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COMMISSIONING A REAL-TIME LEAK DETECTION SYSTEM ON A LARGE SCALE CRUDE OIL PIPELINE DURING START UP

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ABSTRACT

This paper describes the process of incremental pipeline filling and the phased commissioning of a real-time leak detection system for the 1768 km long BTC crude oil pipeline.

Due to stringent environmental requirements, it is essential for the leak detection system to work from the moment that crude oil is introduced into the pipeline. Without any prior operational data and with the pipeline partially filled, it is challenging for the leak detection system to monitor the integrity of the pipeline throughout the whole filling process.

The application of the pig tracking software to track the oil front as the crude displaces nitrogen is also discussed.

NOMENCLATURE

BTC	Baku-Tbilisi-Ceyhan Pipeline
BV	Block Valve
CCR	Ceyhan Control Room
CTU	Crude Topping Unit
ETA	Estimated Time of Arrival
ICSS	Integrated Control and Safety System
KP	Kilometre Post
LAN	Local Area Network
LDS	Leak Detection System
MBD	Thousand Barrels per Day
NGO	Non Government Organisation
OLE	Object Linking and Embedding
OPC	OLE for Process Control
PC	Personal Computer
PD	Positive Displacement
PTM	Pig Tracking Module
SCR	Sangachal Control Room
SPLD	ATMOS Pipe Statistical leak detection system using SPRT
SPRT	Sequential Probability Ratio Test
TCP/IP	Transmission Control Protocol / Internet Protocol
US	Ultra Sonic

INTRODUCTION

The BTC crude oil pipeline runs from the Sangachal Terminal near Baku in Azerbaijan, via Tbilisi in Georgia, through Turkey to a new export terminal located near Ceyhan on the Turkish Mediterranean coast. Figure 1 shows the geographical layout of the pipeline.

Figure 1: *Geographical Layout of the BTC Pipeline*

BTC has committed to partners, lenders, NGO's and others that the highest possible performance of leak detection will be provided from the point when hydrocarbons are introduced into the pipeline. Following successful completion of all hydrotests and commissioning activities, 700,000 Sm^3 of nitrogen was injected into the pipeline up to IPA1, the first intermediate pigging station along the line. This nitrogen remains in the pipeline all the way to Ceyhan. It is contained by closing block valves downstream of the injection point. When crude is pumped into the pipeline, two "line fill" pigs are used to separate the crude from nitrogen. Therefore, there are two challenging tasks for the on-line leak detection and pig tracking system:

- Accurate tracking of the oil front using the pig tracking system. Due to elevation changes, the speed of a pig varies significantly when travelling in an uphill section compared to when travelling in a downhill section. Since crude is much heavier than nitrogen, the changes in pig velocity are much greater than in a normal liquid filled pipeline.

- Reliable leak detection for the partly filled pipeline section without any historical data. As the crude starts to fill one section, the leak detection system has to monitor the integrity of the section based only on the readings from the inlet flow meter and pressure transducers along the section.

Despite these challenges, leak detection and pig tracking are provided but this requires close analysis of the system data in line with the pipeline operations and close cooperation of the engineering and operations teams.

PIPELINE DESCRIPTION

The pipeline is 1768 km long and is routed through some extremely mountainous terrain, rising to greater than 2500 m in Georgia, remaining above 1500 m until near KP 1650 in Turkey where it falls steeply towards the Mediterranean Sea. Figure 2 shows the elevation profile of the whole pipeline. Slack flow is inevitable at several high points along the pipeline in Georgia and Turkey. The leak detection system has to continue to work under such slack flow conditions.

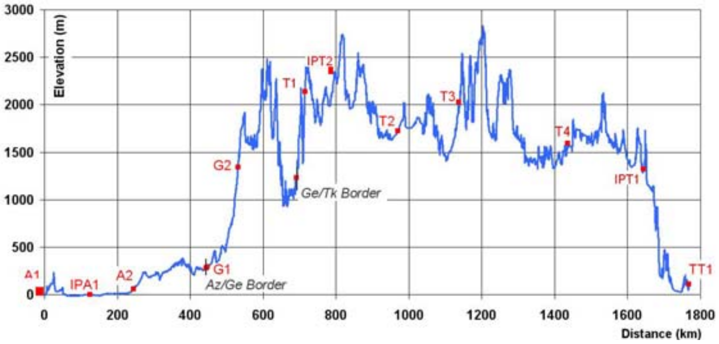


Figure 2: *BTC Pipeline Elevation Profile*

The pipeline is 42” diameter for most of its length. There is a 46” section throughout Georgia and a 34” section in Turkey for the last 500 km into the Ceyhan Terminal.

There are eight pump stations along the pipeline and 87 block valve stations. Pumping stations are at Sangachal terminal in Azerbaijan, a further station in Azerbaijan, two in Georgia and a further four pumping stations in Turkey. Each of these stations has a pig launcher and receiver and there are 3 further intermediate pigging stations.

The pipeline is exceptionally well instrumented. At each of the pumping stations in Azerbaijan and Georgia there are upstream and downstream US flow, pressure and temperature meters available. At the pumping stations in Turkey there are upstream and downstream pressure meters, and downstream US flow and temperature meters.

At all block valve stations there are upstream and downstream pressure meters, and downstream temperature meters. Upstream US flow meters are available at six of the block valves where slack flow is expected when running at reduced flow rates. Additionally, fiscal PD flow and density meters are available at PSA1, PSG1 and PST1, the first pumping station in Azerbaijan, Georgia and Turkey respectively. As an example, Figure 3 (after the last section of the paper) gives the overview of the Azerbaijan Section.

SYSTEM DESCRIPTION

In order to achieve the best possible leak detection performance as committed by BTC, redundancy is provided at several levels:

1. ***Redundancy by LDS technology.*** By the time the pipeline becomes fully operational, there will be two independent leak detection systems running in parallel:

   - *Statistical leak detection:* detects leaks by performing statistical analysis of flow imbalance calculations using the flow and pressure measurements along the pipeline when the pipeline is running. Under static conditions (pipeline shut-in), the system relies on pressure and temperature measurements to perform leak detection.

   - *Hydraulic model-based leak detection:* detects leaks by modelling the pipeline behaviour and then comparing the predicted flow and pressure with flow and pressure measurements from the pipeline instruments. Then it checks the discrepancy to see if it indicates a leak.

