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# New Equipment for the X-Ray Examination of Irradiated AGR Fuel Elements

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## 1. INTRODUCTION

The BNL cave line (Fig. 1) consists of nine work stations and was originally equipped for the examination of Magnox fuel elements. This work continued over a period of approximately 20 years and during this time considerable benefit was obtained from the precision X-ray examination of Magnox fuel elements. In this way it was possible to obtain actual dimensional measurements of the uranium rod without removal of the cladding (Ref. 1).

The magnox programme was terminated in 1986 and the caves are now being reequipped for the examination of fuel elements (Ref. 2) from the Advanced Gas Cooled Reactor (AGR). A diagrammatic view of how the caves will appear when the refurbishment is complete is shown in Fig 2. The equipment to be provided includes apparatus for the X-ray examination of AGR fuel pins and because space was limited it was decided to accommodate this apparatus by removing the sliding partition door between caves 4 and 5 and replacing it with a purpose built shielded plug containing the X-ray equipment. The paper describes the principles and layout of this equipment.

## 2. GENERAL DESCRIPTION OF THE X-RAY APPARATUS

The general assembly of the shielded plug which carries the X-ray apparatus shown is Fig 3. It is carried on wheels so that it can be retracted completely if required. The upper part of the shielded plug carries the X-ray tube with access arrangements for the power supply and the lower part carries the cassette transfer mechanism and the pin presentation arrangement. The operator controls are situated at the back of the plug.

Using the manipulators the fuel pin is loaded into a specially designed trolley (see Fig 4) and the assembly is then driven into the shielded plug where the pin is secured by pneumatically operated clamps. The X-ray film which is contained in a cassette, is then loaded from the rear and an automatic exposure sequence is activated. This brings the cassette into position beneath the fuel pin, triggers the exposure and then retracts the cassette to its recovery position. In this way the X-ray film is beneath the pin for little more than the time of the X-ray exposure. This keeps the gamma fogging to a minimum and enables the film to be used for accurate measurement of fuel pin dimensions. The position of the pin prior to exposure is determined by a TV viewing system.

Construction of the equipment can be considered in five parts:

(i) Method of pin presentation.
(ii) Method of cassette presentation.
(iii) Details of the X-ray tube system.
(iv) Details of the shielded plug assembly.
(v) Details of the control system.

These items are considered separately in the following sections.

## 3. METHOD OF FUEL PIN PRESENTATION

The fuel pin is loaded into the transfer trolley in the cave using manipulators. The trolley then driven by a motor along guide rails into the shielded plug and when in position the pin is gripped by a pair of jaws made from polythene to ensure that it does not move. The polythene jaws prevent obscuration of the image and are activated by a pneumatic cylinder. Distance markers are provided so that the position of the pin can be accurately determined.

All items making up the fuel pin transport carriage can be disassembled using manipulators. The fuel pin is mounted on the trolley between a notched plate and a spring loaded plunger. An aluminium shield is

fixed beneath the fuel pin to prevent debris dropping into the shielded plug during movement.

## 4. METHOD OF PRESENTATION OF THE X-RAY FILM CASSETTE

In order to use the film for measurement of dimensional changes the magnification factor must be reproducible. This is achieved by ensuring that the design fixes the X-ray tube to pin and pin to film distances accurately. The film transport mechanism is arranged so that on transfer the cassette is 100mm beneath the fuel pin centre line and located such that the image of the pin when clamped between the jaws appears on the centre line of the X-ray film. The X-ray film has minimum dimensions of 170mm x 100mm and is held in a cassette which is 200mm long x 130mm wide x 15mm thick. Within the shielded plug the X-ray cassette is fully protected from radiation scattered from the cave.

If the film is stationary below the pin for more than 6 seconds, gamma fogging reduces the quality of the image, thus for design purposes the total radiation exposure time is limited to 4 seconds. By using an X-ray tube with a high speed rotating anode exposure times can be kept between a half and 2 seconds which allows approximately 2 seconds for transfer of the cassette to the X-ray position. Half a second is allowed after the film cassette carriage has stopped for residual vibration to cease before the X-ray exposure is made. Micro switches are used to indicate when the film cassette is in the correct position for exposure and when the film cassette carrier is in the loading position. All micro switches are mounted on outside face of the door plug and signals from these micro switches are used in the control system.

