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ABSTRACT

This memo briefly describes the design philosophy, control actions and functional operation of the instrumentation and control associated with the ORNL-20 in-pile experiment operated in the MTR in 1955-6. This material was previously issued as an undocumented memo.

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I L L U S T R A T I O N S

Figure No. 1 - Temp. Rate of Rise Following Sudden Stoppage of Fluid Circulation.

Figure No. 2 - Electrometer Current/Mr/hr - CO^{60}
(source in air).

Figure No. 3 - $3 \cdot \text{CO}^{60}$ - Mr/hr. (source in air).

Figure No. 4 - 4 Mr/hr vs. Distance in CM.

Figure No. 5 - $5 \cdot \text{CO}^{60}$ - 1 mc Mr/hr vs. Distance.

Figure No. 6 - Data for GM Tube Pairs Using CO^{60}
Collimated Source.

Figure No. 7 - Main Control Panel.

Figure No. 8 - Electronics Rack.

Figure No. 9 - Experiment Annunciator Functions

M. T. R. IN-PILE LOOP INSTRUMENTATION

1.0 PHILOSOPHY OF THE SYSTEM

1.1 GENERAL

Experiments in the ORNL-20 In-Pile Loop present some unique reactor control problems because of the high flux densities and heat generated within the loop. Further, thermal transients due to plugging of the loop, pump failure, etc. give rise to dangerous temperature levels within one second or less (see Fig. 1). These conditions require that, whenever possible, any scram signals or alarms on the system react within a few milliseconds to avoid damage or complete destruction of the loop and possible creation of severe radiation hazards.

Thus, instrumentation must be reliable and trouble-free. This requires that no one instrument or circuit can be completely relied upon to sense or correct a dangerous condition, but that each operation must be supported by an equal, or secondary channel. This requirement increases the tendency of the system to generate false requests for scram because of the more complex circuits involved. Therefore, provision is made to double-track where the most dangerous conditions may exist in the reactor. This double-tracking of the instrumentation may be explained briefly as follows:

- 1) A dangerous condition in the experiment is detected by two or more independent detectors (not necessarily simultaneously) that feed a signal into their respective receivers.
- 2) A request for power reduction actuates a relay or pair of relays located near the experiment, and their contacts pick up two relays in the reactor instrument room. The relays in the instrument room actuate relays which start action to give the required power reduction. Duplicate relays and even duplication of wiring is used to insure proper operation of the scram equipment.

- 3) In the event that the control system does not react when action is demanded by the independently operating detectors, a secondary, backup system is actuated that will control the reactor. The alarm detectors for this backup circuit are set slightly further from the initial control set point than the primary detectors. Means are also provided to operate portions of the system manually while control instruments are being serviced or replaced.

1.2 SCRAM CONTROLS

1.21 General

This experiment can automatically request any of three reactor control options: (Refer to Dwg. Q-1633-80).

1. Slow Scram - Complete shutdown (1% of full power in approximately 1 second).
2. Junior Scram - 1% of full power in 56 seconds.
3. Fast Setback - log. reduction to 1% full power in 90 seconds.

1.22 Slow Scram

1.221 General

The senior scram option is reserved for actions of the most serious order; these actions are those which indicate the loop piping has failed or is in immediate danger of failure. Actions causing automatic slow scram are described in the following sections.

1.222 Coolant Air Activity

This circuit examines the heat exchanger air coolant for large increases in radioactivity. It serves as an additional monitor for checking the piping integrity as in Section 1.221. If the piping containing the circulating fluid were to rupture allowing the coolant air to contact the circulating fluid, the radioactivity of the coolant air would increase greatly.

1.223 High Nose Piping Temperature

This circuit consists of a 12-point Brown strip-chart temperature recorder examining 12 key temperatures on the loop. The bulk of these measured temperatures are on the fission-heated section of the loop piping. A multipoint recorder is used in order to obtain an "auction" type system where the highest temperature initiates control action. The multipoint machine is a compromise since it has dead periods when changing from one temperature to the next. However, by judicious choice of thermocouple inputs to the machine it is insured that if high temperature rate of rise conditions occur, any point on the machine will observe the danger conditions. It is deemed wise to use this type of system for scram purposes since other temperature protective circuitry (see Scram) should insure that this scram is not tripped unless temperature runaway conditions are present.

1.224 Pump Speed Variation

The most likely cause of high temperature accelerations in the piping would be caused by stoppage of the fluid circulating pump permitting static fluid to remain under high flux conditions. Since temperature rates of rise of almost 1000°F/second are possible (see Fig. 1), it is imperative to shut down the reaction as quickly as possible. Since at these temperature accelerations the time required to shut down the reactor is long compared to the allowable upper limits of the pipe temperature this device is heavily relied upon to attempt to save the metallurgical data of the experiment. Variations of up to 450 rpm from the design point initiate a scram. The lower limit would be reached if the pump bearings were to seize. The upper overspeed limit might be reached if the pump impeller sheared off the shaft. A duplicate pickup is provided

in the loop in event of failure of the pickup in use. This duplicate pickup is connected to the spare pump speed monitoring unit and supplies an annunciator signal at $\pm$ 200 rpm variation.

The response time of this device is less than 15 milliseconds.

1.225 Low Hydraulic Oil Flow

This control measures the return oil flow to the sump from the hydraulic motor. Failure of the hydraulic pump or any high pressure lines will result in a low oil flow and consequent stoppage of the fluid-circulating pump. The system first sounds a low oil flow annunciator and upon further flow reduction initiates a scram.

The above six control conditions may be divided into a three information types:

- 1) Anticipatory failure action.
- 2) Impending failure action.
- 3) Post failure action.

Pump speed variation and low hydraulic oil flow from hydraulic motor represent category 1, (prefailure or anticipatory information). The slower low flow signal serves as a "double track" for pump speed variation. High nose piping temperature serves as notice of an impending failure. Small perturbations in operating conditions are handled by the temperature control system while greater excursions from design point are caught by the slow scram. Air coolant activity indications are signs of loop piping failure and call for immediate power reductions.

1.23 Junior Scram

The junior scram option is used for less severe conditions in the loop. Actions causing a junior scram are described as follows:

- 1) High Nose Purge Activity - radioactivity in this purge line indicates

failure of the loop piping and consequently fluid leakage outside the containing piping. A scram is necessary since the failure has already occurred and continued operation of the reactor even at reduced power might discharge large amounts of activity.

- 2) High Liner Pressure - if sufficient water leaks into the inner container to contact the hot piping, possibly dangerous high pressures could be generated. The same result would be obtained if the helium purge line should become plugged. Thus the reactor power should be reduced while this condition is investigated.
- 3) Low Flow Jacket Cooling Water - if water were to be removed from the outer liner during operation, the structure might be damaged by excessive gamma heat. Thus the reactor power is again reduced until the condition is corrected.
- 4) Nose Outlet Temperature - as mentioned earlier these two single point recorders reduce the reactor's power whenever temperature becomes excessively high. Two recorders and independent thermocouples are used to give an extremely reliable system.

1.24 Fast Setback

The fast setback method of reducing reactor power is used in the event the piping temperature is too low and possible freezing might occur. Normally the reactor power will be reduced only until these low temperature control actions are cleared. This system also serves to keep the reactor below 1% full power unless the loop temperatures are in the range for proper operation.

NOTE: All thermocouple recorders mentioned above as causing reactor control action have thermocouple burnout provisions. This mechanism acts to drive the recorder pen in such a direction so as not to cause reactor control action.

Thus if a thermocouple opens on a high temperature alarm machine, the recorder will drive downscale and will not trip the alarm. This places the burden of routine inspection of all recorders on the operator on duty to insure that they are working properly. The burnout direction of any recorder is painted inside the front door of the machine. All electronic recorders should be manually standardized once every 8 hours. At this time the battery condition indicator should be observed to determine if renewal is necessary.

