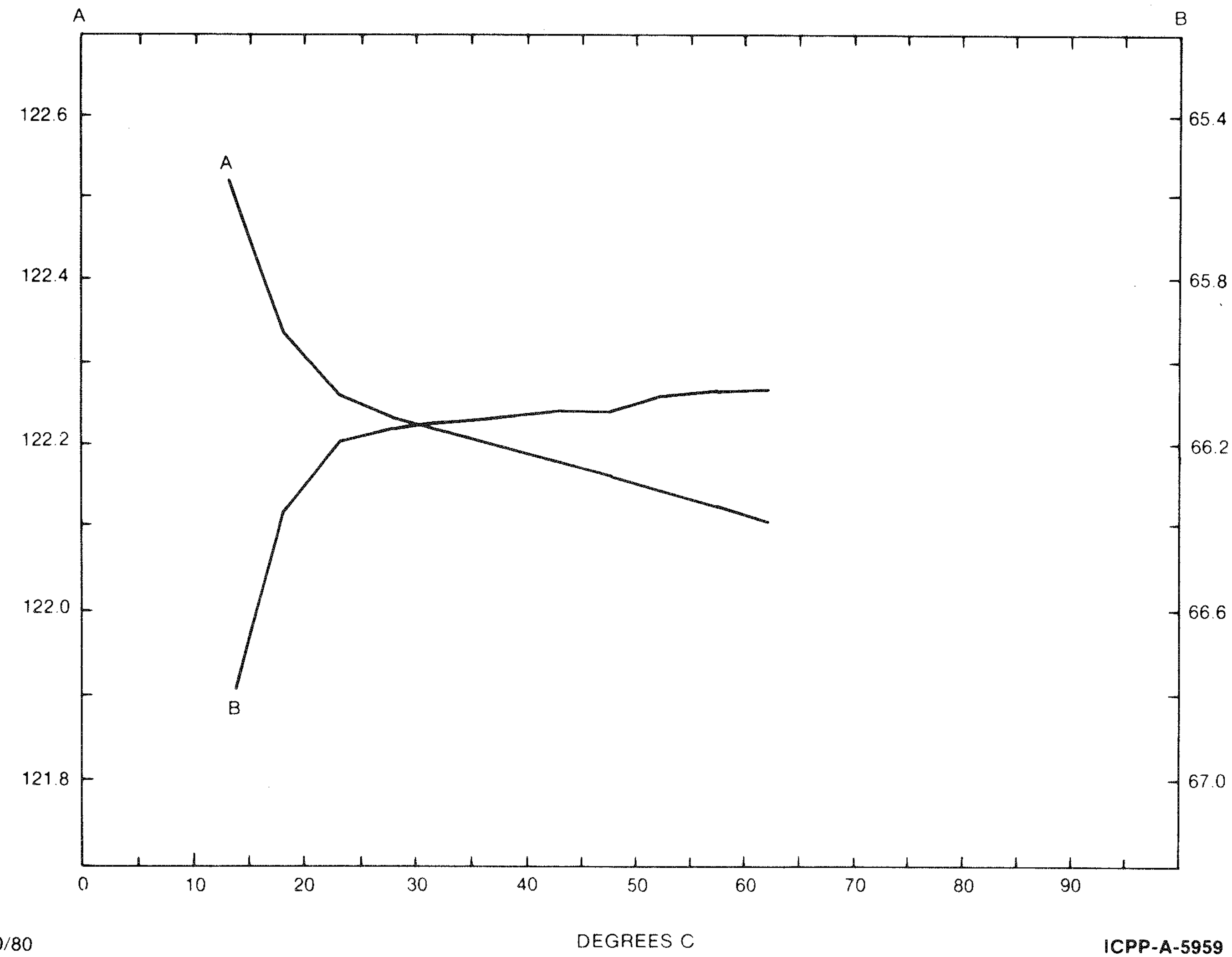


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Figure 5. Transducer Coefficients, Digiquartz #5961

The ultrasonic and thermal sensors can be non-intrusive (they need no sensors or penetrations inside the line), which is an advantage in plant use. The vacuum sensors detect the vacuum used to remove liquids rather than the liquid and are, of necessity, intrusive.

Prototype ultrasonic liquid-in-line sensors and liquid-in-line monitors were built for test and evaluation in the ICPP. The prototype system consists of 16 sealed flexural type ultrasonic sensors with connecting cables and electronics packages designed to drive the sensors, monitor their responses, and indicate their status to a monitoring computer.

Twenty sealed sensors, Figure 6, were built and sixteen were selected for installation in the plant. This type of sensor can be used in-cell and has the advantage that most failure modes will generate the alarm condition.

The coaxial relay scanner, Figure 7, will be mounted near the sensors in the plant. It allows a single oscillator and detector to be used for all sixteen detectors. The electronics package, Figure 8, will be mounted at another plant location near the computer system. This complete system was tested in the laboratory and was mounted in the plant early in FY-1981. A report[4] describing this monitor was published.

A clamp-on ultrasonic detector made by the Envirotech Corp.[l] was purchased and tested in the laboratory. It was suitable for lines 1/2" in diameter or larger but not for in-cell uses. The factory supplied mount was not suitable for all plant lines because of differences in wall thicknesses. Some additional development is desirable. Two of these detectors were installed in the plant for in-service tests.

Early work developed a low threshold flow sensor using RTD's as both heater and temperature sensor. Thermistors (Fenwal Electronics[m]) were tested as replacements for the RTD's used as temperature sensors. As compared to the RTD's, the thermistors were more sensitive, making small temperature changes easily detectable, but were not conveniently available in stainless steel housings. Because of limited funding, the thermistor tests were discontinued.

