J V D V

2.2

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

NORTHERN RESEARCH LABORATORIES - WINDSCALE

COMMISSION OF EUROPEAN COMMUNITIES

WORKING GROUP ON HOT CELLS AND REMOTE HANDLING TECHNOLOGY

1989 PLENARY MEETING - KARLSRUHE

REFABRICATION OF IRRADIATED AGR FUEL PINS FOR RE-IRRADIATION IN MATERIALS TEST REACTORS - RECENT DEVELOPMENTS

by

J C Douglas
J Hosfield

ABSTRACT

Techniques for refabricating irradiated AGR fuel pins and re-assembling them into test rigs for subsequent re-irradiation in materials test reactors have been developed in the AEA Northern Research Laboratories - Windscale and are described in this paper. The techniques are a further development of those previously described at the 1986 Plenary Meeting of the Working Group held at Brasimone, Italy.

INTRODUCTION

A programme of irradiation experiments using refabricated AGR fuel pins is being carried out in the PLUTO Materials Testing Reactor at AERE. The general objective is to test the ability of fuel performance modelling codes to predict the behaviour of high burn-up fuel pins when subjected to rating and flow transients and the consequences of fuel pin failure under abnormal operating conditions.

AGR fuel pins that have been previously irradiated in power reactors are refabricated in hot cells at the UKAEA Northern Research Laboratories at Windscale. Machining, welding, brazing, leak testing and assembly operations are carried out using special purpose machines, so as to produce instrumented test assemblies for subsequent re-irradiation at AERE Harwell.

A description of the early development of some of the techniques and equipment used was presented to the CEC Working Group on Hot Laboratories at the 1986 Plenary Meeting(1). Since then, the techniques have been extended and developed, this paper summarises these developments.

TECHNIQUES FOR REFABRICATING FULL LENGTH AGR IRRADIATED FUEL PINS

General

A CAGR fuel pin is approximately 1 m long and 16 mm in diameter; it contains a stack of 66 annular UO_2 fuel pellets sealed inside a thin austenitic, 20/25/Nb, stainless steel can 0.38 mm thick. The outer surface of the cladding is helically ribbed to improve heat transfer, and a small shoulder at one end provides an axial location of the fuel pin into the bottom grid of the fuel element. A fuel element comprises 36 such fuel pins supported in a stainless steel bottom grid and two upper braces mounted within a tubular graphite sleeve.

The fuel pins are fixed into the bottom support grid by a rolled-over end feature. During the initial dismantling and post-irradiation examination procedures this feature is removed with a special trepanning cutter to release the fuel pin which can then be pushed out of the grid and removed from the fuel element for detailed inspection and examination.

Re-preparation of Irradiated Pins

The bottom end of an irradiated pin is machined and a new stainless steel extension piece is then attached by spot welding without encroaching on the original fuel pellet containment seal welds. The new extension piece, Figures 1 and 2, incorporates a circlip groove at a specific distance from the fuel pin shoulder, and is designed to provide a method of locating and fixing the fuel pin into the support grid of a specially designed test cluster of nine fuel pins for re-irradiation in a gas cooled loop in a materials test reactor. In addition to providing the means of fixing the fuel pin into the new grid, the extension piece also defines the orientation of the fuel pin in the test assembly and carries the fuel pin identification.

The sequence of operations is shown diagrammatically in Figure 3. An initial rough cutting and chamfering operation is followed by reaming and facing to accurate dimensions; deburring is followed by locating and spot welding the new extension piece at four, 90° positions. Excess weld material is then removed by a rolling operation and the finished diameter is checked by ring gauges. These operations are carried out by a specially designed dual purpose machine fitted with interchangeable heads, Figures 4 and 5. To avoid the necessity for cell entry all the main components of this machine can be replaced remotely using master-slave manipulators. Quality control is provided by optical inspection at x6 magnification, supported by metallographic examination of weld samples taken at random from test pins.

The fuel pin is held stationary in a pneumatic collet chuck, but can be indexed into any one of four positions at 90°C. The various cutting machining and spot welding heads are mounted on a two-station vertical slide, which also carries a pneumatic applicator used to position the extension piece during spot welding operations. A cross-slide mounted on the vertical slide provides a manual feed for the various tool heads. Support for the facing cutter is provided by an outrigger incorporating a stepped collar that locates on the end of the fuel pin; accurate finished length is ensured when the stepped collar engages the shoulder on the fuel pin, Figure 6.

Because of the proximity of the existing seal welds on the fuel pin cladding, which provide the primary containment, it was decided not to carry out a continuous weld, but to restrict the weld pool and temperature by spot welding at four 90° positions, using a micro-processor controlled power source intended for high integrity and high productivity TIG welding. During each welding operation the power source current and voltage are shown on analogue meters. Eight welding programmes can be stored in the micro-processor controller; each programme may have a maximum of 20 steps with a current demand of 0.24A-63.75A in increments of 0.25A for each step. The step duration can range from 0.1-99.9 secs in increments of 0.1 sec. A gas flow alarm is fitted which inhibits or stops a welding programme in the absence of the shielding gas. On completion of the spot welds a rolling head comprising three fixed roller is passed over the welds to reduce any irregularities.

Rig Assembly

The experimental test cluster for irradiation in the AERE Materials Test Reactor consists of a nine pin cluster comprising three unirradiated instrumented fuel pins complete with supporting grids, braces and associated thermocouples, Figure 7; into which six irradiated AGR pins, refabricated as described above, are fitted remotely, using a specially designed assembly jig, Figure 8; the irradiated fuel pins are held in place by a circlip fitted into the new extension piece.

The problem of threading irradiated AGR pins remotely through the central and upper braces into position in the bottom grid was overcome by using pre-fitted guide rods with expanding O-rings which attach the guide rods to the inside of the pin ends. Each pin in turn is connected to a guide rod and drawn through the brace into the grid. Correct orientation is governed by a location peg in the bottom grid and a slot in the guide rod. On assembly, the extension piece protruding through the bottom grid is fitted with a circlip which is pressed into place by a pneumatic cylinder. The assembled test cluster is then rotated into the vertical position, lifted and lowered into concentric graphite and zirconium sleeves which form the outer casing, retaining bolts are fitted, and the whole assembly is then loaded into a flask for transport to AERE.

REFABRICATION OF SHORT LENGTH AGR FUEL PINS

General

Techniques developed at the AEA Northern Research Laboratories (Windscale) for refabricating short lengths of irradiated Windscale AGR fuel pins into single test pins for re-irradiation in the UNIT loop of the PLUTO reactor at AERE were described in a previous paper[1] to the CEC Working Group on Hot Laboratories and Remote Handling in 1986. Since then, these techniques have been further developed to enable improved instrumentation to be incorporated in the experimental pins. The operations involved are sectioning and machining of the irradiated AGR pins, followed by the brazing of special end fittings to each end in which are mounted up to three internal thermocouples and purge lines for changing the atmosphere inside the test pin during irradiation or recovering released fission product gases. A general view of the test pin assembly and components is shown in Figure 9.