A complete tabulation of annunciator alarm indications and automatic control actions will be found on

Complete details on instrumentation may be obtained by referring to the individual instrument specification sheets.

1.3 PANEL LAYOUT

1.31 General

The control panel as may be seen from Figure 7, consists of eight standard panels and an enclosed relay cabinet. Mounted over the panel are 32 annunciators and a clock. Power required for the panel is 120/208 V.A.C., 3 ϕ and 220/380 V.A.C. 3 ϕ . Compressed air and He services are also required to place the panel in operation. Provisions are made for complete power distribution within the panel. A separate, independently protected circuit and duplex outlets are provided on the rear of the panel for test equipment, soldering irons, etc.

1.32 Control Panel Layout

The two left hand panels contain the 40 control relays, 12 pressure switches and two main circuit breakers for the entire control panel and electronics rack. These panels are completely enclosed and are fitted with weather stripped doors to permit limited access to the enclosed equipment. The doors must be kept closed at all times to prevent sand, dust, and water from fouling the relay contacts.

Panel #1 contains a strip chart recorder that monitors miscellaneous low temperatures and four running-time meters that measure experiment duration and operating time on the rotating equipment. Below the running time meters is the protected scram button. This switch will scram the reactor at any desired time. The Key-lock equipped experiment bypass "W" switch will, when thrown to "off", remove all automatic protective circuits from the reactor. This permits checkout of the panel with the reactor running. If, during operation, an automatic scram is sent to the reactor, before the reactor can resume operation the scram reset button must be depressed. Two rows of circuit breakers provide power to all of this experiment, i.e., instruments, motors, etc. Each circuit breaker is approximately labelled. These breakers have been carefully chosen as to current-carrying ability so as to preclude any possibility of ever tripping the main circuit breakers. All circuit breakers are of the magnetic type and may be reset immediately.

Panel #2 contains two Brown strip chart recorders. The upper recorder monitors miscellaneous system temperatures. The lower recorder monitors the outputs of the six health physics monitors. If any monitor exceeds 90% of the scale, an annunciator will alarm and the alarm light below the recorder will glow. After the condition causing the alarm has been rectified, depressing the alarm reset button will clear the alarm light and annunciator.

Panel #3 contains a Brown dual-pen strip chart recorder reading nose inlet and outlet temperature. This instrument essentially consists of 2 single pen units contained in one case. Both pens of this machine are tied into the reactor control circuits. There is one pushbutton for each control unit that bypass the recorder and limit switches. This permits work being done on the re-

corder without affecting the control circuit. This dual-pen recorder and the recorder on Panel #4 are designated TRX 2, 4, 6, 8. The pushbuttons for bypass are designated PB 16, 17, 18, 19, as per drawing Q-1633-5_{R9}. On this and other recorders used for control purposes, extreme caution must be exercised in opening the instrument door and swinging the instrument out of the case since the mercury type control switches in the machine may be accidentally tripped by opening the instrument carelessly. Standard Foxboro miniature pneumatic recorders are used to receive the 3-15 psig output of various process pressure transmitters. Complete notes on these instruments are available in the pneumatic instrument instruction book. The remainder of this panel is devoted to hydraulic pump controls. Each hydraulic unit is equipped with on-off pushbuttons and pilot lights. For pump speed control a G.E. SB-1 switch and associated upper and lower limit lights are provided for each of the hydraulic units. For convenience in operation a meter indicating speed duplicates pump speed readings from the unit in the 4th electronics cabinet. This panel also contains the monitron.

Panel #4 contains another dual pen Brown recorder duplicating the readings of the previously-mentioned unit for safety. The miniature Foxboro recorders are similar to the units on panel #3. The center recorder is, however, a controller also and is the unit controlling the air throttling valve. Instructions for transferring from manual to automatic control and methods of initially adjusting the controller are contained in the pneumatic instrument instruction book. Below these units are located the annunciator acknowledge and reset pushbuttons as detailed on Drawing No. Q-1633-79. Adjacent to these pushbuttons are a voltmeter and ammeter indicating the output of the voltage controller. The air compressor on-off lights are also on this panel. These lights are actuated by the air compressor starter and indicate when it is in operation. An annunciator will

alarm whenever the compressor is off.

Panel #5 contains the Nose Piping Temperature recorder used for reactor scram. The alarm light below this recorder indicates when the alarm setpoint has been reached. If the scram is tripped by TRX-1, the recorder must be reset before the scram reset button. This sequence must be followed before the reactor can go back up to power. Two pressure gauges and a flow controller for measurement and control of the nose purge atmosphere are also located on this panel. It should be noted that the flowmeter reading must be multiplied by a conversion factor to obtain scfh of He. The flow control system will maintain a constant mass flow with constant upstream and varying downstream pressure. Regulators, pressure gauges, and flow recorders for instrumentation of the pump He purge systems are also located on this panel. The flow recorder is calibrated in terms of the pressure drop across a section of capillary tubing used as a flow element. For conversion from inches H₂O pressure drop to He flow in scfh refer to D. W. Magnuson's graph on these elements. All instruments in the He control systems on this panel are of the non-bleed type for economy in gas usage and safety of the operator. Since these gas purge systems connect to extremely radioactive sources of gas in the loop it is imperative that gas flow be maintained at all times. A gas flow stoppage could possibly result in radioactive gas appearing in the panel piping and thus forcing evacuation from the control panel area.

Panel #6 contains two Brown single pen strip chart recorders. The upper recorder continuously monitors the power of the MTR. The circuitry of this system is so built that in the event of failure of the sensing element, its connecting cables or the high voltage power supply, the recorder will be driven

all the way upscale. Thus an upscale reading indicates trouble in this channel. This is done to avoid energizing the automatic heater controls as is mentioned elsewhere. The lower recorder is a special, modified unit serving as a thermocouple-to-air output transducer. This unit supplies a signal to the temperature controller previously mentioned. Complete details on this unit are in the pneumatic instrument instruction book. Below these recorders are a bank of ammeters reading variac output currents. These ammeters are in series with the variac outputs. Mention has not been made previously of the variacs on the instrument panel as the writer assumes the operators are familiar with these units. It should be noted that the smaller units have maximum current rating of 9 amps. while the larger units are rated at 25 amps.

Panel #7 contains multipoint Brown strip chart recorders monitoring miscellaneous radiation monitors and pump speed. Both recorders alarm at 90% of scale and have appropriate alarm lights and reset pushbuttons.

Panel #8 contains three pilot lights indicating liquid nitrogen level in the fission gas cold trap. Behind this panel are located three Sola constant voltage transformers. Two of these units are connected and supply power to equipment in the electronics cabinets. The third unit is a spare and is not connected. In back of panel #6 are mounted two manometers. These units cover the ranges of about 90% of the pneumatic instrumentation and will make possible rapid calibration of equipment in the field. This panel also contains the "on" light for the hydraulic system lubricating oil pump and a toggle switch to manually cut in the MTR emergency cooling air in the event of air failure. Trap temperatures are recorded on TRX-14. Lights indicate low trap temperature and aspect of trap coolant control. TRX-14 also has a reset button PB-20.

