Automation and Robotics in Construction X
G.H. Watson, R.L. Tucker and J.K. Walters (Editors)
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# Automatic Machine Welding of the Primary Circuit of the Sizewell 'B' Nuclear Power Station

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**Abstract**

GEC Alsthom Engineering Systems, who were required to weld the Main Loop Pipework as part of their Mechanical Erection contract on the Sizewell 'B' PWR, were approached by its Client to make a significant reduction in the programme schedule for this particular task. This paper will describe how, following a detailed assessment of the process, a change in approach from manual to machine welding enabled a successful acceleration of the programme schedule to be achieved.

## 1. INTRODUCTION

Sizewell 'B' Nuclear Power Station in Suffolk, England, is Britain's first PWR to be constructed. GEC ALSTHOM Engineering Systems (GECA-ESL), a member of the European Construction Institute, was awarded a contract in 1989 for general mechanical installation of the Nuclear Island Plant which included in the scope a requirement to install the Primary Circuit Components.

Sizewell 'B' is a 4 loop PWR with each loop requiring a total of 8 field welded joints to connect the Steam Generator and Reactor Coolant Pump to the Reactor Pressure Vessel, and 7 field welds to complete the Pressuriser Surge Line. The original GECA-ESL approach was to use traditional manual methods to complete the 39 field welds in the original programme schedule of 45 weeks.

## 2. THE TASK

The joint type used for the loop was a compound angle, single sided 'J' prep (see Fig. 1) with weld configurations in the horizontal position (8 total), vertical position (16 total) and 45 degree position (8 total). The pipe/nozzle sections were nominally 38 inches diameter with wall thicknesses of 3½ to 4" for the main loop welds and 14" diameter, 1¼" wall thickness for the Pressuriser Surge Line. The materials involved were forged pipe sections in 304LN and castings in CF3 with 308L weld filler material.

The welding and inspection had to satisfy the ASME Code Sections III and IX, the requirements of which were supplemented by additional criteria defined in the customer specification. The main impact of this was to require the performance of additional procedure qualification tests and an enhanced NDE programme.

The NDE requirements were particularly demanding. The ASME code specifies a liquid penetrant (LT) and radiographic examination (RT) of the finished joint, this customer also required ultrasonic examination (UT). These needs, coupled with those of progressive examination as the welding progressed, resulted in the following NDE programme being applied to each joint:

a) Cleanliness check and 100% LT of all weld preparations
b) 100% LT of the Root and Hot Pass
c) At 25mm depth of fill a 100% LT and RT
d) At 50mm depth of fill a 100% LT and RT
e) On completion of the joint the surface was machined and ground to give a surface finish of 250 CLA and flatness of 0.5mm in 50mm, followed by 100% LT, 100% RT and 100% UT. An extremely rigorous set of criteria.

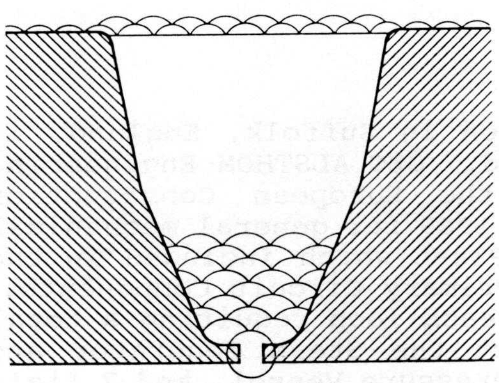

**Fig. 1**
**Joint Configuration and Weld Bead Placement**

**Approx. 190 passes per Butt**

## 3. THE MOVE TO MACHINE WELDING

In July 1990 GECA-ESL were asked to examine the possibility of reducing the programme timescale in order to accelerate this part of the overall site schedule within the Reactor Containment Building. A revised timescale of 24 weeks was identified as a target. Following a detailed review of the position it was clear that one possibility for securing a reduced programme was the adoption of a mechanised approach to the welding operations. The longer arc times, reduced operator fatigue, repeatability, and cleanliness offered the potential benefits of higher overall deposition rates with reduced repair levels, thus matching the task needs.

