The Role of Expanded Metal Network in Preventing BLEVE's*

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I. Background

A BLEVE (Boiling Liquid Expanding Vapor Explosion) is a catastrophic rupture of a high pressure vessel containing a large quantity of pressurized flammable or non-flammable liquid under its own vapor pressure. Using expanded metal as a filler material for gas and liquid volumes has been experimentally demonstrated to substantially mitigate and in many cases prevent the occurrence of such explosions.

Three large scale experiments that have been performed provide a perspective on the role of expanded metal (generally aluminum) network. The first is the Transport Canada tests (254 gal vessel) (Appleyard, 1980), the second the US Department of Transportation (DOT) tests (33,000 gal vessel) (Anderson et al., 1974 and Townsend et al., 1974) and the third is the UK Health And Safety Executive experiments (2700 gal vessel) (Moodie et al., 1988). Expanded metal network was used in several of the Transport Canada experiments while the second test series examined insulated and uninsulated full scale railroad tank cars without metal network. The UK tests also did not use the network and were always terminated before a catastrophic rupture occurred. One major conclusion derived from the Canadian experiments is that BLEVEs occurred in both tests performed without the expanded aluminum network and no BLEVEs were observed with the network installed.

Figure 1 shows the measured vessel pressure histories in two tests (ENIGMA and HOWLER). The ENIGMA test vessel experienced a BLEVE with a peak wall temperature well below those values where creep rupture would be expected in the timeframe of the test, i.e. several minutes. ENIGMA and a similar test in which all the instrumentation was lost are the only tests performed without the expanded metal network and the only two which experienced BLEVEs. Conversely, the HOWLER test (with the Al network) measured an internal pressure history similar to the ENIGMA test and much higher wall temperatures but did not experience a rupture.

Furthermore, measurements of the transient liquid levels show that all tests

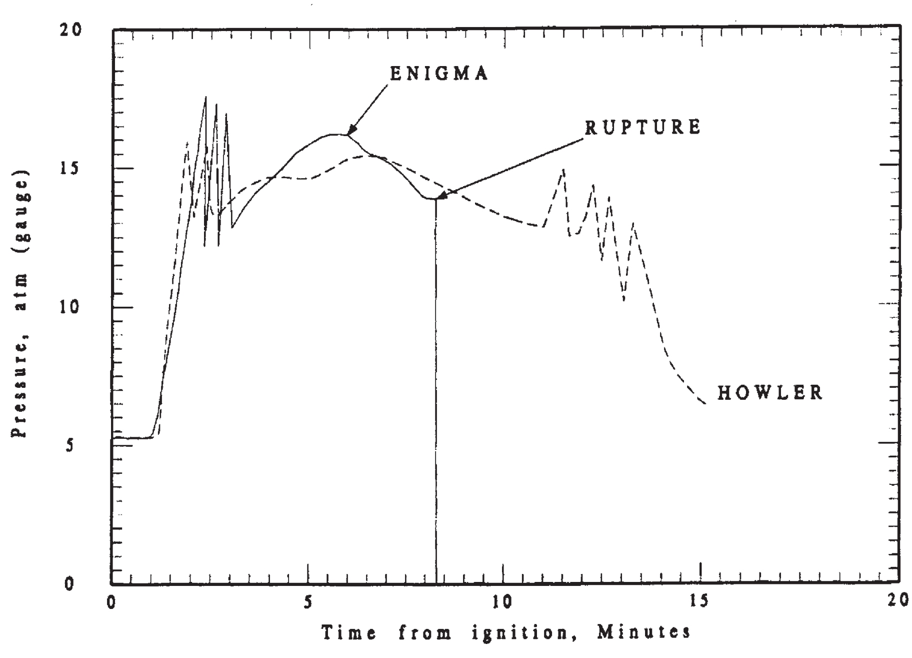

Figure 1 Vessel pressure histories for the ENIGMA and DIABLO tests (taken from Appleyard, 1980).

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had a similar liquid inventory depletion rate. The ENIGMA vessel was about half-full when the BLEVE occurred as was the uninsulated railroad tank car which experienced a BLEVE in the US DOT tests.

Figure 2 illustrates three ways in which the network can prevent a BLEVE.

1. Increased number of nucleation sites stabilizes the boiling process.

2. Prevents impingement on the vessel wall (waterhammer) due to liquid swell.

3. Prevents cold liquid from directly contacting the overheated and stressed wall.

With a rapid level swell and a horizontally oriented cylindrical cross-section, the impact would be focused near top-dead-center (TDC); the failure location in the Canadian tests. This concept was tested in the FAI waterhammer test facility for thermodynamic conditions which repeatedly resulted in strong waterhammer events. The expanded network eliminates these strong waterhammer events.

