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Viewing Systems for Large Underground Storage Tanks (U)

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ABSTRACT

Specialized remote video systems have been successfully developed and deployed in a number of large radiological Underground Storage Tanks (USTs) that tolerate the hostile tank interior, while providing high resolution video to a remotely located operator. The deployment is through 100mm (4in) tank openings, while incorporating full video functions of the camera, lights, and zoom lens. The usage of remote video minimizes the potential for personnel exposure to radiological and hazardous conditions, and maximizes the quality of the visual data used to assess the interior conditions of both tank and contents. The robustness of this type of remote system has a direct effect on the potential for radiological exposure that personnel may encounter.

The USTs typical of the Savannah River and Hanford Department Of Energy (DOE) sites are typically 4.5 million liter (1.2 million gal) units under earth or concrete overburden with limited openings to the surface. The interior is both highly contaminated and radioactive with a wide variety of nuclear processing waste material. Some of the tanks are flammable rated to Class 1, Division 1, and personnel presence at or near the openings should be minimized. The interior of these USTs must be assessed periodically as part of the ongoing management of the tanks and as a step towards tank remediation.

The systems are unique in their deployment technology, which virtually eliminates the potential for entrapment in a tank, and their ability to withstand flammable environments. A multiplicity of components used within a common packaging allow for cost effective and appropriate levels of technology, with radiation hardened components on some units and lesser requirements on other units. All units are completely self contained for video, zoom lens, lighting, deployment, as well as being self purging, and modular in construction.

The remote video systems developed are uniquely packaged, per site and tank specific requirements. Several of the systems are being deployed as precursors to the deployment of the Light Duty Utility Arm (LDUA) at the Hanford site, as a

means of monitoring the position and operations of the LDUA. They have been deployed into hydrogen contaminated USTs following an exhaustive evaluation of their flammable atmosphere suitability.

The units are deployed on a flexible extension of their pressurized housing, with the camera housing, deployment support, and support reel being a single pressurized and interlocked housing. Camera aiming is accomplished in a manner that never extends the components beyond the envelope of the tank entry port, eliminating the potential for entrapment by component failure. The control of the camera housing is from a remote location, up to 275 meters (900 ft) away, over a single coaxial cable or fiber optic link, thus minimizing the difficulties of coupling to a radiological environment.

Stereo versions of the remote camera systems have also been developed and provide a remote operator sense of in-tank presence. Both single unit devices, suitable for permanent tank interior viewing, and multiple part devices, suitable for hand carry deployment, have been built and are in use at the Savannah River and Hanford sites.

I. INTRODUCTION

The Robotics Development Groups at the Savannah River Site (SRS) and at the Hanford site have developed remote video and photography systems for deployment in underground radioactive waste storage tanks at the Department of Energy (DOE) sites as a part of the Office of Science and Technology (OST) program within DOE. Viewing and documenting the tank interiors and their associated annular spaces is an extremely valuable tool in characterizing their condition and contents and in controlling their remediation. Several specialized video/photography systems and robotic End Effectors have been fabricated that provide remote viewing and lighting. All are remotely deployable into and out of the tank, with all viewing functions remotely operated. Positioning all control components away from the facility prevents the potential for personnel exposure to radiation and contamination. Only the remote video systems will be discussed in this paper.

Field versions of the Portable Overview Video System, Overview Stereo Video System, and Portable Overview Video Systems were completed and delivered to the Hanford Cold Test Facility (CTF) for qualification testing and deployment. Some of these systems have already been used in radioactive waste tanks at Hanford. Details are covered in the following sections. These systems represent the matured designs of remote tank entry stand-alone video systems.

Remote video systems for deployment in Underground Storage Tanks (USTs) will significantly increase the information available concerning the tank conditions and contents during all phases of remediation. The low cost and light-weight remote systems capable of small port entry into hazardous, or flammable, environments provide another valuable tool in the assessment and remediation of limited knowledge areas. The systems will enhance the operation of other equipment in the tank, such as the Light Duty Utility Arm (LDUA), and will provide a "first-in, last-out" view of all remote operations, further increasing the confidence in remediations. The potential for personnel exposure to hazardous materials and radiation will be reduced with the application of such equipment.

