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TIMING TESTS: AUTOMATIC VALVE CLOSURE FOR TRITIUM LEAKS

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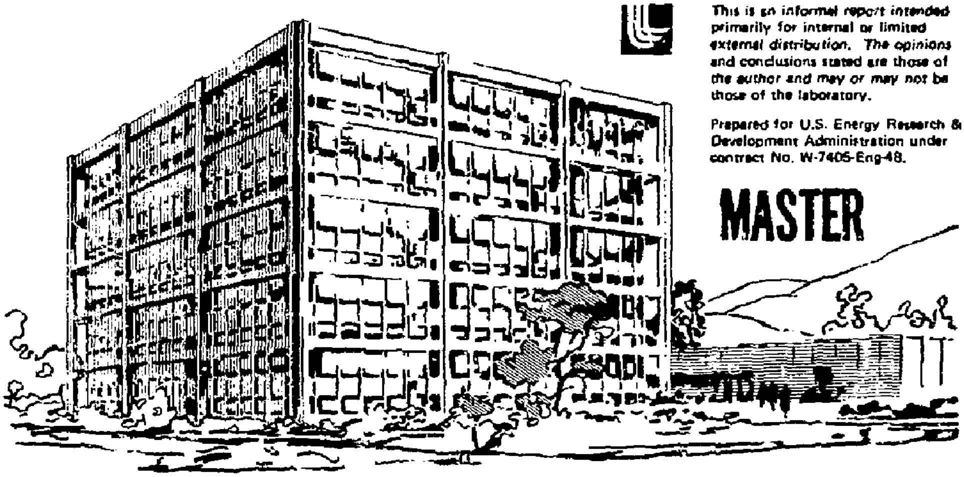

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ABSTRACT

How fast can an automatic valve be closed after a tritium leak occurs in a system? Tests described in this report found a valve can be closed within fifteen seconds of leakage. In one practical example considered by the author, this delay would limit loss of tritium from a plumbing leak in a tritium system to 1-1/4 gram. The tests were made in a typical LLL air-flush hood in which a tritium handling system had been installed. Incidental observations suggest that further study be made of a possible leak-actuated recovery system for an entire tritium facility.

INTRODUCTION

A typical tritium system consists of vessels, uranium beds, etc., which contain the bulk of the tritium. These vessels are connected by a plumbing system consisting of tubing, fittings and valves. At LLL the plumbing system typically contains less than 1 gram of tritium, while the vessels may contain 40 grams or more. If automatic valves between the plumbing and bulk storage areas could be closed quickly enough, the amount of tritium lost by a leak in the plumbing system would be much less. Therefore the plumbing system would not have to meet the exacting requirements of certified construction* used for the storage vessels.

A typical LLL air-flush hood containing a low pressure tritium-supply system was selected for testing. The test consisted of two phases. In phase 1, we used smoke particles to survey the hood for the most appropriate places to test "leak" the tritium. In phase 2 we used 1/2-curie tritium releases to check the time needed to detect the leak and close an automatic valve.

TEST REQUIREMENTS

It was correctly assumed that the major time delay would be the time required for the tritium to travel from the point of release to the tritium sensor, located in the exhaust duct from the hood. To locate the most representative points of release while minimizing the amount of tritium released, phase 1 testing was done with smoke particles (of dioctal phthalate smoke).

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*For more information on certified construction, see: S.L. Hanel, Quality Assurance Guidelines For High Pressure Gas Systems, Lawrence Livermore Laboratory, Rept. UCRL-77864 (1976).

