Flow induced vibrations on nuclear pipings – Comparison between vibration test and stochastic FE analysis with SYSTUS

J.L.Beguin
Framatome/CS, France
N.Bang & A.Abisror
Framatome/ITM, France

1. INTRODUCTION

We will distinguish in the following :

. pipes with fluid flow, whose diameter are greater, in general in plants, than one inch, and which will be called collectors,

. small pipes which are connected to the previous ones, such as vents and drains, whose diameter are in general less than one inch, and which will be called connected pipes.

Fluid circulation inside collectors is at the origin of vibrations of pipe networks when some singularities such as elbows, valves, and especially diaphragms and pumps, are belonging to the circuit.

The flow is turbulent at the singularity and this turbulency creates a variation of fluid pressure along the wall of the collector which is responsible for fluctuating forces on the pipe structures. Thus, the singularities will be called vibration sources.

As a consequence of this fluid-structure interaction, the forces are exciting the modes of piping structures. In general only the first modes are excited because the power spectral density functions (PSDF) of the fluctuating pressures and of the forces are very weak for the upper frequencies. The level of these PSDF is an increasing function of the speed of the fluid flow.

As a consequence of these vibrations, it can be observed on operational industrial installations fluctuating displacements of pipe.

These vibrationnal loadings are not taken into account in the classical design process of power plants because the phenomenon is not responsible, in most of cases, of any stress or fatigue failure for the collectors. In fact, the response of the pipe to this loading could be studied by realizing a fluid-structure dynamic analysis of the pipe and by computing the stochastic response of the pipe to the spectra of all sources of the circuit. Since the spectra of the sources are poorly known, it is difficult to be predictive. The difficulties of using the results of a stochastic analysis (computation of the root-mean-square-RMS of the response) in a design code (ASME or RCCM), and the cost of such computations (because fluid-structure interaction has to be taken into account) make also very uneasy this kind of study.

however, this kind of study has been done in FRAMATOME for a particular auxiliary pipe (safety injection line), and the results have confirmed the very weak risk of any failure ; the ratio between the endurance limit and the RMS value of the pipe equivalent stress was greater than 100.

Mechanized welding machines and other equipment for component replacements

D.Pellkofer, K.Fäser & A.Hümmeler
Kraftwerk Union AG, Erlangen, FR Germany

An ever-increasing number of nuclear power plants in the Western World are operating safely and satisfactorily. Nevertheless, new developments and improvements in the field of safety or efficiency frequently require relatively large-scale upgrading work in existing plants. Modern plants are subjected to regular, systematic in-service inspections which allow timely detection and repair of any flaws and defects which may be present. Welding fabrication techniques are of particular significance in the repair, replacement and upgrading of components. Mechanization of welding has substantially broadened its application.

The extent to which mechanized or automatic equipment is implemented is determined primarily by the intensity of local radiation and the applicable statutes pertaining to dose rates. These devices must be capable of operation from remote control stations and must incorporate monitoring equipment. Traditional techniques are by no means obsolete; however, transistorized power sources, computerized welding programmers and auxiliary devices do open up a broader range of application.

KWU has been directly involved in the development of its own mechanized and automatic welding techniques for some time in order to take full advantage of the benefits mentioned above. A description of recirculation loop replacement in a BWR will be given as an example not only for the planning and actual performance of the work, but also as an illustration of the mechanized and remotely-controlled equipment used.

Stress corrosion cracking is a special problem encountered primarily in boiling water reactor pipework made of unstabilized austenitic stainless steel. Fig. 1 shows a schematic representation of the factors which cause stress corrosion cracking.

This phenomenon can be controlled, provided one of the three primary causes - stress, medium, sensitized material - can be eliminated. KWU's decision, to opt for stabilized CrNi steels for components whose surfaces come into contact with the medium, i.e. surfaces in the primary system and large portions of the nuclear auxiliary systems, made during light water reactor development work as early as 1959, was of major significance here. The Nb stabilized steel X 10 CrNiNb 18 9 (German material no. 1.4550) was optimized in chemical composition with regard to the elements carbon, niobium, phosphorous and sulfur, and also with respect to the stabilization ratio of niobium to carbon. Niobium chemically binds free carbon and avoids sensitization of the steel with regard to intergranular corrosion.

This ensures on the one hand that the steel is resistant to intergranular attack during pickling, storage and operation under oxidizing conditions. On the other hand, workability, resistance to hot cracking and the toughness of the steel are improved. This optimized steel was introduced into the general specification "Basic Safety" in 1979 and is now also stipulated in KTA 3201.1 and KTA 3204.7. Extensive research and test programs initiated in other countries to deal with the above form of cracking have led to the development of a new steel alloy, AISI 316 NG, which is comparably resistant to intergranular attack and has mechanical strength properties similar to those of stabilized steels (1-16).

Before work began on developing new materials and planning the replacement of entire recirculation loops, American engineers attempted to influence another of the essential factors which cause intergranular stress corrosion cracking, namely, stress. The various measures investigated are listed in Fig. 2. It has become clear in the meantime that all of these measures are only temporary solutions. In each case, it is questionable to what extent tensile stresses on the inner surface are sufficiently relieved. This point is particularly critical in the case of pipes which already contain cracks.

Several operators of boiling water reactor plants, e.g. Mühleberg NPP (Switzerland) and Santa Maria de Garoña (Spain) have already opted for partial or complete replacement of pipework systems relevant to plant safety made of AISI 304 steel.

Of the options available for performing high-quality pipework welding, the only viable alternatives are conventional manual arc welding (combined with manual GTA root welding), and mechanized GTA welding for out-of-position pipe welds; the latter is used preferably as a pulsed GTA technique, performed by an orbital welding head running on a circumferential guide ring (17-21). Mechanized GTA narrow-gap welding is a further refinement which has been proven not only in initial fabrication, but also in service activities. The following discussion describes the advantages of this technique (refer also to Table 1) and gives references for its proven on-the-job performance.

Laboratory development and on-the-job application (fabrication and service) of orbital equipment have led - initially with conventional weld geometry - to reduced repair rates and high reproducibility as demonstrated in acceptance tests, consistent quality (filler pass zone and root formation) and a high degree of pipework welding fabrication accuracy and reliability. Integrated on-line monitoring of welding process data enables immediate detection and correction of welding parameter deviations which could otherwise result in flaws requiring repair; welding records ensure reliable documentation of the welding sequence as performed.

NARROW-GAP MECHANIZED WELDING

One serious disadvantage of the mechanized GTA welding mentioned above, compared to manual welding, is its relatively low rate of deposition, which, combined with the substantial equipment investments involved, would appear to undermine the cost-effectiveness of the technique.

