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CONF-631012--13

D. P. Report 225

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**Dragon Project Report**

PRELIMINARY REPORT

# DRAGON PROJECT HELIUM LEAK TESTING

MA

by
F. WADE



Dragon Project Engineering Symposium,
Bournemouth, 21st, 22nd and 23rd October, 1963



A.E.E. Winfrith, Dorchester, Dorset, England

October, 1963

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by

F. WADE

ABSTRACT

This report gives information on the many aspects and principles of helium leak testing by helium sensitive mass spectrometers. Results of leak tests made at manufacturers and at the Reactor site, are given together with the necessary precautions that must be observed if the results obtained are to be relied on.

CONTENTS



LIST OF ILLUSTRATIONS

LIST OF TABLES

DRAGON PROJECT HELIUM LEAK TESTING

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## 1. INTRODUCTION

The concept and design of the Dragon Reactor calls for standards of leak tightness that are normal to laboratory scale apparatus but distinctly unusual to a reactor plant. The primary circuit is required to contain an active coolant gas with all necessary precautions with respect to health hazards. The coolant gas, helium, is a comparatively expensive gas and, therefore, the circuit must be of a high standard of leak tightness to avoid wastage of helium.

In order to meet these exacting requirements the method of helium leak testing proposed by the Project is to use leak detectors embodying a mass spectrometer sensing element that is sensitive to helium. This decision was made after a careful consideration of other methods of test. The permitted leak rate of the reactor is 0.1% of contained gas per 24 h. Thus, each of the many components made in the different contractors' works throughout Europe must each attain this standard as an individual item. Thought was given to the various possibilities of making pressure drop tests; but it was considered that these would be both inaccurate and time consuming. The mass spectrometer, however, offered the possibility to ensure that each component was well within the acceptance standards within a period of 24 h.

## 2. HELIUM LEAK TEST INSTRUMENTS

A helium sensitive mass spectrometer can be used in two different modes. A vessel can be evacuated to a pressure lower than $10^{-4}$ Torr and at this stage the mass spectrometer sensing element, which is itself at a pressure lower than $10^{-4}$ Torr, can be connected directly to the evacuated volume. If helium is then sprayed over the surface of the vessel and the vessel contains a leak, helium will pass through the leak and will in turn enter the sensing element and give an indication on the output meter of the leak detector.

In the second mode of operation, if a vessel is pressurised with helium or helium/air mixture and the vessel contains a leak, helium will escape to the outer atmosphere. If a sample of the atmosphere from the vicinity of the leak is admitted to the sensing element via a fine needle valve, otherwise known as a sniffer, an indication of the presence of helium will be given on the output meter of the instrument.

Leak testing for the Dragon Project involves both methods of detection and particular attention has been given to instrument performance when specifying the instruments to be used. To ensure that all parts of the reactor have been tested to the same standards of leak tightness it has been necessary to specify the sensitivity of the instruments to be used at the works of the various manufacturers and on the construction site.

The first requirement to be met is that the mass spectrometer when used under vacuum conditions should have a sensitivity of $10^{-10}$ cc/s. The second requirement is that when it is operating as a sniffing device it should be capable of detecting the helium content in the atmosphere, i.e., 5 ppm. The instrument must also have a facility to back off the atmospheric helium content signal so that the instrument can operate with full sensitivity on the most sensitive range.

Four different instruments have been approved for Dragon Project work. These are listed in Table 1.

Table 1
Mass Spectrometers approved for both Vacuum and Sniffing Test

| Make of Instrument | Type No. |
|---|---|
| C.E.C./Elliott | 24-120 |
| C.E.C. | 24-110 A |
| Helitest | 2002 |
| Atlas Werke | Model C |

In the majority of the instruments that were investigated, the sensitivity to helium when operating under vacuum conditions was up to the standards required by the Project. This was not so, however, when they were used as sniffing detectors. A considerable part of the Project leak testing involves the use of sniffing techniques and it was, therefore, necessary to adhere to the specification of instrument acceptance. This does not mean that all of the other instruments investigated were not good mass spectrometers. Many of them were excellent instruments which, unfortunately, could not be used due to the unusual requirements which were dictated by the nature of the circuit under test.

## 3. METHODS OF HELIUM LEAK TEST

With the wide variety of components in the Primary Circuit the helium leak test must cover tests for acceptability of gasket sealing features, welds, plate materials, forgings and electrical penetrations containing ceramics. Tests for these items fall into two distinct categories, each requiring a different technique.

### 3.1 Leak Test of Welds, Plate Materials and Forgings

These tests are made whilst the items being tested are at full test pressure, normally at 1.1 times design pressure. The detector is then used as a sniffing device. In order to cover the large surface areas of plate material and tubes, special techniques have been evolved to make surveys of such areas. With the small diameter sniffing probe it would be impossible to cover these areas by a simple probing technique. In order to overcome this difficulty the vessel under test is covered in sheet polythene after it has been pressurised. It is left in this condition for a period of 24 h, at the end of this isolation period the contained volume beneath the polythene is monitored for helium content. If this is above the normal background level a more complete survey must be made. This is done by covering the suspected areas in smaller pieces of polythene and then monitoring these smaller pieces after a suitable interval of time to determine in which area the leak exists. Having eliminated a large number of small areas a methodical probing must then be carried out.

### 3.2 Leak Test of Flanges

Many of the flanges in the reactor circuit have a soft metal gasket which is backed up by a secondary seal formed with a rubber O-ring. To test a flange of this nature the leak detector can be used in the vacuum condition by creating a vacuum in the interspace between the O-ring and soft metal gasket.

Where a flange is eventually to be seal-welded the prime purpose of the soft metal gasket is to provide the means for pressure testing the seal weld without necessarily pressurising the whole circuit. This is shown in Fig. 1a. The quality of this gasket seal is, however, tested during the manufacturing stages and also on site during the erection sequences. It is essential that this should be of a high quality for it is often very desirable to leave making the final seal weld until after a comprehensive series of tests have been made on the reactor circuit. With such a high quality seal it does virtually mean that the flange seal weld is a secondary seal to the gasket.

In order to test the gasket leakage of such a flange before welding it is sometimes possible to fit an O-ring around the weld preparation as shown in Fig. 1b. Where this is possible the interspace can then be evacuated and the mass spectrometer connected directly into the interspace. Should this method not be practicable the flange is bagged in polythene and tested for leaks with the sniffing probe after a 24 h isolation test.

### 3.3 Leak Test of Electrical Penetrations

Electrical penetrations of the pressure vessel have presented a number of design problems. The basic features must of course be an electrical conductor sealed to an insulating body which is in turn effectively sealed to the wall of the pressure vessel. A typical design is shown in Fig. 2. This design utilises a commercially available metal to ceramic seal with a central conductor wire brazed in the metal ceramic seal.

A secondary seal is provided by a compressed rubber insert which produces an effective seal between the conductor wire and the body of the seal plate. The space between the two seals enables a full mass spectrometer test to be made, i.e., mass spectrometer connected directly to the interspace, on the quality of the metal ceramic seal both during the manufacture and site erection. A test of the effectiveness of the rubber seals can also be made by pressurising the interspace and sniffing over the top of the rubber seals.

## 4. LEAK TIGHTNESS SPECIFICATION AND ACCEPTANCE STANDARDS

Before laying down a precise statement of leak tightness specification, an extensive programme of investigation was made by the Project on a test vessel at Mannesmann A.G., Hückingen [1]. The test vessel included a six foot diameter flange and similar weld contours as on the main pressure vessel for the reactor. The results obtained were satisfactory in all respects and from the results obtained the following standards of acceptance have been used throughout all Project work.

### 4.1 Soft Metal Gaskets

The maximum permitted leak rate at a test pressure of 1.1 times design pressure is $10^{-10}$ atmospheric cc/s/cm of gasket length.

4.2 Welds, Plate Material and Forgings

No individually detectable leaks are permitted with the component at a test pressure of 1.1 times design pressure and the mass spectrometer operating on its most sensitive range as a sniffing detector.

4.3 Overall Leak Rates

Wherever possible, components of a complex nature have been given an overall leak rate figure for acceptance. An example of this is the Fission Product Delay Beds, Fig. 3, the overall leak rate from the charcoal filled tubes to outer container being $10^{-6}$ cc/s.

## 5. LEAK TEST RESULTS

The results of helium leak testing to date have shown that by a combination of good design and good workmanship reactor components can be made helium leak tight to the standards of the mass spectrometer leak detector. Throughout the whole leak testing programme both at manufacturers and on site consistently high standards have been obtained. The complexity of the primary circuit with its many flanges can be seen from Figs. 4a and 4b.

Probably the most outstanding feature of the circuit with respect to the problem of leak tightness is the results obtained with the main flange gasket seal feature, Fig. 5. The results obtained with this seal have been consistently good. The results of the final test made at Mannesmann and the first test made at the reactor site are given in Table 2.

Table 2

Leak Rate from Main Flange 78.6" Dia. at 385 psi

| Place of Test | Gasket | Measured Leak Rate |
|---|---|---|
| Mannesmann | Aluminium | $10^{-8}$ cc/s |
| Reactor Site | Silver | $2.5 \times 10^{-8}$ cc/s |

The leak rate per unit length of gasket for the site test is thus $4 \times 10^{-11}$ cc/s/cm.

Another example of gasket leakage is the good results obtained at the reactor site with the flanged joints between the Absorber Rod Pressure Vessel and the Main Pressure Vessel. The flanges were tested as shown in Fig. 1b. Helium pressure was applied to the flange through a specially designed bung that enabled pressure to be applied to the gasket alone without pressurising the whole circuit. Out of the twenty-four flanges only three showed any sign of leakage. These are listed in Table 3.

