

## **TCEM Incident Investigation Report - 117A Tilt Cart Explosion**

### **INCIDENT DESCRIPTION**

On June 13, 2019 at approximately 1150, a Department of Environmental Health and Safety (DEHS) technician (Tech A) was comingling flammable solvent waste in the Thompson Center for Environmental Management (TCEM) Room 117 – Flammable Liquids Processing Area Pour Station B (Figure 1). Another technician was in TCEM 106A (Operations Office), and another technician was in the dock area of TCEM. The process of bulking flammable solvent waste consists of pouring variously sized containers (typically 500 mL to 20 L) into an 85-gallon drum (SOP included as Appendix 1). To perform this task, the technician stands on an elevated operating station that has a funnel and drain pipe leading to a drum (Figure 2). The standard PPE worn while performing this task consists of a full-face respirator with organic cartridges, a flame/chemical-resistant chemical apron, rubber boots, and disposable nitrile gloves. Waste containers are opened and liquid waste is poured into the funnel. The empty glass containers generated during the process are tossed into a 1-cubic yard Rubbermaid utility tilt cart (Figure 3) for recycling. Often the glass containers in the tilt cart break as new containers are added/tossed in. At the time of the incident, Tech A had just begun a new drum. He added 6-8 gallons of waste to the drum and 8-10 empty glass containers to the tilt cart. The majority of the waste added to the drum was in 500 mL and 1 L amber glass containers consisting of pure solvent, as well as two 4-liter containers, one of which contained a waste solvent mixture. After Tech A emptied a 1-liter bottle into the drum, he tossed it into the tilt cart. As soon as the container landed inside of the cart, Tech A observed a bright flash; he then turned his head away and immediately there was an explosion. He turned around to see that the tilt cart had been ripped to pieces and broken glass was spread all over the room (Figures 4 - 7). Tech A reported being hit in the back of the head with glass, but the glass did not cut his skin. There was also smoke and a strong smell of burnt plastic in the room. Tech A immediately evacuated room 117. As Tech A entered the dock area of TCEM, the other technicians working in the facility, having heard the explosion, met him outside of room 117. Tech A removed his respirator and immediately reported that the tilt cart had exploded. The other technicians opened the door to room 117 to ensure that there was no fire. The hazardous waste supervisor, who was across campus at the time, was immediately contacted. The supervisor asked if there were any injuries and if Minneapolis Fire Department response was needed. Tech A did not appear to be injured and the incident was over; there were no hazards or emergencies for the fire department to respond to. Therefore, it was decided not to implement the facility contingency plan. Upon arrival at TCEM at approximately 1205, the supervisor worked with the hazardous waste staff to develop a plan for cleanup and began trying to determine the cause of the incident.

Tech A reported ringing in his ears for 2-3 hours after the event, but it eventually subsided. He did not suffer any other injuries. A First Report of Injury was submitted on June 13, 2019.

## CLEANUP ACTIONS

Hazardous waste staff carefully inspected room 117 for evidence of further shock sensitive/explosive material, such as salts or crystallization on glassware. Nothing other than small pieces of glass remained (largest piece of glass left was approximately the size of a quarter); therefore, they felt it was safe to move around the room and approach the drum. A technician donned appropriate PPE, collected a 200-mL sample of the drum's contents, placed it into a 1-L sample jar, and moved it to the TCEM 115 fume hood for further evaluation. The following tests were performed on the sample:

- pH – Result: 7
- Oxidizability (KI starch paper) – Result: negative
- Organic peroxides (0-100 ppm indicator strips) – Result: 0 ppm
- Water reactivity – Result: non-reactive
- Water solubility – Result: not soluble

Glass and plastic debris waste throughout room 117 were collected and properly disposed of. The debris/plastic showed no signs of charring which might indicate a fire. While the contents of the drum did not display any concerning properties such as the presence of organic peroxides, approximately 8 gallons of aqueous sodium bisulfite solution (reducing agent) was added to the drum as a precautionary measure. The drum was then topped off with non-halogenated organic solvents and pumped into the 2500-gallon tank. The drum was then rinsed with an additional 80 gallons of non-halogenated solvents and pumped into the 2500-gallon tank.

## INVESTIGATION

The investigation began on June 13, 2019 as soon as the incident was stabilized and the impacted areas cleaned up. The investigation began with an inspection of the facility for additional impact or damage. There was no visible damage in room 117 other than to the cart and glass containers. The blast panels located on the north wall did not show any signs of damage. All three tanks in room 117A were inspected and none showed any signs of damage. Brittle paint from duct work and dust was seen on the floor and on shelving in room 116 (Figure 8). The door leading from 117 to 117A had clearly been opened by the blast/secondary shock wave (Figure 5). Insulation was seen on the floor in room 118 (Figure 9).