II. BACKGROUND

A cooperative program has been underway with multiple DOE sites to develop remediation systems and techniques for UST high-level waste containments typical of many sites. The SRS and the Hanford site contain the largest number of USTs and are the major players in developing specialized video systems for deployment within these tanks.

In response to a need for new and improved technology, the DOE Office of Science and Technology (OST) was created. To complete this task, several major new technology demonstration efforts were initiated. One such effort is the UST program. This program focuses on the characterization and remediation of underground radioactive waste storage tanks and is funding the development of the LDUA system. The LDUA system consists of a seven degree of freedom robotic arm, which will function as a deployment platform for various surveillance and inspection End Effectors, and a mobile deployment vehicle to maneuver the system to waste tanks. End Effectors that will assist in these tasks will be developed by DOE laboratories, industry, and academia.

The SRS and the Hanford site are developing the remote viewing systems to be used in conjunction with the LDUA. Remote viewing will be used to assist in positioning and controlling the LDUA in USTs and as the end product of a portion of its work. Remote close-up, high resolution, and stereo views of tank components and contents will be gathered by the LDUA using the remote viewing End Effectors.

In the past, tank surveillance and inspection was performed by lowering film cameras, primitive video cameras, and other instruments through existing risers to positions directly below the riser and obtaining data from a single location, possibly at multiple elevations. The capability for positioning cameras, sensors, or other equipment at multiple orientations away from the riser axis did not previously exist, and remote visual inspection operations have been hindered by these limitations. The photographic methods, which have predominated, are particularly limiting since they are not useful in real time.

The field of remote video/viewing is now being used extensively in other areas to extend the data gathering and control of personnel into environments not suitable for entry. The provision for viewing remote locations from a safe distance has allowed inspection, documentation, and verification of pipes, tanks, vessels, ducts, rooms, and pits.

This report addresses the development of the remote overview video technology for the LDUA, in the form of "stand off" devices, which view the LDUA from an offset perspective. All will be used in conjunction with the "hot" deployment of the LDUA at Hanford, and may also be used in other applications. Some systems are already in use in radioactive tanks at Hanford.

III. TASK DETAILS

The USTs are nominal 4.5 million liter (1.2 million gallon) tanks used to store liquid high-level radioactive waste that is generated by the sites and awaiting final disposal. Approximately 200 USTs exist at SRS and Hanford, and smaller numbers exist at other DOE sites.

The waste tanks are of two general configurations: single shell and double shell. A wide variety of internal tank configurations are in use depending on tank service. These internal configurations vary from nearly free of obstructions to containing hundreds of distributed vertical cooling coils.

Both general types are of flattened shape (wider than high), with all types having a sealed carbon steel primary tank. The double shell tanks have a dry secondary containment pan. The annular space between the tank wall and the secondary containment wall is continuously monitored for liquid intrusion and periodically inspected and documented.

The single shell tanks have only a concrete support structure around the primary tank wall with no annular space. Wells have been drilled in the surrounding areas to monitor for any tank leakage.

The interior conditions of the tanks and dry annular spaces have been historically monitored with remote still photography. A wide variety of 35 mm or 120 mm film cameras have been manually deployed to record and document tank structures and conditions.

IV. LIGHT DUTY UTILITY ARM PROGRAM

The Light Duty Utility Arm (LDUA) Integrated System is a truck-mobile robotic in situ surveillance and inspection system designed to remotely inspect, map, and characterize waste and waste tank conditions. The LDUA Integrated System is being initially developed for use in the single shell tanks, of which Hanford has 149.

