PIPELINE STUDIO™
APPLICATION AND TECHNICAL OVERVIEW
WHITE PAPER

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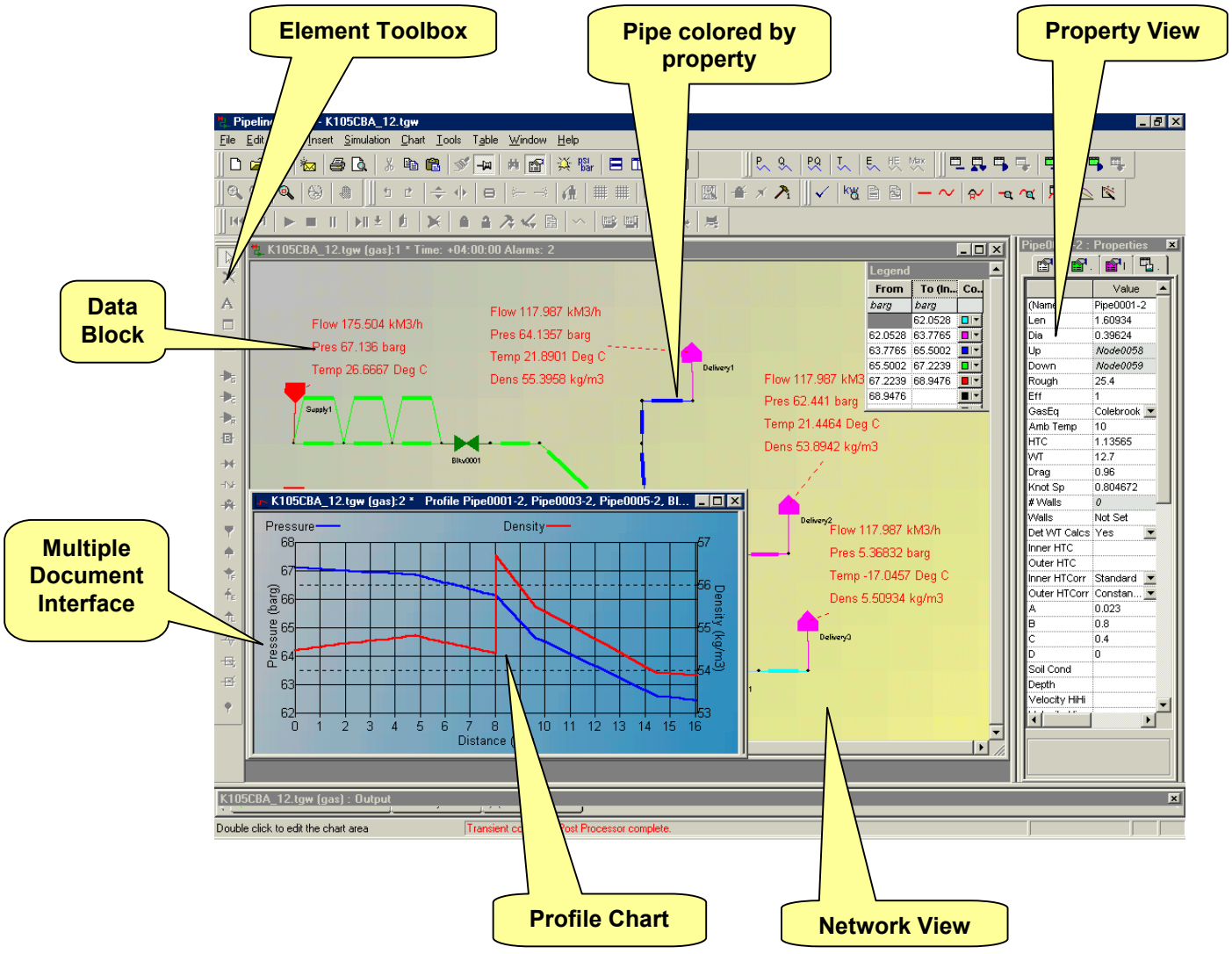
1 INTRODUCTION

This white paper provides an applications overview of the PC based hydraulic pipeline simulator, Pipeline Studio™.

Pipeline Studio™ is a state of the art hydraulic simulation tool that quickly and accurately performs steady state and transient analysis of single-phase fluid flow in pipeline networks. The software incorporates an acclaimed intuitive Graphical User Interface that facilitates the rapid configuration of complex pipeline models. Simulation results are easily accessible in many forms, such as graphs, tables and formatted ASCII files. Data may also be easily exchanged with other applications such as Microsoft® Excel™. Pipeline Studio™ is a powerful engineering and analysis tool designed to aid qualified users in their design, analysis and planning tasks.



