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FINAL REPORT FOR FISCAL YEAR 1979

ADVANCED SAFEGUARDS SYSTEMS DEVELOPMENT FOR CHEMICAL PROCESSING PLANTS

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I. SUMMARY

The ENICO safeguards development program at Idaho National Engineering Laboratory (INEL) is installing a computer system to test and evaluate safeguards monitoring concepts in an operating nuclear fuel processing plant. Safeguards development sensors and instruments installed in the Idaho Chemical Processing Plant (ICPP) provide plant information to a computer data acquisition and analysis system. The objective of the system is to collect data from process and safeguards sensors and show how this data can be analyzed to detect diversion operations or improper plant operation. The system also tests the performance of the monitoring devices to verify manufacturer specifications and determine the accuracy and reliability of the sensor data. During the ICPP fuel processing campaign in late fiscal year (FY) 1980 and 1981, data will be collected for detailed safeguards information analysis and evaluation of several monitoring concepts:

- demonstrating increased measurement accuracy for process tank levels and densities

- measuring solution weight and volume changes in the process and comparing to expected operational procedures and flow sheets

- estimating SNM distribution in the process by combining the dynamic process measurements and the analytical SNM assay results

- demonstrating numerous process activity and diversion path monitors such as remote control valve indicators, pump and jet detectors, flow meters, and liquid-in-line detectors for both normally empty and normally full (no flow) lines.

These process monitoring concepts can significantly enhance current material control (and containment/surveillance) capabilities for domestic and international safeguards. Approximately one-third of the installation designs and one-eighth of the installations were completed in FY 1979. The ICPP processing schedule for FY 1980 permits installation of the remaining monitoring devices before process startup in the fourth quarter of FY 1980. All computer hardware was delivered and checked out in FY 1979. Computer software system designs were completed with the majority of the programming scheduled for FY 1980.

Sensor and instrument development in FY 1979 emphasized device testing for ICPP monitoring applications. Device selection criteria focused on existing process monitoring/control sensors and instruments. This test and evaluation of current technology in FY 1980-1981 will show safeguards capabilities for enhancing domestic material control and international containment/surveillance techniques and will complement other DOE accountability studies and demonstrations and non-destructive analytical instrument development.

II. MASS SPECTROMETER DEVELOPMENT (Task 1.2)

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 spectormeters used for isotope ratio measurements are bulky, expensive, and must be located in controlled environments.

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 for timely detection of attempts to conceal diversion of SNM by isotopic substitution in any location. For inspection or auditing of SNM plant operations, independent verification by the inspecting agency is greatly enhanced with a portable instrument which is operated and controlled by the inspector.

The principal competing technique for direct mass analysis is gamma spectrometry. As compared to gamma spectrometry, mass spectrometry uses a very small sample (one microgram or less) and does not require self absorption or matrix corrections. The mass spectrometer responds directly to the numbers of atoms present rather than to their activities. Two types of portable mass spectrometers are being evaluated for safeguards use. These are quadrupole and small magnetic deflection instruments.

A. Extranuclear* Quadrupole Evaluation (M. Echo)

This quadrupole mass spectrometer was originally evaluated in fiscal year 1976. Results at that time were encouraging but not conclusive (Reference 1). The tests indicated the need for modifications to improve the performance of the instrument. Figure II-1 shows the instrument after modifications. The modifications included:

1. The source and analyzer regions were pumped by a turbomolecular pump instead of a diffusion pump.

2. A different manufacturer's pulse preamp was used instead of the Extranuclear equipment. (For tune-up purposes, the EL ratemeter and scope readout were used).

3. A double filament source was used instead of the single. This eliminated the need for treatment to suppress oxides.

4. In order to automate measurements, the digital mass programmer was replaced by the H-P 9830 calculator and 16-bit (digital-to-analog converter) interface and the H-P 5302 counter. The strip chart recorder was replaced by the H-o 9866 printer.

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*Extranuclear Laboratories (EL), Inc.

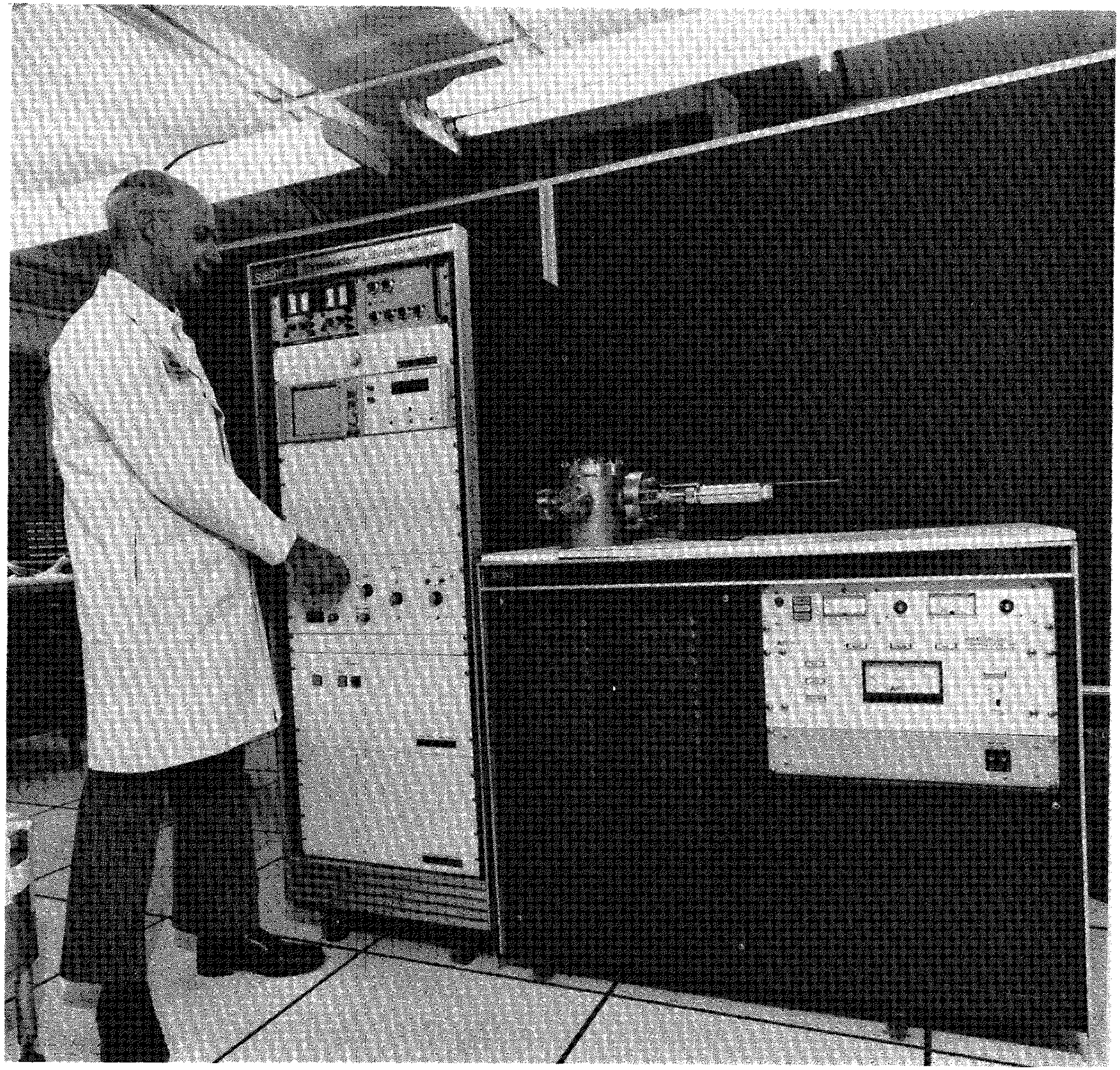

Figure II-1 Tests have been completed on the Extranuclear Laboratories Inc. Mass Spectrometer

A series of known samples were run to evaluate the modified instrument. Samples of National Bureau of Standards reference materials ranged from 5% to 93% enrichment with U^{235}. Some natural U was run but it was of uncertain characterization, so it was excluded from the reduced data. The samples were prepared for analysis by dissolution in nitric acid. Approximately 2 microliters of sample solution were pipetted onto the 1 x 30 mil Rhenium filament and dried. The concentration of the sample solution was approximately one gram per liter, so about 2 micrograms of U were deposited on each filament. In the spectrometer, this loading provided a useful ion beam for an hour or two. One filament lasted several hours.

To accumulate the data needed for evaluation for each filament loading, a series of measurements of the isotope ratio were taken, summed, and the arithmetic mean calculated, as well as the 95% confidence level value for the mean, the standard deviation for the ratio values and the percent standard deviation. The mean value was compared to the NBS standard value. The results were occassionally erratic. Analysis of data obtained from a series of these standard samples suggest that the accuracy of the instrument depended upon the difference in size of the two peaks of interest. For peaks of equal size (NBS-500), the measured isotope ratios are within $\pm$ 1½% of the standard value, while for the 19 to 1 peaks of NBS 050 the measured ratios were as much as 45% in error. However, the results of the NBS-930 samples were much better than this finding. The accuracy of the NBS-050 material (ratio 19:1) would be expected to be very similiar to that for the NBS930 material (ratio 13:1). The accuracy of the NBS-930 samples, however, appears to be about +2%, much more nearly resembling that for NBS200 (ratio 4:1) which is about $\pm$ 5%. The accuracy for NBS-750 (ratio 3:1) is about +1½.%, about the same as for the NBS-500 samples.

Several suggestions may be offered in explanation of the erratic results. The infinite dynode or "channeltron" type multipliers are not noted for their precision response, and could be a large contributor to the problem. Filament position might be a cause. The amplifier/counter system parameters could be a problem, such as threshold position. To evaluate these and other aspects of the instrument would have required additional time and effort. - The completed tests still indicate the potential for improving the repeatability of the Extranuclear instrument. However, these improvements were deferred pending the results of tests of another quadrupole spectrometer made by Hewlett-Packard. The preliminary evaluation of the Hewlett-Packard mass spectrometer tests showed it to be a more reliable, accurate, and simple-to-use instrument for safeguards use because of its light weight (less than half the weight of the 600 plus pounds of the Extranuclear instrument). For this reason, further testing of the Extranuclear Laboratories Inc. mass spectrometer was indefinately deferred.

B. Modified Hewlett-Packard* Quadrupole Evaluation (M. W. Echo)

A Hewlett-Packard Corp. Model 5992 GCMS was purchased for modification of the quadrupole to use a thermal emission filament source.

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* Hewlett-Packard Corporation

Figure II-2 shows the H-P quadrupole mass spectrometer after modification. The gas chromatograph portions of the instrument were removed and a vacuum lock installed so that solid samples could be introduced and analyzed without breaking vacuum. Figure II-3 shows the gate valve and vacuum lock assembly. Figure II-4 shows and exploded view of the probe, including the plug-in filament assembly. A mechanical device for insertion and removal of the vacuum lock probe was designed. The frame shown in the lower part of Figure II-2 could be shortened to further reduce size and weight.

Operation of the spectrometer without the gas chromatograph chamber required extensive changes to the instrument control software. There was no control of the mass spectrometer except with the binary program suplied with the H-P 9825 calculator. The binary program could not be changed until unsecured tapes were obtained from the manufacturer. Preliminary tests identified several problems, mostly related to the vacuum. Ultimate vacuum is now below the range of the cold cathode gauge (10^{-7} torr), and the vacuum recovers rapidly from pressure excursions caused by sample changing. At first, sample changes resulted in accidental admission of air through the vacuum lock, but with experience this problem ceased, and recovery to 5×10^{-7} torr now requires about one to two minutes. The sample handling mechanism previously mentioned will eliminate this problem.

