



Virtual Intelligence Dynamic Model

In this paper, a detailed dynamic simulation model of environmentally controlled off gas is used to determine exact design parameters needed to anticipate an unwanted rise in methane composition and divert the off gas when needed. The virtual intelligence model provides a digitally-based tool which predictively confirms proposed solutions to prevent an unwanted unsafe process upset.

**PREDICTING
SAFETY/EMISSION
EXCURSIONS IN
ENVIRONMENTAL
MITIGATION
SYSTEMS**

“Virtual Intelligence: Predicting Safety/Emission Excursions in
Environmental Mitigation Systems”

Amudha Narasimhan, KBR; Cristina Murcia, KBR

Confirmation of retrofit engineering to detect and divert off gas excursions to maintain safe and sustained operations

A detailed dynamic simulation model of environmentally controlled off gas which is sent to a regenerative incinerator is used to determine exact design parameters needed to anticipate an unwanted rise in methane composition and divert the off gas when needed. The virtual intelligence model provides a digitally-based tool which predictively confirms proposed solutions to prevent an unsafe process upset. The configured model is developed using industry process simulation software and first principal chemical engineering algorithms. It uses equipment design criteria to generate time-based response [$f(t)$] curves for multiple solution strategies. It includes equipment design, high accuracy fast response laser detection analysis and the quick response isolation valves to confirm and optimize the best solution which meets existing design constraints. The chosen solution predicted by the virtual intelligence dynamic model is further refined to provide the client team with the engineering specifics and digital validation needed to complete the design.

Introduction:

The first LNG plants were established in the 1960’s and since then hundreds of plants have been put into operation. LNG trains, the liquefaction unit that actually produces the LNG, are designed for a range of feed gas composition where they operate at their maximum efficiency. However, over time and due to various reasons, the feed gas composition changes and this affects the performance of the LNG plants. The effect of the feed gas change impacts the refrigeration and liquefaction sections. The feed gas composition change in the acid gas treatment section is also significant. The acid gas from the amine regenerators to the thermal oxidizers end up handling higher levels of methane. They oftentimes exceed their operating limits and environmental regulations leading to failure of oxidizers. This study demonstrated troubleshooting such operational constraints of an oxidizer. The systems' dynamic behavior was studied using the first principle chemical engineering model to establish the proper instrument specifications. Based on the specifications, the instrumentations were upgraded to fast response using laser detection.

System Description:

The Figure 1 below represents a typical LNG facility with thermal oxidizer used to capture and destroy the acid gas from the gas treatment section.

The thermal oxidizers are designed to reduce environmental emissions by destroying Volatile Organic Compounds (VOCs) including minor amounts of Methane, various Sulfur compounds, and BTEX whilst at the same time minimizing the formation of NOx, CO and particulates, P_{2.5} and P₁₀, in an acid gas stream with a Higher Heating Value (HHV) value generally less than 20 Btu/SCF.

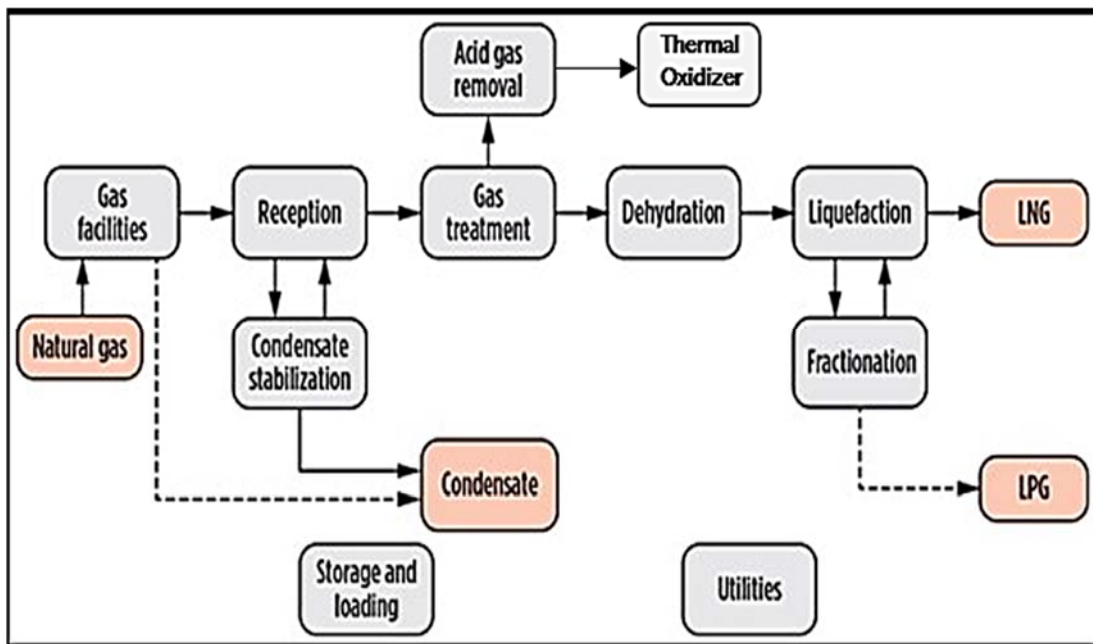


Figure 1: Block diagram of a typical LNG facility

Effect of Feed Gas Change

When the feed gas composition changes, operating problems arise when the CO₂ concentration in the feed gas to the pretreatment section particularly to the amine absorber is greatly reduced. This results in a sudden loss in volumetric flowrate of acid gas and at the same time the Methane (C1) concentration of the acid gas increases considerably due to the amine co-absorbing the C1 when there is insufficient CO₂ to satisfy the absorption capacity of the amine. The result is that the high heating value of acid gas stream going to the oxidizer quickly goes beyond the combustible limit of the oxidizer. The hydrocarbon rich stream creates an explosive environment within the thermal oxidizer. Oftentimes, the oxidizer is not designed to handle such a feed gas and acid gas stream.

