PNNL-14204

Pacific Northwest National Laboratory
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Evaluation of Airflow Patterns in the Transfer Area of the 105 KE Basin

B. G. Fritz
F. Khan
D. P. Mendoza

February 2003

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

This report is a qualitative study of airflow patterns within a building. This study focused on the transfer area of the 105 KE Basin, which is located in Washington State, on the Hanford Site, within the 100 K Area. Smoke was used to evaluate the airflow patterns within the transfer area. The purpose of the study was to determine appropriate locations for air monitoring equipment during sludge water pumping activities within the 105 KE Basin. Continuous air monitor (CAM) alarms required for worker safety, as well as monitors used to estimate worker dose (fixed head samplers), were recommended.

The results of the study indicated that three more CAM alarms, and one fixed head sampler, should be installed within the 105 KE Basin Transfer Area. The stratified nature of the air within the transfer area made predicting movement of contamination within the transfer area difficult, so multiple CAM alarms were recommended.

Acknowledgments

The authors wish to acknowledge William Decker, and Fluor Hanford's Spent Nuclear Fuel project, for providing funding for this study. Mr. Decker also provided valuable assistance in conducting and completing the study. John Buck provided a valuable peer review. Launa Morasch provided editorial review and Lila Andor provided text processing.

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Introduction

The purpose of this study was to provide a qualitative evaluation of airflow patterns within the 105 KE Basin. The KE Basin is located within the 100 K Area of the Hanford Site in Washington State (Figure 1). Within the basin, spent nuclear fuel is stored underwater. Future activities at the 105 KE facility will include pumping sludge that has accumulated at the bottom of the basin. This sludge will be pumped into a shipping cask, and hauled to a separate facility for separation and treatment of any contamination that may have become entrained in the sludge. The shipping cask will be transported on an engineered shipping trailer. The potential exists for radioactive contamination to become airborne during pumping activities. The results of this study indicated that additional continuous air monitor (CAM) alarms need to be installed within the 105 KE Basin. The results of the airflow study dictate placement of CAM alarms and fixed head air samplers used to estimate worker dose.

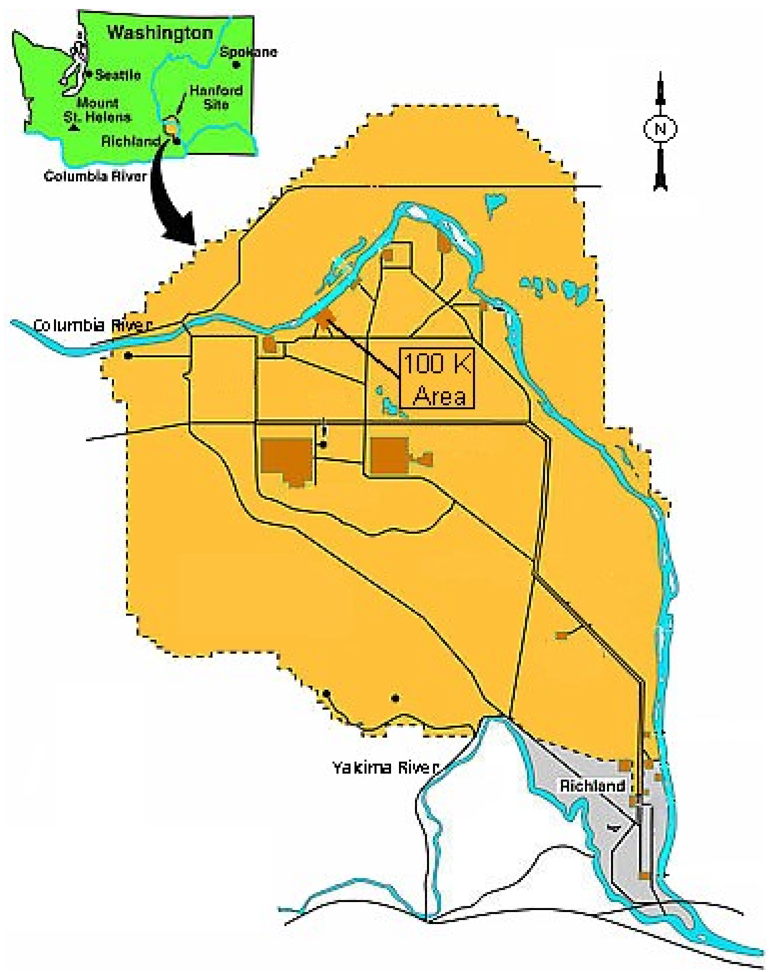

Figure 1. Location of the 100 K Area within the State of Washington

The focus of this study was within the transfer area of the 105 KE Basin. The transfer area was identified as the area most likely to experience a leak of radioactive material from sludge pumping activities. The work was conducted in accordance with sampling guidelines and procedures established by NUREG-1400, *Air Monitoring in the Workplace* (Hickey et. al. 1993) and Regulatory Guide 8.25 (U.S. NRC 1992). More details about the study are contained within the Statement of Work (Decker 2003). Airflow patterns within the remainder of the 105 KE Basin have been characterized by previous studies.[1,2]

Methods

To qualitatively evaluate the airflow patterns within the 105 KE Basin transfer area, smoke candles (Superior Signal Co.) were used to generate visible, near-neutral buoyancy smoke particles with diameters between 0.01 and 1 micrometers. The use of smoke to qualitatively evaluate airflow patterns is recommended by the Regulatory Guide 8.25 (U.S. NRC 1992) and by NUREG-1400, *Air Monitoring in the Workplace* (Hickey et al. 1993). Two types of smoke candles were used; size 1A smoke candles generated 4,000 cubic feet of smoke, and size 2B generated 8,000 cubic feet of smoke. For each smoke release test, a single smoke candle was used, with approximately 10 minutes between releases to allow for smoke to dissipate. Different basin configurations were tested to provide information about airflow during different conditions within the transfer area. One configuration had the heaters within the transfer area on, while the second configuration had the heaters off. Figure 2 illustrates the locations of each smoke release within the transfer area, and Table 1 outlines information about each release. For each smoke candle release, two Pacific Northwest National Laboratory (PNNL) employees observed the smoke dispersal pattern and took notes on a diagram of the transfer area layout (Figure 3). A third PNNL employee recorded each release on video to provide a visual record of the airflow patterns observed. The field notes were compiled, compared to the videotape, and are summarized for each test in the Appendix.

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(1) Letter report, *Evaluation of Air Flow Patterns in 105 KE and 104 KW Basins*, from E. E. Hickey and G. A. Stoetzel (Pacific Northwest National Laboratory, Richland, Washington) to W. A. Decker (Fluor Hanford, Inc., Richland, Washington), dated August 2002.

