Health and Safety Executive **Information Document**
HSE 288/6 (REV)

ASPHYXIATION HAZARDS IN WELDING AND ALLIED PROCESSES

1 This document contains internal guidance which has been made available to the public. The guidance is considered good practice (rather than compulsory) but you may find it useful in deciding what you need to do to comply with the law. However, the guidance may not be applicable in all circumstances and any queries should be directed to the appropriate enforcing authority.

2 Several people have been killed when they have entered inert atmospheres created by gas shielded arc welding processes where oxygen is excluded from the welding arc or where inert gas has been used to fill all or part of a fabrication to enhance weld quality by excluding oxygen from the weld pool. This document describes the processes and associated hazards and gives advice on precautions to ensure the safety of all persons who may be affected.

3 This document does **not** deal with:

(1) the fire and explosion properties of welding gases;

(2) the toxic or harmful properties of welding fumes; nor

(3) the effectiveness of weld shielding.

WELDING GASES

4 Inert gases are used in electric arc welding to exclude air from the vicinity of the arc and the weld pool so as to prevent the oxygen in the air adversely reacting with the weld.

5 The most common welding gases are listed in the table at the appendix. They are sometimes used as mixtures and the mixtures will have a combination of the properties of the constituents. Most gases used for inerting are classified as simple asphyxiants and are not defined as 'substances hazardous to health' in the Control of Substances Hazardous to Health Regulations 1994. The exception is carbon dioxide. However, the levels at which it causes incapacitation are relatively high and the risks from its use in welding processes are generally comparable with those for simple asphyxiants.

6 Whilst acetylene and propane have distinctive smells, the other gases are odourless and direct measurement of them is difficult. All are colourless. Detection tubes are available for some and the flammable gases can be detected with suitably calibrated flammable gas-detection equipment. The most appropriate detection method when checking oxygen levels is the use of a suitably calibrated oxygen meter.

7 Apart from oxygen, all the gases listed at the appendix can create a risk of asphyxiation if at sufficient concentration. Gases denser than air will collect in the bottoms of tanks, vessels, pits and other low-lying areas. The denser gases, eg argon, can act almost like a liquid if undisturbed and will form dense, low-lying layers which will disperse only slowly. Lighter gases may collect in high-level spaces which could pose a risk if this is at head level.

8 Inert gases are usually supplied to the weld pool by the welding torch as in the metal inert gas (MIG), metal active gas (MAG) or tungsten inert gas (TIG) processes. In addition, inert gases may be used to purge internal parts of fabrications in order to exclude air from the weld root. Purging may be used in conjunction with inert-gas welding processes or with manual metal arc (MMA) welding. A variety of techniques for generating and maintaining a purged atmosphere can be employed. These are described in more detail at paragraph 15.

MEDICAL EFFECTS

9 Inhaling an atmosphere which contains no oxygen causes loss of consciousness in a matter of seconds because such an atmosphere not only fails to provide fresh oxygen but also removes oxygen already present in the bloodstream.

10 The concentration of carbon dioxide in the bloodstream is monitored by the respiratory centre in the brain and, when the concentration reaches a certain level, the respiratory centre makes the lungs inhale. Normally, oxygen diffuses from inhaled air to the blood circulating in the lungs because the concentration of oxygen in this blood is relatively low. Conversely, carbon dioxide diffuses from this blood to the air in the lungs because the concentration of carbon dioxide in the blood is relatively high.

11 However, when an oxygen-free atmosphere is breathed, the process is reversed and the oxygen diffuses from the blood in the lungs to the inhaled air. At the same time, carbon dioxide is removed from the blood normally and the respiratory centre is not stimulated.

12 There will be little sense of breathlessness to warn the victim that something is amiss and the person will rapidly lose consciousness. The respiratory centre will cease to function and breathing will stop. The heart will continue to function for a short time but will then arrest and circulation will fail.

13 When the gas contains some oxygen, the loss of oxygen from the bloodstream takes place more slowly. Victims feel very fatigued and will find it impossible to help themselves because of the irrationality induced by lack of oxygen. If normal concentrations of oxygen are restored at this stage brain function will be restored and the victim will recover. However, prolonged exposure to such an atmosphere will result in loss of consciousness and then death.

