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EDDY-CURRENT EXAMINATION OF LARGE-DIAMETER INSULATED PIPES

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Abstract: A new concept eddy-current technique has been developed to examine large-diameter insulated pipes without removing the insulation, and in many cases, without securing system operation. The new concept allows the in-place examination of piping systems using an encircling eddy-current coil that is a proven eddy-current technology. Eliminating the requirement to secure or drain the system or to remove the insulation from the pipe provides significant cost savings. The new concept also provides a significantly higher percentage of inspection volume coverage than ultrasonic techniques despite limitations of pipe brackets and other physical obstructions. The technique has been demonstrated on copper, copper nickel and limited carbon steel pipe ranging from 4 to 8 inches in diameter with insulation thicknesses from 1 to 2 inches.

Key Words: Condition monitoring; diagnostics; encircling coil; eddy current; pipe examination;

INTRODUCTION: Operational piping systems in general are subject to a number of degradation effects such as corrosion, erosion, fatigue, pitting, and wear. Non-destructive examination (NDE) of piping systems is essential in cases where a failure of the system could result in a loss of product, damaged equipment, or injured personnel. The NDE of large-diameter piping systems has typically been done by manual ultrasonic testing (UT) of expected degradation locations. The UT examination normally requires removing pipe insulation or lagging, extensive surface preparation, and time consuming manual or automated scanning of a grid pattern at the suspect location followed by system restoration. The UT examination provides a costly but very accurate characterization of expected degradation locations, but provides no information on other unexpected degradation locations in the piping system. Other NDE techniques could require system shutdown, cooldown, draining and insulation removal.

Framatome Technologies, Inc. (FTI) has developed a unique method of eddy-current examination for large-diameter piping systems that does not require system shutdown or insulation removal. The proven technique of using an encircling eddy-current coil had been adapted for use on an installed and insulated pipe. The method provides a rapid examination with good sensitivity. The technique has been proven in laboratory testing as well as in field examination of operational piping systems.

SYSTEM DESCRIPTION: The Framatome Technologies encircling coil system consists of several components. A rail system or a movement fixture is used to provide a smooth movement of the coil relative to the pipe surface. Coil forms are used to define the coil geometry and minimize any unwanted movement of the coils during the examination. The coils are designed to provide good defect sensitivity and allow rapid installation and removal. Figure 1 shows a typical setup for an encircling coil examination. Each of the components will be discussed below in more detail.

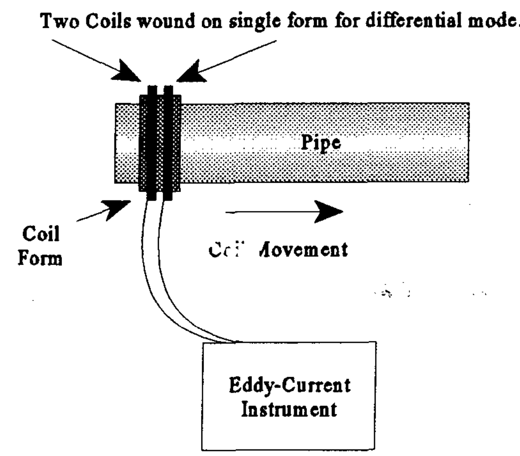

Fig. 1 - Eddy-Current Encircling Coil

Movement Fixtures: The first critical requirement for the application of an encircling coil for pipe examination is that the coil movement be coaxial with the pipe centerline. Side to side movement of the coil produces undesirable signals which complicate data interpretation. In conventional encircling coil examinations of tubing, the coil form contacts the tube outside diameter (O.D.). This direct contact with the pipe O.D. is not possible in the case of an insulated pipe. Instead, a system of rails or a mechanical movement fixture is used to maintain the coil alignment during the data scan.

Figure 2 shows a system of rails or thin tubular forms which can be placed on the top or side of a straight insulated pipe segment to provide a reference surface for the coil movement. The insulation surface is often rough or uneven and would add significant liftoff noise to the eddy current data. The rails provide a smooth surface for the coil travel and closely approximate the pipe wall contour.