Direct liquid contact on an overheated vessel wall induces localized thermal stresses. These could approach 100,000 psi and are additive to the primary stresses from the internal pressure. This exceeds the yield and ultimate stresses for most steels. With the metal network there are numerous surfaces to "catch" the liquid before it contacts the wall thereby preventing or substantially limiting the contact and the consequential thermal stresses.

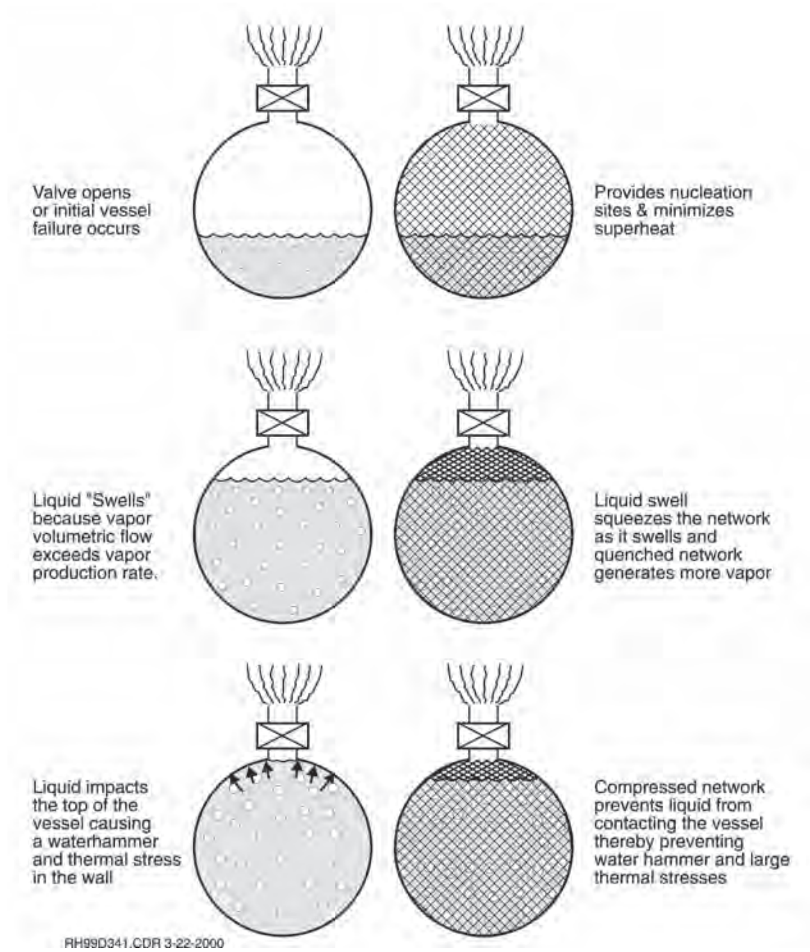

Figure 2 Illustration of what the network does to prevent a BLEVE.

II. Possible Causes for BLEVEs and the Role of Expanded Metal

A) Pool Fires

The Transport Canada tests demonstrate that BLEVEs can be initiated in a vessel without the vessel failing due to material creep. In these cases, the likely candidates for an accelerated failure condition are: (1) local cooling and overstressing of a sensitized vessel wall due to thermal stresses, and (2) localized impingement resulting from a rapid level swell that is combined with the initial failure or possibly the opening of an oversized relief valve. In both cases, the expanded aluminum network mitigates or prevents such conditions from occurring. Hence, it plays a significant role in mitigating those conditions where a BLEVE could be initiated.

B) Torch Fires

The influence of the dynamic processes following initial failure of the vessel wall are specifically related to those conditions characterized as "torch fires". Such localized failure and the potential for a subsequent dynamic response of the liquid were experimentally investigated by Birk and Cunningham (1994) using both strong tanks (wall thickness of 6.4 mm) and thin walled tanks (wall thickness of 3 mm). If the imposed thermal stress are sufficient to crack the inner surface (and in this case they were), the crack follows the developing thermal wave through the wall thereby rapidly reducing the effective wall thickness. Considering that this failure occurs over approximately 1 second, with rapid cooling, the thermal wave and therefore the cracks would form and propagate to a depth of 3 mm after approximately 1 second, such that a 6 mm tank wall is effectively only 3 mm thick.

As with pool fires, with this sensitivity to local cooling as well as the dynamic effects resulting in a waterhammer like event, the expanded metal network provides for substantial mitigation of both the local cooling and any dynamic effects due to liquid swell.

References

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