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REMOTELY OPERATED PIPE CONNECTIONS FOR SPENT FUEL REPROCESSING EQUIPMENT

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ABSTRACT

The nuclear research centre of Karlsruhe (KfK) has intensified the R&D-activities related to remote handling in spent fuel reprocessing plants. Among other things, improved remote pipe connecting techniques are being developed. Prototypes of triple pipe, multi bolt flange and clamping ring connectors are manufactured. The PAMELA vitrification plant is equipped with a multitude of these connectors. Remote handling tests of pipe jumpers with all types of connectors are carried out as well as fatigue beding tests. The results are encouraging so far.

The Nuclear Research Centre of Karlsruhe (KfK) has developed remote handling equipment for post irradiation examination hot cells [1,2], radwaste handling facilities [3] and various other nuclear applications [4] [5] for a period of more than twenty years. Since an increasing part of KfK's R&D programme was devoted to the nuclear fuel cycle during the last decade, the potential of remotely maintained nuclear fuel reprocessing plants was carefully investigated. It became evident that the use of remote maintenance techniques not only in the mechanical, but also in the chemical part of such facilities could increase the plant availability and reduce the radiation exposure of personnel. These results are very similar to those other investigators obtained a that time [5,6]. Moreover, savings of space required for inter cell walls, equipment redundancies and maintenance accessibility seemed to be possible and the flexibility of both process and apparatus could be improved once the replacement of components was performed by remote means. In a later design study for a LMFBR fuel reprocessing pilot plant [7] these presumptions could be confirmed.

Having this in mind KfK started to intensify its R&D activities in 1978 in order to improve the corresponding remote handling techniques and to develop the necessary equipment.

Such a complete handling system consists of "active" subsystems like viewing systems, cranes, manipulators carrying out remote operations and "passive" components like devices, tools, connecting elements and process equipment which are remotely handled. The "active" elements prove to be of a largely universal character and, to some extend seem to be independant from process details and the type of remote work they are scheduled for. On the contrary the design of the "passive" elements is much more influenced by the type of process to be served or maintained and the particulars of the remote operations foreseen.

In a solvent extraction plant for nuclear fuel reprocessing the remote pipe connection technique appears to hold a key position among the "passive" elements. Therefore, a considerable amount of development activity has been devoted to it.

In order to keep the number of pipe connections as small as possible it was obviously an advantage to subdivide the whole process into functional coherent sections (e.g. dissolution, extraction, evaporation) and to install the equipment and apparatus of each section in a modular rack which is remotely replaceable. Typical numbers of connecting ducts and pipes between this kind of module on one hand and the cell wall or other modules within the cell on the other are 20 to 50 connections in the 10 to 20 mm diameter range more or less independant from plant capacity; and 10 to 30 connections of 20 to 150 mm diameter depending on the througthput of the plant. The quick and safe dis- and reconnecting of these ducts and pipes by remote means are the most important operations during module replacement.

Certainly cutting/welding and flanging come into question. It was started off by the development of flanging because it offered less problems and was more universally applicable. A study was made concerning possible and existing technical solutions partially similar to [8] and preliminary tests of prototypes.

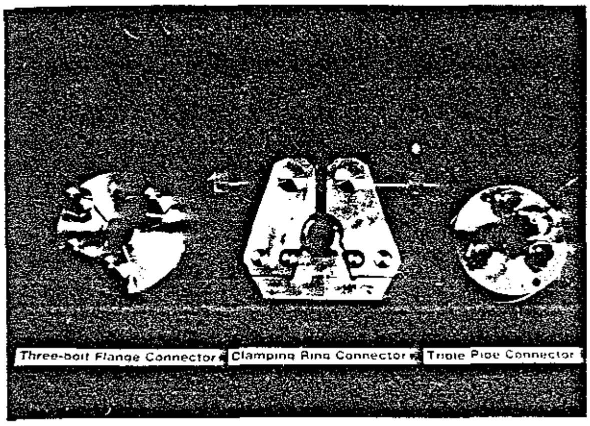

Fig.1 Prototype Pipe Connectors

A gasketless conical sealing technique was selected for pipes up to 20 mm diameter. Three connectors of this type were combined in a common flange plate with one central bolt (Fig. 1 and 2).

