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Practical Remote Viewing Systems for the Nuclear Industry

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ABSTRACT

For conventional operations in radiation areas viewing has been through windows 1.5 metres thick installed in the shielding walls. This method of viewing is not always satisfactory and CCTV viewing has been employed.

Practical designs of a number of TV viewing systems for a range of nuclear applications are described together with up-to-date developments on stereo TV systems. A short section outlines current studies, being carried out at Harwell, on Visual Perception Factors related to the health, well-being and efficiency of operators who use industrial CCTV.

Introduction

Conventional viewing of highly active cells is through windows about 1.5m thick which have the same shielding properties as the concrete walls. This system has its disadvantages as the operator is forced to work at the window face and his area of vision is limited.

In order to assist the operator in his vision and, at the same time, limit his cumulative radiation dose advantages are to be gained in the use of Closed Circuit TV systems utilising such techniques as special optics, three dimensional viewing and computer aids. Consideration is also being given to the ergonomics of the control with special reference to the man machine interface problems and the analysis of Visual Perception Factors.

Developments are continuing to assist the operators with their present day problems and then to anticipate the viewing requirements which will be necessary to carry out some of the future work in the nuclear industry.

It is considered that for future installations the design and development of remote viewing systems should have the same priority as the design and development of the building and its plant. In other words there should be a systems approach with the viewing equipment playing an important role.

1 Recent Practical Applications

1.1 CCTV Inspection System

A CCTV system has been developed at Harwell as a maintenance and inspection tool for use in situations where a direct view through a window is inadequate and where radiation levels are too high to permit entry of a TV camera into the active area. The camera unit has been designed for wall-entry through a 300 mm diameter hole. The reason for this is that cell access is limited by the available penetrations through the shielding wall, often the only holes available are those vacated by the master slave manipulators. These are about 300 mm in diameter and 1.65 metres long and are normally positioned 5 metres above floor level.

A diagrammatic view of the TV camera unit is shown in Fig 1. The front section houses a conventional TV camera, remotely operated zoom lens, and scanning optics. The rear section contains a lead biological shield with provision for cable entry.

Scanning in the fore and aft direction is achieved by rocking a regular prism , the centre of which lies on the camera optical axis. The prism mount and driving mechanisms are attached to the window housing, which, by rotation through a remotely operated gear system, provides an annular view. The camera rotates within the housing to give an erect picture in all angles of view.

In the early stages of this development, a Power Manipulator broke down in an Active Cell at Harwell. Attempts to recover it mechanically failed and it was found that the travel was limited to 250 mm. It was thought that a 10 mm diameter steel pin, which was part of the clutch, might have slipped out of position but the area around the clutch was not directly visible from any of the windows. Man entry was not possible as the gamma radiation measured at floor level was of the order of 3000 Rad/hour.

Fig 2 is a photograph of the TV screen showing the pin in close up in a spare manipulator. The pin was 6 metres distant from the camera and a manipulator was used to replace the pin and carry out a successful repair.

Fig 3 shows a photographic enlargement and it can be noted that the diameter of the pin was equivalent to just 9 lines on the TV screen. This indicates the need for a camera and lens system with high resolution.

2 TV Camera Assemblies for Use in High Radiation Cells

2.1 Wall Entry Unit

In the Magnox fuel reprocessing plant which is now under construction at Windscale it is planned to instal about 100 TV viewing stations. Most of these will monitor production type operations and will be continuously in position.

For this type of operation, as opposed to the intermittent inspection, the previous concept has been extended.

Fig 4 shows a wall-entry unit where the camera and lens are shielded from direct gamma radiation by a lead block. A hole in the lead block, offset from the axis of the camera, houses a lens system which combines with an off-setting periscope to provide an optical path to the camera. A conventional type of prism close to the window is angled remotely in order to obtain a scan of the area within the cell.

In practice the outer tube, with its sealed window, remains in position during maintenance. The inner tube housing the complete television and optical assembly with shielding is withdrawn as a unit. With an anticipated dose rate of 5×10^3 Rad/hour at the inside face the camera and lens have a life expectancy of 5 years.

In a current version of this development the end window is being replaced by a hemispherical glass dome to permit a greater field of view.

2.2 Roof Mounted Unit

The radiation levels at the roof are usually lower than those at the walls so a simplified design of viewing system is possible.

Fig 5 shows the roof module in which lead glass blocks are used to protect the camera and lens assembly. In order to obtain a scanning system from the fixed camera a system using two rotating prisms has been devised. The principle is shown diagrammatically in Fig 6. By the correct rotation or contra-rotation of the two prisms it is possible to scan a cone of vision in straight lines, the total angle of view being determined by the combined angle of the two prisms. Fig 7 shows a cut away section of a manufactured assembly.

3 Radiation Tolerant Camera

There are occasions when it is necessary to introduce the camera into the radiation environment. This may be so when no access is available through the walls or roof of a cave or when close inspection is required. The camera may be deployed by a manipulator or mounted on a movable structure such as the gantry of a power manipulator.

A split head, radiation tolerant system coomprising a monitor, controller, camera head, lens and connecting cables is as shown in Fig 8.

The split-head camera has been achieved by simply dismantling a low cost CCTV camera with a 17 mm vidicon and removing the tube and coil assembly. The head end consists of these two components, along with a radiation tolerant video head amplifier and high voltage board in a small, sealed, lightweight metal tube. The head end of the system will be tolerant to a lifetime exposure of greater than 2×10^8 Roentgens of gamma radiation.

The control unit contains the rest of the camera, plus any motorised pan/tilt or zoom lens function required. This unit, together with the television monitor will be external to the cave.

The camera head and lens will be suited to either motorised or MSM handling in confined spaces. The only limit on handling being set by the stiffness of the multicore connecting cable, which will have a diameter of about 10 mm and a bending radius down to 80 mm.

Picture resolution will be about 550 lines at the centre from a fully interlaced 625 line signal.

4 Switched Viewing

One problem experienced with a narrow angle or telescopic lens is that while a detailed view of the object under observation is possible it is difficult to maintain orientation of the object, expecially if it is one of a number of identical objects.The system shown in Fig 9 has been designed to overcome this problem. Rotation through 90^{o} of the moving mirror on the camera axis permits a change of view from the narrow angle to the wide angle or vice versa. The system has an advantage over using a zoom lens in that the picture on the screen gradually changes from one view to the other by a sideways movement as opposed to that of a tunnel view opening or closing which can affect the brain. The transfer from one lens to the other may be switched quite rapidly to prevent loss of orientation.

