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Using AI to Manage Sulphur Transport Pipelines – How Big Data Can Lead to Peace of Mind

MIKE ALLENSPACH P.E.

GUSTAVO SALDARRIAGA P.E.

KENT KALAR

nVent Thermal Management / Topside Solutions
Houston, Texas, USA

Abstract

How do you ensure that you have the best trained professionals to operate a Sulphur pipeline in the safest and most reliable way? The key is to leverage as much information as is available during both normal operations and extreme events, (such as re-melting plugged Sulphur or during minimum flow operation). Unfortunately, the human brain has a limited capacity to segregate and assimilate "useful" information, and what should be data-driven decisions sometimes become a matter of one's opinion or judgement. The current best practice is to rely solely on skilled operators (who may or may not be specialty trained) to manage the complexity of a heated Sulphur pipeline. There is a better way.

As the potential exists for Sulphur cool down and/or re-melting to occur at different rates in various portions of the pipeline, it is imperative to perform pipeline O&M activities in a manner that does not create overpressure, overheating or other pipeline failure scenarios. Localized thermal discontinuities (from a heat transfer perspective) can create a complex and dynamic environment along a Sulphur pipeline, making it difficult to manage. These discontinuities could include pipeline void spaces, excessive heat loss zones and the impact of elevation changes along the alignment.

Until now, the potential to utilize Big Data and Artificial Intelligence (AI) to manage Sulphur transport pipelines has been largely untapped. This paper presents an industry leading approach for a safe and reliable heated Sulphur pipeline management program in a customized software. Utilizing the compelling pipeline operating data extracted from a fibre optic Distributed Temperature Sensing (DTS) system on the pipeline, combined with other pipeline and electrical equipment instrumentation, decision-based outcomes become much more predictable by leveraging the enormous amount of available data.

What are the benefits of utilizing AI on a pipeline? There are many, and they offer both operating efficiencies and the reduction of risk:

- *Improved Operating Efficiency & Reduced Electricity Costs*
- *Increased Asset Utilization & Maximized Throughput*
- *Optimizing Pump Utilization & Minimizing Pump Downtime (Flow Interruption)*
- *Reducing Unscheduled Pump Maintenance / Extending Service Life of Pumps*
- *Reduced Maintenance Costs*
- *Environmental Stewardship & Improved Human Safety*

What if you could keep your pipeline flowing, or ready to flow at ALL times? Moving into the era of AI allows for proactive and predictive analysis, giving operators the ability to address a potential problematic scenario before it becomes a crisis. Utilizing data and customized algorithm-based software, it is possible to add a virtual pipeline "analysis expert" to your staff. The good news is that the algorithms work around the clock, with no time off – they become a 24-hour-a-day member of your team.

1. THE HUMAN BRAIN

There is something called Moore's Law (an observation made by Intel co-founder Gordon Moore), which basically states that computing power doubles every 18 months. Moore's Law suggests exponential growth, though it is unlikely to continue indefinitely. Nonetheless, that is a staggering concept, and explains the phenomenal growth of computer technology applied to real life situations. Transport pipelines are not exempt; technology is advancing at a rapid pace. The ability to utilize streaming fibre optic distributed temperature data from a Sulphur pipeline can produce enormously valuable insight for a pipeline operator. The question becomes, what will that operator do with this insight?

1.1. Limitations of the Mind

Typical of most individuals in their occupational endeavours, a myriad of necessary job activities compete for our limited time during any given day. Thus, we attempt to prioritize those tasks to fit the time we have to spend on them, often leaving us with unfinished business. This becomes especially true when it comes to using our own cognitive thinking and performing detailed analysis of complex situations. Unfortunately, the human brain has a limited capacity to segregate and assimilate “useful” information, and so what should be data-driven decisions sometimes become a matter of one’s opinion or judgement. The current best practice to manage a heated Sulphur pipeline from day to day is to rely solely on skilled operators (who may or may not be specialty trained) to manage the complexity of the Sulphur pipeline.

Could computers help us leverage our time and talent by offloading some of the responsibility to machines? The answer is absolutely yes. The real value of this approach is that computers never take a day off and they don’t make a mistake (at least if it is programmed properly). Humans do, on both counts.

1.2. Rational versus Emotional Decision Making

First of all, it is worthwhile to understand a little bit about the most amazing aspect of humankind . . . the human brain. Some have said that the human brain may be able to hold as much information in its memory as is contained on the entire Internet. No other animal or thing on the planet has the ability to assimilate thousands upon thousands of inputs and perform cognitive reasoning like the human brain. We call it decision making. Cognitive thinking is described as: “*of or pertaining to the mental processes of perception, memory, judgment, and reasoning*.”

