# STATUS OF WELDING FOR POWER PLANT FACILITIES

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**ABSTRACT**

The welding technology for production of power plant facility as for other industries has been progressing forward automation and mechanization for cost reduction and shortening of cycle time. The welding for boiler tube is automated or mechanized as the parts and subassemblies of tubes are conveyed automatically in the shop. The temperature of boiler steam is being progressively increased for higher plant efficiency. The welding of nuclear component is characterized by heavy thickness and narrow gap Submerged Arc Welding. Narrow gap Gas Metal Arc Welding and Electron Beam Welding is applied to turbine diaphragm. To improve the resistance of solid particle erosion of turbine blade and nozzle partition, HVOF spray technology and boriding process has been applied.

**KEYWORD**

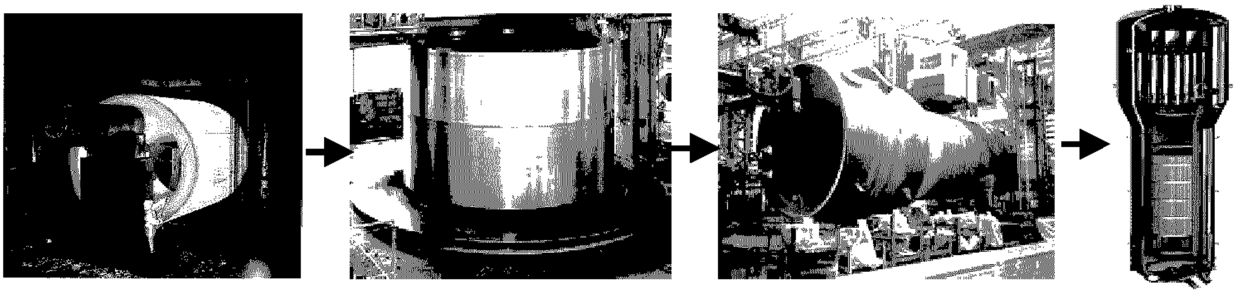
Power Plant, Boiler, Turbine, Nuclear Power Plant, Narrow Gap Welding, Laser Brazing

## 1. Introduction

In Korea, localization of manufacturing of power plant facility has been progressed since late 1970's. Supply of the whole components of fossil and nuclear power plant became possible by domestic manufactures. Welding is one of the key operations in manufacturing and installation of power plant facility, and Doosan has accumulated various experience over thirty years in this area. The welding process and method being applied to production is introduced herein.

## 2. Casting and forging

Castings and forgings are being produced in Doosan. Forged shell, head and nozzle for nuclear component are major products to be welded in fabrication. The classification is ASME SA508 Cl.3(0.75Ni-0.5Mo-Cr-V) which has good weldability and toughness. Fig. 1 shows the manufacturing sequence of forged shell.



(a) Ring Forging (b) Machining (c) Welding (d) S/G

Fig. 1 Manufacturing process of steam generator for nuclear power plant

### 3. Boiler

Doosan has manufactured boilers of 15,328MW(52 units) since South Jeju power plant which was commissioned in 1980. Through this experience, it has possessed the capability of own design and manufacturing technology. To improve plant efficiency, the temperature of steam is being increased progressively from 538℃. Table 1 is a typical material selection according to steam temperature. As the steam temperature is higher, the material with advanced high-temperature characteristics including weld metal and HAZ shall be used.

Table 1 Material selection according to boiler steam condition

| Operating Condition / Boiler parts | Main Steam Temperature | | | |
|---|---|---|---|---|
| | 538℃ | 566℃ | 593℃ | 621℃ |
| Header & Main Steam Pipe | P22, P91P92, P122 | | P91, P92, P122 | P92, P122 |
| Super heater tube | T91, 304H347H | | Super 304H | Super 304H |

In manufacturing the boiler, the main welding operations are tube butt welding, panel welding, nipple to header welding and coil assembly welding. Followings are typical welding practice being used in the shop.

#### (a) Straight Tube Butt Welding

Tube moved by conveyor is welded automatically and it is examined by radiograph in next stage.

