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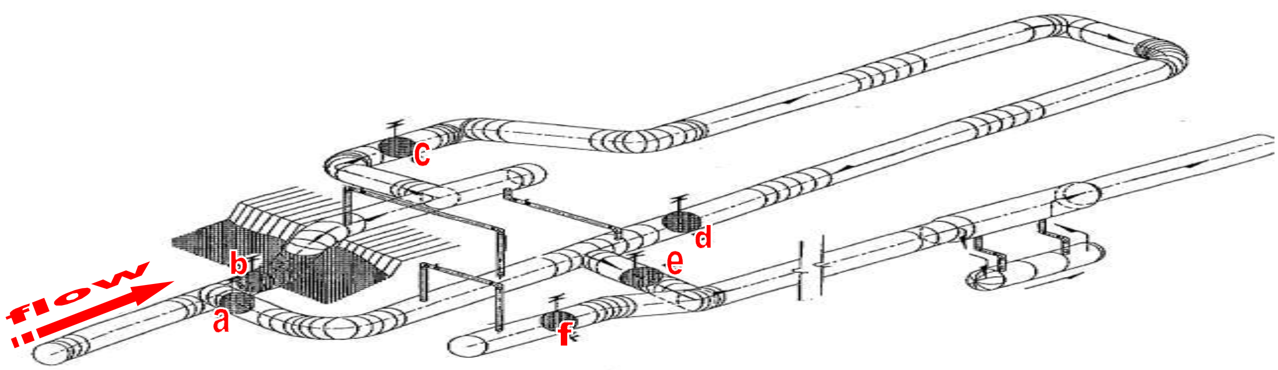
Innopipe Liquid Slug Stabilizer System for Natural Gas Pipelines

Natural gas pipelines often contain significant amounts of liquids that can interfere with the proper operation of the pipeline and related equipment such as compressors, regulators, filters, meters and valves. The liquids normally found include hydrocarbon condensations, lubrication oils, produced water, and chemicals used in production, treatment, compression or dehydration of the gas. The liquid to gas ratio in gas production pipelines can be as high as 100 Bbls/ MMSCF of gas. When gas and liquid flow in hilly terrain pipelines, liquids tend to accumulate in the low spots or valleys of the pipeline.



It is generally accepted that significant liquid holdup and resulting slug formations will occur whenever superficial gas velocities are less than 4 m/sec. When the gas velocity increases to a point where the liquids can be carried along, receiving equipment such as separators, storage tanks and slug catchers are required to handle the large variable amounts of liquid.

Liquid slugs can exist in a region between the superficial liquid velocities of 1 to 4 m/s and a superficial gas velocity of 4 to 20 m/s. These liquid slugs travel at the same velocity as the gas through a pipeline and can cause significant damage to, or operational problems for, gas processing equipment. Gas pipelines have typically used “Slug Catchers” to dissipate the energy of the liquid slugs that intermittently propagate through a gas pipeline.

Current “Slug Catcher” designs are based on reducing fluid velocities to promote a “stratified” flow regime and subsequent gravity separation. To attain this the slug catcher must control and dissipate the energy of the incoming gas stream as it enters the slug catcher to minimize turbulence and ensure that the gas and liquid flow rates are low enough so that gravity segregation can occur. Velocity reduction is achieved by enlarging the pipe n. diameter. A rule of thumb is that the gas velocity cannot exceed 1.5 m/s (5 f/s) for liquid removal to occur. The current slug catcher design must not only promote stratification, but must also be capable of handling the largest slug volume without permitting slug formation in the slug catcher. Thus, selecting slug catcher length is an important part of the slug catcher design. To conserve on land area, it is common to use "finger storage" which is essentially a mesh of interconnected slug catchers

