



Aerial view of site after explosion

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Health & Safety Executive

A report by HM Factory Inspectorate

# The explosion and fire at Chemstar Limited 6 September 1981

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Enquiries regarding the publication should be addressed to:  
Area offices of the Health and Safety Executive, or  
the general information and enquiry point,  
Health and Safety Executive, 1 Chepstow Place,  
London W2 4TF Tel. 01-229 3456.

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## PART I

At approximately 23.30 hours on the night of the 6 September 1981, a violent explosion occurred in a factory at the Carrbrook Industrial Estate, Stalybridge, killing one man, injuring another and demolishing a two storey building on the site. There was minor window damage to nearby residential property as a result of the blast; the house nearest the site suffered radiant heat damage and a 200 litre drum landed on the roof; another four drums landed outside the site boundary.

The explosion was caused by the ignition of hexane vapour, discharged after a loss of cooling water to the condenser of the pot still in which 6000 litres of contaminated hexane were being distilled; this occurred at a time when the normal water supply from a reservoir was not available to the company and what proved to be an erratic temporary supply was in use. The most likely source of ignition was the flame from an oil-fired steam boiler situated in a nearby room. The fire which followed spread rapidly to the remainder of the site where drums of solvent were stored.

The philosophy on which the Health and Safety at Work etc Act 1974 is based is that those who create the risk must be responsible for control. In the period prior to the explosion the management of Chemstar Limited were faced with a number of difficulties not of their making. Nevertheless, the explosion could have been prevented if:

- (a) the vent pipe from the condenser had discharged to atmosphere;
- (b) there had been a proper indication and supervision of the flow of cooling water; with
- (c) appropriate managerial supervision and training of the plant operator; and
- (d) an appropriate emergency procedure.

Although no member of the public was injured and the damage beyond the boundary of the site was relatively slight, the incident, nevertheless, caused great concern to those living nearby. Their reaction reinforced the national interest and concern about the siting of potentially hazardous processes near to residential property. These wider issues are dealt with in the second part of the report which also explains the proposals that are currently under consideration for certain sites.

Although there are no new technical lessons to be learned, the report makes three recommendations. In the light of this incident employers should analyse the ways highly flammable liquids and their vapours may escape from plant and if releases can be foreseen they should take appropriate precautions. Employers should also reappraise their own arrangements for supervision, instruction, information and training at their plant for dealing adequately with foreseeable failures which might occur. In particular, such arrangements must include the provision of additional procedures whenever temporary services are in use. In view of the duty imposed by Section 3 of the Health and Safety at Work etc Act 1974, it would be helpful if further guidance were made available to employers to assist them to meet the obligations imposed where potentially hazardous substances are stored or used.

## Brief history of site and company

### Site

1 Carrbrook is a village located 3 km north east of Stalybridge\*. It is situated 200 m above sea level with hills rising steeply 120 m above the village to the north, east and south. The textile, printing and bleaching factory and houses in the immediate vicinity were built many years ago; the housing developments on both sides of Buckton Vale Road were built after 1960. The factory closed down in 1970, was subsequently bought and renamed Carrbrook Industrial Estate and parts were let off as individual industrial units.

2 The plan of the site is shown on the map. From this it can be seen that at the western side of the site there was a house immediately adjacent to the boundary wall. On the northern side there was one house situated on the steep hillside at a distance of approximately 100 m from the boundary and on the eastern side Buckton Grange was the only house, at a distance of approximately 250 m. The nearest of the houses in the developments along both sides of Buckton Vale Road was approximately 250 m from the southern boundary of the site.

3 The remainder of the industrial estate was on the southern side of the internal roadway. However many of the buildings were unoccupied and partly demolished.

### Company

4 In 1975 Chemstar Limited† occupied the 1.1 hectare site shown on the map at the back of this report, which included a two storey building. At this time there were two working directors and one employee. By 1981 external plant and bulk storage tanks had been erected and there were 15 employees including operators, a fitter, drivers and office and laboratory staff. The operators reported directly to the works director (an industrial chemist previously employed by two small chemical companies) who was responsible for the day to day running of the factory. He reported to the two senior directors, the managing director (an industrial chemist whose experience included previous employment by a major chemical company) and the technical director (a chartered electrical engineer with experience in the chemical industry). Laboratory analysis of the contaminated and processed materials was carried out by the works chemist who also occasionally operated the plant.

5 There were no manuals describing the operation of the various plants. Operators were trained by verbal instruction from one of the directors. The day to day operations were decided usually by the works director who wrote instructions in a log book, supplemented these with verbal instructions and also acted as a supervisor.

6 Night shift work involving two employees was introduced during 1979. The arrangements for night

working were substantially the same as for the day except that there was no direct supervision; instead provision was made for the employees to contact the works director by telephone in the event of a problem operators felt unable to solve.

## Description of process and storage of highly flammable liquids

### Process

7 The main activity of Chemstar was solvent recovery from contaminated highly flammable liquids. This was carried out by heating the contaminated solvents to generate a vapour which was subsequently condensed and collected. In 1976 batch distillations using pot stills were carried out in the western part of the building (see site plan at Fig 1). By 1978 a continuous distillation plant was installed here and in 1980 a larger continuous distillation plant in the eastern yard of the site.

8 The original two storey building (67 m long, 38 m wide and 11 m high) was constructed of solid walls with a stone exterior, brick interior and slate roof. The first floor was of timber supported by rolled steel joists which along with the roof were supported by cast iron columns 7.5 m apart in rows 3.5 m apart. There was a brick internal dividing wall upto roof level in a north/south direction along the fifth row of columns from the western wall. On the western side of this dividing wall there were further breeze block divisions upto first floor level creating what was known by Chemstar as the flameproof room, the boiler room and the despatch area. Access to these rooms is shown on Fig 1; the door to the boiler room and the adjacent door into the flameproof room were self closing and of fire resisting material.

9 The glass in the large windows (each being about 2 m high and 1 m wide) in the flameproof room and at first floor level above had been replaced by open mesh, and the ceiling in the flameproof room had been lined with fire resisting material.

10 The flameproof room housed the mixing vessel, S1 and the pot stills S2, S3, S4 and S5, and the continuous distillation plant. Two of the pot stills had capacities of 7700 litres and the other two had capacities of 4500 litres. There were six 4500 litre receiving vessels, B1 to B6, and a 9000 litre final product tank, A7. The two condensers, C1 and C2, serving the pot stills were located above them on the first floor.

11 Contaminated solvents could be pumped into the stills from bulk storage tanks outside the building, and a debarrelling tray at first floor level enabled drums to be emptied into any of the pot stills.

12 The pot stills in which the contaminated solvents were heated were secondhand vessels converted by Chemstar. Each was fitted with a valve set to relieve at 34500 Pascal (5 psi), through a pipe to outside the building.

\* OS grid reference SD 990010

† referred to throughout as Chemstar

13 The 75 mm pipework connecting the stills to the two condensers was so arranged that it was possible for either of the condensers to be used. Condenser C1 had a mild steel jacket with phosphor bronze tubes; the water passed through the shell of the condenser and the recovered solvent through the tubes. On the outlet side of each condenser there was an atmospheric vent pipe and both pipes terminated near stills S3 and S4 about 1.5 m above the floor of the flameproof room. The distillate from each condenser was pumped through 25 mm pipework to the receiving vessels (see flow diagram at Fig 2).

14 Mixing vessel S1 was used to blend the recovered solvents contained in the receiving vessels. These solvents or blends of solvents were emptied into drums or cans from product tank A7. Mechanical exhaust ventilation was provided at this position.