1.33 Electronics Rack

The electronic equipment is housed in 4 standard 76" relay cabinets mounted on a common base serving as a structural support and cable tray. All cabinets are equipped with blowers and filters to circulate cooling air. These blowers must always be on. Cabinet one (on left facing front of equipment) (see Fig. 8), contains 6 model 410 Atomic Instrument Company count rate monitors serving as fission gas Health Physics devices. The sensing elements for these monitors are 6 halogen filled G-M tubes immersed in activated charcoal filled glass jars. Air from any desired location is drawn through tygon tubing to the charcoal by a vacuum pump. Any gaseous radioactives will be trapped in the charcoal and counted by the G-M tubes. The outputs from the count rate monitors are recorded on a Brown strip chart recorder on the main instrument panel. Cabinet #2 contains the radiation monitoring equipment used to control the reactor. Also, included are the Count Rate Meters used to monitor these control channels. Before each experiment, the vacuum pumps must be completely cleaned and serviced. The charcoal must be changed, and the charcoal filters in the traps must be changed.

Cabinet #3 contains further radiation measuring equipment used for monitoring purposes only. Also included are 2 spare instruments in case of failure. Cabinet #4 contains the pump speed monitoring device and the power supply for the 3" pep chamber used to monitor the MTR's power. For further details see section 2.47 and 2.42. Also included in this cabinet are 2 more spare instruments. Located on the right hand end of the rack assembly are 2 Co⁶⁰ sources of 1 mc and 11.7 mc. These sources are to be used in pretesting and calibration of the radiation instrumentation. They are always to be kept in the lead shield pro-

vided and should only be handled by persons experineced in radiation hazards. Also, they should not be carried about the MTR area without notifying the MTR shift supervisor. Means are also provided to operate portions of the system manually while automatic control instruments are being serviced or replaced. This cabinet also contains a dual electrometer for monitoring cubical activity.

1.4 SYSTEM OUTLINE

1.41 Temperature Recording and Control

- 1) Nose piping temperature control of calrod heaters.
- 2) Nose outlet temperatures.
- 3) Pump-oil, water jacket.
- 4) Heat exchanger and pump
- 5) Fluid pump discharge.
- 6) Mean temperature controller.

1.42 Flow

- 1) Helium-to-pump sump flow.
- 2) Helium-to-pump bearing housing.
- 3) Water from loop.
- 4) Oil from motor.
- 5) Cooling air from loop.
- 6) Helium purge to loop nose.

1.43 Pressure

- 1) Helium purge from nose.
- 2) Cooling air from loop.
- 3) Oil-to-pump suction.
- 4) Oil-to-pump gland.
- 5) Oil outlet from motor.
- 6) Oil inlet to motor.

7) Cooling air to loop.

1.44 Radiation Detection

1) Coolant air outlet.

2) Helium outlet.

3) Water outlet.

4) Oil sump.

5) Working area.

6) Pile level monitor.

1.45 Liquid Level Measurement

1) Liquid Nitrogen Level

1.46 Speed Measurement

1) Pump speed.

2.0 FUNCTIONAL DESCRIPTION

2.1 TEMPERATURES

2.11 Nose Piping Control

(Refer to flow sheet Drawing Q-1633-1.) The nose piping temperature control system used to maintain fluid temperature during reactor operation consists of a thermocouple located on the loop piping at the pump discharge outlet and feeding into a 1-second Brown temperature transducer (TY-7). This device converts the thermocouple millivoltage to a proportional 3-15 psi air signal which is fed to a standard miniature Foxboro recorder and controller (TR-7 and TC-7).

The controller output is coupled to a heat exchanger air-throttling valve. The throttling valve operates in the range from 3 to 11 psi. All other nose piping temperatures as shown on Drawing Q-1633-1, are recorded by both multipoint and dual pen Brown recorders. Recorders TR-2 and TR-4 are provided with mercury

switches to give scram signals. TR-6 and TR-8, provide fast set back for the reactor, using the same type switch.

2.12 Loop Heater Controls

The purpose of these heaters is to preheat the piping to the operating range. Heaters are located at 7 positions on the loop and are controlled individually from separate variacs. All variacs are manually operated with provisions for turning on or turning off power to all the loop heaters simultaneously and automatically. When the heaters are on manual control, adjustment can be made at will. During reactor operation it is assumed that the variacs are placed on automatic operation and preset to a voltage which has previously been determined to give isothermal operation of the loop. If the reactor power suddenly drops below, say 10%, and the nose piping temperatures are not excessive, the variacs are automatically turned on to assume control of the loop heating. This circuitry is provided in an effort to minimize operational malfunction leading to destruction of the heaters. Brown potentiometers with mercury switches and equipped with either upscale or downscale burnout, as required, are used to monitor and record these temperatures.

2.2 FLOW

(For detailed information refer to specification sheet numbers Q-1633-F-1-I, through Q-1633-F-8-I.) Flow measurement is accomplished in the system by the use of orifice plates or capillary tubes working in conjunction with differential pressure transmitters. The transmitters are fed to Foxboro miniature receiver-recorders mounted on the panelboard.

2.3 PRESSURE

(For detailed information refer to specification sheets Q-1633-P-1-E through P-38-I.) Pressure measurement is handled in the same manner as flow measurement,

using pressure transmitters and recorders of standard design. (See Technical manual for pneumatic instruments).

2.4 RADIATION MONITORING

2.41 Radiation Detectors, General

Radiation monitoring is accomplished by the use of ion chambers and Halogen quenched Geiger Mueller tubes.

The ion chambers are used at the following points: the pump purge trap outlet line with two chambers located in a lead shield; a single chamber at the nose purge trap outlet. The cubical ion chambers are located as follows: one in a lead shield; one exposed. The chambers work into Electrometers, type Q-826-C, with associated alarms and recorders.

G-M tubes are used at five positions on the loop; nose purge line, air coolant line, water coolant and two on hydraulic oil purge lines. At the first 3 positions four paired tubes are used for protection against failure. These tubes work into the G-M tube monitor and ratemeter through a preamplifier.

The G-M tube monitor provides a strip chart record of the activity of the detectors plus scram and annunciator signals should the radiation intensity rise above a preset level. The response time of the circuit is 7.5 milliseconds with a sensitivity of 10-200 mr/hr.

Protection against failure and false scrams is accomplished by using four detectors in each group as follows:

- 1) Operating the tubes in pairs.
- 2) Providing a separate power supply for each pair of tubes in a group with separate voltage sources for each supply.
- 3) Both tubes in a pair to provide a trigger signal before a scram signal is generated.

- 4) One pair in a group to generate a scram signal independent of the other pair.
- 5) Cable shorts or G-M tube discharge is shown by G-M control panel light and trouble alarm on G-M monitor selector panel.

Single G-M tubes are used as monitors at two positions in the loop, the hydraulic oil sump and purge lines. Signals from these tubes are fed into rate-meters to generate alarms only.

2.42 Reactor Power Detector

A 3" P.C.P. Safety Chamber, Q-975, located in hole VG-3 is used in addition to the MTR chamber, to monitor the reactor power. The signal from the chamber is fed into the safety chamber monitor which drives a Brown recorder. The recorder provides an annunciator signal on the panel and a signal to turn on the heaters when the reactor power falls below a preset level. Failure of the safety chamber power supply causes a special burnout signal to drive the recorder full scale.

The safety chamber is inserted in the VG-3 vertical hole and suspended by a 1/8 diameter cable. The cable is tied off at the cap with provisions for raising and lowering the chamber in the hole.

After the reactor is up to some given power level, 10 MW for example, the chamber is raised or lowered until its output reads 10 MW on the Brown recorder in the panel. At this point, and as the reactor goes up in power, the reading should correspond to the reactor power level as determined by the MTR power indicator. After positioning the chamber such that its response matches that of the MTR power level, it is tied off at the plug cap by the attached cable clamp.

2.43 Loop Monitors (RE-4, RE-5, RE-6, See Dwg. Q-1633-1)

A total of 3 ion chambers are furnished and used to monitor 2 positions on

the loop. *RE-5 and RE-6 monitor the stack off-gas line at a single point and RE-4 services as a "back-up" monitor on the purge nose line. The monitors generate alarms and actuate relays which can be used for control purposes if desired.