To determine the most representative positions, a grid pattern of 19 "points of release" and two points of interest (points 20 and 21) was selected, based on the locations of both the tritium handling equipment and the slowest air velocities in the hood. This grid pattern is shown on Fig. 1. The effect of the positions of the hood doors (open or closed) was then checked by ten tests, each with smoke released at grid points 1 through 19. The ten test arrangements are (refer to Fig. 1):

I — Door 3 west side open, top doors open, all others closed.
II — Doors 2 and 3 west side open, top doors open, all others closed.
III — Door 3 east and west side open, top doors open, all others closed.
IV — Doors 2 and 3 east side open, top doors open, all others closed.
V — Door 3 east side open, top doors open, all others closed.
VI — All doors closed.
VII — Door 3 west side open, all other doors closed, fan at position 20 (to stir a stagnant air space there).
VIII — Door 3 west side open, all other doors closed.
IX — Door 3 west side open, all other doors closed, gravity damper held open.
X — All doors closed, gravity damper held open.

PHASE 1 TESTING (SMOKE PARTICLES)

This consisted of timing (with a stop watch) the delay from the release of a visible puff of smoke at the point of release until the meter of the sensor indicated smoke. For the results of phase 1 testing see Table 1.

PHASE 2

Testing

The door positions from phase 1 testing selected for phase 2 testing were those of arrengement VIII — door 3 west side open, all other doors closed. This arrangement was selected as the most typical of that used in operation of a tritium system. Four grid positions were selected for phase 2 testing as follows: Position 11 is on top of the Savannah River container, at the tube-to-container joint. This position was selected because it is a possible point of tritium release and would have a long time delay between release and detection. Position 13, on the Sprengel pump, is at the bottom of the mercury