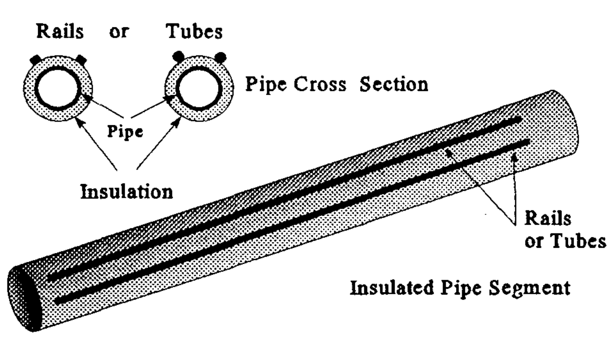

Fig. 2 - Straight Movement Fixtures

With the proper selection or design of rail material to conform to the pipe geometry, the rails could be used for examination of pipe bends or elbows.

Examination of bends and elbows provides a more significant challenge. Figure 3 shows two possible solutions. A mechanical movement fixture could be used to define the coil path by setting a pivot point at the center of curvature for the bend or elbow. Alternately, a set of flexible rails could be installed on the bend or elbow. The actual geometry and access restrictions would determine the best method for this case.

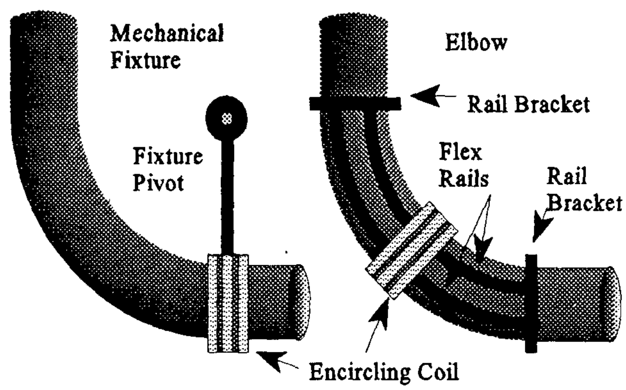

Fig. 3 - Elbow Movement Fixtures

Coil Forms: The second requirement for the use of an encircling coil in examining insulated piping is that the coil geometry must remain stable during the examination. In the case of a differential coil, the relative positions of the two windings must remain constant. A special design coil form is used to provide the stable structural geometry of the coils during a pipe examination. The coil form is constructed of a rectangular sheet of nylon or delrin with a hole pattern for attachments and guide posts. Typical coil form top, side and end views are shown in Figure 4.

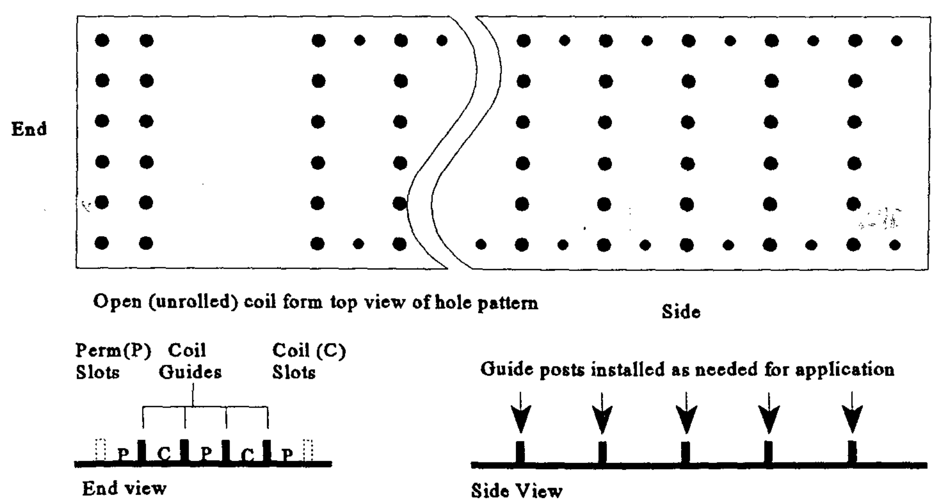

Fig. 4 - Coil Form

The coil form is wrapped loosely around the insulated pipe after the rails have been installed. The start of the form is secured to the end to create a rigid right circular cylinder around the pipe. Figure 5 shows a cross-sectional view of the installed coil form.

