Hamworthy

VOC Recovery and Power Generating System

Gas Systems

VOC emission problem

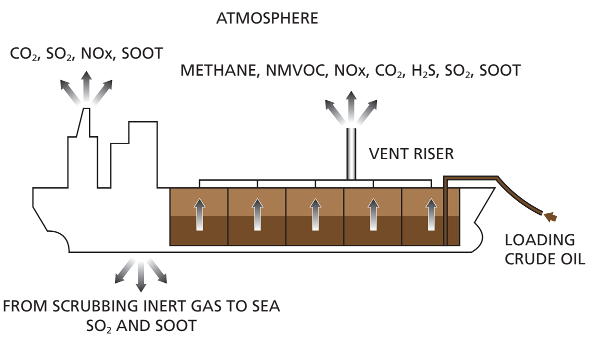
Volatile Organic Compounds (VOC) emissions from the global sea transportation of crude oil and associated products represent in total more than 5 million tons per year.

Emissions consist of a mixture of light-end hydrocarbon components from methane and ethane, to heavier fractions such as heptane and pentane. The gases are evaporated from the crude oil surface in the cargo tanks when loading and transporting the crude oil.

Loading of crude oil
Light crude (API 30 and up) can contain up to 5 % VOC. Actual VOC emissions are found to be in the range of 0.08 to 0.15% of the total cargo volume loaded, corresponding to 50 - 200 tons of VOC emissions per loading depending on the size of the vessel.

Sailing
Temperature and duration of voyage will have an effect of the amount of VOC releases.

EMISSIONS FROM A CRUDE OIL TANKER, FSO



Environmental effects

Environmental impact to the atmosphere is wide ranging as VOC consists of more gas fractions.

- **Methane is a greenhouse gas and the effect of one unit emitted is equivalent to 21 units of CO_2 emitted.**
- **The non methane fractions of VOC (NMVOC) react with nitrous oxides and create a toxic ground level ozone and smog layer, which has detrimental environmental effects on vegetation and on human health – particularly on eyes and lungs.**

Regulations

Splitting up VOC emissions in Methane and NMVOC is done in order to treat the emissions within existing regulations:

- **The *Kyoto convention* treats Methane as a greenhouse gas similar to CO_2.**
- **UN ECE (The Gothenbourg Protocol) states that NMVOC emissions are to be reduced by 30% from the level in 1990 in 2010. For Norway this goal is already about to be achieved, due to VOC recovery onboard shuttle tankers in the North Sea.**
- **IMO is active in describing how to handle the VOC emission (VOC management plan). However, today it is up to the national governments to impose regulations within their own territories.**

Hamworthy solution

Without VOC equipment, emitted crude oil vapours, - and inert gases are vented through the vent riser when loading the vessel, and during transit.

A VOC plant in operation will ensure that the pressure in cargo tanks is maintained low enough to keep the vent valve to riser shut, ensuring no VOC emitted!

The gas is instead fed to the VOC recovery module, where it is treated by compression and condensation. The liquefied gas is fed to the VOC fuel tank.

