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Your reference

To all Chief Fire Officers

Our reference
FIR/70 15/16/1
Date
16 August 1971

Dear Chief Officer

I attach a copy of a paper on fires in, and fire prevention recommendations in connection with, agricultural silos which has been approved by the Joint Training Committee and which will, in due course, be issued as a Technical Bulletin.

I hope you will find this advance copy of the information of value to you.

Yours sincerely

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FIRES IN AGRICULTURAL SILOS

INTRODUCTION

1. The guidance contained in this Bulletin was prepared by a Working Party constituted for the purpose. The membership of the Working Party comprised Chief Fire Officers who had experience of silo fires and representatives of the Home Office, the Ministry of Agriculture, Fisheries and Food and the Joint Fire Research Organisation.

2. The storage of green forage or haylage in silos, forage or haylage towers as they are variously described is extensively established in the United States of America. It is increasingly gaining favour in the United Kingdom and the number of silos being erected is growing. Mechanisation of farming with the consequent reduction in the number of farm workers favours the adoption of silo storage. The nature of the process, requiring as it does limited fermentation of the raw material, can introduce hazards unless the appropriate safeguards are adopted.

FIRE AND OTHER HAZARDS

3. One of the main hazards, which also include risk of exposure of personnel to toxic gases within the silo, is that of fire resulting from the overheating and ignition of silage if air gains access to it.

4. It was estimated that in 1967 there were about 500 to 600 silos in use in the United Kingdom. A recent estimate suggests that the number is now nearer 1600. Although in the last five years only eight fires have occurred, four of these were in 1969. Research carried out by the University of Wisconsin, United States of America in 1969 showed that the number of fires in silos was causing concern. It was noted that although the annual damage to farm crops arising from spontaneous ignition was considerable, spontaneous ignition in silos was of recent origin and increasing in frequency. Not the least of the hazards was the added danger of explosions due to accumulation of flammable gases. Although (in this country) the number of fires proportional to the silos at risk is small, such fires pose difficult problems for the fire service. It is the object of this Bulletin to provide guidance on these problems.

PRINCIPLE OF SILO OPERATION

5. The principle of silo storage is based on cutting green forage, which consists mainly of grasses but which may also contain alfalfa, lucerne and similar materials, and storing this in silos until required for animal feedstuff. The green material is fed into the top of the silo, usually by a blower system, as soon as possible after cutting. It settles into a compact and dense mass and may be subsequently removed by a rotating cutter and conveyor system.

6. To preserve the silage and ensure the maximum nutritive value, limited fermentation is necessary. After the silo is charged, respiration of oxygen from the air within the compacted material occurs and is followed by microbiological action in the silage. These processes are accompanied by the evolution of a relatively small amount of heat. If, however, the moisture content of the silage material is initially lower than the recommended minimum and the silage is insufficiently compacted, entry of oxygen due to inadequate sealing of the silo will permit more vigorous heating which will raise the temperature to a point where microbiological action ceases (said to be about 75°C (167°F)) and heating continues by chemical oxidation alone. The continuing availability of oxygen will cause a runaway condition and ignition will occur. The temperature to which fermentation should be allowed to proceed is between 27°C (80°F) and 49°C (120°F). A temperature in excess of 60°C (140°F) indicates the onset of dangerous heating.

SPONTANEOUS HEATING

7. There are three major controllable factors which influence spontaneous heating of the silage. These are the size of cut or chop of the material fed into the silo, the moisture content of the material and the accessibility of oxygen (air) to the stored material. If the cut of the material is too long or varies in length the silage will not become adequately compacted and air will be occluded within it. The moisture content is vitally important. A number of farmers in the United States of America who had fires in silos were interviewed in the course of the research referred to earlier and in each case it was estimated that part or all the material put into their silos had a moisture content of 40 per cent or less, most less than 30 per cent.

8. It is possible to assess the moisture content of the cut material with the use of instruments but an experienced farmer can tell by squeezing the material in the hand whether the moisture content is about right. The time of day and weather conditions when the crop is cut can have an influence on the moisture content and need to be taken into account. Ideally the crop should be cut and loaded into the silo without delay. It should be fed in continuously in such a way that a minimum depth of 10 feet (3.05 m) is achieved at one loading. If there is delay the unloaded material may become partially dry.