The 250 cc, nitrogen filled, brass ion chambers Q-1680, are surrounded by five inches of lead shielding. The lead housing is included in the design to protect against external radiation that would cause large signals to be emitted from the chambers. One lead shield is provided for each of the following chambers:

RE-4 Drawing Q-1637-6 and RE-5 and RE-6 Drawing Q-1637-1.

The radiation detectors "see" a 1-inch section of $\frac{1}{4}$ inch copper tubing that contains the gas to be monitored. Chamber RE-4 monitors the Helium purge line with no expected background radiation. Chambers RE-5 and RE-6 monitor, at one point, the off-gas line which emits 2 mev. average energy gamma rays.

The alarm set-point for the chambers RE-5 and RE-6 is 20 curies/hour or 13.3 mc/cc of the gas as calculated from the data supplied. A response of 5.7×10^{-12} amperes for 20 curies or .24 R/hour is obtained using this set point and the empirical formula $R/\text{hour at 1 ft.} = 6 CE$, where C = source strength in curies (20), E = energy of radiation (2 mev.) and 1 R/hour $\sim .926 \times 10^{-13}$ amps/cc for an air equivalent ion chamber.

For full scale meter deflection this current fed into an electrometer Q-826-C having .3 volt sensitivity (.3 volt for full scale deflection of the meter), will require an input resistance of 5.32×10^{10} ohms.

* See Drawing Q-1633-1.

The actual values used are as follows:

<u>Range</u>	<u>Ohms</u>	<u>Curies/hour (full scale)</u>
1	1×10^7	100,000
2	1×10^8	10,000
3	1×10^9	1,000
4	1×10^{10}	100
5	1×10^{11}	10

The chambers were calibrated in air without lead shielding using Co^{60} - 11.7 mc, which emits gamma rays of 1.33 and 1.17 mev, respectively. The sources were placed on the top and 6 inches from the side of the chamber. The average results shown in Section 2.431 were obtained.

2.431 Calibration

<u>Electrometer Range</u>	<u>(Source on Chamber Top)</u>	<u>(Source 6" from center at side of chamber)</u>
	<u>Meter Deflection Divisions</u>	<u>Meter Deflection Division</u>
3	11	8
4	110	80

Calibration procedure is as follows:

- 1) Turn on electrometer and allow warm up period of at least 5 minutes before connecting chamber.
- 2) Adjust zero on electrometer.
- 3) Check each range for drift or leakage by the following method: Turn range switch* to each position, allowing 1 to 5 minutes to observe any drift of the meter from the zero position. If leakage is found (indicated by a fast rise from the zero position), clean both the cable connectors and chamber seals; to clean chamber seals, remove the chamber

* Use range switch on pre-amps for RE-5 and RE-6.

connector housing (see Q-1680-1).

- 4) Remove plug from the chamber shield and place, on top and at the center of the chamber, a 11.7 mc Co^{60} source (range switch positions at 4). Observe the meter deflection (should be 110 divisions plus background reading).
- 5) After reactor is up to operating power check meter deflection beginning from range 1. Adjust the set point by moving the sympliytrol pointer to the desired point above background level.
- 6) Check the zero at least every 8 hours by switching range selector to "0" position and observing meter deflection. If zero point has shifted, readjust to zero.
- 7) The range detector switch sensitivity scale must be set on "off" prior to turning instrument power on.

2.432 Loop G-M Tubes

Fourteen halogen-quenched Anton Geiger Mueller tubes are used to monitor five points in the loop, RE-1, 2, 3, 7 and 8 (see Q-1633-1). RE-1 and 7 work into scram circuits, while RE-3, RE-2 and RE-8 work into alarm circuits. The counters at each position, with the exception of RE-3 and RE-8 are contained in lead shields for protection against external background radiation. The shield drawings for RE-1, 2 and 7 are as follows: RE-1, Q-1637-3; RE-2, Q-1637-9; RE-7, Q-1637-7.

A total of 46 G-M tubes were tested using a Co^{60} source. The tubes were placed in a lead shield similar to that which will be used in actual operation. The source was collimated 6" from the tube giving 36 mr/hour at the tube. High voltage was -900V. Both the signal and current from the source was fed, through a microammeter, into a scaler. Readings of both counts and current were than

taken for all 46 tubes. The average counts per minute was 124,830 and the average current was 7.7 microamperes. A counting efficiency of 1.8% was computed for 36.6 mr/hour of Co^{60} by computing the number of photons intercepting the tubes and dividing the result into the counting rate. Further tests indicate that the efficiency decreases with an increase in radiation intensity. The maximum intensity that can be measured with any degree of accuracy is 200 mr/hour since the counting rate and current begin to decrease (see curves - Fig. 2 and 3), after this intensity level is reached.

The tubes were matched in pairs and numbered according to their current response (see Figure 6) then taped together and labelled for easy identification.

2.433 G-M Tube Response Check for RE-1, RE-2 and RE-7

The response should be checked for each group of tubes before placing them in operation. This is accomplished in the following steps:

- 1) Remove the plug containing the tubes from the lead shield.
- 2) Place a radiation source at a known distance from the tubes (see Figures 4 and 5.
- 3) Observe the counting rate and compare for each tube in a group. The response for all four tubes should match.
- 4) Observe the neon lights on the G-M tube monitor and adjust sensitivity so that all four lights in a group flash at the same rate.

The radiation response of each tube may be checked by comparing the counting rate (for RE-3 and RE-8 the current) and the intensity level to Figure 2 and Figure 3. When in operation, the intensity level can be found by observing the counting rate or current and computing the intensity from Figure 2 and 3.

When tubes RE-1, RE-2 and RE-7 are replaced they must be replaced in pairs with identical responses. Replacement is accomplished in the following manner:

- 1) Remove the plug from the shield.
- 2) Remove the aluminum housing.
- 3) Remove the old tubes from their sockets (Caution: tubes have 900V on their insulated shell) and replace with new ones.

A graph (Fig. 4 and 5) of radiation intensity in mr/hour versus distance in cm is provided for each of the Co⁶⁰ sources. A shield is included for mounting the sources on the side of the electronic instrument panel.

2.434 G-M Tube Locations

The G-M tubes are located on the loop as follows:

- 1) Hydraulic oil sump tank (RE-3 and RE-8 are shown on Dwg. Q-1633-1).

Single G-M tubes are used to monitor the oil sump tank at two points.

At RE-3 the G-M tube is inserted into the oil tank through a pipe.

At RE-8 a bracket (Q-1637-12) is provided to attach the tube to the $\frac{1}{4}$ " copper tubing. The signal from each G-M tube is fed into a rate

meter Q-1639-1 to generate an alarm only. The alarm set point for

both positions should be adjusted after the reactor is up to power

and the background level determined. Note: The scram and alarm set

points for RE-1, 2 and 7 are adjustable by the sensitivity controls on the G-M tube monitor panel.

- 2) Nose purge line (RE-1, Q-1633-1). The nose purge line is monitored by two pairs G-M tubes with the output of each tube fed into a scram circuit (Q-1634-1, -2). Two pairs of tubes are selected having current response as near alike as possible. The scram set point is adjusted after the reactor is up to power, to some point above the normal background.

(The scram point at present is set at 15 mr/hour).

NOTE: The scram and alarm set points for RE-1, 2 and 7 are adjusted by the sensitivity controls on the G-M tube monitor panel.

