VENTED SUPPRESSIVE SHIELDING PROTECTS PERSONNEL AND FACILITIES FROM POTENTIALLY EXPLOSIVE EVENTS

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INTRODUCTION

If you have safety responsibilities in plants that handle and process reactive materials or hazardous chemicals you know there is a potential to injure or kill someone and cause devastating damage to facilities. As liability issues in accidents continue to be defined in the courts they are used to provide monetary compensation for accident victims. The high cost of accidents and how to prevent them are always on our minds.

In our business, it becomes important to design systems that minimize or mitigate the hazards of our operations. Where possible we must *"Eliminate identified hazards or reduce associated risks through design, including material selection or substitution."* (Mil Std 882C, para.4.3 a). If hazards can be eliminated by better design, then we don't have to rely upon safety systems that can fail, or rely upon procedures that are often not followed, to operate processes safely.

Vented Suppressive Shields are unique steel structures designed to mitigate and protect personnel and facilities from the hazards of blast overpressure, fragments and fireballs. This paper provides an overview of the VSS technology that was first used over twenty years ago. It will discuss some of the structures designed and used to protect personnel and equipment from explosive reactions. Global Environmental Solutions (GES) owns the rights to the licences and patents for the VSS technology. GES employs accepted explosive safety siting analysis techniques to assess the potential blast overpressure, flame, and fragment hazards in processes. GES draws upon accepted military criteria and other commercial requirements to design effective VSS structures to defeat these identified hazards.

Since the enactment of OSHA's Process Safety Management regulation (29 CFR 1910.119) in May of 1993, many commercial industries have been required to evaluate plant processes for potential hazards by performing Process Hazards Analyses. Some evaluations have identified potentially hazardous reactions which are potential liabilities to these industries. Nearby communities continue to grow and encroach upon our industries, that were once located at safe distances away from these communities. Safety management can see that this continuing encroachment also increases their company's liability. Reduction in liability can be made by costly relocation of facilities to remote areas. An expensive alternative is to harden facility structures to withstand and contain the potential hazards. Another less expensive alternative is to use the Vented Suppressive Shielding technology to mitigate the effects of an explosion related incident.

