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Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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HYDROLASING OF CONTAMINATED UNDERWATER BASIN SURFACES AT THE HANFORD K AREA

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ABSTRACT

This paper discusses selecting and implementing hydrolasing technology to reduce radioactive contamination in preparing to dispose of the K Basins; two highly contaminated concrete basins at the Hanford Site. A large collection of spent nuclear fuel stored for many years underwater at the K Basins has been removed to stable, dry, safe storage. Remediation activities have begun for the remaining highly contaminated water, sludge, and concrete basin structures. Hydrolasing will be used to decontaminate and prepare the basin structures for disposal.

The U. S. Department of Energy's (DOE) Hanford Site is considered the world's largest environmental cleanup project. The site covers 1,517 Km^2 (586 square miles) along the Columbia River in an arid region of the northwest United States (U.S.). Hanford is the largest of the U.S. former nuclear defense production sites. From the World War II era of the mid-1940s until the late-1980s when production stopped, Hanford produced 60 percent of the plutonium for nuclear defense and, as a consequence, produced a significant amount of environmental pollution now being addressed.

Spent nuclear fuel was among the major challenges for DOE's environmental cleanup mission at Hanford. The end of production left Hanford with about 105,000 irradiated, solid uranium metal fuel assemblies – representing approximately 2,100 metric tons (80 percent of DOE's spent nuclear fuel). The fuel was ultimately stored in the K Basins water-filled, concrete basins attached to Hanford's K East (KE) and K West (KW) reactors. K Basin's fuel accounted for 95 percent of the total radioactivity in Hanford's former reactor production areas.

Located about 457 meters (500 yards) from the Columbia River, the K Basins are two indoor, rectangular structures of reinforced concrete; each filled with more than 3.8 million liters (one million gallons) of water that has become highly contaminated with long-lived radionuclides. At the KW Basin, fuel was packaged and sealed in canisters. At the KE Basin, fuel was stored in open canisters that were exposed to water in the basin. The irradiated spent nuclear fuel corroded during long-term, wet storage; resulting in thousands of fuel assemblies becoming severely corroded and/or damaged. Corrosion, especially in the KE Basin, contributed to the formation of a layer of radioactive sludge in the basins. Sludge removal is now progressing and will be followed by dewatering and dispositioning the concrete structures.

The DOE Richland Operations Office (RL) has given Fluor Hanford Inc./Fluor Government Group (Fluor) the task of preparing Hanford's K Basins for decontamination and disposal. Prior to dewatering, hydrolasing will be used to decontaminate the basin surfaces to prepare them for disposal. By removing highly contaminated surface layers of concrete, hydrolasing will be used to meet the dose objectives for protecting workers and complying with regulations for transporting demolition debris. Fluor has innovated, tested, and planned the application of the hydrolasing technology to meet the challenge of decontaminating highly radioactive concrete surfaces underwater. Newly existing technology is being adapted to this unique challenge.

INTRODUCTION

The 105-K Basin facilities (105-KE and 105-KW) are located approximately 457 meters (500 yards) from the Columbia River near the north end of the Hanford Site. The basins were constructed as part of the K Reactor Complex built in the early 1950s for the purpose of irradiating nuclear fuel to produce weapons-grade plutonium for the U.S. defense mission. Each of the two K Basins contains approximately 3.8 million liters (one million gallons) of treated water, which was used to store irradiated (spent) fuel. When the U.S. decided to shut down plutonium production in the 1980s, the spent fuel was stored underwater in the K Basin pools.

Since this irradiated fuel was not designed for long-term storage, it became corroded, which in turn resulted in the formation of a layer of radioactive "sludge" on the basin floors. The degraded fuel also released radioactive contaminants, including cesium, into the water. Because of differing operating conditions between the two basins, 105-KE Basin experienced water leakage at the construction joint, and the concrete walls and floors absorbed significant amounts of radioactive cesium. Therefore, remediating the 105-KE Basin is the highest priority of the K Basins Closure Project.

Fluor, under contract to the DOE, successfully completed removing more than 2,100 metric tons of fuel (105,000 fuel assemblies) representing 2.04 million TBq (55 million curies) and transferred it to safe interim storage on the Hanford Site in 2004. In addition, Fluor permanently isolated the construction joint in 105-KE Basin using a specially formulated concrete mixture.