(2) Letter report, *Evaluation of Air Flow Patterns in K-East and K-West Fuel Storage Basins*, from G. A. Stoetzel and G. R. Cicotte (Pacific Northwest National Laboratory, Richland, Washington) to S. S. Lewis (Fluor Hanford, Inc., Richland, Washington), dated September 29, 1994.

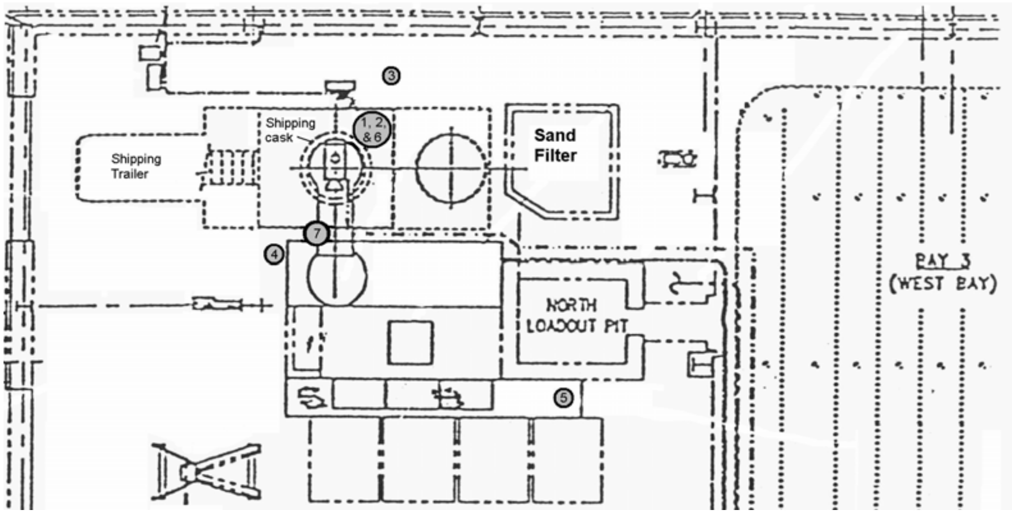

Figure 2. **Smoke Release Locations within the 105 KE Basin Transfer Area (Image scanned from drawing number H-1-86771, KE-SWS General Arrangement Plan)**

Table 1. **Information About Each Smoke Release within the 105 KE Basin Transfer Area**

Release #	Time	Configuration	Size Smoke Candle	Release Location
1	6:10 pm	Heaters on	1A (4000 ft^3)	Top of trailer
2	6:16 pm	Heaters on	2B (8000 ft^3)	Top of trailer
3	8:36 pm	Heaters on	2B (8000 ft^3)	North wall catwalk
4	8:44 pm	Heaters on	1A (4000 ft^3)	Platform south of trailer
5	8:55 pm	Heaters on	1A (4000 ft^3)	Platform south of trailer
6	9:13 pm	Heaters off	1A (4000 ft^3)	Top of trailer
7	9:25 pm	Heaters off	2B (8000 ft^3)	Floor south of trailer

Results

To determine the airflow patterns of the 105 KE Basin transfer area, seven smoke release tests were conducted. Smoke was released at various locations within the transfer area (see Figure 2). Details about the flow pattern observations for each individual release are summarized in the Appendix. Although two transfer area configurations were tested (heaters on & heaters off), the observed airflow patters were similar for each configuration. The effect of the heaters was limited to the uppermost layer of air, which was well above the breathing zone of any potential worker. All airflow patterns observed were consistent with the results from previous smoke release tests within the transfer area.[3]

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(3) Letter report, *Evaluation of Air Flow Patterns in 105 KE and 104 KW Basins*, from E. E. Hickey and G. A. Stoetzel (Pacific Northwest National Laboratory, Richland, Washington) to W. A. Decker (Fluor Hanford, Inc., Richland, Washington), dated August 2002.

