Title of Innovation:
Magnetic Tomography Method

Nominee(s)
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Category:
Pipeline Inspection

Dates of Innovation Development:
(from November, 1999 to November, 2012)

Web site:
http://transkorgroup.com/

Summary Description:
Magnetic Tomography Method (MTM) Technology is developed for assessing safety and integrity of pressurized pipelines of any purpose made of ferromagnetic materials. Quality of assessment is not influenced by transported product. MTM is based on the inverse magnetostrictive effect (Villary effect) - the change of the magnetic susceptibility of a ferrous material when subjected to a mechanical stress. Method uses "natural" magnetization the ferrous pipes by magnetic field of the Earth. MTM equipment remotely registers magnetic field from the pipe while moving along its axis. MTM does not measure the dimensions of geometric defects alone but instead it measures the stress caused by these defects and identifies their type, location and orientation in accordance with the location and orientation of the area of stress. MTM determines the comparative degree of danger of defects by a direct quantitative assessment of the stress-deformed state of the metal.

This technology ensures probability of detection (POD) of anomalies of stress-deformed state greater than 80% at SMYS from 30% to 85%. POD is never less than 60% for any SMYS value.
This unique proprietary method of pipeline inspection is based on the *inverse magnetostrictive effect* (Villary effect) – the change of the magnetic susceptibility of a material when subjected to a mechanical stress. Method uses “natural” magnetization of the ferrous pipes by magnetic field of the Earth. Magnetic tomography charts the attributes and characteristics of pipe sections by registering and analyzing changes in the magnetic field of the pipeline. These changes are related to stress which in turn are related to defects in the metal and insulation. Magnetic measurements data is collected from the ground surface and anomalies detected are a function of stress, mechanical loading and structural changes in the metal. Magnetic tomography does not measure the dimensions of geometric defects alone but instead it measures the stress caused by these defects and identifies their character, location and orientation in accordance with the location and orientation of the area of stress. Linear and angular coordinates of flaws in the metal and coating are defined within a tolerance of $+/–0,25m$.

MTM determines the comparative degree of danger of defects by a direct quantitative assessment of the stress–deformed condition of the metal. Conventional surveys only measure the geometrical parameters of a defect. Their subsequent calculations to assess the impact of the defect on the safe operation of the pipe do not take into consideration the stress caused by the defect. Therefore conventional surveys may fail to detect dangerously stressed areas of the
pipe or, conversely, classify a defect as one which requires urgent attention when, in reality, the stress level may be low and the defect presents no immediate threat to the operation of the pipe. Since MTM directly measures the stress caused by defects it is an inherently more accurate guide to the safe operation of the pipeline than conventional survey methods.

When and how was the innovation developed?
The technology has been developed by group of scientists in 1999 in Russia, Moscow.

How or why is the innovation unique?

1. Applicable for the unpiggable pipelines or other objects where in-line inspection method is inapplicable. This objects include but not limited to:
   - compressor stations pipelines;
   - pipeline inclusions;
   - water-supply pipelines in cities
2. MTM doesn't require any preparation of the pipeline for testing such as cleaning, opening the pipe, or stopping pipeline operation. Magnetic field measurements are performed with pipeline operating as usual.
3. Doesn't require magnetizing of the object's pipes;
4. Method detects defects of various types including long crack-like defects of the pipe and the welding;
5. Doesn't have limitation on the diameter, configuration, and method of protection of pipelines tested. These include:
   - change of pipe diameter and wall thickness,
   - pipeline turns and their directions,
   - transported product (e.g. gas, oil, or water)
   - pressure inside the pipeline
   - pipeline protection (e.g. cathodic protection, etc)
6. Method evaluates the degree of danger of defects by the level of concentration of mechanical tensions rather than defect geometry (e.g. length-width-depth)
7. Method is optimal for running a database on condition certification of objects of any length and any monitoring period
8. Method guarantees minimal customer resources use for monitoring preparation and repair works such as:
   - reduces work volume and total costs of pipe access works;
   - greatly reduces time of full diagnostic - repair evaluation - repair planning - repair cycle;
   - gives pipe corrosion prognosis and estimates levels of tense-deformed state of the pipeline under current operating conditions.

What type of corrosion problem does the innovation address?
All types of corrosion in pipelines that cause changes in stress.

What is the need that sparked the development of the innovation?
Inspecting unpiggable pipelines.
Are there technological challenges or limitations that the innovation overcomes?