Over the whole sequence of erection to date, the same quality of gasket sealing has been achieved and, so far, the problem of whether to reject or accept has not arisen.

Welding during the work done for the Project has been of an extremely high standard. Naturally, there have been some leaks but so far they number less than twenty. An example of the high standards reached concerns the Primary Heat Exchangers.

| Table 3<br>Helium Leakage from Flange Joints between Pressure Vessel and Absorber Rod Pressure Vessel | |
|---|---|
| Flange No. | Helium Leak Rate cc/s |
| 7 | $10^{-9}$ |
| 16 | $2.7 \times 10^{-9}$ |
| 8 | $1.6 \times 10^{-8}$ |

Each Heat Exchanger contains approximately four hundred welds, seven units including the prototype have been made and during the course of manufacture five welds were found to be leaking. On the final acceptance test three units were found to have leaks, these were located and repaired. Table 4 gives the results of the final acceptance tests made on the units.

| Table 4<br>Final Leak Test Figures for Primary Heat Exchangers Test Pressure 385 psi | | |
|---|---|---|
| Unit No. | Leak Rate cc/s | |
| | First Test | Second Test |
| 1* | $3 \times 10^{-6}$ | $5.6 \times 10^{-9}$ |
| 2* | $2 \times 10^{-4}$ | $8.7 \times 10^{-9}$ |
| 3 | $4.2 \times 10^{-9}$ | Not Necessary |
| 4* | $3.4 \times 10^{-6}$ | $2.4 \times 10^{-9}$ |
| 5 | $2.4 \times 10^{-8}$ | Not Necessary |
| 6 | $2.3 \times 10^{-8}$ | Not Necessary |

*Unit subject to repair after first test.

Table 5 gives the results of the leak test made at the reactor site on the delay beds after they had been lowered down into position. These tests were made by evacuating the outer container and connecting the mass spectrometer directly into the container.

| Table 5<br>Leak Rates for Delay Beds. Test Pressure 385 psi | | |
|---|---|---|
| No. | Leak Rate cc/s | |
| | Charcoal filled Tubes to Outer Containment | Outer Containment to Atmosphere |
| 1 | $7.4 \times 10^{-7}$ | Nil |
| 2 | $6 \times 10^{-8}$ | Nil |
| 3 | $4.4 \times 10^{-8}$ | Nil |
| 4 | $2.3 \times 10^{-6}$ | Nil |
| 5 | $1.3 \times 10^{-8}$ | Nil |

A further example of the degree of leak tightness of the circuit is the thermocouple penetration plates, Figs. 6a and 6b. These plates utilise 240 commercially available metal ceramic seals. There are three such plates in the circuit and considerable difficulty was experienced in making an acceptance test of the plates. To make a test each seal had to be individually blanked off in such a way that no damage was done to the plate. Soft solder was not permitted because of the final brazing operation. A successful method was evolved by inserting a copper wire through the seal and melting a small bead of vacuum wax over the end of the seal. This produced an effective seal that gave a good indication of the quality of the plates. Table 6 gives details of the plate acceptance tests carried out in the laboratories of the Project Techniques Group.

| Table 6<br>Leak Rate of Ferranti 240-way Thermocouple Penetration Plates during Acceptance Test | | | |
|---|---|---|---|
| Helium Pressure | Leak Rate in cc/s for Plate | | |
| | 1 | 2 | 3 |
| Atmospheric | - | - | - |
| 20 psi | - | $6 \times 10^{-8}$ | $6 \times 10^{-8}$ |
| 100 psi | $8 \times 10^{-7}$ | $2.5 \times 10^{-7}$ | $3.1 \times 10^{-7}$ |
| 200 psi | $1.7 \times 10^{-6}$ | $10^{-6}$ | $6.3 \times 10^{-7}$ |
| 300 psi | | | $1.6 \times 10^{-6}$ |
| 385 psi | $3 \times 10^{-6}$ | | $2.5 \times 10^{-6}$ |

The rate of rise of leak rate was slow and from previous test made in the laboratory this could be identified as a leak through the temporary wax seal.

The first 240-way plate is now on the Reactor having had the thermocouple conductors brazed in position. On the first test of this plate, No. 1 from Table 6, the leak rate at 385 psi was of the order of $10^{-4}$ cc/s. A systematic investigation of the plate was made and after individually testing 190 seals the leaking seal was was located and the source of leakage pin pointed. Fortunately, it was in the braze between the conductor wire and seal and could be easily repaired. After repair the plate was then strength tested to 450 psi, after holding the pressure at this value the pressure was reduced to 385 psi and an overall leak test made by placing a vacuum chamber over the back end of the plate. There was no detectable leak after a test period of thirty minutes with the mass spectrometer operating on its most sensitive range where a leak rate of $10^{-10}$ cc/s would have been measurable.

## 6. LABORATORY INVESTIGATIONS IN SUPPORT OF LEAK TEST PROGRAMME

A small scale programme of work has been made in the laboratory to investigate the effectiveness of the methods used for leak detection. [2] This work has shown that even though the polythene sheet used in bagging the various components under test has a natural permeability to helium of approximately $2 \times 10^{-6}$ cc/s/cm$^2$, this accounts for a helium loss of the order of 20% coming from a known leak during an isolation period of 24 h. The investigations have also shown that the isolation period of 24 h is a realistic interval for isolation. In the experiments carried out equilibrium conditions were reached after a period of 17 h.

When a vessel is covered with polythene and monitored for leaks with the sniffer probe as shown in Fig. 7, it is necessary to insert the probe at a number of points. Laboratory tests have shown that a point source of leakage $6.6 \times 10^{-7}$ cc/s will give 75% of the maximum possible signal at a distance of 80 cm from the point source. Thus, if a sheet is probed to cover a radius of 60 cm adequate coverage is obtained.

## 7. LEAK PREVENTION

The techniques of leak detection are, once mastered, straight forward, though perhaps time consuming. During the period of leak testing covered by this report a lot of effort has been put into the prevention of leaks. This mainly concerns flanged joints. The experience gained at Mannesmann A.G. proved conclusively that considerable care must be given to the preparation and handling of soft metal gaskets. Gaskets must be free from radial scratches, grease and dust. Attention must also be given to the annealing of gaskets.

The same attention must be given to the flange sealing features. They must be mechanically sound, free from rust, grease and dust. To achieve these near clinical conditions it is necessary to swab both gaskets and flanges with acetone and should there be dirt in the flange sealing features this must be carefully removed with a soft brass wire brush followed by further washing with acetone. A simple but effective test of the cleanliness of a flange is to wipe it with a freshly laundered white handkerchief. If there is no visible sign of dirt on the handkerchief the flange can then be considered clean enough to make a successful flanged joint.

To avoid leaks on site it is absolutely essential that all components are leak tested before installation under the condition that they are going to work.

Experience has shown that it is not permissible, or wise, to assume that because a component is leak tight under one set of conditions, e.g., vacuum, it will also be leak tight under different circumstances, e.g., pressure.

The bellows in the Overwind Mechanism are required to withstand a test pressure of six atmospheres. During final tests at works four bellows units were suspected of having leaks. These units were investigated in the laboratory at Winfrith with the results shown in Table 7.

Table 7

Leak Tests on Overwind Bellows

Test Pressure 6 atmospheres

| Bellows No. | Pressure at which leak appeared | Final Leak Rate at 6 atmospheres |
|---|---|---|
| 7 | 3-4 atmospheres | $5 \times 10^{-7}$ cc/s |
| 13 | 3-4 atmospheres | $> 10^{-5}$ cc/s |
| 20 | 4-5 atmospheres | $> 10^{-5}$ cc/s |
| 21 | 3-4 atmospheres | $> 10^{-5}$ cc/s |

Another example of the wisdom of testing a component under working conditions relates to one of the Re-entrant Tubes. The mode of test called for the tube to be pressurised on the outside to 385 psi and a helium leak test made on the inside, this being carried out by evacuating the tube and connecting the mass spectrometer directly to the tube. At pressures up to 250 psi there was no detectable leak but between 250-300 psi a leak became apparent and at 385 psi the leak stabilised at a value of $1.2 \times 10^{-5}$ cc/s.

In many instances it would have been much easier to have tested pressure retaining components under vacuum conditions, however, the two instances above clearly illustrate the necessity of carrying out acceptance tests under full working conditions.

## 8. FUTURE LEAK TEST PROGRAMME

The work that has been reported on, whilst this has been extensive, has been carried out in many different places throughout Europe and has been spread over a period of approximately eighteen months. We are now rapidly reaching the stage when the Primary Circuit is complete and ready for its first test in the cold condition.

Before commencing the first leak test in the cold condition the circuit will be subjected to a strength test with compressed air. During the period when the circuit is pressurised with dry, oil free compressed air, the functional operation of certain valves will be checked. Following these tests helium will then be introduced into the circuit in sufficient quantity to give a 10% helium/air mixture at the test pressure of 385 psi.

At this stage it is the intention to leak test all welds that have not been previously tested, to leak test all flanged joints that have not been previously tested at 385 psi and to check the interspaces between the ceramic metal seals and the rubber secondary seals in the cable penetration plates. Table 8 gives an indication of the number and type of flange included in the circuit, Figs. 4a and 4b.

Table 8

Primary Circuit Flanges

| Flange Type* | Number Off |
|---|---|
| A | 83 |
| B | 146 |
| C | 13 |

*Type A flange = Non demountable flange. Metal gasket - seal welded.

Type B flange = Demountable flange. Metal gasket backed up with rubber O-ring.

Type C flange = Demountable flange. Metal gasket with seal weld feature on flange.

During the construction of the Reactor all of the flanges between the Absorber Rod Pressure Vessels and the Main Pressure Vessel have been leak tested at pressure. It is the intention, time permitting, to test 25% of these flanges again.