During the latter part of the test runs, a complete sample cycle required seven minutes. This included filament change, sample insertion, pump down, data taking and printing of results. This time can probably be shortened to less than five minutes. For the performance evaluation modified instrument, a series of test samples were made from NBS standards. One microgram of uranium was loaded onto each filament. Six concentrations were used, ranging from natural to 93% enrichment. The sample solution formed a bead about 1mm long on the filament and dried to about the same dimension. Some beads were up to twice as long and some were slightly off center.

Sample lifetime at emission temperature was influenced by the warm-up procedure. Longer lifetimes seemed to result from a slow advance thru the 2 to 3.5 amp current span. Emission of UO^+ started at about 3.6 amps and changed rapidly to U^+ ions as the pump oil vapor reduced the oxides to metal. This was fortunate since it was expected that with a single filament source the sample would have to be pre-treated to reduce the oxides. Most samples ran at about 3.8 to 4.0 amps.

Once the final testing started no parameters except mass offset were changed or adjusted. All samples ran smoothly and no problems or irregularities occured during the tests. The maximum for each peak was determined and the information compared to the addressed position to determine mass drift. If the mass drift became excessive (e.g. 1.0 amu), it was re-zeroed by changing the "Mass Offset" parameter. A routine to automatically adjust this parameter will probably be incorporated in the next iteration of programming. The actual mass drift appears to be very low.

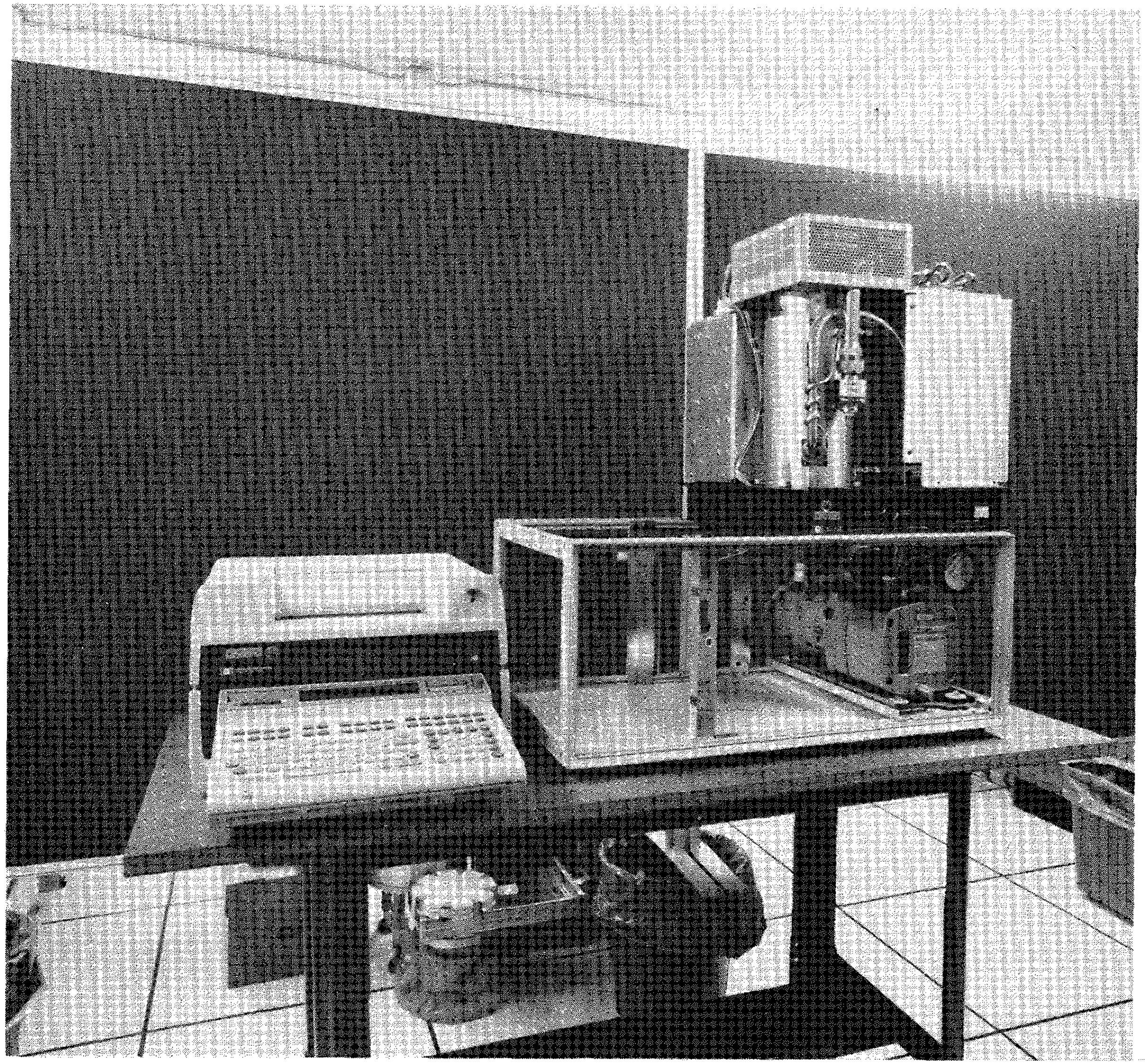


Figure II-2 Modifications to the Hewlett-Packard Corp. Model 5992 GCMS have converted the instrument to a solid (or liquid) source, thermal emission filament.

