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AUSTRALIAN NUCLEAR SCIENCE
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BEHAVIOUR UNDER EXTENDED DRY STORAGE

by

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LUCAS HEIGHTS RESEARCH LABORATORIES

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BY

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ABSTRACT

Previously unpublished obsevations of the behaviour of HIFAR spent fuel under extended dry storage conditions are reported. The two fuel elements EC270 (MarkII type) and ED802 (MarkIII type) were irradiated in 1966, first examined in hot cells in 1967 and again examined in hot cells in 1983 following 16 years of storage, 11 years of which were in the ANSTO engineered dry storage facility. The elements showed negligible deterioration over this extended dry storage period, lending considerable confidence to the viability of dry storage technologies for the long term storage of spent aluminium clad research reactor fuels.

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The following descriptors have been selected from the INIS Thesaurus to describe the subject matter of this report for information retrieval purposes. For further details please refer to IAEA-INIS-12 (INIS: Manual for Indexing) and IAEA-INIS-13 (INIS: Thesaurus) published in Vienna by the International Atomic Energy Agency.

ALUMINIUM ALLOYS; CLADDING; CORROSION; DEFECTS; DRY STORAGE; ENRICHED URANIUM; FUEL CANS; FUEL STORAGE POOLS; HIFAR REACTOR; SPENT FUEL ELEMENTS; USDOE.

SPENT HIFAR FUEL ELEMENTS
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A Note by A Ridal and P Bull
Australian Nuclear Science and Technology Organisation
September 1994

1. Introduction

Spent HIFAR fuel elements have been stored at Lucas Heights Research Laboratories since 1963, the date at which a single shipment of spent fuel elements was returned to the United Kingdom for reprocessing. In November 1993, ANSTO had 1621 spent fuel elements from the operation of HIFAR in interim storage at the Lucas Heights site and a further 36 elements are discharged from the reactor each year.

To assess the effects of extended dry storage on the condition of the accumulated fuel elements, two of the older elements were retrieved from dry storage in 1983 and examined in the High Activity Handling Cells. The two fuel elements EC270 (MarkII type) and ED802 (MarkIII type) had previously been examined in 1967 as they were suspected during use, and subsequently proven, to have cladding defects. Well documented photographic evidence of the condition of these fuel elements was available from this 1967 examination, so a comparison of their behaviour in storage for a period of 16 years (11 years in dry storage) could be ascertained.

In December 1985, the Australian Government had approved the shipment to the US of 450 HIFAR spent fuel elements of US origin, for reprocessing in a US Department of Energy (USDOE) facility. A contract was signed with USDOE for reprocessing the 450 elements and in late 1988 the US designed and manufactured LHRL-120 Cask was delivered to Lucas Heights. However, in January 1989, before the first shipment could be prepared, the USDOE announced that no further deliveries of spent fuel would be accepted pending a review of its policy on return of "foreign" research reactor spent fuel.

In July 1993, the USDOE announced the decision to resume accepting foreign research reactor spent fuel containing US origin HEU subject to completion of an Environmental Impact Statement (EIS). The USDOE proposes to accept all foreign research reactor fuel containing uranium of US origin (15,000 elements) over a 15 year period. The US would take over ownership of all returned elements. The USDOE proposes to store, without reprocessing, the spent fuel at one or more existing DOE sites for an indefinite period pending ultimate disposal. The principal technologies being examined for this spent fuel involve dry storage. Given that there is only limited experience worldwide of extended dry storage of aluminium clad fuels there is considerable interest in ANSTO's successful experience with this technology. It is in this context that the present note was prepared to make available previously unpublished observations of the behaviour of HIFAR spent fuel under extended dry storage conditions.

2. HIFAR Fuel Elements

HIFAR fuel elements consist of assemblies of fuel plates fabricated from enriched uranium alloyed with aluminium. For protection against corrosion the uranium aluminium fuel is clad in pure aluminium. Each curved rectangular fuel plate therefore has a central sandwich of fuel clad both sides with pure aluminium and surrounded by an edge ('picture frame') of aluminium.

Mark II fuel elements consist of ten parallel curved fuel plates fitted longitudinally into an open ended aluminium box. These were used in HIFAR between 1958 and 1971. Mark III fuel elements consist of ten curved plates fitted as spiral fins in the annulus between inner and outer aluminium tubes. These were used in HIFAR between 1962 and 1971. (Since 1970 a new design using four concentric fuel tubes has been utilised.)

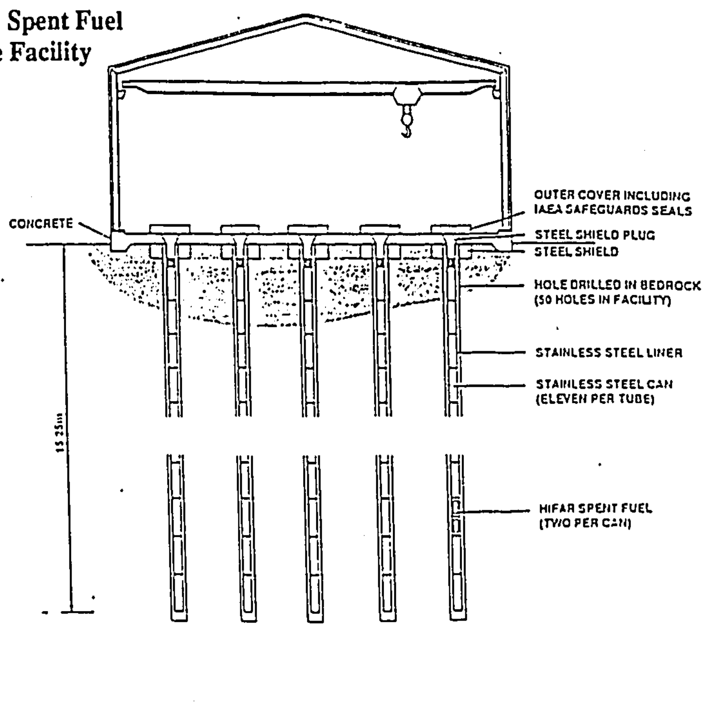
The HIFAR core contains 25 fuel elements, each some two metres in length and 100 mm in diameter. The amount of uranium-235 in the fuel elements has increased from 115 g in early elements to 170 g in recent elements and the enrichment reduced from 93 % to 60 % uranium-235. The fuelled section is 600 mm long. During reactor operation, the fuel is cooled by heavy water flowing up through the fuel elements. After discharge, the top and bottom aluminium sections of the fuel element are cropped to a length of 638 mm which contains the spent fuel.

All HIFAR fuel elements were manufactured by AEA Technology (previously known as the United Kingdom Atomic Energy Authority). The high enriched uranium (HEU) content was supplied by the UK and USA for approximately equal numbers of fuel elements.

3. Storage Facilities at Lucas Heights

The fuel discharged from HIFAR is stored under water in the reactor storage block for up to one year, then stored under water in the irradiation pond for another 2-3 years and most then is moved to dry storage in the engineered Spent Fuel Storage Facility (Figure 1) or placed in stainless steel casks.

Figure 1. **HIFAR Spent Fuel Storage Facility**



The HIFAR Spent Fuel Storage Facility is an engineered dry storage facility built in 1968 at Lucas Heights to store 1100 spent fuel elements. The facility consists of 50 lined holes, 16 metres in depth, drilled into sandstone and lined with 14 cm internal diameter sealed stainless steel tubes. HIFAR spent fuel elements are stored in individual aluminium cans, two cans in each stainless steel canister, and eleven canisters in each lined hole.