2 APPLICATION

Pipeline Studio™ is used throughout the world to deliver a range of pipeline solutions:

- **Design:** Design of networks, line size and capacity studies.
- **Engineering:** Determination of line, pump/compressor sizes.
- **Planning:** Evaluating pipeline response to operational changes.
- **Contingency Analysis:** Simulation of upsets, unusual events and the evaluation of recovery actions e.g. compressor station failure.
- **Operational Planning:** Demand balancing and inventory analysis.
- **Operational Analysis:** Evaluation of alternative modes of operation.
- **Strategic Planning and Investment Program Analysis:** Determine network requirements for typically, 5, 10, and 15-year periods.
- **Staff Training:** Pipeline hydraulics and operations training in a safe environment.

Pipeline Studio™ enables the pipeline engineer to determine solutions to engineering and design problems. Pipeline Studio™ also provides a valuable decision support function to the pipeline operator. In general, Pipeline Studio™ addresses two main application areas:

- Simulation of normal operations to determine the most efficient physical design or mode of operation.
- Simulation of upset conditions, caused by equipment failure or leakage, to determine safe and corrective procedures.

Investigations are normally performed through a series of case studies. For example, to investigate an existing network the base case would logically be a steady state simulation of the network under normal operating conditions. Subsequent simulations might be for varying demands or time-varying phenomena followed by physical or dynamic changes. By comparing the results of these simulations with the base case, the user can determine the most effective modification to pipeline operations or optimum physical change.

Typical applications of Pipeline Studio™ software include:

- **Deliverability Analysis:** Determine whether the network can meet increasing future demand with or without additional equipment. Scenarios such as the start-up/shutdown, scheduling of key compressor units or utilisation of storage facilities can be investigated.
- **Pumping Cost Analysis:** Determine the pump cost of fluid transportation based on peak and off peak energy costs.
- **Economic Comparisons:** Determine the equipment needed and associated costs for looping the pipeline or adding pumps/compressors to improve throughput.
- **Survival Time:** Determine the possible corrective actions for prolonging survival time caused by a supply disturbance e.g. equipment failure, rupture or shutdown.
- **Maintain Contract Pressure:** Line pack analysis and manipulation of supply/delivery set points to maintain key pressures in the network.
- **Energy Balancing:** Investigate the mixing effects of different quality/composition fluids, supply/delivery set points and delivered product

quality/energy. This can be used to ensure that energy supplied to each delivery point satisfies contractual obligations.

- **Surge Analysis:** Simulate upset conditions, e.g. leaks, valve closure or pump start-up/shutdown, to determine if surges exceed design limits anywhere within the network.
- **Risk Assessment:** Investigate network response and requirements to various failures.
- **Batch Tracking and Routing:** Track configured fluid batches in a pipeline network. Route specified fluid batches into other parts of a pipeline network.
- **Start-up and Shutdown Procedures:** Study and compare different control methods to determine procedures that accomplish operational objectives most effectively. Schedule pumps/compressors, regulators, and other equipment to a time-varying cycle and investigate the effects on the network.
- **Reduce Fuel Gas:** investigate different compressor schedules to optimise fuel gas consumption.
- **Gas Purchasing:** Improve acquisition decisions by studying network effects due to different supply and routing scenarios.
- **Operator Training:** Quickly and safely train operators to understand the hydraulic effects of pipeline control decisions; in real time and faster-than-real-time. Observe emergencies without risk to life, equipment or the disturbance of normal pipeline operations.

2.1 SELECTED ENGINEERING APPLICATIONS

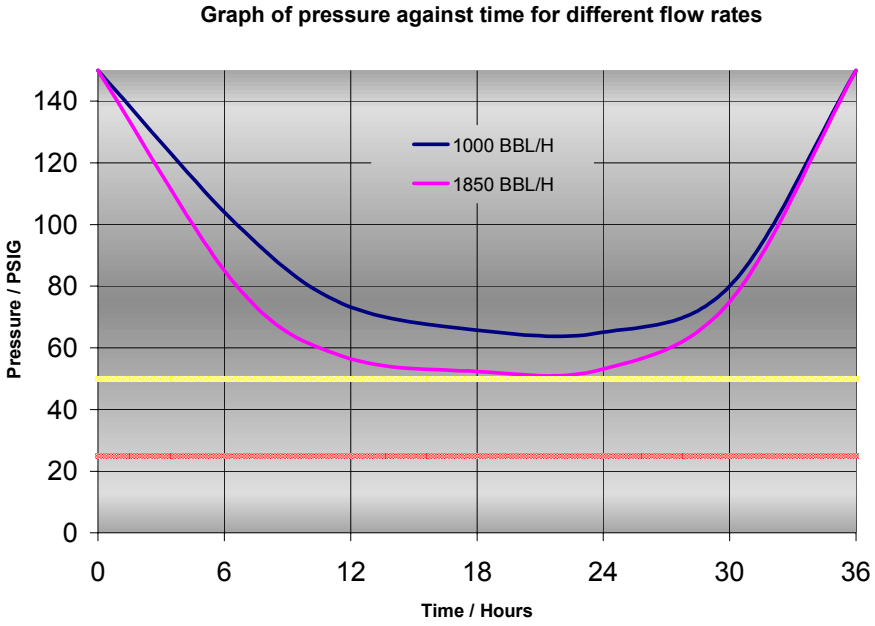
Pipeline Studio™ is used by design engineers and operators worldwide. The accuracy and simplicity of Pipeline Studio™ enables the engineer to rapidly investigate multiple designs such as pipe sizes or routes, and present recommendations to the client.

