Control room applications aided by pipeline simulation

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Executive summary

Transporting products in a pipeline involves monitoring and control of operating conditions. There is a wide variety of tools and applications available to assist the controller in operating the pipeline. Some of these applications are pipeline simulation software based, and this paper looks at the benefits of using software simulation applications when operating the pipeline. The paper also outlines some of the major requirements associated with using pipeline simulation applications and typical functionality provided.

Other resources

For further discussion about the use of pipeline simulation models for leak detection, see the following Schneider Electric White Paper:

Pipeline Integrity - Best practices in prevention, detection and mitigation.pdf

Introduction

Oil and gas production is continuing to increase globally, which means that pipeline infrastructure — our safest mode of transporting hydrocarbon products over long distances — will become even more important in the years to come. Current oil and gas production is already driving demand for new pipelines, storage, and other facilities, and this demand is only expected to increase. While the industry pushes to bring new infrastructure online, nearly half of the existing global infrastructure is quickly aging and may already be obsolete.

Moving tons of hydrocarbon products through miles of pipeline is no easy feat when the expectations are that it should be done safely, efficiently, and reliably. Although it does take a whole company to transport the hydrocarbon products in the pipeline, the day-to-day operation is typically entrusted to a number of individuals who are located in the pipeline control room, some may call them operators, however, in line with latest API recommendations, we will call them Controllers in this paper.

The Controllers would typically have a Supervisory Control and Data Acquisition system, more commonly known as a SCADA system, to assist them in this day-to-day operation. The SCADA system would monitor both the facilities associated with the pipeline (e.g., if a door at a remote RTU has been opened) and how the product is moving in the pipeline (e.g., measuring pressure at several locations in the pipeline). The SCADA system contains all this information that could be used by a variety of applications and could add value to the Controllers' attempts to operate the pipeline safely, efficiently, and reliably.

Some of these applications could be nonsimulation based:

- Metering – calculating gross standard volume for measurement points
- Ticketing – to store, view, and edit pending, active, and complete tickets
- Tanking – to store, view, and manipulate data associated with tanks
- A number of other applications are available

And some of these applications could be simulation based:

- Visualize the hydraulic profiles in the pipeline
- Calculate the linepack or inventory in the pipeline
- Monitor and calculate whether pressure violation is occurring in the pipeline
- A number of other applications are available

This paper will review control room applications based on pipeline simulation models as outlined above, however, it will not cover any use of pipeline simulation models for the use of leak detection, since that is covered in another white paper from Schneider Electric; see side bar. The paper will also look at the types of pipeline simulation models available, the requirements associated with each type of model, and the benefits with each type of model.

Modeling methods for simulating pipelines

There are several ways of modeling a pipeline from a real-time perspective, some examples are listed below:

- Real Time Transient Model (RTTM) pipeline simulation
- Balance model pipeline simulation
- Neural Networks by creating a back-propagation feedback network
- Big data analytics by creating a reliability model

In this paper we will focus on those models that are generated based around hydraulics, hence will focus on the RTTM and balance model.

Pipeline simulation — Real Time Transient Model (RTTM)

The RTTM, is an advanced pipeline model that attempts to accurately model the physical behavior of the product transported within the pipeline by using measurement data from a variety of locations on the physical pipeline. The RTTM solves the following partial differential equations:

- Momentum, including the conservation of linear momentum
- Mass, including the conservation of mass
- Energy, including the conservation of energy
- Equation of state or similar

These partial differential equations are then typically solved using one or more of the following solution methodologies:

- Method of characteristics
- Implicit finite difference method
- Explicit finite difference method

For those that want more information about these equations and solution methodologies it is recommended that the Internet be used to meet their requirements. Suffice it to say that the RTTM contains some highly sophisticated math. However, all RTTMs are not created equal and some vendors use less flexibility in the input data required to make approximations rather than perform calculations every time.

The configuration of the RTTM would typically be achieved by using a graphical configuration tool that allows the user to specify both the layout of the pipeline segments and the equipment associated with each RTTM. The equipment might be placed in stations or directly on the pipeline. Typical equipment that could be added to an RTTM is listed below:

- Pumps/compressors – type (centrifugal, etc.) and actual location are important
- Tanks – dimensions, elevations, and pipeline connections are important
- Filters – dimensions and location are important
- Valves – type (check, control, etc.), diameter, CV, and location are important
- Transmitters – type (pressure, flow, etc.) and location are important
- Heaters/coolers – type, size, and location are important

In the end, the design of the pipeline segment or the stations associated with the pipeline could look something like the figure below within the graphical configuration tool:

Figure 1

Design of a pipeline segment or station is typically done using a graphical configuration tool like the one seen here.

