METHOD AND APPARATUS FOR LEAK DETECTION AND PIPELINE TEMPERATURE MODELLING METHOD AND APPARATUS

This is a division of application Ser. No. 07/949,076, filed Sep. 22, 1992.

BACKGROUND OF THE INVENTION

The present invention relates to a leak detection system for pipelines, and furthermore relates to a temperature modelling method and apparatus, particularly for use in a leak detection system for a pipeline.

The need for sensitive, reliable and affordable leak detection for petroleum and other fluid carrying pipelines is evident, based not only the economics of pipeline operation, but on the inevitable imposition of government regulatory requirements, for example, environmental regulations. Since hundreds of thousands of miles of pipelines are already in place, many with provision for periodic pigging or cleaning, the need for a non-intrusive leak detection system is also evident.

The detection of leaks in pipelines presents a number of technically challenging problems, together with a need to solve them. Not only is it necessary to preserve the value of the product in the line, but it is essential to detect product leaks for environmental considerations. A leak of product can seriously contaminate groundwater or the environment, and for some products, create the risk of fire or even explosion.

Compounding the difficulty of leak detection is the fact that pipelines often travel through difficult terrain, or under riverbeds where access is not possible. In addition, the lengths of line are great, requiring that each leak detection site station be sufficiently accurate to monitor large sections of the line, so as to avoid the need for an unaffordable number of monitoring points. In addition, the leak detection response rate must be extremely fast, even considering the long distances between site stations.

The method used must take into account a number of realities, which if not recognized, would lead to frequent false leak alarms, or the failure to recognize a true leak quickly. For example, the length of pipe between monitoring points will, in many cases, be many miles. Changes in temperature can cause the volume of liquid, and pipe, between these points to increase or decrease by a magnitude larger than the volume of leak which could be tolerated. In addition, operating conditions such as pressure variations, presence of free gas, slack line and line packing add further obstacles to accurate leak detection.

In addition, pipelines frequently sequentially transport many different products, often of unknown density and viscosity, especially at the interface between two liquids. The flowmeter itself must resist error as it measures these different liquids. To further complicate matters, temperature variation will, in addition, change these characteristics, even for the same liquid, at different locations on the pipeline. In response to these properties, and to the operating requirements of the pipeline, the flow rates may vary over a large range, frequently entering the transition region between turbulent and laminar flow. Detecting a leak under these circumstances is a difficult job.

It is also essential to recognize that the ultimate performance of the leak detection system depends directly on the operational accuracy of its flowmeter; not its "rated" accuracy based on laboratory tests under idealized conditions, but rather its ability to perform under the real and difficult conditions encountered in most pipeline applications, which frequently include the harshest of environmental conditions encountered on Earth, such as those which apply to the Alaska pipeline, or to operation in the deserts of Saudi Arabia.

As a practical matter, the flowmeters used for this service must also withstand the often corrosive or abrasive nature of the liquids themselves. They must be capable of long, maintenance-free service. Above all, their calibration must remain stable, and should not be prone to shift due to wear or to variable liquid properties. Since there are many pipelines which were in place prior to industry and public awareness of the environmental consequences of product leakage, it is important that the flowmeters install easily, and without altering the operation of the pipeline itself, such as in the passage of cleaning pigs, or introduction of performance affecting pressure drops.

As many pipelines are of long length, and require a considerable number of measurement points, the question of economy is of great concern. The cost of large size turbine and PD meters is high, without even considering the cost of installation and maintenance. And in lines which are pigged, the required pipe bypassing is an additional expense of some magnitude.

The heretofore known clamp-on transit-time ultrasonic flowmeters, e.g., those manufactured by Controlotron Corp. of Hauppage, N.Y., are ideally suited for adaptation in a leak detection system, possessing the accuracy, sensitivity, rangeability, speed of response, economy and reliability required of a practical leak detection system, in addition to being able to perform all functions non-intrusively. Furthermore, these devices possess the ability to identify the liquid itself, and obtain essential data on liquid density and viscosity.

The system according to the invention to be described preferably includes an important feature, the ability to compute the temperature at all points on the pipeline on an essentially continuous basis, and account for the expansion or contraction of the liquid and the pipe, so as to correct the flow emerging from any segment of the pipeline for these factors. The system according to the invention thus detects excess flow produced during expansion of the liquid, without presenting a false leak alarm, and determines reduction of pipe volume, which might mask a true leak. It also identifies non-leak causes of flow deficiency due to liquid contraction or pipe expansion, which might otherwise cause a false leak alarm, with consequent loss of confidence in the system.

As will be shown below, the attributes of clamp-on transit-time ultrasonic flowmeters make them particularly adaptable to resolve each of the limitations and requirements discussed above. The system according to the invention using such flowmeters offers a means of practical, effective and affordable pipeline leak detection.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a leak detection method and apparatus for pipelines.

It is a further object of the present invention to compensate such a leak detection system for temperature variations along the length of the pipeline, so that changes in flow rate or product volume caused by temperature changes do not result in false leak alarms, or mask actual leaks.

It is yet still a further object of the present invention to