Increasing the performance of the technique logically became the next focal point of further development.

One of the conceivable solutions is GTA narrow-gap welding. In principle, it was only necessary to design and construct a suitable welding head compatible with existing mechanized welding peripheral equipment developed previously (transistorized power source, programmer, orbital welding head carrier, guide ring, welding process data monitoring equipment) (22).

The result is a welding system which, in terms of cost-effectiveness, is already competitive with manual welding, owing to reductions in welding time and filler metal requirements. Narrow-gap welding, as seen in Fig. 3, is an option which is worthwhile at wall thicknesses of 20 mm and above (this cost comparison of mechanized versus manual welding does not allow for the lower proportion of repairs required with mechanized welding) (23).

Personnel radiation exposure is also lower, since fewer weld passes and consequently fewer electrode changes are required than with conventional geometry.

These obvious advantages of narrow-gap welding are augmented by a further series of positive aspects arising from improved root formation compared with that of other techniques. They become particularly obvious in previously described cases of remedial work performed in various boiling water reactors to avoid intergranular stress corrosion cracking detected in (unstabilized) austenitic stainless steel piping (24).

These improvements in quality became evident in a testing program which evaluated and compared several circumferential pipe welds of narrow-gap and conventional geometry. Pipes of diameter 460 mm and wall thickness 20 mm, made of AISI 304 L (carbon content = 0.022 %) and AISI 316 LN (carbon content = 0.016 %) were welded in the Q position (vertical pipe axis), partly in combination, using ASTM 308 L/Si (carbon content = 0.020 %) filler metal and comparable welding parameters.

Details of the results are as follows (27):

- less axial shrinkage (Fig. 4 and 5) which means that
  . ultrasonic examinability is improved (28) and
  . root grinding is not necessary
- improved residual stress profile (Fig. 6)
- reproducible weld structure (Fig. 5) with
  . reliable root formation and
  . consistent, favorable mechanical and physical properties
- lower overall heat input and therefore
  . short holding time in the critical temperature range between 500 and 800°C which is responsible for chromium depletion at the grain boundaries (Fig. 7)
  . reduced susceptibility of unstabilized steels to intergranular stress corrosion cracking (Fig. 8)
- favorable fabrication experience
  . high degree of welding quality
  . low proportion of required repairs

About 800 qualification, training, process qualification and fabrication welds of this type have been made to date. Virtually no repairs were necessary in the filler pass zone of narrow-gap GTA fabrication welds. Isolated flaws due to inadequate purging gas were detected in the root zone.

MECHANICAL EQUIPMENT

Implementation of the various generations of orbital welding equipment at KWU started with commercially available equipment. KWU did, however, begin using equipment of its own design at a very early stage. The model line currently in use is shown in Fig. 9. A distinction is made between two types of orbital welding heads. Those used for small-bore pipes have an integrated centering and clamping system. Orbital welding heads for larger pipes run on a guide ring.

An entirely new generation of remotely-controlled orbital welding heads was developed especially for narrow-gap GTA welding (29, 30). These welding heads feature precision mechanisms and adjustment and control of all functions. The overall height of the unit for welding pipes with wall thicknesses up to 45 mm is only 130 mm (Fig. 10).

The weight of the guide ring has been reduced to facilitate installation and shorten set-up times. Furthermore, the orbital welding system has been broadened in scope and now also includes pipework machining attachments. The guide ring is not only used in conjunction with the welding head, additional attachments can also be used for performing milling and surface grinding work, as well as mechanized ultrasonic examination. The welding head is designed for making external welds, however an optional attachment allows conversion for making internal welds near the open end of the pipe. The welding head can be fitted with a normal ceramic tip or with a narrow-gap attachment.

A welding head fitted with two video cameras is available for remotely-controlled welding. These cameras have been redesigned and are about as large as a pack of cigarettes. They produce high-contrast video images, since they can compensate for the extreme range of brightness and contrast occurring between the arc and that of the area surrounding the weld (31).

A system of lenses and prisms and not a glass fiber cable is employed for achieving the correct angle for viewing the tip of the electrode and the completed weld. This avoids the need for costly fiber optics without undue image quality compromises. The welding head unit consists of individual modules which are easy to manipulate and can be quickly and simply replaced. This type of orbital welding head is shown in use in Fig. 11. If welding is to be performed in the radiation area, the welder operates the equipment via remote control from a location outside the containment; current hardware permits control from a distance of up to 65 m away from the actual welding location. The control stations used for performing remotely-controlled welding at the Santa Maria de Garoña NPP are shown in Fig. 12. Up to five welding heads were in use at any given moment. It was even possible to continue welding work during radiographic examination, when any entry of personnel into the containment was expressly forbidden.

A circumferential belt grinder which can be mounted on the guide ring is shown in Fig. 13. It can also be fitted with a dust extraction attachment for removal of grinding dust. This grinder not only performs grinding far more quickly than manual equipment, the surface quality achieved is also higher.

An automatic ultrasonic search unit attachment is shown in Fig. 14. This attachment can be mounted on the guide ring used for orbital welding as well. Once the guide ring is fitted and aligned, mechanized welding, grinding and examination can all be performed. This reduces set-up times, thereby keeping personnel radiation exposure times to a minimum.

PROVEN IN ACTION, AS DEMONSTRATED, E.G., IN THE MÜHLEBERG NPP (SWITZERLAND)

The narrow-gap welding technique described above was employed during replacement of the Mühleberg NPP recirculation loops which had been damaged by intergranular stress corrosion cracking (Fig. 15). This boiling water reactor plant is owned by Bernische Kraftwerke AG (BKW) and has been in operation since November 1972.

The customer selected narrow-gap geometry, since with this technique, as described above, more favorable corrosion and sensitization behavior, less shrinkage and more favorable residual stress conditions can be expected than with conventional weld geometry. These factors were taken into consideration at an early stage of planning. The overall scope of preplanning is summarized in Table 2 (32).

A survey of the KWU scope of supply and services in the course of this project is given in Table 3, but this presentation refers only to welding. Table 4 provides information on the scope of mechanized welding of main, branch and small-bore pipes.

Main pipes were welded using the narrow-gap GTA orbital welding system, branch lines and small-bore pipes were welded with clamp type orbital welding units.

Personnel involved in this welding work was trained in advance and each welding operator was in possession of a valid qualification certificate according to the ASME Code.

In light of the expected dose rates, work was divided between two crews and performed on a two shift basis (two-out-of-three). A total of 62 welding operators were trained and qualified according to the ASME Code so that personnel outages could be covered. Training times varied with the individual operator's previous experience, but did not exceed 160 hours for any individual.