System Description:

The following Figure 2 demonstrates the acid gas flow path to the thermal oxidizer. The methane content in the acid gas to the thermal oxidizer is measured by the existing analyzer in the given location. If the methane concentration exceeds the limit, the acid gas flow is bypassed to flare. The existing analyzer response time is 10 minutes. This analyzer response time is very slow for this system and has less time to react causing overpressure and safety issues in the thermal oxidizer. The client approached KBR to troubleshoot this problem and find a suitable solution. A Hysys dynamic process simulation model was developed to mimic the plant condition and to troubleshoot.

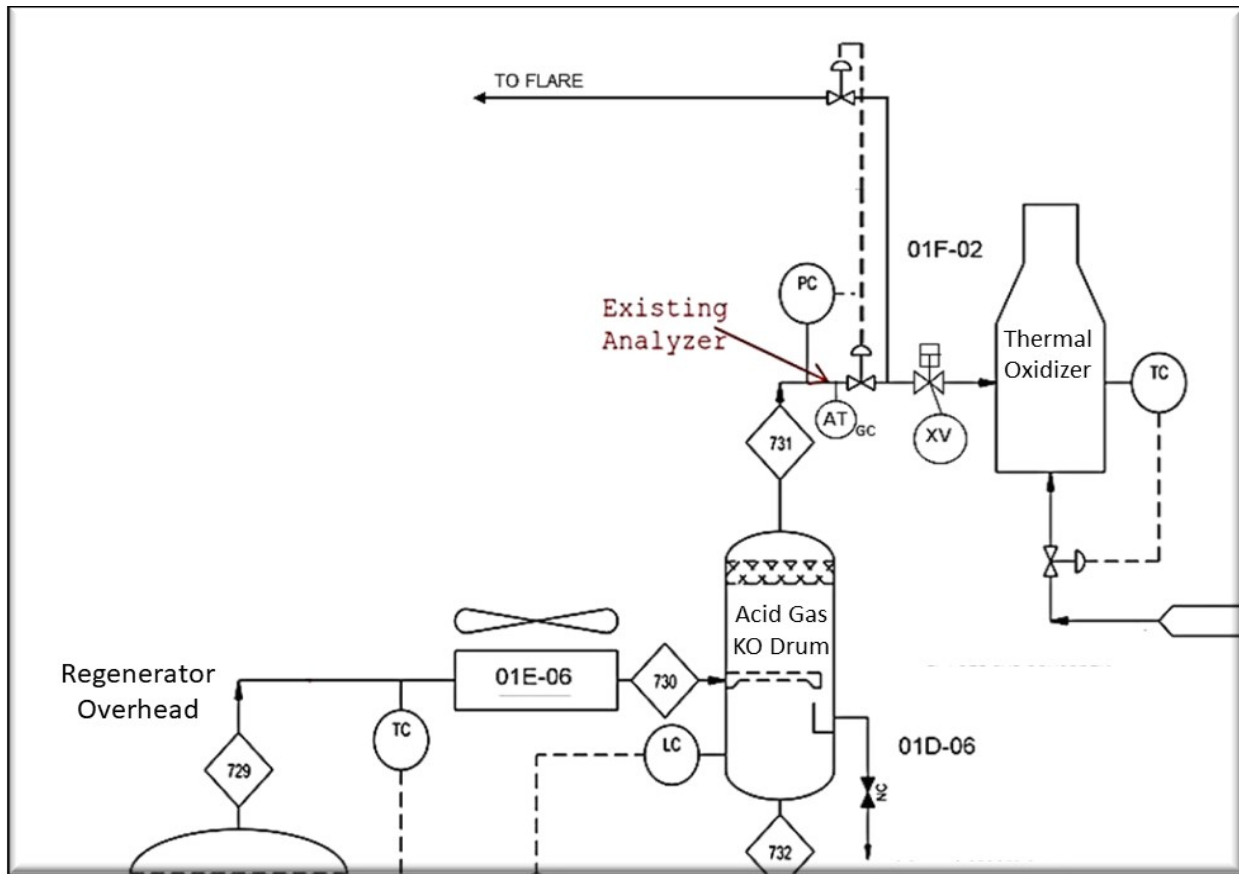


Figure 2: Acid Gas to Thermal Oxidizer and Plant Analyzer location

Dynamic Process Simulation Model:

Figure 3 represents the HYSYS™ process model mimicking the overhead of the regenerator, air cooled condenser, acid gas knockout drum up to inlet of the thermal oxidizer. In case of higher unsafe concentration of C1 (Methane, CH₄), the block valve to the Thermal Oxidizer is closed and the flow is diverted to the flare line.

