

**High Level Waste Remote Handling Equipment in the Melter Cave Support Handling System at the Hanford Waste Treatment Plant - 8208**

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**ABSTRACT**

Cold war plutonium production led to extensive amounts of radioactive waste stored in tanks at the Department of Energy's (DOE) Hanford site. Bechtel National, Inc. is building the largest nuclear Waste Treatment Plant in the world located at the Department of Energy's Hanford site to immobilize the millions of gallons of radioactive waste. The site comprises five main facilities; Pretreatment, High Level Waste vitrification, Low Active Waste vitrification, an Analytical Lab and the Balance of Facilities. The pretreatment facilities will separate the high and low level waste. The high level waste will then proceed to the HLW facility for vitrification. Vitrification is a process of utilizing a melter to mix molten glass with radioactive waste to form a stable product for storage. The melter cave is designated as the High Level Waste Melter Cave Support Handling System (HSH). There are several key processes that occur in the HSH cell that are necessary for vitrification and include: feed preparation, mixing, pouring, cooling and all maintenance and repair of the process equipment. Due to the cell's high level radiation, remote handling equipment provided by PaR Systems, Inc. is required to install and remove all equipment in the HSH cell. The remote handling crane is composed of a bridge and trolley. The trolley supports a telescoping tubeset that rigidly deploys a TR 4350 manipulator arm with seven degrees of freedom. A rotating, extending, and retracting slewing hoist is mounted to the bottom of the trolley and is centered about the telescoping tubeset. Both the manipulator and slewer are unique to this cell. The slewer can reach into corners and the manipulator's cross pivoting wrist provides better operational dexterity and camera viewing angles at the end of the arm. Since the crane functions will be operated remotely, the entire cell and crane have been modeled with 3-D software. Model simulations have been used to confirm operational and maintenance functional and timing studies throughout the design process. Since no humans can go in or out of the cell, there are several recovery options that have been designed into the system including jackdown wheels for the bridge and trolley, recovery drums for the manipulator hoist, and a wire rope cable cutter for the slewer jib hoist. If the entire crane fails in cell, the large diameter cable reel that provides power, signal, and control to the crane can be used to retrieve the crane from the cell into the crane maintenance area.