E. Bubble Flowmeter (T. C. Piper)

Development work on the bubble flowmeter was continued. The flowmeter measures the time an injected gas bubble takes to pass between two ultrasonic sensors. Accuracies of 0.5% were sought. In past work, 0.5% accuracies were achieved only occasionally. The objective of the work was to determine if the instrument could serve as a reliable plant instrument.

The instrument was reassembled in the laboratory with a glass "tee" installed at the bubble injection point so that bubble formation could be studied. Observations made with the glass tee showed that the parameters (bubble injection pressure, angular inclination, and injection pipe sizing) affected the accuracy of the flow measurement. After considerable testing, it was apparent that the factors causing bubble

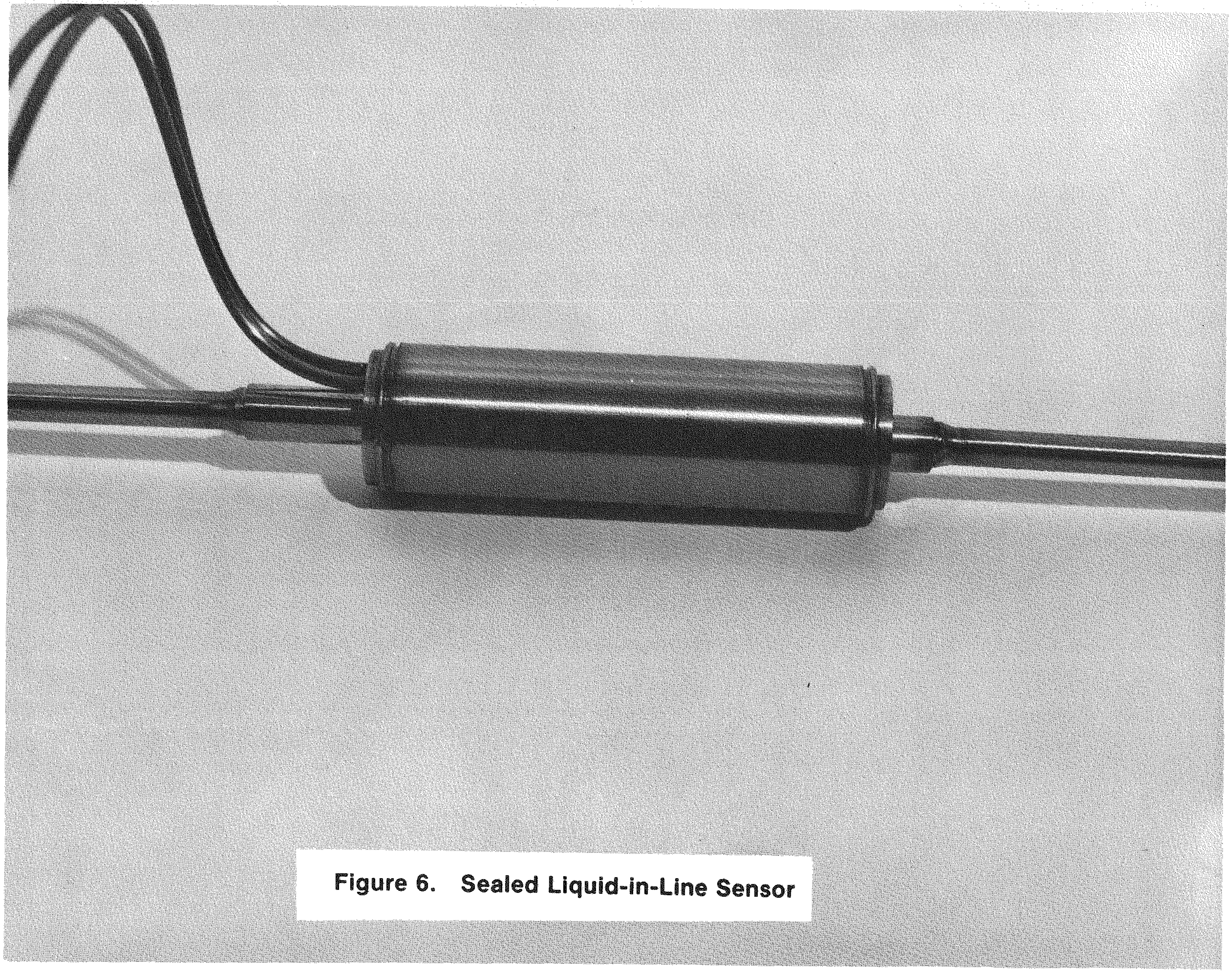

Figure 6. Sealed Liquid-in-Line Sensor

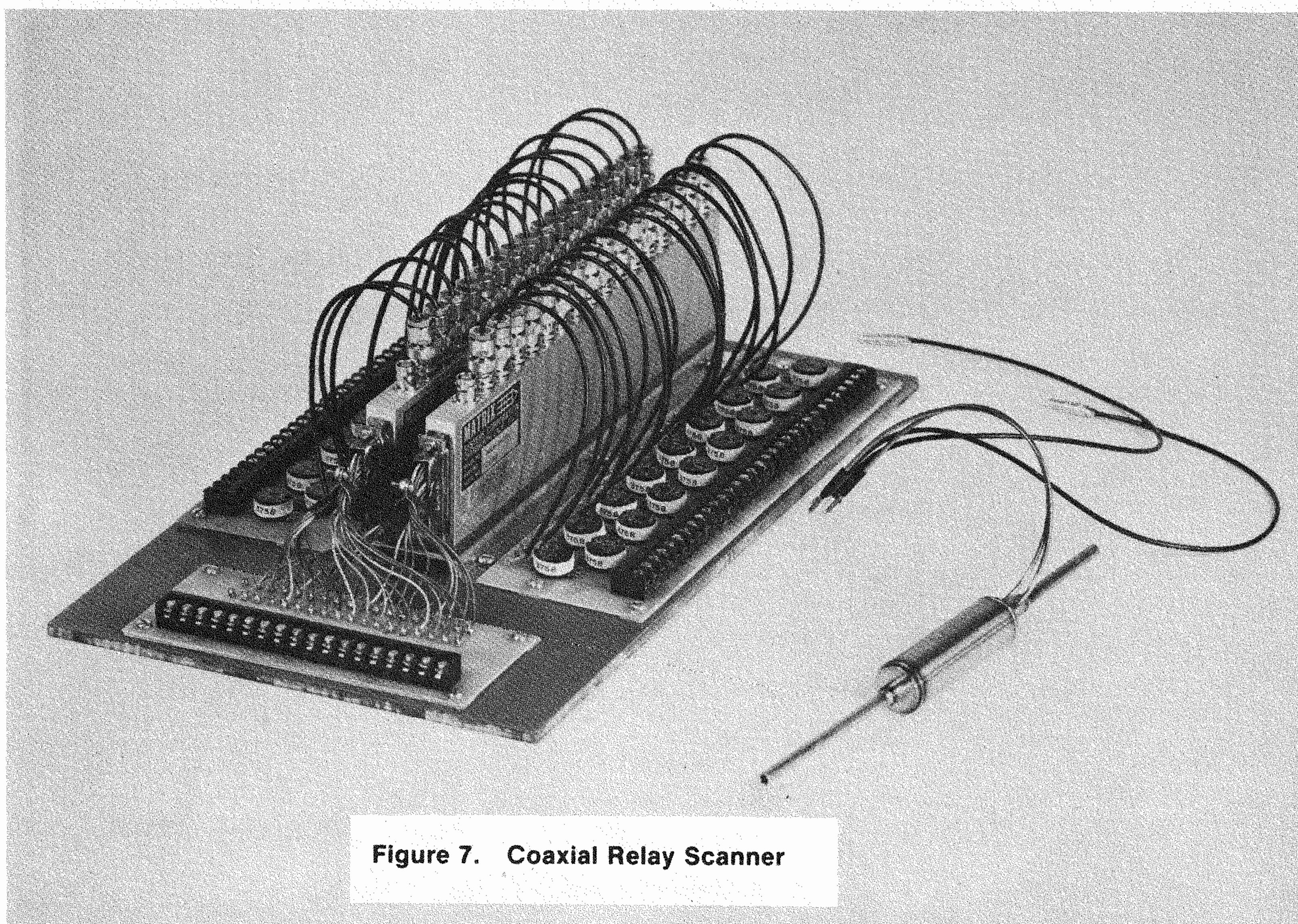

Figure 7. Coaxial Relay Scanner

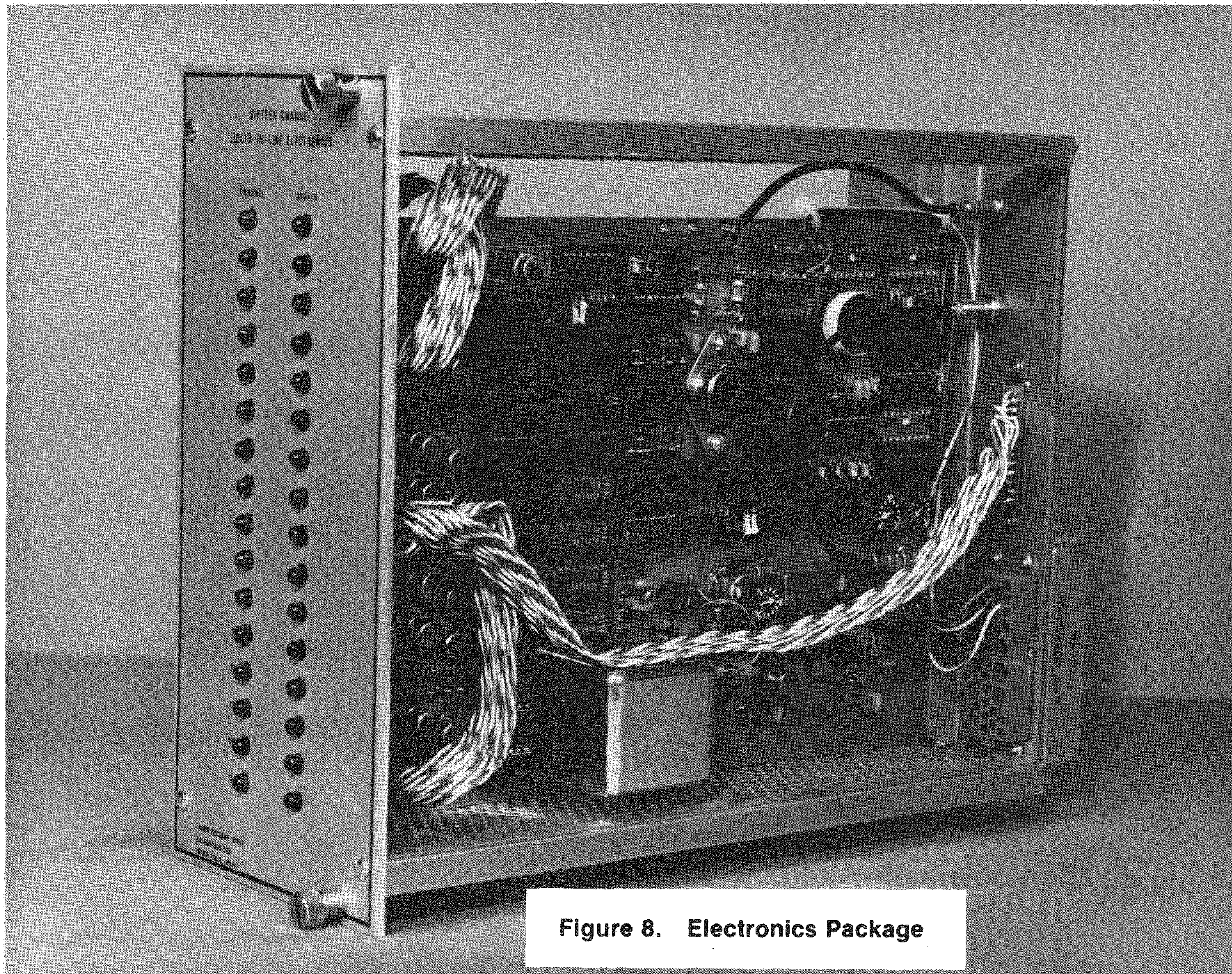

Figure 8. Electronics Package

sticking, non-reproducible surface conditions, and fluid bypassing were not understood and that an effort much larger than the currently-funded program effort would be needed to achieve the desired 0.5% accuracy under plant conditions. Further work on the flowmeter was dropped.

IV. TEST AND EVALUATION SYSTEM DEVELOPMENT

Background

An integrated Safeguards development computer system is being installed in the Idaho Chemical Processing Plant (ICPP). The proposed system will provide two general functions: (1) A demonstration of the process solution monitoring and tracking capabilities of the Test and Evaluation system, and, (2) Measurement of the performance of individual process monitors and other system components under ICPP operating conditions. For the demonstration function, the computer monitors process control operations, tank levels, and densities to confirm that static tank levels don't change and compares solution quantities moved in the process. For performance testing, the computer collects data from candidate sensors installed in the ICPP. These candidate sensors are selected from commercially-available process sensors and instruments. Analysis of the precision and reliability of this collected data will determine the suitability of the tested sensors.

