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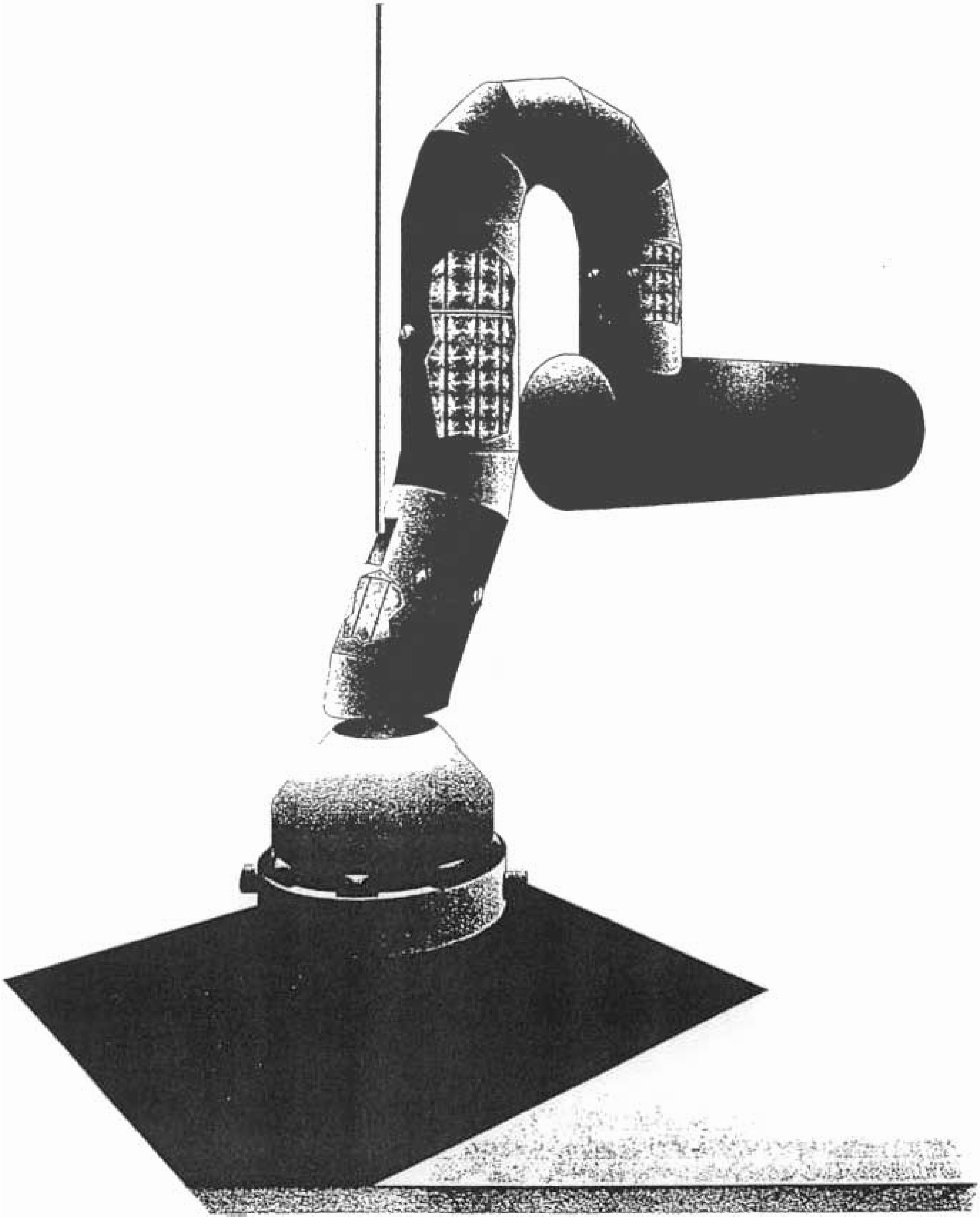
APPLICATION OF SPRAY COOLED TECHNOLOGY TO A BOP SHOP FURNACE HOOD

BY: PABLO E. QUINTANA
MAINTENANCE ENGINEER



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In 1993, U.S. Steel learned of an innovative system to cool BOF hoods known as spray cooling. The method was discovered as plans for replacing the hoods of No. 2 Q-BOP were being researched. While the application of spray cooling was not used to replace the hoods of No. 2 Q-BOP, the new method is being tested in the No. 1 BOP Shop. The method has been remarkably successful.