- ✚ The model emulates the volume of the overhead lines from plant isometric data, air cooled condenser information from datasheet, the valve characteristics and Cv from the datasheet.
- ✚ This model mimics the resistance in the pipeline and the time it takes for the concentration of Methane to travel through the pipeline.
- ✚ This model captures the system response time, analyzer response time and instrument delay times to divert the flow from the thermal oxidizer to the flare during high methane concentration in the acid gas.

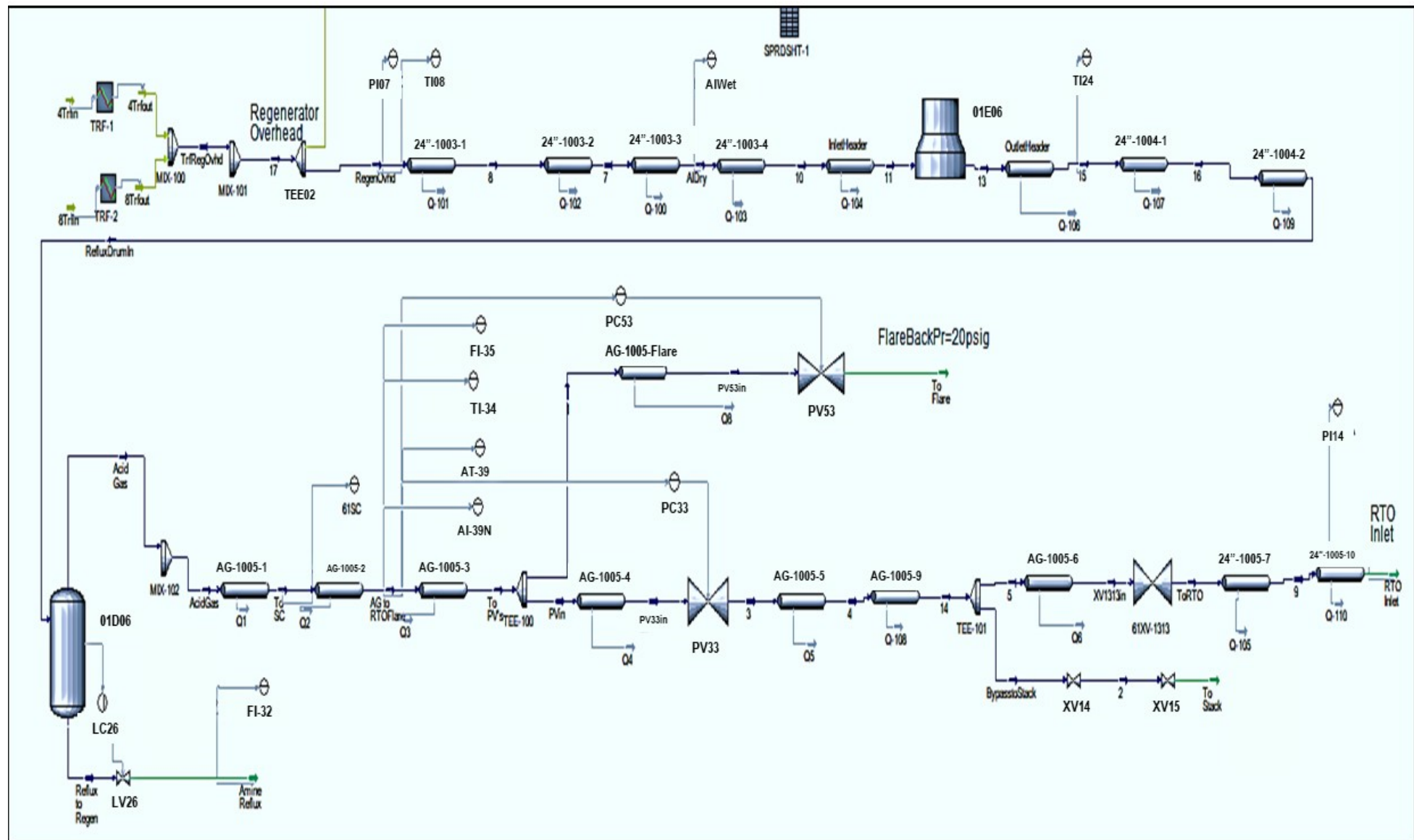


Figure 3: HYSYS™ Dynamic Process Simulation Model

Plant Analyzer Location and Response Time:

When the feed gas becomes leaner with higher methane content and lower CO₂ content the amine unit was not able to satisfy the low CO₂ concentration and will co-absorb more methane. This leads to more methane in the acid gas stream going to the thermal oxidizer, soon exceeding the operability limit of the thermal oxidizer. The thermal oxidizer is protected from high methane concentration, by diverting the acid gas flow to the flare.

The analyzer location measuring the methane concentration was at the overhead of the acid gas knock out drum. The analyzer was too close to the thermal oxidizer and its response time was too long for the system. Figure 4 below represents the time it takes for the methane concentration to travel from the existing analyzer location to the thermal oxidizer. It takes about 5 seconds for the composition to travel from the overhead of the acid gas knock out drum to the inlet of the thermal oxidizer. However, as the analyzer response time is 10 minutes, the interlock receives the signal to close the inlet XV to the thermal oxidizer only after 10 minutes. This led to higher concentration of methane in the thermal oxidizer due to delay in taking the corrective measures. The corrective measure is to close the inlet XV to the thermal oxidizer and open the PV to the flare line when the analyzer measures a higher C1 concentration in the acid gas.

