

# The explosion at Laporte Industries Ltd, Ilford 5 April 1975



Health &  
Safety  
Executive



**Health & Safety Executive**

A report by HM Factory Inspectorate

# The explosion at Laporte Industries Ltd Ilford, 5 April 1975

© Crown copyright 1976  
First published 1976

ISBN 0 11 880333 6

# Contents

Summary	4
Introduction	5
The site	5
The process	5
The plant	5
Plant operation	5
History of the plant	6
Events immediately prior to the explosion	6
Circumstances of the accident	7
Investigation of the accident	7
Damage caused by the explosion	7
Immediate cause of the accident	8
Dismantling the cell block	8
Discussion	11
Analysis of the product gases	11
Effect of sludge formation	12
Safety organisation	12
Conclusions	12
Risk to the public	13
Lessons to be learned	13
Other action	13

## Appendices

1	Site plan	15
2	General arrangement of electrolytor	17
3	Sketch of cell	18
4	Extract from manufacturers' handbook	19
5	Extract from log sheet	21
6	Management organisation	22
7	Ilford plant organisation chart	23
8	Risk to the public	24

On 5 April 1975, an explosion occurred at the factory of Laporte Industries Limited which resulted in extensive damage to an electrolytor plant and the subsequent death due to injuries, of the plant operator.

The Health and Safety Commission directed the Health and Safety Executive on 22 April 1976, to investigate and make a special report on the accident. The investigation was conducted by HM Superintending Inspector of Factories, London and Home Counties (East) Division, under Section 14(2)(a) of the Health and Safety at Work etc. Act 1974. Certain metallurgical examinations of material from the site were carried out by the Research and Laboratory Services Division.

The report was presented to the Commission on 19 August 1975. HM Factory Inspectorate had by then decided that Laporte Industries Ltd should be prosecuted in the Magistrates Court, and an information alleging a breach of Section 2 of the Health and Safety at Work Act 1974 had been laid. It was considered right to delay publication of the report until legal proceedings were completed. The hearing of the case was concluded on 17 March 1976 after several adjournments and the company was fined £300. Since the report was presented, further discussions have been held with the manufacturers, and much of the evidence on which the report is based was subject to close scrutiny in the Magistrates Court hearings. The authors have concluded that the results of these discussions and hearings do not significantly change the views contained in the report.

The Commission have decided that the report should be published in the form in which it was presented to them in August 1975, with a minor modification to Appendix 5, which has been made for reasons of clarity.

The original report to the Health and Safety Commission did not resolve the question of risk to the public. Further calculations have been made by HM Factory Inspectorate and Laboratory Services Division and the results are set out in Appendix 8.

## Introduction

On 5 April 1975 at 11.10 hrs there was an explosion at the factory of Laporte Industries Ltd, Uphall Road, Ilford, Essex. It occurred in the process plant called a Lurgi Electrolytor and as a result of uncontrolled release of the caustic electrolyte used in the plant one man subsequently died from his injuries. The plant itself was extensively damaged by the explosion and there was some local damage to the building on the site.

## The site

1 The site had been occupied since about 1900 by Howards of Ilford Ltd who carried on a variety of chemical and pharmaceutical processes. A number of processes involving the use of hydrogen were being undertaken in 1960 when Howards made a planning application to the then planning authority (Ilford Borough Council acting on behalf of Essex County Council) for permission to erect an electrolytor to provide hydrogen for hydrogenation processes. Permission was granted on 17 October 1960 and the plant was installed in 1962 by its makers Lurgi Gesellschaft Fur Warme Und Chemotechnik MBH. The plant was installed in a single-storey building approximately 37.5m × 11.5m × 6m high with a lightweight roof and upper walls. Laporte Industries Ltd acquired control of the company after installation and commissioning was complete.

## The process

- 2 The purpose of the electrolytor is to produce hydrogen by the electrolysis of potassium hydroxide solution. The process also produces oxygen which is discharged as a waste product.
- 3 Electrolysis is achieved in a "Zdansky-Lonza cell" containing two gauze electrodes. The cells are circular, about 1.5m in diameter and 25mm thick. (Appendix 3.) Application of an electric current to the electrodes causes the electrolyte to give off hydrogen at the cathode and oxygen at the anode.

## The plant

- 4 The Electrolytor consists of four blocks of narrow cells, each block containing 135 cells (540 in all). Each cell is sealed on both sides by embossed steel plate (goffer plates) walls which are nickel plated and inserted in ring-shaped frames. Nickel plated steel wire gauze is placed on the anode and cathode side of the goffer plate to act as the active electrodes. The surface of the gauzes are activated by a special process. Anode and cathode compartments are separated by asbestos diaphragms and the cell frames are sealed on the outside by ptfе gaskets. (Appendices 2 & 3.)
- 5 The cell blocks are bounded by head plates which are connected by tie rods. The blocks are forced together to provide a tight seal for each individual cell. The two

lower tie rods rest on base insulators and support the whole unit.

6 The electrolyte (potassium hydroxide solution) is fed in through bores in the electrolyte duct at the bottom of the unit. The duct consists of separate members in the form of rings of a similar width to the cells. The electrolyte passes to the cathode side of the cell through a 2mm hole and a partial stream of electrolyte passes through openings in the goffer plates to the anode side of the cells. A mixture of electrolyte and gas flows upwards through the cells and is accumulated in separate ducts for hydrogen and oxygen. The ducts for gas and electrolyte are composed of a number of individual members fitted to the goffer plates.

7 The gas and electrolyte pass through bores in the ducts (5mm × 2.5mm for hydrogen, 5mm × 2.4mm for oxygen) to separating drums (one for each gas) where the gases are separated from the electrolyte. The drums are sited on supports on top of the upper tie rods and are connected by pipes below the liquid level in the drums to give a pressure balance between them. The mixture of gas and electrolyte leave the ducts from both ends of the electrolytor and connections lead them into the appropriate separating drum. The gases leaving the separating drums are cooled in collecting domes packed with Raschig rings. The gases subsequently pass through water separators in order to remove traces of water before the hydrogen is sent to storage and oxygen to atmosphere.

8 The electrolytor pressure is controlled at 425 psig by a control valve in the hydrogen line from the unit. The separating drums are fitted with liquid level indicators and are also provided with low-level float-operated control valves. If the liquid level falls below a certain level the gases are discharged to atmosphere and if the level falls still further safety switches disconnect the power supply to the electrolytor. The vessels were not boilers within the meaning of the Boiler Explosions Act 1882, and were not subject to existing statutory requirements relating to pressure vessels.

9 Design loading of the electrolytor is 6000 amps at 1.78 volts. The operating temperature is 70–90°C.

## Plant operation

10 One operator per shift was employed on the electrolytor, each shift being 12 hours. The plant was normally operated 24 hours a day, 7 days a week. The operator's duties included starting up the electrolytor and shutting it down, noting relevant temperatures and pressures and carrying out purity checks on hydrogen and oxygen.

11 Hydrogen and oxygen can combine together with explosive force if there is a source of ignition. It is essential that steps are taken to ensure that they are kept separate once they have been generated by the electrolytor. The plant is designed to achieve this and the manufacturers have included in their instructions certain

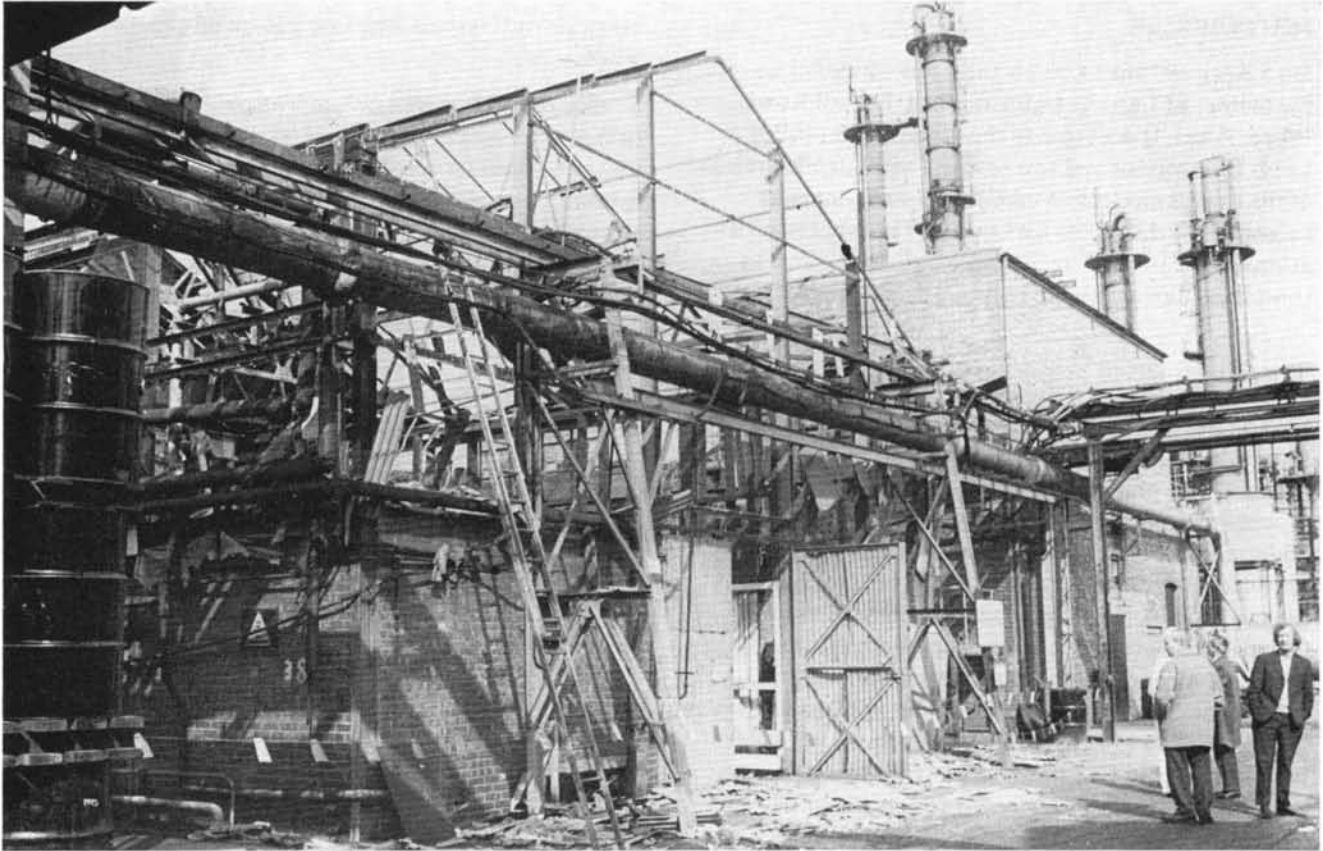


Fig 1 Exterior of plant building

procedures for routine tests and inspections. The relevant extract from the manufacturer's handbook is at Appendix 4.

