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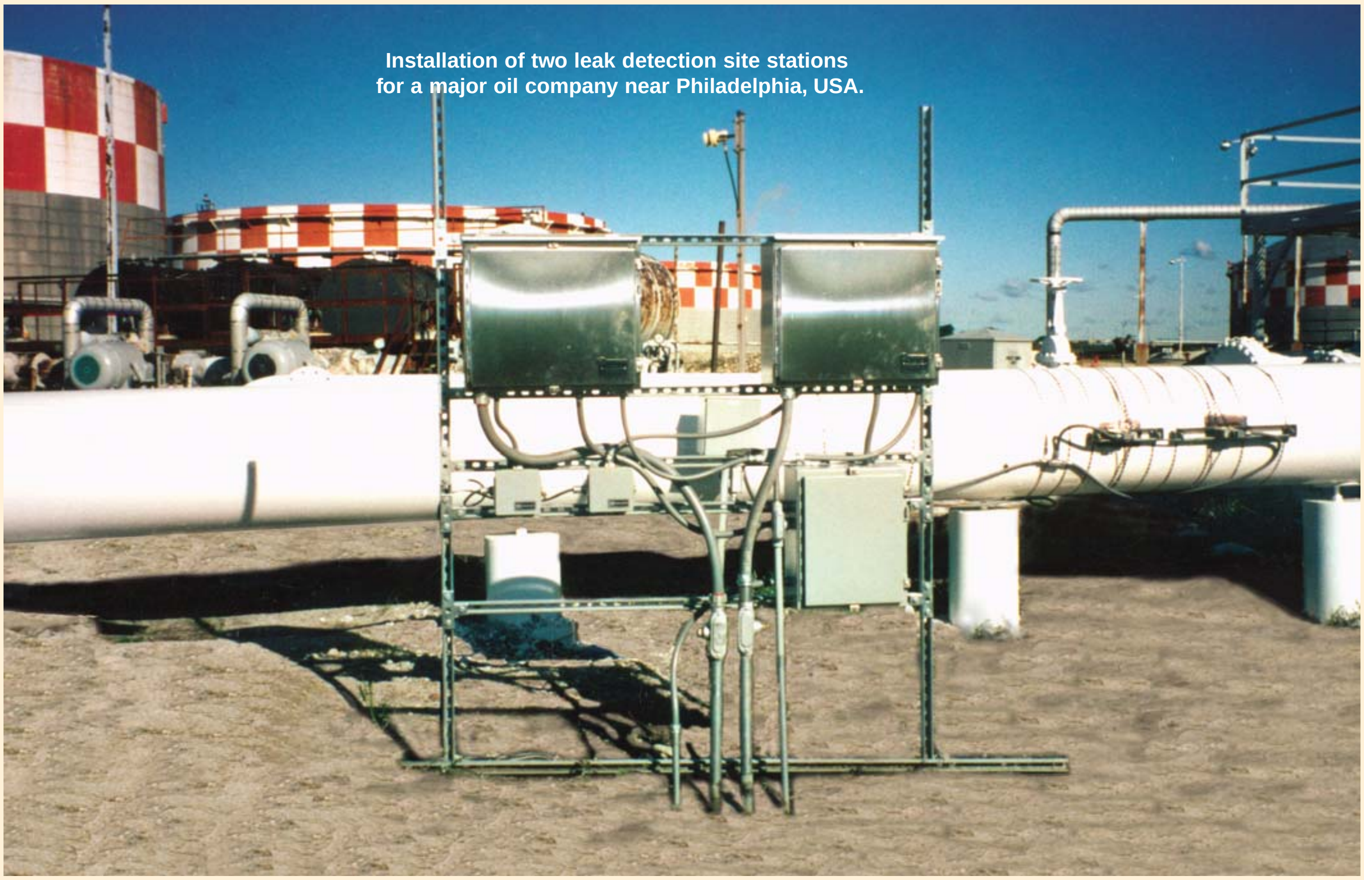
Leak Detection & Prevention


Installation of two leak detection site stations for a major oil company near Philadelphia, USA.

Joseph Baumoel, Controlotron, USA, Provides an overview of the ongoing problem of pipeline spills and evaluates the technologies available for the identification and control of pipeline leaks.

From time to time, world news headlines describe the catastrophic effects of an oil spill in an environmentally sensitive location. The blame is usually placed on the petroleum suppliers, as if these companies did not care about the effects on the environment or on the public when an accident occurs. It is not only the environment and the public that suffers the consequences but also the producers and transporters. These companies experience loss of expensive product, cost of remediation, imposed fines and irreparable damage to their reputation. Therefore, when leaks or spills happen, everyone loses.