5 Stereo Television

Over the past few years there has been a growing recognition of the need to employ closed circuit televison techniques in the Nuclear Power Industry and CCTV systems are being developed either to aid direct viewing through windows or as the sole means of viewing in areas which are inaccessible to direct view.

A list of typical CCTV applications is shown in table 1.

CCTV Applications in the Nuclear Power Industry

	APPLICATION	TYPE
1	Power manipulator inspection	Inspection
2	Unloading of fuel elements from skips	Operator aid
3	Inspection of interior of fusion torus for damage	Inspection
4	Supervision of manipulator tasks	Operator aid
5	Monitoring guidance of a CAGR pin removal indexing machine	Operator aid
6	Tool guidance in a glove-box dismantling facility	Operator aid
7	Waste disposal - concrete filling of drums	Operator aid

TABLE 1

A number of these applications require some measure of depth perception, particularly when guidance and manipulation are involved. In certain cases it is possible to obtain this perception of depth by mounting two TV cameras mutually at right angles to the task, for example one camera in line with the observer's vision, and one camera either viewing from the side or above.

This method is quite accurate in pick and place tasks, but is slower in operation than a true 3-D system. There are a number of Stereo CCTV systems which have been developed over the years, eg;

1 2 cameras, 2 monitors + viewing hood

2 1 camera + image splitter, 1 monitor + viewing hood

3 Anaglyph (coloured spectacles) method

4 PLZT method

5 Lenticular screen display (vertical)

6 Lenticular screen display (rotating)

7 Binocular transformer method

8 Polarised light projection TV

All of these systems produce 3-dimensional images, but there are a number of requirements related to the industrial environment which make some of them unsuitable for industrial use.

We consider that the desirable features of an industrial stereo TV system are:

1 No loss of resolution.

2 The viewer must be able to move about whilst viewing.

3 More than one person should be able to view at the same time.

4 The display should not adversely affect the well-being or health of the operator.

5 The display should be satisfactory in a certain amount of ambient light.

Of the stereo TV systems listed, the one which fulfils the requirements set out is polarised light projection TV. The principle is illustrated in fig 10.

A stereo TV system based on this principle is in an advanced stage of development at Harwell.

Studies in Visual Perception Related to Industrial CCTV

In the nuclear industry, the general direction of research and development into remote handling of radioactive materials has been guided by legislative and economic pressures which require continuing reduction in operator dose levels and improvements in remote handling techniques. At Harwell, Engineering Projects Division has been working for a number of years on a programme of investigation into remote handling technology, based on the concept that all manipulative tasks which are carried out in a radioactive environment will be remotely controlled and supervised by remote viewing techniques.

In 1980, a laboratory was set up at Harwell to study such problems as eyestrain, fatigue and stress, by means of a sseries of experiments designed to measure objectively, the effect on the health, well-being and efficiency of nuclear plant operators. (Fig 11).

The investigations are being carried out by Engineering Projects Division in collaboration with the Department of Visual Sciences Institute of Opthalmology, University of London and Environmental and Medical Sciences Division, Harwell.

The aims of the project are:

a) to determine the factors (human or technical) which affect the health and well-being of operators under a variety of remote viewing conditions, and

b) to measure the effect on efficiency of task performance of a variety of viewing systems, including stereo TV.

The experimental method used in these investigations is as follows:

Each volunteer subject, who need have no special manipulative skills, is seated at the viewing station. The task is to guide the pen of an X-Y plotter, by remote control, over a number of target circles which are drawn on a sheet of paper. The task is viewed by TV cameras only. Each target is marked by remote control of the pen switch in a sequence which is called out by the experiment supervisor. Time is recorded automatically each time the pen marks a target.

The task has been designed to require minimum dexterity, so that the results, in terms of accuracy and speed, are dependent solely on the viewing factors, human and technical.

During each task, psycophysical data, relating to performance, is recorded, plus objective, physiological data relating to fatigue and loss of concentration, using measurement techniques recently developed at the Institute of Opthalmology. The data obtained is processed and analysis made in relation to the results of ophthalmic tests on each subject; these tests are being carried out by medical staff of the Environmental and Medical Sciences Division, Harwell.

Examples of investigations in hand are:

a) Optimum TV monitor position for an operator using a master-slave manipulator.

b) The effect on task throughput of increased TV system resolution.

c) A comparison of colour and monochrome TV in relation to operator well-being and efficiency.

d) A comparison of TV viewing systems, such as the orthogonal (2 cameras right angles) and true stereo TV.

e) Investigations into the need for spectacle-wearers to have spectacles prescribed for the viewing distance to the TV display.