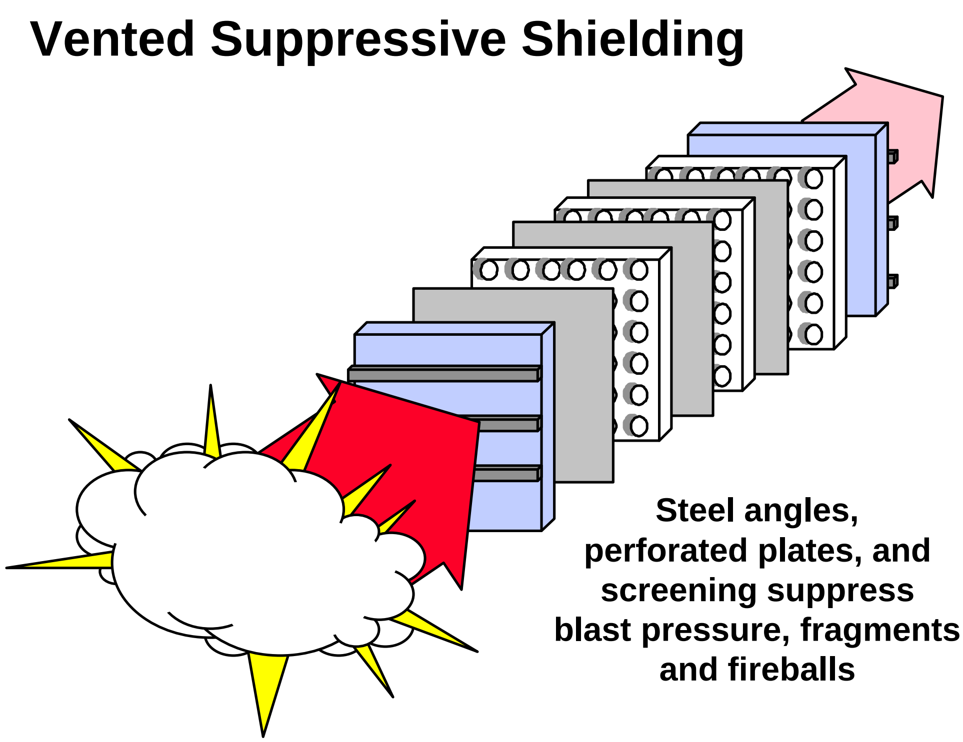
ORIGINS OF VENTED SUPPRESSIVE SHIELDING

Vented Suppressive Shielding (VSS) was first applied by the U. S. Army in the mid-1970s to protect personnel and equipment from the hazards of accidental explosions in ammunition plants. This technology was then enhanced through extensive engineering analysis, design and testing work by the U.S. Army and U.S. Navy.

Seven general classes or groups of VSS were eventually designed, fabricated, tested. These seven groups of shields have been approved by DoD Explosives Safety Board (DDESB) for detonating and deflagrating materials. Each of these groups were designed for specific military hazards and required a specifically designed structure. For example, the group 1, 2, and 3 shields are cylinders designed for high blast overpressure and severe to moderate fragment exposure of High Explosive operations. The Group 5 shield is a box configuration designed for low blast overpressure and light fragment exposure of igniter slurry mixing operations with less than two pounds of materials. The VSS technology is now being applied in commercial applications as well as military needs.

VSS STRUCTURE SCHEMATICS

To better understand how the VSS structures work, lets look at a typical wall schematic. The wall consists of a series of layers of steel plate. The first panel is the principle fragment barrier providing an oblique striking surface. Succeeding layers of the shield provide additional fragment barriers. Fireball aerosol impingment layers are provided by metal plates and screens. Blast attenuation is controlled by perforated plates. The number of layers is dictated by the charge size and the requirements for blast overpressure reduction. The VSS wall provides a relatively light weight containment barrier for primary and secondary fragments, reduces blast overpressure to tolerable levels, and provides for significant attenuation of flame and fireball. See the schematic below.



VSS STRUCTURES IN USE

Some of the Vented Suppressive Shield structures designed and built for use in hazardous operations are mentioned below.

Warhead Shield - Model P 8934.0 was designed to contain 75 lbs TNT Equivalent material in a warhead finishing operation for the Navy. It is a cylinder set on end and is 17 feet high and 16 feet wide as the outside diameter. It weighs 90,000 pounds.

Qatar Shield - Model P 8605.0 was designed to dispose of explosives found in luggage and packages at airports. It is a cylinder set on its side and is 7 1/4 feet long and about 5 ½ feet wide as the outside diameter. It weighs 9,600 pounds.

Bomb Squad Shield - Model P 8801.0 was designed for Maryland Fire Marshall's Office to detonate pipe bombs and small packages of explosives. It is a cylinder set on its side and is 4 feet long and about 3 ½ feet wide as the outside diameter. It weighs 2,500 pounds.

Labyrinth Wall Shield - The structure was designed to protect operators from potential fire and fragments hazards in an igniter closure disk induction soldering operation. It was constructed in about 4 foot wide by 8 foot high panels.

Mobile Cart Shield - Model F 8603.0 was designed for temporary safely storage of $BKNO_3$ pellets being loaded into igniters. It was constructed as a mobile cabinet on wheels with 4 large drawers on either side of the unit. The cart could be moved around by one person.

Insulation Resistance Test Box - Model F 8601.0 was designed to protect test personnel from ignitions during wire harness electrical tests. It was constructed of special designed perforated plates in the VSS wall configuration and the inside was about one foot cubed in size. .

Other units have been designed to:

Attenuate the blast overpressure in ducts ahead of pollution control equipment.
Attenuate the noise generated in test chambers.
Protect personnel from blast effects of propellant loading operations in nearby bays.
Protect EOD personnel from fragment hazards of exploding ordnance.

HOW VSS STRUCTURES MITIGATE HAZARDS

VSS can be designed to mitigate identified hazards by attenuating the blast overpressure, containing the fragments within the structure, and absorbing the thermal heat by the structural members.

