*Gamma Radiation Detectors of the
TA-55 Waste Line Monitoring System*

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Jack E. Malcom

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GAMMA RADIATION DETECTORS OF THE TA-55 WASTE LINE MONITORING SYSTEM

by

Jack E. Malcom

ABSTRACT

This report covers the gamma detectors, measurement instrumentation, and testing results of a system developed at Los Alamos National Laboratory. This system monitors the process liquid waste streams at the Plutonium Facility (TA-55) for the presence of radioactive contamination. The detectors are at various points on the acid, caustic, and industrial waste lines. Two of the detectors are on the sanitary sewer lines from the facility. A custom interface unit associated with these two detectors furnishes the facility operation center with a notification of the detection of material. All of the detectors furnish measurement information to a central computer system for storage and trending.

PART I. DETECTORS AND COUNTING SYSTEM

I. INTRODUCTION

The waste monitoring system (WMS) developed by the Nuclear Materials Technology process control team at Los Alamos National Laboratory's Plutonium Facility, TA-55, includes the use of gamma radiation detectors.¹⁻⁵ These detectors are at various locations on the caustic, acid, and industrial waste pipes that are within the facility. The detector locations are selected to help in determining the possible origin point where radioactive contaminated liquids are introduced into a facility waste line. Detector data is sent to the remote computer for data storage, trending, and display.

Besides the gamma monitors on the process waste lines, two of the gamma detectors, SSD1 and SSD2, are mounted on the sanitary sewer lines (see Appendix A). The resultant data from these detectors is sent to the remote computer and to a local alarm interface. This interface is connected to the facility control system for monitoring of Alarm, Alert, and Power Fail modes. Redundancy of the alarm modes is available from the computer system, which does data storage, display, and trending.

II. DETECTORS AND COUNTING SYSTEM ELECTRONICS

The gamma detectors are Bicron Model 2M2/2-AM-241-X. These are thallium doped, two inch sodium-iodide crystals coupled to B50B01-4 Photomultiplier tubes. These detectors are attached to Canberra Model 2007P Photomultiplier Tube Base preamplifiers. The crystals are seeded with a ²⁴¹Am alpha activation method. This gives a gamma energy peak in the energy area of 800 keV to 1.4 MeV (nominally 1.2 MeV). This area has a count rate of one thousand counts per second. There is also some gamma emission in the low energy area near 60 keV.

The waste lines have been in place and in use for several years. Because of this usage, residual material may be present from which the detectors could derive a signal. Count information from the activation of the crystal, the residual material, and surrounding area is the normal background for that particular detector location.

A Harshaw Model NA-23 stabilized amplifier/single channel analyzer module amplifies the signal from the detectors. The single channel analyzer is adjusted to monitor the count rate of the high-energy activation area and its output is coupled to an Ortec Model 661 rate meter. The linear output of the amplifier is coupled to a Canberra model 2030 single channel analyzer (SCA). This SCA's output goes to another model 661 rate meter and monitors the low energy region from 50 keV to 150 keV. The rate meters are adjusted for a zero to five thousand counts per second input rate and have recorder outputs of 10 volts full scale. These outputs are coupled into a multiplexer, which is connected to the remote computer. The counts in the high energy area are used nominally as an indicator that the system electronics are functioning correctly. A count rate over the normal background rate in the low energy area indicates the presence of material.

III. SYSTEM CALIBRATION

The gain of the system is adjusted using a ^{241}Am source and a multichannel analyzer (MCA). The source is placed near the face of the detector so that the detector can detect the emission of the gamma rays. The amplified linear signal from the NA-23 unit is connected to the MCA and a spectrum is collected from the detected gamma rays. The amplifier gain is adjusted to place the 60 keV peak collected on the MCA in the 50–65 channel area of the MCA display. With the gain adjusted to this level the linear output pulse height will be close to 10 volts in amplitude. The MCA is adjusted for 1024 channels with an ADC conversion gain of 1024 and a plutonium spectrum is shown (Appendix B) that was collected at these settings.