After the layout of the pipeline segment or pipeline system has been established by using the graphical configuration tool, it is important to realize that what has been achieved is the creation of a connectivity model that allows the RTTM to know what is connected to what. Now data must be added to the connectivity model.

Data requirements for RTTM

All RTTMs require a set of data to be able to calculate useful results. These data can be divided into three categories:

Fixed pipeline data: These are data that are classified as constant for the specific pipeline. Five examples in this category are:

- Length of pipeline or pipeline segment
- Diameter of pipeline or pipeline segment
- Elevation above/below sea level for pipeline or pipeline segment
- Maximum allowable operating pressure (MAOP)
- Burial depth and potential insulation type and thickness

It is important to note that the majority of fixed data are classified as input data for the RTTM, however some could also be classified as output (e.g., internal area calculation and heat transfer in walls calculation).

Product properties data: These are data that indicate what the fluid in the pipeline should be and how the fluid could potentially be modeled. Five main examples in this category are:

- Dynamic and/or kinematic viscosity of fluid
- Celerity or speed of sound in fluid
- Density in general for fluids or API gravity for liquids
- Composition for compositional fluids
- Bulk modulus, either isothermal or adiabatic

It is important to note that the majority of product properties data are output data, although some of the data are both input and output, like density and composition, where the measurements at one location are used to calculate product properties, including density and composition at locations where there are no measurements.

Operational data: These are data that would typically be classified as changing as a result of the transport of the fluid in the pipeline segment. Four main examples in this category are:

- Pressure of fluid in the pipeline (sometimes measured as head in liquid pipelines)
- Flow (massflow or volumeflow) of fluid in the pipeline
- Temperature of fluid in the pipeline
- Ground temperature outside the pipeline (also called ambient temperature)

It is important to note that the majority of the operational data are both input and output data, for example, in that a measurement of pressure at one location is used within the RTTM to calculate the value of pressure at a location where there are no measurements.

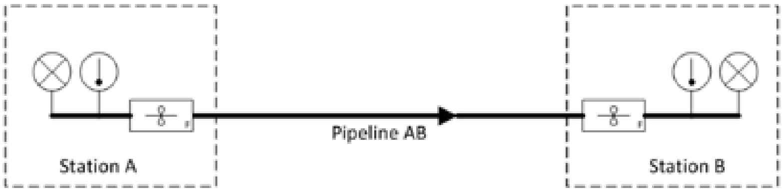
The fixed pipeline data, product properties data, and operational data identified above, together with the pipeline system layout and equipment, has enabled a model to be created. However, to complete the model building it is important to establish what control points should be used for the model to accurately reflect how the pipeline segment is operated.

To control an RTTM, some locations would be designated as boundary points for control purposes. Typically these are the same locations that the real pipeline is controlled from. This means that when a pump is controlled on suction pressure, the RTTM would be modeled with a control on suction pressure as well. Similarly when the real pipeline has a flow control valve located in the pipeline at a specific location, the modeled pipeline would have this flow control valve modeled as well. This is an important difference between an RTTM and an offline design tool.

Typically the control points or boundary points are located at either end of the simulated pipeline segment as follows:

Figure 2

Simple pipeline model showing boundary flow, pressure, and temperature measurements upstream and downstream of pipeline segment.



From a simplistic point of view this can be split into two models, the temperature model and the flow/pressure model. Let's look at each in more detail.

Modeling temperature in RTTM

Temperature model

The purpose of the temperature model is to make sure that the RTTM is able to calculate the correct product temperature at all locations in the pipeline where there are no measurements.

In the figure above, there are temperature measurements upstream and downstream, hence an argument could be made that the temperature along the pipeline could be found by using simple linear regression (i.e., the temperature changes with an equal amount of degree for the same distance step you take anywhere in the pipeline). This could be true for some pipelines, but for the majority of pipelines the temperature profile is nonlinear. To be able to model this nonlinearity, the upstream temperature would be used as input into the equations discussed earlier to create a temperature profile along the distance of the pipeline. This would mean that the measured temperature in the field would always be seen at the upstream end of the temperature profile for the pipeline segment.

