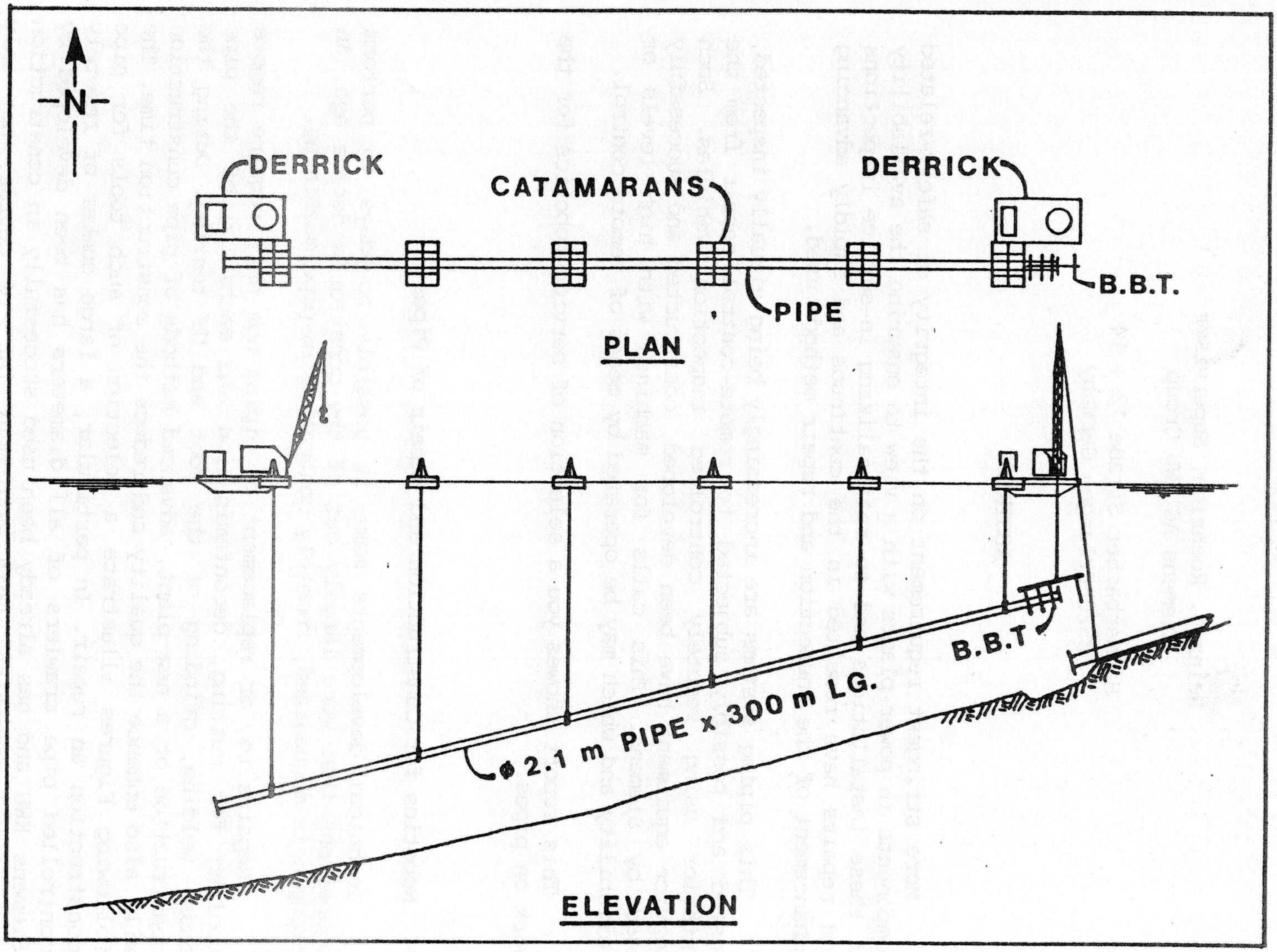

FIG. 4. – LOWERING THE PIPE

ROBOTICS FOR CONSTRUCTION AND MAINTENANCE OF PIPES

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ABSTRACT

More stringent requirement on the integrity of safety-related components in power plants with a view to ensuring the availability of these installations and to rationalizing in-service inspections and repairs have resulted in the continuos and rapidly advancing enhancement of the inspection and repair methods used.

This piping systems are increasingly being visually inspected, tested and possibly subjected to remote-control repair from the interior using remotely controlled inspection vehicles. Such service equipment have been developed, constructed and successfuly used by Siemens. This calls for machines with high levels or reliability and which may be operated by means of remote control.

This report showes you a selection of service robotics for the work on pipes.

1. Robotics for Construction and Repair of Pipes

Technical developments make it possible nowadays to perform operations that were largely out of the question a decade ago. An example is mechanized, remotely controlled in-pipe machining.