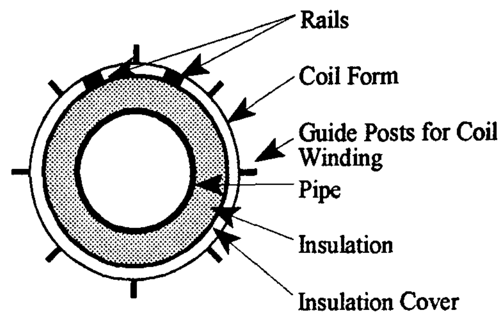

Fig. 5 - Coil Form Wrapped Around Insulated Pipe

Encircling Coils: A typical encircling coil is composed of 50 (or more) lengths of insulated copper magnet wire. The length and wire gage are determined by the pipe and insulation diameter and the number of turns required for the coil sensitivity and proper frequency range. The conductors are grouped together in heat-shrink tubing to provide structure and protect against abrasion. One end of the bundle has a male connector and the opposite end has the mating female connector as shown in Figure 6.

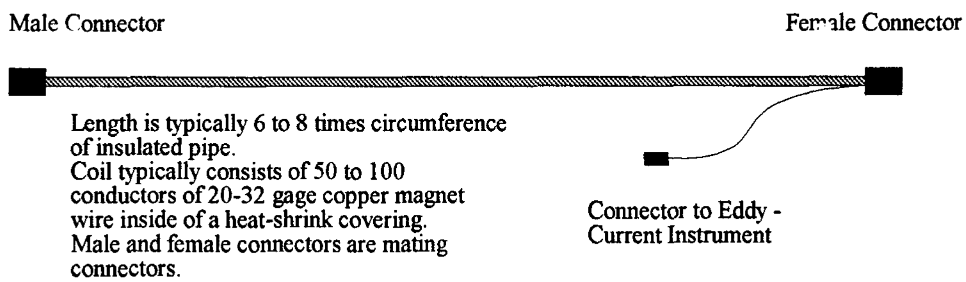

Fig. 6 - Coil Winding Design

The pinout of one connector is shifted one pin such that connection of the two ends provides a continuous single loop of the 50 (or more) conductors as shown in Figure 7. When this long coil of 50 conductors is wrapped around the pipe 6 times, the resulting encircling eddy current coil has 6 * 50 = 300 turns, which can be installed in about 4 minutes. This is one of the more unique features of this technique. **The coil design allows a sensitive encircling coil to be easily installed on an intact and operational piping system without system shutdown or insulation removal.**

The time and ease of coil installation can be improved significantly with minor design changes.