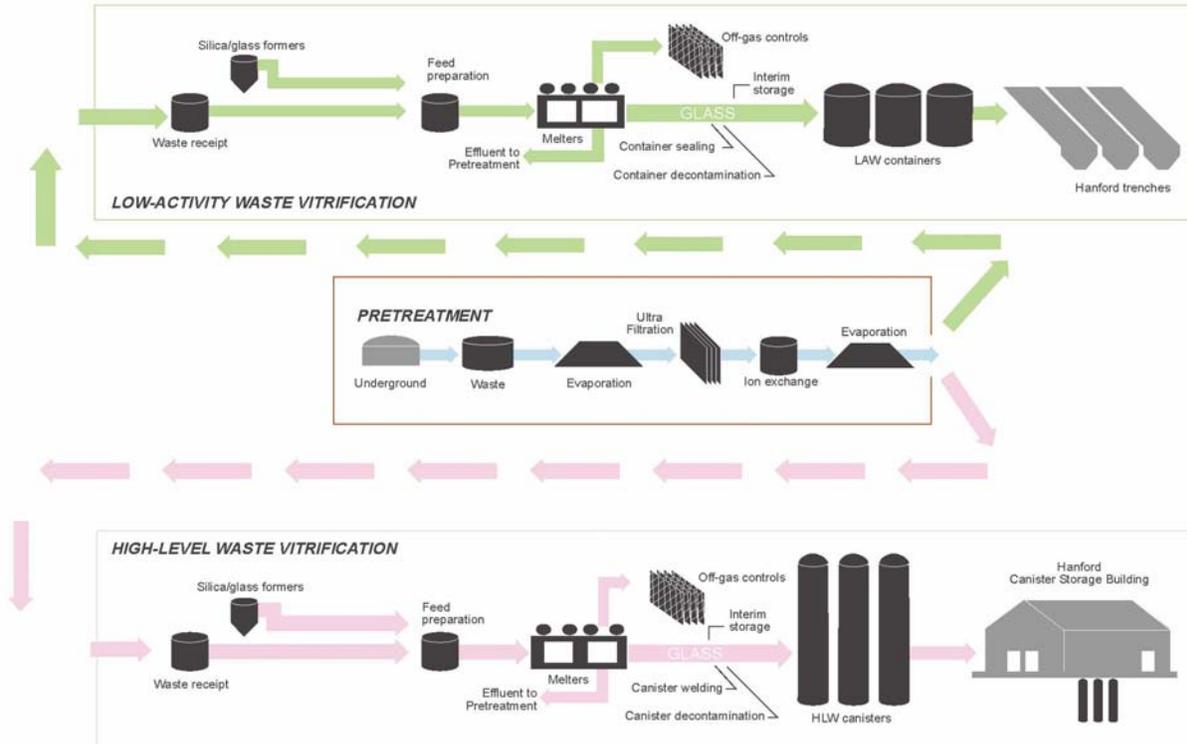
**INTRODUCTION**

The 50-mile stretch of the Columbia River known as the Columbia Reach is the last free-flowing section of the river in the U.S. This natural wonder is now a National Monument. A few miles west of the river, there remains a deadly legacy of the Cold War - 53 million gallons of radioactive and chemical wastes stored in 177 underground tanks. The stored radioactive waste has the potential to contaminate and leak into the groundwater as well as the Columbia River. The Hanford Tank Waste Treatment and Immobilization Plant (WTP), which will process the waste, is located in the 200 East area of the Hanford Site, near Richland, Washington.

## WTP FACILITY

The Department of Energy (DOE) awarded Bechtel National, Inc. (BNI) a contract in December of 2000 to design and construct the world's largest radioactive waste treatment plant to meet the challenge of safely immobilizing the millions of gallons of waste. Bechtel National, Inc. is designing and building the waste treatment plant to vitrify Hanford's nuclear waste. Vitrification is a process of utilizing a melter to mix molten glass with radioactive waste to form a stable product for storage.

The waste will be pumped out of the existing storage tanks and into the Pretreatment (PT) facility where it will be analyzed. It will then be separated into High Level Waste (HLW) or Low Activity Waste (LAW) depending on the radiation levels of the waste, see Figure 1. The tanks and other equipment are connected to the hot cell process equipment through a series of "jumpers" which are remotely removable items for fluids, gases and electricity.

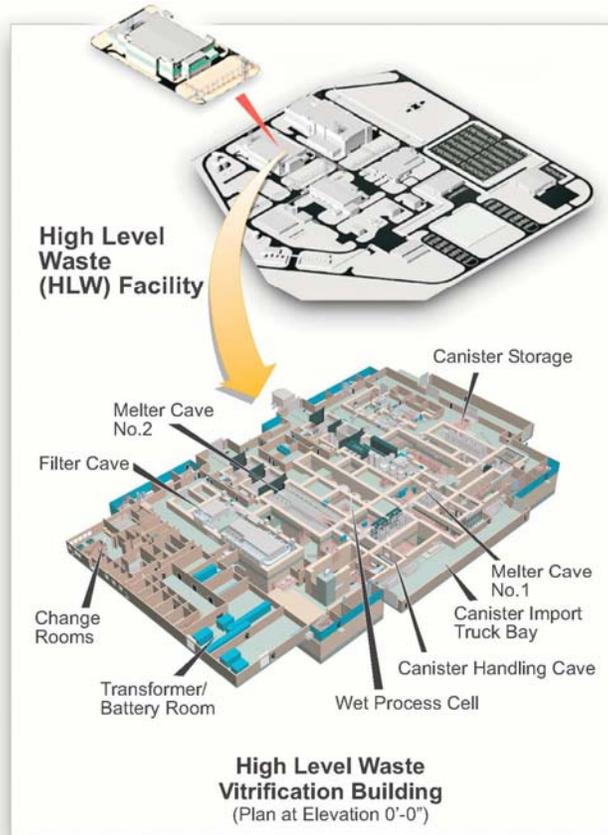


**Fig. 1. A process diagram of the waste handling in the different facilities is shown above.**

The HLW facility will contain the most radioactive and dangerous waste making it the most complex facility, see Figure 2. HLW will measure 275 feet wide by 440 feet long by 95 feet tall, or approximately 8,600,000 cubic feet. The HLW facility will immobilize high-level radioactive waste in a glass matrix for long-term storage. When the waste and the glass-forming materials are mixed, they will be vitrified in two melters, one inside each of the two identical High Level Waste Melter Cave Support Handling System (HSH) cells. Air flow through all HLW facilities moves from the least contaminated to the most contaminated areas prior to entering the filter caves. The High Level Waste Filter Cave Handling System (HFH) cell filters the air for all of the HLW facilities.

