EFRC Training Workshop

Control of Emissions in Reciprocating Compressor Systems

Emission Reduction within NAM

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NAM

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UPHOLDING THE ENVIRONMENTAL CREDIBILITY OF GAS

PROVIDING MORE AND CLEANER ENERGY

With world population expected to increase by a billion by 2030, gas is one of the few energy sources that can meet growing demand while reducing greenhouse gas emissions.

Using natural gas instead of coal or diesel is helping to **reduce carbon dioxide and improve air quality.**

Gas supports an increasing role for renewables, **providing support for wind, solar and hydroelectricity,** helping match the supply and demand of cleaner electricity.

Gas will continue to play a **critical role in difficult to electrify sectors** such as the production of steel, cement and chemicals, as well as long-distance transportation.

SECURING THE FUTURE OF GAS

To realise greater greenhouse gas emissions benefits, the gas industry must increase its focus on **reducing emissions of methane across the supply chain.**

EXAMPLES OF SHELL'S GAS AND LNG SUPPLY CHAINS*

The supply chains – which include Shell assets as well as operations run by third parties – cover the full process (including liquefaction for the LNG supply chain) that gas molecules undertake from production to point of delivery to the customer.

Across over 80% of Shell's total gas and LNG supply chains, Shell estimates that the **methane emissions intensity is less than 1%.**

Netherlands	UK	USA	Australia QGC
0.1%-0.4%	~0.5%	~0.6%	~0.3-0.7%

WHAT IS METHANE?

Methane is a potent greenhouse gas, which has a **higher impact on global warming than carbon dioxide**. It is emitted during the production, processing, transport and incomplete combustion of oil and natural gas.

WHERE DOES METHANE COME FROM?

Globally, around **60% of total methane emissions come from human activities,** according to the IEA.

The remaining **40%** of global methane emissions are naturally occurring, from natural seeps, wetlands, animals such as termites, and vegetation decay.

About **13%** of total global methane emissions come from oil and gas related activities, split roughly equally.

IMPACT ON GLOBAL WARMING

Greenhouse gas emissions from natural gas are lower than coal in electricity generation up to a methane leakage rate of 3.5% when measured over 20 years.

This jumps to 7.5% over 100 years.

Today, the IEA estimates that natural gas operations have an average **methane leakage rate of 1.7%**

At this rate, natural gas emits between 45% and 55% lower greenhouse gas emissions than coal.

1.7%

SHELL TARGET

2025

Shell has announced a target to maintain methane emissions intensity below 0.2% by 2025.

This target covers all oil and gas assets for which Shell is the operator.

DATA UNCERTAINTY

The total methane intensity number is an estimate only as there continue to be limitations to the comprehensive measurement of methane emissions.
Regulatory recording and reporting requirements for methane emission varies significantly between countries. We are working, both within Shell and in collaboration with other oil and gas producers, to improve the accuracy of the quantification of methane emissions data.
*We acknowledge these calculated percentages use data from third party sources, including countries' national greenhouse gas inventories. Calculations for the Shell operated parts of the supply chains are based on 2017 data.