Once the facility inspection was completed, employees who were involved with the incident were interviewed. Employees located in room 108 (office area) all reported hearing the explosion. One employee said that he initially thought the autoclave in room 114 had exploded. Another employee reported that the windows in room 106A (operations office) shook. These reports indicate that a significant shock wave was created. Personnel located in room 100 (office area) did not report hearing the explosion. Several experts from other departments, universities, bomb squads, and high-hazard teams were also consulted.

### Findings:

- This incident involved an explosion. However, there are differences of opinion on whether this explosion should be categorized as a deflagration or a detonation.
  - *Explosion*: a violent expansion in which energy is transmitted outward as a shock wave.

- *Deflagration*: an explosion in which the speed of burning is lower than the speed of sound (subsonic) in the surroundings.
  - *Detonation*: an explosion in which the speed of burning is faster than the speed of sound (supersonic) in the surroundings.
- The 1-cubic yard Rubbermaid utility tilt cart (Figure 3), which is made of thick plastic and weighs 120 pounds empty, suffered severe damage and absorbed the majority of the energy that was generated. However, the blast panels in room 117 located approximately 15 feet from the cart at the time of the incident did not sustain any visible damage.
- Tech A stated that the majority of the waste that he added to the drum were pure solvents with normal viscosity that appeared to be in good condition. He remembers most of the waste being colorless and pouring easily; there were no solids or other potentially concerning properties. Most of the containers were 500 mL and 1 L amber glass jars and two were 4-liter containers, one of which contained a waste solvent mixture.
- It is believed that the material that caused the incident originated from a chemistry lab that has not been active in approximately 4 years and was being cleaned out by DEHS. This research lab focused on analytical and bioanalytical chemistry, environmental and green chemistry, and nanoscience and materials chemistry. Many of the containers picked up from this lab are more than 10 years old. A review of the lab's chemical inventory showed that there were high-hazard chemicals used in the lab such as picric acid, diethyl zinc, and lithium aluminum hydride. There were also several peroxide forming solvents used (*i.e.*, isopropyl ether, diethyl ether, tetrahydrofuran, 2-methoxyethanol, isopropanol). The full chemical inventory for the lab has been left out of this report due to the size of the inventory (> 3,000 chemicals), but is available for review.
- DEHS moved the chemicals from the lab located on the third floor of the chemistry building to the central accumulation area (CAA) located in the basement of the chemistry building where they were inventoried and entered into hazardous waste database for waste disposal. They were then moved from the CAA to the loading dock, loaded onto the DEHS box truck, transported to TCEM, unloaded onto carts, and eventually processed in TCEM 117. Nothing unusual about these chemicals was observed by DEHS staff that processed them; they were mostly pure chemicals that appeared to be in good condition.
- An accurate waste inventory of contents of the 85-gallon drum at the time of the incident does not exist. When flammable liquids are processed at TCEM, all of the flammable liquids present in TCEM at the time (typically between 300 - 400 gallons) are electronically scanned into a database and associated to a 2500-gallon tank (Tank 2, UMND004006 - full content inventory is available for review). The waste containers are then poured into an 85-gallon drum, a compatibility check is performed once the drum is full, and the contents of the drum are pumped to the 2500-gallon tank, and so on. The drums get filled up and pumped into the tank 4 - 5 times during the course of the day. An accurate inventory of the entire tank is maintained, but not of each individual 85-gallon drum. However, the waste containers from the chemistry lab that may have contributed to drum at time of the incident are displayed in Table 1.
- It is DEHS protocol to test common peroxide forming solvents in TCEM before they are processed (SOP included as Appendix 2). When peroxide forming solvents are submitted via Chematix, they are designated to a TCEM process shelf (O-O CERT) for storage until they are tested using 0-100 ppm or 100-1000 ppm indicator test strips. In this case, one peroxide forming solvent, 2-methoxyethanol, was added to the drum without first being tested for organic peroxides. This was missed by TCEM staff and inadvertently placed in the CERT process area rather than the (O-O)CERT process area. The likely reason for this is the similar names of the two designations (both designations have the

acronym "CERT"). It is unknown whether the cause of the incident was related to the 2-methoxyethanol container.