The 105-KE Basin is a below-ground, reinforced-concrete, rectangular pool with a nominal operating water depth of several meters to maintain shielding of radioactive contamination. The basin floor is constructed of reinforced concrete mats. The area in which the basins are located was excavated and backfilled with sandy gravel. An asphaltic membrane, located below the basin is connected to an under-basin drain system that collects any potential water leakage.

Currently, Fluor is removing the radioactive sludge from the 105-KE Basin and plans to decontaminate and decommission (D&D) the basin, removing it to a permitted Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) facility on the Hanford Site. As part of the D&D effort, Fluor plans to remove the radioactive water from the basin, displacing it with a specially formulated concrete mixture designed to encapsulate and shield radioactivity. This approach will allow the 105-KE Basin to be safely excavated and removed.

Included in this document are a process description and the management approach to hydrolase (underwater scarification or scabbling of the outer concrete surface) the walls and floor of the 105-KE Basin.

NOMENCLATURE

ALARA	as low as reasonably achievable
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
D&D	decontamination and decommissioning
DOE	U. S. Department of Energy
EPA	U. S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
Fluor	Fluor Hanford Inc./Fluor Government Group
FMP	Facility Modification Package
KE	K East Area
KW	K West Area
PCB	polychlorinated biphenyl
RHTRU	remotely handled transuranic (waste)
RL	U. S. Department of Energy, Richland Operations Office
TRU	transuranic (waste)
UHP	ultra-high pressure

Data collected in 1981 showed that contamination levels in 105-KE were at ten micro curies per square centimeter; 2003 data showed a hundred-fold increase to readings averaging between 37.04 MBq and 55.6 MBq (1,000 and 1,500 micro curies) per square centimeter. Dose modeling revealed that the expected dose would be approximately 0.2 Sv to 0.5 Sv (20 to 50 rem) at the basin's edge unshielded (with the water removed). This dose would exceed the goals established for radiation worker exposure, as well as U.S. Environmental Protection Agency (EPA) goals:

- Exposure to the public of less than 0.25 mSv/yr (25 mrem/yr) at the 100K Area
- Worker protection less than .05 mSv/hr (5 mrem/hr) at the facility boundary.

The facility design also contributed to the difficulty in selecting a resolution. The basin pool has a decking system suspended from the roof structure. From this decking system, there are access penetrations into the basin that are 38.1 mm (1.5-inch) wide about every one meter (40 inches). It is through these access slits in the decking that long-pole tools are used to affect all aspects of work underneath the decking.

As a result, Fluor developed a plan to select a method for decontaminating the concrete underwater.

TECHNOLOGIES CONSIDERED FOR DECONTAMINATION

While the original baseline considered decontaminating the surfaces of the basin's walls and floors through scabbling, the approach was based on conducting the work in a dry atmosphere after the water had been removed from the basin. However, the high radiation levels from the 2003 dose measurements showed the need for either shielding or remote application of the decontamination method while the water remained in the basin. Fluor considered five technical approaches to extract/remove the radiological source-term from the basin surface:

1. Chemical Leaching – this application would not be practical because it would need to be performed in a "dry" (basin water removed) state that would have resulted in unacceptable radiation dose rates.

2. Dry Scarification – dry scarification techniques, such as milling, were also rejected considering the high source-term that would be encountered without the benefit of water shielding.

3. Sand Blasting - while abrasive "grit" blasting would have been effective in removing surface contamination imbedded in the basin concrete, the technique would not be effective underwater. Therefore, this too was rejected considering the high source-term that would be encountered without the benefit of water shielding.

4. Engineered Cover Blocks for Shielding – this approach would apply cover blocks for shielding while water was removed. This approach was dismissed following the 2003 dose measurements for two reasons: the cover blocks would have to be installed before water was removed; and removing the blocks during demolition would have resulted in unacceptable radiological conditions.

5. Ultra-High Pressure Hydrolasing (UHP) – the one option in the original baseline that was reviewed. However, the traditional approach of hydrolasing surfaces was performed in a dry environment utilizing a vacuum/moisture separator technology for spoils capture. Due to the excessive dose that would be encountered by dewatering the basin to perform hydrolasing, the technology was rendered unacceptable. However, it was postulated that with innovations incorporated with this technology, it could be accomplished in an underwater environment. For this reason, Fluor innovated, tested, and demonstrated hydrolasing technology to meet the challenge of decontaminating highly radioactive concrete surfaces underwater.