The tubes in the storage facility are filled with dry nitrogen to inhibit corrosion of the fuel cladding. Periodic monitoring of the nitrogen gas when the nitrogen is replaced shows no traces of krypton-85, a long-lived fission-product gas, except in the one hole which contains the two fuel elements EC270 and ED802 that are the subject of the current report and that were sectioned in 1967 for detailed metallurgical examination. The lack of any released krypton-85 in the other holes indicates that there is no significant deterioration of the fuel elements.

The Research Reactor Review, conducted in 1993 to examine the need for a new multi-purpose reactor for Australia, concluded that the present interim storage of spent fuel at the ANSTO site is in conformity with world best practice and is the most practicable and safest short-term storage arrangement.

4. History and Results of Examination of Fuel Elements EC270 and ED802

Table 1 summarises the history of the retrieved elements.

Table 1
Details of Elements Retrieved from Storage

Element No.	ED802	EC270
Element Type	Mark III	Mark II
Total Burnup	58%	56.8%
Reactor Irradiation Time	1713.6 MWD	1772.8 MWD
Loaded in Reactor	July 1966	September 1965
Removed from Reactor to Pond Storage	April 1967	May 1966
Transferred to Hot Cells, disassembled into fuel plates for examination	23 June 1967	19 May 1967
Returned to Storage Pond	18 August 1967	7 August 1967
Transferred to Dry Storage	19 July 1972	19 July 1972
Retrieved and Examined in Hot Cells	29 July 1983	1 July 1983

During the 1967 Hot Cell examination element EC270 was found to have a total of eight blisters on six plates and one region of marked corrosion. In addition, there were numerous ridges in the braze metal region. Subsequently a total of seventeen punchings (3 cm diameter) were removed from five of the fuel plates for closer examination.

Element ED802 had a total of fifteen blisters on five plates, all the blisters were located at the edges of the fuel plates where they had been brazed to the cover tube and were predominantly over the 'picture frame'. A total of ten punchings were removed from four plates for further examination.

The conclusions of the 1967 examination were that there was strong evidence that the cladding defects were due to brazing flux occluded in the brazed junctions at fuel plate edges, and that the defects did not develop during service but were well advanced during the prolonged storage before use in the reactor.

It follows that these two fuel elements are representative of the worst possible cases to examine for behaviour under extended storage since (a) corrosion was already present before commencement of storage due to occluded brazing flux, and (b) the uranium-aluminium alloy fuel was directly exposed to the storage environment due to the sectioning for removal of samples for metallographic examination in 1967.

A representative selection of the 1967 photographs of both defective and sound fuel plates is attached along with the corresponding 1983 photographs of the same fuel plates. The principal observations are:

- all fuel plates have maintained their physical integrity and indeed show little change even in minor surface markings and discolourations over this sixteen year storage period, eleven years of which has been in dry storage,

- close examination of the defective plates showed indications of additional corrosion in 1983 compared with 1967 but only of a minor extent and only in the immediate vicinity of the cut edges, where samples had been removed exposing the fuel alloy directly to the storage environment, and adjacent to known occlusions of brazing alloy,

- plates that were wholly intact in 1967 showed negligible deterioration in 1983.

5. Conclusion

The direct comparison of the condition of the same fuel elements first in 1967 and again in 1983 following five years of wet storage and eleven years of dry storage showed that, even under the worst initial conditions of defective fuel, the fuel still retained its physical integrity and showed negligible deterioration over this extended period of storage. This lends considerable confidence to the viability of dry storage technologies for the long term storage of spent aluminium clad research reactor fuels.

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Figure 5B	Element EC 270 Plates 9-12, 1983 Inside Surface
Figure 6	Element ED 802 End View, 1967 After service but before cutting into separate plates.