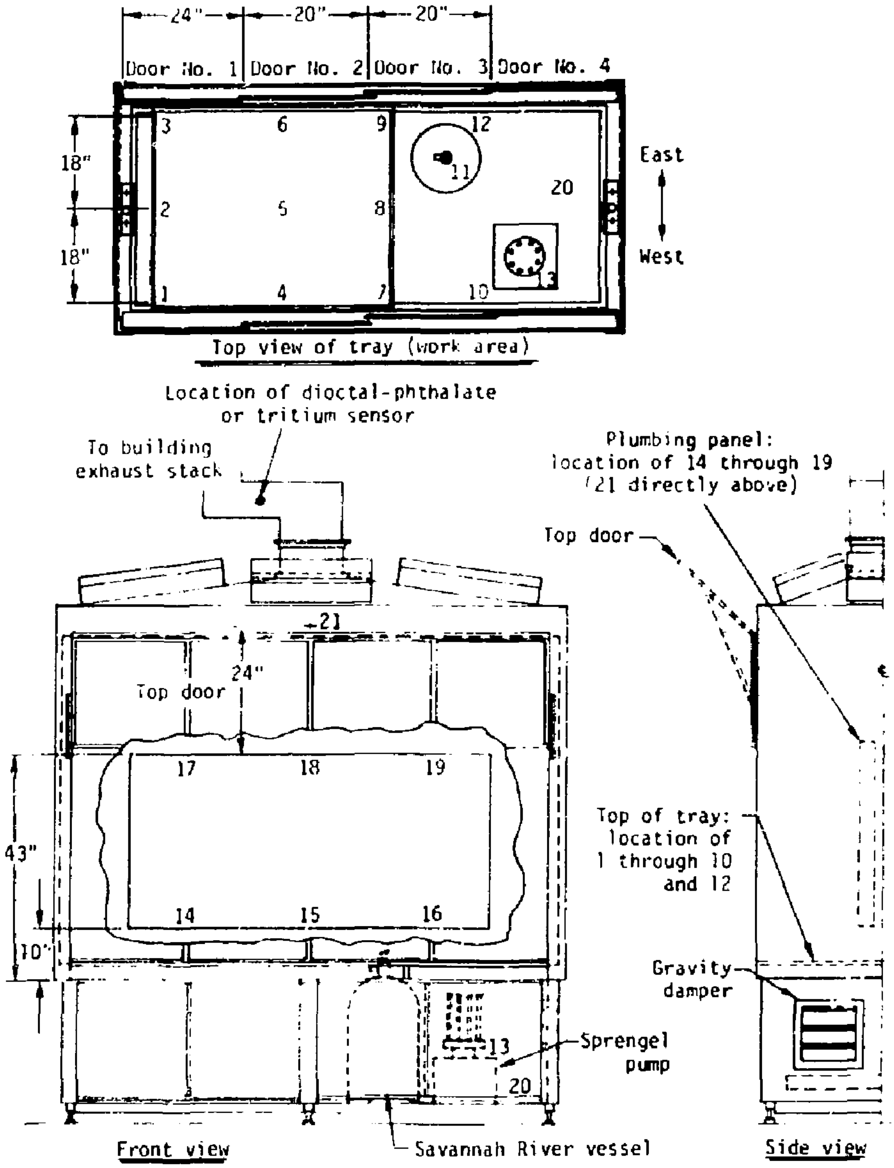


Fig. 1. Grid pattern of release points (1-19) and points of interest (20 and 21) used for timing tests of smoke and tritium discharge.

Table I. Phase I test data: time (in seconds) between visible release of smoke and detection of it by the sensor located in the hood's exhaust duct.

	Test Arrangement													
Release point	I			I(av)	II	III	IV	V	VI	VII	VIII	IX	X	Average from release point
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			11
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]			[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]			[illegible]
6	[illegible]	[illegible]	[illegible]											
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
8	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
9	10	9	[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	8	[illegible]	[illegible]			[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
13	28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	22	[illegible]		[illegible]									
14	[illegible]	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
16	10	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
18	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]			[illegible]
20					[illegible]									

columns. It was selected because it is a possible point of failure and would also have a long time delay. Position 14 is located on the bottom of the main plumbing panel. It could be a typical failure point in the plumbing system. Position 21 is located in the entry to the exhaust duct of the hood. It was selected to determine how much time could be saved by locating the sensor there rather than at the location in the duct actually used for the sensor.

The phase 2 test consisted of releasing tritium in amounts of 1/2 curie. An equipment list and a schematic of the system is shown in Fig. 2.

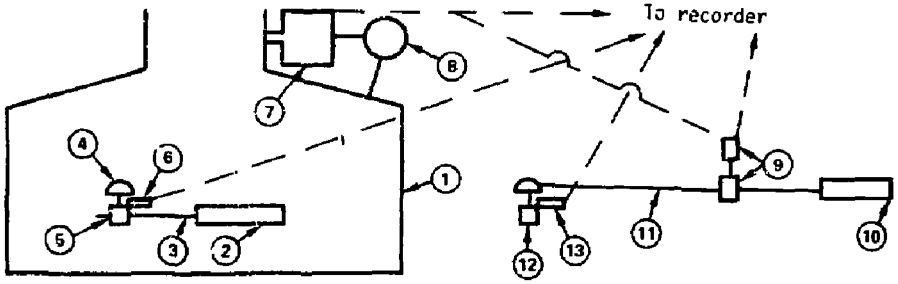
The controlled release was of tritium mixed with deuterium in a ratio of 1/2 curie/5 cm^3 volume at STP conditions (0°C and 101.3 kPa). The mix was contained at 414 kPa (60 psia) in a vessel (item 2, Fig. 2) connected to pneumatically operated autoclave valve (item 4). The pneumatic autoclave valve was opened, which actuated a microswitch (item 6). The microswitch gave the zero-time signal to a recorder to show the start of the tritium leak. The opening of the autoclave valve allowed the tritium to leak out of a 0.00254-cm (0.001-in.) orifice (item 5).

When tritium arrived at the tritium sensor (item 7), the sensor signaled the recorder and also energized the solenoid valve (item 9). The solenoid valve signaled the recorder and also opened, allowing argon to flow to the pneumatically operated, Supro "U" series valve (item 12). The argon opened the Supro "U" series valve, actuating a microswitch (item 13), which sent a signal to the recorder.

