# Fire Research Note

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## TESTS FOR SELF-IGNITION OF OIL-SOAKED LAGGING

by

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## SUMMARY

Constructional and procedural details are given of two experimental methods of investigating the self-heating to ignition of oil-soaked lagging.



MINISTRY OF TECHNOLOGY AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

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## INTRODUCTION

These notes provide constructional and procedural details for ignition tests designed to assess the self-ignition hazard in oil-soaked lagging. The notes supplement a more general account given in reference 1. Reference 1 should be consulted for further information on the ignition behaviour likely to be encountered, on the choice of ignition criterion and on the interpretation of the results of the tests.

Two test methods are described. One, based on the determination of the minimum temperatures for ignition of cube-shaped samples, is suitable for screening purposes when, usually, a large number of tests will be required. It also permits rough estimates to be made of the ignition behaviour of the lagging on a pipe. The other test is based on an electrically heated pipe simulating practical conditions, and yields more directly applicable results; but it is not suitable as first choice when a large number of tests need to be carried out.

## 1. OVEN TESTS

These tests are straightforward and employ commercially available equipment entirely (appendix). For these tests a laboratory oven, the temperature of which can be controlled to $\pm$ 1° or 2°C is required, preferably with fan circulation of the air in the oven. The oven should be of such a design that there is no possibility of the leakage of oil from the interior onto the heaters or into the control compartment.

It is convenient to work with cubical specimens which may be cut from slab stock. Convenient sizes are 1, $1\frac{1}{2}$ and 2 inches (2.5, 3.8 and 5.1 cm) respectively. A minimum of two thermocouples must be arranged in the oven, these should be of small gauge, such as 30 S.W.G, Chromel/alumel. One thermocouple junction should be arranged to be in the vicinity of the cube in the oven, the other couple is used to register the temperature within the specimen. Heavier gauge compensating leads may be used for connections outside the oven.

If several specimens are to be tested simultaneously, additional couples can be added as required.

The thermocouples are connected to a multi-station recorder, preferably of the potentiometric type. A multi-range instrument is most convenient, suitable ranges being 0-10, 0-20, and 0-40 mv. Chart speeds of ½ in (1.0 cm) per hour and 2 in (5.0 cm) per hour should cover most requirements.

## TREATMENT OF LAGGING WITH OIL

In general it is necessary to determine the optimum concentration of oil for self-heating in the lagging. The concentration of oil in the lagging is expressed as a percentage of the voids in the lagging filled with oil. The volume of voids per unit volume of lagging is obtained from measurements of the bulk density and the density of the lagging material. Oil is added slowly from a burette to give the required concentration. Treated cubes should be left for some hours, preferably overnight, to allow the oil to become as evenly distributed as possible within the cube. With highly reactive oils, however, limitation of the standing period may be desirable in order to reduce undue oxidation before test.

Experience indicates that an optimum oil concentration will lie between 30 and 50 per cent of the voids, this value not being very critical.

## IGNITION TEST PROCEDURE

It is convenient to determine the minimum ignition temperature for the smallest size of cube first as this can be carried out quickly. The oven temperature should be adjusted to a suitable value. For a 1 in (2.5 cm) cube treated with mineral oil this temperature may often be in the region of 150°C, or higher. The cube is then suspended in the oven, near its centre, and one of the thermocouple junctions is thrust into the centre of the cube.

Occurrence of self-heating and ignition is then observed from the recorder traces.

As pointed out in reference 1 the determination of the critical ignition temperature does not necessarily require active combustion to be observed in every test, more often it will depend on a limited rise in temperature. Adequate allowance must be made for the presence of long induction periods in deciding on non-ignition; preferably a small temperature rise due to sub-critical self-heating should always be recorded in these cases.

Tests of this type are repeated with fresh cubes and different oven temperatures until the minimum oven temperature for ignition of a cube can be bracketed to within narrow limits, preferably not more than ± 3°C. It is important to note that fresh cubes must be used for each test, also a test must be continued to completion without interruption.

