Chemically Speaking LLC

Project Jack Rabbit,

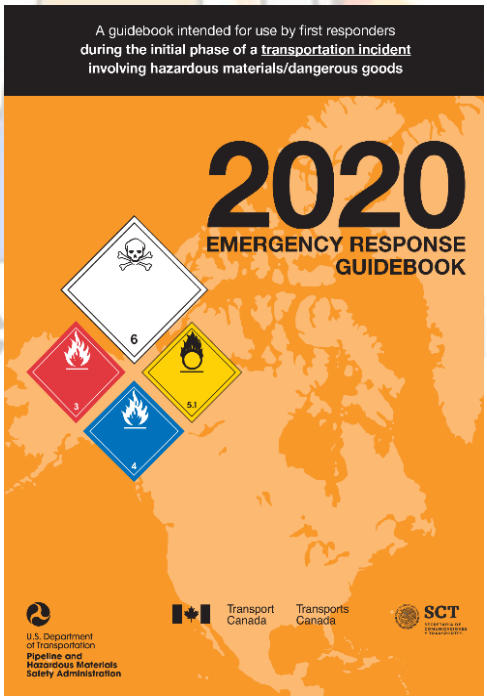
July 2022

The Jack Rabbit Project, sponsored by the United States (U.S) Department of Homeland Security (DHS) Transportation Security Administration (TSA), was a study designed to improve the understanding of rapid, large-scale releases of pressurized, liquefied toxic inhalation hazard (TIH) gases.

Objectives:

1. Execute a reduced-scale test of each of two chemicals (chlorine and anhydrous ammonia) to identify potential vulnerabilities before full test conduct.
2. Develop and evaluate a mechanism for the controlled, rapid release of liquefied, pressurized gases from containment to approximate the conditions hypothesized to generate a persistent vapor-aerosol cloud in a 90-ton railcar release.
3. Characterize the vapor/aerosol cloud movement, behavior, and physiochemical characteristics and compare those characteristics with known observations and testing of large-scale releases of the testing materials.
4. Determine if anhydrous ammonia can potentially act as less expensive and less dangerous dense gas for studying the component phenomena of large scale releases of dense gas TIH materials.
5. Field and evaluate instrumentation that can be used for the study of the large-scale release of the testing materials, and develop and evaluate testing methodology for future additional and potentially larger-scale tests.

Ensure that the ERG Table 3 – “INITIAL ISOLATION AND PROTECTIVE ACTION DISTANCES FOR LARGE SPILLS FOR DIFFERENT QUANTITIES OF SIX COMMON TIH (PIH in the US) GASES” is accurate



Terrorism Concerns with TIH

Chemical shipments of chemcials in the US

Chemical	Road	Rail	Water	Total	% of Total	
Ammonia (NH_3)	**5,793,000**	**3,470,592**	**1,718,974**	**10,982,566**	**52.8%**	
Chlorine (Cl_2)	**724,000**	**3,750,372**	**137,202**	**4,611,574**	**22.2%**	***~75%***
Sulfuric Acid (H_2SO_4)	257,000	207,560	2,057,721	2,522,281	12.1%	
Acrylonitrile (C_3H_3N)	29,000	277,200	671,474	977,674	4.7%	
Ethylene Oxide (C_2H_4O)	106,000	671,260	1,132	778,392	3.7%	***~95%***
Hydrogen Fluoride (HF)	29,000	264,560		293,560	1.4%	
Sulfur Dioxide (SO_2)	72,000	172,480	361	244,841	1.2%	
Hydrogen Chloride (HCl)	2,000	8,400	166,027	176,427	0.8%	
Hydrogen Cyanide (HCN)	33,000	31,600		64,600	0.3%	***~99%***
Bromine (Br_2)	61,000			61,000	0.3%	
Nitric Acid (HNO_3)	3,000	35,800	44	38,844	0.2%	

Numerical down-select of Toxic Inhalation Hazards (TIHs) based upon:

Volatility/Toxicity

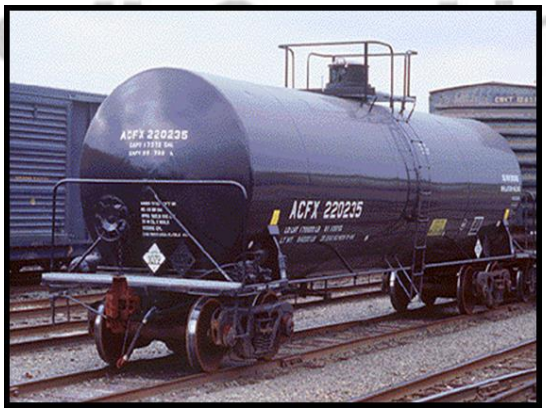
Availability

The approximate downwind inhalation hazard: Volatility/AEGL-3

TIC	Volatility AEGL-3	Rail	Road	Water	Total	
Chlorine	**379,687**	**160,000**	**38,500**	**11,000**	**84,290**	***~90%***
Ammonia	**8,824**	**3,400**	**7,200**	**3,200**	**4,659**	***~95%***
Hydrogen Chloride	461,095	440	130	16,000	3,689	
Sulfur Dioxide	79,000	1,500	800	6	948	
Hydrogen Fluoride	27,140	800	110	0	380	
Ethylene Oxide	8,557	650	130	2	317	
Hydrogen Cyanide	64,431	230	300	0	193	

Cl_2 is routinely used in as a chemical weapon

Greatest concern is Cl_2 railcar containing 90 tons of Cl_2.



DOT 105J500W

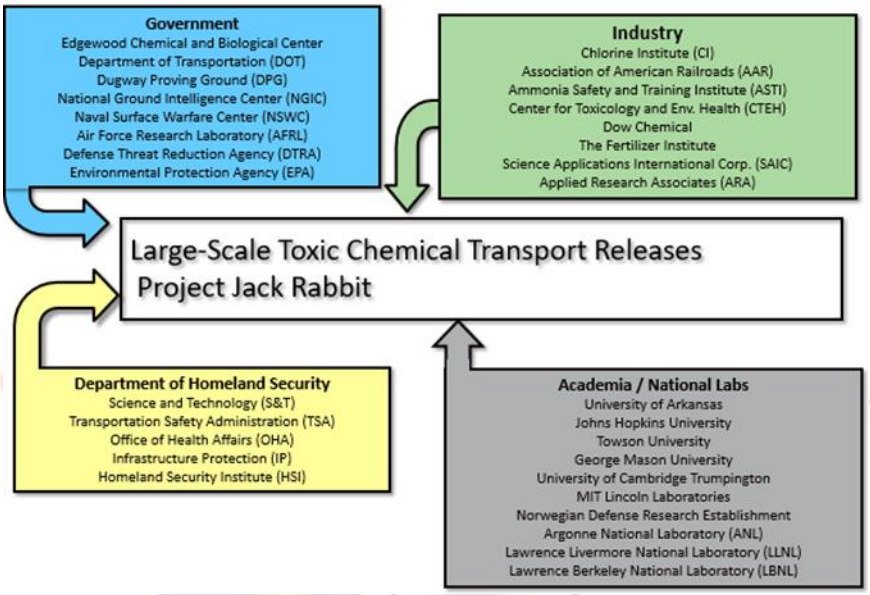
Very robust, crash protection on each end 1” thick

Outer metal jacket 1/8”, 3-4” insulation and ¾” inner shell

Can a terrorist compromise a railcar? FBI and DHS tested a Cl_2 railcar loaded with water at Aberdeen Proving Grounds. The testing showed that a properly placed IED can make a hole 3-6” dia.