## CONCLUSION

While the exact cause of this incident is unknown, after conducting the investigation and speaking with several experts, here are the two most plausible explanations:

1. One of the solvents added to the drum contained a shock-sensitive chemical, either an organic peroxide or some other unknown compound. It is possible that shock-sensitive crystals formed inside of the container and were kept stable by the solvent. As the solvent was poured into the drum, shock-sensitive salts remaining in the empty container were exposed to air, the solvent quickly dried, and the force of the container being added to the cart was enough energy to detonate the shock-sensitive compound. It is unclear whether the container that had the shock-sensitive compound was the 1-L container thrown into the cart at time of the explosion, or another container that was already in the cart.
2. This was not a detonation involving a shock-sensitive chemical, but rather a deflagration caused by a buildup of flammable vapors in the tilt cart from residual vapors remaining in the empty containers. As the empty containers were being added to the cart, an ignition source was generated (possibly by static electricity or by reactive material such as a metal), and the vapors ignited causing a deflagration.

## DISCUSSION

- Tech A stated that he witnessed a flash, then turned his head, and the explosion followed. He also reported glass in back of his hair which supports the statement that he had time to turn away.
  - What does this flash and slight delay indicate; that this was a deflagration rather than detonation? The various experts consulted have mixed opinions about this. A shock-sensitive chemical such as an organic peroxide compound would likely cause a detonation. While an ignition of flammable vapors or reactive metal would likely cause a deflagration.
  - If a water-reactive or pyrophoric chemical caused this incident, the container sizes involved are unusual for reactive compounds. The majority of reactive chemicals such as diethyl zinc or alkyllithium compounds used by universities are not 500-mL or 1-L quantities, but rather 100 mL or less.
  - There was clearly a pressure/shock wave created with this explosion. Does the amount of damage sustained by the cart support a detonation or deflagration?
- If organic peroxides were present in solution at high enough concentrations to be shock sensitive, it is logical to think that the waste solution taken from the drum would have tested positive for organic peroxides. The test strip indicated 0 ppm organic peroxides. Even though there was dilution (6-8 gallons of liquid had been added to the drum at the time), it is logical to think that the waste solution still would have tested positive for organic peroxides.
- If this was not caused by an organic peroxide forming solvent, could it have been caused by some other shock sensitive compound (*i.e.*, dinitro, trinitro, azide compound, *etc.*)? The use of explosive and shock sensitive compounds is not common at universities. If a shock sensitive compound or some other reactive chemical was involved with this incident, the container label did not indicate it. It is unlikely that lab staff would knowingly put a shock sensitive or reactive compound in solution and not label it properly.

- There were high-hazard chemicals removed from the chemistry lab (*i.e.*, organo-metallics, peroxide forming solvents). Even though the chemicals were at least 4 years old (several were 10+ years old), it should be noted that the containers removed from this lab all appeared to be in good condition (*i.e.*, no crystal formation, no unexpected layers or colors were observed).
- The containers were handled by DEHS staff several times before the incident occurred. This suggests that if a shock-sensitive compound caused the incident, it was in solution and therefore stabilized. It seems unlikely that a truly shock-sensitive compound could be handled so many times without incident. Although that depends on how much energy/force is required to initiate the reaction, which of course is unknown in this case.
- An alternative explanation is that the incident did not actually involve a shock-sensitive compound, but rather an explosive environment was present in the tilt cart and a deflagration occurred. But what was the ignition source, static electricity, a reactive metal such as diethyl zinc? While the tilt cart is not grounded, most of the equipment, drum, and ergonomic mat that the technician stands on are all grounded. This process has occurred weekly at TCEM since 1994 and similar operations at many other facilities without incident to my knowledge. It seems likely that a similar incident would have occurred in the past if explosive vapors could form in the tilt cart. Additionally, only 40 ppm VOC concentration was measured during a recreation of adding empty organic solvent glass containers to a tilt cart. This is not a high enough concentration to cause an explosion as was observed. It should be noted that there were many flaws with this recreation and several unknown factors (*i.e.*, solvents/concentrations involved) that could not be recreated.

## **FOLLOW UP ACTIONS**

### **DEHS Regulated Waste Staff:**

- The remaining organic solvents from the chemistry lab cleanout will not be poured into drums. Each container will be closely inspected and then lab packed.
- The (O-O)CERT designation will be changed so that CERT is not in the name. Considering TCEM staff handle approximately 10,000 containers per year labeled with the CERT designation, it is easy for staff to get complacent and mistakenly place the (O-O)CERT containers where CERT containers should be placed. The new designation for all peroxide forming solvents will be changed to BO-OM.
- Review the list of peroxide forming solvents in the Chematix Chemical Abstract Database for accuracy and completeness.
- More closely inspect peroxide forming solvents, especially those coming from lab cleanouts. Inspect containers for signs of crystallization and contaminants before handling. Incorporate the inspection processes into the Chemical Waste Pickups SOP.
- Distribute this incident report to all DEHS Regulated Waste staff for review and discuss during a weekly team meeting. Allow everyone an opportunity to speak about this incident and provide input.
- Discuss this incident with other college and university hazardous waste staff. Benchmark TCEM's solvent pouring operations and handling of peroxide forming solvents with other hazardous waste programs.