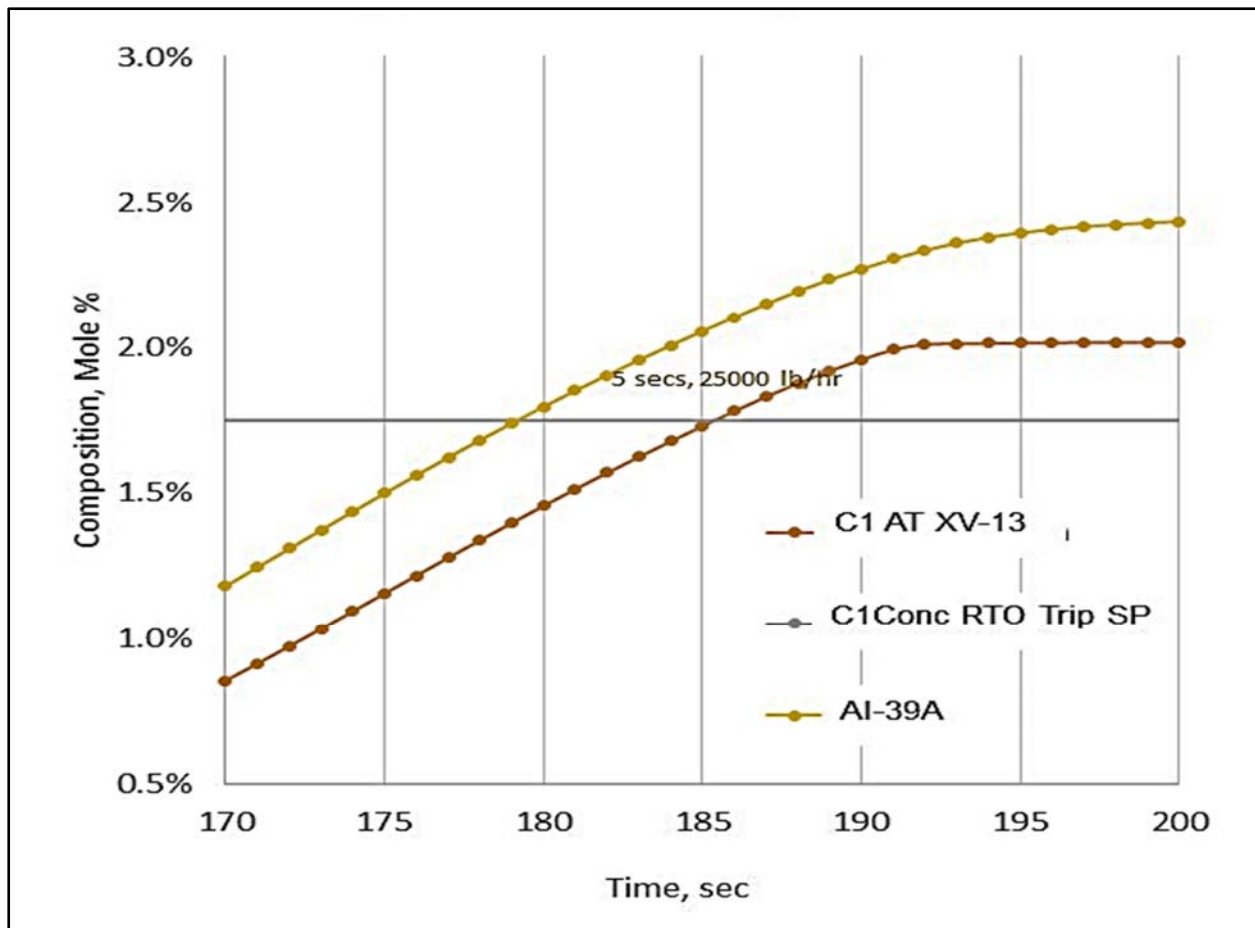


Figure 4: Plant Analyzer location and response time

Recommended Analyzer Location and Response Time:

The time required for the safety system to respond include the analyzer response time, the closing time of the pressure control valve in the acid gas line, the closing time of the inlet block valve (XV) to the thermal oxidizer, the opening time for the flare PV, and the total instrumentation and signal delay times. This safety time was calculated to be about 8 seconds excluding the analyzer response time. Figure 4 suggests that we need have an analyzer that is quick to respond within a few seconds. Considering a 2 second response time for the analyzer a ,total safety response time of 10 seconds was estimated. Even if we have the fastest analyzer, the safety system could fail with the analyzer in the existing location. The system response time of 5 seconds (refer Figure 4) is less than the minimum safety response time of 10 seconds. Hence, it was decided to move the analyzer further upstream at the overhead of the regenerator in order to have more time for the composition to reach the thermal oxidizer inlet or more system response time. Figure 5 below shows the new proposed location for the analyzer.

