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ULTRASOUND PERIODIC INSPECTIONS OF REACTOR PRESSURE VESSELS

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ABSTRACT

The report reviews the problems associated with ultrasound testing of pressurized parts of reactor power stations. The method of direct and indirect reflection are presented, as well as the continuous check of proper function of electronics and acoustic bond. The author also describes the procedure of performing the test, and the apparatus for performing ultrasound periodic inspections enabling the probes to be used in a tandem.

INTRODUCTION

Modern human society is characterized by high productivity of work and large producing units. This imposes ever increasing requirements on the producers of power of all kinds. These requirements necessitate to search for and use new sources of power. One of them is the nuclear power and it may be said that this source has already been adopted as an industrial source of power. Toward the end of 1978 there were together some 180 operating nuclear power stations in the world, most of them with pressurized water or boiling water reactors. These nuclear power stations have unit power ratings in the region between 200 and 1 300 MWe and the operating temperature of water circulating in these reactors revolves around 300 °C at a pressure of some 15 MPa.

Increasing number of nuclear power stations is of course associated with a satisfactory solution of their safe operation. One of the techniques of how to obtain data characterizing the state of pressurized components of the primary circuit and reactor pressure vessel is the method of periodic inspections. This activity is carried out during each planned shutting-down of the reactor and its main purpose consists in testing welded joints and other dangerous locations of the material, susceptible to initiate the cracks during operation, or, if the cracks have already originated, the purpose of the test is to study their behaviour and development. This testing is done in the whole depth of the material of the pressurized component, and the basic method of detecting the flaws is the ultrasound test.

The method of testing

Because tested components of an operating reactor are contaminated or radioactive, the testing is carried out using remotely controlled manipulators carrying the measuring head with ultrasound probes. The examination is done either from the external or internal surface. The most often used method is the gap method, while the immerse method is not used so frequently. The probes are moved in the vicinity of tested surface continually in a meander way. After covering the whole circumference of tested material the manipulator performs a step in crosswise direction and the measuring head starts a backward movement along the adjoining track.

The testing may be accomplished using either direct reflection or indirect reflection. In the first case, the emitted energy is reflected from the flaw into the transducer which had emitted the energy (one-transducer operation), or into the neighbouring transducer (two-transducer operation), this neighbouring transducer being either in the same probe or in the adjoining one. The principle of the direct reflection method is shown in fig. 1. The indirect reflection method requires two transducers. One of them emits the energy into tested material, this energy being reflected from the flaw to the opposite surface and from it into receiver as shown in fig. 2. As this couple of probes is capable of detecting flaws only in a certain layer, it is necessary for the whole depth of the material to be tested to use several probes (a tandem of probes). The arrangement of probes in a tandem may be different. Fig. 3 shows an arrangement in which one half of the probes serves as emitters and the other one as receivers. It may be seen that this arrangement divides the whole depth of the material into several layers as shown in section A-A. For an equal decrease of the ultrasound energy on the interface of individual layers the layers would be different. Fig. 4 shows another arrangement; here one probe (the last one in the direction of movement) operates as receiver while the other probes as emitters. In this case the layers will be equal. The receivers may be gated. This means that their inputs may be initiated by means of gating pulses, but only for a time in which an echo from a flaw in the pertinent section is expected to come. This prevents the so called false echoes to be received and, moreover, knowledge of the layer from which the echo has been received indicates approximatively flaw distance.

The tandem method may be used also for the direct reflection technique. One of the possibilities coming into consideration is shown in fig. 5. The main disadvantage consists in the fact that in this case it is necessary to use a probe in which the angles under which the energy enters the material differ.

Because the measurement proceeds automatically it is necessary to adopt measures for continuous check of proper function of all circuits of the apparatus and the acoustic bond. One of the possibilities is shown in fig. 6. The measuring probe has, in addition to a measuring transducer, an auxiliary one. The refraction wedge contains a small reflection surface situated in the point of intersection of the emitting patterns of both transducers. As the reflection surface may serve, for instance, a bored hole. If one transducer emits energy, the other one works as receiver, and the echo emerging as a reflection of a part of the energy from the reflection surface will be processed by the whole amplifying and processing electronic devices. After processing the echo we evaluate its size which must exceed a preset value and provides information about proper function of the apparatus. The existence of the check echo is not dependent on the acoustic bond of the probe. In performing the test, the auxiliary transducer is used as emitter and the measuring transducer of the same probe as receiver, while in the other step their function is reversed.

For checking the proper function of the acoustic bond is used the auxiliary transducer which emits into the material under examination a longitudinal wave and receives an echo from the opposite surface. The existence of the end echo and its proper size provide the information about the acoustic bond of the probe.