<table>
<thead>
<tr>
<th>Item</th>
<th>Parameter Description</th>
<th>Limitation</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Maximum distance from the magnetometer to inspected pipeline</td>
<td>15 pipe diameters (can be up to 20 diameters depending on OP)</td>
</tr>
<tr>
<td>2</td>
<td>Minimum Diameter of inspected pipeline</td>
<td>3” (for underground line)</td>
</tr>
<tr>
<td>3</td>
<td>Maximum Diameter of inspected pipeline</td>
<td>No limitations</td>
</tr>
<tr>
<td>4</td>
<td>Min/Max pipeline wall thickness</td>
<td>From 1/8” to no limitations</td>
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<tr>
<td>5</td>
<td>Type and presence of protective coating</td>
<td>No limitations</td>
</tr>
<tr>
<td>6</td>
<td>Type and presence of cathodic protection</td>
<td>No limitations</td>
</tr>
<tr>
<td>7</td>
<td>Maximum pressure of fluid in pipeline</td>
<td>No limitations</td>
</tr>
<tr>
<td>8</td>
<td>Direction and presence of fluid flow in pipeline</td>
<td>No limitations</td>
</tr>
<tr>
<td>9</td>
<td>Minimum length of pipeline segment for MTM survey:</td>
<td>330’ (100 meters)</td>
</tr>
<tr>
<td>10</td>
<td>Maximum length of inspected segment</td>
<td>No limitations</td>
</tr>
<tr>
<td>11</td>
<td>Maximum speed during inspection</td>
<td>6.5’ per sec</td>
</tr>
<tr>
<td>12</td>
<td>Limitations in determining** metal loss type anomalies: General Corrosion - Single Pitting</td>
<td>From 6% to 90 % of w. thek &gt; 3/8”(10 mm) long and 30%w.t.</td>
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<tr>
<td>13</td>
<td>Minimum length/opening of crack-like type anomalies</td>
<td>from 10 mm \ 300 mkm</td>
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<tr>
<td>14</td>
<td>Presence of residual magnetization from prior in-line inspection</td>
<td>Shall be nil or at least 2 years after MFL inline inspection</td>
</tr>
<tr>
<td>15</td>
<td>Minimum distance from the inspected pipeline to the parallel foreign or other utility line without an impact on MTM data</td>
<td>4’ (1.2 m)</td>
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<tr>
<td>16</td>
<td>Size of foreign metal objects, structures located near inspected pipeline and impacting MTM data</td>
<td>Equal or larger by mass than inspected pipeline</td>
</tr>
</tbody>
</table>
| 17   | Utility lines running in parallel to the inspected pipeline that could cause signal interference: | - DC lines  
- Communication cables  
- Fiber optic line in steel casing  
- High voltage AC lines: (100 kVt and higher) |
| 18   | Crossovers with underground lines or cables or overhead power lines | Will be called out as interference points or omitted from survey |
What are the potential applications of the innovation?
Inspection of any types of pipelines.

How does the innovation provide an improvement over existing methods, techniques, and technologies?
This is the only technology that allows to inspect unpiggable pipelines.

What type of impact does the innovation have on the industry/industries it serves?

Miles of unpiggable and hard to access pipelines all around the world were inspected with MTM technology and explosions were prevented.

Does the innovation fill a technology gap? If so, please explain the technological need and how it was addressed prior to the development of the innovation.

Has the innovation been tested in the laboratory or in the field? If so, please describe any tests or field demonstrations and the results that support the capability and feasibility of the innovation.
The technology has been tested in laboratory and on the fields.
September 23, 2013

To Whom It May Concern

Re: Inspection Trials with Stress Magnetic Tomography Method

Enbridge successfully completed the company’s first set of inspection trials with the magnetic tomography device developed by Transkor Group Inc. (MTM Tool). The results from preliminary field validation work show that the features reported by the MTM tool during inspection for the most part coincide with actual features that are being found on the pipeline though visual inspection and non-destructive (NDE) evaluation. Although the features found were benign, we feel that this is a positive indication that this technology does work and shows great potential for further development and enhancement of its inspection capabilities.

Enbridge has plans to continue working with this technology with the hopes that it will at least provide a method of screening for indications on unpiggable and difficult to inspect pipelines that would otherwise require expensive excavations that may or may not align with defective pipeline segments that are of major concern.

Should you require further information, please contact myself, Juan Mejia, Supervisor of Facilities Integrity Technology at 1-780-420-8589 or juan.mejia@enbridge.com

Sincerely,

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Canada
Is the innovation commercially available? If yes, how long has it been utilized? If not, what is the next step in making the innovation commercially available?

Yes, this technology has been utilized since year 2002.

Are you aware of other organizations that have introduced similar innovations? If so, how is this innovation different?

No

Are there any patents related to this work? If yes, please provide the patent title, number, and inventor.

There is a patent in Russia #971.863. And also we just have got the patent in USA. (we’ll provide number if you are interested.)