14 Many people are unaware of the speed at which unconsciousness will result after exposure to an inert atmosphere and incorrectly believe that it would be possible to rescue themselves in such circumstances.

PROCESSES AND RISK OF INERT GAS ACCUMULATION

15 The following circumstances may result in asphyxiant gases accumulating in confined spaces.

(1) During MIG, MAG or TIG welding on the outside of fabrications, torch shielding gas can enter the fabrication through the weld root.

(2) Torch shielding gas can rapidly accumulate inside a fabrication during internal MIG, MAG or TIG welding.

(3) Vessels and pipes etc can be purged of air by sealing all openings and flooding the entire internal volume with inert gas.

(4) Purge gas damming can be used to purge a section of a fabrication either side of a joint (see paragraphs 17-20 and illustration A).

(5) Shoes (perforated steel blocks from which inert gas diffuses) can be held against weld roots by someone inside a fabrication who moves the shoe as the work progresses. **This is a particularly dangerous practice (see also paragraph 37).**

(6) Backing bars or channel strips can be used to inert behind butt welds between 2 flat plates (see illustration B for details).

(7) Transparent plastic bags fitted with integral gauntlets are available and can be used to enclose the workpiece completely. They can be as large as a small room and may contain several cubic metres of gas.

(8) Purging and/or shielding gases discharged after use can leak into other sections of a complex fabrication or plant or into a nearby room, cellar, sump, pit or other enclosed low-lying area and so must be safely disposed of after use.

16 Paragraph 15 is not an exhaustive list of processes which may give rise to accumulations of asphyxiants nor is the list intended to infer effectiveness at shielding. There may be other techniques which generate similar hazards. Employers should always assess the risks and take appropriate precautions whenever asphyxiant gases are used as part of a welding process.

TYPES OF DAM

17 Purge gas dams or bladders (paragraph 15(4)) are inserted to seal off a section of a fabrication and inert gas is introduced between them. Home-made dams are often made from cardboard or pieces of foam rubber which are sometimes reinforced with rigid plastic. The seal between the dam and the wall of the fabrication may be improved by the use of tape.

18 Proprietary dams are available which may consist either of solid discs with flexible rubber seals or an annulus (similar in configuration to a vehicle wheel rim) with twin flanges to which similar rubber seals are attached (see illustration C). The latter type can reduce the risk because they do not completely block the workpiece thus preventing the creation of additional temporary spaces in which gas can collect.

19 Water soluble plastic or cellulose materials can also be used to fabricate dams, which can be cut to shape on site and held in place using water soluble adhesive. When the weld procedure has been completed, they can be flushed out with cold water often at the same time as hydraulic pressure testing is performed.

20 Dams are rarely capable of achieving a complete seal between themselves and the internal wall of the fabrication (nor are they designed to do this). Consequently there is usually significant leakage into adjacent sections of the workpiece. Furthermore, damming may well create temporary spaces (other than the isolated section between the dams) behind which gas can accumulate but from where it will be released when the dams are removed.

LEGAL REQUIREMENTS

21 The Confined Spaces Regulations 1997 will apply to places where there is a risk of accumulation of asphyxiant gases from welding. The Regulations introduce 3 important requirements:

(1) the need to avoid entry to confined spaces, where reasonably practicable (regulation 4(1));

(2) if entry to a confined space cannot be avoided, a safe system of work must be followed (regulation 4(2)); and

(3) adequate emergency (rescue) arrangements must be put in place before work starts (regulation 5).

22 Further information and guidance is given in the HSE publication L101 *Safe work in confined spaces. Confined Spaces Regulations 1997. Approved Code of Practice (ACoP), Regulations and Guidance*, which is available from HSE Books PO Box 1999, Sudbury, Suffolk CO10 6FS, tel 01787 881165 fax 01787 313995.

23 The Personal Protective Equipment at Work Regulations 1992 require that where risks cannot be adequately controlled by other means which are equally or more effective, suitable personal protective equipment (PPE) should be provided and maintained in efficient working order and in good repair. Employees should also be adequately trained in the use of the PPE.

