REMOTE CONTROLLED IN-PIPE MANIPULATORS FOR DYE-PENETRANT INSPECTION AND GRINDING OF WELD ROOTS INSIDE OF PIPES

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Abstract

Technical plants which have to satisfy stringent safety criteria must be continuously kept in line with the state of art. This applies in particular to nuclear power plants.

The quality of piping in nuclear power plants has been improved quite considerably in recent years. By virtue of the very high quality requirements fulfilled in the manufacture of medium-carrying and pressure-retaining piping, one of the focal aspects of in-service inspections is the medium wetted inside of the piping.

A remote controlled pipe crawler has been developed to allow to perform dye penetrant testing of weld roots inside piping (ID ≥ 150 mm). The light crawler has been designed such that it can be inserted into the piping via valves (gate valves, check valves, ...) with their internals removed. Once in the piping, all crawler movements are remotely controlled (horizontal and vertical pipes incl. the elbows).

If indications are found these discontinuities are ground according to a qualified procedure using a special grinding head attached to the crawler with complete extraction of all grinding residues. The in-pipe grinding is a special qualified three (3) step performance that ensures no residual tensile stress (less than 50 N/mm²) in the finish machined austenitic material surface.

The in-pipe inspection system, qualified according to both the specifications of the German Nuclear Safety Standards Commission (KTA) and the American Society of Mechanical Engineers (ASME), has already been used successfully in nuclear power plants on many occasions.

1. INTRODUCTION

Technical installations that are subject to special safety considerations have to be constantly checked and brought into line with the latest developments in the state of the art. This is especially important in the case of nuclear power plants. The longer they have been in service, the greater the maintenance and repair effort are required.

Piping systems form the links between the components of the reactor coolant system (RCS) and between the RCS and the auxiliary systems, and they are thus required to meet the stringent safety standards prescribed for nuclear systems. It is frequently necessary to inspect, test or perform machining operations on the inside of pipes.

A range of equipment is available for such purposes which makes it possible to perform visual inspection, ultrasonic (US) and eddy current (EC) testing and grinding, cleaning, milling and welding work inside of horizontal as well as vertical pipes.

A special remote controlled manipulator has recently been developed which enables to perform dye penetrant inspection inside of pipes in combination with local grinding. This system of manipulators is able to be inserted into the pipe via valves (gate valve, angle valve, check valve, etc.) with their internals removed. So, it is not necessary to cut the pipe to get access to the inner pipe surface.

The in-pipe manipulators cover the inner diameter from 80 mm to 1000 mm.

2. DESCRIPTION OF THE IN-PIPE MANIPULATOR TECHNOLOGY

2.1. General Requirements to be fulfilled by the manipulators

A relevant criterion for the design of an in-pipe manipulator is, apart from the task itself, the situation regarding accessibility in the section of piping on which work is to be performed. It is necessary to negotiate horizontal and vertical pipes including the elbows. Generaly it should be possible to introduce the manipulator into the piping via a valve with its internals removed.

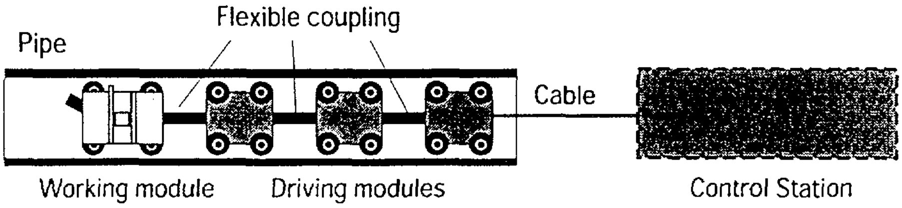
The design of the driving unit must be such that piping junctions can be negotiated. Furthermore account must be taken of the following pipe specific factors:

- Coverage of as large as possible a diameter range
- No obstruction as result of changes of inner diameter and ovalities
- It must be possible to negotiate edge misalignment and weld sag without any problem
- Adaptability of various working module to the driving module
- It must be possible to negotiate projecting parts such as sensors

It is technically difficult and not economically expedient to design the pipe manipulator for all eventualities. Before used for in-pipe operations, an examination of interferences must be performed, and if necessary, the manipulator must be adapted to specific requirements.

2.2. General Equipment Configuration

The general arrangement of the equipment is that the manipulator is inside of the pipe, connected with a cable, going to the outside located control station.



