ROOT CAUSE DETERMINATIONS OF HAZARDOUS MATERIAL INCIDENTS REDUCES COSTS & LIABILITIES

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PURPOSE AND BACKGROUND

The purpose of this paper is to present a method for conducting hazardous materials incident root cause determinations to recover costs and reduce liabilities. This approach may be used by companies, which are self-insured or covered by insurance. This approach is illustrated herein by three (3) Remtech case histories.

A large percentage of hazardous material incidents are due to failures or faults outside the control of the industry or mode of transportation when the release occurs. Root cause determinations should be conducted whenever there is potential for significant impacts to health, property, or the environment. It is noteworthy that it is not always apparent when an incident will progress from minor to major liabilities and costs.

Determination of the root cause of hazardous materials incidents can be used to implement loss prevention programs to lower the probability of incident reoccurrence and/or transfer or recover response and remediation costs from responsible party(s) and/or their insurance companies. Root cause determinations may be conducted immediately following an incident, during cleanup, or post cleanup. Subrogation and cost recovery opportunities generally wane with the passing of time.

Root cause determinations should be integrated with remediation operations to reduce liabilities. Evidence is frequently undetected or destroyed by fire departments, demolition crews, cleanup contractors, and emergency services personnel. Opening the interstate or restoring operating conditions at a facility is generally emphasized over causation investigations.

Incident causes are frequently uncovered during site cleanup operations. Response personnel with the appropriate experience and training to identify, document, and determine root causes are essential to control costs and reduce liabilities.

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TYPES OF ROOT CAUSES

A partial list of hazardous materials incident root causes documented by Remtech on over 2,500 incidents are summarized below by failure and industry type:

Human Error

Inadequate sleep - falling asleep, choking on food or drinks, use of drugs and/or alcohol, heart attack, other heath problems, Lack of adequate or proper environmental and safety training, failure to perform pre-trip or pre-operation inspections, improper driving judgment (speeding, rapid lane changes, running red lights, vehicle collisions, rollovers, at grade collisions with trains), impacting overhead clearance objects (pipes, bridges, etc), overfilling containers, improper unloading procedures, improper use or lack of protective gear, pumping against closed valves, transferring the wrong product into the wrong container, use of improper cleanup techniques, sabotage, illegal dumping, spreading or dispersion of contamination

Container Failure

Wrong type of container (Not DOT or UN certified), wrong or defective materials of construction, inappropriate reuse of single trip containers, container stress fractures, corrosion failures, weld or seam failures, mechanical punctures, inadequate container cleaning, container incompatible with product, missing, malfunctioning, or wrong type of venting or pressure release devices, missing or deteriorated gaskets, pallet failures (wrong type of pallet, rotten wood, fasteners puncturing container, missing pieces), improperly located or protected unloading valves in container handling zone, unprotected container bladder projections in container handling zone, fitting or fitting connection leaks or failures, loading incompatible materials adjacent to each other

Handling Failures

Railroads – humping cars, rough handling by intermodal crane equipment, bumping railcars during yard consist makeup, sparks from brakes and engine exhaust, derailments, welding operations, improper labeling-placarding-manifests

Intermodal – improper loading or bracing, dropping or jarring containers during ramp loading operations, projections in container puncturing product containers, improper labeling-placarding-manifests

LTL Carriers – inadequate equipment maintenance, tire failures, impacting road hazards, overloading resulting in structural failure, vehicle collisions, negotiating turns too fast, rollovers, improper loading or bracing, brake failure, projections in trailers puncturing product containers, fork lift puncturing, load shifts with containers puncturing/ crushing each other, improper labeling-placarding-manifests

Tankers – improper connections during loading or unloading, overfilling, failure of overflow prevention devices, transferring product into wrong tank, pumping against closed valves, liner failures, inadequate equipment maintenance, rollover from negotiating turns to quickly, gasket missing or failure, valve failure, failure to ground or bond during product transfer, tire failures, striking road hazards, overloading resulting in structural failure, vehicle collisions, improper labeling-placarding-manifests

