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CRUDE OIL BLENDING
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Introduction

Blending of Crude oils is a process of mixing two or more crude petroleum components together and is done to improve the overall value or quality of the blend. The reasons vary but may be done to improve pipeline capacity, improve the value of the blend or to help a refinery improve the product yield from its processes.

Blending operations can be expensive requiring pumps, meters, tanks etc. Consideration must be given to the cost of infrastructure, cost of diluent, and what measureable property will you use e.g. Viscosity or API gravity.

Questions that must be answered include: How will the pay back occur? Will the value of the product be increased? Will the pipeline work more efficiently? Can you blend on someone else's behalf and charge a blending fee?

Care must be taken to evaluate all the parameters because one of the blending features may cancel out the benefit initially realized. For example, if two crudes were blended to reduce the overall sulphur concentration the sum of the parts may result in more volume than the pipeline can physically handle.

There are a number of applications that require blending of crude oil or other hydrocarbons and they include pipeline capacity, product value and refining efficiency.

Considerations to evaluate the usefulness of Blending

To determine the amount of diluent needed to blend the crude to the target gravity it is best to set up an algorithm that calculates the weighted average of the gravities and also the amount of shrinkage. This should be an iterative process that recalculated the shrinkage 3 or 4 times until an endpoint is determined. Just doing it once will not give the correct volume of diluent. If the facilities are available you can check the accuracy in a lab to be able to fine tune the blend.

The price difference between the crude oil and the diluent must be considered. The cost of diluent is usually higher than that of crude so the cost of blending may be more than can be recovered.

The cost of a blending facility can be large. The cost of installing pipe, pumps, meters and automation equipment needs to be examined and the potential lower operating costs for energy (less horsepower) to move the oil may justify the facility installation.

Be sure to consider all the fluid properties that might affect the outcome of the blend. Lowering the viscosity by adding diluent may raise the sulphur, vapor pressure or increase the gravity below acceptable limit and therefore the price of the blend.

Viscosity is very dependent upon temperature in an inverse and non-linear manner. Small changes in temperature can create large changes in viscosity. Therefore, using viscosity for the controlling parameter for blending may be difficult. Often the target viscosity may be at a specified reference temperature that can be different than the actual stream's flowing temperature. This adds another level of complexity as the line or measured stream viscosity must be determined at the reference temperature.

Blending for Pipeline Transportation

Pipeline capacity is affected primarily by viscosity, API Gravity and pipe diameter. Together, along with velocity these factors roll into a factor called Reynolds number that gives an indication of the overall flow profile of the oil inside the pipe. These flow regimes are called laminar, transitional or turbulent flow. It is enough to say that the most efficient flow pattern in a pipeline is turbulent flow and that there will be more mixing using turbulent flow rather than laminar flow.

For any given size of pipeline, a crude oil with a lower viscosity and higher API Gravity will have reduced horsepower requirements and larger throughput capabilities than a crude oil with a higher viscosity and low API Gravity. The API Gravity has a direct impact on the horsepower required due to the weight of product moved whereas the viscosity will impact the pipe capacity by affecting the pressure drop along the pipeline due to increased drag within the fluid itself. Pipelines must operate below a maximum operating pressure (MOP) that they were designed and licensed for. If the pressure drop in a pipeline increases due to increases in viscosity, the flow rate must be reduced to maintain pressures below the MOP. The alternatives are to increase the pipeline line size or to add a diluent that will reduce the viscosity or increase the gravity. Of course increasing the pipe size has both capital and maintenance costs associated with it. The downside to blending is that the volume increases by the amount of the diluent so increased flow rate must also factor in the extra volume to be pumped.

Blending a lighter crude oil or diluent with the heavier crude oil that is to be transported can reduce the resulting blended crude's viscosity and increase the API Gravity. As a rule of thumb, the higher the crude oil's API Gravity, the lower the viscosity. This rule also applies to most diluents but there are some exceptions and therefore not all diluents are equal. For instance, two different diluents may have the same API Gravity but have different viscosity characteristics.

Here are some concrete examples.

Weight or Mass Example

First consider the weight that must be moved. In the US it relates to the API gravity and pounds per gallon. The heavier the fluid the more energy it takes to pump. Therefore less energy is required to move 100 bbl of 40 API gravity oil than the same amount of 30 API gravity oil. Pipelines that operate with the same gravity of product throughout the length of the pipeline are not concerned about this but when moving batches with various gravities the energy requirement and the flow rates change due to the differing product weights in the line. It is important to note that any sort of diluent used also increases the total weight of product to move. If, for example, a pipeline is operating at near it's MOP you can use diluent to reduce the overall weight in a certain section of pipe and therefore reduce the weight to move in that section of pipe.