- **Driving module** for manipulator movement inside the pipe
- **Working module** for different tasks to be performed inside pipes
- **Cable** for power and signal supply
- **Control station** remote controlled operation of the manipulator
- **Flexible coupling** Flexible connection between the moduls

Sketch 1 shows the general arrangement of in-pipe manipulator

The manipulator consists of two (2) main parts, the driving module and the working module. These components are linked with flexible couplings that allow to pass elbows and enables the insertion of the manipulator via valves.

Responsible for movements inside of the pipe is the driving module. If a high pulling force is required the number of driving modules will be increased to ensure proper and reliable function.

There is a choice of six (6) different driving modules, the different design (A to F) has different advantages and disadvantages.

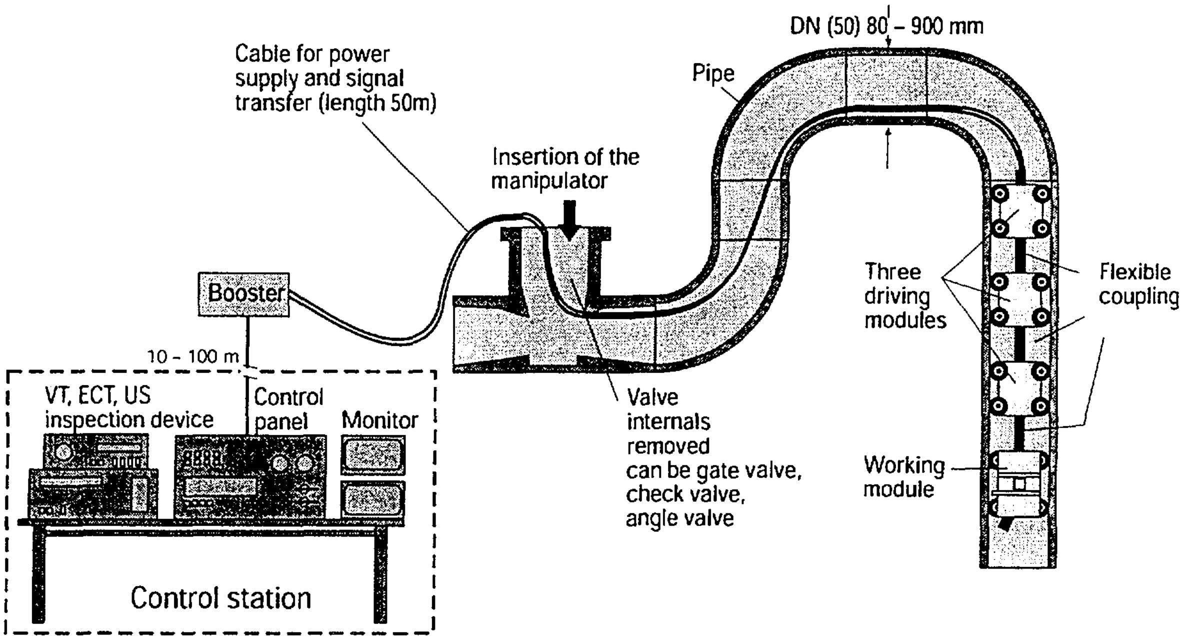
The basis for the decision what design shall be applied is always the requirement-specification for the application of the manipulator in the pipe. E.g. how to insert the manipulator into the pipe or wether there are obstacles in the pipe or how many elbows must be negotiated or what task(s) has to be performed, ...

The different driving modules are described as follows

A) module with spring loaded wheels
B) module with pneumatically loaded wheels
C) module with hydraulically loaded wheels
D) module with spider legs
E) module with stepping mechanism
F) module with guide elements and vacuum unit

To be able to perform the demanded in-pipe task a working module is necessary. The working module is attached to the driving module via a special flexible coupling and can be installed in front of the driving modules, between or in the back.

It is possible to use different working modules with only one set of driving modules together with one (1) set of control station. But it is also possible to have different tasks on only one (1) working module, e.g. milling, EC-testing and cleaning.