The low energy region from 50 keV to 150 keV, which is approximately 0.1 volts to 1.1 volts of the total pulse height, is bracketed by adjusting the Canberra 2030 E and delta E potentiometers. Adjusting the E and delta E potentiometers on the Harshaw NA-23 module encloses the high energy area from 600 keV to 1.4 MeV which is in the five volts to ten volts pulse-height amplitude.

IV. SYSTEM SENSITIVITY

A. SSD1 and SSD2: Sanitary Sewer Detector Sensitivity Tests

A system was assembled in a test area using signal processing modules and detectors of the same type as those found in the measurement systems. Ortec Model 871 counter/timer modules were added to the test system to give a counts per second (cps) reading. The detectors are placed on the bottom of a segment of pipe that matches the facility piping. Radioactive sources are placed over the detector area and transported through the pipe while the detectors are active. The movement of the sources at various speeds and heights is to simulate the flow rate of the effluent. Measured count rates for sources of various gram quantities are taken. By comparison of the source measurements results to

the normal background results, one can derive a gram value that can be used as the sensitivity level of the detectors. This sensitivity level would be applicable for detectors mounted flush against the surface of the pipe with no shielding on their faces.

TABLE 1

BACKGROUND RATES

Low energy area: 50 keV–150 keV		High energy area: 600 keV–1.4 MeV	
Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)	Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)
694	0.7–0.8	958	0.9–1.0
677		931	
739		980	
664		890	
698		899	
Recorder output: 1.4–1.6 Vdc		Recorder output: 1.8–2.0 Vdc	

Table 1: Background rate results from a 4" diameter cast-iron sewer pipe.

TABLE 2

RESULTS OF MEASUREMENTS WITH ^{239}Pu STANDARDS

Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)	Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)	Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)
LLW0.1: Outside, top of pipe		LLW0.1: Inside, bottom of pipe		LLW0.1: Inside, top of pipe	
803	0.7-0.8	3815	3.8-4.0	1109	1.1-1.2
748		3883		1093	
746		3934		1056	
774		3838		1085	
777		3913		1077	
Recorder output: 1.4-1.5 Vdc		Recorder output: 7.3-7.6 Vdc		Recorder output: 1.8-2.0 Vdc	
LLW0.25: Outside, top of pipe		LLW0.25: Inside, bottom of pipe		LLW0.25: Inside, top of pipe	
902	906 0.9-1.0	6734	6643 Full scale	1474	1.3-1.4
972	937	6830	6769	1416	
939	933	6695	6736	1432	
947	890	6698	6795	1390	
Recorder output: 1.7-1.8 Vdc		Recorder output: 12.85 Vdc		Recorder output: 2.3-2.6 Vdc	
LLW0.5: Outside, top of pipe		LLW0.5: Inside, bottom of pipe		LLW0.5: Inside, top of pipe	
980	1.10	11301	Full scale	1787	1.6-1.7
1094		11412		1730	
1063		11372		1697	
1152		11272		1769	
Recorder output: 2.0 Vdc		Recorder output: 15.18 Vdc		Recorder output: 3.2-3.4 Vdc	
LLW1.0: Outside, top of pipe		LLW1.0: Inside, bottom of pipe		LLW1.0: Inside, top of pipe	
1326	1.30	15685	Full scale	2321	2.3-2.4
1186		15550		2270	
1225		15646		2284	
1285		15889		2264	
1257		15740		2292	
Recorder output: 2.2-2.6 Vdc		Recorder output: 15.18 Vdc		Recorder output: 4.4-4.6 Vdc	

Table 2: Results from tests using a set of ^{239}Pu standards with gram values of 0.1, 0.25, 0.5, and 1.0 grams.

