Automatic Data Recording for Manual Ultrasonic Examinations

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Abstract
There exists a need for improving the productivity and reliability of manual ultrasonic examination teams performing PSI or ISI work on nuclear power reactor systems. An analysis of current methods and procedures revealed that the greatest improvement in both areas can be obtained by streamlining data measurement, recording, and reporting. A research and development program for accomplishing this goal is currently near completion. The approach used in this program is to automate the tasks of position measurement and ultrasonic data recording and to use computers for data analysis and reporting. This presentation discusses the automated Search Unit Tracking and Recording (SUTARS) data acquisition system that is being developed. When using the SUTAR system, the only function that the operator will need to perform during the examination is to guide the search unit so as to obtain complete coverage of the volume of interest. The system will automatically measure search unit position and yaw angle by a noncontacting method that eliminates the encumbrances inherent in a mechanical position sensor. To measure the ultrasonic data, a commercial flaw detector was modified so that an auxiliary subsystem automatically digitized video information obtained from the volume of interest. The examination data will be recorded on a digital magnetic tape recorded situated at a convenient location remote from the operator. Also recorded will be ten different items of examination documentation data such as operator identification, refracted beam angle, data sheet number, instrument serial number, etc.

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AUTOMATIC DATA RECORDING FOR MANUAL ULTRASONIC EXAMINATIONS

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ABSTRACT

There exists a need for improving the productivity and reliability of manual ultrasonic examination teams performing PSI or ISI work on nuclear power reactor systems. An analysis of current methods and procedures revealed that the greatest improvement in both areas can be obtained by streamlining data measurement, recording, and reporting. A research and development program for accomplishing this goal is currently near completion. The approach used in this program is to automate the tasks of position measurement and ultrasonic data recording and to use computers for data analysis and reporting.

This presentation discusses the automated Search Unit Tracking and Recording (SUTARS) data acquisition system that is being developed. When using the SUTARS system, the only function that the operator will need to perform during the examination is to guide the search unit so as to obtain complete coverage of the volume of interest. The system will automatically measure search unit position and yaw angle by a noncontacting method that eliminates the encumberances inherent in a mechanical position sensor. To measure the ultrasonic data, a commercial flaw detector was modified so that an auxiliary subsystem automatically digitized video information obtained from the volume of interest. The examination data will be recorded on a digital magnetic tape recorded situated at a convenient location remote from the operator. Also recorded will be ten different items of examination documentation data such as operator identification, refracted beam angle, data sheet number, instrument serial number, etc.

Southwest Research Institute's (SwRI) newly developed Search Unit Tracking and Recording System (SUTARS) represents a major advancement in manual ultrasonic inspection of welds. In conventional manual inspection, a large part of the inspection personnel's work effort is spent measuring position of the search unit and manually recording the data from indications that exceed the recording criteria of the code or standard. If an indication is detected which exceeds the acceptance criteria, additional inspection time is required to record data that is required to perform an evaluation. A need existed to reduce the time and cost associated with manual ultrasonic inspections and to improve the accuracy and credibility of these inspections. SUTARS was designed to accomplish these goals.

SUTARS automates the recording of all data pertaining to the ultrasonic inspection of welds, thereby relieving operating personnel of the time-consuming task of data recording and allowing evaluation to be performed with the assistance of a computer.

The data acquisition portion of the SUTARS system is schematically shown in Fig. 1 and pictorially in Figs. 2 and 3. As can be seen, this subsystem includes an ultrasonic search unit, a linear array of sensors for detecting airborne acoustic signals, a SUTARS control and display console, and a magnetic tape recorder.

The acoustic sensors are a part of a system used to measure the position and angular orientation (skew angle) of the search unit (see Fig. 4). These sensors detect airborne acoustic pulses emitted by two beacons located at two corners on the search unit. The two beacons are activated alternately, and the location of each beacon is calculated from the measured time of flight of acoustic signals from the beacons to the closest two sensors. The skew angle is then calculated from the relative position of the two beacons.

The tracking system provides accurate measurements over an area called a sector which is approximately 25 inches long in a direction parallel to the sensor array and approximately 8 inches wide. Areas larger than a sector are examined by repositioning the sensor array as many times as is necessary.