DEMONSTRATION TESTING OF HYDROLASING

It was decided that hydrolasing the basin's surfaces was the most suitable technology for reducing dose of the basin's surfaces. While it was recognized that underwater hydrolasing had been performed in the United Kingdom, it had not previously been performed in the DOE complex or elsewhere in the U.S. in a similar environment with such a high level of radioactive contamination.

Fluor developed a performance specification and conducted an industry search identifying several contractors with the existing equipment that could be readily adapted to meet the specifications. Fluor then contracted to procure a system consisting of the following features:

- Underwater Hydrolasing – High-Pressure Delivery "Head" – a double-shrouded cover assembly to capture concrete spoils from the basin water to control turbidity. A jeweled-nozzle hydrolasing blast head is rotated by hydraulics to direct the spray pattern for a scabbling effect. An UHP pump supplies demineralized water (at approximately 15 L/min [four gpm]) to the hydrolasing head at nominally 234,422 KPa (34,000 psi).

- Underwater Waste Recovery – this subsystem recovers the water and scarified waste stream (concrete fines, saturated in soluble and suspended fine particulate radionuclides). This recovery subsystem meets the Fluor as low as reasonably achievable (ALARA) goals as well as minimizes the turbidity of the water.

- Remote Control (Robotic) Arm – this component provides positive controls for deploying the hydrolasing assembly (resolves concerns with possible detachment) and is adapted to accommodate cameras and radiation detectors to determine real-time dose reduction and visual verification of scarified surfaces. In addition, this remote-controlled system is operated on the existing facility overhead monorail minimizing the need for expensive facility modifications.

Selecting the design, Fluor developed a three-phase demonstration of the underwater hydrolasing technology to assure that the system would be successfully demonstrated before it was deployed in actual radiological conditions:

1. An underwater demonstration was performed in a non-radioactive environment at the vendor's site. Results from a post-review of this demonstration were incorporated as lessons learned into the second phase.

2. The second phase was a full-scale mockup demonstration in a radiologically clean sedimentation basin located at the Hanford Site. This phase integrated all aspects of the operating equipment, including the hydrolasing head, the UHP pump, the deployment arm, and the spoils-recovery skid. Lessons learned from this phase were incorporated into the third phase.

3. The third phase, an actual field deployment of a prototype in the 105-KE Basin was executed in December 2003 involving 9.3 square meters (100 square feet) of underwater, contaminated wall surface. With this phase complete, a post review of all three phases was performed, and lessons learned were factored into the production model that would be used to complete the hydrolasing objectives in the 105-KE Basin.

DEMONSTRATION TESTING CONCLUSIONS

The hydrolasing system "hot" demonstration test met or exceeded all of its performance criteria:

- Depth and rate of "cut": At 234,422 KPa (34,000 psi), the system achieved a rate of 45.7 meters^2 (150 ft^2)/hr at a cut depth of 12.7 mm (.5 inch) per pass (only one pass was performed).

- No visual increase in turbidity was observed with the underwater waste recovery unit and hydrolasing head shrouds.

- Radiation levels were reduced from 3.8 rem/hr to approximately 0.2 mSv/hr (20 mrem/hr) after 12.7 mm (0.5 inch) of concrete was removed.

- Ability to capture solids down to one micron.

PREPARATIONS TO PERFORM PRODUCTION HYDROLASING AT 105-KE BASIN

Following the successful "hot" radiological demonstration test; design and fabrication of a production hydrolasing system was initiated. Fluor employed a system engineering approach to address all functions and requirements relevant to operation in a DOE Hazard Category 2 Nuclear Facility. The approach included the application of the DOE's Integrated Safety Management System process, which focuses on protecting workers and the environment as well as applying project management principles of cost, schedule, and quality.

