LT Industries'

PetroScan™

Near Infrared (NIR)
Technology

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Near Infrared Technology at Work

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1. Summary: Key advantages of LT's PetroScan™ NIR technology

- Complete integration of predicted properties into your Distributed Control System (DCS) for use in Blend Ration Control and Blend Property Control packages

- Use of the blend's recipe from the DCS to control which components will be measured in the blend

- Prediction of Olefins, Aromatics, Benzene, Octane Numbers (Ron, Mon and Road), Distillation Points, Oxygenates for Blender's Output and component streams to meet the requirements of the reformulated gasoline complex model market.

- Laboratory Unit with identical optics to develop calibration and LT's unique TRANS™ calibration transfer software to transfer the calibrations to the process analyser. This is a key factor to speed the calibration development.

- The Absolute Reference Cell (ARCell™) is LT's patented dual-flow sampling cell to provide robust self-referenced measurement.

- Optical Multiplexer provides multiple measuring points per analyzer, reducing the cost per individual measurement.

- Internal In-line™ polystyrene wavelength calibration standard provides continuos wavelength accuracy.

- Sample Conditioning of the Blender's Output and automatic outlier capture in all components streams.

- Modem support for instant remote assistance anytime during the project.

2. LT Industries' Company Information

LT Industries designs, manufactures, sells and services state-of-the-art Near Infrared (NIR) electro-optic systems for measuring and characterizing chemical and physical properties of materials used for process monitoring and control applications. Founded in 1981, LT Industries has developed and produced a series of Near InfraRed (NIR) systems over a 18-year period. The company has an installed base of about five hundred (500) systems, about 60% of which are used in process applications. The installed instrument base is geographically centered in North America and Europe, with recent expansion in Asia. The company has strong presence in the petroleum-refining market. The Texaco organization has granted LT Industries a worldwide approved-vendor status and has procures three increasingly larger blend monitor systems under that agreement.

LT Industries has a patent estate that covers its unique technologies. The chief areas of coverage are: NIR scanner drives which allow long field life of the equipment, sensing probe technology which permits precise measurement in spite of artifacts such as bubbles and particles, and mathematical software which enables transfer of statistical calibrations from instrument to instrument.

LT Industries philosophy is to provide hardware and software to our customers and to provide exemplary support after sale. We work hard on each and every installation making them showcases within their organizations as well as for our own. Product continuity is maintained through upgrades. Software maintenance has provided state-if-the-art performance without discarding whole systems. In fact, we have never obsoleted nor discontinued one of our products, but have enabled our customers to take advantage of all our developments through upgrade programs. Our commitment to non-obsolescence is unique in the industry.

New technologies are the key to survival in the long term. LT's position in this industry has been to be the technology leader. We are continually improving and enhancing our multivariate calibration software and developing new instruments and accessories to complement our high-resolution line of NIR process systems.

2.1. References

LT has long experience both in the process applications and specifically in refinery and blending systems, ranging from one-stream one-property applications, to 16 streams and 200+ properties. The specific list of references is included in the Appendix. Visit to installations that closely match your application can be arranged with previous notice.

LT structures the NIR Process Analyzer based on key components that can be customized to the installation's specific requirements. Every blending installation is singular based on the refinery's needs. It ranges based on the number of streams to be measured, the properties to be measured in every stream, the use of protofuels (gold standard), the functionality and design of the sample conditioning system, how the predicted properties are transmitted to the distributed control system, the control of field devices (solenoids, valves, temperature transmitters), etc.

This range of options demonstrates the flexibility and scope of LT's NIR technology and the technological advance of its key products. The following section will describe the basic components of a process NIR Analyzer.

3. LT Industries' NIR Technology

3.1. System Configuration

The components of a NIR Process Analyzer system are:

I. **Near Infrared Spectrometer Module:** This module includes the NIR Process Analyzer, as well as the computer, and all of the spectrometer operations for spectral data acquisition, control, diagnostics and fault isolation.