- 3) Coolant water line (RE-2, Q-1633-1). The water line uses 2 pairs of tubes for monitoring with the output fed into annunciator and alarm circuits only. As before the tubes are selected with identical response characteristics. The source consists of $\frac{1}{2}$ " of stainless steel pipe filled with water which contains N^{16} as its principal source of radiation. The N^{16} , according to calculations, emits 1.8×10^5 photons/second incident on the tubes. Assuming approximately 1% counting efficiency, the counting rate was computed and found to be 100,000 counts per minute. Lead of $\frac{1}{4}$ " thickness will be inserted between the counter and source to stop the 10-mev. Beta particles emitted by N^{16} . At present the scram set-point is adjusted to 50 mr/hour. However, it should be noted that the actual response as calculated could be in considerable error due to the uncertainty of the water activity, requiring the background level be checked after the reactor is up to full power.
- 4) Air coolant line (RE-7, Q-1633-1). The air coolant line monitor contains two pairs of G-M tubes selected as previously described. The source is a section of pipe containing 377 cc of air. Assuming 1.7% efficiency, this gives 28 counts per minute.

2.44 G-M Tube Monitor

Three points are to be monitored using fast response detectors, the nose purge gas line, air coolant line and water coolant line.

The monitors consist of the group of four Halogen filled Geiger tubes described previously, operated as shown on the Instrument Flow Diagram Q-1633-1.

The circuitry consists of a pre-amp and trigger pair for each counter and a coincidence amplifier for each pair of counters.

Provision is also made for count-rate monitoring of each counter. The simplicity of the circuitry provides protection against failure. Only four tubes are used for each channel. Three of these are 5692 tubes. The circuits are insensitive to high frequency transients. The trigger pairs have considerable hysteresis while retaining a fast response time. All component parts are de-rated to minimize failure.

The monitor provides a strip-chart record of counting rate at each of these three points, and provides scram and annunciator signals should either of the points rise above a preset, safe level, or a level that indicates a leak in the loop. The instrument consists of three preamplifiers (see Dwg. Q-1634-2) each of which contain four G-M tube inputs. One heater supply is included for the preamplifiers (Q-1634-3), one control chassis (Q-1634-1), two power supplies, P-1 and P-2 (Q-1634-4), two 900 volt negative supplies (Q-1651-1), one selector panel and an alarm panel (Q-1635-1) and three linear count rate meters (Q-1511-1).

Since the G-M tubes are arranged in pairs, beginning with the preamplifier (Q-1634-2), each has $\frac{1}{2}$ of a 5692 dual triode used as a cathode follower to transmit pulses over the long line to the selector panel.

The voltage pulses to the instrument result from an IR drop across the 470K Ω resistor that is in series with the d.c. output signal. This same resistor also doubles as decoupling for the d.c. circuits. The selector panel will select any one of the four G-M tube outputs at any monitoring point and feed this signal to the count rate meter. Each pair of G-M tubes and their associated cathode followers is provided with a common power supply and H.V. supply at any one monitored point which is not common to any other pair of tubes. This provides added protection in case of power supply failure.

The G-M tubes double as ion chambers, and since they have a large gas amplification factor they supply a sufficient d.c. voltage to operate the "scram" and alarm circuits that are located at the G-M control panel (Q-1634-1). In the input circuit (V1) is an uncompensated trigger pair having a hysteresis of 5V. The frequency compensation is omitted purposely to make the circuit less sensitive to transients, thus offering protection against false scrams. In its quiescent state the input section of V1 is conducting with the NE51 glowing and the second triode cut off. When the radiation flux rises above a given value (determined by the potentiometer setting in the input grid), grid 1 becomes sufficiently negative to allow the stage to trigger. When this occurs the grid of the relay tube V2a swings from below cut-off to zero bias, thereby energizing the relay in its plate circuit. Simultaneously the input grid of V3 swings from $\pm 6V$ to $\pm 70V$, yet no signal appears at the cathode of V3 as this is a cascode coincidence circuit. If, however, V5 should trigger at the same time as V1 the second triode grid in V3 would rise from $\pm 20V$ to $\pm 125V$ and the cathode voltage would rise from approximately 5V to approximately 70V. Thus, if only one trigger pair fires, an alarm signal is initiated (see relay contact diagram at lower right of Drawing Q-1634-1) and the NE51 is extinguished indicating the trouble point, but no scram signal is produced. However, if both trigger circuits in a given pair trigger, a d.c. scram signal is fed through the diode coupling to the X1 and X2 buses, which, in turn are connected to the Sigma amplifiers, Q-947 thus closing the control circuit (see relay wiring diagram at lower center of Drawing Q-1634-1). Since the cathode of V3 normally rides at 6V and the X1 and X-2 buses are set at 22V the circuit is completely isolated from the Sigma amplifier until a scram signal appears.

NOTE: The electronic scram circuit X1 and X2 will not be used on the first experiment.

The remaining 5 pair are identical to the pair just described.

WARNING: To avoid false scram signals, when the instrument is turned on (if the reactor is in operation) always remove the control circuit cables during the warmup period, and again before the instrument is turned off. For calibration - refer to section 2.434 and for trouble shooting circuit refer to Drawing Q-1634-1.

2.45 Electrometers

The Q-826-C electrometers RIX-5, RIX-4 are standard. However, the following precautions in start-up and operation should be re-emphasized:

- 1) Voltage must be applied to the chambers at least five minutes before the range selector switch is changed from zero point.
- 2) The electrometer should never be turned on immediately after having been turned off. (Wait for a length of time equal to that marked on the front panel before turning instrument back on.)
- 3) Turning the electrometer on or off and changing ranges while in operation will produce a false alarm which should be disregarded.
- 4) Never remove or install ion chamber or cable to the ion chamber without first turning selector switch to zero.
- 5) The selector switch on the panel of these three electrometers is not used (the switch on the preamplifier at the chamber is in the circuit).

Electrometers RIX-3 and RIX-9 monitoring RE-3 and RE-9 (see Q-1639-1) are Q-826-C electrometers modified per Drawing Q-1639-1.

Although these electrometers are not as sensitive as the standard instruments, the same procedures should be followed that are used with the standard electro-

meters (see calibration procedure for calibrating instructions).

The safety chamber consists of a high voltage supply, ion current metering circuit, a relay and voltage metering circuit (see Drawing Q-1640-1).

If the cables to the safety chamber are accidentally disconnected or open circuited the voltmeter on the front panel will fail to read H.V. and the Sigma relay will become de-energized providing an upscale burnout signal to the recorder.

2.46 Linear Count Rate Meters (Q-1511)

2.461 Specifications

- 1) Range: 200 cts/minute full scale to 2,000,000 cts/minute full scale.
- 2) Linearity: better than 1%.
- 3) Accuracy: 3% on panel meter, 1% on recorder.
- 4) Input Sensitivity: 3V for either positive or negative pulses.
- 5) Resolving time: 3.5 microsecond.
- 6) Stability: zero drift; average 1% 1,000 hours.
- 7) Calibration drift: less than $\frac{1}{2}\%$ 1,000 hours (in air conditioned room).
- 8) Range: The range of the Q-1511 is covered in five steps plus a multiplier factor of 100, and a scale expander having a range of slightly greater than two.

2.462 Calibration, General

For servicing data on Q-1511 linear count rate meter see Dwg. Q-1511-1 and Q-1511 test data sheet IV-B-11.

