Safety Systems Failures

Purposes

To explore the idea that a changing workplace creates a different Systems of Safety (S.O.S.) view.

To recognize multiple root causes of an incident and to eliminate or reduce hazards based on Systems of Safety (S.O.S.).

This Activity has three tasks.

Task 1, Sugar Dust Explosion and Fire

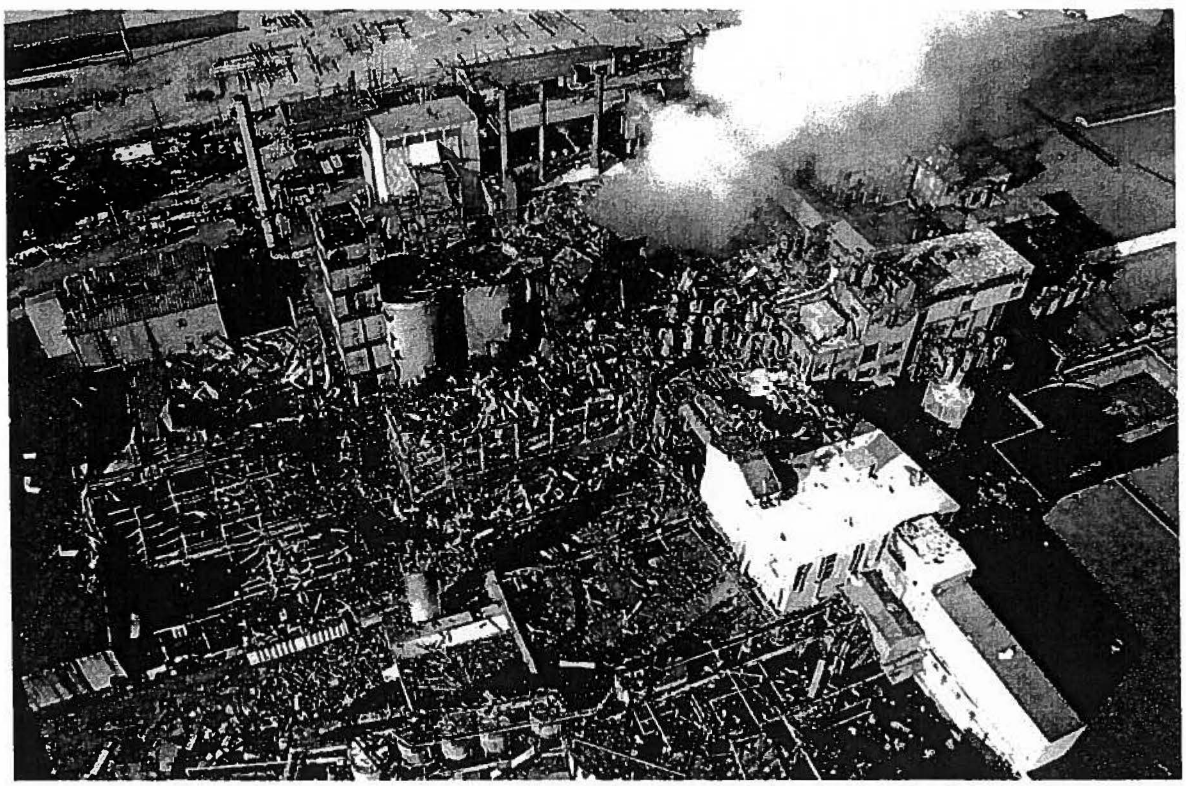


Photo courtesy of Chemical Safety Board, available at:
http://www.csb.gov/investigations/detail.aspx?SID=6.

Task 1

Scenario:

Your facilitator will show a brief video on the sugar dust explosion and fire that happened at the Imperial Sugar Company in Port Wentworth, Georgia.

Note: The scenario has also been printed below.