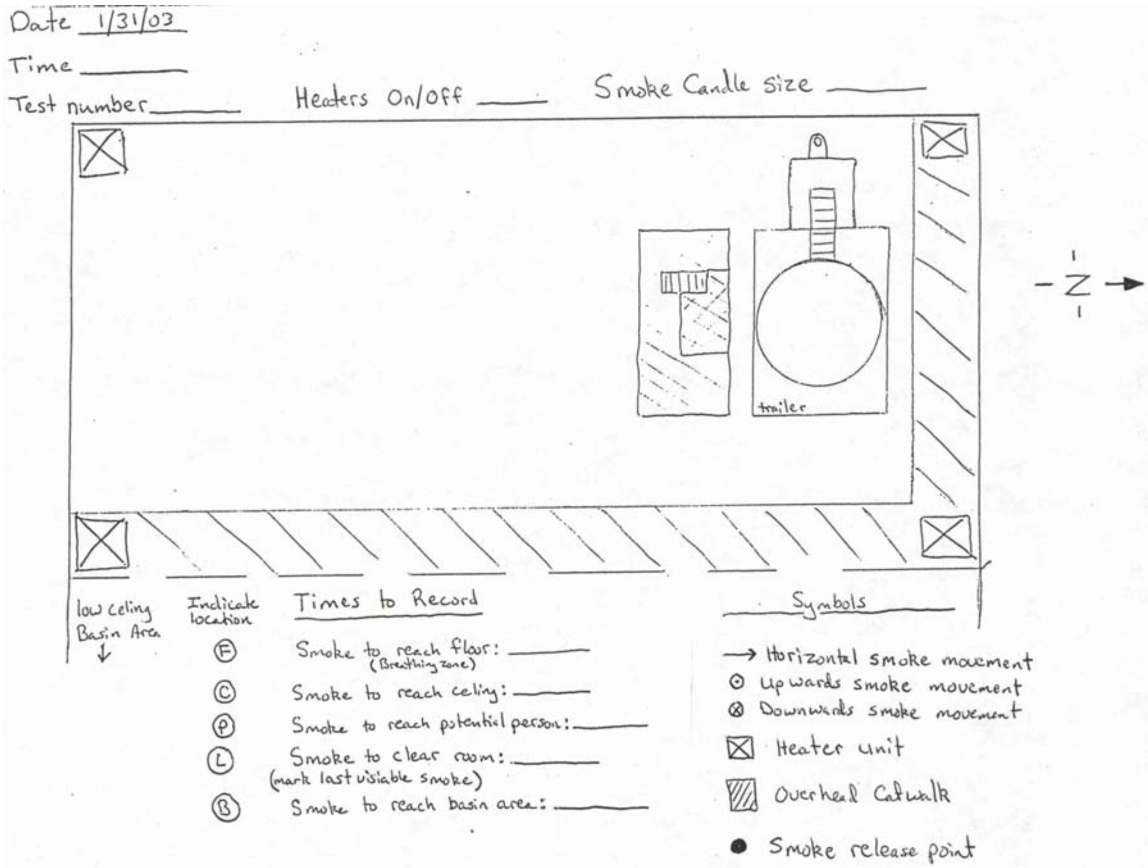


Figure 3. Example of Blank Diagram Used for Field Notes

Configuration 1 - Heaters On

In the configuration with the heaters on, five smoke release tests were conducted. The airflow patterns observed in this configuration showed three distinct layers of air within the transfer area. There was a stagnant layer of air extending up several feet from the top of the shipping cask, with a well-mixed layer above that. Below the stagnant layer was a layer of air that appeared to move from the transfer area over the basin. The interface of the stagnant layer and the layer below it occurred approximately at the height of the basin ceiling (Figure 4). The exhaust fans over the basin influenced airflow in the transfer area below the stagnant layer, but had little effect on airflow in the stagnant layer. There was little exchange of material observed between the stagnant layer and the layer below it. This was due to the decoupled nature of the air in the transfer area.

Upon ignition, the smoke candles provided enough vertical momentum to carry some smoke through the stagnant layer and into the well-mixed layer above it. Smoke that was lifted through the stagnant layer was dispersed around the ceiling of the transfer area by the heaters. A heat lamp mounted to a support beam just to the south of the shipping trailer also provided enough thermal convection to lift some material up through the stagnant layer and into the well-mixed layer. No downward movement of smoke in this upper layer was observed. Material that remained in the stagnant layer moved very slowly.

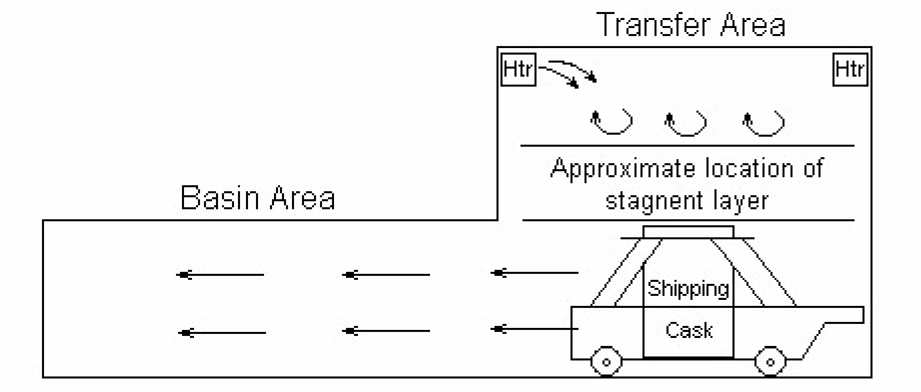


Figure 4. Profile Sketch Illustrating the Approximate Location of the Stagnant Layer, and Observed Airflow Patterns, within the 105 KE Basin Transfer Area with the Heaters On

During release 3, it took 7 minutes for the layer of smoke over the shipping trailer to dissipate. With the heaters on, smoke along the east wall was observed to move toward the center of the basin. Some smoke was observed to move up along the east wall above the catwalk. This was presumed to be from warm air collected along the ceiling over the basin moving out and up into the transfer area. During release 5, smoke moved away from the east wall, going up and back toward the center of the transfer area.

Configuration 2 - Heaters Off

In the second configuration, two smoke release tests were conducted. Release 6 indicated that the stagnant layer was still in place. Smoke from release 6 spread mainly east and west through the stagnant layer above the top of the shipping cask. Some smoke from this release rose straight up to the ceiling of the transfer area. Without the heaters on, there was no turbulent dispersion of the smoke. With the heaters off, the stagnant layer appeared to extend up to the ceiling of the transfer area. During release 7, smoke was pulled from the area near the floor around the shipping trailer into the basin area; it took less than two minutes for smoke to move from the base of the trailer into the basin area. Once over the basin, the smoke moved east and south, and was well mixed vertically. It was assumed that the exhaust fans over the basin forced this movement of smoke.

Conclusions

The primary potential source of airborne contamination within the transfer area is where the sludge delivery hose connects to the shipping cask. Since this is near the bottom of the stagnant air layer, the operation of the heaters did not have any impact on where the CAM alarms should be located. With the heaters on, turbulence can advect material out of the top of the stagnant layer, but the movement is up and toward the transfer area exhaust, away from any potential workers. The stagnant layer of air present in the transfer area represents a virtual boundary near the top of the shipping cask. Material in the stagnant layer will move differently than material below the stagnant layer, and little exchange of material between the layers will occur.

Three CAM alarms are recommended for the 105 KE Basin transfer area (Figure 5). Material originating at the top of the shipping cask could move in the stagnant layer of air, or in the layer below it. It is recommended that two CAM alarms be located at worker breathing height on either side of the shipping trailer. These CAM alarms should be located as close as possible to the shipping trailer, since any material becoming airborne in the stagnant layer will disperse horizontally at whatever height it is released at within the stagnant layer. Small pressure or temperature gradients could dictate which direction material will move within the stagnant layer, so a CAM alarm on both sides of the shipping trailer is recommenced. The alarm on the south side of the trailer should be mounted at a height several feet above the top of the shipping cask. Qualified personnel from the 105 KE Basin should determine the exact position of the CAM alarms based on the expected position of workers. It is recommended that a third CAM alarm be located near the interface of the basin and the transfer area, directly east of the sand filter and shipping trailer. Any material becoming airborne below the stagnant layer will move in this direction.