Pipelines & Utilities – pipeline failure due to inadequate line inspection program, inadequate maintenance, pumping against closed valves, corrosion failure, construction impacts

Manufacturing & Terminal Storage Facilities – facility design/construction errors, equipment malfunctions, inadequate equipment maintenance, lack of corrosion protection, lack of adequate tank inspection program, filling and draining tanks from bottom, pump seal failures, overfilling tanks, overfill protection device failures, valve failures, transferring product into wrong tanks or reactors, freezing of lines, impact of lines, failure of control systems, welding ignition, entering tanks without proper confined space monitoring and protection equipment, lack or failure of secondary containment systems, leaking roofs, clogged lines, chemical reactions, power failures, improper labeling-placarding-manifests

Fires or Explosions

Chemical reactions, lightening, power failures, electrical shorts, arson, lack of or improper grounding, bonding, lightening arrestors, explosion proof equipment,

Product Failures

Chemical reactions (polymerization, omission of product stabilizers, product degradation beyond shelf life, moisture picked up during manufacturing process, incompatible packaging), product contamination introduced during manufacturing or during repacking

Natural Disasters

Rain, ice storms, snow, tornadoes, floods, hurricanes, mudslides, earthquakes

Planning & Training Deficiencies

Lack of or inadequate Spill Prevention Control & Countermeasures Plan (SPCC), lack of training and drills testing plans, DOT and OSHA HAZMAT Training

ROOT CAUSE DETERMINATION APPROACH

The cause(s) of environmental releases are not always readily apparent and properly identified. Each incident is unique and requires a systematic approach to identify the root cause. Incidents should be investigated by personnel employing good engineering practices, a multidisciplinary approach, best industry practices, and considering safety and environmental regulations.

A good technical data base should be developed to defend against potential latent liabilities – personal injury claims, property damage claims, business interrupt claims, cargo damage, environmental damage, citations, and environmental fines.

Thorough incident photo documentation before, during, and post remedial action with cameras or video cams frequently provides the investigator with documentation to determine the cause following the incident. Documentation of background conditions (surrounding and pre-incident conditions) is also paramount.

Observations may be made initially, as the incident is uncovered or cleaned up, or post incident.

Root Cause Assessment Methodology

Elements of an effective root cause determination are presented below and include: employing qualified and experienced investigators who properly document, identify failure causes, evaluate failures, select a probable cause (based on evidence, accident reconstruction, and testing), and prepare an thorough incident response report.

- Documentation
    - Photo document incident, incident setting, background conditions
    - Identify material(s) involved
    - Identify containers involved

    - Identify potential responsible parties (manufacturers, shipper, loading entity, carrier)
    - Identify storage or load secured conditions
    - Determine properties including reactivity/compatibility of materials with container
    - Determine environmental setting - Locate incident within local potential transport means (air, water, ingestion, direct contact), pathways and receptors affected by release

- Identify potential failure types

    - Human error, container failure, handling failures, fire or explosions, product failures, natural disasters, planning and training deficiencies

- Evaluate potential failure types

    - Perform structural evaluation, load capacity, load distribution (balanced) container integrity, compatibility, bracing and load securement, stacking, double stacking, foreign objects (nails, other protrusions), environmental stress fracturing, inspect container appurtenances, pressure release devices, caps or manways - seated and with gaskets, drain valves operational
    - Container certified, DOT test dates, type of container, appropriate container
    - Container failure during loading, in transit, or inherent in container, proper loading – stacking, bracing, compartmentalization, anchoring
    - Container bulging – amble headspace, vents, compatible container, contaminants in product, product instability
    - Type of container failure, stress fracture, compression failure, shear failure, failed seam, failed liner, degradation of container, previous container's contents, putting wrong product in wrong container
    - Fire – heat of reaction - autoignition, explosive gas generation, flammables/combustibles with external ignition source
    - Explosion – polymerization, confined space, dust, vapor, BLEVE

- Select most probable incident cause based on evidence and experience.

    - Preserve evidence
    - Accident reconstruction to determine incident cause

- Prepare incident response report with environmental assessment, probable cause determination, remediation tasks implemented, and suggested follow-up action to limit further or future liability. Identify responsible party(s).

