Incident

The Boston, Massachusetts, incident of January 15th 1919

Dr V C Marshall

Introduction

This incident, in which 21[1] people were killed and 40 injured, and in which there was serious property damage, was, by any criterion, a serious industrial disaster. Yet the substance responsible for it is not listed as a dangerous substance under the CIMAH (Control of Industrial Major Accident Hazards) Regulations, or indeed under any other similar regulations. The substances was molasses, better known in the UK as treacle.

The effects of the disaster

A storage tank on the dock side containing about 12,500 tonnes of molasses burst and disintegrated into seven pieces. The resulting flood engulfed people, swept away timber houses, one of which became jammed under the elevated railway, and carried away motor trucks. It drowned or seriously injured dozens of horses. A piece of the tank struck a support of the elevated railway and caused serious damage to the track. Another piece weighing 2.5 tonnes, and with an area of 40 sq. metres, was carried 55m into a playground by the flood. A fire station 50m away suffered severe structural damage. A fireman was found dead in it with a billiard table and a piano on top of him (see Figure 1).

A reporter who came to the scene shortly afterwards recounts that he saw what looked like a wave of lava running down the street towards him and engulfing people. He tells of the frightful mess which was caused and how, when the worst of the flow was over, the rescuers became coated in the sticky fluid which spread over the city and beyond. Every phone booth in Boston was sticky and up to 70km away passengers in public transport stuck to their seats. Nurses who went into treat the injured emerged with their persons and uniforms in an indescribable state. Some bodies were not recovered until a week afterwards. Fire hoses using the public water supply proved ineffective in swilling the molasses away but the use of sea water by the fire service seemed to 'cut' it. There were serious difficulties in pumping it out of cellars.

The properties of molasses

Molasses is the mother liquor which remains after sugar has been refined. Cane sugar molasses contains about 80% total solids such as sucrose and other sugars as well as proteins and mineral substances, the rest being water. It has a density of about 1,4000 kg/m^3. The fluid is Newtonian and has a viscosity in the low hundreds of N sec/m^2. Molasses is usually slightly acidic with a pH of 6.5 to 5.5.

Description of the tank

The tank had dimensions 27.43 m diameter by 15.24m high. Its volume was thus 9,000 m^3. At the time of the disaster it was nearly full and thus contained ca. 12,5000 tonnes molasses. It was made of structural steel and was of riveted construction (see Figure 2) with plates in strakes of ca. 2m high. The thickness of these plates varied from 16mm at the bottom to 7mm at the top. The bottom was flat and rested on a foundation consisting of a cement/sand mixture laid dry. It was provided with a 0.5m manhole near the bottom. The roof was conical on light steel trusses. The tank had been ordered from an outside contractor and the tender documents specified a safety factor of 3.0. When completed the tank was tested by running 150mm of water into it.

The tank after its collapse

The tank had been known to leak at its seams which had sometimes had to be caulked. After the collapse into seven pieces it was noted that the bottom had bulged near its centre and that there was a depression in the sand/cement mixture under the bulge. This mixture had only partially set and a substantial portion had been washed away by the flood. The principal tear ran from a point in the bottom about 3.5m from the side and ran up through the manhole cover and eventually through the line of vertical riveting. The steel was tested and found to have an ultimate tensile stress of 55,000 to 56,000 lb/inch^2 (ca. 3.85 * 10^8 Pa). Stresses of up to 38,000 lb/inch^2 (2.66 * 10^8 Pa) were calculated by experts to have existed in the tank which thus had a safety factory of 1.5 at its weakest point. This compares with the safety factor of 3.0 in the specification provided for the contractor. At every level the plates were thinner than in the drawings which had to be submitted to the authorities in order to obtain a building permit. They were thinner, on the average, by 5.0%.