FIGURE 1A
ELEMENT ED802
PLATE 1 1967
INSIDE SURFACE

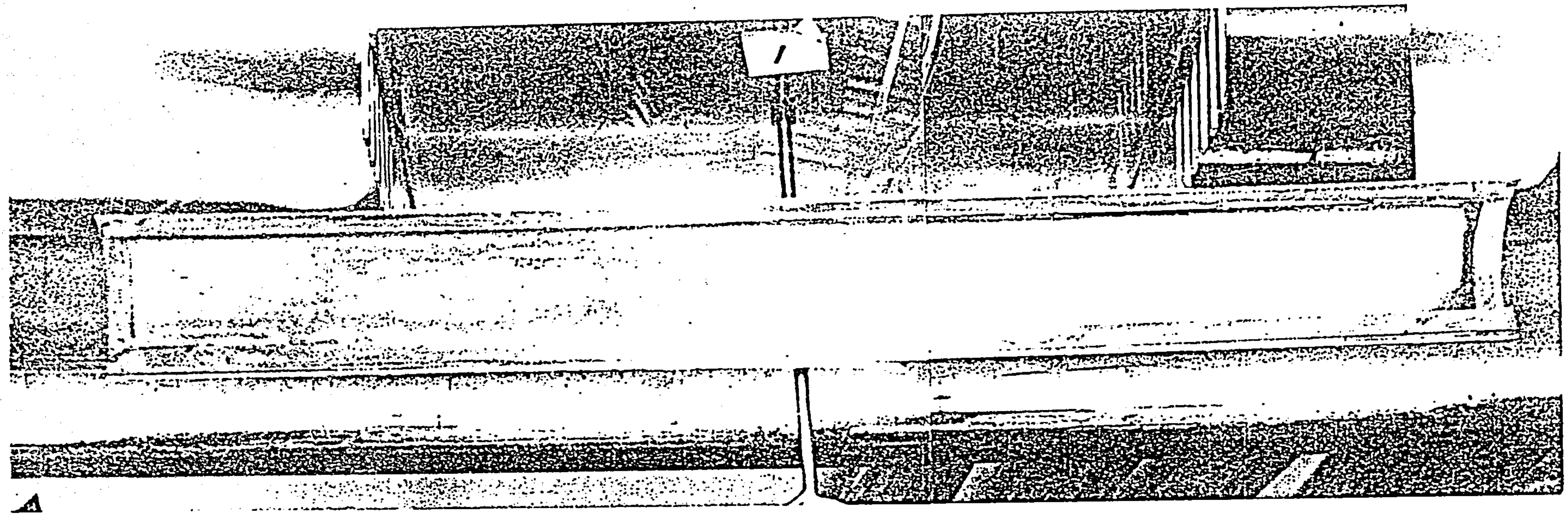


FIGURE 1B
ELEMENT ED802
PLATE 2 1967
INSIDE SURFACE

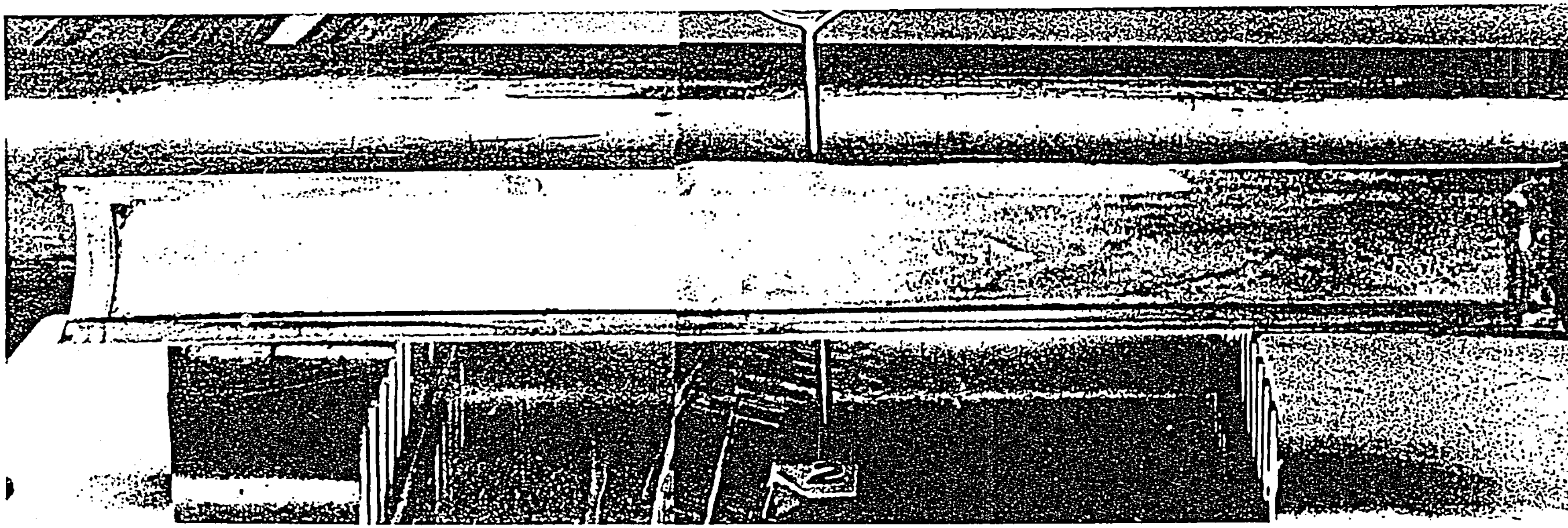


FIGURE 1C
ELEMENT ED802
PLATE 3 1967
INSIDE SURFACE

