INSTRUMENTS AND OBSERVING METHODS

REPORT No. 13

METEOROLOGICAL BALLOONS

THE USE OF HYDROGEN FOR INFLATION OF METEOROLOGICAL BALLOONS
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INFLATION OF METEOROLOGICAL BALLOONS

SECRETARIAT OF THE WORLD METEOROLOGICAL ORGANIZATION
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Preface

At its seventh session in Hamburg (1977), the Commission for Instruments and Methods of Observation appointed Mr. A. Van Dijk (Australia) as Rapporteur on the Use of Hydrogen for Meteorological Purposes (Resolution 8(CIMO-VII)).

As a result of his work, information has been made available on the hazards involved with the use of hydrogen and on specific measures which can be taken to reduce the risks to safety.

The main body of this report is essentially the new information on the subject which shall appear in the fifth edition of the Guide to Meteorological Instruments and Methods of Observation (WMO-No.8.TP.3) which will be published in English late in 1982. The appendix and annex are reproduced from the rapporteur's report.

This report is being made available at this time at the specific request of the eighth session of CIMO (Mexico City, October 1981), which desired that such information should be made available quickly in order to allow early application; in this manner, it was hoped that possible accidents could be avoided through adherence to the guidance provided in this report.
The two gases most suitable for meteorological balloons are helium and hydrogen. The former is much to be preferred on account of its freedom from risk of explosion and fire. But since the use of helium is limited mainly to the few countries which have an abundant natural supply, hydrogen is more generally used. The buoyancy (total lift) of helium is 1.115 kg m\(^{-3}\) at a pressure of 1013 mb and a temperature of 15°C. The corresponding figure for pure hydrogen is 1.203 kg m\(^{-3}\) and for commercial hydrogen slightly lower than this.

It should be noted that the use of hydrogen aboard ships is no longer permitted under the general conditions imposed for marine insurance. The risk of an explosion leading to the loss of a vessel and crew is considerable. In these circumstances the extra cost of using helium has to be reckoned against the hazard to life and the extra cost of insurance, if such insurance can be arranged.

Apart from the cost and trouble of transport, the supply of compressed gas in cylinders affords the most convenient way of providing gas at meteorological stations. But at places where the cost of difficulty of supplying cylinders is prohibitive, the use on station of a hydrogen generator should present no great difficulty.

For general use steel gas cylinders, capable of holding 6 m\(^3\) of gas compressed to a pressure of 18 MPa (10 MPa in the tropics), are probably the most convenient size but where the consumption of gas is large, as at radiosonde stations, larger capacity cylinders or banks of standard cylinders all linked to the same outlet valve can be useful. Such arrangements will minimize handling by the staff. In order to avoid the risk of confusion with other gases, hydrogen cylinders should be painted a distinctive colour (red is used in many countries) and their outlet valves should have left-handed threads to distinguish them from cylinders of non-combustible gases. Cylinders should be provided with a cap to protect the valves in transit.

Gas cylinders should be tested at regular intervals ranging from two to five years, depending on the national regulations in force. This should be done by subjecting them to an internal pressure at least 50 per cent greater than their normal working pressure. Hydrogen cylinders should not be exposed to heat and in tropical climates they should be protected from direct sunshine. For preference they should be stored in a well ventilated shed which permits any hydrogen which leaks to escape to the open air.

The two main types of transportable generators are the high-pressure and the low-pressure types. The former has the advantage of being able to store the
gas under pressure, whereas in the latter type the gas is passed straight into the balloon. In the more recently developed electrolytic generators, the gas is provided at low pressure and then compressed for storage.

Of the various materials which can be used for the production of hydrogen the following have proved to be the most suitable for meteorological purposes:

(a) Ferro-silicon and caustic soda
(b) Aluminium and caustic soda
(c) Calcium hydride and water
(d) Magnesium-iron pellets and water
(e) Liquid ammonia with hot platinum catalyst
(f) Water (electrolysis)
(g) Methanol (with added water)

The use of caustic soda requires considerable care on the part of the operator, who should be adequately protected, especially at the eyes, from contact not only with the solution but also with the fine dust which is liable to arise when the solid material is being put into the generator. A neutralizing agent, such as vinegar, should be kept handy in case of accident.