## RADIATION

The total integrated radiation dose over 40 years within the HSH hot cell ranges from 1.0E+07 Rad (100 Rads per hour) at the bridge elevation to 3.5E+08 Rad (500 Rads per hour) at the manipulator arm. To help



**Fig. 2. A cross section of the high level waste vitrification facility is shown above.**

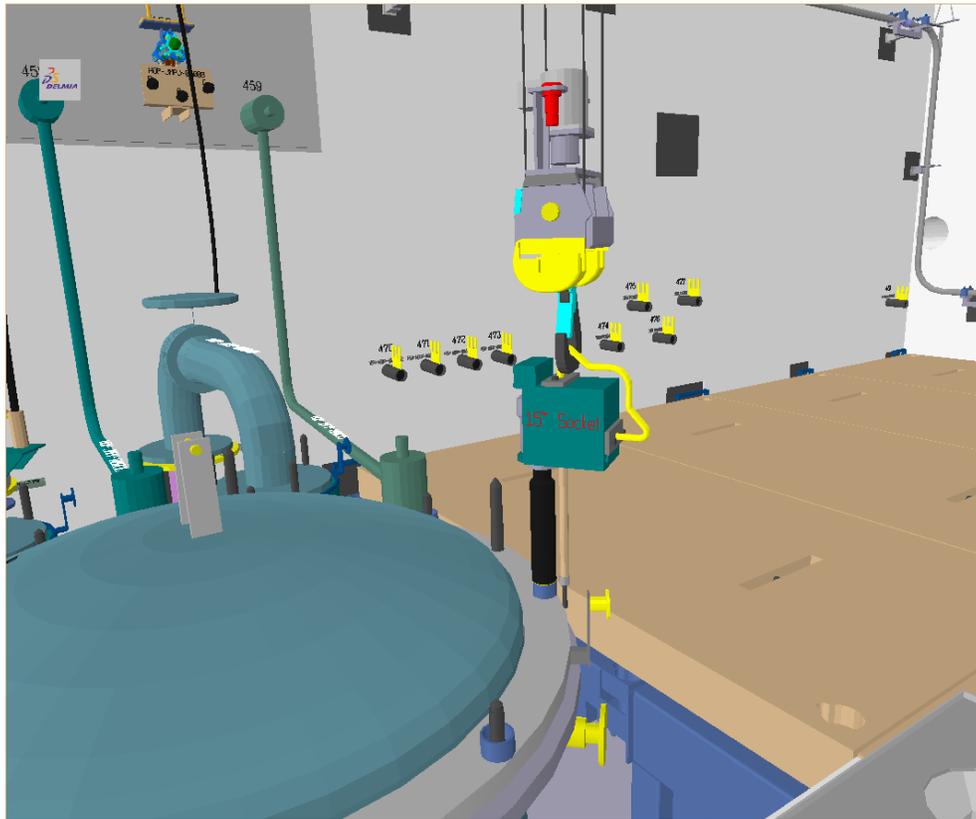
put this in perspective, the National Regulatory Commission recommends an annual dosage limit of 5 Rad above and beyond what one would normally be exposed to from natural background radiation. Due to the high level of radiation, the hot cells are closed off to human intervention. All access to the cells is handled remotely through viewing windows or cameras mounted in the cells or on the cranes. Special consideration must also be taken in choosing organic materials. All gaskets, o-rings, insulation, and cable jacketing must be chosen to withstand these high levels of radiation. BNI has also taken precautions in the design of the shield doors that separate the hot cell from the decontamination area and the decontamination area to the crane maintenance area to eliminate or reduce radiation shine paths. Human intervention is only allowed in the crane maintenance area after items have been decontaminated.