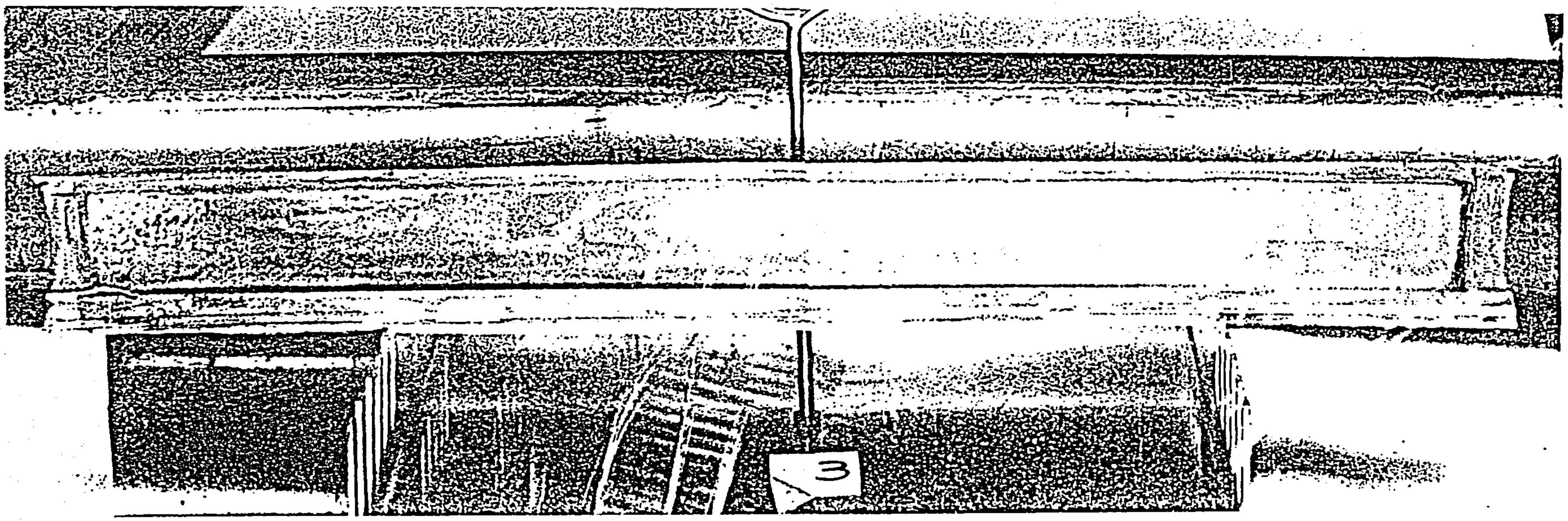


FIGURE 1D
ELEMENT ED802
PLATE 4 1967
INSIDE SURFACE

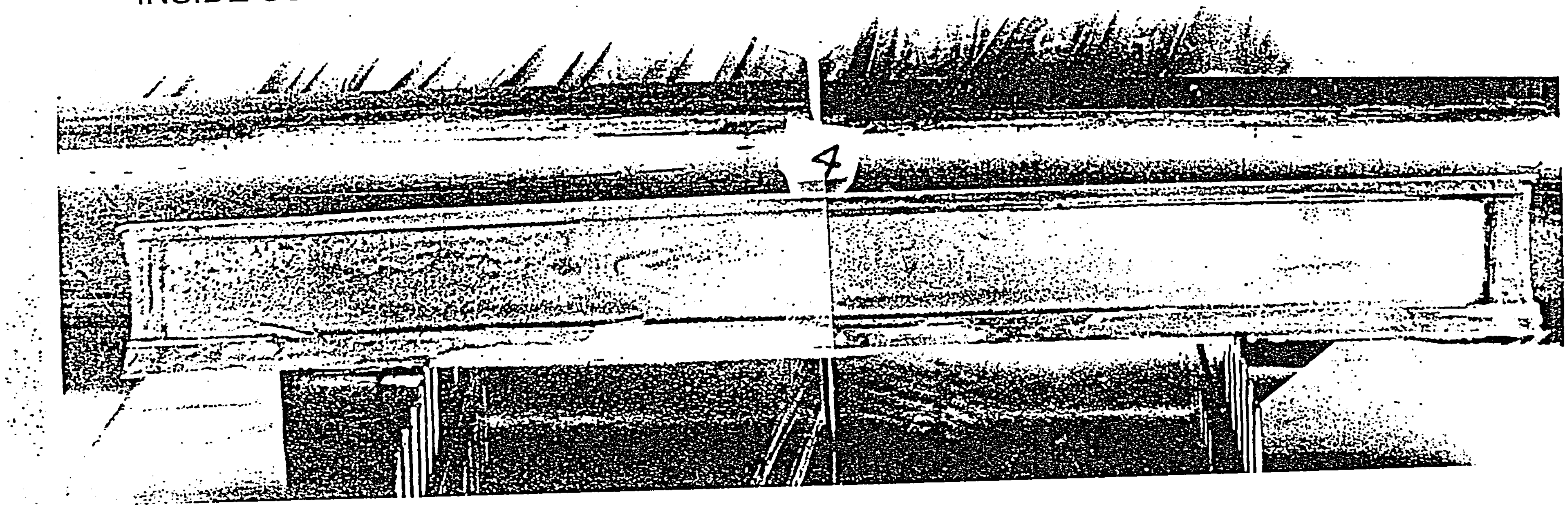


FIGURE 2A
ELEMENT ED802
PLATE 1 1967
OUTSIDE SURFACE

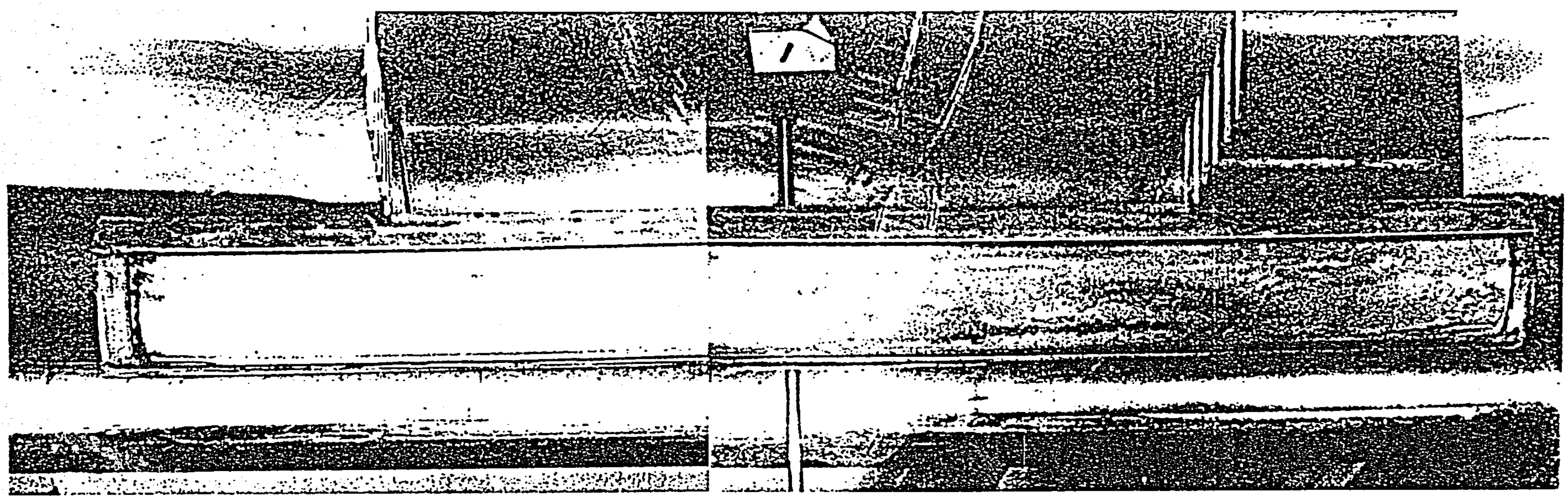


FIGURE 2B
ELEMENT ED802
PLATE 2 1967