Physically the system consists of three parts: (1) the sensors installed in the ICPP process area, (2) interfaces and a data acquisition computer system used to collect the data, and (3) a larger computer used to consolidate, store, and analyze the data. The data acquisition computer is in the ICPP; the larger computer is at the Central Facilities (CF) area, several miles from the plant.

Some of the Safeguards tasks that the system will do are: (1) Precisely measure liquid volume and weight for accountability use. (2) Monitor process control operations to be sure that approved procedures are followed. (3) Monitor transfers of nuclear materials solutions and solids to maintain an estimate of the material distribution in the plant. (4) Monitor non-standard or rarely used solution withdrawal routes to test for diversions or bypassing of accountability measurement points; and (5) Cross check instrument readings and process parameters to confirm values, assist instrument calibrations, and detect maintenance problems. This safeguards testing of current equipment technology in a working nuclear facility will guide future DOE safeguards policy.

In FY-1979 initial installations were completed. The data acquisition and analysis systems were designed as a distributed computer system with the data acquisition and communications processors at the ICPP and the analysis computer at CF-633 several miles away. System sensors were identified and most were purchased for testing and installation. The installation of the system in the plant was planned as a series of separate work packages for installation by ICPP craftsmen. Test data for some previously installed sensors were collected to confirm device selections and operational techniques.

A. System Sensor Installations (E. P. Wagner, T. Boland (consultant))

On the basis of an early decision, a central rather than a distributed system was chosen to connect the plant sensors to a single data acquisition interface. All plant sensors are wired to panel boards in an equipment shelter mounted on the upper level of the ICPP plant building. The sensor installations in the plant were divided into eleven area specific (process cell-oriented) work packages. Although a few sensors were installed in-cell, most work-package sensors were mounted on instrumentation outside the cell or in the operating corridor. The work packages also provided the signal conduits, junction boxes, and cable runs needed to connect the sensors to the panel boards in the equipment shelter.

