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HYDROCARBON PROCESSING®

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Control valve design challenges for green diesel processes

Green (or renewable) diesel is a biofuel that offers several advantages over biodiesel, so many refineries are increasingly including it in their production portfolios. The downstream portion of the refining process is very similar to traditional diesel hydrotreating processes, making modifications less onerous than switching to the production of a totally different fuel.

While similar, there are some process differences between green diesel and standard diesel that are more difficult to handle for the critical control valves in the unit. This article discusses the green diesel process, and it offers suggestions for choosing the best valves for reliable, safe and profitable production.

Biodiesel vs. green diesel. Biodiesel has its roots from experiments conducted in the 1930s, and it has been produced in quantity since the 1980s. It uses a transesterification process to convert various vegetable oils and/or animal fats into fatty acid methyl esters (FAME). The burn characteristics of FAME are like diesel fuel, but it is chemically different and tends to gel in colder temperatures. This gelling limits the amount of FAME that can be blended to 10%–20% of the total diesel volume, and, even then, the fuel can be troublesome to handle during colder winter months.

Green diesel is a more recently introduced process that starts with the same collection of vegetable oils and/or animal fats, but the result is a product chemically identical to diesel. Since diesel and green diesel are the same in terms of end product, there is no blending restriction, and any engine can operate on 100% green diesel. **FIG. 1** compares biodiesel, green diesel and regular diesel.

	Biodiesel	Renewable/Green Diesel	Diesel
Feedstock	Vegetable Oils & Animal Fats	Vegetable Oils & Animal Fats	Crude Oils
Process	Transesterification	Hydroprocessing	Hydroprocessing
Finished Product	Biodiesel (FAME)	Green Diesel, Hydrotreated Vegetable Oil (HVO), or Renewable Diesel	Diesel
Chemical Composition	O ‖ R-C-O-R'	C_nH_{2n+2}	C_nH_{2n+2}

FIG. 1. Like biodiesel, green diesel can be created from various vegetable oils and animal fats. However, unlike biodiesel, green diesel has the same chemical composition and physical properties as standard diesel and can be used as a direct replacement.

The significantly increased blending rates for green diesel enable producers to achieve much lower carbon intensity in their final product. Carbon intensity is a method of measuring how much carbon is emitted in the production and burning of a particular fuel. Gasoline, jet fuel and diesel derived from crude oil have a carbon intensity of about 100. Biofuels derived from non-crude oil feedstocks have substantially lower carbon intensity values—as low as 20, depending on the raw materials used as feedstock. The overall carbon intensity often drives regulatory credits, so the low carbon intensity and high blend rates of green diesel offer attractive incentives for refineries to switch at least some of their production.

The green diesel process. Green diesel can be created from a large variety of renewable feedstocks (**FIG. 2**). There is no significant advantage in production yield from one type of feedstock to the other, and each takes about 7.5 lb–8.5 lb of raw material to create a gallon of fuel.

The production of green diesel starts with pretreatment (**FIG. 3**). Feedstocks must be separated and treated differently to convert them into a common intermediate, which feeds the hydrotreater processing unit downstream.

The pretreatment process requires a wide variety of processing steps, with particular steps depending on the raw materials used as feedstock. The best control valves for pretreatment will vary widely (depending on the specific operations required), and selecting the proper materials of construction and alloy components will play heavily in the design effort.

Once pretreated, the green diesel intermediate is fed into the same hydrotreating process used in typical diesel production (**FIG. 4**). Green diesel processing usually produces an elevated level of corrosion due to the oxides and acids in the intermediates. Temperatures and pressures can also run higher in a green diesel hydroprocessing unit. This can create challenges for instrumentation and control valve selection.

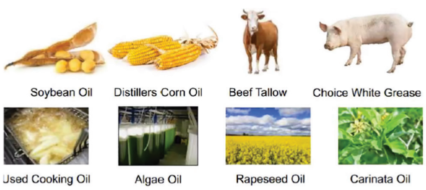

FIG. 2. A wide variety of renewable materials can be converted to green diesel. Carbon intensity values vary by product but generally favor used cooking oil and tallow. Source: Renewable Energy Group.

The temperatures, pressures and corrosive nature of green diesel production pose unique challenges for operations. Paraffin-like components also make the process more "sticky," causing control problems over time. The reactor section of the hydrotreater is the most critical unit for maximizing profitability, with reliable and tight control required for smooth operations. Poor control performance can shorten catalyst life and reduce yield, so picking the right control valves is a crucial step in the design process.