   The hydraulic model-based leak detection system cannot become operational until the pipeline is full and running in steady state. Therefore, this paper focuses solely on the application of the statistical system for the incremental line fill leaving the traditional system to be commissioned when the line is full during production.

2. ***Redundancy of LDS hardware.*** The statistical leak detection system runs on a stand-alone PC at both Sangachal Control Room (SCR) and Ceyhan Control Room (CCR).

   The LDS PC at SCR interfaces with the ICSS at SCR and the PC at CCR interfaces directly with the ICSS at CCR as shown in Figure 4. Communication is by means of OPC over an Ethernet network using TCP/IP. The system at CCR is a copy of that at SCR. Once commissioned, they will run independently of each other.

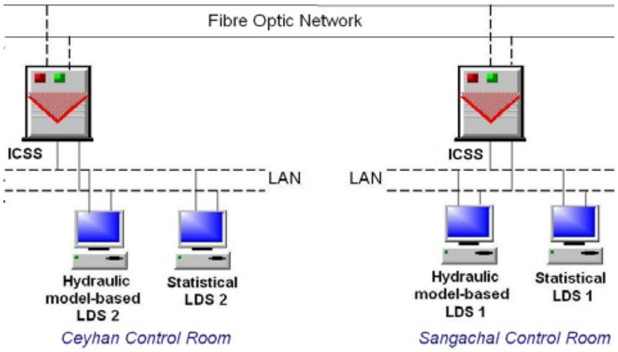


Figure 4: *Leak Detection LAN*

3. ***Redundancy within the LDS Architecture.*** The pipeline is being considered in discrete sections as shown in Figure 5:

- Seventeen sub-sections where flow readings are available
- Three main "country" sections – Azerbaijan, Georgia and Turkey
- One further section – monitoring the entire pipeline

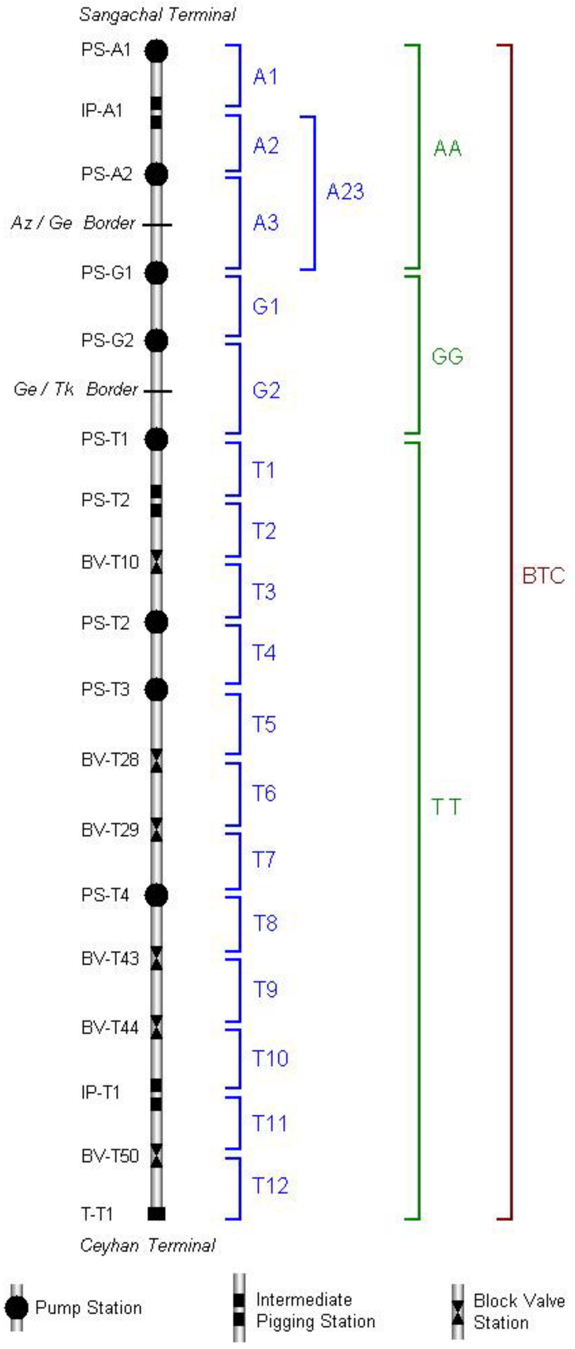


Figure 5: *Leak detection sections*

This configuration allows the LDS to achieve the best possible leak detection sensitivity and response time, and provides a high level of redundancy.

In the event of losing a sub-section, for instance due to a critical instrument fault, there will still be leak detection provided by the "country" section. It also allows slack flow areas to be isolated so that the sensitivity and performance of other sections do not have to be compromised.

Figure 6 (at the end of the paper) shows the summary screen of the above leak detection sections.

Each of the redundant leak detection systems rely on flow, pressure and temperature measurements along the pipeline to determine if a pipeline leak has occurred. Therefore to have the leak detection capability available, it is essential that the following conditions are satisfied for the pipeline section to be filled prior to start-up:

- The pipeline instrumentation commissioned and in good working order
- Communications from the field and ICSS verified
- The interface between the ICSS and LDS tested and commissioned

Typically, commissioning of a leak detection system starts when the pipeline is already full, the above conditions have already been satisfied and the following conditions have been met:

- Most model-based systems rely on the pipeline being in a steady state before the tuning process can begin. Thus leak detection during the filling operation is not possible.
- Some mass balance and neural network systems require leak trials to be carried out before they can be tuned.
- Statistical systems require "normal operation" including transients caused by pumping operations, pump trips and changeovers.

In the case of the statistical leak detection system for the BTC Pipeline given that it is sectionalised, it can be commissioned as soon as sections are filled and therefore, provide leak detection from the moment crude oil has filled the first section. As more pipeline sections are filled, more pig tracking and leak detection systems are activated. To provide full support to BTC, one project engineer from ATMOS is on site for each of the incremental pipeline fill periods. In addition to the daily support to the commissioning team, the engineer is also responsible for tuning the leak detection systems for the liquid filled sections so that their performance is optimised.