When the cassette is loaded into its carriage the assembly is moved towards the X-ray position at high speed by an Origa rodless pneumatic cylinder to which the carriage is attached. A rotary actuator then moves the cylinder, carriage and film cassette into the X-ray position. This rotation can only occur after the carriage has reached its end stop. After exposure the cassette is withdrawn by a reversal of the insertion process.

## 5. DETAILS OF THE X-RAY TUBE AND MOUNTING ARRANGEMENT

Since a short exposure time is necessary a medical X-ray tube with a high speed rotating anode is used. It is cooled by a compressed air supply which discharges into the maintenance area at the rear of the shielded plug. This tube together with a closed circuit TV camera and two quartz halogen lights is mounted in a removable aluminium box which is inserted into a hole in the shielded plug structure. The complete box system can be withdrawn from the rear and is provided with ball casters and centralising supports together with lifting points to ease removal. To ensure reproducibility of the X-ray image the design is such that the focal point of the X-ray tube is 1220mm above the fuel pin centre. The X-ray beam passes through a lead collimating plate so that it overlaps the film by a maximum of 20mm. The TV camera is located adjacent to the X-ray tube and allows the fuel pin to be viewed when the pin is clamped in the jaws. The quartz halogen lamps located on either side of the camera provide illumination and a glass panel seals the box.

## 6. DETAILS OF THE SHIELDED PLUG ASSEMBLY

The shielded plug is constructed to give the same degree of shielding as the cave walls which are of concrete construction, approximately 5 feet thick and encased in ½ inch steel plate. The shielded plug is designed in four sections which are fabricated separately and then joined together. The mating surfaces are arranged so that no shielding weaknesses exist at the junctions. Jointing has been designed so that no relative movement can take place between the parts after assembly.

Thin aluminium sheets are used beneath the X-ray tube and beneath the fuel pin which allow passage of X-rays but prevent the escape of contamination. The X-ray tube is fully shielded from the cave environment and receives radiation only when the pin is in position.

The shielded plug is carried on wheels which are not powered and it can be retracted completely from the wall if required. A lifting beam is provided at the rear of the door which carries a small hoist that can be used to remove the box containing the X-ray tube when replacement is necessary.

## 7. DETAILS OF THE CONTROL SYSTEM

The apparatus is controlled from the rear face via a master panel but can also be operated from the cave face using a slave panel. Normally the rear face panel controls the operating sequence as follows.

Firstly the X-ray facility is switched on together with the television camera, monitors and lamps. The control key is then removed and transferred to the cave face operating position. At this position the fuel pin is loaded onto its transport trolley and then moved into the X-ray position. Command is then returned to the rear face and the pin moved to its exact required position as judged using the TV monitor. The cassette is then loaded into the cassette transport mechanism and an automatic sequence initiated which causes the following actions to occur.

1. The X-ray head anode is switched on and the X-ray film transported to its exposure position.

2. When the film is stationary beneath the fuel pin a signal is transmitted to start the exposure.

3. On completion of the exposure the film is automatically returned to its start position.

4. The cassette is manually extracted for processing.

5. The fuel pin is unclamped and the transport trolley either moved to the next exposure position or taken back into the cave for replacement of the fuel pin.

With the system in the manual mode the film transport cassette can be moved in and out of position with the X-ray system switched off. This allows system testing and cassette recovery in case of a malfunction.

## 8. DISCUSSION

Experience with the use of X-ray films taken of fuel elements over a period of 20 years has shown that dimensional measurements accurate to ± 0.02mms can be obtained if care is taken with the design of the equipment. The crucial factors are the reproducibility of the magnification factor, the elimination of vibration when the cassette is in position for the film exposure and the minimisation of time in which the film is held beneath the fuel pin in order to limit gamma fogging. When these precautions are taken and the processing is carefully controlled the quality of the image is such that measurements can be taken on automatic measurement equipment. This considerably increases the range and number of measurements and reduces the amount of operator time required.