### **HSH MELTER CAVE**

The melter cave is designated as system HSH. There are several key processes that occur in the HSH cell that are necessary for vitrification and include: feed preparation, mixing, off-gas control, pouring, and cooling. In the feed vessel, silica and other glass-making materials are mixed with the waste, which is then heated to nearly 2,000 degrees Fahrenheit in a joule-heated melter. The melter runs constantly to prevent the glass pool from solidifying and is only stopped if it malfunctions and prevents normal operation. At this point the melter needs to be removed and replaced in order to mitigate impacts on the Pretreatment plant, which continues to produce HLW for processing. Both the feed vessel and off-gas controls must operate in conjunction with the melter to ensure its longevity. Air bubbles are pumped into the mixture to help mix the waste and the molten glass. Air is also pumped into the molten mixture within the discharge spouts causing the volume of the mixture to increase and overflow. This molten glass overflow is poured into large stainless steel canisters on a transport system in the pour tunnel below the cave. The melter has two spouts, which operate in an alternating manner. One spout pours while the other canister is cooling. After cooling, the canisters are moved to another location for lid weldment and decontamination. Each canister is two feet in diameter, stands 14.5 feet tall and will weigh more than four tons. They will be

temporarily stored at Hanford's 200 Area canister storage building. Eventually, the canisters will be shipped to an approved federal geological repository for permanent disposal.

The only process equipment located in the HSH cave is the melter, and its associated feed and off-gas vessels, and interconnecting pipe-work. The remainder of the equipment is aimed at maintaining these items, and keeping them running. All components within the cell must be remotely maintained. The melter, feed and off-gas vessels have been designed to permit in-situ maintenance to the greatest extent possible. All interconnecting pipe-work, electrical supplies, controls systems are remotely replaceable. Vessels containing pumps, agitators and monitoring systems as well as the melter containing thermocouples, agitators, cameras, air-lances and monitoring systems are also remotely replaceable. All items in the hot cells have lifting points that are accessible by various hooks or a manipulator hand. Any fastened component in cell can be remotely removed with impact wrenches or nut runners, see Figure 3. In total, there are over 1700 interface points for remote maintenance.



**Fig. 3. A demonstration of a remotely handled nut runner is shown above.**

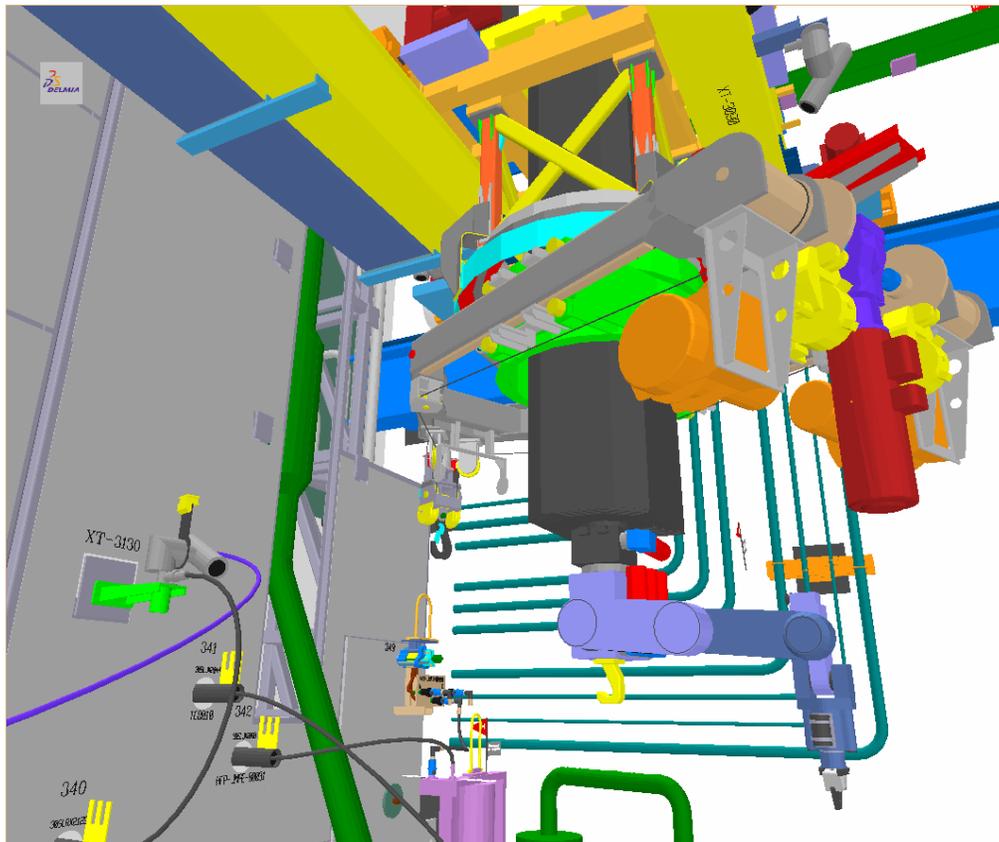
Items being removed are either maintained or discarded. The HSH cave has a large false floor that is level with the top of the melter. The false floor is a modular design such that it can be removed and provide access to equipment beneath. It also allows equipment to be laid down during the change-out process as close as possible to its destination. This eliminates down time so that a system can start running correctly again as quickly as possible. The old component can then be processed. Maintained items are typically decontaminated in the decon area, and repaired in the crane maintenance area.