Optimum oil concentrations for ignition may be established by testing several cubes treated with different concentrations of oil simultaneously at each oven temperature.

## 2. HOT PIPE TESTS

A convenient apparatus has been designed for this test consisting of a length of steel barrel heated by two pencil-type heaters connected in series, thermostatically controlled. For vertical and horizontal tests the general layouts are similar, differing only in the manner in which the oil is distributed at the interface between the lagging and the pipe. Both types are shown in Figs. 1 and 2. It should be noted that these figures give essential dimensions but are otherwise not drawn to scale. Plate 1 shows the vertical pipe with an ignited lagging test section being removed. A description of some of the details to facilitate construction of the apparatus is given below. Details of those parts of the equipment which were available commercially are given in the Appendix.

### CONSTRUCTIONAL DETAILS OF THE HOT PIPE, VERTICAL AND HORIZONTAL

The pipe - In both cases this is a 2 ft 9 in (84 cm) length of 2 in B.S.P. steel barrel. For vertical operation the upper end should be fitted with a 2 in B.S.P. cap.

Oil Feed - In both vertical and horizontal operation, oil is fed from a small metering pump, and is circulated through 10 close coils of copper tubing, of $\frac{1}{8}$ in nominal I.D., brazed to the steel barrel. The positioning of these coils on the barrel is shown in the diagrams. For vertical operation the oil is allowed to leak from 1/16 in diameter holes drilled at $\frac{1}{2}$ in centres in the lowest of the copper tubing coils, the end being closed. In the horizontal position the oil is allowed to leak from a limb of the copper tubing brazed to the top surface of the steel barrel and drilled with 1/16 in holes at $\frac{1}{2}$ in centres, again with the end closed.

Pipe heater - Two 12 in 1 kw pencil type electric fire elements are used. The end caps are removed and the heater wire ends restrained by doubling back the last coil and twisting the loop with the free end, in the manner commonly used for electric tube furnaces. The heaters can then be slid on to a $\frac{1}{4}$ in O.D. mild steel rod, threaded at both ends, and fitted with asbestos wood spacing discs to hold the whole assembly centrally in the pipe (see Figs. 1 and 2). Bridging connections between the two elements, to the central steel axis at one end and to the mains supply at the other are made by brazing heavy gauge copper wire to the twisted ends of the elements. The output leads are fitted with woven glass sleeving and connected to the power supply from the temperature controller <u>via</u> a porcelain connector and a length of 5 amp TRS cable; the live line is connected to the steel rod running through the elements, the neutral is connected to the end connection of the adjacent heating element and the earth line is joined to the steel barrel, a good connection being ensured by anchoring the earth lead to the pipe by means of a brass screw.

<u>Temperature Control</u> - One 28 S.W.G. Chromel/Alumel thermocouple junction is peened into the barrel wall at the mid point of the pipe and is connected to the temperature controller. A good quality proportional controller is required with facilities for adjustment of power output to the load. A second thermocouple peened into the pipe wall near the control couple is used for recording the pipe temperature.

<u>Hot-pipe Supports</u> - The hot pipes are supported in an angle iron frame by two support plates of asbestos wood ¼ in thick. Each support is 6 in wide and has a hole cut to be an easy fit on the hot pipe. The pipe in the vertical position is retained in the supports by set screws in the pipe wall, the supports being rigidly bolted to the frame.

To obtain an even temperature distribution over as great a part of the central section of the hot pipe as possible, the spacing between the two heater elements is important and the optimum was found in practice to be 2 in (5 cm). A further measure is to lag the pipe ends with 1 ft (30 cm) guard pieces at each end as shown in the diagrams. Further insulation is achieved by plugging the guard piece with loose fibreglass lagging material. Using these precautions a uniform temperature over the central 10 in (25 cm) of the pipe was obtained to $\pm$ 2.5°C in the vertical position and $\pm$ 1.5°C in the horizontal.