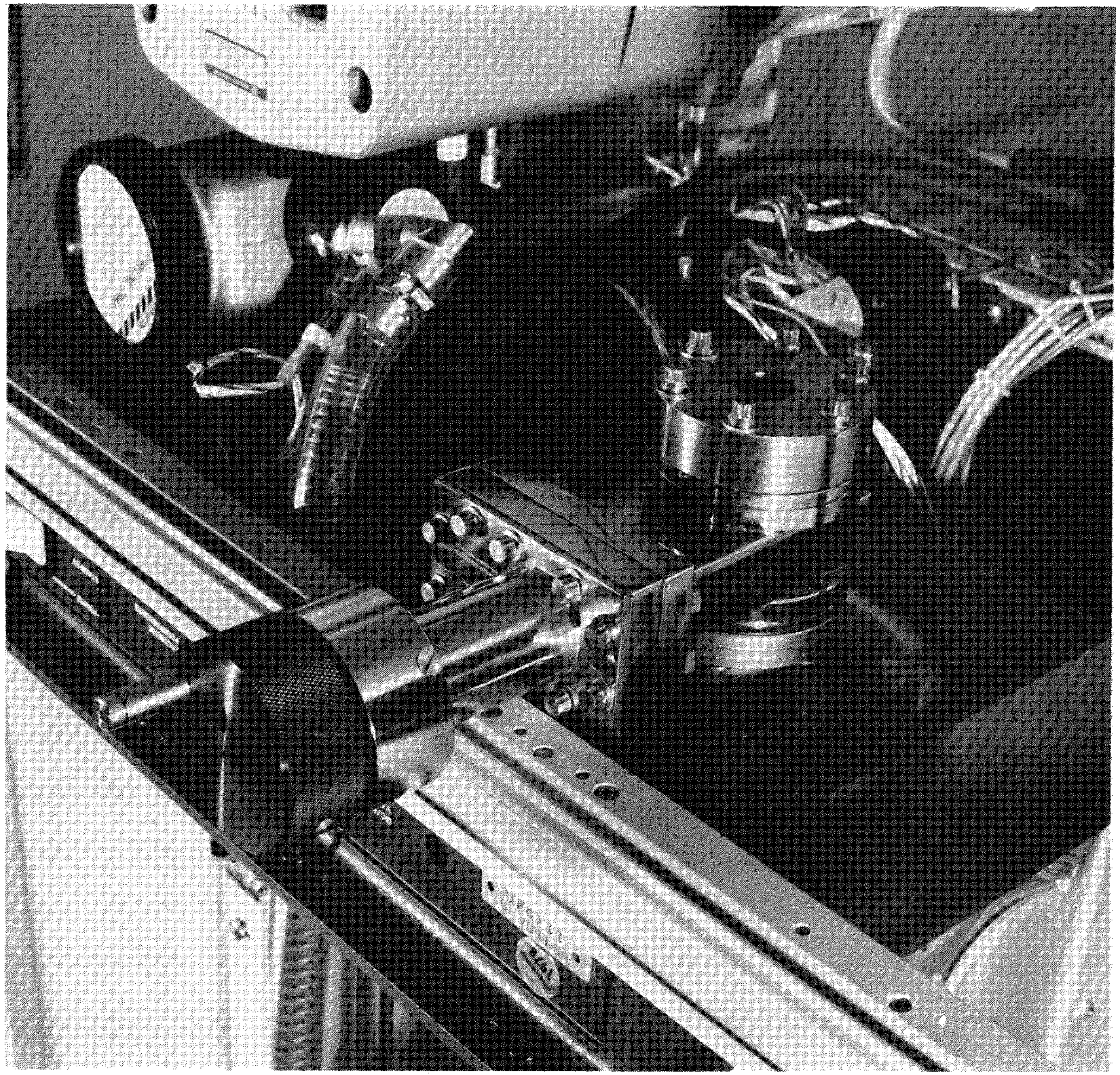


Figure II-3 Vacuum lock with probe removed

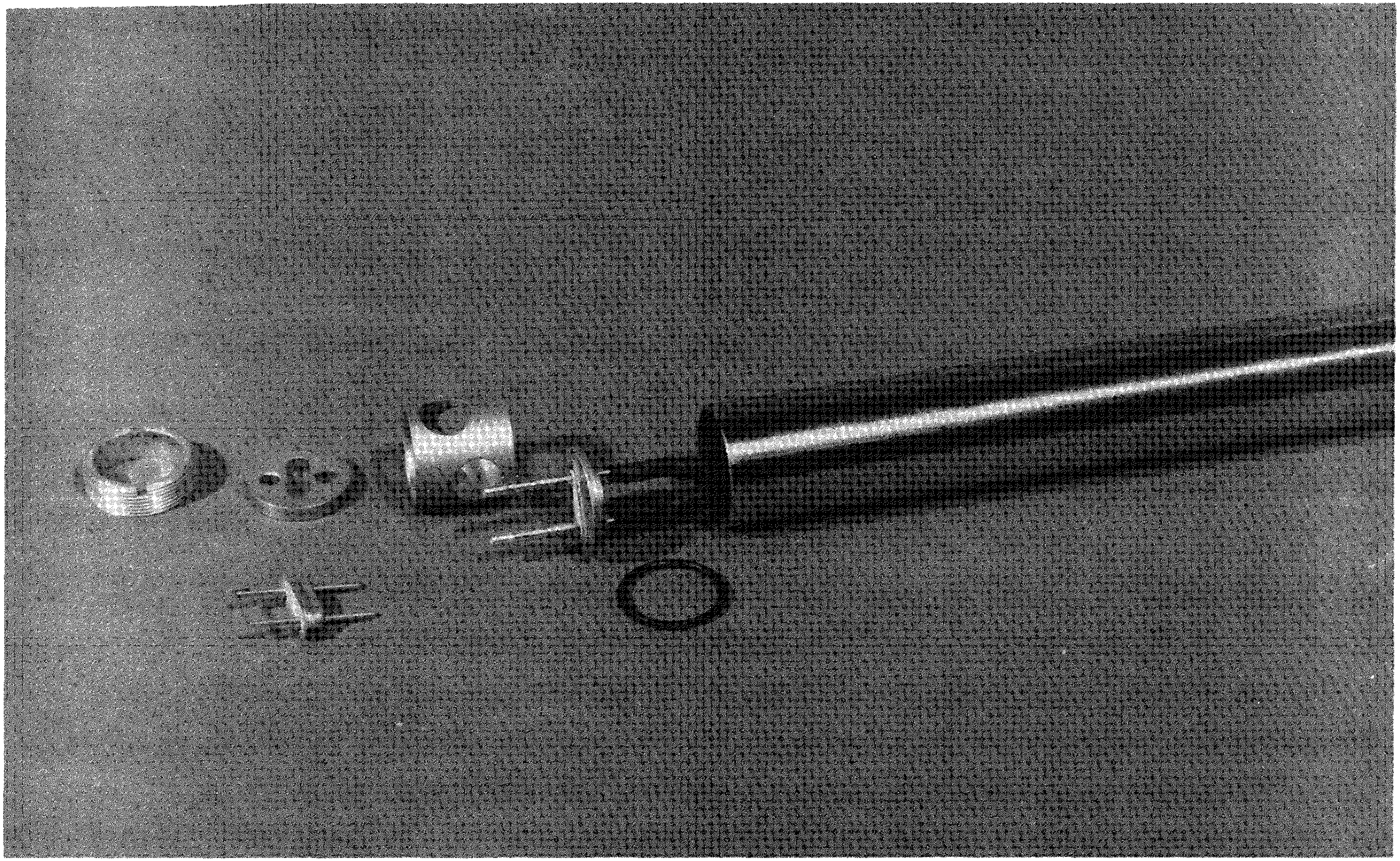


Figure II-4   Exploded View of Vacuum Lock Probe

A smoothing function was applied to the data to improve the results. Smoothing improved the accuracy in most of the runs. There was need for additional improvement, and further work should be planned to find a more optimum smoothing function. The test data show that for Uranium in the enrichment range of 5% to 93% (NBS050 to NBS930), the instrument will measure the 235 to 238 isotope with an accuracy of better than 1%. Figure II-5 shows a plot of a typical spectrum with results. This plot is actually three consecutive runs on the same sample with the traces superimposed. The separate traces are indistinguishable. Resolution is 230 and abundance sensitivity is 8800. These tests concluded the preliminary modification and evaluation program and showed the modified instrument to be a successful candidate for Safeguards work.

Work on the Hewlett-Packard instrument will continue into FY 1980 and will include mechanical improvements, data reduction and program improvements and completion of the cabinet work.

C. Ion Instruments Inc. Magnetic Sensor Instrument (M. W. Echo)

A transportable, magnetic mass spectrometer was specified and bid for construction in FY 1980. Although somewhat larger and heavier than the Hewlett-Packard instrument, the magnetic instrument appears to be an otherwise competitive candidate. The contractor did not progress satisfactorily and the contract was terminated. The new contract was awarded to a different contractor, Ion instruments Inc., of Tulsa, OK. Originally scheduled for delivery in late May, 1979 the machine was not delivered by the end of the fiscal year, due mostly to programmming difficulties. However, this instrument was inspected and operated at the vendor's plant by ENICO engineers in September, 1979 and lacked only some final adjustments and software revisions before delivery.

Testing and evaluation of the instrument will start as soon as it is received, and should be completed within first quarter, FY 1980.

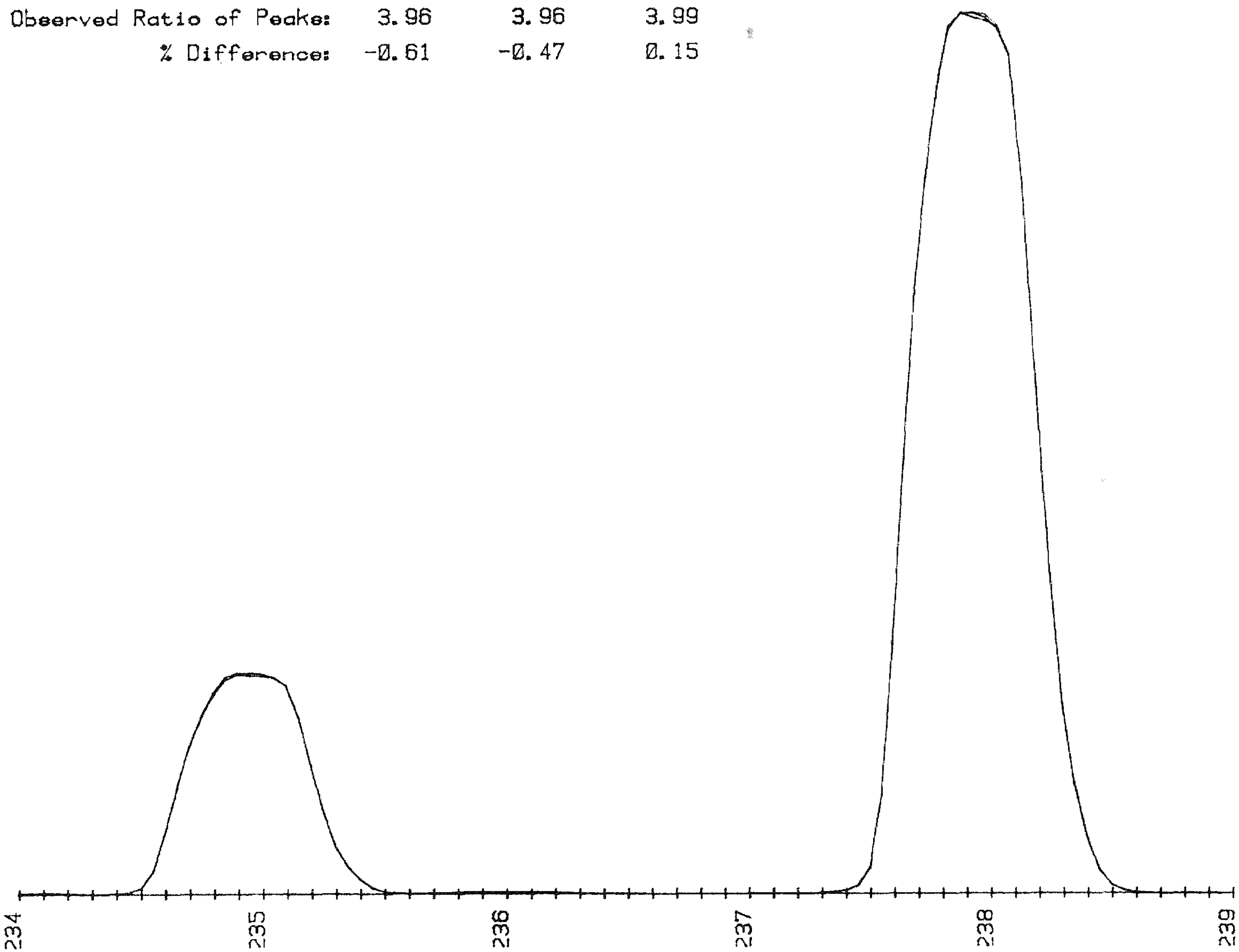
Plot of Uranium Std NBS 200   7/30/79

True Ratio of 238/235= 3.9800

FIGURE II-5

Observed Ratio of Peaks: 3.96   3.96   3.99

% Difference: -0.61   -0.47   0.15



III. SENSOR AND INSTRUMENT DEVELOPMENT (Task 1.3)

The objective of the Sensor and Instrument Development task is to identify and evaluate candidate devices with safeguards monitoring potential. As specific safeguards monitoring objectives are identified, the latest sensor and instrument technologies are surveyed for applicability, and candidate or prototype devices are selected (or developed), tested and evaluated. Successful tests in the laboratory may be followed by testing in the operating plants under the Task 1.4, Test and Evaluation System.

A number of devices were developed and tested in FY-1979. These potential safeguards devices include flow detectors, liquid-in-line detectors, a uranium analyzer, a flowmeter, and level and density transducers. Criteria considered in the evaluation are better accuracy, improved reliability, ease of installation, environmental problems, and operability.

A. Transit-time Bubble Injection Flow Meter (T. C. Piper)

This flow meter operates by measuring the time for an injected bubble (large enough to fill the tube) to pass a fixed distance between two ultrasonic sensors attached to the tubing. The flowmeter is calibrated by measuring transit times at known flow rates. The obvious problems are: bubble shape and size must be reproducible, bubble detection must always occur at the same location on the bubble as it passes each sensor, the flow tubing must be level so that the bubble bouyancy does not assist or impede the bubble movement, and the tubing inside surface must be smooth so that the bubble does not stick.

Initial laboratory tests of the transit time, bubble injection flow meter concepts were made several years ago. At constant flow it was shown to measure flows with errors of 0.5% or less. These tests also showed decreased device accuracy and repeatability if the bubble injection was not carefully controlled or the flow path was irregular.

This year, a bubble flow meter test was assembled in the ICPP low bay pilot plant for a combined test with the gamma absorptiometer. The module constructed for the tests had flow stability and bubble injection problems. As a consequence, the previously demonstrated flowmeter performance was occasionally reproduced. The bubble flowmeter concept offers the possibility of accurate measurement at low flow. It is adaptable for measuring flow of highly corrosive liquids. It should not require repeated calibration. Because of the importance of accurate flowmeters for process measurement, the test program was restarted to isolate problems and determine whether the concept can be implemented to operate reliably. Components for tests were gathered and the assembly of the apparatus is nearing completion. Tests are scheduled to start next fiscal year (FY 1980).

B. Pressure Transducer Tests (F. L. Bentzen)

Precision pressure transducers measure level and density in plant tanks. The initial tests identified zero drift and stability in the candidate transducers. Two types of transducers were tested in a temperature controlled environmental chamber. These were Digiquartz* and Kavlico Corp. differential pressure transducers.

Figure III-1 shows the effective zero shift with temperature for two 0 to 1.0 Kg/cm^2 Digiquartz transducers. The pressure was measured every 30 minutes and the temperature changed 5^oC every 4 hours for a week. The graph illustrates the small temperature variation and excellent repeatability of these units.

Figure III-2 shows the zero shift with temperature for a single 0.07 to 1.0 Kg/cm^2 transducer, manufactured by Kavlico Corp. Note that each division on the ordinate is ten times larger than on the previous graph indicating a zero shift with temperature of about ten times greater than that of the Digiquartz units. A more significant effect is the repeatable discontinuity at approximately 30^oC which developed over a period of 6 months operation (possibly due to cycling to high temperature). Nevertheless, interest in the Kavlico units remains because the transducer mechanism, a ceramic capacitor, has promise of excellent repeatability and the unit cost is less than one-tenth of the Digiquartz units. The lower cost could justify installation where a single, more expensive unit or where multiplexing was undersirable. Additional Kavlico Corp. gauge and absolute pressure units have been purchased and are scheduled for testing next fiscal year.

A Ruska Corporation Model DDR-6000 pressure calibrator was ordered to provide computer-controlled pressures of sufficient accuracy for testing precision transducers. Expected delivery is second quarter of fiscal year 1980. Twelve Digiquartz transducers for the ICPP safeguards system were received and are scheduled for evaluation prior to installation.