Table 9 gives information relating to the location and number of electrical penetration plates in the Primary Circuit.

## 8.1 Areas of Testing

In order to carry out the cold leak test of the Primary Circuit it is the intention to use four mass spectrometers, 2 type 24-110A and 2 type 24-120: the latter type of instrument being more portable. The circuit has been divided into four areas of operation and these areas are designated A, B, C and D. Tables 9, 10, 11 and 12 give details of the items of plant and the flanges involved in each area as taken from Figs. 4a and 4b.

Each area presents to some extent problems of handling instruments and accessibility, the worst case being in the Dump Tank Area D. In all areas special provision is being made for parking areas to accommodate mass spectrometers and ancillary equipment. Power supplies are also being made available on long trailing leads so that instruments can be moved whilst they are still operating.

| Table 9<br>Electrical Penetration Plates in Primary Circuit | | |
|---|---|---|
| Location | Number Off | Type of Penetration |
| $2\frac{1}{4}$" Thermocouple lead assembly | 1 | Ferranti metal ceramic seals<br>18 seals |
| Coolant Ducts | 6 | Ferranti metal ceramic seals<br>16 seals per plate |
| Absorber Rod Pressure Vessels | 24<br>1<br>1<br>1 | Ferranti metal ceramic seals<br>27 seals per plate<br>8 seals per plate<br>4 seals per plate<br>2 seals per plate |
| Valve Drives Primary Heat Exchangers | 6 | Ferranti metal ceramic seals<br>27 seals per plate |
| Thermocouple Penetrations | 3 | Ferranti metal ceramic seals<br>240 seals per plate |
| Viewing Facility | 2<br>1<br>1 | Ferranti metal ceramic seals<br>24 seals per plate<br>29 seals per plate<br>16 seals per plate |
| Charge/Discharge Machine | 6 | Ad-Vac metal ceramic seals<br>30 seals per plate |
| Main Entry Valve Drive | 1 | Ad-Vac metal ceramic seals<br>30 seals per plate |
| Primary Gas Circulators | 6 | Each circulator has six glass to metal seals |

| Table 10<br>Leak Test. Area A - Inside Biological Shield from Main Flange to top of Charge Machine | |
|---|---|
| Item | Flange No. |
| Main Pressure Vessel | 1, 8 |
| Clean helium return line | 16, 48 |
| Charge Machine | 2, 2a, 36*, 37, 38, 38a, 50, 51 |
| Cabling Mounting Cage | 14, 39, 39a |
| Transfer Flask and Main Entry Valve | 6, 40, 41, 53, 54, 55, 56, 57, 58 |
| Primary Heat Exchanger Transfer Units and Primary Circuit Coolant Circulators | 17, 18, 19, 52 and Ferranti seals |
| Viewing Systems | 5 |

*Flanges already tested to DSTS 10.

| Table 11<br>Leak Test. Area B - Inside and Outside Biological Shield from Main Flange down to Pressure Vessel Skirt | |
|---|---|
| Item | Flange No. |
| Viewing Facility Branches | 26, 26a (1) (1) 26, 26a (2) (2) and Ferranti seals |
| Absorber Rod Pressure Vessel Control Mechanism, Electrical Penetrations, Instrument Drive Electrical Penetrations | 13*, 20, 21, 21a, 22, 23 |
| $2\frac{1}{4}$" Thermocouple lead assemblies | 21, 42 and Ferranti seals |
| Thermocouple Branches Coolant Ducts | 49, 49a and Ferranti seals |
| Core Unclamp Transverse Tube, Pressure Sensing and Monitoring Tubes Core Unclamp Valve | 10, 24, 25 |

*Flanges already tested to DSTS 10.

| Table 12<br>Leak Test. Area C - Inside Biological Shield from Skirt down to Pit Area | |
|---|---|
| Item | Flange No. |
| Main Pressure Vessel | 3 |
| Primary Circuit Pipe Work | 7 |
| Purge Gas Precooler | 4 |
| Neutron Source Drive Pressure Vessels | 45, 46, 47 |
| Re-entrant Tubes | 11, 9 |
| Bottom Dome Thermocouple Lead Assemblies | 9*, 43, 44 and Ferranti Seals |

*Flanges already tested to DSTS 10.

| Table 13<br>Leak Test. Area D - Dump Tank and Delay Bed Area | |
|---|---|
| Item | Flange No. |
| Primary Circuit Pipe Work | 28, 29<br>32, 33, 34 |
| Heat Sink | 30, 31, 35 |
| Dump Tanks | 27 |

## 8.2 Scope of Cold Leak Test

During the cold leak test the atmosphere in the building will be monitored for helium content. Should there be any general increase, as distinct from a local increase, it will then be necessary to contain the total volume within the biological shield into specified smaller volumes and to monitor each containment for increase of helium background after a period of isolation. Area D would have to be treated as one separate unit.

Whilst the probability of a general increase is small it cannot, however, be ignored. The most likely cause would be a leaking flange, failure of the seal between Transfer Flask and Main Entry Valve or failure of a cable penetration plate.

Flanges will be tested as in Section 3.2 and any leakage from these should be observed at a fairly early stage of the test. The seal between the Main Entry Valve and Transfer Flask will be dealt with as a separate test and will be covered in the tests made in area B.

Electrical penetration plates will be tested in accordance with Section 3.3, and here also leakages, if any, should be detected at a fairly early stage.

It is not intended to establish at this time what the overall leak rate of the plant is by the use of mass spectrometer techniques. It has been accepted that such a test is not a practical proposition. The use of the containment shell as a means for an accumulation measurement has been considered. The volume is, however, so great that the result would be unreliable.

A similar problem has already been encountered on the Helium Purification Pilot Plant where it was also impossible to make a containment of small free volume. The leak rate for the plant has been established from the knowledge of the volume of the plant and the amount of gas taken from a make-up cylinder, of known volume and pressure, after the plant had been running for a given period of time.

During the cold leak test a record of any leaks found will be made. These will then be added to those of already known small leaks, e.g., Delay Beds, Heat Exchangers. This will enable an approximation to be made as to the likely overall attainable leak rate.

## 9. CONCLUSION

The leak testing programme to date gives every indication that the permissible leak rate for the Reactor of 0.1% contained gas per 24 h will be met. The programme of leak testing carried out has by its nature been extensive and has obviously cost money. The cost of hiring a mass spectrometer plus all ancillary equipment and the services of a skilled technician is of the order of £150 per week. Where a firm or organisation, including the Project, have their own mass spectrometers this figure would become considerably smaller, even so, helium leak testing is an expensive business.

At this stage of the Project it is difficult to say with any degree of certainty just how much the leak testing programme could have been curtailed. It is clear, however, that there are certain items like electrical penetration plates and heat exchangers where it is necessary to carry out careful testing during manufacture.

Failure to do this could result in a stage being reached where it is impossible to carry out any repair work because the leak is either impossible to find or it is inaccessible.

One of the problems that has remained with the leak test programme is the question of making temporary seals and ensuring that the pressure lines to the item under test are free from leaks that will give false readings. On a number of occasions false alarms have occurred due to the contamination of polythene containers by helium leaking from pressure lines and passing through the polythene.

Helium contamination of the atmosphere is a continual problem that requires careful attention. Apart from adequate ventilation around the helium supply it is essential that when a helium containing vessel is blown down, it must be blown down to the atmosphere outside of the building where the test is being made. Failure to observe this precaution can result in a complete suspension of leak testing and/or many hours of careful preparation being wasted.

The results of leak testing at the various manufacturers and at site clearly indicates that with the application of good engineering practice and conventional techniques, reactor components can be manufactured that will pass the mass spectrometer helium leak test.

## 10. ACKNOWLEDGMENTS

The writer would like to acknowledge the efforts of his colleagues in the Project Techniques Group and the many firms throughout Europe for their help and assistance in carrying out the extensive Helium Leak Testing Programme. The help of the Project Engineering Division, UKAEA, Inspection and Progress Section, and the Construction Group is also gratefully acknowledged.

## 11. REFERENCES

[1] F. Wade and D. Barnes, Leak Testing of the Test Vessel and Experimental Gaskets at Mannesmann, Hückingen, West Germany. D.P. Report 23, D.P. Report 44, D.P. Report 66.

[2] J. Milne and A. D. Hammond, Helium Leak Testing Techniques: Containment of Helium Escaping from Leaks by Polythene Sheets. D.P. Report 201.