In addition, some parameters of the standard algorithm are temporarily modified during the line fill phase to be able to provide leak detection in the partially filled pipe section. This means that leak detection is possible as soon as oil first enters the pipeline.

There is also an application to track pigs in the pipeline; both cleaning and line fill pigs. The location of the line fill pigs defines the location of the oil front as the pipeline is filled.

This has proven particularly valuable during line fill whereby traditional on-the-ground pig tracking techniques can suffer as a consequence of vapour pockets and steep downhill land profiles.

FILLING OPERATION

The line is filled with crude oil at a fixed rate of approximately 150 mbd. The Oil/N_2 interface is maintained using two high seal, bi-directional pigs known as the “line fill” pigs, which are spaced approximately 400 m apart. Ahead of the “line fill” pigs is a large pressurised nitrogen blanket approximately 120 km long. The nitrogen is used to inert the pipeline and maintain a backpressure to help control the speed of the pigs in downhill sections.

Selected block valves in the section to be filled are used to control the nitrogen pressure ahead of the “line fill” pigs. These specific valves are left closed and the nitrogen throttled around them using their bypass valves as the oil front approaches. Once the pressure has equalised at either side of a closed block valve, the bypass valve is closed and the block valve is fully opened. Nitrogen pressure then builds up against the next closed block valve and the procedure is repeated. This ensures the pressure in front of the pigs is maintained as much as possible throughout the Oil/N_2 displacement.

Because a partially filled section behaves so differently from a full section, leak detection under these conditions is normally considered impossible. However with the high level of instrumentation on the BTC pipeline, ATMOS Pipe Statistical Pipeline Leak Detection (SPLD) System is applied to each partially filled section as soon as crude enters the section.

Due to the uncertainties in the pig behaviour and potential faults in the newly installed instrumentation system, all leak alarms are diagnosed in conjunction with the pig tracking system.

LEAK DETECTION ON FILLED SECTIONS

Once a section gets filled, the actual pipeline data for this section is used to tune and optimise the leak detection system. As more sections are filled, more sub-systems are activated to monitor more kilometres of the pipeline. The performance of each sub-system improves as more actual pipeline data becomes available.

Each section is tuned to full sensitivity during steady-state operations. However, transients (such as unexpected pump trips) during this time are not expected to be representative of normal operations so the system is tuned to a reduced sensitivity during line fill transients.

The ATMOS Statistical LDS is now (at the time of writing) close to being fully tuned and commissioned by the time the entire pipeline is full. However, the final fine tuning of the system will be slightly different from the initial tuning carried out during incremental line fill and will require the whole pipeline to be in operation.

Once a section of the pipeline is full, the standard leak detection algorithm can be applied as the minimum instrumentation requirements are fulfilled: flow and pressure measurements at both the inlet and the outlet of the pipeline section.

The principle of the standard system is illustrated in Figure 7. Flow and pressure measurements along the line are the significant variables feeding the algorithm after data validation checks are carried out.

Then statistical analysis is performed on the flow imbalance calculation to determine whether a leak condition is present. If a leak is detected then an alarm is generated and an estimate of the leak size and location is reported.

The system also adapts itself to changes that occur in the pipeline. The system accommodates inventory changes by monitoring pressure variations in the pipeline and normal metering errors by continuously estimating the flow difference between the inlet and the outlet.

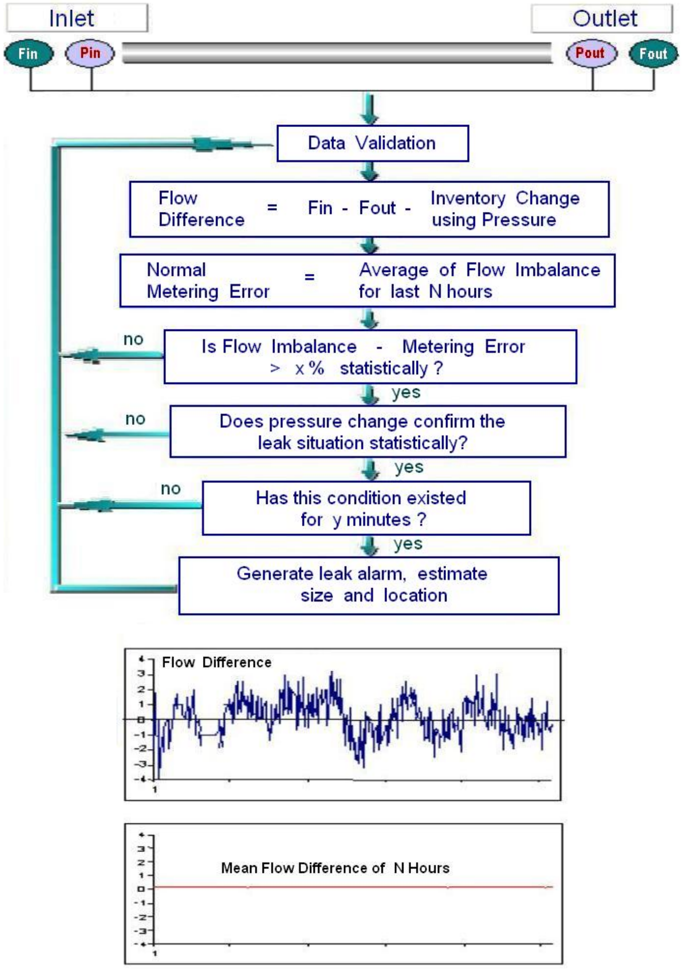


Figure 7: *Leak detection logical steps*

The minimum the system requires to be tuned is a sample of “normal operation” including transients caused by pumping operations and throughput changes.

Once a filled section of the pipeline has been tuned, then the settings for this tuned section can be used as a starting point for subsequent newly filled and un-tuned sections.

This allows newly activated sub-sections to start off at a more realistic sensitivity minimising the number of false alarms being generated.

LEAK DETECTION ON THE “LINE FILL” SECTION

When the crude oil first enters a pipeline section, the reliability and performance of the overall instrumentation system are uncertain, particularly for the part where no crude is present.

During a line fill operation, the hydraulics in the pipeline are significantly different from those in a filled section. The pressure downstream of the “line fill” pigs is governed by nitrogen being moved along the pipeline. This gas filled section provides a compressible cushion for the “line fill” pigs to push against and as such does not behave as a liquid would.