9. There is sometimes an arrangement for sprinkling water into the top of the silo during loading, but this cannot be regarded as a very satisfactory way of making up for loss of moisture prior to loading.

The makers of the silos and the National Forage Tower Council (Dominion House, Gravel Hill, Henley-on-Thames, Oxfordshire, RGG 2EG) issue recommendations on correct procedures for safe operation and the making of good silage. Their recommendations should be followed rigorously and their advice should be sought in the event of overheating.

10. It has been suggested that additives or 'improvers' which can be put into the silage may have some influence on the possibility of spontaneous heating. No data is at present available on this.

CONSTRUCTIONAL DETAILS

11. Silos or forage towers are vertical cylinders with a diameter of between 20 and 25 ft (6.10 - 7.62 m) and a height of up to 70 ft (21.37 m). A silo 65 ft (19.81 m) high and 25 ft (7.62 m) in diameter may contain up to 500 tons (508 tonnes) of silage (based on a 50 per cent moisture content). There are two basic forms of construction:

a. precast concrete blocks interlocked both horizontally and vertically, restrained at each course by steel hoops or bands;

b. steel plated sections bolted together.

In either construction, the base of the silo is set in concrete. To prevent corrosion both forms of shell usually have an internal lining of vitreous or other protective material.

12. The top or cap of the silo is usually dome-shaped and is constructed with sheet steel, aluminium or glass reinforced polyester. A door or hatch in the dome gives access to the interior for the assembly, maintenance and removal of cutting and elevating machinery. A series of hatchways is provided vertically up the side of the silo. These are closed on the inner side by doors either of wood or steel plate which are secured in position by latching and bolting devices. Rubber gaskets are used to ensure a gas tight seal between the hatchway and the door. A metal ladder, protected by safety rails or a ladder cage, gives access to all the hatchways and the top of the silo.

13. The cut material is loaded into the top of the silo by a blower system terminating in a goose-neck shaped head which is traversed to ensure even disposition. The silage is subsequently discharged from the silo by an electrically driven rotating cutter and conveyor system which is lowered on to the surface of the silage by a winch and control device at the base of the silo.

14. The cut silage falls to the base of the silo via a chute either at the centre or the perimeter of the silo. The latter type of chute is usually v-shaped and is formed by hinged plates fitted to the access hatches. After the silo is unloaded and before any recharging can commence the cutting machinery has to be dismantled and removed.

15. It is important that air be prevented from reaching the silage but however well the silo may be designed to ensure this, unless the operating instructions are fully observed and attention is given to the proper maintenance of doors and sealing gaskets, such design features will be valueless.

16. In one particular type of silo designed for maximum sealing against intake of air, a heavy gauge plastic bag communicating with the outside atmosphere is fitted inside the top of the silo. Pressure changes within the silo, due to atmospheric and temperature differentials, cause the bag to breathe and compensate for the ingress and egress of air to the silage which would otherwise occur. In this type of silo the cutter and conveyor device for unloading is permanently fitted in the base.

RECOMMENDATIONS: FIRE-FIGHTING

(a) Pre-planning

17. The value of pre-planning is well known in the fire service and it follows that station personnel should be encouraged to undertake 1(1)(d) inspections: it is from this source, together with information from reports of fire officers who give fire prevention advice that effective pre-planning stems.

18. It is suggested that, amongst other things, the following information would be of value to the operational officer:

(i) Knowledge of the silo design and its ability to withstand reasonable internal pressure as the result of the introduction of water.

(ii) Hard standing (if available) around the silo and load-bearing capacity. Preferably for a hydraulic platform or a turntable ladder.

(iii) Water supplies.

(iv) Details of availability of water-probes together with the volume of water discharged by the probe per minute. (See Appendix 2).

(v) Availability of a steel pointed probe and a temperature-recording probe to determine the extent of the fire or overheating.

