Howden
A Chart Industries Company

White paper

Hydrotreated Vegetable Oil

Sustainable fuels production from bio and waste feedstock

Revolving Around You™

www.howden.com

Abstract

Howden, a Chart Industries Company, has a long record of achievements in its 165-year history.

Howden combines technology and worldwide engineering expertise to design and deliver solutions for our customers.

The oil and gas industry traditionally focuses on extracting and processing oil and gas resources in a safe and cost-effective manner. The industry is also actively addressing concerns around global warming and environment preservation, for instance, through development of renewable fuels from bio-based feedstocks. This is an important part of the energy transition process, which requires harnessing the collective knowledge and expertise across the value chain. All players must work together on solutions to achieve short and mid-term environmental objectives.

Howden equipment is operating in the new generation of refinery units dedicated to the production of renewable diesel (RD), sustainable aviation fuel (SAF) and other bio and waste-sourced products. Converting vegetable oils, waste /by-products and other renewable feedstocks into biofuels requires high-pressure hydrogen compressors continuously supplying the large flow rates of gas needed for hydrogenation and isomerisation reactors.

Howden's knowledge for the engineering of reciprocating compressors for hydrotreating applications, and air blowers for sulphur recovery units (SRU) is very robust, with large installed bases already in place at refineries across the world. Equipment selection is carefully conducted with licensors and end-users, taking into consideration site-specific conditions, and ensuring reliable and safe operation. At Howden, sustainability is deeply rooted in what we do, and we work in partnership with our customers to deliver reliable and tailored solutions that minimise the total cost of ownership (TCO).

Reciprocating compressor

API618

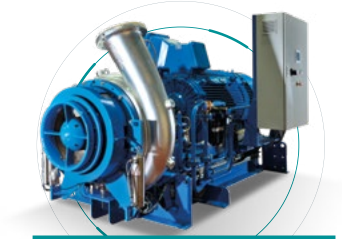
H_2 and acid gas compressor

Steam turbine

API611

Steam turbine generator

Turbo blower



API617/672

Air blowers for sulphur recovery

Screw compressor

API619

Oil Injected / Oil Free

Tail gas compressors

Summary

Acronym list

CVC	Combined vane control
FAME	Fatty acid methyl esters
HEFA	Hydroprocessed esters and fatty acids
HDN	Hydrodenitrification
HDO	Hydrodeoxygenation
HDS	Hydrodesulphurization
HGU	Hydrogen generation unit
HVO	Hydrotreated vegetable oil
MOV	Most open valve
NG	Natural gas
PD	Positive displacement
PSA	Pressure swing adsorption
RD	Renewable diesel
SAF	Sustainable aviation fuel
SG	Single-stage, integrally geared
SMR	Steam methane reformer
SRU	Sulphur recovery unit
TCO	Total cost of ownership
VFD	Variable-frequency drive
ZLD	Zero liquid discharge

What is hydrotreated vegetable oil?

HVO represents a new generation of biofuels. HVO can be produced by the hydroprocessing of a vast array of raw materials containing triglycerides and fatty acids, such as vegetable oils, fats, a wide range of waste products, used cooking oils, fatty acid distillates, acid oils, etc. HVO is an important part of the production of renewable diesel and sustainable aviation fuel (SAF).

Why is HVO important?

Refineries continue to develop units for renewable fuels production from sustainable sources. The use of renewable fuels based on HVO results in up to 90% reduction in net CO_2 emissions. It is a key and fast-growing component of the energy transition. When produced using waste and by-products, HVO has a low overall environmental footprint and a limited impact on food supply. This is a very significant advantage compared to first-generation biofuels.

HVO is chemically comparable to petroleum diesel and can be used without engine modifications, while also being cleaner-burning than diesel because, once processed, it contains no sulphur compounds or aromatics. It has a longer shelf life and requires less engine maintenance than conventional biodiesel based on fatty acid methyl esters (FAME). Compared to gasoline or diesel, the combustion of HVO emits less nitrogen oxides (NOx) and particulate matter (PM), and no sulphur oxides (SOx).