So now that we have found the upstream model temperature and we know that the equations are calculating the temperature profile, we are good, right? Not yet. The temperature profile calculated would have a downstream calculated temperature that could be compared with the measured temperature downstream and, initially, it is very plausible that these calculated and measured temperatures would not match. To be able to get a closer match you would look at the heat transfer and the ambient temperature to adjust them so that the calculated and measured temperature become equal or very close to each other in numerical value. A typical temperature profile along a pipeline segment could look something like the figure on the next page:

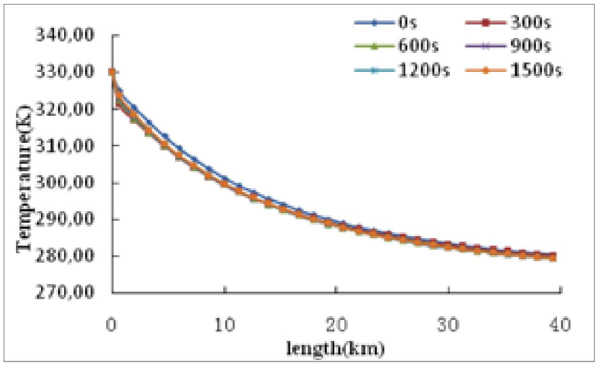


Figure 3

A typical temperature profile along a 40 km long pipeline segment, showing the nonlinearity of temperature vs. length for a variety of calculation periods in seconds.

One thing to remember with attempting to adjust the temperature profile is that any change could take a long time to materialize, since temperature changes move slowly in the pipeline segment.

Modeling pressure/flow in RTTM

Pressure/flow model

The purpose of the pressure and flow model is to make sure that the RTTM calculates the correct pressures and flows at locations in the pipeline where there are no measurements.

In the figure above, there are pressure measurements upstream and downstream, hence an argument could be made that the pressure along the pipeline could be found by using simple linear regression (i.e., the pressure changes with an equal amount of psi (bar) for the same distance step you take anywhere in the pipeline). This could be true for some pipelines, especially if they operate close to steady state. Similarly, it could be argued that performing a linear regression between the upstream and the downstream flow measurements would be sufficient for modeling purposes. Although both of these approximations for pressure and flow might work well for certain short pipelines, any pipeline over a certain length and where potentially packing/unpacking of linepack could take place would make the results less useful.

Looking at the equations mentioned earlier it becomes clear that there is a relationship between pressure and flow that is more complex than the one seen above for temperature and, as such, it is possible to generate a number of control relationships for the model to utilize as illustrated below:

Type of model	Description
PP-model	In this model the upstream and the downstream pressure measurements from the field are used as boundary points for the pressure calculations in the model. This means that the pressure profile has known start and end points, while the values in between are calculated by the RTTM. The flow profile with such a control scenario is free to calculate whatever is appropriate, and when a model like this is utilized time is spent on matching calculated flows with measured flows at either end of the pipeline segment.

(chart continues on next page)

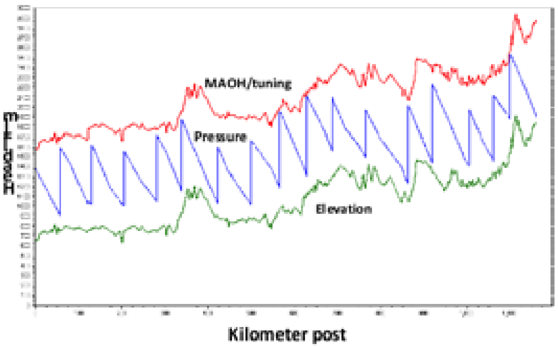
QQ-model	In this model the upstream and the downstream flow measurements from the field are used as boundary points for the flow calculations in the model. This means that the flow profile has known start and end points, while the values in between are calculated by the RTTM. The pressure profile with such a control scenario is free to calculate whatever is appropriate, and when a model like this is utilized time is spent on matching calculated pressures with measured pressures at either end of the pipeline segment.
PQ-model	In this model the upstream pressure measurement and the downstream flow measurement are used as boundary points. This means that the start point of the pressure profile is equal to the pressure measurement upstream, and the end point of the flow profile is equal to the flow measurement at the downstream end of the pipeline segment.
QP-model	In this model the upstream flow measurement and the downstream pressure measurement are used as boundary points. This means that the start point of the flow profile is equal to the flow measurement upstream, and the end point of the pressure profile is equal to the pressure measurement at the downstream end of the pipeline segment.