An average of 1.5 orbital welding units were in operation at any given moment during the actual welding stage. For brief periods, up to four units were simultaneously in operation. A special procedure was employed when welding in the final sections of loops to ensure low-stress installation. An orbital welding head was mounted at each end of the pipe section and first the root pass and first filler pass of one weld was made. After completion of the root pass and first filler pass of the other weld, the remaining filler passes were made by simultaneously operating both units. No serious equipment outages threatening extended standstills were encountered.

A maximum of 40 welding operators (orbital welding unit and small-bore pipe orbital welding unit) were on duty at any given time. Deployment of site personnel (welding operators) is shown in Fig. 16.

A total of 57 rem were absorbed during mechanized welding. Personnel dose rates averaged 1425 mrem; the peak individual dose was 1650 mrem (see Fig. 24 for further dose rate data).

PERIPHERAL WELDING EQUIPMENT

Three types of peripheral equipment were used to machine pipes, i.e. for cutting, preparing the edges to be welded, and minimal interior machining, e.g. in the cladding zone, where necessary. A commercially available device was modified in such a way that it could be operated by remote control. Fig. 17 includes a schematic diagram of this device and a summary of peripheral equipment used.

Tight clearances (as low as 130 mm) around some pipes up to DN 609 mm in certain areas of the Santa Maria de Garoña plant made it necessary to construct an additional special device. This rectangular shaped cutting device is shown in Fig. 18.

Both of these two devices are used primarily for cutting pipes. With the aid of a template, they can also be used to machine the pipe edges to be welded.

The devices described above are centered with respect to the pipe circumference. A more suitable device, which is centered with respect to the inner diameter of the pipe, was developed for preparation of the pipe edges. This ensures that the edge prepared prior to making the root weld has a precisely uniform thickness around the entire pipe circumference. This factor is of particular significance where mechanized welding techniques are employed. The unit features a modular design and can easily be assembled by one man. Fig. 19 shows the assembly sequence of the unit.

Our pipework machining system and associated tooling also includes

- a pipe expansion unit for matching and calibrating inside diameters (Fig. 20)
- a pipe centering unit for alignment of centers, correction of ovality and for supplying purging gas (Fig. 21).

This system of pipe machining equipment and the associated tooling is designed primarily for pipe diameters ranging from DN 200 - DN 800. A schematic for preparation of the two pipes to be welded can be seen in (Fig. 22). Using the pipe expansion unit, as shown in the schematic, the pipe ends can be precisely matched and then machined. The unit employs hydraulic pressure supplied by a hand pump.

The pipe centering unit facilitates exact alignment of centers and simplifies setting the weld gap between the two pipes. It is most frequently used when pipe and bend ends differ slightly in diameter or where out-of-roundness or ovality are present. The pipe centering unit is capable of elastically correcting pipe cross-section discrepancies of up to about 5 % wall thickness/diameter ratio to virtually exact roundness and of holding the pipe in this position during welding. If necessary, pipe misalignments of up to 5° can be established with the unit. After completion of welding, the equipment is released by remote control and removed from the pipe as a complete unit.

CLOSING REMARKS

Our experience shows that it is possible to plan the replacement of a piping system in a nuclear power plant with a high degree of accuracy. The planned sequence of work given in Fig. 23 shows good agreement with the actual sequence (dark bars). Deviations from the schedule seen here must be effectively compensated for by a professional site management staff. In the case of the Mühleberg recirculation loop replacement, it was actually possible to complete work 22 days ahead of schedule. Adjustments of this magnitude are not the result of faulty planning: the high fabrication accuracy and reliability made it unnecessary to use the time allotted for making repair welds. The need for and expediency of meticulous planning and preparation are thus confirmed by this field experience.

A significant reduction of personnel radiation exposure was achieved by implementing high-efficiency decontamination techniques and shielding measures not previously metioned in this presentation. Appropriate measures taken as a result of the initially high radiation actually led to a reduction of the manrem dose rates, in spite of increases in personnel numbers and hours worked, as shown in Fig. 24.

Substantial reductions in the personnel residence time in the radiation area can be achieved by the implementation of sophisticated pipe installation and welding systems. A very high level of quality is also attained at the same time. Factors which cannot be quantitatively predicted, such as impermissible edge offset or pipe ovality, can be dealt with.

LITERATURE

/1/ Rösler U., Debray W., 1986. Meilensteine der Werkstofftechnik auf dem Weg der kerntechnischen Entwicklung. VGB-Sonderdruck

/2/ KTA-Regel 3203, Fassung 3/84. Überwachung der Strahlenversprödung von Werkstoffen des Reaktordruckbehälters von Leichtwasserreaktoren. Köln: Carl Heymanns Verlag

/3/ Debray W., Stieding L., Weiß E., Wieling N., 21-24 Febr. 1983. Experience with Stabilized Stainless Steels in Light-water Reactor Technology. Tokyo/Japan: The 2nd Japanese-German Joint Seminar

/4/ Anhang zu RSK-Leitlinien für Druckwasserreaktoren, Kapitel 4.2, 2. Ausgabe, 24. Januar 1979. Rahmenspezifikation: Basissicherheit von druckführenden Komponenten

/5/ Lundin C.D., Stansbury E.E., Lee C.H., Progress Report May 1984, Welding Research Engineering. The Effect of the Welding Variables on Corrosion Behavior of Austenitic Stainless Steel

/6/ EPRI NP-2531, project 1166-1, Interim Report, Aug. 1982. Intergranular Stress Corrosion Cracking of Austenitic Stainless Steels in PWR Boric Acid Storage Systems

/7/ R.R. Irving, Iron Age/Oct. 1, 1984. Cracking up?

/8/ Briant C.L., June 1982. Effects of Nitrogen and Cold Work on the Sensitization of Austenitic Stainless Steels. EPRI Final Report, NP-2457, Research project 1574-1

/9/ Kiessling L., Nilsson F., Trolle M., Skanberg L.. Licensing and Research Aspects on Stress-Corrosion Cracking in Swedish Boiling Water Reactors

/10/ Danko J.C., Stahlkopf K.E., 1982. Status of research on pipe cracking in BWR's. Nuclear Safety 23, pp. 653-664

/11/ Devine T.M., March 1978. The Mechanism of Intergranular Corrosion and Intergranular Stress Corrosion Cracking in Duplex 308 Stainless Steel. Houston/Texas: The International Corrosion Forum, Paper No. 189

/12/ Ogawa T., Abe S., Febr. 2, 1979. Weldability of Type 347 Stainless Steel with Improved Resistance to Intergranular Stress Corrosion Cracking. Nippon Steel Corp.