The risk of accident is greater with high-pressure generators than with the low-pressure types, since even if the safety device is efficient, its operation is very liable to be accompanied by the ejection of hot caustic soda solution. The safety device is usually a bursting disk and it is very important that the operational instructions should be strictly followed with regard to the material, size and form of the disks and the frequency of their replacement. High-pressure generators must be carefully cleaned out before recharging since remains of the previous charge may considerably reduce the available volume of the generator and thus increase the working pressure beyond the design limit. High-pressure generators should be tested every two years to a pressure at least twice that of the working pressure.

Unfortunately, calcium hydride and magnesium-iron, which have the advantage of avoiding the use of caustic soda, are expensive to produce and are therefore only likely to be acceptable for special purposes. Since these two materials produce hydrogen from water it is essential that they should be stored in containers which are completely damp-proof.

The processes using the electrolysis of water or the catalytic cracking of methanol (with added water) are attractive because of their relative safety and economy, and because of the non-corrosive nature of the materials used. However, for these two processes, and for that which uses liquid ammonia, additional power generator fuel is needed at those stations which have no access to a general electrical power supply.

4. Hydrogen precautions

Although accidents involving hydrogen occur infrequently, they can be dangerous. Hydrogen can be ignited readily by a small spark and cause flash burns. When diluted with air over a wide range of proportions, the mixture can explode. In either case a nearby operator can receive severe burns over the whole of his exposed skin, while an explosion can hurl the operator against a wall or to the ground, causing serious injury.

In general, the procedures, protection methods and equipment safety features provided with hydrogen generation equipment are well designed to safe-
guard against explosion or fire. However, the provision of adequate safety features for the buildings in which hydrogen is generated and stored, or for the areas in which balloons are filled or released has received less than adequate attention. Too often, special precautions for avoiding static charges and sparks and for providing adequate ventilation, fire alarms and fire extinguishers have not been implemented.

A good starting point for consideration of hydrogen precautions are the various national standards and codes of practice that are concerned with the risks presented by explosive atmospheres in general. Additional information upon the precautions which should be followed will be found in publications dealing with the explosion hazards in hospital operating theatres, where the problems are very nearly identical.

4.1 Building design and layout

Provisions should be made to avoid the accumulation of free hydrogen and of static charges and the occurrence of sparks, in any room where hydrogen is generated, stored or used. The accumulation of hydrogen must be avoided even when a balloon bursts within the shelter during the course of inflation. Some features which can aid in this latter circumstance, as well as being of use in the event of an explosion or fire include the provision of:

(a) a roof of light construction capable of readily venting from its highest point any free gas or the products of an explosion;
(b) an automatic sprinkler system.

Some of the safety provisions mentioned form part of the structural design of hydrogen buildings. Climatic conditions and national standards and codes, are constraints within which it is possible to adopt many designs and materials suitable for safe hydrogen buildings. Codes are advisory and are used as a basis of good practice. Standards are published in the form specifications for materials, products and safe practice. They deal with topics such as flame proof electric light fittings, electrical apparatus in explosive atmospheres, ventilation of rooms with explosive atmospheres, the use of plastic windows, bursting discs, etc.

Both codes and standards contain much information which is helpful and relevant to the design of hydrogen buildings and furthermore, are consistent with recommended national practice. Guidance should be sought from national standards authorities when hydrogen buildings are designed or when the safety of existing buildings is reviewed and, in particular, for aspects such as:

(a) the preferred locations for hydrogen systems;
(b) the resistance to fire of proposed materials, as related to the fire resistance ratings that must be met;
(c) ventilation requirements;
(d) suitable electrical equipment and wiring;
(e) fire protection (extinguishers and alarms).

Measures should be taken to minimize the possibility of sparks being produced in rooms where hydrogen is handled. Thus any electrical system (switches, fittings, wiring) should be kept outside these rooms; otherwise special spark-proof switches, pressurized to prevent the ingress of hydrogen, and similarly suitable wiring should be provided. Also it is advisable to illuminate the rooms by exterior lights shining in through windows. For the same reasons, any tools used should be non-sparking. The observer's shoes should not be capable of striking
a spark, and adequate lightning protection should be provided.

