REMOTELY OPERATED MOBILE SYSTEM EXCAVATES BURIED NUCLEAR WASTE

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Abstract

This paper describes a 1,500 metric ton, mobile, remotely operated worksystem that has been designed to excavate and retrieve buried hazardous and low level nuclear waste. The mobile worksystem includes seven independent, multi-degree-of-freedom, telerobotic excavation tools and four remotely operated, double-lid transfer systems to move the waste through the system's negative pressure confinement barrier. Ten human operators in a separate building control the worksystem's functions from computer based control consoles communicating over a fiberoptic umbilical. A computer controlled anti-collision, radiation monitoring, and mapping system keeps track of each tool's position and prevents inadvertent excavation of high radiation sources. The mobile worksystem structure is a bolted joint, steel gantry approximately 75 meters long, 30 meters wide, and 20 meters high mounted over a 38 meter wide pit. The pit surface is completely confined by geomembrane liners deployed by the mobil worksystem during the retrieval operation.

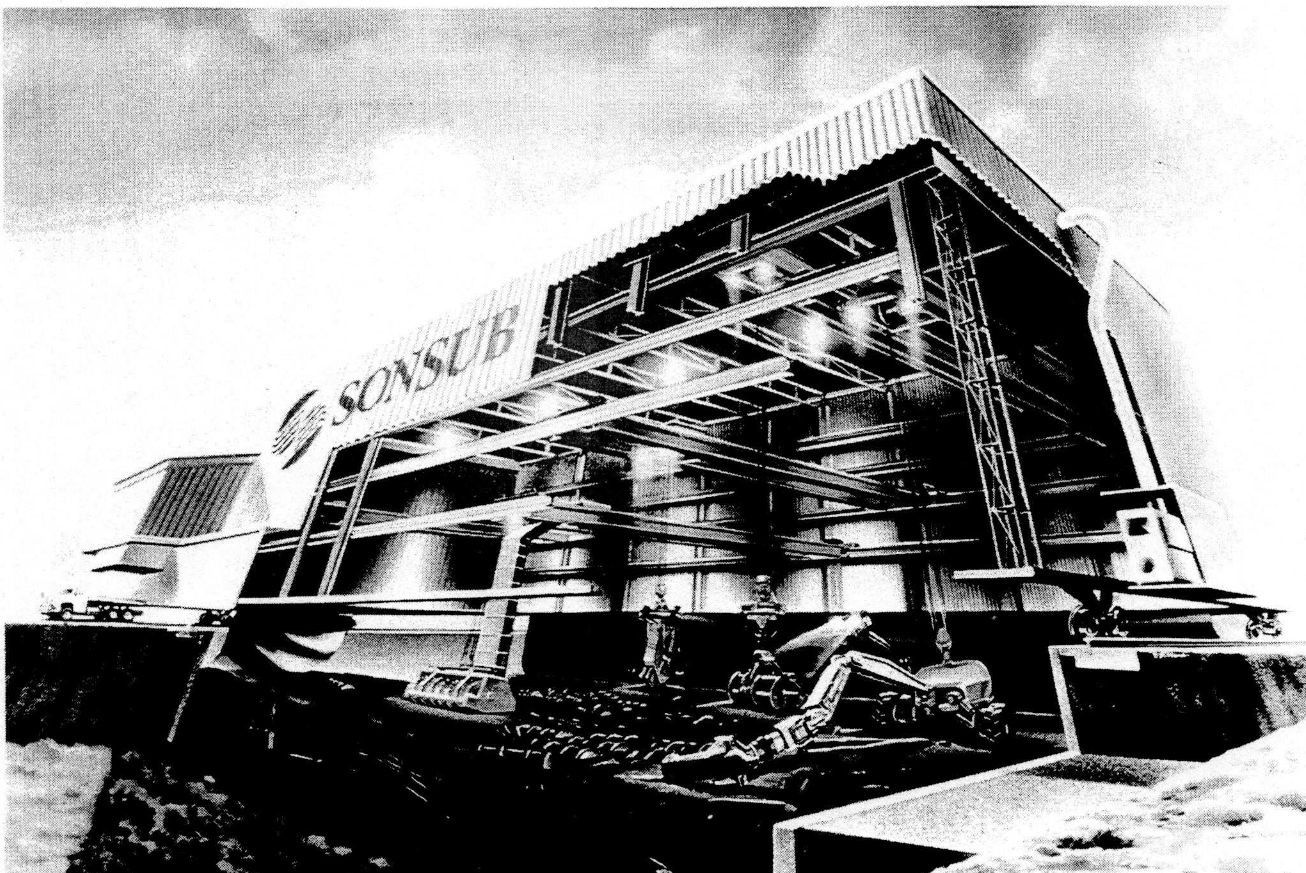

Fig. 1 - OVERVIEW OF THE MOBIL WORKSYSTEM

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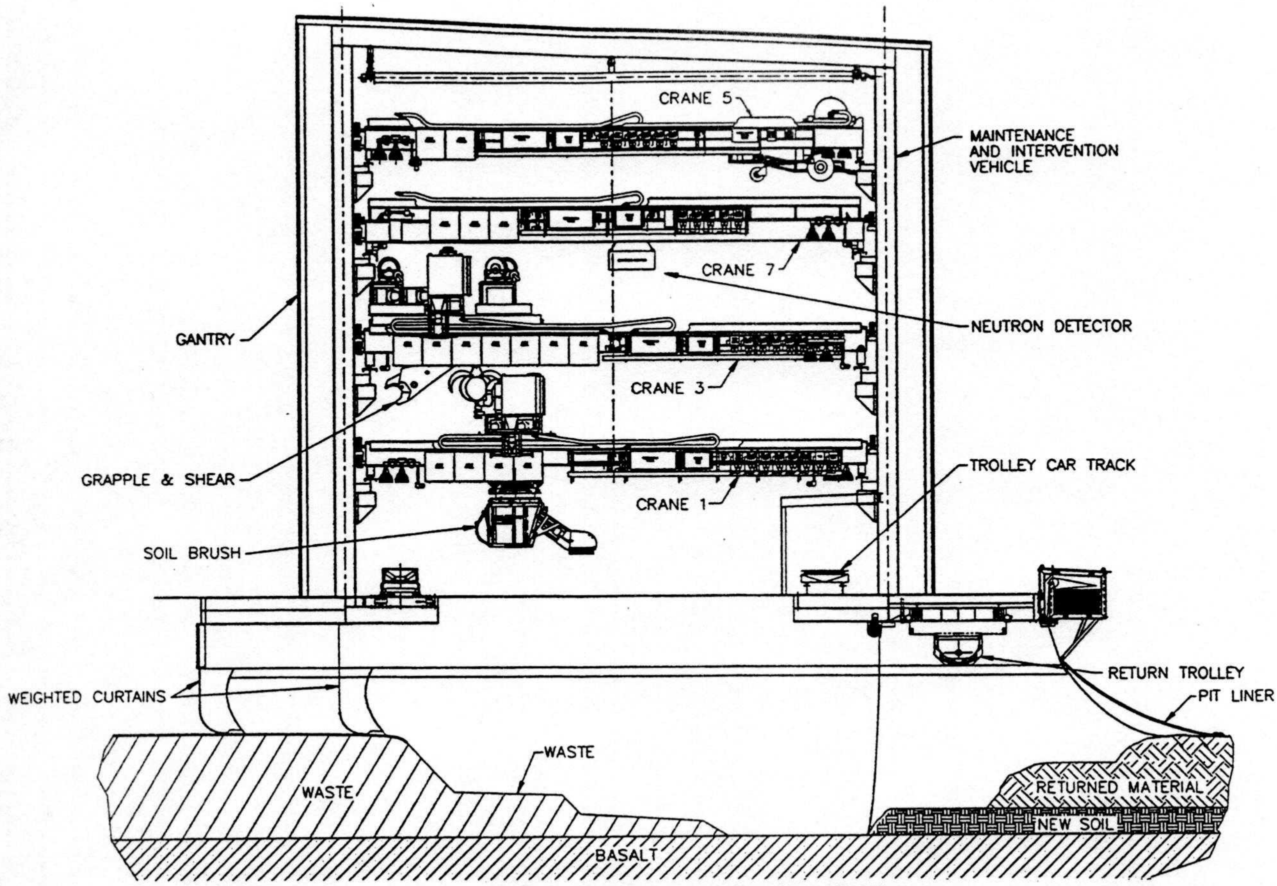