During FY-1980, seven work packages were installed before installation work was temporarily stopped to eliminate possible conflicts with instrument checkout and calibration preceeding plant startup. The Z-cell (Product area) work package, the cell 5 package (Dissolution Area), the G and H cell package (Dissolution and First-Cycle Extraction Area), the E and F cell package (Dissolution and Centrifuge Areas), the equipment shelter, the J-cell (Hot Recycle Area) package and the N-cell (Intercycle Storage Area) packages were installed. The installation of the remaining work packages: for the PM area; Z cell-II; P, Q and S-cell; and U, W, and Y-cell were postponed until the first part of FY-1981.

Sensors were installed on lines, tanks, and on measurement points that were identified by a survey as important to Safeguards or to the evaluation of Safeguards sensors. The Z-cell (plant product storage area) package included a number of modifications and valve replacements that simplified cell operations and greatly reduced access to the cell. The cell 5 package picked up monitoring points in the electrolytic dissolver and in related PM areas. The G and H cell package connected monitoring sensors and instruments in the aluminum dissolver and 1st-cycle extraction areas. The E and F-cell dissolver added inputs from the zirconium dissolver and centrifuge area. The equipment shelter included the signal termination boxes and the interfaces to the data acquisition system. The J-cell package added points in the process rework area and the N-cell package added inputs in the intercycle storage area. The basic structure and wiring for the system and all the 1st-cycle sensors were installed before work was stopped. This included 425 monitoring points.

The remaining work packages when installed early next year will complete the process coverage of the system. The PM area package will add monitoring points in the product makeup area including a number of liquid-in-line sensors; the P, Q, and S-cell package will add the 2nd and 3rd-cycle processing and reconcentration inputs; Z-cell II will complete some points in the final product storage area and the U, W, and Y-cell package will add points in the aqueous and organic waste systems.

The types of sensors installed for the Test and Evaluation system are listed in the next section.