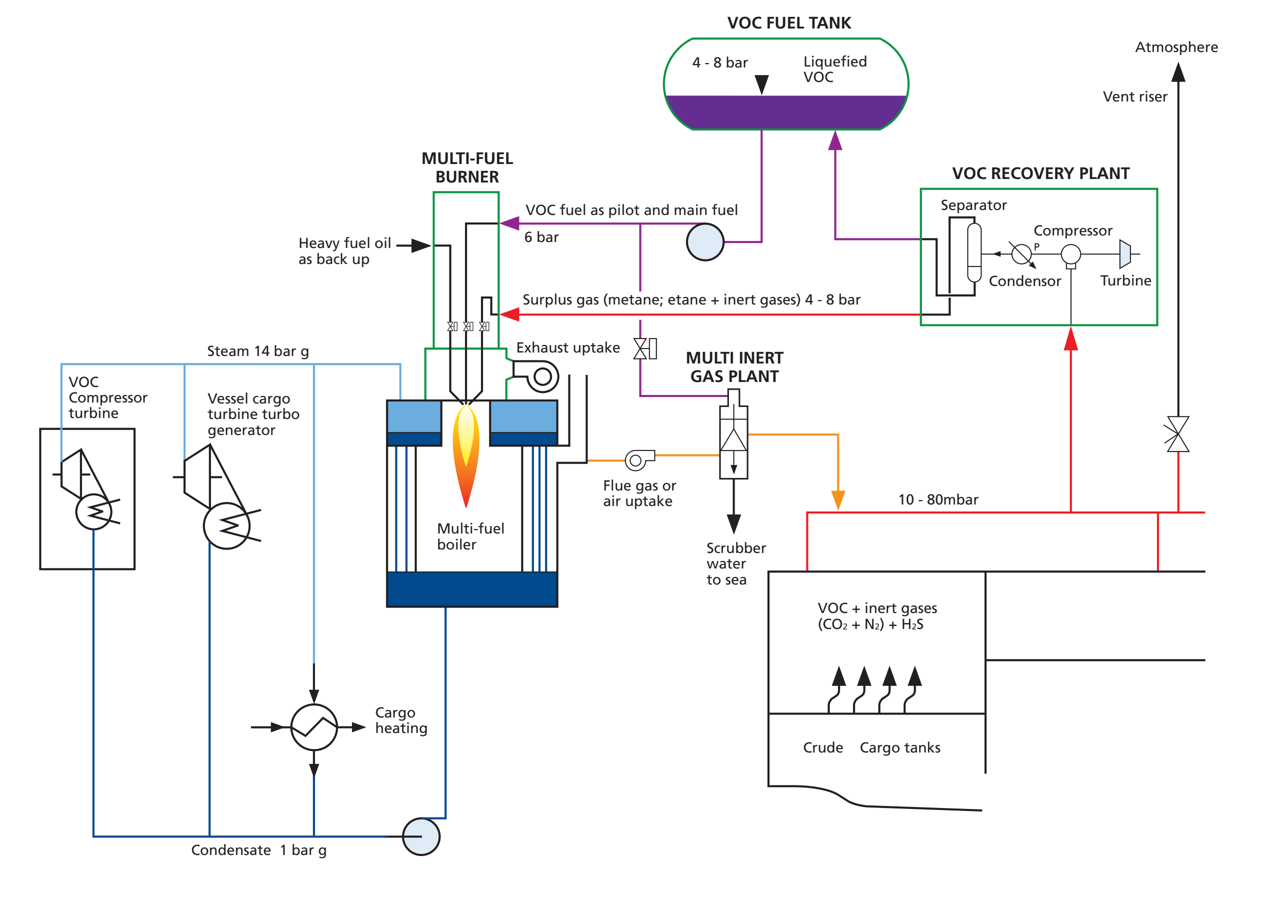
The light HC fractions however are not condensable with the pressures and temperatures set in the plant. These gas fractions and inert gases make up a surplus gas that should not be emitted to atmosphere (mainly Methane). The surplus gas is therefore used as a supplemental fuel for the boiler. Up to 90% of the energy fed to the burner will be from the surplus gas, during operation of the plant. This is done by a patented* system converting the energy in the vapours to steam as energy carrier.

Any dangerous H_2S is also combusted with the surplus gas forming SO_2 in the exhaust.

When there is additional need for steam during discharging or cargo heating the stored VOC fuel, a pure and highly potent fuel (LPG mix), is ideal for further power generation onboard the vessel. Ensuring clean operation of boilers and clean inert gas supply to cargo tanks and finally exhaust emissions without SO_2 and reduced NOx.

* Ref. US Patent: 7032390. Also for several other countries.