In addition, the minimum instrument requirements are not met: the outlet flow measurement needs to be disregarded, as that section of pipe is effectively empty. Also the number of pressure measurements increases as the section is gradually filled.

Due to the above challenges, standard leak detection technologies cannot perform leak detection effectively.

For the “line fill” section, some parameters in the standard algorithm need to be adapted. There is no outlet flow measurement so a raw flow difference is not available. The whole inventory is continually changing so the inventory correction is not as it would be for a filled section. The algorithm is modified to use the available data. i.e. the inlet flow reading and all available pressure measurements.

As the pipeline section is filled, data is analysed so that the rate of change of pressure in the line can be monitored for leaks alongside the inlet flow measurement. The inlet flow of the section is also monitored to establish whether the pipeline is under shut-in or running conditions. The performance of the “line fill” section gradually improves as the oil front passes more block valves and more valid pressure measurements are incorporated into the calculations.

This system relies on maintaining the pressure along the line and having a functional inlet flow measurement at all times as these are the inputs into the statistical algorithm.

This adaptation is only required for partially filled sections, once full this method is disregarded and the standard algorithm is applied.

LEAK DETECTION ON FULL PIPELINE

After the crude fills the whole pipeline, the leak detection system will be fine-tuned and all the sub-systems, whole country and whole pipeline systems activated. The system performance will be optimised with minimum false alarms and highest sensitivity.

PIG TRACKING

The Pig Tracking Module (PTM) integrates with the ATMOS leak detection software, and adds the capability to track the position of a pig that is inserted into the pipeline.

The PTM provides the estimated position of the pig within the pipeline, the velocity of the pig and the estimated time of arrival (ETA) at the pig receiver, as well as the ETA at every intermediate block valve along the way. The PTM allows for multiple pigs within the same section of the pipeline and allows a library of default characteristics to be stored for a number of different pig types e.g. cleaning, intelligent, etc.

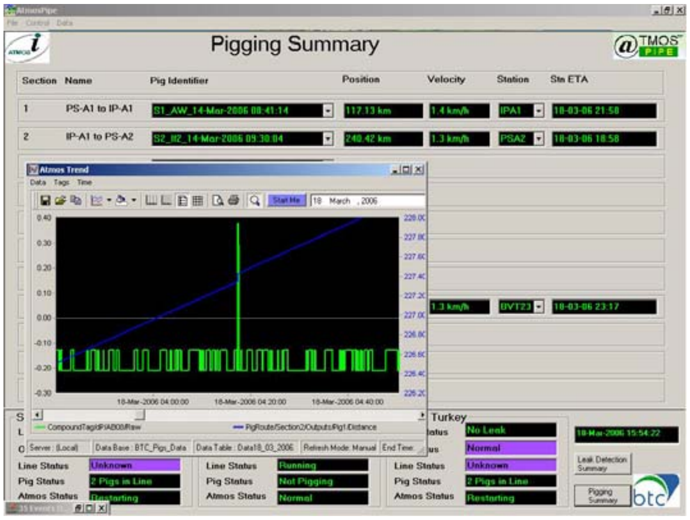
When a pig is launched into the pipeline, the PTM receives its signal to start tracking from the Pig Launcher. The pig velocity, location and ETA are updated based on previously saved data for “Pig Friction Factor”. When the pig passes a block valve, the “Pig Friction Factor” is updated and corrected. The Pig Velocity and ETA are also updated and corrected at this time. On the first pig run, this “Pig Friction Factor” is a “best guess” based on an operator entered slippage/bypass figure, but it is corrected as soon as the pig passes the first block valve and then re-corrected on passage through each block valve as slippage may change during the pig run with for example pig wear, wax build up, etc.

Normally, the PTM uses the upstream and downstream pressure signals at every available location to monitor, correct and update the Pig Position and “Pig Friction Factor” which is used in the calculation of Pig velocity. Experience suggests that this method is more reliable than using traditionally unreliable Pig Signals at each block valve. If Pig Signals at the block valves are received, then they are acknowledged and used. However the system is not dependent on receiving these pig signals.

If the “Pig in Line” signals from the Pig Launchers fail, then the operator has the ability to enter / update the “Pig Launched Time”.

During the line fill operation, the PTM is used to track the “line fill” pigs, which are representative of the oil front moving along the pipeline, replacing the nitrogen ahead. This function has proven to be valuable to BTC in terms of tracking the oil front as well as diagnosing leak alarms when a pig moving downhill generates an increased pressure drop upstream.

Figure 8 gives an example of pig position correction based on pressure changes at a block valve.



Section	Name	Pig Identifier	Position	Velocity	Station	Stn ETA
1	PS-A1 to IP-A1	S1_AW_14-Mar-2006 08:41:14	117.13 km	1.4 km/h	IPA1	18-03-06 21:58
2	IP-A1 to PS-A2	S2_II2_14-Mar-2006 09:30:04	240.42 km	1.3 km/h	PSA2	18-03-06 18:58
				1.3 km/h	BVT23	18-03-06 23:17

18 March , 2006

Server : (Local) | Data Base : BTC_Pigs_Data | Data Table : Data18_03_2006 | Refresh Mode: Manual | End Time:

Line Status	Unknown	Line Status	Running	Line Status	Unknown
Pig Status	2 Pigs in Line	Pig Status	Not Pigging	Pig Status	2 Pigs in Line
Atmos Status	Restarting	Atmos Status	Normal	Atmos Status	Restarting

Status: No Leak
Normal
18-Mar-2006 15:54:22

Figure 8: *PTM Summary and Trend illustrating pig position being corrected based on the pressure differential at the BV*
Primary Axis: Pressure differential (Green)
Secondary Axis: Pig Position (Blue)

EXAMPLES OF LINE FILL

Line fill to PT2 – validation of LDS behaviour using land profile

In the event of a leak occurring, the expected behaviour of a line fill section is that the line pressure in the filled section would drop and there would be a consequential increase in the inlet flow.

If the terrain is flat, the line pressure rises continuously as the line is filled. However given the elevation profile, the average line pressure can sometimes fall depending on where the oil front ("line fill" pig) is with respect to the elevation profile i.e. on downhill sections. This is due to the "line fill" pigs and the oil front behind them free falling against the pressurised nitrogen ahead.

