CECO Peerless

White Paper

Go with the Flow: Advanced natural-gas-compression separation and filtration solutions for optimum LNG plant and midstream compressor station performance

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Introduction:
Finding the optimal solution

The benefits of optimizing filtration and separation systems for removing contaminants in a natural gas pipeline are well known. Suppliers compete to develop the smallest, most economical equipment to process the gas to achieve the specified performance, whether customers are looking for years of uninterrupted process uptime or for ultra-pure natural gas streams to generate high-quality feedstocks. The challenge for an end user's engineers is to understand the nature of contaminants that need to be separated in order to select the most appropriate technology.

Going with a fully customized solution typically involves a lengthy design, approval, and delivery period. Going with an off-the-shelf solution can be faster, but long-term performance may be compromised.

A superior approach is to go with a crafted array of engineered configurations that implement advanced separation/filtration technologies to optimize performance, equipment size, and installation schedules

To help engineers and procurement professionals understand the advantages of this approach, the following presentation examines the input considerations, situation diagnostics, and technology options available for an optimal solution.

Identifying input considerations:
Understanding the challenges

Conventional wisdom typically calls for customized natural gas separation and filtration solutions for a simple reason: Every hydrocarbon stream produced from the wellhead is different. Stream composition includes a mixture of methane, heavy hydrocarbons, water vapor, liquid water, natural gas liquids (NGL), and a variety of contaminants—from chemical (mercury, acid gases, and ammonia) to solids (silica, sand, and iron-sulfur oxides "black powder")—all in different proportions. These components also behave differently when subjected to various temperatures, pressures, and speeds as the stream moves through the pipeline. The constituents also vary over time as the well matures.

Nevertheless, the properties of various natural gas compositions and contaminants are well understood. But considerations become complicated because requirements for gas-plant processing and gas compression and transmission differ. When facing many variables, it's valuable for decision makers to know that proven methodologies and pre-engineered configurations can be used to significantly streamline the planning, design, specification, and payback of separation/filtration systems.

The best starting point for a project is to understand the gas stream's conditions and the end user's objectives. There are a number of considerations shared by natural gas processing plants and midstream compressor stations. Relevant input considerations include:

1. **Liquid and vapor conditions:** Removing oil and condensates is the primary challenge, but other liquids are present in a wet gas stream. Some liquids, such as free water, can be dealt with by simple separation methods employed at or near the wellhead. Removing water vapor from the stream is more complex. Various dehydration treatments are needed depending on gas temperature, volume, and other variables.

   Removing liquids from a natural gas stream usually involves two basic steps. First, the liquids must be extracted from the natural gas. Second, the natural gas liquids themselves must be separated down to their base components.

2. **Sweet and sour gas conditions:** Some wells produce natural gas with significant amounts of carbon dioxide and/or sulfur compounds. High amounts of hydrogen sulfide are contained in so-called "sour gas," which can be extremely corrosive. Amine gas treatment is used to remove highly corrosive sulfides, thereby "sweetening" the gas.

3. **Stream volume and speed:** Pipe size is a factor determining the flow velocity of the natural gas stream. This factor will influence separator selection because certain systems are best suited for higher and others for lower flow velocities. The operating pressure must also be considered as this will alter the gas density. Separator designers will evaluate velocity and density together so that equipment can be applied properly at operating different pressures.

Using diagnostics: *The value of expert insight*

Thoroughly understanding the application is essential to obtaining the right equipment at the right time at the best price. Looking at initial cost can be misleading, because a slightly higher upfront investment can deliver huge long-term operational savings. For example, buying a single-stage filtration system is less expensive than a multistage design. But initial savings will quickly disappear when frequent stoppages for filter replacement and maintenance disrupt process flow.

Expert diagnosis of the fluid mixture of a hydrocarbon stream is necessary for designing, sizing, and selecting filtration-separation equipment. Stream composition can vary depending on the source:

- In low-pressure oil wells, the volume of the liquid phase will typically be greater than the gas phase.
- In high-pressure gas-distillate wells, the gas volume will typically be greater than the liquid volume.
- With high-pressure gas, the produced liquid is generally composed of lightweight hydrocarbons.
- In both low-pressure oil-wells and high-pressure gas-distillate wells, the stream may contain free water.

The gas-liquid flow can exist in different flow regimes:

- As a dispersed mist
- As a "slug" in the form of an intermittent, large-volume wave traveling slower than the gas velocity
- As an "annular" flow in which the liquid coats the pipe walls. With this flow regime, liquid initially forms at the pipe bottom where the high-velocity gas imparts a wave action that may atomize the liquid into a mist
- As a multi-phase mixture composed of the above regimes

Furthermore, mixtures of liquids and solids can co-exist together. Dry solids can also be encountered.