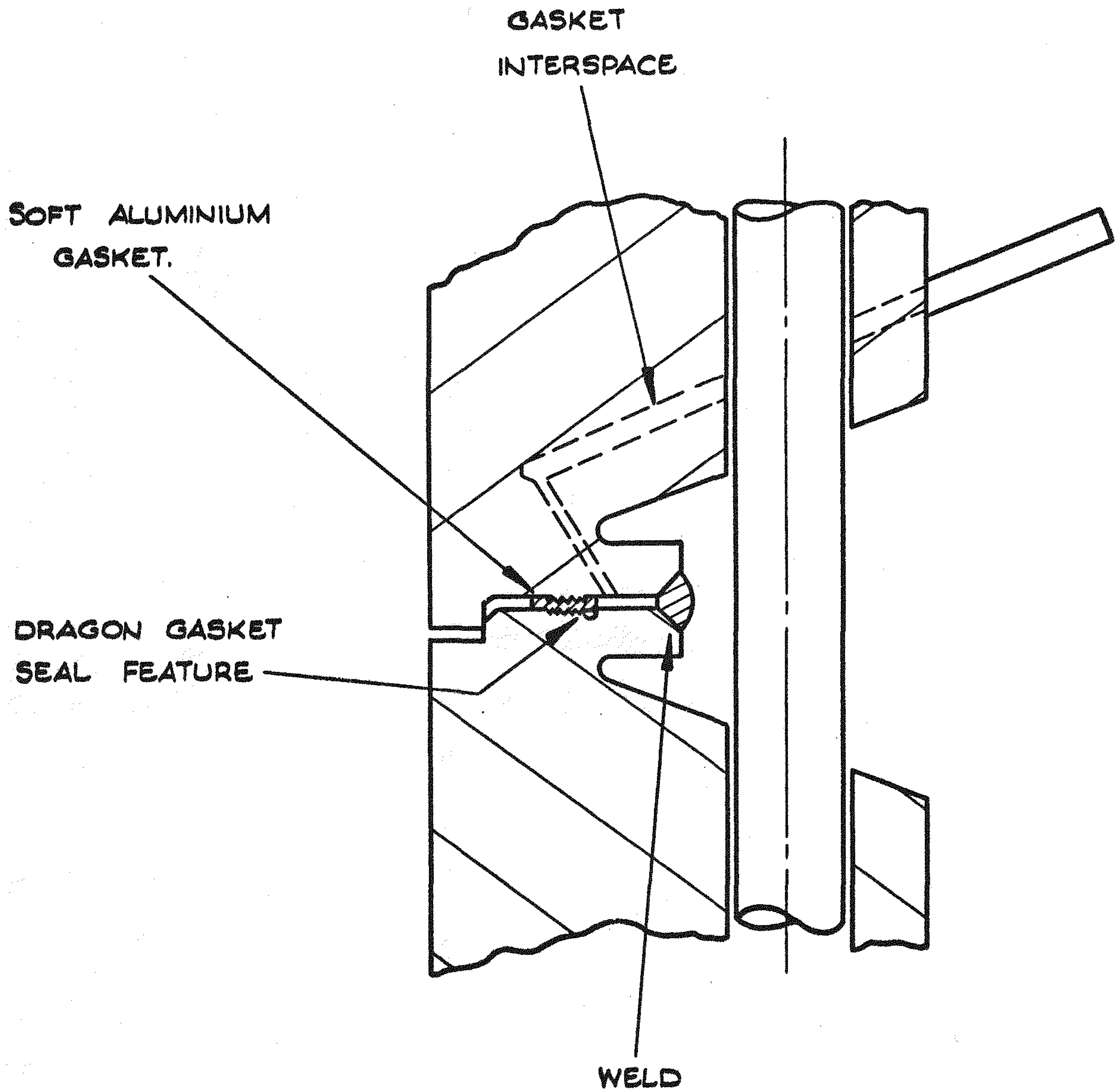



FIG. 1A DRAGON FLANGE TYPE A.

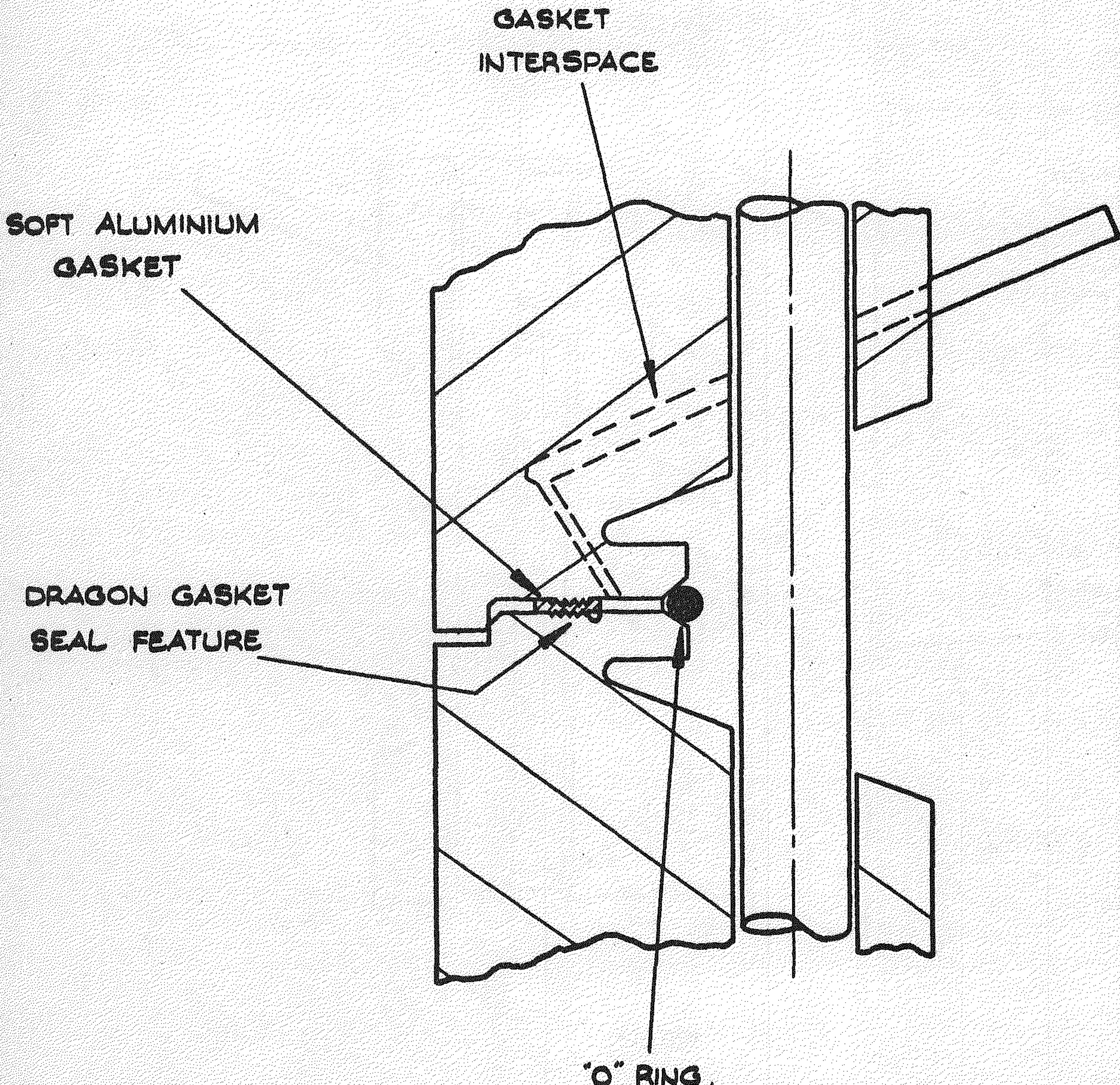



FIG. 1B DRAGON FLANGE TYPE A.