An integrated Safeguards development computer system is being installed in the Idaho Chemical Processing Plant. Sensors capable of monitoring plant operating parameters (flows, volumes, levels, densities) and the status of plant operations (valves, pumps, jets, sparges, air lifts, samplers) are essential for such a system. Sensors were selected and tested for installation in the plant Safeguards system based on continuing evaluations of current sensor and instrument technology, the ICPP environmental restraints, and past experience gathered in the operation of the ICPP. Table II is a summary of the various classes of sensors and their use in the plant system.

TABLE II

CANDIDATE SENSORS AND APPLICATIONS

1. Pressure Switches

   Steam jet monitoring
   Sample air jets
   Remote-controlled valves

2. Air Flow Monitors

   Air sparge mixing
   Sampler air lifts
   Process air lifts

3. Pneumatic Instrument Signal (3-15 psi) Monitors

4. Liquid-in-Line Detectors

   Instrument Lines
   Sampler suction lines
   Jet steam line
   Decontaminating line
   Sampler air lift line
   Process air lift line
   Sparge line

5. Jet Temperature Detectors

   Thermocouple
   Temperature Switch

6. Electrical Current Detectors

7. High-Precision Differential Pressure Transducers

8. Manual Valve Position Indicators

9. Plant Pressure/Vacuum Transducers

10. Tank Temperature Transducers

11. Electrical Instrument Signal (4-20 ma) Monitors

12. Process Liquid Flow Monitors

These sensors and their various applications in the system are described in ENICO-1025[5]. The sensors selected for installation and evaluated in FY-1980 are described in the following section.

1. Class 1 - Pressure Switches

Requirements for all three applications for class 2 sensors were satisfied by the Static-"O"-Ring Inc.[k] "Omni" pressure switch. This model features Type 316 stainless steel internals, 1500 psi overrange pressure, and the choice of either a field adustable setpoint or a tamperproof factory fixed setpoint. Standard external construction is aluminum, but stainless steel construction for in-cell mounting is available and was used in the Z-cell installation.

More than 280 SOR switches were acceptance tested. Fifteen were found to be erratic and were replaced.

2. Class 2 - Air Flow Monitors

For air flows exceeding 1.5 cfm, the Brooks Model 7930 MAG/NA/LARM II[n], mounted on a rotameter, provides a suitable flow monitor. This product has a dry reed switch mounted beside the rotameter tube, which is tripped by a magnet in the float. The Brooks MAG/NA/LARM unit can go to somewhat smaller flowrates using an extension type rotameter. Because of the low flowrates, no suitable flow monitor was found for sampler air lifts, sparges for 5" diameter tanks, or for certain process air lifts which use less than 0.5 SCFM air flows.

3. Class 3 - Pneumatic Instrument Signal Monitors

A 64 channel Scanivalve[j] pneumatic multiplexer and pressure transducer was selected. This instrument was operated for more than one year for collection of process data. The unit monitors the 3-15 psig (0.2-1.0 kg/cm^2) pneumatic signal produced by ICPP transmitters for pneumatic plant instruments. These units were fitted with controllers that use the IEEE-488 instrument data bus for operation by the plant data acquisition HP-9825 computers. An on-line automatic calibration system was designed and installed in the ICPP for these monitors. The calibration system uses Schwien and Sons[o], precision pressure regulators as high (15 psig) and low (3 psig) pressure references.

4. Class 4 - Liquid-in-Line Detectors

This class includes devices whose purpose is to detect or prevent the removal of process liquids through abnormal routes, such as through instrument lines Several candidate devices are being evaluated for detection of liquids using ultrasonic and thermal techniques.

Where significant suction would be required for liquid removal, Static"O"-Ring vacuum switches (Model 54B-KB-41-M4-C1A) were selected.

A non-intrusive ultrasonic sensor manufactured by Envirotech Corp.[l], model 6215, was purchased for testing. It was tested with water and was shown to be acceptable for service outside processing cells.

An ultrasonic transducer suited to lines smaller than 1/2" and associated electronics were designed, successfully tested in the laboratory, and will be installed in the ICPP early in FY-1981 (See section III.D). A thermal flow sensor was laboratory tested and was also installed in the plant for in-service tests (See section III.D).

A design for an improved low-cost tubing block was selected. This device will be placed in certain plant lines to block the insertion of suction removal tubes without restricting the usual flows through such lines.

5. Class 5 - Jet Temperature Detectors

Stainless steel clad, MgO-insulated type K thermocouples successfully monitored steam jet transfers in the zirconium dissolver cell (E-cell). The devices were installed in other cells (F and G) where pressure switches on steam lines cannot unambiguously signal jet startup because of cell wall block valves between the switches and jets. The thermocouples were fastened to the jet discharge pipe with stainless steel hose clamps and routed through a cell wall penetration to an external junction box. Thermocouple lengths range from 15 to 80 feet.

6. Class 6 - Electrical Current Detectors

Standard enclosed relays were selected for this application.

7. Class 7 - High Precision Differential Pressure Transducers

Paroscientific Inc. "Digiquartz" model differential pressure transducers[t] were selected for plant installation. The devices were selected on the basis of demonstrated accuracy and reliability, small physical size, and small volume for minimum pneumatic switching equilization transients.

A box containing the transducers and pneumatic multiplexing equipment was designed for plant installation (See section III.B). This box allows up to five tanks to be monitored with one pair of transducers. The current design is based on Scanivalve pneumatic wafer switches, but a backup design with solenoid valves and interlocking electrical relays was constructed for the Z-cell installation. Three of those boxes were installed in the ICPP as part of the Test and Evaluation system. One more is scheduled for installation in FY-1981.

A programmable pressure source with a Ruska DDR-6000 model precision pressure transducer[i] provides a controllable reference for on-line calibration.

8. Class 8 - Manual Valve Position Indicators

No suitable candidate devices were found. Fortunately many plant valves that are not designed for the addition of monitors will be replaced by remote controlled valves which can be more easily monitored in future plant upgrades.