The apparatus currently described is now in its last stage of manufacture and initial commissioning trials will begin soon. Similar principals were used in the X-ray facilities for ceramic fuel pins installed in the cave lines at Winfrith and these have been operated successfully for almost 15 years. The detailed design and manufacture of the current apparatus has been subcontracted to Gravatom Projects

Limited of Fareham who are responsible for demonstrating its performance before acceptance. It is expected that the equipment will be installed in the BNL cave line by September 1991 and its use on AGR fuel pins will begin in January 1992.

## 9. REFERENCES


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## 10. ACKNOWLEDGMENT


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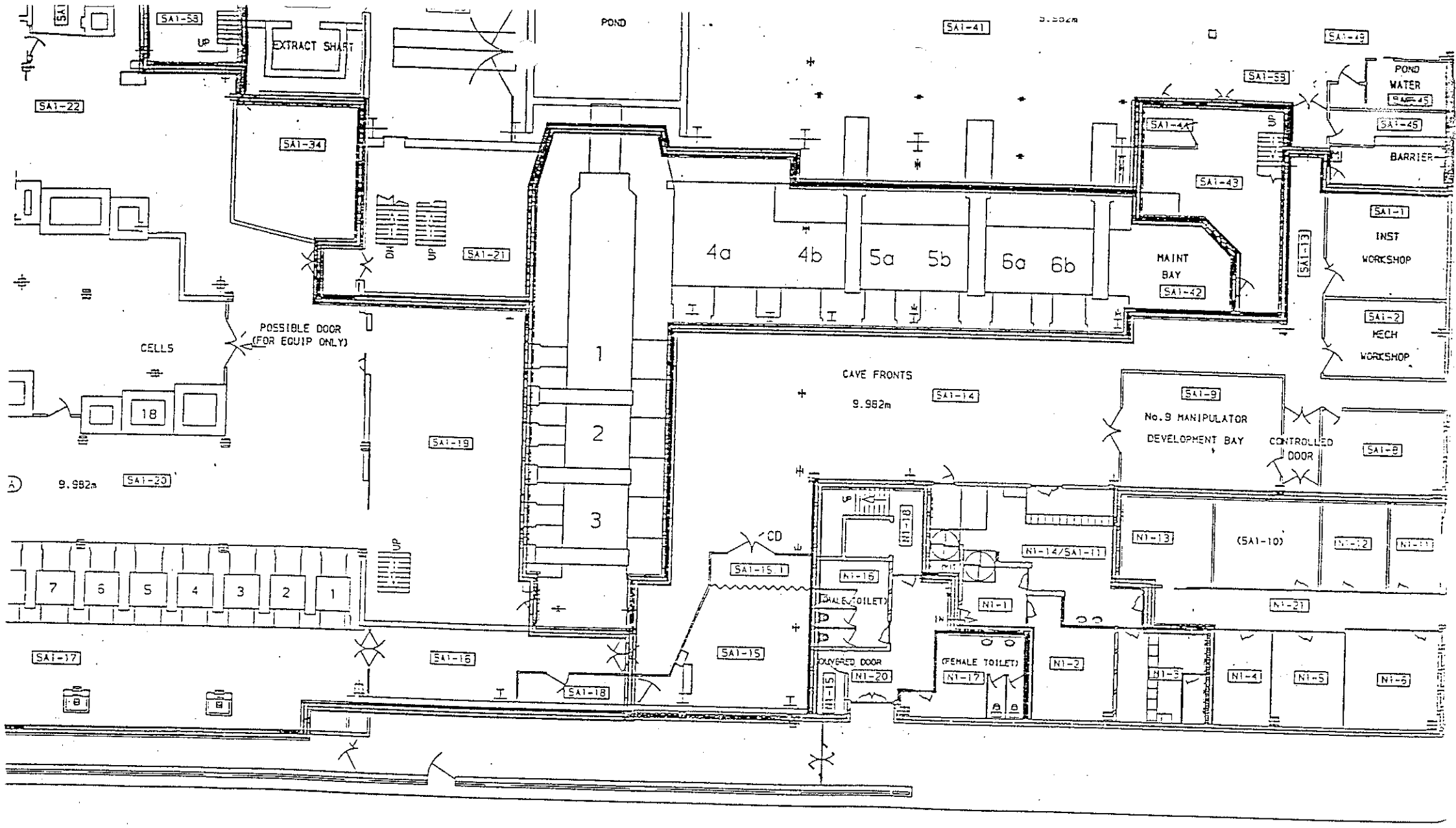