## History of the plant

12 The plant was commissioned in May 1962 and has run since then partly on two of the four cell blocks and partly on all four. Between 1962 and 1966, excessive sludge deposition causing blockages in the cells (identified by high cell temperatures and voltage readings) caused changes to be made in the material used for the external electrolyte filters so as to improve their efficiency. The subject of sludge formation and its effects is discussed on page 12.

13 In 1966 the blockages became so bad that the electrolytor was dismantled. Sludge was seen to be blocking the small (2mm diameter) gas and electrolyte passages causing high cell temperatures and voltages. At the same time, some corrosion/erosion effects were seen on the goffer plates adjacent to the gas off-take ducts and there was slight attack on the anode gauzes (but not the cathodes).

14 Half of the total number of cells were replaced and polyethylene baffles were fitted near the (top) gas off-take ducts. This proved fairly effective in preventing subsequent blockage of the narrow gas passages at the top of the cells.

## Events immediately prior to the explosion

15 At 02.00 hrs on 2 April 1975 the plant was running normally when the operator heard (and logged) cracking noises from the cell block. He did not shut the plant down but reduced the cell current and the noise disappeared. After three hours he raised the current to its normal value, the cracking noise did not recur and the plant continued operating until 13.00 hrs on 2 April. A substantial leak of electrolyte was then observed at the periphery of the cell block, between two plates at the top centre of the middle of the cell block, in the vicinity of cell 79. The plant was shut down because of serious loss of pressure by the operator on duty (R Church).

16 The works engineer telephoned the makers, Lurgi, at 15.40 hrs on the same day. Lurgi were asked to send a German fitter over to caulk leaks on the electrolytor cell block.

17 The manufacturers sent one of their erectors (F Nickel) and he repaired the leak between 2 and 4 April. On 4 April he and the works engineer (C Jacobs) checked the repair as far as possible with the plant cold and decided to bring the plant up to operating pressure and temperature to test the repair fully. When after this there were no further leaks and the plant had been seen by the production manager (G Wood) it was decided to apply current and put the unit back into service. Mr Wood



stated that he spoke to both the start-up operator, Mr Church, and the night shift operator, Mr Campbell, for whose arrival Mr Wood had waited. He said that both operators were told that the repair had been completed and appeared satisfactory. A special light was installed in the area of the repair for the operators to observe any leaks which might have developed. In the event none did develop. Mr Wood stated that he stressed to both operators that if the latter had any doubts about the unit they must contact their shift supervisor immediately for contact to be made with the plant manager, with the site manager, or with himself, as necessary. The day foreman, Mr Atkins, stated that he spent some time in the Lurgi electrolytor unit on Saturday, 5 April, with the operator to establish that no untoward happenings had occurred or were occurring.

### Circumstances of the accident

18 On Saturday 5 April the operator on duty was R Church. He had come on duty at 06.30 hrs. At about 11.10 hrs there was an explosion in the oxygen separator drum which ruptured. This liberated a large quantity of caustic solution which splashed over the operator and covered most of his body. He was alone in the room at the time in accordance with normal practice. He was heard shouting for help by the shift supervisor (FW Howe) who was nearby and had hurried to the building after hearing a loud noise. Mr Howe found Mr Church kneeling on the floor of the building and led him outside. The factory rescue team took him to the washroom and put him in the shower. Shortly afterwards he was taken to hospital and died later as a result of caustic burns. Mr Howe, and RJ McCool who assisted Mr Church both received burns as a result of contact with the caustic solution on his clothing, and RS Boxall, a lorry driver who was passing the building at the time was also splashed with caustic on the head and arms. He was detained in hospital for a few days, but all three men were able to resume their work in a short time.

### Investigation of the accident

19 A preliminary visit to the site was paid by HM Deputy Superintending Inspector of Factories on the day of the accident, and the investigation proper was begun by HM District Inspector with the assistance of specialist inspectors from Headquarters on the following day, Sunday 6 April. At the same time an investigation team from Laporte Divisional Headquarters and representatives from the plant manufacturers from Germany were conducting their own enquiries. National Vulcan Engineering (for the insurers of the plant) and Burgoyne and Partners (consultants to Laporte) also carried out investigations. The plant was dismantled in the presence of HM Factory Inspectorate, and a number of items were sent to the Safety in Mines Research Establishment at Sheffield for metallurgical reports. A general discussion between the various parties was held on 13 May 1975 to agree as far as possible the cause of the accident and the appropriate action to prevent a recurrence.

### Damage caused by the explosion

20 The lightweight roof was almost completely blown off the building (fig 1) but adjacent and other buildings were hardly affected. There was no damage outside the factory, but the considerable damage to the electrolytor and its associated equipment included:

- Bolts and flanges connected to the oxygen collecting dome to the oxygen drum, in the main end flange of the oxygen drum and in the flange where the liquid level gauge bolted into the end of the drum were all stretched.

- The oxygen separator drum was ripped open and had expanded along its entire length.

- The vented float controlling the outlet from the drum and the float on the liquid level switch were both crushed.

- The take-off pipe welded to the top of the oxygen water separator was blown off.

- The oxygen water separator was severely distorted by internal pressure.

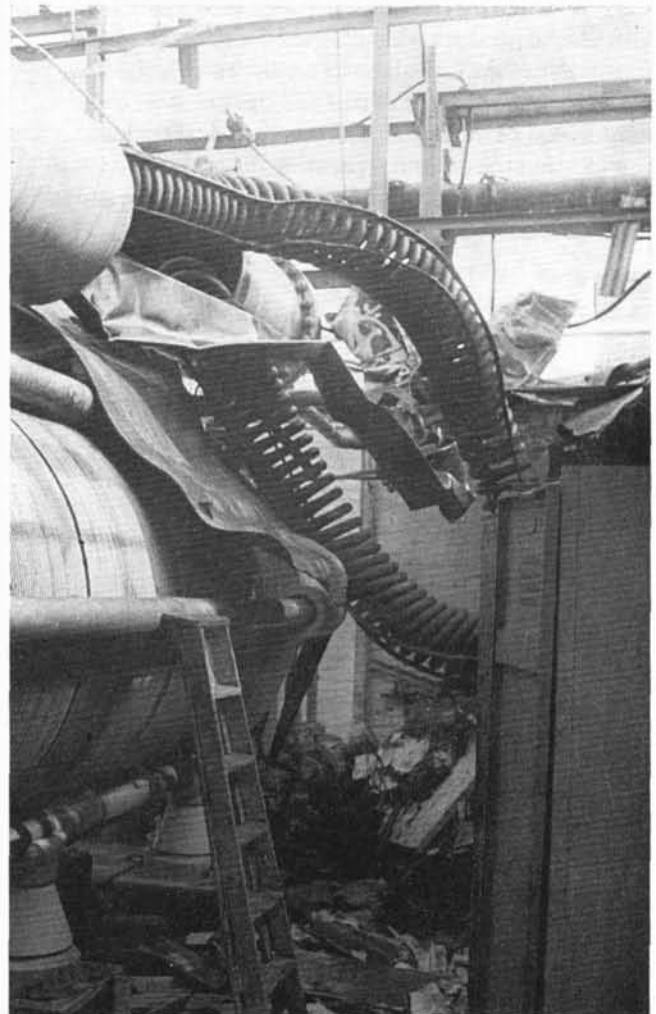


Fig 2 Electrolytor showing cell block and oxygen separating drum with cooling coil



## Immediate cause of the accident

21 Several theories were advanced about the cause of the explosion:

The explosion of a mixture of oxygen and oil which entered the plant in some way.

Blockage of the product hydrogen line resulting in electrolyte being blown into the oxygen separating drum through the balancing U-tubes.

Blockage of the product oxygen vent, resulting in a gradual build up of pressure within the separating drum.

A stress crack in the oxygen separating drum which resulted in a flow of hydrogen and electrolyte into the oxygen separating drum followed by ignition of the hydrogen/oxygen mixture.

Physical breakdown of the cell blocks resulting in mixing of hydrogen and oxygen to give a flammable mixture which was ignited.

22 The first question to be resolved was whether the rupture of the oxygen separating drum was a straightforward pressure vessel failure at the normal operating pressure of 425 psi (relief valve pressure 515 psi), or whether the pressure which caused the rupture was far greater than this. If the latter were the case the ignition of a flammable mixture of fuel and oxygen within the plant would be indicated. The metallurgical evidence suggests that the oxygen separating drum ruptured at a pressure of about 2000 psi, i.e. that the damage was due to an ignition.