- ▶ Welding process : GTAW
- ▶ Tube size
  : O.D ø 38.1~63.5mm
  : Thickness 3.8~8.6 mm

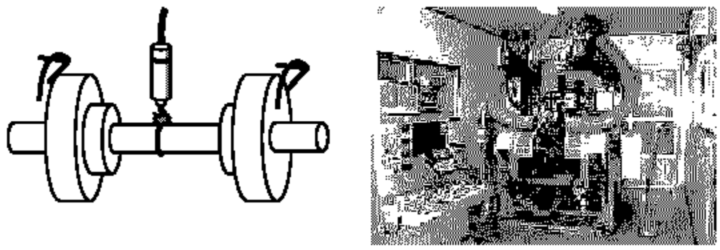


Fig. 2 Specification of straight tube butt welding

#### (b) Panel Welding

Tube and fin on conveyor is welded through the welding machine and automatically turned over and stored.

- ▶ Welding process : SAW
- ▶ Welding head : 6 Torch
- ▶ Tube size
  : ø28.8~76.2mm
  : Length Max 21,000mm
- ▶ Panel width : Max 1,500mm

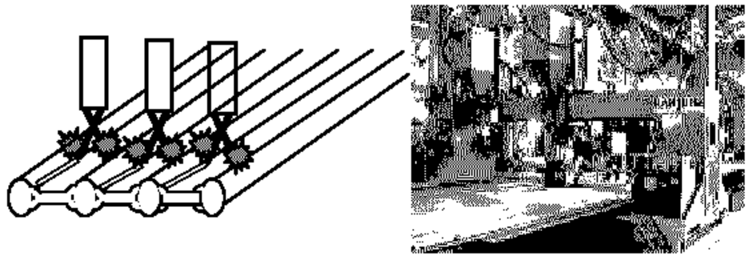
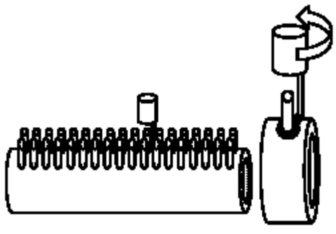


Fig. 3 Specification of panel welding

**(c) Nipple to Header Welding**

Tack welded nipple on header is welded automatically and continuously.

- ▶ Welding process : SAW
- ▶ Pipe size
  : O.D. ø150~900mm
  : Thickness 15~80mm
  : Length 2,000~20,000mm
- ▶ Nipple size
  : O.D. ø20~80mm
  : Length Max 200mm



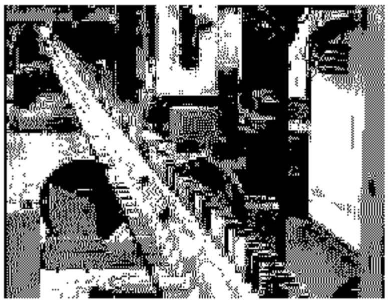


Fig. 4 Specification of nipple to header welding

**(d) Coil Assembly Welding**

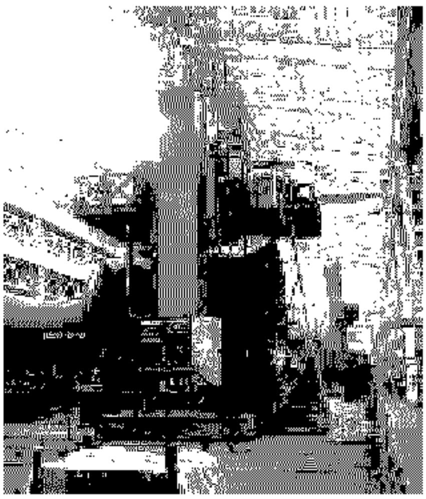
Butt welding of bent tube is done by GTAW orbital or manual GTAW method.

**4. Nuclear**

11 units of nuclear power plants have been constructed and 6 units are under construction since Yonggwang unit 1 and 2. Localization of manufacturing technology for nuclear power plant is completed by reactor vessel internal and control element drive mechanism(CEDM). Shell girth seam welding and overlay cladding is introduced herein.

**(a)Shell Girth Seam Welding**

Narrow gap SAW process is applied to shell girth seam welding of max. 280mm thickness. Groove angle with max. 2°, 2 pass and 1 layer technique is used. To shorten cycle time in heavy thickness welding, narrow gap welding is an effective way. However, precise seam tracking and good slag removability is required to get a sound weld. And also, preheat maintenance and post heating is strictly controlled to prevent hydrogen induced crack.