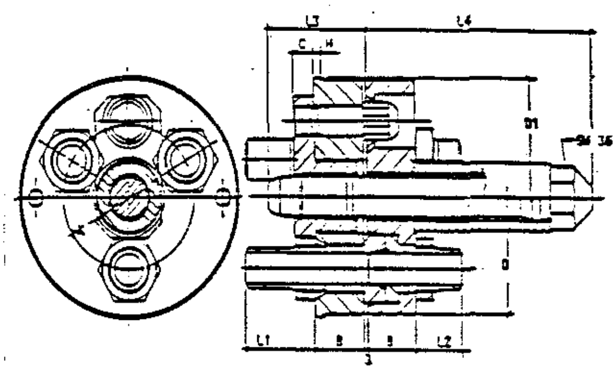

Fig.2 Triple Pipe Connector

By this means it is possible to solve the problems arising from the multitude of pipes having a smaller diameter. For the average and large diameters, single tube flanges appeared to be preferable. A flat gasket consisting of a graphite foil coated stainless steel sheet ring turned out to be the appropriate sealing solution with regard to ease of handling as well as radiation, chemical and mechanical insensibility. As for flange connecting, three or four flange bolts proved to be the most economic solution (Fig. 1 and 3).

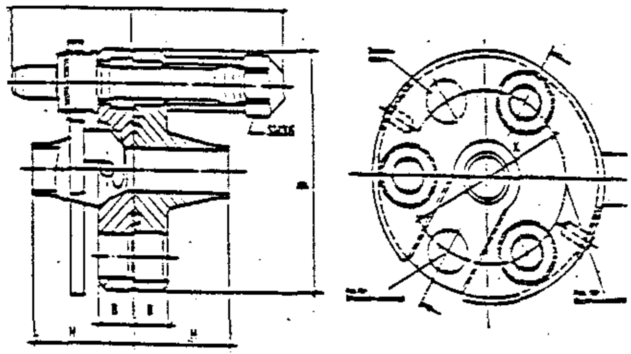

Fig.3 Three Bolt Flange Connector

This system is used whenever possible. The main disadvantage is the bend of the tube that is required immediately in front of the flange in order to permit free access for the impact wrench needed for remote screwing. For that reason a clamping ring was developed as an alternative solution (Fig. 1 and 4).

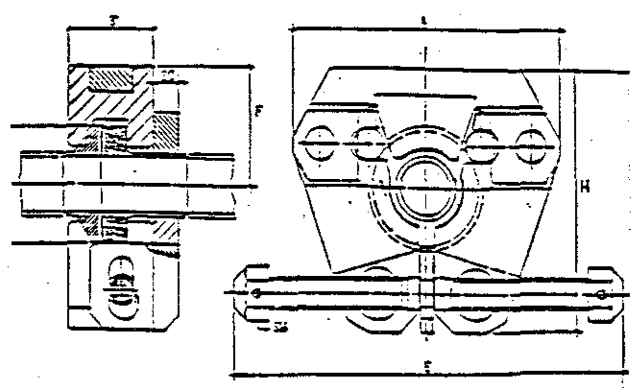

Fig.4 Clamping Ring Connector

It can be actuated tangentially and allows to connect long straight tubes (Fig. 5). Furthermore, this type of connector should be used to connect large diameter tubes (e.g. >100 mm).

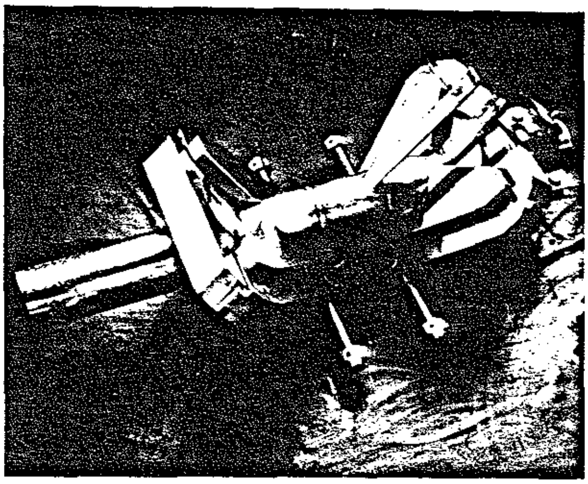

Fig.5 Clamped Tube Intersection

In 1980 it was decided to establish the PAMELA radioactive waste vitrification plant, at Mol, Belgium. As the process applied was mainly a KfK development, demonstration under real conditions of the KfK connectors became possible at the remotely replaceable components. A full scale mock-up of the central melter cell was erected at KfK during that same year and a number of connectors of various diameters were built and tested [9]. In order to reduce their quantity we tried to avoid jumpers as far as possible and to use direct coupling instead with one connector only for one tube. However, with regard to safe component handling free of collision this attempt was not thoroughly successful.