If the material is examined using a tandem method, the testing devices operate in steps, with some steps being used as measuring steps and others as checking ones. In dependence on which transducer operates in a given step as emitter and which as receiver we determine whether there is carried out a test using either direct reflection method or indirect reflection method, or whether there will be performed a check of the electronics or the acoustic bond. The instruction prescribing the working operations of transducers (as well as generators and preamplifiers associated to them) in individual steps constitutes the algorithm of the instrument, the instruction being dependent on the weld under examination, the measuring head, and the number and types of the probes being used.

Evidently, we can detect the flaw the more easier, the more suitable is its orientation in relation to the direction of emitted and received energy. In carrying out the periodic inspection of pressurized equipment, the highest attention is devoted to flaws perpendicular to the surface because these are mostly cracks capable of propagating from various reasons in the basic material. These cracks may be most easily found by means of the indirect reflection. Practically speaking, if it is possible on the surface being examined, a tandem of probes is most often used in which both direct reflection method as well as indirect reflection method is used for the most perfect testing of the material.

Each welded joint is tested twice. Once, the probes are arranged on the measuring head in such a manner as to emit the ultrasound energy in planes parallel to the movement of the measuring head, while in the second run the head moves along the same tracks, the ultrasound energy being emitted in planes which are perpendicular to the direction of movement. In case of a suitable arrangement of the head both these tests may be carried out in one movement, reducing thereby the necessary time to one half but, simultaneously, increasing the number of probes which must be used. Moreover, the measuring head is in this case greater.

The electronics is divided into two parts. The first one is independent on the type of the weld under examination as well as on the measuring head being used. The following items belong into this group: the clock, the generator of steps, frequency dividers, generators, preamplifiers, attenuators, A/D converter, digital indicator of echo amplitude, distance meter (if used), light indicators of proper function of the eletronics, displaying module with a CRT, etc.

The second part of the electronics is associated with the type of the measuring head and must be changed if the head is changed.

Into this group belong mainly programmators attributing for each step which working operations will be performed by the apparatus, which transducers will be in operation, whether there will be made a measurement or a check of the electronics or the acoustic bond and the associated circuits generating required gating pulses. From the structural viewpoint, the electronics may be divided into the following three parts: measuring head with the probes; input electronics containing generators and preamplifiers with associated programmators, (the electronics being situated in the vicinity of probes); the central electronics situated in the vicinity of the operator.

CONCLUSIONS

This report describes briefly some problems associated with performing periodic inspections of pressurized components of nuclear power stations.

The report does not cover the manipulators; these are structurally associated with the particular type of the weld. In cooperation with the research institute in Běchovice (SVÚSS) two alternatives for ultrasound periodic inspection of pressure vessels have been devised, the first one being based on using exchangeable programmators with a solid-state logic, the second one uses programmable logic with semiconductor memories (RAM). The device is to be used for the first time for the inspection of the weld on the upper part of the V1 reactor pressure vessel.