Hence, the LDS is expected to generate a leak alarm when the "line fill" pigs briefly free fall on the downhill sections as this behaviour mimics the flow and pressure pattern expected during a leak.

The trend in Figure 9 shows the land profile of the "line fill" pipeline section from IPT2 to T2.

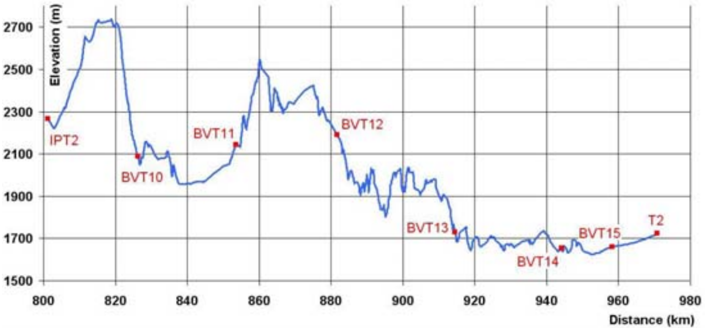
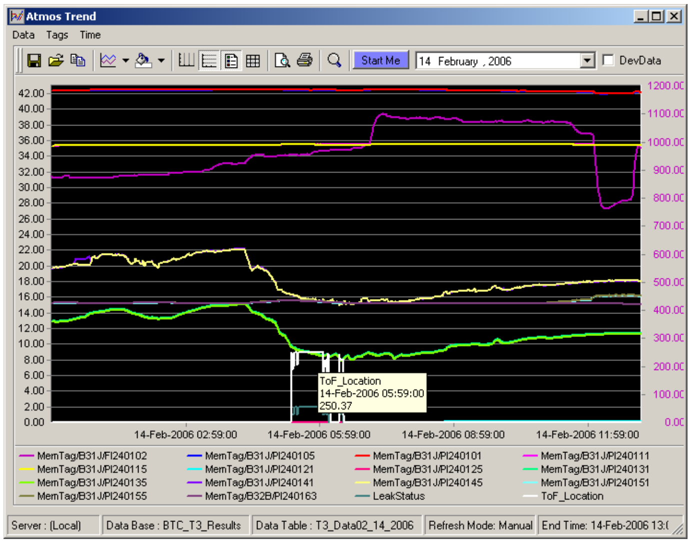


Figure 9: *BTC Pipeline Profile from IPT2 to T2*

In the LDS, this section is considered as two discrete sections to isolate the high point between IPT2 and BVT10 where slack flow will be a regular occurrence when running at reduced flow rates. This sectionalisation is possible as a flow measurement is available at BVT10 specifically to mitigate this scenario, unlike at other block valves in sections not susceptible to slack flow.

Figure 9 and 10 below show the response of the "line fill" leak detection sections as the line-fill pigs travel downhill in the area downstream of BVT14.

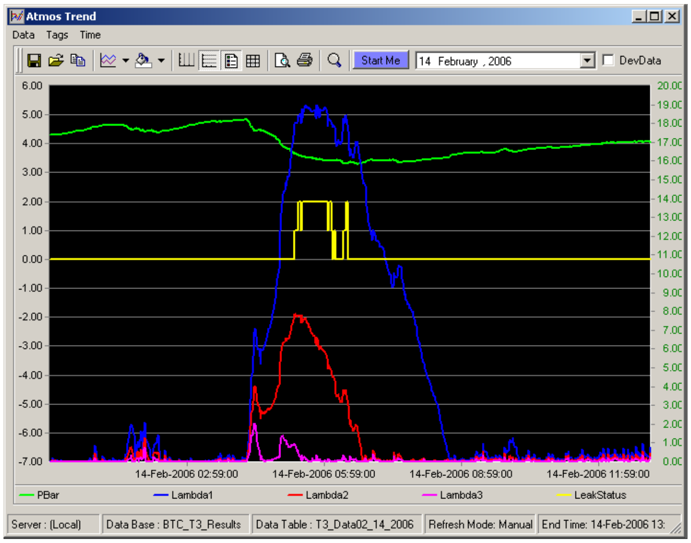


ToF_Location
14-Feb-2006 05:59:00
250.37

Server : (Local) | Data Base : BTC_T3_Results | Data Table : T3_Data02_14_2006 | Refresh Mode: Manual | End Time: 14-Feb-2006 13:(

Figure 9: *Trend displaying "line fill" LDS response*
Primary Axis: Pressure measurements
Secondary Axis: Inlet flow (Purple) and Leak Location (White)

Figure 9 shows a rise in the inlet flow and a drop in line pressure as the "line fill" pigs go downhill in the proximity and downstream of BVT14. The system reported a leak location close to BVT14 and hence the alarm can be regarded as triggered by the downhill event.



Server : (Local) | Data Base : BTC_T3_Results | Data Table : T3_Data02_14_2006 | Refresh Mode: Manual | End Time: 14-Feb-2006 13:

Figure 10: *Trend displaying "line fill" LDS response*
Primary axis: Lambda variables and Leak Status (Yellow)
Secondary axis: Average Line Pressure (Green)

Figure 10 shows the response of the statistical leak detection variables (lambdas) to the flow and pressure pattern triggered by the "line fill" pigs going downhill which matches a typical leak pattern. Lambda rising implies an increased probability of a leak condition. Once a lambda value reaches the alarm threshold, a leak alarm is generated on the system.

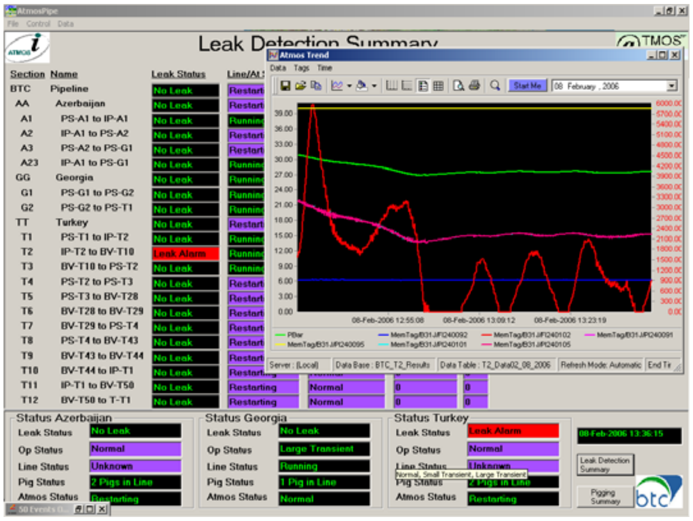
Because the PTM is predicting the location of the "line fill" pigs, it can be seen that the pigs are in a downhill section and that this alarm is most likely triggered by the pigs and oil front travelling downhill and is not a leak.