Refabrication of Short Length Pins

Full length irradiated AGR pins discharged from commercial power reactors are cut into short lengths ~20 cm long and the ends are machined using a bench lathe modified for remote handling in a lead shielded cell, Figure 10. During cutting operations a free standing air ejector/suction generator fitted with a high efficiency filter positioned close to the tool removes machining swarf and minimises the spread of contamination.

Four cutting operations are required to cut through the cladding at pre-determined UO_2 pellet interface positions and remove the external heat transfer ribbing over a distance of 10 mm from each end. The fuel pin is gripped in a soft jaw chuck, a pre-set pointer on the tool post is used to relate the position of the cuts relative to a fixed datum on the fuel pin. The diameter of the 10 mm plain machined portion at each end of the cut length is then measured using a set of ring gauges allowing each new end-cap to be individually bored out to provide the correct brazing clearance of 0.03 mm.

The brazing alloy, Nicrobraze 30 (a commercially available chromium nickel phosphorus alloy) is then applied in paste form to the grooves inside the stainless steel end-caps which are then pressed on to each end of the fuel pin using a special jig to ensure accurate alignment of the components, Figure 11. The pin is then transferred to a high frequency induction coil and the ends are brazed in position under an argon blanket. The braze temperature is recorded by a thermocouple inserted through the bore of the end-cap and carefully positioned in relation to the braze material. Control of the brazing is achieved by progressively raising the power until a temperature of 1120°C is reached over a period of 6-7 minutes; the optimum conditions for braze penetration were established by metallographic examination of a series of brazed test pins.

The refabricated fuel pin is then assembled into an aluminium duct unit and is held in place by a circlip fitting incorporated in one of the end-caps, a special jig is used for this assembly operation; Figure 12. The internal thermocouples (located at various axial positions within the bores of the annular fuel pellets) together with the purge lines for controlling the internal atmosphere within the fuel pin are then fitted through the fuel pin end fittings to which they are sealed by compression couplings. The complete assembly is then pressure tested at 10 bars, and the pin evacuated and filled with He at 1 bar, prior to mounting on a transit fixture before loading it into a transport flask for transfer to the reactor at AERE.

CONCLUSIONS

The further development of techniques and equipment at the AEA Northern Research Laboratories for refabricating irradiated fuel pins from both prototype and commercial power reactors so as to enable experimental test programmes to be carried out in materials test reactors, has provided much practical experience in the design of special machines and equipment for use in hot cells. Although developed for application to AGR stainless steel clad fuel pins, the remote handling techniques can be adapted to Zircaloy clad water reactor fuel pins. The importance of studying the performance of irradiated fuel pins under conditions and in circumstances, which cannot normally be achieved in operating power reactors, makes this capability increasingly significant in terms of both reactor safety and improved fuel designs.

ACKNOWLEDGEMENTS

The work described in this paper was carried out in the UKAEA Northern Research Laboratories (Windscale) and funded jointly by the Dept of Energy, CEGB and SSEB.

REFERENCES

1. NEWBIGGING A W P, DOUGLAS J C, JEPSON M D, LOWE J. The manufacture of irradiated AGR fuel pins for re-irradiation and fission gas release studies in the PLUTO Materials Test Reactor at AERE.
CEC Working Group on Hot Laboratories and Remote Handling, 1986 Plenary Meeting, Brasimore, Italy.