It must be emphasized here that the control model chosen for a pipeline segment within an RTTM has to be similar to the control of the real pipeline. This means that the number of solutions are fewer and narrower compared to an offline design tool where there are more degrees of freedom to create a solution that is not limited to a particular control regime.

Combining all the types of data (fixed pipeline, product properties, operational data, and control data) in an RTTM could create profiles as seen in the below figure:

Figure 4

This display shows the RTTM profiles for MAOH, pressure (head), and elevation along a 1,100 km long pipeline.



This hydraulic display is for a pipeline that is more than 1,100 km long. The hydraulic display also shows the head profile for this pipeline (the blue saw-like graph between the red and the green line). This saw-like figure indicates that this pipeline has at least 16 pump stations and it goes over terrain that is gradually increasing in elevation, as seen by the green line at the bottom.

The last line to notice on this hydraulic display is the red line at the top indicating the MAOH for this pipeline. For those with sharp eyes, it can also be seen that the blue line on some occasions has a change in slope, which indicates that this pipeline probably transports multiple products or that there are some diameter changes occurring for large parts of the pipeline. All these factors and more should affect the results calculated by the RTTM.

Pipeline simulation — Balance model

The balance model compared to the RTTM discussed above provides a much more simplistic picture of the hydraulics in the pipeline. The balance model does not concern itself with solutions to mass, energy, and momentum balance equations, and so cannot provide internal details about the pipeline system. The balance model is a balance application that looks at meters on the boundary parts of the system and tries to infer what may be happening inside. The concept of the balance model is shown below:

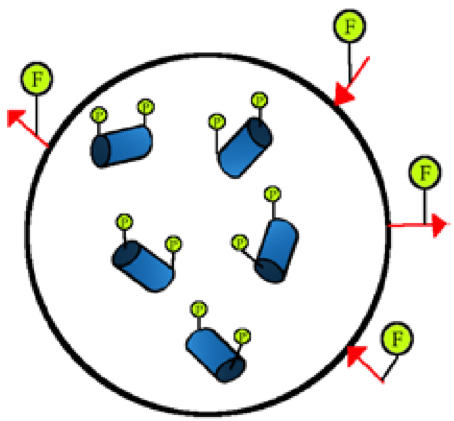


Figure 5

The concept of the balance model is shown in this display.

Having said that, although the concept of the balance model is relatively simple as seen above, the more advanced balance model would employ a connectivity model to indicate how pipeline segments are connected physically.

The best balance models typically use the same connectivity model as the RTTM, allowing for common configuration utilities and pipeline layout. The additional benefit is that upgrading from a balance model to an RTTM becomes simpler since they use the same connectivity model.

Data requirements for balance model

Due to its simplicity, the balance model has less stringent data requirements than what was outlined for the RTTM. Just like the RTTM, certain data is required for the balance model to calculate adequate results. Using the same terminology as for the RTTM above, the following data is required:

Fixed pipeline data: These are data that would be classified as constant for the specific pipeline segment.

- Length of pipeline or pipeline segment
- Diameter of pipeline or pipeline segment
- Elevation above/below sea level for pipeline or pipeline segment

It is important to note that the fixed data are classified as input data for the balance model.

Product properties data: These are data that indicate what the fluid in the pipeline should be and how the fluid could potentially be modeled.

- Density in general for fluids or API gravity for liquids

It is important to note that the density is both input and output for the balance model, where the measurement at one location is used to calculate density at locations where there are no measurements.

Operational data: These are data that would be classified as changing as a result of the transport of the fluid in the pipeline segment.

- Pressure of fluid in the pipeline (sometimes measured as head in liquid pipelines)
- Flow (massflow or volumeflow) of fluid in the pipeline
- Temperature of fluid in the pipeline

It is important to note that the operational data are both input and output data, for example, in that a measurement of pressure at one location is used within the balance model to calculate the value of pressure at a location where there are no measurements.

The fixed pipeline data, product properties data, and operational data identified above, together with the pipeline system layout, has enabled a model to be created. The control of the balance model is typically achieved by using boundary flow measurements.

Typically the balance model monitors volumetric variations for a configured pipeline bounded by flow meters. The model calculates the imbalance between volumes received and delivered by the system and the overall linepack change. The linepack change is calculated based on SCADA telemetry such as pressure, temperature, and product properties.