/13/ Horn R.M., 1982. The growth and stability of stress corrosion cracks in large-diameter piping. Palo Alto: Electric Power Research Institute Report NP-2372

/14/ Abe S., Ogawa T., et. al., 1979. Development of SCC Resistant 347 LP. Nippon Steel Corp.

/15/ Okada H. et. al., 1978. Improvement of IGSCC Resistance of Austenitic Stainless Steels in High Temperature Water. Brazil: Proceedings of 7th Int. Congr. on Metal Corr.

/16/ Kass J.N., Lemaire J.C., Davis R.B., Alexander J.E., Danko J.C., 1980. Comparative Stress Corrosion Behavior of Welded Austenitic Stainless Steel Pipe in High Temperature High Purity Oxygenated Water. Corrosion-NACE
/17/ Cerjak H., Pellkofer D., Schmidt J., Aug. 83. Entwicklung des mechanisierten WIG-Impulsschweißens zur Anwendung an Rohrleitungen im Kernreaktorbau. VGB Kraftwerkstechnik 63, Heft 8
/18/ Schmidt J., Pellkofer D., Schmidt G., May 83. One-side joint-weld of weld-clad pipes. Tokyo: Japan-German-Colloquium, Welding Technology and Economics, Gemeinsames Kolloquium von JWS, DVS und JWES
/19/ Pellkofer D., Schmidt J., Hümmeler A., 1984. Remote-Controlled Welding of Internally Clad Tubes during Steam Generator Replacement. Madrid: ADESOL-Conference
/20/ Hümmeler A., Pellkofer D., Nov. 85. Steam Generators and Pipe Replacement of German Light Water Reactors. Knoxville, Tenn.: AWS, Maintenance Welding in Nuclear Power Plant/III
/21/ Schmidt J., Weiß E., Pellkofer D., April 86. Avoiding IGSCC in Austenitic Pipe System of BWR Nuclear Power Plants from the Standpoint of Welding Technology. Chicago: Proceedings of the American Power Conference
/22/ Pellkofer D., Engelhard G., Förner S., 1985. Vorteile des WIG-Engspaltschweißens. Jahrestagung Kerntechnik München, Tagungsbericht
/23/ Weiß E., Wesseling U., Schmidt J., 1986. 20 Anos de Experiencia en la Soldadura de Aceros Austeniticos Estabilzados. Madrid: ADESOL, Sectas Jornadas Technicas de Soldadura
/24/ Disney J., Simpson M., September 20-21, 1984. BRWOG Workshop on BWR Recirculation Piping System, Replacement Materials and Installation. Weld Joint Studies
/25/ Disney J., Feb. 85. Welding of Nuclear Grade Materials to Minimize Residual Welding Stresses. Charlotte/North Carolina: EPRI NDE Center
/26/ Schmidt J., Löhberg R., Pellkofer D., November 1986. Vorteil und Bewährung der WIG-Engspaltschweißung. Nürnberg: 5. Internationales Kolloquium "Schweißen in der Kerntechnik" (DVS-Band 106)
/27/ VÖEST-Patent, Europäisches Patent Nr. 14820. Verfahren zur Ultraschallprüfung von Schweißnähten austenitischer Stähle und Verfahren zur Herstellung von zur Durchführung dieses Prüfverfahrens geeigneten Schweißnähten
/28/ Hoch G., 1979. Vorbereitung einer Großreparatur mit Geräten zum halbautomatischen bzw. automatischen Arbeiten an Rohrleitungen im Bereich hoher Strahlendosen in Kernkraftwerken (Preparation for large-scale repairs using equipment for semi-automated or fully automated work on pipes in areas with a high radiation level in nuclear power plants). VGB-Kraftwerkstechnik 59, Volume 9
/29/ Dilthey U., Pellkofer D., May 1983. Automatic orbital TIG welding of thick-walled ferritic and austenitic steel tubes with diameters greater than 120 mm. Tokyo: Japan-German-Colloquium, "Welding technology and economics", Joint colloquium of JWS, DVS and JWWS
/30/ Förner S., Idler S., Pellkofer D., Weber R., 1984. Automatisieren, Fernsteuern und Überwachen von Schweißvorgängen mit TV-Anlagen (Automation, remote control and monitoring of welding processes using TV systems). Publication "Maschinen Anlagen, Verfahren", Volume 11

Convent. weld-preparation SMAW	Convent. weld-preparation GTAW-mechanized	Narrow gap geometry GTAW-mechanized
• time for prepare favorable • high flexibility • wide fabrication tolerances (misalignment, gap) possible • low investment for equipment • no equipment breakdown	• remote control possible • high reproducability • constant quality • high fabrication reliability • simple reconstruction of deviations by parameter-documentation • uniform root formation	• remote control possible • high reproducability • constant quality • high fabrication reliability • simple reconstruction of deviations by parameter-documentation • consumption of welding materials favorable • short welding time • low irradiation load • uniform root formation • low shrinkage/strain rate • low stress concentration in root area • low grinding volume of root area • X-Ray/US-testability favorable • low sensitization time • residual stress distribution favorable

One-Side Butt-Weld (not grainded root)
Advantage of Welding-Procedures

E 86 030 e

Table 1

Concept and detailed planning for the replacement of both recirculation loops with emphasis to

- compilation of the licensing document (general specification)
- planning and detailed design of special tools, mechanical and welding equipment
- planning of manpower and equipment requirements
- planning of shielding and the necessary special equipment
- planning of mock-ups for personnel training
- planning of radiation dose application
- planning and detailed design of nozzle decontamination and equipment
- planning of the survey measurements
- planning of piping including modification of the supports and pipe whip restraints
- drafting of training programs
- sequence planning
- time scheduling
- site installation and personnel deployment

Muehleberg Recirculation Pipe Replacement
Scope of Planning Contract

E 87 260 e

Table 2

Tools and equipment for

- cutting and weld edge preparation
- welding
- nozzle and equipment decontamination
- grinding of weld top layer

Personnel training for

- decontamination
- cutting and weld edge preparation
- welding
- adjusting of special shielding

Dismantling and re-installation

Deliveries

- auxiliary pipes
- new and partially modified tools and mechanical equipment
- insulation
- valves
- mock-ups
- special shielding

Services

- site installation and site management
- scheduling at the site
- QA/QC at the site
- project management

Muehleberg Recirculation Pipe Replacement
KWU Scope of Supply and Services

E 87 259 e

Table 3

	Diameter	Total welds	Pre-fabricated	In-stallation
Main pipes	18"	29	10	19
	10"	16	–	16
Branch lines	DN 200	6	3	2
	DN 150	4	1	2
	DN 80	13	–	8
Small-bore pipes	DN 50/25/15/ Fillet welds	168	–	47