The very public that condemns the suppliers of oil products when a leak occurs would be the first to complain if the oil fields, pipelines, and refineries were shut down. However, it is natural to want the best protection against the consequences of an undetected leak that modern methods can provide. This paper concerns the current technology in pipeline leak detection and leak location.

There are a number of issues to deal with when considering the installation of a leak detection system. They include:

- Are leak detection systems really necessary, or are leaks just too infrequent and unlikely to worry about?
- What technologies are currently available, and do they really work?
- What is the actual cost of a leak detection/location system?

The Need For Leak Detection

As pipelines get older, and as population centers encroach on territory that was originally built on vacant land, the danger of a significant event becomes more and more likely. Considering the huge mileage of pipelines that are required to transport the world's oil on which both industry and our daily lives depend, it is impossible to move the pipelines 'out of the way.'

Non-Intrusive Flowmeters Provide Superior Analysis

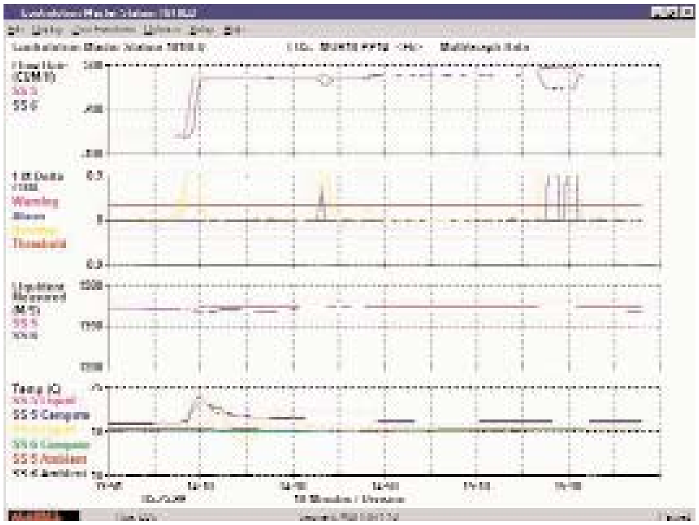


Figure 1. Graphic Presentation of a typical leak detection screen for a clamp-on ultrasonic detection system.

Two site stations at Hong Kong airport that are part of a leak detection system for jet fuel.

According to figures published by the United States Office of Pipeline Safety (OPS), every year there are a substantial number of spills that cause significant damage to the environment, to property, and, in some cases, to life itself. Plus, the financial loss to the industry runs into millions of dollars.

Based on OPS regulation of over 600,000 km of gas pipelines and 300,000 km of oil and petroleum pipelines operated by over 2500 major companies, Table 1 shows the combined statistics of recorded leaks. (Historical totals may change as OPS receives supplemental information on incidents.)

Given the advanced technology that is available today, it is possible to mitigate the consequences of a spill by quickly detecting the existence and location of even a small leak, so that it can be quickly repaired before major damage is inflicted.

Available Tecnologies

This paper discusses the installation of a leak detection system that is designed specifically for that purpose, not a system that is 'tacked on' to an existing SCADA system.

To understand this issue, it is important to review what systems are available, how they work, and how well they perform. To provide a perspective on how a leak detection system works, Figure 1 shows a System 1010LDV MultiGraph screen taken during a leak test.

How does one detect a leak in a pipeline? Petroleum products expand and contract due to temperature and pressure changes along the pipeline, which may be as long as thousands of kilometers. Many pipelines carry more than one product. Therefore, simply saying that barrels in must equal barrels out is not precise enough. The system must account for the effect of varying flow rates, temperature, pressure, and the different behavior of the different products that may be somewhere in the pipeline at the same time.

Accordingly, it is necessary to state that 'the mass flow into the pipeline must equal the mass flow out of the pipeline.' Therefore, instead of using conventional volumetric flowmeters to perform leak detection, this application requires mass flowmeters.

In addition, when a pump is started, the flow into the pipeline cannot equal the flow out of it until all the oil in the pipeline has been fully compressed. This process is called line pack, which can take many minutes. During this period, the flow into the pipeline must be greater than its output. If no leak occurs during this time, it is necessary to avoid declaring a false alarm. However, it is during the start of flow, when pressure is increasing, that a pipeline is most likely to fracture. How is a leak detected during startup of flow, when it is guaranteed that the flow into the pipeline must be larger than the flow out, sometimes for up to 10 minutes? A good leak detection system solves this problem.

Pipeline leaks do not all develop suddenly when a pipe ruptures. In fact, normal corrosion causes small leaks that, over a period of time, can spill enormous quantities of oil. Therefore, it is essential that the leak detection system be sensitive enough to detect very small leaks. But if this sensitivity is accompanied by instability of the leak detection system, the resultant number of false alarms will soon make operators ignore a real leak alarm.