A major objective of the UST program is to demonstrate waste retrieval technologies in preparation for UST remediation and waste disposal. Waste retrieval is directly dependent on knowledge of chemical and physical properties of waste, and on operating experience in the tank environment. Because the in-tank environment precludes human entry, a remote system is required to deploy characterization and retrieval devices. The requirement for a light duty device to meet the characterization needs and operating experience will be addressed with the LDUA. The system will include the robotic arm and all required subsystems working as an autonomous field unit.

The deployed LDUA system will include the truck-based robotic arm, the tank top support frame, the remotely located control trailer, and all other support devices. The overview video units will be deployed as separate units that interface to the robotic arm. All controls and services will be consolidated to tank top interfaces prior to transmission on the more than 275 meter (900 foot) tether to and from the control trailer. The long distance is required to allow most personnel to work only in "clean" areas.

The LDUA system will minimize any potential for personnel exposure to radiological hazards. A special emphasis is being placed on minimizing any set-up time or maintenance time requiring personnel to be present on the tank top. Figure 1 shows the LDUA and Hanford style waste tank.

V. REMOTE VIDEO SYSTEMS

The remote video systems provided for the LDUA system are "stand alone" overview systems. One unit has been routinely used in a Hanford radioactive and flammable UST for several months. The overview units are positioned prior to the LDUA deployment into the tank and remain in use until the arm is removed. Once deployed, the overview systems provide assurance that the LDUA deployment and subsequent operation are free from collision potentials. They are used by the LDUA to support specialized inspections and documentation, as required throughout the UST environment.

The systems were designed to perform a "first-in, last-out" role in UST operations. They have minimized any potential for collisions upon deployment and have no potential for tank damage. They are designed to be deployed before any other equipment and will monitor all entries that follow to provide optimum collision avoidance and anomaly resolution.

Overview video systems, both monoscopic and stereo versions, include a camera, zoom lens, camera positioner, vertical deployment system, and positional feedback. Each independent video package can be inserted through a 100 mm (4in) diameter opening. A special attribute of these packages is their design to never get larger than the entry hole during operation and to be fully retrievable. All video systems implement a multifunctional design that uses a single coaxial cable for all data and control signals over the more than 275 meter (900 foot) cable (or fiber optic) link.

The monoscopic video system may be used with radiation-hardened components or with conventional components in lower radiation, cost-sensitive applications. The stereo systems are radiation resistant using conventional components, and they provide multiple magnification viewing while avoiding the inherent difficulties of matching zoom lenses. The remote deployment method is a unique flexible method that gives the required stability during deployment while retaining ease of handling.

All systems are designed to NFPA-70 Class 1, Division 1 requirements to satisfy those deployments that require flammable atmosphere protection. Protection is included for all portions, including cabling, with constant pressurization and electrical interlocking.

A. Common Design Features

The overview systems include two types of camera assemblies and two types of deployment devices, with three of the four possible combinations of these now being tested or in use at Hanford. All types share common design features in construction, and deployment methodology. These features will be discussed in this section and particular details of each in following sections.

The camera housings are constructed on a circular cross section approximately 90 mm (3.5in) in diameter with downward facing camera(s) and lens assemblies. All motions and aiming of the camera view are within this diameter, thus preventing any protrusions to be hang points upon assembly removal from the UST. This concept eliminates the possibility of any motion related failure mode preventing withdrawal of the camera assembly. Figure 2 shows some of the details of the camera assemblies. The downward aiming camera design allows the interchange of a variety of long and short video camera and lens combinations, making radiation hardened cameras applicable, without jeopardizing the UST deployment options.

Normal viewing is in the horizontal plane utilizing an external tilting mirror (stereo version is non-tilting) to provide above and below horizontal viewing and to provide straight down viewing for initial entry. The exhaust purge air is also used to defog this mirror. The mirrors used are an optical quality first surface mirror that has been deposited on a stainless steel substrate, to provide quality viewing and ruggedness of design.