(vi) Estimate of the amount of steel scaffolding (and associated platform) required, together with the necessary transport, telephone numbers and address from where the scaffolding can be obtained.

(vii) Availability of breathing apparatus.

(viii) Location and details of cold cutting equipment necessary for perforating hatch doors.

(ix) Address and telephone number of:

(A) Agent who supplied and/or erected the silo, or the National Forage Tower Council.

(B) The local branch office of the Ministry of Agriculture, Fisheries and Food.

The local branch office of the National Farmers' Union.

(b) Locating the fire

19. As in the case of dealing with any fire situation, the first essential, apart from rescue work, is to locate the seat of the fire. Time spent on this aspect can be rewarding in silo incidents. If flames are showing from the top of the silo, the possibility is that the fire is not deep-seated and can probably be dealt with by a reasonable application of water to the top crust, bearing in mind that no attempt should be made to enter the silo owing to the possible formation of cavities and the collapse of the crust.

20. If the fire is deep-seated, its location then becomes a question of elimination and the pertinacity with which a suitable metal probe, introduced through a hole drilled in selected hatch doors, is used to gauge the intensity and depth of the fire. The design of the internal chute behind the doors has an important bearing on the penetration problem, but practical fire experience indicates that in spite of structural difficulties probe penetration can be made. Access to the hatch doors is gained via a vertical metal ladder which is provided with a protective metal shield to guard against a man falling from the ladder. It follows that this could be a source of danger to firemen working on the ladder in that it could retain dangerous gases and a build-up of heat when working on a hatch door. Experience has indicated that it is necessary to remove a section of the metal shield for the reasons stated above. The initial penetration work could prove to be so difficult that it may be necessary to make use of a hydraulic platform or suitable scaffolding as mentioned in paragraph 25. Firemen engaged in the above work should wear protective gloves as a precaution against heat blast from the hole when entry is being made to the silage. Goggles would also give protection to the eyes from chips of the vitreous lining or other protective material used in the construction of the silo.

(c) The explosion hazard

21. With a deep-seated, spontaneous fire of this nature, care has to be exercised in the disposition of personnel, because whilst an explosion in the type of silo under discussion has never occurred in the United Kingdom, the possibility is always present: it follows, therefore, that men should not be permitted to go on the roof of the structure for this reason and the fact that the evolution of dangerous vapours is always a possibility. It is also advisable for personnel to be withdrawn from the fixed external platform giving access to the dome hatch whilst water is being injected using water probes at lower levels.

(d) Sealing off

22. At the same time as an attempt is being made to delineate the seat and extent of the fire, every effort must be made to retard the heating by sealing all apertures where air could enter the silo. Wet clay or any suitable (mastic) sealing material can be used for this purpose, and it cannot be stressed too strongly that a thorough inspection of the silo should be made to prevent the

ingress of air. Experience indicates that the sealing process is likely to give the impression to onlookers that little is being done to extinguish the fire, and officers may well find themselves under pressure from the farmer to take more positive action. This pressure must be resisted in the knowledge that the sealing action is a pre-requisite to successful fire extinction.

(e) Attacking the fire

23. As soon as the seat and extent of the fire have been located, an attack on the fire should commence. It is perhaps appropriate to mention at this stage that on two occasions high expansion foam was used in an attempt to control a fire without success as was the use of 'dry ice'. There is no reason to believe that low or medium expansion foam would have proved any more successful. Consideration was given to the use of bulk carbon dioxide, but difficulties of injection were such that its use was rejected. The possibility of using 'wet' water was also considered, but present experience indicates that any advantages gained would only be minimal.

24. The silage is packed so tightly in the silo that high pressure water jets applied to the exterior of the silage are quite incapable of penetrating the mass. It also follows that flooding the upper crust will not be effective; further, the increased weight applied to the silo structure could bring about collapse.

