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MEASUREMENT OF THE PORTSMOUTH GASEOUS DIFFUSION PLANT CRITICALITY ACCIDENT ALARM

By

Robert W. Tayloe, Jr.
Battelle - Columbus for
MMES Portsmouth under
Contract Number OT 0049

and

Brent McGinnis
Instrument Technology Department

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Abstract

Measurements of the Portsmouth Gaseous Diffusion Plant's nuclear criticality accident radiation alarm signal response time, alarm sound wave frequency, and sound volume levels were made to demonstrate compliance with ANSI/ANS-8.3-1986. A steady-state alarm signal is produced within one-half second of obtaining a two-out-of-three detector trip. The fundamental alarm sound wave frequency is 440 hertz. The sound volume levels are greater than 10 decibels above background and ranged from 100 to 125 A-weighted decibels. The requirements of the standard were met; however the recommended maximum sound volume level of 115 dBA was exceeded. Emergency procedures require immediate evacuation upon initiation of a facility's radiation alarm. Comparison with standards for allowable time of exposure at different noise levels indicate that the elevated noise level at this location does not represent an occupational injury hazard.

Introduction

The nuclear criticality accident radiation alarm system installed at the Portsmouth Gaseous Diffusion Plant was tested extensively at critical facilities located at the Los Alamos National Laboratory. The ability of the neutron scintillator radiation detection units to respond to a minimum accident of concern as defined in ANSI/ANS-8.3-1986[1] was demonstrated[2]. Placement of the detectors and the trip points established are based on shielding calculations performed by the Oak Ridge National Laboratory and criticality specialists at the Portsmouth Plant[3-5]. Based on these experiments and calculations, detector trip points of 5 mrads per hour in air are used[6,7]. Any credible criticality accident is expected to produce neutron radiation fields greater than 5 mrads per hour in air at one or more radiation alarm locations. Each radiation alarm location has a "cluster" of three detectors which employs a two-out-of-three alarm logic.

Section 4.4.2 of the standard requires that the fundamental sound wave frequency be less than 1000 hertz and have a modulation rate less than 5 hertz. It is recommended in section 4.4.3 that the signal generator produce a sound pressure level not less than 10 dB above the overall maximum typical ambient noise level, and in any case not less than 75 dB at every location from which immediate evacuation is deemed essential. It is also recommended, in section 4.4.4, that the maximum A-weighted sound level not be in excess of 115 dB since excessive noise levels can be injurious to personnel. Section 5.5 requires that the radiation alarm system be produced within one-half second of activation by the minimum accident of concern. As mentioned above, the alarm trip point will be exceeded at one or more locations from a minimum accident of concern. Earlier work focused on testing the alarm logic latching circuitry. This work is directed towards measurement of the actual audible alarm signal delivered.

Procedure

The X-770 Facility is the responsibility of the Shops and Utilities Maintenance Department and contains the gaseous diffusion plant Test Loop equipment. The radiation alarm system in X-770 is typical of that found elsewhere throughout the Portsmouth Plant. The alarm system can be placed in the TEST mode and the alarm signal measured without disrupting operations elsewhere around the plant.

The measurement of the X-770 radiation alarm signal response time was performed during the morning of July 18, 1990 by the Applied Nuclear Technology Department at the request of the Nuclear Criticality Safety Department. All participants used hearing protection equipment. Those persons closest to the alarm horn wore earplugs and earmuffs.

The equipment and set-up used is shown in Figure 1. As indicated, a microphone was placed near the alarm horn. The horn is powered by a cylinder of compressed nitrogen gas which had an initial pressure of about 1400 psi. The nitrogen gas is throttled to 125 psi to drive the horn. The line from the nitrogen gas cylinder to the alarm horn is 55 feet long. The solenoid valve in the nitrogen line opens upon receipt of a two-out-of-three alarm signal from the detector cluster. Two of the detectors were manually tripped to initiate the alarm. The signals from the detectors, alarm logic latching circuits, and output from the microphone were recorded on oscillograph paper. The oscillograph was capable of generating up to 160 inches of output per second. The time line calibration of the oscillograph was checked using a 100 hertz signal produced by an NIST traceable signal generator.