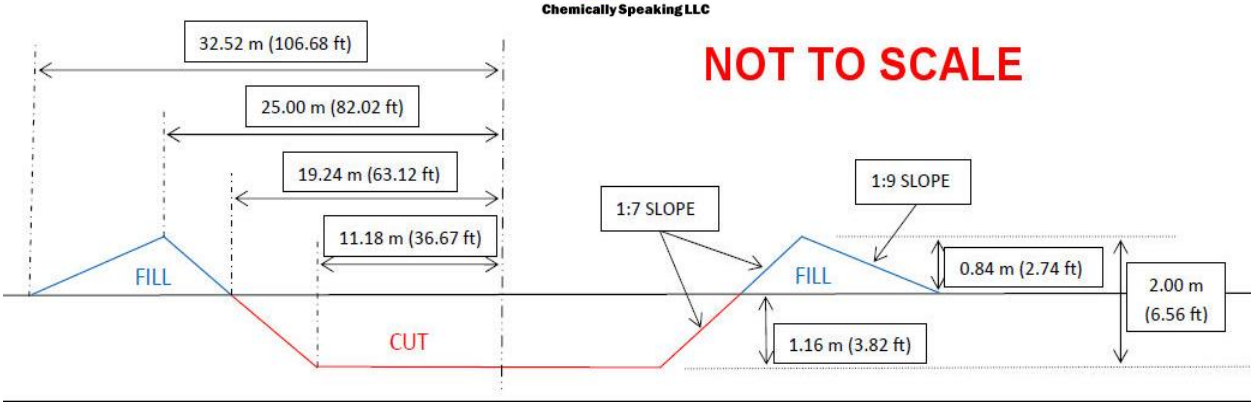
Jack Rabbit I, April-May 2010

The project involved outdoor release trials of 1- and 2-ton quantities of chorine and anhydrous ammonia in 10 successful trials. The project was managed by the Chemical Security Analysis Center (CSAC), part of the DHS Science and Technology (S&T) directorate, and executed at Dugway Proving Ground (DPG), a U.S. Army testing installation in Utah.



Pilot 2-1 ton releases to test equipment and systems

Discharge directly down into crater 25 m radius, 2 m deep onto metal plate



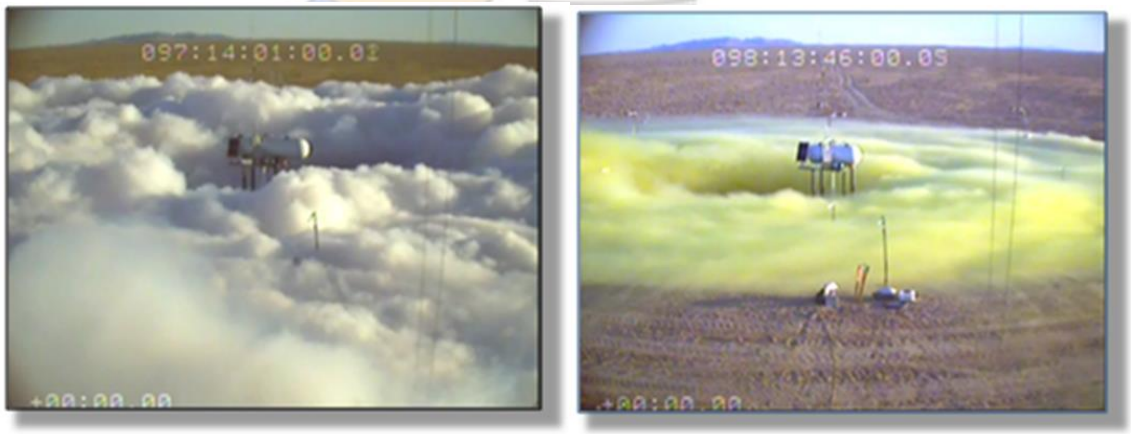
The chlorine disseminator was a modified 500-gal propane tank with a remotely controlled 3-in ball valve assembly mounted to the bottom of the tank.

The anhydrous ammonia disseminator was a modified 1,000-gal propane tank with a remotely controlled 4-in ball valve assembly mounted to the bottom of the tank.

Both disseminators had an appropriately sized manual knife gate valve mounted between the tank and the remotely controlled valve as a safety precaution.

The disseminator was mounted on a large metal stand, with the outlet of the remotely controlled valve placed at a distance of 2-m above the depression basin. The outlet from the remotely controlled valve was 2-m above the depression basin and directed in a downward direction. The jet from the disseminator impinged against a 12-ft × 8-ft × 1-in steel plate, which served as the base for the metal disseminator stand.

Ammonia and Chlorine after 60 sec



Ammonia **Chlorine**

Key Notes NH_3

<2 m height

150-200 m in all directions

-20°C

15 min to boil off liquid
45 min to disperse
2 ton NH3 cleared fairly quickly but the ground fumes for hours. Technician walking on the surface reported his shoes were fuming

Key Notes, Cl_2

One ton released in 45 sec
Hovers in basin for 45 minutes as a dense fluid
Degasses for 4 hours
Low winds and stable atmosphere
results in cloud persistence
Cold, dense gas is held up near release site and collects in low-lying areas

Additionally, a previously unreported phenomenon was discovered during the chlorine trials. It was observed that eruptions were occurring with the Cl_2 releases. After 15 minutes a column of gas would shoot out of the ground sometimes up to 10 ft. These were termed rapid phase transitions (RPT) where the cold liquid Cl_2 may be pooling in the ground and freezing water above it. As it warms the Cl2 vapors burst through. These events were not noted for the anhydrous ammonia trials.