II. **Sample Conditioning Systems:** This is a self-contained module that is based on an Absolute Reference Cell and is responsible for sample capture, temperature control, filtering and water removal. The control of the Absolute Reference Cells is pneumatic and automatically directed by the Analyzer's Controller.

III. **Analyzer System Control Computer:** This module is the analyzer system supervisory computer. It handles all of the system operations ranging from spectral processing to communications with plant computer systems. System performance is continuously monitored and fault isolation and notification carried out. Full states, data and operations logging are continuously available. The computer console is the principal means of maintenance and diagnostic operations.

IV. **Calibration Development Support Services:** Calibration, that is the development of the chemometrics estimators for the analyses provided, involves analyses of analytical data from process samples. Expert application support from LT involved in this phase, based on LT's extensive field experience.

V. **Universal Calibration:** Provided by LT Industries. This large calibration database is used to refine the final calibration through the addition of specific "local" samples from the customer's process.

VI. **Modbus Interface:** A software communication interface between the NIR analyzer and the Distributed Control System via an RS-232/RS-422 signal using the Modbus protocol. The customer is responsible to configure the Distributed Control System to read-in the appropriate Modbus values. Honeywell TDC3000, Foxboro I/A and other DCS are fully supported.

VII. **Fiber Optics:** The on-line analyzer requires fiber optic cables to connect the Absolute Reference Cells (ARCell) to the spectrometer. These cables are 60 fiber "bundles" rather than single fibers because bundles offer better reliability and provide more energy than single fibers. Fiber optics allow safe remote measurement and combined with the optical multiplexer it is a key advantage for multi-point analysis.

VIII. **Field Sampling Units:** Based on an Absolute Reference Cell (ARCell), can include an air actuator or solenoid for grabbing a sample from the component and Explosion Proof Temperature indication and transmission.

IX. **Optical Multiplexer:** 20 Channel optical multiplexer, including a reference channel.

These elements are complete except for local site preparation, local installation expenses and non-NIR sampling and sample analysis costs, which are typically responsibility of the customer. Manpower for training and support are estimated based on the scope of the project.

3.2. Project Structure

A typical blender application consists of the following phases:

1. Project definition
2. Detail design
3. Operational definition
4. Laboratory analyzer installation and training
5. Calibration development based on universal calibration in the lab
6. Process analyzer installation and training
7. Integration with DCS and Refinery Information Systems
8. Calibration transfer to the process

9. Model evaluation and monitoring
10. Personnel training: chemometric, operational and maintenance
11. Support

LT's methodology has been successfully proven in the field and is based on adapting key proprietary technologies to the installation's needs. Near Infrared is the measurement technique, and LT's successful project methodology integrates also systems engineering, process background, DCS integration and modelling expertise for a complete turnkey installation.

The Universal Calibration is used to provide a startup calibration. By combining the universal calibration with LT's Calibration transfer software (TRANS), a model is produced. Model evaluation provides feedback of the model's performance and the model is expanded with local samples to increase accuracy.

3.3. Typical Operations

Component quality determination is based on measuring the spectra of the NIR stream and applying the chemometric models developed for that stream. There are two separated elements

Operationally the prediction of component qualities is fully integrated with the blender's DCS operation and is fully automated. A simplified sequence of the operation is as follows:

- A blend is started. The DCS, based on the components used in the recipe, commands the NIR analyzer to measure a sequence of streams
- The NIR spectra of one stream is measured
- The chemometric model is applied to the spectra and all properties of that component are simultaneously predicted
- The predicted properties are transmitted through a Modbus link to the DCS
- Next stream is selected

This loop will continuously sample, measure, and transmit the properties of the streams being used in the current blend. The command of the analyzer is being controlled by the Distributed Control System. This enables a complete integration of the analyzer into the blender operation, including commanding the anaylzer to stop measuring in between blends, measuring only those streams (components) being used in the current recipe, integrating the predicted values in the Refinery Information System (plant-wide repository database and trending/monitoring software).