The camera housing is coupled by quick disconnect fittings that provide both electrical and air connections to the hanging camera housing, from the deployment flexible member. A non-metallic version of flexible conduit is used to contain the wiring and support the camera housing. An additional top level quick disconnect is used to couple this conduit to the rotating deployment drum.

The achievement of the required Class 1, Division 1 flammability rating is accomplished using a pressurized and electrical interlocked method. The single, contiguous, "housing" is protected from a pressurized connection box on the cable deployment drum, through the flexible conduit and two sets of quick disconnects, to the camera housing. This "housing" is pressurized with flow through air from the safe area to an exhaust at the lowest end of the camera housing. Double flow sensing interlocks are combined with intrinsically safe pressure sensing within the camera housing to complete the system. In all cases an air compressor is included as a part of the assembly to provide the purging function, so that no external services, other than 110 vac, are required.

The deployment drum provides the "tilt" action normally associated with camera aiming. The upper portion of the hanging camera housing rotates the lower portion to provide the "pan" function. The wiring from the cable reel uses either slip rings (on some versions) or a "no slip ring" rotating flat cable bundle design that allows the combination of coaxial, sensitive signal, and high power cables to be combined.

The camera housing provides all required lighting within the camera head package using six each 35 watt halogen lamps supplying the illumination required for the very large USTs. The heat given off by these lights is contained using a refractory type of insulation and is dissipated by the pressurization air that exhausts across the external mirror, for the defogging function, and exhausts below the lights.

The camera units are positioned over a tank entry "riser" that leads into a UST, an then all personnel can retreat to the remotely located control trailer, positioned up to 275 m (900 ft) away. All system controls, camera functions, and positioning are performed from that remote location. The remote connections for each system consist of a single pair of coaxial cables or fiber optic strands. The system controls are intermixed with the video signals. This simplified connection scheme allows for rapid relocation of systems and minimizes the impact of cable costs and deployment.

B. Overview Video System

The Overview Video System (OVS) is a "first-in, last-out" system that is intended to provide a standoff view of the interior of the UST prior to, during, and after the LDUA is deployed. It is completely self-contained and designed for minimum impact on the USTs. It is intended for deployment either as part of a LDUA deployment or completely independent.

The OVS utilizes either radiation hardened camera and lens assemblies or conventional camera and lens assemblies, as required. These two types are electrically identical so they can be interchanged in the field. This flexibility allows the far less expensive conventional assemblies to be used for most applications, while retaining the ability to service all environments.

An externally mounted mirror is used to direct the camera view horizontally during normal operation but can also direct the view 30 degrees above and below horizontal plane. It can be further extended out of the camera view path to allow direct downward viewing. The latter is primarily intended for initial entry viewing, to avoid collisions. The mirror positioning motors and switches are located completely within the camera housing, to retain the required flammable atmosphere capabilities.

The conventional lenses also allow for a much wider range of useful focal lengths and low f-stops. The few radiation hardened zoom lenses available world wide are very limited in capabilities (e.g. focal length ranges available only include 30-150mm, 12-72mm, 20-80mm, and 8-50mm, and are very expensive (i.e. the least expensive lens available is over $10,000 US).

The OVS is a single "phone booth" like assembly, as shown in Figure 3, that is positioned over the riser that leads down into the UST. All personnel can then retreat to the remotely located control trailer from which all system functions are controlled. The one piece design is compatible with the Hanford requirements and the other equipment expected to be deployed as part of the LDUA program.

C. Overview Stereo Video System

The Overview Stereo Video System (OSVS) is a stereo viewing version of the OVS that is used in conjunction with a "Crystal Eyes" stereo viewing and recording system located in the remotely located control trailer. The OSVS provides a stereo view of selectable magnification of the UST interior and is housed in the same diameter housing design as the OVS.

Two independent color video camera are positioned at normal eye spacing within the 90mm (3.5in) housing. Three selectable image magnifications are provided by a rotating lens turret, and motorized control of focus, scene convergence, and vertical alignment. All of these functions are under the control of the remotely located operator.

