Comparison of the fire hazards presented by plastic and timber pallets

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EXECUTIVE SUMMARY

OBJECTIVES

To determine if using plastic rather than timber pallets increases fire risk. This is particularly significant in premises storing large amounts of incombustible but potentially dispersible toxic materials e.g. heavy metal compounds.

MAIN FINDINGS

Comparative tests using empty steel drums on single pallets stacked two high, or arrays of four pallets stacked three layers high have demonstrated a greatly increased combustibility of high density polyethylene (HDPE) pallets compared to standard timber pallets. Salient features are listed below.

- The plastic pallets were easily ignited e.g. by a match
- Timber pallets required a far more energetic ignition source e.g. 1 litre of solvent
- The time taken for fire to spread upwards to the pallet above the ignited pallet was around 18 minutes for plastic pallets and nearly 50 minutes for timber pallets.
- Flames with timber pallets were almost entirely confined to the height of the stack and were seldom greater than 1 m high. Those from the plastic alternative far exceeded the stack height and reached a maximum height of 6-7 m.
- A serious fire could develop in a stock of incombustible but potentially dispersible toxic materials stored on plastic pallets. The rates of burning associated convective upflows are sufficient to drive significant plume seeding.
- Violent spalling of underlying concrete was observed in larger stack tests on plastic pallets. This is likely to increase the efficiency of dispersal of powdered materials stored in containers that are likely to split when falling from racks.
- Large fires involving plastics produce copious quantities of black smoke, such smoke is likely to be more toxic than smoke from a fire involving wood, and would render escape and fire fighting very difficult.

RECOMMENDATIONS

These tests, using one type of plastic pallet, have demonstrated that there is a considerable increase in fire hazard compared to timber pallets. In view of the wide range of types of plastic pallet, lightweight, steel reinforced, molded to retain liquid spills etc., it is recommended that further work is undertaken to determine how widespread the problem is.

The use of large numbers of plastic pallets in stores containing incombustible but potentially dispersible toxic materials e.g. heavy metal compounds should be controlled and if possible eliminated.

If it is established that fire severity is generally greater for plastic pallets than with comparable timber pallets, steps should be taken to ensure that both HSE and industry is made aware, either through articles in trade journals, conferences, presentations to industry groups or HSE guidance notes.
1 INTRODUCTION

1.1 BACKGROUND

Plastic pallets (usually polyethylene or polypropylene) are in use at a range of chemical storage sites and their use is likely to increase in the future. Plastic pallets have a number of advantages over the wood:

i. Plastic pallets do not absorb spillages and can be effectively cleaned.
ii. Moulded plastic pallets can be made with integral spillage/leak containment.
iii. Plastic pallets can be made to nest when idle.
iv. Pallets can be made from relatively low cost recycled plastics.

A warehouse fire in Japan in 1995 illustrated the potential fire hazards form plastic pallets. The goods stored were non-combustible but fire spread on stacks of idle plastic pallets. Three firemen were killed in the fire.

Research in the US on the fire performance of plastic pallets has focussed on the level of additional sprinkler protection needed when wood pallets are replaced with plastic - for standard cardboard-cartoned test commodities. Little information is available on the consequences of uncontrolled fires in pallets in use or stacks of idle pallets.

The fire performance of plastic pallets is particularly important in warehouses storing toxic materials where there is little other fuel available. Plastic pallets are generally much easier to ignite than timber alternatives; many can be ignited by a match.

The purpose of this report is to present the findings of a brief comparative study to determine the relative hazards presented by plastic vs timber pallets when present either as simple stacks, or in an in-use form of pallets of stacked steel chemical drums.
2 EXPERIMENTAL DESCRIPTION

2.1 PALLETs USED

Two pallet types were used, either heavy weight timber pallets intended for drum storage/shipment, weighing between 22-27.5 kg, or medium load, closed top pallets manufactured from recycled polyethylene.

The polyethylene pallets, each weighing 28 kg, are shown in Figure 1 and a timber pallet in Figure 2.

