**GAMMA & BETA-GAMMA STORM WATER MONITOR
OPERABILITY (U)
requestor W. F. Bates (Bill) 703-H**

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HIGH LEVEL WASTE ENGINEERING
FACILITY ENGINEERING SECTION

WSRC-TR-93-323

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GAMMA & BETA-GAMMA STORM WATER MONITOR OPERABILITY (U)

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INTRODUCTION

High Level Waste (HLW) facilities have nine storm water monitors that monitor storm water run off from different process areas for Cesium 137, a Gamma emitter. F - Area has three monitors: 907-2F, 907-3F and 907-4F while H - Area has six monitors: 907-2H, 907-3H, 907-4H, 907-5H, 907-6H and 907-7H (See attachments #1, #2 and #3 for locations). In addition to monitoring for Cesium, 907-6H and 907-7H monitor for Strontium-90, a Beta emitter. Each monitor is associated with one of the following diversion gate encasements 907-1H, 241-15H, 241-51H, 907-1F or 241-23F. Normal flow of storm water from these diversion gate encasements is to the Four Mile Creek. When a storm water monitor detects radioactivity at a level exceeding the Four Mile Creek discharge limit, the monitor causes repositioning of the associated diversion gate to discharge to the H - Area retention basin 281-8H or the F - Area retention basin 281-8F. In response to recent OSR interpretation of storm water monitor calibration requirements, this report is provided to document operability and accuracy of radiation detection.

SUMMARY

Storm water monitors 907-2H and 907-5H have been diverted for a number of years due to elevated background radiation in the manholes where the detectors are positioned. The remaining storm water monitors were solution tested in October 1992 (Ref. 1). As of 6/22/93, all the storm water monitors in service were calibrated. Based on the 1992 test results and the recent calibration data, it is expected that the Gamma and Beta-Gamma monitors in F - and H - Area will alarm and cause diversion of the storm water from the outfall to the retention basin if storm water contains 10 d/m/ml of Cesium-137 or Strontium-90 (± 22.8 % error for the Gamma monitors and ± 26 % error for the Beta-gamma monitors). Only 2.5 % and 10.7 % of the uncertainty can be attributed to the Gamma and Beta-Gamma measuring instruments respectively. The remaining uncertainty is associated with the calibration uncertainties. In addition, the background radiation is allowed procedurally to drop as much as 5 d/m/ml prior to resetting the diversion set point. This increases the set point uncertainty by 50 % (± 72.8 % error for the Gamma monitors and ± 76 % error for the Beta-gamma monitors)

DISCUSSION

Theory of Operations-Cesium Monitor

The Gamma monitor is made up of a scintillation detector, a high voltage de-coupler, a stabilized linear amplifier and single channel analyzer, a single channel pulse height analyzer, two multi-scale ratemeters, and a high voltage power supply (see attachment #4).

The scintillation detector primarily consists of a photo-multiplier tube coupled to a 3 X 3 inch sodium iodine crystal. The crystal contains a small amount of an alpha emitting isotope (Americium 241). The detector is installed in a waterproof stainless steel canister and submerged in 15 inches of water in front of a weir (See attachment #5). This installation has the advantage of using the impounded water to shield the probe against background radiation which in turn increases the monitor sensitivity to waterborne activity. The detector produces pulses of amplitude proportional to the energy of the rays that strike it. These pulses are fed to a stabilized linear amplifier and single channel analyzer via a high voltage de-coupler.

The stabilized linear amplifier and single channel analyzer can be set up to operate in either a differential mode or in an integral mode. All HLW storm water monitors are operated in the differential mode. In this mode, two voltage settings allow the single channel analyzer to delimit a window height and width corresponding to Americium pulses which have a relative energy of 5.5 Mev. The stabilized linear amplifier and single channel analyzer has two outputs: the Single Channel Analyzer (SCA) output and the LINEAR output. The stabilization circuit automatically compensates for temperature shift by

Americium, variation in the SCA output indicates that the stabilization system is not functioning and will initiate a system trouble alarm and cause repositioning of the associated diversion gate. The LINEAR output is fed to a single channel pulse height analyzer. This analyzer can also be operated in either the integral or differential mode. The storm water monitors are operated in the differential mode. Here, as was the case with the stabilized linear amplifier and single channel analyzer, two voltage settings are used to define the window height and width corresponding to the amplitude of Gamma pulses. The output of this analyzer is fed to a ratemeter and is displayed in Counts Per Second (CPS) corresponding to Cesium 137 concentration.