Innopipe Slug handling solution

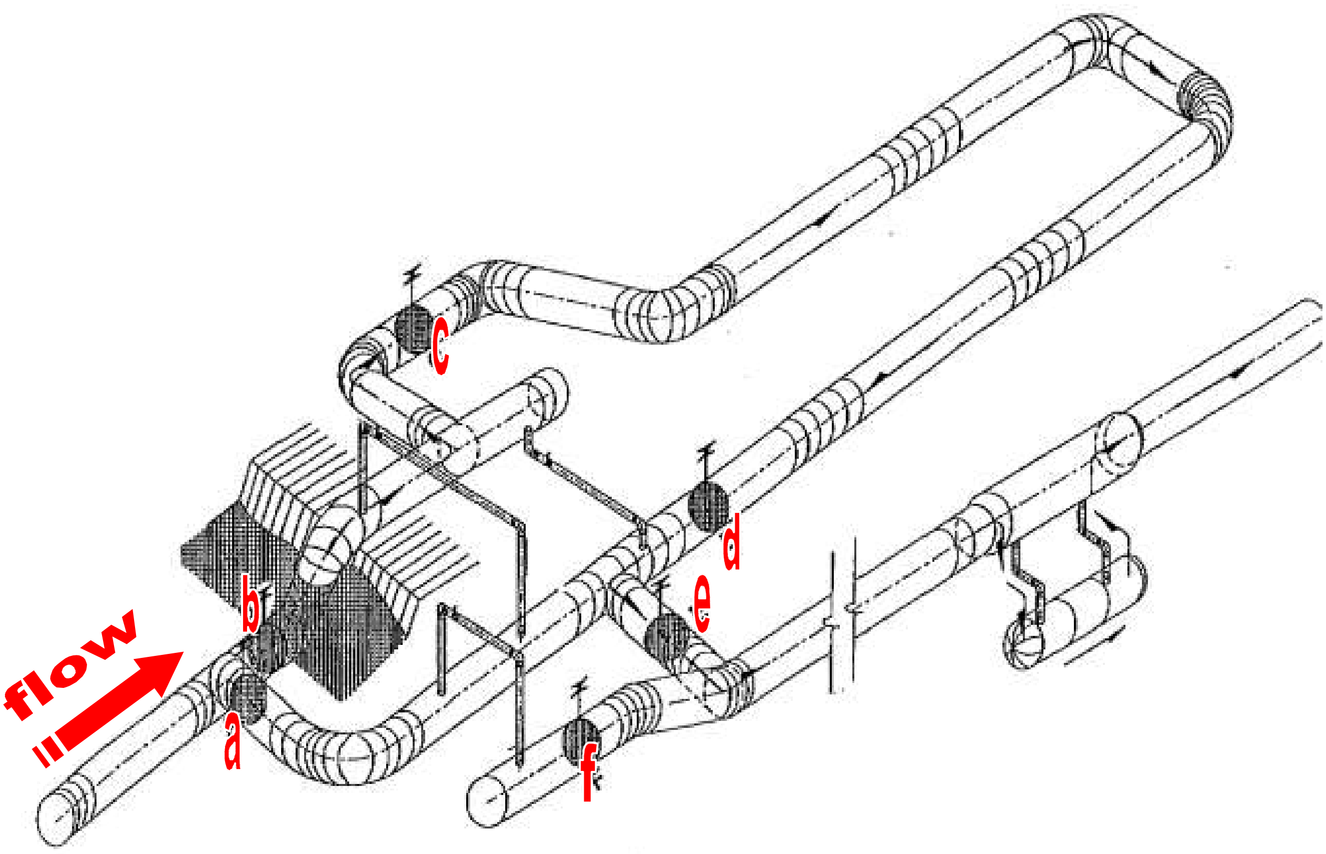
The Innopipe Slug Stabilizer System solution is to re-route the excess gas pressure that propels a liquid slug down a gas pipeline from behind the slug to the leading edge of the slug. The gas pressure increases in front of the slug to reduce the liquid slug's velocity momentum and control of the liquid is achieved. The gas pressure behind a slug is higher than the gas pressure in front of the slug due to high slug friction losses and maintenance of the slug's momentum. The Slug Stabilizer System utilizes this pressure difference to increase the gas pressure ahead of the slug and effectively reduces the slug's momentum. The piping is designed to allow gas flow to continue unimpeded and bypass the now-trapped slug. The liquid slug is suspended in the piping where the liquids can be removed or allowed to slowly re-enter the flowing gas stream. The ability to efficiently "smoothe out" the liquid slug without the requirement to reduce the gas velocity results in significant cost savings over conventional slug catchers. Another benefit is that the downstream liquid separation equipment can be sized for the significantly reduced liquids flow, thus helping realize more savings. To further reduce costs in this equipment, an Innopipe inline separator can be utilized.