## Dismantling the cell block

23 The most obvious way in which a flammable mixture of hydrogen and oxygen could arise is by physical breakdown of the internals of the cell blocks. Before the cell blocks were dismantled an internal examination was carried out by passing an Intrascope (an illuminated viewer) into the gas ducts which pass through the tops of the cells and collect the hydrogen and oxygen, together with electrolyte. Damage was seen in one particular area of one of the cell blocks.

24 The cell blocks were then carefully dismantled, under the supervision of HM Factory Inspectorate. All cells were examined and any which showed any signs whatsoever of abnormality were segregated for further detailed examination. It was found that:

Certain electrolyte and gas passages were blocked with sludge.

Crystalline potassium hydroxide deposits were seen on one plate, indicating gross over-heating.

There was heavy sludge deposition in some cells.

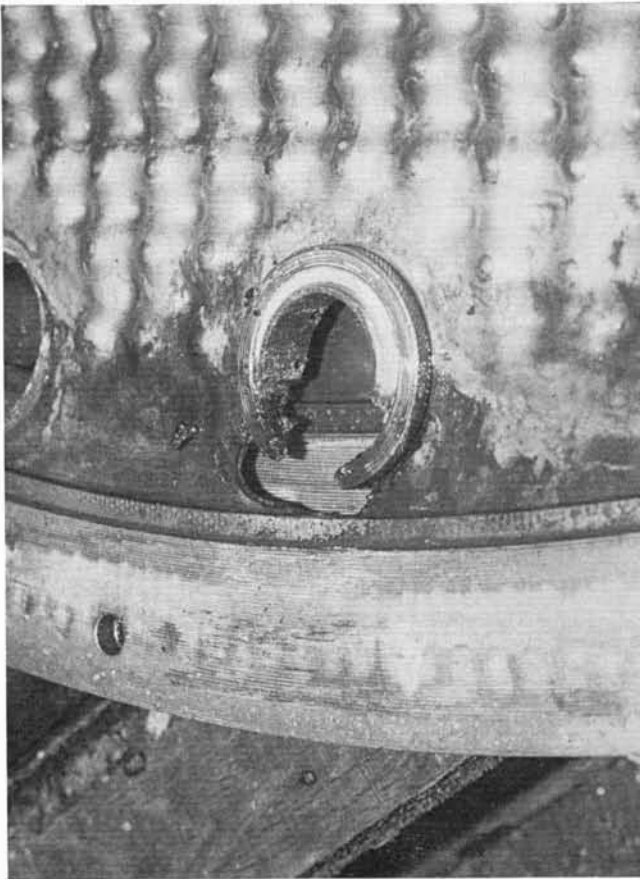
There was surface pitting of the plating on some of the goffer plates. (In some instances this had resulted in a hole right through the plate, fig 4.)

There was corrosion/erosion damage to some electrode gauzes with associated failure of the asbestos separators progressing to complete breakdown of the fabric of the cell, so that there was inter-connection between the hydrogen and oxygen ducts (fig 5).

In one case (at the point where the electrolyte leak was observed on 2 April) the flange of the cell was eroded through to the outside (fig 6).



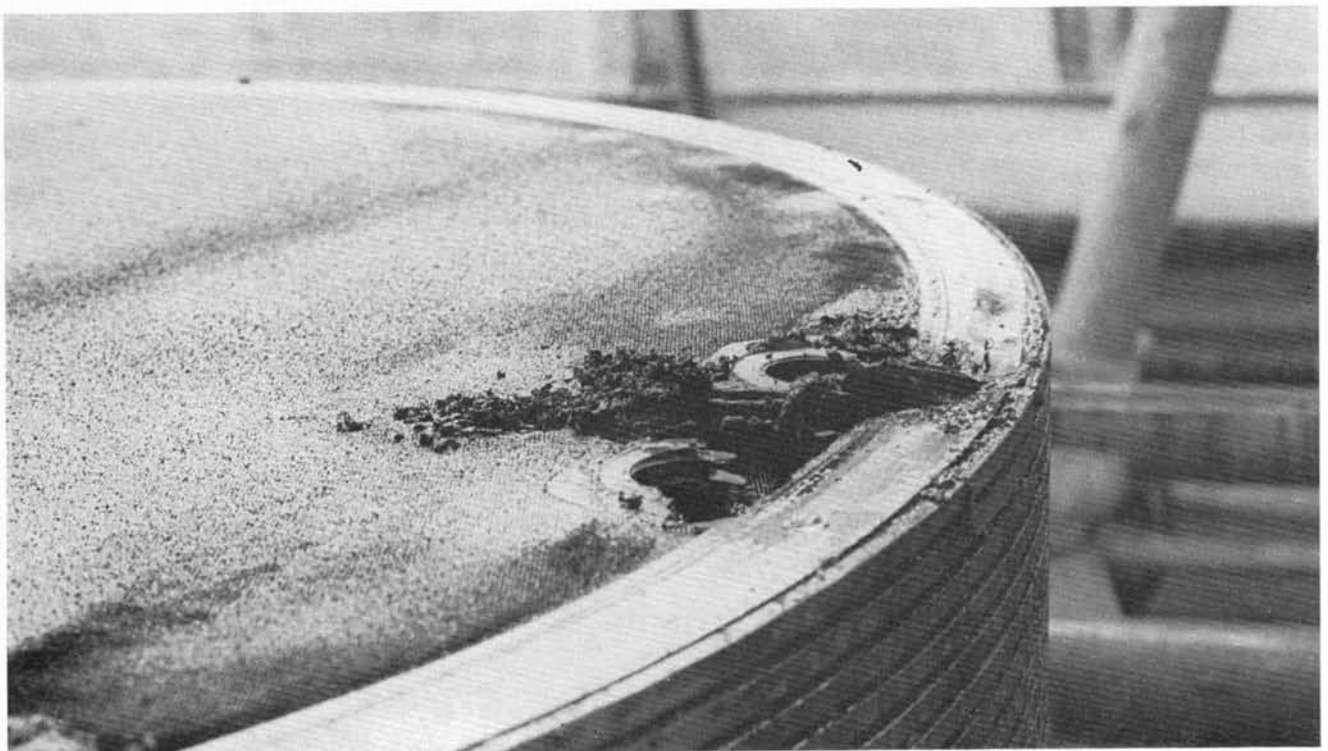
Fig 3 Dismantling a cell



**Fig 4** Perforated goffer plate



**Fig 5** Cell 16/3 showing damage to electrodes and asbestos separator



**Fig 6** Cell 79 showing damage in vicinity of gas off-takes

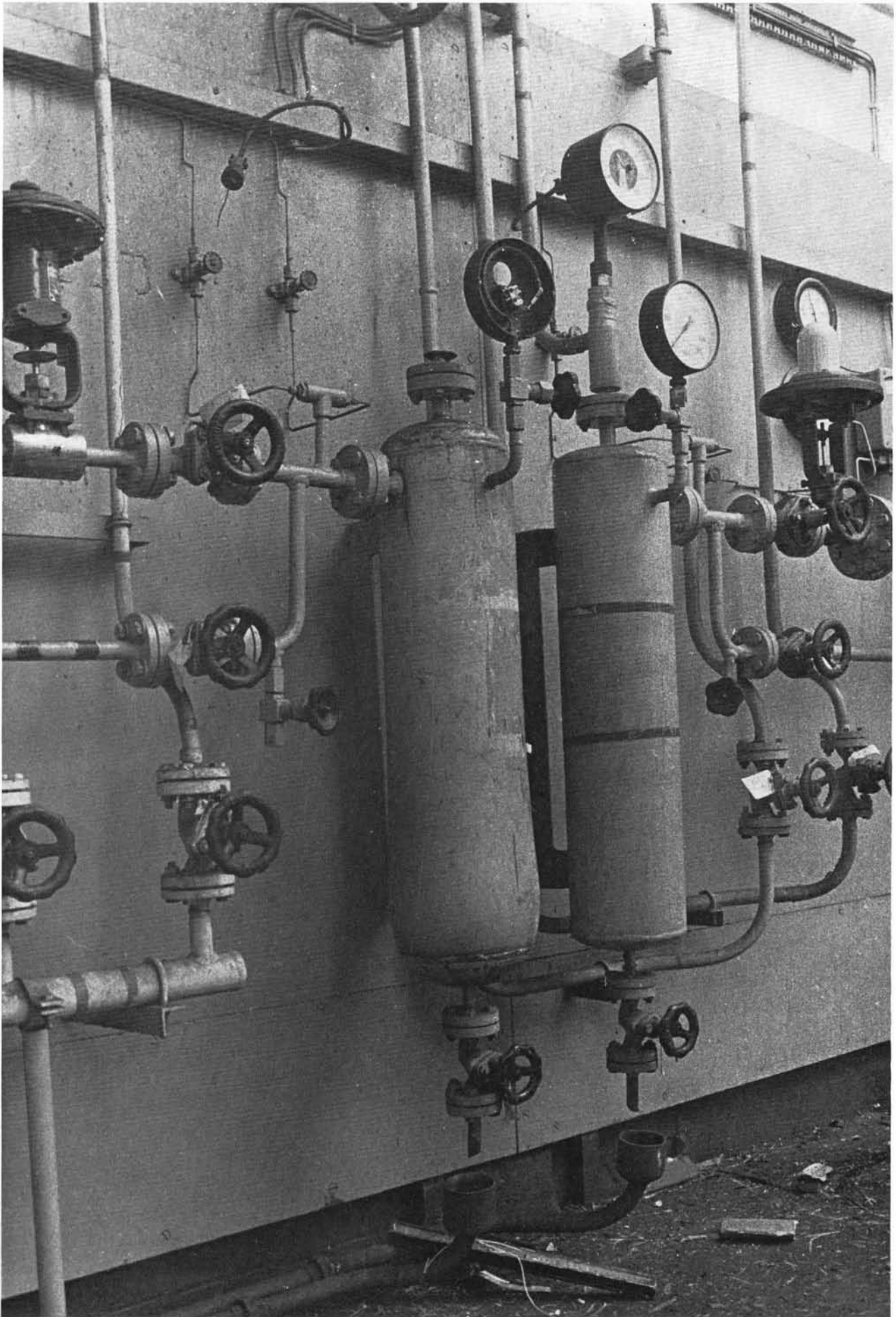


Fig 7 Water separators showing distortion of oxygen separator on left



## Discussion

25 Calculations of explosion energy from observation of the physical damage are very approximate, but an attempt has been made by chemical inspectors. Their best estimate is that the energy required could be obtained from 10 cubic feet of hydrogen, which would be produced by one cell in about 10 minutes.