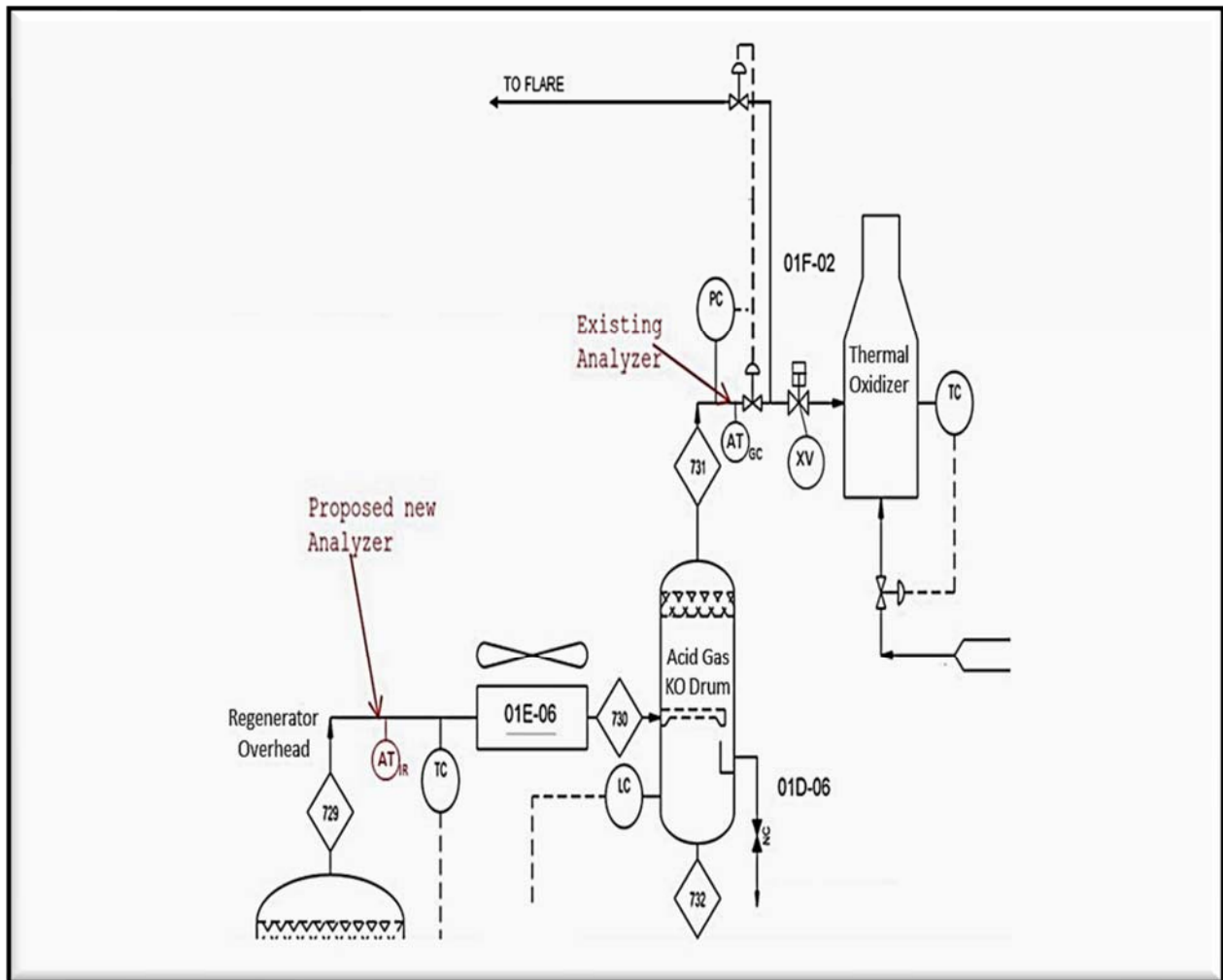


Figure 5: Proposed Analyzer location

Figure 6 shows the higher system time to respond to the composition change with the new analyzer location. Moving the analyzer further upstream gives us 45 seconds to respond to the composition change which is higher than the minimum required safety time of 10 seconds.