The slug catcher design would apply to both situations of self-propelled slug propagation and pipeline pigging. The design incorporates a continuous processing approach to liquids removal. Additionally, the design can be modified to accommodate the pigging spheres used in pipeline pigging operations.

The slug catcher application is well suited to off-shore producing where product must travel long distances in a two phase state before separation can occur. Due to the nature of the off-shore pipelines and the change in elevation, the occurrence of liquid slugs is most common as stratified flow becomes intermittent. The design of the slug catcher minimizes the environmental impact by the efficient use of pipe to create a one time pass and handling of process liquid slugs.

Basic Operation

In its simplest form, the Slug Stabilizer System consists of a branch connection, a slug stabilizing loop, a bypass loop, and another branch connection. In normal operation the gas flow enters the Slug Stabilizer System and divides at the first branch connection between the slug catching loop and the bypass loop before recombining at the second branch connection and continuing along the pipeline. The branch connections will normally be a tee and can be oriented from horizontal trough to vertical position. The branch positions and sizes can be optimized to meet individual gas/liquid pipeline flow characteristics and minimize the volume of liquid entering the branch connection while still allowing sufficient gas flow to bypass ahead of the liquid slug.



Incoming liquid slugs enter the Slug Stabilizer System and the majority of the slug is propelled past the first branch connection. Most of the liquid will continue past the branch connection and into the slug-stabilizing loop due to the liquid's momentum energy and its resistance to change flow direction. The liquid slug will continue passing the branch connection (with some liquids entering the branch) until the gas behind the slug reaches the same branch connection. The gas

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pressure behind the liquid slug is normally higher (to overcome the slug's friction losses and provide the liquid momentum energy) than the pressure in the slug stabilizing loop and the bypass piping. When the higher gas pressure pushing the slug reaches the branch connection the gas will bypass into the branch, as the gas pressure is lower in the branch connection. As the gas flows into the bypass branch the pressure will increase in the branch connection and decrease in the piping behind the liquid slug.

The branch by-pass piping directs the high-pressure gas from behind the liquid slug to the other end of the slug-stabilizing loop where the second branch connection is located. The gas will divide with most of the gas continuing down the pipeline with some gas entering the slug stabilizing loop and increasing the pressure in front of the liquid slug. The second branch connection can also be designed such that most of the liquids that entered the bypass branch (while the slug was passing the first branch connection) will be carried past the second branch connection into the slug stabilizing loop. With the gas pressure increasing in front of the slug and the gas pressure reducing behind the slug (due to gas bypassing around the slug) the momentum of the slug will be reduced until the pressure stabilizes and effectively reduces the slug velocity to nil. The preferred gas flow is now through the bypass piping and the trapped liquid slug along with the bypass liquids are essentially suspended in the slug-stabilizing loop. The size, length and orientation of the slug stabilizing loop can be optimized for the maximum slug expected and the applicable gas flow rates and pressures.