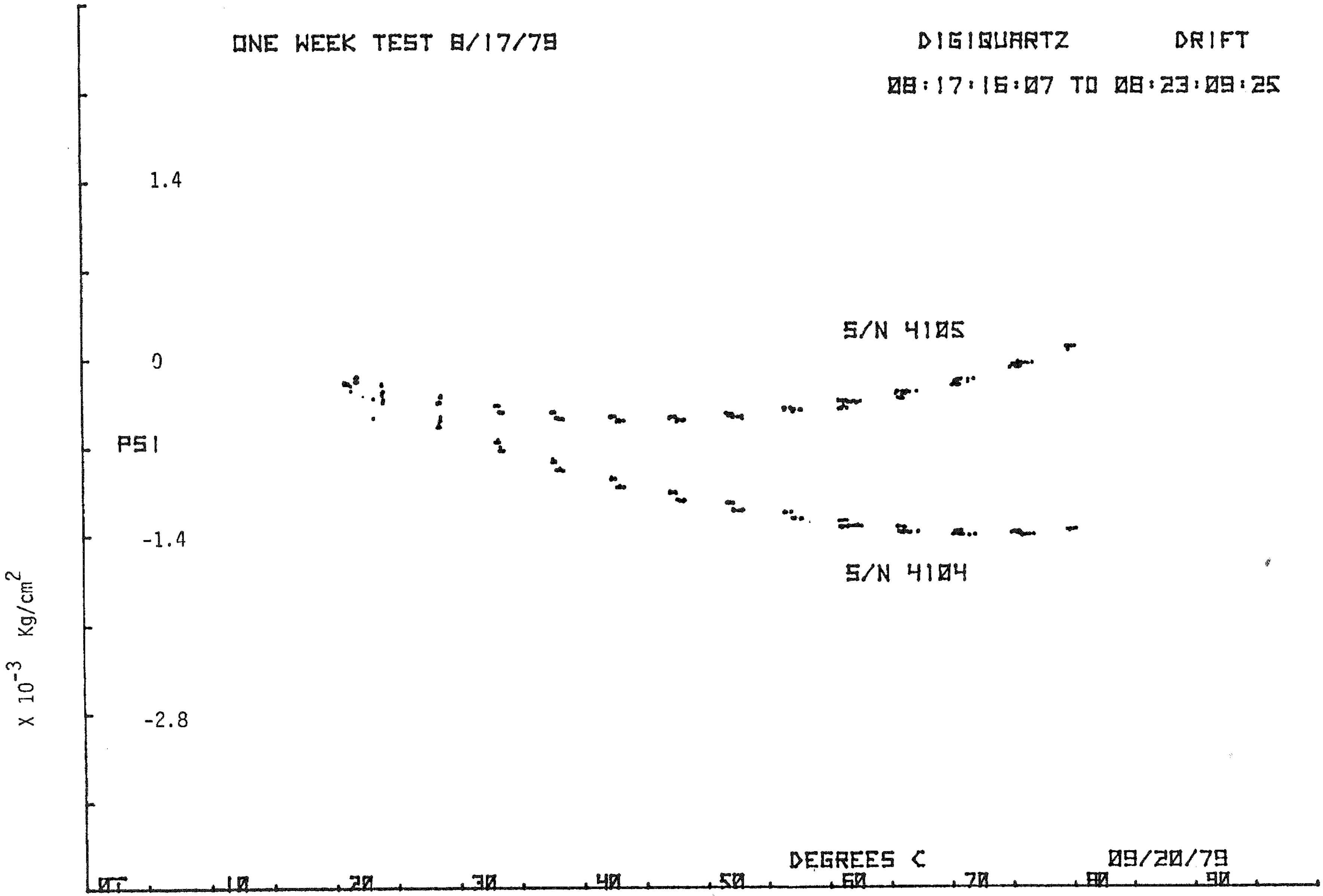


Figure III-1, Digiquartz Pressure Transducer Temperature Drift

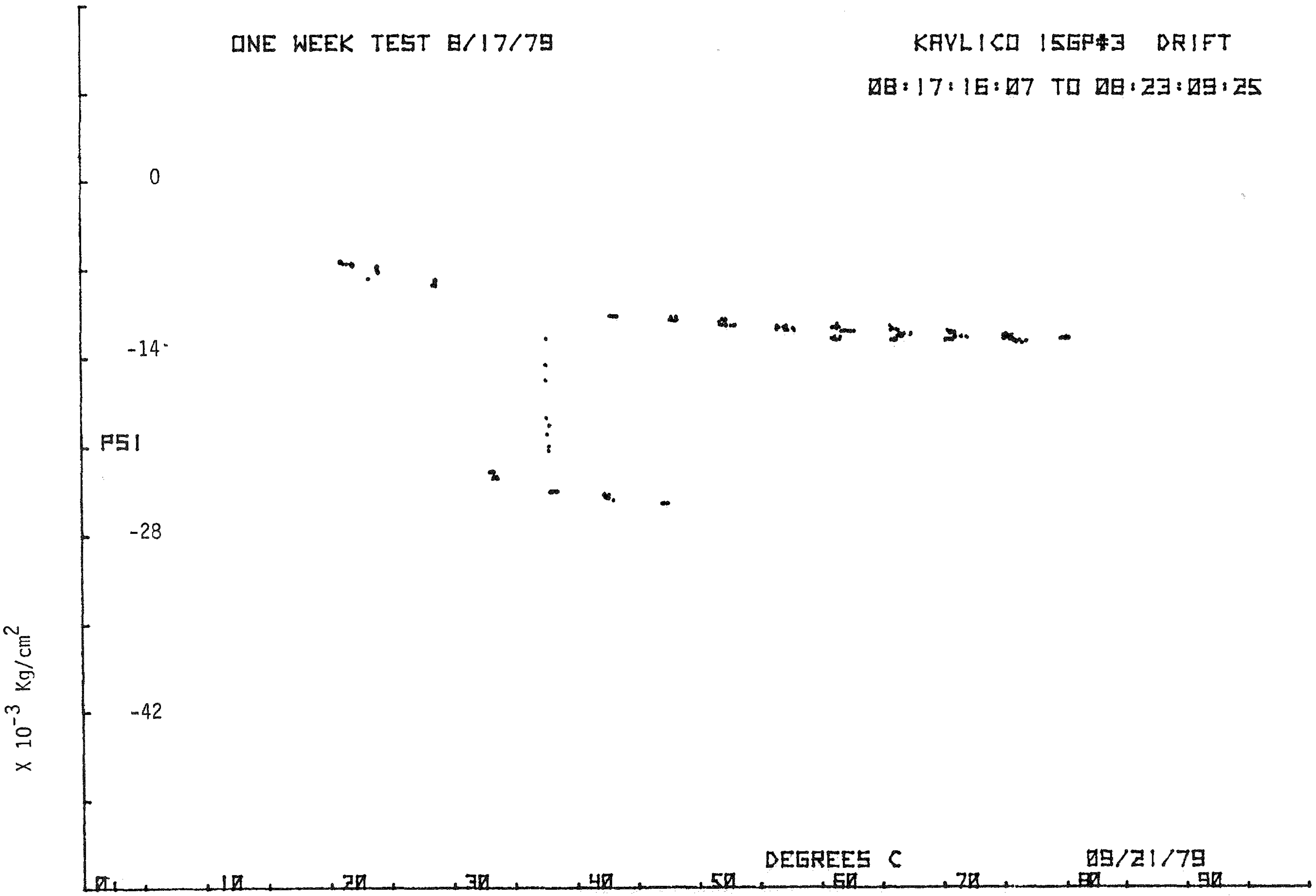


Figure III-2, Kavlico Pressure Transducer Temperature Drift

The environmental chamber was modified to eliminate the use of liquid nitrogen during long runs at temperature slightly below ambient. A cooling coil was installed and an on-off control valve supplies drinking water as a cooling medium. The modifications were for tests over narrow temperature ranges. It was less successful over wide temperature ranges because the large heat removal capacity of the cooler required manual adjustments of water flow to prevent overrunning the capacity of the proportional heater.

C. Gamma Absorptiometer (R. E. LaPointe, F. O. Cartan)

A dual-energy absorptiometer was originally designed and built for the measurement of plutonium product concentration in the G.E. Midwest Fuels Reprocessing Plant. A duplicate instrument was built for uranium product analysis in the Idaho Chemical Processing Plant.

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* Trade name for differential pressure transducer that uses a pressure stressed quartz crystal oscillator. It is manufactured by Paroscientific Inc.

The absorptiometer measures gamma transmission at two energies, 59.6 Kev (Am-241) and 662 Kev (Cs-137). Measurement at two energies allows correction for variations in nitric acid concentration. The isotope source can be blocked which measures background solution radioactivity for correcting readings. The absorptiometer was designed for uranyl nitrate-nitric acid solutions with uranium concentrations of 0-350 g/L.

The instrument was calibrated in a pilot plant module in the ICPP lower bay area. The observed accuracy was less than the instrument in the dual energy mode, the average difference between actual and measured value was 2.24 g/L. Table III-1 shows the results of these calibrations. Based on precision of individual measurements, the precision of the dual energy measurement should have been 0.74 g/L. Operating in the single energy mode, with known acid concentration, the standard deviation of a measurement was 3.0 g/L.

These results were less accurate than previous laboratory data where the standard error (8.35 g/L) and the measurement precision (0.50 g/L) were roughly equivalent. Handling alterations of the standard solutions is suspected as the cause. The solutions will be checked next fiscal year.

The instrument was stable, and the response independent of flow. A measurement took approximately 4 minutes.

The design, construction, and performance of the absorptiometer are described in a document currently being published (ENICO-1019).[2]

DUAL ENERGY GAMMA ABSORPTIOMETER MEASUREMENTS OF URANIUM CONCENTRATION

Acid Conc(M)	Uran. (g/L)	Meas. Uran (g/L)	Diff. (g/L)
0.5	0.0	1.25	-1.25
0.5	98.37	98.08	0.79
0.5	190.60	195.22	-4.62
0.5	245.51	245.46	0.05
0.5	291.67	298.92	-7.26
4.5	0.0	1.18	-1.18
4.5	0.0	0.27	-0.27
4.5	100.53	95.20	5.33
4.5	197.58	197.29	0.29
4.5	274.87	275.22	-0.35
9.0	0.0	0.20	-0.20
9.0	98.21	93.63	-0.42
9.0	192.06	198.84	-6.78
9.0	292.90	297.29	-4.39
9.0	350.42	350.00	0.42

Table III-1 Comparison of actual and measured uranium concentrations in a series of uranyl nitrate nitric acid solutions. Measurements made with dual energy gamma absorptiometer.

D. Ultrasonic Liquid-in-Line Sensor & Electronics (T. C. Piper)

Liquid-in-line sensors are used to detect liquids where they should not be present, such as instrument lines that could be used as diversion routes.

Most commercial sensors that detect liquids in normally vacant lines require pipe penetrations. The only easily implementable, commercial sensor not requiring line penetration is made by National Sonics Corp. and uses ultrasonic through-transmission operation. The National Sonics System is unsatisfactory because instrument failures indicate "liquid-empty" rather than "liquid-full" sense and because it does not work on small (0.64 cm(0.25 in) outside diameter) tubing.