Later on an inactive pilot plant was built and equipped with those connectors projected to be employed in the real facility. After extensive testing and demonstration [10] all connectors are now being cut out and reinstalled in the Mol plant.

Fig. 6 shows some of the elements.

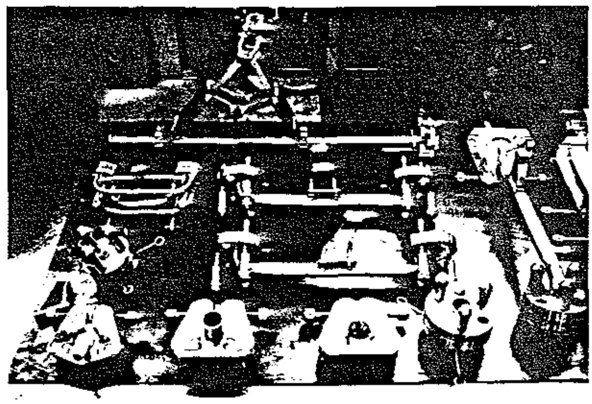

Fig.6 PAMELA Jumpers and Connectors

In 1981, DWK decided to apply a full remote maintenance concept (FEMO-concept) for the German spent fuel reprocessing plant WA 350 [11]. This initiated further activities in the remote handling field. Remote cutting and welding of tubes were investigated and tested, and the flanged remote connectors were subjected to revision and redesign.

The flange bolts are now of the long shaft and necked-down type, made of high strength stainless steel thus showing an increased screw-locking quality when vibrations occur (Fig. 7 and 8).

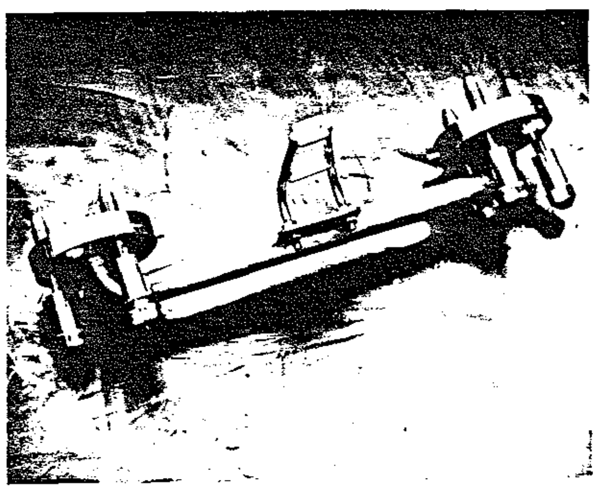

Fig.7 U-Jumper with 3-Bolt-Flanges

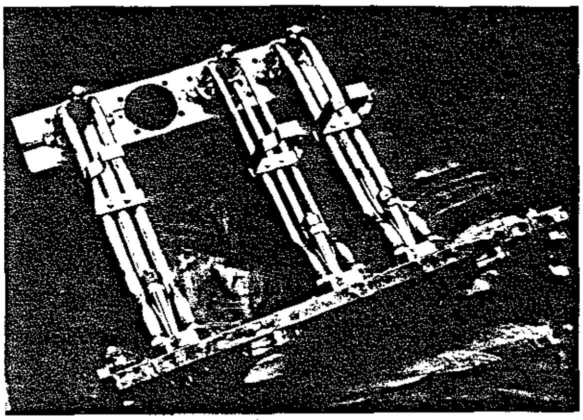

Fig.8 3 Triple Pipe L-Jumpers

The nuts are kept slightly movable in a common support plate which is easy to remove. The sealing surfaces can be cleaned with the aid of an electric tool, and provisions are made for the access with a remote compass saw for bolt cutting in the case of thread galling. Thus it is possible to operate and to repair the connectors by means of simple tools and a rotating crane hook only. Remote fitting of connectors and handling of jumpers of various shapes and sizes are performed in a testing stand (Fig. 9). It is also used for feasibility and time studies as well as for the development of emergency tools and methods.

