

AN EMAT SYSTEM FOR DETECTING FLAWS IN STEAM GENERATOR TUBES*

R.B. Thompson, R.K. Elsley, W.E. Peterson, C.F. Vasile
Rockwell International Science Center
Thousand Oaks, California 91360

ABSTRACT

The detection of flaws in steam generator tubing is often made difficult by environmental considerations. The small diameter, 7/8 inch (2.2 cm), long, 70 feet (21.3m), tubes occur in large bundles with access only being possible from the inside of the end of each tube. Furthermore, inspection must be fully automatic when the steam generator is part of a nuclear power plant because of radiation exposure limits. Consequently, a couplant free probe which can be operated remotely at the end of an automatic probe puller is needed. This paper summarizes the development of an EMAT system for this application. The device uses periodic permanent magnet probes to excite the fundamental torsional mode traveling along the axis of the tube. Included is a discussion of data obtained during a recently completed feasibility study and a description of a prototype system presently under construction.

SUMMARY

Figure 1 presents the problem, which is made difficult by a radioactive environment, difficulty of access, and complexity of flaws.

The ultrasonic approach being developed is summarized in Fig. 2. Ultrasonic waves are excited by an EMAT probe, which has the advantage that no couplant is required. In particular, the periodic permanent magnet¹ geometry is used to excite the fundamental torsional mode of the tube. This will provide new information which is complementary to that obtained by eddy currents, and which experiences less interference in the presence of support plates, dents and other geometrical complexities.

Figures 3 and 4 present data obtained during a previous feasibility study² which demonstrated the unique capabilities of the EMAT approach. In Fig. 3, the use of EMATs to detect flaws in dented regions is demonstrated. In these measurements, made at 500 kHz, it was seen that a 2.5% dent produced a weak ultrasonic reflection, but that a partially through hole produced a much larger reflection. Detection of flaws in dented regions thus appears feasible.

Figure 4 shows that flaws in U-bends can be detected by probes placed outside of the U-bend region. In this experiment, the probes were placed at opposite ends of the U-bend for convenience. However, they could easily be placed at the same end. The multiple signals, produced at the ends of the short sample by mode conversion, would not be present in a real steam generator

tube of greater length. The flaw reflection, signal number 2, would then stand out clearly. These results illustrate the important property that EMATs can detect flaws at a distance.

Figure 5 presents a block diagram, and a photograph, of the system under construction.³ It will be seen that digital signal processing is used because of its flexibility in implementing matched filtering and other signal processing operations.

Figure 6 is a photograph of a steam generator mock-up in which the system will be evaluated.

Figure 7 presents a summary of the present status, and future direction, of the program.

REFERENCES

1. C.F. Vasile and R.B. Thompson, "Excitation of Horizontally Polarized Shear Elastic Waves by Electromagnetic Transducers with Periodic Permanent Magnets," *J. Appl. Phys.* 50 2583 (1979).
2. C.F. Vasile and R.B. Thompson, "Evaluation of Electromagnetic-Acoustic Concepts of Inspection of Steam Generator Tubing," EPRI report NP-519 (Electric Power Research Institute, Palo Alto, 1978).
3. B. Thompson, "Development of a Prototype EMAT System for Inspection of Steam Generator Tubing," in *Nondestructive Evaluation Program, Progress in 1979*, Report EPRI NP-1234-SR (Electric Power Research Institute, Palo Alto, 1979).

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AUTOMATIC, HIGH SPEED INSPECTION REQUIRED

- RADIOACTIVE ENVIRONMENT
- HIGH NUMBER OF LONG TUBES
- LARGE ECONOMIC COSTS OF REACTOR DOWN TIME
- DIFFICULT ACCESS

FLAW INDICATIONS IN EDDY CURRENT INSPECTION CAN BE OBSCURED BY

- DENTS
- U-BENDS
- SUPPORT PLATES

Pressurized water reactor (PWR)

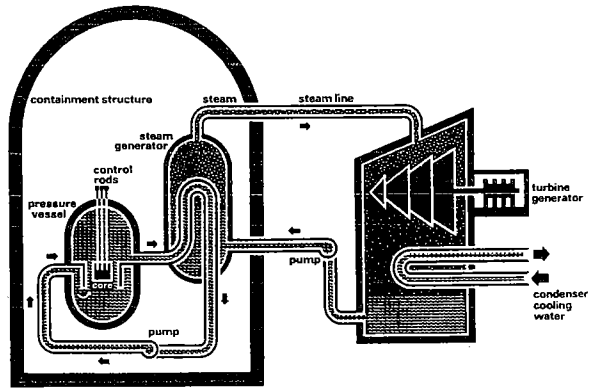
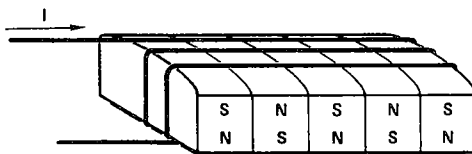


Fig. 1 Statement of problem.