The original hoods of No. 2 Q-BOP consisted of a pressurized system of individual water cooled plate panels bolted together to form a 14'-0" diameter twelve sided duct. The hoods were scheduled for replacement due to excessive downtimes, high maintenance cost and severe distortion. Failures in these hoods were caused primarily by thermal fatigue cracking due to the heavy gauge of the hot face plate and inability of the plate to freely expand, due to the attachment of flow baffles. Additionally, different rates of expansion between the hot and cold faces caused distortion that lead to cracking at the edges of the panels and gaps in the joints which affected the ability of the hoods to handle the waste gases, due to water leaks and air infiltration. After studying the different available hood systems, a membrane tubular hood system was chosen as the best solution for the No. 2 Q-BOP Shop.

During the process of selecting the design and the supplier of the hoods, U.S. Steel received a proposal submitted by UCAR® CARBON COMPANY, INC., with a design that deviated completely from conventional hood construction. This system featured the use of water sprays for the cooling of the hot face. The cooling is achieved by an arrangement of nozzles that produces a pattern of overlapping sprays (see attachment A). This creates a high degree of turbulence at atmospheric pressure which promotes the transfer of heat more efficiently than the conventional flood cooling methods at high pressure. Because spray cooling is an atmospheric pressure process, it is inherently safer in the event of damage to the hot face plate. The absence of pressure on the back side of the hot face makes this hood safer by minimizing water leakage. This also reduces the urgency for shutting down the equipment for repairs. The single piece construction eliminates the need of expensive spare panels and the simplified piping design and lower water pressure reduces downtime.

UCAR® claimed that the application of spray cooling conduced to:

1. SAFER OPERATION
2. REDUCED DOWNTIME
3. LOWER MAINTENANCE COST
4. INCREASED SHOP PRODUCTIVITY

In addition, several other benefits not available with conventional pressurized systems made spray-cooling an ideal application for the BOF hoods. Some of these benefits are:

a. Thinner plate for hot face reduces the magnitude of thermal stresses.
b. Elimination of flow baffles allows the hot face to expand and contract freely.

c. Elimination of flow baffles makes the inner plate independent of the outer plate, minimizing distortion and failures due to resultant stresses.
d. Ability to size and locate spray nozzles according to cooling requirements as it varies throughout the hood conduces to better water management and efficient utilization of water.
e. Simple cylindrical shape makes fabrication more economical.
f. Smooth and continuous inside surface avoids the accumulation of slag.
g. Lighter weight reduces supporting system requirements.
h. Water treatment is not required.

The plan presented by UCAR® was attractive, although its practical use could not be proven as there were no BOP Shops using this concept anywhere, and consequently the design could not be considered for the replacement of the hoods in No. 2 Q-BOP. However, theoretically the idea was workable and the possible benefits attractive enough to justify the investment in a test that would provide enough information to consider the spray cooled design as a possible replacement for future hoods at the No. 1 BOP Shop.

U. S. Steel authorized the test in March 1993, providing that the test would not interfere with production. The test area was chosen on the following criteria:

1. Test area should be large enough to represent performance of the entire hood.
2. Test area should be subject to the worst conditions (i.e. highest temperature).
3. Test area should provide for easy installation without major modifications.
4. Test area should be easily replaced in case of failure.

Based on the above four characteristics, the removable section of the hood meets all the requirements.