Sketch 2 shows the arrangement of an in-pipe manipulator during application on site

The different working modules are described as follows

G) module with high resolution camera for visual inspection
H) module for qualified grinding
I) module for milling
J) module for welding
K) module for in-pipe cleaning
L) module for eddy current testing (ECT)
M) module for ultra sonic inspection (US)
N) module for dye - penetrate inspection
O) module for delta ferrite measurement

3. EXAMPLE OF A SPECIAL DEVELOPED IN-PIPE MANIPULATOR

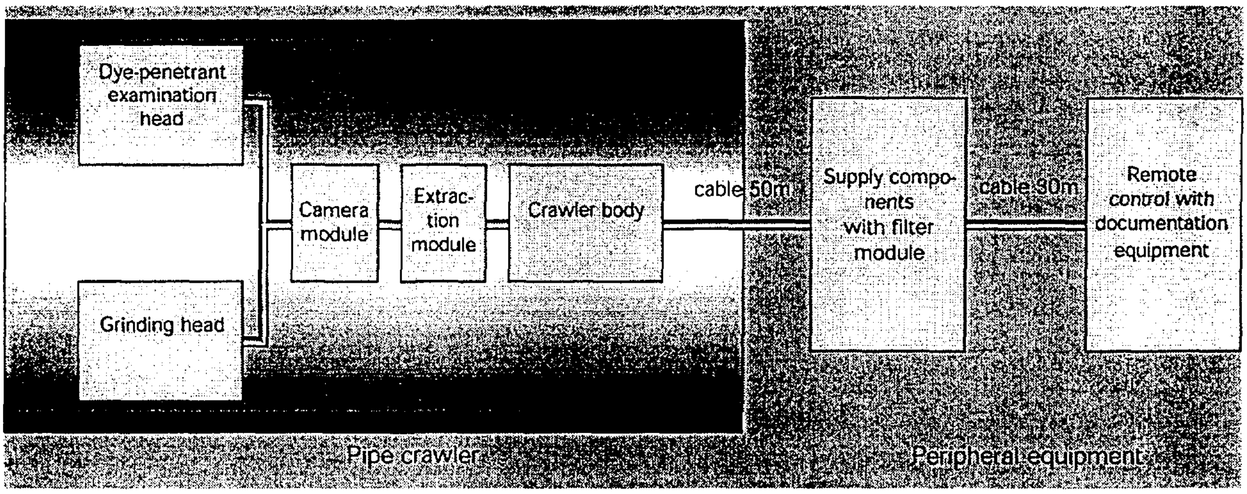
3.1. Remote controlled manipulator for surface crack-examination and local grinding at the weld roof area inside of pipes

A remote controlled in-pipe manipulator has been developed to allow surface crack (dye penetrant) examination of weld roofs inside of piping. The light weight manipulator has been designed such that it can be inserted into the piping via dismantled gate valves or other valves. Once in the piping, all manipulator movements are remote-controlled.

If indication of cracking are found these discontinuities are ground according to a qualified procedure using a special grinding head attached to the driving module. This grinding module is equipped with cleaning features with complete extraction of all grinding residues.

The in-pipe manipulator can be used in piping with an inside diameter of ≥ 150 mm.

This in-pipe surface inspection technology, qualified according to both the specifications of the German Nuclear Safety Standards Commission (KTA) and the American Society of Mechanical Engineers (ASME), has already been used successfully in nuclear power plants on many occasions.



Sketch 3 shows a diagram of the in-pipe manipulator for dye penetrate inspection and grinding