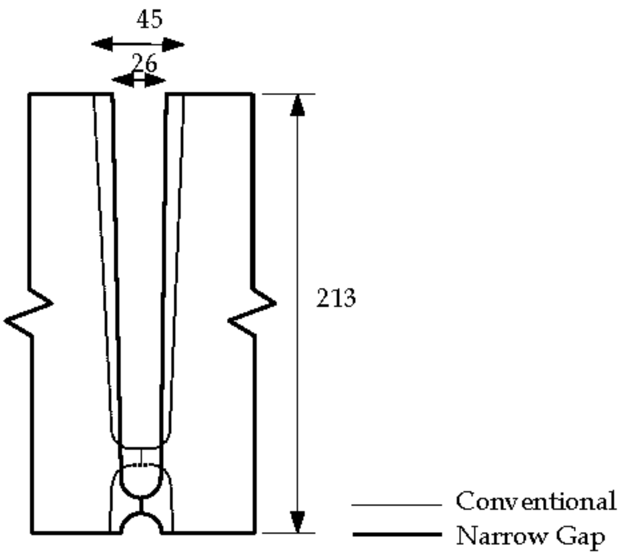



Fig. 5 Shell to shell welding and typical groove shape

**(b) Overlay Cladding of Shell and Head**

The inside of shell and head are is corrosion resistance overlaid to have composition of stainless steel 304L and ferrite content over FN. 5. The overlay cladding is completed in 1 layer by SAW using strip of 60 ~ 100mm width. In order to satisfy chemical composition, ferrite number and minimum thickness by 1 layer, strip and flux and welding parameters, such as current , voltage, stick out, welding speed, overlap, offset are selected considering with dilution with base material and alloy pick up.

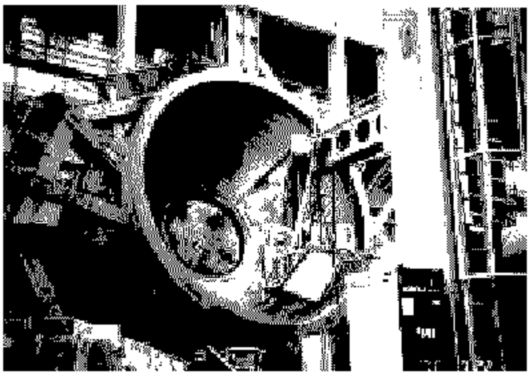


Fig. 6 Inside cladding by SAW

**(c) Overlay Cladding of Tubesheet**

Tubesheet of steam generator is overlaid with Inconel, the same material as tube. Inconel 600 had been used until substituted with Inconel 690 which has improved stress corrosion crack resistance during operation. For Inconel 600, SAW using strip was applied. Hot wire GTAW had been used for Inconel 690 until strip and flux for this material was developed. Selection of proper welding material and process is critical for this operation to prevent weld metal crack.

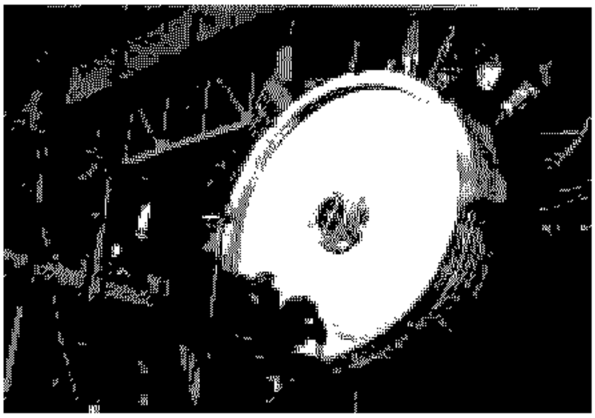


Fig. 7 Tubesheet cladding by SAW

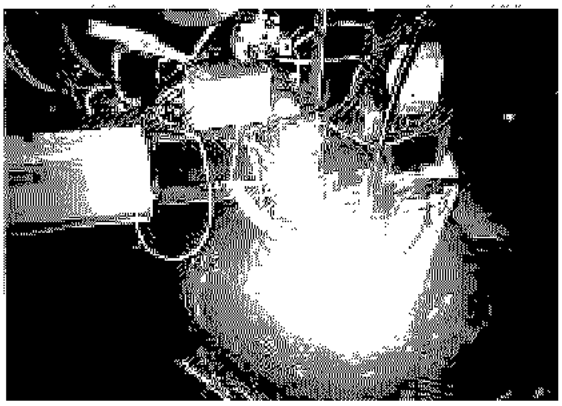


Fig. 8 Tubesheet cladding by hot wire TIG

**5. Turbine and Generator**

Doosan has achieved localization not only boiler and nuclear steam supply system(NSSS) but also turbine and generator. The welding process to fabricate turbine diaphragm, and surface treatment process to prevent various wear would be introduced.