Several configurations of ultrasonic liquid-in-line sensors were then designed, constructed, and tested.(3) Each of these designs utilized some sensing mechanism other than the through-transmission signal. Of these designs, two gave favorable operational results: the flexural drive of a flattened region on a 0.64 cm (0.25 in.) O.D. tube, and multiple reflection of shear waves around the circumference of tubes of about 0.95 cm (0.375 in.) O.D.

Only the flexural mode, 0.64 (0.25 in.) O.D. tubing transducer was developed. It is "fail safe" in the normally liquid-empty sense in that it alarms on the presence of liquid and also on all other normal failure modes. Figure III-3 shows the unit ready for making the final seal welds

The electronics for driving sixteen sensors in a sequential switching method with digital buffered output of the results of each channel was designed, and the finished product assembly was started. Sixteen sensors and one set of multiplexing electronics will be installed in the ICPP in January, 1980.

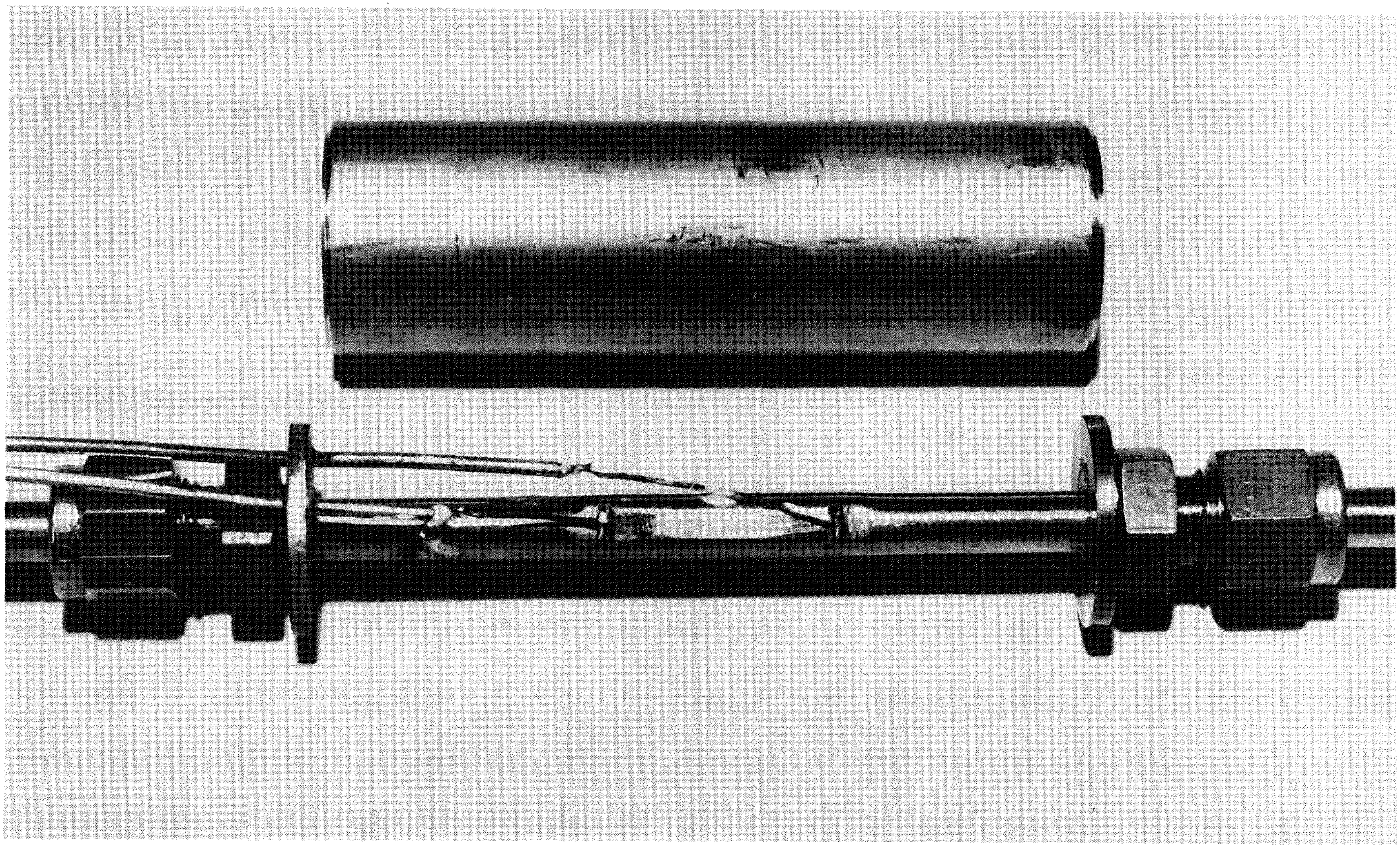


Figure III-3   Ultrasonic detector for liquid in normally empty lines.

E. Thermal Fluid Flow Sensor (F. L. Bentzen)

This class of safeguards sensors is being developed to detect "trickle flows" in plant lines where such flows may indicate incorrect plant or diversion operations.

A non-intrusive fluid flow sensor meeting this need was tested for safeguards monitoring. This sensor can rapidly detect an unauthorized transfer in a monitored line. The device consists of a heater placed on one side of a pipe carrying liquid or gas and a thermal detector placed on the other side. Under non-flow conditions, the heater raises the temperature of a short length of the pipe or tube and its contents to a stable temperature about 10 to 20^{o}C higher than ambient. A thermocouple, thermistor, or resistance thermometer detects the temperature and a monitor verifies the stability. As flow starts, perhaps caused by a diversion or a leaky valve, the heated liquid moves down the line and is replaced by cooler liquid causing the pipe wall temperature to decrease. The change in temperature indicates flow and triggers an alarm.

Laboratory tests were performed using nitrogen or water as fluid with line sizes from 0.64 cm (0.25 in.) tubing to 2.54 cm (1.0 in.) pipe and with thermocouples, thermistors, or RTD's for the temperature measurement. Figure III-4 shows one of the laboratory test arrangements. The speed and sensitivity of flow detection are dependent on the size of the line and the specific heat and conductivity of the fluid within the line. Small lines change temperature faster than large lines, and lines containing liquids change temperature faster than lines containing air. Typical temperature changes range from a low of .01^{o}C in 10 seconds

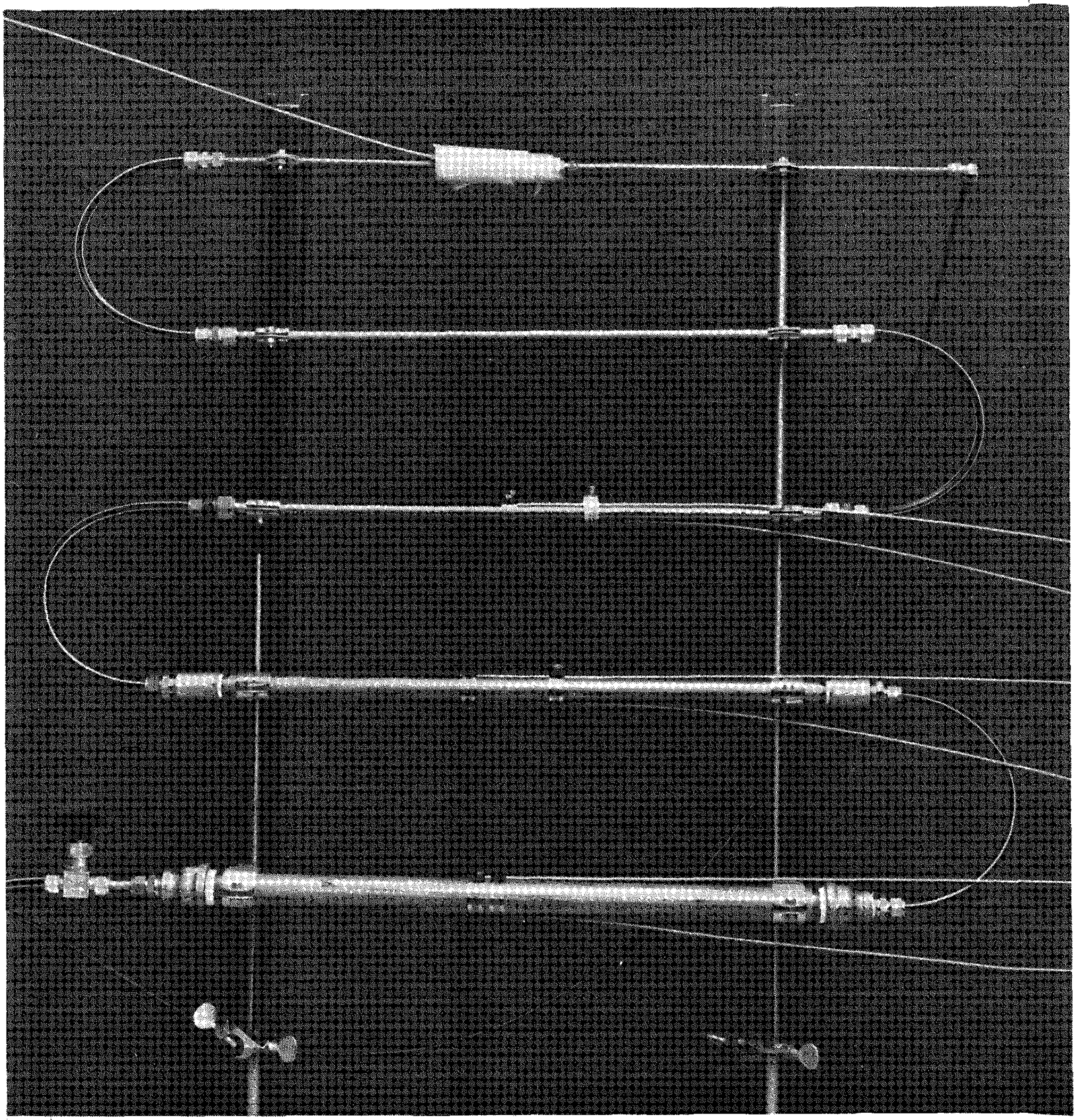


Figure III-4 Fixture for testing Flow Detection in different size pipes.

with a 200 cm^3/min N_2 flow in a ¼" tube to several degrees C for a few ml flow of water in the same time period. As an example of the sensitivity to liquid flow, the pipe temperature dropped more than .1^oC in 10 seconds when only a few drops of water were taken from a 0.64 cm (0.25 in.) line.

Design parameters include the type of temeprature detector, the type of heater and whether or not thermal insulation is required. Other design parameters are affected by the environment around the pipe to be monitored. Some locations within highly radioactive cells with acid decontamination sprays require heater and thermal detector containment in stainless steel.

A sensor design was selected for the ICPP tests. Hundred ohm RTD's (resistance temperature devices) encased in stainless steel will be used for both the heater and temperature detector. For each sensor location, two RTD's will be clamped, one on each side of the pipe, with stainless hose clamps without thermal insulation. Resistance measurement of the

RTD's will be made with a low level scanner or multiplexer and a precision multimeter under computer control. The computer requests a resistance measurement, calculates the temperature and stores the value. A speci- fied time later, e.g. 10 seconds, another reading is taken. If the second reading shows a temperature decrease exceeding a set limit, more than .1^oC for example, a message is sent to the main computer. If the reading difference is less than the change associated with a flow, the computer stores the new temperature value and repeats the process. By updating the temperature at every reading, the system will follow slow changes in temperature without alarming.