The OSVS is deployed, controlled, and protected from flammable environments in the same manner as the OVS. It also utilizes a "phone booth" type of deployment device. The viewing mirror is fixed, at the horizontal plane, due to space constraints.

D. Portable Overview Video System

The Portable Overview Video System (POVS) is a multi-part version of the OVS that has enhanced portability. Many applications can be addressed more easily by hand carrying the equipment to the deployment UST entry riser. The POVS is in several, light weight, portable modules that can be move easily by two operators to a deployment location. Set up takes less than five minutes. Figure 4 shows the components of the POVS.

The tank top portion of the POVS consists of a motorized cable reel which lowers the camera housing into the tank by deploying the connecting cable over an attached monopod stand. The base for this unit is a hand truck which allows easy portability of the system. Also mounted on the base is the purge air supply for the system that maintains positive pressure within the camera housing. The entire deployment unit is positioned next to a previously opened 100mm (4in) tank riser so that the camera housing is hanging directly above the riser opening. The personnel then depart to a protected area.

Vertical motion, rotation, lighting, and lens functions are operated remotely by either stand-alone controls or remotely from the control trailer. The maximum vertical deployment for the tanks at Hanford is 15meter (50 ft), but longer distances are easily achievable. The positional data of the deployed video package is provided on screen and for serial input to another computer system. All data and control functions are combined into a pair of inexpensive coaxial cables.

VI. FIELD EXPERIENCE

The OVS and OSVS have been approved for flammable atmosphere UST at the Hanford site. The OVS is currently being used routinely in radioactive tanks at Hanford. The OSVS, and POVS are at the Cold Test Facility at Hanford undergoing final testing and qualification. All systems are performing above expectations.

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Westinghouse Hanford Co.