Discarded items are typically size reduced to permit export in 55-gallon waste drums. The HSH system has a number of remotely operated tools (saws, plasma cutters, shears, disc cutter/grinder, hydraulic power pack, clamps, vice, local hoist, and weigh scales) that are used for size reduction. Additionally, there are house-keeping tools, such as integral and remotely deployed vacuum systems. All in-cave tools also require maintenance or disposal (e.g., the vacuum system has a collection bucket that has to be emptied and

each piece of in-cave pipe-work has to be remotely replaceable). The cave also features a number of viewing windows and through-wall manipulators (1 power manipulator and the rest master slave manipulators) to assist in the work.

### HIGH INTEGRITY CRANES

BNI awarded PaR Systems, Inc. a contract in May 2003 to design and build high integrity cranes with power manipulators to remotely maintain the HSH cells. Due to the cell's high level radiation, remote handling equipment provided by PaR Systems, Inc. is required for installation and removal of equipment in the HSH cell. The remote handling crane is composed of a double girder bridge and a trolley. The trolley supports a telescoping tubeset that rigidly deploys a seven degree of freedom TR 4350 manipulator arm with a one-ton hook to perform miscellaneous operations in cell. A single one-ton slewing (rotating) jib hoist that can extend and retract as well as rotate 270 degrees around the centerline of the telescoping tubeset is mounted to the bottom of the trolley [1], see Figure 4. The telescoping tubeset passes down through the center of the slewer structure. This allows the slewer to hold items that can be accessed by the manipulator arm below. The slewer design allows for the closest wall approaches. The slewer load blocks have power-rotating hooks for orienting equipment in the hot cell. The manipulator has both a parallel jaw hand as well as a hook hand that can be remotely exchanged in cell.



**Fig. 4. The slewing jib hoist and telescoping mast with manipulator is shown above.**

Both the manipulator and slewer are unique to this cell. The slewer jib hoist can reach into corners with its triangular shaped frame. The HSH manipulator has a shoulder, elbow, and wrist pivot, a shoulder and wrist rotate, and wrist cross pivot and extend abilities. The manipulator's cross pivoting wrist provides better operational dexterity and camera viewing angles at the end of the arm.

Historically, Important to Safety (ITS) functions came from the nuclear field to ensure no radioactive materials escape a plant or that the plant can safely shut down in an emergency situation. ITS components

have a higher degree of quality documentation, verification, and more extensive witnessing. These cranes were designed to several BNI specifications as well as Crane Manufacturers Association of America (CMAA) [2] and American Society of Mechanical Engineers (ASME NOG-1-2002) [3] requirements. In addition to these requirements, BNI dictated specific ITS mandates such as material certifications for all load path items, hoist high and high-high limit switches, overload protection, wire rope misreeving protection, redundant and independent hoist braking systems, drum overspeed detection system, and mast tilt indication switches. These various ITS functions were designed into the equipment to further ensure in cell safety and prolong the life of the equipment.

The cranes for all of the hot cells have been designed to maintain their integrity under seismic conditions. Bridge and trolley restraints have been implemented as necessary to resist uplift and lateral forces. The cranes have been modeled and run through finite element analyses to simulate the design earthquake conditions and confirm member stresses are acceptable. All connection joints have also been analyzed and designed to withstand these associated forces. Although the crane is not required to function after a seismic event, no part of the crane may fall during or after the event.