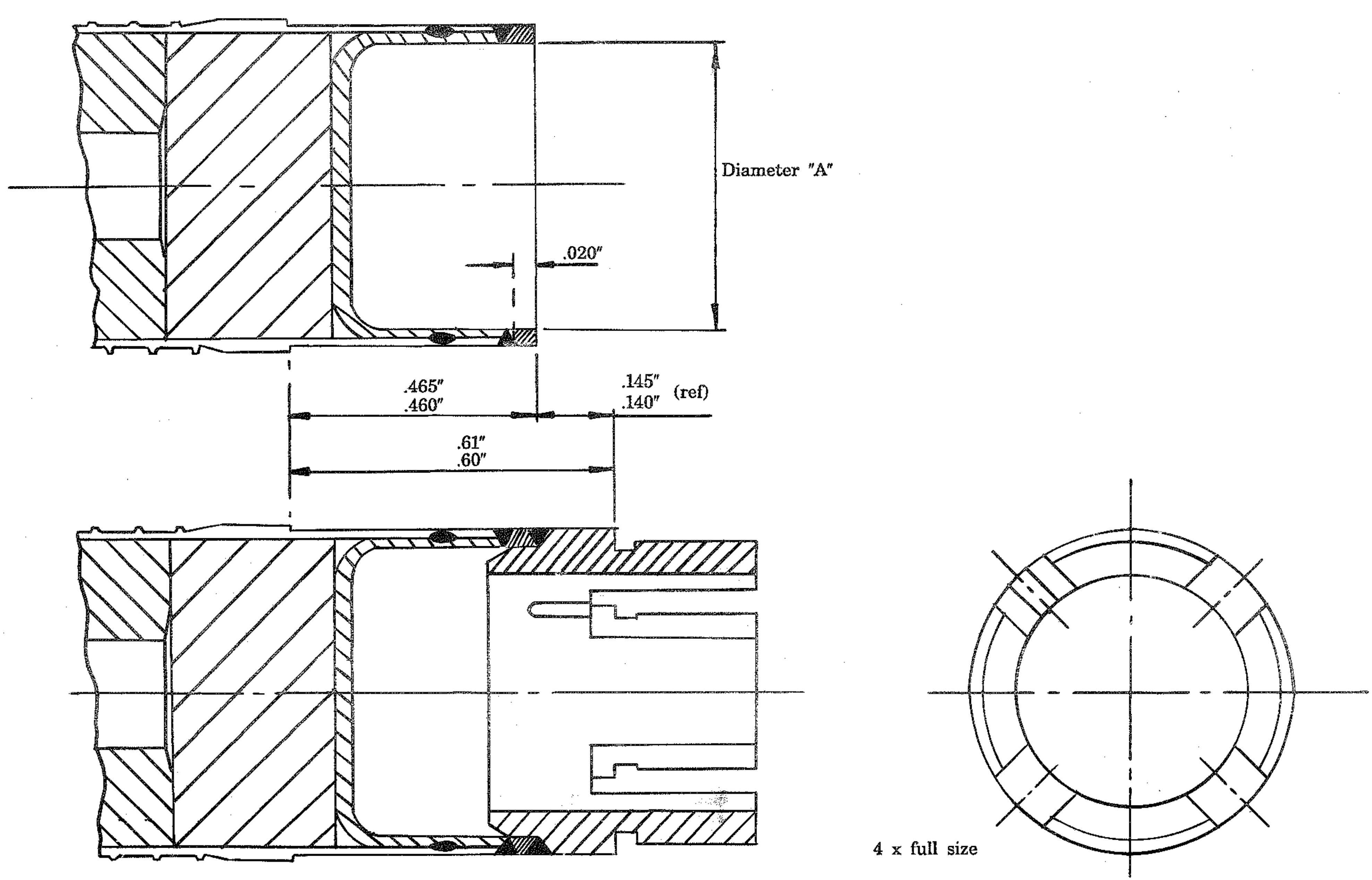
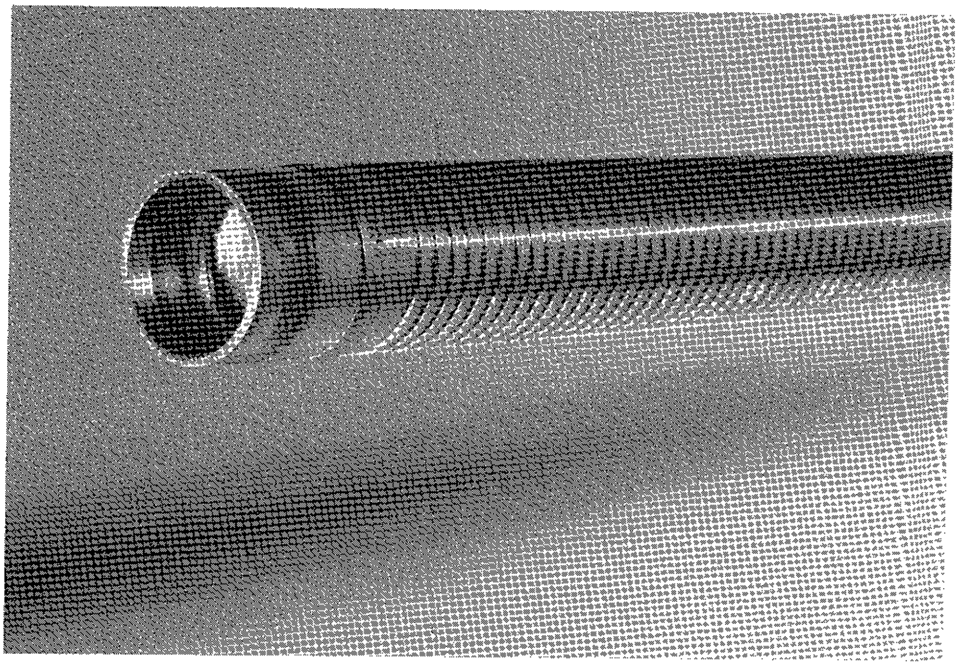
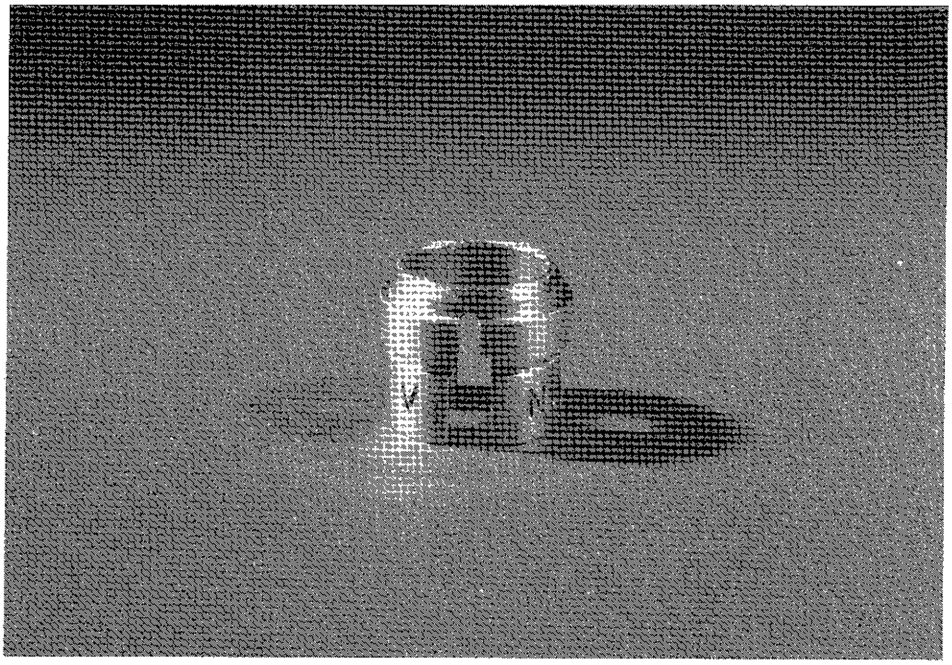