Overpressures generated by detonations and deflagrations can be reduced as they flow through the vented structure. The VSS is designed to partially vent the blast overpressure wave through the structure somewhat like a the car muffler reduces the exhaust system's noise. Examples from some tests are:

The detonation of 20 lbs of TNT (a proof test) in a Qatar Shield generated 4400 psi overpressure at the inside wall of the structure but reduced the overpressure to 1.3 psi at a distance of 6 ½ feet from the structure's outside wall.

The detonation of 94 lbs of TNT in the Warhead Finishing Shield was estimated to generate 3800 psi overpressure at the inside wall of the structure, but would reduce it to 2.3 psi at a distance of 6 ½ feet from the structure's outside wall.

Fragments thrown from an accidental blast can be contained by properly designed VSS. A structure that uses a fragment barrier of interlocking "I" beams, or nested angle irons, etc prevents the passage of fragments through the vented wall.

The Group Three Shields were designed to have the fragment stopping equivalent of 1 inch of steel plate.

The Group Four Shields were designed to have the fragment stopping equivalent of 1.4 inches of steel plate.

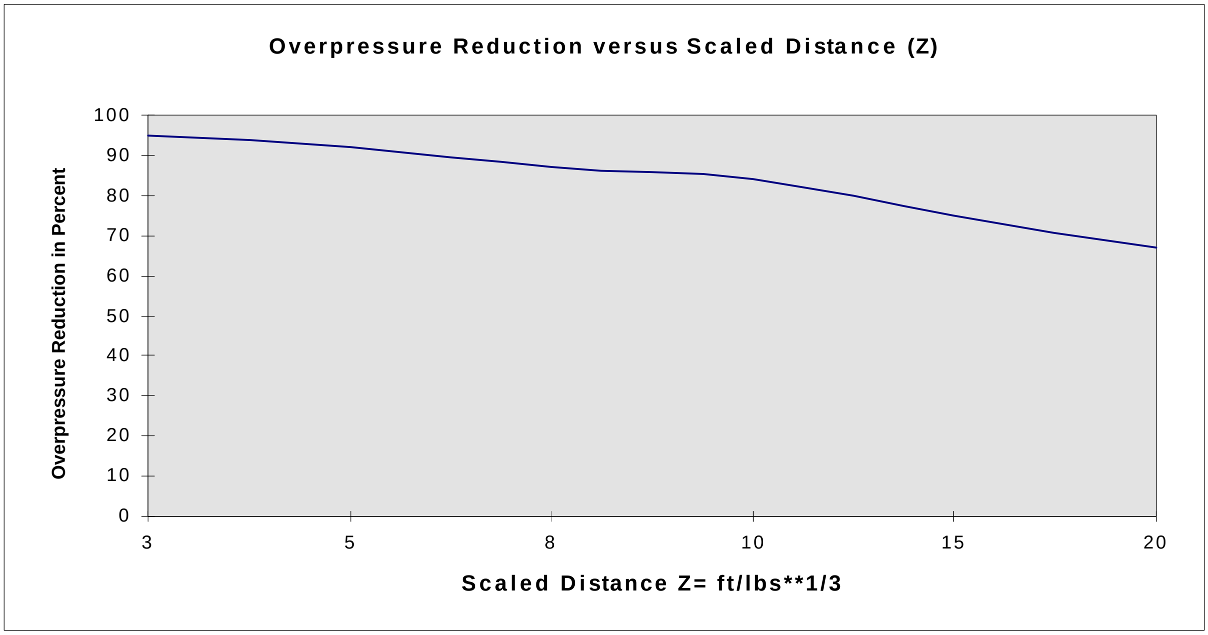
The radiant heat effects of a fireball on personnel and facilities can also be reduced by properly designed VSS. The steel structure consisting of a fragment barrier and other members such as perforated plates and wire screen to absorb the heat flowing through the vented structure.

The VSS Mobile Cart, designed to reduced the radiant heat exposure from the initiation of 5 lbs of $BKNO_3$ pellets to personnel tolerable thermal levels at a distance of 30 inches from the cart sidewall. The personnel acceptable or tolerated radiant heat thermal flux recommended in the military is 0.3 Calories/ cm^2 sec. For comparison, the open air initiation of 5 lbs of $BKNO_3$ pellets generated a 40 foot fireball.