### **DEHS Lab and Research Safety and the University Research Community:**

An emphasis should be placed on the hazards of storing chemicals inappropriately for long periods of time (*i.e.*, allowing peroxide forming solvents and other high-hazard chemicals to remain in a lab for several years). The DEHS Lab and Research Safety group is taking the following actions to assist with prevention:

- Review and update UHS guidance documents in regards to expectations for testing and timely disposal of peroxide forming solvents. Documents to consider include:
  - Chemical Hygiene Plan
  - Peroxidizable Compounds Fact Sheet
  - Lab closeout guidelines
  - Chemical SOP templates
- Ensure departments have processes to properly close laboratories in a safe and prompt manner.
- Ensure laboratory personnel are routinely testing peroxide forming solvents and are adhering to disposal recommendations for peroxide forming solvents.
- Emphasize safe practices for peroxide forming chemicals during lab audits.
- Explore using the Chematix chemical inventory system to send “testing reminder” notices to labs known to be users of peroxide forming solvents.
- Require labs to add expiration dates to peroxide forming chemicals in the Chematix chemical inventory system.
- Distribute a safety alert to the research community and discuss this incident with safety committees.

**TABLE 1: Drum Waste Inventory (all possible chemicals from Smith 311)**

6/11/2019	p-XYLENE	4.0 L
6/11/2019	ACETONITRILE	4.0 L
6/11/2019	1-Butanol	4.0 L
6/11/2019	1-Butanol	4.0 L
6/11/2019	tert-BUTYL ALCOHOL	500.0 mL
6/11/2019	1-Butanol	4.0 L
6/11/2019	DICHLOROMETHANE	100.0 mL
6/11/2019	1-Undecanol	1.0 L
6/10/2019	2-HYDROXYETHYL ETHER	1.0 L
6/10/2019	1,2-PROPANEDIOL	1.0 L
6/10/2019	1,2-PROPANEDIOL	1.0 L
6/10/2019	2-METHOXYETHANOL (ETHYLENE GLYCOL MONOMETHYL ETHER)	500.0 mL
6/10/2019	1,2-DICHLOROETHANE (ETHYLENE DICHLORIDE)	2.0 L
6/10/2019	m-Xylene	2.0 L
6/10/2019	Dimethoxymethane	1.0 L
6/10/2019	ETHYLBENZENE	1.0 L
6/10/2019	BUTYRONITRILE	1.0 L
6/10/2019	TOLUENE	1.0 L
6/10/2019	HEXANE	1.0 L
6/10/2019	ACETONITRILE	1.0 L
6/10/2019	HEPTANE	500.0 mL
6/10/2019	1-NITROPROPANE	500.0 mL
6/10/2019	2,2,2-TRIFLUOROETHANOL	500.0 mL
6/10/2019	2-BUTANOL	1.0 L
6/10/2019	2,2,2-TRIFLUOROETHANOL:	500.0 mL
6/10/2019	ISOAMYL ALCOHOL	500.0 mL
6/10/2019	1-Pentanol	100.0 mL
6/10/2019	3-HEXANOL	100.0 mL
6/10/2019	CYCLOPENTANOL	100.0 mL
6/10/2019	1-PROPANOL	1.0 L
6/10/2019	1-HEXANOL	1.0 L
6/10/2019	2-METHYL-1-PROPANOL	1.0 L