The limited timescale available for the review, validation and approval of a revised method and procedure, and the probable requirement for a significant amount of equipment to support the revised schedule, led GECA-ESL to seek out companies with previous experience of this type of work. In December 1990 PCI Energy Services were contracted to demonstrate suitable equipment at the GECA-ESL facility at Leicester, England. This demonstration proved that the mechanised Gas Tungsten Arc Welding (GTAW) process could cope with the maximum joint gaps and mis-matches and the detail inspection of the completed demonstration weld produced acceptable results.

Following this successful demonstration, PCI were further contracted to provide equipment and manpower to conduct a complete Welding Procedure Qualification (WPQ) at the GECA-ESL Leicester facility. The purpose of the WPQ was to prove that the welding process and procedures would achieve the strict quality requirements imposed by Nuclear Electric, the owner/operator of Sizewell 'B'. The WPQ was conducted on two complete assemblies from pipe test pieces cut from the actual contract pipe. One test piece was welded in the horizontal position, the other in the vertical position. The test pieces produced were also used to manufacture the U.T. test blocks, required to prove the UT inspection procedures.

The opportunity was also taken at this time to obtain information on other processes associated with the weld which were to be used later at site. Site cleaning procedures were developed and tested to ensure that the joints would be chloride free prior to fit-up. Punch marks were located on both sides of the weld prep and dimensions were recorded in order to gauge shrinkage as the joint was welded. This information was necessary to ensure that the accurate fit-ups required at site could make appropriate allowance for weld shrinkage.

The WPQ was also used to verify welding NDE and equipment set up times to assist in the eventual preparation of a detailed site schedule.

Following satisfactory completion of the WPQ, GECA-ESL decided to adopt the process for Sizewell 'B' and contracted PCI to provide the welding service at the site.

## 4. EQUIPMENT DESCRIPTION

The mechanised GTAW pipe welding system provides the capability for joining all types of metal and tubing assemblies to the most critical requirements. The system consists of a power supply with integral programmer, weldhead, track and control pendant.

The power supply used was a standard Dimetric Gold Track II modified by PCI to output 300 amperes welding current. Along with housing the power source for welding, it also houses motor servos, motor power supplies, a water cooler, recirculation pump, output gauges, cooling fan, dual gas solenoid and bulkhead connectors. The approximate physical size is 18" wide x 60" long x 36" tall. The weight is about 415 pounds. There are no operational controls on the power supply. All are located at the remote control pendant which allows the real time control of welding parameters at the location of the weld.

The following functions are programmable to obtain maximum quality and repeatability; carriage travel speed; wire feed speed; automatic voltage control (torch height control); torch oscillation speed and width; and primary and background welding current.

The weld head or carriage is a specially modified Dimetric 'F' head. The weld head is driven by means of a high torque DC motor and drive rollers mounted in the track assembly which is clamped around the pipe circumference. Mounting of the weld head is accomplished by placing it on the track and tightening the latching arm which compresses the head to the track and engages the drive mechanism. The mounting procedure takes less than 5 minutes.

The mounting track assembly is designed to separate into two halves that are joined by two captive socket head screws. Centering and clamping screws are provided on the track to allow for minor variations in pipe concentricity and to firmly clamp the track to the pipe. Depending on the circumference of the track, more than one weldhead may be used on the same weld joint. The mounting tracks used ranged from 42 to 50 inches. The oversized tracks relative to the pipe OD (33.5 to 38 inches) allowed for equipment clearances when mounting on an elbow. Fig. 2 shows a general view of the equipment set up on a pipe.