15 Water, steam and electric power were necessary to operate the plant. The water was supplied to the site through a 150 mm pipe from a reservoir in the hills to the east of the site. An electrically powered distribution pump located at the east end of the yard (see Fig 1) then distributed the water to the various parts of the site. The water to the condensers came from this pump through a pipe at first floor level along the southern side of the building, after passing through a filter box located on the first floor above the south east corner of the despatch area. The water from the condensers was conveyed through pipework to the drainage system. Steam was supplied to the stills from an oil-fired boiler in the boiler room shown in Fig 1a. All fixed electrical apparatus in the flameproof room, that is pumps, switches, motors and lights were understood to have been constructed to a standard suitable for use in zone 1 areas (as referred to in BS 5345).

16 For the actual process of solvent recovery the 7700 litre capacity pot still was filled with 6000 litres of contaminated solvent up to the level of the test cock either from the external bulk storage tanks or from the debarrelling tray (see Fig 2).

17 The steam regulator valve at the vessel was then opened allowing the steam to pass through the coil to heat the contaminated solvent. The valve consisted of a housing with a long handle and pointer which moved through 90 degrees across a metal plate graduated from 0 to 6 corresponding to fully closed and fully open positions. The setting on the steam regulator valve was determined by the works director based primarily on past experience and knowledge of the boiling point of the solvent being recovered. The setting was chosen so that the condenser could sufficiently cool the vapour generated by the still to convert it into a liquid. The recovered liquid (distillate) was conveyed to the distillate pump which then discharged the liquid to the required receiving tank. A typical recovery rate of solvent was 450 litres per hour.

18 When all the solvent had been evaporated the residues were drained from the still into drums. These were then stored on site in readiness for the contents to be

taken away from the site for incineration. The still was then ready for the next batch of contaminated solvent.

## Storage

19 Contaminated solvents were stored in bulk tanks and drums; recovered solvents in bulk tanks, drums and cans. The drum storage areas and bulk storage tanks on site are shown on Fig 1. On average there were in excess of 4000 drums on site but not all these contained highly flammable liquids, e.g. those in areas D, E and F. A large number of the empty drums were stored in the east yard.

20 Drum storage area A was separated by a distance of 8 m between the boundary and the nearest drums, some of which were empty, some contained solid residues and some contained contaminated solvent. The eastern edge of the area was 8 m from the fixed bulk storage tanks; these were horizontal vessels, four having capacities of 16 000 litres each (contaminated solvents) and two of 20 000 litres each (recovered solvents). The distance of these tanks from the building was 8 m.

21 Between the building and the tanks there were two vertical 8200 litre process vessels and the fuel oil tank. The process vessels were used to hold contaminated solvent which was fed directly to the continuous plant. The contaminated solvents were pumped from the horizontal tank either to these process vessels or directly into the pot stills.

22 Drum storage area B extended from the despatch room entrance to the eastern end of the building. There were no windows or doors along this section of wall.

23 Drum storage area C extended from the southern entrance to the site of the eastern end of the yard. It was understood that all the drums except those immediately adjacent to the fence contained highly flammable liquids. Only empty drums were kept in the east yard.

24 At the time of the fire it is estimated that 700 000 litres of contaminated and recovered solvents were in drums (200 litre capacity) and 145 000 litres of solvent held in the bulk storage tanks.

## The explosion and fire

25 In the middle of August 1981 the reservoir which supplied water to the site was emptied at very short notice by the owner of Carrbrook industrial estate. A temporary water supply had to be arranged by Chemstar and this involved the hiring of a diesel powered water pump and 50 mm nominal bore flexible hosing.

26 A 20 m length of this hosing, attached to the suction side of the pump, was laid on the ground as shown in Fig 1, the last 5 m extending vertically downwards into the weir of the stream which ran adjacent to the internal roadway. The end of the hosing in the water incorporated a filter.

27 A similar length of hosing was used to connect the pressure side of the pump to a previously disused section

of 50 mm nominal bore mild steel pipe. This pipe was 6 m above the sloping ground level at the western end of the building and 4 m above at the eastern end of the building. New pipework was used to connect the end of this pipe to a 50 mm nominal bore pipe which had been welded onto the 150 mm main specially for this purpose.

28 This temporary water supply was tested and found to be pumping water up to the electric pump (see Fig 1). However there was insufficient water to run both the large continuous plant at the eastern end of the site and the stills in the flameproof room. As a result the water was directed, by means of existing valves, to the continuous plant in the east yard. At this time the pot stills were not being used.

29 During the first week there were no apparent problems with the temporary water supply. During the following week, that is week commencing 31 August 1981, problems with the diesel pump arose on the night shift. The pump had cut out and the night shift operator, the sole employee on site, who was working at the continuous plant, made three entries into the log book relating to the failure. The operator was unable to restart the diesel pump and the plant was shut down.

30 At the shift changeover the day operator also tried to restart the pump without success; he then contacted the works director by telephone who advised him to contact the pump hire firm and request an engineer to examine and repair it. An engineer from this company came that morning and the pump was restarted.

31 Two days later, on Friday 4 September, the works director and the day shift operator saw vapour being emitted from the large continuous plant in the east yard. They assumed that the diesel pump had failed again and the steam supply to the plant was turned off and the boiler shut down.

32 Their investigation indicated that the diesel pump was in fact working and pumping water. The fitter who had installed the pipework was on holiday, so the works director opened and closed several valves and switches at the electric pump thereby restoring the water supply to the condenser. He was not sure why his actions cured the problem but he thought that there may have been an airlock in the system. The boiler was relighted and the operator turned on the steam to the plant.

33 Drums containing contaminated hexane had been received to be processed as a matter of urgency; as a result it was decided that one of the pot stills should be used. Drums were emptied into pot still S2 using the debarrelling tray on the first floor, with the intention that this batch should be processed the next day.

34 At 22.00 hours the night shift operator telephoned the works director and reported a loss of water to the condenser at the large continuous plant in the east yard. The works director returned to the site and with the operator examined the inlet pipe at the steam. Although the diesel pump was still running there seemed to be no

suction of water through the inlet pipe. The pipe from the stream to the diesel pump was changed in case the filter was blocked but there was still no improvement.

35 At 23.00 hours the works director decided that the plant was to be shut down and the distillation activities ceased for the night. On the following morning an engineer from the pump hire company was called to examine the pump and he carried out a minor repair. The batch of contaminated hexane in still S2 was rescheduled to be processed during Sunday evening, 6 September.

36 On Sunday the works director came in at 20.00 hours. It was a warm, still night. He found the night shift operator trying to start the diesel pump and together they eventually succeeded. The works director satisfied himself that water was being supplied to condenser C1 which was to be used with still S2. He isolated the other condenser and closed the valve which connected the debarrelling tray to the still. The operator was not totally familiar with the operation of these pot stills (having been recruited and trained by Chemstar to operate the continuous plant) and relied on the works director to set all the valves in the correct sequence.

37 The operator ignited the oil-fired boiler and went upstairs to obtain instructions from the works director, who told him to fill cans with the contents of product tank A7 and also to fill 200 litre drums with the contents of one of the receiving vessels. He was also told to assist a driver who had been asked to load a lorry later that evening and drive to Kent early the following morning. After this the works director told the operator to put the steam regulator valve at a setting of 1 on the scale 0 to 6.

38 The works director left the site and the operator returned to the flameproof room and opened the steam regulator valve to position No 1. He used the liquefied petroleum gas (LPG) powered fork lift truck to carry three pallet loads of empty 200 litre drums (four drums to each pallet) into the flameproof room, switched the engine off, and started to fill these drums.