This behaviour is exploited to verify that the LDS is behaving as expected and is operational given that this event generates a leak alarm. The alarm generated triggers the leak location algorithm, which reports a location that corresponds to the BV immediately upstream of the oil front/pig. This information can then be correlated with the data from the PTM.

The leak detection system for the partially filled section is sensitive. However, some alarms are generated and the system needs to be interrogated intelligently and in line with the prevailing operational scenario to decide if the alarm is genuine.

Line fill to BVT10 – reverse flow in a valley.

Another example of the analysis required to diagnose a leak event can be seen in the trend below which illustrates the behaviour of the LDS for the section between IPT2 and BVT10. BVT10 experiences a reverse flow as a result of the line fill operation.



Section	Name	Leak Status	Line/At			
BTC	Pipeline	No Leak	Restart			
AA	Azerbaijan	No Leak	Restart			
A1	PS-A1 to IP-A1	No Leak	Runnin			
A2	IP-A1 to PS-A2	No Leak	Restart			
A3	PS-A2 to PS-G1	No Leak	Restart			
A23	IP-A1 to PS-G1	No Leak	Runnin			
GG	Georgia	No Leak	Runnin			
G1	PS-G1 to PS-G2	No Leak	Runnin			
G2	PS-G2 to PS-T1	No Leak	Runnin			
TT	Turkey	No Leak	Restart			
T1	PS-T1 to IP-T2	No Leak	Runnin			
T2	IP-T2 to BV-T10	Leak Alarm	Runnin			
T3	BV-T10 to PS-T2	No Leak	Runnin			
T4	PS-T2 to PS-T3	No Leak	Restart			
T5	PS-T3 to BV-T28	No Leak	Restart			
T6	BV-T28 to BV-T29	No Leak	Restart			
T7	BV-T29 to PS-T4	No Leak	Restart			
T8	PS-T4 to BV-T43	No Leak	Restart			
T9	BV-T43 to BV-T44	No Leak	Restart			
T10	BV-T44 to IP-T1	No Leak	Restarting			
T11	IP-T1 to BV-T50	No Leak	Restarting	Normal	0	0
T12	BV-T50 to T-T1	No Leak	Restarting	Normal	0	0

Server: (Local) | Data Base: BTC_T2_Results | Data Table: T2_Data02_08_2006 | Refresh Mode: Automatic | End Ti

Status Azerbaijan		Status Georgia		Status Turkey	
Leak Status	No Leak	Leak Status	No Leak	Leak Status	Leak Alarm
Op Status	Normal	Op Status	Large Transient	Op Status	Normal
Line Status	Unknown	Line Status	Running	Line Status	Unknown
Pig Status	2 Pigs in Line	Pig Status	1 Pig in Line	Pig Status	2 Pigs in Line
Atmos Status	Restarting	Atmos Status	Normal	Atmos Status	Restarting

Normal, Small Transient, Large Transient

08-Feb-2006 13:36:15

Figure 11: *Trend displaying "line fill" LDS response*
Primary Axis: Pressure measurements
Secondary Axis: Inlet flow (Blue) and outlet flow (Red)

Figure 11 shows the LDS displaying a leak alarm in the section from IPT2 to BVT10. According to the PTM, when this leak event was generated, the "line fill" pigs were starting to travel uphill towards BVT11.

From the elevation profile in Figure 8 it can be seen that the pigs at this point are in the valley downstream of the high point. This high point is expected to be permanently "slack" when running at the reduced "line fill" flow rates. Consequently, reverse flow behaviour is observed at BVT10 as the oil front travels backwards and forwards across the valley. Eventually, the valley section of pipeline is filled, the pressure behind the line fill pigs builds up and the oscillation is dampened.

Line fill in later sections – fully operational LDS in earlier sections.

Sections of pipeline that have been filled and that have seen enough representative pipeline data can be optimised to remove false alarms and provide the highest possible leak detection sensitivity. These sections are then left to run as "normal" and the only changes expected to these are further fine-tuning changes once the pipeline is fully operational.

Server: (Local) | Data Base: BTC_A23_Results | Data Table: A23_Data03_13_2006 | Refresh Mode: Manual | End Time: 13-Mar-2006 23:59:59 | Refre

Figure 12: *Trend displaying full section LDS response to a "simulated leak" under shut-in conditions*
Primary Axis: Average Line Pressure (Purple)
Secondary Axis: Lambda variables (Blue and Green) and Leak Status (Red)

Figure 12 illustrates the LDS sensitivity of the section between IPA1 and PSG1 under shut-in conditions. This section has been tuned to "Filled Line" sensitivity. Unfortunately, it is missing some instrumentation at an intermediate pump station due to a communications fault, so its performance is degraded. The trend shows the system reacting to what was indicative of a very small shut-in leak. The "leak" was in fact generated by extracting oil from the upstream side of PSG1 to fill the pipe work and Crude Topping Unit (CTU) Feed Tank located at PSG1 for the first time. This was extraction of oil from the shut-in section of pipeline into an un-metered empty section of pipeline and process equipment. The "leak" started at an extremely small volume, rising after 30 minutes to approximately 10 m^3/h as confirmed by the engineer responsible for the site works. The LDS detected this simulated leak in 45 minutes. This corresponds to a leaked volume of approximately 6 m^3 before alarm. The leak location was reported as at PSG1. This is the correct location.

CONCLUSIONS

Traditionally, leak detection is one of the last systems to be commissioned and come on line in a pipeline project. This is sometimes due to a lack of commitment or a lack of belief in leak detection technology, leading to a lack of urgency. Inevitably, this often results in the production taking priority over LDS commissioning until some time after the pipeline is in full flow.