Theory of Operations-Strontium Monitor

The Beta-Gamma monitor provides equal response to Sr-90 and Cs-137 in the 10 to 20 d/m/ml range. It is made up of a waterproof Geiger Mueller (GM) tube, a modified Val-Tech Mod IV count rate meter, a pulse stretcher, an accumulator, two time delay relays, a strip chart recorder and a Direct Current Alarm (DCA) module (See attachment # 4).

A GM tube is immersed in water in front of the collection weir in the storm water manhole where it responds to beta, gamma, and alpha activity in the water. Pulses from the GM tube are fed to a modified count rate meter. The count rate meter is modified so that pulses of 0.5 μ sec duration and negative 10 volt amplitude from the count rate meter front end signal conditioning circuit are used as input to a pulse stretcher. The pulse stretcher takes each negative 10 volt, 0.5 μ sec input pulse and converts it to a positive 10 volt, 10 msec output which is fed to an accumulator. The accumulator totalizes incoming pulses for 10 minutes and generates a 4-20 mA output signal which is proportional to the number of pulses accumulated. The ten minute count period increases the accuracy at low d/m/ml concentrations. Should a high count rate be detected during the count period, the count rate meter will alarm, even though the 10 minute count period has not expired. Two time delay relays are used to establish the ten minute totalization time and provide a nominal 15 second settling time between count periods. The DCA is used to provide a high radiation alarm to the control room.

Test History and Methodology

Early OSR interpretation required the storm water monitors to be functionally tested once a month. This monthly qualitative verification is performed by Health Protection Operations (HPO), High Level Waste Operations (HLWO) and High Level Waste Maintenance (HLWM). Here HLWM verifies that each monitor is configured per procedure HLWM-14321. Once the monitor configuration is verified, HPO verifies that the monitor alarms when a solid Cs-137 source is positioned near the detector and HLWO verifies that the associated diversion gate is automatically repositioned so that flow of storm water is diverted from Four Mile Creek to a retention basin (281-8H or 281-8F).

In October 1992, all the storm water monitors were solution tested and their responsiveness to 10 d/m/ml of Cesium 137 was documented per special procedures WMM-SP-3908, WMM-SP-4110, WMM-SP-4113, WMM-SP-4142, WMM-SP-4128, WMM-SP-4114 and WMM-SP-4149. Since then, some of the monitors have had critical components replaced without solution testing as a post-maintenance test. These monitors were taken out of service and the flow of storm water was diverted to the appropriate retention basin when it was determined that their status was unknown.

All the storm water monitors in service were re-calibrated between 5/19/93 and 6/22/93. The Gamma monitor calibration was performed using two 30 gallons drums, one containing 20 gallons of a 10 d/m/ml Cesium solution and another containing 20 gallons of clean water. The probe was immersed in the clean water and the monitor response was recorded. The probe was then immersed in the 10 d/m/ml Cesium solution and the monitor response was recorded again. The difference between the monitor response in the 10 d/m/ml and its response in the clean water defined the alarm set point. A five point liquid calibration was deemed unnecessary because the electronic calibration of the ratemeter (using a pulse generator) per procedure HLWM-14454 requires a five point calibration. The Beta-Gamma (beta) monitor calibration was performed using five different solutions.

System Adequacy

The calibration solutions were analyzed by the Environmental Technology Section (ETS) of SRTC and Environmental Monitoring Section of the Environmental Protection Department (EPD/EMS) using analysis methods which are traceable to the National Institute of Standards and Technology (NIST) and have a systematic error of less than 5 % (Ref. 2) and 10% (Ref. 3).