Fig. 2 - TOOL SYSTEM ARRANGEMENT

Introduction

Sonsub's 1,500 metric ton, mobile, remotely operated worksystem is currently being assembled in the Idaho desert to excavate and retrieve buried hazardous and low level nuclear waste. The waste is buried at the Idaho National Engineering Laboratory in a 5 meter deep pit known as Pit 9. 4,000 Cubic meters of plutonium contaminated low level and mixed waste and 7,000 cubic meters of interstitial soil were buried in Pit 9 between 1967 and 1969. Part of the waste is contaminated with plutonium from the Department of Energy's Rocky Flats weapons plant. The chief health hazards are breathing or ingesting the plutonium contaminated dust and volatile organic compounds. Dust generated in excavating the waste is the primary reason for remote operations. During excavation, the surface of the pit is completely covered with geomembrane liners so that the only exposed portion of the pit surface is inside the worksystem. The inside of the worksystem is kept at negative pressure at all times so that any air leakage flows into the confinement and then exhausted through nuclear grade filters. Excavation and retrieval operations include removing the overburden soil, surveying for high radiation sources, separating the soil from the waste, packaging the waste and soil in separate transport boxes, air locking the boxes through the confinement barrier, and returning safe waste back to the pit after assay at the treatment building. The volume of the contaminated waste will be reduced by 90% in the treatment building.

The mobile worksystem includes seven independent, multi-degree-of-freedom, telerobotic excavation tools and four remotely operated, double-lid transfer systems to move the waste through the system's negative pressure confinement barrier. Ten human operators in a separate building control all the worksystem's functions from computer based control consoles communicating over a fiberoptic umbilical. A computer controlled anti-collision and mapping system keeps track of each tool's position and prevents inadvertent excavation of high radiation sources.

Description

The mobile worksystem structure is a bolted joint, steel gantry approximately 75 meters long, 30 meters wide, and 20 meters high. The gantry spans the 40 meter wide waste pit supported by steel rails and concrete piles on the east and west sides of the pit. The gantry is skidded down the 130 meter long rails by three 300 mm diameter hydraulic cylinders. The gantry provides four levels of crane rails to support the retrieval tools. The gantry also supports a 75 meter long belt conveyor for soil transfer, a trolley car track for waste containment boxes, an elevator and under running trolley for returned material, and four double-lid transfer systems. The entire gantry is enclosed in a double walled, minimum leakage steel skin and sealed to the ground with geomembrane liners and weighted curtains. A fully redundant air handling and filtration system provides negative pressure confinement for the radioactive and hazardous waste.

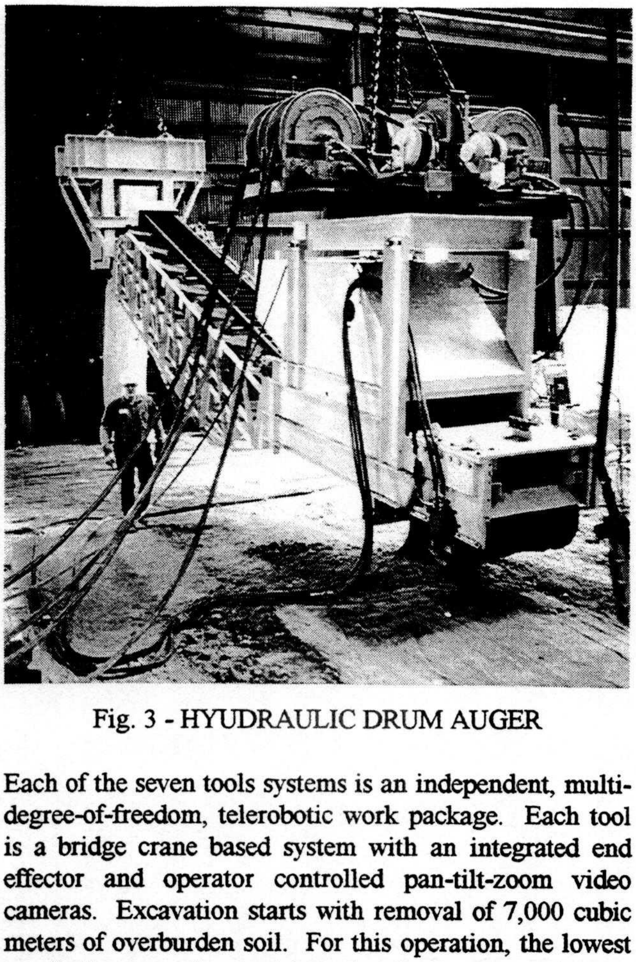

Fig. 3 - HYUDRAULIC DRUM AUGER

Each of the seven tools systems is an independent, multi-degree-of-freedom, telerobotic work package. Each tool is a bridge crane based system with an integrated end effector and operator controlled pan-tilt-zoom video cameras. Excavation starts with removal of 7,000 cubic meters of overburden soil. For this operation, the lowest two bridges are fitted with hydraulically powered drum augers that break up the extremely hard, sun baked, volcanic ash based surface soil. The soil is then carried by a series of telescoping conveyors to the 75 meter long belt conveyor which transports the soil to waiting dump trucks at the soil transfer station. Starting at the north end of the pit, the entire worksystem travels 130 meters to the south to remove the overburden.