9. Class 9 - Plant Pressure/Vacuum Transducers

Gould Co.[p] Model PTG-1000 series pressure transmitters were selected for monitoring 3-15 psig pressure lines in remote areas or in areas where there are too few signals to justify the installation of a Scanivalve Inc. 3-15 psig monitor. Gould Co. Model PA-3000 series absolute pressures transducers were selected for monitoring absolute pressure in certain vessels and in glove boxes. Both transmitters are constructed of Type 316 stainless steel and are hermetically sealed.

10. Class 10 - Tank Temperature Transducers

Parallel connections to existing plant thermocouples provide needed signals.

11. Class 11 - Electrical Instrument Signal Monitors

Existing plant devices will provide signals for all required applications.

12. Class 12 - Process Liquid Flow Monitors

A candidate device was developed to detect temperature changes caused by moving fluid in a heated, insulated section of pipe (See section III.D). Stainless steel clad RTD's are used for the heating and detection elements. The device is mounted on the pipe surface and requires no penetration of process lines.

B. Data Acquisition System (H. R. Deveraux)

The data acquisition system was installed in the equipment shelter, CPP-601, and in room 274, CPP-637. The system consists of a desktop computer (Hewlett-Packard 9845T)[q] as system controller to manage data acquisition and to assemble and format the data for transmission to the analysis computer, a Digital Equipment Corp. model VAX 11/780[s], at CF-633. Two smaller processors (Hewlett-Packard 9825S) are connected to the HP-9845 to control data acquisition. The connection between the HP-9845 and the two HP-9825's is via "common carrier interfaces" which extend the IEEE-488 instrument control bus to the equipment shelter for control of instruments and the plant data interface. A second HP-9845 purchased for another plant program provides backup.

The plant data interface is composed of Computer Products[r] RTP (Real-Time Products models) equipment for digital signals and low accuracy analog signals and Hewlett-Packard instruments for the high accuracy analog and frequency measurements. Figure 9 is a block diagram of the data acquisition system.

Programs were written for the control of the Computer Products interfaces and systems sensors by the HP-9825's. These programs let the HP-9825's collect digital and low accuracy analog data and operate the 3-15 psi Scanivalve monitors, the high precision level/density boxes, the precision level/density transducer frequency counters, analog channel scanners, and the digital voltmeters.

Basic programs were written for the collection of the data from the HP-9825's, its formatting, and for communication with the VAX computer at CF-633.

C. Safeguards Analysis Computer (A. V. Grimaud, E. R. Deveraux, J. A. Dixon, R. Fairbourne (summer hire), G. Reid (DEC), D. Metcalf (EG&G), Neil Liester (EG&G))

The Safeguards Analysis computer is a DEC VAX 11/780 32 bit computer. Figure 10 is a block diagram of the computer. The computer receives plant data, converts it to engineering units, and stores it in a user-accessible data base. In addition, the computer controls a number of terminals to display information, plot data, and allow several analysts' simulations the access to information. A second tape drive and two additional terminals were added to the system during FY-1980 to support these interactive functions.

The original design of the computer software was completed in FY-1979. Figure 11 is a flow chart of this software. Programs 1-5 are part of the data acquisition computer system. Programs 7-10 were written during FY-1980. They format and store the plant data and generate convenient historical and analytical data bases.

The programs written store raw data on tape and convert and format the data for later use. The programs build maintenance and recalibration histories for each sensor point and are designed for easy additions and modifications of the data base. Completion of work on the data base and generation of the analysis and production support programs is scheduled for FY-1981.