Experts will tell you there are two types of decision-making conducted by our brain – rational and emotional. Rational thinking is where an individual will think in a logically consistent way. Often, these individuals see the world as a puzzle or machine where their actions change the circumstances and thus the end result. Oftentimes, this type of thinking can be considered as A+B=C.

Emotional thinkers, on the other hand, often see the world through the lenses of how their actions make an individual or group feel, also known as “empathy”. These individuals have the ability to notice the value of things that do not directly benefit themselves. Their weakness is that often this becomes short-sighted in nature. At the end of the day, emotional responses may not have a rational outcome.

1.3. The Power of Computing

The beauty of computing is that it can be programmed to make determinations (or, decisions) based solely on input data, by introducing algorithms that create rule-based outcomes. It is not emotional, and it does not have a “bad day” every once in a while, like we humans do. The examples of using computing software today to benefit us are endless. One only has to look at what has been accomplished already by machines using customized and complex algorithms. There is targeted advertising based on your unique buying patterns, or fraud prevention software for credit card users and map applications that select an optimum route and a predicted arrival time. These all utilize complex algorithms to get the job done.

What’s in the future? Who can say? Self-driving cars? Rockets that re-enter the earth’s atmosphere and land themselves, ready for the next voyage to outer space? The same exciting potential exists for pipeline management and safety!

2. FLOW ASSURANCE – THE HOLY GRAIL

So what does the human brain have to do with pipelines? Well, what every pipeline Owner/Operator wants to do is to go to sleep at night and not awaken to a pipeline problem – the pumps deadheaded; the line jumped off the pipe rack; or, your worst nightmare . . . “*we’ve experienced a rupture*”. Basically, it boils down to Flow Assurance – the peace of mind to know that you are taking all of the proper precautions to operate and maintain your pipeline safely and reliably.

How can you achieve this state of mind? The answer is, to build the proper foundation for your pipeline technology and to apply that technology in a way that gives you the best opportunity to see a problem coming. The recent advances of fibre optic Distributed Temperature Sensing (DTS) have the potential to revolutionize the world of pipeline operation and maintenance, as it relates to Flow Assurance. If, we'll only let it!

2.1. Limitations of Point Sensing Control & Monitoring

The long-time conventional method of collecting data for heater control on a heated pipeline has been to rely on discrete sensing points at the front or back end of a pipeline. When relying on point-sensing temperature control the temperature along a pipeline is often assumed to be uniform, or constant along its length. In this scenario the on/off control for heat is dictated by a single sensing point. However, the actual temperature is NOT uniform as many people assume, for a myriad of reasons.

The black line in Figure 1 below is a DTS temperature profile (at a point in time) for five back-to-back heating circuits, with temperature on the vertical axis (y-axis) and line length along the bottom (x-axis). In this scenario, a 24-km pipeline is divided into five heating circuits (segments) and incorporates a fibre optic DTS system that monitors the temperature for the entire pipeline. Each heating circuit has a controlling RTD measuring the pipe temperature near the beginning of the circuit (flow direction is left to right).

As shown in Figure 1, if a pipeline operator assumed that an entire heated circuit exhibited the same temperature as a single RTD (Tactual) reading at the beginning, it could be a grossly incorrect assessment for that circuit.