OUTSIDE SURFACE

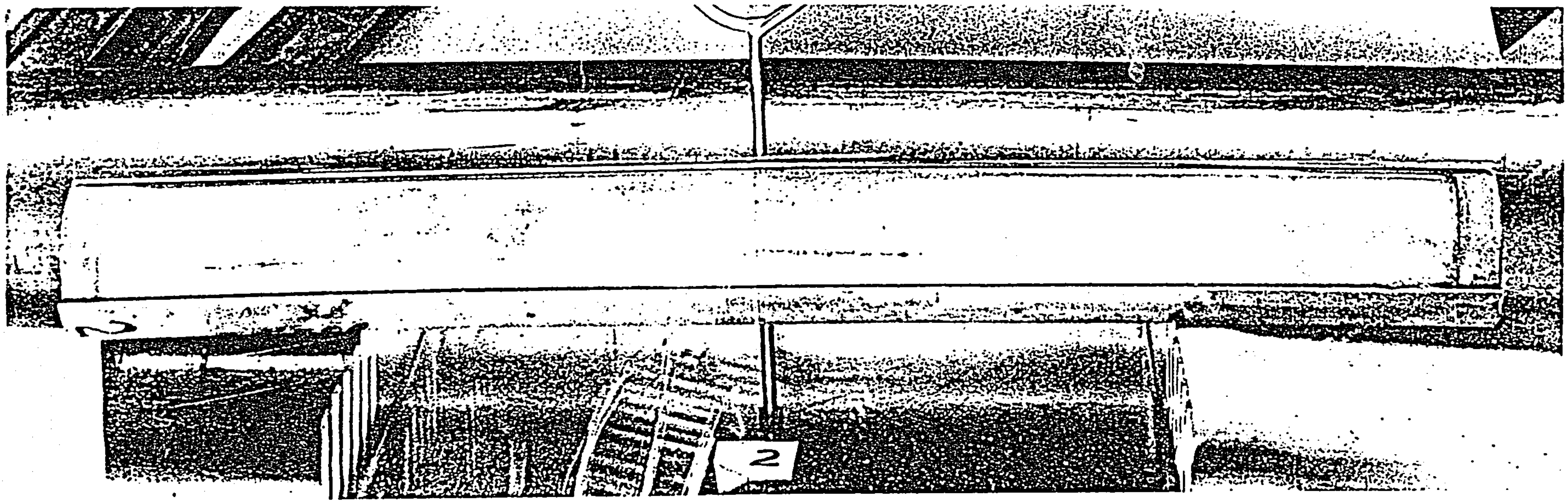


FIGURE 2C
ELEMENT ED802
PLATE 3 1967
OUTSIDE SURFACE

FIGURE 2D
ELEMENT ED802
PLATE 4 1967
OUTSIDE SURFACE

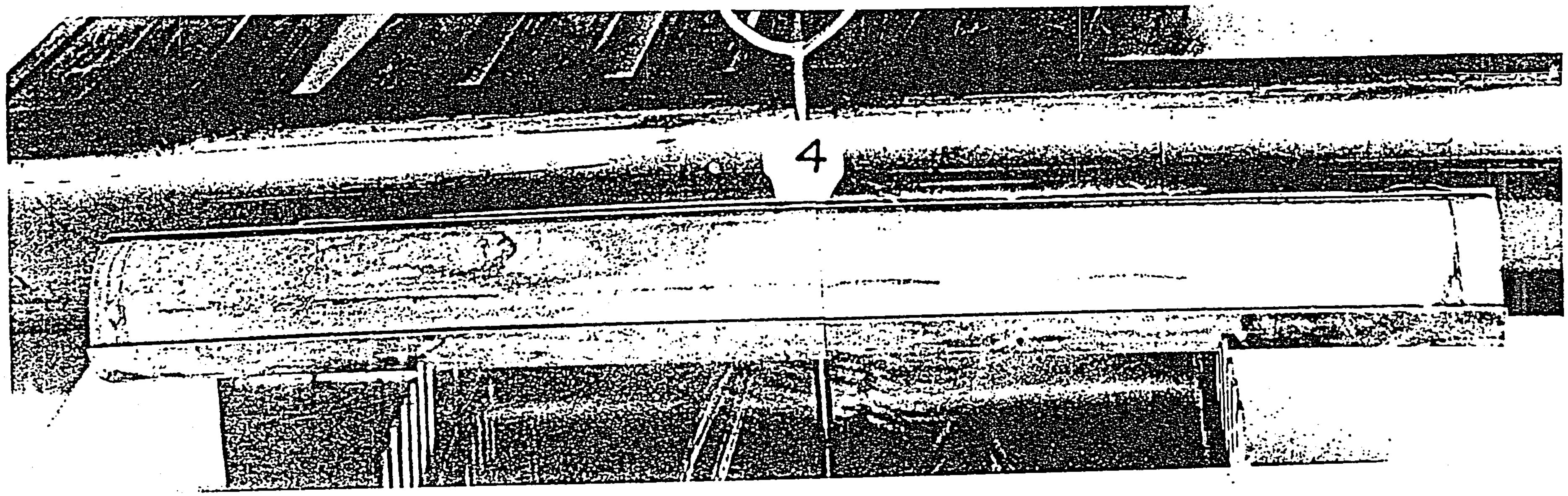


FIG 3A

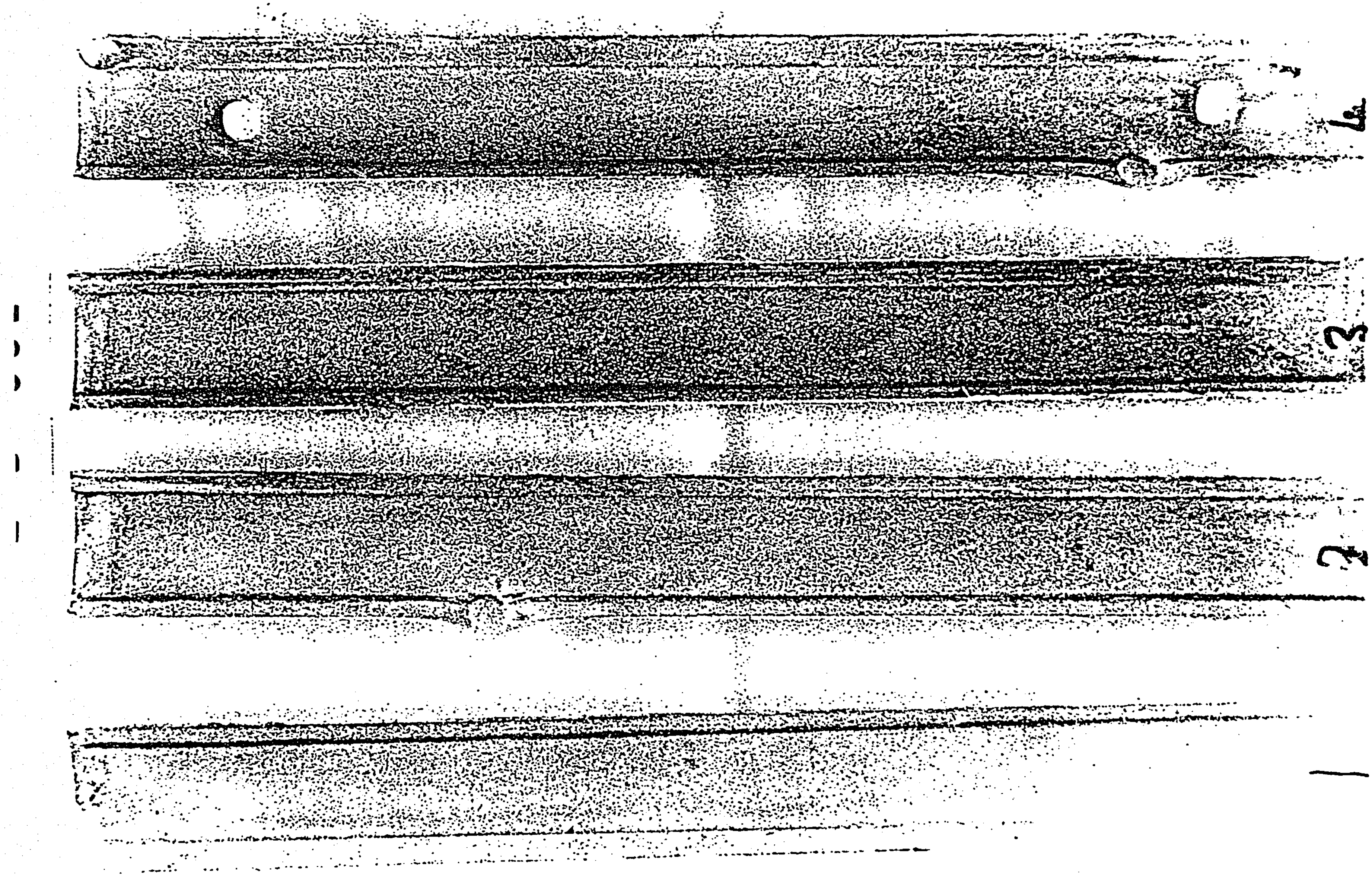