ULTRASONIC WAVES EXCITED BY EMAT'S

- COUPLANT FREE PROBES HAVE OPERATIONAL CHARACTERISTICS COMPATIBLE WITH EXISTENT EDDY CURRENT PROBE PULLERS AND REMOTE CONTROLLERS.
- ULTRASONICS PROVIDES NEW INFORMATION
 - COMPLEMENTARY TO EDDY CURRENT INFORMATION
 - LESS OBSCURED BY SUPPORT PLATES DENTS, ETC.
- LOW LOSS AT 340 KHz ALLOWS WAVES TO RECOVER INFORMATION FROM U-BENDS WITHOUT PROBE ENTERING REGION.
- TRANSDUCERS DESIGNED TO EXCITE SINGLE, TORSIONAL MODE PROPAGATING ALONG TUBE AXIS.

BASIC EMAT ELEMENT



FUNDAMENTAL TORSIONAL MODE

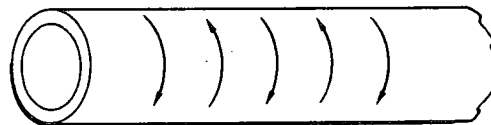
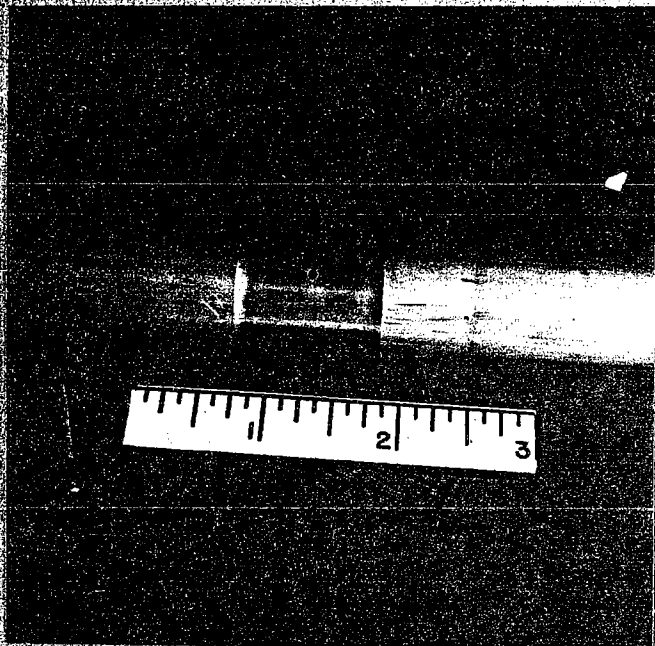


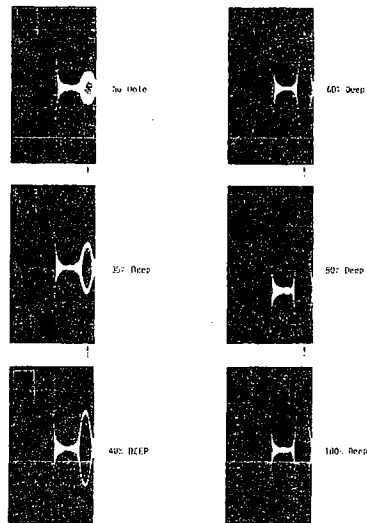
Fig. 2 Summary of EMAT solution.

INITIAL FEASIBILITY STUDY

SAMPLE



SIGNALS



(b) Defect signals for 2.5% reduction in diameter.

Fig. 3 Detection of flaws in dents.