TABLE 3
MEASUREMENTS OF ²³⁵U STANDARDS

Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)	Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)	Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)
STDSFU0.5-1: Outside, top of pipe		STDSFU0.5-1: Inside, bottom of pipe		STDSFU0.5-1: Inside, top of pipe	
675	0.7-0.8	1238	1.3-1.4	809	0.8-0.9
699		1260		779	
720		1261		820	
669		1254		821	
713		1219		799	
Recorder output: 1.3-1.5 Vdc		Recorder output: 2.1-2.4 Vdc		Recorder output: 1.5-1.7 Vdc	
STDSFU1.0: Outside, top of pipe		STDSFU1.0: Inside, bottom of pipe		STDSFU1.0: Inside, top of pipe	
758	0.7-0.8	1901	1.7-1.9	989	0.9-1.0
750		1819		901	
762		1838		919	
764		1877		897	
Recorder output: 1.3-1.5 Vdc		Recorder output: 3.4-3.6 Vdc		Recorder output: 1.7-1.9 Vdc	
STDSFU4.0-32: Outside, top of pipe		STDSFU4.0-32: Inside, bottom of pipe		STDSFU4.0-32: Inside, top of pipe	
865	0.9-1.0	4213	4.2-4.5	1699	1.5-1.7
877		4311		1637	
901		4280		1639	
949		4256		1586	
Recorder output: 1.5-1.6 Vdc		Recorder output: 7.9-8.1 Vdc		Recorder output: 3.2-3.4 Vdc	

Table 3: Results from tests using a set of ²³⁵U standards ranging in various gram values. Each standard is a 5-inch long by 1-inch diameter cylinder containing uranium oxide material dispersed throughout the length of the cylinder.

TABLE 4

MISCELLANEOUS TESTS USING ONE GRAM ²³⁹PU STANDARD

LLW1.0 1" above detector area, inside pipe	
Counter/timer	Rate meter
Model 871	Model 661
units (cps)	units (kcps)
3548	3.6
3566	
Recorder output: 7.2 Vdc	
LLW1.0: At top, inside pipe with a cadmium shield 1/16" thick	
1899	1.9
1874	
1864	
1836	
Recorder output: 3.8 Vdc	
LLW1.0 with a cadmium shield and moving on the bottom of the pipe	
no 871 counts	4.0
Recorder output: 8.0 Vdc	
The LLW1.0 source was then attached to a ruler and pulled through the inside, top portion of the pipe to simulate a flow of 1" per second. Only the Model 661 rate meter readings of the low energy regions were recorded. The dwell time of the 871 counter/timers would cause incorrect readings when the source is in motion so no readings are taken from this unit for this type of test.	
Model 661 rate meter readings @ 1"/sec	
	2.5
	2.6
	2.5
Recorder output: 5.0 Vdc	
LLW1.0 with a 1/16" thick lead shield and moving at 1" per second	
	1.6
	1.7
	1.5
Recorder output: 3.1 Vdc	

Table 4: Miscellaneous tests with a 1.0 gram ²³⁹Pu standard.

TABLE 5

DEPLETED URANIUM TESTS

One D-238 source inside pipe over detector		Two D-238 sources inside pipe over detector		Three D-238 sources inside pipe over detector	
Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)	Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)	Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)
1004	0.9-1.0	1274	1.2-1.3	1457	1.4-1.5
1043		1230		1447	
997		1258		1435	
1022		1231		1425	
Recorder out: 1.8-2.1 Vdc		Recorder out: 2.4-2.6 Vdc		Recorder out: 2.8-3.0 Vdc	

Table 5: Tests on D-238 sources used in the facility by Radiation Control Technicians. These sources are approximately five to nine grams of depleted uranium in a solid disk with a diameter of 3/4".