Note: the Supro "U" series valve was opened rather than closed. The time for the gas to flow into the pneumatic operator and open the valve against the spring is assumed to give a more dependable measure of valve motion and be a more conservative time than the time for the valve to close. Testing had been done to check the time of valve closing. The valve moved 1/4 s after the argon pressure to it was relieved, but whether the valve fully closed was not determined. Because the valve time is a small portion of the total time delay, any difference between valve closing time and valve opening time would not appreciably affect our results. Hence this difference was not considered important enough to check further.

Results

The total elapsed time varied from 3-1/4 s to 13-1/4 s. As expected, the bulk of the time delay is due to the gas flow from point of discharge to the



① LLL air flush hood [1.42×10^4 liters/min (500 cfm) air flow], containing the low pressure tritium system.

② Pressure vessel containing tritium-deuterium mix (1/2 curie/5 cm^3 at 0°C and 101.3 kPa). Bottle pressure: 414 kPa (60 psia).

③ Connecting capillary line: 0.159-cm (1/16-in.) OD X 0.0305-cm (0.012-in.) ID X 1.22 m (4 ft) long.

④ Pneumatically operated autoclave valve.

⑤ Blind plug, with 0.00254-cm (0.001-in.) drilled orifice, screwed into valve (item 4).

⑥ Microswitch, to signal recorder of opening or closing of item 4. (Signals recorder at time of release.)

⑦ Tritium detector (Bendix Model T-446). This detected the leaked tritium and provided timing signal to the recorder as well as a signal to actuate the solenoid valve (item 9).

⑧ Booster pump, to create faster flow through detector and make it more sensitive.

⑨ Solenoid valve (Skinner V53-ADB 1150), to fill or exhaust argon from vessel valve (item 12). Also provided a timing signal.

⑩ Argon gas supply: 7.24×10^2 kPa (105 psia).

⑪ Tubing: 0.953-cm (3/8-in.) OD X 0.749-cm (0.295-in.) ID X 6.1 m (20 ft) long.

⑫ Pneumatically operated, Nupro "U" series valve (vessel valve).

⑬ Microswitch, to signal recorder of opening or closing of item 12.

Fig. 2. Schematic and equipment list for phase 2 test of automatic valve closure.

tritium sensor (item 7). Only 1-1/4 s is lost from the moment the tritium sensor senses the leak until the vessel valve microswitch signals the opening of the vessel valve. Only about one second was required for actuation of the vessel valve.

Test Results (Tritium)

1. Test 1 was made without the use of the booster pump (item 8) on the tritium detector. The point of release was grid position 13. The detector did not sense any tritium.
2. Test 2: The 0.00254-cm (0.001-in.) orifice was removed and a controlled release of 5 cm^3 (equivalent to 1/2 curie) was made. After this release, the building tritium monitor was checked and it showed a total release of 1 curie had occurred. This showed the tritium release system was working properly, but the tritium detector in the hood's exhaust duct was not working properly. A small booster pump (item 8) was connected to the tritium sensor to pull more air through the sensor. Its exhaust was returned to the hood.
3. Test 3: With the booster pump in the system, test 2 was repeated. Time from point of release to actuation of the vessel valve microswitch was 11-1/2 s. The orifice was replaced and the remainder of tests were conducted as originally planned.
4. The results of the rest of the tests are given in Table 2.
5. Tests 14, 15, 16, and 17 were done to check if a very low concentration of tritium — 0.05 curie could be detected and they showed that it could. The testing was oriented toward a low tritium concentration, such as might occur through a weld crack. This was done by releasing the gas for about one second instead of ten seconds (see column 8 of Table 2).

Incidental Observations

A review of the test data indicates that two important questions are favorably answered. The first question is: In a typical air-flush, exhaust-duct system, does the tritium travel at the speed of the air flow? The exhaust system in this test is typical as it is one of the two exhaust systems for the building. It collects the airflow from 22 outlets within the building and exhausts the air at 5.947×10^5 liters/m (21 000 cfm) up a 30.48-m (100-ft)

Table 2. Phase 2 test data: time in seconds between signals from various components of the test equipment.