6/10/2019	2-METHYL-2-PROPANOL	500.0 mL
6/10/2019	2-METHYLCYCLOHEXANOL	250.0 mL
6/10/2019	3-METHYL-1-BUTANOL	100.0 mL
6/10/2019	2-Propanol	100.0 mL
6/10/2019	3-METHYL-1-BUTANOL	100.0 mL
6/11/2019	p-XYLENE	100.0 mL
6/11/2019	CYCLOOCTANE	100.0 mL
6/11/2019	2-HEXANOL	25.0 mL
6/11/2019	3-ETHYL-3-PENTANOL	25.0 mL
6/10/2019	CYCLOHEXANOL	500.0 mL
6/10/2019	1-OCTANOL	1.0 L
6/10/2019	DECYL ALCOHOL	1.0 L
6/10/2019	3-HEPTANOL	100.0 mL
6/10/2019	1-OCTANOL	1.0 L
6/10/2019	Heptyl alcohol	250.0 mL
6/10/2019	1-OCTANOL	250.0 mL
6/10/2019	NONYL ALCOHOL	100.0 mL
6/10/2019	1-HEPTANOL	100.0 mL
6/11/2019	METHYL BENZOATE	500.0 mL
6/11/2019	N-Isopropylbenzylamine	100.0 mL
6/11/2019	1-Nonanol	100.0 mL
6/11/2019	DL-3-Octanol	100.0 mL
6/10/2019	o-NITROTOLUENE	1.0 L
6/10/2019	2-NITRO-m-XYLENE	500.0 mL
6/10/2019	2,2,2-TRICHLOROETHANOL	100.0 mL
6/10/2019	PULEGONE	100.0 mL
6/10/2019	PULEGONE	100.0 mL
6/10/2019	PULEGONE	100.0 mL
6/10/2019	BENZYL ALCOHOL	500.0 mL
6/10/2019	HEXADECANE	500.0 mL
6/10/2019	HEXADECANE	500.0 mL
6/10/2019	BENZALDEHYDE	1.0 L
6/10/2019	BENZYL ALCOHOL	1.0 L



**FIGURE 1: TCEM Layout (room 117 shaded yellow)**



**FIGURE 2: TCEM 117 Flammable Liquid Processing Station**



**FIGURE 3: Rubbermaid 1-Cubic Yard Utility Tilt Cart**



**FIGURE 4: Explosion Aftermath**



**FIGURE 5: Explosion Aftermath**



**FIGURE 6: Explosion Aftermath**



**FIGURE 7: Explosion Aftermath**



**FIGURE 8: TCEM 116 Damage (paint chips)**



**FIGURE 9: TCEM 118 Damage (insulation)**

**APPENDIX 1:  
POURING OF CERT ORGANIC SOLVENTS  
Standard Operating Procedure and Hazard Assessment**

**1. Task:**

Pouring of CERT organic solvents is the consolidation of compatible flammable and/or combustible liquids into one of three transfer drums, which are later transferred to one of three 2,500-gallon tanks, in accordance with vendor established waste profiles for supplemental fuel disposal.

**2. Hazards Identified:**

<b>Head:</b>	chemical exposure	<b>Body:</b>	chemical exposure
<b>Eyes/Face:</b>	chemical exposure	<b>Feet:</b>	chemical exposure
<b>Hands:</b>	chemical exposure	<b>Respiratory:</b>	chemical exposure
<b>Other:</b>			

**3. Personal Protective Equipment (PPE) Requirements:**

<b>Head:</b>	none	<b>Body:</b>	FR-lab coat/apron
<b>Eyes/Face:</b>	full-face respirator	<b>Feet:</b>	chemical resistant boots
<b>Hands:</b>	butyl rubber gloves	<b>Respiratory:</b>	full-face respirator
<b>Other:</b>	<b>Hands:</b> 4 mL neoprene gloves as well (double glove)		

Proper doffing technique should be used when removing all PPE to ensure that the skin does not come into contact with the outside surfaces that are potentially contaminated. Wear clean gloves when doffing PPE. If PPE becomes grossly contaminated (i.e., large splash) during pouring operations, the PPE should be removed immediately.

**4. Designated Area:**

The processing of CERT organic solvents must be performed at the pouring station located in TCEM 117. **NOTE:** It is recommended but not required to perform this procedure in pairs; however it is required that additional TCEM staff be present at the facility when this procedure is performed.

**5. Engineering Controls:**

- The processing of CERT organic solvents must be performed at the pouring station located in TCEM 117, which is equipped with an exhaust system designed to exhaust hazardous vapors.
- The nearest eyewash and emergency shower station is located in TCEM 117A
- The nearest pull station for the fire alarm is located directly outside of TCEM 117.
- There is an ABC fire extinguisher located inside of TCEM 117.
- The transfer drums must be grounded and bonded before pouring operations occur (Figure 1).



Figure 1 – Grounding/Bonding of Transfer Drum

Gas Detection Alarm System

There is a gas alarm detection system located directly outside of TCEM 117 (Figure 2). This system monitors the lower explosive limit (LEL) and oxygen concentration within TCEM 117, 117A and 118 O<sub>2</sub> only). The system is designed to alarm if oxygen levels decrease to 19.3% or below, or if 9% of the LEL is detected. Figure 3 details the gas alarm detection system sequencing process.



