THIEVES IN THE NIGHT

Harry Smith, Atmos International, UK, provides an overview of the global pipeline theft problem and analyses a range of leak and theft detection technology which can help provide asset protection.

Pipeline theft is now a global issue. The thieves are well organised, with resources including commercial grade welding equipment, measuring instruments, night vision goggles, and vans with modified suspension or exit holes in the floor. They are well-trained engineers with the skills and knowledge required to avoid detection, employing a host of different tactics when stealing oil from pipelines:

- Pre-install the tapping point, hose, associated valves and equipment before the pipeline is commissioned.
- Select remote and well-hidden sites such as abandoned buildings.
- Bury and cover the hosepipe and all other devices underground.

Figure 1. Typical theft event carried out at night. Image courtesy of Atmos International.

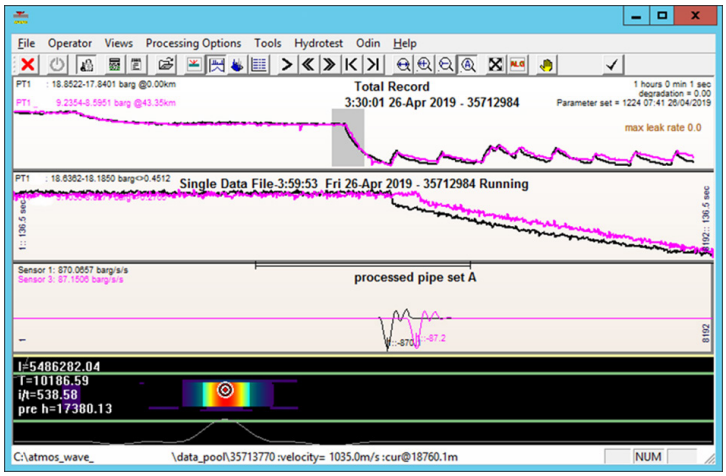

Figure 2. An example of a theft event generating 0.4 bar pressure drop.

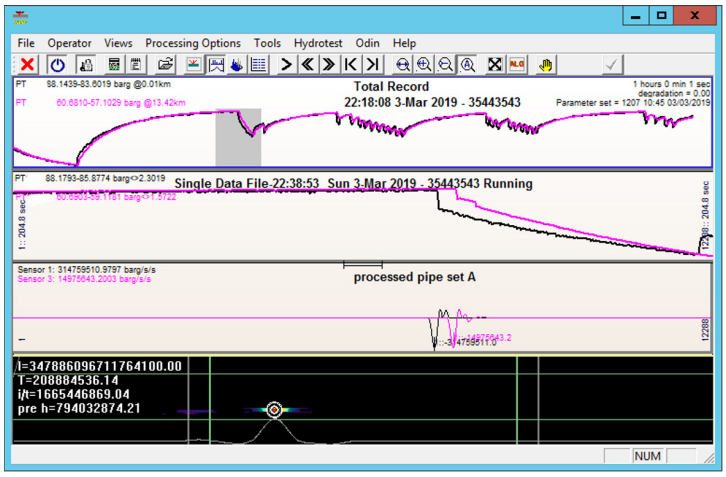

Figure 3. An example of a theft event generating 1.5 bar pressure drop.

- Open theft valves very slowly to generate a small pressure change over an extended time period.
- Maintain theft rate below flowmeter repeatability level, e.g. 0.1% of pipeline throughput.
- Carry out activities at night.
- Steal often but small volumes each time.
- Perform thefts at multiple locations along the same pipeline.
- Use dangerous techniques including angle grinding and plastic equipment.
- Adapt vehicles (such as old milk tankers or vans) with upgraded suspension to handle the weight of fully filled intermediate bulk containers (IBCs).

All these different tactics make it difficult for pipeline companies to detect and locate thefts quickly and accurately.

Theft detection technologies

Avoiding detection is a key target when thieves are going to commence an operation to extract product from a pipeline. Therefore, in order to not trigger a leak detection system alarm, thieves ensure that:

- A small amount of product is stolen (ranging from 10 - 3000 l).
- Theft flowrate can be less than 0.1%.
- Theft events usually last for less than one hour, although occasionally a theft continues unchecked.
- Changes in pressure are very small when the tapping point is opened/closed at the end of a long hosepipe.

Consequently, the main requirements of theft detection include:

- Sensitivity – detecting small product withdrawal.
- Accuracy – locating tapping points as accurately as possible.
- Response time – detecting product withdrawals as quickly as possible.

Different leak detection technologies can be adapted to meet the above requirements, including negative pressure wave, statistical volume balance, and Atmos International's Theft Net service.

Negative pressure wave

This technology relies on high-speed analogue pressure sensor readings to identify whether a leak or theft has occurred on the pipeline. This type of system acquires and analyses pressure data at a frequency much higher than the typical 5 sec. supervisory control and data acquisition (SCADA) rate, capturing data at 60 samples/sec. Specialised equipment is needed to acquire data at such high frequency. The main advantages of this system are:

- Accurate leak location within meters of the actual location.
- Short detection time for all leak sizes.
- High sensitivity provided through the 60 Hz sample rate.

These are the key features in effectively detecting theft events in all operational conditions. Figures 2 and 3 show examples of theft events being detected by the negative pressure wave system.

