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Use of NIR Technology as Applied to Steam Cracker Monitoring and Optimization

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Near Infra Red (NIR) technology can overcome the major problems associated with obtaining real time on-line process hydrocarbons streams analysis. The analysis of these is based usually on Gas Chromatographes and specific analyzers for special properties.

NIR methods quantify samples' properties based on a model which correlates the NIR absorption spectrum to the desired properties.

NIR instruments can give true on-line real time data for hydrocarbon process streams such as Freeze Point, Pour Point, Flash Point, Cloud Point, % Distillation Points, Motor Octane Number (MON), Research Octane Number (RON), Reid Vapor Pressure, Viscosity, Gravity (physical properties) and chemicals properties such as Chemical Compositions, Benzene Content, MTBE Content, PIONA and others. Obtaining these until now, by use of the "classical" analyzers, has involved lag times between sampling and determination of the data as well as complicated and expensive procedures such as sample conditioning and calibrations - to mention a few.

Advance control systems need accurate real-time data to enable adequate response to changes in process conditions - to maintain the most economical operation of the processing unit..

Advances in the electro-optic technology over the last few years and the big leap in computer speed lead to the development of the **"Beacon"** technology. A new approach to the instrument design is aimed to solve the existed problems with process analyzers including former NIR instruments.

The system consists of one main analyzer and up to 25 (twenty five) field units each located up to 3 (three) kilometers away from the main unit. This is possible due to the utilization of telecommunication fibber optics technology.

Steam Crackers used to analyze its feed in the laboratory. The feed stream properties are important because it enable the operator to fine tune the plant to best utilize the feed and the process units. The laboratory tests, mainly off line GC's, are complicated, time consuming, expensive, scarce and ineffective. The bottom line is that this data is seldom available for any practical purposes, the operator has no real means

to identify any variations in the feed properties and he is in no position to react to these changes.

The "**Beacon**", which is a NIR Technology based instrument, offers the properties on-line in real time and brings the process control of steam crackers into a totally new era.

For on line Process Control and Process Optimization in Ethylene plants the following properties are quantified:

- Density;
- Average Molecular weight,
- Distillation curve (IBP, 10%, 50%, 90%, FBP - or similar);
- Methane (C_1), Ethylene ($C_2^=$), $C_3^=$ and $C_4^=$ unsaturated products potential yield,
- Coking tendency

and

- PIONA (%Parafines, %Isoparafines, %Olefins, %Naphthenic parafines and %Aromatics).

Table 1, "PIONA Prediction using NIR" and Table 2, "Distillation Curve Prediction Using NIR" are giving the models performance parameters of a current project to implement a NIR feed analysis **"Beacon"** system for Process control and optimization.

Utilizing this information enables optimization of plant operation. With the Products Potential Yields and the Coking Tendency, the furnaces firing intensity, the radiation tubes setting, the Transfer Line eXchanger (TLX) conditions and other plant parameters can be regulated to enhance the operation to get the best possible products line, the optimal coking rate and the desired decoking schedule.

Some operators might prefer other properties to be included instead of the above mentioned or in addition to these. The "**Beacon**" can measure other properties if so required. For each property a specific model will be fitted.

Model building is a straight forward process which involves regression of measured samples and some sophisticated techniques to give better interpolation and some limited extrapolation abilities. To avoid restarting the modeling process from scratch for each new application, an existing database of spectral data and reference parameters is utilized. A good modeling process will be able to apply this database to a new similar installation with the addition of minimal number of new samples for fine adjustment of the model to the actual case. This process of model building can take up to two working days in most cases.

The models, which are based on extensive set of analysis paired with the spectral data of these samples, can effectively predict chemical and physical properties of interest, including those where non-linear effects involved (as in Octane number for example). After the system installation, a small number of actual samples in the plant give the last needed adjustment to the model.

Older NIR systems may had difficulties whenever a sample was outside the boundaries of the original set. The re-calibration and model upgrade resulted in system unavailability for routine operation. In this new system, calibration needs are minimized. A special algorithm is built to take care of "outliers". A **"confidence factor"** is calculated with every result. When an "outlier" is detected, an automatic sampling mechanism is activated and the spectrum is stored in the system. When the analysis of the "outlier" is available, "Petrometrix" experts, in the central service center, read the stored spectrum from within the system through extensive telecommunications capabilities, update the model, insert it back into the system - all *without actually interrupting the ongoing system operation. The user is assured of* having the best experts to deal with his model building, updating and upgrading , and is freed from employing and training chemometric specialists.