To account for these variables, Computational Fluid Dynamics (CFD) is a unique tool to model fluid flow. CFD can evaluate fluid properties, create a visualization of fluid flow patterns, and predict fluid dynamics. A CFD tool can handle very complex phenomena, such as laminar flow, highly turbulent flow, complex chemistries of hydrocarbon liquids, moving bodies, and fluid structure interaction. Nevertheless, the expertise of an application engineer is needed to understand the flow dynamics and determine the appropriate metrics and models.

Each separator must be configured to handle the specific conditions determined by the diagnosis. In the case of annular pipe flow, for example, the velocity of the gas and the amount of liquid in the gas can be evaluated using empirical formulas to help determine the separator size. Properly sized separation and filtration systems are much more efficient and less costly to operate than incorrectly sized systems. Incorrectly sized equipment will often result in a lifetime of operational challenges to plant equipment like compressors, amine treatment systems, or dehydration systems.

Applying technological options: *Crafting proven solutions for superior performance*

As a global leader in high-efficiency filtration and separation equipment for natural gas, CECO Peerless offers a broad array of proven solutions to handle a wide range of conditions. At the beginning of a project, a CECO application engineer will discuss input conditions and perform a flow analysis to determine the liquids, particles, and droplets that need to be separated from the gas stream. Then, our application experts will design, select, and support CECO Peerless brand products and solutions that will meet the specific performance objectives.

Typical performance objectives may involve:

- **Maximum separation efficiency of submicron liquid droplets**: Absolute Coalescing Filters can be specified as a single or multistage device. At the inlet of the Primary Separation Section in a multistage design, flow baffles, cyclones, or vanes remove liquid and solid particles by utilizing the dynamics of centrifugal force and gravity. By removing the bulk of the entrained liquid in this stage, a multistage design increases the life of the high-efficiency coalescing elements and holds the pressure drop buildup to a minimum.
- **High-efficiency separation of both solid and liquid contaminants:** Filter-Separators provide economical, effective, and highly-efficient removal of large and small solid and liquid particles from gas streams to help protect valuable mechanical equipment and optimize the efficiency of processes. Combining the filtration and separation stages into one pressure vessel also helps to control costs.
- **Handling high liquid rates and large slugs:** Vane Separators or Multicyclone Separators are configured to evacuate large volumes of incoming liquids before applying a polishing separation stage to remove any airborne mists. Combining the effects of momentum, gravity, and droplet interception delivers high-efficiency, high-capacity, and low-cost gas and liquid separation with low pressure drop and high turndown. Vane separators often provide liquid removal within smaller pressure vessels, which results in lower initial cost, space savings, and minimal maintenance requirements. A horizontal separator is used for high liquid rates and large slugs; a vertical separator for slug

removal in small footprint installations; and a line separator for tight spaces when slugs are not expected. All of these designs operate in steady-state mode, not requiring periodic maintenance or filter replacements.

- **High efficiency-separation of liquid and solid (dust) contaminants**: Multi-Cyclone Centrifugal Separators use centrifugal, gravitational, and inertial forces to separate solutions, gas mixtures, or other matter that can be physically parted. Centrifugal separation occurs when a mixture is spun very quickly, and heavy materials typically settle at different levels than lighter ones. A swirl tube centrifugal separator is used for liquid removal in small footprint, most commonly horizontal flow, installations.
- **Highly efficient and economical removal of dust, dirt, scale, rust, and other solids from various gas-stream types**: Dry Gas Filters can be customized in both vertical and horizontal configurations with premium quality materials ensuring a long-life system and low overall costs.

Technological advantages enable superior performance

The superior performance of CECO Peerless products is the result of an extensive research and development testing and modeling that innovated several unique features:

- **Advanced vane designs**: At the heart of a separator are vane elements that divide entering gas into many vertical ribbons. Peerless vane designs subject each ribbon of gas to multiple changes in direction as the moisture-laden gas follows its path through the vane passages. The direction changes cause a semi-turbulence and a rolling of the gas, and the centrifugal force of these directional changes hurls heavier liquid droplets out of the main gas stream, drive the liquids into sheltered pockets provided at each turn of the vane for transport into the liquid reservoir at the bottom of the assembly. The liquid-free gas stream exits the vane unit. Unique Peerless vane profiles are typically specified to match specific applications and to balance efficiency, liquid capacity, and pressure-drop considerations.
- **Efficient cyclonic separation**: Particulates can be removed from a gas stream by employing vortex fluid mechanics rather than filtration (which may still be applied in a separate stage). Centrifugal effects and gravity within the vortex separate mixtures of solids and fluids, and can even separate fine droplets of liquid from a gaseous stream. CECO Peerless uses a unique multi-cyclone principle of operation using multiple, small-diameter cyclones arranged in parallel to achieve separation of small and large size particles. Depending upon the application, a bank of cyclones may contain hundreds of cyclone tubes. These cyclonic units can serve as an effective substitute for traditional filtration systems, especially in remote locations or when replacing filter elements is not practical. By implementing these solid-state cyclonic separators, end users completely avoid the ever-growing health and safety (HSE) concerns related to opening pressure vessels for maintenance.
- **Ultra-filtration technology**: Advanced CECO Peerless multistage filter-separators are capable of removing 99.99% of 0.3 μm solids and 0.5 μm liquid droplets from a gas stream. To achieve this level of performance, the CECO Peerless design employs patented features originally developed for NASA applications. It combines three technologies:

    1. Inlet T-baffles deflect incoming gas flow for optimum distribution into the filter chamber
    2. A larger filter-media surface area where solids are removed and small droplets coalesce

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3. High-efficiency vanes (described above) where the coalesced liquids are captured and drained away from the gas stream

This unique combination delivers better performance, smaller filter-separator vessel diameters, resulting in lower cost options than standard filter-separator offerings.

Expediting your project with a standardized, incremental approach

Employing a customized solution may require waiting 24 to 30 weeks for a piece of equipment to arrive. In contrast, CECO Peerless uses a standardized, crafted approach that can significantly shorten the design and delivery period. This method utilizes common design configurations, managed incremental size ranges, and consistent specifications to avoid the needless complexity of an infinite number of variations. For example, although CECO Peerless offers nearly a dozen vane options, it focuses on two or three selections to cover common conditions and retains the other options only for specialty applications. Based on end-user consultation, a select number of vessel diameters is offered rather than customizing each project with myriad size increments. Standard, larger-increment diameters that are readily available substantially shorten the delivery period without significantly affecting capacity. And for facility consistency, standardized specifications for everything from inlet/outlet nozzles to instruments and controls to safety connections make it possible to adopt standard best practices across the entire network. That means for facilities in different locations, equipment differences can be minimized between sites. Consistent equipment specifications simplify the design process, reduce the end-user's design review cycle and facilitate operator training while still providing the flexibility to meet individual end user's needs.

Application advantages: *Proven accomplishments in the field*

Case 1: LNG Plant – Propane Separator CFD Performance Evaluation

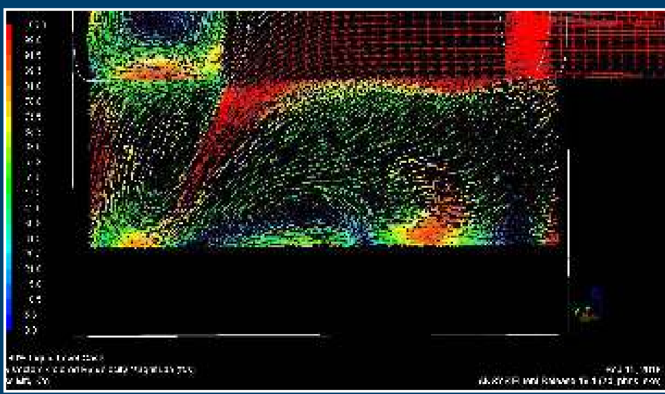
CECO Peerless performed a CFD evaluation in 2016 to check the internal flow patterns for one if its existing propane separators that had been in service for over ten years. New flow conditions were being considered and site personnel needed to confirm whether the system could be operated without a liquid protection plate, as there was not enough time during the plant outage to modify internal hardware. Through CFD analysis, CECO Peerless determined that a simple modification to the level controls could be applied to lower the operating liquid level within the vessel. This adjustment allowed the plant to restart operation during the scheduled outage and avoid lost production of LNG. As depicted in the following CFD images, CECO Peerless engineers were able to determine the required liquid level, such that the incoming gas would not

Vessel Layout

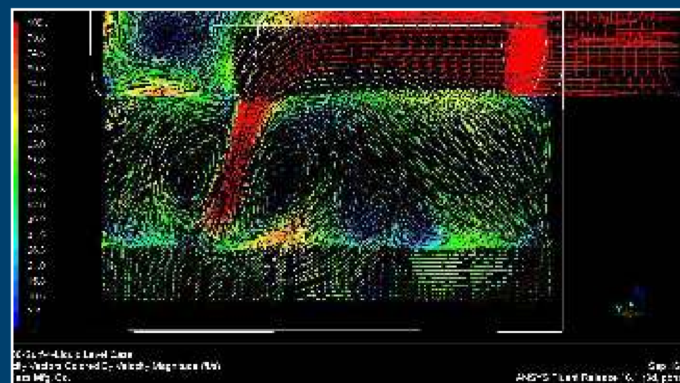
Main gas inlet at side and gas outlet at top. Bright green area shows flow space where wet gas emits from inlet ½ pipe baffle. Orange square is the four-bank vane unit which removes entrained moisture from the gas.

liquid from the lower section of the vessel. A careful evaluation of gas flow patterns passing through the vessel was made to confirm that proper flow distribution to the upper four-bank vane unit would be maintained so that moisture separation would not be compromised.