The heater can be powered with either alternating (A.C.) or direct (D.C.) current. The ICPP installation will use D.C. to evaluate heater reliability during the test period.

Design was started for a microprocessor controlled monitoring system for these sensors. The separate monitor may be viable in locations where the signal leads to a central computer would be too expensive or too long for reliable operation. The microprocessor could combine and interpret temperatures from many sensors and provide alarm signals to the main computer in the Task 1.4, Test and Evaluation System over two-wire, shielded pair cable.

F. Load-cell Evaluations (T. C. Piper)

In some safeguards applications, a reliable method of measuring tank contents independent of the usual bubbler probes is needed. Direct weighing with load cells is an attractive method. Because of the need to make accurate tank weight measurements, a program of testing and comparing load cell from various manufacturers was started. Device accuracy of about 0.05.% full-scale was the goal in order to compete with precision pneumatic level (and volume) measurement. High Precision load cells with full scale ranges of 100 to 300 pounds were purchased from three U.S.manufacturers and one German manufacturer. The first tests were measurements of the zero-load stability of the cells at three hour intervals with the cells operating at room temperature. In these very basic tests, three Lebow Associates, Inc. load cells and a single Sensotec, Inc. load cell showed too much zero drift to meet the primary safeguards accuracy goal of .05% of full-scale. The single Celesco Inc. load cell purchased had the strain gage bridge intact but one lead of the connecting wires was "open". Four, German fabricated, 100 pound, Hottinger Baldwin Measurements Inc. (HBM) load cells were also tested for no-load zero-stability.

The HBM load cells passed the zero-stability checks, with variations of only ±0.003 lbs., they will be started on the remaining evaluation tests such as drift under load, hystersis, and repeatability. A single HBM cell was tested for drift under load. The results of this test were not complete but indicated that drift under load may be significant.

IV. TEST AND EVALUATION SYSTEM DEVELOPMENT (Task 1.4)

An integrated Safeguards development computer system is being installed in the ICPP (Idaho Chemical Processing Plant) to test the performance of Safeguards sensors and to develop methods for analysis of the sensor data. The system consists of: sensors detecting plant parameters, a small computer system collecting sensor information, and a powerful computer to consolidate and analyze the information. The analyses include determining sensor reliabiltity, stability, decontamination properties, and repair history. This information will influence sensor selection in future systems. For the development of Safeguards analysis techniques, the data base collected by the system will support test and evaluation of the analysis software. The system will also serve as a demonstration and training tool. Most of the sensing devices are process monitoring sensors and instruments currently available from equipment suppliers. The devices are selected and qualification (preliminary) tested within Task 1.3, Sensor and Instrument. The Development successful candidates are added to the system to provide the safeguards material control and monitoring functions as outlined in Table IV-1. System implementation in FY 1979 consists of several tasks needed to design the system, install the sensors in the Idaho Chemical Processing Plant (ICPP) and install/program the computer data acquisition and processing systems. Major implementation tasks established criteria for ICPP installation.

- System sensor and instrumen selection identified the initial devices for ICPP testing and evaluation.
- Plans for the system installation were designed as well-documented work packages for device installation by ICPP craftsmen.

- Previously installed process monitors provided test data for concept refinements and device selection information.

- Data acquisition and processing systems were designed as . distributed computer system with data acquisition and communications processors at the ICPP and the analysis computer at Central Facilities, several miles from the plant.

Table IV-1, Safeguards Concepts for Testing at the ICPP

- Precisely measure volume and weight to compliment and enhance accountability measurements.

- Monitor the process to observe process activity and confirm operation according to approved procedures.

- Observing solution and material movements to detect and confirm transfers and estimate material balance changes.

- Monitor abnormal material withdrawal routes as possible diversion paths.

- Compare multiple instruments and check process parameters to verify monitoring system information and insure detection of information tampering.

A. System Sensor and Instrument Selection (E. P. Wagner)

The selection of monitoring devices required review of monitoring concepts to identify information needs, surveys of current sensor and instrument technology for suitable candidates, and review of ICPP instrument experience and environmental constraints. This information was compiled in a design criteria document to guide implementation.

System Design Criteria Report

The System Design Criteria Document (ENICO-108)[4] was used as a working paper throughout the year and has been revised several times. The document breaks the sensors into twelve sensor classes listed in Table IV-2 and describes their various applications in the system. The number and location of sensors in the plant system is given on a cell-by-cell basis. The process is described in a separate section.

Sensors Selected for Plant Installation (See Table IV-2)

1) Class 1-Pressure Switches

Requirements for all three applications for class 1 sensors were satisfied by the Static-"O"-Ring Inc. "Omni" pressure switch. This model features 316 stainless steel internals, 1500 PSI overrange pressure and the choice of a field adjustable, set-point 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 Z-cell.

2) Class 2-Air Flow Monitor

For flows exceeding 1.5 CFM, the Brooks Model 7930 MAG/NA/LARM II, 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 flow rates using an extension type rotameter. No suitable flow monitor was found for sampler air lifts, sparges for 5" diameter tanks, or certain process airlifts which use less than 0.5 SCFM air flows.

3) Class 3-Pneumatic Instrument Monitors

A 64 channel Scanivalve pneumatic multiplexer and pressure transducer was successfully operated for more than one year for collection of process data. The unit monitors 3-15PSIG (0.2 1.0 Kg/cm^2) plant instrument signals in parallel with control panel process instruments.

4) Class 4-Liquid-in-Line Detectors

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

Table IV-2 Candidate Sensors and Applications (24 different devices)

- Pressure Switches

  Steam Jet Monitoring
  Sample air jets
  Remote-controlled valves

- Flow Monitor
  Air (sparging)
  Sampler air lifts
  Process air lifts

- Pneumatic Instrument Signal J(3-15 psi) Monitor

- Liquid-in-Line Detector

Instrument lines	Jet steam line
Sampler suction lines	decontaminating line

Sampler air lift line   process air lift line

Sparge line

- Jet Temperature Detector

  Thermocouple

  Temperature Switch

- Electrical Current Detector

- Precision Differential Pressure Transducer

- Manual Valve Position Indicator

- Pressure Transducer

  Differential Pressure

  Absolute Pressure

- Tank Temperature Transducer

- Electrical Instrument Signal (4-20 ma) Monitor

- Process Liquid Flow Monitor

Where significant suction would be required for liquid removal, Static-"O"-Ring vacuum switches (Model 54BA-KB-4-C1A) were selected. Two types of blocking devices have been designed to block the insertion of siphon tubes without restricting flows in lines with access to vessels and tanks.

5) Class 5-Jet Temperature Detectors

Stainless steel clad, MgO insulated type K thermocouples successfully monitored steam jet transfers in the Ziconium dissolver cell (E-cell), See Figure IV-2. The devices will be used in other cells (F and G-cells) where an unambiguous steam pressure signal cannot be obtained. The. thermocouples are 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 Detector

Standard enclosed relays are adequate for this application.

7) Class 7-High Precision Pressure Transducers

Paroscientific Inc., "Digiquartz" model pressure transducers have been selected for plant installation. The devices were selected on the basis of proven accuracy and reliability, small physical size, and small pneumatic switching volume.

A box containing the transducers and pneumatic multiplexing equipment has been designed for plant installation. This box allows as many as four tanks to be monitored with one pair of transducers. The favored 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.

8) Class 8-Manual Valve Position Monitors

No suitable candidate devices have been found.

9) Class 9-Pressure Transducers

Gould Co. Model PTG-1000 series pressure transmitters were selected for monitoring 3-15 PSIG pressure lines in areas where there are too few signals to justify a Scanivalve Inc. device. Gould Co. Model PA-3000 series absolute pressure transducers were selected for monitoring absolute pressure in certain vessels and glove boxes. Both transmitters are constructed of 316 stainless steel and hermetically sealed.

10) Class 10-Tank Temperature Monitors

Existing plant thermocouples will be tapped to provide needed signals

11) Class 11-Electrical Instrument Monitor

Existing plant devices will provide signals for all required applications.

12) Class 12-Process Liquid Flow Monitor

A candidate device was developed to detect temperature changes caused by moving fluid in a heated, insulated section of pipe (See section III.E.) 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. System Design and Installation (E. P. Wagner)

Detailed Work Package

The test and evaluation system installation design is a series of nine work packages for accomplishment by ICPP maintenance personnel. Each work package provides the installation design for part of the system. The installation areas within individual work packages approximate process cells, but some have been grouped and others divided between two packages to correspond with field installation conditions. Each package has several stages:

1. Detailed design, specification writing, and drafting.

2. Design review and approval.

3. Planning and scheduling.

4. Construction

5. Inspection and testing. The Z-cell (Uranium Product area) package construction was 80% complete with installation remaining for the new control panel. This work was subcontracted to an out-of-state contractor for FY 1980.

The Cell-5 (electrolytic dissolver) and PM (Process make-up) conduit work package and the G (aluminum dissolver) and H-cell (First cycle extraction) work package are in maintenance planning and scheduling. Construction will begin in first quarter FY 1980.

The E (aluminum dissolver) and F-cell (centrifuge) work package is ready to submit for planning and scheduling.

The J-cell (Hot recycle storage) work package is being reviewed.

The P,Q, and S-cell (second and third cycle extraction) work package design is 75% completed.

Work package designs for N (First cycle storage), U, W, Y (Raffinate storage) and the PM (Process make-up) area were not started.

Procurement

All individual components for the Z-cell package were procured before start of construction.

A subcontract was awarded to Contronics of Columbus, Ohio for fabrication of the new Z-cell instrument and control panel. Delivery and installation is expected in early December, FY 1980.

Precision Pressure Transducers and associated hardware for fabrication of pneumatic multiplexer boxes were procured for the remaining work packages. Pressure and vacuum switches and instrument tubing were also obtained for the remaining work packages.

Interconnection Document

A document was drafted for a systematic list of all possible flow paths for process fluids and the valve, pump, or transfer jet sequences necessary to define them. This document, (ENICO-110), provides a check on the adequacy of the system design, and a basis for computerized analysis of plant data.