Each segment has a given enclosed pipe volume that is calculated from the fixed pipeline data based on inside diameter and length of pipeline segment. This pipe volume is corrected for pressure and temperature based on an average thermal expansion coefficient and compressibility for steel.

For each calculation performed, the average pressure and the average temperature are calculated in a pipeline segment based on real-time measurements within the pipeline segment, and the standard volume for that segment is computed.

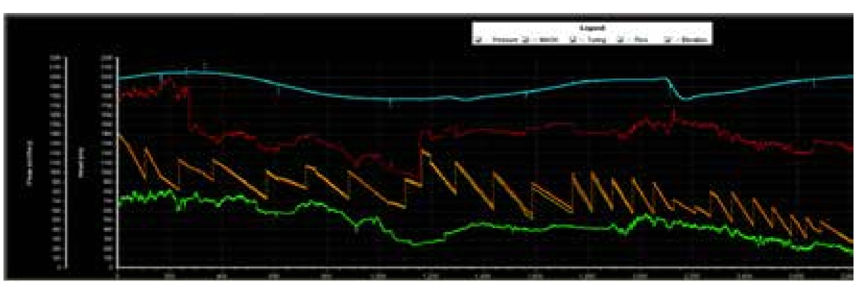
Applications based on pipeline simulation models

On the basis of either the balance model or the RTTM as outlined above, several functionalities and applications could be made available for assisting the controller in the pipeline control room. This section of the paper describes such applications in more detail.

Hydraulic profiles: As indicated in the sections above, the main outputs of both the balance model and the RTTM are the hydraulic profiles that are available to indicate what pressure, flow, density, etc., are at locations in the pipeline where there are no real-time measurements. Due to its more advanced calculation methodology, the RTTM provides more profiles than what are available from the balance model. Similarly, the accuracy of the profiles calculated by the RTTM is far superior to that calculated by the balance model point of view. A typical hydraulic profile display is seen below:

Figure 6

This display shows the hydraulic profiles for pressure, MAOH, tuning, flow, and elevation.



Hydraulic product tracking: The balance model and RTTM will track the movement of single products (e.g., crude, ammonia, etc.) through the simulated pipeline based on the measured and calculated flows. This functionality allows the user to see how fast the various types of single product are hydraulically moving down the pipeline segments.

The types of single products are tracked using an identifier that allows the location of all significant changes in single products to be calculated within the simulated pipeline, hence enabling users to track their single product fronts in the pipeline as illustrated in the figure below:

Figure 7

This display shows how the single product fronts in three interconnected pipelines can be tracked by the RTTM or balance model.

At injection points in the pipeline, it is typical to inject (blend) the single product into the batch that is currently traveling past the injection point. The RTTM allows these single product types to essentially create a new type of single product that will then be tracked within the simulated pipeline. In comparison, the balance model will track the front of when the blending took place, but will not create a new single product.

It is important to understand that the product changes illustrated in the figure above could be of a different single product pipeline, however this functionality allows a new batch identifier to be created when a condition is met to create a new batch/product.

Batch tracking: The balance model and RTTM will track the movement of batches through the simulated multiproduct pipeline based on the measured flows and calculated flows. A multiproduct pipeline that is transporting a variety of different refined products (e.g., kerosene, jet fuel, gasoline) would be interested in tracking the fronts of their batches. This is illustrated in the figure below:

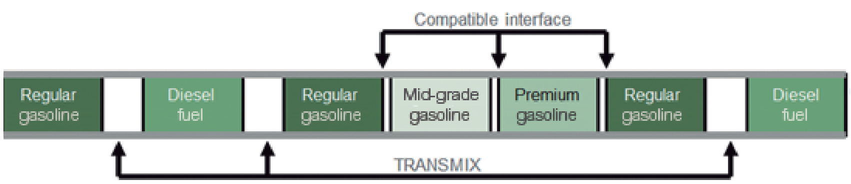


Figure 8

Batch tracking can track the growth of both compatible interfaces and transmix as the batches travel along the pipeline.

In a multiproduct pipeline this functionality should also accurately calculate how much the interface (transmix in the figure above) between two adjacent products (fluids) in the pipeline segment is growing as the products are transported down the pipeline segment.

In comparison with single product tracking mentioned above, the batch tracking functionality would typically not expect injection into batches that are passing the injection point. It then becomes more important to make sure that the injection points used are allowed to interject a batch in the middle of the pipeline and that this batch also has a unique batch ID.

Similarly, it is important for the batch tracking to potentially strip parts of batches at several deliveries along the pipeline, hence it is important for the batch tracking module to keep this information as long as the batch is in the pipeline.

