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January 6, 1993

Mr. Roop Jain
R.J. Environmental, Inc.
6197 Cornerstone Ct. East
Suite 108
San Diego, California 92121

RE: SwRI Project No. 01-4959

FINAL LETTER REPORT

Subject: Qualification Test Program for the R.J. Environmental Emergency Chlorine
Scrubber Systems

Dear Mr. Jain:

This letter constitutes the final report for Southwest Research Institute (SwRI) Project No. 01-4959: Qualification Test Program for the RJ 150 and 2000 Emergency Chlorine Scrubber Systems. A description of the test program along with the tests results is included below.

INTRODUCTION

Southwest Research Institute (SwRI) was contracted to perform qualification testing of the R.J. Environmental Model No. RJ 150 and 2000 Emergency Chlorine Scrubber Systems for compliance to the 1991 Uniform Fire Code (UFC) requirements for indoor storage of toxic compressed gases. The full scale laboratory tests were conducted at SwRI during the period of April 13 - 26, 1992 and involved simulating chlorine leaks of 150, 550, and 1800 lb to confirm that the scrubber systems would meet the UFC requirements for a maximum chlorine discharge concentration of less than 15 ppm from the scrubber exhaust stack and operation of the cylinder storage room at A negative pressure throughout the treatment of the chlorine vapors.

CHLORINE SCRUBBER SYSTEMS

The RJ 150 and 2000 scrubber systems represent a three stage absorption system designed to provide the required room ventilation rates through induced draft fans and supply of caustic solution for treatment of the chlorine vapors. The scrubber components include a three stage absorber, integral caustic storage tank, air exhaust fan, caustic recirculation pump, electric control panel, and associated piping. The RJ 150 scrubber was designed to handle 150 to 300 lb chlorine leaks, while the RJ 2000 was designed to handle chlorine leaks from one ton cylinders and bulk storage tanks.



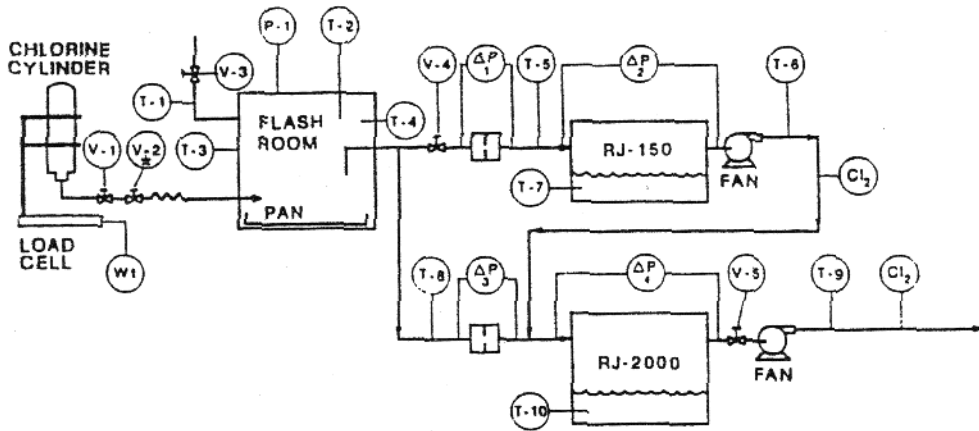
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TEST SET UP

The test set up for the qualification tests included chlorine cylinders, pressure vessel, load cells, flash room, instrumentation, data acquisition system, and video equipment. The chlorine cylinders were mounted on external support structures which included load cells for monitoring weight loss. A flash room measuring 12 x 11 x 12 ft was constructed to contain the chlorine leaks and was instrumented with thermocouple wire for monitoring room temperatures and a transducer to monitor room pressures. Observation windows were installed in the walls and ceiling of the room to allow for video documentation of the liquid chlorine leaks and vaporization process.