Sugar Dust Explosion and Fire
Imperial Sugar Company,
Port Wentworth, Georgia

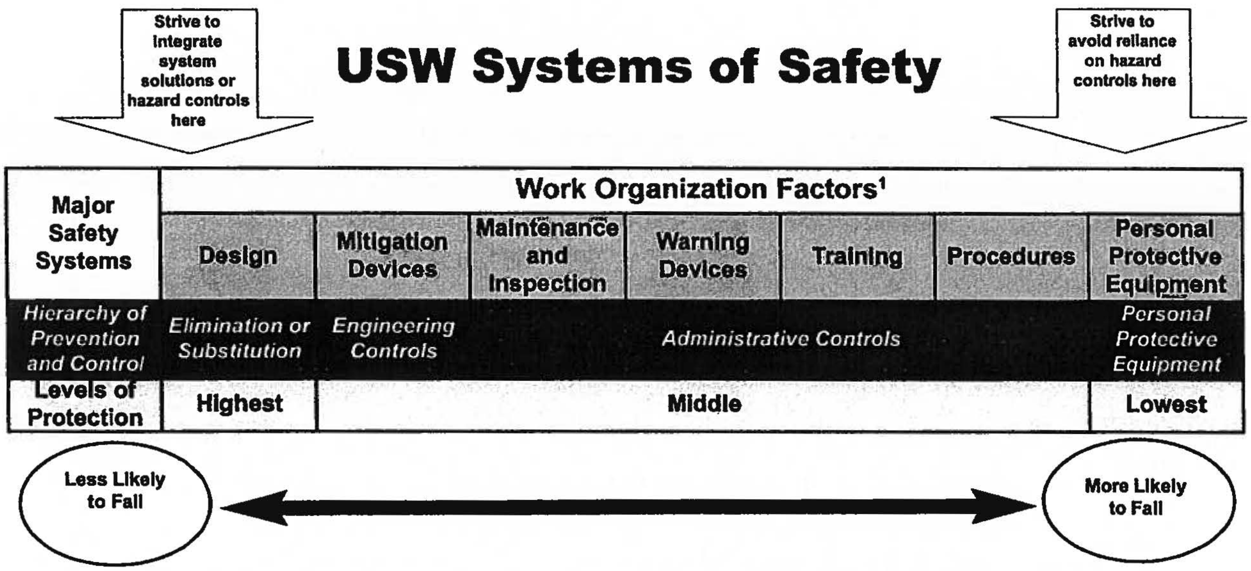
> At about 7:15 p.m. on February 7, 2008, a sugar dust explosion occurred in the enclosed steel conveyor belt under the granulated sugar storage silos at the Imperial Sugar Company sugar manufacturing facility in Port Wentworth, Georgia. Seconds later, massive secondary dust explosions propagated throughout the entire granulated and powdered sugar packing buildings, bulk sugar loading buildings and parts of the raw sugar refinery. Three-inch thick concrete floors heaved and buckled from the explosive force of the secondary dust explosions as they moved through the four-story building on the south and east sides of the silos. The wooden plank roof on the palletizer building was shattered and blown into the bulk sugar railcar loading area. Security cameras located at businesses to the north, south and west of the facility captured the sudden, violent fireball eruptions out of the penthouse on top of the silos, the west bucket elevator structure and surrounding buildings.
>
> When Garden City and Port Wentworth fire department personnel arrived minutes later, they were confronted with dense smoke, intense heat and ruptured fire water mains. A large amount of debris was strewn around the fully-involved burning buildings. Workers at the facility had already started search and rescue efforts and injured workers were being triaged at the main gate guardhouse.

Eight workers died at the scene, including four who were trapped by falling debris and collapsing floors. Two of these fatally injured workers had reportedly reentered the building to attempt to rescue their coworkers but failed to safely escape. Of the 36 workers transported to Savannah Memorial Hospital, nineteen who were severely burned were transported to the Joseph M. Still Burn Center in Augusta, Georgia, where six eventually succumbed to injuries, bringing the number of total fatalities to 14 workers. The last burn victim died at the burn center six months after the incident. Thirty-six injured workers ultimately survived, including some with permanent, life-altering conditions.

Source: U.S. Chemical Safety Board, "Imperial Sugar Company Dust Explosion and Fire," February 7, 2008, available at: http://www.csb.gov/investigations/detail.aspx?SID=6.

Your facilitator will now give an overview of the chart below. After that your will be given a few minutes to review the factsheets on the pages that follow.

Systems of Safety and Subsystems



[1] Work Organization Factors exist in virtually all workplaces. They often contribute to a hazard ***or its control***, or may be a hazard in and of themselves. They should be considered when identifying system failures and when integrating system solutions. They should also be accounted for when documenting failures and solutions.

A few examples of the above chart are listed below, but there are many other examples that are not listed.