39 At about 23.00 hours the driver arrived at the factory. The operator stopped filling the drums and checked by listening that the distilled liquid was running to the receiving vessel B5. When satisfied that this was happening he went to help the driver. The first job was to load boxes containing 5 litre cans of solvent, which were in the centre of the despatch area outside the flameproof room. The men discovered that the cans were not labelled. Each can had then to be removed from its box and labelled before being moved to the lorry.

40 About 20 minutes later, when he stooped to handle the bottom layer of the cans, the operator experienced a very strong smell of the vapours of the liquid in the still. He immediately entered the flameproof room and turned off the steam at the steam regulator valve. In the meantime the driver telephoned the works director, who by that time was at home, telling him that the fumes were



bad. The operator came out of the flameproof room and also spoke to the works director.

41 What was subsequently said between the works director and the operator is a matter of disagreement, however there appeared to be no discussion about extinguishing the boiler. Following this telephone conversation the operator returned to the still and reopened the steam regulator valve to a position halfway between 0 and 1. It was then that he thought fumes were being emitted from the condenser vent pipe (located near vessels S3 and S4). He put his hand under the pipe, felt hot vapour, immediately realised that there was no water being supplied to the condenser and both men went to the first floor level where the condenser was located.

42 The operator checked that all the valves controlling the water supply to the condenser were apparently open; the cover on the water filters, located in the south east corner of the first floor, was raised and he saw that water was not running through them.

43 The men went outside to the diesel pump and the driver climbed down into the stream to see if the inlet pipe was blocked. The operator loosened the outlet pipe from the diesel pump and found that there was plenty of suction; he walked over to the stream and shouted down to the driver that there was nothing wrong with the diesel pump. The operator walked up to the electric pump, checked the outlet and found that there was just a trickle of water being emitted. He switched the electric pump off and on, and by so doing found that the water was being pumped normally. Throughout this period steam was still being supplied to the still.

44 The operator walked down to the yard and as he reached to turn into the area in front of the southern entrance to the despatch area, there was an explosion followed by a ball of flame which shot out of the building.

45 The time that had elapsed between the operator first smelling the vapour and the explosion was estimated as being half an hour.

46 The explosion was followed by a fire involving the drums and cans within the despatch room and the flameproof room; this spread to drums and tanks to the west of the site and also to the drums to the south of the building. The fire brigade received the first call about the explosion at 23.43 hours. At the height of the blaze there were 37 fire appliances in attendance. The fire service had visited prior to the fire having been told that the reservoir on which the firm relied for cooling water had been emptied. Adequate alternative sources were used including an open supply 800 m away in the surrounding hills.

## Injury and damage

47 One employee, the driver, was killed. His body was found lying on top of stones and slates in the area corresponding to the south east corner of the despatch area. His movements during this final period were

unknown but it is considered likely that he reentered the building possibly to see if water was running through the filters on the first floor. The operator suffered flash burns to his head and arms. No member of the public was injured but in view of the proximity of housing the emergency services decided to evacuate people living nearby.

48 The damage within the Chemstar site was extensive and only the eastern yard and associated plant and storages were not affected. The maximum structural damage occurred within the flameproof room and despatch area. There was significant charring with examples of plastic deformation of steel work and columns within the flameproof room. The wall behind the pot stills was in position up to ground floor ceiling level, the first floor section having been blown out almost as one piece onto the ground outside. The walls forming the western and southern edges of the building and the internal walls creating the division between the despatch room and the flameproof room were demolished. A large portion of the south facing wall of the boiler room was still in position as were the shell of the boiler and most of its associated equipment. The internal dividing wall and rest of the building was mostly intact although severely damaged and considered to be in a dangerous state.

49 Damage beyond the site as a result of the explosion and fire included the gutting of the small building adjacent to the southern entrance which was occupied by an electrical contracting company, and radiant heat damage to the industrial building to the south of the site and to the nearest house on the west of the site. There was some minor window damage to other houses further west and north west. Five drums were positively identified as being ejected from the site; one landed on the roof of the nearest house causing slate damage before it rolled off down to the ground. The window damage and the positions of the drums ejected beyond the boundary are marked on the map. Trees and vegetation particularly on the western side of the site were scorched. Cars parked outside the southern entrance to the site were destroyed by the fire.

## Investigation

50 The principal inspector of factories of the chemicals group covering Greater Manchester, accompanied by another inspector, arrived at the factory at 08.50 hours on the 7 September. Arrangements were made for specialist and scientific support staff from the North West field consultant group in Manchester to assist in the investigation. By this time the fire was under control and a damping down operation was being carried out. Although it was not safe for any detailed examination of plant, it was possible to examine damage beyond the site. Window damage to houses and the positions of drums ejected beyond the site boundary were noted (see the map), though it was not possible to identify from where they had come.

51 The detailed investigation began on the following morning and extended over several days. During this investigation the severely burnt remains of an LPG fuelled fork lift truck were found half-way through the doorway between the despatch area and the flameproof room. The front of the truck faced the stills. Closer examination later revealed that the key to the fork lift truck was in the ignition lock, which was found on the floor of the truck; however, because of the charred condition of the whole assembly it was not possible to determine whether the engine of the truck was running at the time of the explosion, although all the evidence suggests that it was not.

52 Still S2, condenser C1 and associated pipework were examined; it was confirmed that the regulator valve which controlled the steam to the coil at the still was set between 0 and 1.

53 The residual risks as a result of this incident related to the unsafe structures that remained on site and the discovery of blue asbestos, crocidolite, in the damaged unoccupied industrial buildings to the south of the internal roadway. On 18 September a prohibition notice was served on Chemstar preventing work in the vicinity of the damaged walls, columns and roofs until such dangerous structures had been made safe either by demolition or adequate support.

54 Samples of lagging material in the fire affected building on the other side of the site were analysed and confirmed as being crocidolite. Subsequent advice was given relating to the safe removal of the asbestos by a competent contractor as part of the demolition programme for the building.

## Legislation

55 The premises occupied by Chemstar were subject to the Health and Safety at Work etc Act 1974 and constituted a factory subject to the Factories Act 1961. The premises were first visited in October 1975 before processing was started and registration as a factory occurred at the beginning of 1976. The offices were subject to the Offices, Shops and Railway Premises Act 1963. The premises were also subject to regulations made under the Factories Act namely the Electricity (Factories Act) Special Regulations 1908 and 1944 and the Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972. The death of the driver, the injury to the operator and the explosion and fire were reportable under the Notification of Accidents and Dangerous Occurrences Regulations 1980.

56 Regulation 27 of the Electricity (Factories Act) Special Regulations 1908 and 1944 requires that all electrical apparatus exposed to inflammable surroundings or explosive atmospheres should be so constructed as may be necessary adequately to prevent danger. The occupier had designated the flameproof room as a zone 1 area, defined in BS 5345 as being a hazardous area in which an explosive gas-air mixture is

likely to occur in normal operation. In such areas special precautions for the construction and use of electrical apparatus are necessary; examination of pumps, switch boxes and lighting after the explosion indicated that such equipment was constructed to be suitable for use in zone 1 areas. However the fork lift truck found in the doorway to the flameproof room was not explosion protected.

57 A highly flammable liquid is defined by the Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972 as being a liquid which, when tested in the manner described in the schedules of these regulations, has a flashpoint of less than 32°C and supports combustion.