LIST OF ABBREVIATIONS

h - distance of flaw from surface

E - emitter

R - receiver

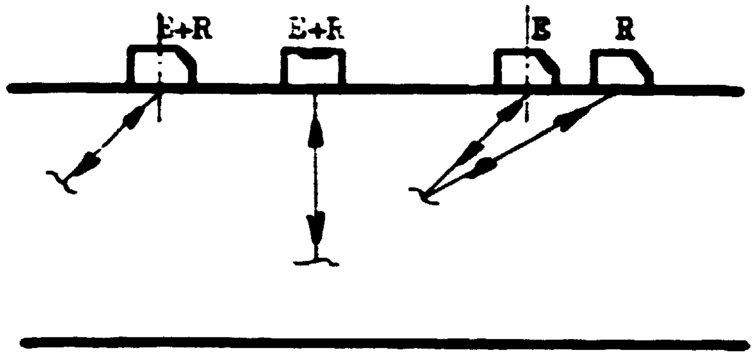


Fig. 1. Direct reflection

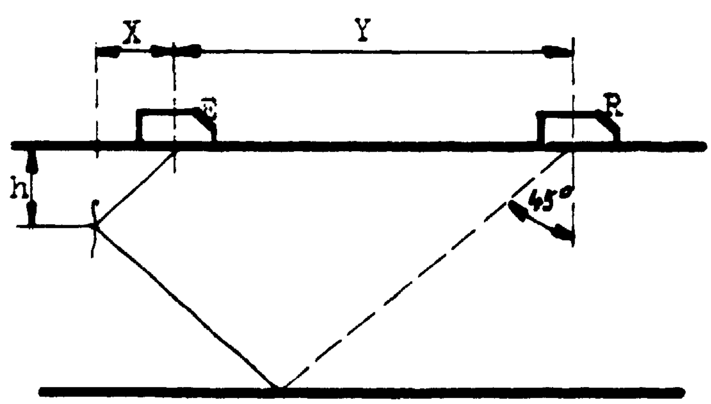


Fig. 2. Indirect reflection

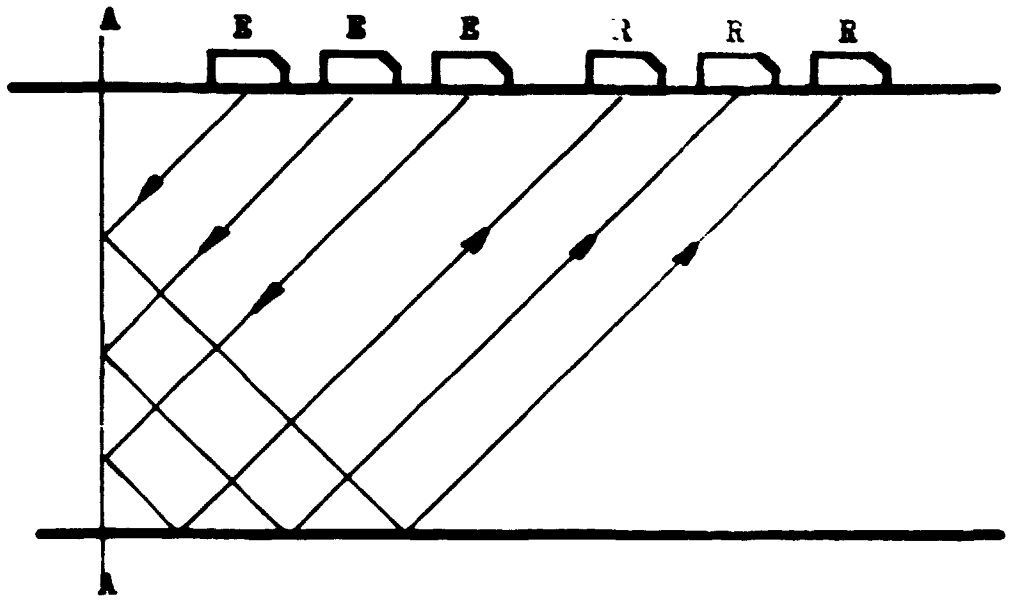


Fig. 3. Tandem for indirect reflection

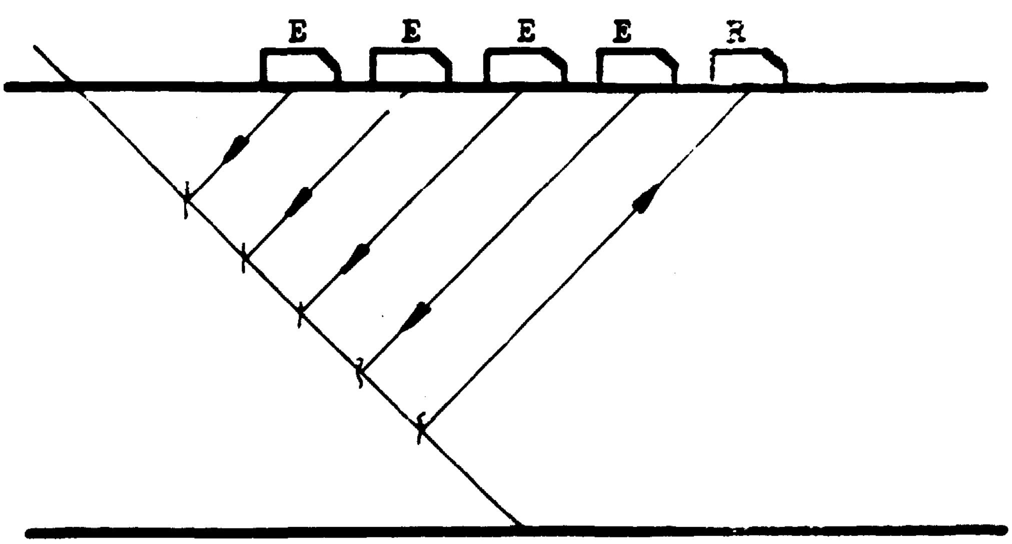