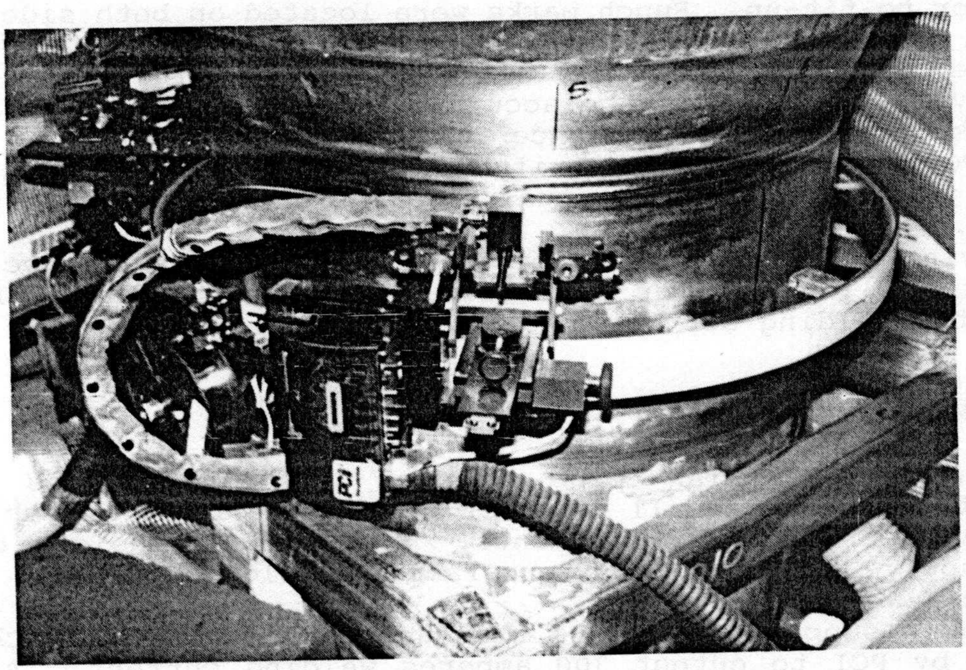

**Fig. 2 Typical Equipment Set Up in the Horizontal Position**

The completely equipped carriage weighs 15 pounds not including the service cable. The carriage produces sufficient torque to lift up to 80 pounds of added load while maintaining the specified speed to within 1%. The radial clearance of the weld head varies with the size of track, torch and wire nozzle configuration, and the depth of the weld groove. With special set-ups, it is possible to reduce the radial clearance down to 2 inches. The motorised cross adjustment and width is enclosed in the weldhead carriage and is capable of oscillating the weld torch up to 1¼". The Automatic Voltage Control (AVC) assembly is mounted on the front of the weldhead carriage. This unit carries the water cooled torch block with gas lens, gas cup, tungsten and wire manipulators.

A special 10 pound cold wire feed unit is also attached to the carriage. This design keeps wire spool changes to a minimum while its low profile is advantageous when working near obstructions. Cable extensions allow for weld head operations up to 250 feet from the power supply.

## 5. ADAPTIONS MADE FOR SIZEWELL 'B' USE

There were several key equipment challenges that had to be addressed before welding could begin at Sizewell 'B'. First, the joint configuration used had a relatively tight included angle. While this benefitted overall production rates, it made the first 1/3 of the weld difficult to complete with a standard equipment configuration. PCI designed and built a special AVC assembly that had 4 inches of usable stroke. Since the loop piping was less than 4 inches in wall thickness, no AVC adjustments were needed throughout the entire weld other than adjusting the torch tilt. Additionally, the wire manipulators on the torch assembly were threaded their entire length to eliminate the need to change this part as the weld progressed.

Purging the inside of the weld joint was another problem that needed to be addressed. Because of parallel activities within the reactor vessel, no argon could be allowed to enter the vessel. Normally purge dams would be installed to cover the entire pipe cross section. However, as it was essential that a ventilation system be installed in the pipe to vent argon safely, another solution was developed. PCI designed and built special lexan purge chambers that only encapsulated the weld area. These devices were in the shape of a ring that allowed air to flow past them yet maintained the argon purge on the weld area. This system maintained a less than 1 percent oxygen content in the weld area but allowed free access to piping, Reactor Vessel and Steam Generator channel heads.

To cope with minor breakdowns, a modular system of spare components was utilised. The four main components to this were the weldhead carriage, wire feed assembly, AVC assembly and the power supply. If any one of these sub-assemblies broke down or needed maintenance, they could be detached within a matter of minutes and another one installed into the system.

## 6. THE SIZEWELL 'B' APPLICATION

The welding activities on the Sizewell loop were scheduled to take place during an intense period of overall construction activity inside the Reactor Containment Building and a very detailed programme schedule integrating all the installation, setting, welding, inspection and cleaning activities on a day to day basis was drawn up before work started. This reflected a revised target for completing the welding of 24 weeks.

To meet this demanding production schedule four butt welds needed to be welded simultaneously with all work activities carried out on two shifts. With two welding systems on each joint this meant a minimum of eight systems had to be running at all times.