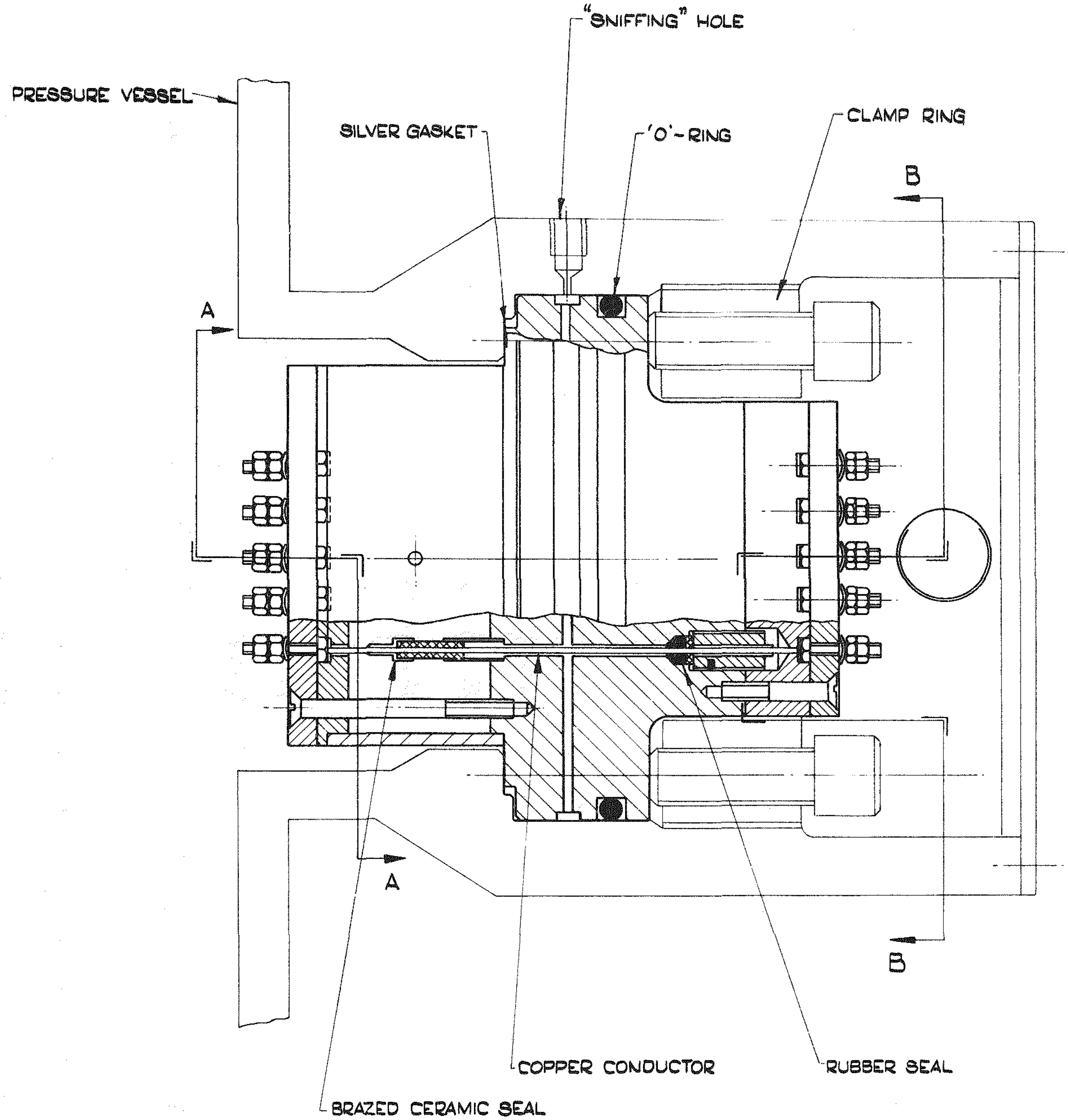



FIG. 2. ELECTRICAL PENETRATION ASSEMBLY

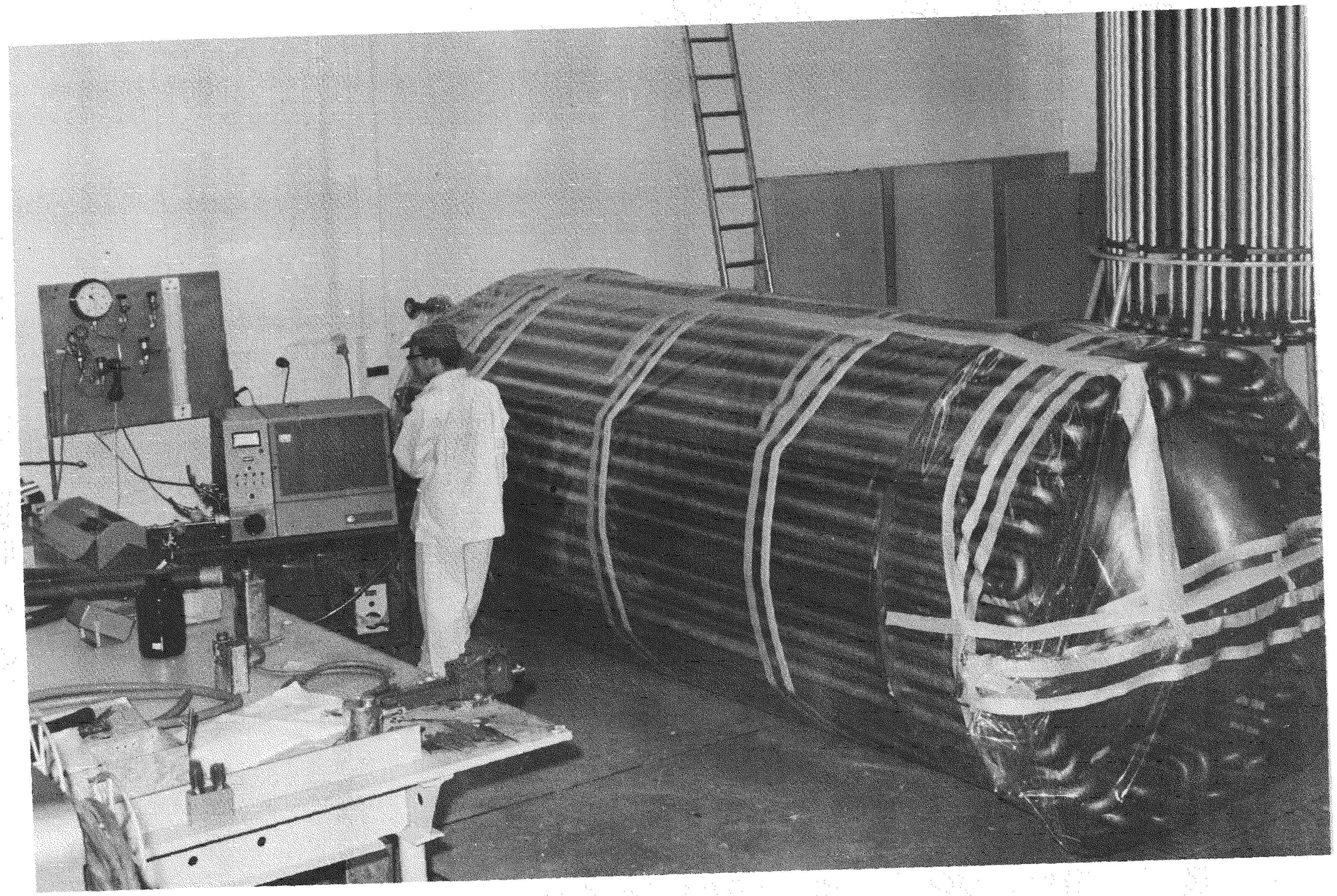
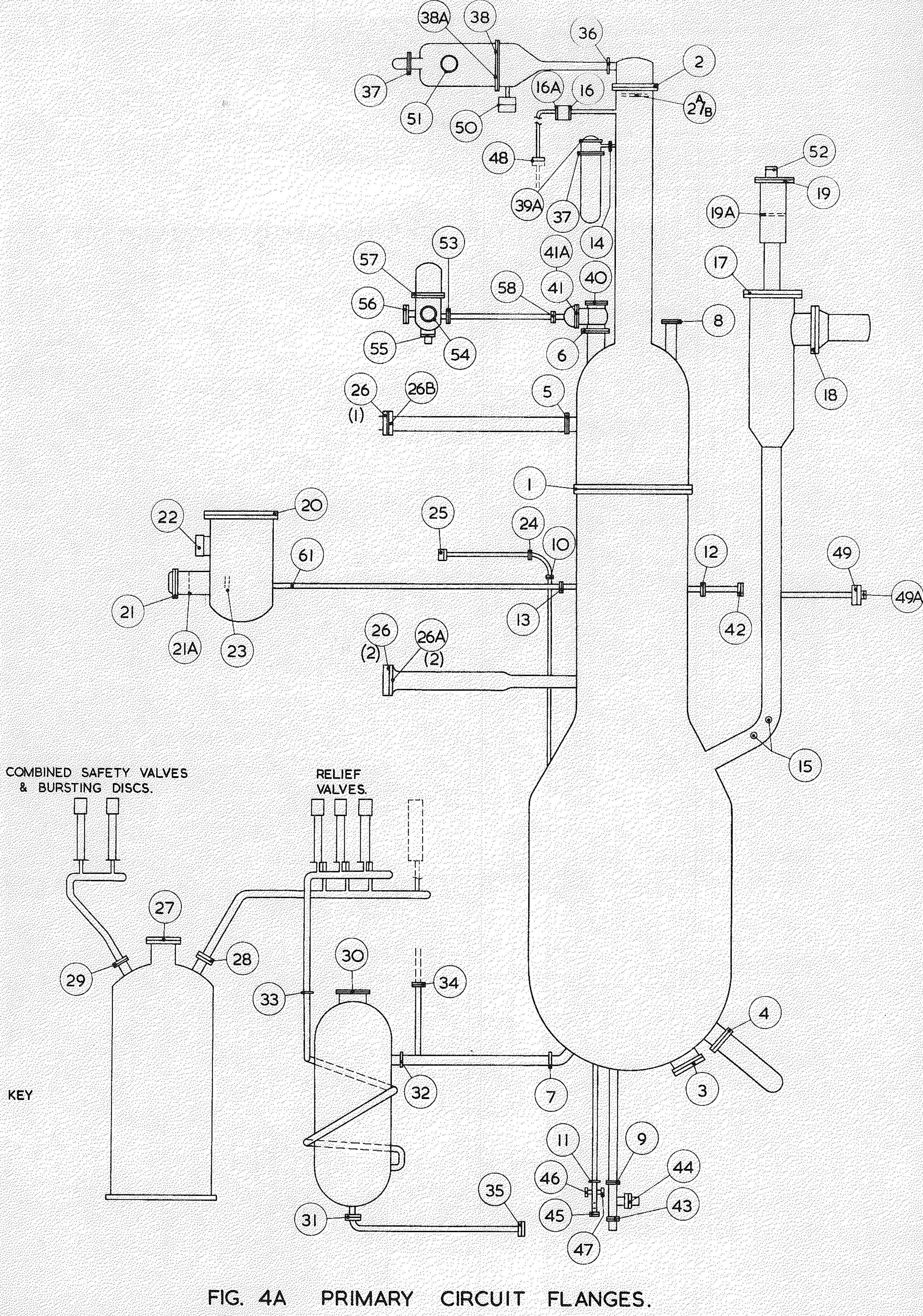


FIG. 3. HELIUM LEAK DETECTION OF TUBE BUNDLE AFTER FILLING




REFER TO KEY IN FIG. 4B.

FIG. 4A PRIMARY CIRCUIT FLANGES.