PRECAUTIONS

24 The first step in the development of precautions is to undertake a risk assessment. The priority when carrying out the risk assessment is to identify measures needed so that work in confined spaces can be avoided. If it is then not

reasonably practicable to avoid entry, the risk assessment will help to identify the precautions required in a safe system of work.

Avoiding entry into confined space

25 Employees may wish to enter a fabrication, eg to inspect the weld root, to retrieve equipment used in the work process or to carry out further work once the welding process has been completed. Employees could enter fabrications of very small dimensions, eg pipework with an internal diameter as small as 450 mm.

26 Employees may also enter hazardous locations under less foreseeable circumstances, eg when they have fallen in.

27 Accidents have even occurred when employees have placed only their head and shoulders into a confined space.

28 Entry and/or work in a confined space should only be considered when no alternative is available. The first aim should therefore always be to prevent the need for workers to be exposed to the risks arising from work in confined spaces.

29 One way of avoiding entry is to consider alternative methods of welding when it is considered likely that there will be a need to enter any associated confined spaces.

30 If asphyxiant gases must be used, then production and inspection methods should be adopted which avoid the need for entry into the spaces into which asphyxiant gases have been introduced. For example, when purge gas damming is used, it is usually possible to insert the dams before the 2 parts of the fabrication are aligned and tack welded together. Dams can be removed remotely through the use of pull-cords or, in circumstances when they become jammed, through the use of drain rods. Where successive joints have to be welded, pull-cords attached to either side of the dam can be used to position it at each weld in turn. Final inspections can be carried out using long-handled mirrors or fibre-optic video cameras.

Safe systems of work

31 If entry into a confined space is unavoidable then a safe system of work must be followed. The first step in the development of a safe method of working in confined spaces is a risk assessment. General guidance on risk assessment is given in the ACoP paragraphs 20-27.

32 The precautions required in a safe system of work will differ in detail depending on the findings of the risk assessment. The main elements to consider when designing a safe system of work are given in the ACoP paragraphs 35-79.

33 A 'permit-to-work' system is the most effective way of managing entry to or work in confined spaces. A permit-to-work procedure is an extension of the safe system to work, not a replacement for it.

34 Experience demonstrates that safe systems of work will be most effective and workable where those who will use them are consulted during their design. Systems of work should be reviewed from time to time and modified as necessary. Changes in working methods or practices should lead to an immediate review of the risk assessment.

35 An important part of a safe system of work is to ensure that where an inert gas has been used in a confined space, the space should be vented and purged to ensure the atmosphere is safe to breath before any person enters. It may then be necessary to test/monitor the atmosphere in a confined space to check the concentration of oxygen prior to entry. The ACoP paragraphs 40-46 provide guidance.

36 Testing can be done using appropriate meters and without entry into the confined space. Even placing just the head inside the confined space should not be attempted. The test should encompass the entire volume especially the deepest areas where a dense gas may be present. There are substantial risks if the concentration of oxygen in the atmosphere varies significantly from normal (ie 20.8%). Movement of air in the confined space work environment should be ensured by suitable means of ventilation which may be artificially assisted. The work atmosphere should never be ‘sweetened’ using oxygen as oxygen enrichment considerably increases the risk of fire.

37 Work involving the use of asphyxiant welding gases whilst persons are in a confined space should be avoided. If such work is essential, effective arrangements will be required to prevent accumulation of the asphyxiant gas and suitable respiratory protective equipment (RPE) will be required. In these circumstances, the RPE should use an independent air supply, ie fresh air hose, compressed air line or self-contained breathing apparatus.

Emergency arrangements

38 Before any person enters a confined space of any type, arrangements for rescue in the event of an emergency should be in place. The arrangements required will depend upon the findings of the risk assessment and on the nature of the likely emergency. The ACoP paragraphs 80-92 give further guidance on what is required.

39 There should be measures to enable the alarm to be raised in the event of an emergency. Normally entry to a confined space should be permitted only if there is at least one further person in attendance (either inside or outside the space). This person should be trained and equipped to initiate emergency rescue procedures. Appropriate rescue equipment, which may include suitable breathing apparatus, belts/harnesses, lines and hoists should be provided.