The scrubbers were instrumented with thermocouples to determine the temperatures at selected locations and monitors to measure the chlorine levels from the exhaust stack emissions. A data acquisition system provided continuous online data recordings of the cylinder weight loss, temperatures, pressures, and flow rates every five seconds during each of the tests. Figure I illustrates the layout of the test set up.



T-1	Intake air to flash room	T-9	RJ-2000 Air outlet
T-2	Flash room	T-10	RJ-2000 Sump
T-3	Flash room	T-11	Ambient (room)
T-4	Flash room	T-12	Open
T-5	RJ-150 Air inlet	P-1	Flash room pressure
T-6	RJ-150 Air outlet	Wt	Load cell
T-7	RJ-150 Sump	Cl ₂	Exhaust stack chlorine
T-8	RJ-2000 Air inlet		

ΔP-1	Orifice plate
ΔP-2	Scrubber ΔP
ΔP-3	Orifice plate
ΔP-4	Scrubber ΔP

FIGURE 1. RJ Environmental Chlorine Scrubber Test Process Flow Diagram

INSTRUMENTATION AND EQUIPMENT

The following list identifies the test data recorded and the instrumentation utilized for the qualification tests:

- a. Flash Room Static Pressure: The static pressure was monitored with a calibrated pressure transducer having an accuracy of ± 0.01 inch w.c.
- b. Chlorine concentration: The chlorine concentration at the outlet of the scrubber was monitored with an Enterra Model 4000 chlorine analyzer calibrated and certified by the manufacturer. The analyzer was field checked frequently against a calibration kit provided by Enterra.
- c. Chlorine Release Rate: The chlorine release rate was calculated from the measured chlorine cylinder weight loss versus time. The weight of the cylinders were monitored continuously with calibrated load cells.
- d. Temperatures: Temperatures of the ambient air, flash room, scrubber Wet and outlet, and scrubber sump were measured with certified Omega Type K thermocouple wire.
- e. Pressures: The pressure differentials across the specially designed orifice plates and scrubbers were measured with Dwyer pressure gauges.
- f. Scrubber Air Flow: Volumetric air flow rates were measured with an orifice plate installed at the scrubber inlet. The orifice plate was calibrated by measuring the air flow at several orifice plate pressure drop settings. Air flows were measured using a standard pitot tube in accordance to EPA Method 2.
- g. Data Acquisition System: A calibrated *John Fluke 2289A Helios I* analog to digital converter was utilized for recording the test data. This data was then sent to a VAX 750 mainframe computer for processing and storage.

SAFETY PROGRAM

The test program was conducted in accordance with the SwRI safety procedure written to ensure the safety of the test personnel, environment, and equipment. The test personnel received training regarding the use of protective clothing, respirators, hazards involved, and compliance to the safety procedures. The test program was monitored by the SwRI Safety Office to ensure compliance to the safety and environmental regulations.

TEST PROGRAM

A total of seven tests were conducted for evaluation of the scrubber systems. The first three tests were conducted as functional checks of the test apparatus and involved controlled releases of nitrogen and chlorine to ensure that the scrubber systems were capable of treating the chlorine

vapors. The tests were scheduled such that the severity level of the chlorine leaks was gradually increased to confirm that the systems were operating satisfactorily and the chlorine levels from the exhaust were within the allowable limits.

Test No. 1, 2, and 3

The first test was a functional checkout of the test apparatus, instrumentation, and data acquisition system by venting available room air and nitrogen through the test set up. The functional check verified that the scrubbers and the instrumentation were functioning properly.

The second functional test was conducted by leaking 19 lb from a 150 lb chlorine cylinder into the flash room. The chlorine vapors were vented from the room into the scrubber for treatment and exhausted into the atmosphere. The maximum chlorine level measured from the stack emissions during the functional test was 0.1 ppm.

The third test involved the release of 75 lb of chlorine into the flash room. The maximum chlorine level recorded at the scrubber exhaust stack was 0.2 ppm.