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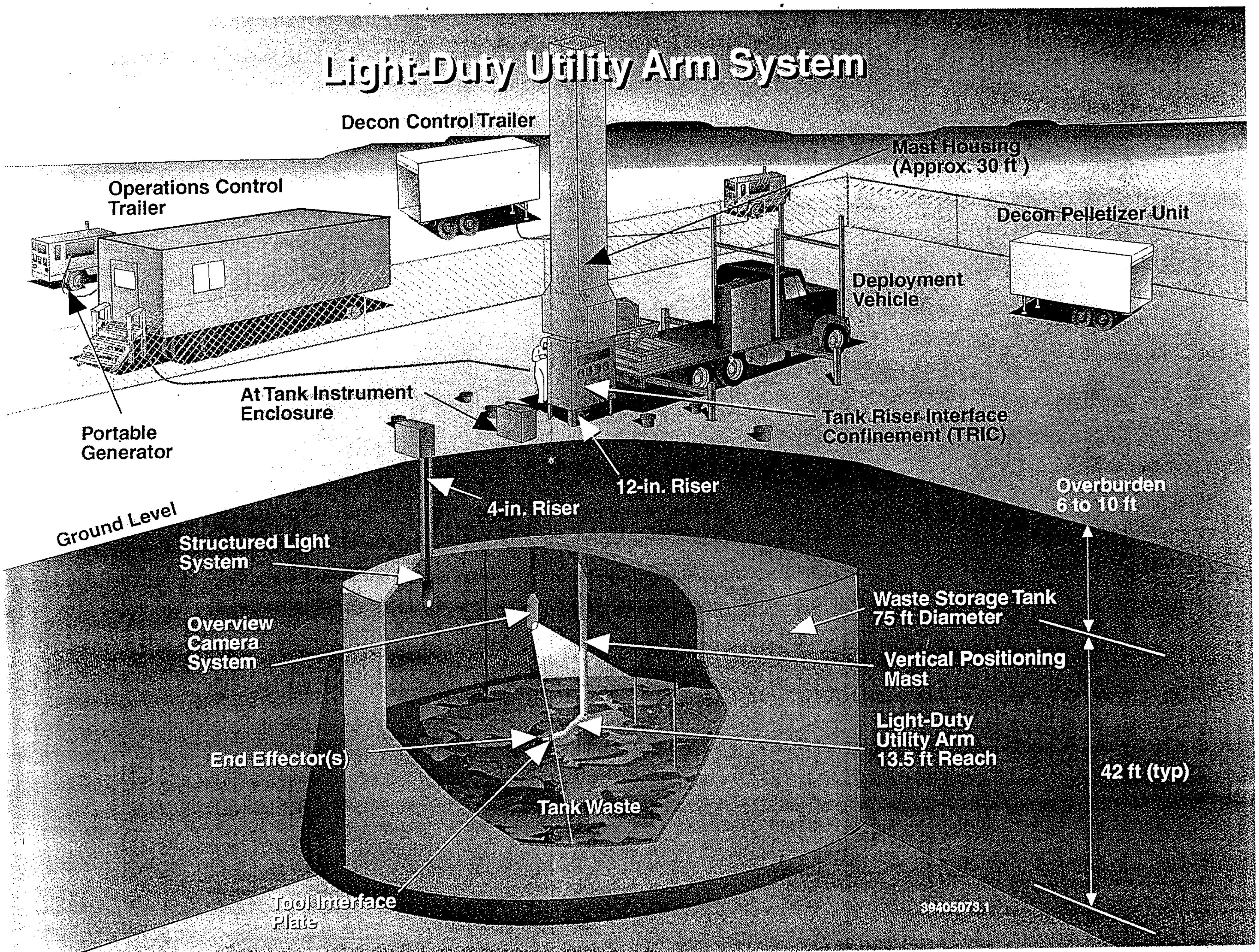
Light-Duty Utility Arm System
Decon Control Trailer
Operations Control Trailer
Mast Housing (Approx. 30 ft)
Decon Pelletizer Unit
Deployment Vehicle
At Tank Instrument Enclosure
Portable Generator
Tank Riser Interface Confinement (TRIC)
12-in. Riser
4-in. Riser
Ground Level
Overburden 6 to 10 ft
Structured Light System
Waste Storage Tank 75 ft Diameter
Overview Camera System
Vertical Positioning Mast
Light-Duty Utility Arm 13.5 ft Reach
End Effector(s)
42 ft (typ)
Tank Waste
Tool Interface Plate
39405073.1