SYSTEM ARRANGEMENT



Features and benefits

Zero VOC gas venting
Compliance with all future VOC emission regulations

Benefits of combusting the light VOC components:

- Methane converted to CO_2 (10 times less environmentally damaging
- Any dangerous H_2S safely converted to SO_2
- Surplus energy used to produce steam for powering VOC recover plant

Burning ‘free’ liquid VOC fuel in boilers instead of HFO would:

- Provide for sufficient energy in the VOC fuel to cover the vessel steam demand
- Save up to $10 million per year (high capacity FSU)
- Investment in revenues down to <2 years
- Get cleaner boilers exhaust by:
  - Reducing NOx by 80%
  - Eliminate SO_2 and particulates
- Eliminate acids and ash in the furnace for clean and maintenance free boilers
- Production of clean inert gas with flue gas and inert gas generators

BOILER WITH MULTI-FUEL BURNER

Light VOC components burning. Disposal of H2S in the gas.

VOC RECOVERY PLANT

VOC FUEL STORAGE TANK

Heavy VOC components converted into pure liquid VOC fuel (an LPG mix of mainly propane and butane).

CARGO TANK VENT RISER

Up to 25,000 tonnes per year of environmentally damaging VOC gases are normally vented into the atmosphere.

VOC recovery plant

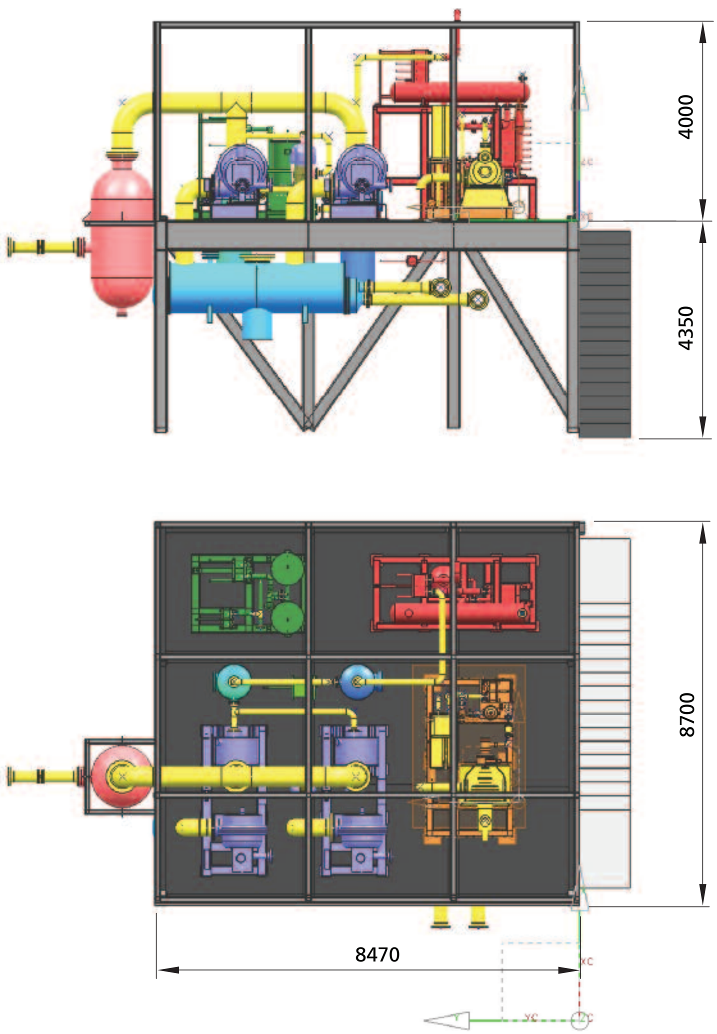
The VOC recovery system must be engineered to the vessel's cargo handling capacity, as gas recovery capacity is linked to the loading rate of the vessel.