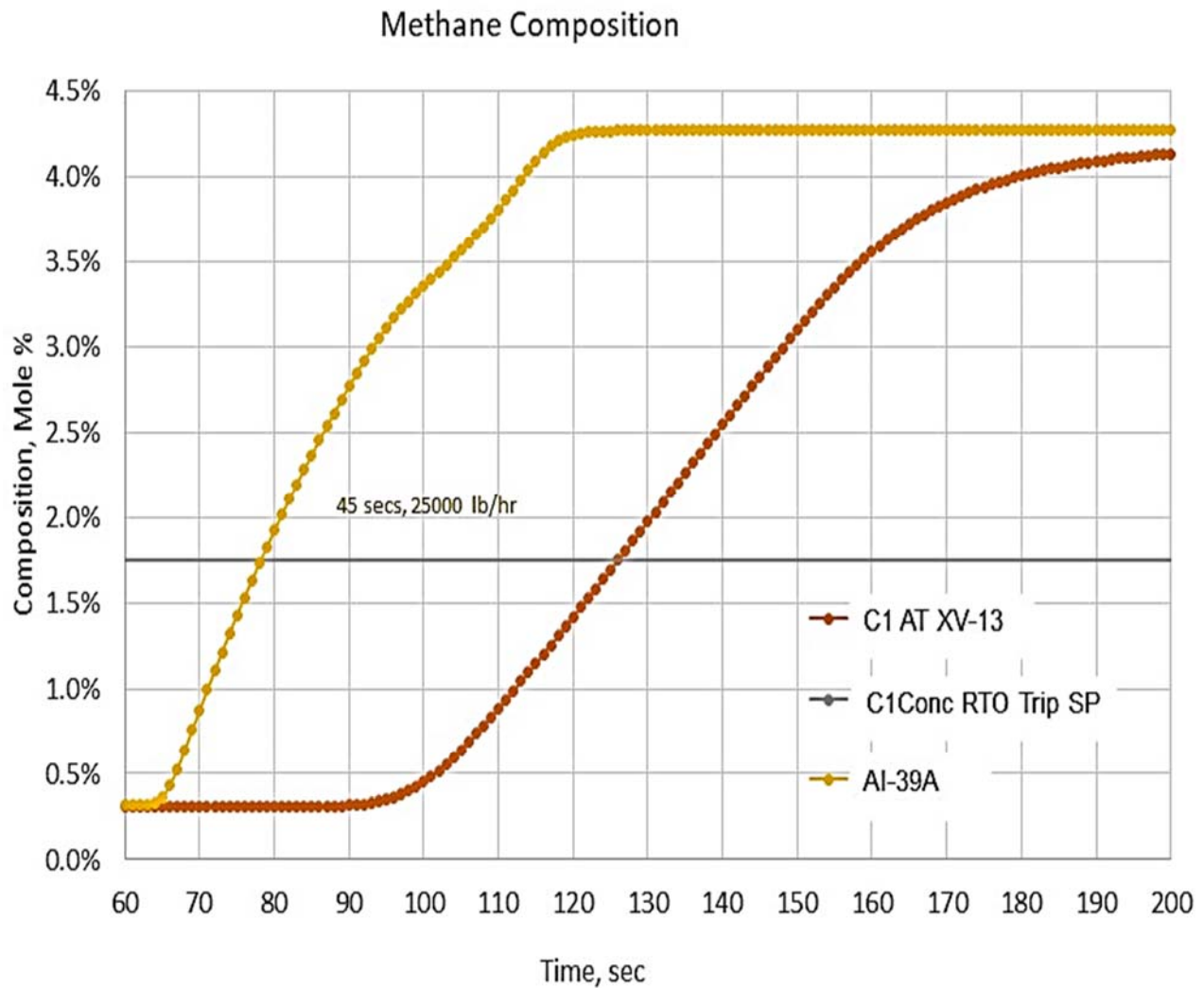


Figure 6: Response time for action at the proposed analyzer location

Challenges in Analyzer Location:

The proposed solution came with a challenge of finding the fastest analyzer able to measure the small methane concentration in a wet environment. Here are the challenges that needed to be overcome before considering moving the analyzer further upstream. The acid gas from the acid gas knockout drum is dry gas and C1 is a direct measurement from the gas chromatograph (GC). However, the regenerator overhead stream is a wet gas that has high concentration of saturated water as vapor. This means we should find an analyzer which can measure the methane in saturated conditions. Also, we have to do some simple DCS calculations to convert the methane concentration on a dry basis which will be used as the trip set point for the safety interlock.

Recommended Analyzer Response Time Down from 10 Minutes to 10 Seconds:

Analytical instrumentation has become available which uses tunable infrared detection capability, and which is reportable via electronic transmission in the order of seconds (point-to-point). Tunable diode laser analyzers are gas analyzers that are used for measuring the concentration of specific species within a gas mixture using laser absorption spectrometry. A laser beam, tuned to identify a particular gas species, passes through the gas to a detector. A tunable laser is a laser whose wavelength of operation can be altered in a controlled manner. While all laser gain media allow small shifts in output wavelength, only a few types of lasers allow continuous tuning over a significant wavelength range. This technology has been incorporated into laser analyzers calibrated for the operating ranges for the measurement of single or multiple components in a stream. Figure 7 shows a graphical depiction of desired measurement relative composition to other background components.