58 Regulation 5 of these regulations refers to the storage of highly flammable liquids. These are required to be stored in suitable fixed storage tanks in safe positions or in suitable closed vessels, e.g. drums, kept in a safe position in the open air and, where necessary, protected against direct sunlight. A guidance note on how compliance with this regulation may be achieved has been published\* by the Health and Safety Executive.

59 Exceptions from Regulation 5 include highly flammable liquids in actual use and petroleum spirits as defined in the Petroleum (Consolidation) Act 1928. the quantity of liquid in actual use is required to be as small as is reasonably practicable and it may be that the vertical process tanks as Chemstar did not constitute storage within the meaning of the regulations. The keeping of petroleum spirits has to be authorised by a licence in force under the 1928 Act and Petroleum (Mixtures) Order 1929.

60 The combined storage capacity of the tanks used for highly flammable liquids was 104 000 litres; the minimum distance recommended by the guidance note between the bulk storage tanks and buildings, boundary or property line is 8 m. The recommended minimum distance from the boundaries of the drum storage areas to any open boundary fences or tank bunds is 4 m.

61 At the time of the explosion and fire the storage of highly flammable liquids in fixed tanks and drums to the west of the building complied with these recommendations.

62 Although there were more than 4 m between the open boundary fence and drum storage area B (see Fig 1) the separation between the building and the storage area was less than 4 m. However a reduction in this recommended distance is considered permissible (see para 44 of the guidance note) when the storage outside the process building in enclosed portable containers is temporary for early use and if further conditions relating to the fire resistance of the building, proximity to building openings and means of escape are also met. These conditions were considered to have been fulfilled.

\* Guidance Note Chemical Safety/2, obtainable from HMSO.

63 Drum storage area C was not 4 m from the open boundary fence but evidence obtained after the fire suggested that the drums nearest the boundary fence did not contain highly flammable liquids.

64 Regulation 8 of the 1972 regulations requires precautions to be taken against spills and leaks. This was achieved by the provision of a totally enclosed system. Liquids were pumped through pipes from external tanks to the pot stills and the continuous distillation plants. Occasionally liquids in drums were taken onto the first floor above the flameproof room and the drums emptied at the debarrelling tray. The purpose of the tray was to prevent spillage onto the floor.

65 Regulation 9 of the 1972 regulations requires that no means likely to ignite vapour from any highly flammable liquid shall be present where a dangerous concentration of vapours from highly flammable liquids may reasonably be expected to be present. For the purposes of the regulation the term 'dangerous concentration of vapours' means a concentration greater than the lower flammable limit of the vapours. The fork lift truck once started would be regarded as a source of ignition for a dangerous concentration of vapours from a highly flammable liquid. The oil burner at the steam boiler was a possible source of ignition (see para 15). However it was in a separate room where under normal operating conditions a dangerous concentration of vapours could not be anticipated.

66 Regulation 10 of the 1972 regulations refers to the prevention of escape of vapours and dispersal of dangerous concentrations of vapours. The condenser vent pipe terminated inside the flameproof room. It was reasonably practicable to guard against the hazard which would arise if vapour from the vent pipe entered the room. Appropriate precautions would include leading the vent pipe outside the room; monitoring the effectiveness of the condenser; providing dispersal ventilation and removing sources of ignition. In this case reliance was placed on the last two precautions. The ventilation in the flameproof room and at the debarrelling tray had been improved by the replacement of glass in the windows by open mesh; mechanical local exhaust ventilation had been provided at the drum filling position and all the electrical equipment was flameproof. During the incident the ventilation and the removal of sources of ignition from the room apparently combined to prevent an explosion for a period in excess of 30 minutes. Had an effective emergency procedure been implemented during this period it is unlikely that the explosion would have occurred.

67 In addition to the specific requirements of the above regulations, Sections 2 and 3 of the Health and Safety at Work etc Act 1974 impose wider general requirements in connection with the activities of Chemstar.

68 Section 2(1) imposes a duty on an employer to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all his employees. This duty extends to include:

- (a) the provision and maintenance of plant and systems of work that are, so far as is reasonably practicable, safe and without risk to health; and
- (b) the provision of such information, instruction, training and supervision as is necessary, so far as is reasonably practicable, to ensure the health and safety at work of his employees.

69 This duty, being a general one, expects an employer to select from a variety of possible choices the method of compliance. In this particular case it is considered that it was important to supervise cooling water flow closely at still S2. This could have been simply done by the provision of a sight glass or tundish on the cooling water return line in the flameproof room.

70 When the supply of cooling water became unreliable arrangements should have been made for the supply to the condensers to be constantly monitored for the whole period of the distillation.

71 In a chemical plant of this nature given the few engineering controls to prevent danger, it was unrealistic to assume that no emergency would ever take place. The obvious problems were easily identifiable and emergency procedures which could be quite simple should not only have been devised by the management but properly and effectively communicated to the process operators as part of their training.

72 The company had developed an informal emergency procedure for the continuous plant which involved the shutting down of the steam supply, the shutting down of the boiler and evacuation from the working area. This procedure was familiar to the operator and would have been equally applicable to the pot stills. When the vapour from still S2 was detected by the operator he shut off steam to the still and spoke by telephone to the works director but the emergency procedure was not invoked.

73 Section 2(3) of the 1974 Act requires the employer to prepare a written statement of his general policy with respect to the health and safety at work of his employees and his organisation and arrangements for carrying out that policy. Exception from this requirement is restricted to an employer who carries out an undertaking in which he employs less than five persons. A policy had been prepared by the managing director of Chemstar but unfortunately the document was destroyed by the fire and no other copies were available for examination and further comment. However, from the recollection of employees and inspectors from the Health and Safety Executive it appears that although the policy of the company was clearly stated the description of the organisation and arrangements was less precise.

74 The organisation consisted of three working directors who directly controlled the activities of all employees. Control of day to day affairs was effectively exercised by the managing director either directly or via the works director.

75 Although, as described in para 5, the instructions for the use of the plant were recorded in the log book, the

operators had no manuals describing the operation of the plants. The safety policy did not specify the procedures to be followed in the event of an emergency.

76 Section 3(1) of the Act requires an employer to ensure, so far as is reasonably practicable, that persons not in his employment, such as members of the public, are not exposed to risk to their health and safety. Although during normal working with an assured water supply the possibility of an explosion was not readily foreseeable, once the water supply became suspect an explosion became foreseeable if certain positive steps were not taken. The effects of such an explosion included the likelihood of injury to employees and members of the public, namely residents living nearby. Consequently, the precautions that were necessary had a dual role to protect both employees and public.

77 The possible effects of a fire were less easy to foresee. During the fire five drums were ejected beyond the boundary of the site and one of them landed on the roof of the house nearest to the site, but again no member of the public was injured. At the time of the incident, the separation distances between boundaries and storages of highly flammable liquids as recommended in guidance note, Chemical Safety 2 were achieved and, in the western yard, exceeded. Inspectors who had visited Chemstar were of the opinion that compliance with the separation distances recommended in the guidance note would be sufficient for the employer to comply with Section 3.

78 The premises were subject to the Fire Precautions Act 1971. They were not subject to the Fire Certificates (Special Premises) Regulations 1976, as insufficient quantities of highly flammable liquids were stored at the site. A fire certificate had been issued by the fire authority under the Fire Precautions Act 1971.

79 Notification of the premises would not have been required under the Notification of Installations Handling Hazardous Substances Regulations in force from 1 January 1983.

80 The storage of petroleum based solvents was subject to the Petroleum (Consolidation) Act 1928 administered by the Greater Manchester Council. Chemstar processed a wide variety of solvents; the majority were not petroleum based and were not therefore subject to the licensing requirements of the Act.