Typical VOC recover plant specification

Model	Capacity (Nm³/h)	Dimensions (m) Length x width x height	Approximate weight (tonnes)
VOC recovery plant Q1000	200 - 1000	6.0 x 7.0 x (3.5 + 3.0*)	30
VOC recovery plant Q3000	600 - 3000	7.0 x 8.0 x (3.5 + 3.5*)	50
VOC recovery plant Q6000	1200 - 6000	8.5 x 9.0 x (4.0 + 4.3*)	60
VOC recovery plant Q8000	1600 - 8000	9.5 x 9.5 x (4.0 + 4.3*)	100
VOC recovery plant Q16000	3200 - 16000	10.0 x 10.0 x (4.5 + 4.3*)	140

*Foundation height is made up from pillars and crossbars from the deck.

EXAMPLE OF VOC RECOVERY PLANT Q6000



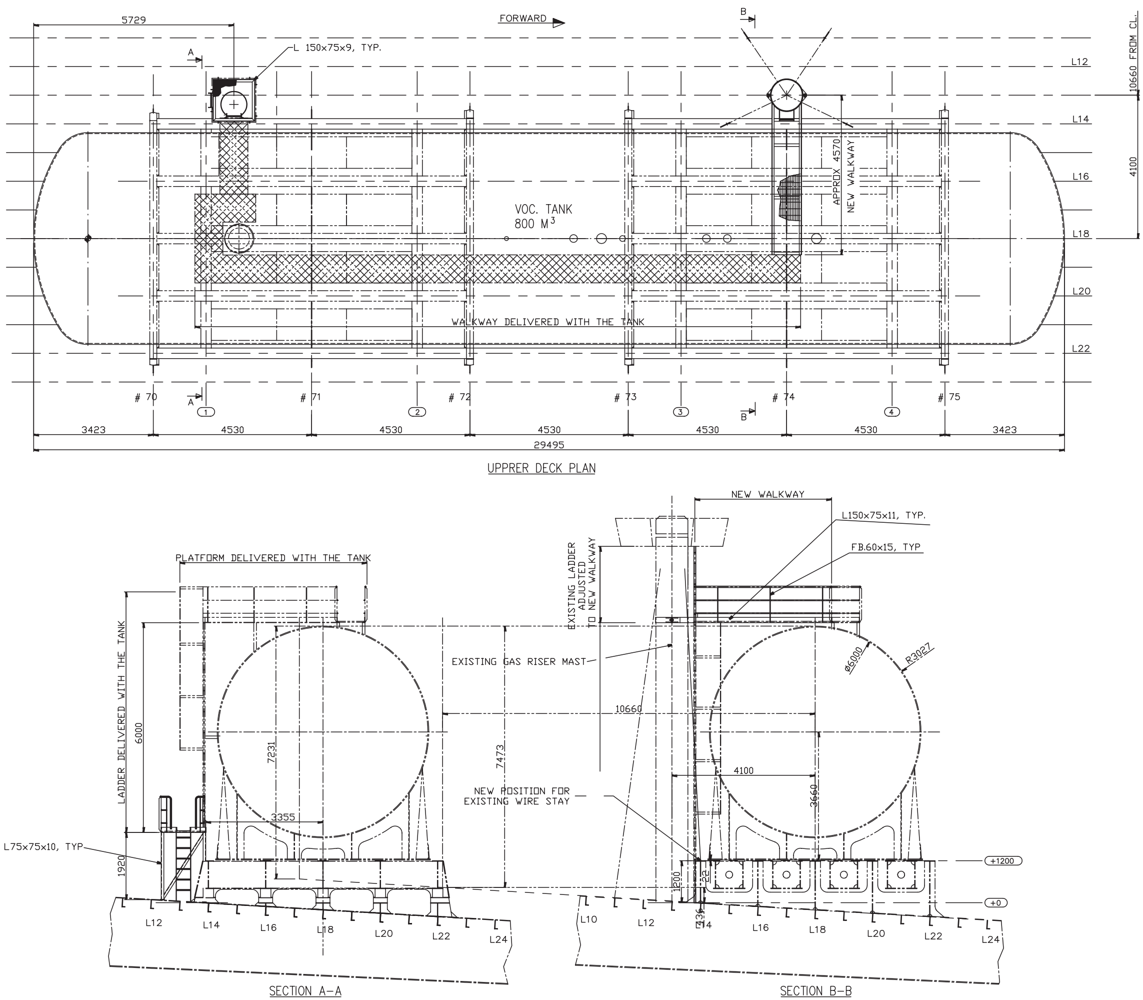
VOC fuel tank

VOC fuel tanks are cylindrical horizontal tanks that are supported on deck foundationsand are usually located on the vessel's main deck in the cargo area. VOC fuel storage capacity is linked to the vessel size and discharging frequency.