The danger level for the presence of hydrogen gas is often taken to be 40 per cent of the minimum explosive concentration. Hydrogen detection systems exist which sense its presence by means of flameless catalytic burning and which can be used to provide a warning should the concentration become dangerous.

4.2 Static charges

The hazards of balloon inflation and balloon release can be considerably reduced by preventing static charges in the balloon filling room, on the observers clothing and on the balloon itself. Static charge control is effected by good earthing provisions for hydrogen equipment and filling room fittings. Static discharge grips for observers can remove charges generated on clothing. However, charges on balloons are more difficult to deal with.

Balloon fabrics, especially pure latex, are very good insulators and charges take a long time (in excess of 1 hour) to dissipate through the fabric to earth or naturally into the surrounding air. More effective methods for charge removal involve the use of water sprays onto the balloon during inflation, the dipping of balloons into anti-static solution (with or without drying off before use) or the blowing of ionised air over the balloon.

The maximum electrostatic potential that can be generated on a balloon surface decreases with increasing humidity. Tests carried out on inflated 20 gm balloons, indicate that spark energies sufficient to ignite hydrogen-oxygen mixtures are unlikely to be reached when the relative humidity of the air is greater than 60 per cent. Other studies have suggested relative humidities from 50 per cent to 76 per cent as safe limits. Thus, static discharge precautions would not seem necessary when the relative humidity exceeds 70 per cent.

Fine water sprays onto the balloon can serve two purposes. The first is that if doors are kept shut, the relative humidity inside the filling room can rise to 75 per cent or higher, so that the occurrence of sparks energetic enough to cause ignition is unlikely. Secondly, the wetting and earthing of the balloon surface will remove charges from the wetted portions. Balloon release should proceed promptly once the sprays are turned off and the filling shed doors opened.

Other measures for reducing the build-up of static charge include:

(a) provision of a complete earthing (grounding) system for the building, with all fittings, hydrogen equipment and the lightning conductor separately connected to a single ground which itself must comply with national specifications for earth electrodes; provision should be made to drain electrical charges from the floor;

(b) static discharge points should be provided for the observers;

(c) the windows should be regularly coated with an anti-static solution;

(d) the operators should be encouraged not to wear synthetic clothing or insulating shoes;

(e) any contact between the observer and the balloon should be minimized; e.g. a balloon filler located at a height of one meter above the floor can facilitate this.
4.3 Protective clothing and first-aid facilities

Protective clothing for balloon filling and release is not nearly as common as for hydrogen generation, since accidents associated with balloon filling and release are more infrequent. Nevertheless, experience and simulation tests have shown that serious burns can result from such accidents, particularly to unprotected parts of the body such as face and hands. Safety would be improved if suitable protection were provided, such as light weight flameproof coats with a hood and a covering for the lower face, glasses or goggles, fingerless cotton gloves, and any locally-recommended anti-flash clothing.

First aid facilities appropriate to the installation should be provided. These should include initial remedies for flash burns and broken limbs. When chemicals are used then suitable neutralising solutions should be on hand, e.g. citric acid for caustic soda burns.
APPENDIX

SUMMARY ANALYSIS OF THE QUESTIONNAIRE ON THE USE
OF HYDROGEN FOR METEOROLOGICAL PURPOSES

1. A questionnaire was prepared by the rapporteur and sent to Members (reference R/IOH, 2 April 1980 (PR-3122)). The questionnaire sought details on the following matters:

(a) Gas supply and usage;
(b) Gas generation, including safety measures;
(c) Buildings used for gas generation, gas storage and balloon filling, including safety aspects;
(d) Balloon filling and balloon release practices;
(e) Accidents and likely causes for hydrogen ignition or explosions.