1	2	3	4	5	6	7	8	9
	Release point (of Fig. 1).	Time elapsed between signals[a] s					Duration of gas release s	Amount of tritium released[c] curies
Test No.		6–13 (total)	6–7	7–9	9–13	6–Building monitor[b]		
4	13	13 1/4	12 1/4	<0.01	1	30	9	1/2
5	13	12 3/4	11 3/4	0.01	1	27	9	1/2
6	13	13 1/4	12 1/4	0.01	1	29	9	1/2
7	11	13	11 7/8	0.01	1 1/8	30	9	1/2
8	11	13	12	<0.01	1	32	9	1/2
9	11	13	12	0.01	1	32	9	1/2
10	14	11 1/4	10 1/4	0.01	1	30	9	1/2
11	14	11 1/4	10 1/4	<0.01	1	27	10	1/2
12	14	12 1/4	11 1/4	<0.01	1	26	9	1/2
13	21	4 1/2	3 1/2	0.01	1		9	
14	21	4 1/4	3 1/4	<0.01	1		1 1/4	
15	21	4 1/4	3 1/4	<0.01	1		1 3/8	
16	11	9	8	0.01	1		1 1/8	
17	11	10 7/8	9 7/8	0.01	1		1 1/4	-

[a] Numbers below refer to signaling components shown in Fig. 2.

[b] Located in exhaust stack of the building. This reading was not part of the basic test but was taken as a point of interest for possible future use. The average time for the tritium to flow from the tritium detector in the hood to the building monitor detector is 17.7 s.

[c] Read from the building monitor system.

exhaust stack. Located part of the way up the stack is the tritium monitor that was used in the test to verify the quantity of tritium released per test (column 9 of Table 2). Column 7 in Table 2 is the time for the tritium to travel from the point of release to this monitor. Subtracting column 4 from column 7 gives the time for tritium to travel from the detector in the hood to the building monitor. The time varies between 14-3/4 s and 20 s, with an average of 17.7 s. This result compares to 17.8 s, which is the air flow time as calculated from building drawings that give duct velocities, cross-sectional areas, and lengths.

The second question is: Does the tritium travel as an aggregate, or is it dispersed by the turbulence in the duct system? A measure of the dispersal in the system is that within 1/2 min after the first indication of tritium, the building monitor showed the total of 1/2 curie. This indicates that the tritium travels more as an aggregate. It is recognized that these data were unplanned, and since the data from the building monitor were gathered by visual observation and verbal communication, additional testing needs to be done.

SUMMARY

Test Results

It is recognized that these tests relate to LLL hood and ventilation systems; however, they demonstrate the magnitude of the time involved in reacting to a leak of tritium. It is now feasible to estimate the amount of tritium that would be lost by a failure in the plumbing system. One practical example of the use of such a system is the transfer of tritium from a uranium storage vessel to a reactor vessel. Within the uranium storage vessel, the bulk of the tritium is stored as a solid compound. By heat, the tritium gas is generated at a rate of approximately 1 g/min. The tritium gas is received by the reactor vessel and converted to another solid compound. If the plumbing should fail between the two vessels, the tests have shown that for a maximum time of 15 s, 1/4 g of tritium would be lost before the valves shut off the vessels, after which the amount in the lines, which is less than 1 g, would also be lost. Thus the maximum loss would be less than 1-1/4 g. This information makes it feasible to consider the risk of loss vs effort (cost) of safeguarding a tritium system against the release of tritium.

Incidental Observations

If one assumes that tritium in an air-flush exhaust-duct system moves at the speed of the air flow and travels as an aggregate, it is feasible to design an exhaust system that could store and process only that portion of air contaminated with tritium. Figure 3 is a schematic of such a system.

The system's main components would be a tritium-leak detector at the outlet of each hood, a length of duct sized to permit a time delay, and automatic valves that, during the time delay, could divert the air flow from that hood to a holding tank and recovery system.