Personnel from the Instrument Maintenance Department assisted in conducting the measurement and replaced the nitrogen cylinder afterwards to restore the system to operability. Surveyors from the Industrial Hygiene Department performed noise level measurements around X-770 to obtain background noise levels and noise levels during the sounding of the alarm. The layout of X-770 and the locations surveyed are shown (as A through D) on Figure 2. The radiation alarm horn is located above the control room approximately in the center of the facility.

Prior to conducting the measurement, the Cascade Coordinator in the X-300 Primary Control Facility (PCF) was contacted and requested to place the X-770 radiation alarm system and facilities slaved to X-770 in the TEST mode. This prohibits the alarm signal from causing the building evacuation horns (separate from the nitrogen powered cluster horn) from sounding and prevents the red flashing lights on the outside of X-770 and its slaved facilities from operating. Facilities slaved to the X-770 radiation alarm system are X-600, X-540, and X-101. The slaved facilities do not contain their own radiation detectors. Slaved facilities are sufficiently close to other facilities where criticality accidents are credible such that personnel working in the slaved facilities should be warned to evacuate to reduce potential radiation exposures. The Cascade Coordinator also announced a warning to all personnel over the public address system and radio network before the horn was sounded. Personnel in adjacent facilities were personally contacted before the sounding of the X-770 radiation alarm horn.