The summary of the replies to the questionnaire will follow these headings. For conciseness and clarity, the presentation will concentrate on the scope and prevalence of the various practices and procedures and will not rely on detailed tables which list the practices of individual Members. Any percentages are calculated from the number of replies received. Special mention will be made when the number of replies to a specific question was specifically less than the list of respondents given below:

Afghanistan, Australia, Austria, Bahamas, Bolivia, Belgium, Brazil, Bulgaria, Burma, Burundi, Canada, Cape Verde, Chile, Colombia, Czechoslovakia, Denmark, Djibouti, Egypt, France, Iceland, India, Federal Republic of Germany, Finland, German Democratic Republic, Ghana, Hong Kong, Hungary, Iraq, Israel, Ireland, Italy, Jamaica, Japan, Jordan, Kenya, Malawi, Malaysia, Mauritius, Mexico, Mozambique, Netherlands, New Zealand, Nigeria, Norway, Oman, Pakistan, Papua-New Guinea, Poland, Republic of Korea, Republic of Mali, Rwanda, Romania, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Socialist People's Libyan Arab Jamahiriya, Spain, Sri Lanka, Switzerland, Syrian Arab Republic, Tunisia, Trinidad and Tobago, Turkey, United Kingdom, United States of America, Uruguay, Yugoslavia.

Gas supply

2. The source of the gas needed for meteorological balloons is given in terms of the percentage of respondents which rely (wholly, or in part) on the following sources:

(a) Helium (transported to stations) 9%
(b) Hydrogen transported to stations 46%
(c) Hydrogen generated at stations 76%
3. The only significant usage of helium is in the United States, with 26 stations. No network relies entirely on helium for balloon soundings. Members with large networks of upper-air stations (in excess of 20) tend to use both generated hydrogen and transported hydrogen to meet their needs. However, hydrogen generated at observation stations is by far the most common source.

Gas generation

4. Amongst those respondents who generate hydrogen at field stations, the most commonly used technique is high-pressure chemical generation (57%), followed by electrolytic generation (38%) and low-pressure chemical generation (8%). Chemical generators are favoured as back-up systems to other supply sources.

5. Other systems, used by a few Members, generate hydrogen, either by thermal dissociation of ammonia using a platinum catalyst or by the catalytic cracking of methanol in the presence of water and a palladium diffuser. These systems have usually been operated at polar bases. Recent information indicates that hydrogen-generating systems involving the cracking of methanol are being considered by some Members as an alternative to electrolytic generation.

6. The chemicals used for generating hydrogen are usually caustic soda and ferrosilicon. Caustic soda and aluminium are also used. The equipment safeguards against explosions in chemical generators which were mentioned in replies included:

(a) Bursting discs to prevent excessive pressures in cylinders;
(b) Regular inspections and pressure testing of high-pressure cylinders.

7. Bursting discs form part of the design of the most common makes of high pressure generators and most would be equipped with them. Regular testing of cylinders at high pressure may be widespread, but replies were not very specific on this point (one to ten-year intervals were mentioned). However, the practice is a sound one, and should form part of system maintenance. Testing of cylinders to a pressure at least 50 per cent greater than the normal working pressure is recommended at least every two years in the WMO Guide to Meteorological Instrument and Observing Practices (see reference 2).

8. Other safety provisions for chemical generation of hydrogen refer to procedures and to the handling of chemicals. The following provisions were specifically mentioned in replies:

(a) Safety clothing and goggles to prevent chemical burns;
(b) First aid facilities with eye wash and bottles of neutralizing agent for caustic burns;
(c) Running water for use in providing first aid, for cooling the cylinders when reactions are proceeding too vigorously and for fire fighting;
(d) Prescribed amounts of chemicals for recharging the cylinders to reduce the risk of excess pressures during generation;

(e) Chemicals prepackaged into convenient quantities to minimize exposure due to handling;

(f) Facilities for the safe disposal of chemical wastes;

(g) Prohibition of flame or smoking nearby.

9. Safety clothing for those involved with the chemical generation of hydrogen is used by most respondents. A fully protective outfit consists of coveralls, mask, goggles, gloves and rubber boots. First aid facilities are also commonly provided; in particular, a neutralizing solution, usually citric acid, for caustic soda burns. The provision of fire alarms will be discussed in the section on buildings for hydrogen generation.