Calibration is provided in both counts per minute and counts per second. A 120 cycle calibration check is supplied with provision for calibrating from the front panel of the instrument. A panel mounted selector switch permits the selection of integrating condensers which are marked in terms of percent-of

standard-deviation. Checking procedure as follows:

2.463 Preparation

- 1) Set range switch to zero and multiplier to X100.
- 2) Make sure that all voltages check with the voltages indicated on the Test Data Sheets.
- 3) Adjust R-1 for 30 volts drop across R-3 (make sure calibrate switch is off).
- 4) Adjust R-12 so that center of hysteresis falls at 0 on the discriminator dial. (Total hysteresis = approximately 2 volts or 10 divisions each side of 0).
- 5) Check NE-2 that couples V-3 to V-4. (They should be on all the time, and should change from bright to dim once every two times the discriminator knob is rocked through zero.)
- 6) Zero the meter by adjusting R-64.
- 7) Turn range selector switch to 200cts/minute and observe zero shift. (Repeat this check with S-5 set in all three positions allowing adequate time on the .2% position.)
- 8) If zero shifts in one or two positions of S-5, check for leakage to ground (Note - that the inside foils of C-15, C-16, C-17, connect to S-5. All insulation in the grid circuit of V-6, S-5, the rotor of X-4, and pin 7 of V-5 must be teflon with a total shunt resistance to ground greater than 5×10^{11} ohms.)

2.464 Calibration

- 1) Turn range selector S-4 to 10K position.
- 2) Throw S-6 to cts/minute.

- 3) Adjust scale expander to 125 μ or - 25.
- 4) Turn S-5 to 0.6%.
- 5) Turn calibrate switch (S-2) to "on" position.
- 6) Throw multiplier switch (S-3) to X1 position.
- 7) Adjust discriminator to μ or - 15 dial reading.
- 8) Adjust C-9 until meter reads 36 which corresponds to 7200 cts/minute.
- 9) Throw S-6 to cts/second position and adjust R-46 for meter reading of 24 μ a which corresponds to 120 cts/second.
- 10) Throw S-3 to X100 position, and range switch (S-4) to 200 position and S-6 to cts/minute position.
- 11) Adjust C-11 for meter reading at 18 μ a (7200 cts/minute).
- 12) Adjust R-47 for agreement between 10 MV recorder and panel meter.

NOTE: See test data sheet for Q-1511-1 linear count rate meter checking procedure.

2.47 Pump Speed Monitor (Q-1724-1)

2.471 General

The pump speed monitor is intended to work at some predetermined loop pump speed. It will indicate the drift from the set point and control when the drift exceeds the upper or lower RPM limits.

The pump speed pickup is a magnetic impulse generator located in close proximity to a 48 tooth gear on the impeller shaft. The impulse generator produces a single sine wave for each gear tooth. The a.c. signal is amplified and fed to a count rate circuit whose output is a d.c. voltage proportional to the frequency of the pickup signal. The d.c. signal is indicated on the pump RPM meter.

Two triggers are used when the count rate circuit d.c. voltage varies beyond

limits which can be set from the front panel. These limits represent the maximum RPM change the monitor will permit before it alarms. The actual RPM drift from the set points is indicated on the RPM change meter.

An output is provided on the rear chassis for a 10 millivolt Brown recorder. An output is also included for a remote RPM meter located at the pump motor speed control position.

2.472 Operation

In setting up the monitor to operate at a pump speed of 3000 RPM, for example, the signal test switch should be in the test position. This position connects the VFO to the input. The VFO dial, calibrated in RPM, is set at the pump speed, (3000 RPM). The pump RPM meter will then read 3000. The RPM change meter must be zeroed, first in the normal position of the sensitivity switch, then with the switch depressed. In the normal position, the RPM change is ten times the dial reading.

The trigger limits may now be set by moving the VFO to the maximum upper RPM, and, with a screw driver, adjust the upper limit to trigger. The lower limit may also be set in the same manner. Make sure that both triggers are reset when a limit is being adjusted. The trigger point can best be observed on the RPM-change meter when the sensitivity switch is depressed.

If the monitor is connected to a scram circuit, it may be disconnected by pushing the sigma disconnect while any adjustments are being made.

2.473 Service and Calibration Procedures

The VFO should be used to make the following adjustments which are all that are necessary for the proper operation of the instrument. The trigger is set in the following manner:

- 1) Amplifier Adjustment: Trigger R7 is rotated to its maximum position. A 10 millivolt signal is applied to the grid of the amplifier, R17 is rotated until V2 triggers. R7 is then readjusted to trigger on a 25 millivolt signal. Since the gain of the amplifier is 250, 25 millivolts is 6.25 volts on the grid of the trigger.
- 2) Meter Calibration: The RPM and RPM-change meters are not independent, consequently their calibration is as follows: Both meter movements should be zeroed with the power off. With the power on and after a 10 minute warm-up the RPM meter is zeroed by R42. With the VFO set at 3000 rpm, the RPM meter is adjusted by R-33. The RPM-change meter is then zeroed from the front panel first on the X10, then X1 sensitivity. The variable frequency oscillator is set at 3500 RPM and the RPM-change adjusted to $\pm$ 500 by the trimmer condenser in the pump circuit. This adjustment affects the zero of both the RPM range and the RPM-change; therefore the previous sequence must be repeated several times until the RPM-change meter indicates the true rpm-change set on the VFO.
- 3) Brown Recorder: The Brown recorder output is adjusted by R35. This adjustment will not affect the RPM range setting.
- 4) Vacuum Tubes: The only tubes that require special attention are the 12AU7's used in the VTVM and d.c. amplifier. These tubes must be well balanced before they will fall into the adjustment range of R-42 and R-43. A trial-and-error method should be adequate if a better balance measurement is not available.

2.474 Specifications -

Sensitivity	10 millivolts R.M.S.
Range	0 - 5000 RPM
Trigger Range	/ or - 500 RPM
Accuracy	Panel meters / or - 2%
Amplifier	Saturages at 500 millivolts input 90 volts output
VFO Accuracy	/ or - 2% (For operating instructions refer to manual on Model 200 AB Hewlett-Packard Audio Oscillator

2.48 Area Radiation Monitors

These monitors consist of 6 Model 410 Atomic Instrument Company rate meters serving as fission gas area monitors. The sensing elements are 6 Halogen filled G-M tubes emersed in charcoal filled glass jars. Air from any point to be monitored is drawn through tygon tubing to the charcoal by a vacuum pump. Any radioactive gas particles will be trapped in the charcoal and counted by the G-M tubes. The outputs from the ratemeters are fed to a multipoint recorder on the main panel which will give an alarm when the activity level reaches a preset level.

Since the G-M tube sensing elements are not shielded, variations in background readings will occur as the reactor power is changed or as "hot" samples are handled on the main floor.

The output of the ratemeters can be converted to MR/hour by assuming the counting efficiency of the activity to be monitored is the same as Co⁶⁰. (See following table).

Range Counts/Minute	Meter Deflection Divisions	MR/HR
x1	200	--
x10	200	.8
x100	50	2
x100	100	.4
x100	150	6
x100	200	.8
x1000	25	10
x1000	50	22
x1000	100	52
x1000	150	95
x1000	200	160

3.0 REFERENCES

3.1 Drawings

3.11 Standard "Q" Circuit Drawings

- 1) Q-1511-1 Linear Count Rate Meter
- 2) Q-826-C-1 Electrometer
- 3) Q-975 - Safety Chamber
- 4) Q-1651-1 - Dual Negative 900V Power Supply
- 5) Q-1653-1 - Regulated $\pm$ 180 and $\pm$ 75 volt supply
- 6) Q-1680 - Gamma Ion Chamber

3.12 MTR Test Loop Drawings

3.13 Vendor's Items

- 1) D-410-1 Atomic Instrument Company Count Rate Meter, Model 410.
- 2) Hewlett-Packard Model 200 AB Oscillator Schematic (Instruction Manual).

3.14 Index of Drawings, MTR Test Loop #1

3.15 MTR Drawings, General

- 1) #AED-C-1160 Elementary Diagram of Pile Control.
- 2) Q-1633-1 R7 Instrument Flow Diagram.
- 3) 3150-603-1A (Rev. #8) - Wiring System for Pile Control.
- 4) 3150-603-1B (Rev. #7) Wiring System for Pile Control.