Information, instruction and training

40 Before any person enters or works in an enclosed or confined space, they should be informed about the hazards and risks involved in the work. They should be instructed on any special precautions to be observed including safe systems of

work and should be adequately trained in the use of work equipment and any personal protective equipment, including RPE. This should include how to recognise changes in circumstances which could increase the risks to health and safety and emergency arrangements, including rescue techniques.

41 Information on the requirements for training are given in the ACoP paragraphs 92 and 113-116. Advice on training with respect to respiratory protective equipment is given in the HSE publication HSG53 *The selection, use and maintenance of respiratory protective equipment. A practical guide,* which is available from HSE Books (see paragraph 22 for address).

APPENDIX
(paras 5 and 7)

PROPERTIES OF WELDING GASES			
Gas	**Colour**	**Odour**	**Density***
Argon	None	None	1.38
Helium	None	None	0.14
Nitrogen	None	None	0.97
Carbon dioxide	None	None	1.53
Oxygen	None	None	1.11
Propane	None	'Natural gas'	1.21
Acetylene	None	Ether-like	0.48

*Density of air =1.00

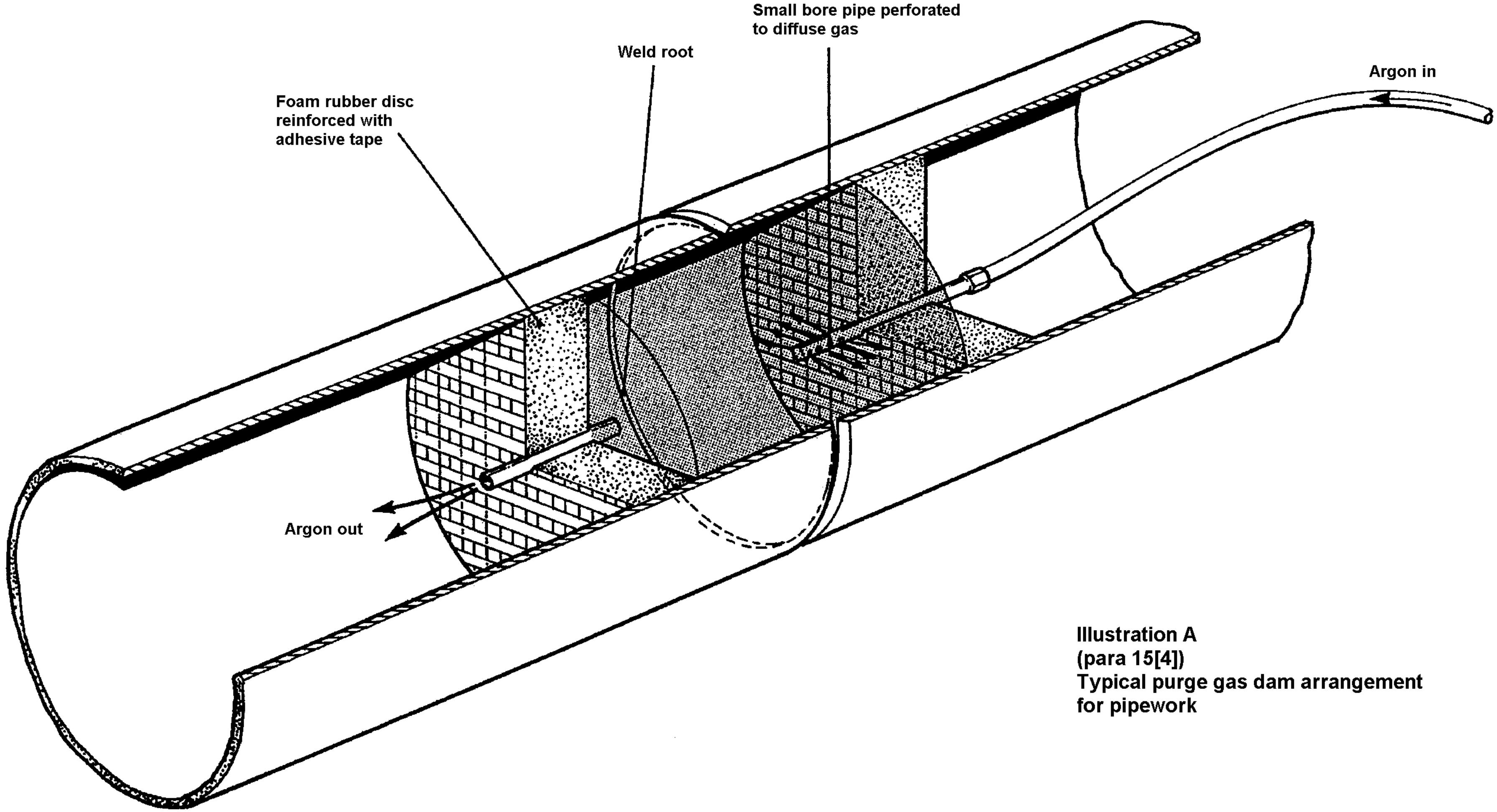
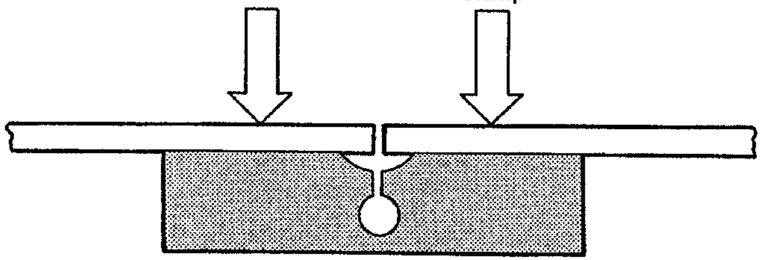