Conclusions

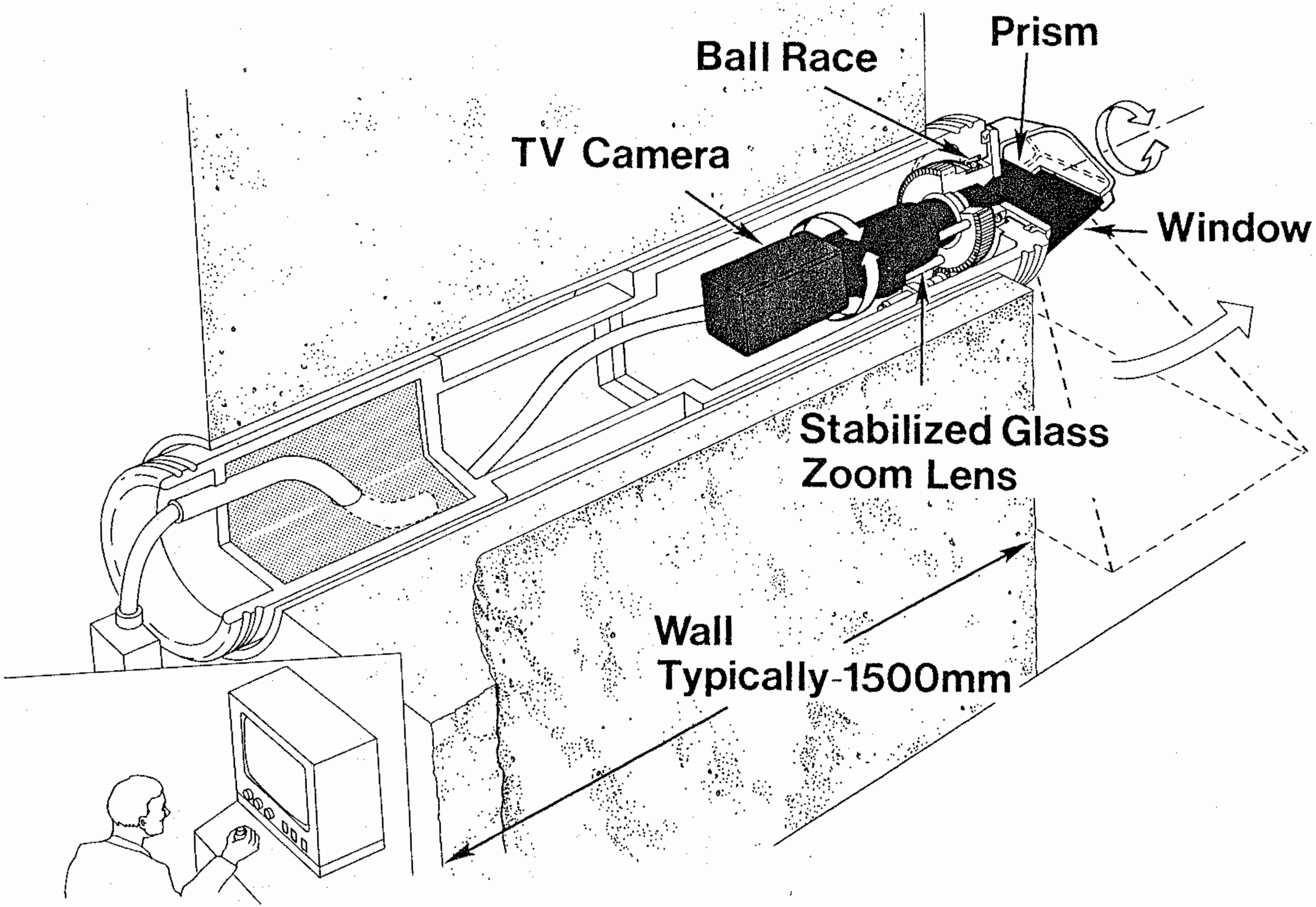
Over the past few years there has been a growing recognition in the UK of the need to employ closed circuit industrial TV techniques in the Nuclear Power industry, to aid direct viewing through windows or as the sole means of viewing in areas which are inaccessible to direct view.

A number of remote viewing systems are in the engineering production stage. These have been developed to meet specific applications for plants which are in being or which are under construction.

For future plants this work at Harwell is backed by a programme development of more advanced systems which include 3-D TV, radiation-tolerant TV, computer aids to vision, and investigations in visual perception related to industrial TV.

There is a need to improve image quality, especially where TV is used as an operator aid in manipulator tasks, but as the technology advances remote viewing methods may supplant direct viewing to the extent that future plants may be operated from positions remote from the radiation hazard.