Expert testimony

The experts brought forward by the plaintiffs argued in evidence that the tank was underdesigned and thus overstressed, citing the low safety factors employed and demonstrating that the rivets at the bottom were stressed to twice what good practice permitted. It was also alleged that some of the rivets had been driven in cold.

The experts called by the defence argued that, though they themselves would have designed such a tank with higher safety factors than those provided in the Boston tank, there was not reason to suppose that a tank with a safety factor of 1.5 at its

[1] *There is some conflict of evidence regarding the number of deaths. Engineering News Record sometimes reports the number as 12 and sometimes as 21. All other sources consulted by the author, including J.R. Nash's 'Darkest Hours', give it as 21.*

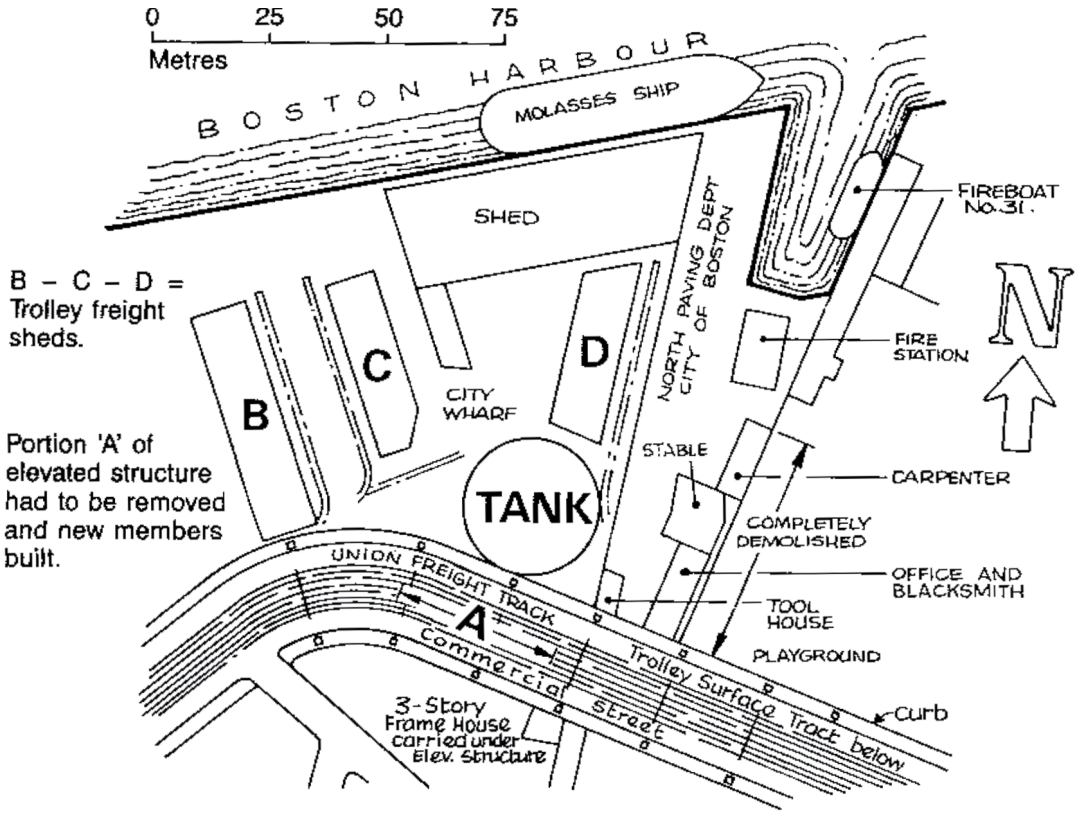

Figure 1: Layout of devastated region near molasses tank

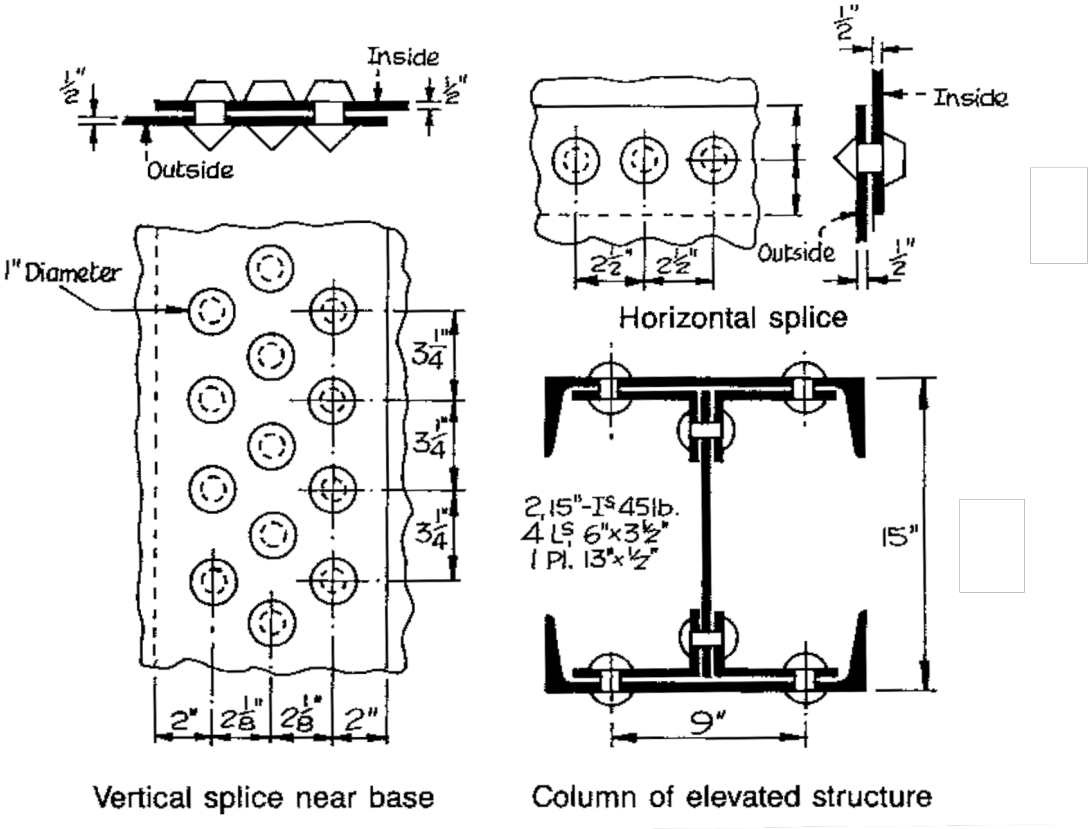

Figure 2: Riveted joints of tank and section of elevated columns

weakest point should fail. They pointed to tanks in other factories with safety factors no higher than the Boston tank which had not burst.

To explain why this allegedly perfectly sound tank had collapsed, they brought forward the argument that an anarchist had planted a bomb in it. (It may be remarked that around that time there had been a number of incidents in America involving bombs and anarchists.)

To demonstrate the truth of their theory they exploded sticks of dynamite in small scale tanks full of molasses and claimed that in one instance they had been able to simulate the failure of the Boston tank. One expert pointed to the bulge on the bottom and a bulge in the side where the tank had failed, as evidence for an explosion. Another expert calculated that the velocity of the molasses, which would have been required to propel the 2.5 tonne section through 55m was 16 m/sec. This compared with his calculation that, on purely hydraulic grounds, the velocity of the molasses could not have exceeded 12 m/sec.

The legal judgement

The trial lasts for 300 days and called 3000 witnesses. Their evidence ran to 6,000,000 words and filled 35,000 pages. Six years after the disaster happened, the auditor decided the case in favour of 119 of the plaintiffs. He totally rejected the explosion theory claiming that there was not a shred of evidence to support it. Of the experts who claimed the tank was perfectly safe and who admitted that they themselves, if called upon to design such a tank, would have applied higher safety factors, he said, "I cannot help feeling that in their position the defendents' experts do not have the courage of their convictions as stated....". Damages to some $300,000 were awarded by the court. Later even larger sums were awarded to Boston Council and to the elevated railway company in an out of court settlement.