Partial List of Resources for Root Cause Determinations

The following list of resources is presented to assist with root cause determinations. Each incident is unique and may require resources not listed below.

- Camera, video camera
- Interviews (witnesses, regulatory authorities, claims representatives)
- Reports - police, fire departments, cleanup contractors, insurance claims, regulatory agency (OSHA, DOT, EPA, State Health Agency, State Fire Marshal)
- Direct observations
- News reports, newspaper articles and photographs, video footage
- Testing options
    - Field characterizations scans
    - Qualitative gas scans, select analytes for analysis
    - Treatability tests
    - Sample collection
    - Small-scale tests
        - Flammability
        - Ignitibility – flash or sustained
        - PH
        - Color, taste, smell
        - Dissolved oxygen
        - Radiation - Geiger counter
        - Hazmat tubes
        - Water reactivity testing
        - Physical state determination
        - Aim meter – oxygen, H_2S, carbon monoxide, combustible gas explosive limits
        - Miscibility – water, alcohol, acetone
        - HNU – photoionization detector
        - Conductivity, salinity
        - PCBs – Chlor-N-Soil, Chlor-N-Oil
        - Anthrax – Smart Tickets

- Laboratory testing (chemical analyte identification, materials testing)

CASE HISTORIES

Three Remtech case histories are presented herein to illustrate successful root cause determinations and the associated cost and liability transfer to the appropriate responsible party(s).

Leaking Intermodal Container

An intermodal container leaking an unknown hazardous material was discovered at a railyard. Remtech responded to the incident to assess and mitigate the incident. Remtech stabilized the incident by placing sorbent and plastic sheeting containment barriers around the railcar allowing the container to be opened an inspected.

Four (4) 300-gallon composite totes were double stacked on the rear of the container. The wood bracing failed allowing a load shift to occur. The bottom tote top rail failed (due to defective mechanical fasteners) with the vertical tote supports puncturing the bottom of the second level tote.

The railroad contacted the intermodal container owner and indicated that the root cause was determined to be inadequate bracing and failure of the top rail of the composite intermediate tote container. To avoid subrogation, the railroad requested that the container owner to agree to pay for the cleanup directly.

Remtech completed the cleanup. Remtech prepared an incident response report certified by a professional engineer that provided the container owner with information to recover costs from the shipper who loaded the container improperly and the tote manufacturer container failed. The container owner instigated a new loading policy banning double stacking of composite intermediate bulk totes and requiring totes to be secured with plywood decking and vertical tie downs.

Major Water Authority Chlorine Dioxide Explosion

A major water authority had a fire at a chlorine dioxide generating facility located at a raw water pumping station. The authority contacted Remtech requesting emergency response assistance. An Air Force Reserve HAZMAT team and county fire department had initially responded to the incident and conducted an assessment in Level A protective gear. Chlorine dioxide was generated by reacting humidified anhydrous chlorine gas with sodium chlorite. The MSDS sheet indicated that sodium chlorite exposed to heat becomes shock sensitive and explodes on contact with friction or impact. The state's pollution control agency advised that the ventilation fans to the pumping station be turned on to exhaust toxic fumes.

Remtech arrived on scene and was given the following information - there was no sign of an explosion and a white powder covered the floor. A Remtech engineer conducted an assessment with a representative of the water authority (in Level C protective gear) and discovered that live electrical wires were draped over the reactors and in water on the floor. Two lids had blown off the reactors and sodium chlorite residues were broadcast on the ceiling, walls, and floor. Remtech advised the fire chief to turn the power off to the building and shut down the exhaust fans to eliminate ignition sources. Apparently the Level A protective gear, unfamiliarity with the process, and fear of stepping on reactive sodium chlorite had inhibited the initial response team from properly assessing the situation and eliminating the primary other hazard – turning off the power.

Chlorine dioxide detector tubes were used to establish toxic corridors. Chlorine dioxide levels declined to background 150 feet from the building. It was determined that it was unnecessary to evacuate a Boy Scout campground located adjacent to the pumping station.