26 Laporte carried out a mass balance on the quantity of hydrogen manufactured and used just prior to the explosion and found that no less than 50% of the hydrogen made could not be accounted for. In other words, during this crucial period, there was gross cross-transfer of hydrogen into the oxygen stream. Probably some cross-transfer had been occurring prior to the final 18 hours of the plant's life. The cracking noises on 2 April point to this. These were probably caused by the internal explosion of relatively small pockets of hydrogen and oxygen, which led to the leak at the periphery. It is probable that the main internal failure occurred at the time of the leak and in the few hours immediately preceding the explosion, contamination of the oxygen by hydrogen was severe. An explosive mixture may have existed in the plant for several hours before it was ignited.

27 The examination of the cell block provided convincing evidence that the explosion was due to the ignition of a flammable mixture of hydrogen and oxygen which arose from a severe physical breakdown inside certain of the cells. When this occurred, not only would the product hydrogen and oxygen from the damaged cells intermingle, but the whole of the gaseous product from the electrolytor would be liable to mix. Because of the magnitude of the damage inside the cells, and the relatively small quantity of hydrogen needed to form an explosive mixture inside the oxygen separating drum, a hazard situation could arise a very short time after the internal breakdown.

28 Lurgi have stripped down a number of electrolytors over the years and say they have never seen internal damage of this magnitude. In the early life of this plant, some pitting of the nickel plating on the goffer plates was seen and these were replaced; also slight degradation of some of the electrode gauzes was observed.

29 Lurgi had previously been aware of cell failure but believed that it would be very slow and that adequate warning would be given by the monthly temperature and voltage checks on the cells and by the hourly analyses of the oxygen and hydrogen.

## Analysis of the product gases

30 Because of the type of pressure control on this plant, contamination of the oxygen by the hydrogen is favoured, rather than the reverse. This is intentional, since the function of the plant is to make very pure hydrogen, the oxygen being a waste product.

31 Normal hydrogen purity is 99.9% compared to the oxygen, which is 99.2%. Reduction of the cell current reduces the quality of both gases but the hydrogen would only drop to perhaps 99.7%, the oxygen to 98.0%. Thus cross-contamination could theoretically be identified from a test on the hydrogen, but the more noticeable effect would be on the oxygen. After the explosion, hydrogen in storage was analysed and its quality found to vary between 99.0% and 99.6%, suggesting that severe cross-contamination had occurred prior to the explosion and that the oxygen was grossly contaminated with hydrogen, probably within the flammable range (lower flammable limit corresponds to 95–96% oxygen).

32 It follows that the most significant process control test for giving warning of an explosion was the oxygen purity test. The Laporte plant operating manual fails to mention the risk of a severe explosion if the quality of the oxygen or hydrogen falls.

33 Other measurements, such as the monthly cell voltage and temperature checks and the hourly gas and electrolyte temperatures, are intended to give a long-term indication of the state of the cells (with respect to blockage by sludge). An extract of the log sheet used on the plant is at Appendix 5.

34 The carrying out of the gas analysis every hour would have been inadequate to identify the massive internal cell breakdown; continuous monitoring would have been better. Nevertheless it is probable that for a considerable period of time, perhaps of days or weeks, some cell failure was occurring and this should have been shown up by deteriorating gas quality, particularly of the oxygen. Reference to the plant log sheets reveals no such indication.

35 The oxygen purity is dependent on cell current, a lower current tending to give poorer quality. It was suggested by Lurgi, and the log-sheets confirm this, that the analysis figures for the hydrogen seldom varied from 99.9% and for the oxygen analyses reported, the only variation occurred when the related cell current was altered. One would expect, however, some variation in the analysis readings for other quite normal reasons (e.g. analyser tolerance). The log-sheets show that if, for example, the cell current is reduced, the oxygen figure written in is also reduced. If the current is then increased the next hourly entry for the oxygen analysis corresponds always to the higher current reading, *whether this was implemented five or fifty-five minutes earlier*. In fact, the oxygen quality should climb gradually back up after an adjustment in the current.

36 The inference is that the operators were not carrying out these analyses at the required intervals and that the hourly figures on the log-sheet were based on their experience, varying, in the case of the oxygen, in relation to the cell current alterations. When questioned by the District Inspector and the Chemical Inspector one of the process operators said that he only carried out the analysis two or three times in every 12 hours.

## Effect of sludge formation on the internal condition of the cells

37 Ever since the plant was first commissioned the production of sludge had been a problem. Its presence manifests itself by increases in the monthly cell temperature and voltage readings. These increases have been regarded as indicative that the sludge had reduced the flow of electrolyte through the cells (another indication is a decrease in the reading for the electrolyte flow rate). When this occurred the plant was flushed through with water and in most cases the readings returned to normal, indicating that the blockages had been removed. If this did not occur on any particular cell, the cell was shorted out and no longer used. After the early experience of sludge formation the external filtration arrangements for removing the sludge from the system were improved. The system was flushed out periodically in accordance with normal practice.

38 The following sequence of events by which a flammable mixture of hydrogen and oxygen arose within the plant can be postulated:

- Blockage by sludge of the narrow electrolyte passages, which admit electrolyte at the bottom of the cells.
- Reduction in electrolyte flow.
- Increase in internal or cell temperature.
- Increase in electrolyte concentration.
- Increased linear velocity of the electrolyte, where the passages are partially blocked.
- Corrosion/erosion of both the electrode gauzes possibly due to hydrogen embrittlement.
- Physical breakdown of gauzes and separators resulting in mixing of the hydrogen and oxygen.

## Safety organisation

39 The overall management structure of Laporte's is shown in Appendix 6 and the safety and health organisation at the Ilford plant at Appendix 7:

*S Durrant*, the Safety Manager, is responsible for controlling the safety activities on the site. Although he has no formal qualifications he has been with the firm nearly all his working life and is fully acquainted with all processes on the site and has worked, at one time or another, on all of them, and has a detailed knowledge of every process. He has been active for many years in assisting and organising health and safety systems at this site and has assisted to a large extent in formulating codes of safe practice; he has also been responsible for safety training.

*C Arnold BSc*, the Site Technical Manager is responsible for process safety, and works in close association with the Divisional Hazards Department who are responsible for auditing all hazardous and other specified plants in the Division, and approving modifications to plant or operating conditions.

*P Lynsky, BSc FRIC CEng FICHEME*, the head of the Divisional Hazards Department reports direct to the Divisional Chief Executive on safety matters; he is assisted by *D Read, BSc*. Functional contact is maintained with the Site Manager, *J Leach, BSc*, the Site Technical Manager, and the Site Safety Manager. *Dr E Hutton, PhD BSc ARIC*, a Group Hazards Manager, is also available. His responsibilities are on a group basis and he can be called upon by the Divisional Chief Executive or Divisional Hazards Manager.

The firm, and specifically the Ilford management, made use of outside consultants to advise on specific problems; these are *Dr JH Burgoyne & Partners*.

*C Jacobs, BSc CEng MICHEME*, the Works Engineer has a team of some two dozen qualified fitters who are responsible to him. Mr Jacobs is responsible for the maintenance of all plant and installations.

Several of the fitters hold Higher National Certificates and City of Guilds Certificates.

*G Wood, BSc*, is the Production Manager, and *M Ellison, BSc*, Plant Manager, is directly responsible to him.

40 The supervisory structure is indicated in the management chart and consists of a day foreman who is responsible for the administration and technical problems reporting through the plant manager. A shift supervisor is available for the site outside normal hours and is responsible for all processes on the site. The firm have at all times been at pains to point out that the operators in charge of the electrolytor plant were senior operators or shift leaders and that this type of operator would be responsible for the control of other process operators working on his plant.

41 The arrangements for reporting unusual occurrences were that the operators were instructed to carry out the following:

- To enter a record of minor abnormalities on the log sheet.
- To use a log book for passing information from shift to shift.
- To report any abnormality which was considered outside normal occurrence to the supervisor so that, if necessary, contact could be made with management.
- To shut down the unit immediately on their own authority in the event of any doubt in their minds.

## Conclusions

42 The oxygen separating drum of the Lurgi electrolytor exploded due to the ignition (possibly from an electrical short in a damaged cell) of an explosive mixture of hydrogen and oxygen inside it.

43 The internal breakdown of the cells probably had been initiated a considerable time before the explosion, the cracking noise in the cell block on the 2 April was

indicative of this, but the breakdown did not become extensive until after the start-up which followed the caulking repair on 4 April. There was probably an explosive mixture of gases within the plant for several hours before the explosion, and a concentration of hydrogen in the oxygen below the lower explosive limit, but high enough to be detected for a considerable period before this.

44 It seems likely that the possibility of failure might have been recognised earlier and the explosion perhaps prevented if:

The gas analysis for determination of the purity of the oxygen produced had been diligently carried out.

There had been a system for checking the accuracy of the gas analysis recordings carried out by the operators of the Lurgi unit.

The dangers that might result from failure to carry out oxygen analysis in accordance with the company's instructions had been emphasised to the operators, for example by means of a permanent warning notice.