TABLE 6

MEASUREMENT RESULTS USING GAMMA REFERENCE STANDARDS

²⁴¹ Am	Model 661 rate meter	Low energy region = 1.0 kcps High energy region = no change
¹³⁷ Cs	Model 661 rate meter	Low energy region = Full scale High energy region = Full scale
¹³³ Ba	Model 661 rate meter	Low energy region = Full scale High energy region = no change
⁶⁰ Co	Model 661 rate meter	Low energy region = 2.5 kcps High energy region = Full scale

Table 6: Test results from measurements using sources from a gamma standard set. The standards in the set were 10 microcurie in strength on 1/Aug/1987. They were placed inside the pipe over the detector face.

B. SANITARY SEWER LINE DETECTION SENSITIVITY

The sanitary sewer waste line detectors can detect the passage of 0.1 grams of material under conditions where the flow rate is slow, material is unshielded, and the material is on the bottom of the

pipe when it passes the detectors. The margin of the readings above normal background for this amount of material is small and does not allow for reliable separation of the two readings. When the material is unshielded and stationary over the detector, the count rate response to sources with 0.25 or 0.5 gram of material is sufficient to be separated from the background level (Table 2). With the material shielded and moving, the count rate drops to a level which is closer to the background level.

The sensitivity of the system that is applicable to the sanitary sewer detectors and the process waste line detectors, including the possible scenario of moving and shielded material, would be at 1.0 gram of plutonium (Table 4). There is a higher degree of confidence that this amount of material would be detected in varied configurations.

This detection level of 1.0 gram is lower than the quantity of material to be detected for safeguards monitoring of the sanitary sewer line. To reduce the possibility of false alarms, the detectors on this line were shielded with two layers of cadmium low energy filters and moved away from the pipe by two inches. Tests with larger gram quantities of plutonium oxide and uranium oxide yielded count rates of 3.5 kcps for the plutonium and 3.8 kcps for the uranium in the low energy area. The source material was placed one pipe thickness of metal above the detectors. These test results indicate that the sensitivity level of the system can be varied by the use of shielding or low energy filters. Increasing the detector to sample distance can also be used as a method of adjusting the system sensitivity.

V. SENSITIVITY TESTS FOR ACID, CAUSTIC, AND INDUSTRIAL WASTE LINES

Steel pipes used for these lines have diameters of 2" or 2 3/8" with wall thicknesses of approximately 3/8." The attenuation of steel versus the cast metal of the sewer lines varies by a small amount. This causes some variations in the observed count rates. These pipes are also smaller in diameter than the sanitary sewer lines which will allow a smaller variation of source to detector distances of material. Results of the tests are in Table 8. Results from tests using one ²³⁹Pu standard are also given.

Reviewing the measurement results for the 2 3/8 inch diameter steel pipe, a detection sensitivity level of one gram of material is found to be applicable for the detectors on the industrial, caustic, and acid waste lines.

TABLE 7

BACKGROUND MEASUREMENTS ON 2 3/8" DIA. PIPE

Low energy area: 50 keV–150 keV		High energy area: 600 keV–1.4 MeV	
Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)	Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)
607	0.5–0.7	901	0.9–1.0
645		969	
701		977	
673		923	
697		974	
Recorder output: 1.0–1.4 Vdc		Recorder output: 1.8–2.0 Vdc	

Table 7: Background rate results from 2 3/8" diameter steel pipe.