Rapid Phase Transition

The testing also revealed up to 50% of the Cl2 is reacted by the water or by organic matter in the ground. The team concluded that a 1814-kg chlorine release could be removed within 20 m from the release point for soil with high organic matter (43%) and/or water content (29%).
This has enormous implications for modeling, planning, emergency response, mitigation Additional data and findings from the study can be found in the publication in Journal of Hazardous Materials, 2013

Contents lists available at SciVerse ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

Deposition of Cl_2 on soils during outdoor releases

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Jack Rabbit II, Testing Sept 2015

Objectives include

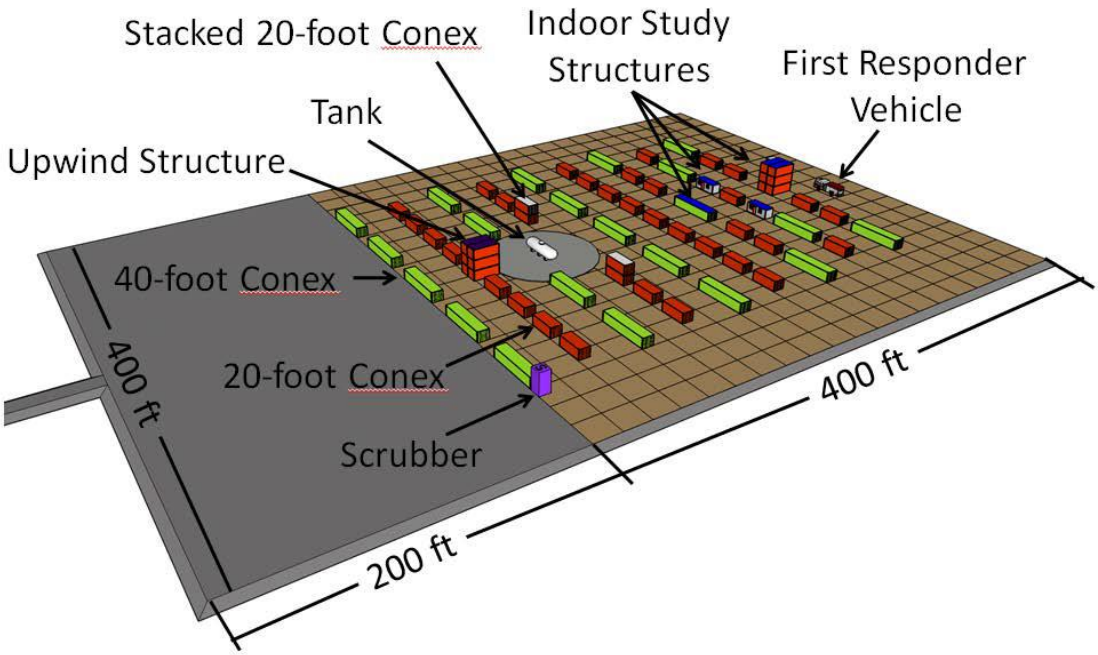
- Rapid Phase Transition
- Soil degassing and dispersion
- Isolation zones
- Videos for training

Involving First Response Community

- Is it safe to shelter in place in emergency response vehicles?
- What is the height at which a responder can survive (reliable vertical concentration)?
- Is it possible/advisable to drive through the chlorine gas cloud?
- Is the 1000 meter initial isolation zone in the current ERG valid?
- What is the significance of various urban barriers?
- What is the impact of long-term off-gassing?
- What is the behavior of chlorine after a catastrophic release?
- What is the behavior of the chlorine interacting with common urban materials?

Larger disseminator to hold up to 10 tons of Cl_2.

Standard and modified conex containers
8’ high x 8’ wide x 40’ and 20’ long containers
400 x 600 m gravel
One triple stack
80 units created nice Urban Test Grid (UTG)
Some containers have exhaust fans to create 0.25-0.5 air exchanges per hour (commercial building)