STATUS OF HYDROLASING

The hydrolasing system has been fabricated and successfully acceptance-tested at the vendor's site. It will be installed in the 105-KE Basin in the summer of 2005. Installation and associated acceptance testing will be followed by a formal Readiness Assessment, performed by Fluor, to confirm the readiness of equipment, documentation, and personnel to support full-scale operations. Hydrolase spoils will be captured in the associated pits (concrete appendages to the main basin) to later be encapsulated in concrete. The hydrolase system will be disassembled and dispositioned potentially for future use at the 105-KW Basin or elsewhere at Hanford and/or other DOE facilities.

PATH FORWARD FOR 105-KE BASIN

After the walls and floors of the 105-KE Basin are hydrolased, Fluor plans to perform parallel activities that involve dewatering the basin as a specially designed cement (grout) is poured. The associated pits will be completely filled with grout; shielding and encapsulating the hydrolasing spoils and selected contaminated debris. In the main basin, nominally 1.8 meters (six feet) of grout will be adequate to encapsulate and shield contaminated debris and any non-hydrolased floor surfaces. Ultimately, the grouted basins will be cut into segments and transferred to the Environmental Restoration Disposal Facility (ERDF) for final disposal.

DETAILED BACKUP

The following provides a detailed description of Fluor's hydrolasing system.

Underwater Hydrolasing Head and Deployment Arm

- An UHP spinning blast head will be used to perform underwater hydrolasing in removing contaminated concrete wall and floor surfaces. (See Figure 1)

- The deployment unit must deploy from two monorails for end-effector stability and north-to-south travel of hydrolasing unit. (See Figure 2)

- Under-deck gantry setup to facilitate east-to-west travel of end-effector.

- The hydrolasing end-effector must have the capability to scarify concrete surfaces between depths of 3.2 mm (.125 inch) and 12.7 mm (.5 inch) nominally (single pass).

- Hydrolasing unit must have production capability to scarify concrete surfaces at a nominal production rate of 45.7 meters^2/hr (150 ft^2/hr).

- Hydrolasing production assembly must be able to be deployed below the deck grating.

- Hydrolasing production assembly must have capability to hydrolase all vertical and horizontal surfaces in the K Basins with the existing water level.

- Hydrolasing head will be double-shrouded; the shrouded assembly will be capable of removing spoils up to the anticipated size of <19mm (<.75 inch) of removed aggregate.

- The hydrolasing arm will utilize an automated tool interface adaptor to facilitate multiple end-effectors and their change-out underwater.

- The payload capacity of the fully extended arm must be a minimum of 34 kg (75 lbs) at the tip of the arm.

- The arm assembly shall be remotely controlled from above the operating deck to a distance of up to 30.5 meters (100 feet) away from the control assembly.

- The control for the arm shall use any combination of foot control, joystick, and touch screen with simultaneous control arm movement by the user.

- All lighting and cameras necessary for operation of the arm shall be provided.

- The arm shall utilize the existing 480v/three-phase and 110v/single phase electrical power supplied in the basin.

- The arm shall be capable of being installed in the basin without modifying the facility.

- Parts, materials, and assemblies expected to degrade or wear during normal use or exposure shall be easily replaceable and available during operation.

- The programmable logic controller shall be preset to allow manual operation at the control panel.

- Portable equipment shall provide post-hydrolasing dose measurement to ensure the required radiological end state is met.

Spoils Collection

- Flow rate/treatment of spoils capture shall be nominally 189.3 L/min (50 gpm [or higher flow rate as needed to ensure spoils capture]).

- Collection of spoils must maintain basin clarity (to facilitate operation of hydrolasing assembly and avoid impact on sludge removal or other basin operations).

- Spoils collection will require filtration and/or separation of particulate (>10 micron) and collection of up to the anticipated size of <19mm (0.75 inch) of removed aggregate.

- Spoils capture system must be designed to operate underwater to ensure radiological dose to personnel is ALARA.

- Spoils collection must be portable underwater and transfer from bay-to-bay and return water back to the basin.

- Spoils design must allow for underwater filter change-out as needed and handling through the basin grating.

- Spoils capture system must allow for thief sampling of spoils.

- The spoils capture system shall utilize the existing 480v/three-phase and 110v/single phase electrical power supplied from the basin.

- Parts, materials, and assemblies expected to degrade or wear during normal use or exposure shall be easily replaceable. This is particularly important for the hose from the shroud to the spoils filters which will have the abrasive feature of the aggregate, sand, and particulate in the water.