Design	Mitigation Devices	Maintenance and Inspection	Warning Devices	Training	Procedures	Personal Protective Equipment
Equipment and Process Design	Safety and Check Valves	Inspection and Testing	Monitors	Hazard Identification	Well-defined, Up-to-date Operating Manuals	Air-purifying Respirators (APR)
Computer Hardware and Software	Suppression Devices	Vibration Monitoring	Hazard Warning Lights	Pre-job Training	Management of Change (MOC)	Self-contained Breathing Apparatus (SCBA)
Proper Material Selection	Emergency Isolation Devices	Quality Control	Facility Alarms	Relevant and Meaningful Training	Pre-startup Safety Review	Chemical Protective Clothing
Use of Inherently Safer Technologies and Chemicals	Relief Valves	Preventive and Predictive Maintenance Programs	Process Instrumentation Alarm Devices	Emergency Response Training	Job Hazard Analysis	Hard Hats, Gloves and Eye Protection
Work Organization						
Management of Organizational Change			**Workload**		**Staffing**	**Buddy System**

Revised March 2010

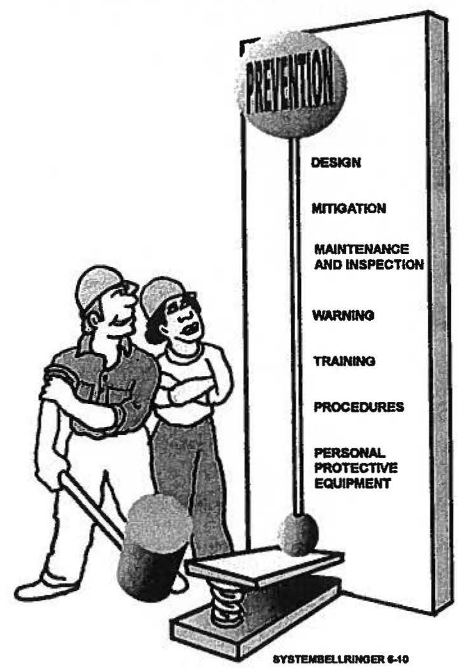
Factsheet 1: What Are Systems of Safety?

Most workplaces should have a developed program which contains some version of Systems of Safety. This program outlines, in detail, how the workplace will operate safely. This is a proactive program designed to prevent disasters and injuries from occurring.

The following components play key roles in eliminating or reducing hazardous conditions at the workplace:

- Design;
- Mitigation Devices;
- Maintenance and Inspection;
- Warning Devices;
- Training;
- Procedures; and
- Personal Protective Equipment.

Work Organization Factors should also be accounted for when documenting failures and solutions.



Source: Adapted in part from Harold Roland and Brian Moriarty, System Safety Engineering and Management, New York: John Wiley and Sons, 1983, p. 202.

Factsheet 2: The Design System

The highest level of hazard prevention is gained by using the Design System. Design involves the machinery and process of work. This includes factors such as:

- Process and equipment design, including redesign — design out the hazard;

- Hardware and software — computer and electronic-controlled equipment and processes require proper installation of correctly designed programs;

- Selection of machinery, chemicals and other materials;

- Ergonomic design of equipment and control panels;

- Use of inherently safer technologies and chemicals (substitution of less harmful chemicals) choosing less toxic, reactive and flammable chemicals;

- Reducing the inventory of hazardous materials; and

- Safe Siting — providing a safe work environment.

If hazards are to be eliminated, workplace design must be improved to the greatest extent possible. Industry either designs hazards into the workplace or designs the workplace so that it is healthy and safe.

Examples of Design at home:

- Magnetic latches on refrigerators that prevent children from being trapped inside; and

- The switch-over to latex-based paints reduced lead exposure.

Source: Adapted in part from Nicholas Ashford, The Encouragement of Technological Change for Preventing Chemical Accidents, A Report to the Environmental Protection Agency, Cambridge, MA: MIT, 1993.

Factsheet 3: The Mitigation System

The Mitigation System of Safety involves the use of equipment that automatically acts to control or reduce the harmful consequences of hazardous incidents. Mitigation should be automatic and reliable.

Typical examples of mitigation devices are:

In industry:

- Safety and relief valves;
- Suppression devices;
- Automatic shutdown devices;
- Emergency isolation devices;
- Dikes;
- Machine guarding; and
- Containment devices.

At home:

- Seat belts;
- Air bags;
- Circuit breakers; and
- Pressure relief valve on water heater.

Factsheet 4: The Maintenance and Inspection System

Properly designed equipment can turn into unsafe junk if it isn't properly maintained, inspected and repaired. If the phrase "if it ain't broke, don't fix it" is used within a workplace, the maintenance system is a failure. If you don't use preventive maintenance, then you end up doing breakdown maintenance. For example:

In industry:

- Preventive and predictive maintenance programs are in place;
- Work repair requests are completed in a timely fashion;
- Spare parts are readily available;
- Equipment is inspected for wear and damage;
- Maintenance workers are properly trained;
- Much needed repair work is not delayed for production requirements; and
- Vibration monitoring and records are kept on critical machinery.