It is necessary to consider the times when the pipeline is not flowing, yet is still full of oil. Though not flowing, the oil is still under pressure, and the pipes feel that stress. Many pipelines develop leaks under this condition, at which time the conventional flowmeters are below their range of operation. Only the bi-directional ultrasonic flowmeter can operate at zero flow.

As a practical matter, most of the pipelines that need leak detection protection already exist. In fact, they are in operation. How can they afford to stop operation for installation of meters on which the leak detection system must depend? Non-intrusive mass flowmeters of sufficient sensitivity and stability are required.

In short, it is not a simple task to make a leak detection system to protect a pipeline. But that is just what the leak detection system must do to provide a quick indication that there is a leak, so that steps can be taken to mitigate it before major damage occurs.

What technology is available to protect the environment, the public, and even the operator of the pipeline from the consequences of an undetected pipeline leak?

There are two primary methods that are presently being employed:

- The pressure based pipeline software modeling system.
- The non-intrusive, ultrasonic, mass flowmeter measurement system.

Actual Mass Balance Measurement Outperforms Modeling

Pressure Based Method

In general, when the issue of leak detection became prominent, either due to governmental regulation or the realizations of liability by the pipeline operator, most operators had a SCADA system in place. These systems measure flow rate and other pipeline operating parameters. The instruments that provide data to the SCADA system were, in the vast majority of cases, neither originally designed nor purchased for leak detection. In general, they do not have the rangeability, nor the sensitivity required for leak detection.

Table 1. Office of Pipeline Safety: Hazardous Liquid Pipeline Operators' Accident Summary Statistics by Year, 1/1/86 to 12/31/00

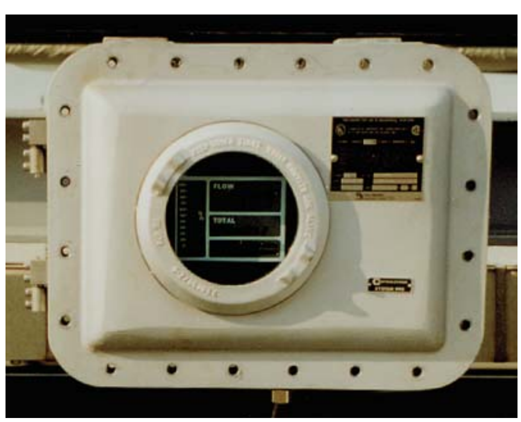
Year	No. of accidents	Fatalities	Injuries	Property damage	Gross Loss (bbls)	Net Loss (bbls)
1986	209	4	32	16,027,846	282,638	220,313
1987	237	3	20	13,140,434	395,854	312,794
1988	193	2	19	32,414,912	198,397	114,251
1989	163	3	38	8,813,604	201,758	121,179
1990	180	3	7	15,720,422	124,277	54,663
1991	216	0	9	37,788,944	200,567	55,774
1992	212	5	38	38,651,062	136,922	68,742
1993	229	0	10	28,873,651	116,802	57,559
1994	245	1	7	56,503,604	162,777	112,389
1995	188	3	11	32,518,689	110,237	53,113
1996	193	5	13	49,662,544	154,960	96,140
1997	171	0	5	38,011,649	186,338	120,934
1998	153	2	6	59,823,660	149,277	60,771
1999	166	4	20	42,752,287	166,975	104,455
2000	130	1	4	104,389,798	94,322	50,887
Totals	**2,885**	**36**	**239**	**575,093,106**	**2,682,101**	**1,603,964**

The modeling method depends on the creation of a mathematical model of the theoretical relationship between the flow rate of the liquid or gas in the pipeline, and the flow and pressure at various points along the line. In general, this method depends on only a few measurements provided by instruments that were either already installed on the pipeline for other purposes, or by installation of moderately accurate meters at a few selected locations. The instruments that serve this method require cutting into the pipe for installation, creating even more potential for leaks.

However, even if the mathematical model of the pipeline's operation was perfect, which it cannot be, it is essential to recognize that the limited sensitivity and stability of the few intrusive instruments that provide data for the software model themselves limit the performance of the system. As a result, the leak detection thresholds must be set high enough to avoid false alarms. Obviously, this prevents detection of small leaks, which are the majority of the leaks that occur.

Non-Intrusive Method

Unlike the software modeling system, the non-intrusive, ultrasonic, mass flowmeter measurement system is based on actual measurement of pipeline mass input, versus actual measured pipeline mass output. No 'theoretical' considerations are involved, just pure, accurate measurement. To do this requires very sensitive mass flow measurement (to within tenths of a percent) at various points along the pipeline, usually creating segments bounded by two mass flow site-stations. The distance between site-stations can be as much as 100 miles. The usual distance is determined by the need for environmental protection. For example, protecting a river crossing can involve two site-stations only one mile apart. As noted before, leak detection requires mass balance of a compressible liquid.