10. Electrolysers for generating hydrogen generally have pressure-activated switches which limit pressures in storage cylinders. As well, a series of valves and manometers regulate the flow of hydrogen into the high-pressure storage or directly into the balloon. At least 70 per cent of the respondents who generate hydrogen electrolytically use equipment manufactured by the Stuart Electrolysing Company. These electrolysers have the following pressure-activated safeguards:

(a) A high-pressure switch which limits storage pressures to 700 kPa (the cylinders are rated at 1300 kPa);

(b) A low-pressure switch which maintains the pressure in storage tanks above 100 kPa to prevent air from entering the hydrogen lines;

(c) A pressure differential switch (optional) which shuts the electrolyzer down if a leak is detected in the high-pressure lines.

11. Faulty electrolytic cells can allow oxygen to contaminate the hydrogen that is collected. Control of the gas purity to avoid explosive hydrogen-oxygen mixtures is a key safety element. Samples of hydrogen from electrolytic cells should be tested for their oxygen content, which should not exceed 1.5 per cent; 70 per cent of respondents indicated that samples of hydrogen were regularly tested for oxygen in their electrolyser systems. Also, the test procedure should be calibrated regularly several times a year to avoid the possibility of false security.

12. The use of safety clothing, a face mask and gloves is generally prescribed during electrolytic generation, and for mixing and handling the potassium hydroxide solution which is used during start-up procedures to form the electrolyte. Other safety practices which were mentioned included soap bubble tests for leaks in electrolyser pipes and hoses, and the earthing (grounding) of operators in situations where some hydrogen is likely to escape into the air.
Hydrogen buildings

13. Buildings for hydrogen generation and storage and for balloon inflation must meet special requirements to prevent the ignition of hydrogen and to minimize the dangers associated with possible fires and explosions. It was difficult to assess how many respondents locate their hydrogen buildings away from other work areas, although this is clearly practised by a number of Members. However, most respondents (72%) collocate their hydrogen generating, hydrogen storage and balloon filling rooms in the same building, and usually in adjacent rooms; where this is not the case, the balloon filling room is isolated from the others.

14. As far as the separation of the hydrogen storage and generating areas is concerned, respondents who generate hydrogen chemically, in almost all cases, store the hydrogen in the generating room. Of those respondents using electrolysis, some 29 per cent store the generated hydrogen in a separate room, which usually is adjacent to the generating area. Balloon filling, with very few exceptions, is carried out in specially dedicated rooms.

15. Concrete or brick walls are the most favoured building materials for hydrogen buildings. Lighter construction methods, such as wood frame with asbestos sheeting are also used. Roofs are generally made of metal or asbestos sheeting. Some are frangible to serve as possible explosion vents. Floors are mostly of wood or concrete. Doors in balloon filling rooms, where specified, are mostly of metal. It is not clear from the replies how many respondents fit doors to two sides of the filling room, in order to cope with a range of surface wind directions at release. It is clear, however, that this is practised by a significant number of Members.

16. As might be expected, there is a great variability in the dimensions of hydrogen generating rooms and of balloon filling rooms. The average dimensions, for both types of room are six metres in length and six metres in width. Floor areas, however, range from 30 to 64 square metres. The height of balloon filling rooms ranges from four to ten metres, with four to six metres most common. The ceiling height of generating rooms ranges from three to five metres.

17. The safety features incorporated into hydrogen buildings, as detailed in replies to the questionnaire, are summarized in Table 1. The replies indicate that similar safety provisions are used in all areas involving hydrogen. It should be pointed out that the replies may not always have been complete, even though a number of possible safety features were listed as examples in the questionnaire. Therefore, the figures shown may underestimate the real situation. Not included in the list are water sprays used for wetting balloons or floors since these will be discussed under balloon-filling practices. It should be noted that the main purpose of an automatic sprinkler system is to cool the room down in the event of a fire or explosion, in order to minimize the possibility of reignition or explosion.
### Table 1