FIG. 4B KEY TO FIG. 4A

| Ref. No. | Description | Mating Flange | Type | No. Off | Nom. Bore |
|---|---|---|---|---|---|
| 1 | P.V. Main Flange | Mating Flange | C | 1 | 75 |
| 2 | P.V. Top Cap Flange | C/D Dome Gear-box Plate | B | 1 | 24 |
| 3 | P.V. Lower Manhole | Cover | A | 1 | 18 |
| 4 | P.V. Fission Product Flange | Fission Precooler | A | 1 | 16 |
| 5 | P.V. Viewing Branch Flange | Viewing Tube Flange | A | 1 | 8 |
| 6 | P.V. Main Entry Valve Port | Main Entry Valve | B | 1 | $12\frac{5}{8}$ |
| 7 | P.V. Relief Line Flange | Relief Line Pipe Flange | A | 1 | 6 |
| 8 | P.V. Access Port | Cover | A | 1 | 6 |
| 9 | P.V. Instrument Flange | Thermocouple | A | 6 | 5 5/16 |
| 10 | P.V. Core Unclamp Mech. Flange | Core Unclamp Mech. Elbow Flange | A | 1 | 3 |
| 11 | P.V. Re-entrant Tube Flange | Re-entrant Tube Flange | B | 6 | $2\frac{5}{8}$ |
| 12 | P.V. Thermocouple Flange | Thermocouple | A | 2 | $2\frac{1}{4}$ |
| 13 | P.V. Control Rod Tube Flange | Transverse Tube Flange | A | 24 | $2\frac{1}{4}$ |
| 14 | P.V. Cable Entry Flange | Cable Cage Flange | B | 1 | 2 |
| 15 | Heat Exchanger Branch Nimonic Support | Plug | A | 24 | $1\frac{3}{4}$ |
| 16 | P.V. Helium Supply Branch Flange | Non-return Valve | A | 1 | 1 |
| 17 | Heat Exchanger Top Flange | Valve Drive Unit | C | 6 | 29 |
| 18 | Heat Exchanger Branch Flange | Circulator Flange | C | 6 | 29 |
| 19 | Heat Exchanger Valve Drive Top Flange | Cover, etc. | B | 6 | $8\frac{1}{4}$ |
| 20 | Absorber Rod Drive P.V. Cover Flange | Cover | B | 24 | $16\frac{1}{2}$ |
| 21 | Absorber Rod Drive P.V. Overwind Flange | Dome Cover | B | 24 | $6\frac{1}{2}$ |
| 22 | Absorber Rod Drive P.V. Cable Entry | Screwed Ring | B | 24 | $4\frac{3}{4}$ |
| 23 | Absorber Rod Drive P.V. Transverse Housing | Transverse Drive | | | |
| 24 | Core Unclamp Mech. Elbow Flange | Tube Flange | A | 1 | 3 |
| 25 | Core Unclamp Mech. Tube Flange | Control Valve Flange | B | 1 | 3 |
| 26 | Viewing Branch Outer Flange | Viewing Equip. Flange | B | 3 | 8 |
| 27 | Helium Dump Tank Manhole Flange | Cover | A | 4 | 18 |
| 28 | Helium Dump Tank Inlet Flange | Dump Pipe-line Flange | A | 4 | 4 |
| 29 | Helium Dump Tank Outlet Flange | Bursting Disc Pipe-line Flange | A | 4 | 2 |
| 30 | Heat Sink Manhole Flange | Cover | A | 1 | 19 |
| 31 | Heat Sink Drain Flange | Drain Pipe Flange | A | 1 | 2 |
| 32 | Heat Sink Flange | P.V. Pipe Flange | A | 1 | 6 |
| 33 | Heat Sink Flange | Relief Valve Pipe-line Flange | A | 1 | 4 |
| 34 | P.V. Pipe Branch Pipe Flange | By-pass Valve Pipe Flange | A | 1 | $1\frac{1}{2}$ |
| 35 | Heat Sink Drain Pipe Flange | Drain Valve Cover | A | 1 | 2 |
| 36 | C/D Machine Pressure Casing Flange | Branch Flange P.V. Top Dome | B | 5 | 3 |
| 37 | Pressure Casing Flange | Hand Drive Flange | B | 5 | $2\frac{1}{4}$ |
| 38 | Pressure Casing Flange | Main Flange | B | 4 + 1 | $18\frac{1}{2}$ $24\frac{1}{2}$ |
| 39 | Cable Mounting Cage Housing Flange | Main Flange | B | 1 | 8 |
| 40 | Transfer Flask Main Flange | Main Entry Valve | Special | 1 | $11\frac{5}{8}$ |
| 41 | Main Entry Valve Body Flange | Drive Flange | B | 1 | 24 |
| 42 | Thermocouple Tube | Thermocouple | B | 1 | $2\frac{1}{4}$ |
| 43 | Flange C | Flange D | B | 3 | 5 5/16 |
| 44 | Branch Flange | Conductor Plate | B | 3 | $7\frac{1}{2}$ |
| 45 | Neutron Source Drive P.V. Flange | Shaft Housing | B | 1 | 5 |
| 46 | Neutron Source Drive P.V. Flange | Cover B | B | 1 | 10 |
| 47 | Neutron Source Drive P.V. Flange | Cover A | B | 1 | 10 |
| 48 | Helium Supply Pipe-line Flange | Cover A | B | 1 | 1 |
| 49 | Heat Exchanger Branch Branch Pipe Flange | Thermocouple | B | 6 | 3 |
| 50 | C/D Pressure Casing Cable Entry Flange | Cover | B | 5 | $4\frac{1}{2}$ |
| 51 | C/D Pressure Casing Window | Cover | B | 5 | $1\frac{1}{2}$ |
| 52 | H.Ex Valve Drive Cable Entry | Cover | B | 6 | |
| 53 | Main Entry Valve Drive Gear-box | Drive Shaft Cover Flange | B | 1 | $1\frac{3}{4}$ |
| 54 | M.E.V. Drive Gear-box | Inspection Window | B | 1 | $1\frac{1}{2}$ |
| 55 | M.E.V. Drive Gear-box | Hand Drive Cover | B | 1 | $2\frac{1}{4}$ |
| 56 | M.E.V. Drive Gear-box | Cable Entry Cover | B | 1 | $4\frac{1}{2}$ |
| 57 | M.E.V. Drive Gear-box | Main Flange | B | 1 | $13\frac{1}{2}$ |
| 58 | M.E.V. Drive Cover | Drive Shaft Cover Flange | B | 1 | $1\frac{3}{4}$ |
| 59/60 | | | | | |
| 61 | Control Rod Drive G/B | Transverse Shaft | B | 24 | |

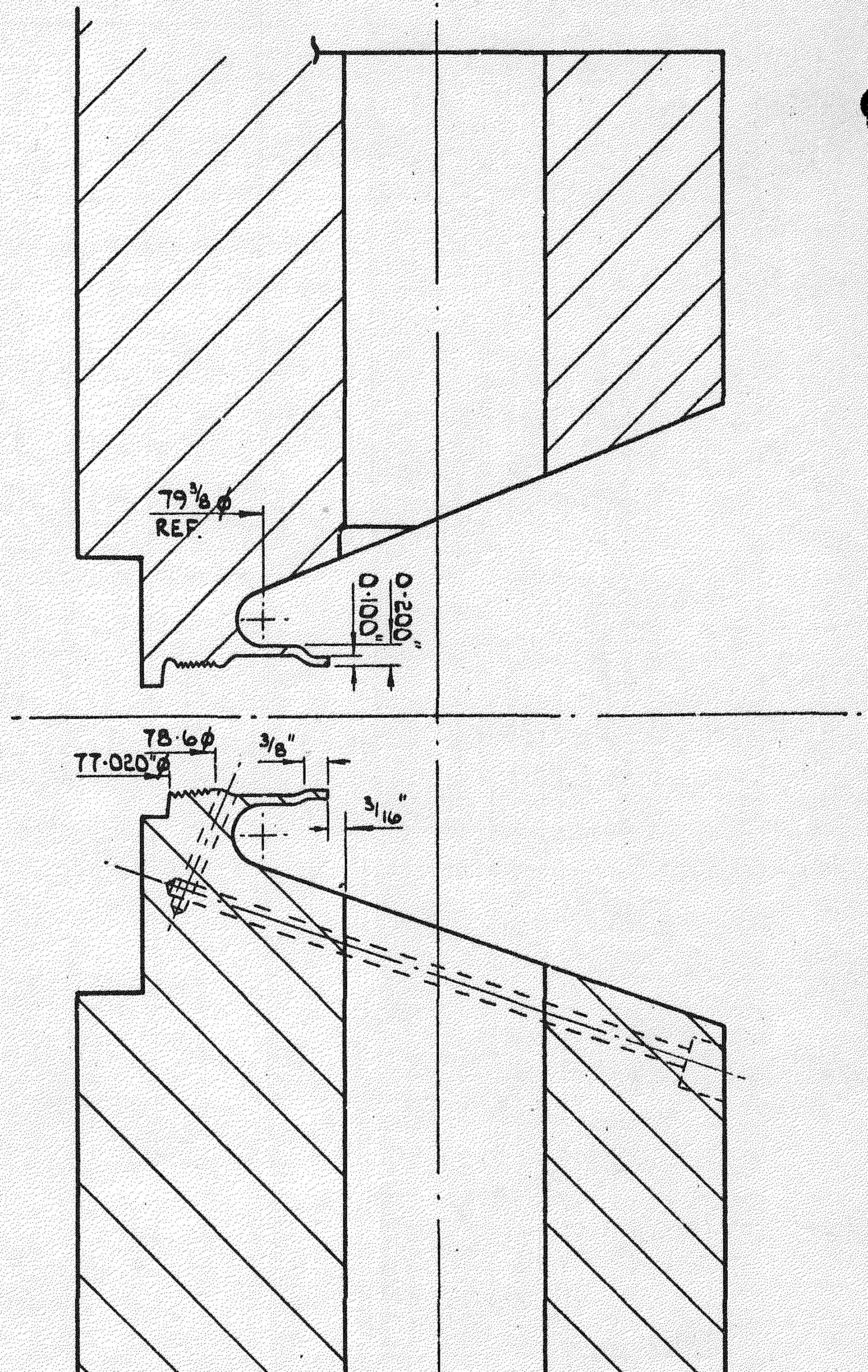



FIG. 5 DRAGON TYPE SEAL FEATURE ON MAIN FLANGE.

