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REMOTELY REPLACEABLE FUEL AND FEED NOZZLES FOR THE NWCF CALCINER VESSEL

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FOR THE INCF CALCINER VESSEL

ABSTRACT

The development and testing of remotely replaceable fuel and feed nozzles for calcination of liquid radioactive wastes in the calciner vessel of the New Waste Calcining Facility (NWCF) being built at the Idaho National Engineering Laboratory is described. A complete fuel nozzle assembly was fabricated and tested at the Remote Maintenance Development Facility to evolve design refinements, identify required support equipment, and develop handling techniques. The design also provided for remote replacement of the nozzle support carriage and adjacent feed and fuel pipe loops using two pairs of master-slave manipulators.

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INTRODUCTION

Operating experience with the existing Waste Calcining Facility (WCF) indicates that replacement of the spray nozzles used for adding feed and fuel to the calciner vessel is one of the more frequent maintenance items in the plant. Since the WCF was designed for direct maintenance of any failed equipment, extensive decontamination of vessels and piping is required prior to cell entry to make needed replacements. Nozzle problems have included frequent solids plugging, nozzle tip erosion, and nozzle gasket leaks. Consequently, the NWCF calciner nozzles have been designed to be remotely replaceable by the use of shielded viewing windows, master-slave manipulators, and impact wrenches.

DESIGN CRITERIA

The design criteria for the NWCF calciner nozzles and associated piping include:

1. remotely removable using impact wrenches and master-slave manipulators
2. metal-to-metal seal between the nozzle and the calciner vessel
3. 5.1-cm (2-in.) minimum nozzle diameter at the calciner end, i.e., that portion that projects into the calciner vessel
4. internal nozzle design based on the existing nozzle design
5. tapered nozzle design to provide quick release during nozzle removal, and
6. feedlines having smooth bends and continuous downward slopes to prevent plugging.

NOZZLE DESIGN

The basic external design for both the feed and fuel nozzles started with a 13 cm (5 in.) long tapered section that was 5.1 cm diameter at the calciner vessel and increased to 6.4 cm (2-1/2 in.) diameter outside the vessel. The 6.4 cm diameter was selected to permit using a commercially available remote connector which also provided a metal-to-metal seal between the nozzle and the vessel hub. This size was also adequate to incorporate the existing internal nozzle designs for both the feed and fuel nozzles. The calciner vessel end of each nozzle has a 1.9 cm (0.75 in.) end cap of Haynes 25 alloy to resist abrasion and the calcining temperature. The remaining portion of each nozzle is 304L stainless steel. The feed rates for the two nozzles types are as follows: feed nozzle, 202.5 L/h (53.5 gph) radioactive feed and 0.91 sm^3/min (32.5 scfm) air; fuel nozzle, 27.8 L/h (7.35 gph) kerosene and 0.84 sm^3/min (30 scfm) oxygen.

NOZZLE AND PIPING ARRANGEMENT

The original nozzle piping loop arrangement included two three-bolt flanges for connecting the liquid and gas lines to the lower end of the piping loops welded directly to the nozzle. Because of an added requirement that new (replacement) nozzles be introduced into the calciner cell through a 15-cm (6-in.) diameter tool port, the size of the nozzle assembly had to be reduced. To accomplish the necessary size reduction, a commercially available remote connector was added to the nozzle assembly to permit separating the piping loops from the nozzle. A remote connector was also added at the upper end of the piping loop to replace the two three-bolt flanges that separated the loop from the permanent cell piping. The two new remote connectors were 5.1-cm dual port units

with two seal rings in each connector, one for liquid and one for gas. These connectors accomplished the desired size reduction. The final nozzle arrangement is shown in Figure 1. To further reduce the weight of the nozzle assembly, the remote connector between the nozzle and the calciner vessel was reduced from 6.4 cm to 5.1 cm and the nozzle body was reduced from 10.2 cm (4 in.) to 7.3 cm (2-7/8 in.) in diameter. The smaller diameter also made handling the units with the master-slave manipulators easier.

Reducing the nozzle-calciner vessel remote connector to 5.1 cm also required reducing the diameter of the nozzle top to retain the tapered nozzle design. The final nozzle tip diameter of 3.7 cm (1.46 in.), although slightly smaller than the design criteria of 5.1 cm, is significantly larger than the present 2.6 cm (1.03 in.) nozzle diameter and was considered a satisfactory compromise.