Some comments

Design factors

At the time of the judgement even the most qualified persons in the field were largely working in the dark. This was because the science of fracture mechanics was in its infancy and concepts such as those of critical crack length had not by then been developed. Safety factors cloaked ignorance of such phenomena as " stress raisers", sharp corners at which local stresses much exceeded the mean value in the material. Safety factors arose from experience which had shown that vessels could fail even though they were stressed well below the theoretical breaking stress. Nevertheless, even today when such factors are much better understood, designers of storage tanks use factors for vital members which work out at about 3.0:1 if based upon the ultimate tensile stress of the steel.

It may be significant that the failure at Boston ran through the manhole port. Was the vessel adequately reinforced to compensate for the aperture? Unfortunately the documents available do not disclose whether this had been discussed.

The evidence, as summarised by the technical reporter of Engineering News Record, made no mention as to whether the purchaser of the tank made any attempt to check whether the design incorporated safety factors of 3.0 as specified, whether the tank as erected corresponded to the drawings, or whether good practice was adhered to in the fabrication.

Expert evidence

Those defence experts who claimed that the tank was safe were giving approval to underdesigned store tanks throughout the United States and in consequence were putting other lives at risk. Fortunately, in the end, the judgement of the court exposed them as charlatans.

Safety precautions

The vessel did not have a bund wall around it. This would have had to have been a massive structure to have withstood the hydraulic forces and to have contained the contents of the tank. There was no room for such a structure at the chosen location as Figure 1 clearly shows. The potential energy of the molasses would have been of the order of 1000 mega joules and the power generated by its flow in the first few seconds would have been comparable with that of the output of a medium sized power station. Even the most benign of fluids has great potential for damage when thousands of tonnes of it are stored up to a height of 15m.

The death toll must have been increased by the highly congested nature of the surroundings. There were many houses in the immediate neighbourhood; the house which became jammed under the elevated railway was located little more than 50m from the tank.

Decontamination

The difficulty experienced in swilling away the molasses raises interesting questions because it is wholly miscible with water. Yet, perhaps because of its high surface tension, the process is very slow. Does salt water mix more easily with it than plain water?

Food products may still be dangerous

It is a mistake to believe that any liquid stored in large quantities is innocuous. Just because it is a food product does not mean it cannot harm people. An escape may drown people or give rise to pollution of streams and rivers. Therefore, precautions for bunding need to be taken with all large storage facilities no matter what they contain.

The role of politics

In this disaster technical questions became entangled with politics. We have an echo of it today in that Union Carbide have claimed that the Bhopal Disaster was brought about through sabotage by a Sikh extremist.[2]

Sources and acknowledgements

The following sources have been used:
Engineering News Record, Vol. 82, No. 20, p 974, May 15th 1919; Vol. 85, No.15, p691, Oct.7th 1920 and Vol. 94, No.5, Jan. 29th 1925; The Boston Post, Jan. 16th and 17th 1925; and Reader's Digest, Vol. 67, No.400, p63, Aug.1955.

The author's best thanks are due to Mr Henry F Scannell of the Boston Public Library for searching the records and providing off-prints.

[2] *The Bhopal sabotage theory was expounded to the full in the paper given by Dr Kalekar at the 'Preventing Major Chemical and Related Process Accidents' Symposium, 10-12 May 1988, London, see IChemE Symposium Series No. 110, available from the Institution of Chemical Engineers, 165–171 Railway Terrace, Rugby, CV21 3HQ, England. Dr Kalekar does not claim that the person who admitted the water was actually a Sikh terrorist though this had been earlier alleged by Union Carbide.*