The plant had been kept shut down until the cause of the cracking noises of 2 April, and the subsequent leak of electrolyte had been determined. (A check on gas purity at this time would probably have given an indication of cross contamination).

The cause and effects of sludge formation had been more thoroughly investigated.

45 Lurgi and Laporte should have considered more carefully whether the manual hourly test for oxygen and hydrogen purity was an adequate safeguard for this plant or whether continuous gas analysis, interlocked so as to shut down the plant should have been provided. As it was, the manual gas analysis was the most important safety precaution being taken in relation to the plant, much therefore depended on its being carried out conscientiously every hour. Laporte should have ensured that it was done. If the analysis had been carried out diligently, it would almost certainly have given warning that a dangerous situation was being approached, probably hours or days before the explosion, although it would not have identified a rapid approach to danger, in a period of less than an hour. In addition, the accuracy of the analyser should have been checked by means of a test gas.

46 These conclusions were considered by HM Factory Inspectorate in the light of Section 2 of the Health and Safety at Work etc. Act, which requires "It shall be the duty of every employer to ensure, so far as is reasonably practicable, the health, safety and welfare at work of his employees . . ." including "in particular, the provision and maintenance of plant and systems of work that are so far as is reasonably practicable, safe . . .". The inspectorate formed the opinion that there was, *prima facie*, a contravention of this section and on 5 August 1975 an information was laid against Laporte Industries Limited under Section 2 of the Health and Safety at Work etc. Act 1974.

## Risk to the public

47 No member of the public was injured as a result of the explosion, and damage to property was entirely confined within the factory site. The question whether the failure of the plant could, in other circumstances, have affected the general public is considered in Appendix 8. The general problem of siting of hazardous plant in relation to the public is currently being considered by the Advisory Committee on Major Hazards, and this report will be drawn to their attention.

## Lessons to be learned

48 The principles of the legislation which regulates the thorough examination of steam boilers, air receivers, etc. should be extended to pressure systems of this type.

49 The following precautions should be taken in the operation of this type of plant:

1 Both hydrogen and oxygen quality should be monitored by intrinsically safe continuous analysers linked to indicator/recorder/controllers. These should actuate visual and audible alarms when oxygen purity falls to 98.8% or hydrogen purity to 99.7% and shut down the plant when oxygen purity falls to 98% or hydrogen purity to 99.5%. The continuous monitoring instruments should be regularly checked, serviced and calibrated.

2 The continuous monitoring should be backed up by hourly manual gas analyses carried out by the operators, and these in turn should be checked by a similar analysis by laboratory (or other skilled) personnel once every 24 hours. Persons making such tests should be under clear instructions to report *any* variations in gas purity and to close the plant down instantly in the event that purity falls below 98% for oxygen or 99.5% for hydrogen.

3 The internal condition of the plant should be systematically monitored:

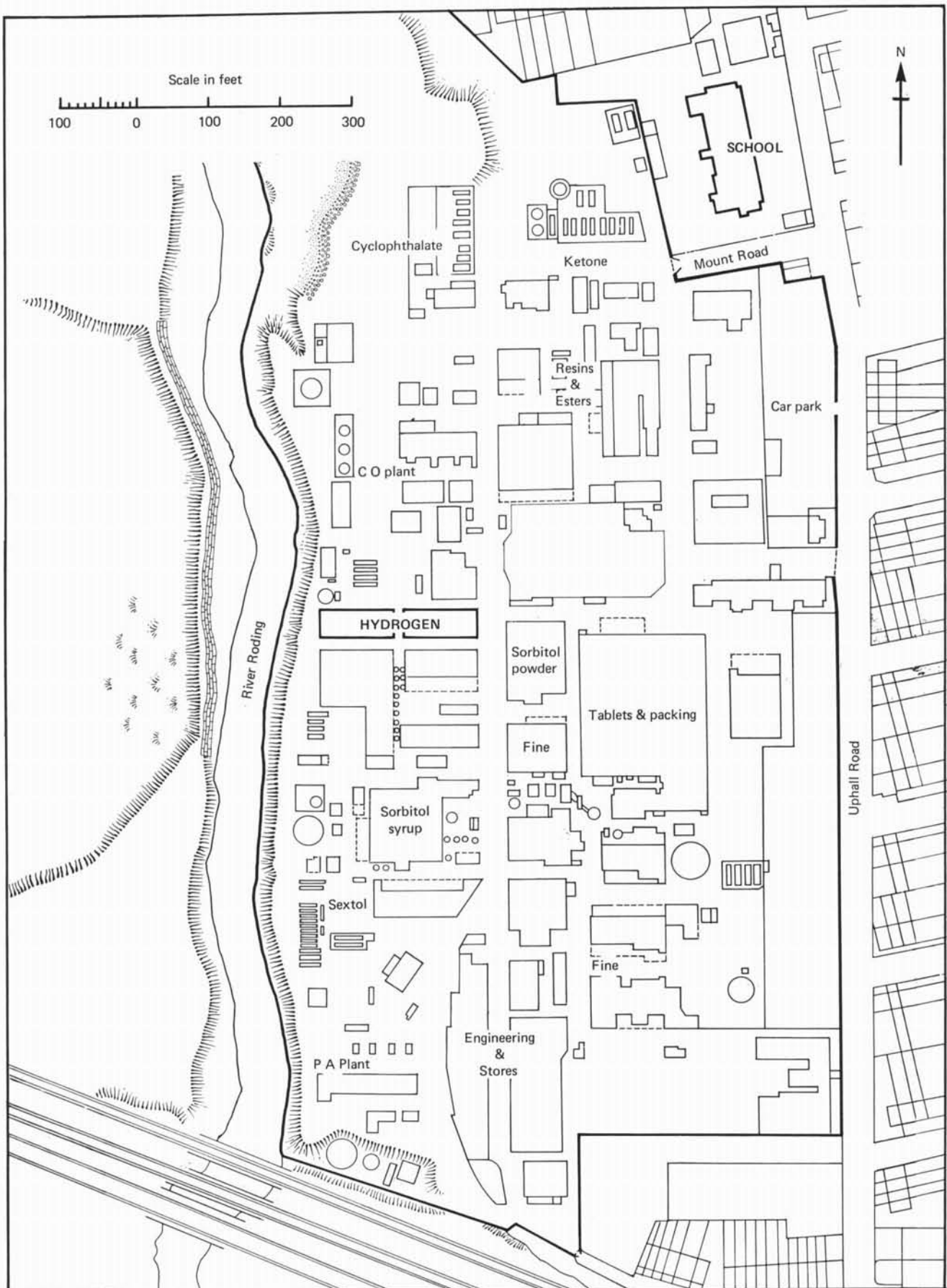
- (i) by the measurement and study of sludge formation,
- (ii) by the studying of the pattern of:
  - (a) cell voltages and temperatures;
  - (b) gas/electrolyte temperature,
- (iii) by the internal examination of the gas ducts by means of a remote viewing instrument.

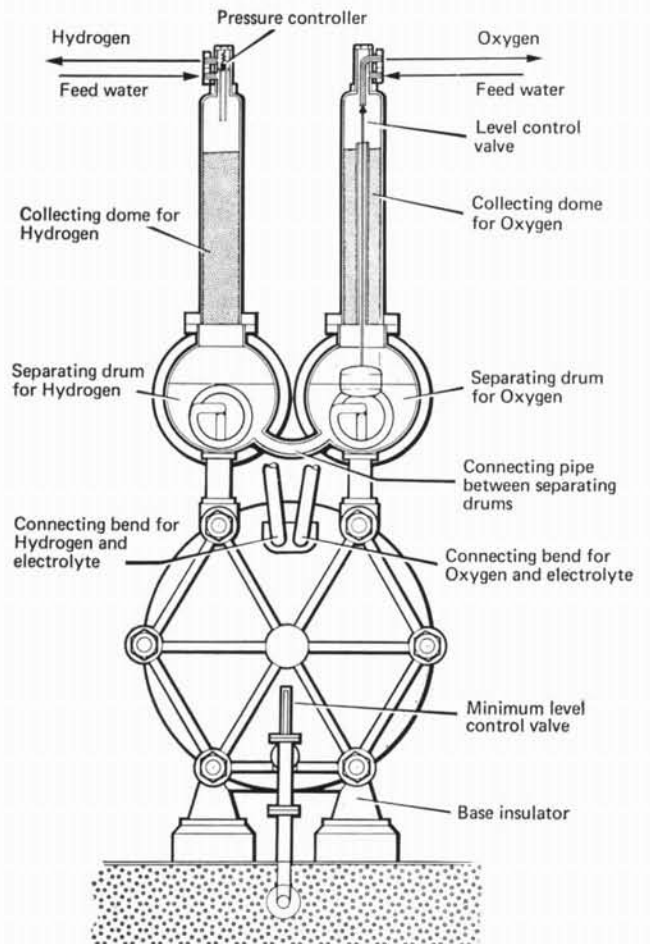
## Other action

50 Early in the investigation contact was made with the two other users of this equipment in the United Kingdom, so that appropriate information and advice could be given to them. They have now been advised of the above conclusions and of the lessons to be learned in paragraph 49. The question of stripping down and examining their plants internally for signs of corrosion/erosion has been discussed with them.