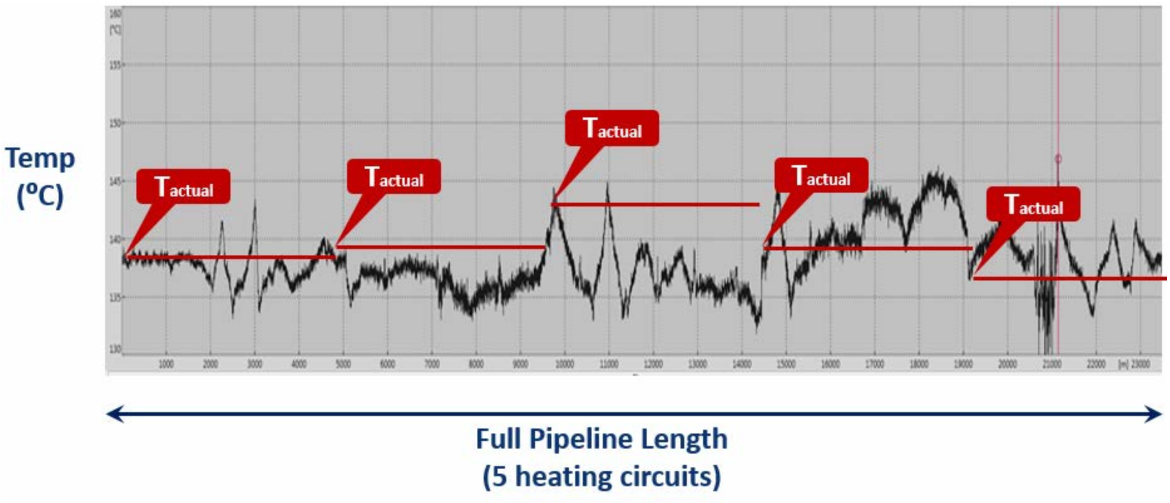

Figure 1: FO DTS Temperature Profile for a Sulphur Pipeline

For many reasons, each circuit segment exhibits temperatures that range between 5-10°C above and below the desired setpoint of 135°C. Those reasons may be from non-uniformity in the thermal insulation system, the presence of heat sinks along the pipeline (such as vents and drains), or even the effects of elevation changes. Furthermore, the effect of differing ambient conditions such as temperature swings, solar exposure levels, wind, rain, snow and sand buildup around the pipeline can cause thermal discontinuity in the temperature profile of a long pipeline. Understanding all these complexities and dynamic changes is important when dealing with Flow Assurance for a Sulphur pipeline. In a continually changing environment, constant analysis of this data while tracking the changes is an impossible task for any human.

2.2. Leveraging Technology to Improve Flow Assurance

So, how does one find the holy grail of Flow Assurance for a Sulphur pipeline? Flow Assurance can be partially implemented through well planned engineering and design. For a Sulphur pipeline, one can incorporate design features such as full (100%) redundancy, multiple power (heat) output levels, pressure relief strategies and proper safety factors.

However, Flow Assurance also requires the prudent use of technologies. Until recently, Flow Assurance for temperature critical fluids such as Sulphur has relied strictly on only pipeline heating and thermal insulation. A few of these systems have required that temperature and electrical data information be sent from the heating control panels to the process Distributed Control System (DCS) and/or to the Supervisory Control and Data Acquisition (SCADA). By doing this, the level of Flow Assurance is increased slightly with some operational data. This concept is depicted in Figure 2 below, which shows that a pipeline can climb the "Confidence Curve" for Flow Assurance with the addition of technology. The added benefit of a system like SCADA increases the level of confidence that your pipeline will flow all of the time.

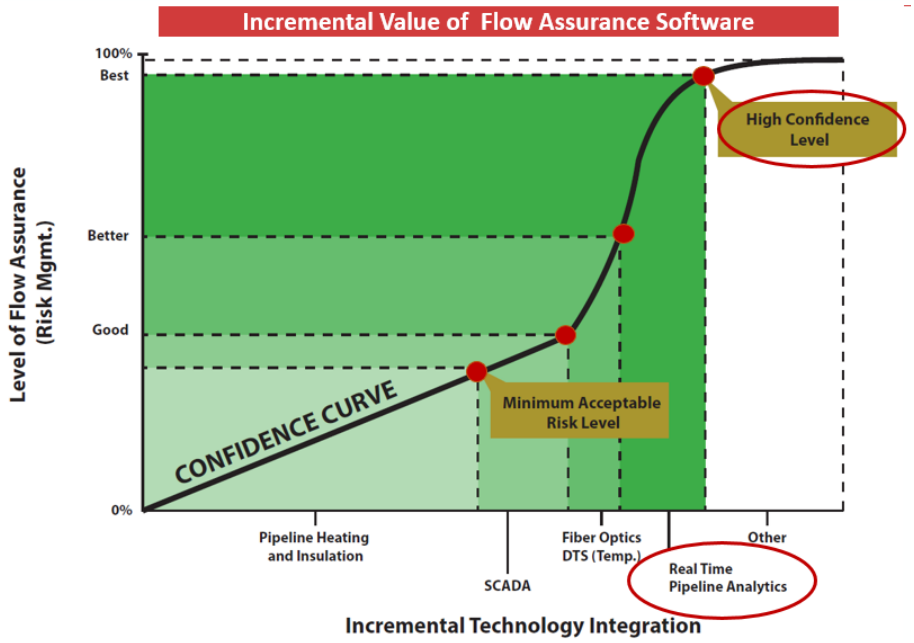

Figure 2: Incremental Value of Flow Assurance through Software

More recently, especially on long Sulphur pipelines, another level of growth toward complete Flow Assurance has been made available by incorporating fibre optic DTS to monitor the temperature of the entire pipeline. This enhancement offers a significant leap forward, as pipeline operators are no longer blindly operating the heating system, especially during abnormal conditions such as low flow or re-melt. However, the use of streaming DTS still requires constant monitoring of the system by human beings, with the risk that critical data goes unnoticed or is lost.

Finally, the next available technology step to improve Flow Assurance is to implement real-time advanced analytics in the form of Flow Assurance software. Custom algorithms interpret the streaming data coming from DTS to create data-driven assessments and suggest actionable tasks to mitigate a potential problem that may be occurring. The ability for software to track temperature trends over time is a huge advantage and time saver.