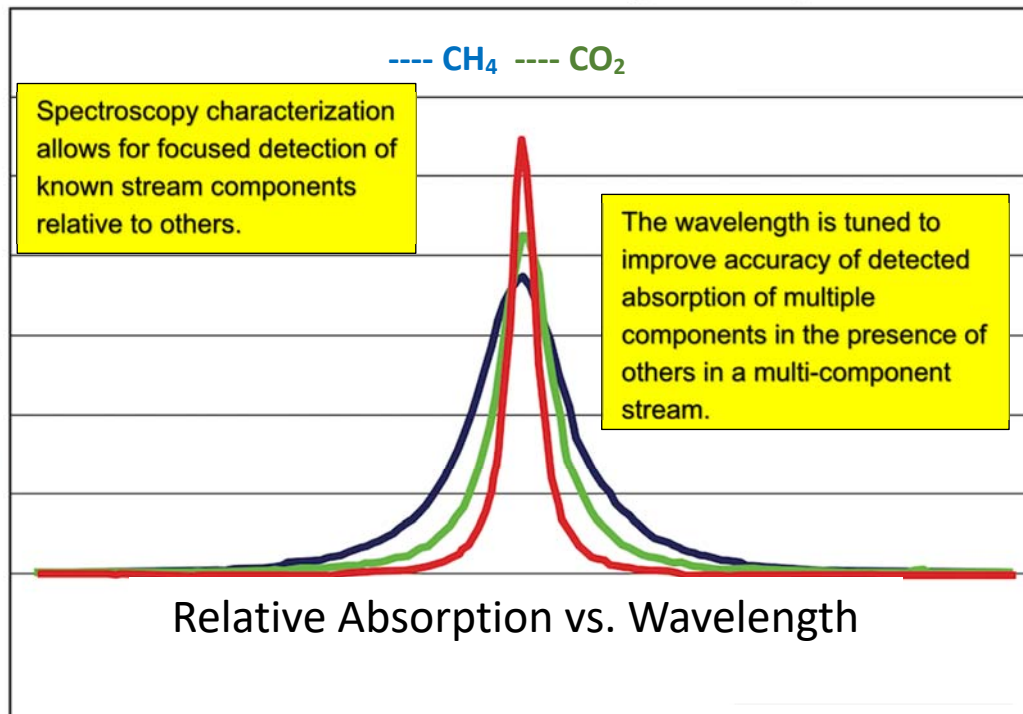


Figure 7: Laser Spectroscopy- Measurement of Tuned Component Absorption/Component Wavelength

A typical installation showing the measurement path across the measurement location and the local interface mounted directly is depicted in Figure 8, which is replicated at the control console and plant facility control system historian.

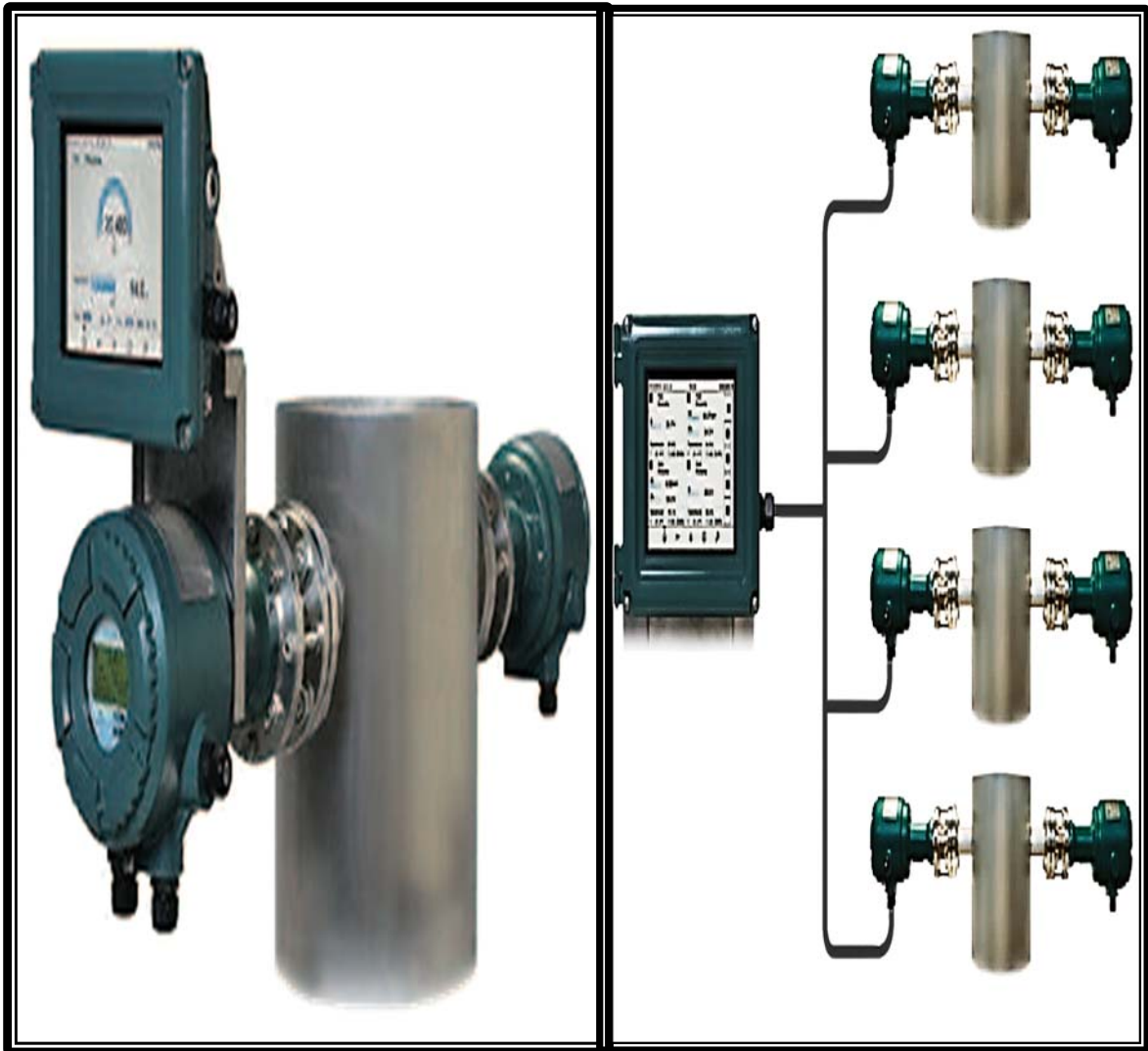


Figure 8: Yokogawa Tunable Laser Analysis for Single/Multiple Components (typical)

Significance of Analyzer Response Time with Latest Technology:

The ability to confidently detect key components to monitor as an indicator of upset conditions in seconds allows facility operation teams to predictively prevent environmental off spec and unsafe condition in an automated fashion or proactively at first site of the detection via the confirmed analysis.