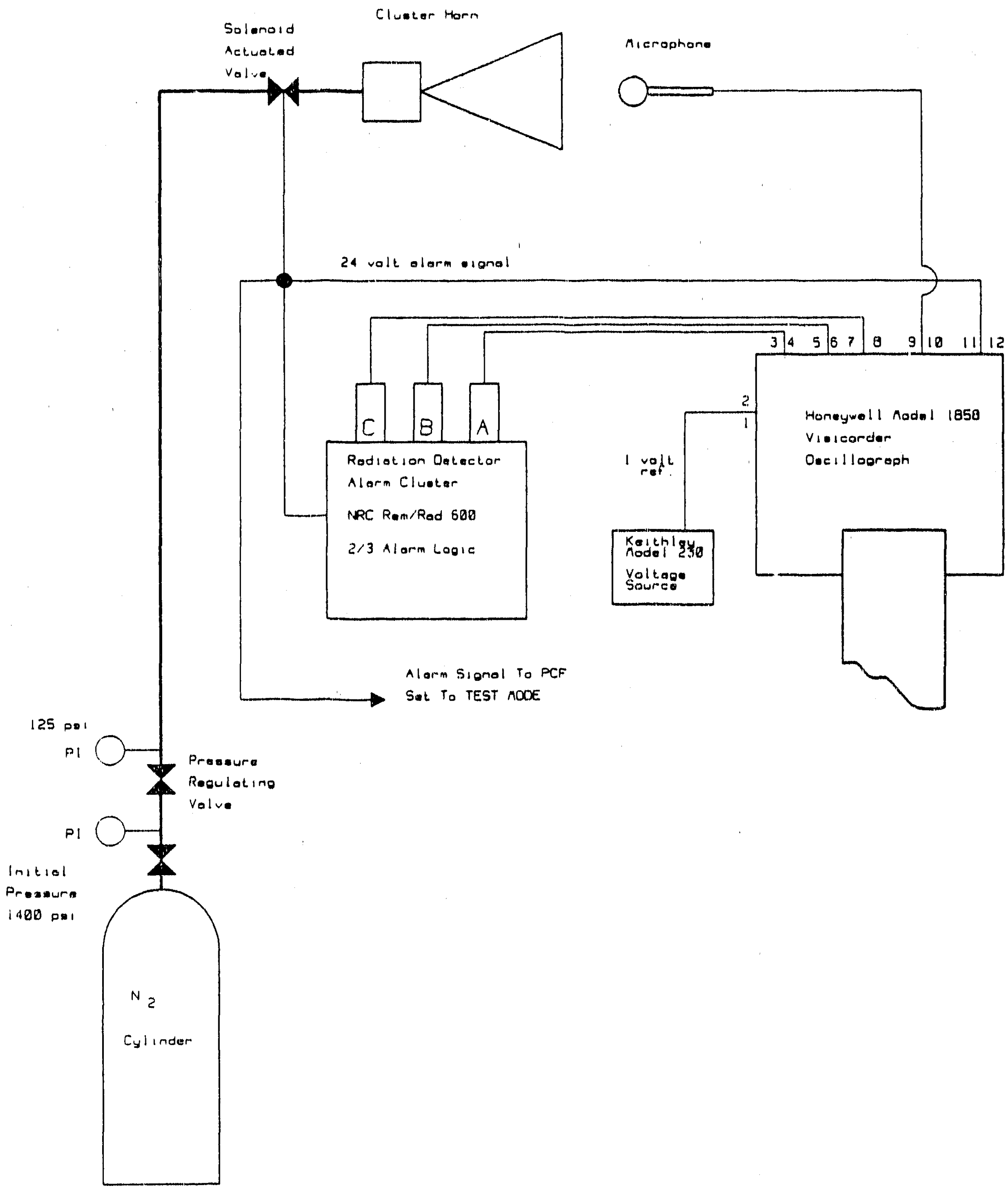

Figure 1. Equipment Set-Up To Measure Radiation Alarm Response

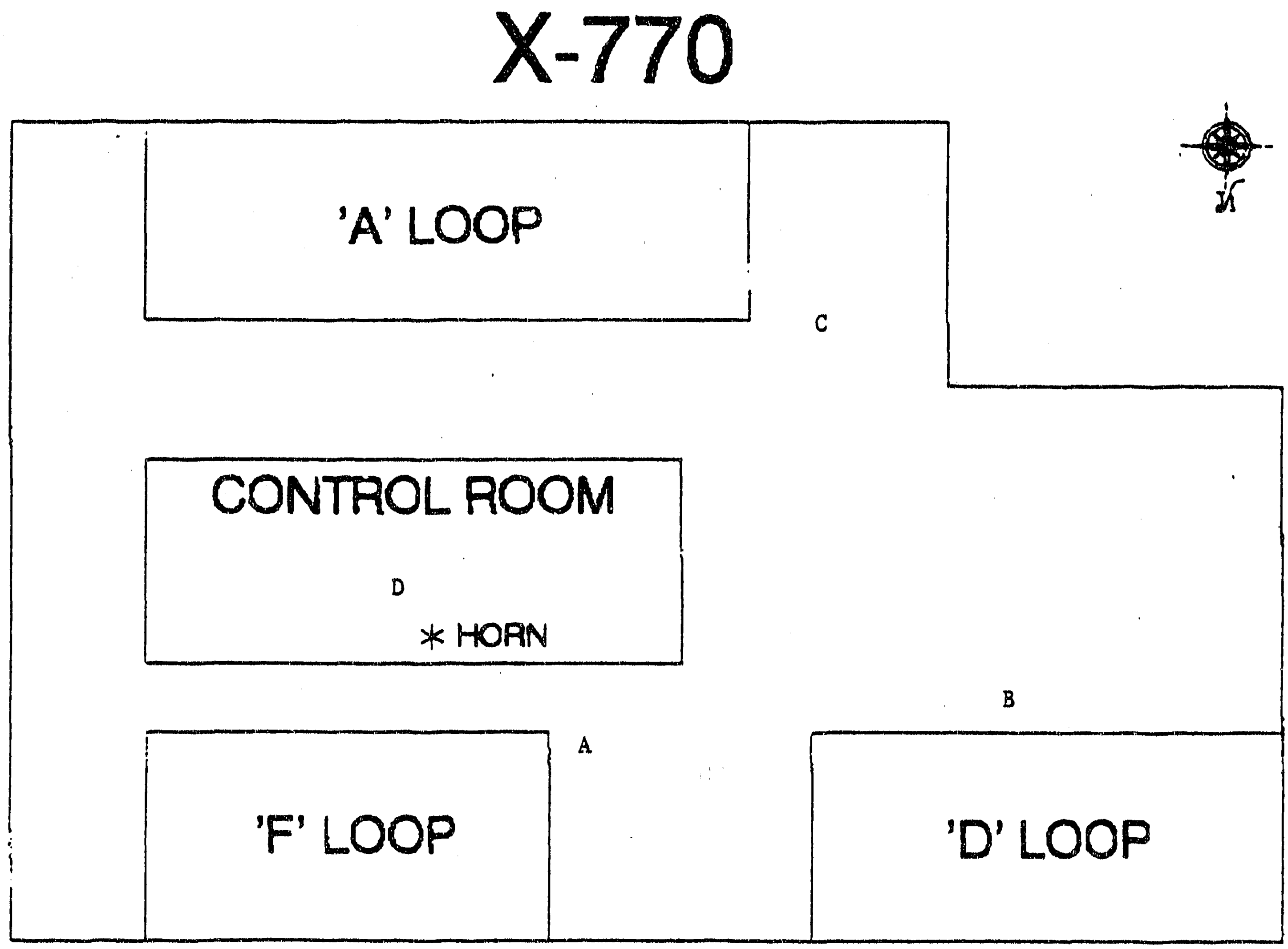

Figure 2. Facility Layout and Noise Level Survey Locations

In order to determine proper settings for the oscillograph recorder, the nitrogen cylinder valve was closed and the alarm horn was "burped" using just the pressure in the line between the nitrogen cylinder and the solenoid valve. After the proper settings were determined, the nitrogen cylinder valve was opened and the detectors tripped. The solenoid valve opened and the alarm horn sounded until the nitrogen in the cylinder was depleted. The pressure in the cylinder was initially about 1400 psi; that was sufficient to drive the horns for around six minutes during which time sound level measurements were made.

Results

The first 0.6 seconds of output from the oscillograph recorder after two of the three detectors were tripped is shown in Figure 3. The output is annotated. As indicated, the microphone begins to receive the sound waves from the horn about 0.15 seconds after the second detector trips. The steady state alarm signal is clearly being produced within one-half second of the detector trip. Since the detector trip has previously been shown to respond to the minimum accident of concern, the alarm signal response time is in compliance with the ANSI/ANS-8.3-1986 requirement.

As mentioned above, the oscillograph time base calibration was checked using a 100 hertz signal generator. It may be observed that the 24 dc volt alarm signal has a sawtooth shape such as produced by a full wave rectifier and has the expected 12 peaks per 0.1 seconds (2 x 60 hertz). Since 44 waveforms are received per 0.1 seconds by the microphone, the fundamental alarm frequency corresponds to 440 hertz. The standard requires a fundamental frequency of less than 1000 hertz. The alarm modulation is also less than 5 hertz.

Figure 4 shows the frequency response characteristics for sound level meters[8]. The A-weighted frequency response is closest to that of the human ear and is the most useful for obtaining a meaningful measure of hazardous noise levels. A logarithmic scale is used to convert sound pressure levels into units of decibels. Figure 5 shows the relationship between A-weighted decibel levels and sound pressure levels[8]. Shown adjacent to the appropriate sound level scale are a variety of common noise producing activities.