INITIAL FEASIBILITY STUDY

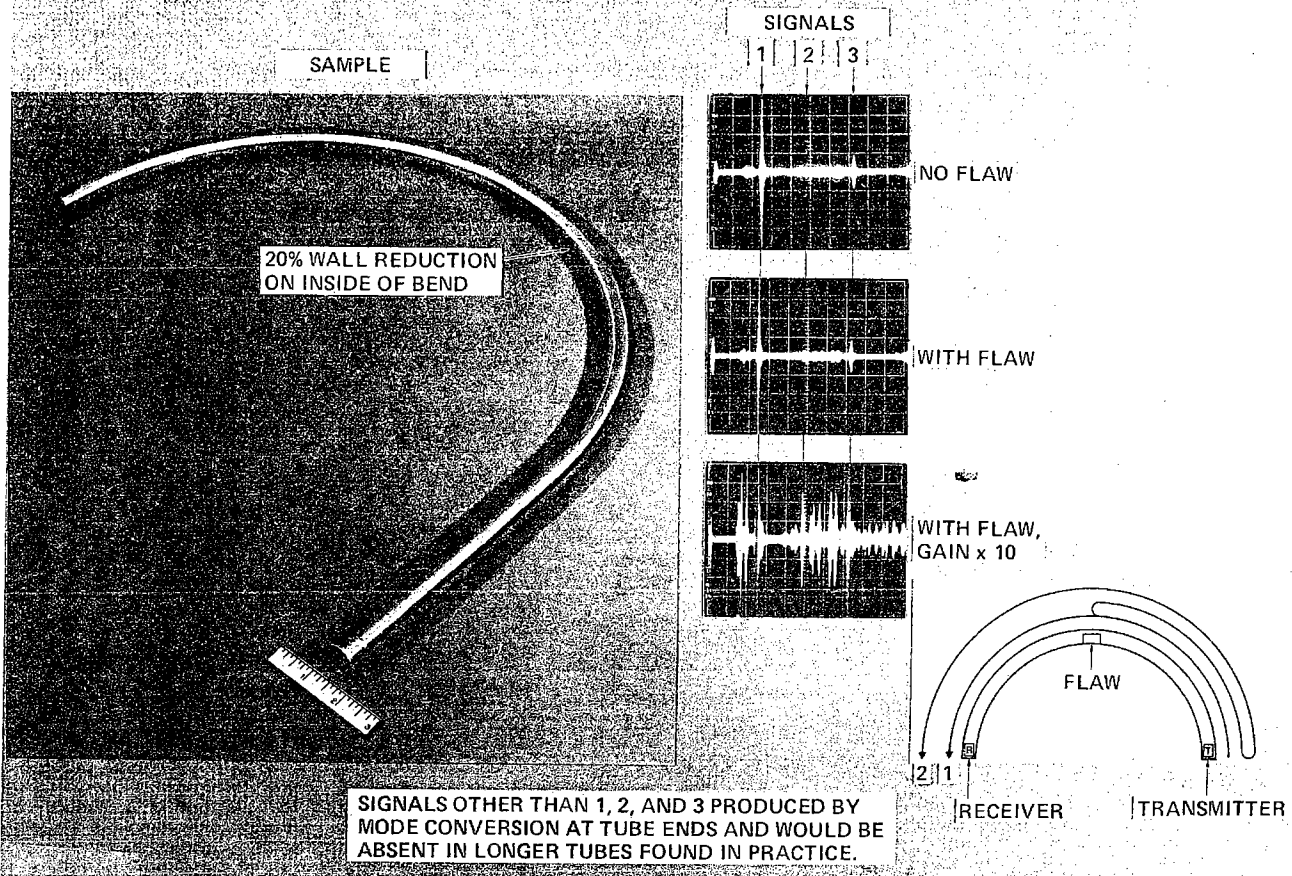


Fig. 4 Detection of flaws in U-bends.