Separator letdown. One critical control element is the separator letdown control valve. This valve controls the liquid level in the high-pressure separator and passes hydrocarbons with entrained gas and particulate. Temperatures can exceed 260°C (500°F), and the valve must reduce an upstream pressure of 1,100 psi to 900 psi. The high pressure drop and very high temperature would be a challenge for any valve, but the corrosive and sticky nature of the material makes this a particularly difficult application.

A typical letdown valve would employ many very small internal passages to stage the pressure drop and handle the flashing conditions, but this type of valve would quickly plug in this service. Instead, the preferable valve design employs a multistage letdown arrangement with large flow passages to allow particulate to move through the valve. Particular proprietary high-pressure multi-stage angle valves[a] (**FIG. 5**) can be an excellent choice for this application.

These types of valves are typically offered with a variety of corrosion-resistant alloys, and they are designed to handle the very high temperatures and pressures encountered in this application. These types of valves also have large, multistage flow passages to handle the entrained solids and offgassing that are typical in this service.

The hot/high-pressure and cold/high-pressure separator letdown valves are similar applications, but within the hydrotreater unit. The best valve design in these services will often depend on the expected ratio of outgassing of the material. A very high gas volume ratio will

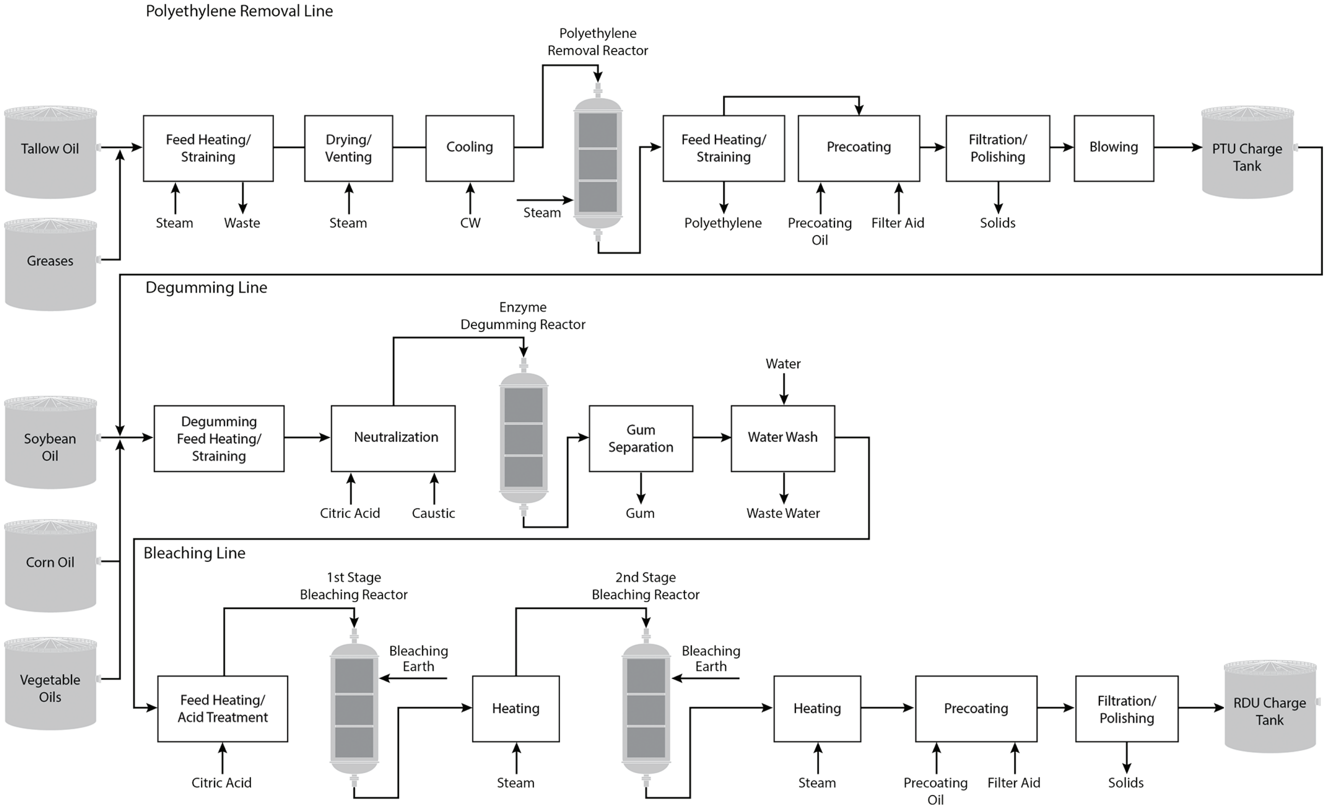

FIG. 3. Green diesel pretreatment involves different processing steps, depending on which raw material is used as a feedstock. Some combination of polyethylene removal, degumming and bleaching is usually required to convert the feedstocks into a common intermediate for further processing.

usually require a high-pressure, multistage or sweep-flow angle valve like the separator letdown.