At home:

- Preventive maintenance (checking air in tires);
- Inspection (checking tires for wear);
- Predictive maintenance (replacing worn tires); and
- Breakdown maintenance (changing a flat tire).

Factsheet 5: The Warning System

The Warning System of Safety includes the use of devices that warn of a dangerous, or potentially dangerous, situation. These devices require a person's intervention to control or mitigate the hazardous situation.

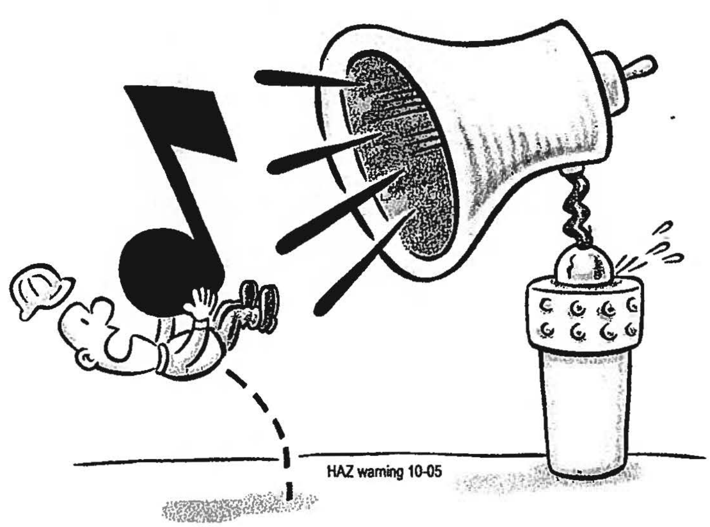
Examples of warning devices include:

In industry:

- Fire, spill and evacuation alarms;
- Control room alarms;
- Worker-in-trouble alarms;
- Fixed continuous monitors and alarms for hazards and toxic releases; and
- Back-up alarms on vehicles.

At home:

- Smoke alarms;
- High temperature or low oil light on an automobile; and
- Weather alerts and warnings.



Factsheet 6: The Training System

The operation and maintenance of processes that are dangerous require an effective training system. The greater the hazard, the greater the need for training. Examples of training include:

In industry:

- Hazard identification and response;
- Regulations which apply in your workplace;
- Emergency response; and
- Sources of information for your industry.

At home:

- Training to identify hazards at home;
- What to do in case of a fire; and
- What to do in case of a medical emergency.

Factsheet 7: The Procedures System

The operation and maintenance of processes that are dangerous require a system of written procedures. The greater the hazard, the greater the need for procedures.

Elements of an effective procedures system include:

In industry:

- Permit programs for hot work, lock and tag, confined space, etc.;
- Procedures for emergency response plans; and
- Operating procedures.

At home:

- Procedures for programming a VCR;
- Procedure for cardiopulmonary resuscitation (CPR); and
- Evacuation procedures and fire drills.