Muehleberg Recirculation Pipe Replacement
Scope of Supply and Services Provided for Mechanized Welding

E 87 261 e

Table 4

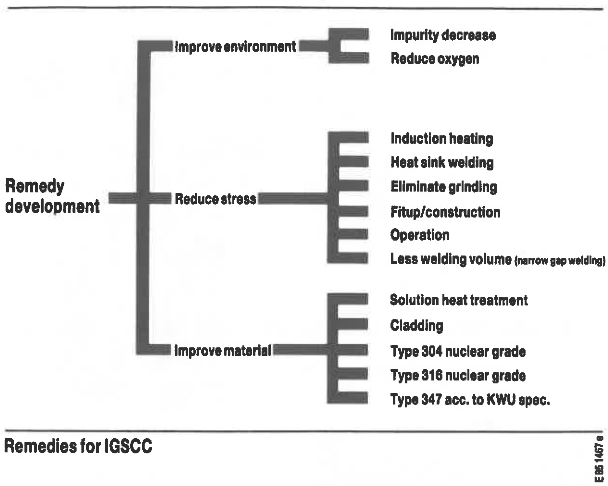


Figure 1

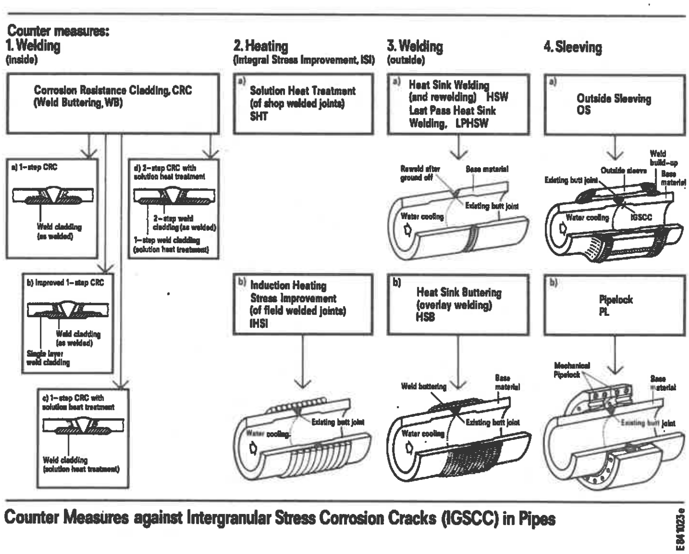


Figure 2

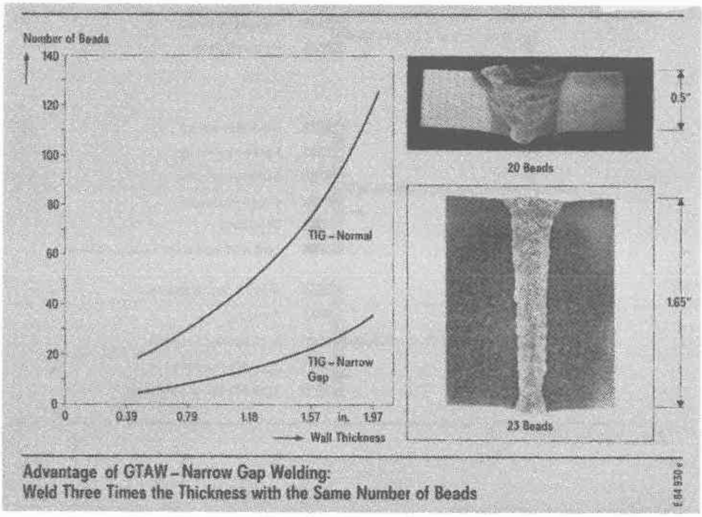


Figure 3

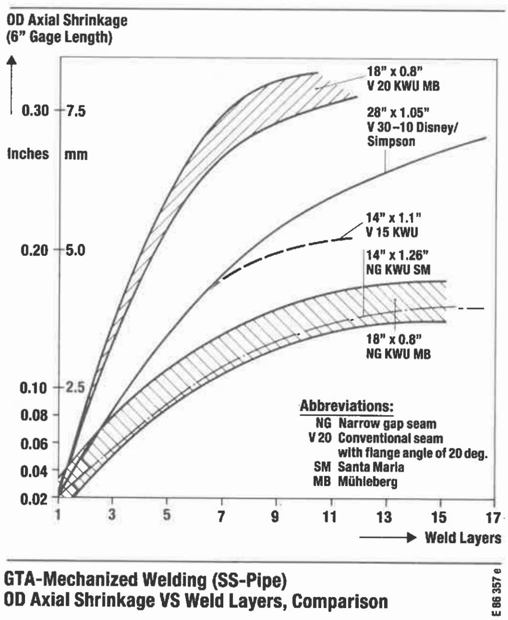
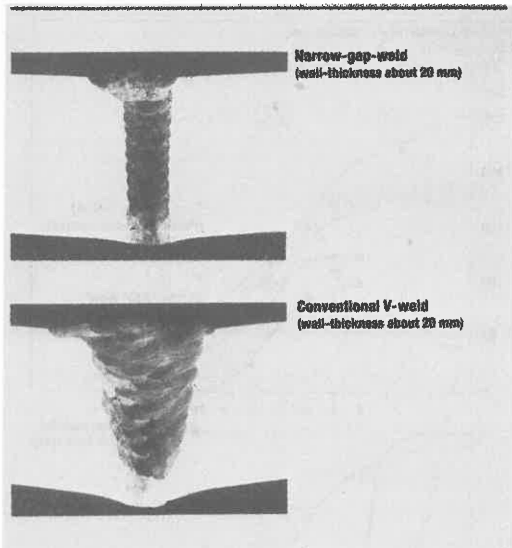
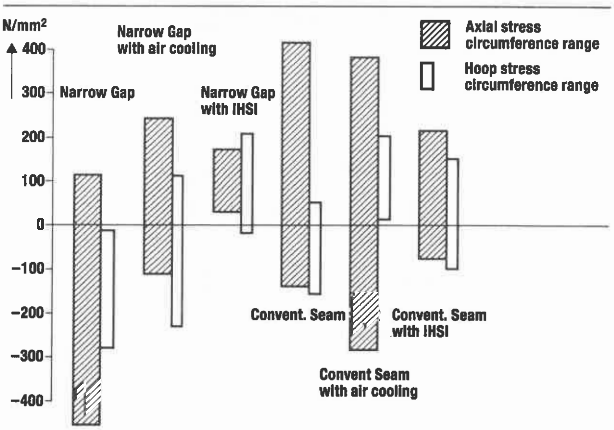