FIGURE 1   END PREPARATION AND NEW EXTENSION PIECE FITTED TO AN AGR FUEL PIN



A) MACHINED PIN END



B) EXTENSION PIECE

FIG 2 MACHINED PIN END AND EXTENSION PIECE

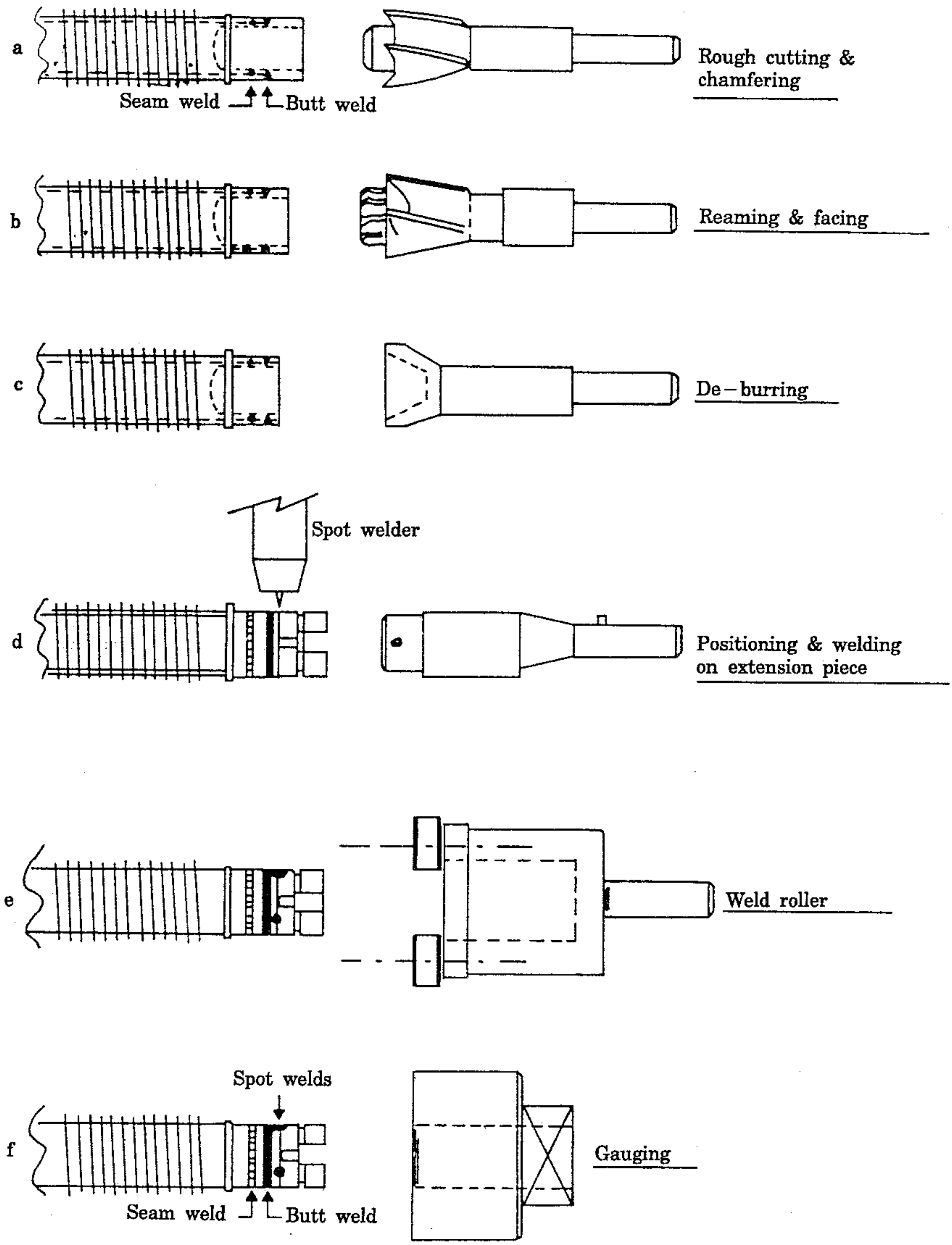


FIGURE 3 PIN END REFURBISHING SEQUENCE

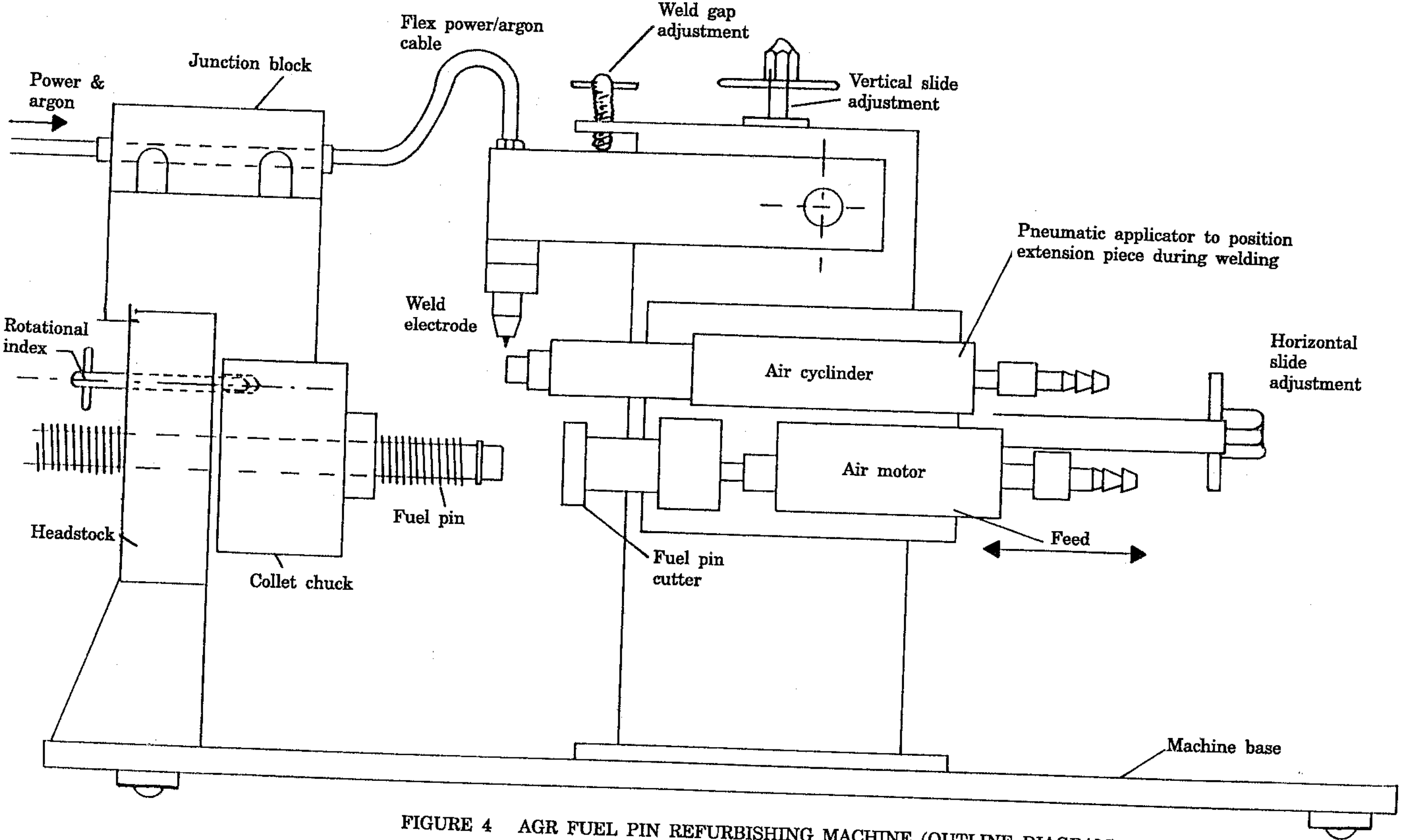


FIGURE 4 AGR FUEL PIN REFURBISHING MACHINE (OUTLINE DIAGRAM)