Proposed Layout

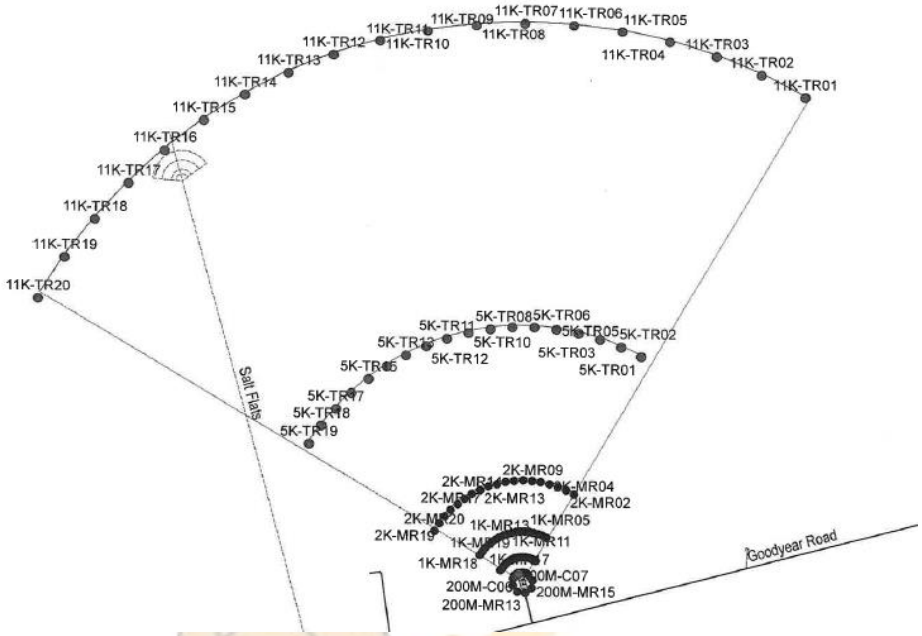
Actual Layout

Instrumentation downwind

Jazz Instrument good for 100,000 ppm
PID good up to 2,000 ppm, 50 units downwind
ToxRae inside vehicles, max 50 ppm

LIDAR

A well to measure Cl2 liquid thickness



Parked SUV, EMS Vehicle, Fire Engine, all running to see if they will continue to operate in large release. Gas detection in conex containers, vehicles and dummies. Same vehicles used for all tests

Looking Downwind Immediately Adjacent to Concrete Pad

Firefighter Positioned On Top of EMS Vehcile

5 (2), 7.5 and 9 (2) ton releases
Liquid discharge from tank bottom, 6" dia, explosive bolts
Discharges from 45-69 secs
Onto circular concrete pad with a 1" metal lip on the perimeter to prevent liquid from soaking into gravel

A 5 ton Cl_2 release where there was no inversion, one sensor measured 20 ppm at 7 miles
Exposed various materials (copper, concrete, carbon steel, telephone pole, rr tie.

- Telephone pole smoked and charred when liquid splashed onto it
- Asphalt shingles melted when liquid splashed onto them
- Copper rusted

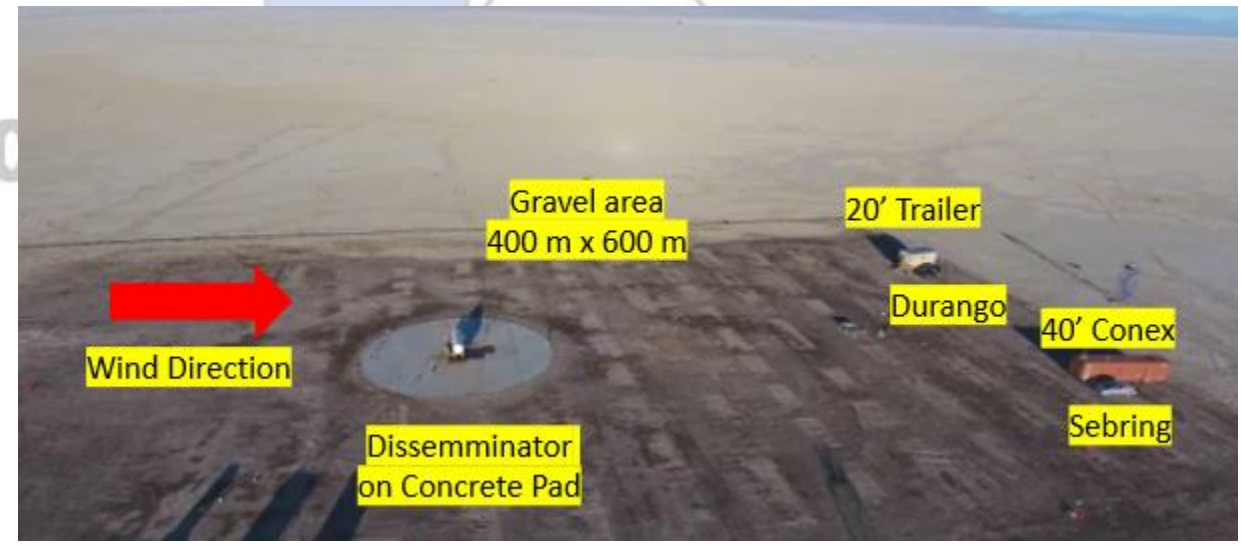
The release acted like tsunami wave. Splashed over the containers facing the disseminator
Channels between containers
Momentum carried it upwind a considerable distance
Concrete TC measured -50°C. This froze moisture