- The system utilizes an UHP compressor that delivers water up to 248,211 KPa (36,000 psi) (qualification testing resulted in data that supports normal operating pressures up to approximately 206,483 KPa [30,000 psi] and a pressure relief valve lift point of 251,659 KPa [36,500 psi]).

- Blast head has seven cutting nozzles imbedded on rotating wheel.

- Blast wheel is rotated via hydraulics.

- Cutting jets utilize approximately 17 L/min (4.5 gpm) potable water.

- Blast head is double-shrouded to capture sand, aggregate, and cementious material.

- The system utilizes stand off pads on the outer shroud to prevent head from suctioning to the cement surface as well as preclude "tunneling" into the walls or floor.

- The captured spoils shall not be placed for grouting in a configuration that causes any monolith to be designated as transuranic (TRU) or remotely handled transuranic (RHTRU) waste.

Hydrolasing Production Objectives

The hydrolasing equipment has been tested to assure it will meet as production objective of a nominal 14.0 square meters/hr (150 ft^2/hr) surface area.

In addition, it was determined that the return water from the spoils collection system needed to maintain visibility so that the water is capable of being filtered down to one micron before returning to the basin. The spoils collection system needs to be capable of processing the concrete rubble coming off the walls and floor in a manner that maintains water clarity. Potential issues with water quality (release of cesium and calcium from the concrete into the basin water) are addressed by an engineering evaluation to identify and procure the necessary ion-exchange modules during hydrolasing to maintain basin water clarity.

Hydrolasing Equipment Details

Remote Control (Robotic) Arm – The robotic arm serves as the deployment mechanism for the underwater hydrolasing head. The use of a robotic arm provides positive controls for deployment of the hydrolasing head.

- The system utilizes underwater video cameras to track progress of the hydrolasing.

- The arm has multiple degrees of freedom to provide access to all underwater basin surfaces (wall and floor areas in the main basin, not the pits).

- Telescoping mast assembly expands/retracts underwater to avoid surfacing any contaminants.

- Utilizing carbon fiber technology arms are quite strong but light and can deploy significant payloads.

- A gantry system operates underneath basin decking.

- Utilizes two monorails for deployment for equipment rigidity/stabilization purposes and will operate down the existing deck tracking system with no facility modifications; it can be moved north/south and east/west by current design.

- UHP Pump – An UHP pump system delivers potable or demineralized water to the blasting head.

- The pump operates externally to the facility and runs off a diesel engine.

- An UHP pump water delivery system utilizes industrial hosing made for UHP water and is shrouded by an outer line in case of line failure.

- Industrial grade whip restraints will be provided at all above-basin connection points of the UHP hosing system.

Underwater Spoils Collection – The waste stream coming from the hydrolasing will be high dose residue/concrete or spoils. The spoils capture system will provide underwater waste segregation/capture to prevent uncontrolled dispersion of waste streams in the basin.

- Utilizes the pits adjacent to the main basin for sand and aggregate capture during hydrolasing of the basin wall structures.

- Following completion of sludge removal, the main basin will be utilized for collection of sand and aggregate resulting from the hydrolasing of the basin floor cut lines.

- Filter assemblies provide particulate capture capability down to one micron (turbidity caused by spoils accumulation is acceptable provided that the sludge end point and found fuel removal activities have been accomplished).

- Spoils collection methodology will allow for thief sample of spoils materials as needed.

The spoils collection system will consist of hoses between 38 mm (1.5 inches) and 50.8 mm (two inches) in diameter and a 19 mm (0.75 inch) solids spoils pump.

ATTACHMENTS

1. Figure 1 - Photo - Hydrolasing Flat Cutting Head
2. Figure 2 - Photo – Hydrolasing Arm

REFERENCES

10 CFR 835, *Title 10 – Energy Chapter III – Department of Energy*, Part 835, Occupational Radiation Protection, Subpart K, "Design Control."

BHI-00139 Rev 0, *Environmental Restoration Disposal Facility Waste Acceptance Criteria*, Bechtel Hanford Inc., Richland, Washington (1994).

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HNF-EP-0063 Rev 10, *Hanford Site Solid Waste Acceptance Criteria*, Fluor Hanford Inc., Richland, Washington (2004).