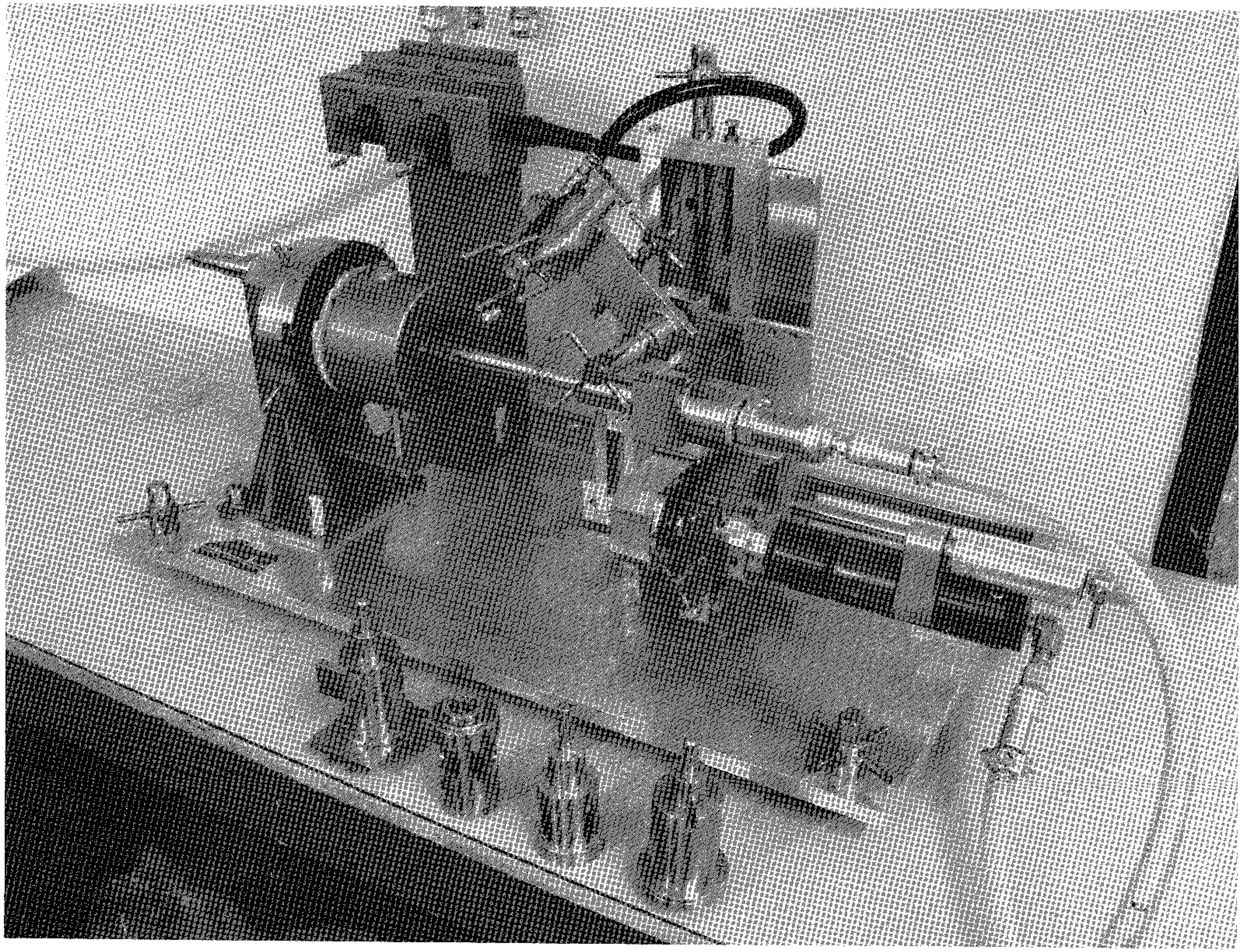


FIG 5: GENERAL VIEW OF AGR FUEL PIN REFURBISHING MACHINE

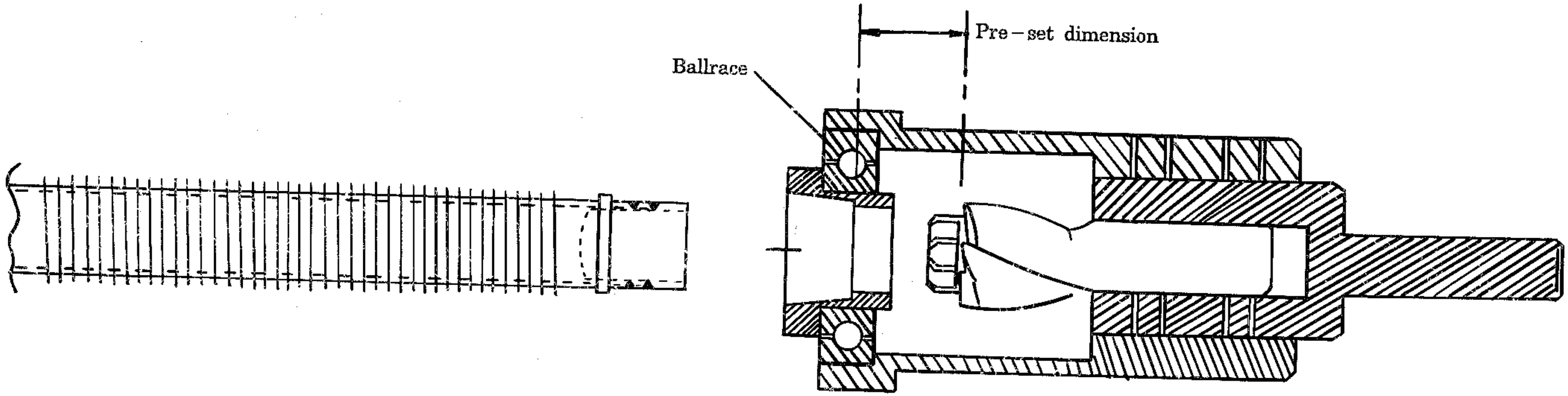


FIGURE 6 REAMING AND FACING CUTTER AND STEPPED COLLAR FOR SIZING