Fig 1



T.V. Inspection Module

Fig 2 POWER MANIPULATOR CLUTCH ASSEMBLY

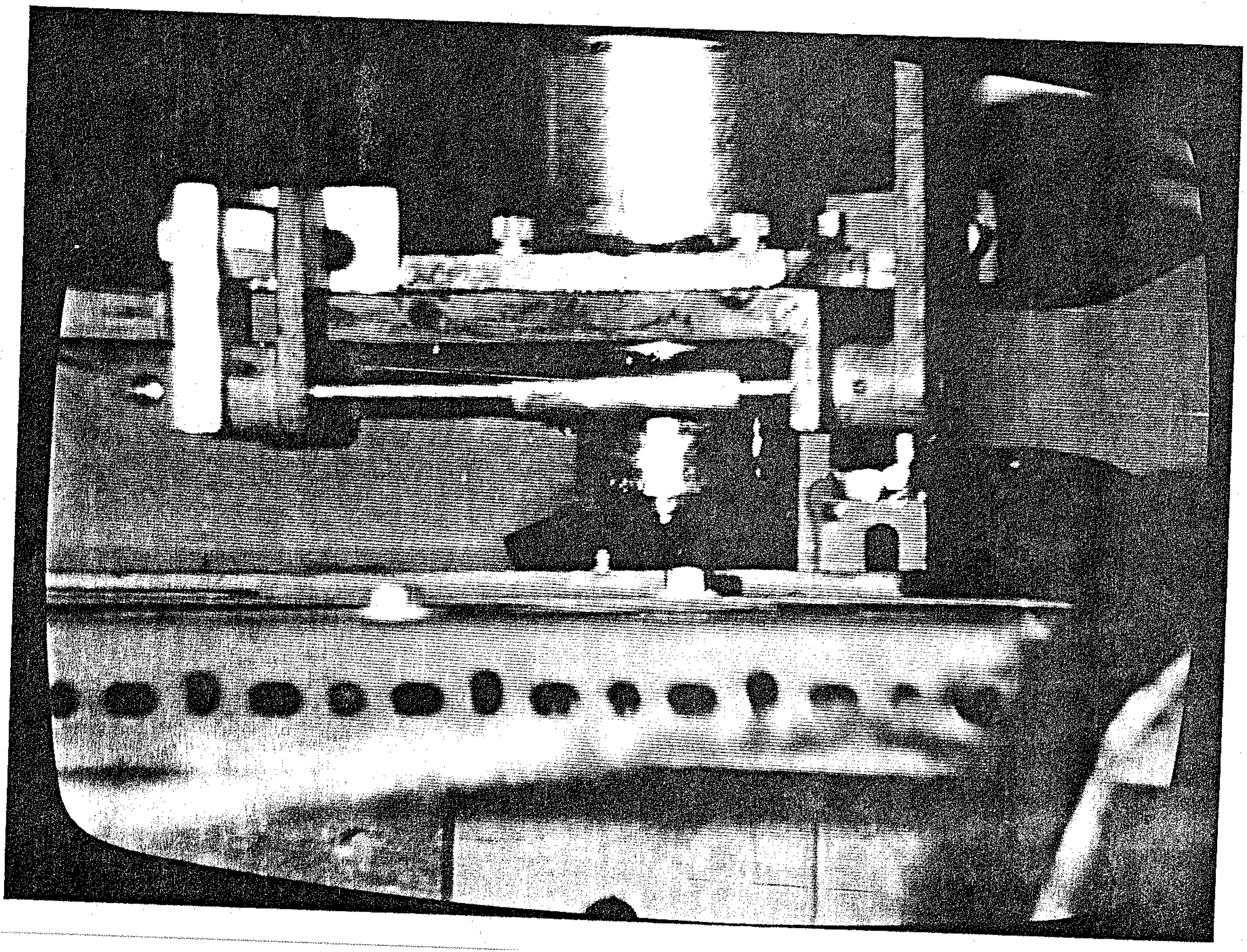