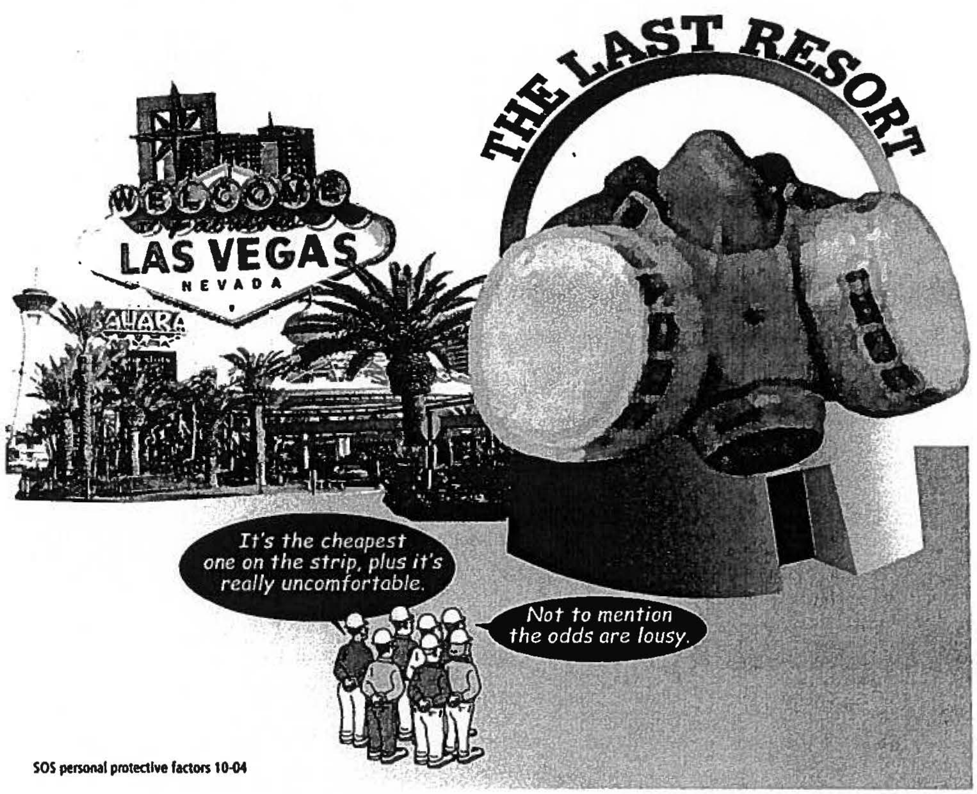
Factsheet 8: Personal Protective Equipment

The Occupational Safety and Health Act guarantees all workers in the United States the right to a workplace free of recognized safety and health hazards. Though we have strived for this goal, we must continue to strive to achieve it.

Past views of workers' role in health and safety:

- Hold that workers' primary contribution to health and safety is wearing Personal Protective Equipment and being continually monitored to make sure they are complying; and

- Places the primary emphasis on Personal Protective Equipment to compensate for hazards that industry has built into or failed to eliminate from the workplace.



Factsheet 8: Personal Protective Equipment *(continued)*

A few examples of Personal Protective Equipment which should be identified and used after efforts have been made to eliminate the hazards include:

In industry:

- Air-purifying respirators (APR);
- Air-supplied respirators;
- Self-contained breathing apparatus (SCBA);
- Chemical protective clothing; and
- Hard hats, hearing and eye protection and safety shoes.

At home:

- Dust masks;
- Gloves;
- Eye protection; and
- Hearing protection.

Factsheet 9: Work Organization and Workplace Health and Safety

Work organization is about the control of work and the division of labor. It includes:

- The tasks performed;
- Who performs them; and
- How they are performed.

Many workplaces are undergoing massive changes in the ways in which work is organized, often made possible by innovations in information and communications technologies.

New forms of work organization must be evaluated with attention to their potential to harm workers and workplace health and safety. Examples of work organization factors include:

- Combined jobs;
- Multi-tasking;
- Reduced staffing levels;
- Increased workload;
- Work intensification;
- Increased work pace and alternative work schedules;
- Electronic performance monitoring;
- Use of temporary workers and contract workers;
- Extended working hours, days or weeks; and

Factsheet 9: Work Organization and Workplace Health and Safety *(continued)*

A growing body of research and investigations in the United States and around the world has linked certain work organization factors with increased risk of job injury, illness, stress and death and with catastrophic workplace events such as explosions. For example, the U.S. Chemical Safety and Hazard Identification Board (CSB) 2007 report "Investigation Report: Refinery Explosion and Fire (15 Killed, 180 Injured), BP, Texas City, Texas, March 23, 2005" (Washington, DC: CSB), made a connection between hours of work/extended shifts and the risk of explosions or other acute, traumatic catastrophes.

Sources: Lessin, Nancy and Kojola, Bill, "Work Re-Organization: A Hazard to Workplace Health and Safety," AFL CIO Fact Sheet, January 2006; Landsbergis, P.A., Cahill, J., and Schnall, P., "The Impact of Lean Production and Related New Systems of Work Organization on Worker Health," Journal of Occupational Health Psychology, 4(2): 108-130, 1999; and U.S. Chemical Safety and Hazard Identification Board (CSB), "Investigation Report: Refinery Explosion and Fire (15 Killed, 180 Injured), BP, Texas City, Texas, March 23, 2005," Washington, DC: U.S. CSB, 2007.

Factsheet 10: Worker Involvement Creates Strong Systems of Safety

Many sites have Health and Safety Committees. These committees have workers who usually concentrate their activity on:

- Handling worker complaints;
- Promoting injury rate reduction goals; and
- Evaluating and recommending changes/enhancements to existing systems.