By incorporation of Advanced Analytics the point on the Confidence Curve on the Flow Assurance graph rises to a very high level that largely eliminates human error. This enormous incremental improvement in the Flow Assurance is shown in Figure 2 as the "High Confidence Level". (Note that the values for Flow Assurance and incremental technology integration are not absolute and are only shown for illustrative purposes).

3. The Power of Advanced Analytics

Advanced Analytics combines the ability to deliver immediate information based on processing High Definition Data, from both real-time and historical sources in a consistent, detailed, and error free manner. This is illustrated below in Figure 3.

3.1. Data Analysis

Processing High Definition Data requires the development of specialized algorithms that can consistently and reliably identify the critical information contained in the relevant data sets. The challenge lies in the fact that, most of the time, the data simply indicates that the system is operating normally, and false alarms only serve to undermine any system's effectiveness in generating a prompt response to the concerns raised by the system.

Algorithms must make the best use of multiple data sources to confirm trends seen in a single key variable, and historical behaviour must be compared with real-time data to increase confidence. Only by the application of Advanced Analytics can the available disparate data sources be simultaneously analysed in an integrated fashion to generate the highest possible level of confidence in determining the status of the asset being monitored.

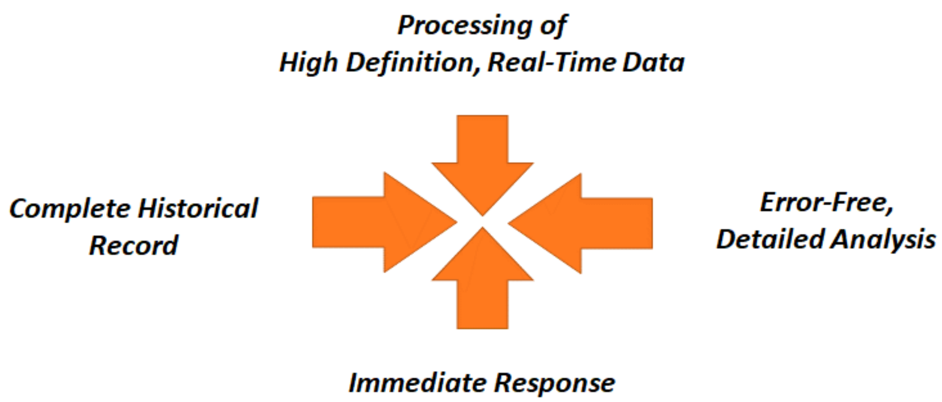

Figure 3: Leveraging the Strengths of Advanced Analytics

The Advanced Analytics tools increase the end user's confidence in the system by correlating data across previously discrete systems. Data is further processed by the calculation of gradients and by data averaging. These techniques allow the system to identify certain types of events through the real time rate of change in the data, while identifying other classes of events by improving data resolution (by averaging out sensor noise over time) to detect small but significant trends in the data.

The use of Advanced Analytics enabled by High Density data collection, available processing hardware, and recently developed data management technology brings pipeline operators new levels of actionable operational and maintenance information and overall monitoring confidence.

3.2. Identifying Actionable Information

By combining Advanced Analytics and agile software development, tools can be generated to efficiently convert High Definition Data into Actionable Information. This is illustrated in Figure 4 below. However, this is not so easy as to simply develop and code smart algorithms. The software framework must also be developed to collect and stage the High Definition Data from the various systems where it is available. System architecture requires attention to different data formats and the data transfer protocols supported by a wide range of legacy data collection and archival systems.

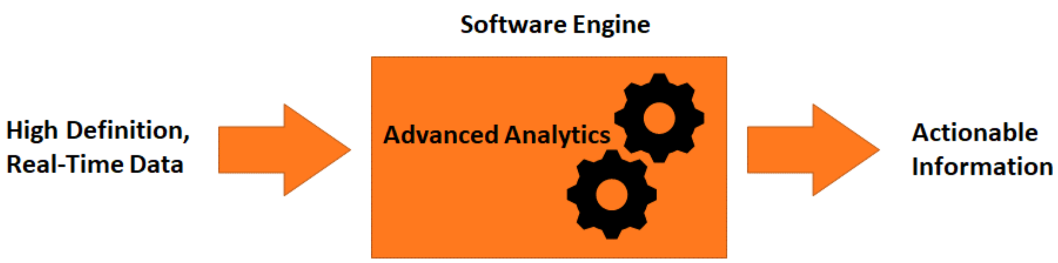

Figure 4: Software Converts High Definition Real-Time Data to Actionable Information

In addition to accessing data from legacy sources, system databases must fully stage all data required by the Advanced Analytics algorithms within the defined measurement cycle. This includes some data pre-processing and data verification; in other words, invalid Data = invalid Information.