25. When the main body of fire has been located, the most satisfactory method of attack appears to be by the use of a 'water probe' fed by a line of $1\frac{3}{4}$ in. (44 mm) hose and discharging about 50 gallons (227 litres) per minute. To say the least, the injection of the probe into the tightly packed silage through a hole made by a cutter or drilling in the hatch door nearest to the seat of the fire is a laborious task. To force the probe into the mass, it is often necessary to use a sledge hammer while radial movement pressure is applied to the probe. The probes shown in Appendix 2 were constructed specifically at the time and used successfully in two separate silo fires.

26. A suggested modification to probe (a) would be a side entry for the hose coupling with the existing coupling removed and the end blanked off by a heavy cap. This would enable a sledge hammer to be used if necessary. Experience indicates that the insertion of the probe, if it cannot be carried out from a hydraulic platform, is a difficult task which calls for the use of scaffolding embodying a suitable working platform.

27. When the probe has been inserted and water applied, which is best carried out in stages, the affect of each application should be carefully observed. As mentioned in paragraph 24, flooding must be avoided for structural stability reasons. It must be stressed that no attempt should be made to enter the silo for 'working-out' purposes. After each application of water, the fire area should be tested for heat reduction by means of the metal probe and, as the temperature is reduced, it may be possible to make use of a 'temperature' probe without damage to the instrument. A typical temperature probe is shown in Appendix 3.

(f) Working out and cooling down

28. When the fire is known to be under control and working out by mechanical cutter is considered to be expedient. it may, under certain circumstances, be necessary for men to enter the silo to free the internal chute from wet haylage. Under such circumstances breathing apparatus must be worn and the operators secured with a lowering line, in addition to stage 1 procedure, to guard against the possibility of falling into a cavity in the haylage.

29. After the fire has been extinguished and the silo and contents are cold, it is necessary for fire brigade personnel to make an inspection from time to time. During such inspections it is recommended that the following precautions be observed:

a. It should be assumed that a layer of gas is present above the ensiled material.

b. The silo should not be entered without breathing apparatus, and the first action should be to remove the doors above and down to the level of the silage and ventilate with the filling blower for 10–15 minutes.

c. When removing the doors, personnel should stand above the doors and remain there for several minutes. Cold carbon dioxide and other gases which may be present will drift downwards.

RECOMMENDATIONS: FIRE PREVENTION

30. From a fire prevention point of view a silo of this type has the characteristics of an item of plant rather than of a building. It is essentially a machine for processing an agricultural product rather than a building for storing it. It follows from this that the most effective approach to fire prevention is by way of preventing an outbreak of fire in the plant rather than by modifying its design so as to minimise the effects of a possible fire, or by including a protective system in its design. To attempt this latter to any worthwhile extent would destroy the basic character of the plant itself and indeed would probably interfere with its function to an unacceptable degree.

31. The advice to users of these silos should therefore be confined to following the recommendations of the silo manufacturers for the correct loading and operation of the silo to avoid any risk of self-heating within it, as follows:

a. The cut or chop of the green material should be uniform. It has been suggested that it should not exceed $\frac{3}{4}$ in.

b. More material than can be speedily handled and loaded into the silo should not be cut otherwise it will tend to wilt.

c. The moisture content should be between 40 and 60 per cent and should not in any case be less than 40 per cent. 'Moisture content' should not be confused with 'dry matter'.

d. A minimum depth of 10 ft. (3.05 m) in the silo should be aimed at in one period of loading. It is important that the material be allowed to spread evenly to allow for proper consolidation.

e. After any loading, except for a pause of very short duration, the silo should be properly sealed to prevent air reaching the silage.

f. The material used for the final loading should have as high a moisture content as possible to form an effective seal or plug.

g. Instructions for operating the silo, issued by the manufacturer or supplier, should be followed rigorously.

h. For the purpose of ensuring good silage and the prevention of conditions likely to result in fire, it is an advantage if a constant check can be maintained on the temperature of the silage. Probe type thermometers or recording thermometers connected to temperature sensitive heads within the silo are not expensive. Any abnormal temperature rise will give early warning of dangerous conditions and enable corrective action to be taken.