Another special quality of the connectors is their tightening capability and their clamping strength. Fitting tolerances in the cm-range have to be anticipated if one takes into consideration that floor supported equipment modules with sizes of 3 m x 3 m and 13 m height are connected at their upper end by a multitude of tubes and pipes of various diameters and rigidity. These tolerances may be permanent if they are caused by settling of the building structure or delayed distorsion due to welding stress in the module. They may be temporary if caused by thermal expansion due to elevated operating

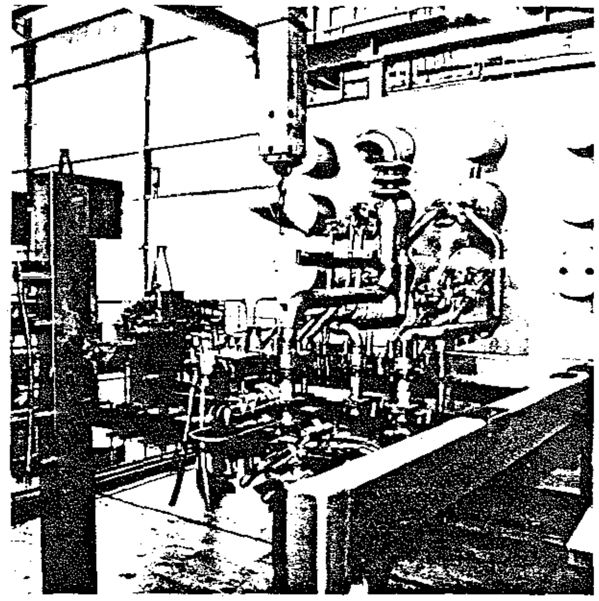

Fig.9 Jumper Handling Test Stand

temperatures, or they may be accidental if caused by manufacturing tolerances or by the sequence of jumper placing and clamping. In any case the connector must be able to bridge these tolerances and to deform the jumper in the necessary way during clamping, as well as to keep the joint tight if deformations occur after the jumper has been fitted. In practice, this means that the connector has to be more rigid than the tubes to be connected. This requirement can be met by heavy clamping rings, although it limits the diameter if triple or single flange bolt connectors are to be used.

A 0.5 MN fatigue bending test machine for tension, compression, bending and torsion of 1 m long L-, U- and J-shaped jumpers and their connectors was built (Fig. 10) and has been operating for nearly one year now. A typical leak rate and flange bolt tension diagram during jumper deformation is shown in Fig. 11.

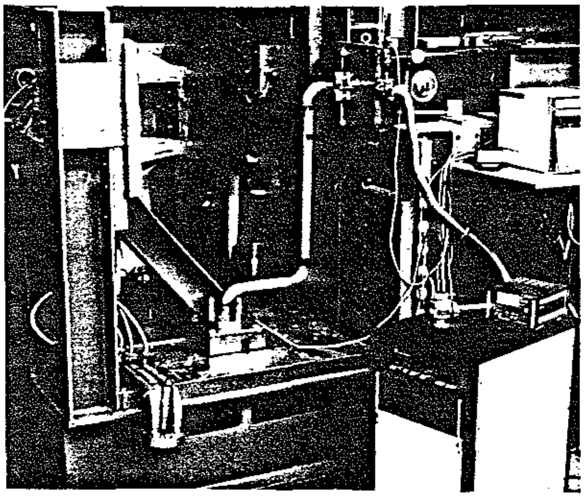

Fig.10 Jumper Fatigue Bending Machine

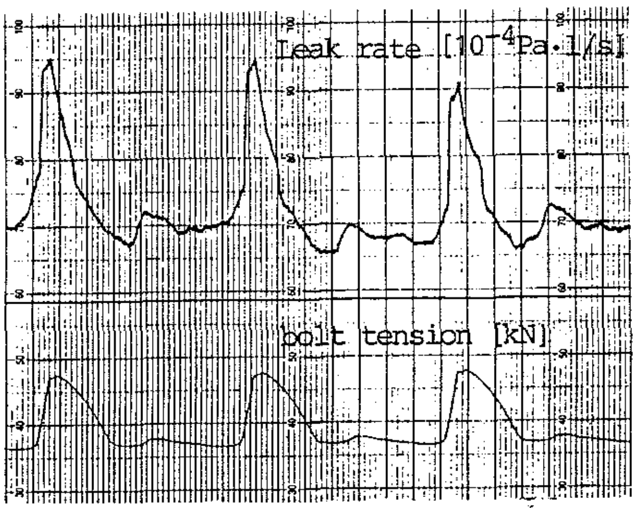

Fig.11 Leak Rate and Bolt Tension of 6 cm-Amplitude Fatigue Bending a Triple Pipe L-Jumper (22.5 min Cycle Time)

For the future it is intended to also dynamically test prototypes in order to finally obtain a type certificate for the use of the connectors in nuclear plants.

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