The UCAR® spray cooled removable section was designed and built for "M" Furnace at No. 1 BOP Shop (see attachment B). The "M" Furnace is a top blown 250 ton heat furnace operating with an oxygen blowing rate of 22000 cfm. The spray cooled unit was installed in September 1993. As of April 8, 1997 the hood has been through 17,960 heats without signs of failure and minimal maintenance.

The UCAR® hood receives 2100 gallons of cooling water per minute. The temperature rise of the cooling water is 50°F. Water is supplied directly from Lake Michigan and requires only straining to remove particles large enough to plug the nozzles. Chemical treatment is not required. The cooling water flow rate was determined based on the desire to keep the discharge water temperature below 150°F. The primary purpose being to prevent scale formation and minimizing corrosion. The design of the hood permits examination of the water side of the hot face at any time. This allows for early recognition of cooling related effects taking place. To date, the spray surface of the hood is clean with some signs of corrosion.

Instrumentation consists of an orifice type flow measurement device and supply pressure sensor to monitor cooling water flow. On the discharge side, a temperature sensor is installed to indicate if an abnormally high temperature condition exists. Flow, supply pressure and discharge temperature are all monitored by the PLC of the furnace. To prevent damage to the removable section resulting from a low or no-flow cooling water occurrence, an interlock feature exists in the lance oxygen supply that will shut off oxygen in the event of a low cooling water flow condition.

The maintenance work done in this hood has been minimal, after three and a half years of operation, the repairs consisted of welding four small cracks of about one inch in length that appeared after about 1,500 heats, replacement of worn nozzles and welding patches over eroded spots after 15,000 heats (see attachment C). The cracks were discovered after the first nine months of operation during detailed inspection of the hood, while the furnace was down for normal maintenance of the entire hood and were detected by small wet areas in the proximity of the lower flange. The cracks originated in welded joints and were probably caused by improper cooling as a consequence of accumulation of slag inside the spray chamber. Slag falling from the lance entered the spray chamber when a hatch in the proximity of the lance door was left open for several days while the furnace was operating.

The accumulation of slag in the lower end of the hood plugged up the drain, reduced the cooling of the hot face in the proximity of the lower flange and caused slight distortion of the plate. The abnormal condition was discovered when water exited the overflow pipe of the hood as an indication of drain problems.

The eroded areas appeared at about 15,000 heats and are the results of abrasive action of the particulate carried by the waste gases.

The replacement of worn nozzles was done at about 2,300 heats as the result of wear caused by silt carried by the cooling water. The original design provided brass full cone jet nozzles. A test using stainless steel nozzles was conducted to determine if the erosion could be minimized by the use of harder material. After several months of operation, the stainless steel nozzles showed similar wear pattern. UCAR® and the nozzle manufacturer concluded that the full cone jet nozzles internal configuration entrap particles of silt in the swirling action of the nozzles and causes the wear experienced on the brass and stainless steel nozzles, and they recommended the replacement of the originally installed full cone jet nozzles with spiral jet nozzles. The spiral jet nozzles distributes water by a different means than the full cone jet. There is no swirling action, nor is there a location where a particle could get trapped.