2.1.1 DETERMINATION OF MAXIMUM THROUGHPUT

Pipeline Studio™ is often used to achieve the optimal operating conditions to satisfy demand whilst taking into account all pipeline constraints.

An example of this is the determination of maximum throughput, which requires calculation of the largest possible flow increase without violating a minimum delivery pressure. The user can compare and evaluate different operating scenarios such as variable flow and delivery pressures over specified time periods.

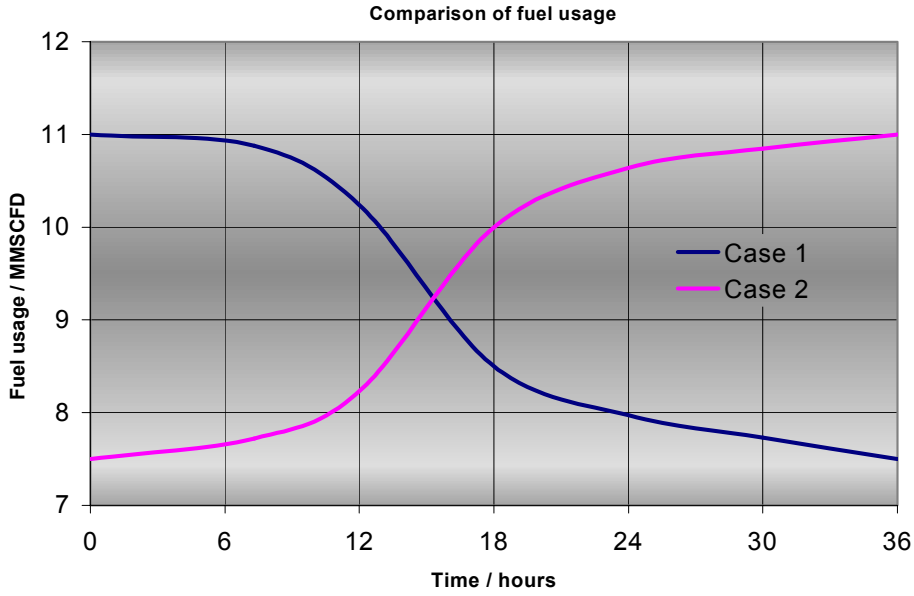
The figure below illustrates the cyclical pressure readings over 36 hours at a delivery point for flows of 1000 and 1850 BBL/HR (159 and 294 M^3/hr). The transient response shows that the average daily flow could be increased to 1850 BBL/HR without endangering the minimum pressure of 25 PSIG (1.72 BARG). If the flow must exceed 1850 BBL/HR, the system may need to be modified to maintain pressure at the delivery point.