A remediation plan was prepared to deactivate the reactor residues while keeping chlorine and chlorine dioxide ambient concentrations below detection limits. Bench scale reactions were conducted to confirm full-scale dechlorination reactions. Partially reacted residues were misted with water and dissolved in containers filled with water. Forty gallons of chlorite burn residues were reacted with 200 pounds of soda ash and 100 pounds of sodium metabisulfite. Placing 150 pounds of cubed ice in the reactors prior to adding the fire residues dissipated heat of reaction energy. Reactions were conducted in closed poly reactors. Off gases were collected and passed through two gas scrubbers with a soda ash/sodium metabisulfite solution. Off gases were monitored to ensure that no chlorine or chlorine dioxide was liberated. The temperature of the reaction vessels was monitored and kept below 120^oF.

Over two (2) tons of residual sodium chlorite were reacted first. The walls and floor were cleaned with a hot pressure washer. Wash water was collected and run through the dechlorination reactors. Burn residues from plastic components left a residue on the ceilings, glass block walls, and concrete floor. These residues were removed with caustic and acid cleaners.

The manufacturer of the chlorine dioxide system and fire investigators for the water utilities insurance company indicated that the most probable cause was contamination in the sodium chlorite reactors. During the cleanup, Remtech discovered that the glass block wall had blistered halfway up the wall and at the floor where the control panels had dropped and burned. The blistering on the wall was directly behind the former location of a motorized control valve that was actuated by a PLC controller. A statement obtained from the operator who first reported the fire revealed that when he activated the pump from a remote location, a clicking sound was observed at the remote alarm panel indicating that the chlorine sensor was trying to report. The operator drove to the pump station (10 minute travel time) and observed a fire in the corner of the chlorine dioxide generation area and attempted to extinguish the fire with an extinguisher.

The fire initiation time line appeared to be coincident with the remote activation of the motorized control valve. Remtech postulated that there was a short in the PLC controller of the motorized control valve that started a fire on the control panel and the external heat of the fire caused the reaction vessels to explode. Six months later, the fire investigators concurred with Remtech's findings by x-ray examination of the PLC panel.

Remtech prepared an engineering report delineating the cause of the fire. This report allowed the insurance company for the water utility to secure reimbursement (several hundred thousand dollars) from the chlorine dioxide manufacturer's insurance company.

Intermodal Railcar Fire

Three 28-foot trailers on a three-car articulated rail flatcar were destroyed by fire. The State Fire Marshal indicated that the most probable cause of the fire was a load shift and autoignition of chemicals mixing together. The railroad filed a claim with the LTL carrier to recover losses to the three trailers and freight on board totaling over $300,000.

The LTL carrier hired Remtech (four months after the incident) to conduct an independent fire investigation. The chemicals involved were dilute janitorial and metal cleaning products and oil based paints. Dental cleaning materials contained 15% sulfamic acid and 10% sodium hydroxide solutions. An aluminum cleaner contained 10 to 30% phosphoric acid. Paints contained solvents, powdered metals (aluminum, titanium). Other potential metal catalysts included the aluminum trailer, copper, brass, aluminum and zinc electrical fittings. Potential combustible reactants included paper, cardboard, and cloth medical dressings. Janitorial cleaning chemicals contained glycols, surfactants, and ammonia compounds.

Samples of the chemicals involved in the fire were obtained from the product manufacturers. Potential reaction consequences were determined using *"A Method for Determining the Compatibility of Hazardous Wastes (1)"*. Reactions with the greatest potential to product heat or fire were selected for testing. Potential binary, tertiary, and synergistic heat of reaction tests were conducted. Induction reaction periods were determined to ensure that adequate reaction times were employed. The order or sequence of chemical reactants was also varied to determine maximum heat of reactions.
Initial tests were conducted in one-quart glass reactors with a digital thermocouple equipped with an immersion probe. Reactions yielding the highest reaction temperatures were scaled up (2 -glass reactors) to determine if the heats of reaction were reactant mass limiting. Results indicated that insufficient heats of reaction were produced to elevate temperatures above threshold autoignition temperatures (for wood and cardboard 400 to 500 ^{o}F).