Figure 4



Radial Shrinkage in Comparison

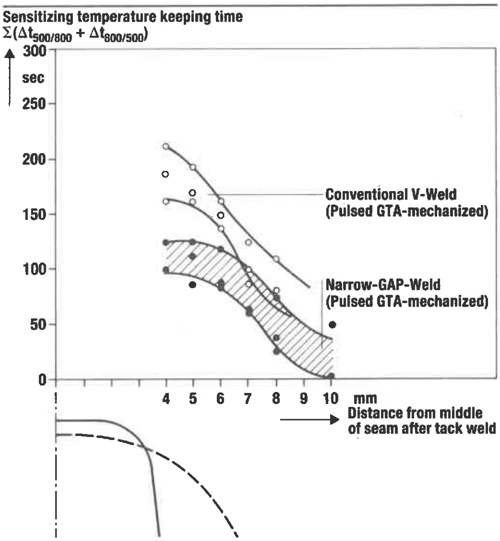
Figure 5



Residual Stresses 18" x 0.8"-Pipe-Weld
ID Surface, Fusion Line

E 86 365 e

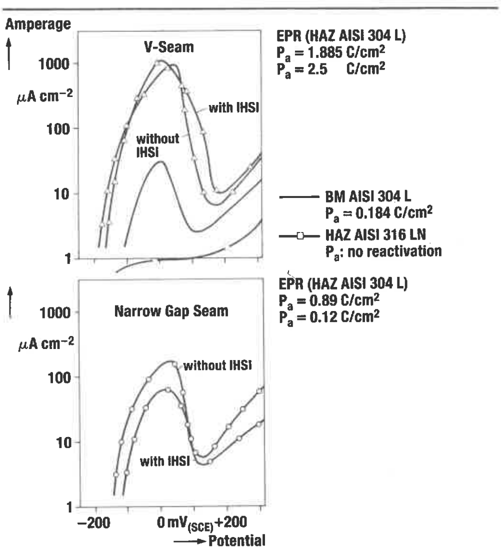
Figure 6



Sensitization by Welding (18" x 0.8"-SS-Pipe)
Total Keeping Time at Sensit. Temperature

E 86 354 e

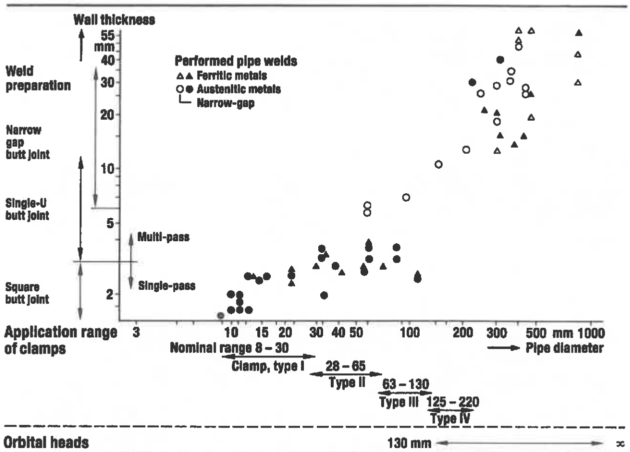
Figure 7



Results of EPR-Investigations
with AISI 304 L-308 LSi-316 LN Weld Joints

E 86 369 e

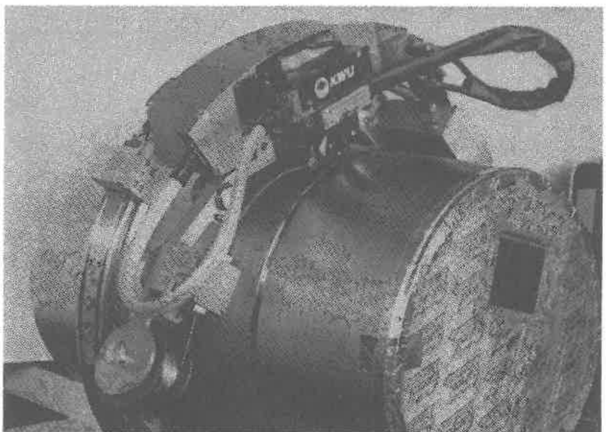
Figure 8



Application Range of Mechanizes Pulse-GTA Welding on Pipes with Various Orbital Heads and Weld Preparations

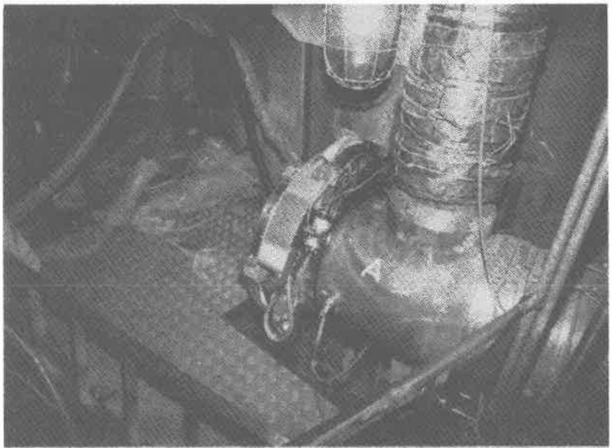
E 86 245 e

Figure 9



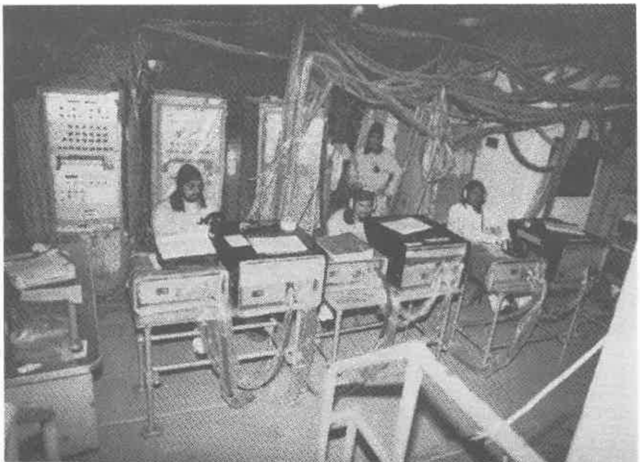
Engspalt Orbitalschweißkopf
Narrow Gap Orbital Welding Head