Pipeline reference data must also be managed. This includes pipeline model parameters which are defined during design and construction, like the location of pipe bridges, underground/culvert segments, elevation, etc., as well as critical baseline performance parameters for the asset.

Lastly, the software must have some interface whereby actionable information can be passed along to the operating company's personnel in a clear and concise manner. Only after each of these required functions has been addressed, can the software fully implement an Advanced Analytics framework.

4. THE EVOLUTION OF FIBRE OPTICS APPLIED TO SULPHUR PIPELINES

Heated pipeline technology has evolved tremendously in the last fifty years, from development of heating cables to control and monitoring systems. The emergence of fibre optic distributed temperature based technology in recent years has become a big part of the story. The advances in technology and lowering of costs has made DTS a very appealing technology for all types of pipelines, but particularly those which carry temperature-critical fluids, like molten Sulphur.

4.1. The Past and Present State

Electric trace heating systems in the past (and even present day) use point sensing for temperature control. Ambient sensing thermostats or RTDs are used to control "freeze protection" circuits. For "process temperature maintain" applications, one or two temperature sensors are used to sense the temperature of the pipe itself and the entire associated heating circuit is energized based on those temperature inputs. This has been sufficient for most applications, where the desired maintain temperature has a relatively wide control range.

For applications like Sulphur that have a narrow temperature range, the design rules are a bit more strict and call for additional measures such as limiting the heating circuit to one flow path only and creating a high temperature cut-off of the heating system by using a separate controller and sensor. In the case of long pipelines with temperature critical fluids such as Sulphur, designs sometimes call for multiple temperature sensors to be installed along the length of the pipeline; however, sensor locations are limited by long distance issues with sensor cabling and no matter how sensors are installed, it is impossible to get temperature data from every location of the pipeline.

In 2004 the concept of using Fibre Optic Distributed Temperature Sensing (FO DTS) for monitoring the temperature of the entire length of a heated Sulphur pipeline was introduced in an IEEE PCIC paper "Controlling Skin Effect Heat Traced Liquid Sulfur Pipelines with Fiber Optics".

In a FO DTS system, a pulsed laser is coupled to an optical fibre located on the pipeline through a directional coupler. The laser's light is backscattered as the pulse propagates through the fibre's core owing to changes in density and composition as well as molecular and bulk vibrations. In a homogeneous fibre, the intensity of the sampled backscattered light decays exponentially with time. Because the velocity of light propagation in the optical fibre is well known, the distance can be calculated from the deterministic collection time of the backscattered light.

The measured temperature and distance can be identified simultaneously, with one-meter spatial resolution and one-degree Celsius temperature resolution. Temperature information gathered from the FO DTS system is normally displayed in user-friendly screens that provide operations and maintenance personnel with temperature profiles for the entire length of the pipeline. If hot or cold temperature spots appear on the pipeline, the operator can easily zoom in to the affected area and alert maintenance staff, (within one meter), to the exact location of the problem. A sample user interface is referenced in Figure 5 below.

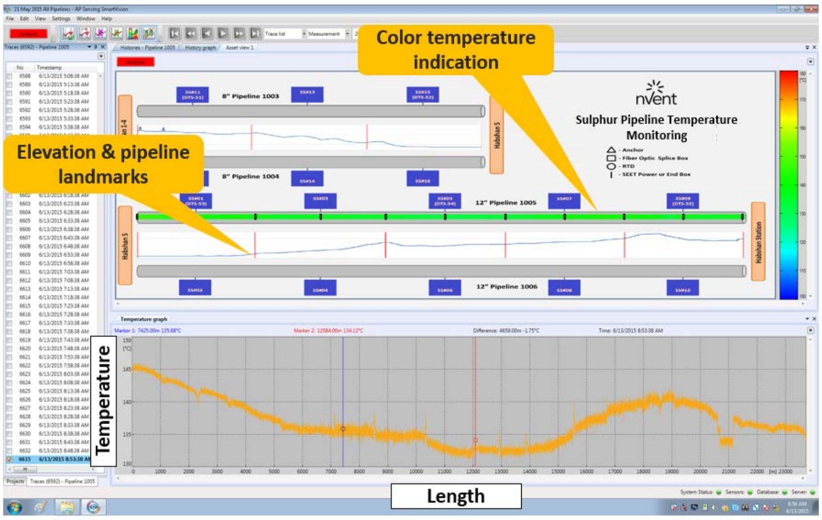

Figure 5: DTS Functionality

Starting in 2006 the concept of utilizing fibre optics was applied to long Sulphur pipelines in Canada and the Middle East. Today, there are more than 200 kilometres of temperature sensing FO cable installed on Sulphur, Phenol and Vacuum Oil Gas (VGO) pipelines. In all of those applications, the FO system is only used for temperature monitoring, not for heating system control. The reasons for this are two-fold. First, most of these systems are installed in conjunction with the skin-effect trace heating system and until recently, the standard for this heating technology was IEEE 844-2000, which did not recognize fibre optic temperature sensing as an allowable temperature sensing method; this changed in 2017 when IEEE 844 was updated [reference new IEEE/CSA standard] allowing the use of FO as a temperature sensing method for skin-effect trace heated lines. Secondly, as with any other new technology application, it takes some time for the technology to be proven and for the industry to feel comfortable adopting that technology.