Retrieval Tools

When the gantry reaches the South end of the pit it is reconfigured for retrieval operations. The overburden augers on the lowest level of bridge cranes are replaced with Sonsub's patented Soil Brush end effectors. Each soil brush has six independent, hydraulically powered excavator brush heads that remove the interstitial soil to reveal the buried waste so that grapple equipped bridges on the second level can pick up the waste and deposit it into waste transfer boxes on trolley car track. However, before removal of the waste can begin, every square meter of the pit surface must be surveyed by two neutron detectors that look for high radiation sources below the ground surface. The 2 meter square detectors are operated by bridge cranes on the third level. The results of the survey at each position are entered into the worksystem's anti-collision software as a safe or restricted zone so that no inadvertent excavation of a high radiation source can be attempted.

Maintenance and Intervention Vehicle

The fourth crane level is reserved for the Maintenance and Intervention Vehicle (MIV). The MIV is an extremely versatile tool system that can be used for a variety of different surveillance and intervention tasks. The MIV can be used in either flying or driving modes. In flying mode, it's bridge crane and umbilical hoist provide three dimensional freedom to move anywhere in the gantry work space. An operator controlled tail rotor provides 360 degree rotation around the vertical axis. In flying mode, the MIV can travel and hover like a helicopter to inspect the other tool systems with it's video camera and microphone. If intervention is required, two five degree-of-freedom manipulator arms can grab on to a fixed object, such as another crane, so that the vehicle is fixed in space and the MIV's seven function manipulator can be used for the intervention task. In the driving mode, remotely controlled wheels are lowered by the operator. Once the MIV is on the ground and the umbilical is slacked, the independently controlled drive wheels can move the vehicle into any position in the pit.

Waste Transfer

Waste excavated by the tools is loaded into specially designed 3.6 cubic meter transfer boxes. The boxes are carried by trolley car to a transfer station that removes the box from the car, installs the lid, and places the box into a specially designed transfer truck that takes it to the treatment building. The operation is conducted in a double-lid transfer mode which acts as an airlock to prevent cross contamination of the transfer area. The double-lid transfer port is designed so that the box and its lid are remotely separated at the transfer port. The lid and its lifter remain at the port to seal the opening. The box, which sits inside a secondary container, is transferred by a dedicated forklift to the trolley car. This method keeps the outside of the box and the lid clean by preventing communication with the atmosphere inside the gantry. When the box is filled and returned to the transfer station, the secondary box seals the transfer port while the box is being removed and replaced. Two transfer trolleys are provided to reduce the time needed to replace a full box with an empty one. The trolleys lower the boxes through a sealed trap door into a transfer truck through a sealed door in the roof of the truck.

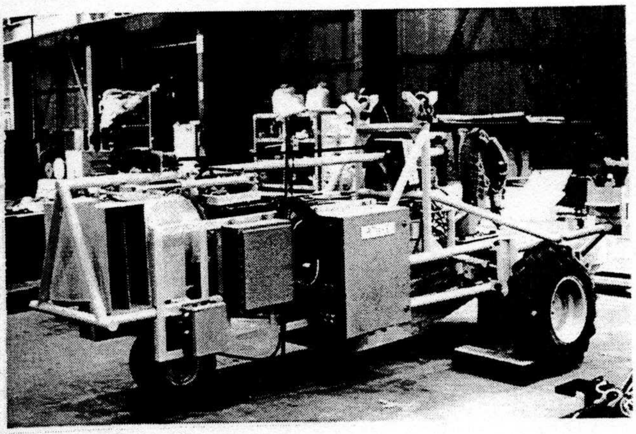

Fig. 4- MAINTENANCE AND INTERVENTION VEHICLE

Excavated soil is transferred through a hopper and volumetric feeder that places a controlled volume of soil in each box. At the soil transfer station, a portable scissors-lift mounted in the transfer truck raises the soil box through the truck's roof door and seals it against the transfer port. A remotely operated lid lifter removes the box lid and a dust containment hood is lowered to seal to the open box. A premeasured volume of soil is then dumped into the box by a pair of gate valves. A separate air filter scavenges the dust from the hood before the hood is disconnected and the lid replaced.