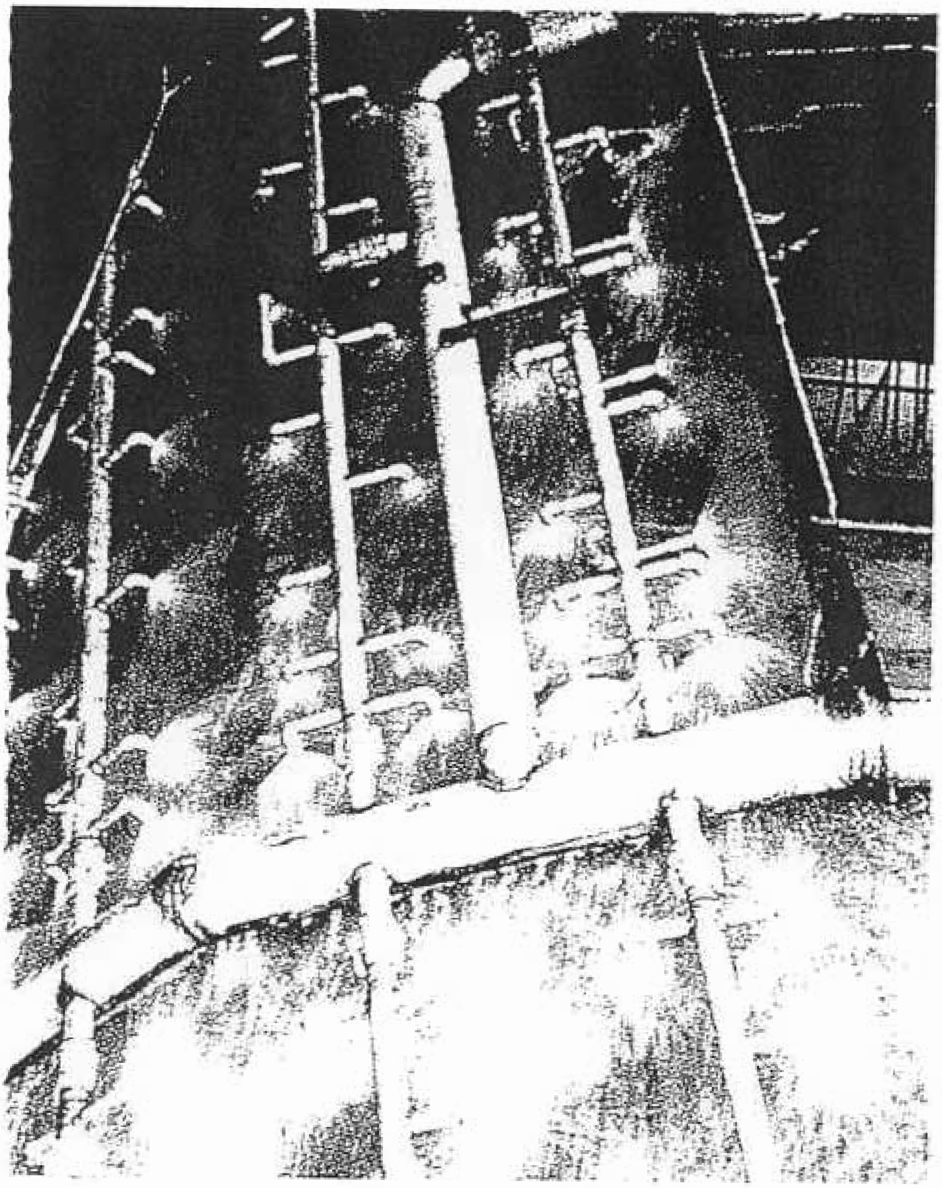
The use of the spiral jet nozzles however, did not solve the problem. Frequent inspections revealed a different wear effect in the nozzles and a distorted spray pattern that was effecting the water side of the hot face, promoting severe corrosion in some areas due to improper cooling.

The spiral nozzles were removed and the original full cone nozzles were installed back in place. The solution of the nozzle wear problem was found when small holes were drilled in a few nozzles in the proximity where the wear took place, to provide an escape route to the swirling particles and stop the erosion.

In the summer of 1996 during the No. 1 BOP Shop PM10 Project, two more spray cooled removable hood sections were installed on the other two furnaces in the #1 BOP Shop, "E" and "D" furnaces. Both new removable sections are performing as designed.

Overall, the general appearance of all three hoods is excellent. None of the hoods have shown the typical symptoms of thermal fatigue cracking. The surfaces exposed to heat have not shown signs of severe wear or distortion and the accumulation of slag is eliminated due to the smooth continuous surface of the hood.