During normal operations, the Analyzer Control Computer will be unattended. It will be used as part of all of the normal maintenance items listed in the last section. In addition, status information will be available on the computer during certain error conditions and other conditions that will result in an alarm type logic signal condition to be posted into the process control computer. Special diagnostic routines will be available for fault isolation and diagnosis in the event of analyzer system failure or octane quality assurance failures.

A outlier is defined as a sample whose properties are not represented in the calibratrion set used to develop the NIR chemometric model. This can be caused by:

- Operational conditions upset the sample presentation to the NIR analyzer. This type of condition clears itself after a short period of time. Using the Absolute Reference Cell and appropriate sample conditioning, this is minimized.
- The component's sample is compositionally outside the calibration set and need to be captured in order to expand the calibration domain. This may be caused by a component that have not been included in the calibration model based on seasonal changes or changes in the blend recipe.

The outlier detection occurs automatically as part of each measurement. Before a model is applied to a component's sample, the spectrum of the sample is evaluated to determine if the sample can be predicted or should it be classified as an outlier. Automatic outlier collection integrated in the sample conditioning systems automatically will save a sample for lab analysis. Then a comparison between the lab primary analysis and the spectra measured can evaluate the outlier. The calibration may be expanded with this additional sample.

3.4. Laboratory analyzer

The use of a NIR laboratory analyzer together with a process analyzer provides the following key advantages to the project:

- Calibrations can be developed in the lab analyzer while the process analyzer is installed in the process. In general, setting up a lab analyzer is a lot faster than integrating the process analyzer in an analyzer house or waiting for appropriate fast loops to be installed, etc.
- Personnel can be trained in the use and operation of the analyzer

LT Industries' unique Calibration Transfer software uses Pair-Matching algorithm that minimizes the number of samples required to transfer a calibration from the lab to the process. And given that both analyzers, the lab and the process, share the same optic systems and the same optical sampling system (Absolute Reference

Cells), the effectiveness of the calibration transfer is assured. This is a very important aspect that impacts the schedule of the project, enabling very fast installations.

The lab analyzer typical configuration is

- Q1200 NIR Lab Analyzer
- Analyzer controller (computer)
- Lab ARCell
- Fiber Optic
- LT's software suite: Spectrametrix, LightCal, Trans

The following options are available:

- Temperature control of the samples
- Optical multiplexer
- Temperature read-out

3.5. Absolute Reference Cell

The Absolute Reference Cell (or A/R Cell) is the heart of the analytical system. This patented LT Industries' invention is best described as a shuttle-based, dual pathlength flowcell.

When the A/R Cell is installed, a flow controller sends the flow through the cell from one side. The force of the liquid causes a shuttle containing two pieces of quartz to slide to one side. In this way, the optical beam passes through one piece of quartz. The thickness of that piece of quartz is carefully controlled so that the sample optical pathlength is a fixed, known value (for example 15 mm).

After spectra are collected for about 25 seconds (this time limit is programmable), the direction of the liquid flow through the cell is reversed. Now the liquid causes the shuttle to move to the opposite side of the cell and presents the other piece of quartz to the optical beam. This second piece of quartz has a thickness that is different from the first pierce (for example, 5 mm). Spectra are again collected for about 25 seconds.

After this period of time, the flow rate is reversed and the sequence begins again. The spectra from the first 25 seconds (which used a 15 mm pathlength) is ratioed to the spectra from the second piece of quartz (which used a 5 mm pathlength). This gives a ratioed spectrum with a nominal pathlength of 10 mm - just about right for gasoline.

The overwhelming advantage of this technique is that any material in the sample that is not related to the concentration of the properties being measured is eliminated. Thus small particles, bubbles, turbidity, etc. are eliminated from the analytical measurement.

As a result of this technique, the NIR Gasoline Analyzer is less sensitive to temperature fluctuations and other disturbances that usually cause other analyzers to give erroneous results.