**Safety features in hydrogen buildings**

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<thead>
<tr>
<th>Safety features</th>
<th>Percentage of respondents using the safety feature</th>
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<td></td>
<td>generating room</td>
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<tr>
<td>Wiring in conduit</td>
<td>50</td>
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<tr>
<td>Spark proof switching</td>
<td>37</td>
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<tr>
<td>Ceiling vents or ventilation</td>
<td>54</td>
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<td>Earthing provisions</td>
<td>49</td>
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<tr>
<td>Flame proof lights</td>
<td>18</td>
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<tr>
<td>Automatic sprinkler systems, alarms or extinguishers</td>
<td>9</td>
</tr>
<tr>
<td>Explosion venting</td>
<td>9</td>
</tr>
<tr>
<td>Static discharge points</td>
<td>3</td>
</tr>
<tr>
<td>Electric wiring and lights outside room</td>
<td>26</td>
</tr>
<tr>
<td>Lightning protection</td>
<td>7</td>
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<tr>
<td>Non-sparking tools</td>
<td>3</td>
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</tbody>
</table>

#### Balloon filling and release procedures

18. Balloons are usually filled to a specified free lift to ensure that all ascents occur at reasonably consistent rates (only one respondent reported specifying the volume of gas). The height of the filler nozzle above ground averages a half metre; one metre is the approximate maximum.

19. Earthing provisions in the balloon filling room have already been touched on. Most commonly, the filler unit itself is earthed, followed in frequency by metal fittings and the gas cylinders located in the room. Some members also earth one or more of the gas feeder pipes, floors, walls and building frames.

20. Antistatic equipment for removing electrostatic charges from the balloon and its environment is not in common use. A few respondents reported the use of an antistatic solution (Rodalone), in which balloons are dipped prior to inflation and the use of static discharge grips for use by the observer prior to approaching the balloon. Other precautions against static charges consist of inflation in an earthed or antistatically treated shroud, of blowing ionised air over the balloon or of earthing the necks of filled balloons which await the attachment of equipment trains. Eight respondents reported the use of water sprays to wet the balloons or filling room floor during balloon filling; some limit the use of such sprays to conditions with low humidity. Low inflation rates were reported in most replies as a means of minimizing the build-up of static charges.
21. It is common practice for the observer to tie off the balloon, to attach the instrument train and to release the balloon. However, two Members reported systems where balloons are released automatically. Details of these systems were not provided, but one is restricted to pibal soundings with surface wind speeds not exceeding 7.5 m/sec.

22. Members reported the following limiting weather conditions for balloon release: active thunderstorms with lightning, heavy rain and strong winds with critical lower limits in the range 10 to 30 m/sec. Respondents mentioned special procedures for launches in strong winds; these make use of string unwinders and shrouds. String unwinders considerably shorten the length of the equipment train at release while ensuring equitable train length during the ascent. Shrouds enable the manipulation of the balloon in gusty winds without unduly stressing the balloon.

23. Protective clothing is not widely used for balloon release. Twenty per cent of the respondents indicated that some form of protective or special clothing was provided, although some stressed that it was rarely worn. Thirty-four per cent of the respondents do not provide protective clothing, but some of these discourage the use of synthetic clothing or insulating footwear. Forty-six per cent of respondents made no reply to this question and it is assumed that most of these would not provide special protection for balloon release. The protective clothing listed in the replies consisted of head covering, cotton garments, protective glasses, flash proof coats, fingerless gloves, and the treatment of books or clothing with an antistatic solution.

Accidents

24. It is not clear from replies how common accidents associated with hydrogen generation and usage are. However, the implication is that serious accidents, involving injury, are rare. Some eight respondents specifically stated that no accidents had occurred, while eleven made reference to accidents.

25. The reported accidents which occurred during hydrogen generation were associated mainly with electrolyser faults, which led to the creation and ignition of hydrogen-oxygen mixtures. Faulty electrolyser cells, faulty pumps and blocked exhaust vents were the main causes mentioned. Contaminated chemicals caused an explosion in a low-pressure generator when the aluminium used in the reaction contained a proportion of magnesium. Accidents associated with the chemical generation of hydrogen received only minor mention, but jets of hot caustic mixture emitted from cylinder openings or burst safety discs can be very dangerous.

26. Ignition of hydrogen was also reported with the rush of hydrogen from outlet valves, particularly when these were not fitted with pressure regulators. Hydrogen needs only a very small spark for ignition and can self-ignite on sudden expansion. Pressure regulators and valves which shut automatically when the observer's hand is removed from them were put forward as solutions to this problem.