**(a) Turbine diaphragm main seam welding**

Diaphragm is a complex structure assembled with several parts that are different size and materials as shown in Fig. 9. To minimize weld shrinkage and distortion is an important point for this component.

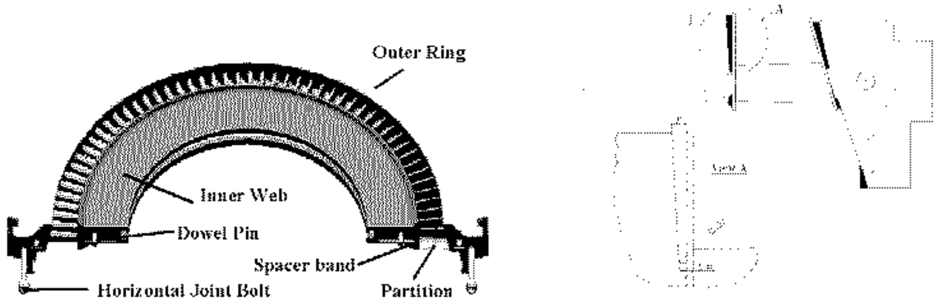
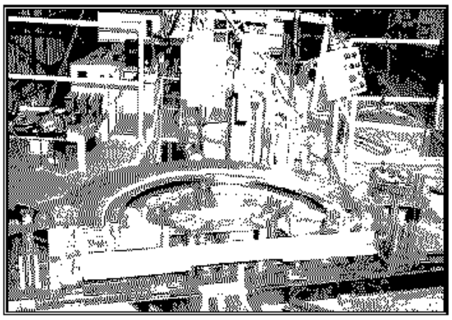



Fig. 9 Cross section of turbine diaphragm

Satisfying this characteristic and also for cost reduction, a specially designed narrow gap welding equipment which can be applied to 5.4mm gap, is developed groove design and the equipment are shown in Fig.10. Additionally, R&D about the electron beam welding(EBW) technology to fabricate diaphragm is progressing.



| Description | Technical specification |
|---|---|
| Groove design | Root gap : 5.4mm<br>Groove angle : 3˚ |
| Welding process | GMAW |
| Electrical characteristics | Pulse(ALC function) |
| Sensing method | Mechanical |

Fig. 10 System and technical specification for narrow gap welding of diaphragm

**(b) Surface Treatment**

Turbine valve components, bucket and partition of diaphragm is damaged by foreign object in steam. To prevent this type damage, ion nitriding, boriding and HVOF spray process is applied. Ion nitriding is to give smooth moving of the valve component(stem, bushing, shaft and etc.) and boriding is applied at 1$^{st}$ stage nozzle of HP turbine. HVOF spray process has merit that heating of product isn't needed and is applied at nozzle partition and bucket of HP and IP turbine. Fig. 11 is solid particle erosion according to impact angle of solid particle and various surface treatments. Surface treated conditions are shown good erosion resistant characteristics comparing with uncoated condition.

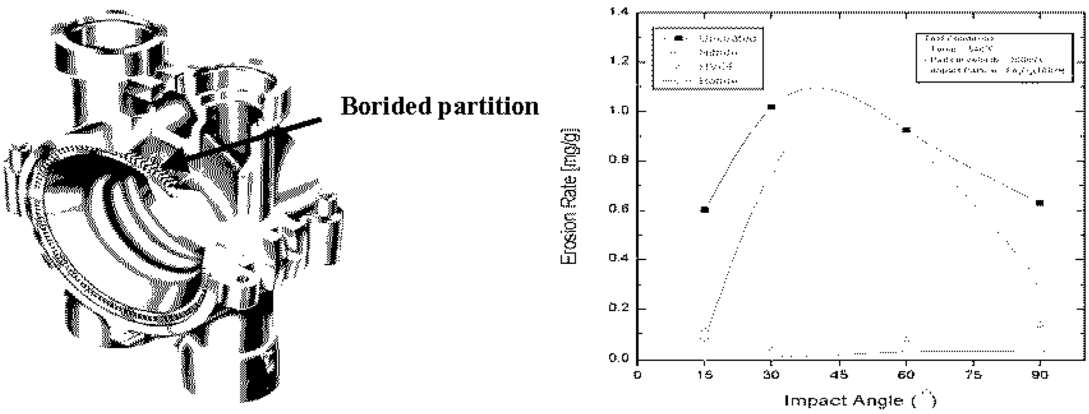



Fig. 11 Shape of nozzle box and Erosion characteristic according to Surface treatment and impact angle

**6. Installation and maintenance**

Installation works at erection site and repair of damaged parts require a special equipment or technology due to limited accessibility. Several examples are introduced herein.