2.1.2 IMPROVEMENT OF SYSTEM-WIDE FUEL ECONOMY

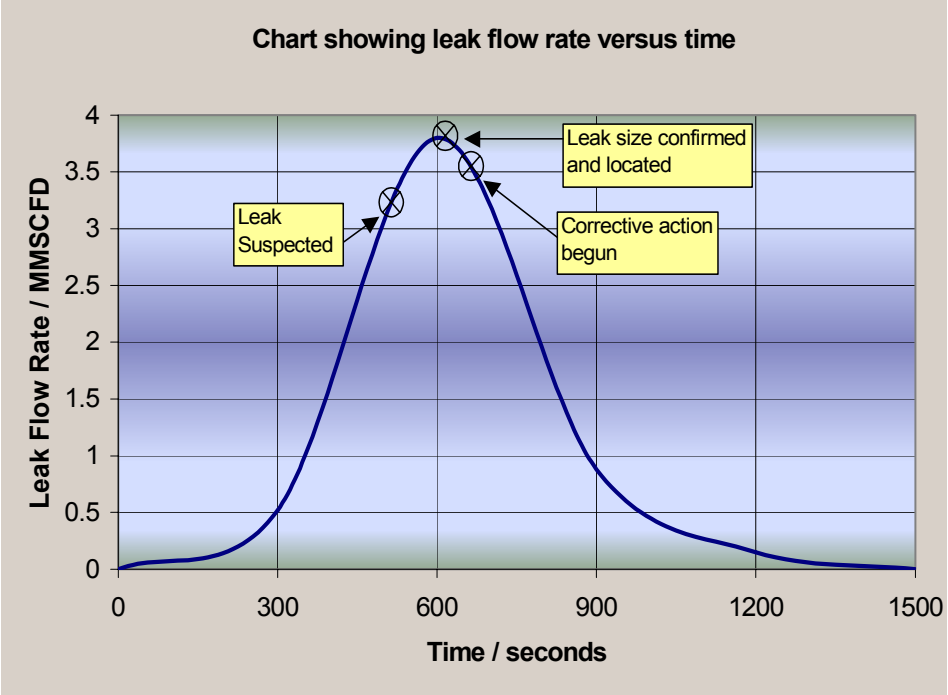
In some pipeline systems, there may be times when cyclic flow conditions cause certain compressor stations to operate below peak efficiency. By shutting down these compressors and shifting the load to others, the user can maximise the available horsepower and thus conserve fuel. Because Pipeline Studio™ allows rapid configuration and simulation of various supply/demand scenarios, the most economical compressor strategy can be determined.

When the associated performance curves and detailed operating specifications are provided, Pipeline Studio™ provides a detailed calculation and report for each compressor unit and its associated driver, including compressor fuel taken from the pipeline.



2.1.3 PREDICTION OF THE ENVIRONMENTAL IMPACT OF A LEAK

Leak detection studies are instrumental in predicting the environmental impact of any accidental leakage resulting from a pipeline rupture. The total volume of gas leakage calculated by Pipeline Studio™ can form the basis for subsequent atmospheric dispersion calculations to determine ground-level gas concentrations near the leak. This data is crucial if a deadly component such as hydrogen sulphide is present in the gas.



Leaks are simulated to determine the gas volume lost between rupture and detection, the transient response to various corrective actions and the total volume of gas lost from the system during the event. Studies can also be performed to determine requirements for the installation of a leak detection system.

2.2 SELECTED OPERATIONAL APPLICATIONS

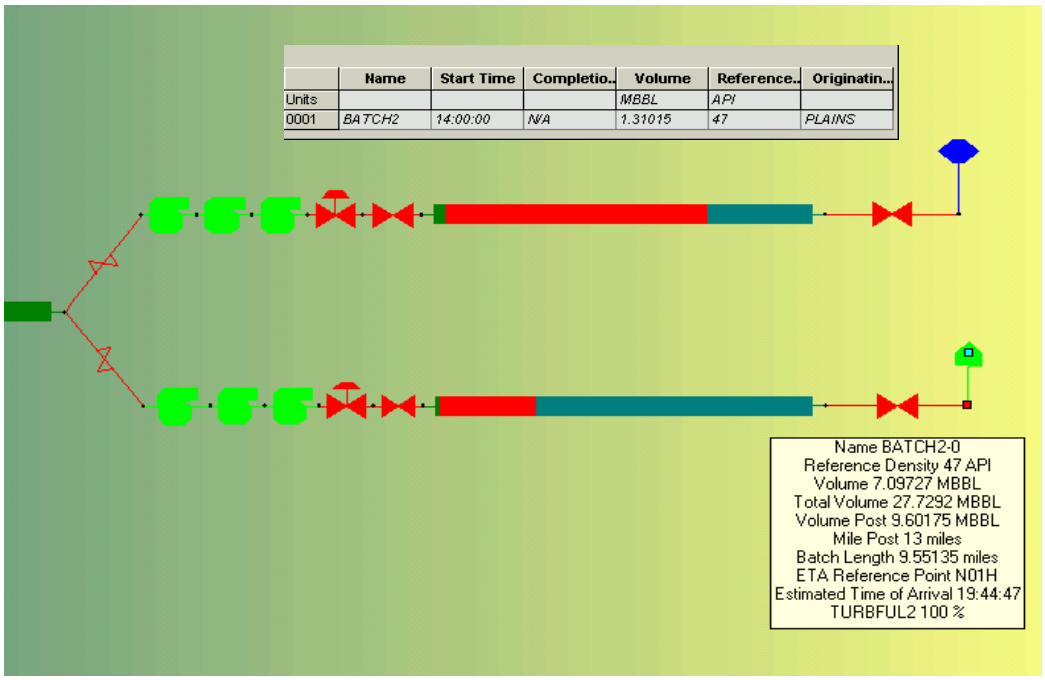
Many dispatching and planning departments for onshore/offshore, oil/gas pipelines employ Pipeline Studio™ in their day-to-day operations. The ability to look ahead many times faster-than-real-time enables the well-informed operator to improve planning, scheduling, throughput, fuel costs, use of storage and line-pack management. Economic performance associated with the purchase and sale of product or marketing of available pipeline capacity can also be analyzed.