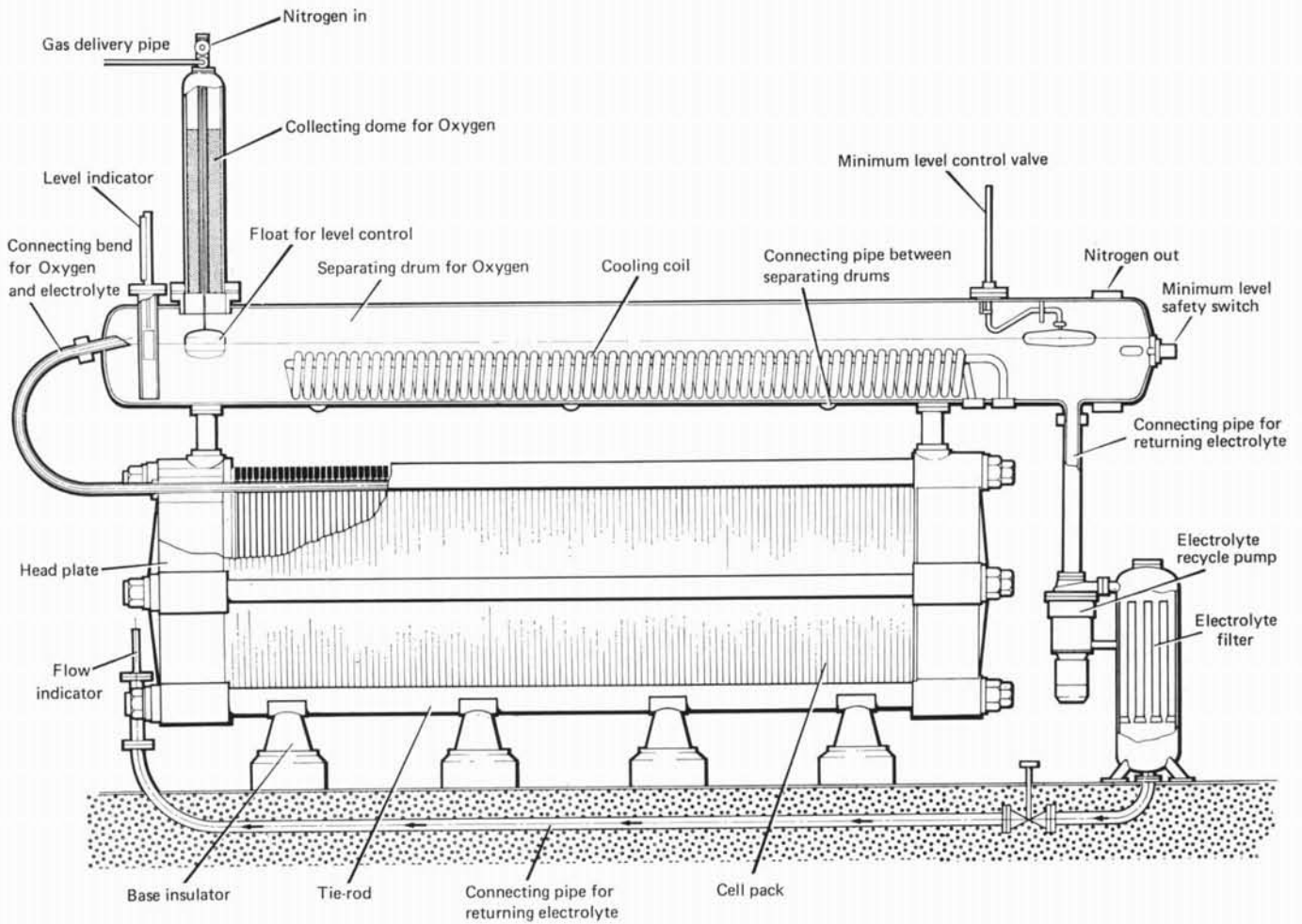


# Appendix 1 Site plan





## Appendix 2 General arrangement of electrolytor





# Appendix 3 Sketch of cell

Section through Zdansky-Lonza cell

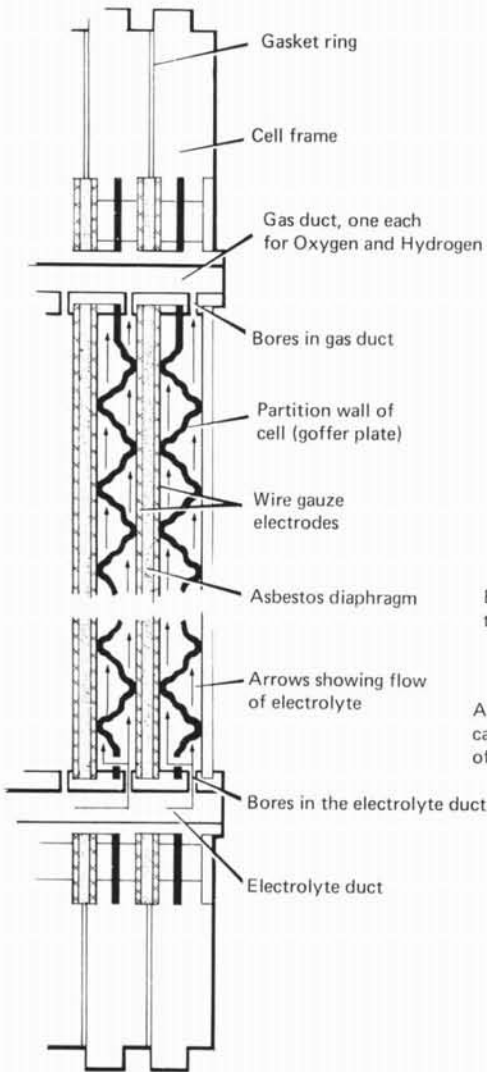
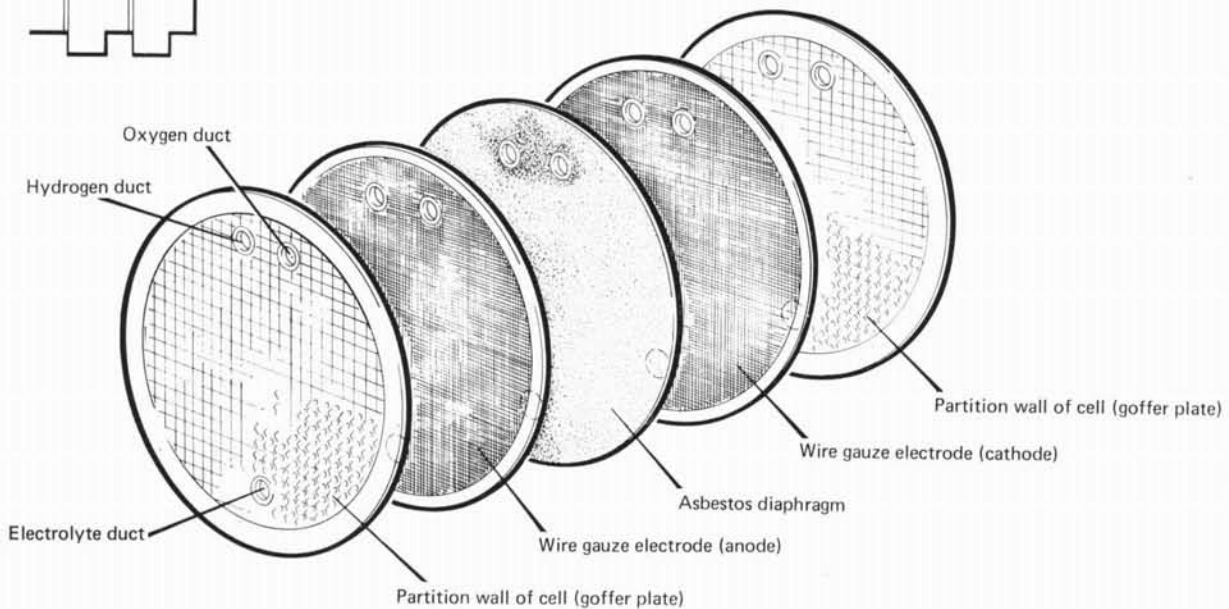
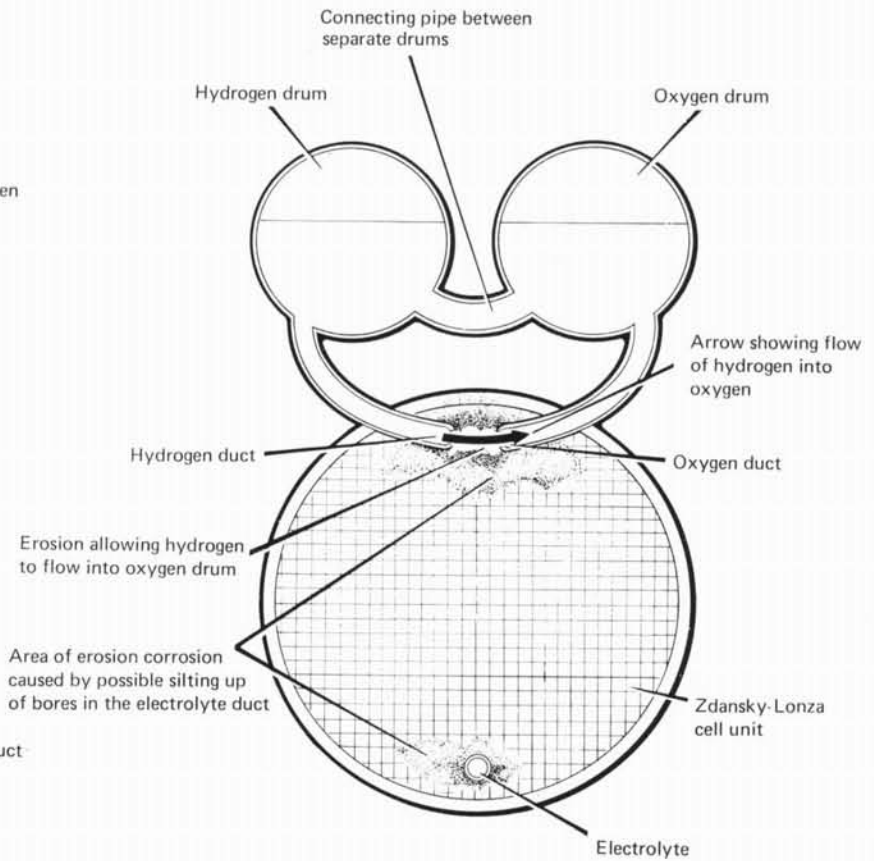


Diagram showing possible cause of explosion



## Appendix 4 Extract from manufacturers' handbook

### Electrolytor operating instructions

#### 4 Supervision of Operation

##### 4.1 Hourly Inspection

The following process variables shall be checked at hourly intervals and recorded in the plant record book:

- Amperage
- Voltage
- H<sub>2</sub> purity
- O<sub>2</sub> purity
- Pressures
- Temperatures
- Rate of circulating electrolyte at the electrolytor (front end and rear end).