NOZZLE SUPPORT STRUCTURE

The structure provided to support the nozzle assembly consists of two steel channels attached to the calciner vessel. The two channels serve as tracks for a rolling carriage which in turn supports both the nozzle and the piping loops. The channels and rolling carriage are shown at the bottom of Figure 1. The rolling carriage allows the nozzle about 24 cm (9-1/2 in.) of horizontal motion and permits inserting and removing the tapered end of the nozzle from the calciner vessel wall. Figure 2 shows a pneumatic impact wrench opening the upper remote connector prior to removing the nozzle from the vessel. In Figure 3 the upper remote connector and the nozzle remote connector have both been opened and the nozzle removed from the vessel. The support unit that

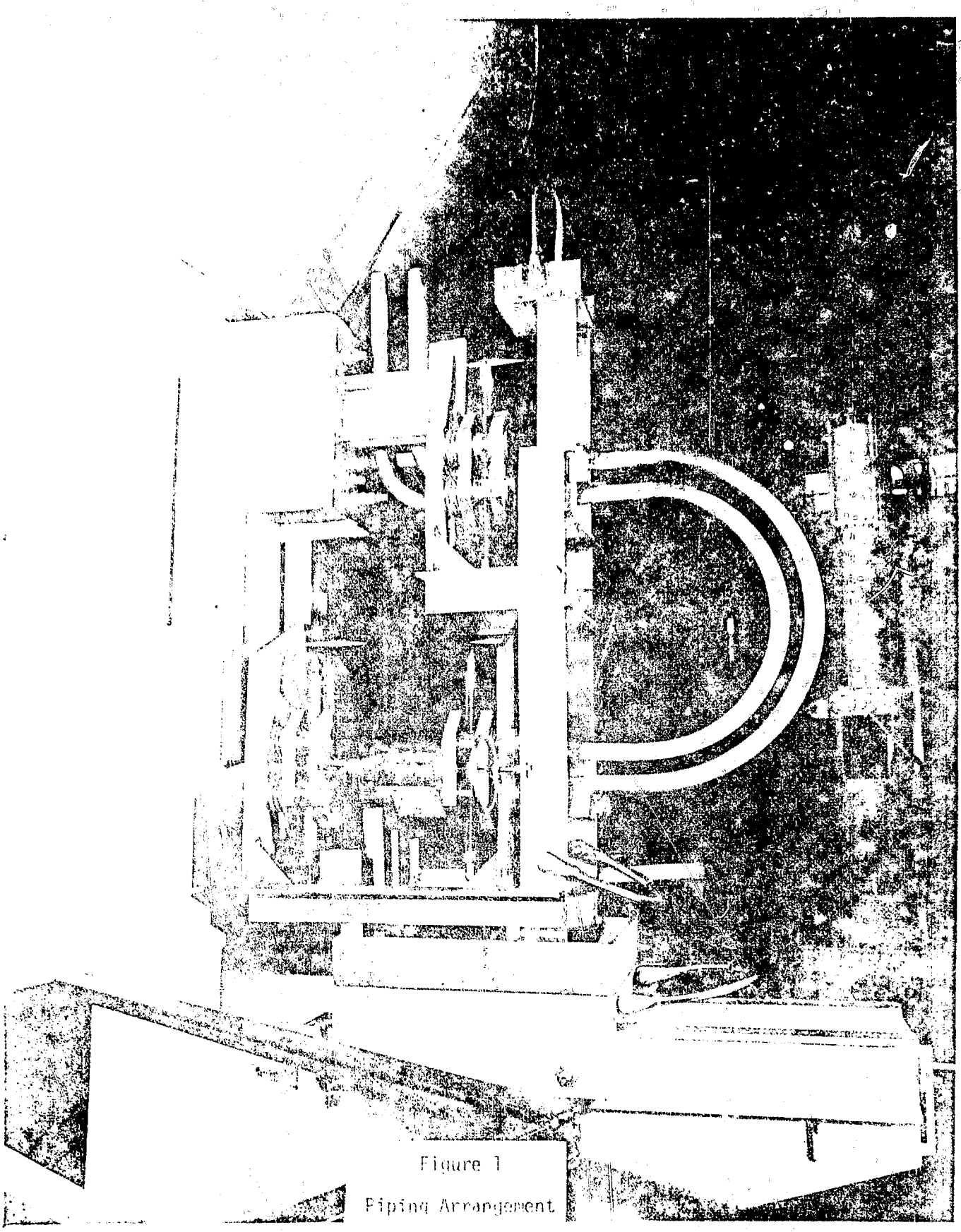

Figure 1

Piping Arrangement

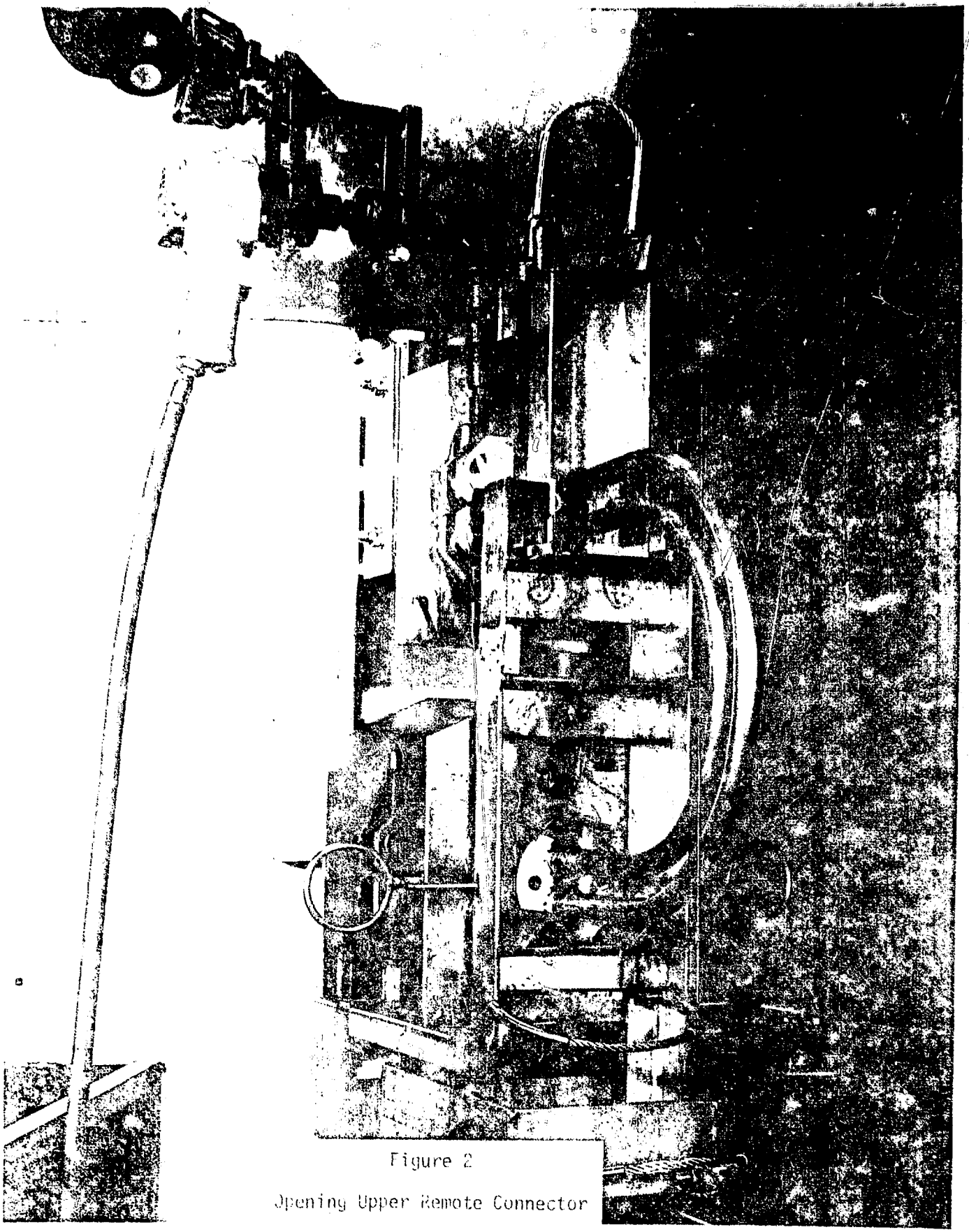

Figure 2

Opening Upper Remote Connector

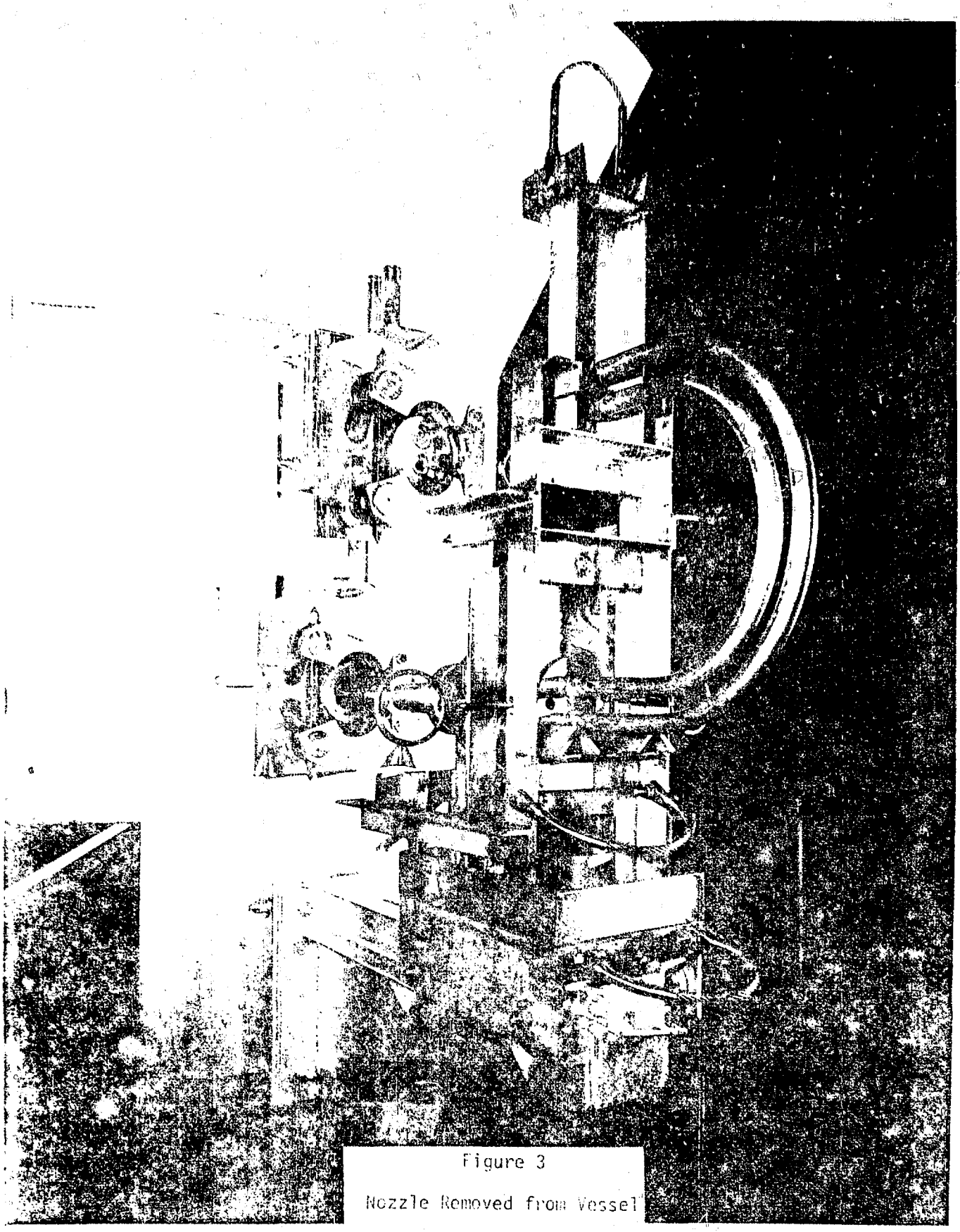

Figure 3

Nozzle Removed from Vessel

rests on top of the carriage and directly supports the nozzle and piping loop contains a pivot pin so that the nozzle assembly can be rotated 90° to permit more direct manipulator access and improved viewing for nozzle assembly replacement. The support unit is shown in the rotated position in Figure 4. In Figure 5, the master-slave manipulator is shown removing the nozzle from the support cradle and the opened third remove connector.