Typical VOC fuel tank specification

Model	Maximum capacity (m^3)	Dimensions (m) Height x length	Weight, empty excluding foundation (tonnes)	Weight, full excluding foundation (tonnes)
HGS VOC fuel tank 100	90	3.0 x 15.0	17	75.5
HGS VOC fuel tank 200	180	3.5 x 21.0	32	149
HGS VOC fuel tank 300	270	4.0 x 24.0	47	223
HGS VOC fuel tank 400	360	4.5 x 26.0	73	307
HGS VOC fuel tank 800	730	6.0 x 29.0	140	615

EXAMPLE OF A 800M³ VOC FUEL TANK



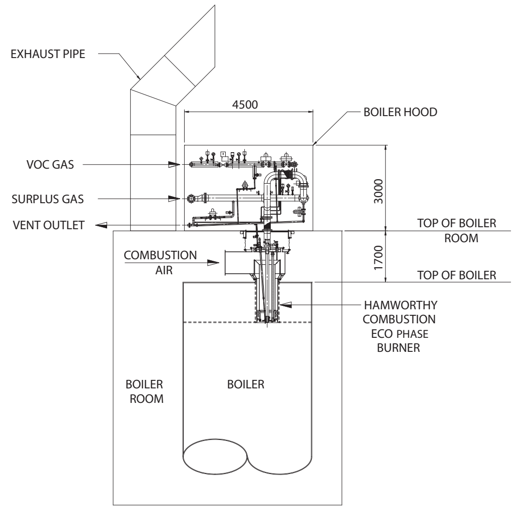
Multi fuel (VOC) fired boiler

A new boiler can be supplied, or an existing auxiliary boiler can be converted by fitting a multi fuel combustion system. A specially developed burner is supplied to fire all of the surplus gas. The surplus gas composition and capacity will vary during VOC recovery operation, from a high inert content to a high hydrocarbon mixture at the end of loading. With high inert content gas a small amount of VOC fuel is burned to ensure stable cis not in operation, the boiler can be fired up to the maximum on VOC fuel to produce steam for users including:

- **Steam driven cargo pumps**
- **Cargo heating**
- **Electric power production with turbo generators**

The boiler can also be fired on HFO as a standby fuel. Boilers are normally down fired and the burner fuel valve and instrumentation systems are enclosed in a burner hood as shown in the typical arrangement drawing (right).