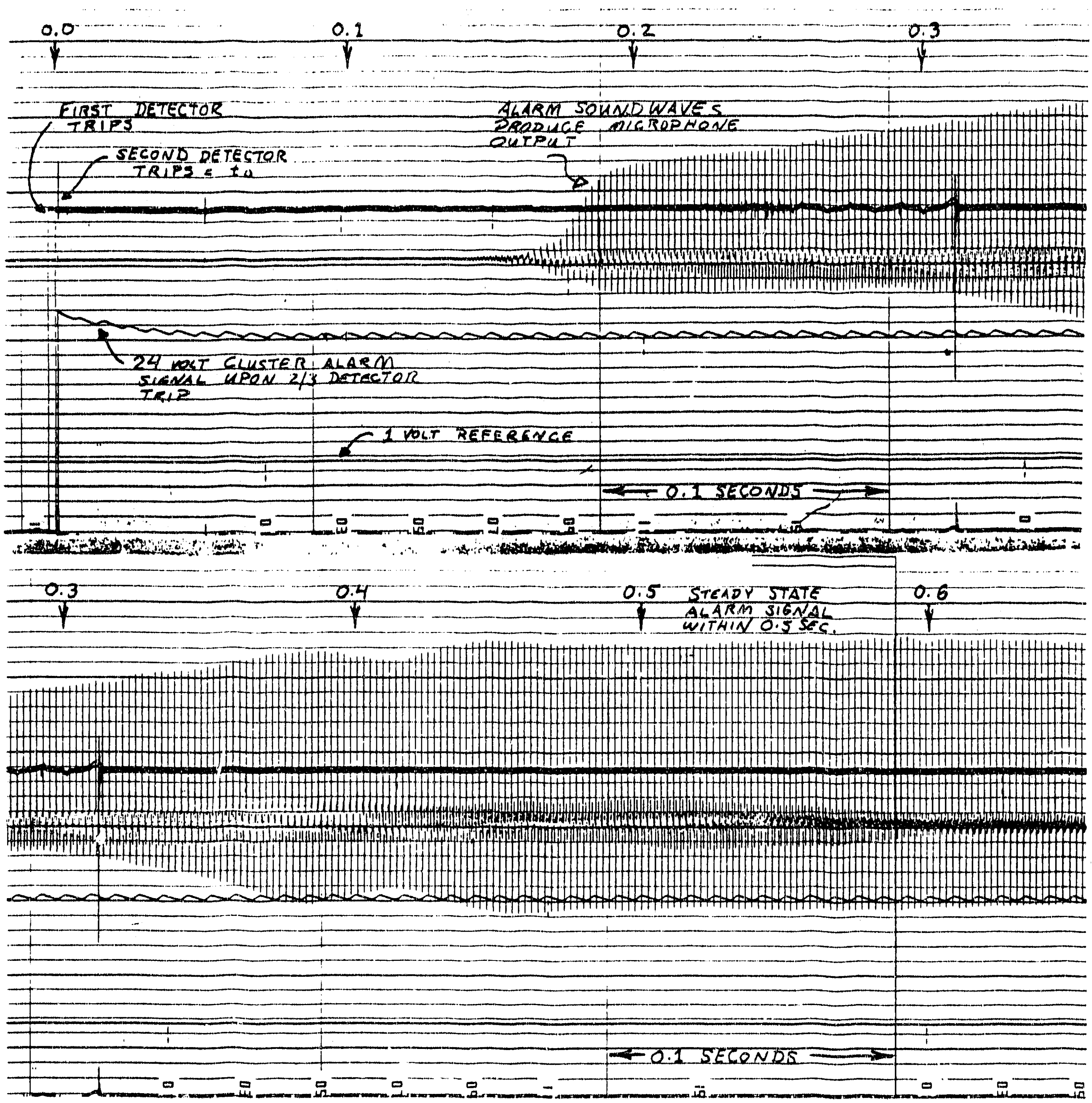

Figure 3. Oscillograph Trace Of Signals After Alarm Initiation

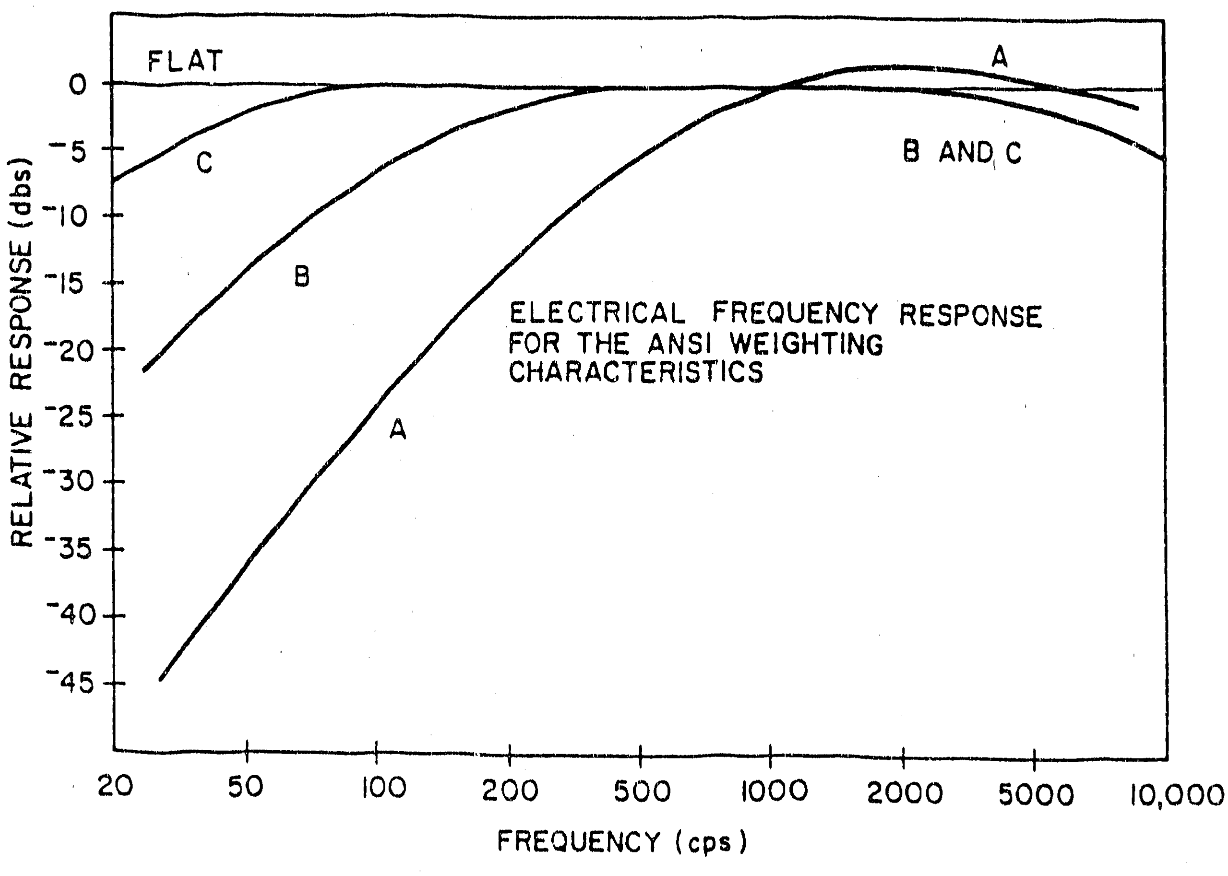

Figure 4. Frequency-Response Characteristics for Sound Level Meters

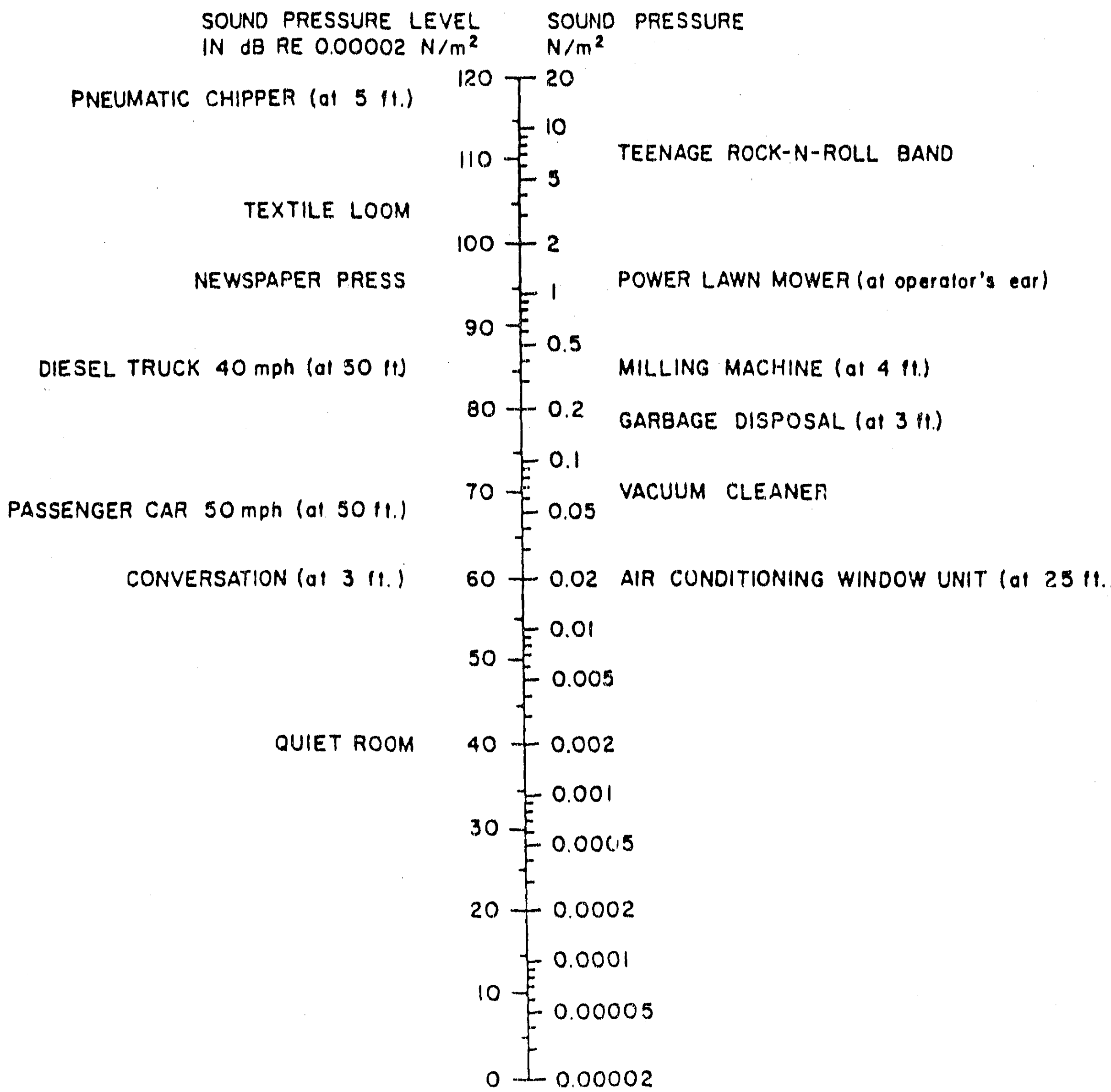

Figure 5. Relationship Between A-Weighted Sound Pressure Level In Decibels [dB] and Sound Pressure In N/m^2

As indicated on Figure 2, sound level surveys were made at locations A through D. The results are indicated below. The field notes from the noise level survey are included in the appendix.

Survey Location	Distance From Horn [ft]	Background Sound Level [dBA]	Alarm Sound Level [dBA]
A	40	67	125
B	65	67	115
C	85	65	116
D	25	61	100

The sound level at location A is substantially above the recommended maximum sound level of 115 dBA. Location D was inside the control room and therefore was the least loud location even though it was the closest to the horn. It should be noted that the distance from the sound meter to the horn shown on the field survey notes is based on an incorrect assumption of the horn location and thus differs from the value given in the table above.