Figure 1 Closed-deck plastic pallet, molded plastic reinforcement visible on underside

Figure 2 Typical timber drum pallet used for comparative tests

Two test configurations were investigated as illustrated in Figure 3.
Figure 3  Appearance of 2 pallet 8 drum stack and 12 pallet 48 drum stacks used for fire tests

They comprised either a single pallet carrying 4 drums, stacked two high, giving 8 drums in total: or an array of four pallets carrying 16 drums, stacked three high, carrying a total of 48 drums.

Two ignition sources were used: standard No. 7 wood cribs or a steel baking tray measuring 303 360 mm containing approximately 1 l of heptane. The latter was used for the 48 drum timber pallet test.

In all tests the ignition source was placed at the base of the stack adjacent to one of the supporting ribs, as shown below (Figure 4).

Figure 4  Number 7 wood crib in-situ as ignition source
3 TEST RESULTS

3.1 SINGLE PALLET CARRYING 4 DRUMS STACKED TWO HIGH

3.1.1 Plastic pallets

The ignition source used in this test was a No. 7 wood crib which was located as shown in Figure 4.

The test was performed in somewhat marginal wind conditions and much of the flame during the early stages of the test was carried beneath the stack and away into the open air. It did, however, mean that flames which were carried beneath the stack would have preheated many of the thin plastic webs molded into the underside of the deck. Molten plastic could be seen to drip from many of these and this would have undoubtedly have helped fire development.

A sequence of captured video stills at 5 minute intervals through the test are included overleaf, (Figure 5).
Figure 5 Sequence of stills at 5 minute intervals showing development of fire in an 8 drum, 2 pallet test – 56 kg HDPE
3.1.2 Timber pallets

Again a No. 7 wood crib was used as the ignition source. This burnt for some 6-7 minutes after which all flaming combustion of the pallet in the vicinity of the crib ceased. Smouldering continued for a few minutes, but this did not develop any further and soon ceased.

The extent of charring of timbers is illustrated in Figure 6 below.

![Figure 6](image-url)

**Figure 6** Extent of charring of timber pallet by a No 7 wood crib
3.2 FOUR PALLET ARRAY STACKED THREE HIGH

3.2.1 Plastic pallets

Initial fire growth in this test was slow as the crib used as the ignition source failed to ignite effectively over its entire surface. Instead it appeared to burn from the top. Gradually fire spread over the crib, fuelled in part, by drops of burning plastic which had fallen from the pallet above.

Fire growth over the initial 20 minutes of the fire is shown in Figure 7.

![Sequence of stills showing first 20 minutes of fire growth in the 48 drum, 12 pallet fire test](image)

**Figure 7**  Sequence of stills showing first 20 minutes of fire growth in the 48 drum, 12 pallet fire test

After 22 ½ minutes the fire reached the next pallet above.

Further fire development and behaviour for both the front and rear cameras is illustrated in Figure 8.
**Figure 8** Fire behaviour for period 25 – 50 minutes after ignition, 48 drum 12 pallet stack – 336 kg HDPE
3.2.2 Timber pallets

A highly energetic ignition source was used in this test as it was known that timber pallets would resist the effects of a No. 7 crib. In place of this a steel tray measuring 303 x 360 mm containing 1 l of heptane was used. This was ignited, time allowed for combustion to become fully established and then slid under the pallet as shown below.

![Fully developed fire in tray](image1)

![Appearance of flames when inserted beneath pallets](image2)

**Figure 9** Tray of burning heptane used as ignition source for 48 drum, 12 timber pallets test

After the tray had been inserted beneath the stack flames were lower and only occasionally reached the next pallet above. After 2 ¼ minutes burning in the tray cased leaving small flames and smouldering of timbers directly above the tray. This smouldering/flaming continued, with flames gradually increasing in size in ‘chimneys’ between drums inside the stack. 50 minutes into the test these flames finally reached the next pallet above. The initial growth of the fire is illustrated in Figure 10, with Figure 11 showing the fully established fire.