**(a)Omega Seal Welding of CEDM**

CEDM, shown in Fig. 12, are installed at erection site. As the weld joint is prepared very precisely by machining, failure of the first welding and rewelding incur various problems. To avoid it, sufficient mock-up test for procedure development and operators training are necessary before application.

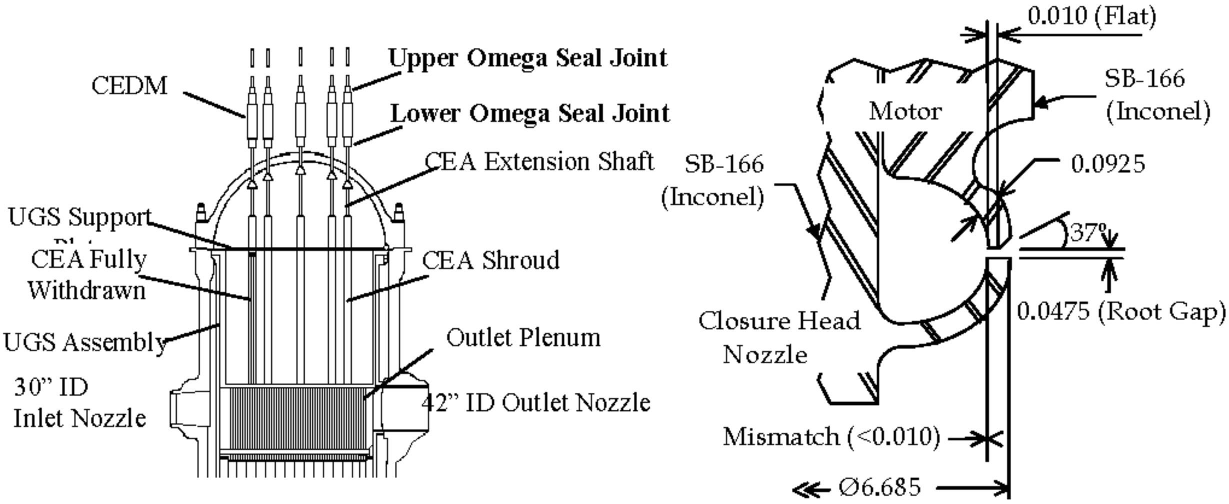
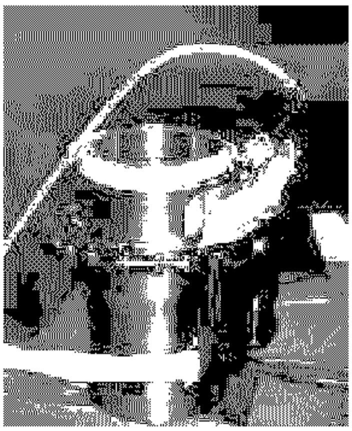



Fig. 12 A schematic diagram and joint detail of omega seal welding



| Description | Technical specification |
|---|---|
| Welding Process | Programmable Orbital TIG Welding (Machine) |
| Wire | Ø 0.035in.(0.9mm) |
| Inside Purging | Argon gas using a small needle |

Fig. 13 Mock-up test of omega seal welding

**(b) Replacement of ICI Tube**

This case is replacement of ICI tubes at an operated nuclear power plant. GTAW orbital process without filler metal was applied on square groove for full penetration. To get uniform penetration and bead shape, minimizing the effect of welding heat, it was required to adjust welding parameter differently on each quarter circumference.