Fig 3 MAGNIFIED VIEW of CLUTCH PIN

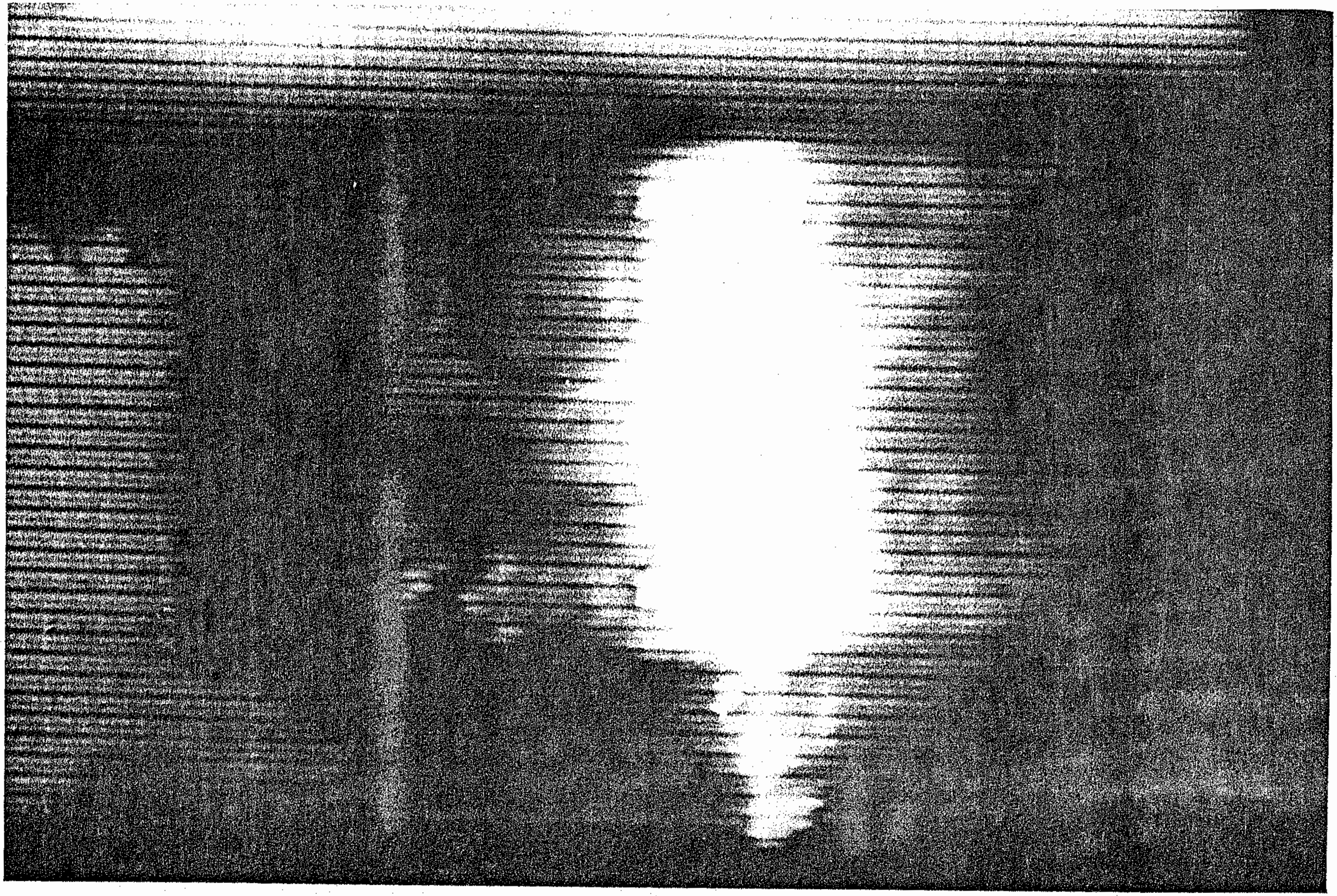


Fig 4

T. V. Camera Wall Assembly