4.2. The Future State

Since its first application on a long Sulphur pipeline, FO DTS temperature monitoring showed its great potential. Initially conceived primarily as a technology that would aid Sulphur pipeline operators safely through the tricky Sulphur re-melt operation, it quickly became apparent that its use would extend much further. For instance, in one of the first two pipelines mentioned above, FO DTS temperature monitoring played an invaluable role by revealing multiple thermal insulation deficiencies caused by poorly-installed field joint insulation on a pre-insulated pipeline. In another project the FO DTS system quickly and accurately helped commissioning personnel identify design/construction issues with pipeline anchors and supports. There was even an instance of electrical fault-location inferred from FO temperature readings that has been documented. All of these examples required extensive manual review and analysis of the DTS data over periods of time. It was a time-consuming and painstaking process.

Until now, there has been no “real time” analysis tool available to identify problematic conditions on a pipeline to drive actionable decisions. It stands to reason that software can be an enormously powerful tool when coupled with streaming temperature data from DTS. The ability to track changes over time creates nearly unlimited types of analyses that are useful to pipeline operators. Below are just some of the tendencies that can be identified with Advance Analytics software in affiliation with DTS:

- Pipeline Fill Percentage
- Flow Restrictions
- Plug Prediction
- Pipeline Troubleshooting
- Heating System Health
- Insulation Integrity
- Predicted Time to Freeze

- Hot/Cold Spot Location
- Re-Melt Assistance
- Rupture Detection
- As-Built Quality

Additionally, the notification aspect of software can proactively communicate with e-mails or texts (SMS) to various personnel in the organization, prompting swift action. Pre-determined rules can even organize to whom these messages are sent, based on the level of situation severity.

4.3. The Future, Future State

The logical next step in software is to incorporate Artificial Intelligence (AI) for the data gathered. Over time, it is possible to identify tendencies of a pipeline's operation based on historical temperature data and other inputs. The algorithms expand and make use of Machine Learning and Artificial Intelligence.

This allows the pipeline management to become ever more prognostic. For example, the pipeline operator could input risk tolerance preferences and/or desired operating cost targets and the adaptive software would adjust the system toward the desired target on a continuous basis. This is known as creating Artificial Intelligence.

5. PipeWise Software

nVent, in cooperation with its partner Topside Solutions, has developed a new generation of software, available under the trade name PipeWise™, to bring Advanced Analytics to pipeline management. The initial product release targets heated pipelines and contains several specialized algorithms specifically developed to address the challenges of sulphur pipelines.

5.1. Data Sources

The PipeWise™ software draws High Definition Data from three primary sources; these are illustrated below in Figure 6.

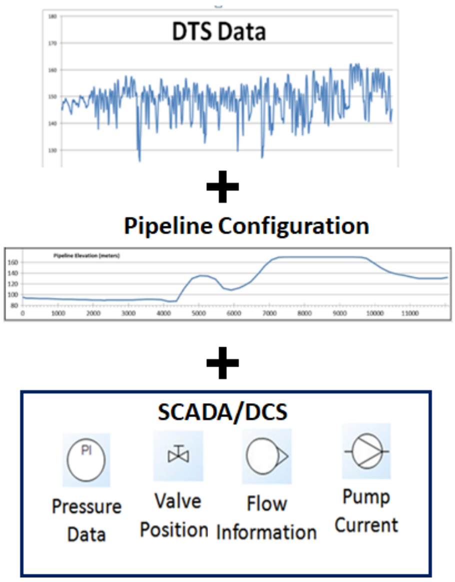

Figure 6: Core Pipeline Data Sources

The first form of core data is Distributed Temperature Sensor (DTS) data. Ideally, the DTS data is collected every half meter at a minimum interval of 5 minutes. As the software compares trends in historical data with the real time data being collected, the system improves its ability to identify key information in the DTS data over time. In general, a minimum of 1 year's DTS data is kept in the database utilized by the PipeWise™ software.