The cause of the fire was determined not to be due to the autoignition of chemicals on the trailer. The external ignition source occurred while the trailers were in the railroad's possession. A two-volume report and videotape library of over 50 heat of reaction tests provided the LTL carrier with a defense against the railroad's claim.

CONCLUSION

Root cause determinations should be performed immediately following an incident, during cleanup operations, and/or following an incident. Rapid determination of a hazardous materials incident root cause increases cost recovery and liability reduction opportunities. Documenting an accident cause can provide valuable information (for companies which are self insured or covered by insurance) to enhance loss subrogation.

Employing qualified and experienced investigators who properly document, identify failure causes, evaluate failures, select a probable cause (based on evidence, accident reconstruction, and testing), and prepare an thorough incident response report enhances cost recovery and liability transfer to the appropriate responsible party(s).

REFERENCES

1. *"A Method for Determining the Compatibility of Hazardous Wastes", EPA Environmental Research and Development, Cincinnati, OH, April 1980*

2. *"Handbook of Chemical Hazard Analysis Procedures", EPA, 1989*

3. *"Handbook of Reactive Chemical Hazards", Butterworth, 1999.*

4. *Remtech Engineers Confidential Project Reports.*

CASE 1-1: Leaking intermodal container removed from rail flatcar for integrated remediation and root cause determination.

CASE 1-2: Leaking intermediate bulk container on top right.

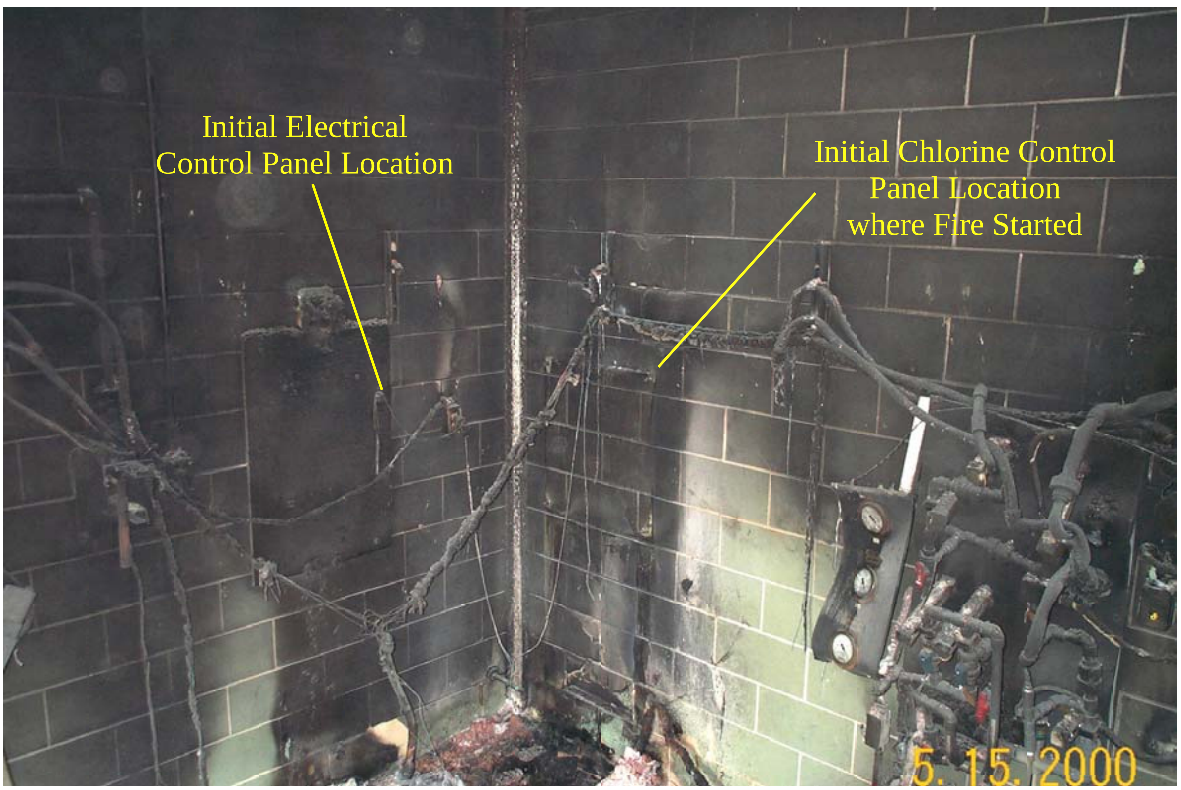
CASE 1-3: Failed top ring connectors allowed vertical supports to puncture second layer container.