The batch tracking module retrieves the location of all batch interfaces and the volume of the associated batch fragments. This information is then formatted for use with batch tracking displays, as seen on the next page.

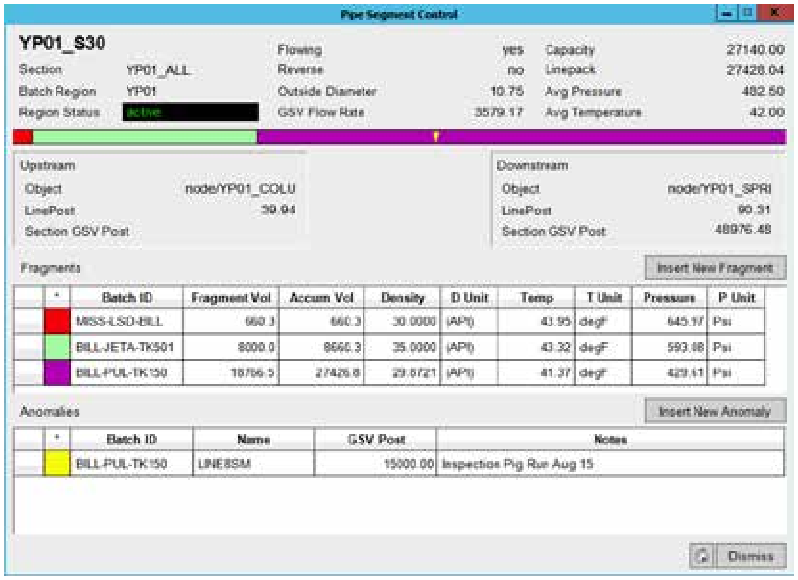


Figure 9

This display indicates the type of information available from a batch tracking user interface, showing both graphical and alphanumeric information.

This information can then be manipulated within the constraints of the pipeline to reflect the correct batch information if required. The batch tracking module calculates the estimated time of arrival of the front of each batch to downstream nodes on the pipeline.

Scraper tracking: The RTTM and balance model can also monitor the movement of pigs or scrapers in the pipeline. When a pig launch event is detected, the RTTM and balance model inserts a marker at the pig launch location. It then models the movement of the pig, adjusting the location each time a pig detection signal is received. When a pig is received at the downstream end of the pipeline, the marker is automatically removed from the system.

The scraper/pig is typically visualized in the batch bar as seen in the figure in the previous section about batch tracking. The movement of the scraper in the pipeline is aided by the use of a slip factor, where a slip factor of 1 indicates that the scraper is moving with the same speed as the product in the pipeline. Typically a slippage factor of less than 1 is utilized to indicate that the scraper is moving slower than the flow in the pipeline, however this is highly dependent on the type of pig/scraper that is launched into the pipeline.

Anomaly tracking including DRA and quality: In a similar fashion to scraper tracking above, the RTTM and balance model can be used to track anomalies in the pipeline (e.g., batch of bad crude or product). The batch editor can be used to flag the batch as bad and it is tracked accordingly in the pipeline. A slip factor is applied to the anomalies to account for the movement of the anomaly compared to the product flow.

The effects of drag reducing agent (DRA) are modeled within the RTTM by reducing the friction factor based on the concentration of DRA in the pipeline. The transportation of the DRA is modeled similar to scraper tracking above, except that the DRA reduces the pressure drop per length, and it is degraded as it is transported through the pipeline. The modeling of DRA is typically dependent on the DRA manufacturers' equations to make sure the degradation of the DRA is tracked correctly in the pipeline. Although there are generic or common degradation equations, typically the DRA manufacturers have their own proprietary equations.