Close up of typical explosion proof controlotron site station used in leak detection system

Obviously, pressure is involved, as it serves to make the liquid denser. How can pressure be sensed non-intrusively? This is one of the many benefits of clamp-on ultrasonic flowmetering. The pressure of the pipeline is actually sensed by its effect on the density of the liquid.

The clamp-on, ultrasonic, flowmeter measures the liquid density by the relationship between density and the measured sonic propagation velocity of the liquid. Therefore, the clamp-on ultrasonic flowmeter is intrinsically a mass flowmeter. Consequently, this type of meter can be installed on any pipeline without cutting pipe, even without stopping flow, since it automatically sets its own 'zero flow' calibration.Each site station includes a clamp-on, ultrasonic, flowmeter, a clamp-on RTD temperature sensor and a means of data communication compatible with the operator's communication system. Once per minute, all site stations are polled by a master station, which collects data on flow rate, temperature, liquid density, liquid viscosity, relative line pressure, and the degree to which the oil is multiphase, with included gas and/or water. The site station measures all of this information non-intrusively many times each second, via its clamp-on ultrasonic flow and temperature sensors. (Figure 2 shows a typical Leak Detection System that uses Ultrasonic Mass Measurement.)

The master station compiles the mass flow rates for the entire pipeline.

Non-Intrusive Ultrasonic Systems Provide Cost Payback

Once per minute, the leak detection system alarms if any segment has a mass input/output unbalance that exceeds its extremely sensitive leak alarm threshold, as good as 0.5% in many cases. Even higher sensitivity is provided by establishing leak alarm thresholds for the last 5, 15, and 60 minutes. Display screens on the Master Station console show the unbalance trends, so that even before the leak alarm threshold is breached, an operator can obtain an early warning, in order to take preventative action. (Figure 1 shows one of the many screens available on the system.)

The very same system can be equipped with the SoniLocator™ system. This is a means of accurately locating the place at which the leak has occurred. This is accomplished by sensing the amount of time that the low-pressure wave (caused by a leak) takes to travel from its source to each of the segment's site stations. The site stations can sense the low pressure wave's arrival by its effect on the density of the fluid, which is being measured many times each second. As can be seen, if the leak is in the center of the segment, the pressure wave will arrive at each of the segment's site stations at the same time. If closer to one site station, it will arrive there earlier, The difference in arrival time determines where the leak is. Location to within 150 m is now available, and even better precision is in sight.

Thirty of these systems are now in successful operation in various parts of the world.

The Cost

Both the software modeling system and clamp-on ultrasonic flowmeter measurement systems have costs associated with them. Since the software system is not based on significant measurement instrumentation, its cost is primarily in the development of the software program that conforms to the equations of state for the various liquids in the pipeline. All of this cost is dedicated to that purpose, and the system does not provide any additional functions of value.

For the clamp-on ultrasonic flowmeter measurement system, there is accost component related to the number of site stations. The number of site stations is indicated by the size of the pipeline and the environmental liability implicit in its location. In some cases, the cost of this system will be less than that of the software modeling system. However in some cases, if many site stations are indicated, it will be higher.

Unlike the software modeling system in which all the expense is dedicated to only one purpose, leak detection, the clamp-on site stations provide significant cost payback due to the added value provided by the extensive list of functions and features included, beyond leak detection and location.

The leak detection master station is actually a pipeline management system. It can be installed, without stopping pipeline operations, just a few weeks after placement of an order. It displays a variety of screens that inform the pipeline operating staff of the following information:

- Custody transfer: calibrated clamp-on site stations provide stan dard volume (mass) accuracy as high as 0.15% of actual batch total over a wide flow turndown ratio. Bi-directional operation is standard.

- Batch tracking: defining the location of each batch in the pipeline and its estimated arrival time at the terminal.

- Interface detection: indicates the arrival of the interface between two batches at each site station to permit diversion of non-fungi ble liquids to their individual holding tanks.

- Liquid type and quality: defines the American Petroleum Institute number and density of each product, and indicates the presence of gas and water. The system also indicates liquid viscosity.

- Pig detection: identifies the passage of a pig at each site station and identifies the location of a lost pig.

  Pipeline operations:
  Monitors proper sequence in valve/pump operation.
  Detects over-pressure conditions.
  Identifies hot-tap theft of product in real time.

Given the pipeline operating cost payback that these functions provide, the actual cost of a leak detection/location system using clamp-on transit-time ultrasonic flowmeters may actually be less than the cost of the system itself. Above all, it provides extraordinary protection against the consequences of an undetected leak.

CONTROLOTRON

How to Order

Contact your local Controlotron representative
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