FIG 3B

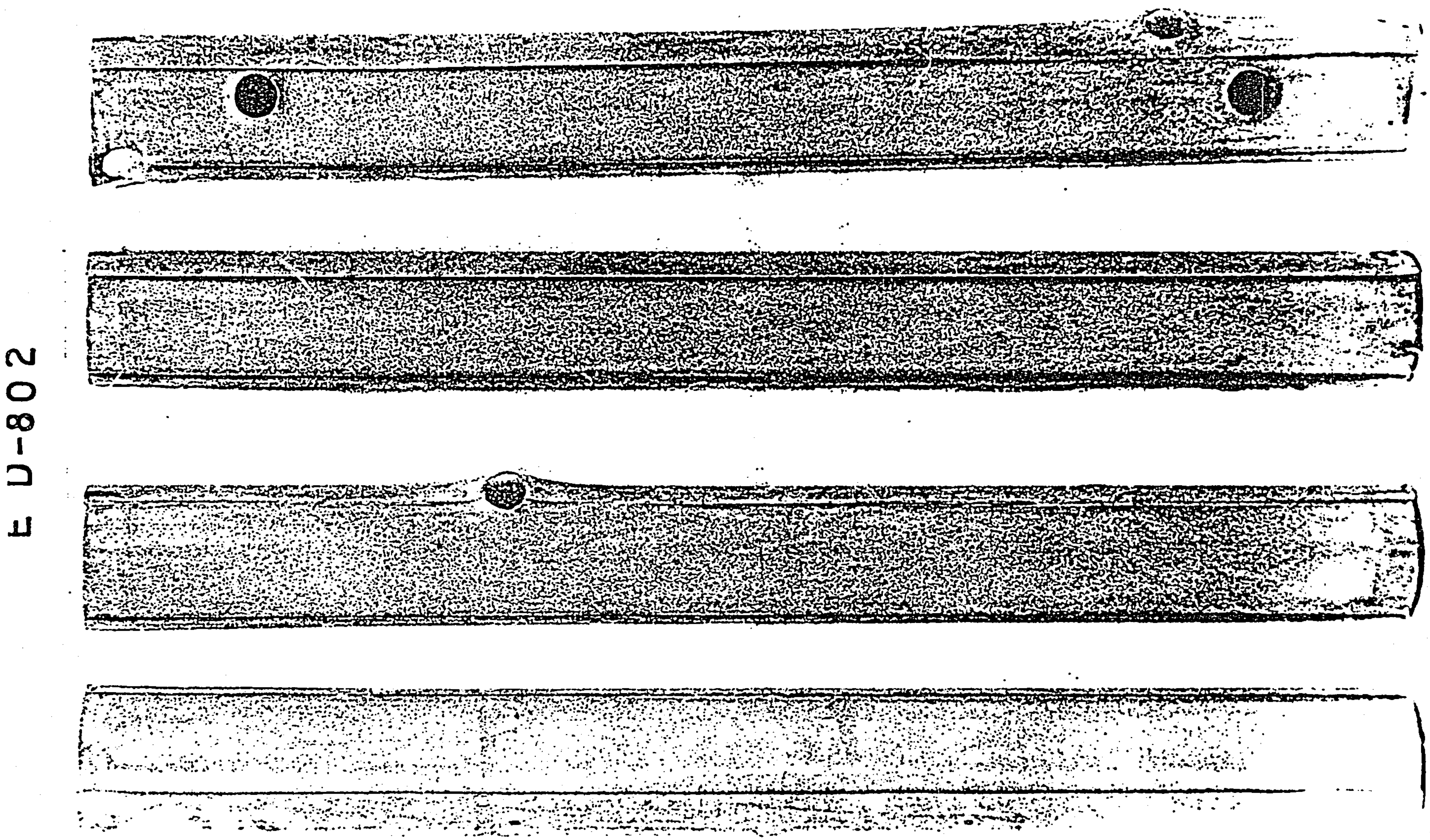


FIGURE 4A
ELEMENT EC270
PLATE 12 1967
OUTSIDE TOP

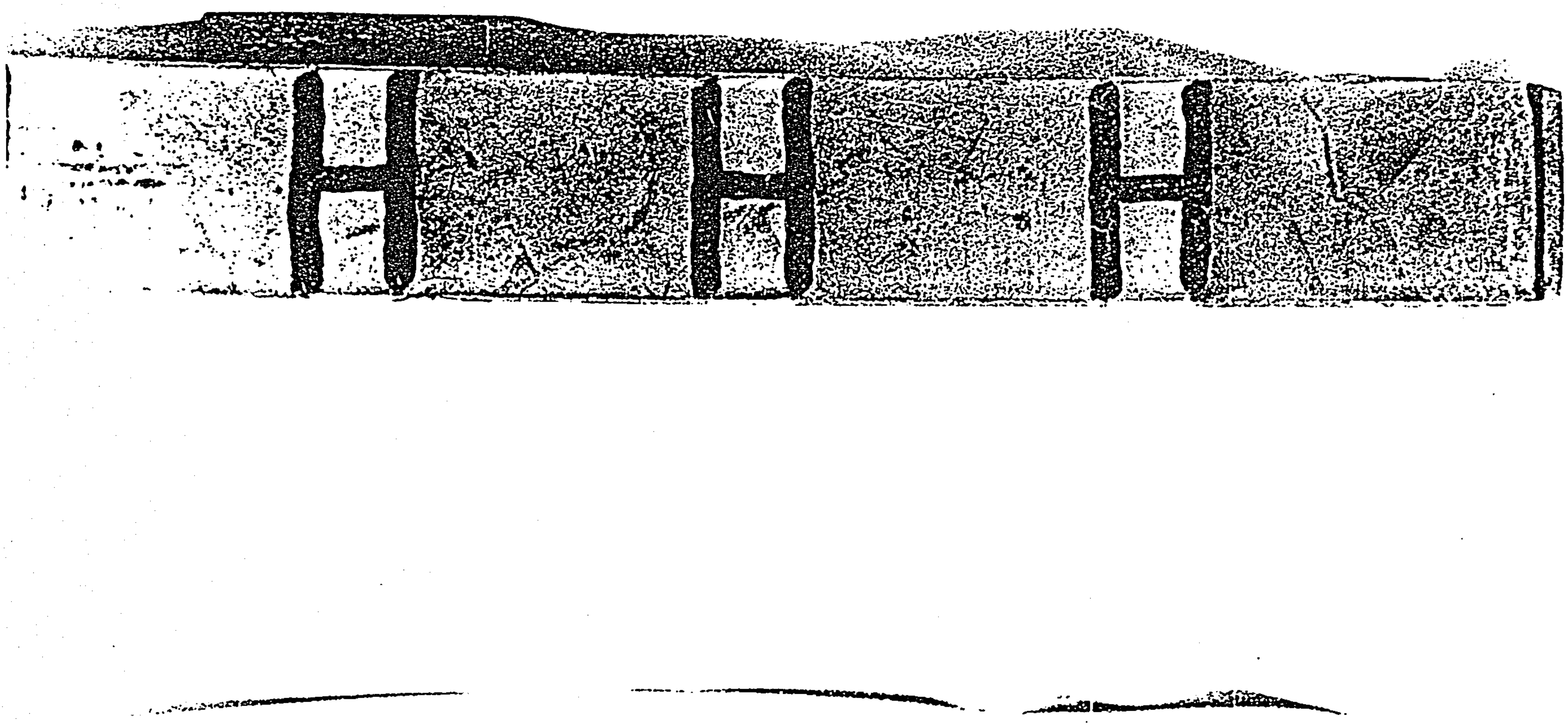


FIGURE 4B
ELEMENT EC270
PLATE 12 1967
OUTSIDE BOTTOM

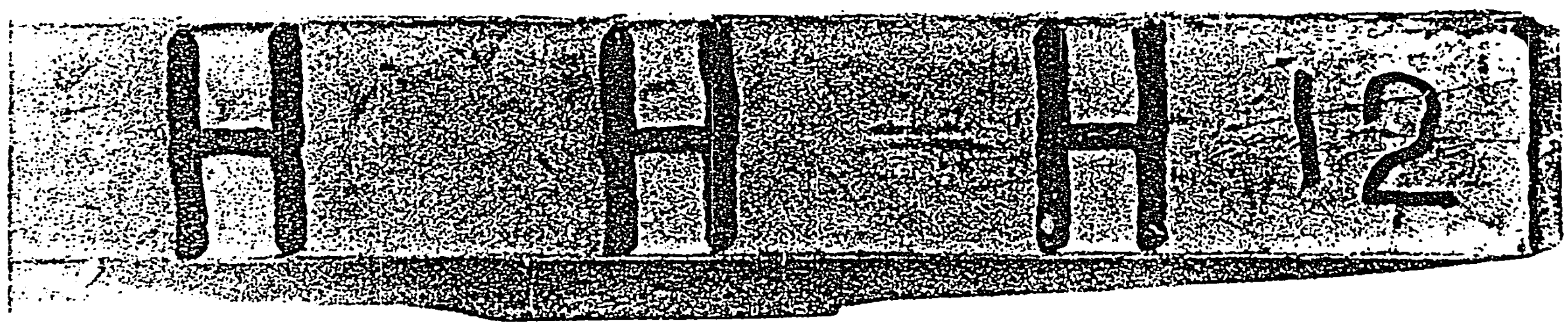


FIGURE 4C
ELEMENT EC270