During an examination scan, the operator manually guides the search unit about the workpiece and, simultaneously, monitors the CRT display of a commercial flaw detector which is a part of the display console. It is important to note that, when using SUTARS, an operator uses exactly the same skills and procedures in manipulating the search unit that are used in conventional manual examinations. The location and angular orientation (skew angle) of the search unit are to be carefully adjusted to produce optimum signals for each reflector encountered throughout the examination.

Position data are acquired and recorded at the same time and rate as are ultrasonic data. During data processing, search unit position and skew angle data are used to calculate the true location of flaws relative to the weld. Since the operator is allowed to orient the search unit for optimum signal without introducing errors in calculated flaw location, SUTARS has a greater degree of freedom and repeatability than do most mechanical scanning systems in use today.
The SUTARS control unit, shown in Fig. 3, is the heart of the data acquisition subsystem and contains such features as:

1. An electronic memory for storing examination parameters such as the gate starting and gate stopping points, operator identification, refracted beam angle used for a particular examination, the data sheet identification number pertaining to a particular examination, and so forth. The content of this memory is automatically recorded on the magnetic recorder along with search unit position and ultrasonic data.

2. A time-corrected gain circuit that offers improved performance over conventional circuits.

3. Numerical readouts which display search unit position.

4. Several status indicators to notify the operator of important system conditions.

Of special important is the gate circuit developed for SUTARS. This gate detects and digitizes ultrasonic indications which occur between the gate starting and stopping points defined by the operator. The gate is equipped with a signal amplitude threshold detector that the operator can adjust to any desired level. When an ultrasonic signal large enough to exceed the threshold is detected, the gate is armed and goes into operation. The gate is capable of two different modes of operation, both of which are illustrated in Fig. 5. In mode 1, the gate examines the video signal and detects the peak value of every separate indication within the gated region. The peak values and the time location of the peaks are recorded and transmitted to the magnetic recorder. Since only the signal peaks are recorded, this mode is very economical in terms of magnetic tape consumed.

In mode 2 operation, as soon as any signal exceeds the threshold, the gate proceeds to sample and digitize the complete video trace at very fine intervals. This mode of operation records even the finest detail in the signals and is valuable for performing signal analysis with the highest possible accuracy.

Figs. 6 and 7 show SUTARS at the Edwin I. Hatch Nuclear Power Plant for a preservice examination of certain recirculation piping welds in austenitic material. If the data were being gathered during an in-service rather than preservice examination, data recording could be accomplished at a remote position of up to 200 meters from the point where the examination would be occurring.

After the examination data are recorded, the tape is converted and placed on a nine-track tape record. Thus, the original digital tape may be cycled back into service and be available for further data acquisition on a subsequent examination. Hardware typical of this process is shown in Fig. 8, and a schematic of the data flow through this system is shown in Fig. 9. The nine-track record, which represents the data base, can now be interrogated by utilizing the minicomputer; and many forms of data format and output are available. Currently the most useful formats for nuclear power plant component examinations have been in the formats shown in Figs. 10, 11, 12, 13, 14, and 15. These data formats include parameter information as shown in Fig. 10, reflecting information regarding the component that was examined, the person that performed the examination, initial instrument settings for sensitivity, instrument settings reflecting parameters that were controlled and established regarding the gate position, all referenced information concerning procedures, and other required traceable items. Fig. 11 is a coverage plot showing positive confirmation that the examination was performed in the area of interest and that no interruptions occurred during that examination. The crosses indicate the physical location of the search unit in relation to the centerline of the weld and the receiving array units. This plot is extremely useful when meeting quality assurance requirements necessary to indicate that, in fact, the examination was performed in a satisfactory manner. Fig. 12 represents sequential sector locations on a given examination region should there be more than one involved. It allows presentation of the relationship of each sector with the other sectors to be established and recorded. Fig. 13 represents a tabular data sheet very similar in nature to those currently generated by manual ultrasonic examination. Parameter data are located at the top; tabulated below by sector is the identification number of each indication that exceeded the interrogation level (in this case 100 percent DAC). The transducer location on the surface of the component is recorded in both X and Y coordinates, along with the metal path dimension to the target reflector and the peak amplitude. Fig. 14 presents the same data as shown in Fig. 13, but in a different format. The difference is that reflector location is given in terms of the X, Y, and Z dimensions of the component where Z represents the throughwall dimension.