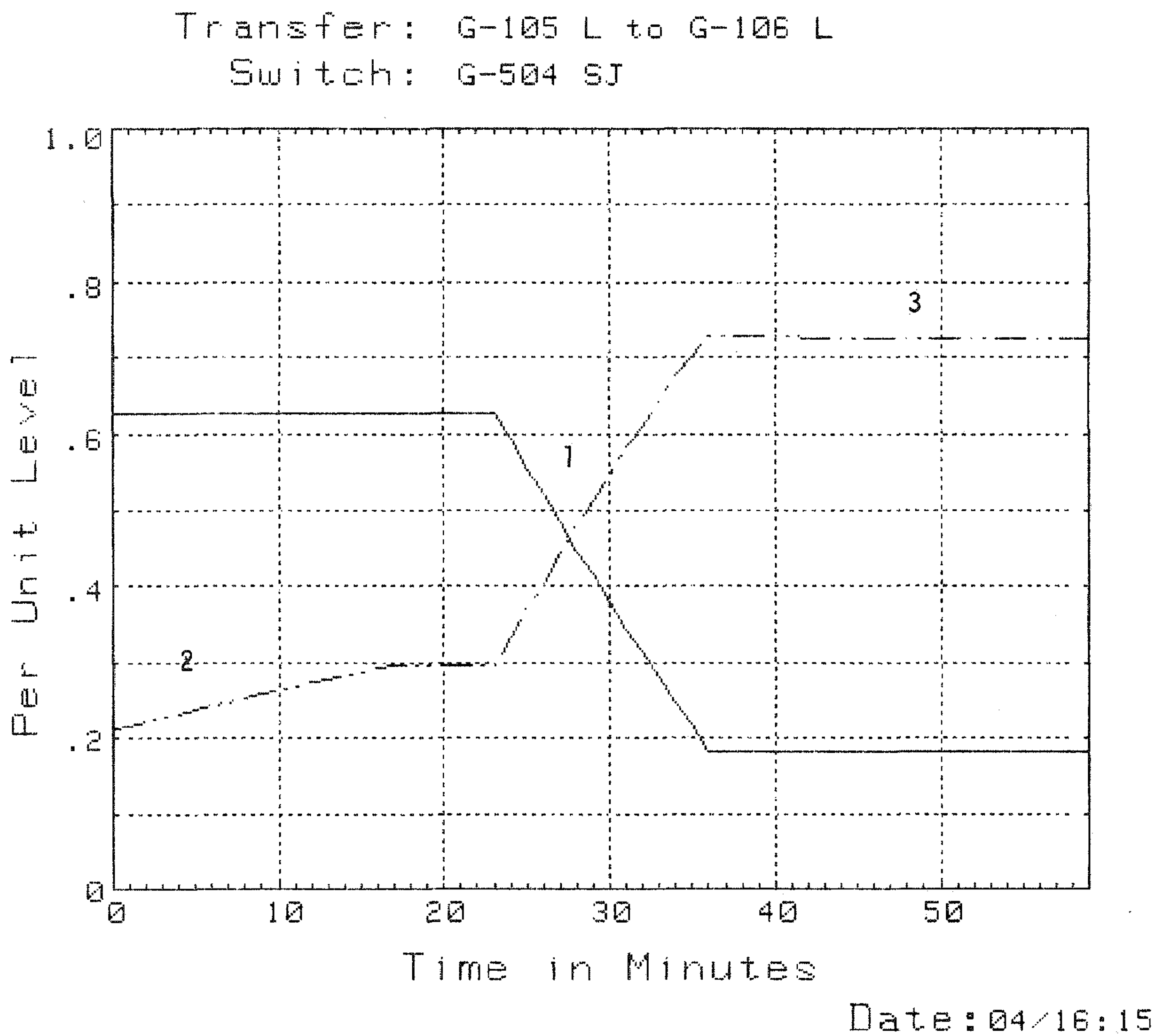
In the process of writing this document, several potential problem areas were noted, which were identified to plant operations personnel for correction.

C. Interim System Test and Evaluation (E. P. Wagner, H. R. Deveraux)

A small-scale (60 inout) monitoring system collected data during the plant sweepdown during April and May. A report, currently under review, gives more detailed analysis of the date (ENICO-109).[6]

Pneumatic Signal Monitoring

The Scanivalve Inc. unit performed well throughout the period plant pneumatic for monitoring the 3-15 PSIG (0.2-1.0 Kg/cm level and density signals. The major limitation to tracking material transfers with this unit seems to be non-homogeniety of tank contents, leading to erroneous density values. This limitation is probably worse during sweepdown than during normal operations. The effect will be studied in more detail during subsequent processing. Figure IV-1 shows levels for the G-105 accountability tank and the G-106 first cycle feed tank. Notice: 1) the



Transfer: G-105 L to G-106 L
Switch: G-504 SJ
1.0
.8
.6
.4
.2
0
Per Unit Level
0
10
20
30
40
50
Time in Minutes
1
2
3
Date: 04/16:15

Figure IV-1

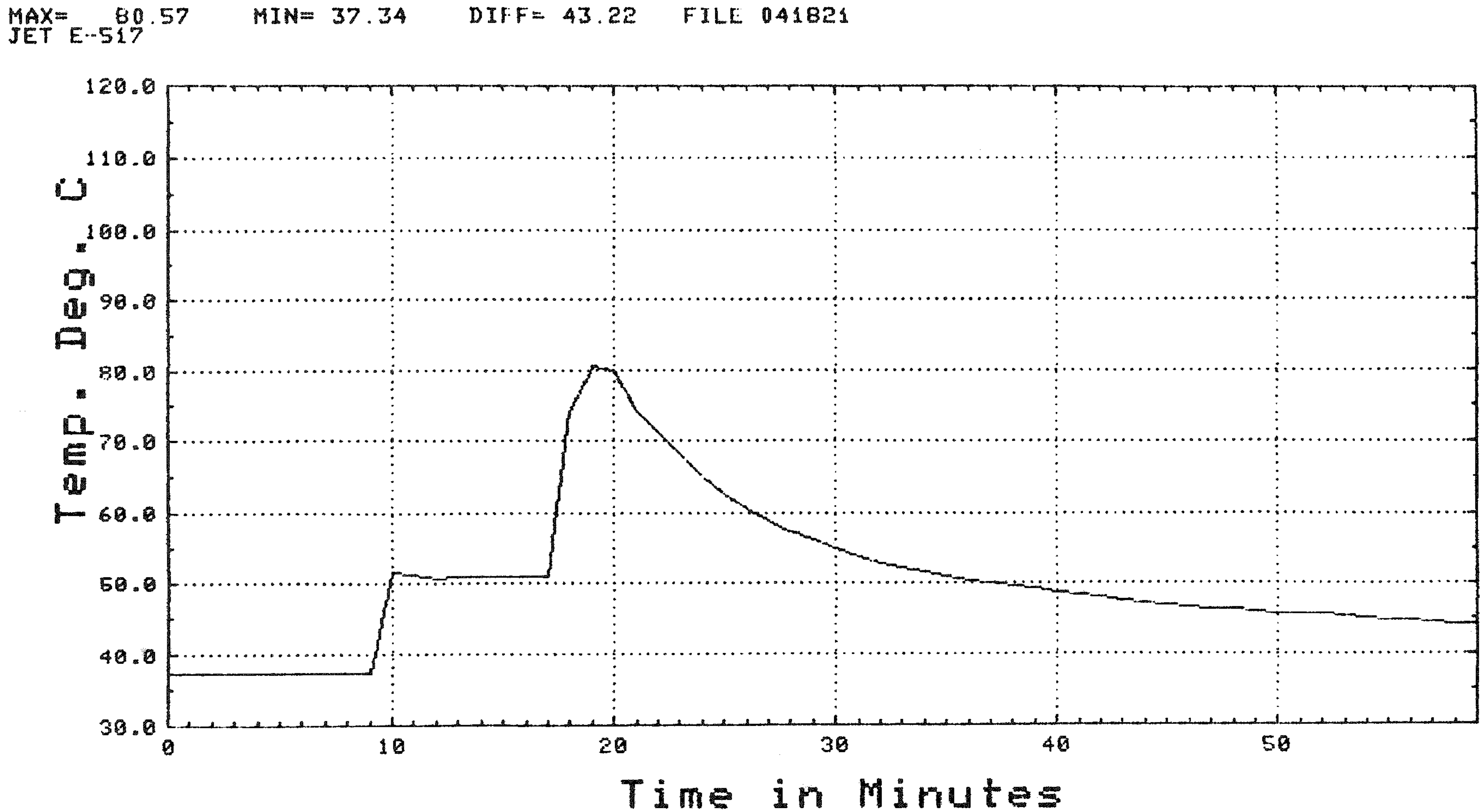
transfer from G-105 to G-106 which can be correlated in time and quantity transferred, 2) the transfer to G-106 not originating from G-105 and, 3) the stable level of G-106, which shows no feed to the first cycle extraction columns. This operational information verifies other monitors such as remote controlled valves, transfer jets, and other tank density and level indications.

The experimental thermocouples mounted on E-cell steam jets function well. Significant information about the performance of the jets was collected which may provide a significant new tool for plant operations. The thermocouple data was sufficient to define the beginning and the end of transfers. Figure IV-2 shows the temperature profile for a G-cell steam jet. The plot shows steam jet activiation (37^{o}C to 51^{o}C jump) a stable 51^{o}C temperature plateau during the transfer, and a sharp temperature rise to 80^{o}C after all liquid is transferred.

Precision Pressure Transducer Box

A multitransducer test box was installed in the PM (process make-up) area in FY 1978.The goal was to test three level and three density precision pressure transducers. The precision transducers were arranged for switching the primary Pneumatic signals from the G-105, 155 accountability tanks and the G-106 feed tanks with solenoid valves with the objective of collecting data for performance comparison. Switching transients introduced into palnt instruments limited this operation. Data collected during the sweepdown consisted of the three transducers in parallel without pneumatic switching.

Figure IV-2, Temperature Profile for Normal Steam Jet Operation



Good level data were obtained from all three tranducers. The data correlates well with that obtained from plant transducers via the Scanivalve. An as yet undetermined failure prevented data collection on the density transducers. Pneumatic multiplexing was suspened to prevent introduction of spurions signals into plant instrumentation. Table IV-3 shows comparative data for the precision Ruska Inc. and Paroscientific Inc. pressure transducers. Pressures are the level probe data from the accountability tank, G-105 as it was emptied.

The level variations very closely match the plant instrument readings. Note the very close agreement in difference between pressure readings between time 0 and time 22. The mean and standard deviation of pressure difference is .01743 PSI and .00023 PSI. This standard deviation corresponds to less than 0.01% F.S. or to about 0.016 inches of water.