Altogether, twelve systems were staged inside the Containment Building allowing the technicians to install welding equipment not in use on the next available butts as they were released from setting up by GECA-ESL, thus minimising welding down time due to equipment change over. It also allowed for a contingency in case of equipment failure. Because of the lack of space in Containment during construction, special racks were fabricated to stack power supplies two high. The equipment was staged adjacent to the Reactor Vessel in the bottom of the refuel pool. Extension cables were routed through the primary shield wall to the weld areas.

To handle the volume of argon shielding gas that was needed a liquid cryogenic system was used. Containers that held approximately 4000 cubic feet were staged inside Containment near the welding power supplies. A manifold system was connected to the liquid argon container and hoses routed the proper amount of gas to each welding system in use.

Once the fit-up was completed and dimensional surveys recorded, it took an average of one shift to set up the machine welding equipment. After equipment set-up and tacking, welding of the root pass commenced. This activity took about one-half shift. Quality Control would then be called to inspect the root pass visually, then LT the outside of the root. With acceptance verified, welding continued to the 25mm stage. This usually took approximately two shifts. Radiography then took place in the two hour gap between shifts and the film was read as soon as it came from the processor. Again, after the review was completed, welding re-started. The next inspection hold point was at the 50mm stage. Reaching this stage was normally accomplished in four more shifts. The timescale from 50mm to completion varied depending on which part of the piping system was being worked on. Welding to completion of each butt from this stage varied in time to complete from 10 to 18 shifts depending on the actual thickness of the pipes being welded.

Shrinkage was a variable closely monitored. Once the fit up was achieved, data base line marks were vibro-etched onto the pipe on each side of the weld joint. The measurements were recorded in the Quality Control Records for each particular weldment. The actual shrinkage measurements ranged from 7.5mm to 12.5mm after completion of the weld.

Records of the actual welding parameters and bead placements were kept by the welding operators in the work areas. Since several welding operators worked on each joint, their work needed to be tracked for baseline information. The weld log contained information such as Weld Number, Weld Procedure Specification (WPS), Bead Number, Layer Number, Pulse Arc Setting/Sync. Pulse Setting, Amp/Volt Settings, Wire Speed and Travel Speed setting along with the Welders Identification Number. There was also a map of the weld groove that contained the actual placement of the bead. Each bead was numbered on the map to tie this to the Weld Log and there were approximately 190 beads per weld. Such a detailed record needed to be kept so that any defects discovered by the several inspection methods could be compared to the welders log as an aid to determining the cause.

In order to meet daily production goals a great deal of effort went into the close co-ordination of the various groups undertaking component installation, joint set up, equipment movement, welding, inspection, cleaning, grinding, safety and access control to ensure that the overall programme schedule was maintained.

At the peak of the welding activity a total of approximately 72 people were directly involved in the Loop welding operation and services, which included some 28 staff from PCI supporting the welding activities.

In liquidating the work on the 32 large diameter welds associated with Pressure Vessel, Steam Generators and Main Coolant Pump loops, approximately 2,500 pounds of welding wire and 640,000 cubic feet of argon were used.

## 7. RESULTS ACHIEVED

The first butt to be welded was tacked up on schedule on the 7 October 1991 and the final butt weld was completed ready for final radiography on the 19 February 1992, giving an overall duration of 20 weeks, some 4 weeks inside the original timescale of 24 weeks.

The incorporation within this time frame of the numerous inspection hold points and the application of an average of 40 man hours worth of internal and external scanning of each joint was in itself a major success.

In total over 53,000 linear feet of weld bead was laid into the Primary Circuit and Surge Line welds resulting in 270 linear feet of completed weld. Throughout the programme ultrasonic testing detected defects requiring repair in only some 18 feet of completed weld.

## 8. CONCLUSIONS

The basis for the successful outcome of this project, as in most others where a mechanised process is to be used, was the careful attention to:

a) The selection of appropriate well proven processes and equipment
b) The careful attention to detail and planning of all supporting requirements for the operation
c) The extensive training of all personnel involved to ensure the achievement of the highest levels of productivity and efficiency

The project has been, we believe, a good example of the application of an applied mechanised welding system to solve what was a complex construction problem in terms of the timescales, locations, inter-relationship of activities and the levels of reliability required to deliver the schedule requirements in these testing circumstances.

I would finally add that the success was also due in no small measure to the will of all involved in this Anglo-American venture to make the project succeed.