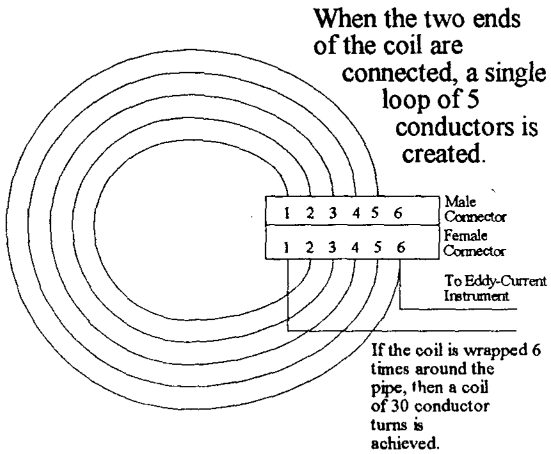

Fig. 7 - Encircling Coil C^^cept

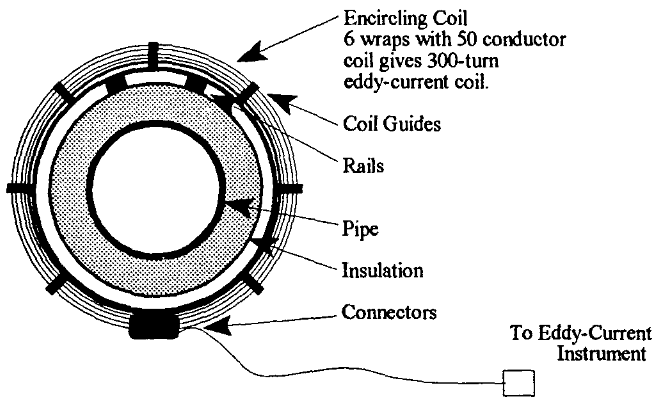

Fig. 8 - Coil Winding on Coil Form

Once the coils are wrapped in place on the coil form as shown in Figure 8, the ends are connected to complete the circuit and the wraps are secured in place. The coil form provides structure and uniformity for each coil winding.

The coils are connected to a standard reflected impedance eddy-current instrument and an electrical balance or nulling is performed as in a ypical differential eddy-current application.

Examination Procedure: After the coil has been installed on a section of pipe, appropriate locating and identification information is recorded and the coil is moved to the start of the section. Eddy-current data is recorded as the coil is slowly pulled past the examination region. As shown in Figure 9, data may be recorded in either a differential or absolute mode for reflected impedance operation. It is also possible to operate the coils in a driver pickup (or remote field) configuration if required for examination of ferromagnetic piping.

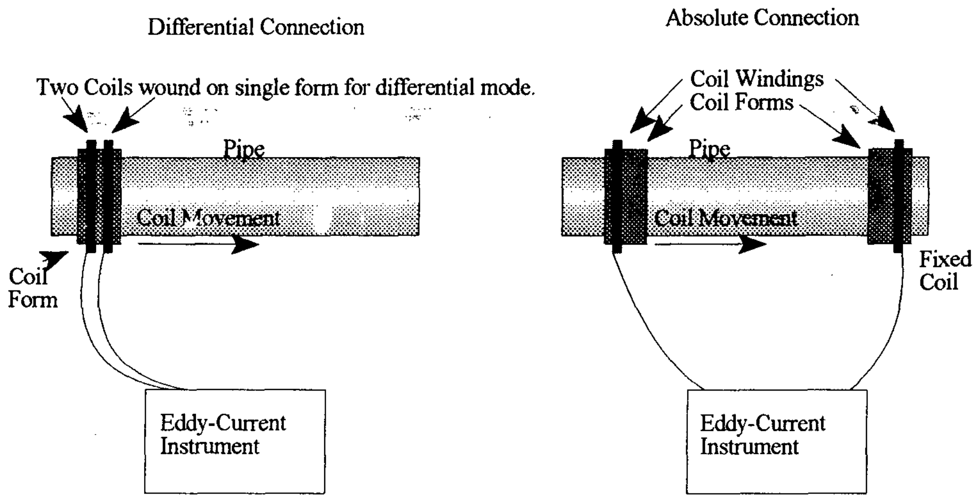

Fig. 9 - Eddy-Current Differential and Absolute Mode Connections

Disposition of Indications: Eddy-current responses can result from several conditions. The examination procedure must determine which signal responses should be eliminated and which represent pipe degradation. Signals are first correlated with brackets and fixtures external to the pipe. Eddy-current responses clearly resulting from factors external to the pipe are eliminated. Some signal response locations may require examination with an eddy-current driver pickup pancake coil for better localization / characterization. For example, a pipe weld would be detectable by the pancake coil for a full 360° around the pipe circumference.

Indications that are not eliminated as external influences would then require localized removal of the pipe insulation to determine the cause of the eddy-current indication. Visual examination of the pipe O.D. would show any denting or significant O.D. wall loss. After the insulation has been removed, the encircling coil sensitivity could be increased by wrapping the coil in a smaller diameter (closer to the pipe O.D.). If needed, ultrasonic examination techniques could then be applied to measure any inside diameter (I.D.) wall loss or pitting.