A 15 to 18 inch high weir is installed at each storm water monitor to guarantee detector immersion (see attachment #5). Radioactive solids in the storm water settle in front of the weir in the manhole. The buildup of radioactive solids creates a gradual increase in background radiation. Removal of the radioactive solids from the manhole either by storm water flows or by manual removal creates an abrupt decrease in background radiation. As a result of background changes, operating procedures require that the high Cesium alarm set point be changed to mitigate background shifts in excess of 50 %.

The overall measurement uncertainty may be as high as 72.8 % for the Gamma monitors and 76 % for the Beta-Gamma monitors. The uncertainty for the Gamma monitors is obtained by adding the maximum percent of background variation to the accuracy of analysis of the test solution, the accuracy of the monitoring instruments and the accuracy of manhole background calculation. These calculations are based on the as-left conditions of the Gamma and Beta-Gamma monitors following completion of solution calibration.

Maximum percent of potential background variation = 50 % (a)

Accuracy of analysis of the test solution = 10 % (b)

Accuracy of the monitoring instruments = 2.5 % (c)

Accuracy of manhole background calculation = 10.3 % (d)

Overall uncertainty = (a) + (b) + (c) + (d)

= 50 % + 10% + 2.5 % + 10.3 % = 72.8 % (e)

The accuracy of the Gamma monitors (c) is calculated using the statistical average of M&TE allowable uncertainty, ratemeter linearity, ratemeter stability, stabilized linear amplifier and single channel analyzer linearity, single channel pulse height analyzer discriminator threshold voltage stability, single channel pulse height analyzer discriminator threshold voltage linearity, single channel pulse height analyzer discriminator window width stability and single channel pulse height analyzer discriminator window width linearity .

M&TE allowable calibration uncertainty = 2.0 % (f)

Ratemeter linearity = 0.25 % (g)

Ratemeter stability = 1 % (h)

Stabilized linear amplifier and single channel analyzer linearity = 0.1 % (i)

Single channel pulse height analyzer discriminator threshold voltage stability = 1 % (j)

Single channel pulse height analyzer discriminator threshold voltage linearity = 0.25 % (k)

Single channel pulse height analyzer discriminator window width stability = 0.1 % (l)

single channel pulse height analyzer discriminator window width linearity = 0.25 % (m)

$$(c) = ((f)^2 + (g)^2 + (h)^2 + (i)^2 + (j)^2 + (k)^2 + (l)^2 + (m)^2)^{0.5}$$

$$= ((2.0)^2 + (0.25)^2 + (1.0)^2 + (0.1)^2 + (1.0)^2 + (0.25)^2 + (0.1)^2 + (0.25)^2)^{0.5} = 2.5 \%$$

The accuracy of background calculation was derived from the statistical average of the instrument accuracy and the accuracy of analysis of the water sample from the manhole.

Instrument accuracy = 2.5 % (c)

Accuracy of analysis of water sample from the manhole = 10 % (n)

$$(d) = ((c)^2 + (n)^2)^{0.5}$$

$$= ((2.5)^2 + (10)^2)^{0.5} = 10.3 \%$$

The uncertainty for the Beta-Gamma monitors is obtained by adding the maximum percent of background variation to the accuracy of analysis of the test solution, the accuracy of the monitoring instruments and the accuracy of manhole background calculation.