## Conclusions

81 There is no doubt that the explosion was caused by the ignition of a hexane/air mixture. As the vent pipe from the condenser terminated inside the building hexane vapour was discharged into the flameproof room when the water supply to the condenser failed. There was no clear indication of the flow of cooling water to the plant and a high degree of supervision was therefore necessary following the provision of a temporary water supply. Furthermore, the employee working at the still was not

totally familiar with the plant and indeed had asked the works director to set all the necessary valves correctly so that the distillation could be carried out.

82 There were several possible sources of ignition, but the two most likely were the fork lift truck and the oil-fired boiler. As the indications were that the fork lift truck was not in use and the engine was not running, it is concluded that the most likely source of ignition was the oil burner of the steam boiler.

83 This process of distillation was simple yet the potential consequences of a malfunction (e.g. the loss of cooling water) were considerable. It was vital therefore that a proper emergency procedure should have been formulated to include the following:

- (a) upon identification of a plant malfunction, which was apparently causing an emission of vapour into the room, the steam to the still should have been shut off and left off;
- (b) all obvious sources of ignition should have been turned off, including the oil-fired boiler and any electrical equipment not essential to the safe operation of the plant;
- (c) the building should have been evacuated, the manager or supervisor informed and no entry attempted until vapours had dispersed. In this case at least half an hour may have been necessary;
- (d) a member of management or a supervisor should have attended the works to give technical consideration to the cause of the malfunction;
- (e) atmospheric testing of the workroom for both toxic and explosible concentrations of vapour should have been carried out and no attempt made to reenter the building or restart the plant until it was safe to do so.

84 The above emergency procedure is one which would be found in most chemical works and there was at least half an hour for such a procedure to have been safely and effectively carried out. Had this been done it is most unlikely that the explosion and fire would have occurred. Further guidance on emergency procedures is contained in the booklet *Recommended procedures for handling major emergencies*, published by the Chemical Industries Association, Alembic House, 93 Albert Embankment, London SE1 7TU.

85 The technical explanation of the accident is simple; but technical failures are seldom the sole cause of accidents. As the booklet published by the Health and Safety Executive entitled *Managing safety*\* points out, management's responsibility is to control work, and accidents are caused by failures of control. The events which led up to the explosion illustrate once again the vital role of management in ensuring that clear procedures for the safe operation of the plant and to deal with any emergencies are both communicated to employees and followed. This will require proper supervision, adequate instruction and training.

\* obtainable from HMSO

## Recommendations

86 Employers should in the light of this incident analyse the ways highly flammable liquids and their vapours may escape from plant which should be designed and operated to prevent such escape so far as is reasonably practicable, for example, by monitoring condensers for malfunction. If release can be foreseen, precautions should be taken such as discharging vent pipes to a safe place outside the building.

87 Employers should consider the circumstances of this incident, and reappraise their own arrangements for supervision, instruction, information and training to deal adequately with all foreseeable failures in process plant; in particular such arrangements should include the provision of additional procedures whenever temporary services are in use.

88 In view of the duty imposed by Section 3 of the Health and Safety at Work etc Act 1974, it would be helpful if further guidance were made available to employers to assist them to meet the obligations imposed where potentially hazardous substances are stored or used.

### **Action by HSE**

89 HSE has been reviewing its own guidance on storage and use of potentially hazardous substances. Further guidance which is under preparation will be issued as soon as possible.

## PART II

### Introduction

90 Part 1 of the report described the explosion and fire at Chemstar on the night of 6 September 1981, an event which caused considerable alarm and inconvenience to members of the public living near to the site. Part 2 summarises:

- (a) the complaints which had previously been made by local residents about the safety of the site;
- (b) the inspections of the site by inspectors from the Health and Safety Executive;
- (c) the planning history of the site;
- (d) the controls for installations handling large quantities of hazardous substances.

91 A summary of the complaints made by local residents about smell and noise from the Chemstar site is contained in the appendix.

### Complaints by local residents, summary of visits by inspectors from the Health and Safety Executive

92 The development of Chemstar is described in Part 1. The first visit by a factory inspector was in October 1975, before production had started, when general advice was given on the storage of highly flammable liquids. The site continued to develop and further visits were made in December 1975 and in March and July 1976 by inspectors from the Ashton district office of the Factory Inspectorate.\*

93 With the reorganisation of the Factory Inspectorate at the end of 1976, the Ashton office of the Factory Inspectorate was closed and inspectors moved to the Health and Safety Executive area office for Greater Manchester†. It was here that the first of the four complaints between 1977 and the date of the explosion was received. In a letter from the Chairman of the Carrbrook Conservation Committee dated 22 April 1977, the attention of the Health and Safety Executive was directed to unpleasant smells and to the storage in the open air of several hundred drums of chemicals within 10 m (approx 30 ft) of domestic property. The complaint about smell was referred to the local authority; the complaint about the drum storage was investigated by the principal inspector in charge of the chemicals group (which had been formed as part of the reorganisation already described).

94 On the 25 April 1977, the inspector visited the chairman at his home during the evening; there was a lengthy discussion during which the standards which the Inspectorate would seek to enforce were explained. It was also pointed out that the Inspectorate's powers were limited to matters affecting the health and safety of the residents and did not extend to control of unpleasant smells or loss of visual amenity.

95 When the inspector left the chairman he found that the Chemstar factory was still open and he therefore paid an initial visit before returning home. At that time the firm was still establishing itself and the inventory of highly flammable liquids on site was very small in relation to the very large inventory which had built up at the time of the explosion. The drums were numbered in hundreds rather than thousands; there was no continuous distillation plant and no external bulk storage tanks in the western yard. The threat from fire which the site might pose to residents appeared to be confined to drums stored on open ground between the factory building and the boundary wall.

96 The inspector could not carry out a comprehensive inspection on that night but he returned on 3 May and again on 28 May with a specialist inspector from the North West field consultant group. At these visits it was found that the separation distances of the boundary wall on the western side exceeded those quoted in guidance note, Chemical Safety 2, but other recommendations in the note were not being satisfied; for example, drums were not stored on an impervious surface and there were no sills to contain leakages. A letter was sent to Chemstar about these matters and a copy of the guidance note was also enclosed.

97 On 24 June a letter was also sent to the chairman of the Carrbrook Conservation Committee to confirm the discussion which had taken place on the 25 April and to give the reassurance that the chairman had sought. The inspector enclosed a copy of the guidance note and expressed the opinion that in the event of fire there should be no risk to adjacent property if the separation distances recommended in the guidance note were maintained. In April 1977 and in the subsequent period up to the time of the explosion, inspectors who visited Chemstar based their advice and opinions on the contents of the guidance note both in respect of separation distances and general conditions of storage. Section 3 of the Health and Safety at Work etc Act 1974 requires an employer to ensure the safety of persons not in his employment, so far as is reasonably practicable. Part 1 has recommended that in

\* Ashton District office of HM Factory Inspectorate, Department of Employment Building, Scotland Street, Ashton-Under-Lyne

† Health and Safety Executive, Greater Manchester Area Office, Quay House, Quay Street, Manchester, M3 3JB

view of this duty it would be helpful if further guidance was made available to employers to assist them to meet the obligations where potentially hazardous substances are stored or used.

98 One of the conditions attached to the planning permission granted in September 1980 (see para 107) was that the drum storage should be moved from the western yard by the end of December 1980. This condition was imposed primarily to deal with the complaints about smell, noise and visual amenity. It was the inspector's opinion that this condition could not be enforced within the terms of the Health and Safety at Work etc Act 1974 and the Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972.