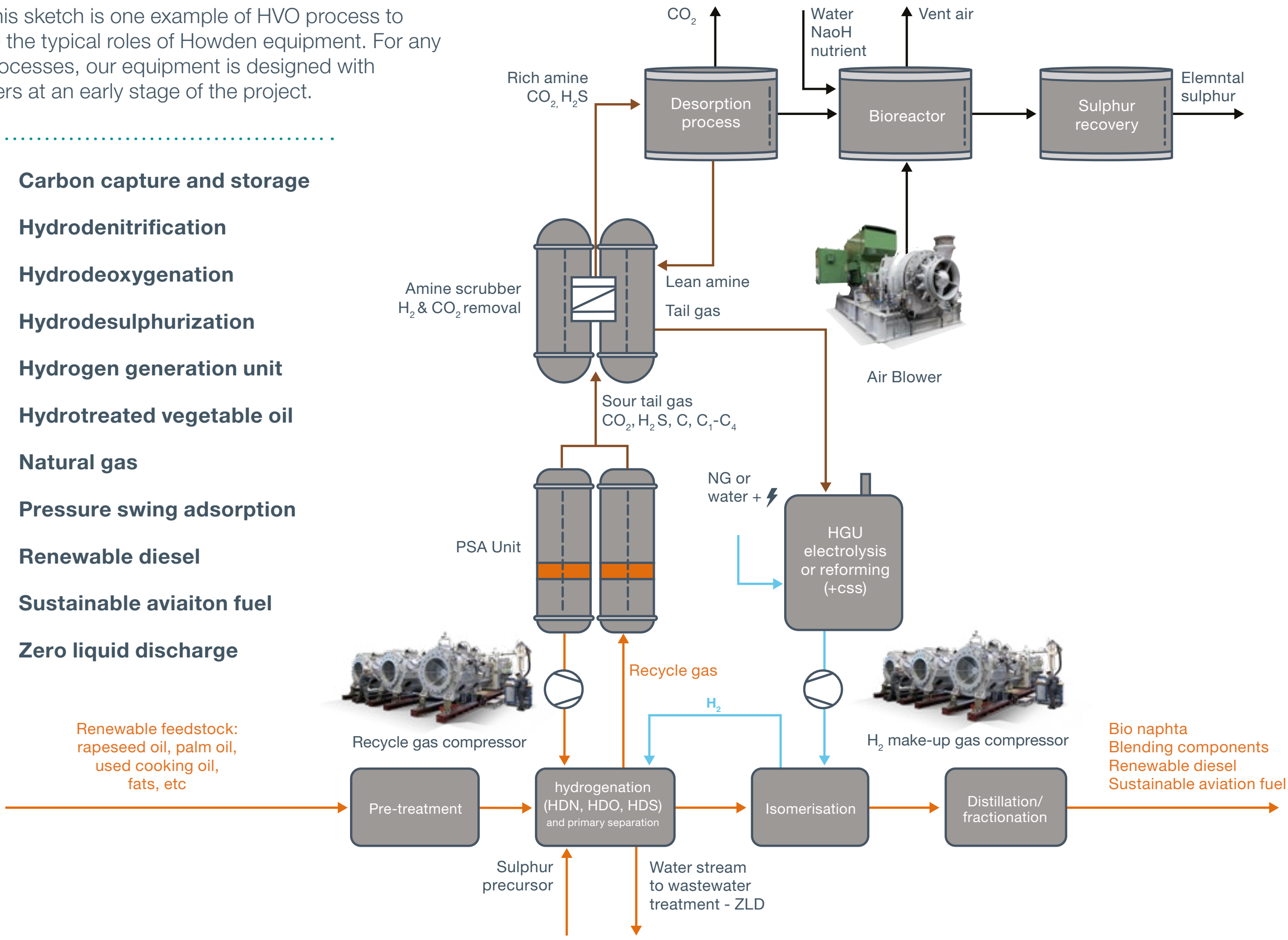
With increasing environmental initiatives, HVO and SAF are poised for substantial growth. New production capacity is coming online, supported by growing investments and favourable policy mechanisms around the globe. HVO and HEFA are expected to be the biggest sources for SAF in the coming decade.

Policies in the USA and Europe already support the demand development. European regulation mentions that aviation fuel must include 2% SAF from 2025, rising to 85% by 2050. HVO capacity will double between 2018 and 2024, according to the International Energy Agency (IEA).

Introduction to HVO process

Note: This sketch is one example of HVO process to illustrate the typical roles of Howden equipment. For any other processes, our equipment is designed with customers at an early stage of the project.