Based on observations made during the initial scrubber systems operation, modifications were made by RJE to improve and optimize the gas and liquid caustic distribution for a more efficient scrubbing process.

Test No. 4

This test involved the release of approximately 1800 lb of liquid chlorine from a one ton cylinder into the flash room. The maximum chlorine leak rate reached during the test was 52 lb/min. As shown in the respective data tables, the flash room was maintained under negative pressure throughout the entire test period and the maximum chlorine level measured from the RJ 2000 scrubber exhaust was 0.0 ppm.

Test No. 5

This test was conducted to simulate a catastrophic chlorine leak rate to determine the capability of the RJ 2000 scrubber to treat the chlorine vapors within the allowable limits set by the UFC. To optimize the leak rate, 550 lb of liquid chlorine were transferred from a one ton cylinder into a 250 gal pressure tank and pressurized with a nitrogen blanket.

The liquid chlorine was released from the 250 gal pressure tank into the flash room with the chlorine valve in the full open position. The 550 lb of chlorine were leaked into the flash room at a maximum leak rate of 99 lb/min. The flash room maintained a negative pressure throughout the test and the chlorine levels measured from the exhaust stack ranged from 0.1 to 0.6 ppm which is well within the limits set by the UFC.

Note: After the leak was completed, a propane burner was utilized in the flash room to speed, up the cleanup time. It appears that the burner exhaust gases contributed to the increased chlorine levels (0.6-1.2 ppm) measured by the chlorine monitors.

Test No. 6

This test was conducted with the RJ 150 scrubber system and involved leaking the contents from a 150 lb liquid chlorine cylinder into the flash room. The maximum release rate reached during this test was 28.5 lb/min and the maximum chlorine levels measured at the exhaust was 1.3 ppm. The flash room maintained a negative pressure throughout the test.

Test No. 7

A demonstration test of the RJ 2000 scrubber system was witnessed by industry representatives and involved leaking the contents from a 150 lb liquid chlorine cylinder into the flash room. The maximum chlorine level measured at the scrubber exhaust was 0.2 ppm which is within the UFC limits.

CONCLUSION

The qualification tests performed on the RJ 150 and 2000 emergency chlorine scrubber systems were performed under controlled laboratory conditions at SwRI using calibrated equipment and instrumentation as well as certified materials. The test results were video taped for documentation purposes and the data processed and recorded on the Department of Fire Technology VAX mainframe computer.

The qualification tests confirmed that the RJ 150 and 2000 scrubber systems neutralized the chlorine gas releases and met the UFC requirements for reducing the maximum allowable discharge concentration of chlorine to one-half of the Immediate Danger to Life and Health (IDLH) rating (15 ppm) at the point of discharge into the atmosphere. The scrubber systems also maintained a negative pressure in the flash room during treatment of the chlorine vapors.

Sincerely,

Approved:



Michael R. Gonzalez
Senior Research Engineer
Fire Testing Services



Alex B. Wenzel
Director
Department of Fire Technology

MRG/jgm

Enclosures

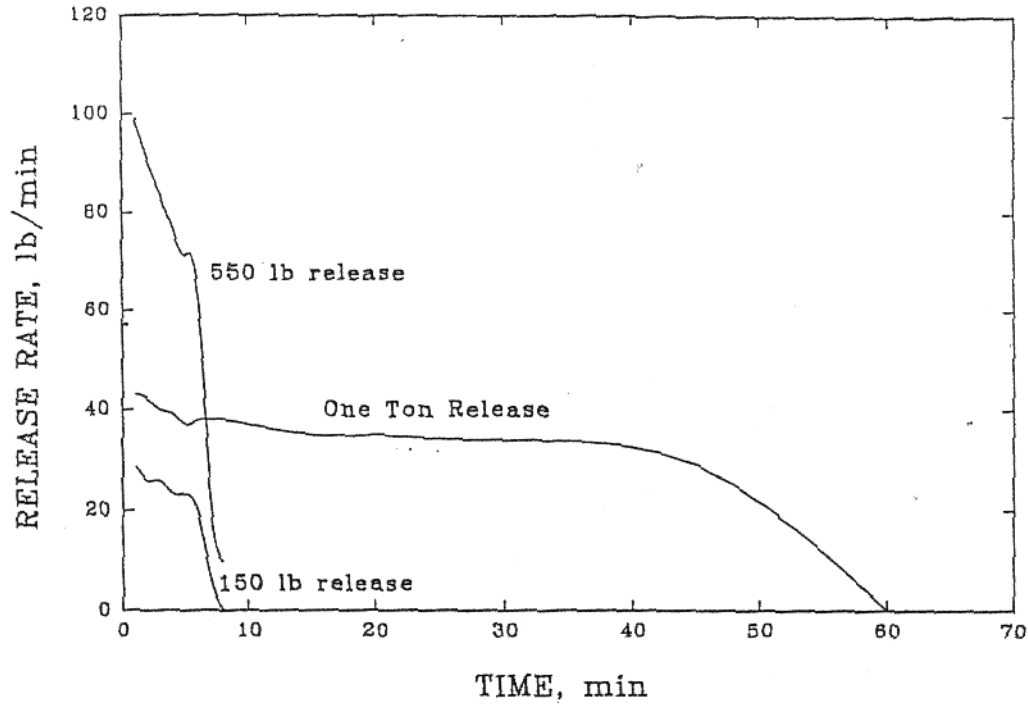


Figure 2. Chlorine release rates

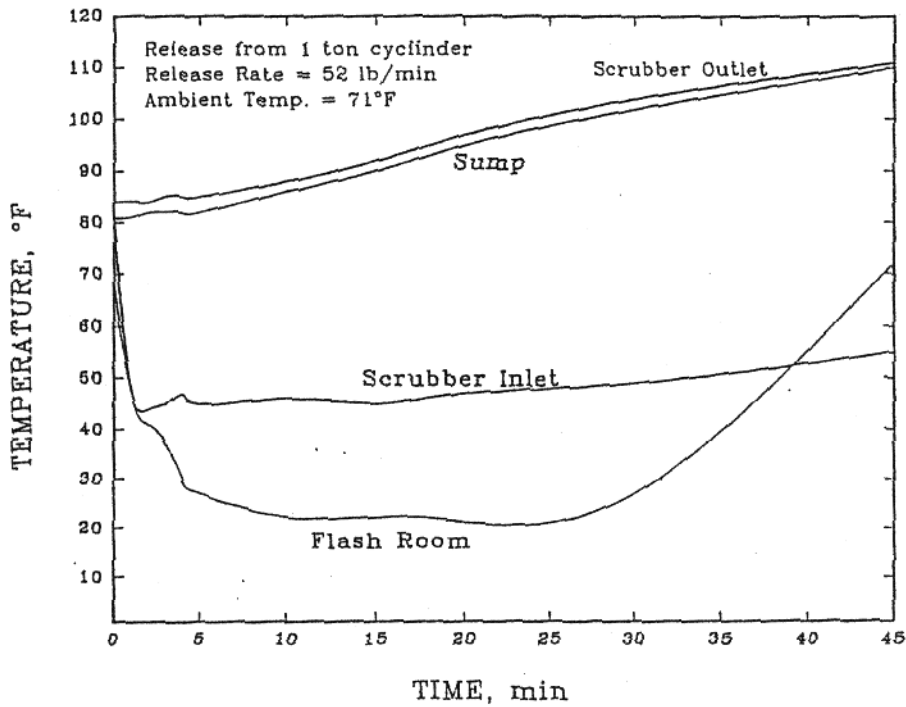


Figure 3. Temperature profiles

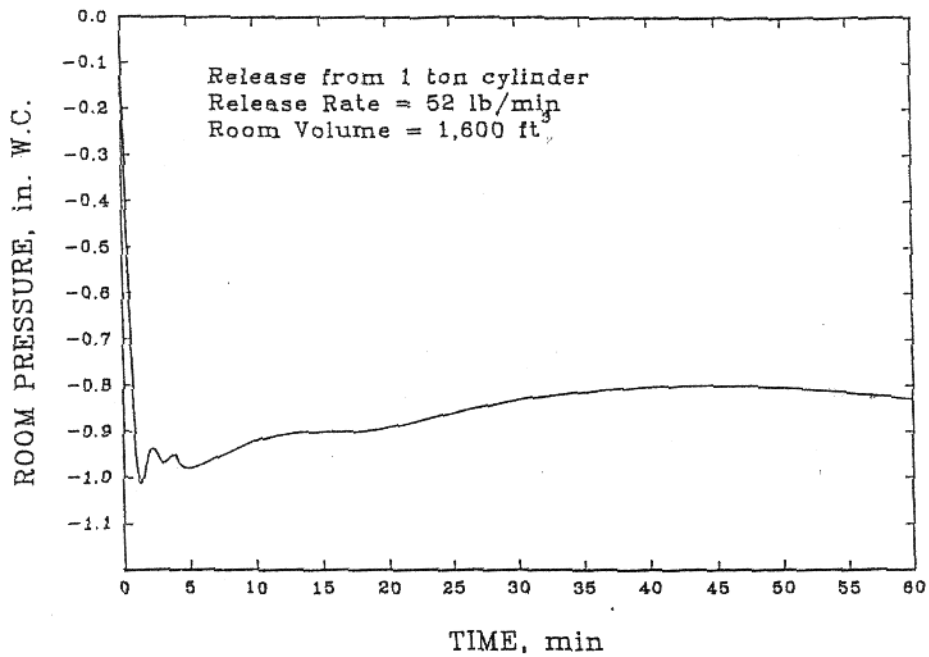


Figure 4. Flash room static pressure

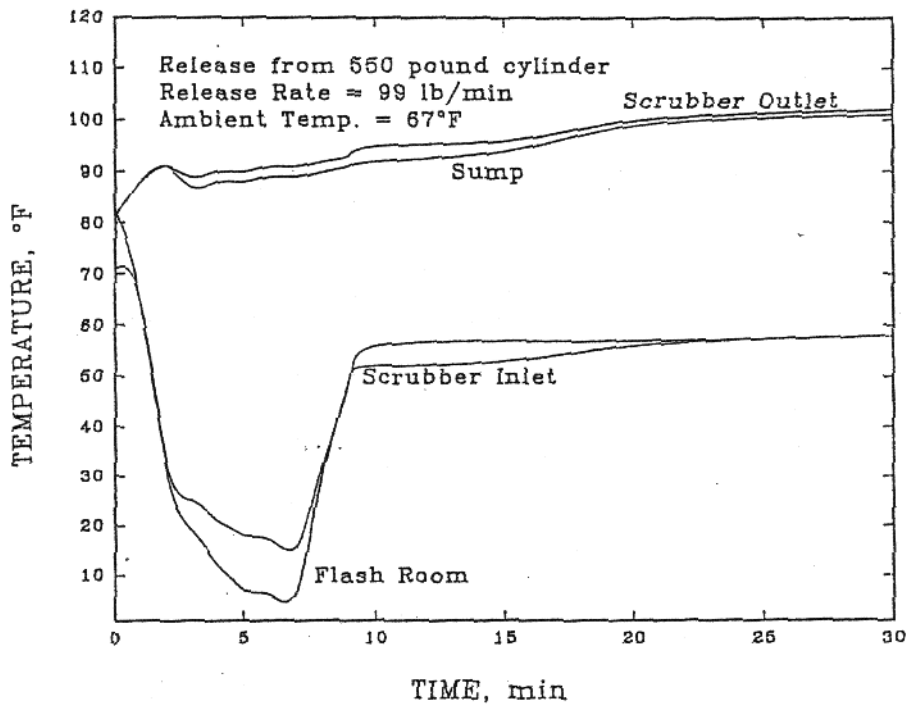


Figure 5. Temperature profiles

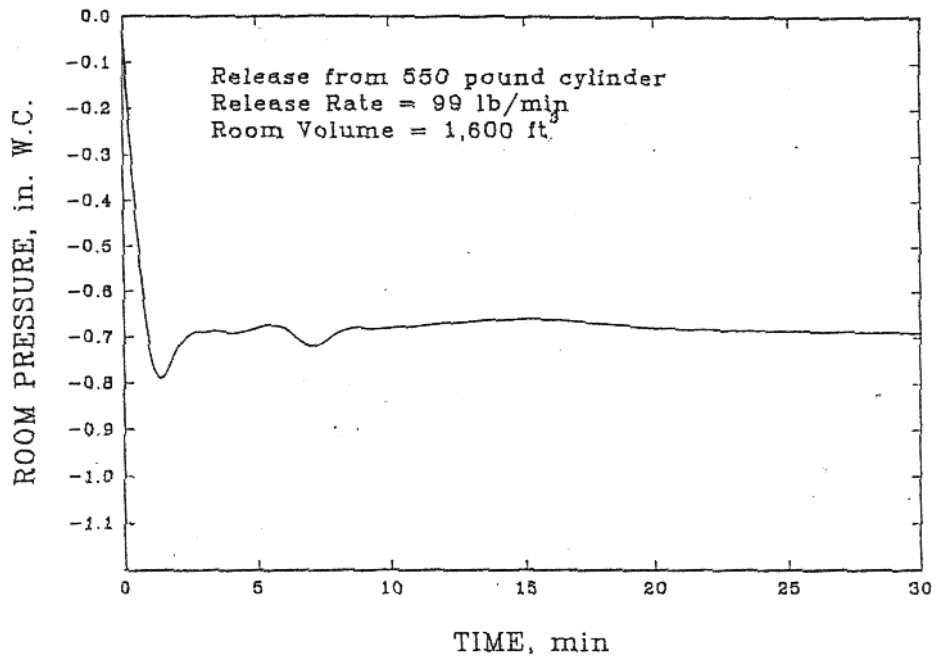