However, it is also widely accepted that leak detection and pig-tracking systems cannot be commissioned before the pipeline is fully operational. This is largely true in that the final LDS commissioning cannot take place before the pipeline is fully operational.

BTC and ATMOS have cooperatively striven to break this paradigm and develop a Leak Detection system that delivers real benefit at the first point of hydrocarbon introduction and is close to optimal tuning on day one of full production.

BTC and ATMOS have demonstrated that leak detection is possible in a partially filled pipeline, and during line-fill - i.e. at all times from the moment fluid first enters the pipeline. The results from the LDS and the PTM during line-fill must be used with a high degree of understanding and could not be used in isolation from other systems. e.g. knowledge of where the oil front is with respect to the elevation profile, knowledge of the current state of commissioning of all the associated systems - pumps, stations, status and accuracy of instrumentation, block-valves, and in-depth knowledge of how the LDS and pipeline operations interact with each other.

ACKNOWLEDGMENTS

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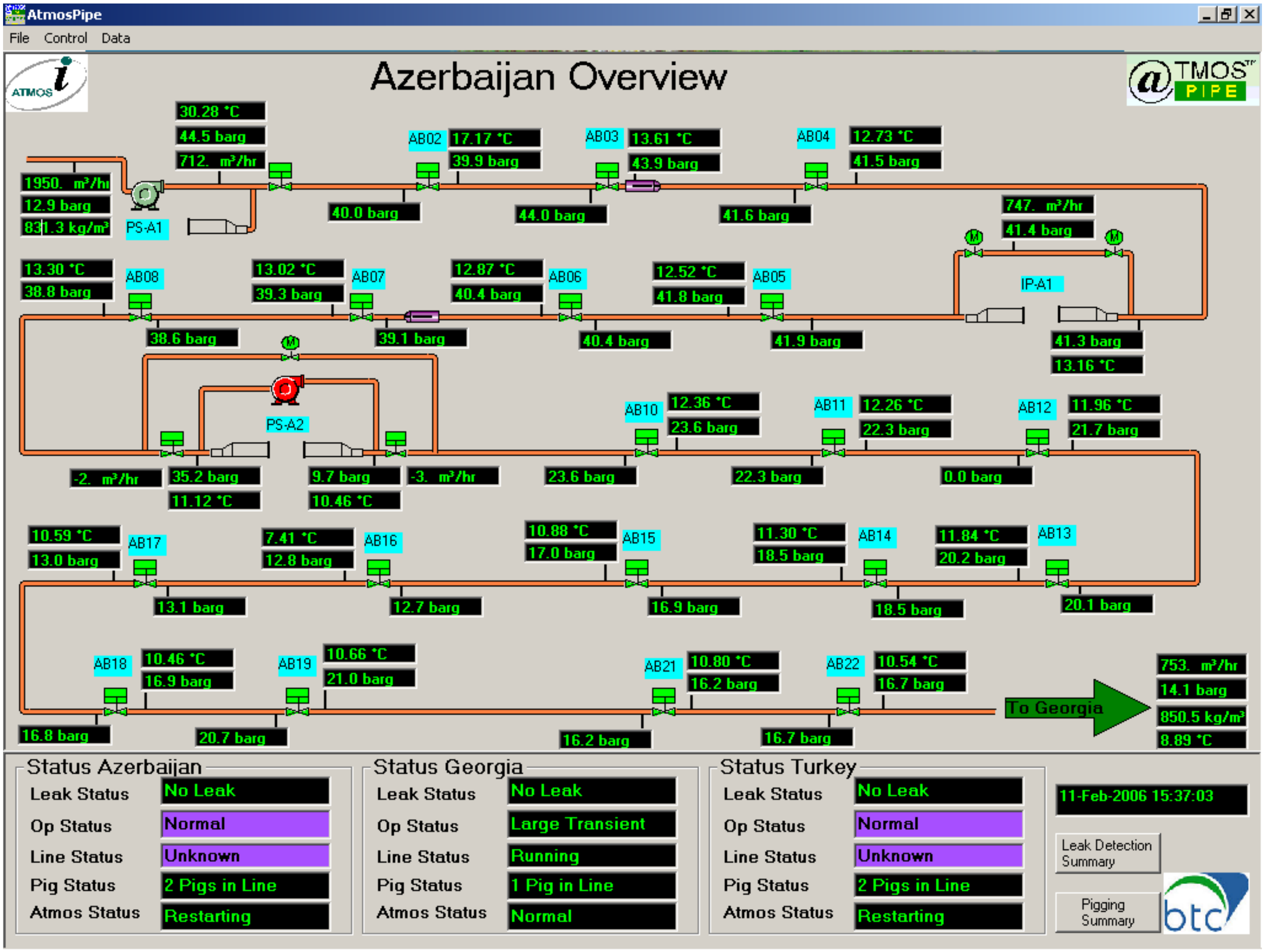
REFERENCES

1. Keefe Murphy, Dr. Jun Zhang, 2004, “Transient leak detection in crude oil pipelines”, Presented at the International Pipeline Conference 2004, between 4th and 8th October 2004 in Calgary, Canada

2. John Lewis, Joep Hoeijmakers, 2002, “Pipeline leak detection methodology change on the crude oil pipeline network for NV Rotterdam Rijn Pijpleiding Maatschappij (RRP) in the Netherlands”, Presented at the International Pipeline Conference 2002, between 29th September and 3rd October 2002 in Calgary, Canada



Status Azerbaijan

Leak Status	No Leak
Op Status	Normal
Line Status	Unknown
Pig Status	2 Pigs in Line
Atmos Status	Restarting

Status Georgia

Leak Status	No Leak
Op Status	Large Transient
Line Status	Running
Pig Status	1 Pig in Line
Atmos Status	Normal

Status Turkey

Leak Status	No Leak
Op Status	Normal
Line Status	Unknown
Pig Status	2 Pigs in Line
Atmos Status	Restarting