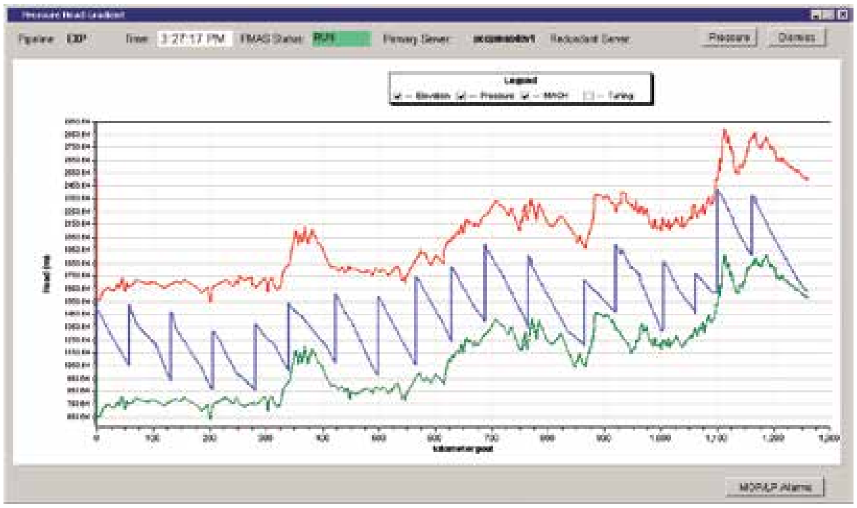
Since DRA behavior is highly dependent on the specifics of each DRA manufacturer and products being transported in the pipeline, most vendors expect that the customer will provide the specific constants to be used for their applications. If these constants are not available, the uncertainties in the system are increased and, therefore, the calculated hydraulics profile and tracking might become more inaccurate.

For gas pipelines this can be further extended within the RTTM to track the quality of the natural gas at any point in the pipeline network including at mixing points of two or more natural gas mixtures.

Pressure violation: The hydraulic pressure of a pipeline would typically be located between the pressure generated by elevation and the MAOP as seen in the figure below:

Figure 10

The hydraulic profile display seen here indicates how alarms could be issued if the blue line calculated by the model should intercept the red or green line, causing a pressure violation.



The RTTM allows the user to configure the MAOP profile so that pressure violations can be detected quickly at locations where the pipeline is not instrumented with an actual measurement. This is typically not functionality available with the balance model.

Linepack/inventory calculation: The linepack calculation algorithm determines the gross standard volume in each pipe segment based on the type of fluid within the segment, its density, and the temperature and pressure conditions within the pipe.

The RTTM has detailed accounting of the transient movement of mass and associated energy transfers inside the pipeline creating more accurate density, temperature, and pressure conditions compared to the balance model. As a result, the RTTM will calculate a more accurate linepack compared with the balance model.

It should be understood here that the difference in accuracy between the RTTM and balance model is fully dependent on the type of pipeline that is supposed to be modeled. Let us look at a couple of examples.

Example 1

A 12-inch pipeline transporting crude over relatively flat terrain for 10 miles. Assuming the measurements provided are identical, it is probable that the difference in linepack calculated between RTTM and balance model is less than 0.5% of the pipeline volume, hence both the balance model and the RTTM model the pipeline well.

Example 2

A 20-inch pipeline, transporting multiple products over terrain that is undulated for 200 miles. Assuming the measurements provided are identical, it is probable that the difference in linepack calculated between RTTM and balance model is more than 5% of pipeline volume, hence the RTTM is much more accurate than the balance model.

Linepack or gross standard volumes should be calculated using American Petroleum Institute (API) 2005 standards where applicable, as well as other recognized industry standards where necessary, such as for chemicals and chemical feed stocks.

Linepack or inventory for each pipeline can be trended as illustrated in the figure below:

Figure 11

The linepack or inventory of a pipeline or pipeline segment could be trended as seen in this display.

Requirements for operating a balance model and RTTM

We have looked at the requirements associated with creating either a basic (balance model) or advanced RTTM pipeline simulation model and the applications that are available based around such models. What is missing is to make some comments related to the maintenance and/or requirements for keeping these pipeline simulation models running.

As can be expected, the RTTM and the balance model do have different requirements related to maintenance. They have been grouped below as appropriate for easy reference.

Calibration: Both the RTTM and balance model are dependent on measurements from the field, the difference is that RTTM typically requires more measurements. Either way, the accuracy and repeatability of those boundary measurements that are used to drive/control the models is very important from a pipeline simulation point of view. This means that there should be a maintenance process in place to make sure that those boundary measurements are calibrated with a certain agreed frequency to avoid the model degrading due to drift or other inaccuracies imposed by the measurements used to drive/control the RTTM or the balance model.

It is important to also realize that the models require the measurement to be as accurate as possible, hence if the range of a meter in field is 0 – 100 bar, but the pipeline is only operating between 0 and 60 bar at the upstream end and between 0 and 30 bar at the downstream end, then the calibration should be done accordingly for those pressure measurements that are used as boundary measurements for the model, rather than calibrating using the whole range of the meter.