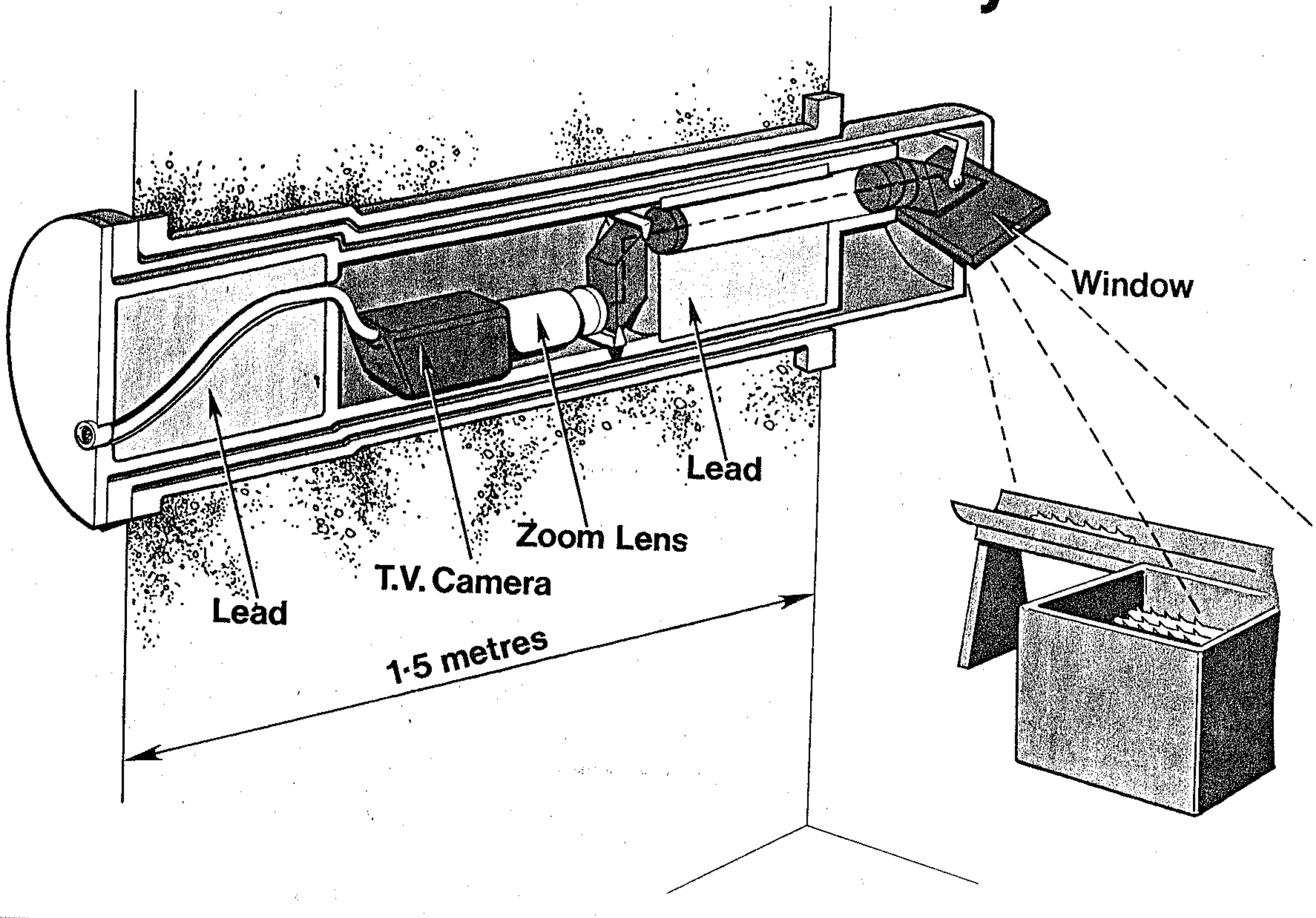
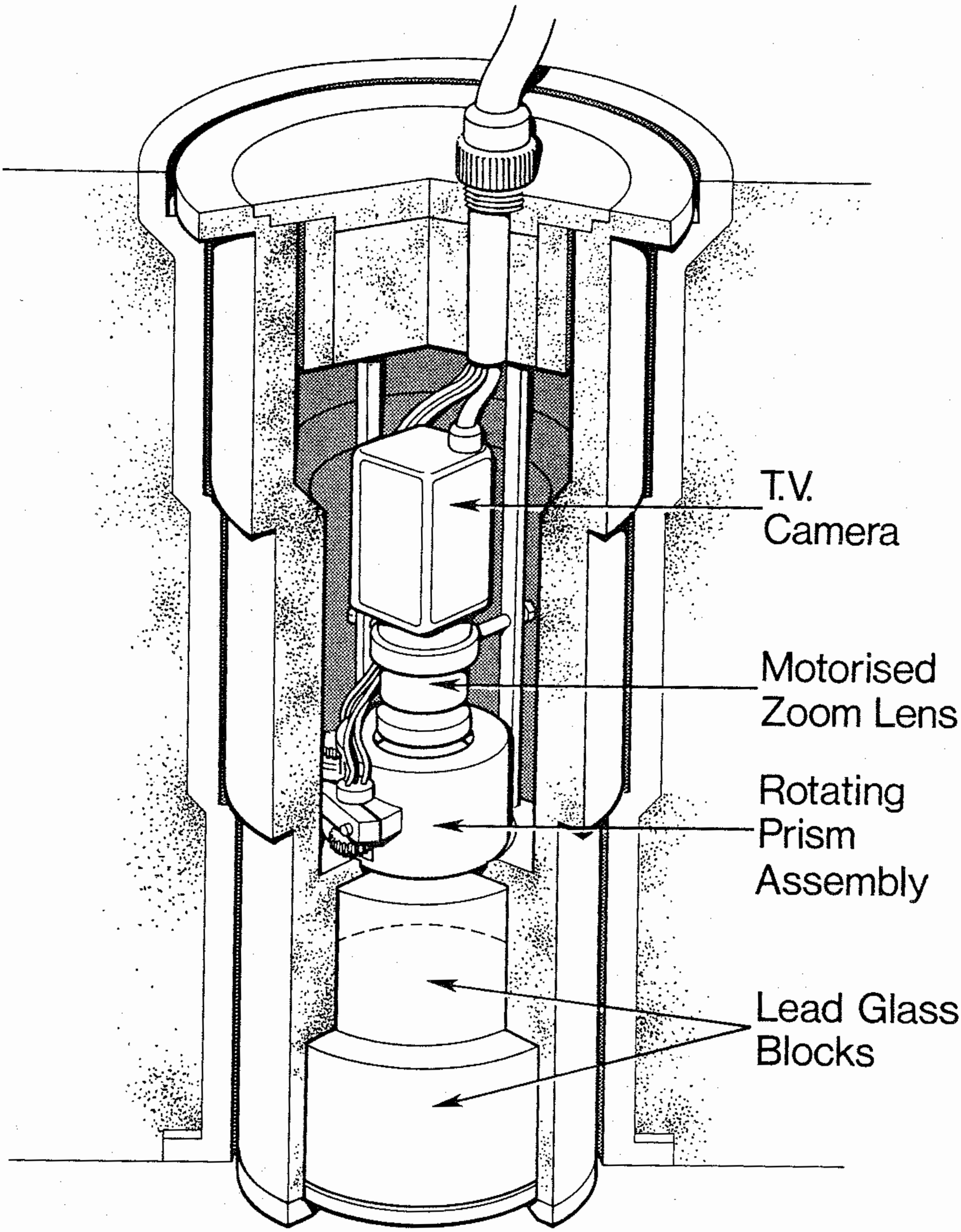
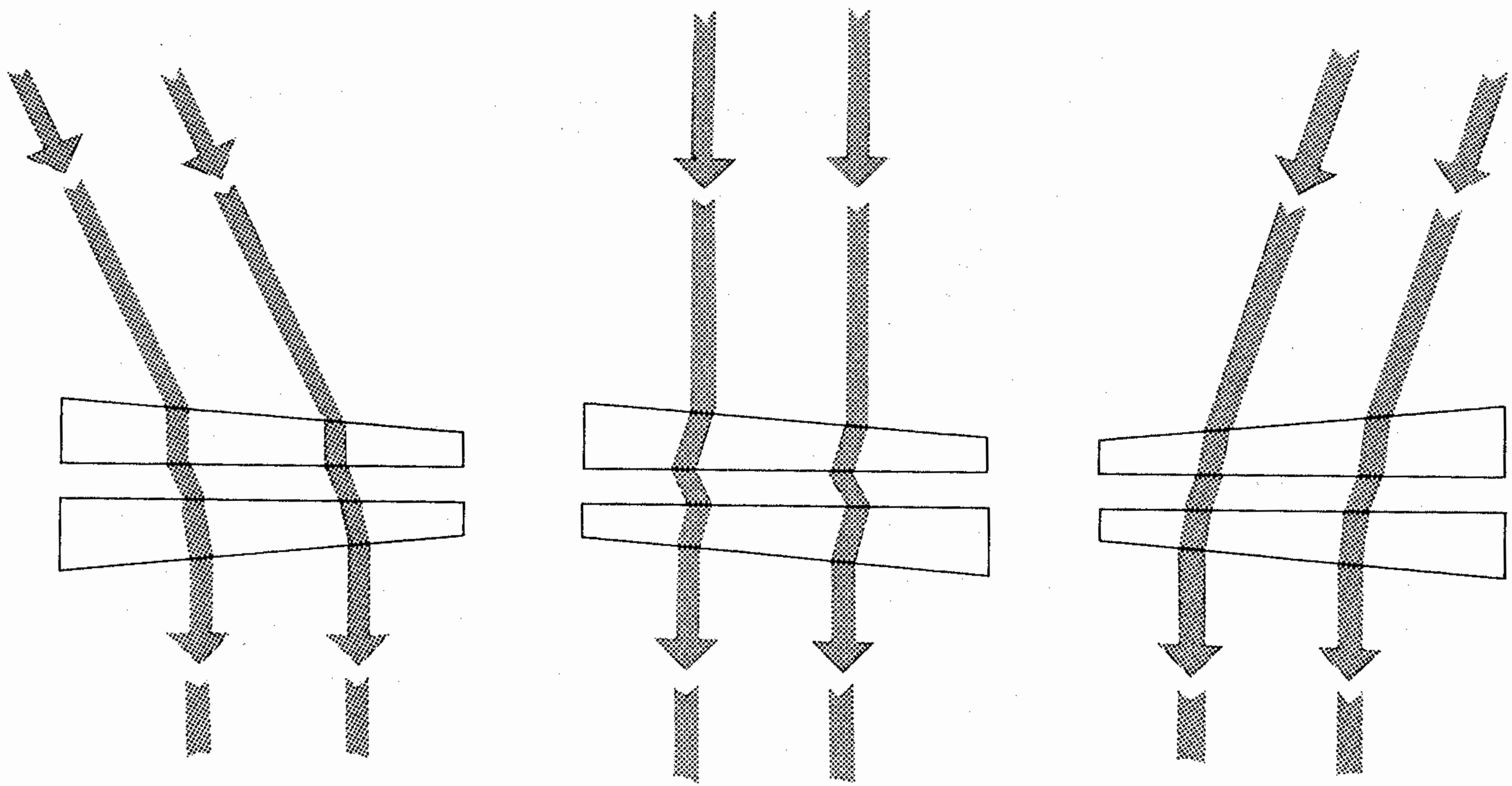