BOF HOOD SECTION SPRAY SYSTEM



BOF hood section spray system

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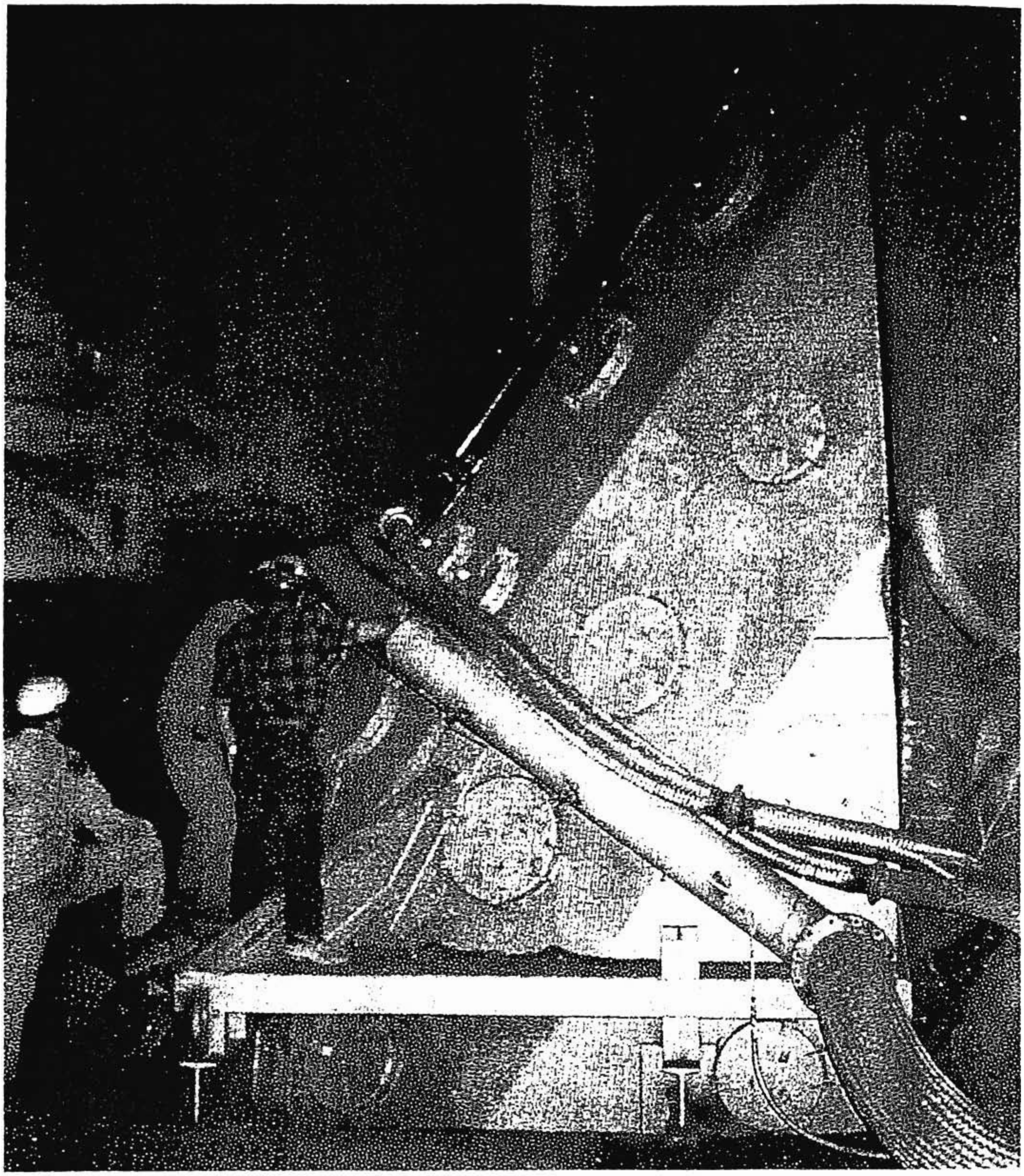

UCAR[1] Spray-Cooled Removable Hood Section for 225 tonne ~~(250 ton)~~ 325 BOF.

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