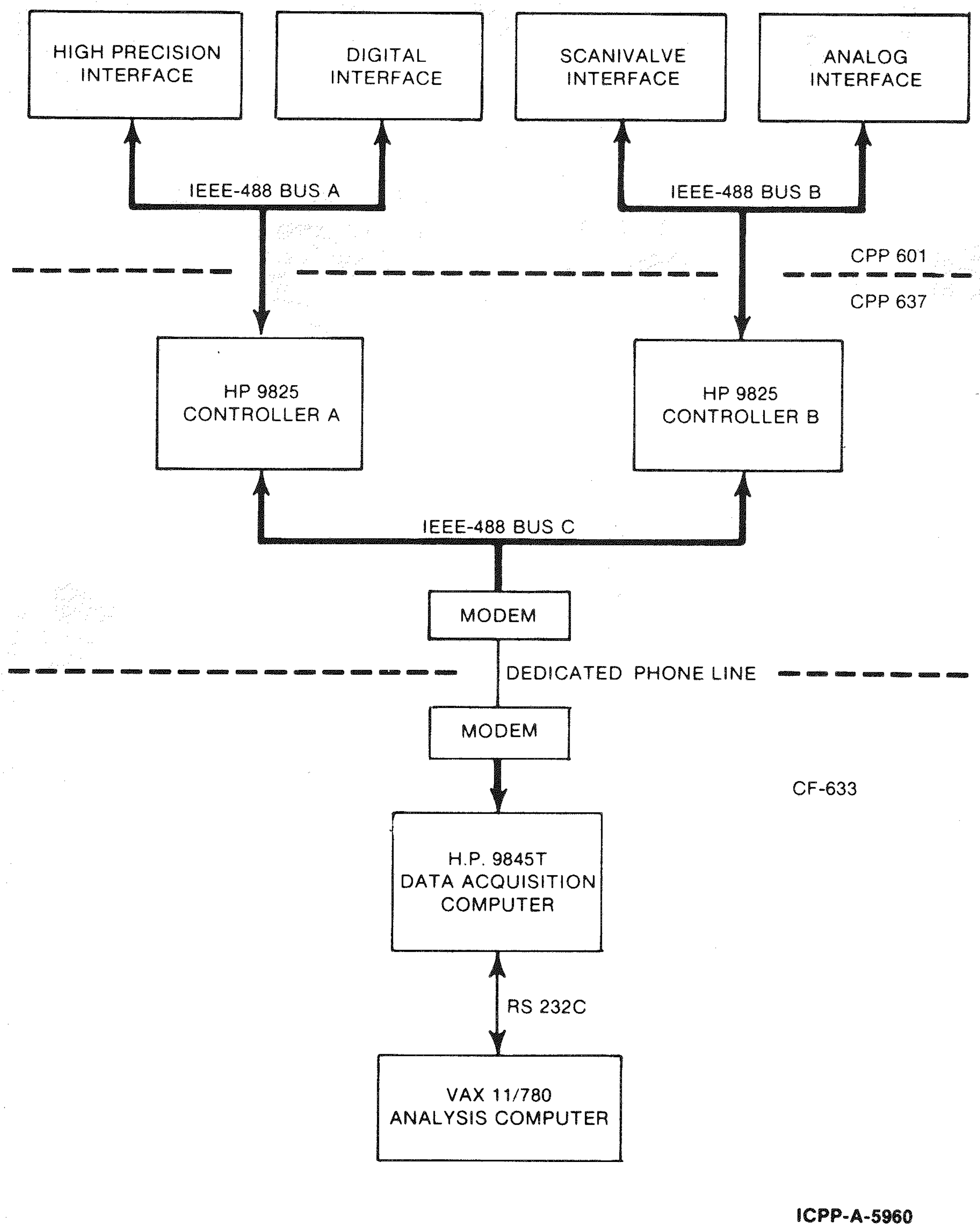

Figure 9. Block Diagram of Data Acquisition System

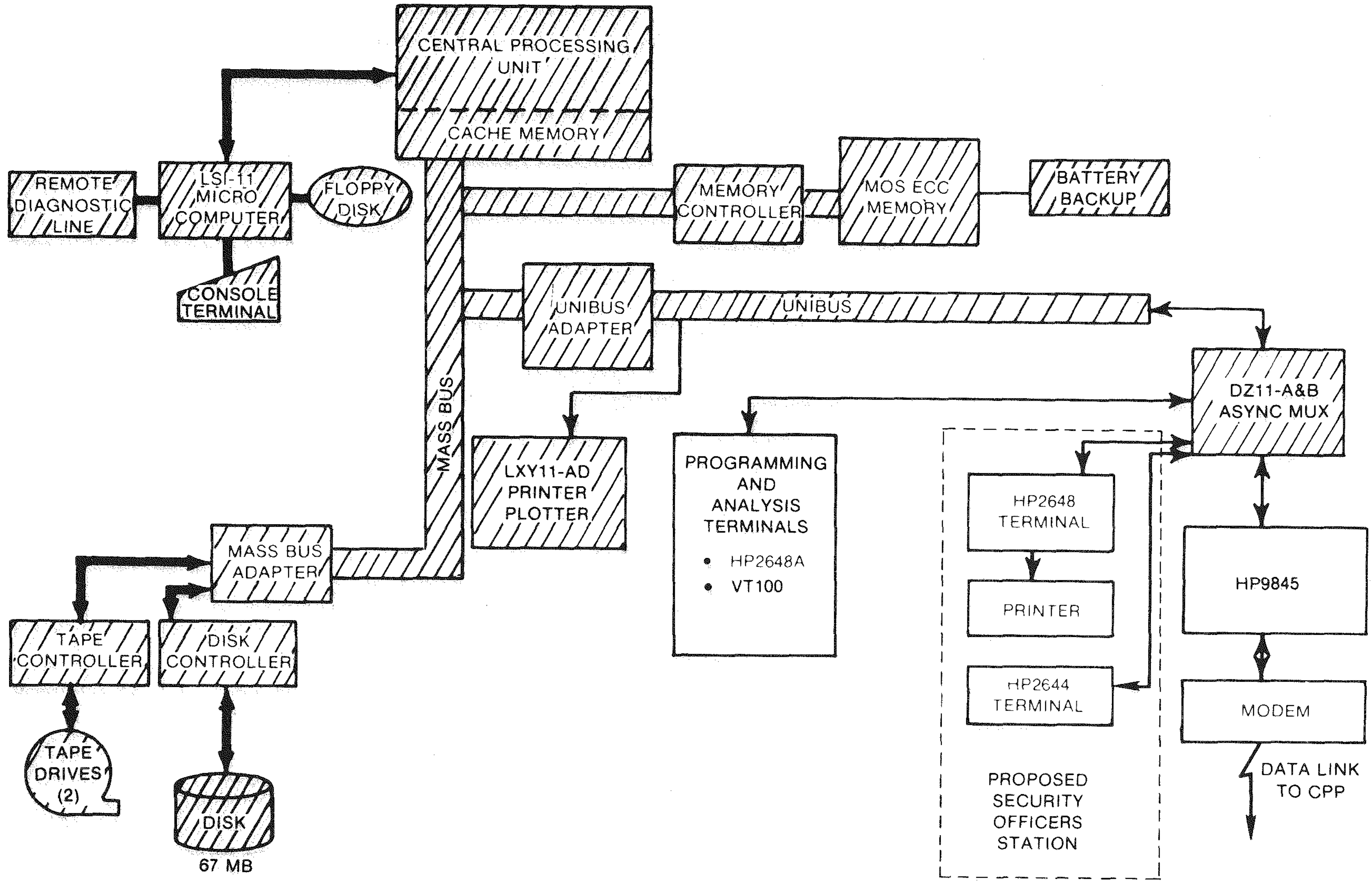

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Figure 10. Block Diagram of Safeguards Analysis Computer