2.2.1 BATCH TRACKING

The batch tracking functionality of Pipeline Studio™ enables the tracking of multi-product batch interfaces and provides accurate Estimated Times of Arrival (ETA) for each batch. This information supports the generation of a pipeline-operating schedule.

This type of operational application uses a fixed configuration of the pipeline network; the model is normally supplied with a batch queue - the sequence and volume of ingress batches at pipeline inlets. In faster-than-real-time, Pipeline Studio™ accurately simulates the transport time of each batch from its inlet to its arrival. Batch routing allows specified fluid batches to be routed through configured equipment to outlets, storage facilities or different pipeline sections.

Contract cost may also be included to determine individual and total electricity cost of pumping each schedule.

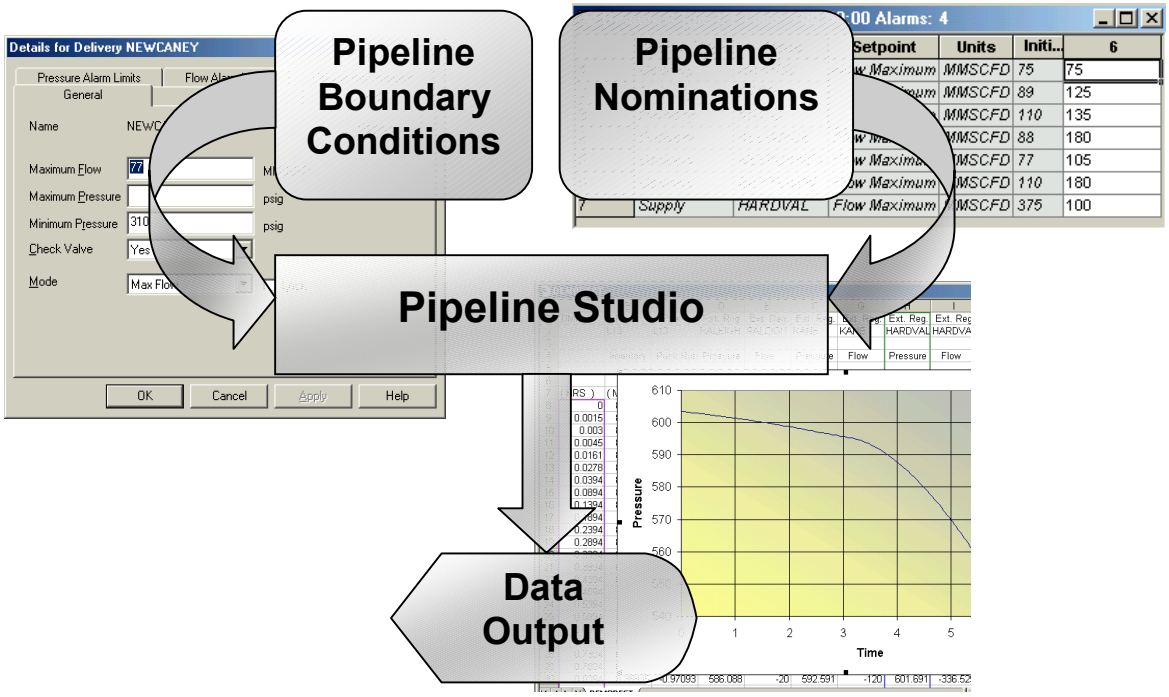


2.2.2 VERIFICATION OF PIPELINE SCHEDULE

Gas dispatching departments are responsible for maintaining pipeline safety and ensuring that pipeline operations satisfy throughput requirements, whilst maintaining the pipeline pressure within operational limits - an increasingly contractual matter.

Using a fixed configuration of the network, Pipeline Studio™ is supplied with flow and pressure boundary conditions from a SCADA system. Nominations, provided by a gas load forecaster, are used to create a transient scenario. Using the supplied boundary conditions and scenario, Pipeline Studio™ automatically runs steady-state and transient simulations at the start of the gas-day. The software completes a faster-than-real-time simulation of the pipeline for the next gas day and the results are presented to the operator.

This decision support application helps identify any problems associated with the nominations and provides information ensuring that the pipeline is operated safely whilst satisfying contractual obligations.



3 TECHNICAL OVERVIEW

Incorporating the industry standard simulation engines TGNET and TLNET, Pipeline Studio™ models both the steady-state and transient behavior of single-phase fluid flow in pipeline networks.