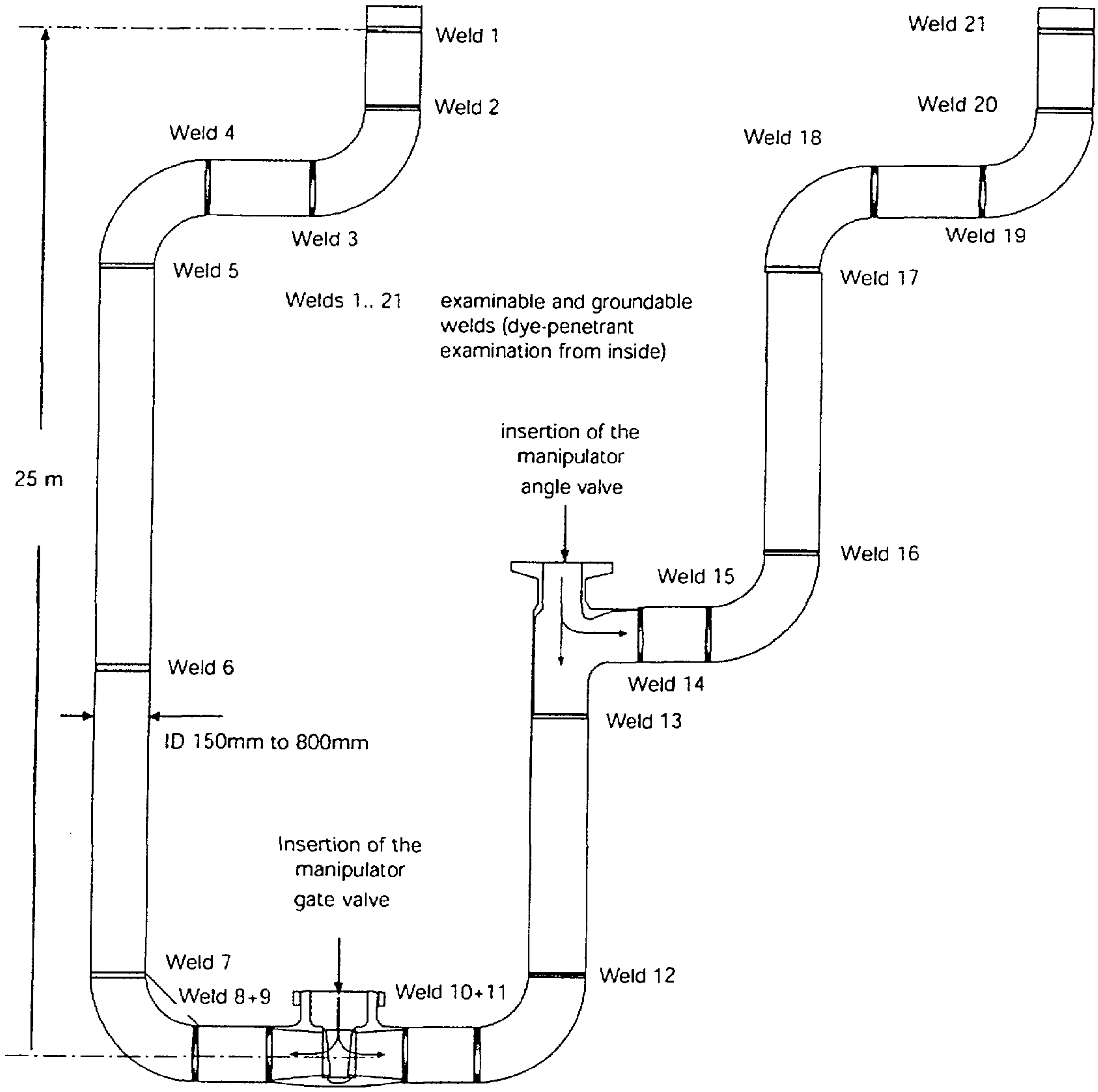
3.2 Main features of the manipulator system for dye penetrant inspection

- light weight, modular design, can easily be handled
- can be used in a large range of diameter, e.g. inside diameter of 450 mm to 650 mm or 150 mm to 250 mm
- it takes only around five (5) minutes to insert or retrieve via gate valve with trim removed (e.g. gate valve of recirculation pipe line of BWR)
- dye-penetrant examination capability in line with KTA and ASME requirements
- qualified grinding of austenitic materials in three passes up to 10 mm depth of material removal (first pass: qualified grinding with a special disc to remove material, second pass: polishing to avoid material hardening, third pass: super polishing to avoid tensile stress on the finished material surface)

features of qualified grinding

- no material hardening
- no residual tensile stress in the finish-machined material surface
- material temperature during grinding < 75 °C
- resistance to intergranular corrosion as per DIN 50914
- no cracks, no impurities (electron-microscopic examination)
- notch-free surface with surface roughness Ra < 1 µm

- grinding residues are completely extracted
- can be used in both, horizontal and vertical piping including elbows (bend radius 1,0 times pipe inner diameter)
- freely adjustable speed of travel from 0 to 5 m per minute
- can travel up to 80 m into piping
- visual inspection capabilities with high resolution zoom-camera



Sketch 4, example: pipe line showing examinable/grindable welds (the manipulator is inserted via the gate valve or via the angle valve).

4. CONCLUSION

Siemens has been active in the field of in-pipe manipulator technology for over 20 years and can boast numerous successful applications in nuclear power plants, so that Siemens pipe manipulator technology is at an extremely advanced stage of development.

Our continually expanding knowledge in this field, along with the expertise gained during project planning, equipment design and qualification, as well as during actual field applications in nuclear power plants, forms the basis of our scope of supplies and services.