M T R TEST LOOP #1

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6	Y-12 Test Loop

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Q-1633-4	Elementary Diagram Control System (Sheet 2 of 2)	Q-1633-53	Relay Rack, Rear Left Internal Wiring
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Q-1633-57	Power Distribution Single Line Diag. (Obsolete)	Q-1633-75	Instrument Panels 5-8 (Rear) Wiring Diag.
Q-1633-76	Electronic Instruments Rack Panel Layout	Q-1633-92	Piping Schematic
Q-1633-79	Annunciators Elementary Diagram	Q-1633-104	Power & Controls Junction Panel Wiring Diagram
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Q-1634-6	Block Diag. Electronic Diag. (Obsolete)		

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Q-1633-83	Pressure Transmitter Stand. Type II	Q-1634-1	G-M Control Circuit
Q-1633-93	Helium Purge Flow to Nose	Q-1634-2	G-M Tube Pre-Amp Circuit
Q-1633-94	Emergency N2 Valve	Q-1634-3	Fil. Supply for Control Circuit
Q-1633-95	Instr. Air Reducing Station	Q-1634-4	Pos. 180V, Neg. 75V Regulated Power Supply Circuit
Q-1633-96	Vacuum Transmitter	Q-1634-5	Remote Heater Supply for G-M Pre-Amp Circuit
Q-1633-97	Pressure Transmitter	Q-1635-1	Monitor Selector & Alarm Circuit
Q-1633-98	Orifice Flant, Plate & Trans- mitter Flow Assembly	Q-1724-1	Pump Speed Monitor Circuit
Q-1633-99	Helium Flow Assembly	Q-1639-1	Modified Q-826C Electro- meter
Q-1633-100	Press. Gages in Process Line	Q-1640-1	#1 Safety Chamber Electrometer Circuit
Q-1633-101	High Press. Switches in Pro- cess Line	Q-1641-1	Bearing Noise Detector Amp. Circuit
Q-1633-102	Pressure Transmitter	Q-1651	-900V Power Supply
Q-1633-103	Press. Switches in Pro- cess Line	Q-826C	Low Drift A.C. Electro- meter
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Q-1633-68	R.H. Storage Cabinet Details	Q-1637-9	Shield for H ₂ O Coolant GM Tube RE-2 ² Assembly
Q-1633-69	R.H. Storage Cabinet Details	Q-1637-10	Isometric Stack of Shields RE-1, 4, 5, 6, 7
Q-1633-70	R.H. Storage Cabinet Details	Q-1637-11	Source Shields
Q-1633-71	R.H. Storage Cabinet Details	Q-1637-12	Mounting for G-M Tube RE-8
Q-1633-72	R.H. Storage Cabinet Details	Q-1638-1	Detector Mounting
Q-1633-73	Ann. & Clock Mtg. Details	Q-1638-2	Detector Mounting
Q-1633-84	Storage Cabinet Panel Cutouts	Q-1638-3	Meter Box
Q-1633-85	Storage Cabinet Panel Details	Q-1638-4	Ladder
		Q-1638-5	Steps
		Q-1638-6	Scram P.B. Cover

DWG. NO.

TITLE

CATEGORY #6
Y-12 TEST LOOP

Q-1633-21	Y-12 Channel Base
Q-1633-34	Isometric of Control Panel Y-12
Q-1633-58	Y-12 Control Panel Layout
Q-1633-77	Instrument Panels 1-3 Y-12 (Rear) Wiring Diagram
Q-1633-78	Instrument Panels 4-5 Y-12 (Rear) Wiring Diagram
Q-1633-88	120V Power Distribution Y-12 Elementary Diagram
Q-1633-89	Y-12 Test Loop #1, Elementary Diagram
Q-1633-90	Y-12 Test Loop #1, Loop Heaters Elementary Diagram
Q-1633-91	Y-12 Test Loop #1, Annunciators, Elementary Diagram
Q-1633-105	Relay Rack - Rear Left Internal Wiring
Q-1633-106	Relay Rack - Front Left Internal Wiring
Q-1633-107	Elementary Diagram - Wiring System

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Fig. 1. Temperature Rate of Rise Following Sudden Stoppage of Fluid Circulation.

Fig. 2. Electrometer Current/mr/hr - Co⁶⁰ (source in air).

480 045

Fig. 3. 3 Co^{60} - mr/hr (source in air).

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Fig. 4. 4 mr/hr vs Distance in cm.

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Fig. 5. 5 Co⁶⁰ - 1 mc mr/hr vs Distance.

DATA FOR G-M TUBE PAIRS USING Co⁶⁰
COLLIMATED SOURCE

Tube No.	Current μ - amp.	Tube No.	Current μ - amp.
1	7.6	14	9.4
28	7.4	17	10.6
18	5.4	27	7.8
19	5.8	31	7.8
23	6.2	7	6.4
25	6.2	46	6.4
42	8.0	38	8.8
34	8.0	8	8.8
9	7.0	40	7.6
21	7.2	45	7.6
44	6.4	37	8.2
20	6.6	5	8.4
10	6.2	41	6.6
30	6.2	24	6.8
35	7.8	13	8.0
36	7.8	2	7.8
15	7.8	16	14.2
39	7.8	4	13.8
29	6.8	12	8.6
33	6.8	11	8.6
22	6.8	6	8.2
26	7.0	32	8.2

Figure 6

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Fig. 7. Main Control Panel.

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Fig. 8. Electronics Rack.

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Fig. 9. Experiment Annunciator Functions.