Clearly the sound level is greater than 75 dB and more than 10 dB above the background sound levels as recommended in the standard.

Discussion

The ANSI standard recommends that the maximum noise level not exceed 115 dBA since excessive noise levels can be injurious to personnel. This is consistent with industrial hygiene recommendations for occupational noise levels. The pain threshold for humans is approximately 120 to 140 dB in low noise areas. In high noise areas, hearing protection would be worn and the pain threshold would be higher. Earplugs will add about 30 to 35 dB to the pain threshold level. Adding earmuffs to the earplugs will add an additional 5 dB, thus under the best circumstançes the pain threshold may be raised to around 160 dB. Above that level the skull will act as a coriductor of sound waves to the inner ear.

The American Conference of Governmental Industrial Hygienists has recommended that the maximum occupational noise level be 115 dBA and that exposure times at that noise level be limited to 15 minutes. The National Institute for Occupational Safety and Health has developed an equation for determining exposure times at various noise levels. For new facilities that equation is:

$$T = \frac{16}{2^{(L-80)/5}}$$

Where L is the effective noise level in dBA and T is the permitted exposure duration in hours. This equation also assumes a maximum noise level of 115 dBA. However if we extrapolate to 125 dBA, one obtains an exposure time of 112 seconds.

The emergency procedures at the Portsmouth plant require all personnel to immediately evacuate facilities in which radiation alarms sound. It is only necessary to move approximately 25 feet to reach the recommended maximum noise level. It is unlikely that an individual will be exposed to alarm noise levels for more than a few seconds while they are evacuating.

References

1) "Criticality Accident Alarm System", an American National Standard published by the American Nuclear Society, ANSI/ANS-8.3-1986, 8/29/86.

2) "Criticality Cluster - Post FAE Test Meeting", Crandall, G.M., GAT-557-84-51, 7/12/84.

3) "Radiation Levels in a Gaseous Diffusion Plant Assuming a Low-Enriched Criticality Event Corresponding to the ANSI-Standard Minimum Accident of Concern", Westfall, R.M. and Knight, J.R., ORNL/CSD/INF-82/7, 1/17/83.