Analyzer Location and Thermal Oxidizer Operation-Solution:

With a fast response analytical measurement, the boundary of normal thermal oxidizer operation can be more safely monitored and controlled by operations, even if there is an upset situation which increases the Methane (CH₄) concentration in the acid gas. The flexibility of this type of analytical instrumentation technology is that it is tunable

and adjustable when required. The life of a facility will have excursions which can then be addressed by the window provided by this type of automated measurement. Gas chromatography is the librarian of the acid gas being sent to thermal oxidizer and provides a detailed analysis needed for that purpose. The key lookout for upset operation and management is the speed of laser spectroscopy engineered to detect specific elements.

Analyzer Location and Performance - a key role in operation:

The **virtual intelligence model** can predict the time needed to anticipate a change in operation based on real time and historized measurements. It allows the safe operation of critical environmental mitigation and show facility engineering and operation how to manage and engineer any required changes.

Summary:

Digital engineering using virtual dynamic analysis according to a step-based approach is illustrated in Figure 9:

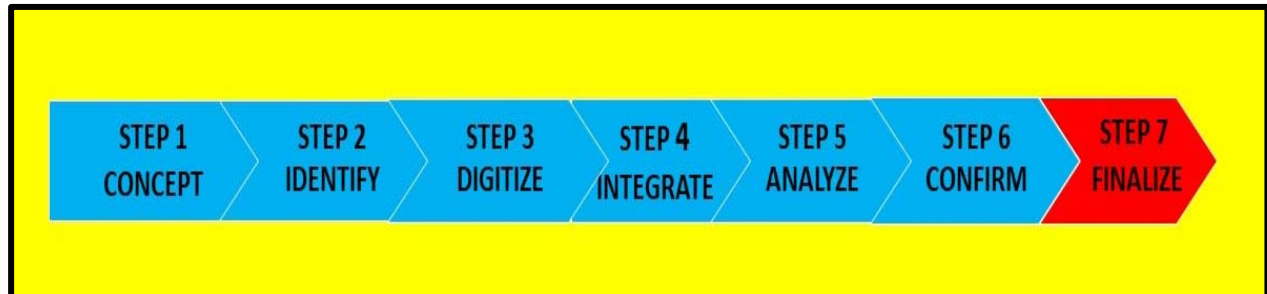


Figure 9: Virtual Intelligence Dynamic Model Step Method

- ❖ **Step 1: Concept:** Propose operational targets to be examined virtually
 - Amine Offgas Emission incineration design constraints
- ❖ **Step 2: Identify:** Design and control requirements to meet operational targets
 - Analytical measurements and flow diversion
- ❖ **Step 3: Digitize:** Dynamic digitization of the process design envelope
 - HYSIS™ Dynamic Model Environment
- ❖ **Step 4: Integration:** Consolidate design and control devices in dynamic model
 - Fast response Tunable Laser Infrared inline analyzer(s)
 - Fast diversion valve actuation
- ❖ **Step 5: Analyze:** Virtual dynamic model analysis/test run for all proposed case solutions
- ❖ **Step 6: Confirm:** Plot dynamic model response curves confirming results of dynamic model
- ❖ **Step 7: Finalize:** Process design and control recommendations

Recommendations:

LNG Amine Offgas Digitalization and Dynamic Analysis recommendations are as follows:

- ✚ Early detection of LNG Amine Offgas composition for environmentally controlled emissions were confirmed as key for prevention and mitigation of unwanted surge heating value to plant incinerator. Fast response Laser Tunable Infrared technology (and similar) was shown to be a driving factor for anticipating a spike in offgas composition.
- ✚ Proactive response to detected spikes in LNG Amine Offgas compositions require quick actuation diversion valves using a dedicated line for rated capacity
- ✚ This analysis can be shared with design teams on all projects to improve both project “Safety by Design” and Environmental Sustainability avert future unsafe and unwanted offgas compositions to RTO.

Conclusion:

The benefits of “Virtual Intelligence Dynamic Model” are that it provides a digital venue to capture and mimic the plant operations. The first principal process dynamic model helps to demonstrate and optimize engineering design. It allows a closer view to better define solutions for implementation as well as, troubleshoot as-built designs. The work is in the use of these models to identify (with more confidence) the refinements in process design and automation which can help prevent and mitigate abnormal conditions.

Close interaction between the plant operations and the KBR engineering / simulation team has resulted in thorough analysis of the model and the recommendations. This collaboration also ensured quick resolution of the problem and arrive at a realistic solution. We often need to remember that there are continuous improvements in the technology: For example, availability of faster analyzers available now than earlier. Plant troubleshooting exercise shall certainly consider such developments in technology. Implementation of the recommendations from the study will eliminate frequent plant shutdowns due to high methane excursions in the acid gas line to the RTO. This study will also prevent any unsafe RTO operation and avoid mechanical damage to the RTO.