TABLE 8

MEASUREMENTS WITH ^{239}Pu STANDARDS ON 2 3/8" DIA. STEEL PIPE

Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)	Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)	Counter/timer Model 871 units (cps)	Rate meter Model 661 units (kcps)
LLW0.1: Outside; top of pipe		LLW0.1: Inside; bottom of pipe		LLW0.1: Inside; top of pipe	
879	0.8-0.9	4415	4.7-4.8	1815	1.8-2.0
939		4452		1819	
945		4483		1861	
852		4591		1814	
871		4570		1885	
Recorder output: 1.6-1.7 Vdc		Recorder output: 8.3-8.5 Vdc		Recorder output: 3.4-3.6 Vdc	
LLW0.25: Outside, top of pipe		LLW0.25: Inside, bottom of pipe		LLW0.25: Inside, top of pipe	
1251	1.2-1.3	9462	Full scale	2709	2.6-2.9
1319		9287		2712	
1176		9336		2713	
1268		9395		2748	
1228		9420		2803	
Recorder output: 2.2-2.3 Vdc		Recorder output: 15.18 Vdc		Recorder output: 4.9-5.2 Vdc	
LLW0.5: Outside, top of pipe		LLW0.5: Inside, bottom of pipe		LLW0.5: Inside, top of pipe	
1547	1.6-1.8	14335	Full scale	4417	4.5-4.7
1543		14525		4384	
1578		14553		4382	
1558		14597		4304	
1579		14429		4329	
Recorder output: 2.8-3.0 Vdc		Recorder output: 15.18 Vdc		Recorder output: 8.1-8.3 Vdc	
LLW1.0: Outside, top of pipe		LLW1.0: Inside, bottom of pipe		LLW1.0: Inside, top of pipe	
2121	2.0-2.2	18730	Full scale	5180	Full scale
2145		18913		5175	
2102		18359		5245	
2078		18699		5261	
2107		19064		5181	
Recorder output: 3.9-4.1 Vdc		Recorder output: 15.18 Vdc		Recorder output: 15.18 Vdc	

Table 8: Results from tests using a set of ^{239}Pu standards with gram values of 0.1 grams, 0.25 grams, 0.5 grams, and 1.0 grams on steel pipe with a diameter of 2 3/8".

The LLW1.0 source will cause a full-scale reading on the low energy region Model 661 rate meter while it is drawn through the pipe at an approximate rate of 1" per second. This reading occurs at the top inside the pipe and the bottom inside the pipe. With a 1/16" lead shield inside the pipe over the detector face area, the rate results of the LLW1.0 source in the low energy region while moving are

Counter/timer	Rate meter
Model 871	Model 661
units (cps)	units (kcps)
2108	2.1-2.2
2146	
2019	
2160	
Recorder output: 3.9-4.2 Vdc	

VI. RESULTS ON LLW2.5 TESTS

Periodic tests to verify system operation, accuracy, and reliability could be required on this system. Tests were performed with 2.5 grams of plutonium material on the sanitary sewer line detector system (see Table 9). The top shield of the detectors was removed so the source could be placed on top of the pipe in line with the detector. The detectors were flush with the bottom of the pipe and no low energy cadmium filters were on the detector face.

TABLE 9
RESULTS OF TESTS USING LLW2.5

TEST SYSTEM	SSD1	SSD2
Canberra SCA Model 2030 E = 0.07 Delta E = 1.0	Canberra SCA Model 2030 E = 0.05 Delta E = 2.0	Canberra SCA Model 2030 E = 0.05 Delta E = 2.0
Model 661 Rate meter low energy region background = 0.7 kcps source = 2.1-2.3 kcps Recorder output: 4.2-4.5 Vdc	Model 661 Rate meter low energy region background = 0.6 kcps source = 2.8-3.0 kcps Recorder output: 5.6-6.0 Vdc	Model 661 Rate meter low energy region background = 0.8 kcps source = 3.3-3.7 kcps Recorder output: 6.6-7.0 Vdc
Canberra SCA Model 2030 E = 0.05 Delta E = 1.0	Canberra SCA Model 2030 E = 0.05 Delta E = 1.0	Canberra SCA Model 2030 E = 0.05 Delta E = 1.0
Model 661 Rate meter low energy region rate = 2.1-2.3 kcps Recorder output: 4.2-4.5 Vdc	Model 661 Rate meter low energy region rate = 1.9-2.2 kcps Recorder output: 4.0-4.4 Vdc	Model 661 Rate meter low energy region rate = 2.0-2.3 kcps Recorder output: 4.0-4.6 Vdc
E = 0.05 Delta E = 2.0 rate = 3.2-3.5		

Table 9: Results of tests using a 2.5 gram ²³⁹Pu standard.