4) "Summary of 1-Dimensional Transport Calculation Results for Line-of-Sight Dose Estimates at Radiation Alarm System Cluster Sites", Lewis, K.D., GAT-T-3269, 12/5/83.

5) "Minimum Critical Accident of Concern", Westfall, R.M., ORNL letter to Legeay, A.J., ORGDP, 11/21/83.

6) "Replacement GDP Cluster Placement", Jones, S.A., GAT-521-86-22, 2/11/86.

7) "GDP Criteria for Radial Coverage and Alarm Set-Point for Neutron Sensing Radiation Alarm Clusters", Woltz, F.E. and Duncan, J.M., GAT-DM-1535, 5/12/83.

8) Industrial Noise and Hearing Conservation, Olishifski, J.B. and Harford, E.R., editors, National Safety Council, 1975.

Appendix

Field Notes From Noise Level Survey

A-1873 (5-82

NOISE DATA SHEET

Code No. ____
Page 1 of 2

Location Code	No. of Ft. from Source	dBA*	☐ dBC* ☑ dB Linear*	dB Peak Hold*
A	40'	125	125	
		67	81	
B	65'	115	118	
		67	81	

Octave and One-Third Octave Center Frequencies (Hertz)*

Location Code: A	31.5	63	125	250	500	1K
Source	85	77	76	95	110	122
Background*	73	73	75	67	64	62

20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250

	2K	4K	8K	16K	31.5K	SIL
Source	119	110	104	95		
Background*	59 —	54	42	37		

1600	2000	2500	3150	4000	5000	6300	8000	10K	12.5K	16K	20K	25K	31.5K	40K

Date/Time of Survey: 2-18-90 0940
Source of Noise: Radiation Alarm
Noise Type: Steady ☑ Impulse ☐ Impact ☐
Environment: Walls Tesco. Floor Concrete
Ceiling Metal Other Noise Source (s) none
Elevation of Microphone: 5' Ft.
90 dBA Boundary: ______ Ft.
85 dBA Boundary: ______ Ft.
80 dBA Boundary: ______ Ft.

*Background noise levels or data for a second location be recorded in the lower blocks.

INSTRUMENT	SLM	OBA-1/3 OBA	OTHER (Specify)
Model:	BK 2215		
Serial No.:	786720		
Calib. Date:	2-18-90		
Batt.-Start/End:	✓ ✓	✓	✓ ✓

Noise Source is Properly Posted - Yes ☐ No ☐ Not Required ☑

Remarks: One Alarm unit used. One Nitrogen cylinder used for the Stembox horn test. Duration of Test was six minutes

Surveyor McDade / Stephenson

HC-D/923 (07-150 127)

A-1473 (5-85

NOISE DATA SHEET

Code No. ______
Page 2 of 2

Location Code	No. of Ft. from Source	dBA*	☐ dBC* ☑ dB Linear*	dB Peak Hold*
C	85'	116	116	
		105	78	
CONTROL RM	8'	100	101	
		61	73	

Octave and One–Third Octave Center Frequencies (Hertz)*

Location Code	dB Linear (Freq. Analysis)	31.5				63			125			250			500			1K		
	Source																			
	Background*																			
		20	25	31.5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250

2K			4K			8K			16K			31.5K			SIL
1600	2000	2500	3150	4000	5000	6300	8000	10K	12.5K	16K	20K	25K	31.5K	40K	

Date/Time of Survey: 7-18-90 1030 HRS
Source of Noise: EVACUATION ALARM
Noise Type: Steady ☑ Impulse ☐ Impact ☐
Environment: Walls TRANSITE Floor CONCRETE
Ceiling METAL Other Noise Source (s) NONE
Elevation of Microphone: 5 Ft.
90 dBA Boundary: ______ Ft.
85 dBA Boundary: ______ Ft.
80 dBA Boundary: ______ Ft.

*Background noise levels or data for a second location be recorded in the lower blocks.

INSTRUMENT	SLM	OBA–1/3 OBA	OTHER (Specify)
Model:	BK 2218		
Serial No.:	2040		
Calib. Date:	7-18-90		
Batt.–Start/End:	✓/✓	/	/

Noise Source is Properly Posted – Yes ☐ No ☐ Not Required ☑
Remarks: ______

Surveyor [signature]

RC-D/923 (07-450-127)

END

DATE FILMED

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