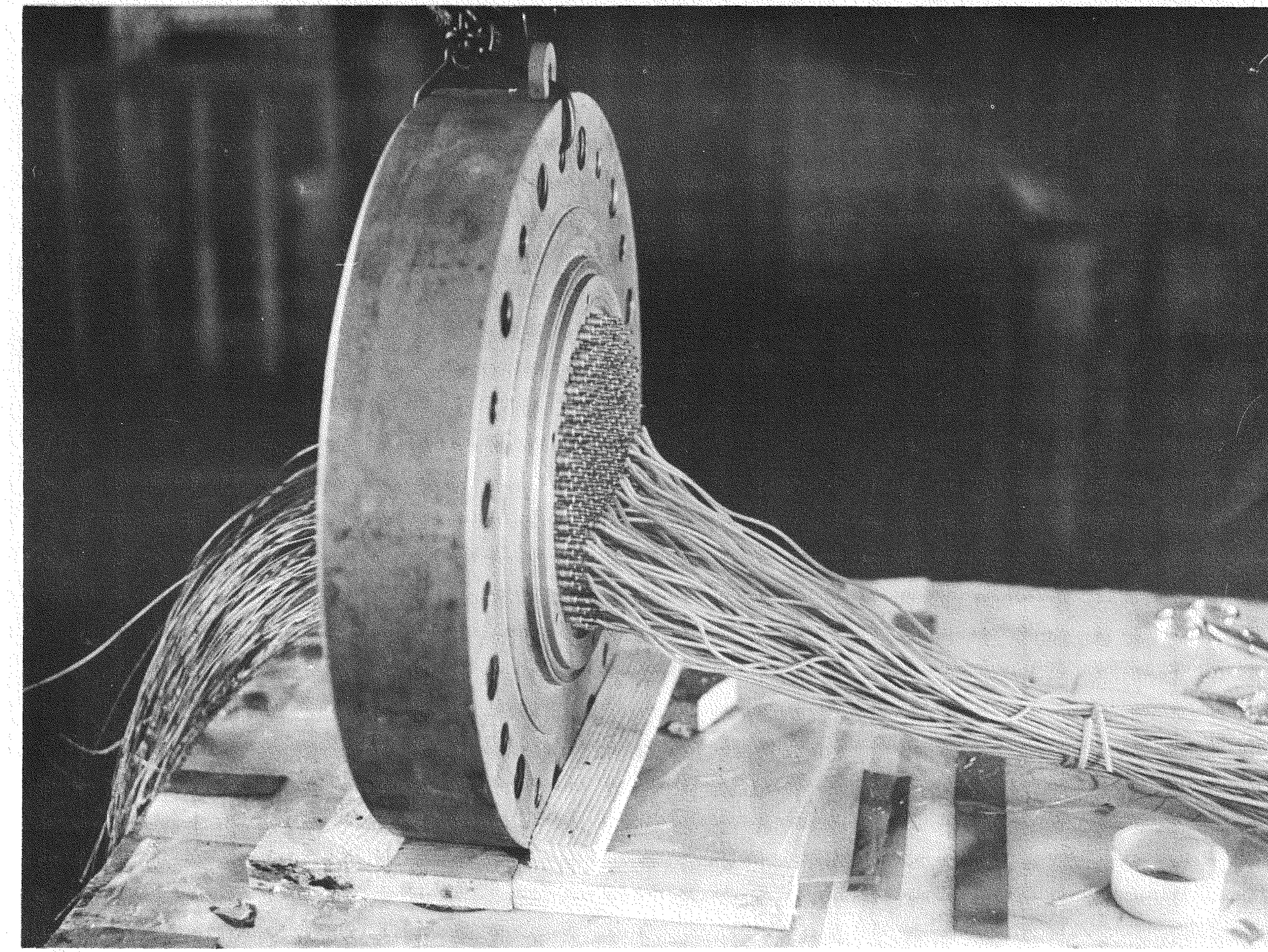


FIG. 6A. FERRANTI THERMOCOUPLE PENETRATION PLATE 240 METAL CERAMIC SEALS

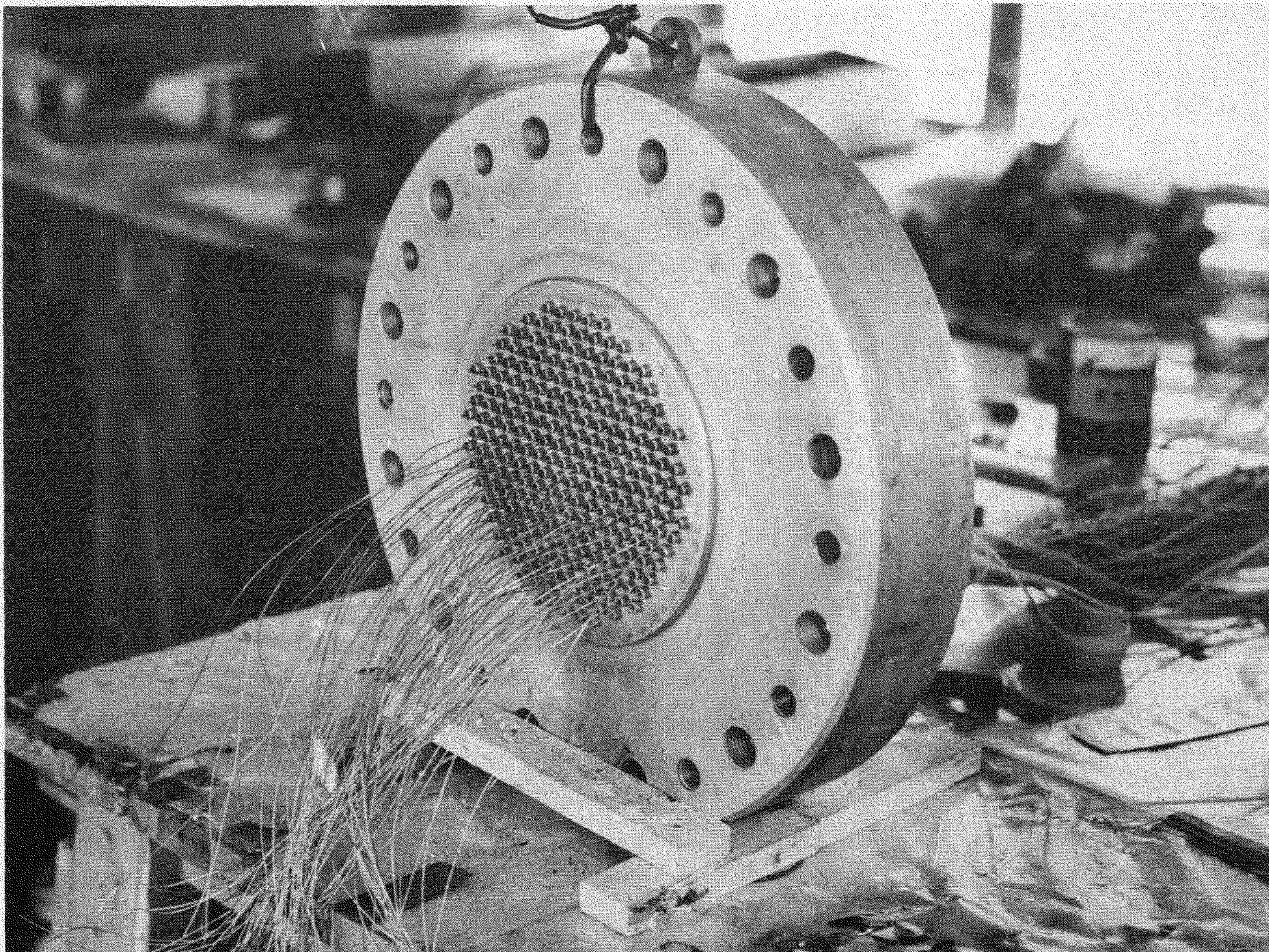


FIG. 6B. FERRANTI THERMOCOUPLE PENETRATION PLATE 240 METAL-CERAMIC SEALS

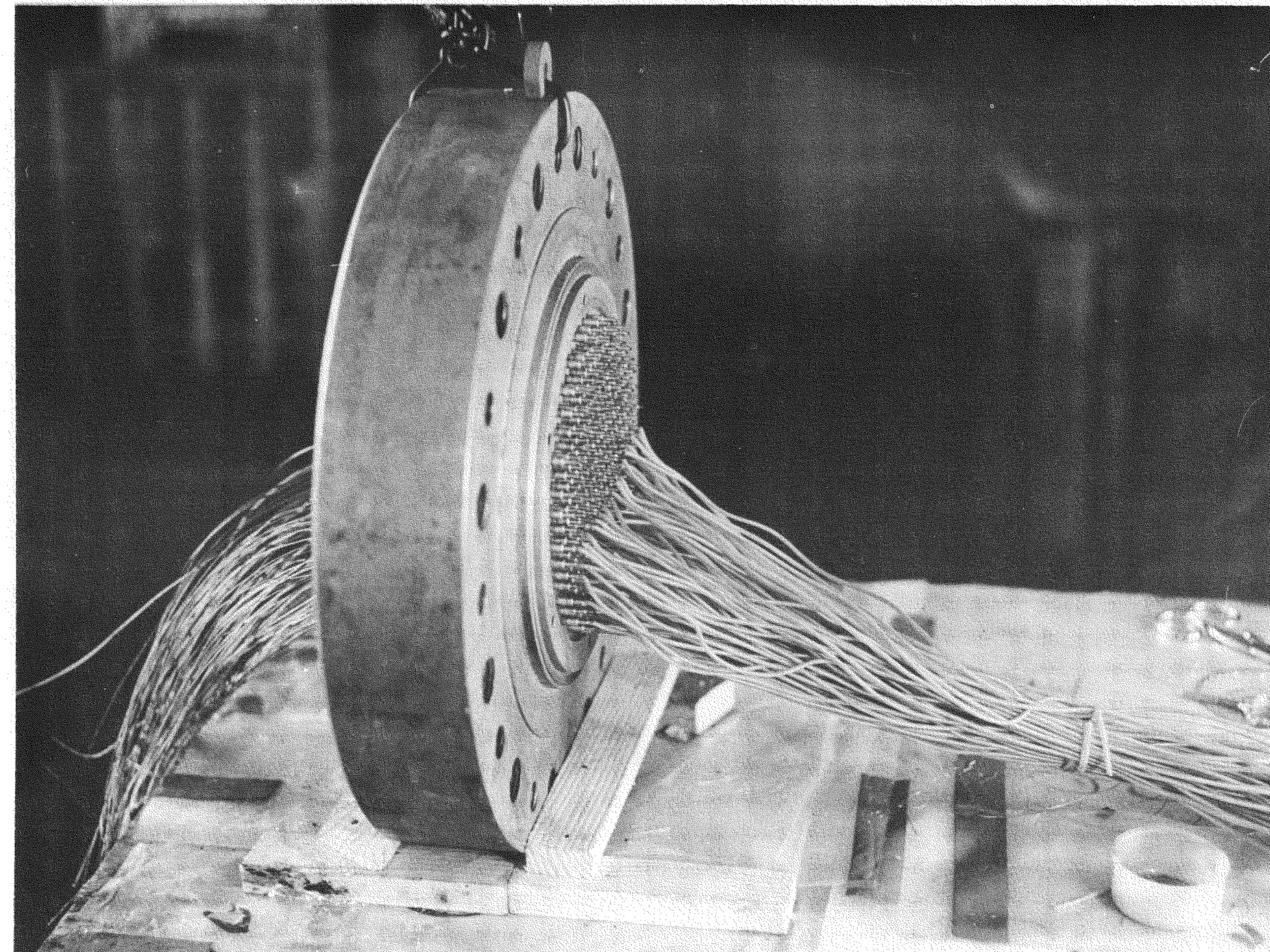