99 At a subsequent visit in December 1977, it was apparent that an effort had been made to carry out the improvements that had been recommended and it was noted that there had also been an improvement in the general operating conditions. At visits in January and May 1978, proposals by Chemstar to install further process equipment and the use of bulk storage tanks were discussed.

100 On 2 June 1978, the Chairman of the Carrbrook Conservation Committee made a second complaint; he reported a serious deterioration in the general housekeeping on the site, that drums were being stored on soft ground and that they were leaking. An inspector visited on 12 June. The managing director of Chemstar was interviewed and he gave an undertaking, subsequently confirmed in a letter, that the drums would be cleared from the soft ground, an area of concrete with sills on three sides would be laid and the height of the drums stored would be reduced; all this work was to be completed by the end of July 1978. The complainant was advised of the promised action.

101 In February 1979 an inspection was carried out at Chemstar and during this visit an anonymous complaint claiming unauthorised use of phenol, received via the Pollution Control Section of Tameside Environmental Health Department, was investigated. The Principal Pollution Control Officer was subsequently advised that a small amount of phenol was kept at Chemstar for laboratory purposes and that authorisation for the storage or use of phenol was not required by any legislation enforced by the Health and Safety Executive.

102 At a visit in June 1979, the drum storage areas were considered to meet the recommendations contained in the guidance note. In February 1980 an inspection was carried out and also plans by Chemstar for further expansion including chemical manufacturing were discussed.

103 In March 1980 a local resident wrote to the local authority expressing concern about the site and seeking information about the processes. The letter was referred to the Health and Safety Executive and an inspector arranged a meeting with the complainant. Following that meeting and with the agreement of Chemstar the complainant was invited to the site and was given a tour

of the works by the technical director who offered a detailed explanation of the processes and the operation of the plant. As a result of his visit the complainant wrote to the Health and Safety Executive offering comments primarily about the drum storage of solvents and some electrical equipment which, in his opinion, was not suitably constructed for use in areas where flammable vapours may be present. The complainant believed that the drum storage should be replaced completely by a system of bulk storage which would be located behind blast walls at the rear of the factory and provided with water sprays. This suggestion was not regarded as enforceable since the Highly Flammable Liquids and Liquefied Petroleum Gases Regulations 1972 specifically allows for drum storage. The comment about the electrical equipment was not considered justified. Extracts from guidance note Chemical Safety 2 and the Health and Safety Executive publication, HS(G)4 *Highly flammable liquids in the paint industry*, pages 23 to 27, were sent to the complainant.

104 Further visits were paid during 1980 to deal particularly with the problem arising from the demolition of the mill chimney adjacent to the eastern yard of the site where bulk storage tanks and the large continuous distillation plant were located. The final inspection was on 4 August 1981. At this visit only the laboratory and the large continuous distillation plant were in use. Concern was expressed about standards in the laboratory and major improvements were required. The inspector planned to visit during October to ensure that these improvements had been carried out.

## Planning history of Chemstar

105 The Town and Country Planning Act 1971 requires that planning permission should be obtained for carrying out development and such permission should be obtained by the developer from the local planning authority. The term 'development' has a particular meaning attributed to it by the Act (Section 22) but broadly it includes the carrying out of building or similar operations and also the making of a 'material change of use' in the buildings or land.

106 In 1975, Chemstar occupied the site which had previously been used for industrial purposes as a print and bleach works. The planning authority concluded that no planning consent was necessary as development of the land was not proposed and the processes to be carried out by Chemstar were of the same class in planning law as the previous use. There was therefore no opportunity to consider from a planning point of view whether the processes involved in solvent recovery were appropriate for this site and what effect they might have on those who occupied the neighbouring property.

107 It was not until 1980 when some buildings on the site were demolished and external storage tanks and processing plant installed that the opportunity to require a planning application arose. This change was noted by a technical officer from the Pollution Control Section of the

Environmental Health Department during visits to investigate complaints about smell, and the Planning Department of Tameside Metropolitan Borough was advised accordingly. The development was considered to affect materially the external appearance of the premises and planning permission was therefore required. Chemstar was informed and a retrospective application was made. The Health and Safety Executive was consulted about this application and the planning department was informed that there were no reasons on health and safety grounds why the erection of the external storage tanks and processing plant should not be permitted. Planning permission was granted in September 1980, subject to three conditions being fulfilled. These required the removal of storage drums from the western yard by the end of 1980, the relocation of a storage area to comply with the requirements of the Petroleum Licensing Authority and the prevention of emissions of smoke, dust, fumes or odours which might interfere with the comfort, amenity or convenience of the local residents.

108 Chemstar failed to comply with the first condition and in February 1981 the council served an enforcement notice on the company requiring steps to be taken to secure compliance. However, in the meantime, Chemstar had appealed against this condition to the Secretary of State for the Environment and this appeal effectively suspended the enforcement notice; the company was not required to comply with the condition while it was subject to appeal.

109 The appeal was heard by an inspector appointed by the Secretary of State for the Environment at a public local enquiry at the town hall, Ashton-under-Lyne on 30 June 1981. Evidence was heard from the local authority and from local residents on the histories of both planning matters and environmental pollution caused by Chemstar. Public safety was not a separate issue although the inspector, in his report dated 24 July 1981, took into account the response from the Health and Safety Executive about the proposed new plant. He concluded that whilst the environmental nuisance generated by the activities of Chemstar was largely a matter for other legislation, the use of the western yard was a matter for planning control. As the condition which required the removal of drums from the western yard would have the effect of reducing the movement of heavy vehicles and the visual impact, noise and odour associated with the handling and storage of the drums, he considered such a condition to be reasonable. However, because Chemstar had estimated that the end of December 1981 would have been a more reasonable time and since the planning consent had only been issued in September 1980, the inspector considered the original three month time limit to have been unreasonably restrictive. He therefore allowed the appeal by Chemstar and substituted an amended condition which required the drums to be removed by 31 December 1981 — that is, within about five months of the determination of the appeal.

110 Between the determination of this appeal and the explosion there was some reduction in the number of drums in the western yard. Had all the drums been removed before 6 September the explosion and subsequent fire would still have occurred. However, in the opinion of the Health and Safety Executive the radiant heat effect on the property adjacent to the western boundary would clearly have been reduced. It is less certain, however, to what extent this move would have affected the number of drums ejected from the site.

## Installations handling large quantities of hazardous substances; controls

111 At installations where hazardous substances are stored, processed and used the operations are subject to the Health and Safety at Work etc Act 1974 and this includes both the protection of people at work and the prevention of risks to the safety of the general public who live nearby. However, as acknowledged by the Advisory Committee on Major Hazards, it is not possible to provide absolute safety and there will always remain a risk, however small, that an incident might occur. If such an incident were to involve large quantities of hazardous substances there could be a number of casualties both on and off the site. It was for this reason that the Department of the Environment in Circular 1/72 drew the attention of planning authorities to the need to take account of the health and safety aspects of planning applications involving major hazards and to consult the Health and Safety Executive. The scale of the process at Chemstar would not have brought this factory within the scope of the circular. Following the disaster at Flixborough in 1974, the Health and Safety Commission appointed the Advisory Committee on Major Hazards who in December 1979 completed recommendations for changes to safety and planning controls. They specified substances which if present in threshold quantities at an installation should require it to be notified to HSE. They endorsed proposals for hazard surveys at about ten times the threshold notifiable quantities and this is consistent with the recently adopted EC directive on major accident hazards which also contains requirements for emergency plans and information to be given to the public. Installations which have less than the notifiable quantity of any of the specified substances are considered to present a lower level of hazard and it was the view of the advisory committee that existing safety legislation provided adequate control in these circumstances. Chemstar had less than the notifiable quantities of hazardous substances and therefore would not have become subject to either the proposed notification requirements or the provisions of the EC directive.