3.6. Optical Multiplexer

The Optical Multiplexer or MUX is a device that sequentially directs the output radiation from the spectrometer to one of a series of sampling locations. LT Industries' MUX has 20 channels which allow the use of 19 sampling locations and 1 reference channel.

The purpose of the reference channel is to provide a constant reference energy level against which the performance of the system can be measured. In this way, the system performance can be quickly verified whenever the operator desires. Furthermore, the system performance can be automatically verified at a rate chosen to provide maximum reliability in the system.

The channels in the MUX are designated 1, 2, 3, etc. through 20. Each channel can be accessed in a sequential manner or access can be programmed based on the installation's needs.

4. LT Industries' Technological Advantages

4.1. Hardware

The Petroscan 2000 NIR Process Analyser employs a rapid scanning and high resolution grating to provide the necessary wavelength dispersion of the infrared light.

1. The spectrometer design employs fiber optics to couple the sample to the spectrometer. This design separates the hydrocarbon-containing cell from all electrical components and provides an intrinsically safe design. It also permits an inherently modular design that permits the replacement of entire modules in the event of failure, non-routine service or future expansion of system capabilities.

2. An Indium-Gallium-Arsenide semi-conductor detector will be used. This allows the spectrometer to be operated in a spectral region that optimizes the sensitivity of the measurements. This also allows the

use of sample size characteristics that reduce or eliminate the need for maintenance intensive filter sampling.

3. Low Maintenance: The Analyzer System spectrometer has exceptional up-time in excess of 99.6% annualized, including preventive maintenance. This being due to its ruggedness, simple design and few moving parts.

4. Internal optical referencing and dark referencing are performed in the hardware and firmware of the spectrometer. This enhances the long-term reliability of the system by enabling self-compensation for many of the key variables in the measurement. Internal quality control tests will identify any possible component degradation before failure of the analyzer.

5. The spectrometer will be packaged in a temperature stabilized, purged NEMA 4X enclosure. Under normal operation the package will not have to be opened.

LT's 20 channel optical multiplexer provides measuring of up to 19 channels. One channel is used for internal analyzer reference. A description of the analyzer is provided in the Appendix.

LT's complete software suite consists of Spectrametrix, LightCal, Trans and AutoDiscrim. All software is fully integrated and provides full customization flexibility.

4.2. Spectra Acquisition

In the laboratory, the use of the Lab Absolute Reference Cell (Lab-ARCell) provides a robust automated procedure for sample measurement and spectra acquisition. Using simple menus, the user in the lab requires only a one-key approach. After introducing a sample into the laboratory Absolute Reference Cell, the analyzer's computer will command the analyzer to measure a spectra, preprocess it, store it in the appropriate file and attach a time-stamp or other identification associated with the sample.

The use of a bar code reader is optional, to facilitate the integration with existing LIMS systems.

In the process, spectra acquisition is controlled by the Analyzer's controller. Based on the distributed control system's command, a specific stream is measured. That requires that the optical multiplexer moves to that channel. The NIR is acquired and stored in the Analyzer's controller, in order to apply a chemometric model for prediction. This is a completely automated operation with no human intervention.

4.3. Calibration Methodology

LT's calibration software is very powerful, including PCR, PLS and MLR calibration algorithms. Software is used together with procedures for sample selection, repeatable sample measurement, validation techniques and internal cross-validation. Separate validation sets are used and are composed of samples not included in the calibration set.

By starting the installation with a Lab NIR Analyzer and then transferring the calibrations to the process, the total time required for the calibration is greatly reduced.

4.4. Model Maintenance

To successfully implement a NIR measurement, LT includes as part of the project the following aspects:

- Project management
- Model development
- Validation technique
- Model maintenance
- Hardware & Software maintenance

Model maintenance can be accomplished with LT's remote on-line support. Model maintenance is integrated with refinery's information about stream composition, seasonality, recipe variations, etc.

The combination of AutoDiscrim discrimination software together with the LightCal quantitative models allows detection of the boundaries of the calibration. The use of sub-calibrations reduces the complexity of model maintenance, especially in an installation with multiple component streams.