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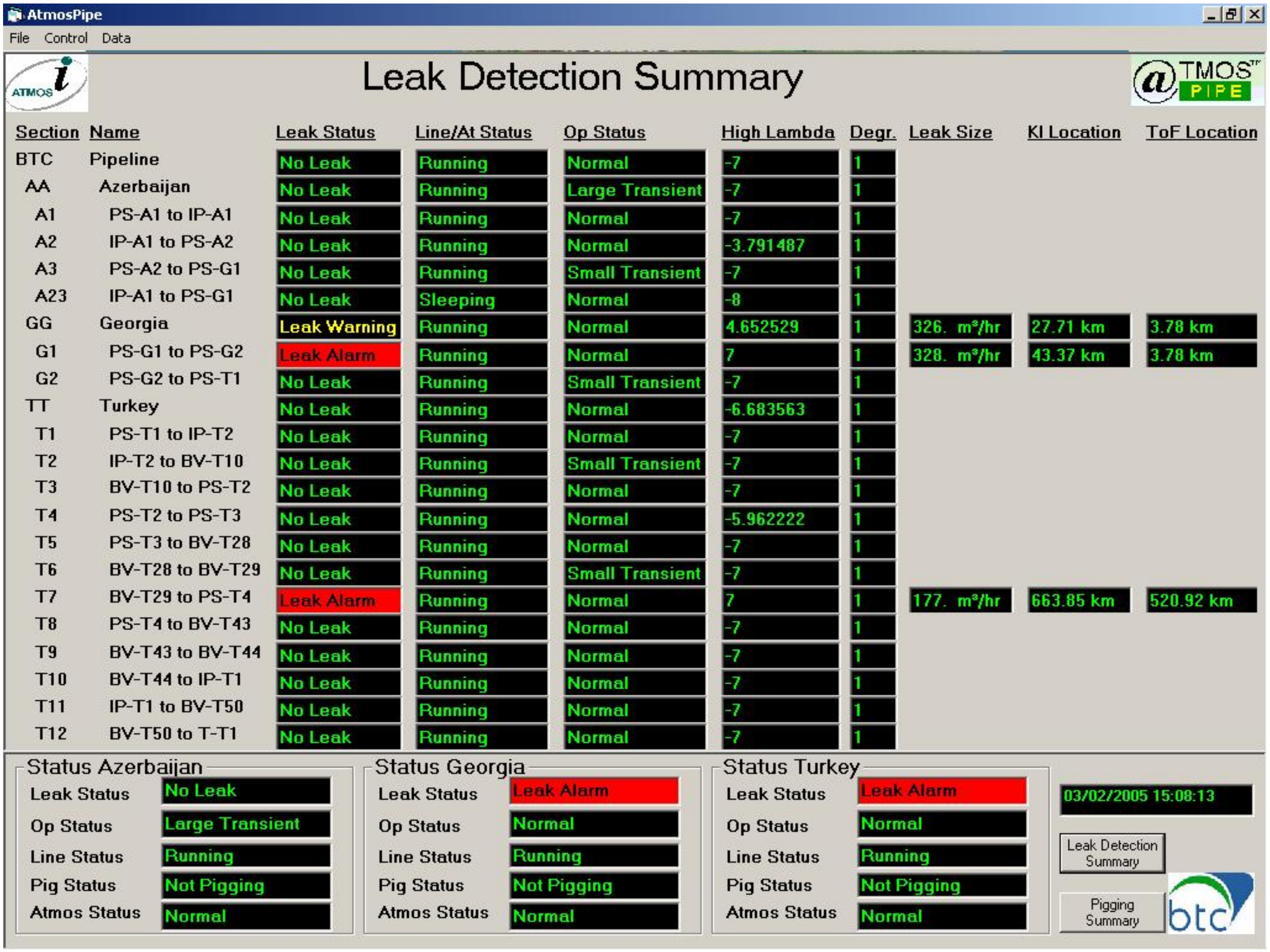
Figure 3: *Overview of the Azerbaijan Section*



Leak Detection Summary

Section	Name	Leak Status	Line/At Status	Op Status	High Lambda	Degr.	Leak Size	Kl Location	ToF Location
BTC	Pipeline	No Leak	Running	Normal	-7	1			
AA	Azerbaijan	No Leak	Running	Large Transient	-7	1			
A1	PS-A1 to IP-A1	No Leak	Running	Normal	-7	1			
A2	IP-A1 to PS-A2	No Leak	Running	Normal	-3.791487	1			
A3	PS-A2 to PS-G1	No Leak	Running	Small Transient	-7	1			
A23	IP-A1 to PS-G1	No Leak	Sleeping	Normal	-8	1			
GG	Georgia	Leak Warning	Running	Normal	4.652529	1	326. m^3/hr	27.71 km	3.78 km
G1	PS-G1 to PS-G2	Leak Alarm	Running	Normal	7	1	328. m^3/hr	43.37 km	3.78 km
G2	PS-G2 to PS-T1	No Leak	Running	Small Transient	-7	1			
TT	Turkey	No Leak	Running	Normal	-6.683563	1			
T1	PS-T1 to IP-T2	No Leak	Running	Normal	-7	1			
T2	IP-T2 to BV-T10	No Leak	Running	Small Transient	-7	1			
T3	BV-T10 to PS-T2	No Leak	Running	Normal	-7	1			
T4	PS-T2 to PS-T3	No Leak	Running	Normal	-5.962222	1			
T5	PS-T3 to BV-T28	No Leak	Running	Normal	-7	1			
T6	BV-T28 to BV-T29	No Leak	Running	Small Transient	-7	1			
T7	BV-T29 to PS-T4	Leak Alarm	Running	Normal	7	1	177. m^3/hr	663.85 km	520.92 km
T8	PS-T4 to BV-T43	No Leak	Running	Normal	-7	1			
T9	BV-T43 to BV-T44	No Leak	Running	Normal	-7	1			
T10	BV-T44 to IP-T1	No Leak	Running	Normal	-7	1			
T11	IP-T1 to BV-T50	No Leak	Running	Normal	-7	1			
T12	BV-T50 to T-T1	No Leak	Running	Normal	-7	1			

Status Azerbaijan

Leak Status	No Leak
Op Status	Large Transient
Line Status	Running
Pig Status	Not Pigging
Atmos Status	Normal

Status Georgia

Leak Status	Leak Alarm
Op Status	Normal
Line Status	Running
Pig Status	Not Pigging
Atmos Status	Normal

Status Turkey

Leak Status	Leak Alarm
Op Status	Normal
Line Status	Running
Pig Status	Not Pigging
Atmos Status	Normal

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Figure 6: *Pipeline sections considered for leak detection*