Lower gas volume ratios may be handled with other valve designs, such as those designed for low, moderate or high gas volume ratios. Regardless of the valve designed chosen, proper alloy selection is critical for long service life.

Hydrogen quench valve. Another critical application involves the hydrogen quench control valves feeding the reactor. These valves control bed temperatures, avoid a runaway reaction and maximize catalyst life and production yield. They should provide tight control and good shutoff. Normally, valves in this service will employ a balanced plug to meet the shutoff requirements and to handle temperatures up to 232°C (450°F) with high pressures. The author's company's proprietary high-pressure globe control valves[b] (**FIG. 6**) are a good option for this service. If the quench valves are exposed to lower temperatures and pressures and there is a concern about particulate buildup, alternate post-guided control valves offer a lower cost alternative.

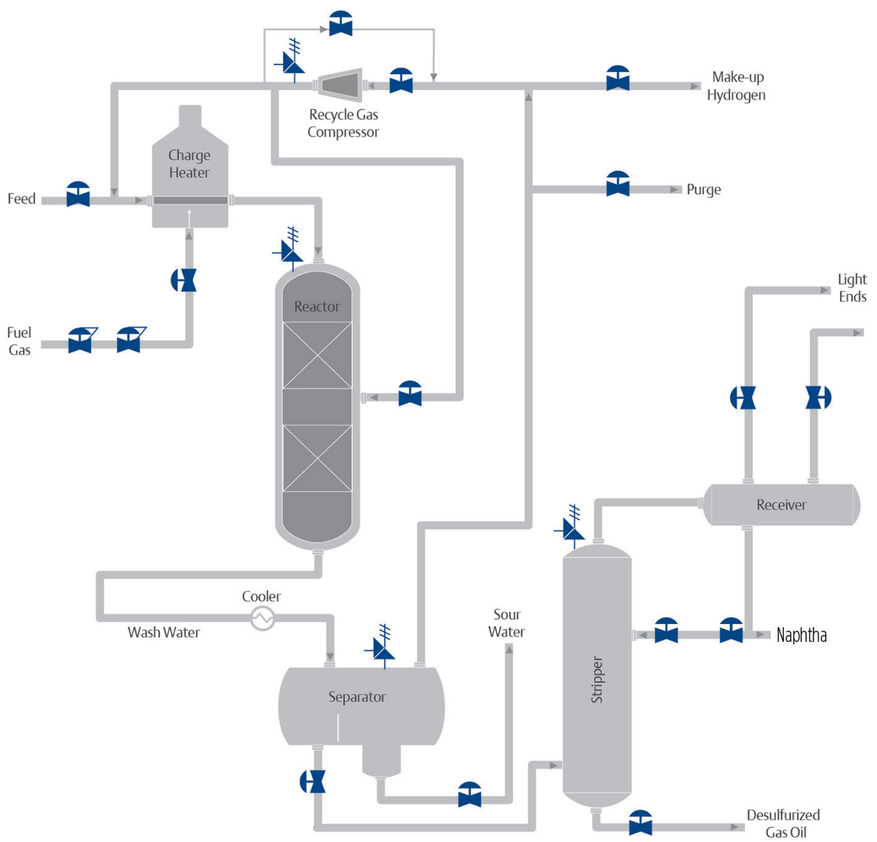

FIG. 4. The pretreated intermediate feeds a typical hydrotreating unit to produce the final green diesel product. The hydrotreating process is the same as a typical refinery but requires higher temperatures and pressures, while posing an increased risk of corrosion.

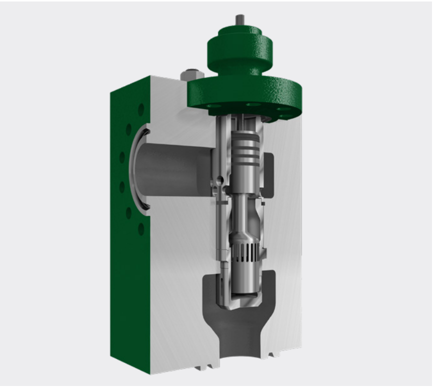

FIG. 5. Proprietary high-pressure multi-stage angle valves[a] can be a good choice for separator service in the hydrotreating process. The robust alloy construction and large, multistage flow passages allow these valves to handle very high temperatures, very high pressure drops, and the plugging nature of the material.