27. The reported accidents which occurred during balloon filling and balloon release were attributed to the rupture of balloons and to static charges generated in the balloon environment. It has been suggested (Defense Standard Laboratories, 1969), that the tearing of the balloon fabric during rupture may itself generate
significant static discharges sufficient to ignite the hydrogen that is released. Synthetic clothing worn by observers and improper earthing of equipment and fittings in the balloon filling room, were found to be significant contributory features to such accidents. It was considered that low humidities also contribute significantly to the build-up of dangerous electrostatic charges.

28. The amount of energy involved in an electrostatic discharge, or spark, is crucial to whether the hydrogen-air mixture will ignite; spark energies of about 17 microJoule are required for ignition (Young, A. F. 1967). Laboratory tests (Young, A. F. 1967) showed that sparks with greater energies can be readily obtained from electrostatically charged balloon surfaces; further, the maximum charges that can be generated and, hence, the spark energies, are reduced with increasing humidity. Investigations on 20 gm balloons showed that sparks with energy in excess of 17 micro-Joule were unlikely to occur with relative humidities in excess of 60 per cent. A study of charges on clothing (Cleves et al, 1971) suggests that 65% RH at 20°C and 76% at 10°C are safe lower limits. A German safety code (vst. No. 17.01) suggests 70% RH as a safe limit.

29. Respondents indicated that they considered dangerous electrostatic charges were unlikely to form with relative humidities in excess of 50 per cent. On the balance, it would seem appropriate to take precautions against static charges when the relative humidity is less than 70 per cent.

30. Accidents during balloon inflation and release are rare. For example, Australia has had three such accidents in the last ten years. Considering the number of balloons inflated and released each day, this is a very low accident rate. Nevertheless, the burns received by an observer in one of these accidents were serious and resulted in a series of tests being conducted to determine the degree and kind of protection that was needed for observers. These tests (Hoschke, B. N. et al, 1979) made use of an instrumented dummy with simulated skin and hair in the tying-off position or standing under exploding 100 gm balloons. It was shown that:

(a) Light cotton clothing provides adequate protection against blast burns, although such clothing was somewhat susceptible to ignition by blazing balloon fragments;

(b) Face, hands and hair were susceptible to serious burns. Unprotected eyes were also subject to damage;

(c) A lightweight flame retardant coat with a hood and protection for the lower face was found to give good protection. Glasses or goggles and fingerless cotton gloves were also advised.

Detection of hydrogen leaks

31. Convenient devices for testing the concentration of hydrogen in a room are provided by gas alarm systems which detect hydrogen in the air through monitoring the temperature of the flameless catalytic burning of the supposed air-hydrogen mixture.
32. Such systems may be portable or they may have detectors fixed in the ceiling of the room. Hydrogen concentrations are indicated on a meter. Lights or audible alarms are triggered when the hydrogen concentration in the air exceeds 1.6 per cent (i.e., 40 per cent of the lower explosive limit). Calibration of such equipment is usually by means of a reference gas and should be carried out at regular intervals several times a year.

33. Only a few Members located such instruments in their hydrogen generation rooms or balloon filling rooms. Members' experience does not indicate any problems with this type of equipment. A limited list of the suppliers of such detectors who have come to notice is given in the annex.

The design of hydrogen buildings

34. Safe hydrogen buildings can be designed in a number of ways. Any particular design is unlikely to be suitable for all climatic conditions. For example, the design of hydrogen buildings for polar regions or stations subjected to tropical cyclones will contain special features not required at the majority of locations. The construction and materials of hydrogen buildings should take into account the climatic extremes of the region.

35. The safety of buildings and of equipment for use with potentially explosive atmospheres is dealt with in safety codes and national standards. Safety codes are advisory and are used as a basis of good practice for users and authorities. Examples of safety codes are the Australian code for static electricity, published by the Standards Association of Australia, and the national fire codes, published in the United States, by the National Fire Protection Association. This latter code makes recommendations on the location of hydrogen systems, such as clearances from other buildings and sources of ignition or flammable materials. It also provides design considerations for hydrogen systems located in separate buildings and in specially dedicated rooms. National standards are published in the form of minimum specifications for materials, products, and safe practices. They deal with topics, such as flame proof electric light fittings, electrical apparatus for use in explosive atmospheres, ventilation of rooms with potentially explosive atmospheres, the characteristics of bursting discs, etc.