Pipeline Studio™ can model both simple and complex pipeline networks and may include pipeline equipment such as valves, compressors/pumps, regulators and heaters. Pipeline networks, which consist of a series of pipes and equipment connected together through common end-points, are rapidly configured through an intuitive and comprehensive Graphical User Interface (GUI). Pipeline element attributes such as pipe length, wall thickness, roughness, elevations are assigned through dialog boxes or tables.

Supplies and deliveries provide pressure and flow boundary conditions for the model as well as providing model constraints; any configured pipeline equipment will also contribute constraints, the most restrictive of which will automatically be used as a set-point. For a transient simulation, a schedule of set-point and constraint changes may be entered. Based on the set-points and constraints, Pipeline Studio™ calculates all hydraulic variables, e.g. pressure, flow, temperature and fluid density, throughout the pipeline network.

The advanced GUI enables users to view simulation results both during and upon completion of the simulation. Results are presented graphically in the form of trends and profiles. Trend and profile data may be imported into Microsoft® Excel™ or other 3rd party applications. Results may also be viewed in tables, data blocks, attached as callouts to pipeline equipment or output data files.

3.1 SIMULATIONS

Pipeline Studio™ performs two types of simulation: steady-state or transient. The steady-state simulation provides hydraulic results under the assumption that mass and energy flows are in equilibrium at every point in the pipeline network. A transient simulation evaluates the dynamic or time varying response of the pipeline system due to changes in one or more system variables.

The user may choose to run the simulator interactively where changes of set-point, constraint or status are applied "on the fly". At any point during the interactive simulation state data may be saved for analysis or as the starting point for another simulation. Both steady-state and transient simulations are supported in this mode.

During the simulation operational mode changes and alarm violations are reported through the GUI. This provides the user with feedback when key events occur.

Simulation results are presented through report files or graphic/tabular trends/profiles and allow the user to fully analyze each scenario and make informed decisions based on accurate information. Simulation results may also be exported for further analysis in 3rd party applications.

3.1.1 STEADY-STATE

Steady-state simulations may be run independently of a transient simulation. Thus, if the user is only interested in steady-state analyses there is no need to configure model attributes that are necessary for transient analysis.

The steady-state simulation determines the value of thermal and hydraulic variables such as pressure, flow and temperature under steady-state conditions. The user defines the pipeline geometry and operating conditions which may include:

- Equipment flow and pressure constraints.
- Equipment set-point and status.
- Supply and delivery flow and pressure constraints.
- Supply and delivery flow and pressure set-points.
- Supply fluid and fluid temperature.

The calculated steady state satisfies all active constraints configured in the system.

3.1.2 TRANSIENT

A transient simulation is defined by its starting (initial) state together with a transient scenario. The starting state may be a steady-state or a previously calculated transient state. Transient scenarios are a time sequence of set-point, constraint or status variations that emulate the operating conditions being studied.

The transient simulation determines the value of thermal and hydraulic variables such as pressure, flow and temperature under transient conditions and this capability enables the simulation of leaks, upsets/surges, survival time and operational changes.

During a transient simulation, the time step is automatically adjusted to maintain accuracy and stability whilst maximizing computation speed. This technique minimizes total run time of a transient simulation.

Transient simulation results can also be displayed through graphical user-defined trends and this data is available in a format that can be directly imported into Microsoft® Excel™.

3.2 MODELING FUNCTIONS

For the pipeline engineer, the comprehensive, intuitive GUI, the use of sensible defaults and idealized controls creates an effective and familiar simulation tool that provides:

- **Accurate and stable results:** Pipeline Studio™ employs a proven, stable, convergent numerical solution of the constituent conservation laws that govern the flow of fluids in a pipeline network.
- **Independent Steady-State Simulation:** Steady-state simulations may be run independently of transient simulations.
- **Interactive Simulation:** Simulations can run in the background or the user can elect to use the interactive simulation mode.

- **Network Validation:** Pipeline Studio™ automatically prompts the user for missing or incorrect data. This network validation function guides the user through an easy to use error-correction process.
- **Sensible Defaults:** Models may be rapidly configured using default options. All model equipment attributes have sensible defaults.
- **On-line Help:** There is an extensive on-line help file, which is accessible through menus. Context sensitive help is available from dialog boxes.
- **Idealized Controls:** Each equipment item, e.g. supply, delivery, block valve or pump, includes user or program-specified constraints. The constraint is an idealized form of control that represents a type of device or control limit. Multiple constraints may be specified for equipment and during the simulation the most restrictive constraint is used as the current control mode thus ensuring all defined constraints are adhered to.
- **Alarm Handling:** Pipeline Studio™ allows the user to define alarm limits. If an alarm limit is violated a message is reported identifying the location and value of the alarm.
- **Configurable Physical Units:** A units database includes Imperial, Metric and SI units. Additional User-defined engineering units can also be applied.
- **Data Exchange:** Both configuration and simulation data is easily exchanged with 3rd party applications such as Microsoft® Excel™. This exchange of data provides an added dimension to Pipeline Studio™ as it allows for extended analysis and presentation of, for example, trend and profile data in other applications. Configuration variables can be imported from formatted ASCII text files thus allowing Pipeline Studio™ to be tightly coupled with other tools. Further, all Pipeline Studio™ models can be rapidly imported into the Energy Solutions International suite of real-time Pipeline Application Software (Pipeline Manager).