The best scenario takes place when workers are involved in creating or changing Systems of Safety.

OSHA recognizes in their Process Safety Management (PSM) Standard that:

- Active worker involvement in the development and use of process Systems of Safety is essential for the prevention of disasters; and
- Workers have a unique understanding of the hazards related to the processes that they operate and maintain.

A report published by the Environmental Protection Agency made the same point:

> ". . . operators have traditionally been more aware than manage-ment of the frequency, severity and nature of chemical incidents. Similarly, workers are often more aware of the ineffectiveness of Personal Protective Equipment and other mitigation devices. Were the company's technological decision-making to be informed by such worker insights, primary prevention would be significantly encouraged."

Source: Ashford, Nicholas, The Encouragement of Technological Change for Preventing Chemical Accidents, A report to the Environmental Protection Agency, Cambridge, MA: MIT, 1993.

Factsheet 11: Eliminate the Hazard with the Design System of Safety

You can design within any System of Safety, but a true Design fix is the one which eliminates the hazard.

For example: A worker is exposed through inhalation to a hazardous chemical which was being used in a cleaning process. The worker's respirator leaked. Suggested recommended fixes were:

1. Design and make a new respirator for the worker to wear. Is this an effort to eliminate the hazard? No! It is a fix in the Personal Protective Equipment System of Safety.

2. Design a new procedure which makes it less likely that the worker will be exposed. Is this an effort to eliminate the hazard? No! It is a fix in the Procedures System of Safety.

3. Design a training program which will address selection and wearing of respirators. Is this an effort to eliminate the hazard? No! It is a fix in the Training System of Safety.

4. Design a warning system to alert the worker when the concentration of the chemical reaches a certain point. Is this an effort to eliminate the hazard? No! It is a fix in the Warning Devices System of Safety.

5. Design a better maintenance and inspection program to maintain the ventilation system, reduce tripping and slipping hazards and make the job safer overall. Is this an effort to eliminate the hazard? No! It is a fix in the Maintenance and Inspection System of Safety.

6. Design a better ventilation system which will remove most of the dangerous fumes. Is this an effort to eliminate the hazard? No! It is a fix in the Mitigation System of Safety.

7. Design the cleaning process to use a cleaning agent that is not dangerous to workers. Is this an effort to eliminate the hazard? Yes! It is a fix in the Design System of Safety.

Task 1 *(continued)*

1. The facts, as determined by the investigation performed by the Chemical Safety Board (CSB), are listed in the chart below. Using your knowledge and the discussion of the factsheets, determine the failed System of Safety for each fact. Be ready to give reasons for your choices. You should circle the selected S.O.S. to indicate your group's answer.

Facts Determined by the Chemical Safety Board (CSB)	System of Safety that Failed
There were significant accumulations of sugar dust throughout the work area.	A. Procedures B. Maintenance and Inspection
The dust collection system was undersized and in disrepair.	A. Design B. Maintenance and Inspection
Compressed air was routinely used to remove the dust from the machines.	A. Training B. Procedures
Over time, large amounts of dust accumulated on overhead, hard-to-reach areas.	A. Procedures B. Maintenance and Inspection
Clumps of sugar would periodically get stuck in the chutes, blocking the flow of sugar and causing it to spill onto the floor.	A. Procedures B. Maintenance and Inspection
Enclosed conveyor system was not equipped with a dust collection system.	A. Design B. Maintenance and Inspection
Sugar came into contact with an ignition source (overheated bearing).	A. Warning B. Maintenance and Inspection
Emergency evacuation drills had not been conducted.	A. Training B. Procedures
There was no type of emergency lighting available.	A. Warning B. Design

Source: U.S. Chemical Safety Board, "Imperial Sugar Company Dust Explosion and Fire," February 7, 2008, available at: http://www.csb.gov/investigations/detail.aspx?SID=6.

Task 1 *(continued)*

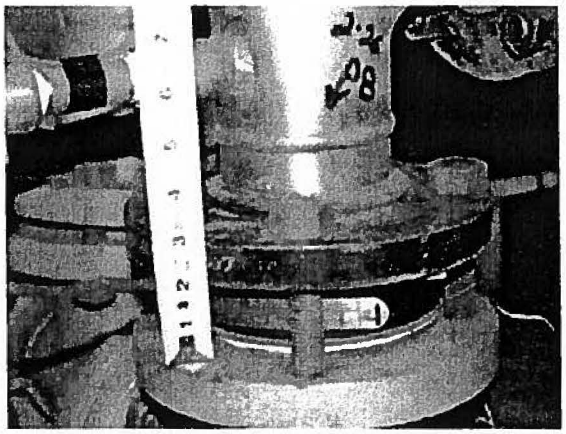
2. Using your knowledge and the discussion of the factsheets, let's review the recommended fixes as determined by the investigation team.