112 The recommendations of the advisory committee and subsequent consultations with interested parties, the EC directive requirements and incidents of the kind that occurred at Chemstar have been taken into account in the drafting of the Notification of Installations Handling Hazardous Substances Regulations in force from 1 January 1983. It is anticipated that further regulations to



complete the implementation of the EC directive will be introduced by January 1984.

113 The advisory committee considered that decisions on the location of hazardous developments should always be a matter for local planning authorities. However, they identified circumstances in which under the present planning regime a major hazard could be created or intensified without prior express planning permission and recommended changes to remedy this situation. The Health and Safety Commission envisaged that these proposed changes would be linked to installations which would become subject to the notification regulations and therefore they would not have applied to Chemstar. The Chairman of the Commission has written recently to the appropriate ministers recommending that planning controls over hazardous installations should be strengthened in the light of the advisory committee's recommendations.

## Appendix

### Summary of the complaints made by local residents about smell and noise from the Chemstar site

1 The complaints about smell began in April 1977 with two in that year, 49 in 1978, 18 in 1979 and 82 from 1980 up to September 1981. In response, technical officers from the Pollution Control Section of the Environmental Health Department of Tameside Metropolitan Borough paid over 150 visits. In June 1979 a notice was served under the Public Health (Recurring Nuisances) Act 1969 as a result of an unpleasant smell in the Carrbrook area from the steam cleaning of a storage tank prohibiting a recurrence of the nuisance from this particular source<sup>1</sup> and giving Chemstar three months to install suitable plant and equipment.

2 At about the same time a complaint was received about noise and the directors of Chemstar asked for a discussion with officers from the Environmental Health Department about the complaints made by local residents and to outline the company policy to deal with them. To reduce the noise it was agreed that in future all doors would be closed during the night and that fork lift trucks would be used only inside the building. By moving drums from the western yard to another part of the site the company hoped that the problem of smell would be alleviated. The western yard would then be turned into a staff car park and landscaping would be carried out at the site boundary.

3 In September 1980, magistrates sitting in the Petty Sessional Division of Ashton-under-Lyne heard that Chemstar had failed to comply with the requirements of the notice and an order of the court agreed by Chemstar was served requiring the installation of suitable and efficient equipment so as to prevent the recurrence of the nuisance. The company was also ordered to pay the costs of the council.

4 In June 1981, following a complaint about a particularly bad smell in the vicinity of the house nearest to the site, a further notice was served on the company 'arising from the premises being in such a state as to be a nuisance'. The notice gave Chemstar 28 days to take such steps as were necessary to prevent a recurrence; it expired three days before the explosion and further action by the council was deferred pending information on the future of the company.