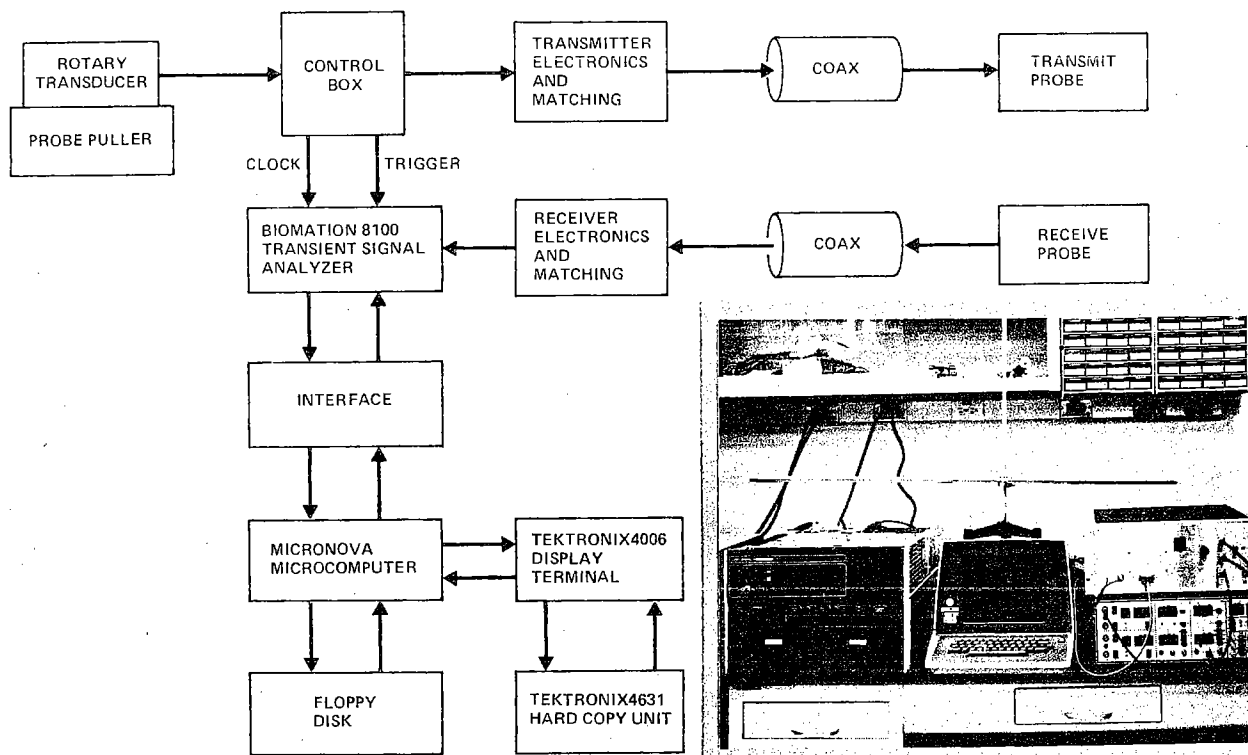


Fig. 5 Prototype system.

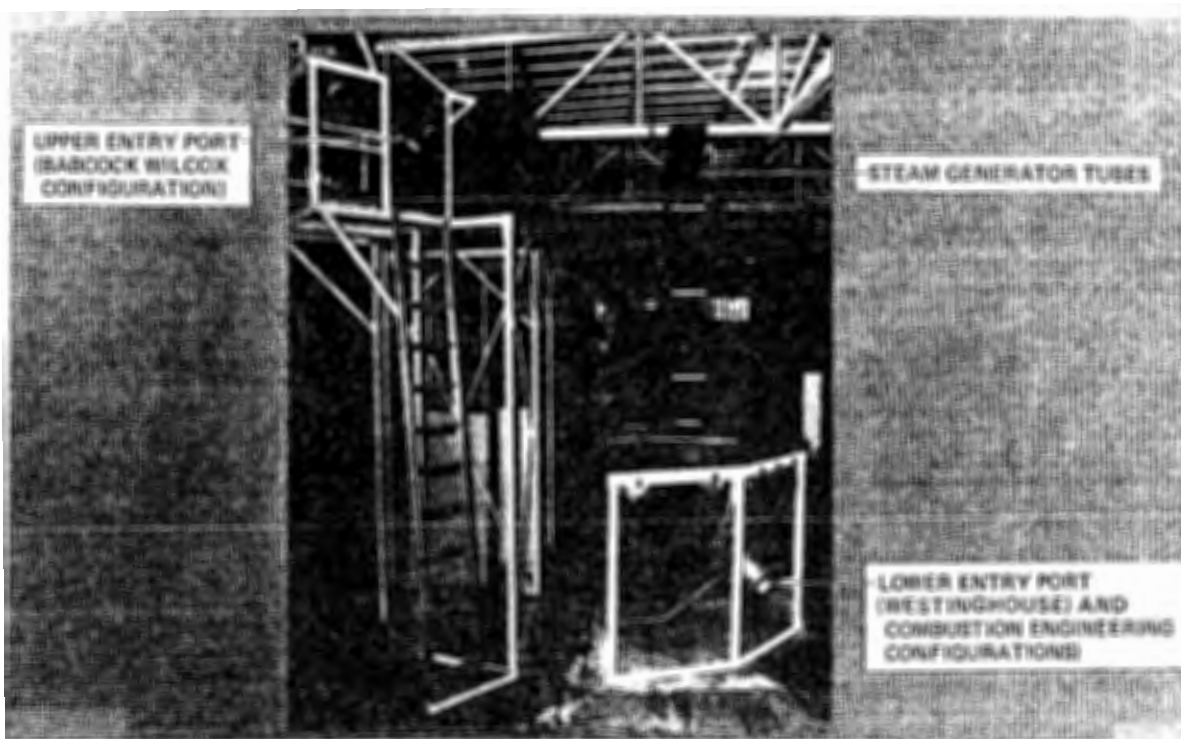


Fig. 6 Evaluation at steam generator mock-up.

- PREVIOUS FEASIBILITY STUDY DEMONSTRATED THAT EMAT'S COULD BE USED TO DETECT FLAWS IN STEAM GENERATOR TUBES.
- PRESENT PROGRAM WILL TEST A PROTOTYPE OF A FULL SYSTEM, COUPLED WITH AUTOMATIC PROBE PULLERS, IN A STEAM GENERATOR MOCK-UP.
- FUTURE EFFORTS WILL DEVELOP FLAW CHARACTERIZATION PROCEDURES AND REDUCE RESULTS TO PRACTICE IN ON-LINE STEAM GENERATORS.

Fig. 7 Conclusions.