PROCEDURE

The lagging, usually in the form of moulded sections, is placed in position and the joints are filled with a plastic cement. Four thermocouple junctions (28 S.W.G. Chromel/Alumel) are then inserted into the lagging, radially in the mid-plane, until they are about 1 cm. from the pipe surface and a fifth is placed on the outer surface of the lagging. These couples are connected to a potentiometric recorder as for the oven tests. When the lagging is in position, the power is switched on with the controller set to a desired pipe temperature. When all the thermocouples are recording steady temperatures the oil supply is started. An optimum rate of feed is not clearly defined; work carried out so far[1], however, indicates a rate of 3.5 ml/min is suitable for 2 in thick lagging and a rather lower one 1-1.5 ml/min is required for 1 in material.

Experiments should be repeated with fresh lagging at different pipe temperatures until the lowest pipe temperature at which ignition takes place can be bracketed to within $\pm 5^{\circ}C$.

Earlier comments on the recognition of ignition in cubes apply with equal force to tests on pipes.

If, from the lagging thermocouple records, ignition is suspected this can often be confirmed by removing the lagging halves from the pipe and standing them together on end as on the pipe, preferably in a draught. It has been found that if this is done the smouldering rate will often increase until glowing ignition can be observed.

## REFERENCES

1. BOWES, P. C. and LANGFORD, B. The spontaneous ignition of oil soaked lagging. Ministry of Technology and Fire Offices' Committee Joint Fire Research Organization. Fire Research Note No. 665.

## APPENDIX

Apparatus used which was obtained commercially is listed below. The list implies no preference; any other equipment meeting the general requirements indicated here and in the text should be equally satisfactory.

1. Oven - Townson and Mercer 'Even Heat' oven with a maximum temperature of 250°C was used with trays and tray holder removed. The oven is obtainable from:-

   Townson and Mercer Ltd.,
   Scientific Equipment,
   Croydon.

2. Recorder - Foster 6-point, potentiometric recorder with 8 in chart. The ranges available on this instrument were 0-10, 0-20 and 0-40 mv. Chart speeds $\frac{1}{2}$, 1 and 2 in per hour. This recorder was not temperature compensated and was used with ice or Sunvic reference junctions. A recorder with temperature compensation and connections to single thermocouple junctions may be used.
   The recorder may be obtained from:-

   The Foster Instrument Co., Ltd.,
   Letchworth,
   Herts.

3. Electric Heaters - For each heater, two 1000 watt, 230/250 volt, 12 in pencil type electric fire elements were used.
   These may be obtained from:-

   Wellco Electric Ltd.,
   Knebworth,
   Herts.

4. Controllers - two types were tried.
   (i) Sifam 'Pyromaxim' electronic proportional controller with variac control of power to the load. This may be obtained from:-

   Sifam Electrical Instrument Co., Ltd.,
   Torquay,
   Devon.

(ii) Eurotherm PID/SCR-10, proportional controller obtainable from:-

Eurotherm Ltd.,
14, Chatsworth Road,
Worthing,
Sussex.

5. Metering pump - A DCL micro-pump, MK 3 with micrometer control of flow rate was used. Range of deliveries 0-700 cc per min. This may be obtained from:-

The Distillers Company Ltd.,
Research & Development Department,
Great Burgh,
Epsom,
Surrey.