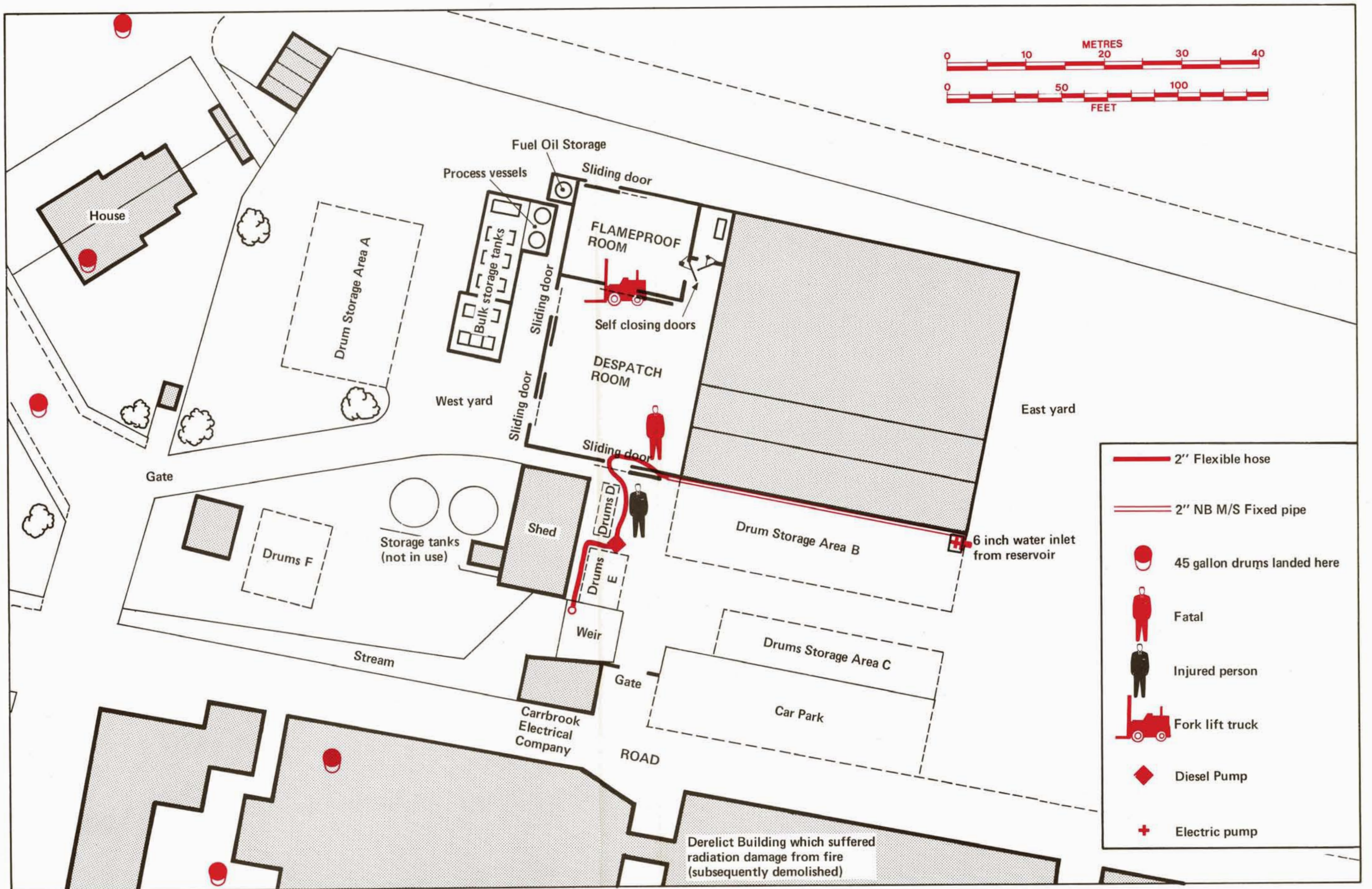


Fig 1 Layout of site

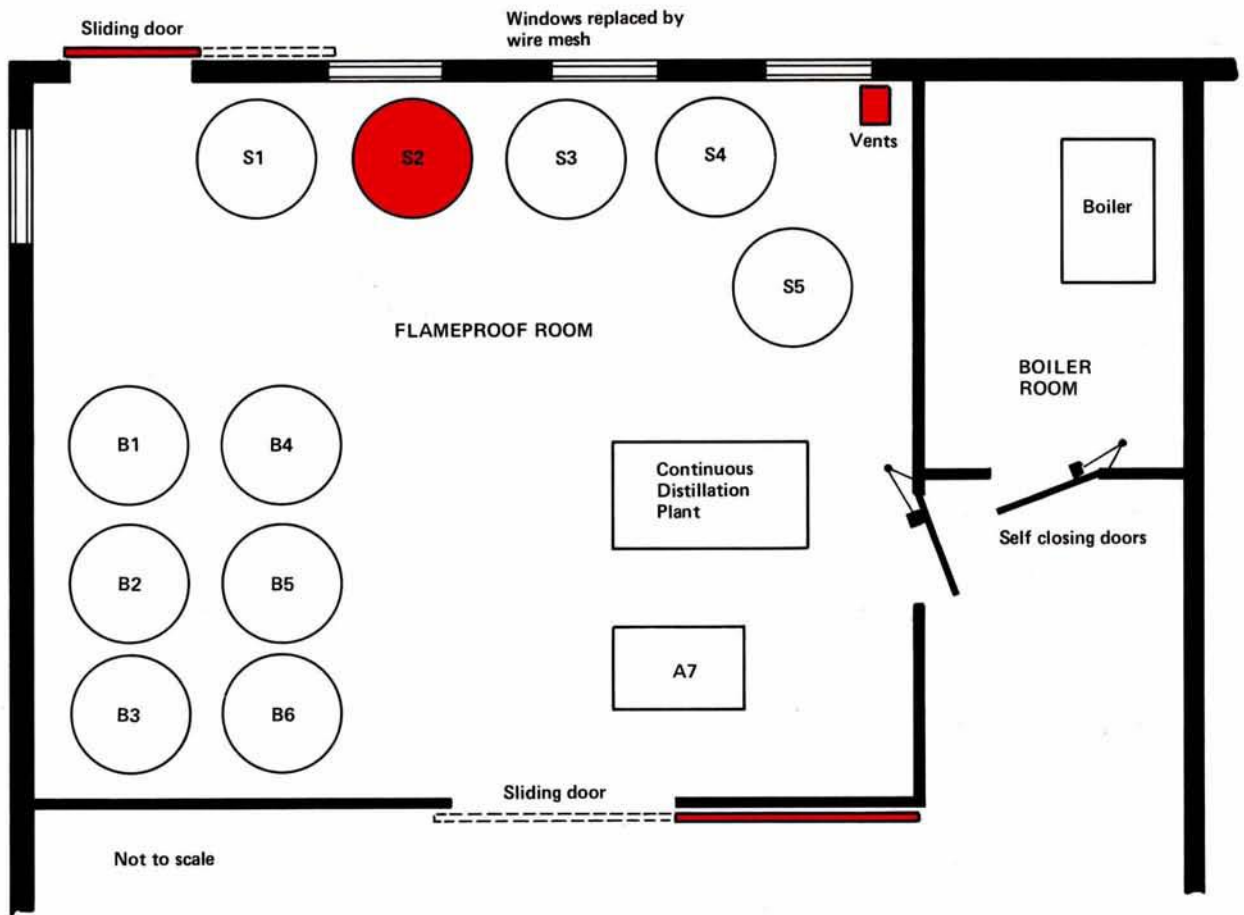
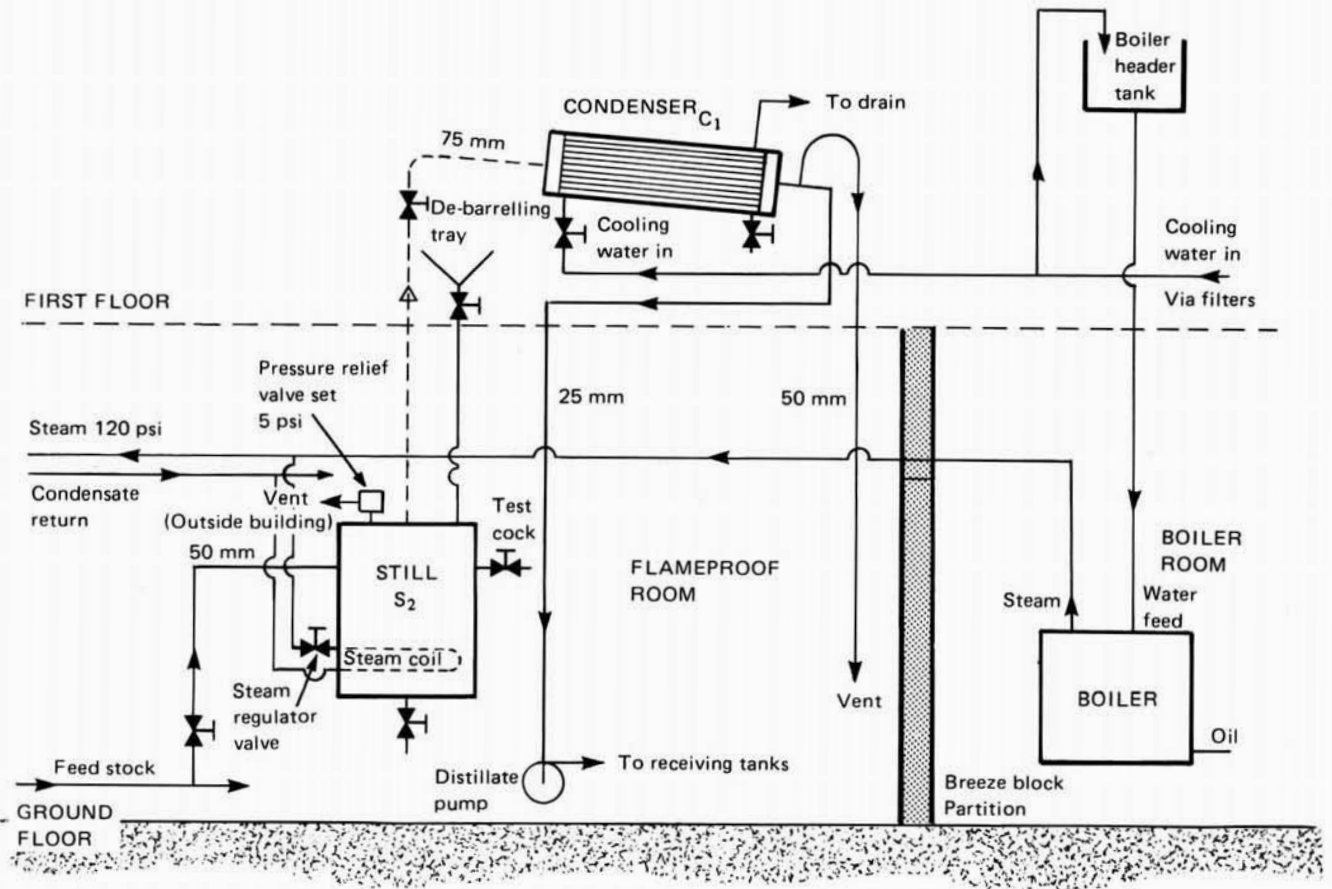
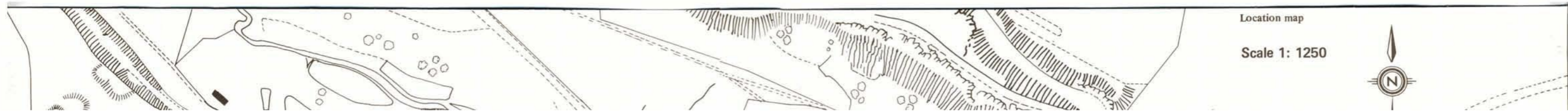


Fig 1(a) Enlargement of flameproof room



Not to scale

Fig 2 Flow diagram of plant



Location map

Scale 1: 1250



# The explosion and fire at Chemstar Limited 6 September 1981