Repairs to, or replacement of piping not only require remote tooling for cutting, decontamination and machining of the pipe ends, welding, grinding of the root and UT testing. During the construction of a new plant, advanced methods of pipe construction will also enhance the quality and reduce the construction time. The following Figures illustrate a selection of such tools for pipe construction an repair. In particular, a large number of remotely controlled pipe crawlers of all diameters has been developed by Siemens KWU and has already been used succesfully in construction and repair operatios. This equipment ist, of course, not only indispensable for all kinds of work on nuclear pipping; it may also be put to advantageous use on conventional pipping.

1.1 Piping Erection

Equipment for pipping erection is designed to rationalize the various processes on the one hand and to satisfy the exacting quality requirements on the weld and weld preparation at joints on the other. This applies particularly to the maximum permissible offset. The equipment available is designed primarily for nominal diameters (DN) ranging from 7,87 in to 39,37 in.

1.2 An Inpipe Clamped Turning Machine (Fig. 1)

These portable turning machines are chiefly used in the local machining of pipe and elbow ends (legless elbow ends), nozzles on valves or vessels, sealing faces on manholes etc.

Machining may be performed both radially and axially to the component axis, the tool rotating about the stationary component.

The machines are assembled from the following units, which may be manually transported preferably when access is problematical and when the machining area is not equipped with suitable lifting gear.

- Hydraulic clamping unit to clamp the turning machine at right angles and centred with respect to the component axis, together with flexible tubing, and hand pump with pressure gange.

- Basic unit with rotor. The turning arms are fixed to the rotor.

- Turning arms. One turning arm performs radial machining, the second attachable arm performing axial machining of the component.

- Drive unit mounted via a spline connection to the basic unit, for driving the rotor.

- Mechanical auxiliary unit for jigging the hydraulic clamping unit in the component (4 jaw chucks with centring mandrel and flange).

To cover nominal diameters ranging from DN 7,87 in to DN 47,24 in, three machines sizes are available as follows:

Turning machine I for nominal diameters DN 7,87 in to 15,75 in
Turning machine II for nominal diameters DN 15,75 in to 25,60 in
Turning machine III for nominal diameters DN 25,60 in to 47,24 in

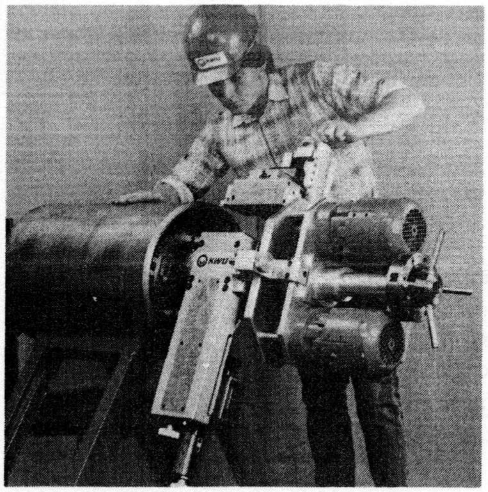

Fig. 1 In-Pipe Clamped Machine

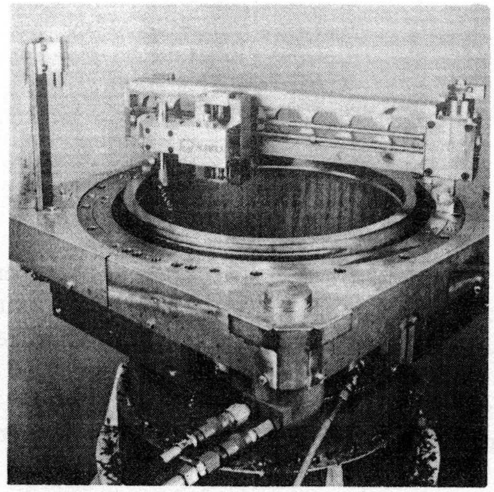

Fig. 2 Out-Side Clamped Machine

1.3 Outside Clamped Lathe-machine (Fig. 2)

As an alternativ to the outside clamped lathe-machine the inside clamped type can be applied. The advantage of the outside clamping type is their possibility to cut closed pipping systems.

The transportable lathe-machine consists of a rotor and a stator. The stator is connected to the pipe by clamping elements. the rotational part serves for fastening the lathe steel or other machining fools. The rotor arme is achieved by hydromotors arranged in the stator.

Our lathe-machines are applicable for diameter range from 7,87 to 47,24 in. However different types respective sizes of machines are necessary for this large range.

1.4 Pipe Machining and Inspection

Pulsed orbital gas tungsten arc welding (GTAW) is so advanced that all out-of-position weld can be successfully performed under site conditions.