Statistical volume balance

This type of leak detection technology relies on pressure and flow measurements taken from a pipeline. It uses

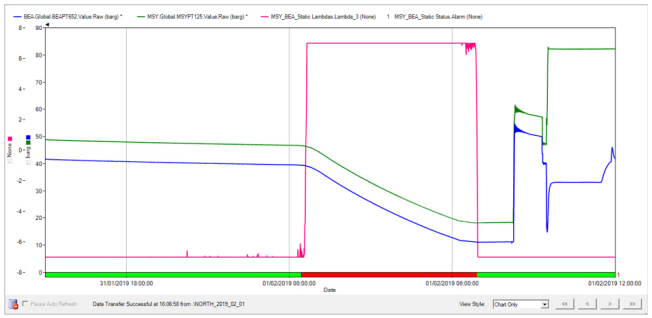

Figure 4. Statistical theft detection during shut-in period (red bar at the bottom indicates theft alarm).

Figure 5. A double tapping point exposed by the pipeline operator following location provided by the leak detection system. The black dot is the location given by the theft detection system, the yellow dot is the actual tapping point, and the yellow line shows the hosepipe route.

Figure 6. A tapping point exposed by the pipeline operator.

existing instrumentation and connects via existing SCADA, programmable logic controller (PLC) or remote terminal unit (RTU) systems. The system monitors the difference between the inlet and outlet flow corrected by the inventory change.

Statistical volume balance is also referred to as the corrected flow difference to determine whether the pipeline is in a leak condition. The statistical hypothesis testing method is known as the sequential probability ratio test (SPRT), and it is applied to the corrected flow difference to decide if the probability of a leak has increased. The main advantages of this system are:

- Low false alarm rate.
- Detects leaks under steady-state, transient, and shut-in conditions.
- Accurate leak size estimate.
- Improved leak location accuracy as a result of a higher data sample rate.

Since theft rate is usually below the flowmeter accuracy and repeatability level, it is difficult for this technology to detect small thefts under running conditions unless false alarms are accepted. The system includes an additional theft module for detecting thefts during shut-in conditions in order to maintain reliability for both leak and theft detection (Figure 4).

An offline service

As theft rates become smaller, it becomes necessary to lower the minimum leak size to be detected. However, in doing this, it can result in increased false alarms as the identified flow and pressure are mostly below the instrument repeatability and process noise level.

Atmos International's Theft Net service is an offline service that is offered to pipeline companies, which can allow improved leak location accuracy and sensitivity without unnecessary false alarms. The service combines portable and fixed hardware and software solutions with offline data analysis by an experienced engineer. Through this service, an engineer's ability to interpret data helps theft to be located down to a few metres. The system uses pressure data collected at a 60 Hz sample rate and sent to a central location via a cloud-based service.

Data is then filtered to present only the relevant information required, and locations of illicit tapping points are reported to pipeline operators.

It is well documented that online leak/theft detection systems must find a balance between sensitivity and false alarms. Some leak detection systems can detect leaks as small as 0.5% of nominal flowrate without the issue of false alarms. However, this becomes an issue as most theft events are less than 0.3% of the nominal flowrate. The capability to analyse the data offline allows companies to detect and locate thefts to within 5 m of the theft, for

volumes as small as 0.1% of the nominal flowrate in static and running conditions.

Combining the Theft Net service with a single or multiple online leak detection system allows for a more reliable leak detection system, with the ability to effectively deal with all types of theft events. In the last two years, this combination of negative pressure wave, statistical volume balance, and offline analysis has successfully detected and located over 400 tapping points.

Examples of thefts detected

The use of the Theft Net service and leak detection systems has led to the detection and location of many illicit tapping points, such as an oil withdrawal through a 12 mm hole that was attached to a 1.5 km (0.9 mile) long underground hosepipe in Europe.

Theft detection systems have even detected the removal of samples between 10 l and 20 l of product from some pipelines during static conditions. These small samples are usually extracted to check what fluid is in the multi-product pipeline before a full product withdrawal is commenced.

Theft with double taps

In the space of four months in 2019, two theft events were detected in the UK by both statistical volume balance and negative pressure wave systems, with the leak location improved further using offline data analysis. Both theft events had a leak location error of less than 50 m. The thefts were found on a multi-product pipeline with varying diameters of 6 in. to 14 in., with a total network length of 650 km. The thieves stole small quantities of product during both events; a total of approximately 4 m^3 was removed before the tapping point was located. These events were detected by the online leak detection systems within minutes of the tapping point being opened.

These events highlight the lengths that thieves will go to remain hidden and how well they can use the environment to hide their activities (Figures 5 and 6).

Conclusion

It is important to differentiate theft from leak detection. Theft detection not only requires high sensitivity but also expert analysis, as well as specialist technologies. As thieves are using multiple methods to remain undetected, with theft rates below 0.3% of the nominal flowrate, leak detection systems must be more sensitive than when they were originally designed. The combination of multiple systems with offline analysis has enabled increased detection of small theft volumes. Theft location accuracy has also dramatically improved down to a few meters. Theft detection will always remain a constant battle between new tactics used by thieves and further advancement of theft detection technologies.