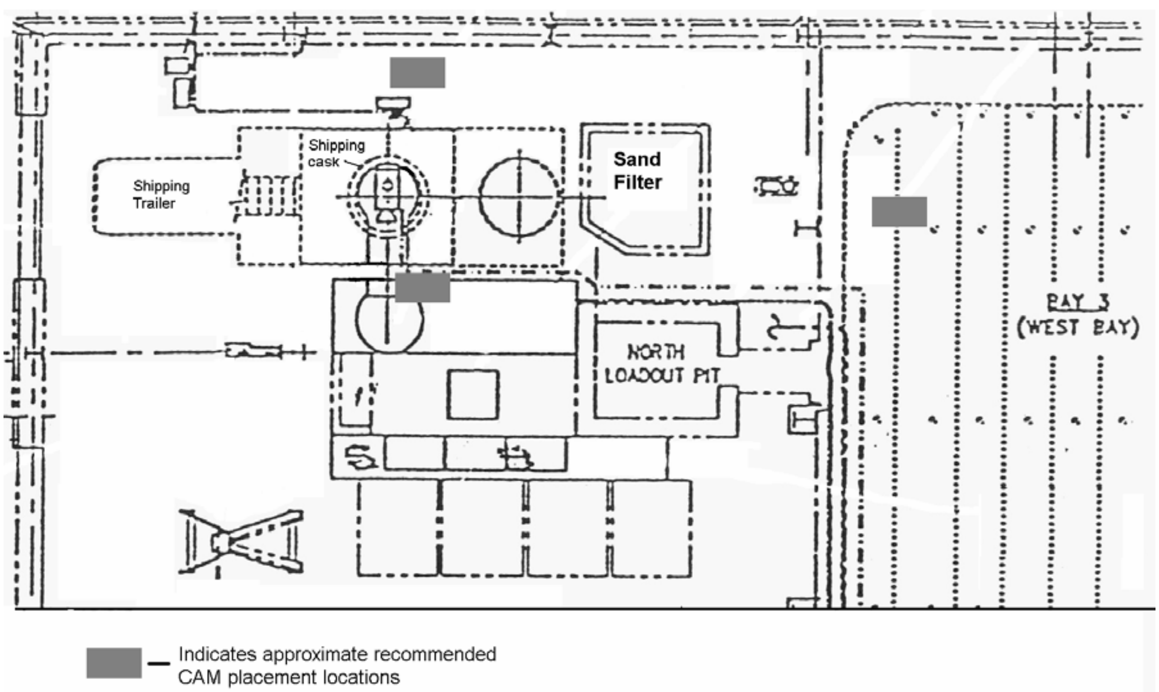


Figure 5. Recommended CAM Placement Locations

In addition to the continuous air monitors, fixed head samplers should also be installed for more accurate air concentration measurements. A fixed head sampler should be installed next to one of the recommended CAMs located on either side of the shipping trailer. The differences in average concentration between those two locations would not be expected to vary significantly, so either side will suffice. There is already a fixed head air sampler over the basin to the east of the shipping trailer, which should accurately reflect air concentrations in that area. This sampler should remain in place.

It should be noted that this study was conducted at night in January. This is considered a worst-case scenario, since the cool temperatures resulted in extremely stratified air. Warmer spring or summer temperatures, and sunlight on the outside walls, could increase the amount of mixing that occurs within the transfer area. This mixing would improve the likelihood of CAM alarms detecting a radioactive leak since the material would be dispersed more.

References

Decker, W. A. 2003. *Statement of Work for Services- 105 KE Basin Air Flow Study for North Transfer Area and Sludge Water System Start Up*. SNF-13932, Fluor Hanford, Richland, Washington.

Hickey, E. E., G. A. Stoetzel, D. J. Strom, G. R. Cicotte, C. M. Wiblin, and S. A. McGuire. 1993. *Air Sampling in the Workplace*. NUREG-1400, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission. 1992. *Air Sampling in the Workplace*. Regulatory Guide 8.25, Revision 1, June 1992. Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D.C.

Appendix

Additional Details of Each Smoke Release

Appendix

Additional Details of Each Smoke Release

In this appendix, details about each smoke release are summarized for future evaluation and comparison to previous air flow studies. For each release, a brief text summary of the airflow patterns observed is included, with pictures of the patterns observed, and the compiled field observation data sheets.

Table A.1. Summary of Release Times, Configuration, Smoke Candle Used and Release Location

Release #	Time	Configuration	Size Smoke Candle	Release Location
1	6:10 pm	Heaters on	1A (4000 ft^3)	Top of trailer
2	6:16 pm	Heaters on	2B (8000 ft^3)	Top of trailer
3	8:36 pm	Heaters on	2B (8000 ft^3)	North wall catwalk
4	8:44 pm	Heaters on	1A (4000 ft^3)	Platform south of trailer
5	8:55 pm	Heaters on	1A (4000 ft^3)	Platform south of trailer
6	9:13 pm	Heaters off	1A (4000 ft^3)	Top of trailer
7	9:25 pm	Heaters off	2B (8000 ft^3)	Floor south of trailer

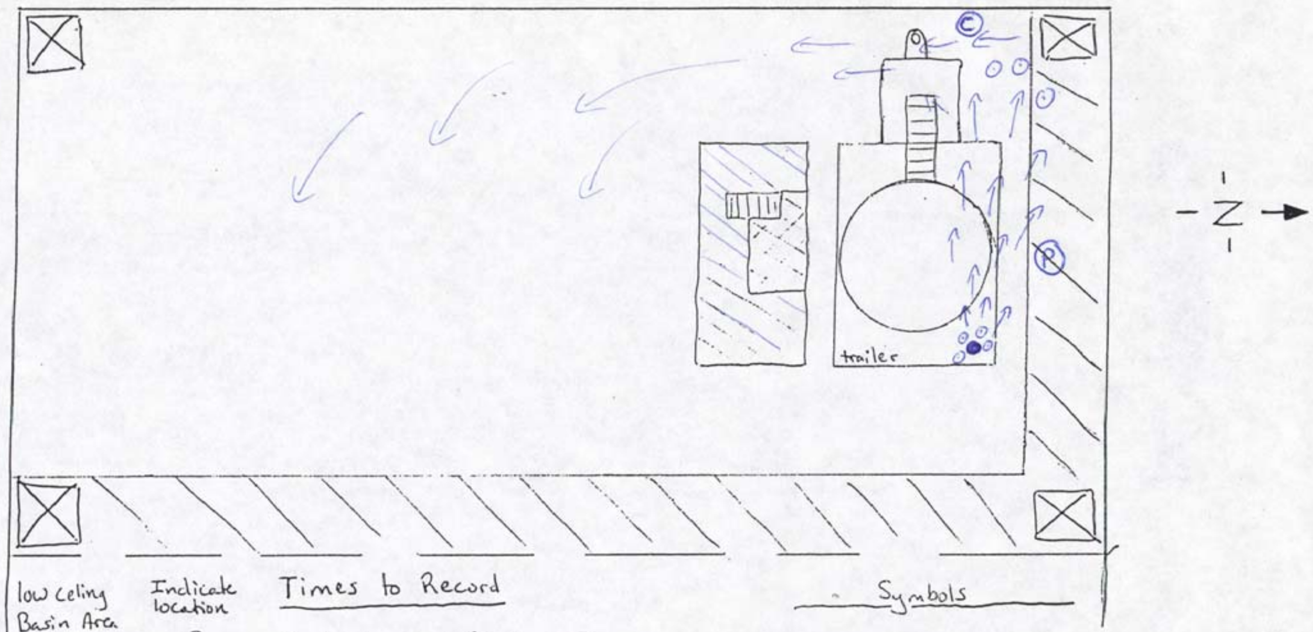
Release 1

Smoke went up to a level approximately 6 feet above the top of the shipping cask. The smoke at the top was blown west by the heater in the northeast corner. Some of the smoke that moved west was pulled up by the heater in the northwest corner and blown to the south. More smoke was simply advected to the south by the heater exhaust. The smoke that was moved around by the heaters was well mixed, and spread out across the ceiling of the transfer area, tending to collect in the middle of the ceiling. This collection in the middle of the ceiling was probably due to a cyclonic effect created by the heaters. No significant amount of smoke was observed to remain in the stagnant layer, due to the initial buoyancy of the smoke release.