3.2.1 GAS MODELING

The TGNET simulation engine incorporates all equations, equipment types and parameters commonly required for modeling gas pipelines. Specifically included are:

- BWRS, Peng-Robinson and SAREM equations of state
- Choice of friction factor correlation:
  - Colebrook-White
  - AGA
  - Weymouth
  - Panhandle A
  - Panhandle B
- Volumetric or mass flow
- Gas temperature tracking options
  - Simple heat transfer through pipe wall (overall heat transfer coefficient)
  - Wall temperature tracking using simple or complex wall layers
- Gas quality tracking options
  - Composition tracking
  - Base quality tracking
  - User defined quality tracking
- Compressor unit modeling
  - Centrifugal compressors including performance maps
  - Reciprocating compressors
  - Generic compressors

- Compressor drivers
  - Generic (electric) drivers
  - Turbine compressor drivers including efficiency map and temperature and elevation de-rating calculations
- Compressor station modeling
- Equipment
  - Block valves
  - Check valves
  - Pressure regulator valves
  - Flow regulator valves
  - Differential (ΔP) regulator valves
  - Heaters/Coolers
  - Resistance elements (flow dependent pressure drops)
- Supply and delivery controls e.g. energy, fuel, leaks

3.2.2 LIQUID MODELING

The TLNET simulation engine incorporates all equations, equipment types and parameters commonly required for modeling liquid pipelines. Specifically included are:

- Fluid property calculations
  - API correlations
  - BWRS
  - User entered tabular data
- Colebrook-White friction factor
- MAOP calculations
  - Explicit
  - Steel
  - Plastic
- Liquid temperature tracking
- Product batch tracking
- Product batch routing through complex networks
- Simulation of Drag Reduction Additives (DRA)
- Pump unit modeling
  - Centrifugal pumps including performance maps
  - Reciprocating pumps
  - Generic pumps
- Pumping cost analysis
- Equipment
  - Block valves
  - Check valves
  - Pressure regulator valves
  - Flow regulator valves
  - Tanks
  - Resistance elements (flow dependent pressure drops)
- Supply and delivery controls e.g. tank nozzles, leaks

3.3 GRAPHICAL USER INTERFACE

Pipeline Studio™ incorporates an intuitive and comprehensive Microsoft®-style GUI with toolbars, Multiple Document Interface (MDI) windows and wizards. This GUI facilitates the rapid creation of pipeline models by using the mouse to select

elements, connect and view the network. A network validation process warns if the model has missing or improper data and guides the user through error correction.

3.3.1 MAIN FEATURES

The Pipeline Studio™ GUI incorporates:

- A familiar Microsoft® Office Look and Feel with drag/drop and copy/paste capabilities.
- User-configurable docking toolbars enable creation of a simple "point and click" interface.
- Configurable style sheets.
- Wizard's to automate and simplify commonly used actions.
- Tight integration with all Microsoft® Windows applications.
- Context-sensitive on-line help.