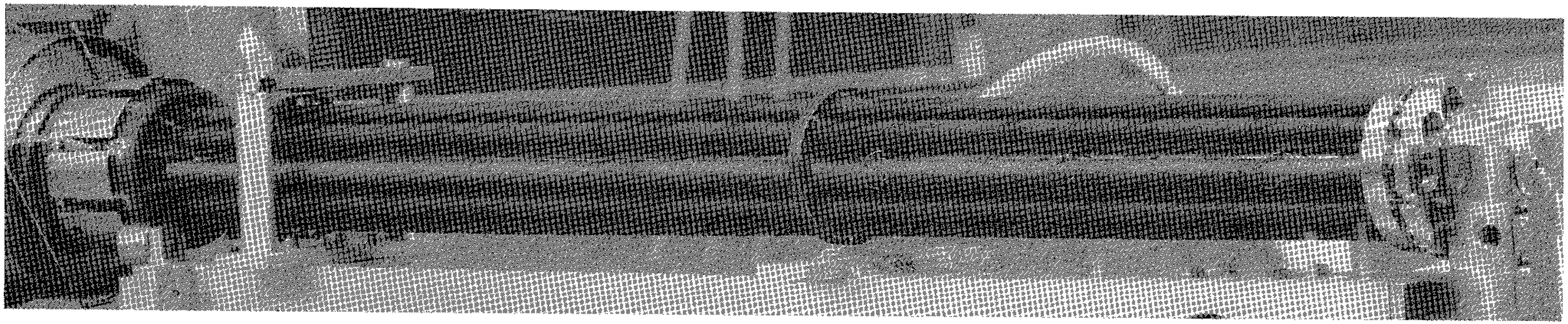


FIG 7: EXPERIMENTAL NINE-PIN TEST CLUSTER FOR MTR IRRADIATION EXPERIMENT

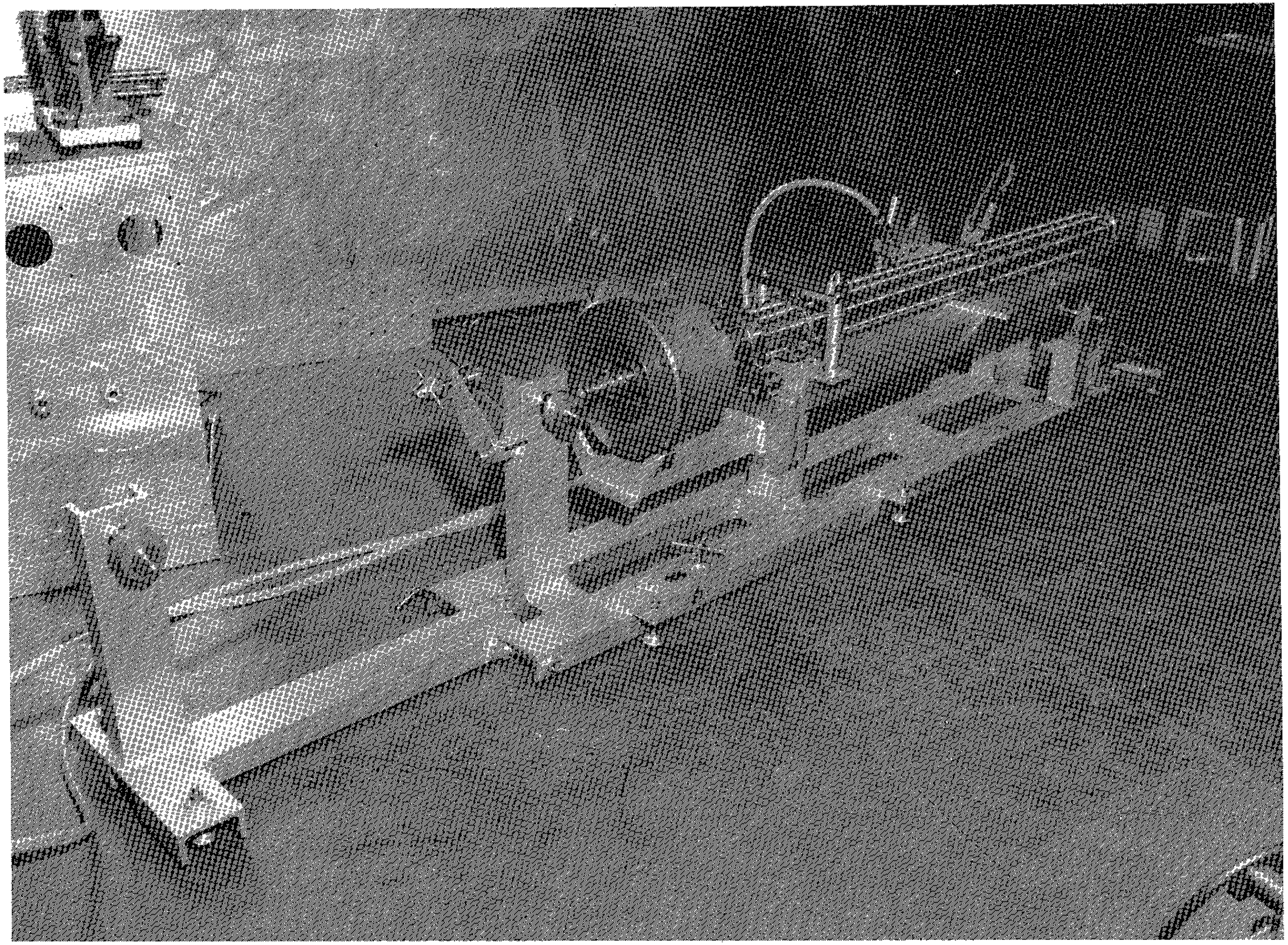


FIG 8: EXPERIMENTAL NINE-PIN CLUSTER ASSEMBLY JIG