Fig 5



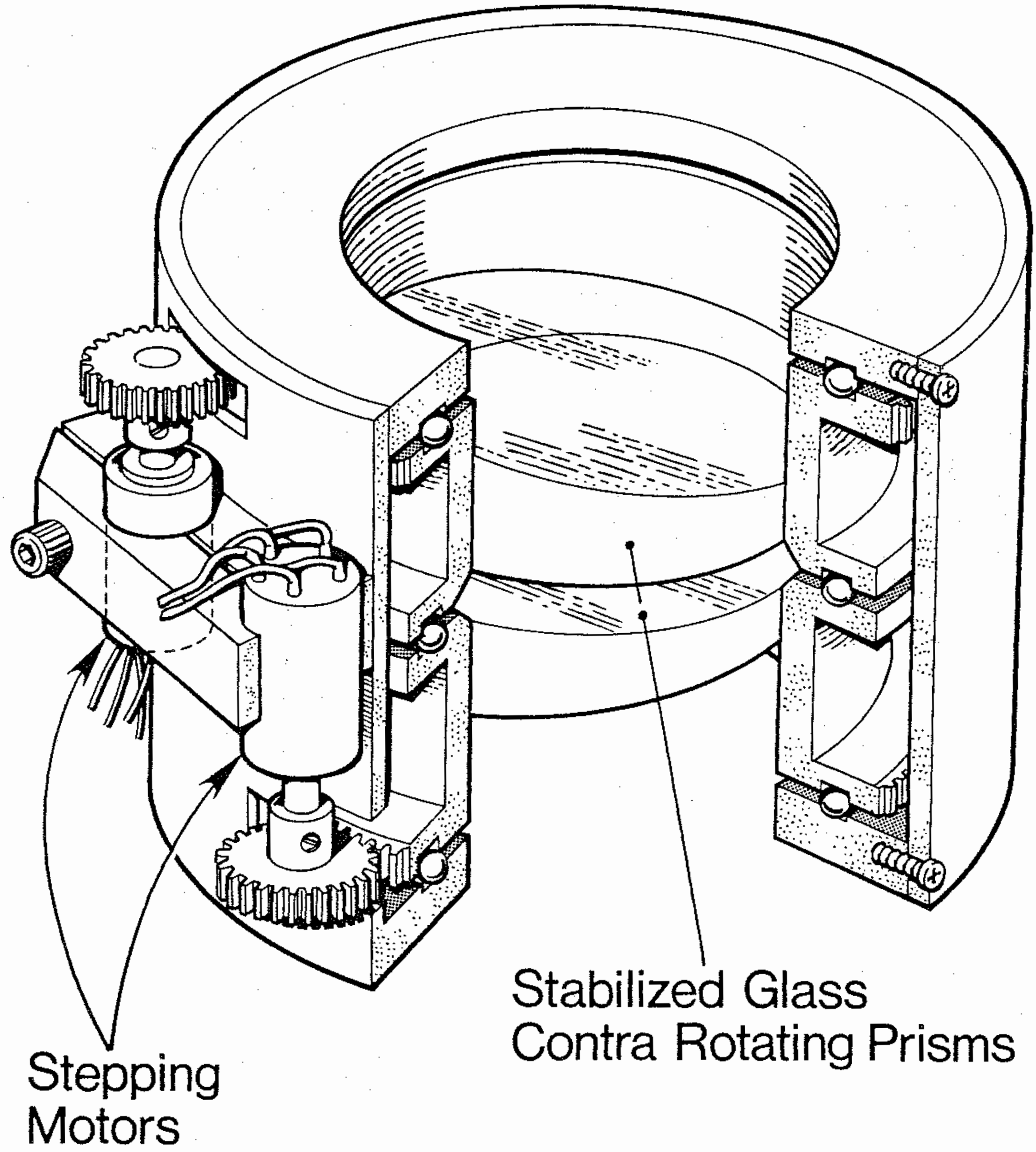
T.V. Camera, Roof Module

Fig 6 **CONTRA-ROTATING PRISM PRINCIPLE**



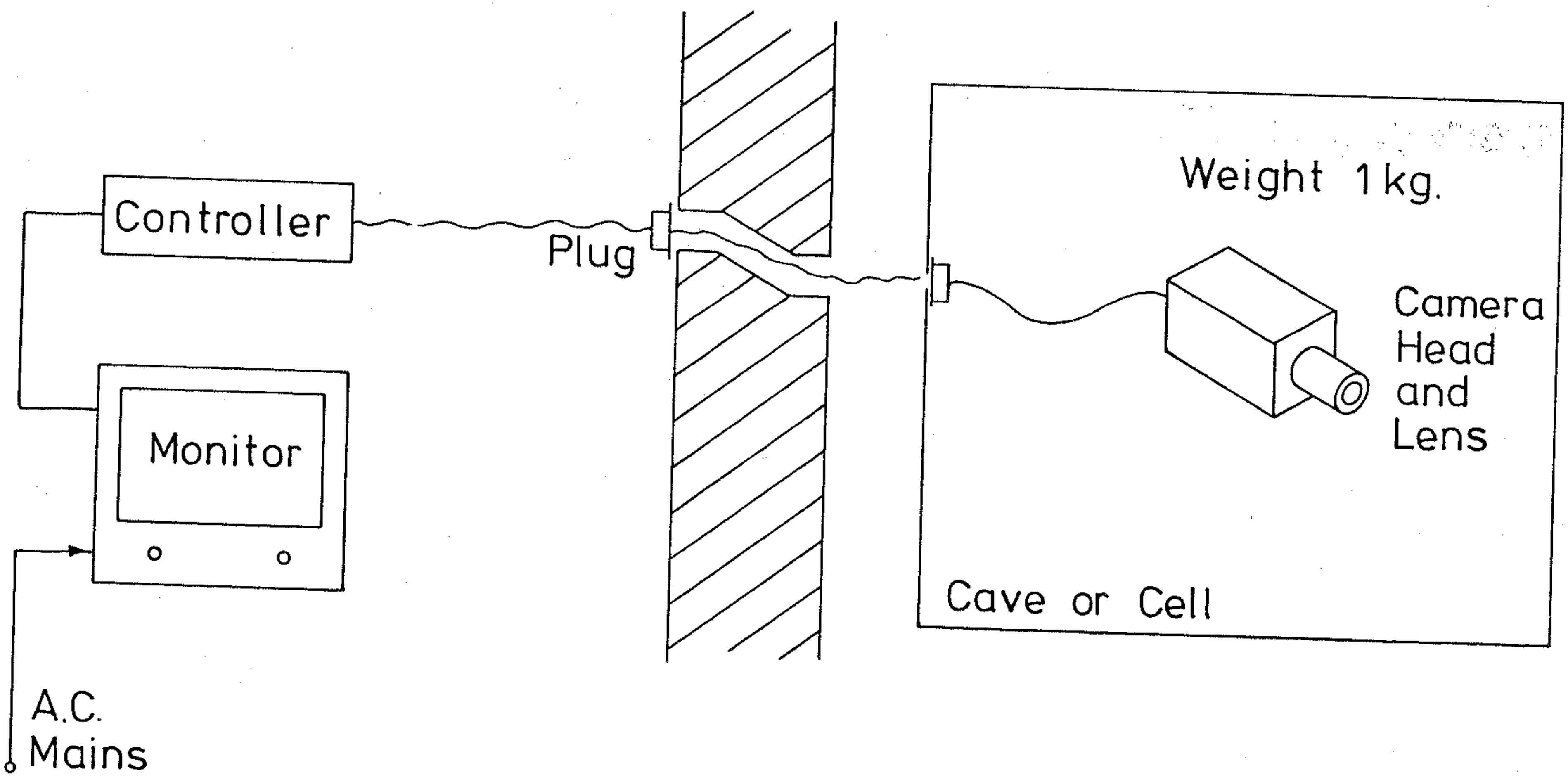
(A) (B) (C)