**PLAN OF THE BNL CAVE LINE**

**FIG. 1**

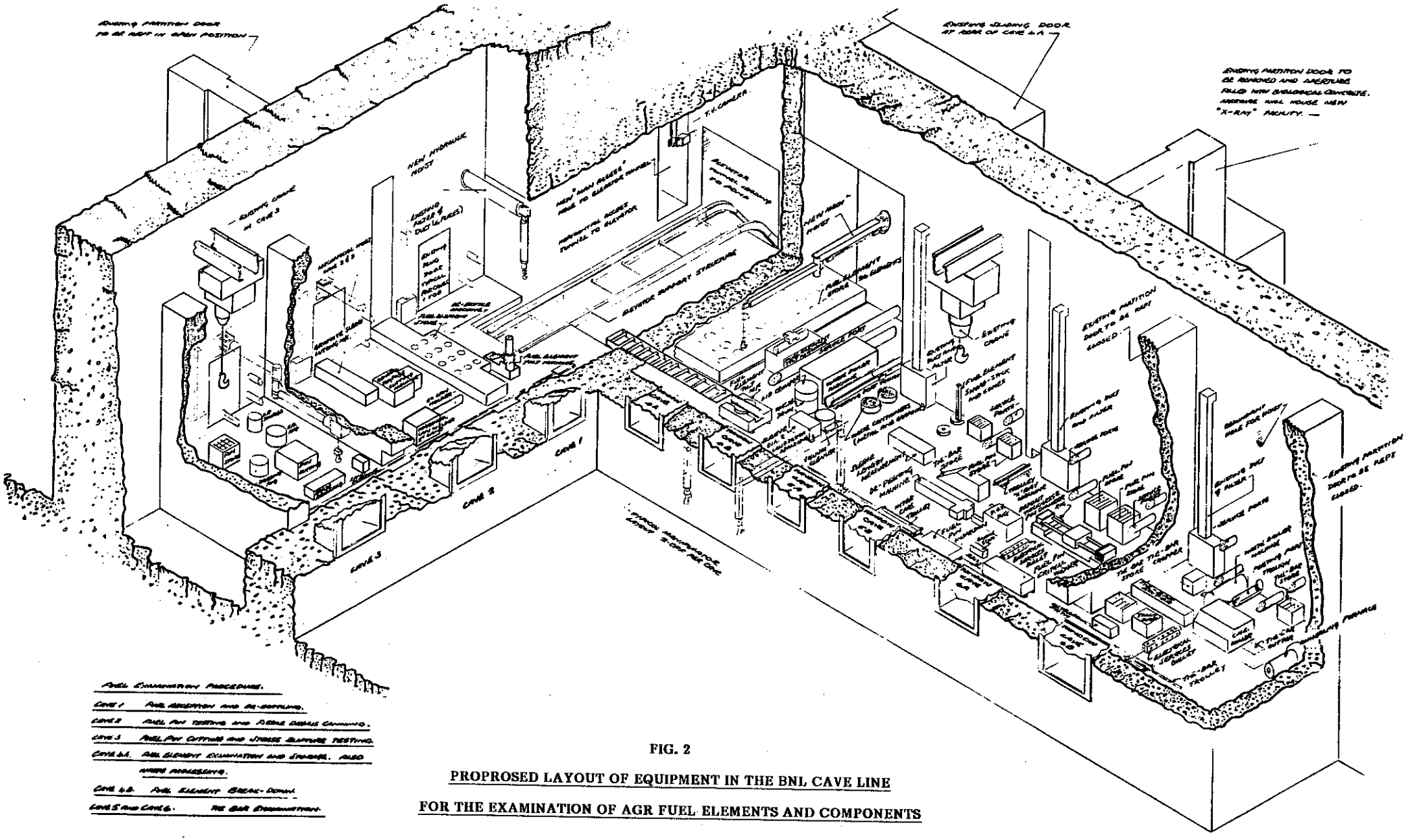


FIG. 2

**PROPROSED LAYOUT OF EQUIPMENT IN THE BNL