Mechanization of the welding process largely eliminated the problems involved in manual welding, where the quality of the weld depends on the welder's skill and efficiency, and resulted in the development of the remotely controlled orbital welding head. Thus the basis had been provided for mechanized, remotely controlled in-pipe welds.

The development of extremely small, vibration and temperature-resistant TV camera systems was an essential prerequisite for the successful use of remotely controlled pipe machining equipment.

1.5 External Pipe Welding (Fig 3)

The mechanization of gas tungsten arc welding (GTAW) for out-of-position pipe welding resulted in the development of orbital welding heads which are mounted on a crawler and which move around the pipe. The method selected was pulsed directcurrent GTAW. The associated precise control of the heat input also makes it possible for out-of-position welding. e.g. root welding, to be corntolled very effectively.

In mechanized pulsed GTA welding with its relatively low meld-off rate, increased significance is attached to the joint geometry and with since this determines the quantity of welding material required. The welding volume is directly related to the welding time, which in turn accounts for a major proportion of the production time and hence production cost.

Consequently, the experience gained with narrow-gap welding in terms of the volume-reducing welding groove was applied to GTA welding. A theoretical comparison of the volumes involved in conventional and narrow-gap pulsed GTA welding shows that the weld metal, and hence the welding time, can be halved with a wall thickness of 0,6 in or more.

These torches can be used to weld both the roots and the filler beads. In order to ensure optimum protection from gases during welding of the top layers, an inert-gas bell was developed which can be pushed over the narrow-gap torch.

Pulsed GTA welding has since attained a high level of productions reliability and its economic viability has been significantly enhanced through the use of the narrow-gap method. The welding time and consumption of filler metals are halved. The quality of the weld and production reliability are significantly superior to shielded metal arc welding.

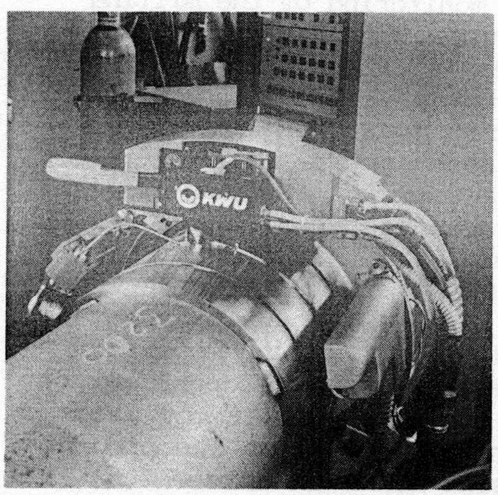

Fig. 3 External Pipe Welding

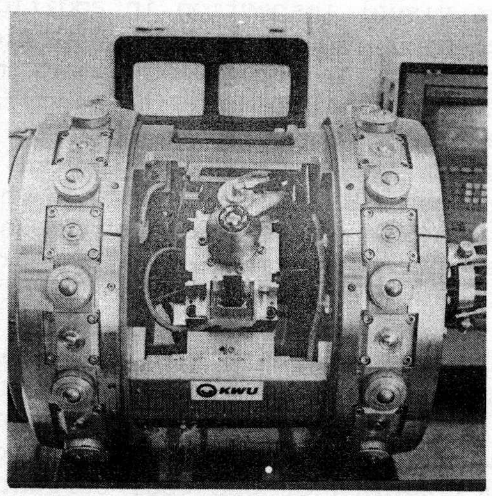

Fig. 4 Milling Machine

2. In-Pipe Machining and Inspection

KWU has developed, for instance, remotely controlled machining units for inspections of and repairs to piping penetrations with an inside diameter of roughly $\geq$ 3,94 in. These remotely controlled in-pipe machining units can move independently inside the piping with a stepping mechanism. The basic configuration consists of two units, the stepping mechanism and the tool carrier, which are inter-connected by means of a universal joint and coupling rod. An electro-pneumatic control mechanism ensures that the machine moves properly in the piping. The system can negotiate pipe elbows with a bend radius of 1.5 x d and gradients up to the vertical. This new generation of machining units originated with the in-pipe grinding machine which has been developed continuously since roughly 1980.

2.1 Milling with TV Monitoring (Fig.4)

The milling machine configuration, for instance, consists of the tool carrier with inspection and milling module, stepping mechanism, swarf extractor, hydraulic unit, TV system, NC controller and the operating and control desk for stepping mechanism control. The milling/inspection machine is designed such that the tool carrier is fitted with the milling module and an eddy current probe. The milling module can be quickly exchanged for the inspection module with ultrasonic and eddy current probes.