The first tests on SSD1 and SSD2 had the E of the 2030 Canberra SCA units adjusted to 0.05 and a delta E of 2.0, settings which allow for a wider energy window from which we receive counts. This wider range would account for the increase in the observed count rate over the previous results with the test system. A second set of tests with the SCA E and delta E adjustments at the same level for the test system and SSDs resulted in count rates which are similar. The test system was also run with a wider window and its results matched the higher readings.

If the delta E is adjusted to a value of 2.0, the resultant count rate is 2.8–3.0 kcps and 3.0–3.2 kcps respectively. When the delta E is adjusted to 1.0 and the E value is varied from 0.05 to 0.1 there is no appreciable variation of the observed count rates. This result can be explained by observing a spectrum which is collected on a Canberra Series 35 MCA unit (Appendix B). The area of the E adjustment from 0.05 to 0.1 is in the region approximately at channel 30 to 40 where there is not a high variation in the incoming count rate. The area of the delta E setting from 1.0 to 2.0 allows the inclusion of counts in the 208 keV area.

VII. RECOMMENDATION ON ANNUAL TESTS

When tests using the 2.5 gram standard are repeated on the SSD1 and SSD2 units, the count rates observed are 2.0 kcps on each unit in the low energy region of 50 keV to 150 keV. The observed value of 2.0 kcps is above or equal to the measured results on LLW1.0 for the tests where LLW1.0 was shielded by lead (Table 1 and Table 4). These results are for the detectors with no low energy filters and the detectors are mounted flush to the bottom surface of the pipe.

With low energy filters and a two inch space from the detector face to the pipe surface, the sensitivity level of the system decreases by approximately a factor of 10. Testing with a 30 gram plutonium standard placed in the same position as the 2.5 gram standard yielded count results of 2.1 kcps. When a 60 gram standard is used the count rates are over 5.0 kcps. The observed rate from the higher value standard is sufficient to achieve count rates comparable to the 2.5 gram standard. This source is of sufficient strength that it can be moved along the top of the pipe to simulate a flow rate.

PART II. ALARM INTERFACE FOR THE SANITARY SEWER LINE DETECTORS

I. INTRODUCTION

The four measurements which are taken from the two detectors are from the high and low energy regions from detectors SSD1 and SSD2. The Ortec Model 661 count rate meters which give the raw count rate data from the energy regions are also equipped with a recorder output which gives a voltage output that is equivalent to the count rate information. A special interface was designed and built by the Nuclear Materials Management, Control, and Accountability Group (NMT-4) for controlling the activation of the Alarm, Alert, and Power Fail modes at various count rates (see Appendices C–F). This interface uses the recorder output voltage levels from the Model 661 rate meters as its inputs. Alarm status is monitored locally and at the remote operations computer.

II. THEORY OF OPERATION

The Ortec 661 Model rate meters are set for a 0 to 5 kcps full scale and the recorder outputs are set for 0–10 volts full scale. This gives a recorder output of 2 volts for every 1 kcps count rate. The recorder outputs are attached to the rear terminal strip of the interface unit. The voltage from the recorder output passes through a voltage divider network that will take a 2 volt input and drop it to 1 volt at the positive input to the first voltage comparator. This voltage is also the negative input to a second comparator. The other input to the comparators comes from adjustment potentiometers on the front panel, one potentiometer per comparator. There are test points at the front panel to measure input voltage, high reference voltage, and low reference voltage.

There are nine states that are monitored by the interface unit: Power Fail, a count rate higher than the normal background in any of the four channels, and a count rate lower than the normal background in any of the four channels. The interface unit activates the Power Fail whenever power is lost to the unit. This indication stays latched when power is returned to the interface unit and must be reset by the appropriate push button. The Alert status and the low count status of the four channels will be active and require resets when the system is first turned on.