Illustration A
(para 15[4])
Typical purge gas dam arrangement for pipework



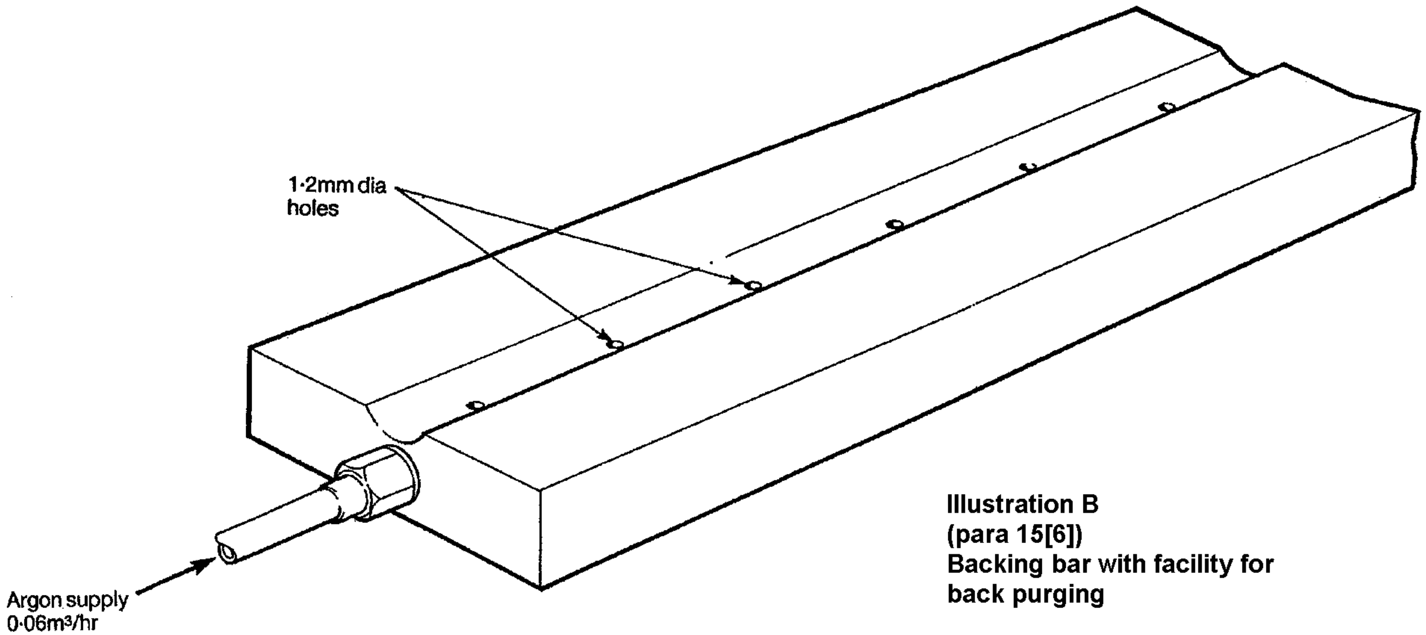


Illustration B
(para 15[6])