The ability of one main **"Beacon"** to serve multiple field units holds a large potential in the plant's process control system: other streams can also be analyzed with the same kind of speed, accuracy and ease by only a small marginal increase in the investment. Detailed analysis of product gasoline for example, which can easily be obtained by the same NIR instrument, enables calculating the best operating parameters to the down stream units such as the cut points for the distillation columns. These are then converted to set points for the controllers of the system..

Steam Crackers very seldom are "stand alone" units and usually are part of larger petrochemical complexes. The investment in advanced technology, which is fully economically justified based on the benefits to the steam cracker, can better utilized, by sharing the extra available capacity of the **"Beacon"** for other sophisticated needs such as blending operation, CCR process control etc..

So far the **"Beacon"** has been installed in several oil refineries and several systems are being assembled for customers all over the world. The system has been implemented so far on Blending System (USA), A Lab Instrument in the central lab of a refinery (Israel), Aromatics Plant (Israel - Under start-up), Reformer Unit (Japan - Under installation).

The system availability is nearly 100%.

The system is fast and a full result is obtained every 30 seconds (e.g. if you have 10 field units you have a result every 5 minutes for each stream).

The system is as accurate as other analysis instruments with a much better repeatability and has very low sensitivity for impurities. The only condition for the system to function is for the sample to be clear enough for the NIR light to get through. Presence of water drops and other particles are of no significance to the performance and the accuracy. Water content of up to 5% is not a problem as long as there is no emulsion.

Minimal sample conditioning is needed. Sophisticated algorithms in the system compensate for temperature variations on all the system components.

The only maintenance needed is light source (lamp) replacement once for 120 days (4 month!).

The "Main Analyzer" is classified as "General Purpose Area" . Only the field unit has to be approved for hazardous service. The main benefits are: Cheaper main unit (high quality available scientific components can be used!) and No shelter is needed.

The only utility needed is "usual" 110/220 Volts AC !

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Table 1: PIONA Prediction Using NIR

Cross Validation Models
%

	RMSEP	*SEP*	*Bias*	*Slope*	*Corr.*
n-Paraph	*1.3490*	*1.3735*	*-0.0235*	*0.9135*	*0.9392*
I-paraphin	*1.1447*	*1.1648*	*0.0474*	*0.9270*	*0.9216*
Olefines					
Naphtene	*0.5587*	*0.5689*	*-0.6442e-2*	*0.8713*	*0.9258*
Aromatics	*0.3750*	*0.3819*	*0.4181e-2*	*0.7486*	*0.8513*

Correlations were done on 28 samples

The samples supplied were very low in Olefines content. It is impractical to build a reliable model for Olefines content out of this data set.

Table 2: Distillation Curve Prediction Using NIR

Cross Validation Models
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	RMSEP	*SEP*	*Bias*	*Slope*	*Corr.*
5%	*1.0224*	*1.0408*	*-0.0257*	*0.6795*	*0.7785*
10%	*0.8245*	*0.8373*	*-0.0616*	*0.8068*	*0.8792*
20%	*0.9142*	*0.9285*	*-0.0677*	*0.8233*	*0.9064*
30%	*1.0075*	*1.0220*	*-0.0885*	*0.8378*	*0.9211*
40%	*1.1311*	*1.1474*	*-0.0993*	*0.8422*	*0.9277*
50%	*1.2606*	*1.2788*	*-0.1104*	*0.8540*	*0.9325*
60%	*1.3593*	*1.3789*	*-0.1185*	*0.8643*	*0.9372*
70%	*1.5686*	*1.5919*	*-0.1292*	*0.8621*	*0.9296*
80%	*1.8007*	*1.8273*	*-0.1504*	*0.8547*	*0.9296*
90%	*2.4119*	*2.4472*	*-0.2059*	*0.8614*	*0.9333*
95%	*3.4013*	*3.4549*	*-0.2422*	*0.8245*	*0.9273*
FBP	*6.3844*	*6.5016*	*0.0126*	*0.8997*	*0.9479*