FIGURE 1

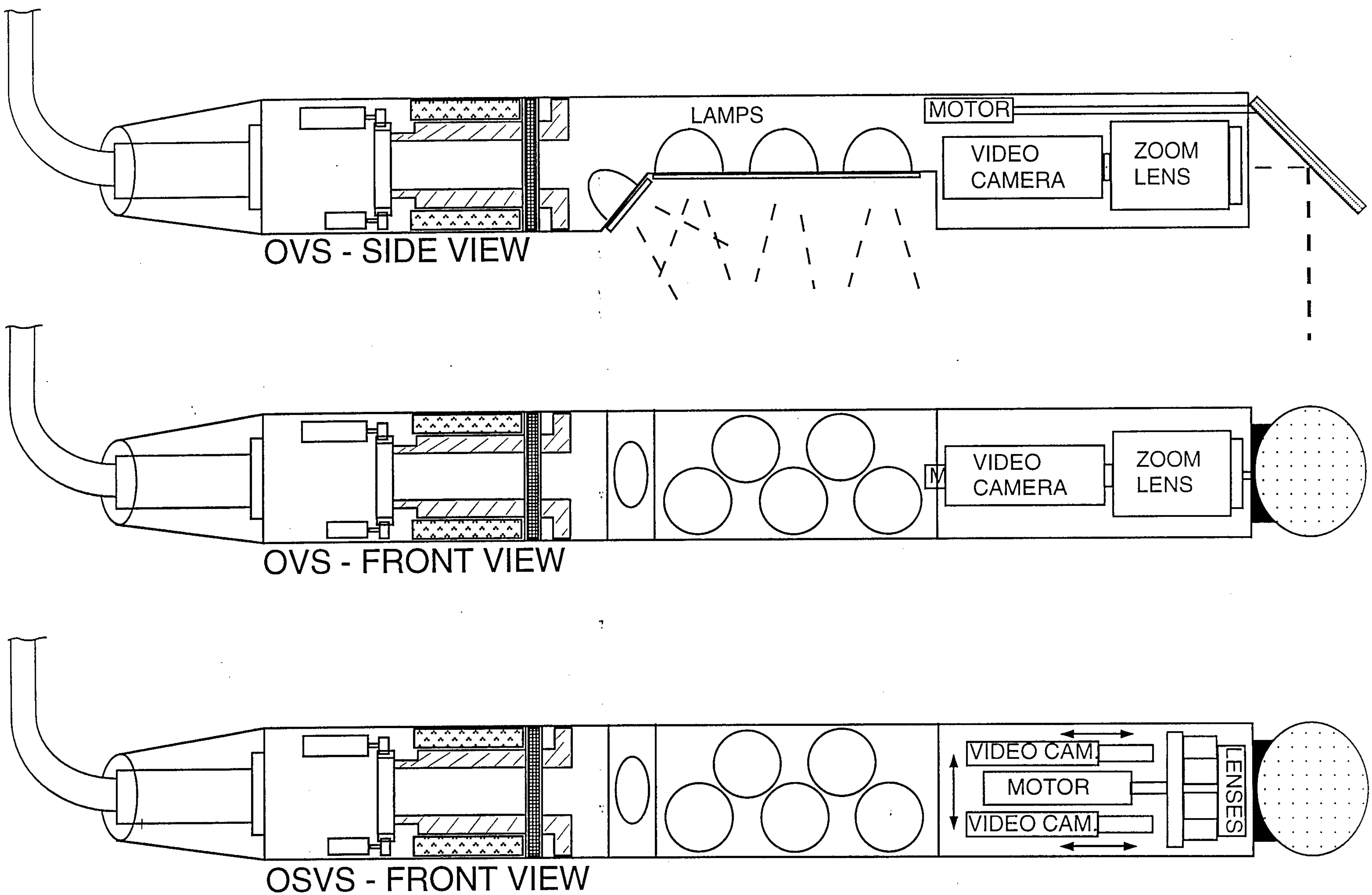

FIGURE 2 - OVERVIEW AND OVERVIEW STEREO VIDEO SYSTEMS