The swarf extractor flange-mounted to the tool carrier together with the swarf collector removes virtually all of the swarf produced during milling. Unlike the welding machines, the tool carrier of the milling machine features a hydraulic clamping cylinder to ensure the necessary stability during in-pipe milling. A complex problem proved to be the adjustment of the TV camera system, which permits visual inspection in addition to monitoring of the milling operation, including swarf extraction. Successful use is now made of modified CCD television camera modules in offset configuration with an integral remote focusing facility as well as a seperate camera electronic unit and lighting fixture. The milling module has a built-in eddy current probe with the inner surface of the pipes is examined for surface cracking. The advantage of this combination is that surface inspection and machining can be performed using a single internal manipulator. The frequency with which the machine has to be moved in and out of the piping system is thus minimized.

The inspection module is substituted for the milling module so that nondestructive examination of the repair weld can be performed after mechanized welding. Consequently, the tool carrier may also be unsed for ultrasonic and eddy current examinations. The probe system consists of one eddy current sensing probe and three ultrasonic search units.

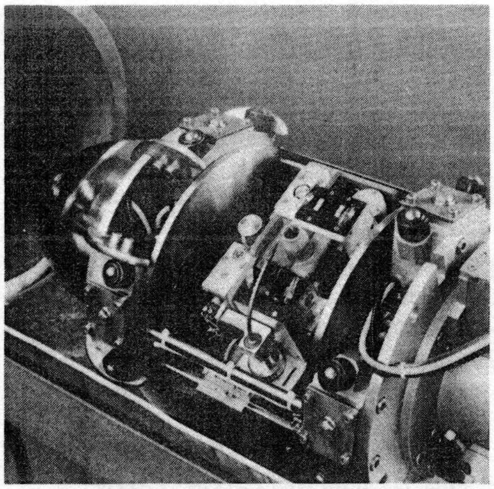

Fig. 5 In-Pipe Welding Machine

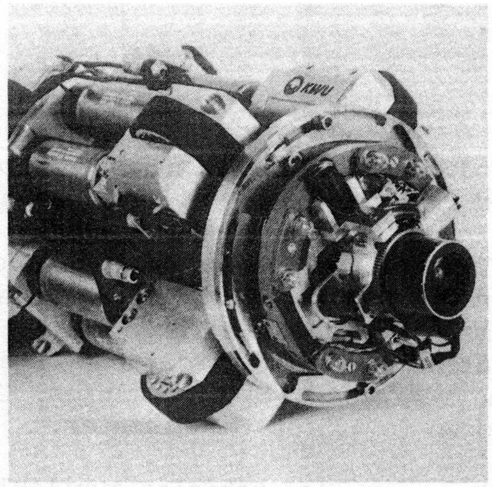

Fig. 6 Inspection Vehicle

2.2 In-Pipe Welding with TV Monitoring (Fig. 5)

For in-pipe welding (repair welds and overlay cladding) the tool carrier is fitted with a welding assembly featuring a special GTWA torch, two special welding cameras and an integral welding wire feed system. A complete assembly basically consists of the welding machine, welding power source, TV system and stepping mechanism control system. The power source and the torch are cooled in closed cooling loops by means of an andditional unit. The maximum cable length between the operators's console and the machining unit (in the pipe) is roughly 213,25 ft.

The welding head is moved parallel to the groove by means of a teach-in controller. The weld preparation contour is first programmed via the TV camera. The welding head then moves automatically over the contour. Paralles movement of the welding head to the next bead may also be preprogrammed. The control desk indicates the position of the welding head and the number of welded beads.

The welder may alter the program via the remote control unit, e.g. to modify the amperage or quantity of additional wire within certain limits. The most important welding parameters (current, voltage, welding speed and wire feedrate) are logged by a recorder. Proper in-feed of the welding wire into the pool is observed by one of the two CCD television cameras attached to the welding head. The second camera monitors the completed bead. After one cycle the current is reduced and welding is terminated. The retur of the welding head, lateral displacement and positioning can be performed manually or fully automatically, as can restarting of the welding process.

Visual monitoring of the welding process is backed by the use of position indicators and recording of the current and voltage levels, welding speed and wire feedrate.

3. Visual Inspection of Pipes (Fig. 6)

Today an increasing number of pipes are visually inspected and rested from the inside by remote controlled vehicles.

These vehicles for inspection of pipes have been developed by Siemens/KWU. They are mostly equipped with cameras respectively TV-Systems. The diameter range of the pipes starts with 3,94 in and ends at approx. 39,37 in at the time being. It is possible to operate the vehicles with pipe slopes. Up to the vertical and also elbows down to 1.5 of the diameter.

There are also vehicles available for the diameter range larger or equal 27,56 in which need no cables. In these case energy is provided by special batteries.

To continuously correlate the TV-picture and the associated pipe position a distance counter is shown in the TV-monitor.

The driving speed of the vehicle can variably be controlled up to a maximum speed of 41 ft/min. The vehicle with cable is able to drive into a pipe up to a depth of 229,66 ft.

Without cable even more than 3 milies can be reached, as vehicle lager or equal 7,87 in the camera is swivel-mounted so that more monitoring flexibility can be achieved.