Figure 6. Flash room static pressure

Table 1

RJE-2000 SCRUBBER

SUMMARY OF RESULTS- RELEASE FROM 1 TON CYLINDER (RJE-004)

Scrubber Air Flow Rate: 1,180 cfm

Time, min.	Release Rate, lb./min.	Exhaust Chlorine, ppm	(T-3) Flash Room Temp. °F	(T-8) Scrubber Inlet Temp. °F	(T-9) Scrubber Outlet Temp. °F	(T-10) Scrubber Sump Temp. °F	Room Pressure, in. WC
1	52	0.0	48	47	84	81	-0.94
2	42	0.0	41	44	84	82	-0.95
3	40	0.0	37	45	85	82	-0.97
4	39	0.0	30	47	85	82	-0.95
5	37	0.0	27	45	85	82	-0.98
10	37	0.0	22	46	88	86	-0.92
15	35	0.0	22	45	92	90	-0.90
20	35	0.0	21	47	97	95	-0.89
30	34	0.0	27	49	104	102	-0.83
45	29	0.0	72	55	111	110	-0.80
60	--	0.0	72	63	114	113	-0.83
120	--	0.0	69	61	109	108	--
180	--	0.0	71	65	106	105	--
240	--	0.0	67	62	106	104	--
300	--	0.0	71	70	105	103	--
360	--	0.0	74	74	101	98	--

The exhaust stack was "sensed" by RJE and SWRI personnel. A faint "swimming pool" type smell was all that could be smelled, further verifying that chlorine levels in the stack were non-existent.