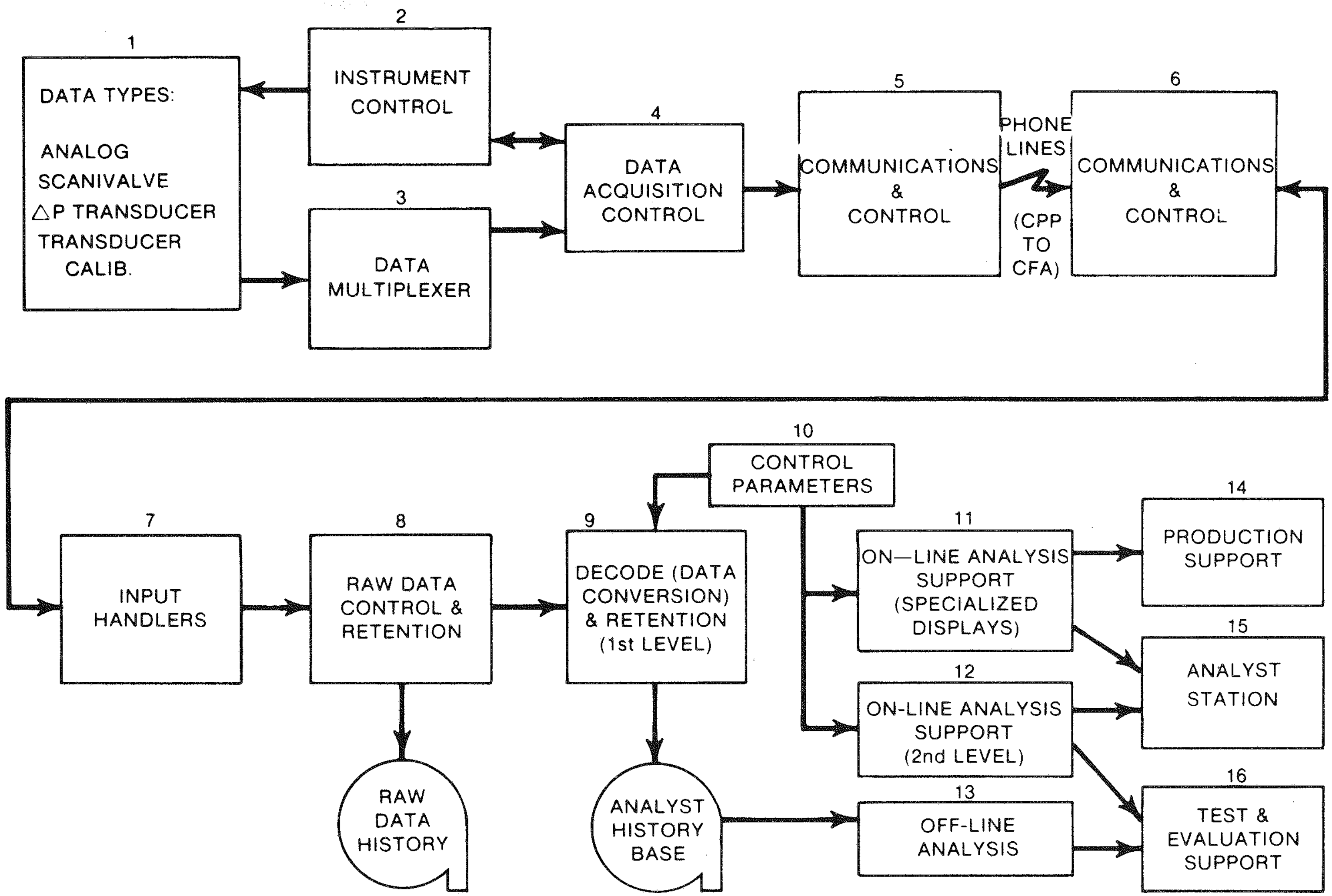

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Figure 11. Software Flow Chart

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b. Hewlett-Packard Corporation, Scientific Instruments Div. 1601 California Ave., Palo Alto, CA. 94304.

c. Ion Instruments Inc. 1875 N. 105 E. Ave., Tulsa, OK. 74116.

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d. Hottinger - Baldwin Measurements, Inc. 10 Strathmore Rd Natick, MA. 01760.

f. Lebow Associates Inc., 1725 Maplelawn Rd., Troy, MI. 48099.

g. Sensotec Inc., 1200 Chesapeak Ave., Columbus, OH. 43212.

h. Kavlico Corporation, 20869 Plummer St., Chatsworth, CA. 91311.

i. Ruska Instrument Corporation P.O. Box 36010, Houston, TX. 77036.

j. Scanivalve Corporation, P.O. Box 20005, San Diego, CA. 92120.

k. Static-O-Ring (SOR Incorporated), P.O. Box 591, 11705 Blackbob Road, Olathe KA. 66061.

l. National Sonics Divison, Envirotech Corporation, 250 Marcus Blvd., Huppauge, NY. 11787.

m. Fenwald Electronics, 63 Fountain St. Framingham, MA. 01701.

n. Brooks Instrument Division Emerson Electric Company, 407 W. Vine St., Hatfield, PA. 19440.

o. Schwien and Son, 293 Ventnor Ave., Aspen, CO. 81611.

p. Gould Company, Measurement Systems Division, 2230 Statham Blv, Oxnard, CA. 93030.

q. Hewlett Packard Corporation, Desktop Computer Division, 3404 E. Harmony Rd. Fort Collins, CO. 80525.

r. Computer Products Inc. 1400 N. 70 St., Fort Lauderdale, FL. 33309.

s. Digital Equipment Corporation, Maynard, MA. 01754.

t. Paroscientific Inc., 15109 NE 68th St., Redmond, WA. 98052.