CASE 1-4: Bottom of second layer tote punctured by vertical supports of first layer tote.

CASE 1-5: Intermodal container unloading operations.

CASE 1-6: Contents of container unloaded, decontaminated, and reloaded.

CASE 2-1: Chlorine dioxide generation system exploded in raw water pump building.



CASE 2-2: Root cause determination discovered during building decontamination operations -- PLC controller to motorized control valve started fire on chlorine control panel.

CASE 2-3: Sodium chlorite burn residue dechlorination operations.

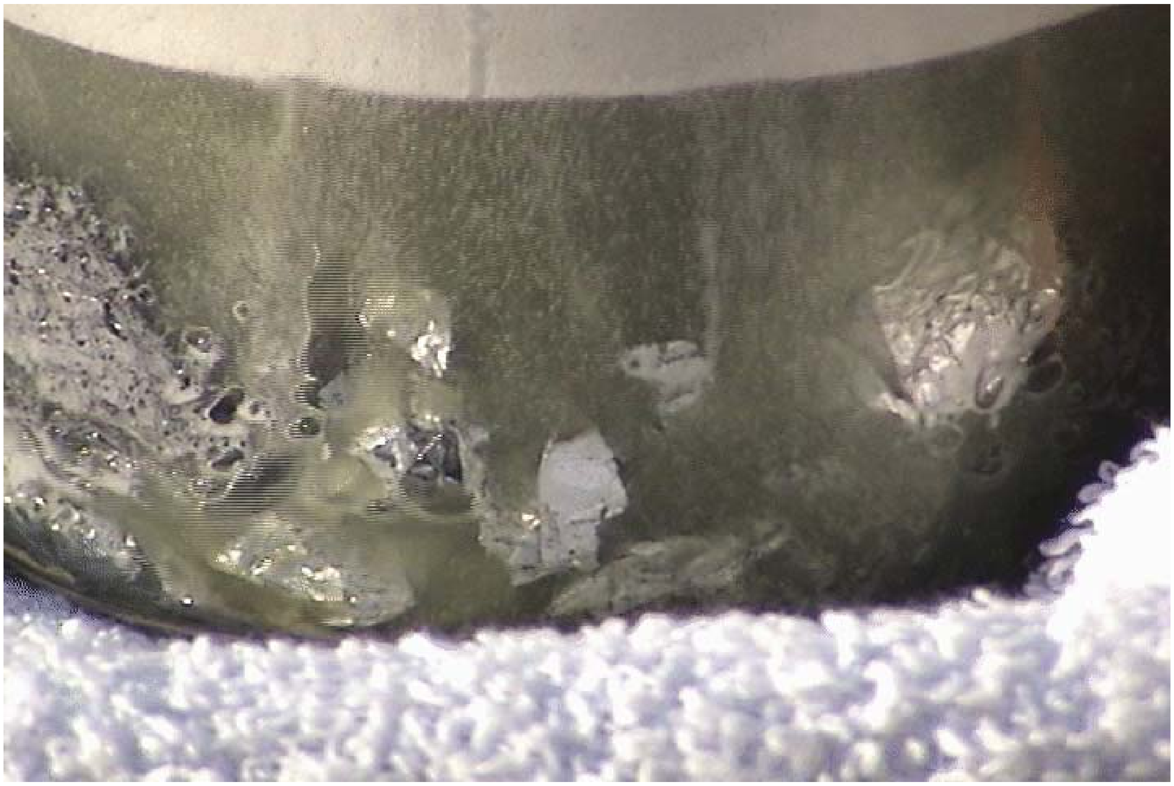
CASE 2-4: Addition of reactants and Ice to reactors stabilize sodium chlorite and control the heat of reaction.