Date 1/31/03

Time 6:10 pm

Test number 1 Heaters On/Off On Smoke Candle size #1A



Indicate location	Times to Record
F	Smoke to reach floor: — (Breathing zone)
C	Smoke to reach celing: 1:15
P	Smoke to reach potential person: 30 sec
L	Smoke to clear room: — (mark last visiable smoke)
B	Smoke to reach basin area: —

Symbols

→ Horizontal smoke movement

⊙ Upwards smoke movement

⊗ Downwards smoke movement

⊠ Heater unit

▨ Overhead Catwalk

● Smoke release point

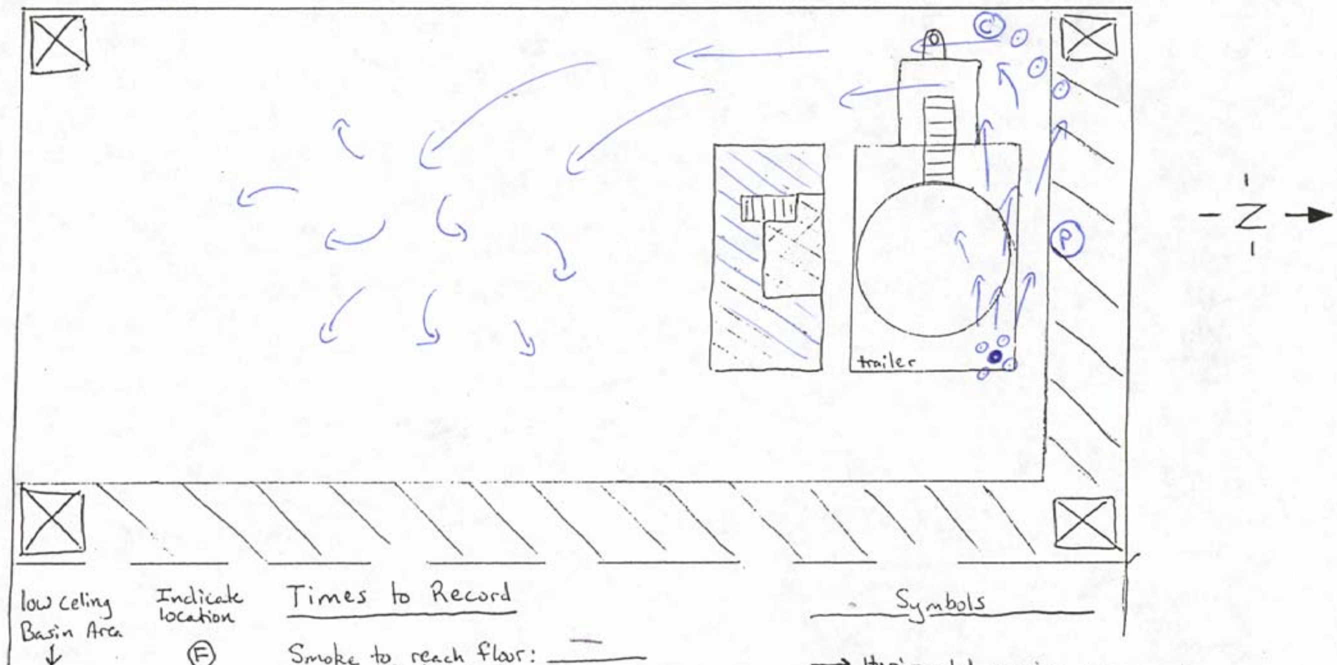
Release 2

This release was nearly identical to release 1. A larger smoke candle was used, so there was more smoke to track. The smoke followed nearly the same path as during release 1, moving west, then south near the ceiling over the center of the basin. Due to the larger smoke candle being used, the dispersion along the ceiling was more apparent over the center of the transfer area.

Date 1/31/03

Time 6:16 pm

Test number 2 Heaters On/Off On Smoke Candle size #2B



Indicate location

Times to Record

Indicate location	Times to Record	
(F)	Smoke to reach floor: (Breathing zone)	—
(C)	Smoke to reach celing:	1:15
(P)	Smoke to reach potential person:	30 sec
(L)	Smoke to clear room: (mark last visiable smoke)	—
(B)	Smoke to reach basin area:	—

Symbols

- → Horizontal smoke movement
- ⊙ Upwards smoke movement
- ⊗ Downwards smoke movement
- ☒ Heater unit
- ▨ Overhead Catwalk
- ● Smoke release point