FIG. 6. A balanced plug with tight shutoff is usually employed in a hydrogen quench valve[b] service. Proper material selection is critical for any hydrogen service application.

Pressure swing adsorption (PSA) applications. PSA units are a critical component for the entire operation (**FIG. 7**). Two (or more) adsorption beds operate in parallel, with one bed getting regenerated, while the others are online. These units typically provide very-high-purity hydrogen to the hydrotreating unit.

The PSA process typically requires many control valves, each constantly cycling open and closed as the beds are regenerated and placed online. In addition to the very high cycle counts, the valves are exposed to high temperature differentials, particulate and pressure from alternate sides. More importantly, the valves must stroke quickly and provide nearly zero leakage because slow-acting or leaking valves degrade purity and reduce production for the entire hydrotreating unit.

The best valves for this application will vary with the pressure and temperature requirements of the process. However, high-cycle, reliable, tight shutoff glove valves are often a good choice. A positioner with advanced diagnostics should be used to monitor valve stroke times and torque at closure, and to sound an alarm when a valve is falling out of specification and requires service.

Compressor anti-surge applications. The green diesel unit will usually employ one or more hydrogen compressors to pressurize hydrogen and feed it back into various points in the process. One of the most important valves on a centrifugal compressor is the anti-surge valve, which protects the machine.

During low-flow, high-discharge pressure conditions, the gas flow can instantaneously reverse through a compressor. When this occurs, the discharge pressure

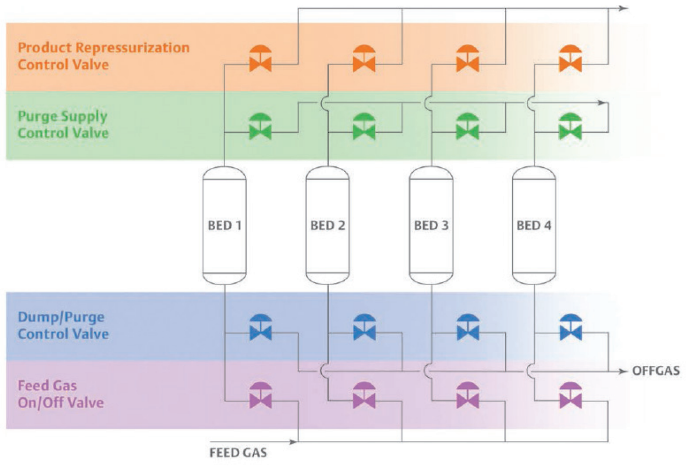

FIG. 7. The PSA process involves many control valves cycling 50,000 times/yr–200,000 times/yr. Each valve must stroke quickly and provide tight shutoff.

immediately falls and the gas flow surges forward again, repeating the cycle. Once compressor surge starts, the repetitive flow reversals can shear turbine blades, destroy bearings and take a compressor out of commission for months.

An anti-surge valve is installed on the discharge of the compressor and tied back to the suction. If the flow through the compressor falls too low or a surge is detected, then this valve is instantly opened to establish forward flow and to take the compressor out of surge.

Surge valves must be carefully designed to respond very quickly, often moving between 0%–100% or any position in 1 sec–2 sec, while passing very high flows. Despite the very high pressure drop and temperatures, these valves must provide precise control. Reliability is paramount for this valve. If it fails to function as designed, the compressor can be destroyed in seconds, so a simple, highly robust valve design is important.

Recent advances in volume capacity allow some positioners to replace the typical combination of positioner and volume boosters that is normally found on most anti-surge valves. These same advanced positioners also offer advanced diagnostics and partial stroke testing to ensure that the anti-surge valve will work when called to action.

Takeaway. Green diesel shows much promise to reduce carbon intensity by replacing some of the petroleum-based diesel now being produced. Although the production process for green diesel is like that for standard diesel, green diesel does pose challenges, including proper selection of control valves and related components. Design engineers must be careful to choose the right alloys and valve designs to provide high performance and long service life.

If a refining unit is considering upgrading to green diesel production, it is important to take the time to understand the options and evaluate the various valve technologies available. New alloy offerings and new valve designs can significantly improve valve performance and service life, and consultation with your valve vendor can ensure proper selection. HP

NOTES

[a] Fisher DST-G valve
[b] Fisher HP series control valves

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