Viscosity Example

As temperatures drop due to seasonal fluctuations the viscosity of the crude will increase. As the viscosity increases, the pumping costs rise and the power bill will be more expensive. However, if 2% of condensate diluent was added to the crude stream at the crude injection point, the viscosity would drop significantly and the pumping costs would be reduced while throughput may be increased.

A cost benefit analysis must be done because condensate is expensive and a tank, pump and metering facility must be installed. There will be an extra 2% volume that must be pumped too.

Blending on a Pipeline Gathering System

A gathering system may have several injection points that need to be blended. The obvious way is to put a diluent injection point at each site that is required. The economics is simple and perhaps a blending charge for each site would be used to recover costs. This option requires a large investment in pumps, meters and tanks for the diluent. It may be possible to use one blending site at the farthest possible upstream site. At this point diluent can be over blended into the line but as it passes the other crude injection points it gradually reduces the dilution to be close to your target. This option is a little harder to manage. You need to have an automation system that manage the total blend and add diluent at the appropriate ratio.

All of this has costs involved so you either need to make the costs back through a better crude price, lower pumping costs or allocation of a charge back to each site based on how much diluent it would take to blend each site.

Blending to Increase the Value of the Crude

The only reason to blend is to add value for your company or customers. Crude types are priced according to their physical and chemical properties and API Gravity, sulfur content, RVP and asphaltene content can all affect the price of the crude. Lower quality crude oil and therefore lower value, may be blended into a larger and higher valued stream. The ratio of the two will be determined to ensure the qualities are within contract specifications. Each crude type will have limitations on these properties in order to fairly price the crude blend.

When blending crudes often the sum of the parts is less than the arithmetical sum due to shrinkage. Blending seldom results in the sum of the parts but there are options where the financial outcome of the blend can also be worth more than the arithmetical sum of the blend.

Example

> There is a price increase of $10 per bbl in crude if the sulphur is below 0.5%. There are 10,000 bbl of crude that have a sulphur content of 0.52% and a value of $50 per bbl and 1000 bbl of Crude B is available and has a sulphur content of 0.20% and is valued at $60. Blended together the sum of the parts is $560,000. However, the whole blend is now at 0.49% sulphur and the whole batch is now worth $60. Now the blend of 11000 bbl is valued at $660,000. A profit of $100,000 less expenses was just realized.

It is important to consider these crude qualities because if high sulphur crude was added to low sulphur crude the whole batch may be devalued. In other cases if the cost of blending becomes too expensive, the benefit realized by blending may become uneconomical.

> For instance if $6000 of diluent was added to a pipeline pumping a viscous crude but only saved $4000 in energy the economics don't hold up. However it may be necessary to deal with operational requirements such as reducing viscosity so you can actually move the oil. This may necessitate renegotiating the pipeline rate structure.

Shrinkage

When blending heavy crudes with a light diluent a volumetric shrinkage of 1.5% to 5% of the diluent will result. So if you blend 1000 bbl of condensate diluent at $60 /bbl with 10,000 bbl of crude at $50 /bbl but suffer a loss of 20 bbl due to volumetric shrinkage then at $60 you lost $1200 in shrinkage volume. This loss has to be factored into your economics.

API 12.3 is the calculation to be used for determining the shrinkage volume. For more information on shrinkage see Class 2280.1 called Shrinkage Losses Resulting from Liquid Hydrocarbon mixing.

Blending Methods

There are 3 main types of blending available. These are On-line blending, Tank Blending and a combination that is called trim blending.

On-line or Ratio Blending

Sequential or batch blending operation is seldom useful in crude oil applications because the target is most often a homogeneous mixture. In this discussion two or more crude components are injected from separate pipelines and are mixed into a single pipe. Ensuring adequate mixing is a necessity and often requires some type of injection quill, an in-line static mixer or other mechanical mixing device. The use of piping elements alone may not provide adequate mixing. The efficiency of this method will depend upon the resulting mixture's Reynolds number (turbulent or laminar flow), the type and number of piping elements, and the time allowed for mixing. The use of an injection quill for the smaller of the two streams will also assist in mixing.

Usually larger stream's flow rate is kept constant while the smaller stream's flow rate is varied. A controlling parameter such as a viscosity or API Gravity must be selected to be monitored and this will control the component ratio. This monitoring can be performed automatically using on-line analytical equipment or manually by periodic collection of samples.