The slug-stabilizing loop can be designed with a grade to collect the trapped liquids and discharge through a drain. An alternative would be to grade the slug-stabilizing loop to allow a stratified flow reintroduction of liquids into the primary gas stream. The liquids can then be removed with downstream equipment that only has to be designed for stratified flow and sized for a liquids withdrawal rate equivalent to the re-introduction liquid flow rate. In effect, the slug stabilizer system allows downstream separation equipment to have liquid capacity design in line with the re-introduction rate which can occur over an hour or longer instead of having to separate the liquid slug in a minute or less. This is a major improvement over the design criterion of existing slug catchers which rely on gas velocity reduction to enable liquid separation in the short time available that the slug travels through the conventionally designed slug catcher.

Pigging Operation Design

For pigging operations, a rubber sphere or similar device is introduced at an upstream location and the pig traverses the pipeline until it reaches or creates a liquid slug. The slug stabilizing system is configured to trap the large slug generated by the pigging operation and can be designed to allow retrieval of the pigs used to remove the slug from the pipeline. In normal operation all the valves are open and the piping allows operation similar to the basic operation described in the previous section.

When the pipeline is being pigged a large volume of liquid can be expected and the gas flow rate may be reduced. For this operation, Valve A on the first branch connection is closed. Incoming liquid slugs pushed by the pig enter the Slug Stabilizer System and the liquid slug is propelled past the first branch connection, through Valve B and up into the above-grade pig receiver. Most of the liquid will continue past the secondary bypass connection that can be oriented vertically on top of the pig receiver. The secondary bypass connection is designed to minimize the volume of liquid that can bypass the slug-stabilizing loop and still allow sufficient gas to bypass and stabilize the liquid slug.

The liquid slug will fill the pig receiver and enter the slug-stabilizing loop through Valve C. The slug stabilizer loop is again sized to accommodate the maximum slug expected. The pig that is propelled by the higher-pressure gas arrives in the pig receiver and once it passes the secondary bypass connection, the gas behind the pig will enter the secondary bypass piping. A substantial pressure difference now exists between the high-pressure gas behind the pig and the low pressure in the bypass piping. The higher pressure behind the pig is developed during the pigging operation to overcome the slug's friction losses; to provide the liquid slug's momentum energy; and to overcome the pig's friction losses.This pressure difference will cause the high-pressure gas to immediately flow into the secondary bypass piping and push the liquids that have entered the bypass to a point downstream of the liquid slug.

The gas pressure will begin to decrease behind the pig as the gas flow rate increases in the bypass piping and into the piping ahead of the liquid slug. The pig will travel until it reaches the branch connection in the receiver where it cannot proceed with the liquid flow. The branch connection in the receiver is designed to not allow progression of the pig into the slug-stabilizing loop and to allow the pig to effectively seal the opening when it arrives. With the pig stopped the liquid slug will no longer be pushed and the pressure behind the slug at the pig receiver branch connection will reduce to nil. The reduction in pressure behind the slug assists in slowing the progression of the slug through the slug-stabilizing loop.

The gas that was behind the pig can now only flow through the secondary bypass piping. The secondary branch by-pass piping directs the high pressure gas from behind the pig to the downstream side of slug stabilizing loop where the final branch connection is located. The gas will divide with most of the gas continuing down the pipeline with some gas entering the slug stabilizing loop and increasing the pressure in front of the liquid slug. The final branch connection can also be designed to ensure most of the liquids that entered the secondary bypass branch (while the slug was passing the secondary branch connection) will be carried past the final branch connection into the slug stabilizing loop. With the gas pressure increasing in front of the slug and the gas pressure reduced behind the slug (due to the pig sealing the pig receiver branch connection) the momentum of the slug will be reduced until the pressure stabilizes and effectively reduces the slug velocity to nil. The preferred gas flow is now through the secondary bypass piping and the trapped liquid slug (along with the bypass liquids) are essentially suspended in the slug-stabilizing loop, to be handled as desired.

The Innopipe slug-stabilizing system is capable of providing slug-handling capabilities at a greatly reduced cost compared to equivalently sized pressure vessels. Call us with your engineering data and we can provide you with a solution to your liquid handling problems.

The Innopipe inline separator and slug management systems are patented. Any attempt to copy these designs is in violation of Patent laws.

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