Analyze CSB's recommendations (listed in the first column of the chart below) to attempt to eliminate the hazards identified in the investigation. More than one System of Safety is listed for each action. Your group should choose the System of Safety (S.O.S.) in which each recommendation was made to attempt to eliminate the hazard. Be ready to give reasons for your choices. You should circle the selected S.O.S. to indicate your group's answer.

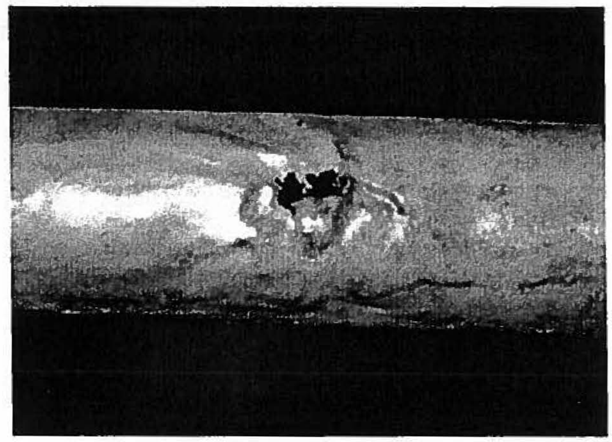
Chemical Safety Board's Recommendations	System of Safety Used in Recommendation
Implement a corporate-wide, comprehensive housekeeping program to control combustible dust accumulation that will ensure sugar dust, cornstarch dust or other combustible dust does not accumulate to hazardous quantities on overhead horizontal surfaces, packing equipment and floors.	A. Training B. Procedures C. Maintenance and Inspection
Require routine emergency evacuation drills and critiques.	A. Training B. Procedures C. Design
Develop training materials that address combustible dust hazards and train all employees and contractors at all Imperial Sugar Company facilities. Require periodic (e.g., annual) refresher training for all employees and contractors.	A. Training B. Procedures C. Maintenance and Inspection
Install an emergency alert (alarm) system in the facility.	A. Training B. Procedures C. Warning Systems

Source: U.S. Chemical Safety Board, "Imperial Sugar Company Dust Explosion and Fire," February 7, 2008, available at: http://www.csb.gov/investigations/detail.aspx?SID=6.

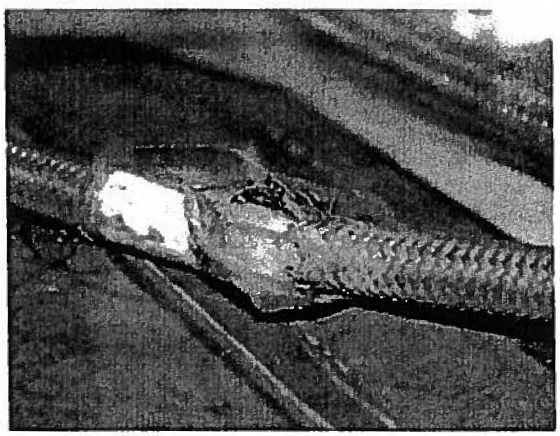
Task 2, Dupont Chemical Exposure Tragedy



Methyl Chloride Release



Oleum Release



Phosgene Release

Photos courtesy of the Chemical Safety Board, available at:
http://www.csb.gov/assets/document/CSB%20Final%20Report.pdf.

Task 2

Scenario:

Your facilitator will show a brief video on the Dupont chemical exposure tragedy that happened at the Dupont plant in Belle, West Virginia.

Note: The scenario has also been printed below.

Fatal Exposure: Tragedy at Dupont, Belle, West Virginia

The DuPont Belle plant is located in Belle, WV, about eight miles east of Charleston, the state capital. The plant occupies about 723 acres along the Kanawha River and sits in an industrial, commercial and residential use area. The plant produces a variety of chemicals.

On January 17, 2010, a production unit was started up after extensive maintenance. Methyl chloride produced in a reaction vessel flowed through an open rupture disk and escaped through an improperly located drain hole. The hazardous gas vented indoors in an area not frequented by workers. Five days later, on January 22nd, an air monitor alarm inside the building alerted personnel of the release. Approximately 2,000 pounds of methyl chloride had escaped. Johnnie Banks, a CSB investigator, stated that, "When the rupture disk burst, an alarm was triggered, but our investigation found that, due to a history of false alarms, operators came to view this alarm as a nuisance that could be ignored."