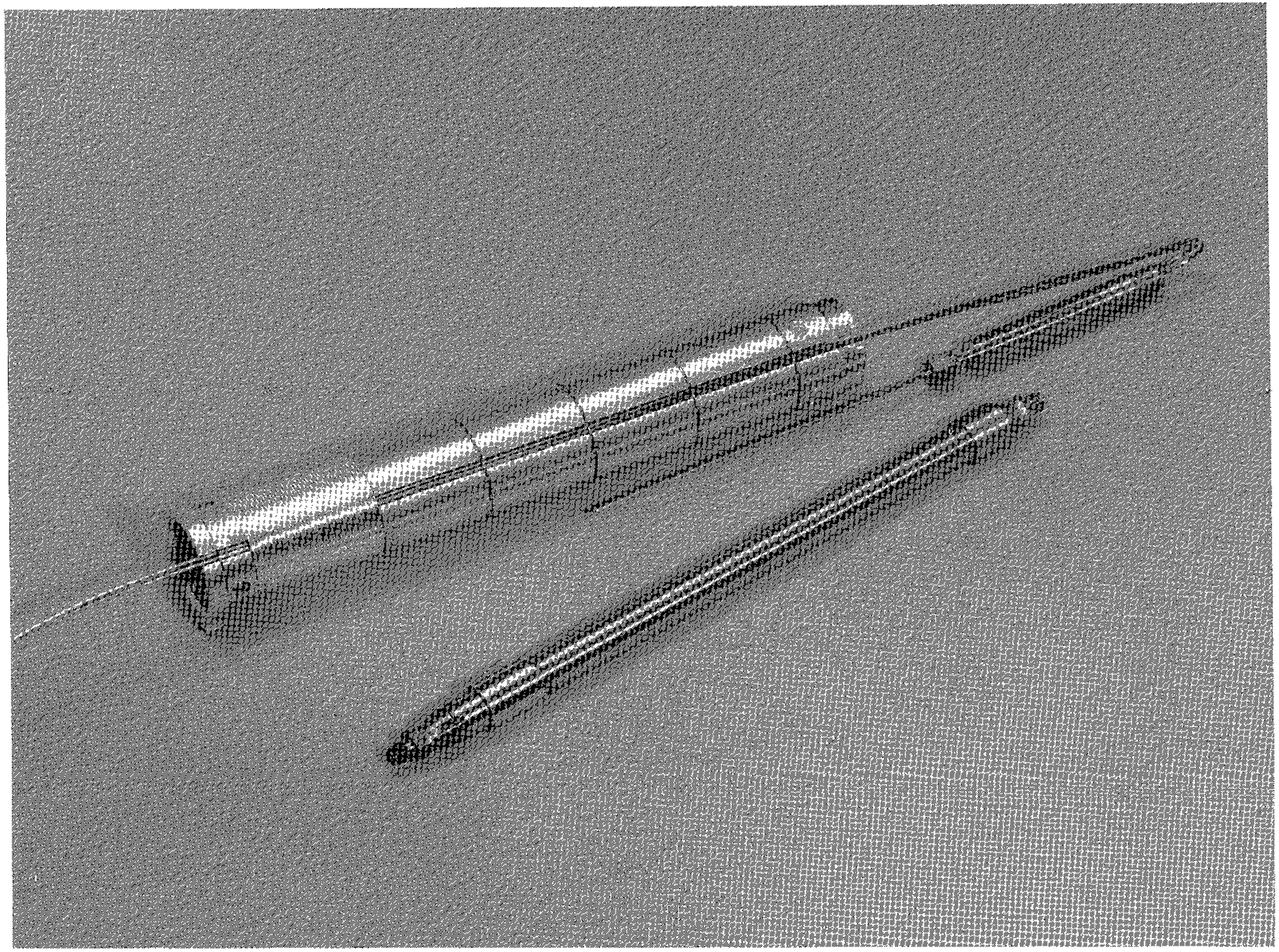


FIG 9: SHORT LENGTH AGR PIN WITH END FITTINGS AND INSTRUMENTATION TOGETHER WITH ENCLOSING ALUMINIUM DUCT ASSEMBLY

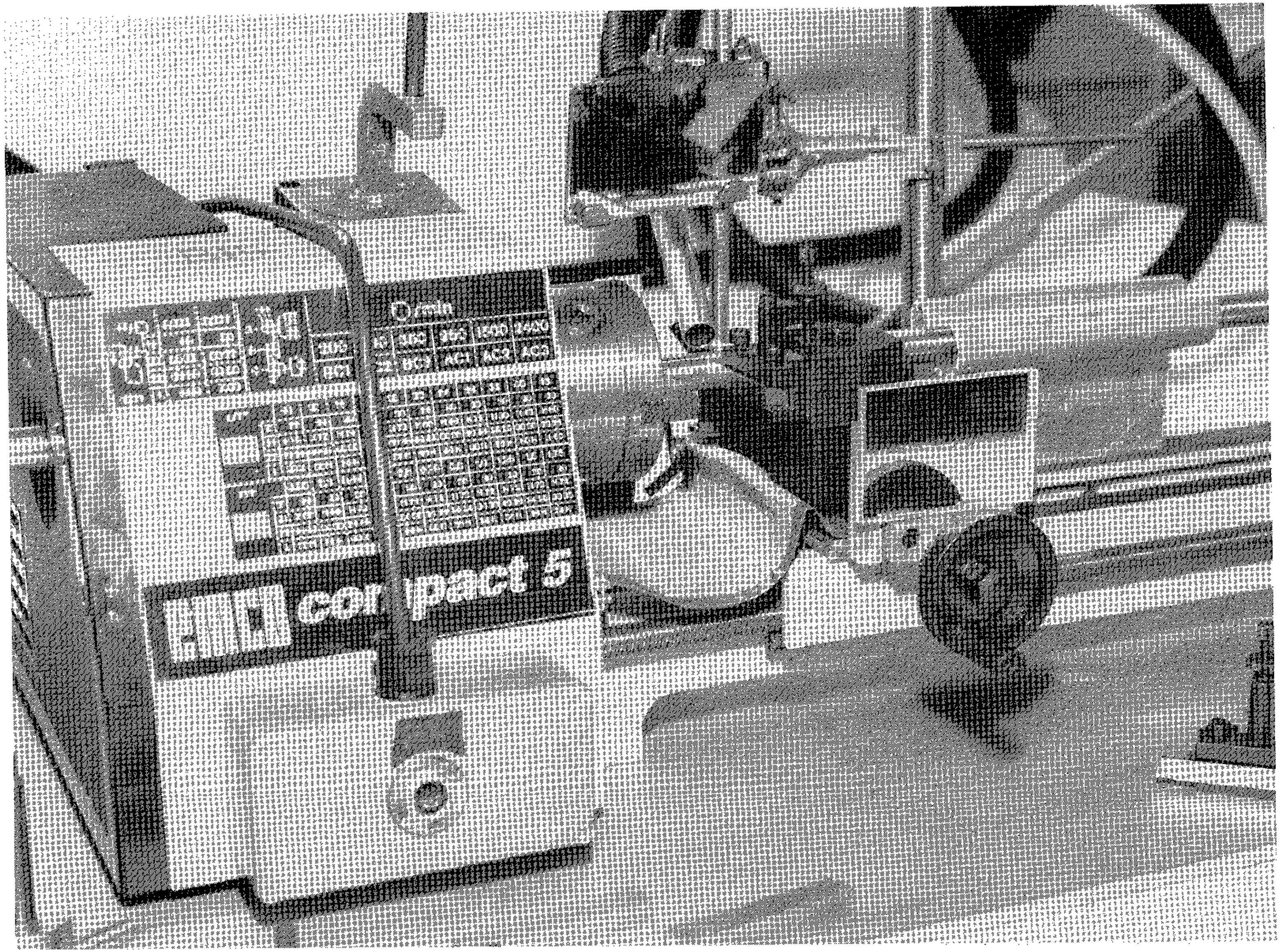