Figure 10



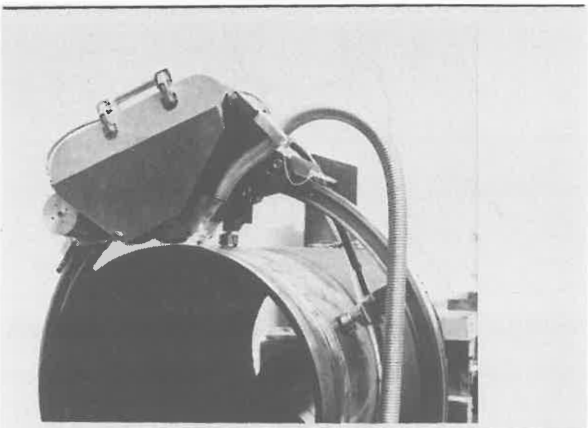
TIG-Orbital Narrow Gap Welding Head
Santa Maria de Garoña, Recirculation Pipe Replacement

Figure 11



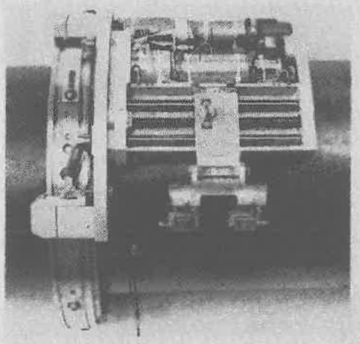
Jobsites for Remote Control Welding in Areas
of High Radiation at Santa Maria de Garoña

Figure 12



Circumferential Belt Grinder for Pipe – OD – Grinding

Figure 13



Features:

- constructed in modules
- four interchangeable assembly groups: circular track, main carriage, slide arm, axial slide
- scan coverage by combined motions of the main carriage around the track and the axial slide perpendicular to the track
- easy adaptation of pipe diameters from 214 mm through 950 mm (8.4 to 37.5 inch)
- up to 20 independent pre-programmed scannings

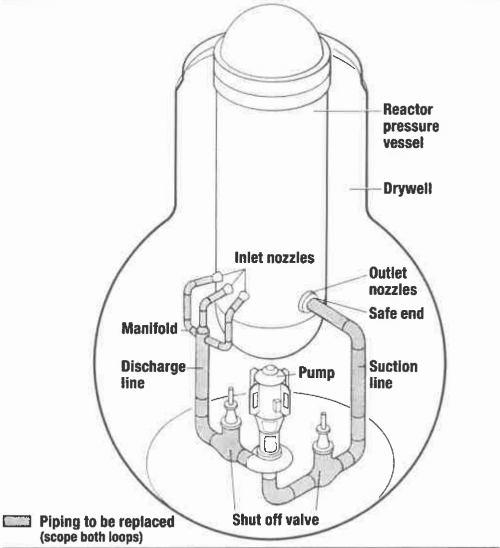
Technical data:

overall height from pipe surface:	70 mm	(2.76 inch)
total weight:	about 25 kg (55.1 lbs)	
manipulator axial length		
equipped with arm "160":	370 mm	(14.6 inch)
equipped with arm "220":	415 mm	(16.3 inch)
maximum scanning speed	100 mm/sec	(4 inch/sec)
maximum number of UT-search units	5	

accessories: adapter for examination of pipe attachment, nozzle and nozzle socket welds

Pipe Weld Scanner

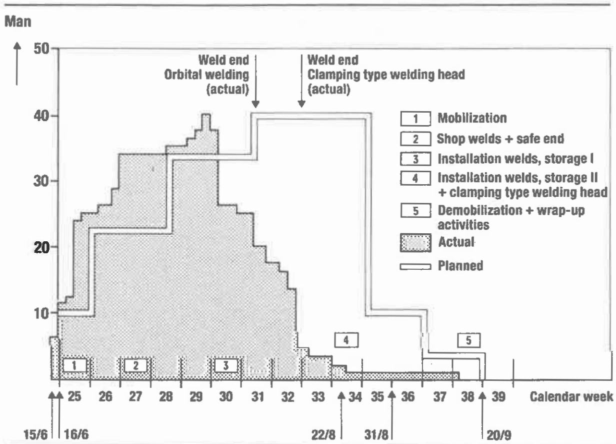
Figure 14



Muehleberg Recirculation Pipe Replacement
BWR Recirculation System

E 87 257 e

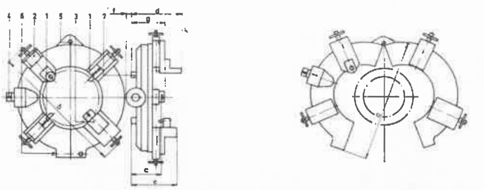
Figure 15



Muehleberg Recirculation Pipe Replacement
Comparison of Planned versus Actually Deployed Personnel

E 87 255 e

Figure 16



Description

1 Tool bit holder for- and with a coarse and fine cutter
2 Bevel device including bevel tool bit
3 ID machining unit including ID tool bit
4 Drive shaft (driving a universal - shaft/clutch connected to a elect.-drive or hydr.-drive)
5 Swivel joint
6 Quick connect
7 Clamping device

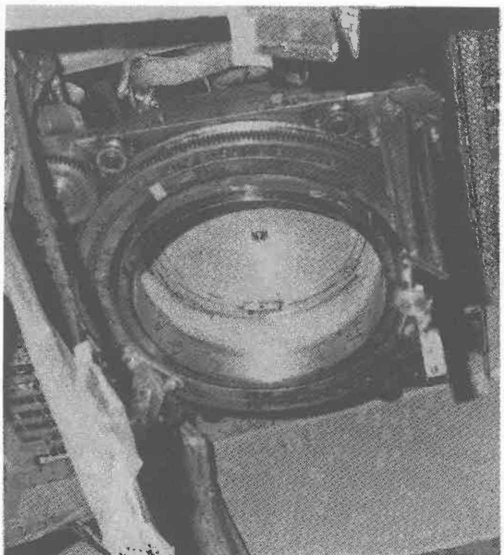
Clamping range

Type	Pipe OD- from – to inch	Pipe wall thickness up to inch	OD inch	Rotation diameter inch	set at pos.1 to cutting edge inch	at pos. 2 inch	at pos. 3 inch	at pos. 4 inch	set at pos. 1 "over all" inch
Pipe 1	0.8 - 4.7	1.2	17.2	20.6	4.6	13.4	9.3	1.4	5.9
Pipe 2	3.9 - 7.9	1.2	20.6	23.7	4.6	13.4	9.3	1.4	5.9
Pipe 3	6.9 - 10.8	1.2	24	26.7	4.6	13.4	9.3	1.4	5.9
Pipe 4	10.2 - 14.2	1.2	27.6	30.3	4.6	13.4	9.3	1.4	5.9
Pipe 5	13.8 - 19.7	3.2	43.3	48.3	8.5	19.1	15.7	.24	9.8
Pipe 6	19.7 - 25.6	3.2	49	54.3	8.5	19.1	15.7	.24	9.8
Pipe 7	25.6 - 31.5	3.2	55.1	60.2	8.5	19.1	15.7	.24	9.8
Pipe 8	31.5 - 37.4	3.2	61	66.1	8.5	19.1	15.7	.24	9.8