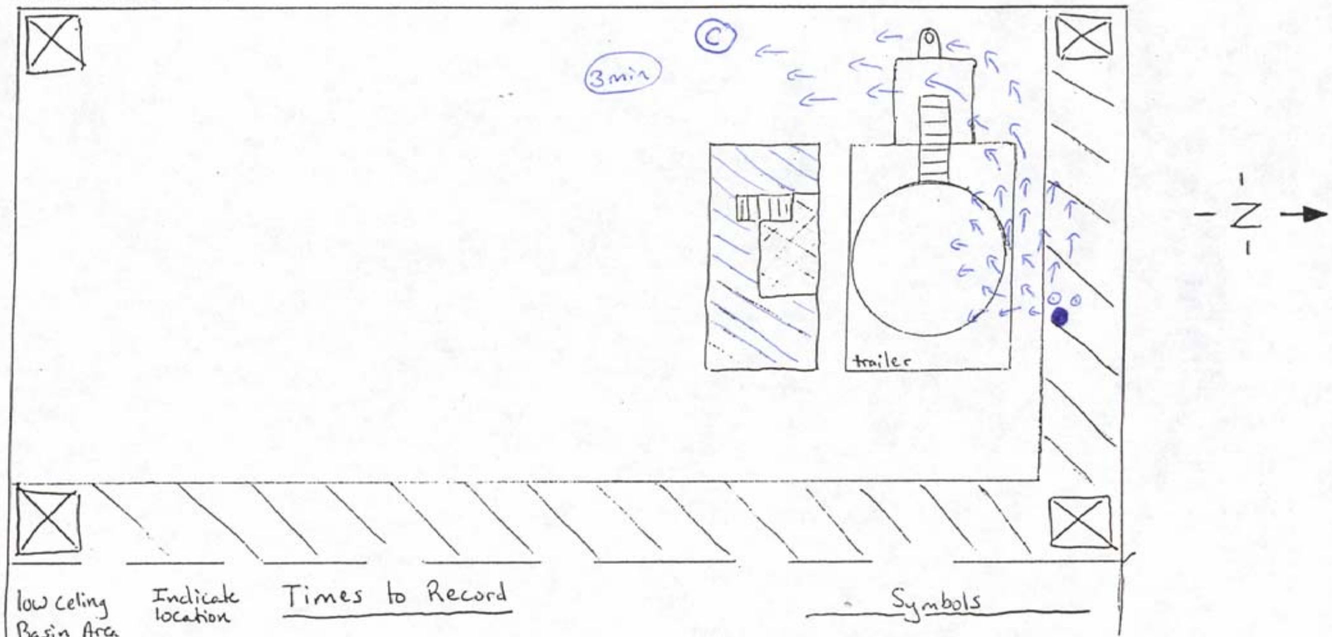
Release 3

This release was started several feet lower than the first two (on the catwalk along the north wall). The lower starting height resulted in less smoke moving up into the well-mixed layer, and more smoke remaining in the stagnant layer. The smoke hung in a thick layer near the top of the shipping cask. Movement of the smoke was very slow, taking 7 minutes for the smoke to dissipate. Movement of smoke within the stagnant layer was to the west and south. This may have been caused by downward moving air close to the wall within the well-mixed layer. Smoke within a few inches of the north wall was observed to move from the well-mixed layer down into the stagnant layer. This movement was limited to the two or three inches closest to the wall, and was likely caused by the wall cooling the air closest to it.

Date 1/31/03

Time 8:36 pm

Test number 3 Heaters On/Off On Smoke Candle size #2B



Indicate location | Times to Record

Indicate location	Times to Record	
(F)	Smoke to reach floor: (Breathing zone)	—
(C)	Smoke to reach celing:	2:30
(P)	Smoke to reach potential person:	0 started on catwalk
(L)	Smoke to clear room: (mark last visiable smoke)	—
(B)	Smoke to reach basin area:	—

Symbols

- → Horizontal smoke movement
- ⊙ Upwards smoke movement
- ⊗ Downwards smoke movement
- ⊠ Heater unit
- ▨ Overhead Catwalk
- ● Smoke release point

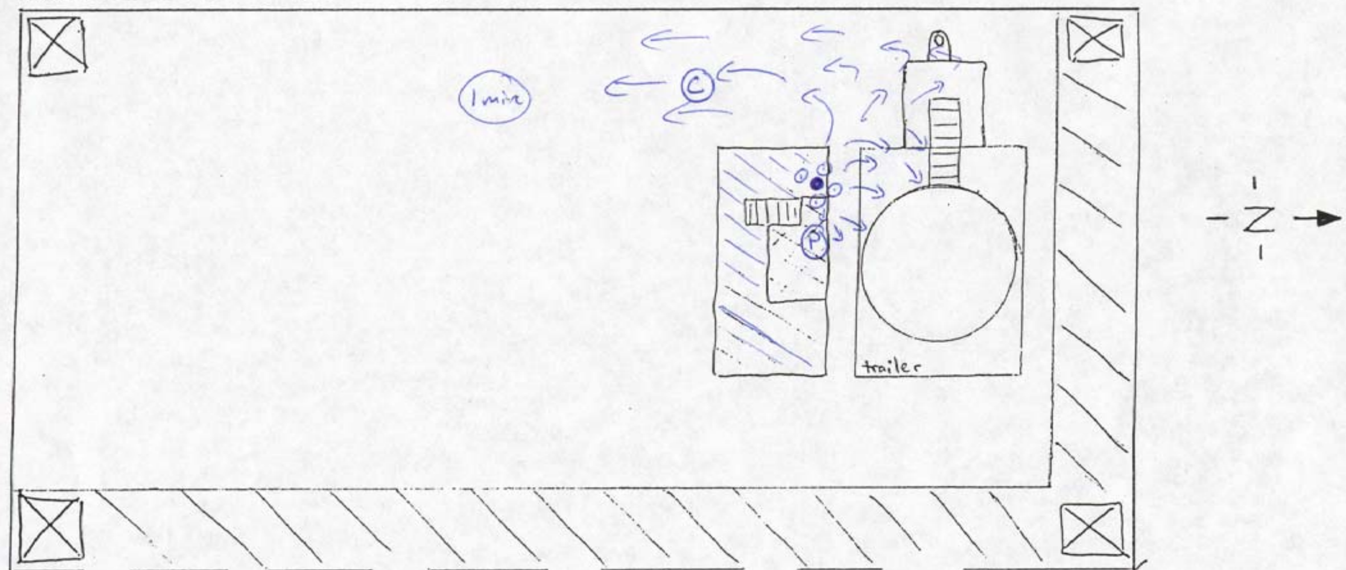
Release 4

This release occurred on the platform south of the transfer trailer. Directly above the release was a heat lamp that provided some convective movement of smoke through the stagnant layer and up into the mixed layer above it. Some of the smoke from this release collected in the stagnant layer near the top of the shipping cask. The smoke from this release that remained in the stagnant layer persisted for about 4 minutes.

Date 1/31/03

Time 8:44 pm

Test number 4 Heaters On/Off On Smoke Candle size #1A



low celing Basin Area ↓

Indicate location	Times to Record	
(F)	Smoke to reach floor: (Breathing zone)	—
(C)	Smoke to reach celing:	1:15
(P)	Smoke to reach potential person:	1:00
(L)	Smoke to clear room: (mark last visiable smoke)	—
(B)	Smoke to reach basin area:	—