Accuracy of the monitoring instruments = 10.7 % (o)

Accuracy of analysis of the test solution = 5 % (b')

$$\text{Overall uncertainty} = (a) + (b') + (o) + (d)$$

$$= 50 \% + 5 \% + 10.7 + 10.3 = 76 \% (e)$$

The accuracy of the Beta-Gamma measuring instruments (o) is calculated using the statistical average of M&TE allowable uncertainty, count rate meter linearity, count rate meter stability, time delay relay repeat accuracy, accumulator accuracy, accumulator stability, Direct Current Alarm repeatability and Direct Current Alarm stability.

count rate meter stability = 1.5 % (q)

count rate meter accuracy = 2 % (r)

time delay relay repeat accuracy = 10 % (s)

accumulator accuracy = 0.1 % (t)

Accumulator stability = 1 % (u)

Direct Current Alarm repeatability = 0.2 % (v)

Direct Current Alarm linearity stability = 0.08 % (w)

GM probe repeat accuracy = 2 % (y)

$$(o) = ((f)^2 + (q)^2 + (r)^2 + (s)^2 + (t)^2 + (u)^2 + (v)^2 + (w)^2 + (y)^2)^{0.5}$$

$$= ((2.0)^2 + (1.5)^2 + (2.0)^2 + (10)^2 + (0.1)^2 + (1.0)^2 + (0.2)^2 + (0.08)^2 + (2)^2)^{0.5} = 10.7 \%$$

There are no technical standards on storm water release limits, however DOE Order 5400.5 allows a maximum yearly release average of 6.6 d/m/ml for Cesium 137 and 2.2 d/m/ml for Strontium 89/90. These yearly release averages do not correlate directly to an instantaneous release concentration. The practice of setting the storm water monitors to alarm and divert at 10 d/m/ml is a conservative setting based on ALARA philosophy and engineering judgement. The data from the last twelve consecutive month summary (0.016 d/m/ml Cs-137 and 0.000637 d/m/ml Sr-89/90) for H-Area tank farm releases as measured at HP-52 (Ref. 4) are well within the DOE order 5400.5 limits. The 10 d/m/ml setting is in a reliable operating range for the storm water monitor detectors and electronics. Lower settings are not considered necessary and may result in unnecessary alarms.

In addition to the alarm and diversion resulting from monitored release concentrations above 10 d/m/ml ($\pm 72.8 \%$ / 76%), the Environmental Protection Department performs proportional sampling at the outfalls. Samples are taken daily, weekly and monthly. These samples are evaluated statistically and compared to the DOE order yearly release limits. If trends rise significantly or if monthly proportional samples indicate high release concentrations, HLW facilities are notified to take appropriate corrective actions to ensure releases remain within the yearly limit.

Table 1 provides information on monitor calibration and establishes acceptance criteria for 6H and 7H storm water monitors. During calibration of the 907-3F storm water monitor, it was determined that the monitor response in the 10 d/m/ml calibration solution was only 4 CPS. This response was deemed inadequate because this low count did not provide acceptable signal resolution, consequently the probe was replaced prior to the monitor being calibrated.

Program-Improvements

In an effort to further improve the storm water monitor systems, an improvement program was initiated in 3/93 (Ref. 5). This program evaluated the storm water monitors for possible deficiencies and a deliberate set of actions was developed. The actions being taken include:

- 1) Developing and implementing calibration procedures. Until recently, many of the storm water monitor electronic components could not be calibrated by HLWM due to the lack of electronic calibration procedures. Electronic component calibration procedures have been developed by HLWE and HLWM and are in use in the field.
- 2) Repairing storm water sampling systems. Each of the storm water monitors is equipped with an automatic water sampling system. This system was designed to take a water sample from the associated manhole every time a high radiation alarm is initiated by the storm water monitor. After the sample is taken, it is sent to the lab where it is analyzed in an effort to determine whether or not the high radiation alarm was a result of an elevated Cesium/Strontium concentration. Many of these water samplers are inoperable due to the inadequacy of the water pumps. This deficiency does not affect the operability of the storm water monitors in that it only takes away our ability to determine that alarms initiated are associated with increased radioactivity. Repairs are required to ensure timely sampling of the storm water during high radiation alarm.
- 3) Establishing a solid source calibration verification procedure. As stated in the History and Methodology section of this report, current practices require that the storm water monitors be functionally tested once a month. This monthly qualitative verification is performed to determine if the monitor will alarm and automatically reposition the associated diversion gate when a solid Cs-137 source is positioned near the detector. This functional test does not verify the monitor calibration.