Figure 2 – Gas Detection Alarm System

	Combustion #1 Room 117			Combustion #2 Room 117A			Oxygen Sensor Room 118			MSA Panel
	CAUTION	WARNING	ALARM	CAUTION	WARNING	ALARM	CAUTION	WARNING	ALARM	TROUBLE
<b>LEVEL</b>	5%	7%	9%	5%	7%	9%	20.2%	19.7%	19.3%	
BSAC notified (note 1)		X	X		X	X		X	X	X
MSA Panel Horn	X	X	X	X	X	X	X	X	X	
Office #106 Amber	X	X	X	X	X	X	X	X	X	
#118 Yellow - Outside							X	X	X	
#118 Red - Inside							X	X	X	
#117 Yellow - Outside	X	X	X	X	X	X				
#117 Red - Inside	X	X	X	X	X	X				
#117A Red - Inside	X	X	X	X	X	X				
"Alarm 1" on Panel	X	X	X	X	X		X	X		

Figure 3 – Gas Monitor Sequence

**6. Protocol:**

- a. All organic solvents to be processed are unpacked and information is verified. The contents on the label should be checked for accuracy and any anomalies (i.e., unexpected layering, solids, etc.) should be addressed. Ensure that no compounds that are not suitable for the tank are present (see list below). All the necessary equipment and materials should be gathered and the containers to be poured should be brought into room 117 for preparation.

Compounds forbidden to be added to the tanks are:

Tetrahydrofuran (THF)

Pyridine

Propylene Oxide

Dimethylformamide (DMF)

Carbon Tetrachloride

NO SOLIDS

- b. Setup:

Funnels – Remove plug, insert strainer, and place bottle holder on top (Figure 4).

Transfer Drums – Remove bung, vent and insert float (Figure 5).



**Figure 4 – Funnel**

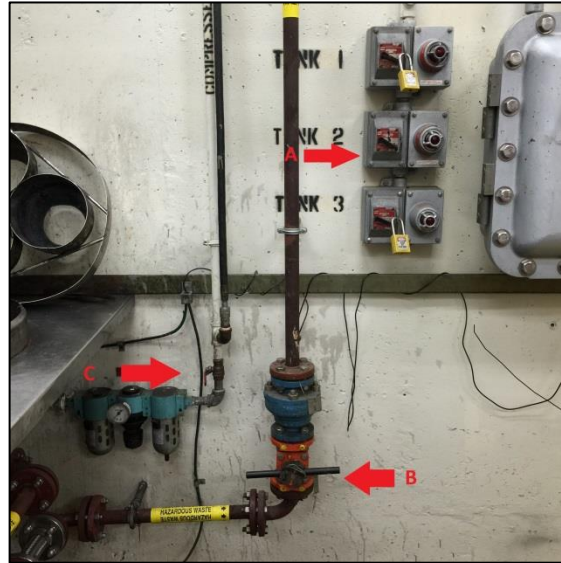


**Figure 5 – Transfer Drum**

- c. Don the appropriate PPE.
- d. Pour bottles:
- Get tubs for glass from 117A and move into 117.
  - Check the label for each container before pouring. Ensure that no FORBIDDEN compounds are added.
  - Slowly begin to pour the liquid into the funnel. If chemical reactions occur that create vapors, smoke, bubbles, polymerization, flashes, etc. occur, immediately stop pouring, cap the bottle and set it aside. Got seek assistance and investigate the cause of the chemical reaction further.
  - Glass bottles should be placed in the glass recycling tubs.
- e. Pour/Pump Returnables:
- Automatic solvent waste streams should be the same every week. Verify that THF, FIXER, BULKACID, BULK CC or SW177 is not accidentally brought into the wrong room.
  - Pour into funnel filling the cone.
  - Use sludge buckets and spatulas to remove solids and improve flow.

Pumping Drums:

- Remove both bungs slowly- keep face away may be slightly pressurized and spray.
- Take sample. Write MDN# on the sample jar
- Connect grounding strap
- Remove pipe with strainer from a transfer drum, insert into CERT drum
- Connect hose
- Turn on pump. (Figure 6)



**Figure 6: 117 Transfer Pump**

- A: Turn on appropriate Solenoid Valve (A)  
 B: Turn the transfer pipe valve to open (B)  
 C: Turn on pump (C)

- When pumping slows, tilt drum on side to access more fluid.
  - Pour residuals into a bucket.
  - If heavy, maybe 'sludge-y' use 'can-opener' to access residuals
  - Place empty container out of the way. Label with EMPTY sticker.
  - Move close to exhaust to air out residuals.
  - Steel drums get sent as 'SCRAP'
  - Plastic get cut up with saw as 'Trash'
- f. Continuously monitor the float throughout the pouring operation to ensure that the transfer drum is not overfilled.
- g. When the transfer drum(s) is full, a sample is taken of the full transfer drum and placed into the 8L jar corresponding to current tank. Observe jar for reactions i.e. bubbling, off-gassing, heating. Once the contents of all the containers have been added to the transfer drum, or when the transfer drum is full, the liquid should be pumped from the transfer drum to the tank (Figure 6 & 8).