4.5. Analyzer Monitoring

Automatic diagnostics provide continuos analyzer monitoring. Internal wavelength reference assures wavelength stability and self-correction.

Monitoring can be performed from the DCS's operator console. Basic alarms provide status information of the analyzer

4.6. Calibration Transfer

LT's unique calibration transfer software (TRANS) uses the pair-matching algorithm to minimize the number of samples required to transfer calibrations between analyzers (from the lab to process) or to transfer the Universal Calibration to a specific installation. TRANS is able to incorporate both the linear and non-linear differences between the analyzers and compensate them mathematically.

TRANS is used together with LT's methodology for calibration transfer. LT's applications scientist select appropriate samples that maximize information content and make effective use of the calibration databases used. TRANS software together with applications scientist expertise works for the customer in maintaining the cost and time involved in developing the calibration databases.

TRANS have been field-proven successfully and is detailed the appendix.

4.7. Near Infrared Training

A complete NIR School is included in this proposal. The objectives of the NIR School is to provide the personnel with concepts and skills to:

- Assess an Application -- Is this feasible by NIR?
- Design the Experiment: Variability, Accuracy, Precision
- Optimize NIR Analyser for Sample Type
- Validity of Data -- Statistical Assessment
- Develop a Calibration
- Validate a Calibration
- Utilize a Calibration
- Maintain a Calibration
- Customize an Application

In order to provide these concepts, the NIR School is structure to cover the following sections:

- Near Infrared History and Principles
- Experimental Design
- Strategy for Successful Application
- Practical NIR Implementation
- LTI Software Overview
- Modelling / Calibration
- Batch Files
- Calibration Transfer - TRANS
- Calibration Maintenance

The NIR School is customized to the customer's installation. Practical hands-on sessions of the NIR School provide the required expertise to operate and maintain the NIR Analyzer.

4.8. System Integration with DCS and PLC

From a system's point of view, LT Industries' NIR Process Analyzer provides an array of possibilities for complete system integration into a refinery's information and control environment.

LT's Modbus interface for the Quantum Analyzer provides real-time communication with a Distributed Control System (DCS) through the Modbus protocol. The Modbus interface integrates the predicted values as obtained from the Analyzer to be communicated to a constituents database on the DCS. Activity on the analyzer can be triggered from the DCS providing complete control of the instrument and integration with a plant-wide control system. Status and performance monitoring information is also communicated to the DCS.

The operator can obtain directly in the console the predicted values of the chemometric models, perform basic diagnostics and also command the analyzer to measure a specific channel. During blending, the DCS will automatically direct the analyzer to measure only the streams that are being used in the specific recipe. The predicted values from the analyzer can be integrated in a blender optimizer, like BOSS or Ratio Blend Controller (RBC), to maximize the information available.

There are two basic possibilities for integration: 4-20 mA signals for small systems, and LT's Modbus Interface.

When a small number of streams/properties are needed, the use of standard 4-20 mA outputs provides a fast, reliable, proven transfer to the DCS. Digital outputs (Normally Close/ Normally Open) are used to indicate alarms to the DCS's operator. The use of 4-20 mA outputs is limited when the number of values to be transmitted increases.

The second, most commonly used, option for integration with DCS is the use of the Modbus protocol. The Modbus is a fast industry-wide de-facto standard for data communication and LT's Modbus interface provides a data channel for control/handshaking signals, diagnostic and prediction of stream's properties. The interface between the Analyzer's controller and the DCS can be performed by a PLC, configured with two Modbus ports. Very basic ladder logic is required to transfer the values between the Analyzer's controller and the DCS.

LT's Modbus Interface is completely developed by LT and therefore complete support is provided, during configuration, installation and during the system operation. Given that the Modbus can only transmit integer values, appropriate scaling is used and the values are scaled back at the DCS.

LT's Modbus Interface has been successfully integrated with Foxboro's I/A series and Honeywell's TDC 3000 trough the Advance Process Manager Serial Interface.