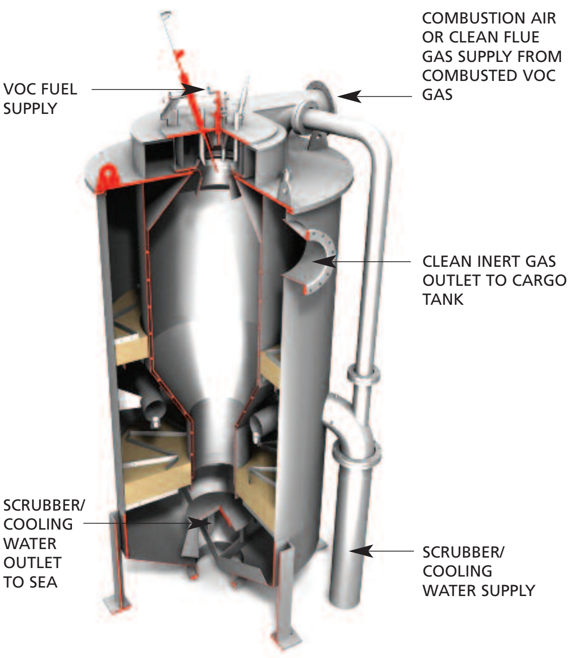
CROSS SECTION OF A BOILER/BURNER UNIT DRAWING. COURTESY OF HAMWORTHY COMBUSTION



Multi fuel (VOC) fired inert gas generator

Inert gas production onboard is improved by using clean VOC gas as fuel. No sulfur or soot particles are washed out to sea, and cargo tanks atmosphere is improved by reduced corrosion and cleanliness. As inert gas generation can be changed from diesel/HFO to "free" VOC gas substantial operating costs are gained.

HAMWORTHY INERT GAS GENERATOR



Auxiliary equipment

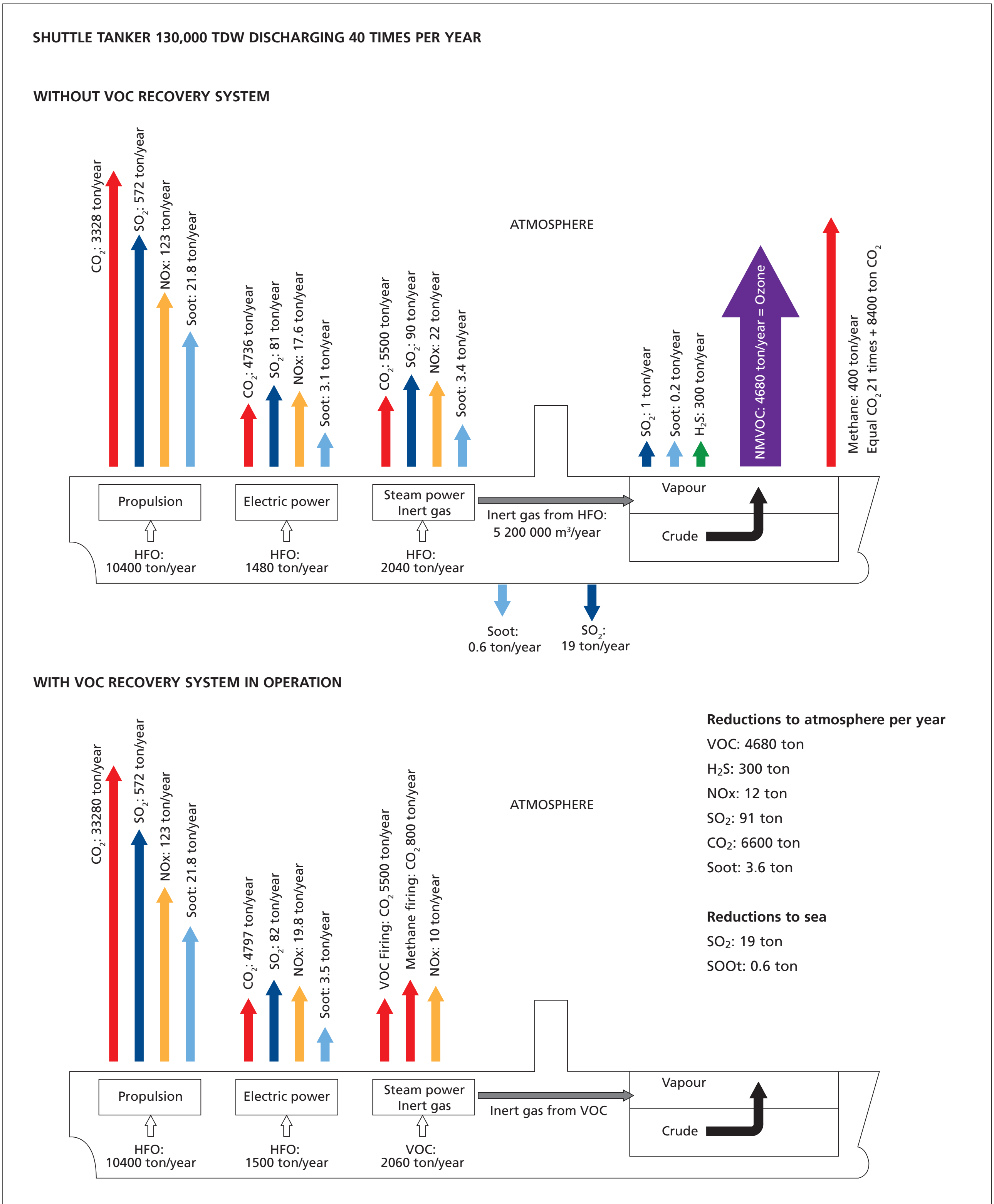
In addition to the main components, the plant is delivered with separate auxiliary equipment including:

- **Cooling water and fuel pumps**
- **Starter cabinets**
- **Control system**
- **Valves**
- **Instrumentation**

Making up a complete equipment package, Piping, foundations and installation of equipment may be supplied by Hamworthy Gas Systems or arranged by the customer.

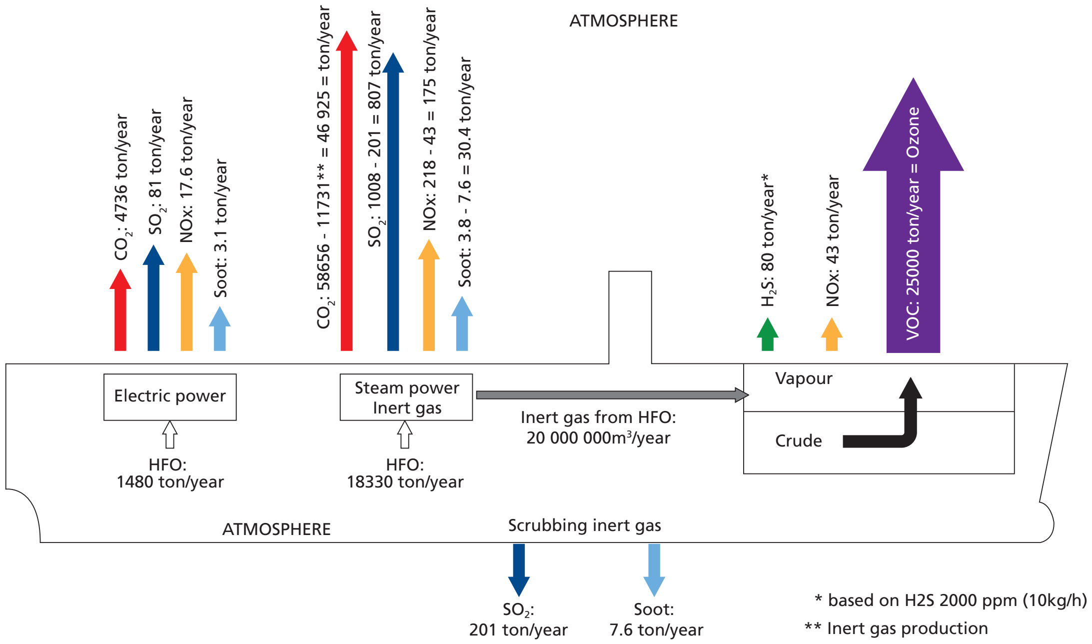
Overall emissions

Below is shown two examples on how emissions are reduced when installing a VOC recovery system. Exhaust emissions (SO_2 and NOx) will be further regulated in the future. Retrofitting a VOC recovery plant can for some installations make an operating vessel compliant with future exhaust emissions restrictions without further modifications.