The manual collection method can provide a semi-automatic operation at best and should only be used when the qualities of the upstream components are fixed and flow rates are constant. The injection rate of the smaller stream is based upon the sample analysis.

An improvement in this method would be a semi automated system using a ratio control automation system where the flow rates of both streams are measured and the analysis from the manual sample determines the flow set point for the ratio. This is beneficial where the flow rate of the larger stream tends to vary.

For complete automation and the best control of the blend, measure the downstream qualities of the blend and add a blend product upstream using an automated control loop system.

The best method will be determined by considering the cost of the automation, price of the blend, cost of diluent and the requirement for accuracy.

Tank Blending

Crude Oil components are added into a common tank, usually on a batch basis. The concentration of the blend is based upon a recipe approach and requires the use of tank mixers. Achieving homogenous blending is difficult and depends upon the ratios of the two components, similarity in physical properties, size of tank, number of tank mixers and mixing time.

The preferred method is to add the components simultaneously as the tank is filled rather than adding one component at a time. If the only available option is to fill with one at a time, the component with the lowest concentration is added first.

When you put two or more crude oils or diluents into a tank the most likely result is that the heavier component will layer on the bottom. To counteract this there needs to be a mixing device such as tank mixer. Tank mixers must be designed properly to counteract the tendency to spin the product horizontally along the bottom of the tank with no significant mixing near the top of the fluid. There are a several tank mixer configurations that can be customized for specific applications. Tank mixer manufacturers and vendors may have simulation and sizing programs that can be used to select the proper mixer for an application.

The mixing activity is important. Consider this example of meter factor shift. If two products are placed in a tank and remain layered until time to ship, the heavier crude oil goes first since the piping is near the tank bottom. A good operator will prove the meter at the beginning of the batch and establish a meter factor. As the batch continues, lighter oil will arrive at the meter and the meter factor will shift but remains unaccounted for. An online densitometer would help to ensure that the VCF is correct in a flow computer but the worst case would be a flow computer with a fixed density.

Obtaining representative samples from large tanks can be difficult at best, and often impossible which is another reason why tank blending uses a recipe style operation. The benefit of a recipe approach is lower capital cost requirements and often, existing equipment can be used. The downside is potentially less homogeneity and less certainty in meeting proper specification, as there is no process feedback until the blending is complete.

Trim Blending

To have a more precise blending operation, a combination of the two methods can be employed. A tank blending procedure can be used to get the product close to the desired specification. When pumping the tank out an online procedure can be used to trim the blend to the final specs.

Blending Calculations

When blending using API gravity, the weighted average of the components can be used. This will result in the calculated blend gravity (assuming no volumetric shrinkage). If however, you need to calculate how much diluent to add to a crude stream to reach a specified gravity an iterative method of calculating must be used.

Viscosity blending is non-linear and viscosity should be tested at 3 temperatures to verify the blending operation. To complicate viscosity blending, the viscosity is stated in cSt at a temperature. Blending two or more crudes together with a target temperature different from the crude temperature requires a sophisticated mathematical model.

API gravity is often used as an analog for viscosity in blending operations because gravity is easier to measure on line than viscosity. Only the testing of samples will confirm whether this works or not but generally this only works for approximations and should be discouraged.

Sulphur and other contaminants are usually determined as the weighted average calculation and are linear calculations. When doing this please remember the measurement units. Most Sulphur measurements are by weight % and do not work with volumetric units such as barrels or gallons.

Refining Efficiencies

Refineries are designed to process a range of crude oils such that their feedstock will provide specific fractions of refined products. Sometimes this range will vary greatly from refinery to refinery. Most refineries are designed to operate using specific blends of crude oil so they set up specifications for the oil they are willing to purchase. Refineries offer their best price for blends that meet their specs. Out of spec blends get penalties applied to the price or in the worst cases a batch could be rejected. Either way if a blend was done poorly it will cost money.

If the feedstock stream changes then there may be voids in the cut or composition of the various processed streams. An example would be a light oil refinery that has asphalt-making capabilities and therefore would require a heavy component in its feedstock. If the regular feedstock stream changed so that it didn't have this heavy component then a heavy stream would need to be added into the main feedstock

Blending in this manner allows the refiner to match the incoming feedstock with existing equipment.

Conclusion

Blending of crude oils can be a complicated operation but is done to create an economic benefit either through increased throughput or improving the value of the crude oil. If done correctly and consistently it can be of financial benefit to the company