When continuously operating recording analysers are available, it will be sufficient to check the reading from these instruments once per day by hand analysis of H<sub>2</sub> and O<sub>2</sub>.

Make sure that the operating values are always in compliance with the Technical Data of the electrolytor given under Section 1 of the present Instructions.

##### 4.2 Inspections at the beginning of each Shift

###### *Nitrogen Supply:*

Make sure that a sufficient number of nitrogen cylinders are connected to permit depressurisation of the electrolytor in case of emergency and subsequent purging with nitrogen.

Moreover, it is recommended to keep available an adequate supply of nitrogen sufficient to re-start and shut-down the electrolytor twice.

###### *Water Separators:*

The water separators should be drained at the beginning of each shift, if necessary at more frequent intervals.

##### 4.3 Weekly Inspections

###### *Cell Voltage:*

The voltage of each cell shall be checked and recorded at weekly intervals.

It might happen that the voltage of some cells rises temporarily. If the voltage rises beyond 1.95 volts at 6000 amperes, the relevant cell shall be short-circuited for a while. As a rule, the short-circuit can be removed again after about 4 weeks, because the voltage has gone back again to a lower value during that period.

Another procedure, which is generally successful, is the purging of the electrolyte duct and the two gas ducts during the shut-down of the electrolytor.

###### *Cell Temperature:*

The temperature of alternate cells shall be checked and recorded at weekly intervals. The temperature should not exceed 95°C, measured at the circumference of the cell frame. If it happens that the temperature of any cell exceeds this limit, the steps described above in case of excessive voltage of any cell shall be taken.

###### *Electrolyte Density:*

The density of the electrolyte shall be measured once per week. It shall be within the range of 1.232 and 1.236 kg/litre, measured at 15°C.

###### *Leakproofness:*

The leakproofness of the complete unit, and in particular of the cell packs of the electrolytor, shall be checked once per week. A leakage may preferably occur at the underside of the cell packs, if the tie-rods are not sufficiently tightened, or if the electrolytor was started at too low a temperature. Minor leakages at the cell packs should be removed by distilled water with the aid of a flat brush, with the current supply being shut off. In the case of more severe leakages (dripping), the tie-rods shall be retightened, with the power supply being shut off.

##### 4.4 Monthly Inspections

###### *Tie-rods:*

The tensile stress of the tie-rods shall be checked once per month with the aid of the deformeter.

During the initial months of operation, it is recommended to measure the tensile stress at weekly intervals, because the cell gaskets might not yet be fully seated, which results in a premature reduction of the tie-rod stresses.

For the taking of measurements, the unit shall be under the following conditions:

- Electrolytor depressurised, filled with electrolyte;
- Temperature in electrolyte ducts between 35 and 40°C.

Under these conditions, the average tensile stress must be \*60 tons per tie-rod at the minimum

The difference between the stresses of the individual tie-rods shall not be greater than 30 tons.

If the average tensile stresses drop below 50 tons per tie-rod, the tie-rods shall be retightened uniformly and carefully until an average stress of

\*max 90 tons per tie-rod

has been established.

The individual stresses must by no means exceed  
\*95 tons per tie-rod.

*Important Note:* Retightening of tie-rods should only be done when the electrolytor is depressurised.

#### *Electrolyte Purity:*

The purity of the electrolyte shall be checked by analysing to make sure that the maximum impurities per litre of caustic potash solution of a density of 1.234 kg/litre at 15°C are not exceeded:

K <sub>2</sub> CO <sub>3</sub>	20,000 mg/litre
K <sub>2</sub> SO <sub>4</sub>	3,500 mg/litre
SiO <sub>2</sub>	2,500 mg/litre
KCl	80 mg/litre
Al <sub>2</sub> O <sub>3</sub>	80 mg/litre

If one of these figures is attained, the electrolyte shall be replaced.

As regards the procurement of caustic potash and caustic potash solution respectively, it should be noted that the raw materials are not contaminated with heavy metals. The impurities contained in the prepared caustic potash solution of a density of 1.234 kg/litre at 15°C should not exceed the following maximum level:

Total of Pb, Hg, Sn, As, Sb : 1 mg/litre.

#### *Measuring Instruments and Switches with Magnetic Transmission:*

These instruments (viz. electrolyte circulation meter, electrolyte level gauge, level switch in separating drums) shall be inspected from time to time, in particular with regard to the proper condition of the transmission magnets. If necessary, the instruments shall be cleaned. Heavy contamination might cause clogging of the magnets resulting in a failure of the instruments and switches.

#### *Measuring Instruments and Switches with Electrical Contacts:*

These devices shall be inspected from time to time as to the correct setting of the contacts and the proper functioning of same.

#### *Intermediary Cooling Cycle:*

Approximately 1 g NaNO<sub>2</sub> per litre of water shall be contained in the intermediary cooling cycle as corrosion inhibitor. This shall be checked by analysing.

#### *Cleaning of Filters:*

The electrolyte filter connected with the electrolytor is equipped with a number of filter bags which collect the foreign matter contained in the electrolyte. The rate of

circulating electrolyte decreases with increasing contamination of the filter bags. By opening the throttling valve installed in the electrolyte recycle line somewhat, the rate of circulating electrolyte can be maintained at the prescribed level.

However during the course of time the permeability of the filter cloths might have been reduced to such a level that the opening of the throttling valve will no longer effect an increase of the rate of the circulating electrolyte. If that condition arises, the filter casing shall be opened, after the electrolytor has been depressurised and drained beforehand. The filter bags are then removed and cleaned carefully.

*Important Note:* Make sure that the filter cloths are not damaged during cleaning.

*Important Note:* When cleaning the filters, the after-filter shall also be opened and cleaned.

## **5 Procedure in Case of Operational Troubles**

- 5.1** Operate the emergency cut-out push button switch.
- 5.2** Shut off H<sub>2</sub> and O<sub>2</sub> production lines.
- 5.3** Completely depressurise the electrolytor to atmosphere gradually (watch levels!).
- 5.4** Purge the depressurised electrolytor with nitrogen.
- 5.5** Inform the plant manager.

*Important Note:* Before the electrolytor is restarted after removal of any operational trouble, the plant manager must satisfy himself that the unit is again ready for operation.

## Appendix 5 Extract from log sheet for 2 April

	A	V	Pressure			Gas Analysis	
			Plant	O <sub>2</sub>	H <sub>2</sub>	% O <sub>2</sub>	% H <sub>2</sub>
01:00	2600	460	420	390	410	99 <sup>2</sup>	99 <sup>9</sup>
02:00	2600	460	420	390	410	99 <sup>2</sup>	99 <sup>9</sup>
03:00	1500	450	410	390	410	98 <sup>4</sup>	99 <sup>9</sup>
04:00	1500	450	410	390	410	98 <sup>4</sup>	99 <sup>9</sup>
05:00	2000	450	410	390	410	98 <sup>4</sup>	99 <sup>9</sup>
06:00	2500	460	410	390	410	99 <sup>2</sup>	99 <sup>9</sup>
07:00	2500	460	410	390	410	99 <sup>2</sup>	99 <sup>9</sup>
08:00	2600	465	420	390	410	99 <sup>3</sup>	99 <sup>9</sup>
09:00	2600	465	420	380	410	99 <sup>3</sup>	99 <sup>9</sup>
10:00	2600	465	420	380	420	99 <sup>3</sup>	99 <sup>9</sup>
11:00	2600	460	420	380	420	99 <sup>3</sup>	99 <sup>9</sup>
12:00	2600	460	420	380	420	99 <sup>3</sup>	99 <sup>9</sup>