If a high count rate, above normal background, causes the high reference voltage level to be exceeded that channel will go to an active state. If a low count rate occurs, the input voltage to the interface will drop below the low reference voltage and that channel will become active. Any one of these eight states being active will set an Alert status. The high or low count states have to be reset by their corresponding reset push button before the Alert state can be cleared.

The Alarm state of the system is set when both (SSD1 and SSD2) detectors exceed the high count level reference voltage. This reference voltage is set above the input voltage caused by the normal background in the low energy regions. There will also be an Alert status set by the first one of the detectors measuring a high count rate. The high count rate states have to be cleared before the Alarm and Alert states can be cleared. If the Alarm, Alert, or Power Fail state is active, the system gives a dry contact relay closure available on the rear panel terminal strip.

III. CIRCUIT DESCRIPTION AND OPERATION

The interface unit is functionally split into four channels: SSD1 low energy region, SSD1 high energy region, SSD2 low energy region, and SSD2 high energy region. (See Appendices C–F.) The input to each channel comes from the recorder output of an Ortec Model 661 rate meter in the counting electronics. Each channel has a high count rate state and low count rate state. The circuit operation for each of the channels is similar so only one channel will be described fully. Some comments will be made in regard to areas that may differ slightly.

The normal background reading on High Ref (SSD1) Low Energy Region is 0.6 kcps with a recorder output of 1.2 volts and TP1 will be 0.6 volts. With RV1 adjusted so that TP2 measures 1.5 volts and RV2 adjusted so TP3 is 0.4 volts, both A1 pin 7 and A2 pin 7 will be low and the circuit is not active. When the reading on the rate meter goes above 1.5 kcps and the recorder output is above 3.0 Vdc, the input will be above 3.0 volts and TP1 is over 1.5 volts; A1 pin 7 goes to a high state activating RL1.

With RL1 active, L1 turns on, A9 pin 2 goes low, and A11 pin 1 is at 5 volts. When A9 pin 2 goes low, A12 pin 9 goes high, A10 pin 10 goes low, and A10 pin 8 goes high activating RL11. If RL11 is active, L9 is turned on and the Alert mode is active. If High Ref (SSD2) were also to go higher than its reference at TP5, A3 would turn on RL3, L3 is illuminated, A9 pin 6 goes low, A11 pin 2 would go high, and A11 pin 3 would go low. This would allow A10 pin 6 to go high activating RL10 which turns on L10 and the Alarm mode would be active.

The relays are of a latching type and to reset the alarm, alert, and channel alarm indication the inputs would have to first return to a normal reading. When the reading is at normal, the individual channel can be reset by pressing a push button for that channel. Once the channels are reset the Alert and Alarm modes can be reset by PB10 and PB9.

If the inputs of any of the channels drop below the reference voltage set at TP3, TP6, TP9, or TP12 then that portion will go active (low count rate failure). This activity would give an Alert indication with the active channel being identified by its illuminated indicator.

When a Power Fail is present, then other alarm signals could be considered as erroneous until investigated. If an Alert becomes active and then Alarm comes on, Alarm would receive highest priority. This sequence would be the normal indication from the system; an alert would always occur before the system would alarm. Since it takes high readings from two detectors to set the Alarm state, it is possible to see an Alert with no Alarm. If the Alert has been set by one of the detectors going high in the low energy region and this channel is not reset, then the system would go to an Alarm state if the second detector were ever to give a high count at a later time.

SUMMARY

The detectors and counting electronics which are used on the waste lines give us the capability to monitor the lines for the presence of radioactive contamination which may be present. With the system connected with the WMS computer we are capable of near real-time checking of the detector count rates through the Internet. The computer also gives us the capability of storage and historical trending of these count rates over time.

The alarm interface that is used on the sanitary sewer line gives us the capability of local alarms that can be easily checked. The same set of alarm signals is furnished to the operation center of the facility through the dry relay contacts available on the rear panel terminal strip. With the operation center manned 24 hours a day, we have constant monitoring capability of this waste line. The response to alarm conditions would be initiated by the facility operation personnel at the computer operation center.