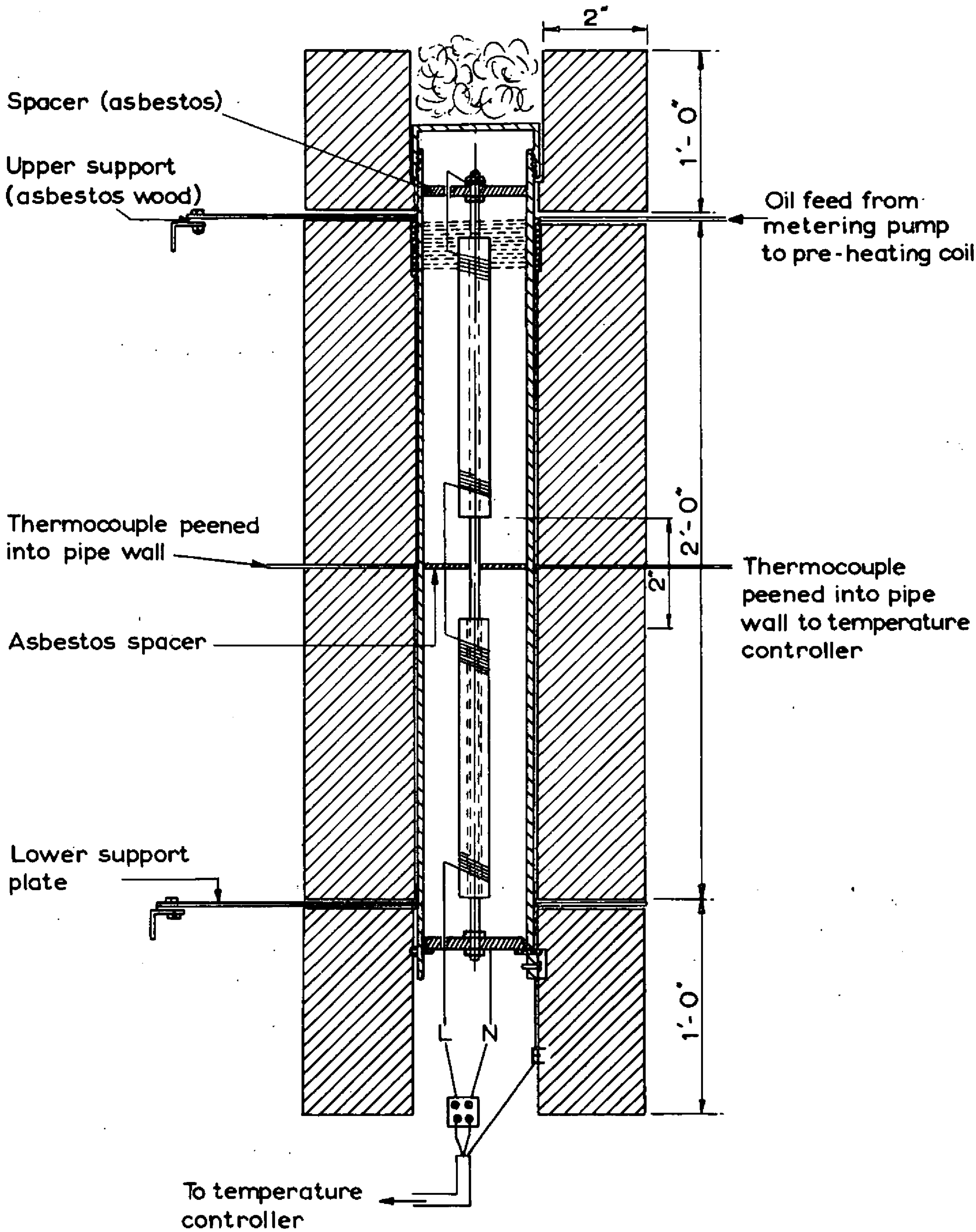


FIG. 1. SECTION THROUGH VERTICAL LAGGED PIPE

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