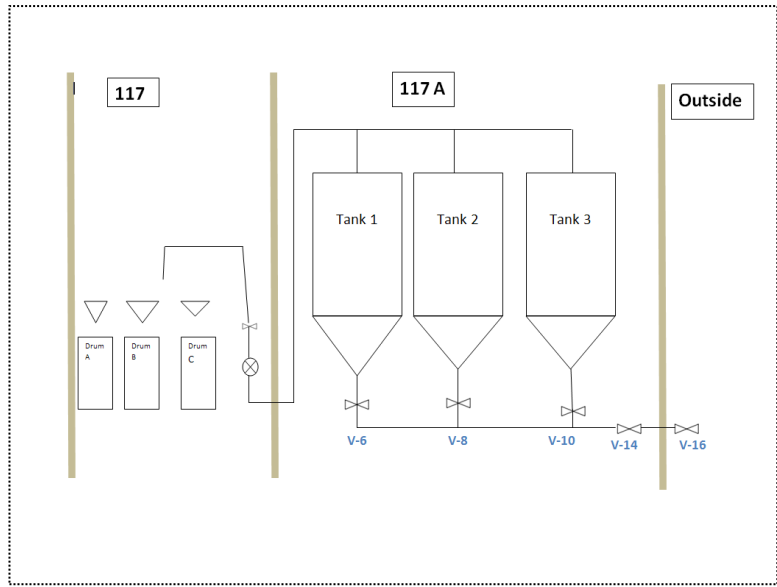


Figure 8 – Tank Pumping System

**APPENDIX 2**  
**TESTING PEROXIDE FORMING SOLVENTS**  
**Standard Operating Procedure and Hazard Assessment**

**1. Introduction:**

Auto-oxidation in common laboratory solvents can lead to unstable and potentially explosive peroxide formation. The reaction can be initiated by exposure to air, heat, light, or contaminants. Most of these solvents are available with inhibitors to slow the peroxide formation. Examples of inhibitors include BHT (2,6-di-tert-butyl-4-methyl phenol) and hydroquinone.

There are three categories of peroxide formers:

- **Group A:** Form explosive levels of peroxides after prolonged storage, especially after exposure to air. Test these for peroxide formation before using and discard after three months after opening.
- **Group B:** Form peroxides that are hazardous only on concentration by distillation or evaporation. Test these before distillation and discard after 12 months.
- **Group C:** Consists of monomers which form peroxides that can initiate explosive polymerization. Inhibited monomers should be tested before use and discarded after 12 months. Uninhibited monomers should be discarded 24 hours after opening.

**Peroxide Table (NOTE: not a comprehensive list)**

<b>Group A. Solvents that may form explosive peroxides without concentration:</b>		
Butadiene	Divinylacetylene	Tetrafluoroethylene
Chloroprene	Isopropyl ether	Vinylidene chloride
<b>Group B. Solvents that may form peroxides after distillation:</b>		
Acetal	Dicyclopentadiene	Methyl isobutyl ketone
Acetaldehyde	Diethyl ether	4-methyl-2-pentanol
Benzyl alcohol	Diethylene glycol dimethyl ether	2-pentanol
2-Butanol	Dioxane	4-penten-1-ol
Cumene	Ethylene glycol dimethyl ether	1-phenylethanol
Cyclohexanol	4-heptanol	2-phenylethanol
2-cyclohexen-1-ol	2-hexanol	2-propanol
Cyclohexene	Methylacetylene	Tetrahydrofuran
Decahydronaphthalene	3-methyl-1-butanol	Tetrahydronaphthalene
Diacetylene	Methylcyclopentane	Vinyl ether
<b>Group C. Monomers which form peroxides that can initiate explosive polymerization:</b>		
Acrylic acid	Chlorotrifluoroethylene	Vinyl acetate
Acrylonitrile	Methyl methacrylate	Vinyl acetylene
Butadiene	Styrene	Vinyl chloride
Chloroprene	Tetrafluoroethylene	Vinyl pyridine