Since late 2016, the plant has been operating and producing LNG without any compromise in performance. This example shows how CECO Peerless can apply cutting-edge design tools to evaluate a non-standard design concept in real time, avoiding a costly loss of production of LNG.

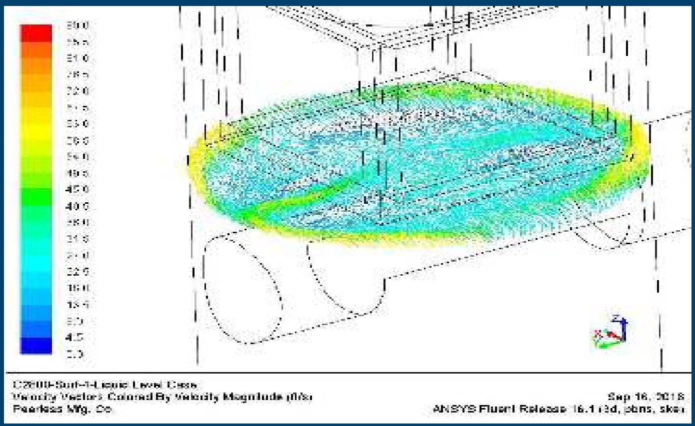


CFD flow patterns at original (high) liquid level indicate scooping action which re-entrains liquids. [Red = high velocity; Blue = low velocity



CFD flow patterns at optimized (lower) liquid level indicate improved flow circulation above separated liquid and elimination of re-entrainment. [Red = high velocity; Blue = low velocity]

CFD flow patterns at optimized (lower) liquid level confirm the gas flow passing around the inlet ½ pipe baffle.



CFD flow patterns at optimized (lower) liquid level approach the four-bank vane unit uniformly after passing the ½ pipe baffle.

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Case 2: Midstream Gas Metering Facility – ULTRA Filter Separators and Slug Catchers

In 2014, CECO Peerless supplied a set of four (4) 54-inch and six (6) 51-inch diameter ULTRA filter separators for the natural gas pipeline that feeds the Sabine Pass LNG plant. These were installed at facilities providing the compression and final gas measurement as the last line of filtration before custody transfer and liquefaction. As shown in the following photo, these ULTRAs are operating in parallel, treating over three billion standard cubic feet per day (3 BCFD) of gas.

After four years of successful operation, CECO Peerless was approached to provide additional inlet slug catching capability at these facilities because the upstream gas composition changed due to a newly connected pipeline providing a new gas source. This new gas source contained significantly more liquids, which were being managed by the original ULTRA filter separators; however, the frequency of filter replacement was increased. By adding new multi-cyclone slug catcher separators upstream of the ULTRAs, the added liquids could be removed, thereby extending the operating life of the ULTRA filter elements. Benefits from this not only include the reduced cost of aftermarket filter elements, but also the reduced frequency of shut-downs and exposure of operators to confined interior spaces within the pressure vessels. Trickle down benefits of reduced filter disposal, project planning, and associated HSE paperwork costs will also be realized.

Multi-cyclone separation internals used for the removal of solid and liquid contaminants within a vertical pressure vessel. This “dense pack” configuration is designed for handling intermittent liquid slugs.

ULTRA filter-separators installed in parallel for final cleaning of natural gas before liquefaction.

These projects demonstrate that project conditions rarely stay the same over time. CECO Peerless engineers can apply different separation and filtration technologies to treat both the initial case of high efficiency gas filtration and the future case of increased liquid separation, including the potential for incoming liquid slugs.

The suite of CECO Peerless technologies can be applied to cover myriad potential multi-phase flow challenges faced by natural gas pipeline operators to effectively protect compressors and remove contaminants to ensure uninterrupted, maximum-purity LNG production.

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Conclusion: *Realize optimal performance now*

Performance instability and operational problems in natural gas processing are caused by poor removal of contaminants due to inadequate filtration-separation equipment. Just because an application faces unique challenges does not necessarily justify the long lead times and the expense of a fully customized solution. Purchasing low-cost, off-the-shelf equipment that can be quickly installed is not reasonable either, because ensuing higher repair rates and downtime will be very costly. A more justifiable approach is to collaborate with expert application engineers offering proven, standardized configurations that can be crafted to meet exacting requirements. CECO Peerless application engineers have the experience to understand today's natural gas compression and transmission challenges. Our combination of talent and technologies help customers remove the obstacles to achieve specific process, economic, and environmental objectives immediately—and years into the future.

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