## **RECOVERY**

Not only does all of the equipment in the cell need to be remotely maintainable, but since no humans can go in or out of the cell, the crane itself must be able to recover from a single random or common mode of failure. All loads must be removable and the crane must be able to return to the crane maintenance area. To achieve this, all bridge, trolley, mast hoist, and slewing rotation, extension, and retraction drive trains must have recovery capability. All bridge and trolley drive trains have remotely deployed jackdown wheels to allow recovery should one of the wheel assemblies fail. All four corners of the bridge and trolley have motor driven wheel mechanisms. In the event that a powered or idler wheel seizes or the drive train fails, the jackdown wheels will deploy at the failed corner as well as at the same corner on the opposite rail. The other two corners will drive the bridge or trolley to a recoverable position. The jackdown wheel is mounted to an eccentric bearing and is deployed as it rotates into position. The manipulator hoist includes a recovery drum that will allow the hoist to raise or lower if the main hoist fails. Due to space constraints, there was no room for a recovery hoist in the slewer design. If the slewer load block gets caught or the hoist fails, a wire rope cable cutter will sever the line and free the slewer from the load block. The slewer rotate, extend and retract drives all have slip clutches in the drive train that allow the structure to be back driven into a recoverable position should the drive train fail.

Large diameter cable reels (up to 12 feet) will supply power, signal, and control to the cranes through two segregated cables. Each cable is approximately 2.5 inches in diameter. One cable is for power and the other is for signal and control to reduce signal interferences. Each cable contains its designated conductors as well as steel cords. These cords strengthen the cable to the extent that should the crane ever fail in cell, the cable reel will be able to retrieve the crane by pulling it back into the crane maintenance area. Prior to the crane entering the crane maintenance area where human contact is permissible, it must be decontaminated in the decontamination area.

## **PLANT DESIGN/OPERATION**

Since the crane functions will be operated remotely, the entire cell and crane have been modeled with 3-D software. Model simulations have been used to confirm operational and maintenance functionality and conduct timing studies throughout the design process. Plant designers can confirm or reject removal or installation of equipment processes and operators can obtain training to better operate the crane and handling equipment through these simulation trials. There is over 60 million dollars worth of equipment packed into the HSH cell. Making full use of the hot cell is critical to operations and plant designers. Wall approaches must be maintained to allow access to items placed close to or on the wall. The hot cells are filled to maximum capacity and space is limited, so the crane hook approaches are critical. Equipment was placed in cell according to these wall approach requirements.

The local operator interface is the operation center for the crane. The crane and other component functions are controlled here through joysticks and hand controls. The crane is viewed through an elaborate camera

system in the cell that allows the crane controller to see all aspects of the cell and the crane. In addition to the eight cameras on the power manipulator crane, there are another seven cameras mounted along the walls (three on the east, two on the south, one on the west and one on the north) plus six more on the overhead main crane. There is the possibility of a hook deployed camera and there are also three shield windows along the east wall and two along the west wall in the breakdown area. The total number of cameras in a melter cave is twenty two. Realistically, no more than about four will be used at any given time. There are twelve wall mounted lights and two through wall lights plus the lights on the power manipulator crane and four more on the overhead main crane. The total number of lights a melter cave is twenty two. These are normally left on unless the operator needs some shadow contrast, in which case they will be individually turned off.

## **CONCLUSION**

The DOE and BNI are committed to stabilizing the liquid radioactive waste at the Hanford site. PaR Systems, Inc. is committed to supporting this effort by providing high integrity cranes and manipulator systems to be used in the WTP HSH cell where human intervention is not possible. The hot cell and cranes have been designed to work in parallel to ensure the waste can be successfully vitrified in a timely manner. Through combined efforts between BNI and PaR Systems, Inc. the hot cells and cranes will remain functioning safely over the forty year life of the plant.

## **REFERENCES**

1. “High Integrity CMAA 70 Cranes with Power Manipulators, Quality Level II, Specification No. 24590-WTP-3PS-MJKG-T0004”, RPP-WTP, Bechtel National Incorporated.
2. CMAA 70, Crane Manufacturers Association of America, Inc., Revised 2000, Material Handling Industry.
3. ASME NOG-1-2002, Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder), An American National Standard, The American Society of Mechanical Engineers.