Fig. 4. Tandem for indirect reflection

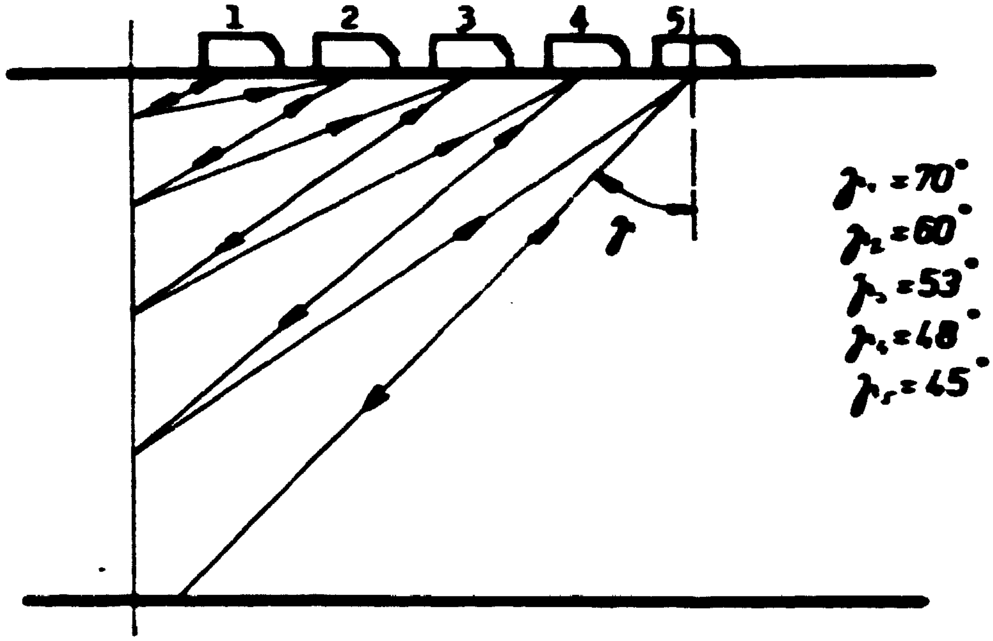
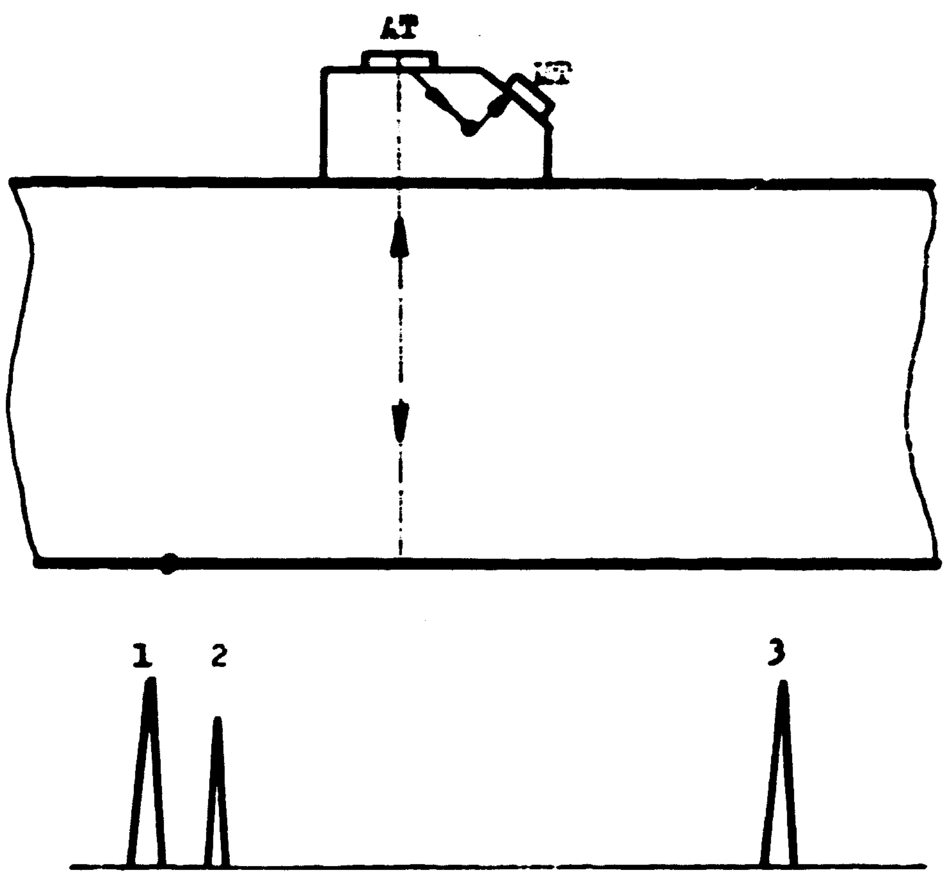


Fig. 5. Tandem for direct reflection



1...emitting pulse

2...echo from reflection surface (check of electronics)

3...echo from back surface (check of acoustic bond)

Fig. 6. Check of electronics and acoustic bond