The following day, plant operators discovered another release. Oleum, a concentrated form of sulfuric acid, had (over time) corroded piping in the plant's spent acid recovery unit. Steam from an attached copper tube mixed with the oleum and created a large hole in the pipe. Oleum escaped through the hole and formed a vapor cloud; discovered by workers shortly after 7:00 a.m. on January 23rd. Approximately 22 pounds of oleum was released. Lucy Tyler, a CSB investigator, stated that, "The CSB found that Dupont had a previous oleum leak resulting in a company recommendation to conduct regular maintenance inspections of the oleum; but the CSB found this was not done due to ineffective communications between Dupont and its inspection contractors."

Task 2 *(continue)*

The third in the series of accidents at the Belle plant came just six hours after the oleum release and it would prove fatal. It involved phosgene, an industrial chemical so toxic it was used as a chemical weapon in World War I. Phosgene severely damages lung tissue. This can result in a deadly buildup of fluid in the lungs, which may not appear until hours after the exposure.

The Belle plant's small lots manufacturing unit purchased phosgene in one-ton cylinders from an outside chemical company. The plant used the phosgene to manufacture five different pesticide intermediates. The cylinders were stored in a one-story, partially walled structure, called a phosgene shed, which was open to atmosphere. During use, the cylinders were connected to other equipment by flexible, braided, stainless steel hoses. Inside each hose was a liner made of teflon or PTFE. One hose used nitrogen to pressurize the cylinder, pushing the liquid phosgene into the manufacturing process. An electronic scale recorded the weight of each cylinder and, when it was nearly empty, an alarm sounded in the control room. An operator then closed the valves to the empty cylinder and opened the valves to a second full cylinder. The stainless steel hoses to the empty container were purged of phosgene with nitrogen. The empty cylinder was then replaced with a new one on the weigh scale.

On the day prior to the fatal phosgene release, operators were experiencing flow problems with one of the hoses and began switching between cylinders to avoid disruption to the chemical process. In the course of switching cylinders, the valve was closed on a partially-filled cylinder. However, the hose was not purged, allowing pressure to build as the liquid phosgene inside warmed up.

Sometime between 1:45 and 2:00 p.m. on January 23rd, a worker was inspecting one of the cylinders when the pressurized hose suddenly burst. He was sprayed across his chest and face with a lethal dose of phosgene. Another worker was exposed to the deadly gas and a third was potentially exposed; but neither reported any symptoms. A total of two pounds of phosgene was released into the atmosphere. Small concentrations of the dangerous chemical were detected by monitors at the plant's fenceline. The worker who had been sprayed with phosgene called for help and was transported to a local hospital. Four hours later, the worker's condition began to deteriorate rapidly. Despite medical treatment, he died the day after the accident.

Task 2 *(continued)*

In your groups, using the information from the video/scenario, your knowledge and the factsheet discussion, make a list of facts that led to the fatality and the failed System of Safety for each fact. Use the chart below.

Facts that Led to Fatality	System of Safety that Failed
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	

Task 2 *(continued)*

Determine a fix for each of the system failures listed in chart on the previous page and decide which System of Safety each fix falls under.

Fixes	System of Safety
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	

After the class has completed Task 2, the facilitator will show the remainder of the video to reveal the Chemical Safety Board's (CSB) findings and recommendations.

Task 3, CSB Propane Tragedies

Your facilitator will show a brief video clip that reflects the dangers associated with propane cylinders.

Propane Tragedies Video Discussion

As a group, answer the following questions:

1. What Systems of Safety failures did you see in the video?

2. What emergency response actions should have been taken?

Source: Chemical Safety Board, "CSB Propane Tragedies," available at: http://www.csb.gov/videoroom/detail.aspx?vid=29&F=0&CID=1&pg=1&F_All=y.

Summary: Safety Systems Failures

1. Major Systems of Safety (in order of effectiveness):

    - Design;
    - Mitigation Devices;
    - Maintenance and Inspection;
    - Warning Devices;
    - Training;
    - Procedures; and
    - Personal Protective Equipment.

    Work Organization should also be accounted for when documenting failures and solutions.

2. Workers should first look to the Design System to address hazards.

3. Personal Protective Equipment should always be the last line of defense.