Table 2

RJE-2000 SCRUBBER

SUMMARY OF RESULTS (RJE-005)

Scrubber Air Flow Rate: 1,180 cfm
Release from Pressurized Chlorine Holding Tank (550-lb. Release)

Time, min.	Release Rate, lb./min.	Exhaust Chlorine, ppm	(T-3) Flash Room Temp. °F	(T-8) Scrubber Inlet Temp. °F	(T-9) Scrubber Outlet Temp. °F	(T-10) Scrubber Sump Temp. °F	Room Pressure, in. WC
1	99	0.1	31	33	91	91	-0.73
2	91	0.2	19	25	89	87	-0.72
3	84	0.3	12	21	90	88	-0.69
4	77	0.2	7	18	90	88	-0.69
5	71	0.3	6	17	91	89	-0.68
6	65	0.2	7	16	91	89	-0.68
7	22	0.5	31	33	92	90	-0.72
8*	10	0.6	49	49	93	91	-0.69
9	--	0.2	56	52	95	92	-0.68
10	--	0.4	57	53	96	94	-0.68
15	--	0.3	57	56	100	99	-0.66
20	--	0.3	58	58	102	101	-0.68
30	--	0.5	60	59	102	101	-0.69
45**	--	1.7	71	78	102	100	--
60	--	2.2	78	82	102	101	--
75	--	1.1	84	93	102	101	--
90	--	1.2	90	99	103	101	--

* Release stopped; tank empty.

**A propane burner was placed at the intake air into the flash room (at about 30 minutes into the test) to help speed up the chlorine vaporization rate. It is known that carbon monoxide can interfere with the chlorine sensor. It may explain the higher chlorine levels in the stack during the later part of the test.

Table 3

RJE-150 SCRUBBER

SUMMARY OF RESULTS (RJE-006)

Scrubber Air Flow Rate: 280 cfm
 Release from 150-lb. Chlorine Cylinder"

Time, min.	Release Rate, lb./min.	Exhaust Chlorine, ppm
1	28.5	0.0
2	25.8	0.0
3	25.8	0.0
4	23.2	0.0
5	23.2	0.0
6	19.6	0.0
7	6.2	0.4
8*	0.3	0.7
9	--	1.1
10	--	1.3
15	--	1.0
20	--	0.4
30	--	0.1
45	--	0.0
60	--	0.0

*Tank empty

* *Cylinder inverted to represent worst case scenario.

RJ ENVIRONMENTAL'S CHLORINE SCRUBBER PERFORMANCE

Test Date: April 1992
Test Site: Southwest Research Institute, San Antonio, Texas
Test No.: RJE-005

Data

Flash Room Dimension: 12'x 11'x 12'
Flash Room Volume: 1,584 ft³
Chlorine Release: 99 lbs *
Release Duration: 1 min.*
Scrubber Air Flow Rate: 1,180 cfm
* Analysis based on 1 minute intervals

Test Observation

The chlorine liquid was entirely "flashed" into vapor during the first few minutes of the test, as observed during the test.

Calculations

The maximum inlet chlorine concentration will be calculated based on all chlorine vapor entering into the scrubber as soon as it is formed, i.e. no mixing in the room.

Lbs of chlorine released/min.: 99
1 lb of chlorine: 5.42 ft³ of chlorine vapor
Rate of chlorine vapor: 99 x 5.42 = 537 cfm

Scrubber flow rate: 1,180

Chlorine concentration in inlet duct to the scrubber:

$$\frac{537 \times 10^6}{1,180}$$

C1₂, maximum = 454,980 ppm

The minimum chlorine concentration will be calculated if we assume all chlorine vapor generated is first well mixed in the room, to a uniform concentration before it enters into the scrubber.

Chlorine Vapor Formed: 537 ft³ (first minute)
Room Volume: 1,584 ft³
Room Chlorine Concentration:

$$\frac{537 \times 10^6}{1,584}$$

C1₂, minimum = 339,015 ppm

Since the room temperature in the flash room was not uniform (at three locations), it suggests that the concentration in the room wasn't the same, thus we expect the chlorine vapor concentration in the room must be somewhere between these two values.