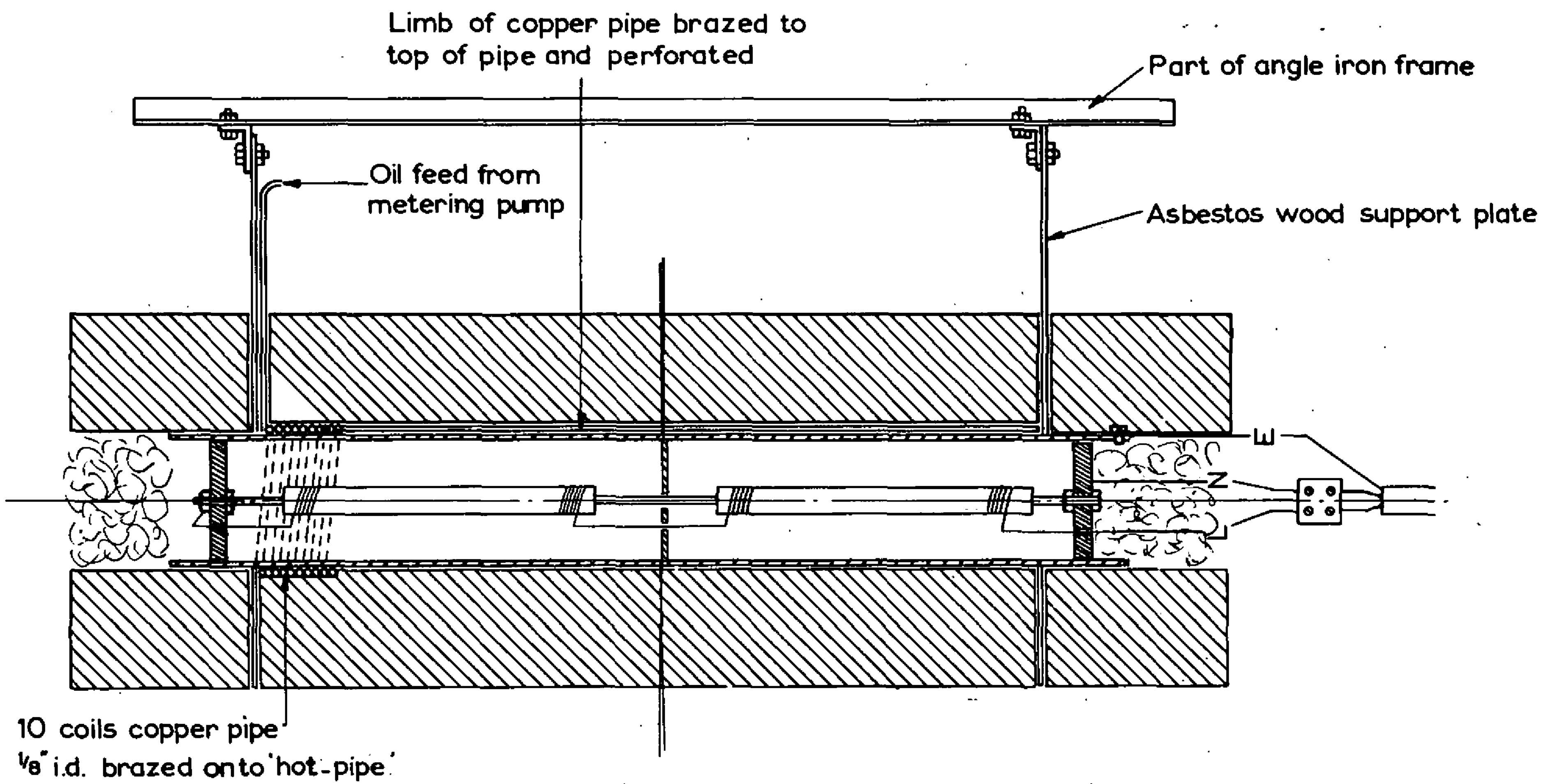
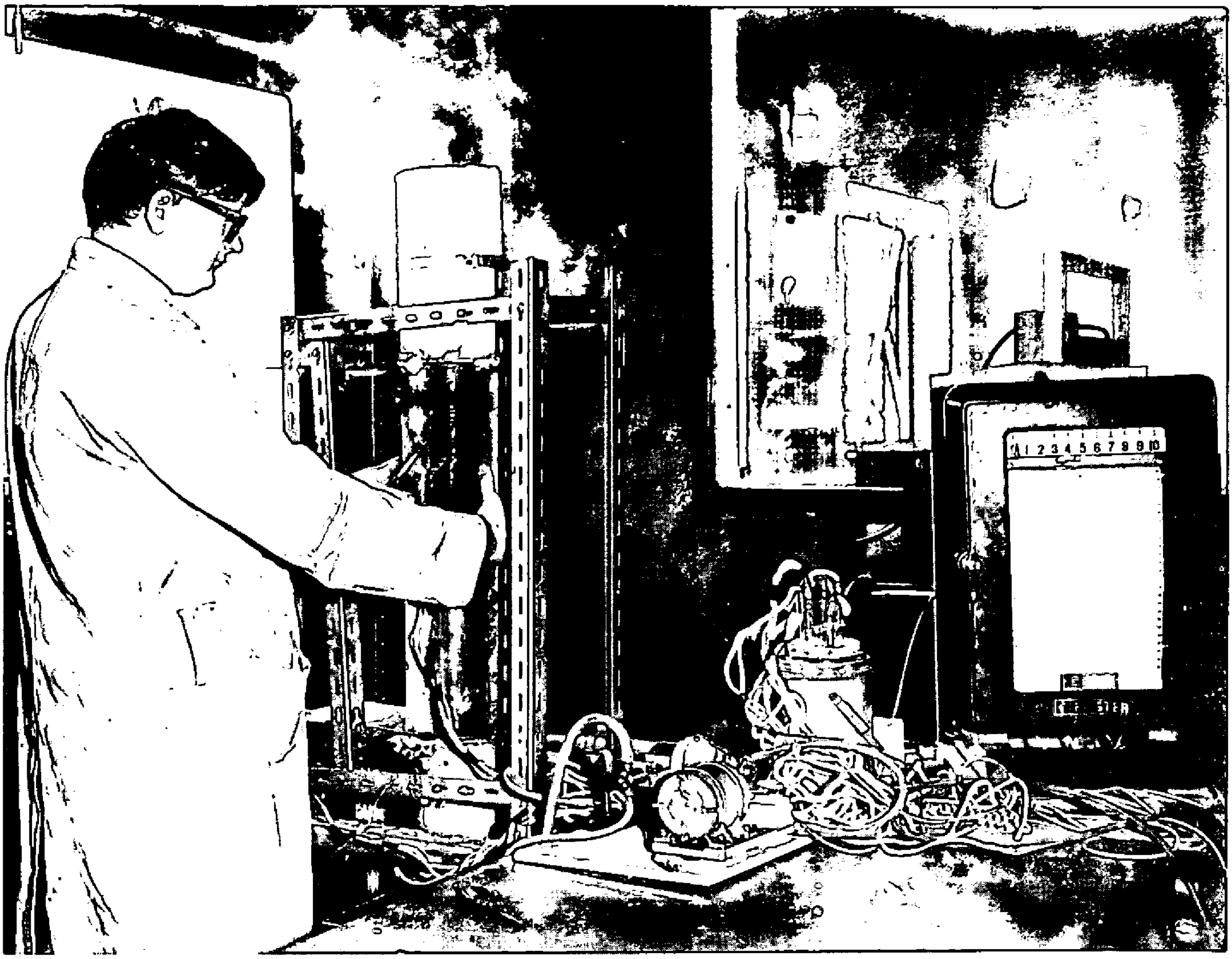



All details of pipe and lagging dimensions, heater and thermocouple arrangements the same as for the vertical apparatus

FIG. 2. SECTION THROUGH HORIZONTAL LAGGED PIPE



IGNITION OF OIL-SOAKED LAGGING
ON HEATED PIPE

PLATE 1