SNF-18703 Rev 1, *Sampling and Analysis Plan for Waste Disposition of KE Basins Wall and Floor Surface Removal Residue*, Fluor Hanford Inc., Richland, Washington (2004).

Washington State Administrative Code 173-303, *Dangerous Waste Regulations*, as amended.

FIGURE 1
HYDROLASING FLAT CUTTING HEAD
(~35.6 centimeters [14 inches] in diameter)

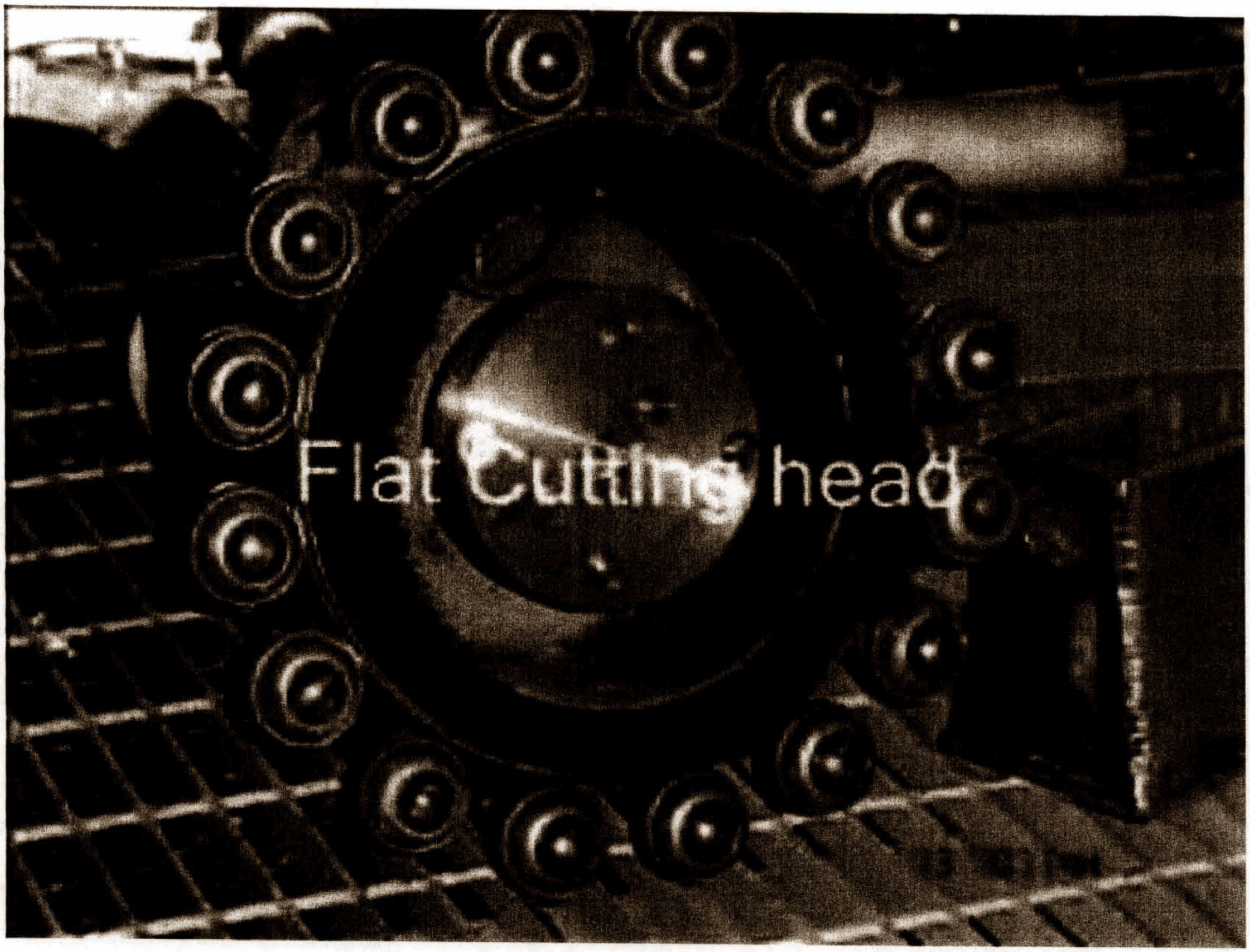

FIGURE 2
HYDROLASING ARM