2 August 1971
Home Office, Fire Department
Ruskin Avenue, Kew, Richmond, Surrey

APPENDIX 1

Manufacturers and suppliers of thermometer probes and recorders:

British Rototherm Co Ltd
Merton Abbey
London SW19 Tel 01-542 7661

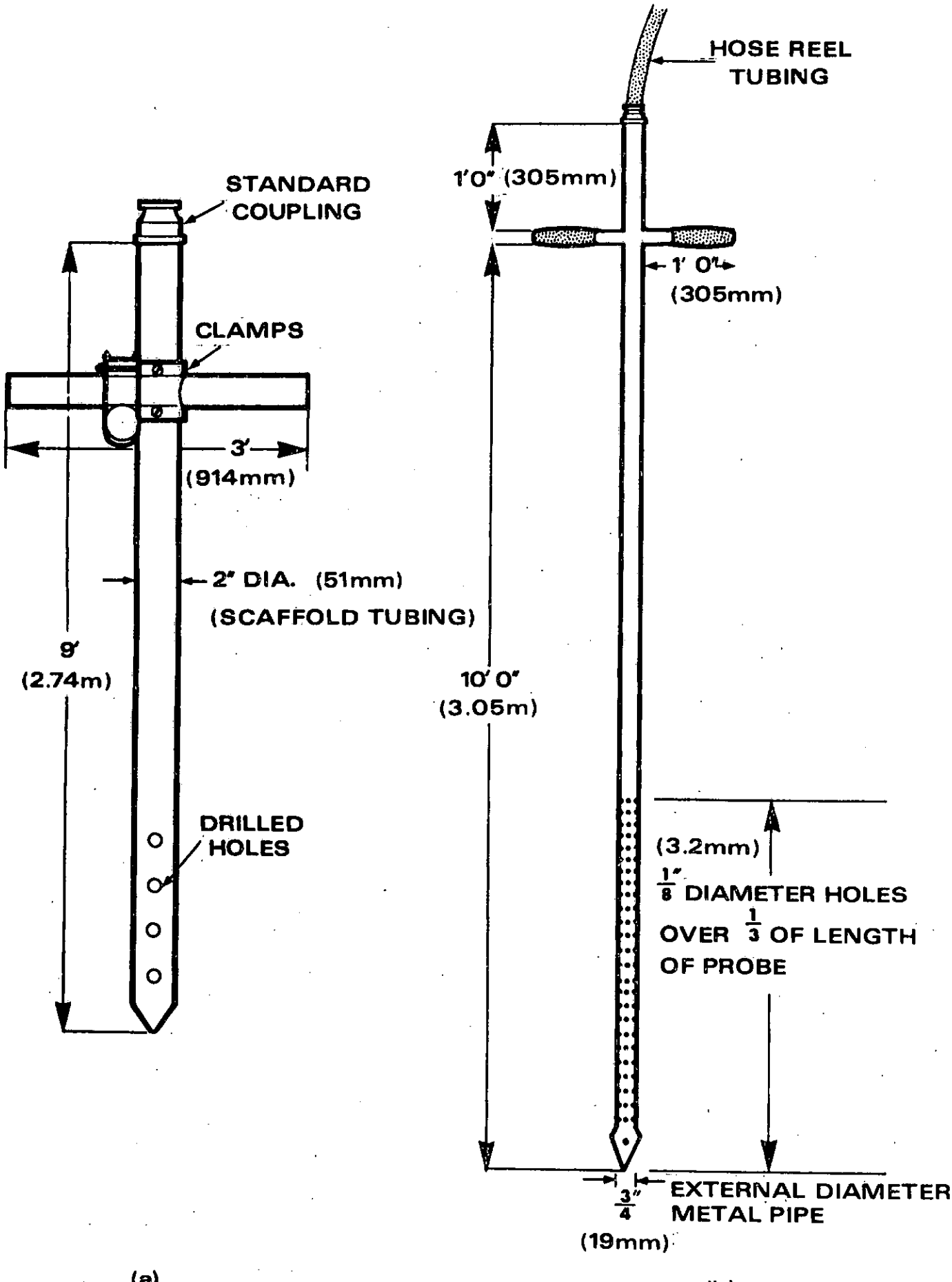
Opancol Ltd
10/11 Gamage Building
Holborn Circus
London EC1 Tel 01-405 0631