FIG. 6A. FERRANTI THERMOCOUPLE PENETRATION PLATE 240 METAL CERAMIC SEALS

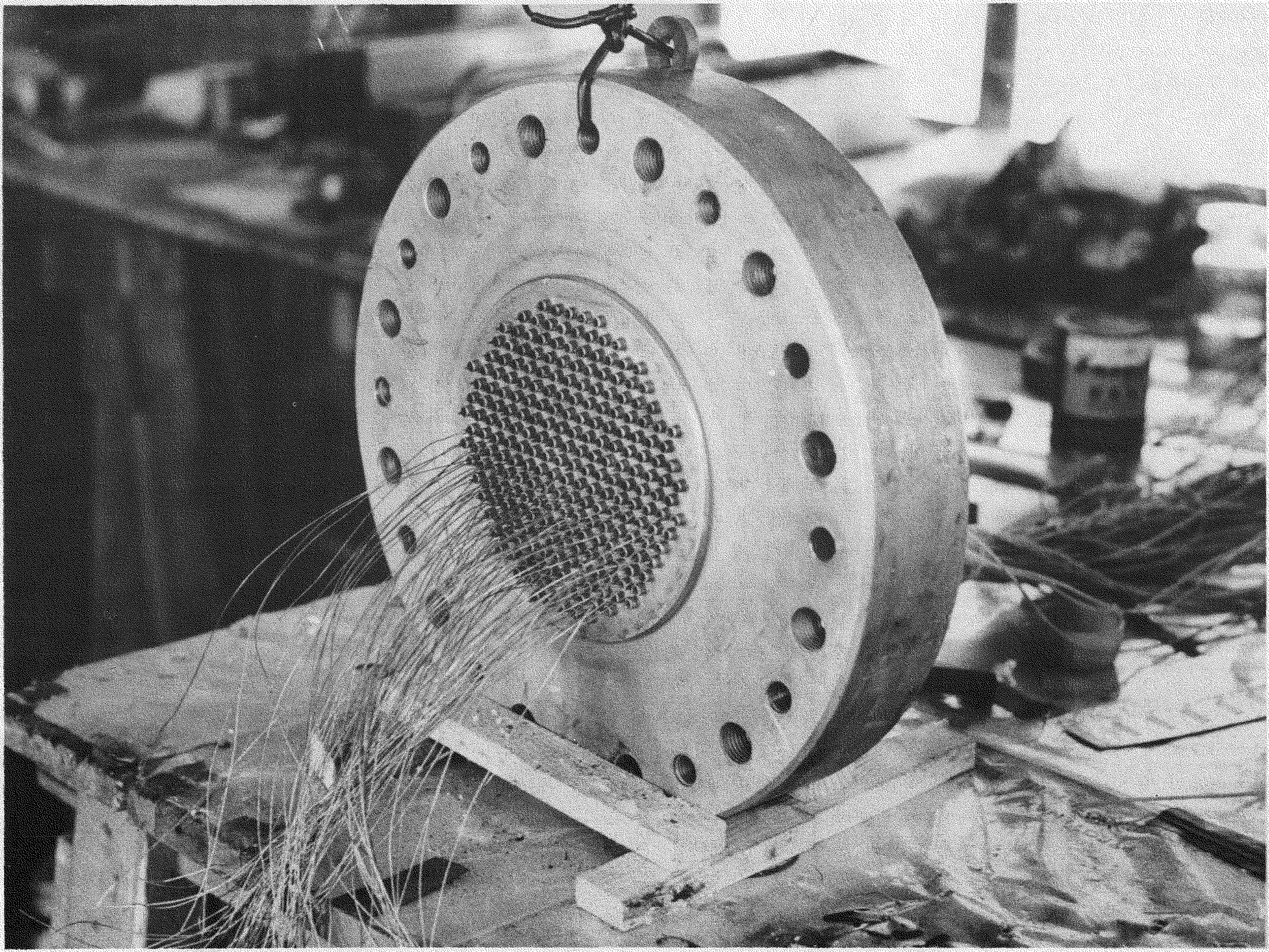


FIG. 6B. FERRANTI THERMOCOUPLE PENETRATION PLATE 240 METAL-CERAMIC SEALS

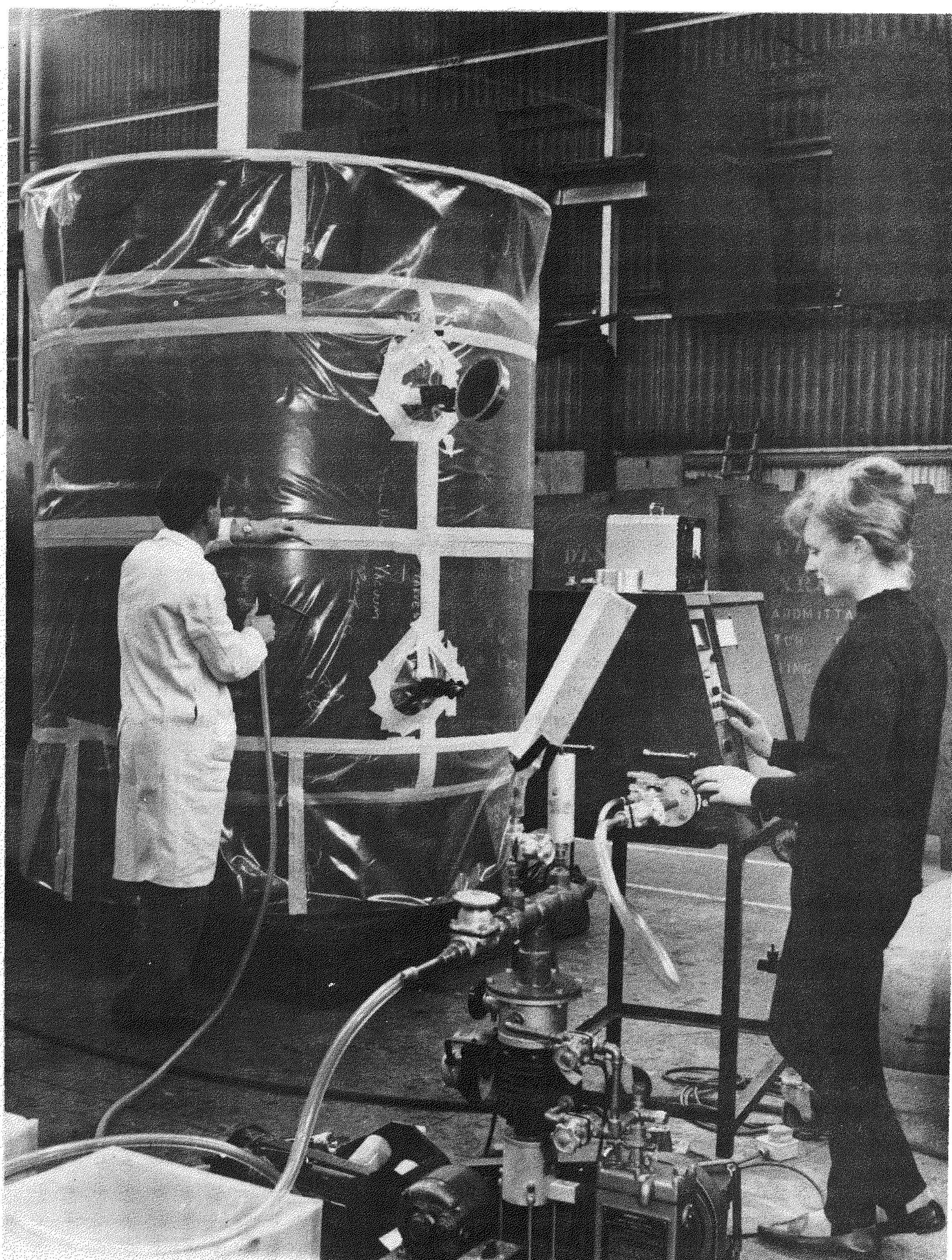


FIG. 7. LEAK TESTING OF DIRTY GAS RECEIVERS