Backing bar with facility for back purging

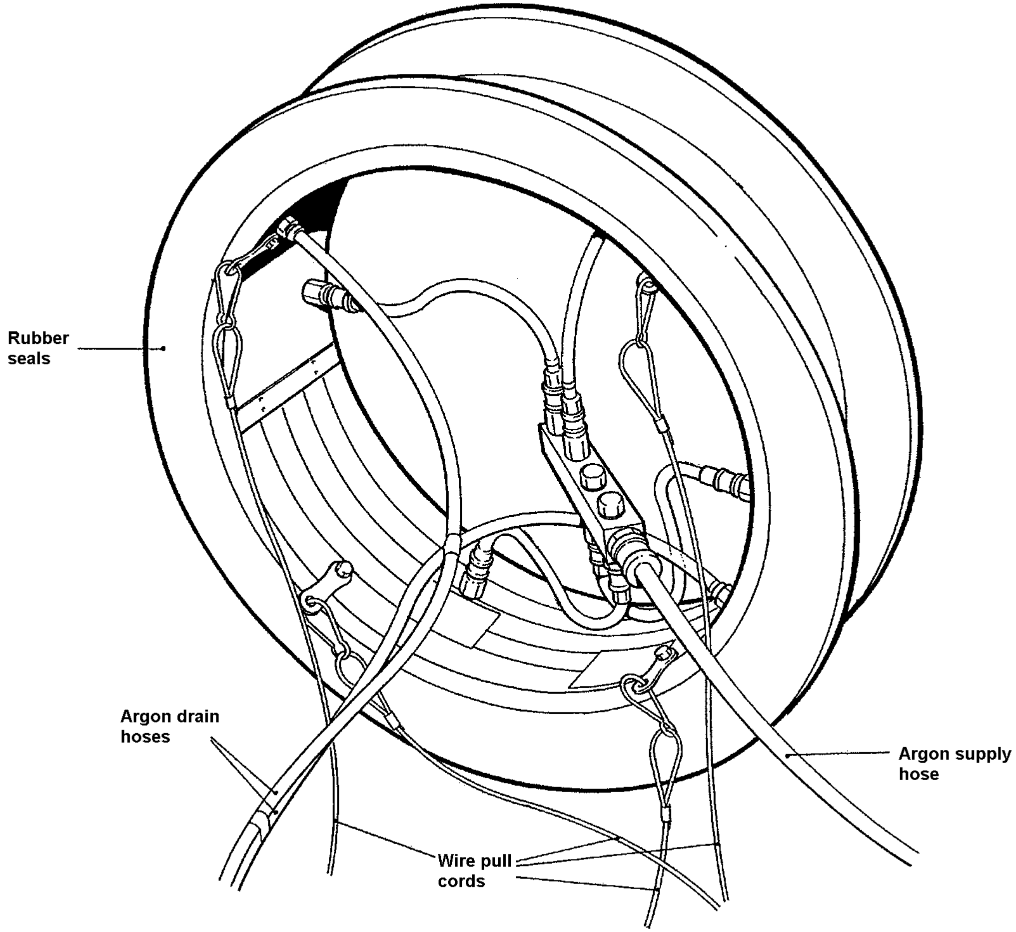


Illustration C
(para 18)
Example of an annular-type proprietary dam