CAVE LINE**

**FOR THE EXAMINATION OF AGR FUEL ELEMENTS AND COMPONENTS**

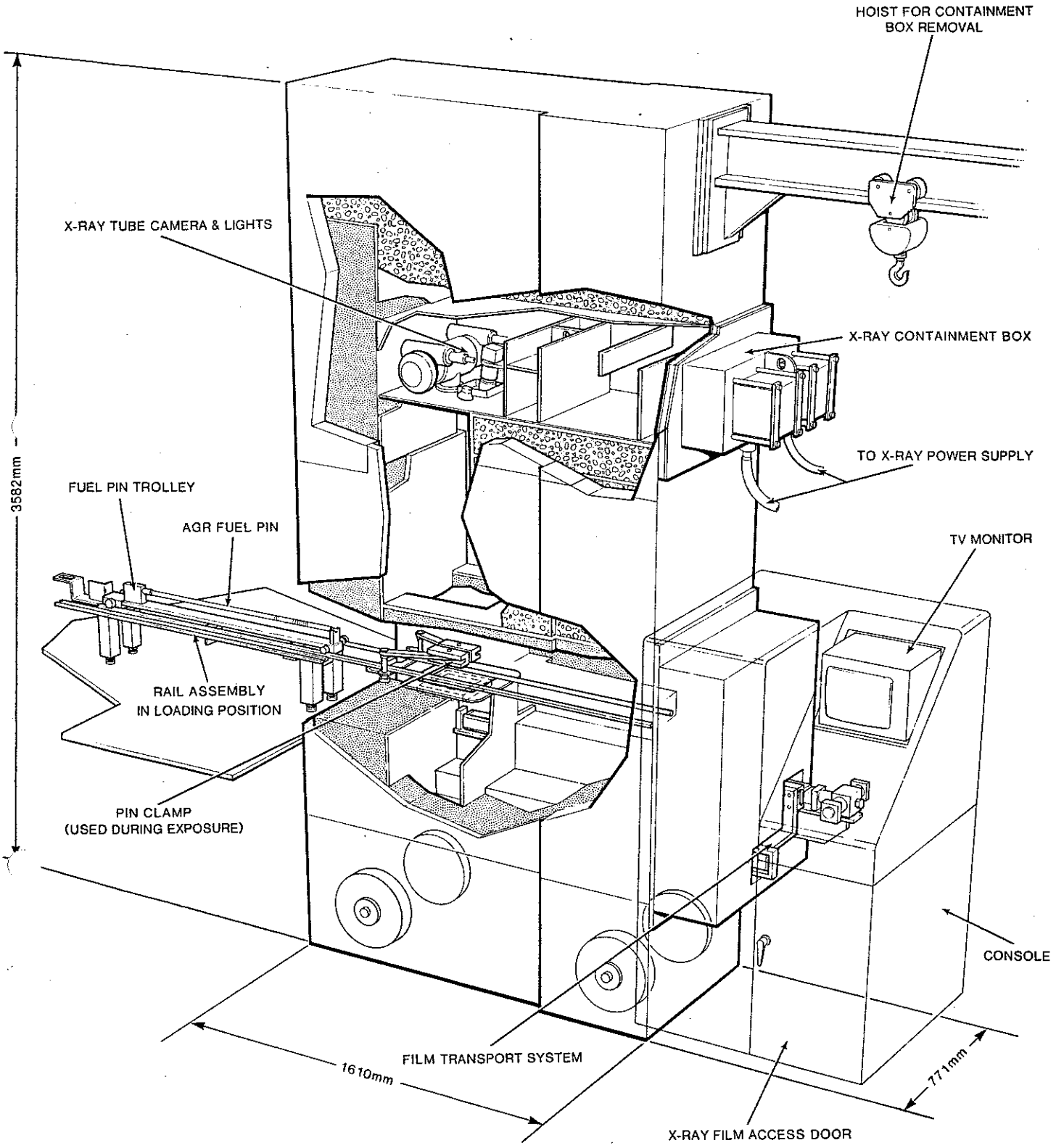


FIG. 3