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Annunciator Title	Cause of Alarm	Operator Corrective Action	Automatic Control Action at Alarm Point	Follow-Up Control Action	Process Variable Setting	Contact Symbol	Contact Location	Wire Nos.	Actual Switch Setting	Switch Aspect	Remarks
Inst air pressure	Inst air supply <17.5 psig	Adjust regulator to 22 psig supply pressure	None	Junior scram	17.5 psig 6 psig 0.5 gpm	PX-21 PX-1B FX-6B	Relay cab Relay cab Relay cab	301,138 175,176 101,168	17.5 psig 9.4 psig 3.8 psig	N.O. N.O. N.C.	High liner pressure Hyd oil flow low
Low He supply	He cylinder pressure <200 psig	Replace depleted cylinder	None	None	200 psig	PX-18	He cylinder	301,139	200 psig	N.O.	
N ₂ supply	Emergency coolant N ₂ cylinder pressure <800 psig	If "N ₂ in use" annunciator is on, call control room and have reactor power reduced. If annunciator not on, repair leak and replace cylinders. See I.	None	None	800 psig	PX-17	N ₂ cylinder	301,140	800 psig	N.O.	Complete loss of N ₂ while in use may result in high temp scram
Nose N ₂ supply	Supply pressure >200 psi	Replace cylinder	None	None	200 psi	PX-103	Basement	301,926	200 psi	N.O.	
Air comp. off	G.E. compressor not operating	Reduce power to 10 Mw - retract loop - use M.T.R. air and N ₂ to cool loop - scram if cooling can not be maintained until trouble clears. Watch nose cold temp.	None	None	Compressor off	R3-1	Relay cab	301,910		N.O.	
Low air flow	Coolant air flow <200 scfm	Investigate	None	Verding of control valve. Operator to ensure that valve is fully open	200 scfm 150 scfm 1475°F	FX-7A FX-7B TX-7B	Relay cab Relay cab P.B. 6	301,146 101,164 164,165	3.8 psig 3.5 psig 8.7 psig	N.O. N.C. N.O.	Control valve is N.O. Air to close This circuit is designed to maintain air flow if the air controller TC-7 fails to operate
N ₂ in use	Reserve N ₂ coolant system in use because of: 1. Air supply pressure <50 psig 2. TY-7 output at 1500°F and TRX-1 > 1600°F (100° above base)	Reduce power to 10 Mw. Turn on MTR air. Watch nose cold temp.	Reserve N ₂ system energized	None	50 psig 1500°F 1600°F	PX-9 TX-7A R-18-3	Relay cab P.B. 6 Relay cab	101,163 101,162 162,163	6.0 psig 9.0 psig 1600°F (TRX-1)	N.C. N.O. N.O.	
Water supply	Cooling water supply pressure <50 psig		None	Junior scram	50 psig 10 gpm	PX-37 FX-4B	Water supply Relay cab	301,141 176,177	50 psig 4.9 psig	N.O. N.O.	Coolant water flow low
Coolant water flow low	Jacket cooling water flow <15 gpm	Increase cooling water flow	None	Junior scram	15 gpm 10 gpm	FX-4A FX-4B	Relay cab Relay cab	301,137 176,177	7.3 psig 4.9 psig	N.O. N.O.	5 gal differential between alarm and control action
Hyd oil flow low	Hyd oil flow from motor <1.0 gpm	Increase oil flow	None	Scram	1.0 gpm 0.5 gpm	FX-6A FX-6B	Relay cab Relay cab	301,128 101,168	6.0 psig 3.75 psig	N.O. N.C.	0.5 gpm differential between alarm and control action
Hyd. sump low pres.	Pressure below 1 psig	Increase pressure	None	None	1 psig			301,904		N.O.	
Pump purge flow low	Pump purge flow rate <10% full scale	Increase flow rate	None	None	-0.01 scfh	FX-2	Relay cab	301,142	4.4 psig	N.O.	
Bearing purge flow low	Bearing purge flow rate <10% full scale	Increase flow rate	None	None	-0.01 scfh	FX-3	Relay cab	301,143	4.4 psig	N.O.	
High liner pressure	Nose N ₂ purge inlet pressure >5 psig	Reduce N ₂ purge supply pressure do not stop flow	None	Junior scram	10 psig 12 psig	PX-1A PX-1B	Relay cab Relay cab	301,134 175,176	6.25 psig 4.75 psig	N.O. N.O.	1 psig differential between alarm and control action
Pump speed variation	Pump speed has varied ±200 rpm from operating speed	Investigate - retract loop if necessary for adjustment or in event of trouble	None	None	±200 ppm	RY upper RY lower	Electronics rack SIX-2	301,911		N.O.	
Pump speed	Pump speed has varied ±450 rpm from operating speed	Check hyd drive unit	Scram	None	±450 rpm	Ry 13-2 Ry 14-2	Electronics rack SIX-1A	101,168		N.O.	To disable scram circuit, hold button on panel of pump speed monitor labelled sigma disconnect
High temp (scram)	Nose outlet temp >1525°F (25° above base)	Check cooling of loop	None		1525°F	TRX2-2	Recorder TRX-2	301,135	1525°F	N.C.	25°F differential between alarm and control action
High temp (scram)	Nose piping temp >1600°F (100° above base)		Scram	None	1600°F	TRX1-1	Recorder TRX-1	101, 71	1600°F	N.O.	To disable scram and annunciator circuits, hold pushbutton labelled "reset" below TRX-1
Low temp	Nose inlet temp below 1075°F	Increase temp	None		1075°F	TRX6-2	Recorder TRX-6	301,158	1075°F	N.C.	
Nose purge activity	N ₂ purge activity >15 m/hr 30,000 cpm	Investigate	Junior scram	None	15 m/hr	Ry 9b, Ry 10b Ry 11b, Ry 12b	Electronics rack G-M control panel	101,166		N.O.	To disable scram and annunciator circuits, hold black pushbutton labelled "He" on G-M control panel. Do not release unless all four He pilot lights on panel are lit
Coolant air activity	Exit coolant air activity >20 m/hr	Investigate	Scram	None	20 m/hr	Ry 5b, Ry 6b Ry 7b, Ry 8b	Electronics rack G-M control panel	101,167		N.O.	To disable scram and annunciator circuits, hold black pushbutton labelled "AC" on G-M control panel. Do not release unless all four AC pilot lights on panel are lit

Coolant water activity	Exit coolant water activity > 50 mr/hr	Investigate	None	None	50 mr/hr	Ry 1b, Ry 2b Ry 3b, Ry 4b	Electronics rack G-M control panel	101, 171 101, 171	50 mr/hr	N.O. N.O.	To disable scram and annunciator circuits, hold black pushbutton labelled "CW" on G-M control panel. Do not release unless all four CW pilot lights on panel are lit
Hyd oil activity	Radiation monitor RIX-3 or RIX-8 above setpoint	Investigate	None	None		RIX-3	RIX-3	301, 160		N.C.	Contact setting is adjustable
Stack activity	Radiation monitor RIX-5 or RIX-6 above setpoint	Investigate	None	None		RIX-5	RIX-5	301, 159		N.C.	Contact setpoint is adjustable
Radiation monitors	Signal on RRX-9 or RRX-10 > 90% scale	Investigate	None	None		RRX-9-1 RRX-10-1 RRX-13-1	RRX-9 RRX-10 RRX-13	101, 79 101, 83 101, 75	90% scale 90% scale 90% scale	N.O. N.O. N.O.	To clear alarm, reset button below Recorder must be depressed To clear alarm, reset button below, recorder must be depressed. After some period of usage, charcoal in sensing elements must be replaced
Health physics monitors	Signal on RRX-13 > 90% scale	Investigate	None	None							
Reactor below 10N _L	Reactor below 10% full power	None	All varies on automatic energized if nose piping temp < 1600°F	None	3 Mw	RRX11-2	Recorder RRX-11	301, 151	3 Mw	N.O.	
Scram	Reactor has been shutdown by this experiment caused by any one of the following: 1. Pump speed 2. Hyd oil flow low 3. High temp (scram) TRX-1 4. High temp (scram) TRX-2&4 5. Coolant air activity	Determine cause and correct it. Notify control room when they may resume operating	Scram	None		R38-4 R41-4	Relay cab Relay cab	301, 155 155, 195		N.C. N.C.	
Junior scram	Reactor has been reduced to 0 power by this experiment caused by any one of the following items: 1. High liner pressure 2. Nose purge act 3. Coolant water flow low 4. Tripping of CB-14 control power circuit breaker	Determine cause and correct it. Notify control room when they may increase to full power	Junior scram	None		R44-3 R47-3	Relay cab Relay cab	301, 154 154, 194		N.O. N.O.	
Fast setback	Nose inlet temp < 1050°F	Correct cause of low temp	Fast setback	None	1050°F	TRX6-1	Recorder TRX-6	101, 178	1050°F	N.C.	See low temp annunciator
High trap temp	Temp on cold trap > -110°C	Investigate	None	None	-110°C	TRX14-2	Recorder TRX-14	301, 127		N.C.	

LIMIT SWITCHES

- LS-1 Main hydraulic unit pilot motor lower limit switch
- LS-2 Main hydraulic unit pilot motor upper limit switch
- LS-3 Standby hydraulic unit pilot motor lower limit switch
- LS-4 Standby hydraulic unit pilot motor upper limit switch

I. N₂ IN USE

1. Request MTR to reduce power to 10 Mw
2. Request that MTR assist by retracting loop as soon as possible.
3. Switch on MTR air supply
4. Use calrod heat to maintain loop temperatures if necessary

II. LIQUID N₂ SUPPLY

1. Log N₂ inventory in sheet summary

NOTE: High temperature control setpoints are typical for a base 1500°F loop max operating temp and will vary depending on operating conditions of specific loops.

CF 58-10-55
Instruments

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