The second form of core data is Pipeline Configuration Data. This data is used to characterize the unique attributes that make up an individual pipeline. It includes information required by the algorithms to explain certain behaviours in the system data. Information about the pipeline layout, the location of pipe bridges and underground/culvert sections, the location of vents and drains, the location of anchor points, etc. PipeWise™ uses this Pipeline Configuration Data to determine which algorithm variants should be applied to specific locations along the pipeline.

The final form of core data is SCADA/DCS data. The PipeWise™ software interfaces with the legacy SCADA/DCS system in the plant to access key parameter data related to pump speeds or flows, inlet and outlet pressure, inlet and outlet temperatures, etc. This data is co-analysed with the DTS and Pipeline Configuration data to improve the overall reliability and robustness of the algorithm package.

5.2. Pipeline Characterization

The actual algorithms (as well as the specific data stream inputs) used by the PipeWise™ software are proprietary. However, Figure 7, below, gives some high-level insight into a few of the basic principles employed.

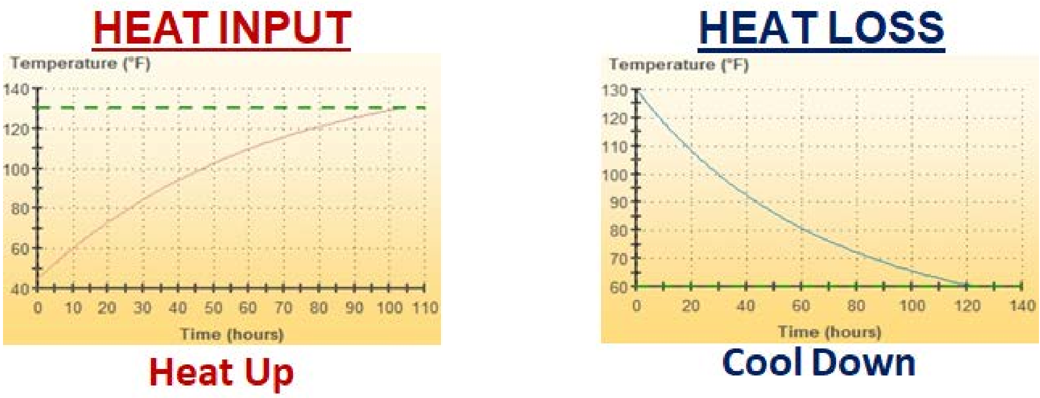

Figure 7: Baselining Pipeline Behaviour

This figure illustrates the fundamental heating and cooling characteristics that result from the physical properties of the pipeline. The Heat Input graph shows how a given section of the pipeline increases in temperature as the heating system is energized, and the Heat Loss graph shows how the pipeline decreases in temperature as the heating system is de-energized. Both graphs are for an empty pipeline. The PipeWise™ software generates this baseline information for each half-meter section of pipeline.

By accounting for ambient weather conditions, input product temperature, pipeline fill percentage, and other key variables; the rate at which the heater is supplying heat to the pipeline in that section can be estimated. This can then be compared to the power being applied to the heater circuit to see if the heater is functioning properly or to determine if a different power output level needs to be applied. Comparative data time trends also indicate if the system is stable or trending in a direction that requires attention.

Similarly, the cooling rate can be corrected to account for the variables known to be influencing the measured rate to determine if a particular pipeline section's heat loss is within the "normal" window or if something material has changed in the pipeline's insulation, cladding, etc.

It is only through this continuous (over time), section by section analysis that potential problems with the heater and/or the insulation envelope can be detected early and accurately. The PipeWise™ software algorithms that manage these functions incorporate real-time, historical, DTS, SCADA/DCS, and Pipeline Configuration data to produce reliable and accurate actionable information.

5.3. Software Output

The PipeWise™ software provides Actionable Information to system users and directs specific messaging to users according to their functional roles and responsibility level within their function. This is illustrated below in Figure 8.