Fig. 15 is a summation of the tabular information just discussed, but presented in the form of a C-scan presentation (shown at the top of the figure) and a B-scan presentation (shown at the bottom). The C-scan presentation gives the relationship of the various reflectors to each other in the X and Y plane, whereas the B-scan presentation gives the relationship of the reflectors relative to the throughwall dimension.

The SUTARS data analysis method utilized a concept that divides each sector into a fixed number of cells and interrogates the data to determine whether or not reflectors exceeding the recording were received from each cell location. In normal operating modes, cell dimension is one-twentieth of an inch. While this is sufficient in most instances, requests have been made for larger and smaller cells. This is easily accomplished by several means and is currently being addressed in modifications to this system.

Fig. 18 shows the correlation between data taken manually and data taken by utilizing SUTARS on a test block approximately 2 inches thick by 25 inches in length and 12 inches in width. The
reflectors, identified as A through H and depicted in the figure by the dashed lines, represent machined notches of varying depths placed in the surface opposite from the transducer. The manual data is plotted as a solid line, and the SUTARS data is plotted as a rectangular box. The dimensions of the box and the relationship of the fit to the actual reflector gives some evidence of the correlation that can be expected by utilizing this system. The dimensions of the SUTARS data box reflect the varying depths of the indicated targets.

One of the most exciting features of SUTARS is the capability of rapidly gathering ultrasonic information that can be converted to hard copy record. This allows data analysis to be done at a later time and at a remote location. In addition, a far more comprehensive amount of data is recorded than is normally taken when manual examination is performed. This is accomplished with fewer personnel in a radiation environment, thus minimizing exposure. These features, coupled with the ability to insure the credibility of the data by providing the sector coverage plot showing the examination as performed in all areas, make this system extremely desirable for a variety of applications. Many modifications are available as well as degrees of freedom which can be utilized for applications not yet envisioned.

SwRI feels that this system provides a major breakthrough in the ability to take sufficient ultrasonic information to allow data interpretation to be performed and data to be maintained in a manner long sought by ultrasonic examination personnel. The system also has much potential application as the technology of transducers evolves for it can be combined with any form of ultrasonic search unit that may be desired.
**Fig. 1.** SUTARS data acquisition subsystem

**Fig. 2.** Receiver array and search unit

**Fig. 3.** SUTARS control and display console
Fig. 4. Search unit tracking system

MODE 1: ONLY PEAK SIGNAL AMPLITUDES THAT EXCEED THE RECORDING THRESHOLD AND CORRESPONDING TIME MEASUREMENTS ARE RECORDED, I.E., POINTS A AND C.

MODE 2: IF ANY SIGNAL EXCEEDS THE RECORDING THRESHOLD, THE COMPLETE SCREEN PRESENTATION WITHIN THE GATED REGION IS RECORDED. THIS CAN LATER BE RECALLED AS AN A-SCAN PRINTOUT THROUGH THE DATA PROCESSING SYSTEM.

Fig. 5. Operating modes
Fig. 6. SUTARS data acquisition at Edwin I. Hatch

Fig. 7. SUTARS data acquisition at Edwin I. Hatch
Fig. 8. SUTARS data processing

CRT/KEYBOARD ESTABLISHES DATA

TAPE PLAYER INPUTS DATA INTO DATA PROCESSING SYSTEM

DATA STORED ON 9-TRACK TAPE AND PROCESSED FOR ANALYSIS

PRINT-PLAYER OUTPUTS DATA IN TABULAR AND GRAPHIC FORMATS

SUTARS PRINTOUTS RETURNED TO MDT ENGINEERS FOR ANALYSIS

Fig. 9. SUTARS data processing configuration
Fig. 10. SUTARS field version parameter listing

Fig. 11. SUTARS sector coverage plot

Fig. 12. SUTARS sector organization plot
Fig. 13. SUTARS data sheet

Fig. 14. Advanced data sheet
Fig. 15. SUTARS reflector map

Fig. 16. Data cell adjacency requirements
Fig. 17. Data cells grouped as indicated

Fig. 18. Calibration block data plots