Turnout, SCBA and Helmet held up without damage even after 5 esposures

Jack Rabbit II, Sept 2016

20 ton propane tank was used for test 1-3

Dodge Durango and Sebring were parked 85 m downwind with gas detection inside at drivers seat and Go Pro Camera. Was not running. Box trailer (20') and conex container 40;' was parked next to each



Gas Sensors in Car with Go Pro

Test 1, 20 tons straight downward (0°) looking upwind

Firefighter Upwind of Release

Test 2, discharge at a 135° (45° angle downwind)

The most significant downwind affect. Five gas sensors at 7 miles had readings over 50 ppm

Cloud Reaching Durango

Test 3, Discharge directly upward (180^{o})

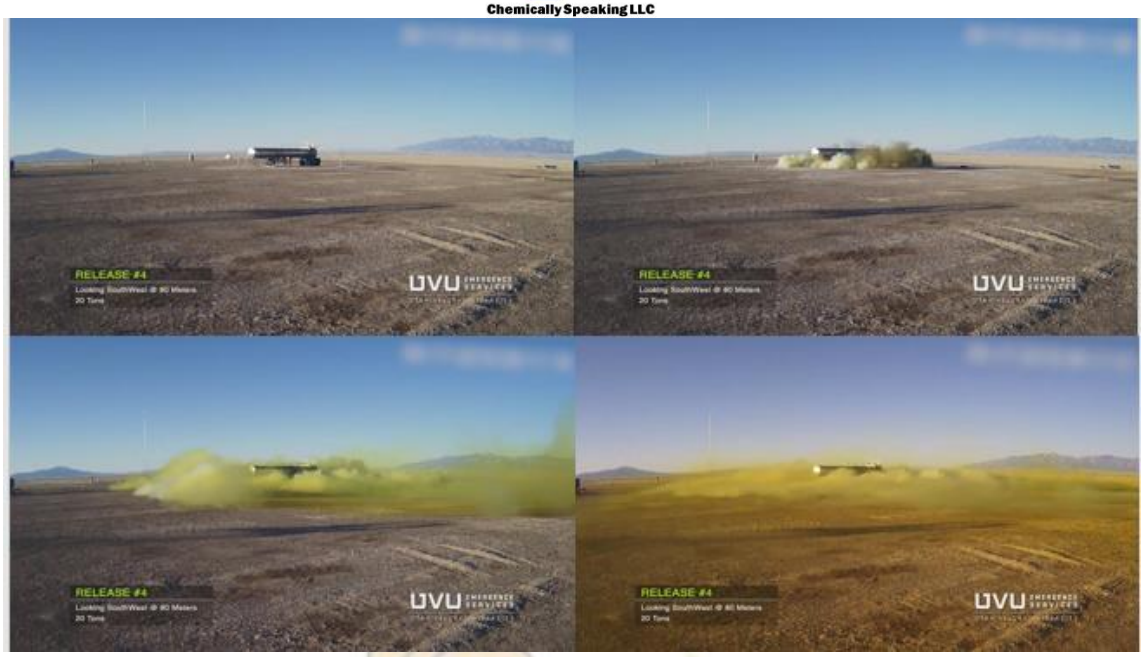
6 tons vented as gas, remaining 14 tons subcooled to boiling point of -29^{o}F

Test 3 Venting Straight Up

Test 4, Discharge straight down

The last test 4 the transport tanker used to fill the tank for test 1-3 was used. A shaped charge punched a 6” dia hole at the bottom of the tank. This released 20 tons in 5 min and 30 sec

Test 4 20 ton Tanker



Test 4, Looking Downwind

20 tons released in 5 in 30 sec.

Firefighter upwind of release was not exposed to Cl2 in any of the releases.

Concentration in car exceeded 50 ppm

Eugene Ngai