3.3.2 DATA INPUT AND OUTPUT

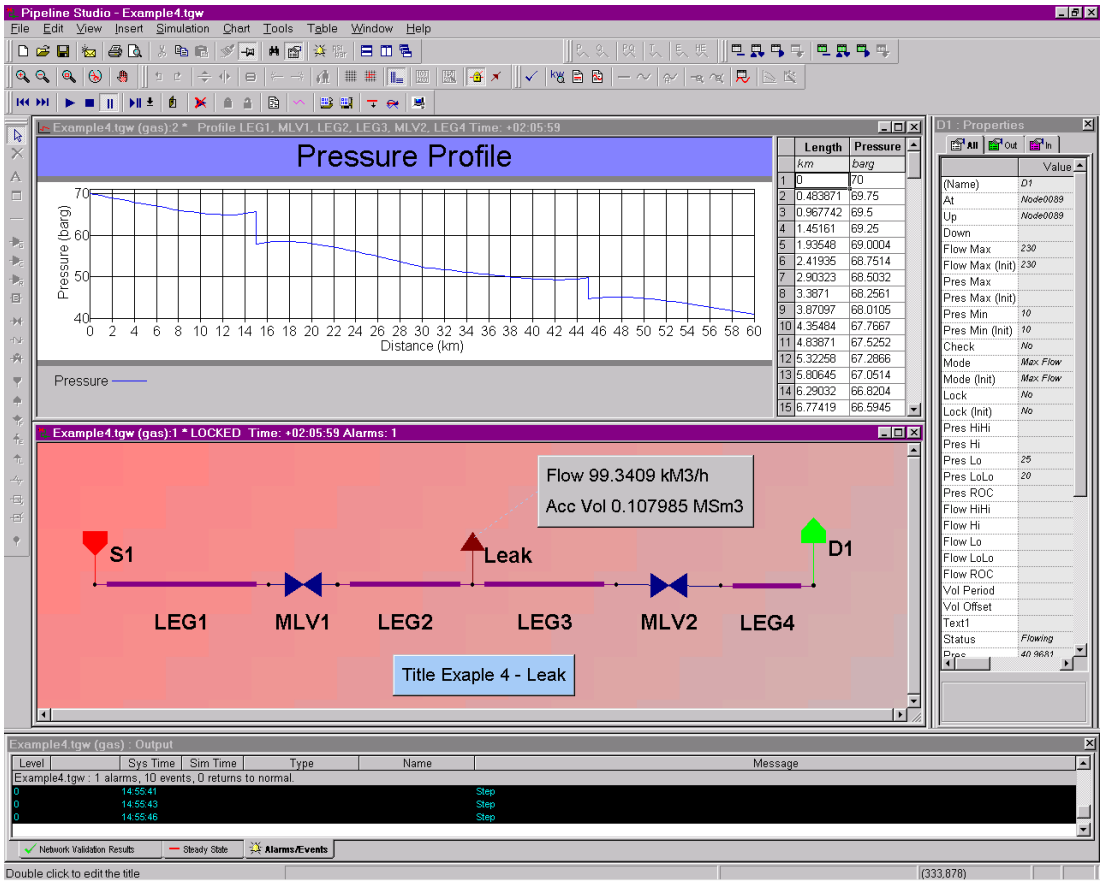
Pipeline Studio™ provides unrestricted access to data and incorporates input/output functions using a variety of formats:

- Data entry is usually by means of dialog boxes that are accessed through context menus, double-click of mouse button on an object, the insert menu (for library type elements) or by double clicking a row in a table.
- Property view shows both input and output data for a pipeline element within the model.
- Spreadsheet controls allow data input and export for all pipeline elements of a particular type, e.g. all pipes or all block valves. Spreadsheet tables are configurable and allow addition or removal of data types. Customized tables may be created to highlight specific data.
- Data blocks can be placed in the network view. Data blocks display both input and output data items for pipeline elements and equipment. Data blocks showing system properties can also be placed in the network view.
- Customizable reports are available to develop user specific output text based reports for publishing simulation data.
- Configurable profile charts and trend plots are accessible to present output data in a graphical format.

3.3.3 DATA PRESENTATION

Pipeline Studio™ incorporates many ways to present and manipulate network and simulation data:

- Pipeline and equipment may be colored to represent property values such as pressure, temperature, flow, internal diameter or roughness.
- Pipeline and equipment configuration data can be included on the network diagram.
- OLE functionality enables the embedding of "objects" to enhance network diagrams.
- The network diagram can be copied and pasted into other applications as a bitmap.
- Data plots can be saved as a bitmap and copied into other applications.



- Profile and trend data can be copied and pasted into spreadsheets.
- Profile and trend data can be exported to text files in a delimited file format.
- Custom tables can be created using filter/sort functions on multiple data sources.
- Property views display all the data associated with each pipeline element.
- Data blocks quickly present input and/or output data for equipment.
- Compressor curves may be displayed which illustrate the operating point during a simulation.

3.4 CONTINUING DEVELOPMENT

A dedicated team of engineers is assigned to Pipeline Studio™ development and customer support. Company commitment to the product is reflected in the support given to the growing number of attendees at the regular Pipeline Studio™ User Group Meetings, which meet to share knowledge and provide input to the product development programs.

The current development cycle, which will culminate in the release of version 2.5 of the software, will deliver the following enhancements, amongst many, to Pipeline Studio™:

- **Open Data Access:** Through the extensive use of XML for model configuration and simulation output.
- **Enhanced Engineering functionality:** More friction factors, more Equations of State
- **Open Architecture:** De-coupling of GUI and simulation engine for tighter integration into bespoke systems
- **Improved Thermal Modeling:** Improved modeling of shut-in temperature
- **Larger Models:** No physical limit on size of network
- **GIS Add-on:** The generation of Pipeline Studio™ configurations from Geographical Information Systems.