Fig 7



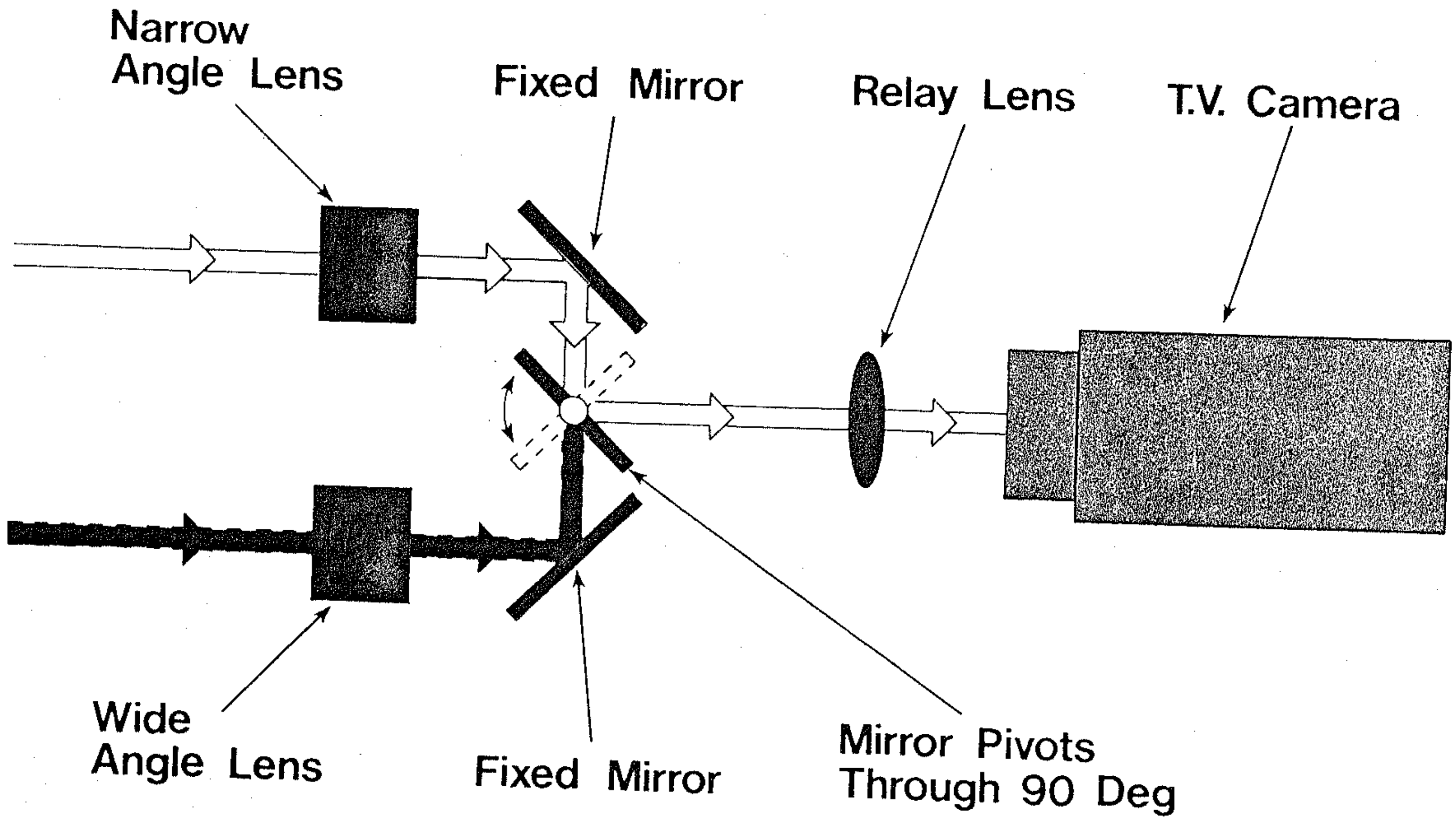
Contra-Rotating Prism Assembly

Fig 8



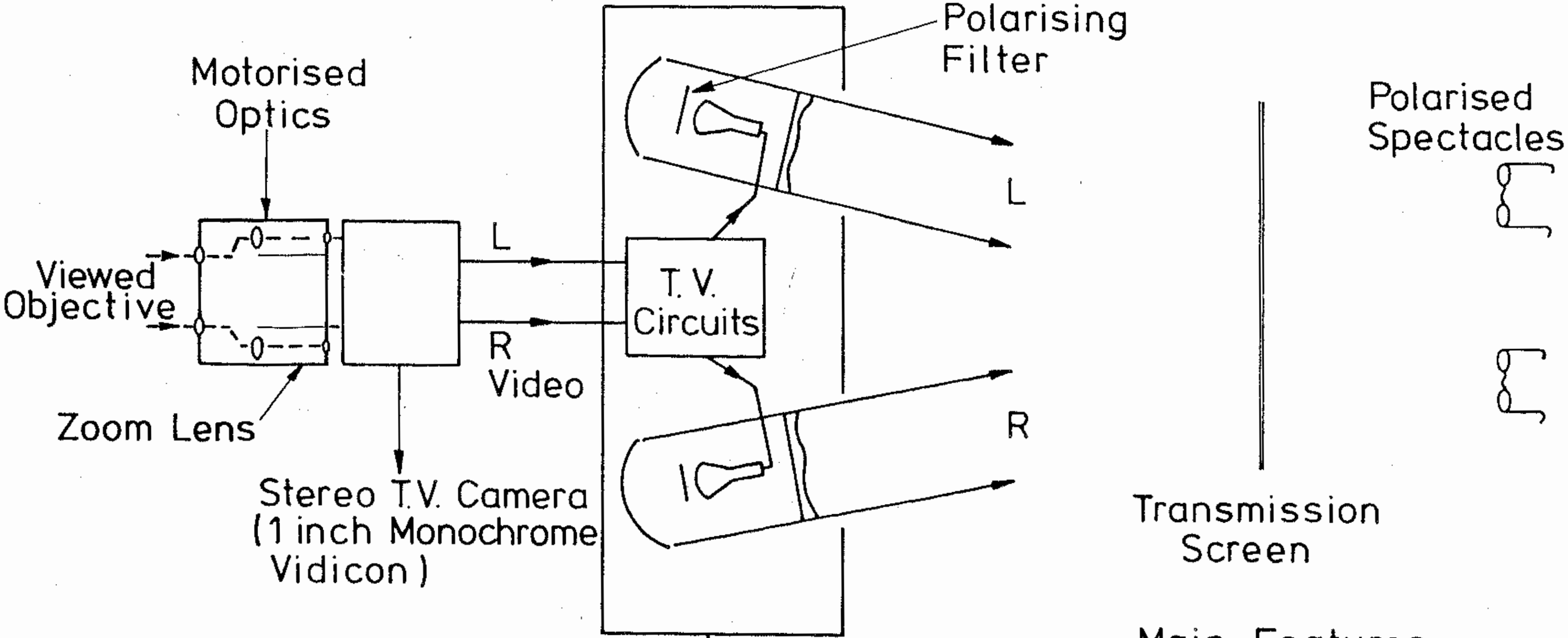
RADIATION TOLERANT T.V. SYSTEM

Fig 9



Switched Lens Optics

Fig 10



STEREO TV SYSTEM

Main Features

1. No Loss of Resolution
2. Can be Viewed by several People Simultaneously
3. No Inconvenience to Operator
4. No Harmful Visual After-Effect

Fig 11 VISUAL PERCEPTION LABORATORY