Symbols

→ Horizontal smoke movement

⊙ Upwards smoke movement

⊗ Downwards smoke movement

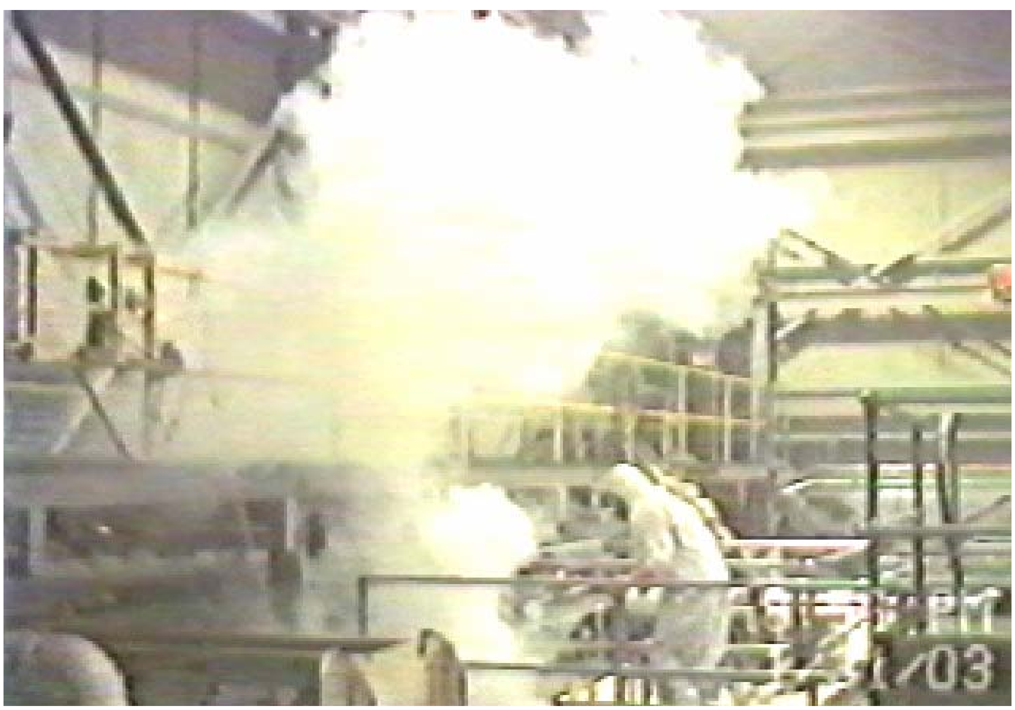
☒ Heater unit

▨ Overhead Catwalk

● Smoke release point

Release 5

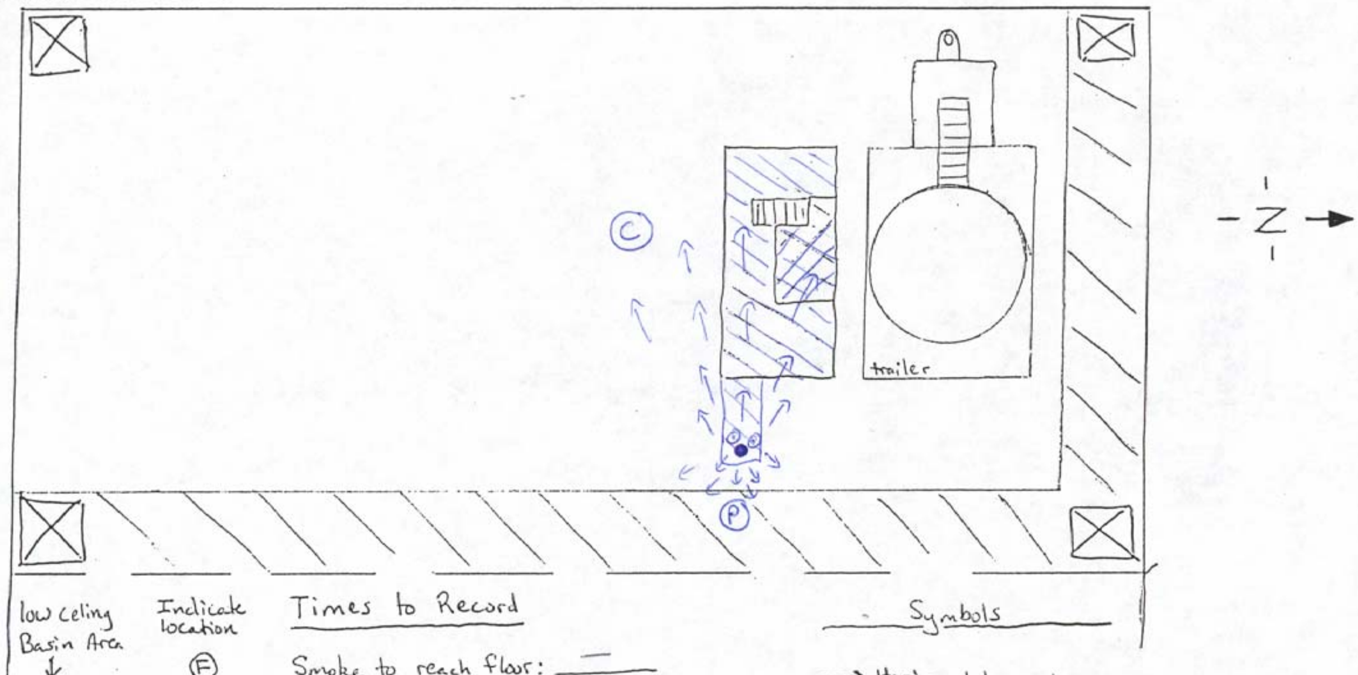
This release occurred on the platform south of the shipping trailer, on a spur close to the east wall. The smoke from this release was generally pushed up and to the west, towards the center of the basin. Some smoke was caught in the stagnant layer and moved north over the top of the shipping cask. This layer persisted for more than 4 minutes.