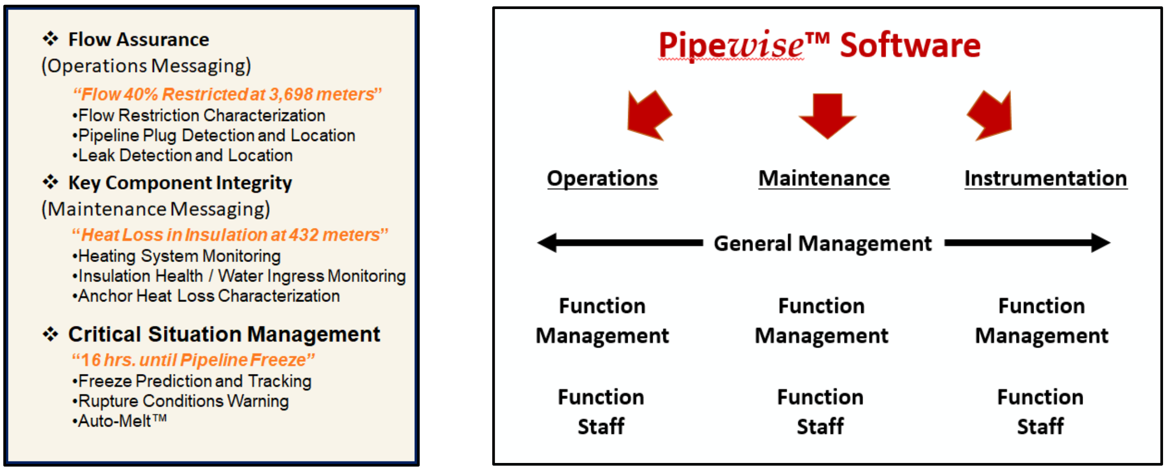

Figure 8: Pro-active Messaging for Actionable Tasks

The software also supports a system console that graphically displays the current status of each of the pipeline properties being monitored by the Advanced Analytics algorithms. This visualization tool is generally available at the pipeline's master control console where it can be easily accessed by operations, maintenance, or instrumentation staff.

The PipeWise™ software also provides an interface to deliver warning and alarm messages via the plant's legacy SCADA/DCS system.

6. Conclusion

The era of managing Sulphur pipelines in a "blindfolded" fashion is quickly becoming obsolete. With today's available fibre optic Distributed Temperature Sensing technology, combined with Advanced Analytics, much of the guesswork in managing a Sulphur pipeline can be eliminated.

Utilizing the compelling pipeline operating data extracted from a fibre optic Distributed Temperature Sensing (DTS) system on the pipeline, combined with other pipeline and electrical equipment instrumentation, decision-based outcomes become much more predictable by leveraging the enormous amount of available data

Moving into the era of Artificial Intelligence allows for proactive and predictive analysis, giving operators the ability to address a potential problematic situation before it becomes a crisis. Utilizing data and customized algorithm-based software, it is possible to add a virtual pipeline "analysis expert" to your staff. The good news is that the algorithms work around the clock, with no time off – they become a 24-hour-a-day member of your team. The key is to construct an Intelligent Pipeline which incorporates the right technologies, and then to utilize data to your biggest advantage. The results are better management of your pipeline asset's risk profile and a higher degree of Flow Assurance.

References

1. PCIC 2004 – Safer Sulfur Transport – Controlling Skin-Effect, Heat-Traced Liquid Sulfur Pipelines with Fiber Optics (Jim Beres, Franco Chakkalakal, William McMechen, Chet Sandberg)
2. Rio Oil & Gas 2014 – Flow Assurance for Cross-Country Pipelines with Integrated Bundled Technologies (Franco Chakkalakal, Mike Allenspach)
3. Sulphur 2016 – Automated Re-Melt Program for Sulphur Pipelines – A Revolutionary Advancement in Safety with State of the Art Bundled Technologies (Franco Chakkalakal, Mike Allenspach, Kent Kalar, Hassan Armaneh)

Authors

MIKE ALLENSPACH, P.E. – NVENT THERMAL MANGEMENT

Mr. Allenspach is a registered Professional Engineer with 38 years of experience in the engineering and heavy construction industries. He served as Project Director for the engineering and construction of the pipeline heating systems for the world's three longest heated Sulphur pipelines. Mr. Allenspach has served in numerous technical and executive management roles during his career and is currently Director of nVent's Specialty Applications Group, which supports their organization's business development and project execution around the world.

GUSTAVO SALDARRIAGA, P.E. – NVENT THERMAL MANGEMENT

Mr. Saldarriaga received a BS degree in Electrical Engineering in 1991 from the University of Houston in Texas. He worked as a Plant I&E Engineer for Hoechst Celanese until 1995. He joined nVent Thermal Management (formerly known as Tyco Thermal Controls and Pentair Thermal Management) in 1995. He has worked the last twenty years as Lead Design and Project Engineer, and as STS Engineering Manager. He specializes in skin-effect tracing systems and has co-authored numerous technical conference and IEEE papers. He is a member of IEEE and is a Registered Professional Engineer in Texas, Louisiana, Washington State and Alberta, Canada.

KENT KALAR – TOPSIDE SOLUTIONS

Mr. Kalar is President and CEO of Topside Solutions, which designs and deploys fibre optic based data solutions to the pipeline and downhole markets. His 31 years of experience include various engineering and management positions and he has founded several companies, including Topside Solutions. He possesses deep expertise in the engineering and deployment of distributed fibre optic based sensing systems and is personally active in designing and delivering fully integrated, turnkey projects for pipeline and well monitoring applications around the globe. Mr. Kalar holds more than twenty patents in the fields of magnetic media, field emission devices, and distributed temperature sensing.