LABORATORY TEST RESULTS: Framatome Technologies, Inc.'s encircling coil concept was proven in laboratory tests prior to the first field examination. Samples of actual piping material for the following sizes were obtained for test purposes:

Pipe Diameter, (in.)	Pipe Wall Thickness, (in.)	Pipe Material	Pipe Insulation Thickness (in.)
8	0.18	CuNi	1 to 2
5	0.13	CuNi	1.3 to 1.8
4	0.12	Copper	1 to 1.5

Defects of 100 % through wall, 50 % O.D. and 50 % I.D. were machined or cut into the pipe standards to determine if the encircling coil could detect the target wall loss of 50 %. The diameter of the encircling coil was set to the maximum insulation diameter plus about 0.5-inch of clearance.

The FTI encircling coil technique was used to examine each standard. In every case, the installed defects were detected with a very good eddy-current signal response. The typical response from the 8-inch copper / nickel pipe is shown in Figure 10.

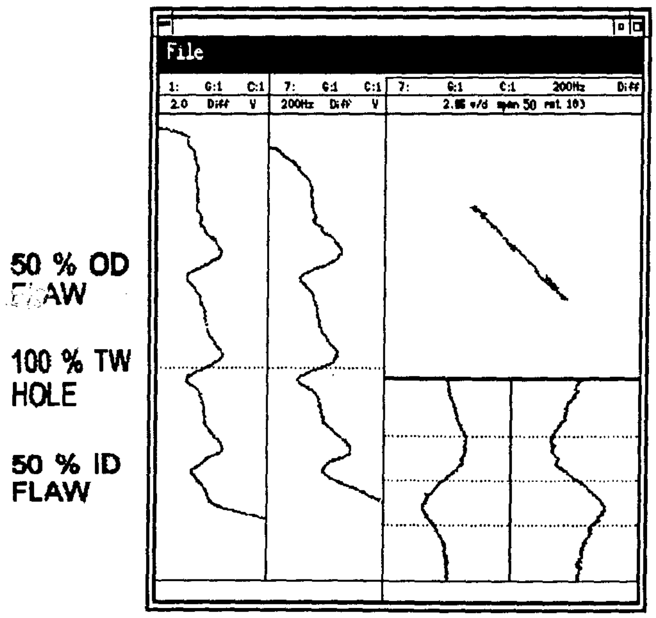

Fig. 10 - Eddy-Current Response for 8-Inch Pipe

FIELD TEST RESULTS: In August of 1995, the FTI encircling coil was used to examine shipboard piping in Norfolk, VA. The system clearly identified piping welds, some denting, and pipe O.D. degradation. At least one actual I.D. wall loss pit with a depth of approximately 40 % was detected and confirmed in an operating system pipe. The pit was confirmed by ultrasonic and visual examination.

DEVELOPMENT PLANS: The encircling coil technique has been proven in the laboratory and in a field examination. Planned and underway improvements will expand the scope of the technique, improve the examination speed and simplify the technique. The specific development plans cover the following areas:

* More work on ca bon steel pipe examination
* Better methods / fixtures for elbow examination
* Improved coil installation methods and speed
* Better rejection of noise and external signal influences.

SUMMARY: FTI has developed a unique new examination concept that allows a proven encircling coil eddy-current technique to be applied to insulated and operational piping system. **The new concept offers the following significant advantages for any industry using large piping systems which require NDE:**

* **REDUCED COSTS FOR PIPE EXAMINATION**
* **IMPROVED EXAMINATION COVERAGE**
* **IMPROVED EXAMINATION SPEED**
* **MINIMAL INSULATION REMOVAL / REINSTALLATION**
* **MINIMAL IMPACT ON SYSTEM OPERATION**
* **MORE FLEXIBLE AND COST EFFECTIVE NDE SCHEDULING.**