A monthly solid source calibration verification requires liquid calibration of each monitor as was recently done to permit correlation of the monitor response in 10 d/m/ml to its response to the solid source located in the manhole. This will supplement the stabilizing circuit by providing an additional means for ensuring that the monitor responsiveness in 10 d/m/ml has remained constant. This effort is currently awaiting completion of the Solid Source Verification Procedure to be provided by Health Protection Technical (HPT).

- 4) Developing a storm water monitor calibration frequency. There is currently no calibration frequency for the storm water monitors. It is recommended that a yearly liquid calibration and a monthly verification of calibration be performed. This recommendation is based on best engineering judgement and present equipment knowledge. The monthly verification of calibration can easily be accomplished by revising Operations source check procedures so that they require documentation of the monitor response to the Cesium source installed in the lead shield located in each manhole. Response will provide confidence that the calibration is accurate based on the expected response by the correlation discussed in item #3.

ACTIONS

NONE

9-16-93

	2F	3F	4F	2H	3H	4H	5H	6H		7H	
MONITOR	GAMMA	GAMMA	GAMMA	GAMMA	GAMMA	GAMMA	GAMMA	BETA-GAMMA	GAMMA	BETA-GAMMA	GAMMA
FUNCTIONAL TEST	N/A	N/A	N/A	N/A	N/A	N/A	N/A	SP-4378	SP-4378	SP-4379	SP-4379
LIQUID CALIBRATION	SP-4390	SP-4390	SP-4391	(2)	SP-4384	SP-4385	(2)	SP-4376	SP-4382	SP- 4377	SP- 4383
ALARM SET POINT CHANGED (CPS ABOVE BACKGROUND)	18 (3)	12(3)	(4)	(2)	9 (1)	12 (1)	(2)	172 (1) (Counts in 10 minutes)	18 (1)	89 (1) (Counts in 10 minutes)	27 (1)
OPERATIONS (241-H-747, 138-PROCEDURE REVISED)	(3)	(3)	(4)	-	(3)	(3)	-	(3)	(3)	(3)	(3)

TABLE 1: Storm Water Monitors Calibration Data and Acceptance criteria.

Notes: (1) Alarm set point reset .
 (2) Background in the manhole higher than normal.
 (3) Procedure revision completed
 (4) Probe replaced since last calibration. Monitor to be re-calibrated.

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6. Memo, T. D. Phillips to T. M. Monahan, "Storm Water Gamma Monitor [SWM]", 5/6/93

ATTACHMENT #1

H-Area Tank Farm Storm Water Monitor Locations

ATTACHMENT #2

H-Area Tank Farm Storm Water Monitor Locations

ATTACHMENT #3

F-Area Tank Farm Storm Water Monitor Locations

ATTACHMENT #4

CESIUM MONITOR ELECTRONIC INSTRUMENTS ARRENGEMENT

STRONTIUM MONITOR ELECTRONIC INSTRUMENTS ARRENGEMENT

ATTACHMENT #5

Typical Storm Water Monitor Probe Installation

CC: G. T. Wright, 703H
J. W. French
R. W. Wilson, 707H
T. M. Monahan, 703H
V. G. Dickert, 703H
H. Handfinger, 5002H
G. Davis, 703F
W. A. Morrison, 241-100F
K. F. Lesko, 707H
W. C. Clark, 703H
M. S. Peters, 241-100F
C. G. Kelly, 707H
T. D. Phillips, 703H
W. A. Wilson, 703H
K. A. Hauer, 241-100F
B. R. Hess, 241-100F
R. L. Salizzoni, 707H
M. A. Ceravolo, 707H
R. R. Salmon, 703-13C
S. A. Epperson, 703F
J. E. Burgin, 241-102F
D. J. Ratchford, 703F
G. D. Thaxton, 241-119H
M. J. Hagenbarth, 742-6G
W. F. Bates, 703H
C. L. Sossman, 992-1W
M. J. Hagenbarth, 742-6G
SRTC RECORDS, 773-52A (4 COPIES)

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