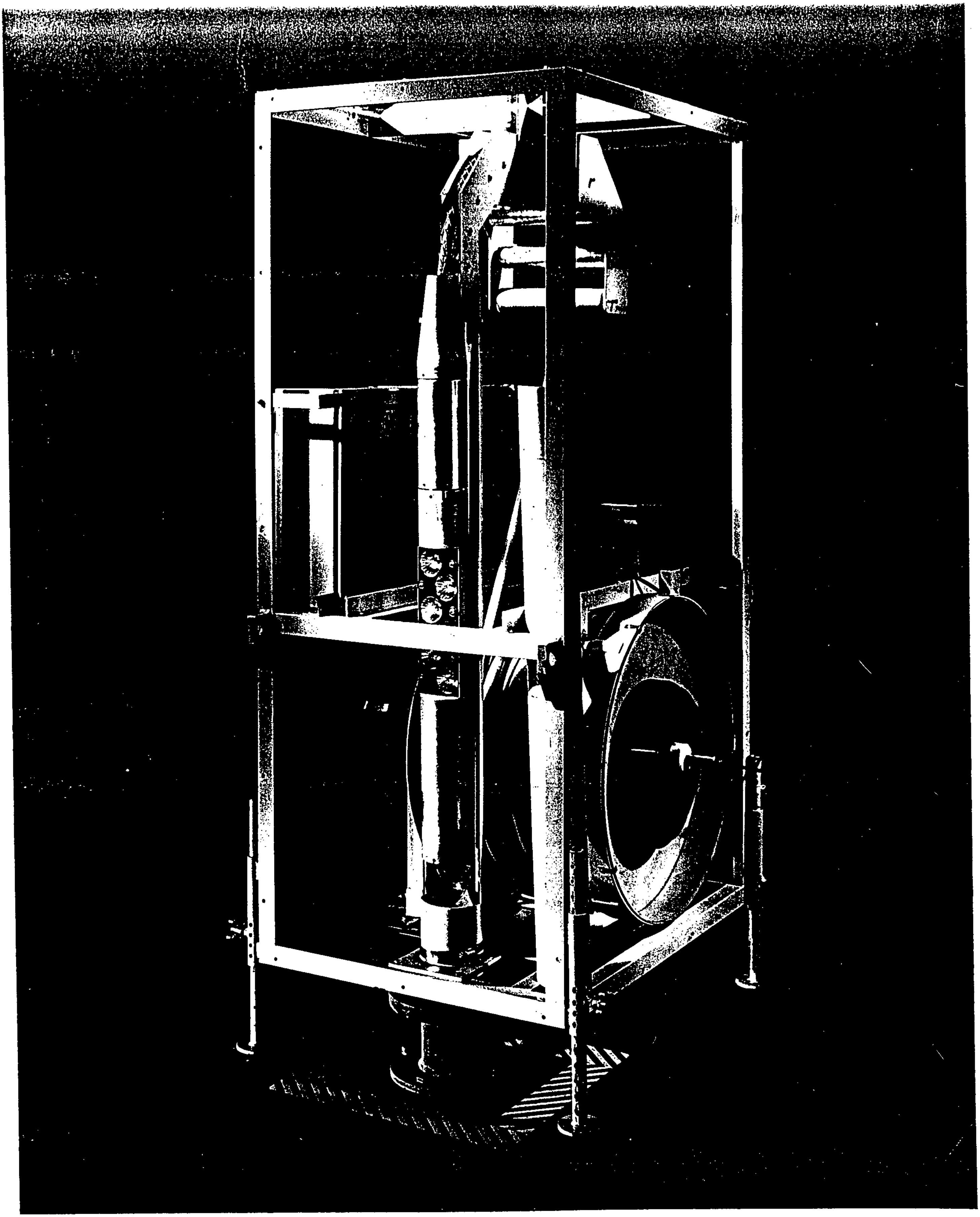

FIGURE 3

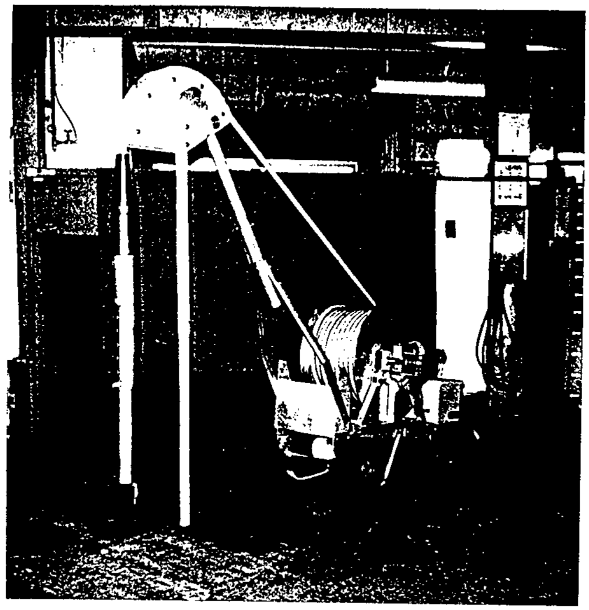

FIGURE 4

DOE

(18) DOE, XF
(19) UC-900, DOE