36. Both codes and standards therefore contain much information, which is helpful and relevant to the design of hydrogen buildings. It is important that hydrogen buildings meet recommended national safety standards. Also, guidance should be sought from national standards authorities when hydrogen buildings are being designed or when the safety of existing buildings is reviewed. Particular aspects of this guidance involve:
(a) Preferred locations for hydrogen systems:

Ideally, hydrogen facilities should be housed in a separate building, but special rooms with a low fire risk can form a part of other building complexes. Least desirable are non-specialized rooms exposed to other occupancies. Safety codes will also recommend clearances of hydrogen systems from ignition sources or sources of flammable materials;

(b) Materials:

Roof and wall materials should be non-combustible. Floors, wall panelling and ceilings should meet the recommended fire resistance ratings;

(c) Ventilation:

Safety codes and standards specify preferred sizes and locations for inlet and outlet openings and discuss various ventilation systems that could be employed;

(d) Explosion venting:

Some hydrogen buildings are designed with frangible roofs or doors. Provision for explosion venting poses design problems when buildings also must be well sealed and insulated to cope with a harsh environment. Codes and standards specify the required sizes of vent for various room volumes and specify the maximum pressure differential between the room and its surroundings before the venting should become operative;

(e) Fire protection:

Hydrogen flames normally cannot be fully extinguished, unless the supply of the hydrogen can be turned off; there is always a danger of reignition or explosion. Secondary fires should be extinguished as soon as possible. Small hydrogen fires can be extinguished by dry chemical extinguishers or with carbon dioxide, nitrogen and steam, but reignition may occur if metal surfaces near the flame are not cooled with water or other means. Water should therefore be available in adequate volume and at adequate pressure for fire protection. It should be noted that hydrogen flames are almost invisible and may only be detected with certainty by detecting heat waves;

(f) Electric wiring and equipment:

There should be no sources of ignition from electrical equipment, open flames or heating equipment.

References and reports received

Canadian Atmospheric Environment Service 1978

The use of hydrogen for meteorological purposes in the Canadian Atmospheric Environment Service (AES)
Cleves, A. C., Sumner, J. F. and Wyatt, R. M. H., 1971


Defense Standards Laboratories, Commonwealth of Australia, 1969


Factory Mutual Research Corporation, 1967


Haschke, B. N., Moulen, A. W. Holcombe, B. V., Grubils, S. J. and Madden, J.J., 1979

Report to the Bureau of Meteorology on Protection against the Burn Hazard from Exploding Hydrogen-filled Meteorological Balloons, CSIRO Division of Textile Physics and the Department of Housing and Construction, 1979.

National Fire Protection Association 1978 (US)

National Fire Codes, Volume 4.

Standards Association of Australia

Electrical Equipment for Explosive Atmosphere:

(a) Protection by Ventilation, Australian Standard 1482, 1973;

(b) Flameproof Electric Lightning Fittings, Australian Standard C99, 1970;

(c) Intrinsically Safe Electrical Apparatus, Australian Standard 1829, 1976.

Standards Association of Australia, 1970


Standards Association of Australia, 1972


Standards Association of Australia, 1968

Committee EL/25 - Control of undesirable static charges (translation of a German code u.st. No. 17.01 - Guide for the Prevention of Dangers from Electrostatic Charges), February 1968.

Trident Engineering Associates Inc., 1978

A safety study of hydrogen balloon inflation operations and facilities of the National Oceanic and Atmospheric Administration National Weather Service. (Contract No. 7-35378).

World Meteorological Organization, 1971


Young, A. F., 1967

Annex

A list of suppliers for hydrogen detection equipment made available by Members

Mine Safety Appliances Company
600 Penn Center Boulevard
Pittsburgh, PA 15235
USA

Beckman Instruments Inc.
2500 Harbor Boulevard
Fullerton, CA 92634
USA

Teledyne Analytical Instruments
333 West Mission Drive
San Gabriel, CA 91776
USA

Bacharach Instruments Company
625 Alpha Drive, Industrial Park
Pittsburgh, PA 15238
USA