NOZZLE TEST

A prototype fuel nozzle burning kerosene and oxygen was fabricated and test fired both in open air and in a 30-cm (12-in.) pilot-plant calciner to verify nozzle operating characteristics and to confirm the integrity of the remote connector metal-to-metal seal following thermal cycling. A test firing of the prototype in open air is shown in Figure 6. The nozzle operating characteristics in the pilot-scale calciner were satisfactory, and thermal cycling from ambient to 533 K (500°F) and from ambient to 913 K (640°C)[a] had no adverse effect on connector seal performance. With a bed temperature of 913 K (640°C), the cooling temperature was approximately 633 K (360°C).

This nozzle was then moved to the Remote Maintenance Development Facility (RMDF) where the remote development work and mockup handling tests discussed previously were performed. As testing progressed and developments were made a second nozzle assembly was fabricated that included all remote fixtures, piping, and connectors. Testing of this assembly then led to design approval and procurement activities.

(a) Calciner bed operating temperature

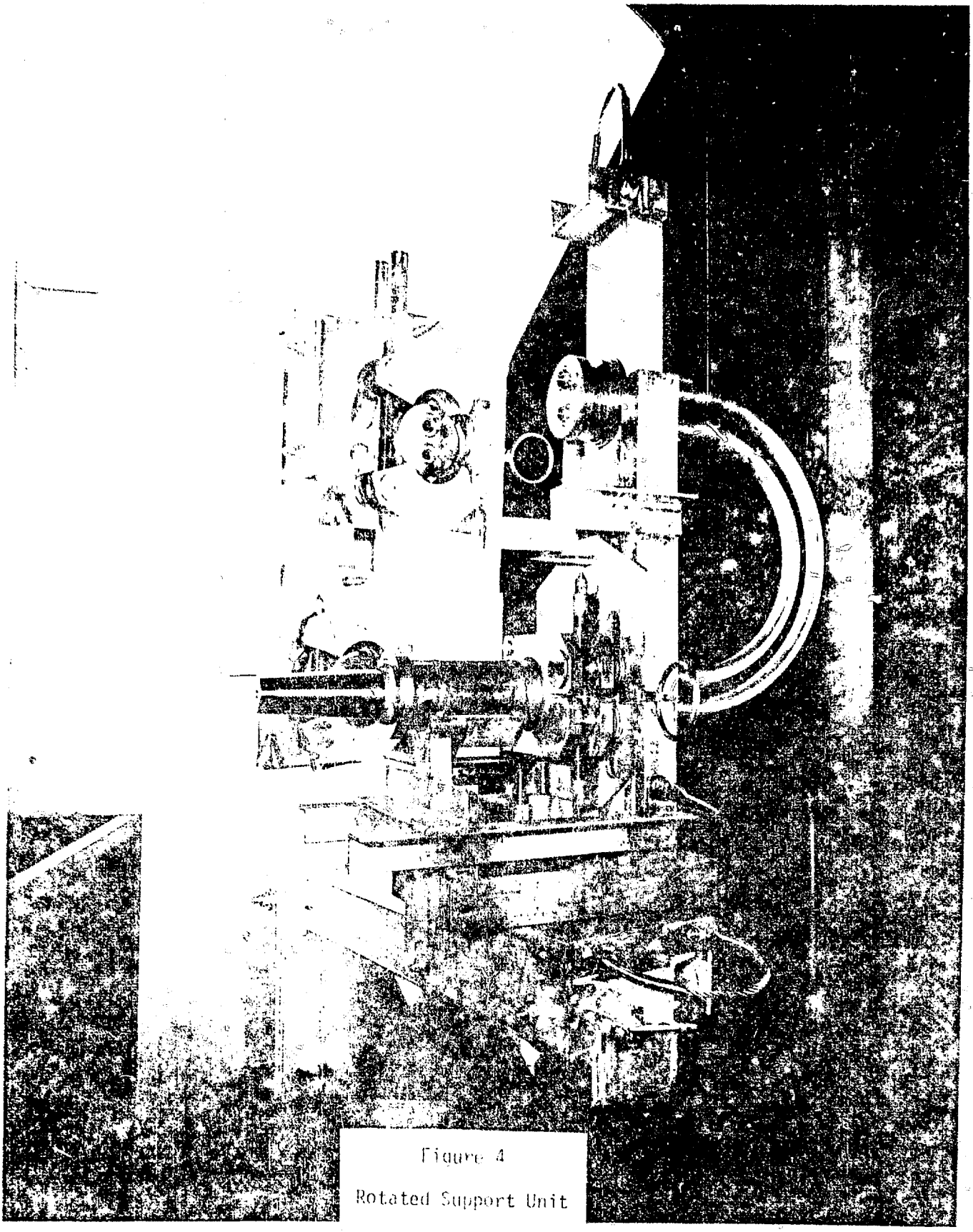

Figure 4

Rotated Support Unit

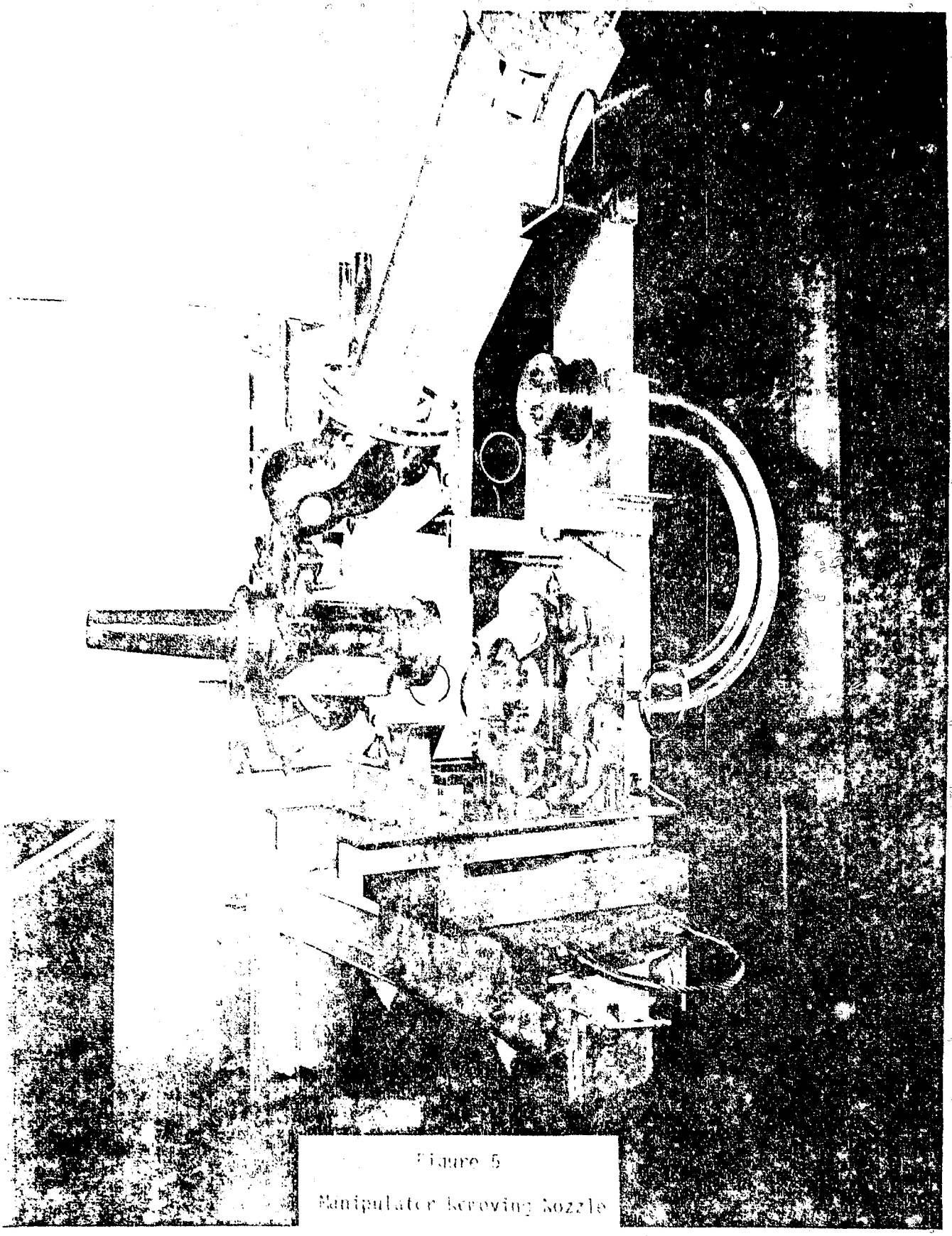

Figure 5

Manipulator Removing Nozzle

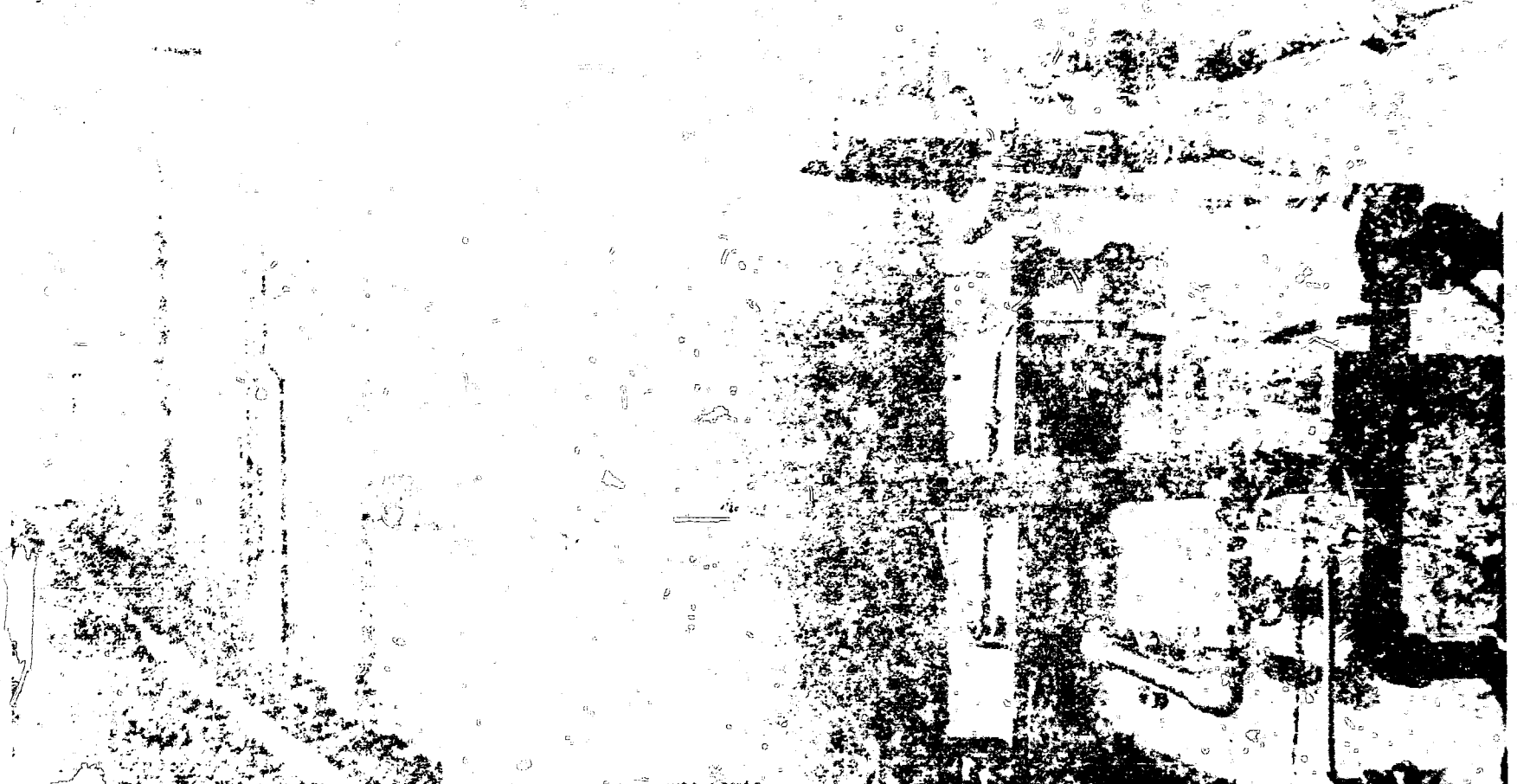

Figure 7

Nozzle Test Firing

FIGURES