Returned Material

Soil and waste that assay below 10 nanocurries per gram is considered acceptable for return to the pit. This returned waste must be placed under the geomembrane liner and behind the digface by the gantry systems. The returned waste enters the gantry through a double-lid transfer system that interfaces with a box dumper. The box dumper latches on to the box, separates it from the lid, and then rotates it 180° so that the waste or soil is dumped into an under-running hopper trolley. After filling, the hopper trolley moves horizontally on to an elevator that lowers it to a second set of rails hanging from the underside of the gantry. The hopper trolley is then remotely driven across the pit so that the operator can choose the position, and direction of the dump.

Hazardous Confinement

The pit is completely confined by geomembrane liners during the retrieval operation. The only portion of the pit that is not covered by the liners is the dig face inside the gantry which is completely sealed to the liners or foundations. During overburden removal, the gantry spreads a geomembrane liner over the north side of the pit surface to protect it from the weather and to provide a confinement barrier for retrieval operations. During retrieval, a second gemembrane liner is deployed from the south side of the gantry. This liner is sealed to skirt walls on the east and west sides that fit into liquid filled troughs in the concrete foundations. The north side of the gantry is sealed to the overburden liner with weighted geomembrane curtains. The interior of the gantry is then kept at a negative pressure by the air handling system that exhausts through nuclear grade filters to the atmosphere. As the gantry moves north, it deploys the pit liner on the South and advances over the overburden liner on the north. At the dig face, the Maintenance and Intervention Vehicle cuts up the entering overburden liner and it becomes part of the waste.

Maintenance

A maintenance area, separated from the dig face by a retractable curtain, is provided on one end of the gantry. The maintenance area provides ample working space where the tools can be decontaminated and maintained. Tools, facilities, and elevating work platforms are staged for ready use. Health Physics technicians and maintenance people in full anti-contamination suits and supplied-air masks enter the maintenance area through double door buffer area rooms. Standard nuclear worker

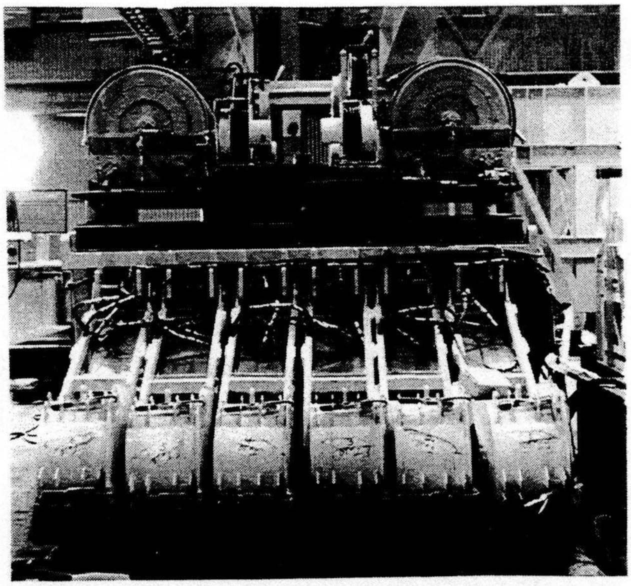

Fig. 5 - SOIL BRUSH END EFFECTOR

Fig. 6 - REOMOTE CONTROL TOOL CONSOLE

decontamination and monitoring programs are followed at all times. Remote Area Monitors (RAMs), Constant Air Monitors (CAMs) and other sensors are monitored in the control room in accordance with DOE and government requirements.

Safety Considerations

Remotely operated systems were chosen for this project because of the hazardous nature of the site. Although this project could be done with people and construction/excavation equipment working inside a large containment building, there are significant advantages to a remote system. Safety of the workers is the most obvious advantage. Typical construction accidents could be fatal if a worker's suit were breached. Breathing air requirements would make the inside of a large building similar to an underwater work site with the same problems that divers face with air bottles or hoses. Maintenance and repair of the excavators could force people to travel across the dig face to work on the equipment. In contrast, the remotely operated tools are suspended from electrically operated overhead cranes for easy retrieval. Production rates are higher for remote systems because operators can be rotated by simply stepping away from the control console. Construction workers in the pit could only work for a short time in full suits and each time they come out, a laborious decontamination procedure would be required. Decontamination of the system at the end of the project is greatly reduced. A containment building large enough to enclose the site would be 10 times as large as the gantry. Finally, full time video monitoring and assay position software provides supervisory control and historical records that are simply not possible with normal construction techniques. Future applications of this technology can be expected to move away from being limited to hazardous areas and toward more automated control systems.