CCS	**Carbon capture and storage**
HDN	**Hydrodenitrification**
HDO	**Hydrodeoxygenation**
HDS	**Hydrodesulphurization**
HGU	**Hydrogen generation unit**
HVO	**Hydrotreated vegetable oil**
NG	**Natural gas**
PSA	**Pressure swing adsorption**
RD	**Renewable diesel**
SAF	**Sustainable aviaiton fuel**
ZLD	**Zero liquid discharge**



The production of HVO involves hydrogenation, hydrocracking and isomerisation using hydrogen and catalysts at moderate temperatures and high pressures. Co-products (e.g. bio-naphtha) and by-products (CO_2, elemental sulphur, and wastewater) are formed, which need to be collected for further processing and/or treating.

The process is summarised in the simplified process flow diagram above and consists of the following steps:

Feedstock pre-treatment

The bio-based feedstock first undergoes a pre-treatment process to remove fine particles and various impurities, depending on the type of feedstock. At this stage, contaminants such as trace metals, phosphorus, and chlorides are removed - through various pre-processing steps - to protect downstream equipment and maximise the hydrogenation catalyst lifetime.

Hydrodeoxygenation (HDO)

HDO is the first reaction step, in which unsaturated fatty acids are hydrogenated and triglycerides are broken down to obtain free fatty acids. Depending on the sulphur concentration in the feed stream, a small amount of hydrogen sulphide (H_2S) is required to maintain catalyst activity. This can be added into the reactor feed through the use of a precursor such as di-methyl di-sulphide (DMDS). There is a recycle gas loop including a pressure swing adsorber (PSA). PSA tail gas is routed to the sweetening process and treated gas is send back to the HDO reactor.

Hydrocracking treatment

The outlet stream from the catalytic deoxygenation step mainly contains normal (straight chain) saturated hydrocarbons in the C15–C18 range. This stream requires further processing through isomerisation and hydrocracking to reach a quality that meets the end-user criteria. This step improves cold flow properties (e.g., the freezing point of the mixture), while reducing the cetane number. Depending on the feedstock, processing technology and desired product quality, a catalytic dewaxing step could also be required.

PSA and sweetening process

During the sweetening process, downstream of the PSA, CO_2 and H_2S are extracted from the PSA tail gas by an amine absorber. The rich amine stream is regenerated and the mixture of CO_2 and H_2S is then directed to the SRU, which produces elemental sulphur. Even though the sulphur concentration in the feedstock is much lower compared to traditional refinery hydrotreating units, a highly flexible SRU is needed to account for the range of feed gas conditions.

Hydrogen generation unit (HGU)

The scrubbed gas can be burned on site for energy recovery or routed to the HGU, which produces H_2 for the main process. Since a large quantity of H_2 is required for the hydrotreatment and conversion units, this can either be supplemented by feeding additional natural gas (or biogas) to the steam methane reformer (SMR) unit, or by using green H_2 produced by electrolysis. To reduce process emissions, a CO_2 capture unit can be coupled with the reformer.

Water treatment

Water is a by-product in the HDO step, where it is separated from the process gas stream. Zero liquid discharge (ZLD) systems were based on thermal processes that take the wastewater and evaporate it in a brine concentrator followed by a brine crystallizer. The condensed distillate water is then collected for reuse, while the produced solids are recovered as by-products. Howden specialises in mechanical vapour recompression (MVR technology) for the evaporation within the brine concentrator.

How Industrial Industries Are Utilising Their Wastewater | Howden

Howden's expertise in the process

H_2 and acid gas reciprocating compressors

Processing bio feeds for HVO brings new challenges that reciprocating compressors can address together with new specialty catalysts based on design and formulations. The renewable organic material reacts with H_2 at an elevated temperature and pressure in a catalytic reactor, making the role of the compressor paramount.

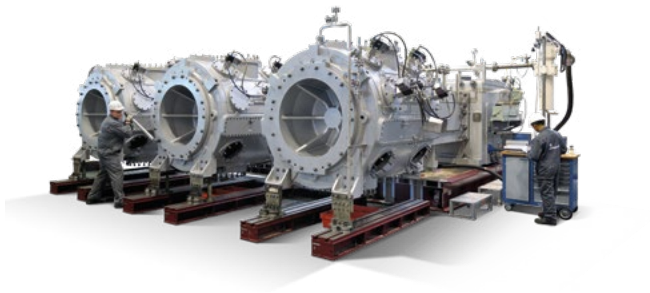
The HVO production process typically consists of two key steps: hydrotreating and hydroisomerisation. The first stage requires a reciprocating compressor for acid gas recirculation (PSA discharge back to reactor inlet). This compressor faces a highly corrosive duty due to the acid gas composition, which includes H_2S, CO_2, and H_2O.