FLOATING STORAGE UNIT LOADING 27,000,000 M[3] PER YEAR

WITHOUT VOC RECOVERY SYSTEM



WITH VOC RECOVERY SYSTEM IN OPERATION

Reductions to atmosphere per year

VOC: 25 000 ton

H_2S: 80 ton

NOx: 221 ton

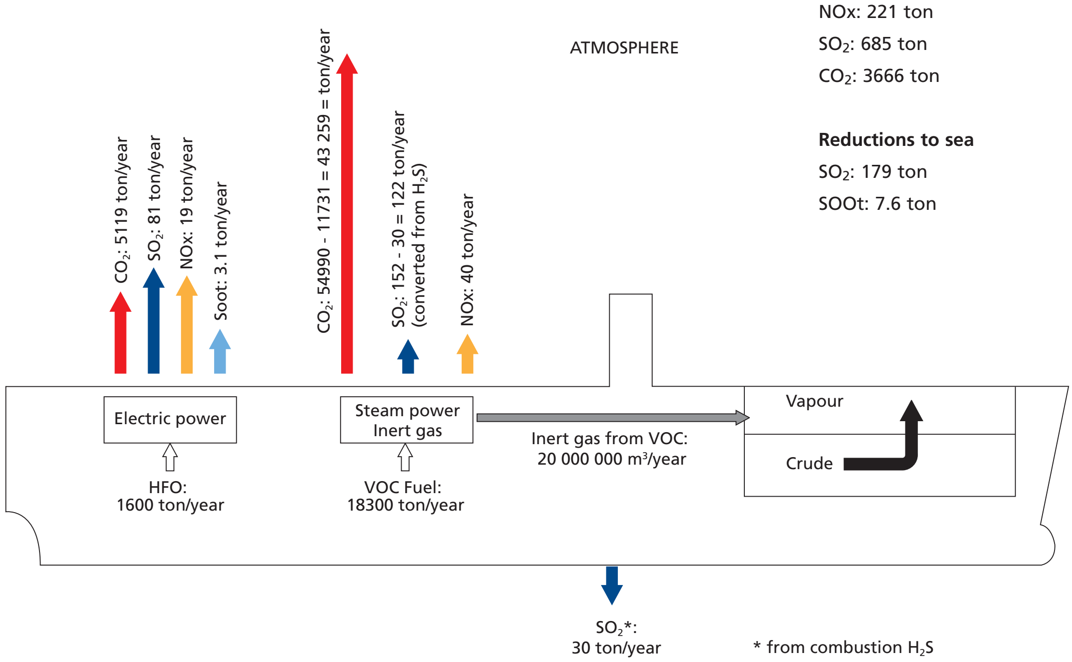
SO_2: 685 ton

CO_2: 3666 ton

Reductions to sea

SO_2: 179 ton

SOOt: 7.6 ton



400m³ VOC fuel tank being installed onboard Shuttle tanker *'Navion Viking'*

Reference list

Shuttle tanker *'Navion Viking'*

Shuttle tanker *'Stena Alexita'*


Shuttle tanker *'Navion Hispania'*

VOC recovery systems installations

System	Year
Shuttle tanker, '***Navion Viking'*** : North Sea VOC gas handling capacity: 7000 m³/h VOC used a main combustible to propel the vessel VOC plant electrically driven	1998
Shuttle tanker, ***'Stena Alexita'*** : North Sea VOC gas handling capacity: 16 000 m³/h Partly integrated for vessel steam production	2003
Shuttle tanker '***Navion Hispania'*** : North Sea VOC gas handling capacity: 16 000 m³/h No integration to vessel steam production	2004
Shuttle tanker '***Navion Britannia'*** : North Sea VOC gas handling capacity: 16 000 m³/h No integration to vessel steam production	2005
'Navion Scandia' : North Sea VOC gas handling capacity: 16 000 m³/h No integration to vessel steam production	2005
Shuttle tanker '***Stena Sirita'*** : North Sea VOC gas handling capacity: 16 000 m³/h Partly integration with vessel steam production	2006
Shuttle tanker '***Grena'*** : North Sea VOC gas handling capacity: 16 000 m³/h Full integration with vessel steam production	2006
Shuttle tanker ***'Stena Natalita'*** : North Sea VOC gas handling capacity: 16 000 m³/h Partly integration with vessel steam production	2007

DNV

NORWEGIAN ACCREDITATION
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