Pressure Switches

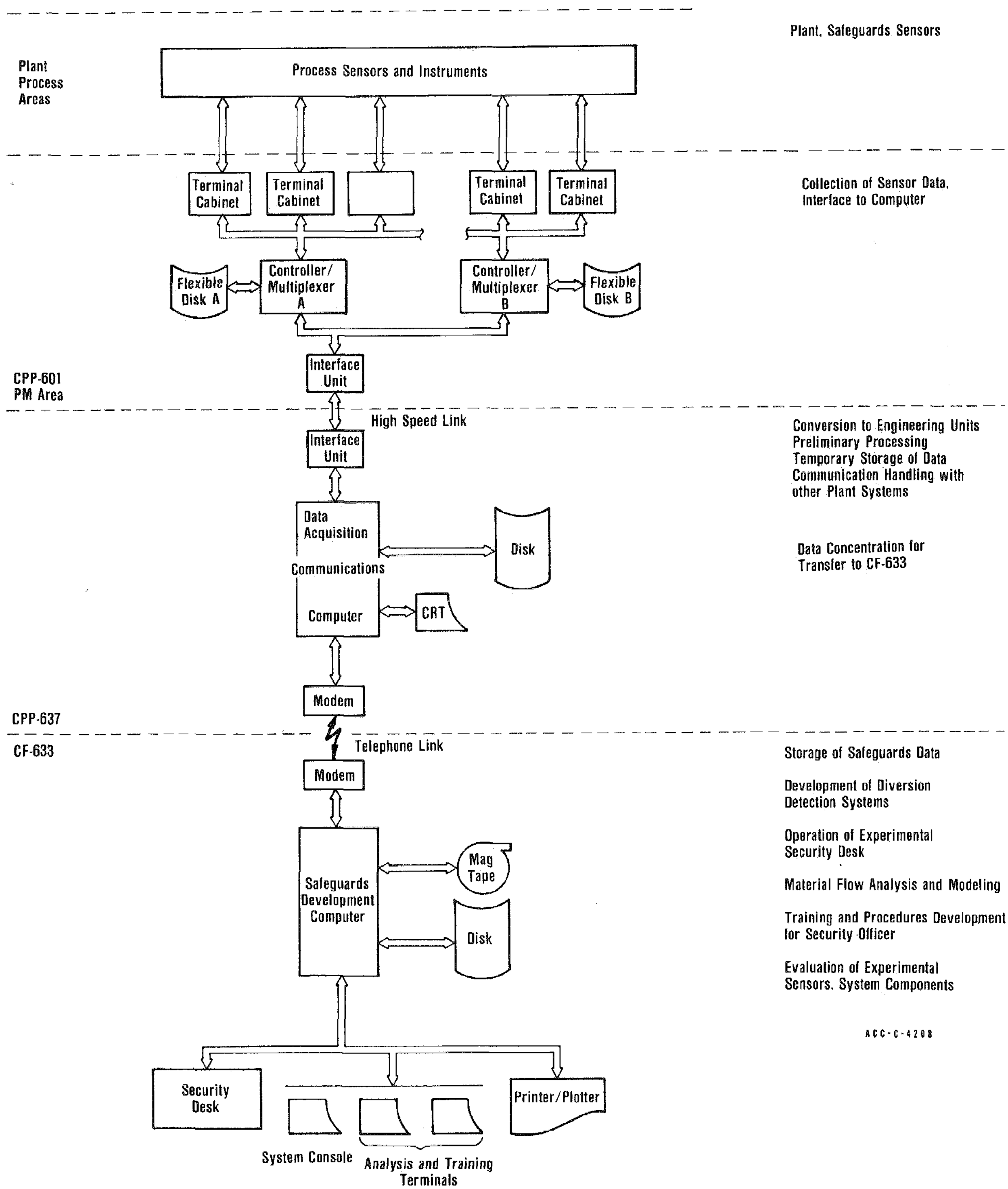
The pressure switches installed to monitor operation of steam jets and air operated valves functioned well and their output correlated with observed changes in tank levels. A few errors in wiring were found during the run which emphasized the need to thoroughly check all system con- nections during installation.

D. Data Acquisition Supervisory System (H. R. Deveraux)

The preliminary design of the total computer system was completed first quarter, Fiscal year 1979. The basic configuration is shown in Figure IV-3. Note the distributed processing capabilities in the design:

SAFEGUARDS DEVELOPMENT SYSTEM

Figure IV-3, Conceptual Design for the Safeguards Development Computer System



the on-line analysis and interactive terminal support on the large mini-comouter at Central Facility, the data acquisition and communications control (Supervisory System) computer at the ICPP technical building (CPP-637) and the distributed instruments and controller processors in the Chemical Processing Plant (CPP-601).

From the manufacturers bids received in March, 1979, the data acquisition and communications control (Supervisory System) complete contract was awarded to Hewlett-Packard Corporation for a Model 9845 desk-top computer. This is the same computer model selected for the Tokai Advanced Safeguards Technology Exercise (TASTEX) program for Tasks E (electric mamometers for input calibra- tion) and I (Monitoring the plutonium product area) (Reference: TASTEX Program Plan, International Safeguards Project Office, Brookhaven National Laboratory. Revised January 15, (1979). Some experience and software developed under the TASTEX program can be applied to th ICPP data acquisition task.

The Supervisory System was delivered in August, ahead of schedule. The components were checked against technical specifications and all capabilities were verified. The computer meets the procurement specifications for data acquisition and instrument control, data communications control, and back-up independent system data storage.

Further testing and programming in the Fiscal year 1980 will complete ICPP data collection and instrument control programs.

Table IV-3, Precision Pressure Reading for The Transfer shown in Figure IV-2

Data for G-105 Transfer. Date: 04/16:15 (All Readings in PSI)

Time	Ruska	Digiquartz	Diff	Time	Ruska	Digiquartz	Diff
0	2.963	2.981	.01763	1	2.964	2.981	.01704
2	2.963	2.981	.01762	3	2.980	2.980	.01737
4	2.964	2.982	.01720	5	2.963	2.981	.01748
6	2.963	2.980	.01701	7	2.963	2.981	.01776
8	2.963	2.980	.01737	9	2.964	2.981	.01724
10	2.963	2.980	.01757	11	2.964	2.981	.01717
12	2.964	2.981	.01762	13	2.962	2.980	.01749
14	2.964	2.982	.01724	15	2.963	2.981	.01757
16	2.964	2.981	.01748	17	2.963	2.980	.01743
18	2.962	2.979	.01764	19	2.964	2.981	.01728
20	2.963	2.981	.01767	21	2.964	2.981	.01711
22	2.964	2.982	.01778	23	2.920	2.914	-.00596
24	2.686	2.672	-.01379	25	2.427	2.414	-.01342
26	2.176	2.162	-.-1387	27	1.924	1.910	-.01378
28	1.674	1.661	-.01360	29	1.432	1.418	-.01383
30	1.194	1.181	-.01320	31	.961	.947	-.01355
32	.733	.720	-.01294	33	.508	.495	-.01359
34	.288	.277	-.01130	35	.129	.122	-.00659
36	.014	.023	.00891	37	.003	.015	.01188
38	-.000	.012	.01211	39	-.003	.008	.01136
40	-.003	.009	.01260	41	-.002	.010	.01202
42	-.001	.012	.01230	43	-.002	.011	.01243
44	-.001	.011	.01188	45	-.001	.011	.01242
46	-.002	.010	.01206	47	-.001	.012	.01227
48	-.002	.010	.01249	49	-.002	.010	.01194
50	-.001	.011	.01246	51	.003	.009	.01214
52	-.002	.010	.01227	53	-.003	.010	.01256
54	-.002	.010	.01200	55	-.002	.011	.01252
56	-.003	.010	.01230	57	-.001	.011	.01218
58	-.002	.010	.01260	59	-.002	.010	.01209

E Safeguards Development Computer (A. V. Grimaud)

Technical **specifications for the** analysis support computer system were completed in the first quarter of Fiscal year 1979. The contract was awarded to Digital Equipment Corporation (DEC) on a model VAX-11/780 mini computer. The VAX-11/780 Safeguards Development Computer was delivered and installed in July, 1979. The system was tested according to procurement specifications and accepted August 15, 1979. The initial warranty period extended into FY 1980. A requisition was issued for DEC contract maintenance support for the remaining part of FY 1980.

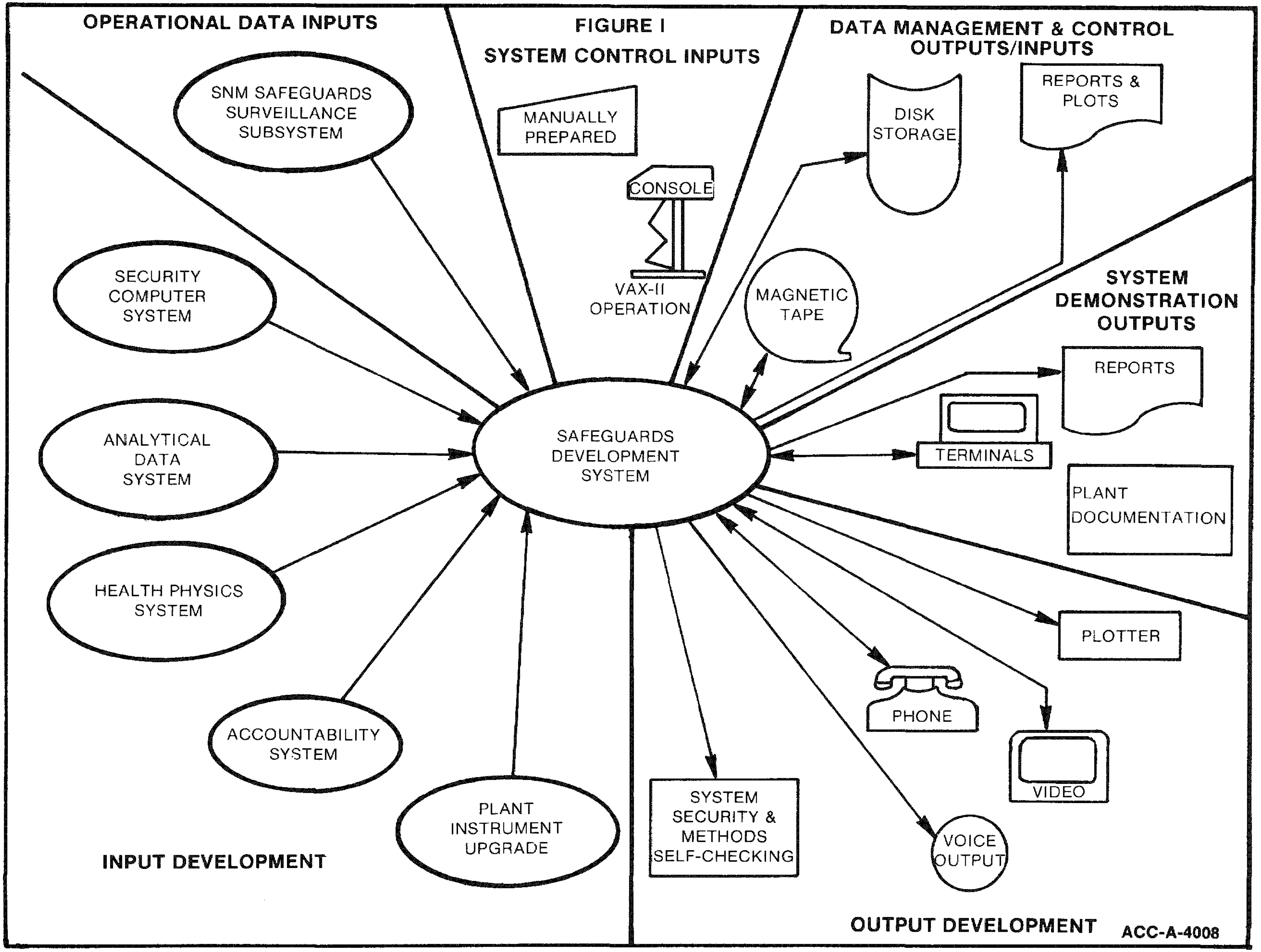
A set of exercise programs were prepared to test the system. The programs were repetitivly executed in the computer background to confirm the VAX reliability and provide operational experience through the warranty period. From installation to the end of FY 1979, several minor components failures have occurred but DEC immediately corrected the problems.

The VAX VMS software system version 1.5 is operating properly. Two Hewlett-Packard Corp. CRT terminals were connected to the system and provide initial input capability. In addition to processing the test exercise programs, a variety of system programs have been tested and appear to be satisfactory. These include the Fortran and Basic compliers, text editing, record management and sorting capabilities.

The system manager completed the VAX Introductory and System Manager Course at the DEC training center. The audio-visual courses for "Introduction to the VAX-11/780" and the "VAX Instruction Set" were procured and were studies by four individuals.

A draft design document for the total safeguards test and evaluation computer system was submitted to DOE-ID for review. This document was revised once to include additional design information. The preliminary design of the Computer Data Base was completed and work started on detailed specifications, flow charts, and programming on initial phases of the system. Figure IV-4 is a schematic of the Safeguards Development system. As implementation progresses, it will receive input from six systems and provide support to a range of output systems using a variety of media.

Figure IV-4, System Diagram Showing Information Inputs and Outputs



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