Remote controlled pipe cutting
Machining of weld preparations and the machining of inside diameters

E 82 1519 Ce a

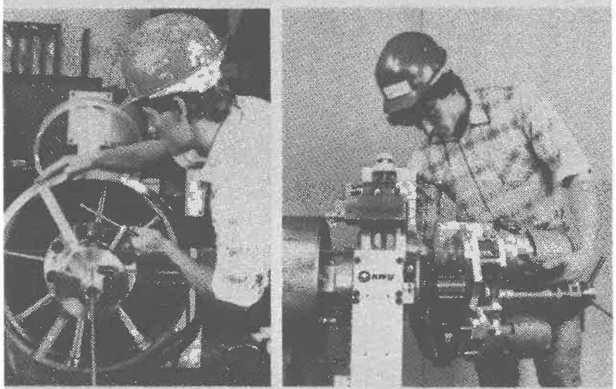
Figure 17



Special Circumferential Milling Machine with a Local Overhead Clearance of 130 mm

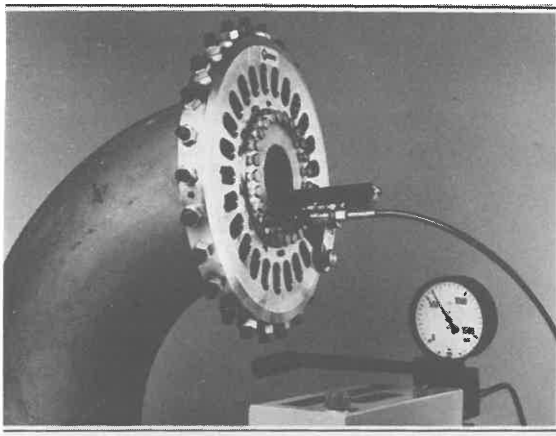
E 86 020 Ce

Figure 18



Mounting of the Inside Clamped Milling Machine

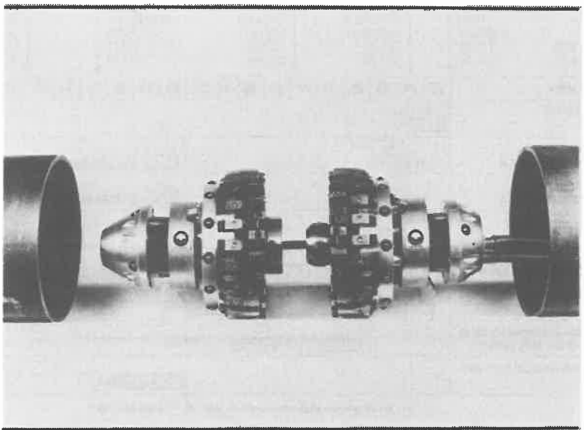
Figure 19



Pipe Repair and Replacement Tools
Pipe Expansion Device (DN 11.8 inch Pipe)

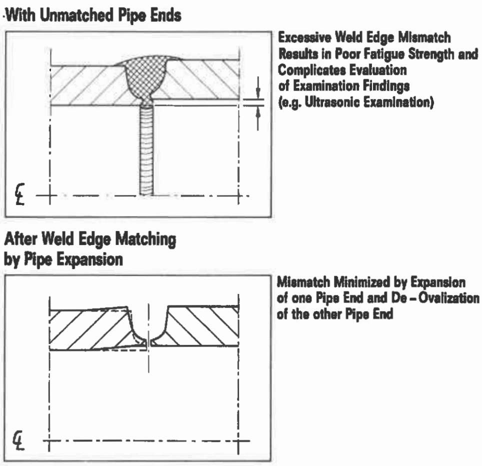
E 84 1983 Ce

Figure 20



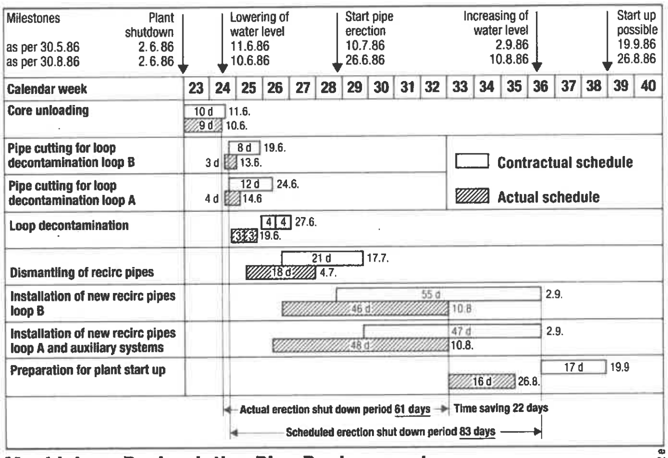
Pipe Repair and Replacement Tools
Pipe Centering Device

Figure 21



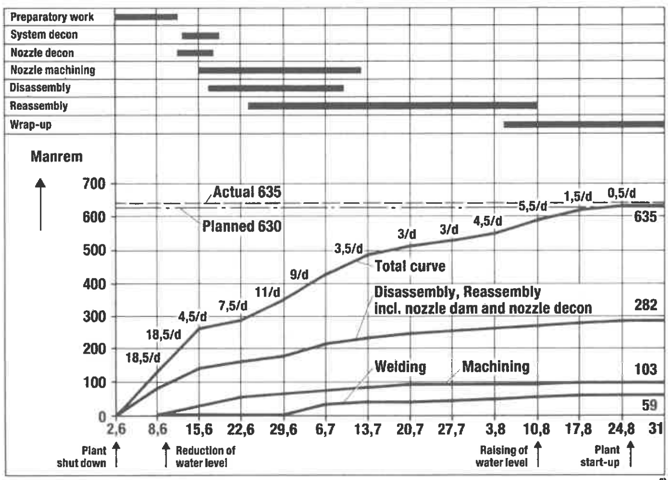
Sketch Showing Weld Edge Matching on a Pipe

Figure 22



Muehleberg Recirculation Pipe Replacement
Scheduled/Actual Critical Path

Figure 23



Muehleberg Recirculation Pipe Replacement
Collective Dose History

Figure 24