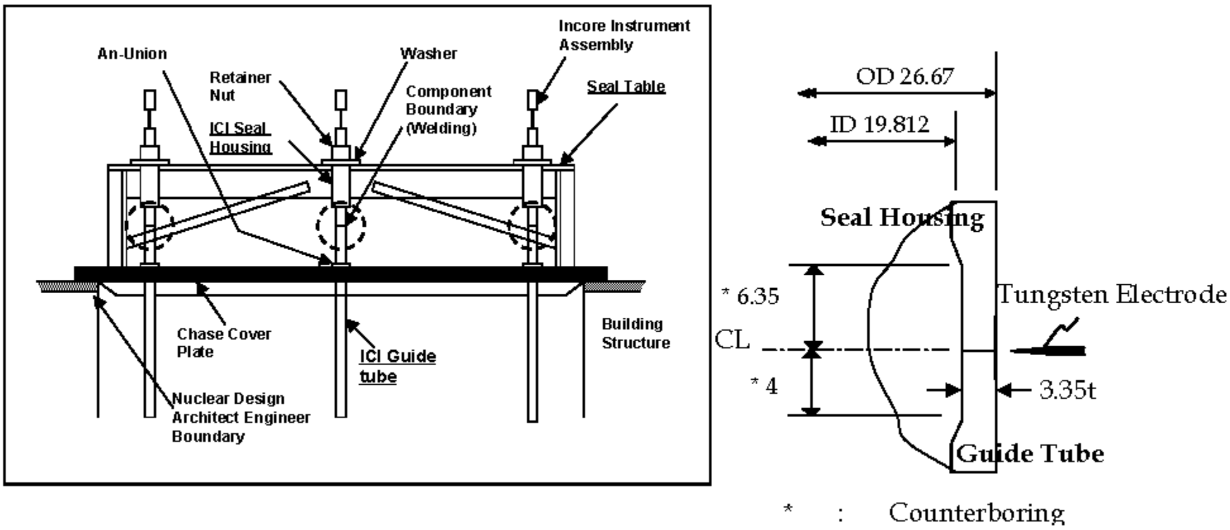
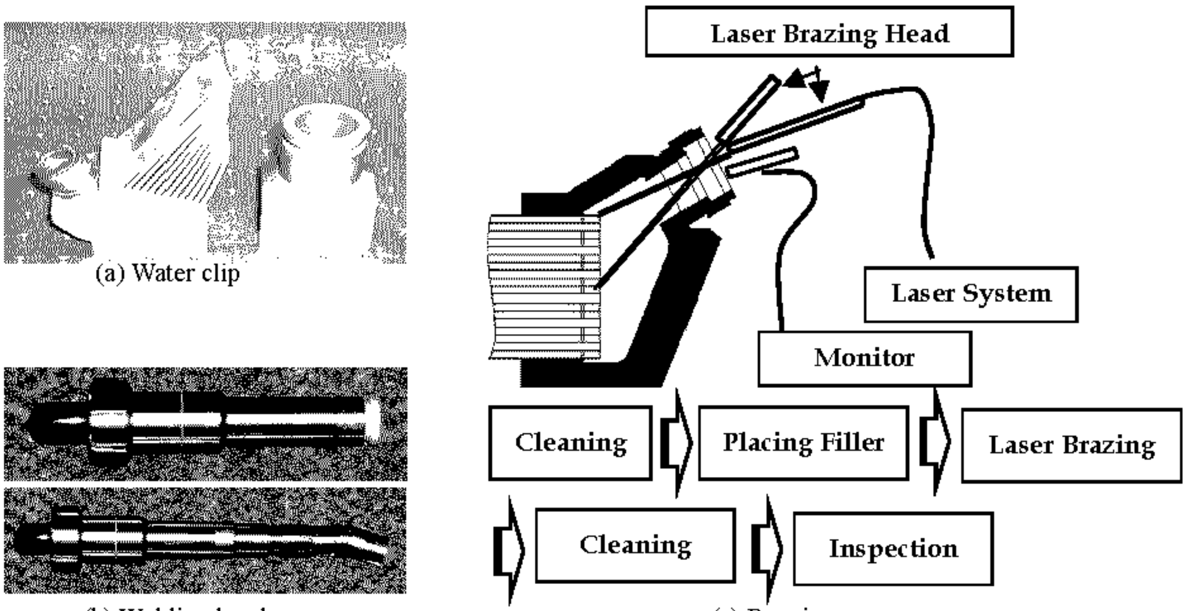



Fig. 14 ICI assembly and joint detail

**(c)Repair Technology for Generator Water Clip Leaks**

The water clip made of copper on the generator is assembled by furnace brazing at shop. After long term operation, the brazed joint would be damaged and result in cooling water leak. Because repair by GTA brazing incurs melting of insulation caused by high heat input, new technology using laser brazing which has high density and low energy is developed. Fig. 15 shows the equipment and the sequence of process.




(a) Water clip

(b) Welding head

(c) Repair process

Fig. 15 Water clip, welding head and repair process

**7. Future works to be developed**

Full automatic welding for heavy wall vessel, ultra narrow gap welding, expanding application of high density welding such as laser and electron beam, development of optimum welding procedure for new materials will be future works to be developed in power plant industry.