Hydrogen makeup gas is typically introduced in the second processing step of hydroisomerisation, which operates at a higher pressure. Within this process, there is also a requirement for a second compressor to handle the high recycle gas flowrate. These two very different compression duties are combined in a single reciprocating compressor, integrating multiple dedicated cylinders and controls. Hence, the solution optimises premium space, reduces TCO, and increases energy efficiency, while delivering a flawless and resilient compression process.

Expectations related to process variations (pressure, temperature, capacity flow control), fluctuations (suction/discharge) and compressor operations (operating hours per year/number of starts and stops per day) are validated by the engineering team at an early stage so the final design stage of the compressor can be reached faster. Based on the compressor design, and duty, a mean time between maintenance (MTBM) can be defined so the available time can be guaranteed. Smooth installation of the compressor is prepared to save time on site – a package approach is taken wherever possible to accelerate installation time and reduce costs. We define the required LTSA with the customer, based on data from Howden Uptime.

We use the Howden Uptime digital twin technology as part of the advanced analytical techniques to gain unprecedented understanding of the compressor activity. This supports the delicate correlation between catalyst structures, function, and process operations.

Our API 618 reciprocating piston compressor technology has a high availability rate and long mean time between maintenance, with the Howden Uptime digital twin system and our global aftermarket service capabilities acting locally.



Reciprocating compressor API618

Tail and vent gas screw compressors

Screw compressors used in the refining sector are designed for heavy-duty applications. Screw compressors handle PSA tail gas with a composition of light hydrocarbons to feed the hydrogen generation unit or other processes. Screw compressors can handle the vent gas or tail gas from other units such as SRU. Oil -injected and oil-free technologies can be selected according to the presence of impurities in the gas composition.

Pressure swing adsorption (PSA) compressors

Bioreactor SRU air blowers

The Howden SG range of packaged turbo blowers, used in the bioreactor feed air application, benefits from the extensive installed base in the Claus process for SRUs.

If a single blower is used for the bioreactor system, the energy efficiency of the blower is maximised by controlling the output of the blower based on either the measured dissolved oxygen levels in the reactor or the calculated flow requirement. Using the blower guide vanes to regulate the output removes the requirement for any downstream control valves, reducing the capital cost and control system complexity.

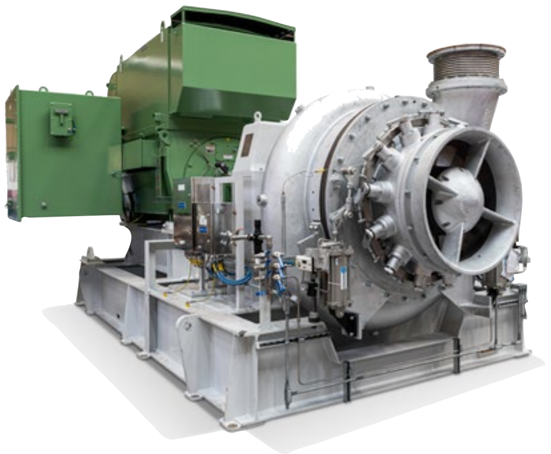
Where either single or multiple blowers are used for multiple bioreactors, downstream distribution/control valves are required. However, the energy efficiency of the system can again be maximised by regulating the blower output using most open valve (MOV) control algorithms, a principle successfully applied by Howden for turbo technologies. MOV can be applied to the sulphur recovery unit to control air levels in the process from the turbo blower, with minimum energy consumption.

With Howden's innovative inlet and outlet guide combined vane control (CVC) system, significant further energy efficiency gains can be made. Improved efficiency and removal of unnecessary controls and their associated systems have the combined advantage of reducing both CAPEX and OPEX costs. By using Howden's CVC system, it is possible and encouraged to remove unnecessary, additional capacity control equipment, such as variable-frequency drives (VFD). A VFD is often specified for alternative compression technologies, for instance positive displacement (PD) machines. While VFDs are effective with PD machines, they reduce the operating envelope for the centrifugal technology with CVC and are an unnecessary additional cost.