![Fire development over period 5 - 55 minutes with timber pallets](image3)
**Figure 11** Progress of fire at 10 minute intervals between 55 – 85 minutes after ignition for 48 drum, 12 timber pallet test
3.3 STACK OF 8 PLASTIC PALLETS

This test served a dual purpose:

a) to establish the rate of fire spread and combustion in stacked pallets; and,

b) to establish the extent of spread of the pool of burning plastic that would form during the fire.

Fire behaviour is illustrated in Figure 12.

Figure 12 Sequence of stills at 5 minute intervals showing fire development for a stack of 8 plastic pallets – 224 kg HDPE
After the fire it was established that the ‘slick’ of molten plastic had spread over an area approximately 6.5 m in diameter, showing great potential for fire spread beyond the footprint of the stack. Figure 13

Figure 13  Extent of spread of molten plastic from a stack of 8 plastic pallets. Flames still visible some 2 hours after ignition

As a result of the considerable amount of heat liberated during this test and the efficient thermal contact between the molten plastic and the concrete floor much spalling of concrete took place. In many cases when spalling occurred flames which had been burning steadily at around 1 m high grew to a height of 3 - 5 m as a result of lift-off of fire balls of burning molten plastic thrown into the air. Such events, as well as the splatter of molten plastic, could render fire fighting more dangerous and aid fire spread, Figure 14.

Figure 14 Fireball resulting from spalling concrete
4 DISCUSSION

The results obtained show clear differences in both ease of ignition and fire severity when comparing combustion of timber or plastic pallets. Significant stages of fire development are presented in Table 1.

Table 1 Comparison of fire behaviour over tests performed

<table>
<thead>
<tr>
<th>Test</th>
<th>Time to become established</th>
<th>Time from establishment to reach next pallet above</th>
<th>Time from establishment to full stack engulfment</th>
<th>Time from establishment to first drum falling</th>
<th>Time from establishment to fire dying out</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minutes/seconds</td>
<td>Minutes/seconds</td>
<td>Minutes/seconds</td>
<td>Minutes/seconds</td>
<td>Minutes/seconds</td>
</tr>
<tr>
<td>8 drums</td>
<td>2</td>
<td>6</td>
<td>14.30</td>
<td>12</td>
<td>≥ 28</td>
</tr>
<tr>
<td>2 plastic pallets</td>
<td>Failed to ignited</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 drums</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 timber pallets</td>
<td>4.40</td>
<td>≥ 18</td>
<td>≥ 30</td>
<td>22.10</td>
<td>≥ 55</td>
</tr>
<tr>
<td>48 drums</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 plastic pallets</td>
<td>2.15</td>
<td>≥ 50</td>
<td>≥ 80</td>
<td>65</td>
<td>≥ 105</td>
</tr>
<tr>
<td>48 drums</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 timber pallets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data in Table 1 is corrected to allow for variation in the time taken for the ignition source to become established. Thus in the 2 plastic pallet, 8 drum test it took 2 minutes for full involvement of the igniting wood crib and pallet above, where as for the 12 plastic pallet, 48 drum test this took 4 mins 40 s as the crib failed to ignite properly over it’s whole surface.

From the above data it is apparent that fires in plastic pallets take hold more readily, spread over the stack far more rapidly than with timber pallets intended for similar duty, and are shorter lived, indicating far greater heat release rates.

As well as the above factors, photographic records show flames are far smaller with timber pallets: around 1 m, or seldom above the overall stack height for timber pallets; compared to a maximum of 6-7 m high for the largest plastic pallet fire.

Large plastic fires produce a large quantity of dense black smoke. Such smoke would render both escape and fire-fighting extremely difficult compared to fires involving similar numbers of timber pallets.
5 CONCLUSIONS AND RECOMMENDATIONS

- The plastic pallets were easily ignited e.g. by a match
- Timber pallets required a far more energetic ignition source e.g. 1 litre of solvent
- The time taken for fire to spread upwards to the pallet above the ignited pallet was around 18 minutes for plastic pallets and nearly 50 minutes for timber pallets.
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