The system would operate as follows:

- Normal conditions — all air flows through the duct up the stack.
- If a tritium leak occurs in hood No. 1, tritium leak detector No. 1 senses it and automatically does the following:
  - Closes valve B-1.
  - Opens valve A-1.
  - Activates the recovery system.
  - Closes valves at vessel openings in the hood's tritium system to isolate the leak.
- As illustrated, the duct from the detector to valve B-1 would have a length that would provide a time delay to permit valve B-1 to close before the tritium got to that point.
- Air would flow through hood No. 1 to the recovery system, but in the remainder of the system the air would continue to flow up the stack.
- When the tritium detector No. 1 no longer senses tritium, it automatically does the following:
  - Opens valve B-1.
  - Closes valve A-1.
- The recovery system would continue to function until other action is taken.
- The vessel valves within the hood's tritium system would remain closed until other action is taken.
- Air now flows through hood No. 1 up the stack.

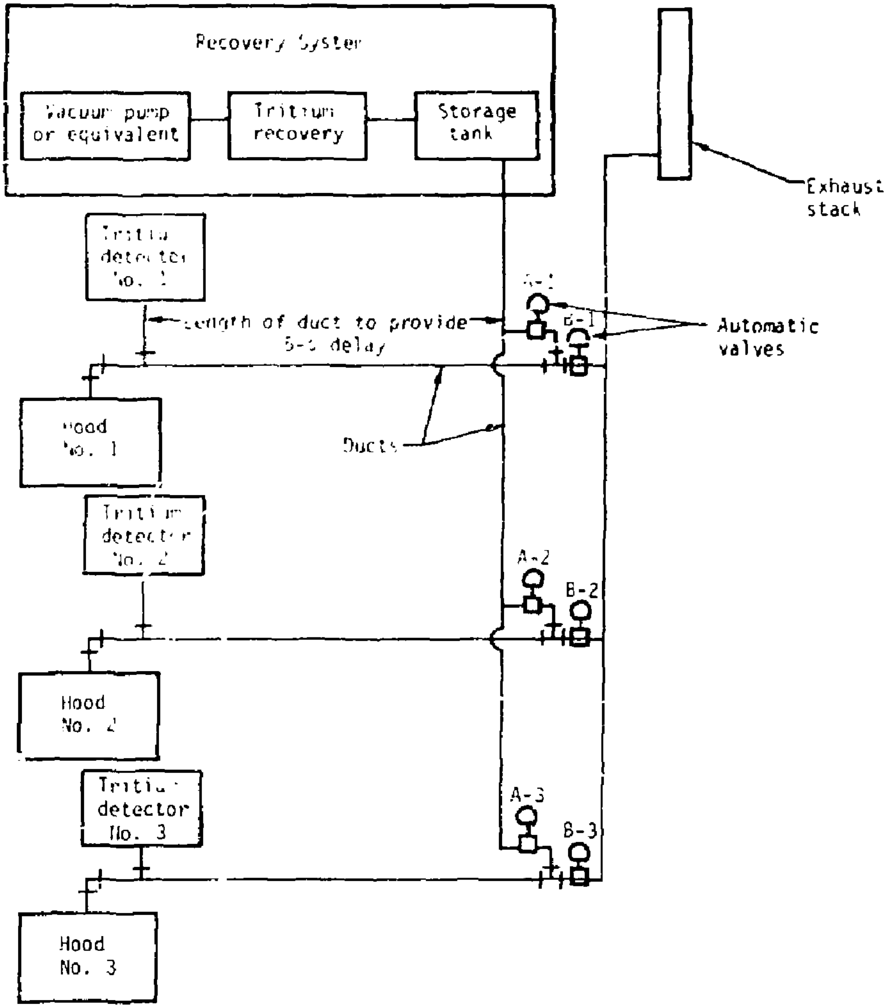


Fig. 3. Possible exhaust system for a tritium facility.

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