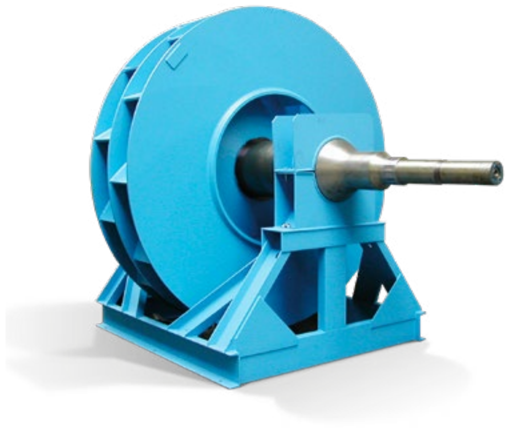
The technical specifications applied to blower technology tend to be project specific requirements, alongside industry standards such as API 672, 617 and 614. SG blower packages have been installed in numerous bioreactor processes around the world for decades. These systems are designed to optimise the process reaction and power efficiency requirements of these applications.

Carbon Capture and Storage

Fans, blowers and compressors extract the CO_2 from the processes, and compressors boost the gas collected CO_2 for transport to treatment, utilisation or storage.



SRU air blowers



Carbon capture and storage (CCS) - CO_2 recovery fans

Howden Uptime

Howden Uptime increases the reliability and availability of process critical assets.

These digital solutions gather the physical sensor data from any kind of rotating equipment, while also:

- **Avoiding unplanned downtime**
  Users will be alerted to any unusual activity and prescriptive advice provided.
- **Extending maintenance intervals**
  Smart and predictive maintenance scheduling allows safe maintenance intervals.
- **Keeping expert advice on hand**
  Intuitive and customisable dashboards provide a real-time view of the critical data for your equipment. This allows closer interaction with Howden experts and instant access to equipment documentation and service history.
- **Providing secure data solutions**
  Robust and verified security is in place to safely manage the transmission of data at every stage in the data journey.

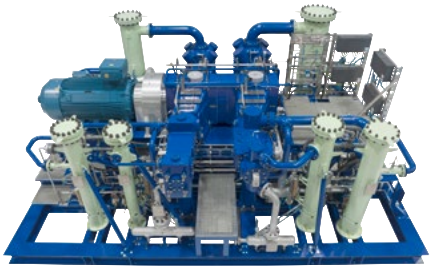
Conclusion

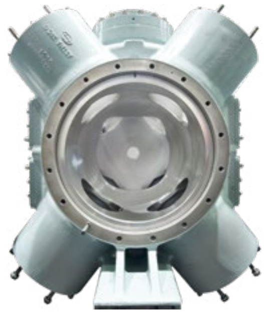
The capacity to produce sustainable fuels is ramping up, supported by environmental regulation. HVO production is expected to double over the 2020-26 period from 0.12 mbpd to 0.3 mbpd. Production capacity will increase even more rapidly with 0.38 mbpd additions over the same period. Projectsare located at stand-alone HVO plants or integrated within existing refineries.

Multiple air and gas handling technologies are required for HVO process units. The use of new catalysts and reactors for HVO production requires a precise selection of embedded equipment, which is able to respond to these new demanding conditions.

Processing equipment must provide flexible performance to deliver the required flow and pressure, together with good efficiency for energy saving, and a high reliability to avoid stops and maintenance costs. Robust, high-performance solutions are required to match typical refinery site requirements with API design guidelines, ATEX classification rules, and high-quality grade materials required for handling aggressive gases. Selecting high-efficiency equipment and implementing energy management systems results in substantial energy savings. Combined with the avoidance of unplanned downtime, this has a positive impact on the TCO. Optimum equipment selection is the result of close collaboration between the project developer and the equipment supplier, to ensure a good understanding of the operating conditions and process requirements.

References





Netherlands

Hydrotreatment reciprocating compressors	Notes
H_2 makeup and acid gas recycle	Design option for a wide range of gases
API618	Designs up to 75 bar
Pressure from 1.5 to 200 Bara	Any operator standards applicable
Free floating piston to increase MTBM	Oil-free design available

India

SRU blowers	Notes
6 x API 617 turbo compressors	Pressure ratios 1-3
2 x 1060kW turbine + 1 x 1060kW motor	Constant pressure turndown to <35%
2 x 725kW turbine + 1 x 725kW motor	Maximised operating efficiency
AP617 and national standards applicable	Designed for maximum availability of plan

Kuwait

PSA tail gas screw compressors	Notes
Hydrocarbon gas 16 000 Am3/h	Design option for a wide range of gases. Capacity control.
Inlet Pressure 1.21BarA - Outlet Pressure 10 BarA	Designs up to 75 bar
API 619	Any operator standards applicable
Oil injected	Oil-free design available

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