James Hughes Instruments Ltd
454 Finchley Road
London NW11 Tel 01-458 5277

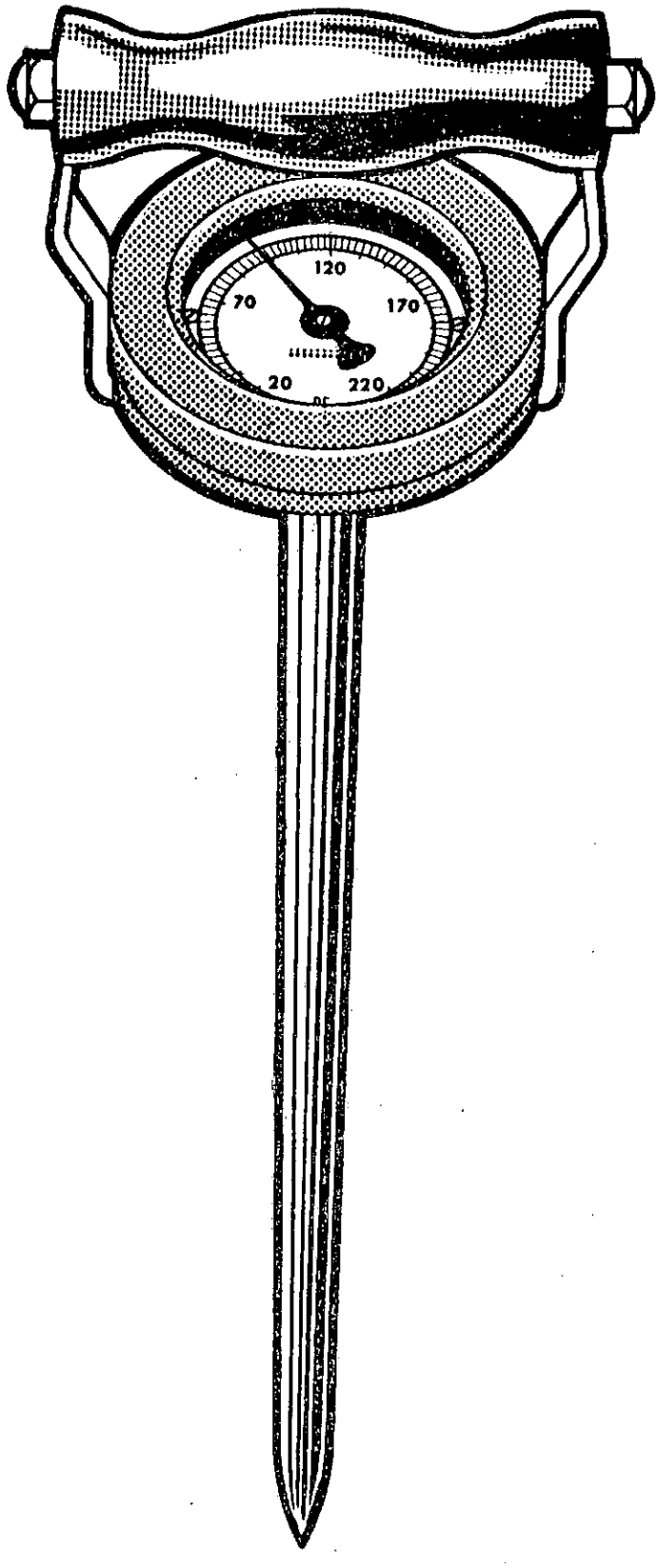
Suppliers and hirers of self-lock scaffolding:

Mills Scaffold Co Ltd
Head Office
Winchester House
53/55 Uxbridge Road
Ealing
London W5 Tel 01-567 3083

(Branches, agents and distributors throughout England, Wales and Scotland)



EXAMPLES OF WATER PROBE



PROBE - TYPE SILAGE THERMOMETER
available in lengths up to 5 ft (1.52m)

The Fire Service College

00123036