# PART CUTAWAY VIEW OF FUEL PIN X RAY FACILITY

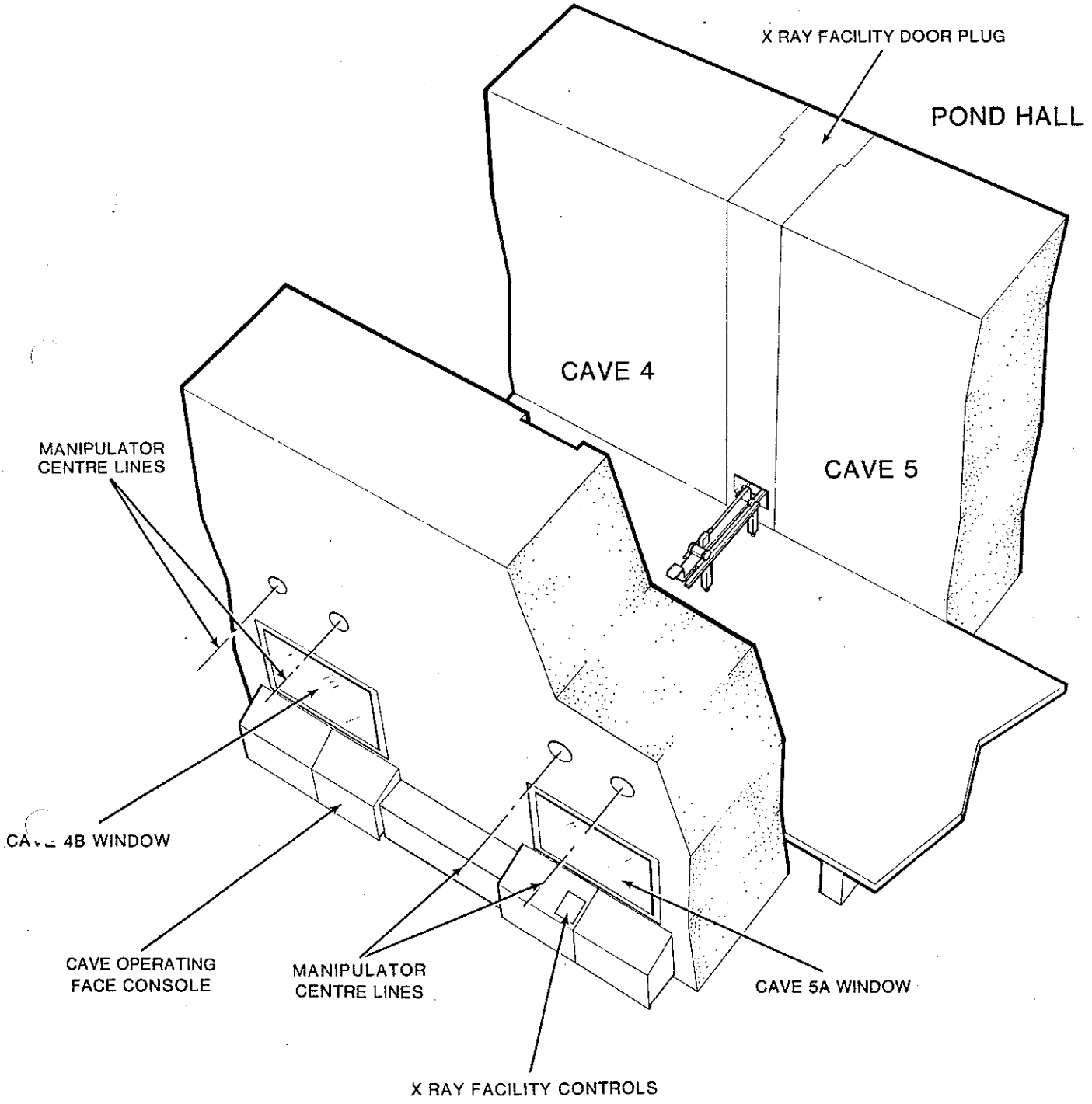


FIG. 4

# LOCATION OF X RAY FACILITY (CAVE ROOF REMOVED)