Two 4.2 inch White Phosphorus mortar projectiles when initiated in open air created a 150 foot diameter fireball. The initial VSS test cubicle built , which was 4 foot long on each side, contained the fireball from two 4.2 inch White Phosphorus mortar projectiles and the tests showed no evidence of a fireball in the test.

The graphs on the following page give an idea of the blast overpressure reduction recorded in tests at Aberdeen Proving Grounds for two different VSS wall configurations. Graph 1 is for a 4 perforated plate VSS wall with an effective vent area ratio of 3 %. Graph 2 is for interlocking "I" beams with an effective vent area ratio of 2.4 %.

Graph 1 for perforated metal plates



Graph 2 for interlocking "I" beams

The above graphs show how effective the Vented Suppressive Shielding (VSS) structures are at reducing the blast overpressure from explosions. The percent reduction in the shock wave (on the y axis) at various scaled distances (on the x axis) decreases slowly with Scaled Distance. The Scaled Distance is a siting term used to evaluate the value for the distance from an explosion in feet divided by the cube root of the Net Explosive Weight of a charge as pounds of TNT.

Note that the x axis numbers are not linear, which is a function of the spreadsheet program used to do the graph work. The interlocking "I" beam configuration in Graph 2, is a much heavier and better fragment catching member than the perforated plate configuration.

TYPICAL DESIGN STEPS FOR A VSS STRUCTURE

An overview of the typical steps used to identify the process hazards and design specific Vented Suppressive Shielding structures to defeat the hazards are:

1. Identify those significant hazardous operations at the plant that could be made safer for personnel and facilities by using Vented Suppressive Shielding. The Process Hazards Analysis required by the Process Safety Management regulation in OSHA's CFR 1910.119 discusses some methods used to identify those candidate operations for you.

2. Determine if there is space available around the operation or equipment to place a VSS structure. Would a VSS structure restrict required access to the operation or equipment for production or maintenance work? Is one of the other groups of VSS structures applicable?

3. Calculate the potentially explosive charge weights and other parameters involved in the hazardous operation (such as the reactive material stored in tanks or bins). A knowledge of the facility siting limits or the explosive quantity distance (QD) requirements of the plant can be useful for the calculations and evaluations. Evaluate the required protection needed for personnel at the plant and for identified facilities and equipment that must be protected from the potential damage caused by an incident. If the evaluation is for a commercial facility and the acceptable limits for personnel and facilities protection are not known, U.S. military safety documents can be a useful reference source and guideline.

4. Evaluate if fragments would be generated from a worst case incident in the hazardous operation. These fragments could come from an exploding tank or casing or could be a piece of equipment that is broken loose by the high blast overpressures or thrown fragments in an incident. Evaluate by calculations the worst case fragment size and velocity for eventual comparison to the VSS structure fragment barrier capability.

5. Evaluate if there is a fireball hazard associated with a worst case incident in the hazardous operation. Estimate the potential fireball size and effect on personnel and facilities. Evaluate the type of fireball generated (it could be from a detonation, a deflagration, or from a vapor cloud explosion of flammable chemical).

6. After the specific worst case hazards of the operation are identified, the best choice of VSS structure can be identified depending on its requirements for blast overpressure reduction, fragments containment, and radiant heat reduction needs. Determine which hazards the VSS structure must defeat and level of protection the VSS must provide. This will identify the specific requirements for the VSS installation. Engineering comparisons for the VSS option and other possible control methods can be evaluated for the more cost effective means of mitigating the hazards of concern.

SUMMARY

There is an increased need for protection of personnel and facilities at hazardous operations. The origin of the VSS technology is from military studies in the 1970s. A basic overview of the VSS structure shows the protection it can provide for blast overpressure, fragment, and fireball hazards. Nunerous VSS structures have been designed, built, and tested to prove they defeat the three main blast hazards types identified. Examples of the blast overpressure reduction for two different VSS configurations are effective at mitigating the effects of explosive incidents. Typical steps are used by the GES Hazards Analysts and Siting Specialists to identify the hazards, and prepare information required for the specific design of each VSS structure.