CASE 3-1: Tractor trailers burned on railroad flatcar.

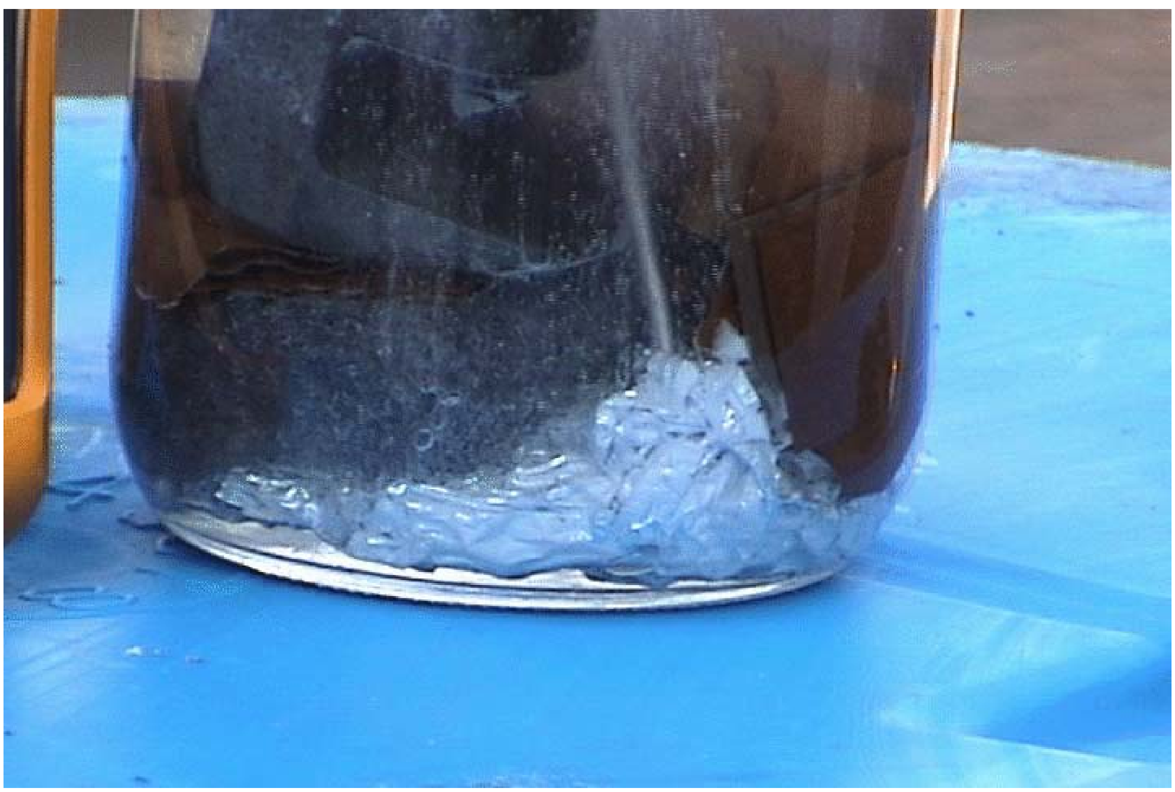
CASE 3-2: Chemical burn residues in middle trailer where fire started.

CASE 3-3: Heat of reaction test with 10% sodium hydroxide and metal catalysts (aluminum, steel wool, copper, and brass).

CASE 3-4: Heat of reaction test yields maximum temperature of 140.2 F - considerably below autoignition temperature for paper or cloth.



CASE 3-5: Close up of heat of reaction test depicting gas generation from 24% hydrochloric acid, 10% sodium hypochlorite, and aluminum reaction.



CASE 3-6: Close up of heat of reaction test with 10 - 30% phosphoric acid and metal catalysts (copper, brass, aluminum, steel wool)