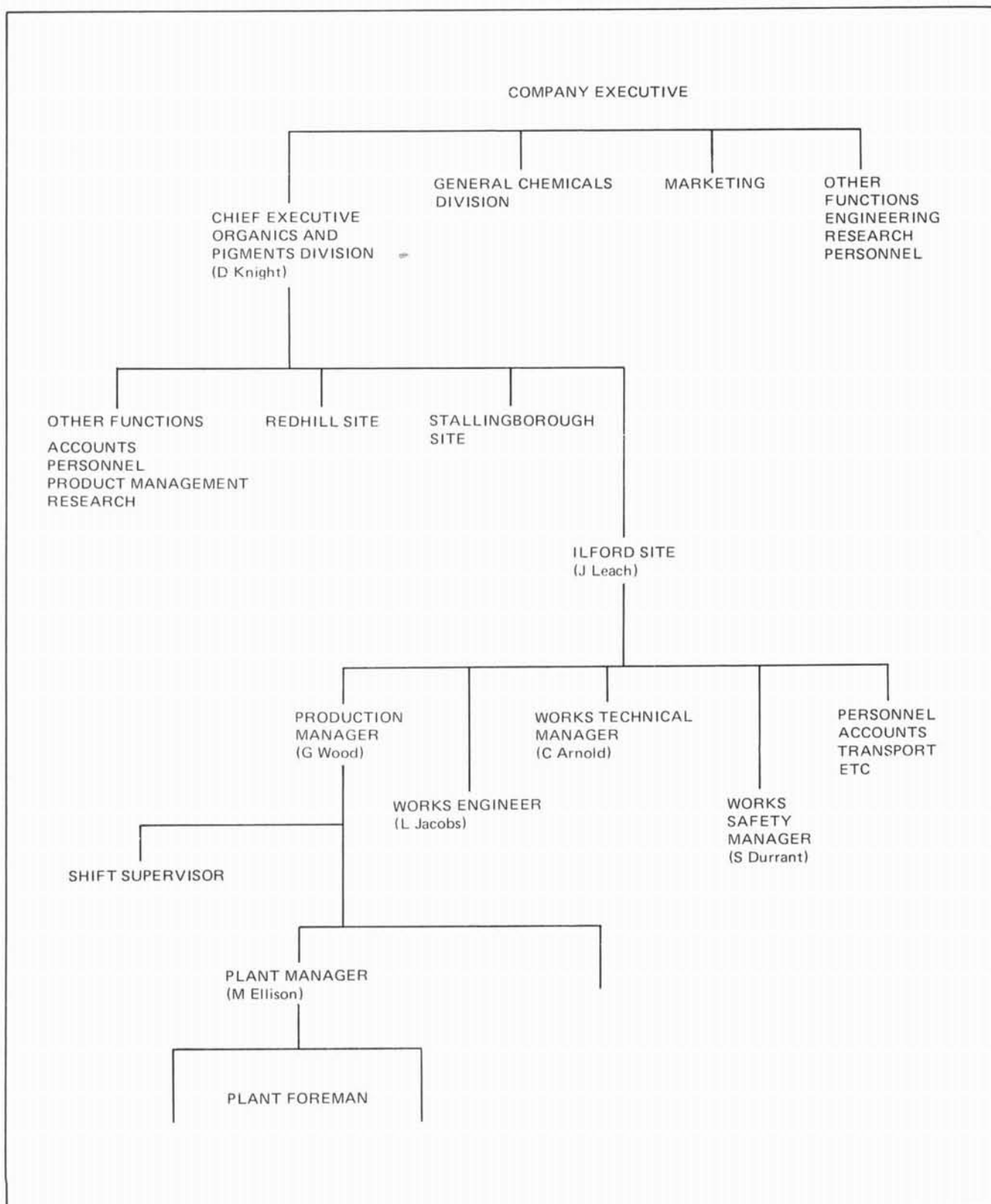
### NOTES

02:00 Cracking noises coming from electrolytor blocks: reduced to 1500 amps for two hours and increased hourly to 2500. Seems OK.

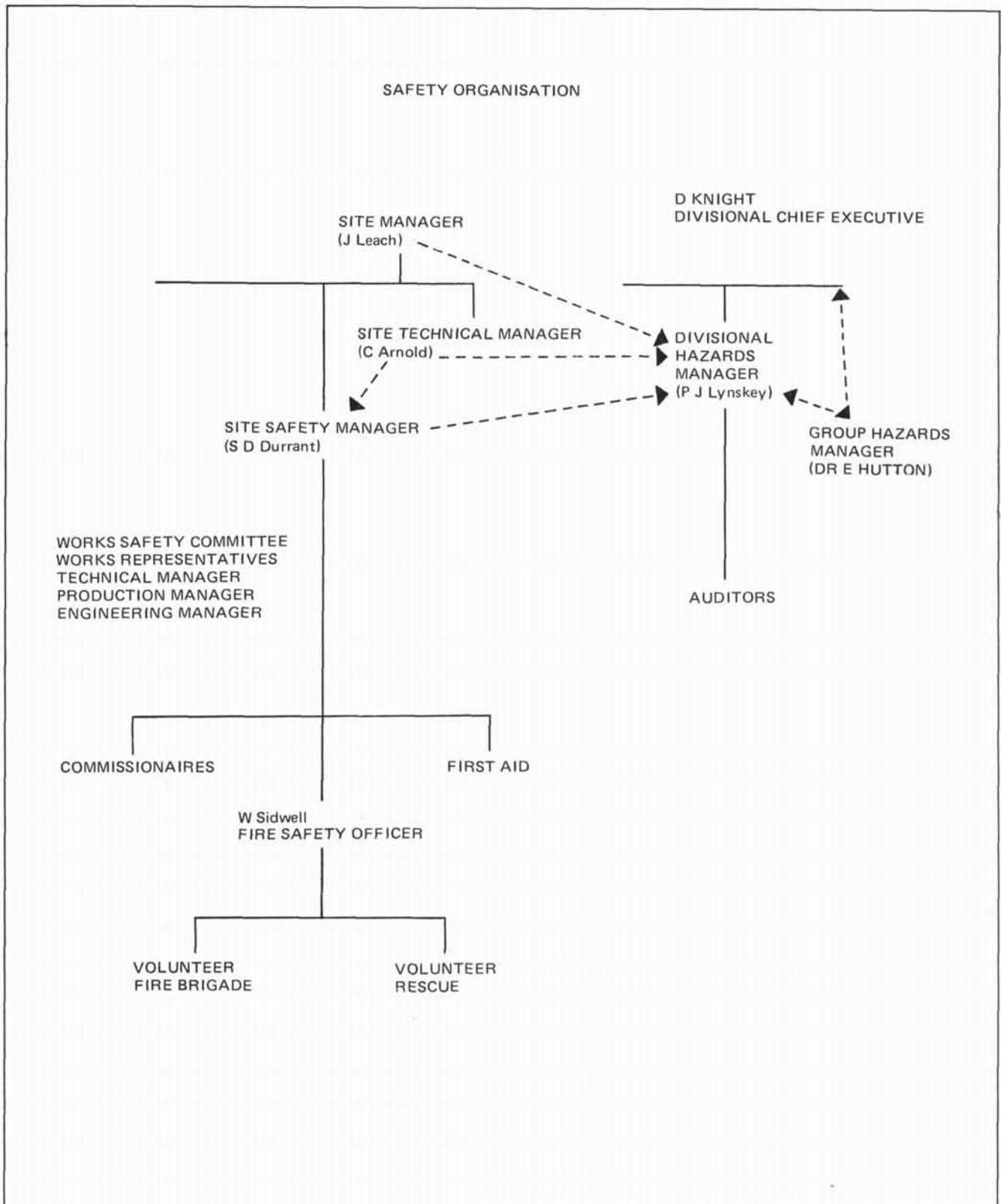
TK CAMPBELL



## Appendix 6 Management organisation



# Appendix 7 Ilford plant organisation chart



## Appendix 8 Risk to the public

In the event no member of the public was injured and no damage was caused beyond the immediate vicinity of the explosion. Nevertheless, it may be asked whether, in other circumstances, injury to persons and damage to property outside the workplace might have occurred. It is possible to calculate, given the volume and pressure of the gas, the energy available from a stoichiometric mixture of hydrogen and oxygen. This occurs when the contamination of oxygen and hydrogen produces a mixture containing  $33\frac{1}{3}\%$  oxygen,  $66\frac{2}{3}\%$  hydrogen. An explosive mixture would have been reached when the pure oxygen produced by the process was contaminated by approximately 5%\* hydrogen, so the likelihood of a stoichiometric mixture being reached was exceedingly remote. The existence of a stoichiometric mixture would necessitate that all the hydrogen and oxygen produced by the electrolytor had become mixed together either in the oxygen drum or elsewhere in the system.

There were two safety devices fitted to the oxygen drum, either of which would have prevented the vapour space exceeding 1690 litres. The relief valve on the drum was set at 515 psig. Accordingly, these figures have been used for the calculation of the energy available. This shows that the worst possible circumstances of a stoichiometric mixture would have produced a shock wave equivalent to that of 90 kg trinitro-toluene. Calculations based on TNT equivalents are difficult, but published sources† indicate that 90 kg will produce an overpressure of 1.0 KPa at a radius of 350 metres on an open field site. An overpressure of this intensity will damage windows. At a radius of 1050 metres, an overpressure of 0.21 KPa might be expected. This is equivalent to an aircraft sonic boom.

It has been calculated on the basis of the damage caused to the drum that the gas mixture in the oxygen drum at the time of the explosion was in the region of a  $13\frac{1}{2}\%$  mole% hydrogen/oxygen mixture. This would have produced a shock wave equivalent to 22 kg TNT. The comparable distances are 220 metres for a 1.03 KPa overpressure and 660 metres for 0.21 KPa.

It might be thought from these figures that the Uphall Road School (range about 210 metres) and houses (range about 180 metres) were exposed to risk, even though no damage occurred in the event. This might have been so if the explosion had occurred in an open field site but this was far from the case. The electrolytor was within a building designed and constructed so that any blast would have been directed upwards, as in fact happened. In addition, the electrolytor building was

surrounded by other buildings which would have attenuated the blast. Accordingly, in the light of the presence of buildings around the site of the explosion and the extremely unlikely possibility of anything more than a limited amount of hydrogen entering the oxygen drum, it is thought that there was no contravention of Section 3 of the Health and Safety at Work etc. Act 1974.

\*"Limits of flammability of gases and vapours" HF Coward and TW Jones.  
US Bureau of Mines Bulletin 503.

†Brasie WC & Simpson DW.  
"Guidelines for Estimating Damage Explosion".  
Loss Prevention in the Process Industries.  
American Institution of Chemical Engineers 63rd National Meeting 1968.

HER MAJESTY'S STATIONERY OFFICE

*Government Bookshops*

49 High Holborn, London WC1V 6HB

13a Castle Street, Edinburgh EH2 3AR

41 The Hayes, Cardiff CF1 1JW

Brazennose Street, Manchester M60 8AS

Southey House, Wine Street, Bristol BS1 2BQ

258 Broad Street, Birmingham B1 2HE

80 Chichester Street, Belfast BT1 4JY

*Government Publications are also available  
through booksellers*

£1.25 net.

ISBN 0 11 880333 6