SCADA/DCS: Most SCADA/DCS would collect data from the field by exception rather than receive a value from the field with a fixed frequency. This creates a deadband associated with the measurement where the value in the field could be changing all the time. However, because the exception has been set to only report changes over a certain limit, values are not reported as frequently to the SCADA/DCS. This is partially done to save bandwidth and, although this is a good thing from a pure infrastructure point of view, these types of deadbands could make the pipeline simulation models unreliable. It is recommended that those measurements used to drive the particular model (i.e., the boundary measurements) are brought as raw as possible into the SCADA/DCS for use in the model.

Another potential problem associated with the SCADA/DCS infrastructure is analog to digital conversion taking place while the measurement value is transferred from field (meter) to SCADA/DCS. It is counterproductive to have a meter that reads an extremely accurate measurement in field, lets say 9.2345, when the 12-bit A/D conversion potentially limits the value to be read in SCADA as 9.3. Similarly, rounding or truncation of these boundary measurements by SCADA/DCS is not helpful.

Survey data: A pipeline that has been put in the ground does not necessarily stay in the location it was laid down in. This might sound surprising, but the pipeline is moving both horizontally and vertically from where it was laid due to both external and internal forces working on the pipeline. This might affect both the elevation profile for the pipeline and the heat transfer due to the pipeline potentially becoming more exposed.

To alleviate these types of issues, the pipeline company typically uses smart scrapers/pigs to not only verify location and elevation of the pipeline, but also to indicate whether the wall thickness is eroded, etc. These types of data are typically maintained in a central repository and called survey data. It is important for the pipeline simulation model to work correctly to make sure that the new survey data is reviewed when available and changes are performed according to the configuration of the balance model or RTTM.

Equipment: The RTTM attempts to accurately model all equipment within the pipeline envelope that could affect the hydraulics of the pipeline, this might include pump characteristic curves, valve curves, etc. This means that when time goes by and valves/pump drivers are replaced, these types of corrections need to be done in the RTTM as well to make sure the model accurately reflects reality.

Similarly, any new equipment added or removed (e.g., new block valve with potentially new measurements) should be incorporated into the model to see if the model can be improved. It should be noticed that equipment is typically only applicable to the RTTM and not to the balance model.

Pipeline: When the RTTM or balance model is originally configured and commissioned, it has been made for a specific pipeline layout, and whenever there are changes done to the pipeline layout, either by extending it or reducing it, it is important to make the same changes in the model to make sure that the results calculated are still accurate.

It is important in this respect to remember that adding or removing a supply or delivery should also be reflected within the model. The advantage with models is that if such pipeline extensions are scheduled in advance, the configuration could be done before the pipeline segment is commissioned to allow the model to come into operation when the real pipeline is available.

Wear and tear: As mentioned above, the smart scraper/pig will provide updated survey data that should be incorporated into the model. These new survey data have essentially captured some of the consequences of the daily wear and tear on the pipeline, however, it is not able to capture everything, hence it is recommended that on a yearly basis the model itself is fine tuned to make sure that further wear and tear has been taken into account within the model.

Conclusion

All pipeline operating companies in the world rely on the control room personnel to operate pipelines safely, reliably, and efficiently. A SCADA system is typically employed to assist the control room personnel in this regard, and although this significantly enhances the operation of the pipeline, there are further benefits available by adding pipeline applications on top of SCADA.

This paper has shown how the introduction of pipeline applications based around pipeline simulation models could assist control room personnel. The paper has outlined both the initial requirements and the ongoing maintenance requirements related to installing both a RTTM and a balance model.

When choosing the pipeline applications based around pipeline simulation models required for your specific pipeline, the selection needs to be based on a thorough evaluation of the business objective against the type of model requirement and cost. At the intersection of those points is where companies will find the appropriate pipeline simulation model underpinning their pipeline applications.

To assist you in evaluating the business objective for implementing pipeline applications based around pipeline simulation models the following steps are suggested:

Step 1: Evaluate the type of pipeline applications outlined in this paper that would be suitable or required for your specific pipeline or pipeline segment.

Step 2: Evaluate the specific pipeline that you are considering pipeline applications for and decide whether it is a simple (ability to use balance model) or more complex (requiring RTTM) pipeline. Take special care in evaluating the instrumentation requirements.

Step 3: Having compiled the information from step 1 and step 2 above, decide on a budget and contact a vendor that is able provide the pipeline applications that you have identified.

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About the author

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