**2. Hazards Identified:**

<b>Head:</b>	chemical exposure	<b>Body:</b>	chemical exposure
<b>Eyes/Face:</b>	chemical exposure	<b>Feet:</b>	none
<b>Hands:</b>	chemical exposure	<b>Respiratory:</b>	minimal hazard
<b>Other:</b>	All testing must be performed in chemical fume hood		

### 3. Personal Protective Equipment (PPE) Requirements:

<b>Head:</b>	none	<b>Body:</b>	FR-lab coat
<b>Eyes/Face:</b>	safety glasses	<b>Feet:</b>	none
<b>Hands:</b>	nitrile gloves	<b>Respiratory:</b>	none
<b>Other:</b>			

Proper doffing technique should be used when removing all PPE to ensure that the skin does not come into contact with the outside surfaces that are potentially contaminated. Wear clean gloves when doffing PPE. If PPE becomes grossly contaminated (*i.e.*, large splash) during pouring operations, the PPE should be removed immediately.

### 4. Designated Area:

Testing of peroxide formers can occur both in TCEM or other locations on campus. However, this process must be conducted in a functional chemical fume hood (*i.e.*, TCEM Room 115 fume hood, campus laboratory fume hood).

### 5. Engineering Controls:

- Testing peroxide formers must occur in a functional chemical fume hood. Typically this process will occur in TCEM Room 115.
- The nearest eyewash and emergency shower station is located in TCEM 115
- The nearest pull station for the fire alarm is located directly outside of TCEM 115.
- There is an ABC fire extinguisher located inside of TCEM 115.
- If testing peroxide formers at another location such as a campus lab, ensure that the process is performed in a functional chemical fume hood.
- A blast shield is available in TCEM 115 as well.

### 6. Chemical Bottle Inspection:

Inspect the chemical bottle for any descriptions or markings (*i.e.*, dates, distillation, contaminants, *etc.*) that will aid in the determination of hazards. Look for crystal/precipitate formation in the solution and around the cap. If solids are seen in the solution, do not open. Contact TCEM technical staff for assistance and further evaluation.

### 7. Protocol:

**Step 1:** Don appropriate PPE.

**Step 2:** Obtain the waste containers to be tested (O-O designation) and quantitative peroxide former test strips located in TCEM 115).

**Step 3:** If you feel that it is safe to do so (no visible solids/crystals), carefully open the container and obtain a small sample (<5 mL) using a pipette. Place the sample in a watch glass or other appropriate vessel. **If you do not feel it is safe to open the container, or have any questions, DO NOT OPEN. Seek assistance from TCEM staff.**

**Step 4:** Immerse a 0 – 100 mg/L quantitative test strip in the sample for 1 second.

**Step 5:** Gently fan the strip back and forth for 30 seconds to allow the sample to evaporate.

**Step 6:** Immerse the test strip in deionized (DI) water for 1 second (DI water can be obtained from the IH lab in TCEM 114).

**Step 7:** Wait 5 seconds and compare the results to the chart on the test strip container/tube.

If the solvent is greater than 100 ppm, test the sample using a 50 – 1000 mg/L quantitative test strip.

- a. Immerse the test strip directly into the sample (DI water is not necessary).
- b. Fan the test strip to shake off excess liquid.
- c. Wait 45 seconds and compare the results to the chart on the test strip container/tube.

**Step 8:** Record the results on the Chematix inventory label.

**Step 9:** Place the peroxide former back in the appropriate TCEM storage room:

- Less than 100 ppm: waste is suitable for bulking (*i.e.*, CERT, THF, FLBULK)
- Greater than 100 ppm and less than 400 ppm: waste needs to be treated using an appropriate reducing agent (*i.e.*, sodium bisulfite)
- Greater than 400 ppm: cases-by-case basis, consider contacting the Minneapolis Police Bomb Squad for assistance

**Step 10:** If the solvent is greater than 100 ppm but less than 400 ppm:

- a. Obtain a large container (*i.e.*, 4 liter beaker).
- b. To the beaker, slowly add 500 mL of water and 200 g of sodium bisulfite (located in TCEM 115 or 116B - flammable cabinet) and start manually mixing the solution.
- c. Slowly add the solvents to the solution.
- d. Continue to stir the solution.
- e. Test the resulting solution with a peroxide indicator strip in verify treatment.
- f. Repeat treatment process if necessary.
- g. Pour remaining solution into an appropriate container for disposal (*i.e.*, CERT, lab pack, *etc.*).