PLATE 12 1967
INSIDE TOP

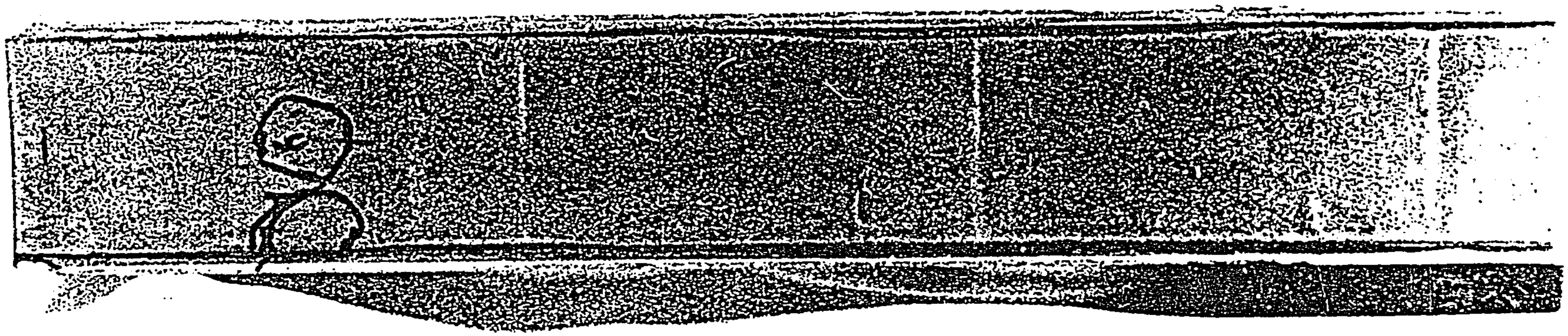


FIGURE 4D
ELEMENT EC270
PLATE 12 1967
INSIDE BOTTOM

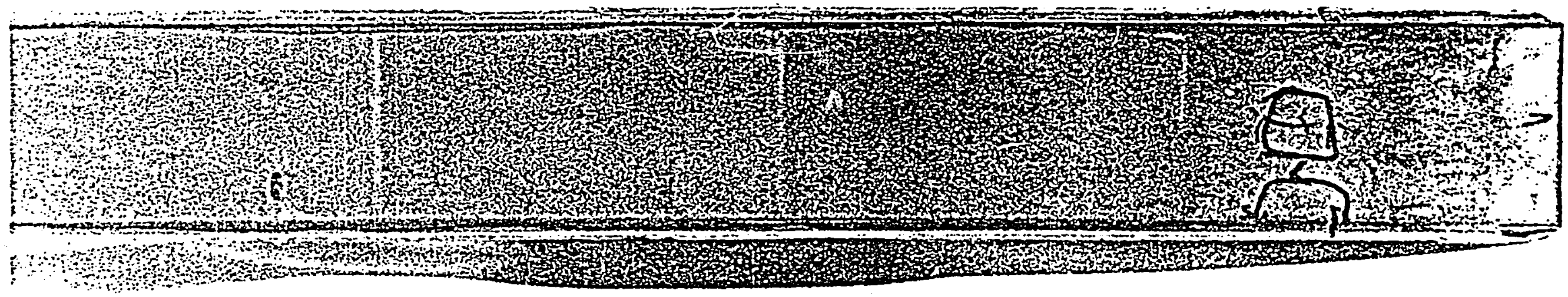


FIG 5A

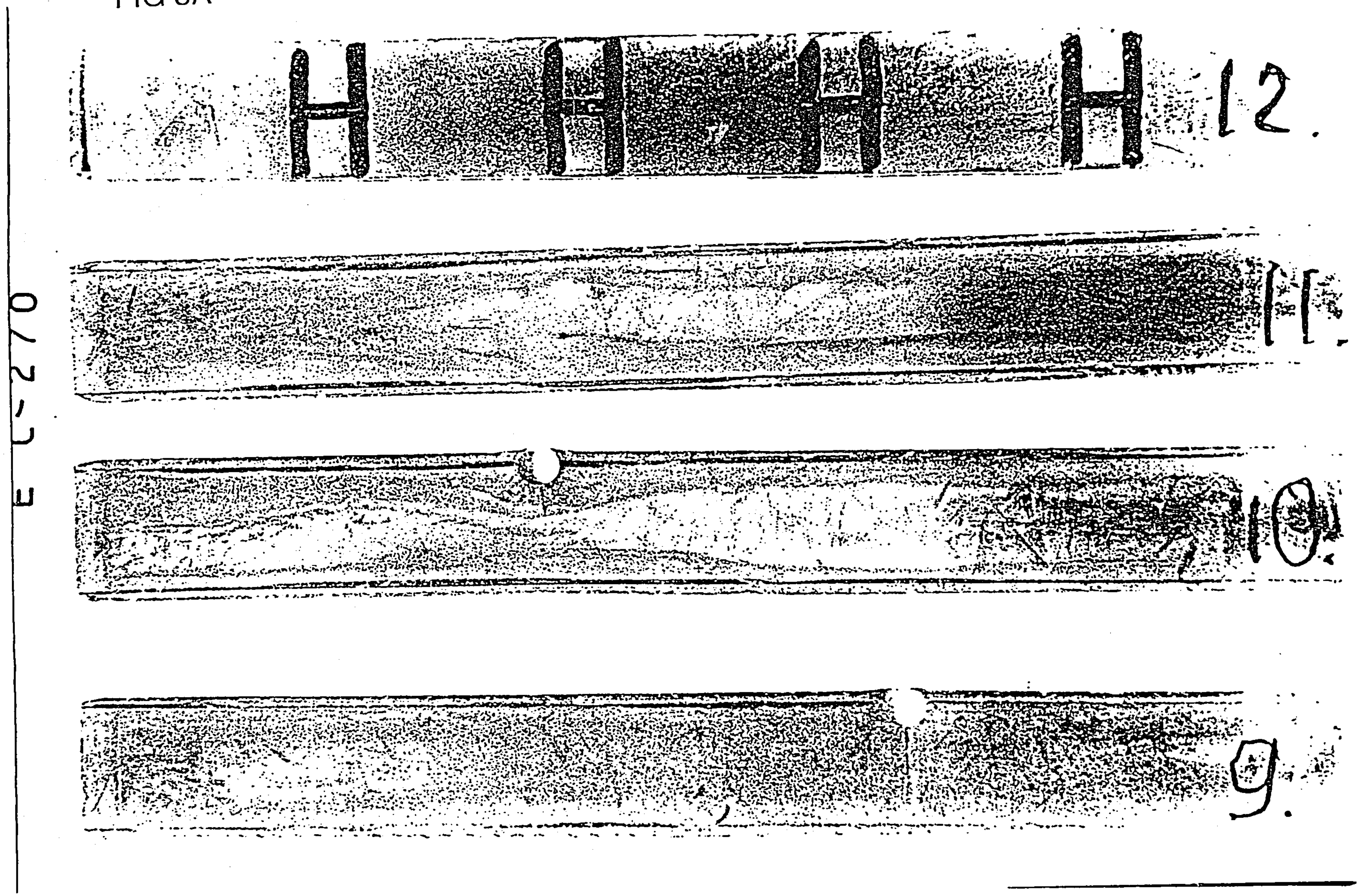
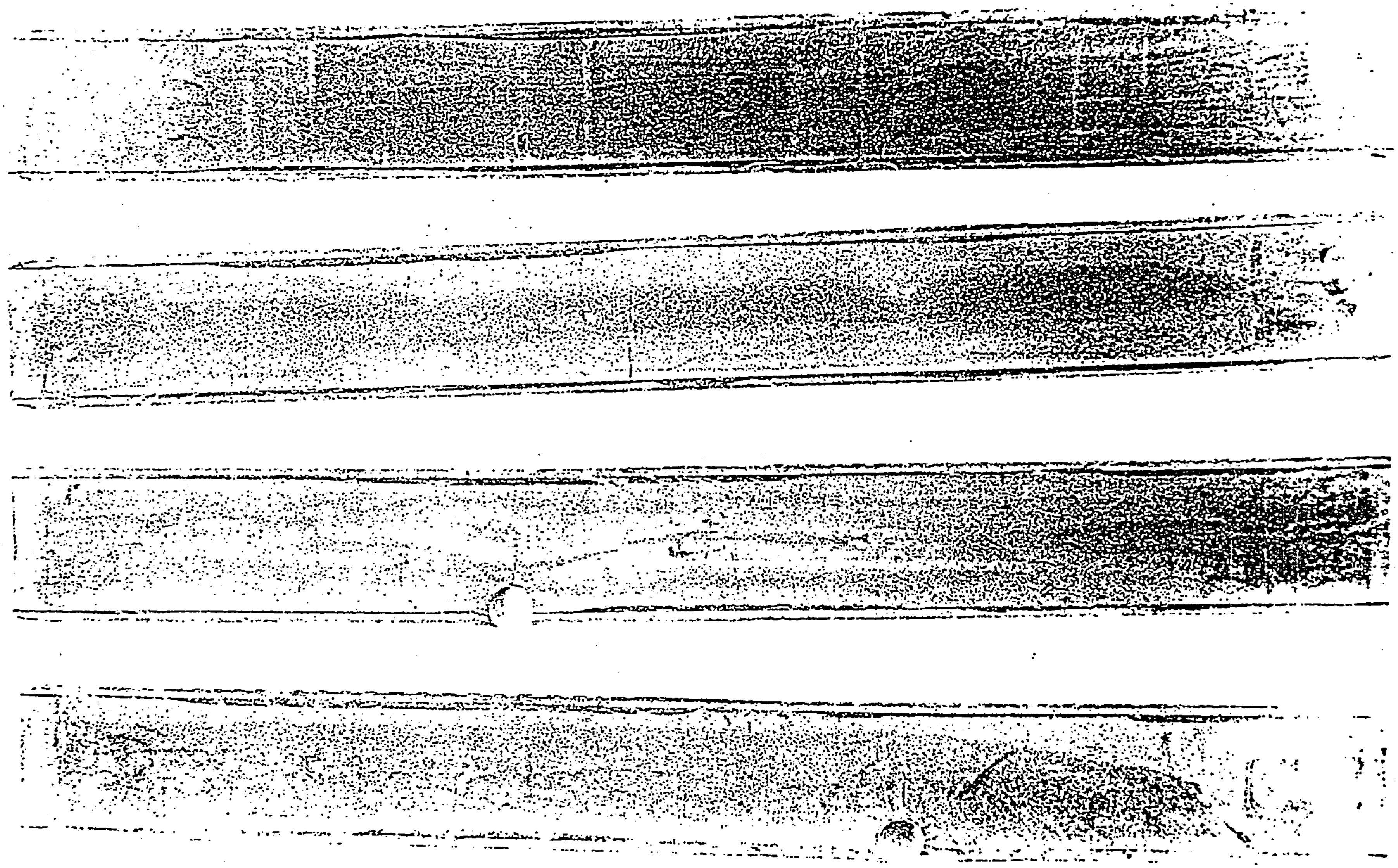