Date 1/31/03

Time 8:55

Test number 5 Heaters On/Off On Smoke Candle size #1A



Indicate location

Times to Record

Ⓕ Smoke to reach floor: (Breathing zone) —

Ⓒ Smoke to reach celing: 2:30

Ⓟ Smoke to reach potential person: 30 sec

Ⓛ Smoke to clear room: (mark last visiable smoke) —

Ⓑ Smoke to reach basin area: —

Symbols

→ Horizontal smoke movement

⊙ Upwards smoke movement

⊗ Downwards smoke movement

☒ Heater unit

▨ Overhead Catwalk

● Smoke release point

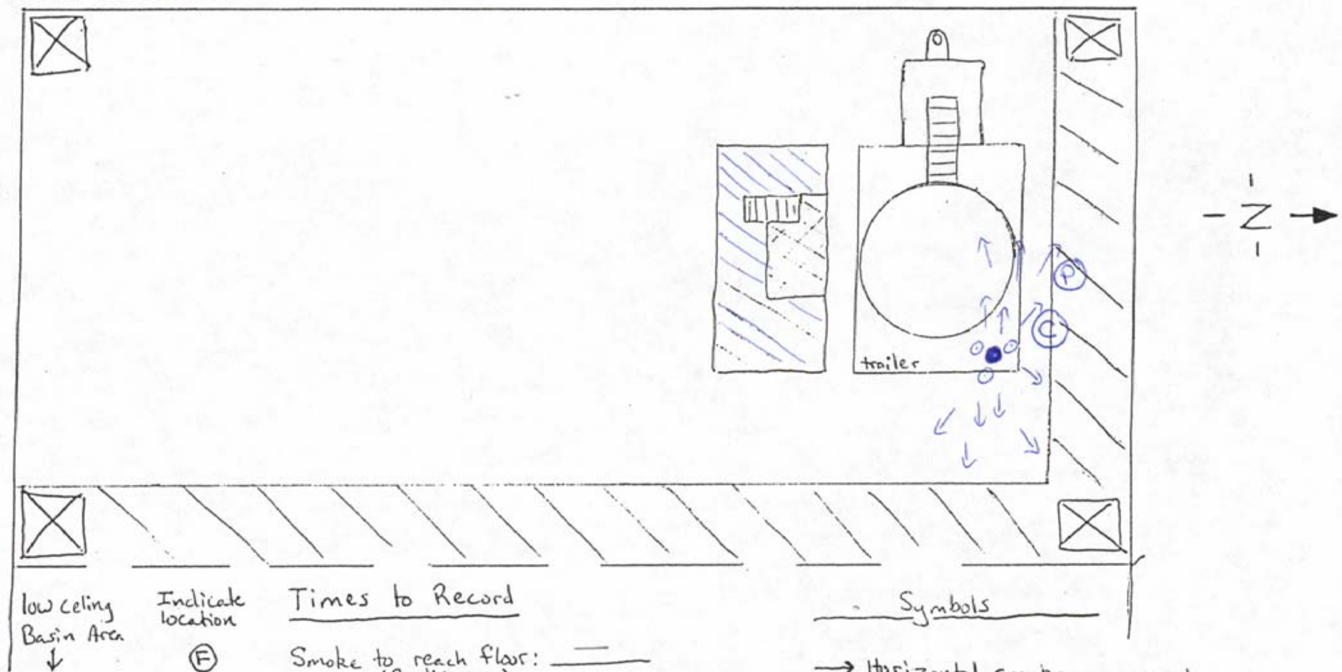
Release 6

This release occurred on the shipping trailer in the same location as releases 1 and 2. This was the first release with the heaters off. The smoke rose higher than during either release 1 or 2, since there was no forced horizontal air movement with the heaters off. The majority of the smoke moved east and west within the stagnant layer, at a height approximately 8 feet above the catwalk on the north wall.

Date 1/31/03

Time 9:13

Test number 6 Heaters On/Off OFF Smoke Candle size #1A



Indicate location

Times to Record

(F) Smoke to reach floor: — (Breathing zone)

(C) Smoke to reach celing: 1:30

(P) Smoke to reach potential person: 2:30

(L) Smoke to clear room: — (mark last visiable smoke)

(B) Smoke to reach basin area: —

Symbols

→ Horizontal smoke movement

⊙ Upwards smoke movement

⊗ Downwards smoke movement

☒ Heater unit

▨ Overhead Catwalk

● Smoke release point

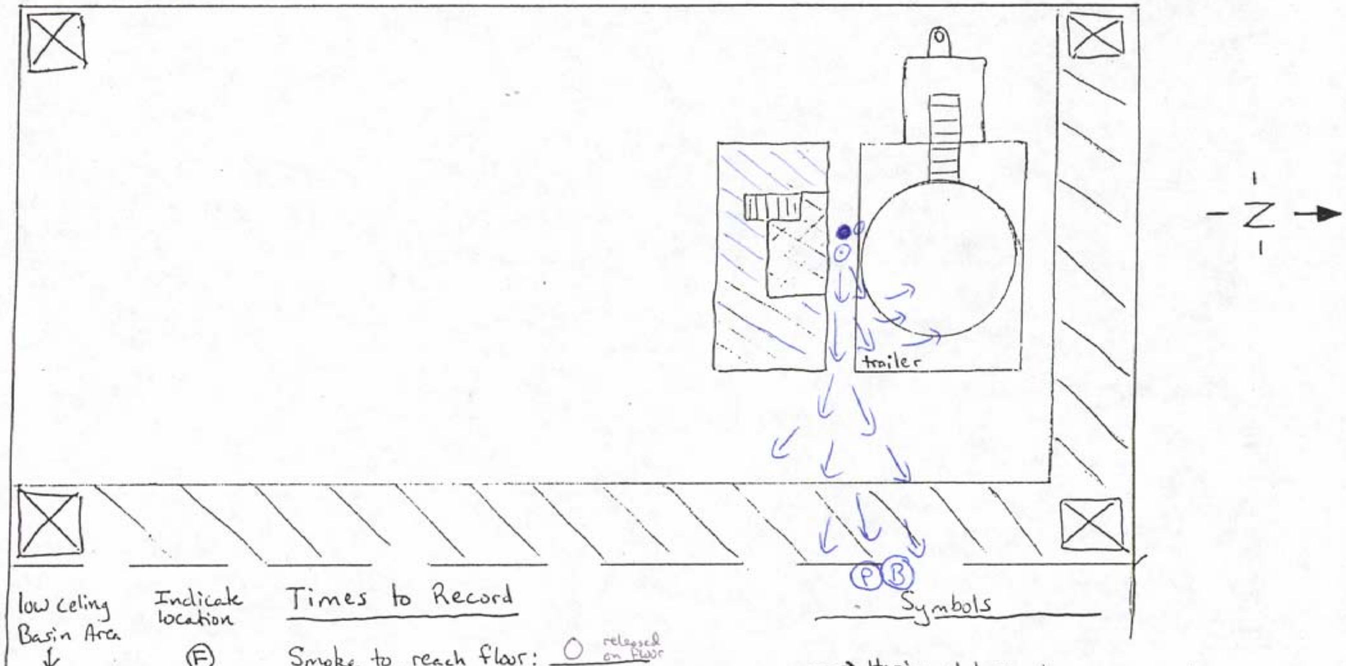
Release 7

This release occurred on the floor next to the shipping trailer. Smoke from this release moved quickly into the area directly over the basin. The bottom of the stagnant layer was observed in this release as very little smoke moved up into the stagnant layer. A pool of smoke was observed to settle between the shipping trailer and the sand filter. Presumably, the sand filter inhibited movement of air from this pocket into the basin. Once the smoke moved over the basin, it was well mixed and dispersed throughout much of the basin. A little smoke from this release was observed to move into the stagnant layer. This smoke was visible for approximately 5 minutes.

Date 1/31/03

Time 9:25

Test number 7 Heaters On/Off OFF Smoke Candle size #2B



Indicate location

Times to Record

Ⓕ Smoke to reach floor: 0 released on floor
(Breathing zone)

Ⓒ Smoke to reach celing: —

Ⓟ Smoke to reach potential person: 1:30

Ⓛ Smoke to clear room: —
(mark last visiable smoke)

Ⓑ Smoke to reach basin area: 1:30

Symbols

→ Horizontal smoke movement

⊙ Upwards smoke movement

⊗ Downwards smoke movement

☒ Heater unit

▨ Overhead Catwalk

● Smoke release point

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