FIG 10: MODIFIED BENCH LATHE INSTALLED IN LEAD CELL

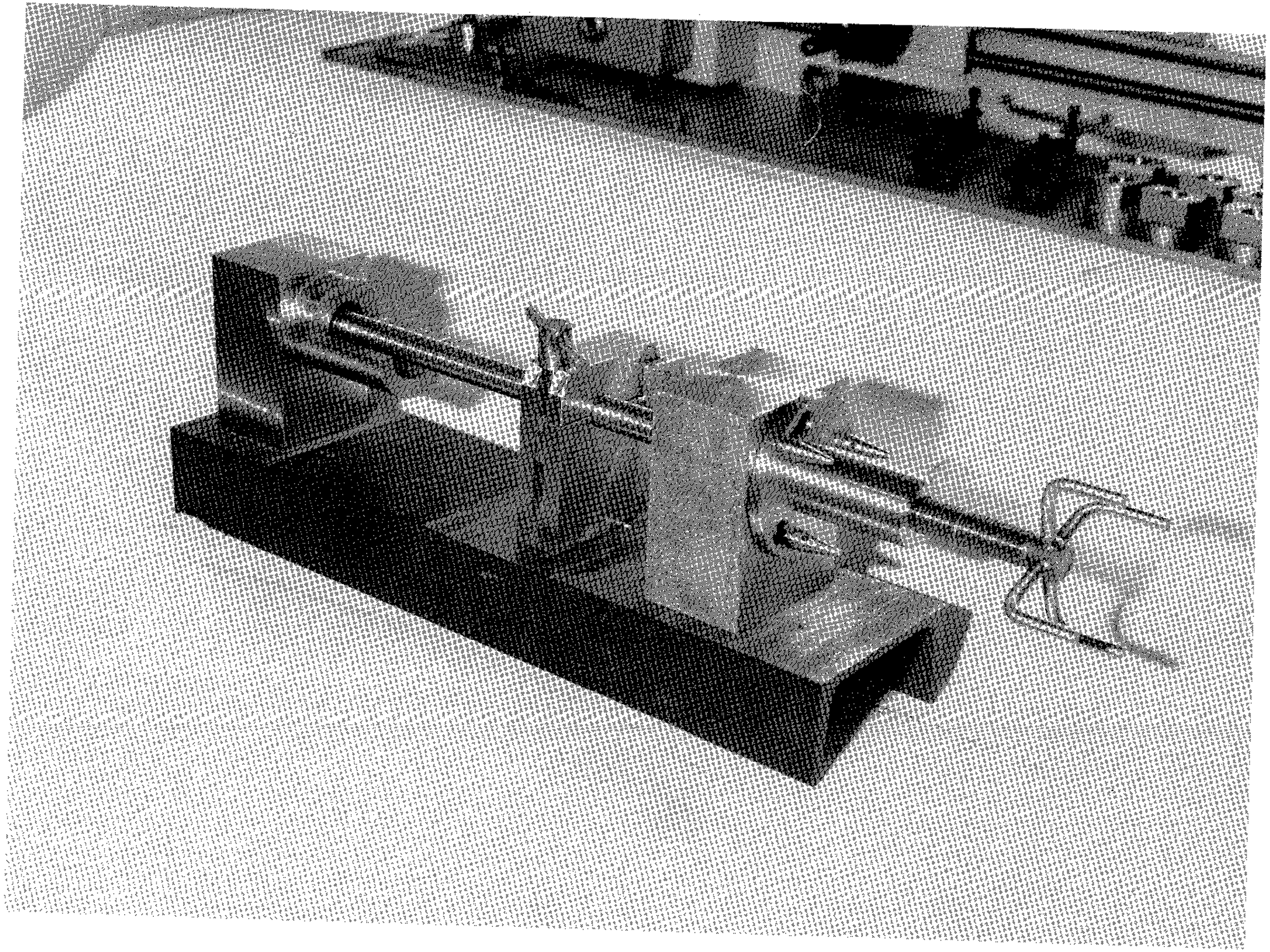


FIG 11: END CAPPING JIG

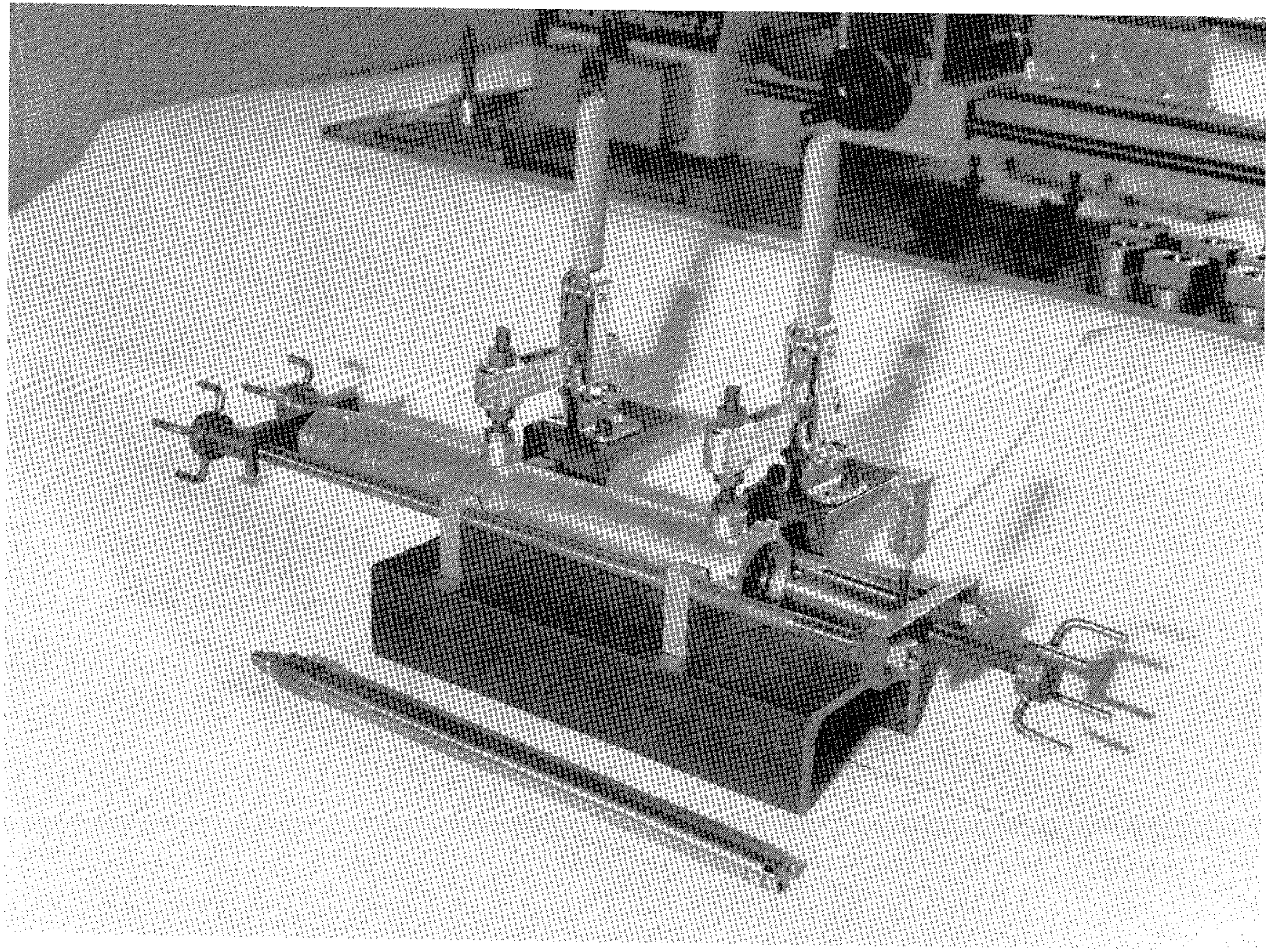


FIG 12: DUCT ASSEMBLY JIG