FIG 5B



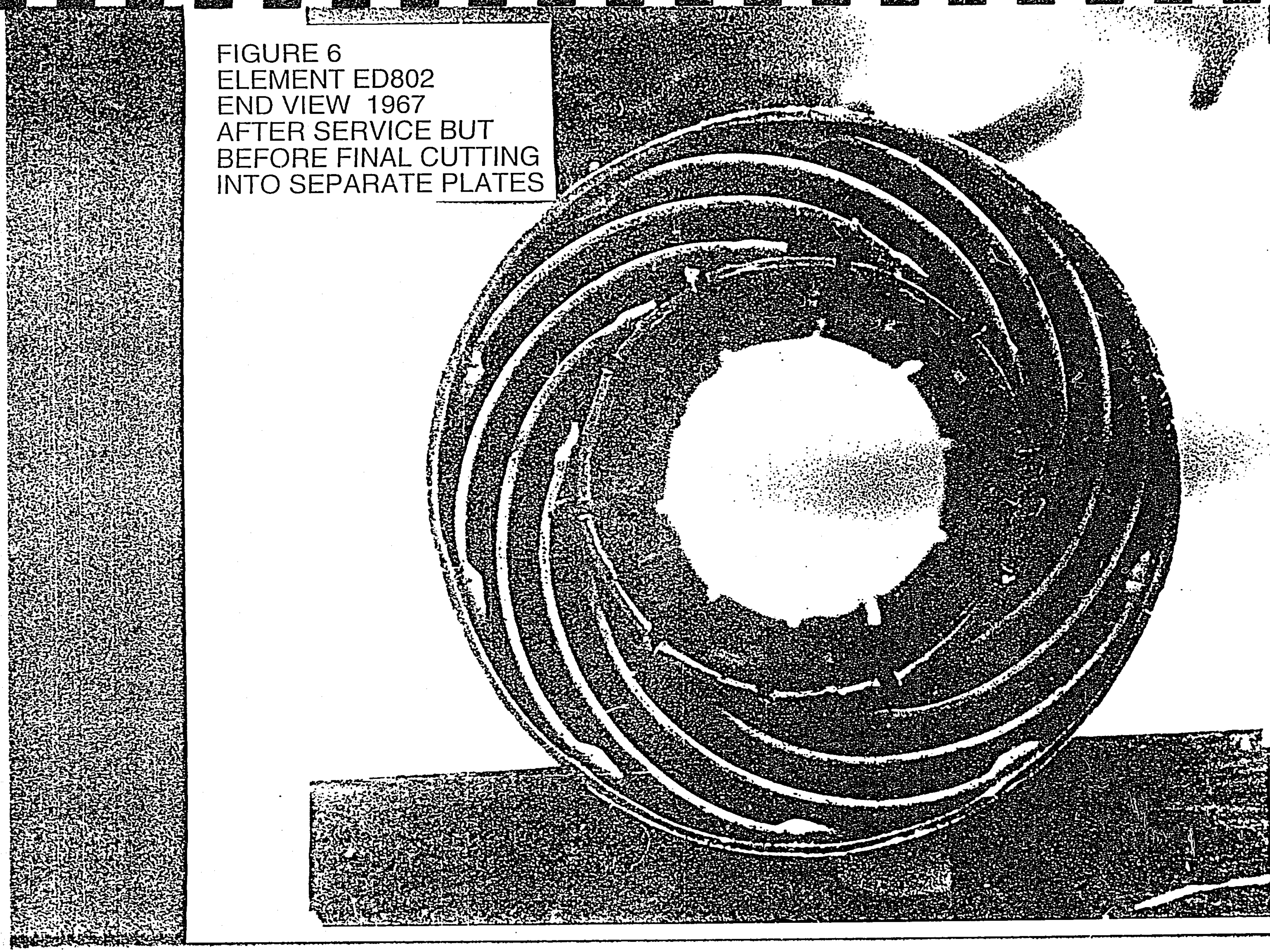


FIGURE 6
ELEMENT ED802
END VIEW 1967
AFTER SERVICE BUT
BEFORE FINAL CUTTING
INTO SEPARATE PLATES