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Appendix A: Waste Monitoring System Block Diagram

WASTE MONITORING SYSTEM BLOCK DIAGRAM

Appendix B: Spectrum from LLW2.5 pm SSD1 and SSD2

SPECTRUM FROM LLW2.5 ON SSD1 AND SSD2
SERIES 35 MCA: 1024 CHNLS
WITH CONVERSION GAIN OF 1024

Appendix C: Front Panel Layout

ALARM INTERFACE

Appendix D: Alarm Control Interface for Sanitary Sewer Waste Lines

Schematic Available Upon Request

Appendix E: Component Layout for Alarm Interface

Appendix F: Wiring List for S-1, S-2, S-3, and S-4

TP1---P1-1---S1-1---A1-2	L1---P2-1---S2-1---RL1-8	PB1---P3-1---S3-1---RL1-2
TP2---P1-2---S1-2---A1-3	L2---P2-2---S2-2---RL2-8	PB2---P3-2---S3-2---RL2-2
TP3---P1-3---S1-3---A2-2	L3---P2-3---S2-3---RL3-8	PB3---P3-3---S3-3---RL3-2
TP4---P1-4---S1-4---A3-2	L4---P2-4---S2-4---RL4-8	PB4---P3-4---S3-4---RL4-2
TP5---P1-5---S1-5---A3-3	L5---P2-5---S2-5---RL5-8	PB5---P3-5---S3-5---RL5-2
TP6---P1-6---S1-6---A4-2	L6---P2-6---S2-6---RL6-8	PB6---P3-6---S3-6---RL6-2
TP7---P1-7---S1-7---A5-2	L7---P2-7---S2-7---RL7-8	PB7---P3-7---S3-7---RL7-2
TP8---P1-8---S1-8---A5-3	L8---P2-8---S2-8---RL8-8	PB8---P3-8---S3-8---RL8-2
TP9---P1-9---S1-9---A6-2	L9---P2-9---S2-9---RL11-9	PB9---P3-9---S3-9---RL11-2
TP10---P1-10---S1-10---A7-2	L10---P2-10---S2-10---RL10-9	PB10---P3-10---S3-10---RL10-2
TP11---P1-11---S1-11---A7-3	L11---P2-11---S2-11---RL9-6	PB11---P3-11---S3-11---RL9-2
TP12---P1-12---S1-12---A8-2	POWER FAIL IN TB1-6	POWER FAIL OUT TB1-10
P1-13---S1-13---GROUND	P2-12---S2-12---RL9-14	P3-12---S3-12---RL9-13
P1-14---S1-14--- +5 V	ALERT IN TB1-7 P2-13---S2-13---RL11-4 ALARM IN TB1-8 P2-14---S2-14---RL10-4	ALERT OUT TB1-11 P3-13---S3-13---RL11-8 ALARM OUT TB1-12 P3-14---S3-14---RL10-8
TB1-1---SSD1 LOW ENERGY REGION---P4-1---S4-1---R1		
TB1-2---SSD2 LOW ENERGY REGION---P4-2---S4-2---R3		
TB1-3---SSD1 HIGH ENERGY REGION---P4-3---S4-3---R5		
TB1-4---SSD2 HIGH ENERGY REGION---P4-4---S4-4---R7		

A = Integrated circuit (located on circuit board)

L = Led (located on front panel)

P = Plug (wiring connector from front and rear panels to circuit board)

PB = Push Button (located on front panel)

RL = Relay (located on circuit board)

S = Socket (located on circuit board)

TB = Terminal Strip (located on rear panel)

TP = Test Point (located on front panel)

TP1---P1-1---S1-1---A1-2====Test Point 1; to Plug 1 pin 1; to Socket 1 pin 1; to integrated circuit 1 pin.