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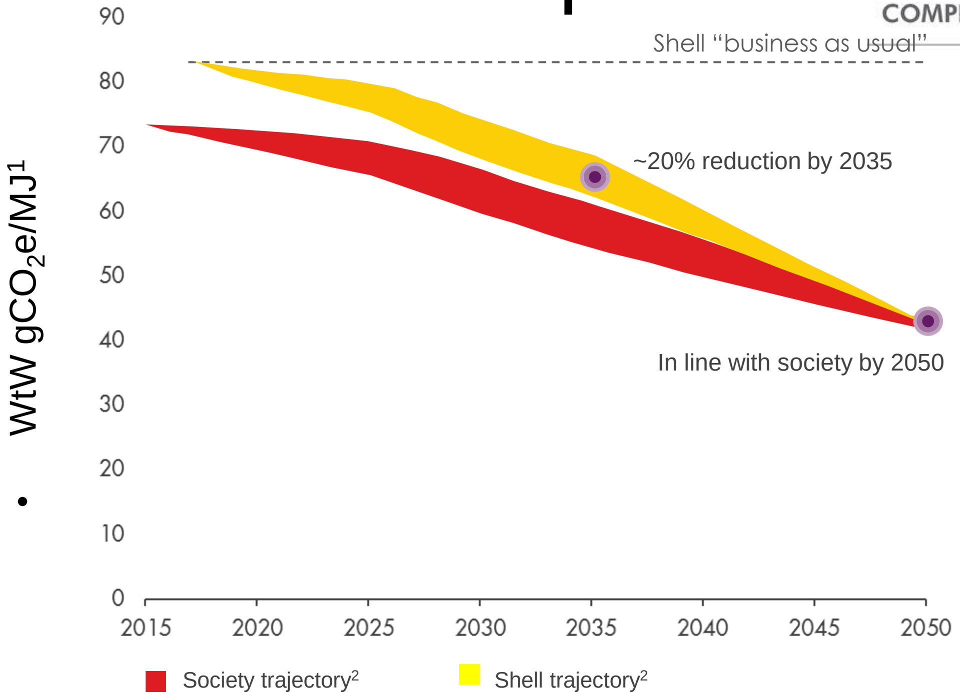
Ambition to reduce Net Carbon Footprint[1] of our energy products by around 20% by 2035

- Covers full range of emissions from energy products
- Aim to reduce overall intensity including production, supply chain, and customers
- Government policy, technology, and consumer choice will drive actual energy transition pace and outcomes
- Drive strategy over time in step with society
- 5-year reviews to ensure in line with societal progress

Ambitions:

- **Reduce Net Carbon Footprint[1] of our energy products by ~20% by 2035**
- **Be in line with society Net Carbon Footprint by 2050**

Ambition for Net Carbon Footprint[1]

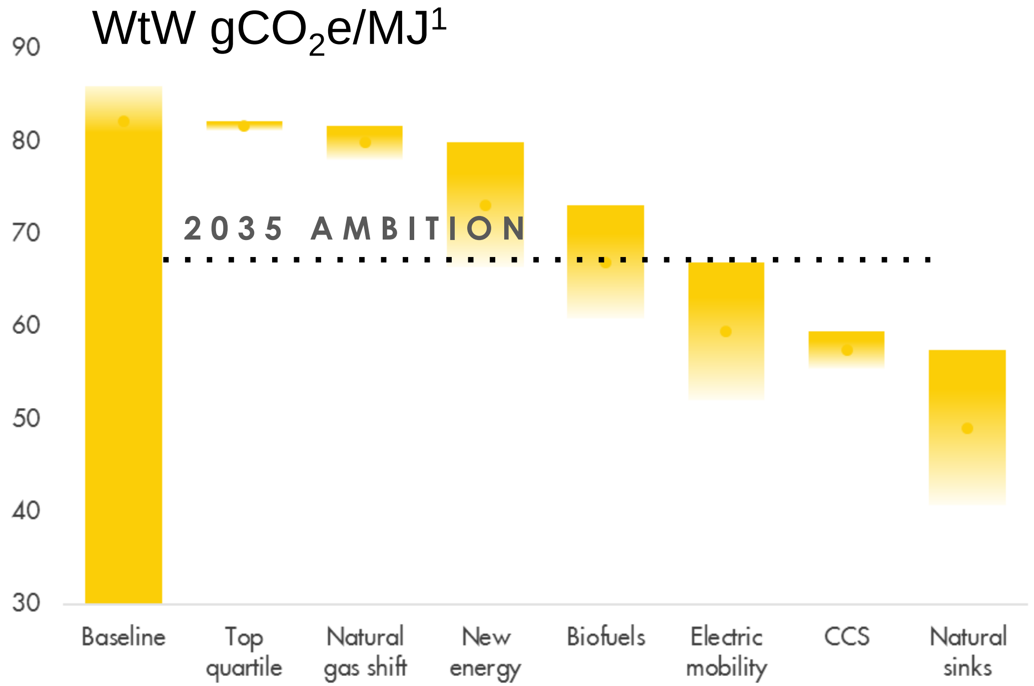


1: Net Carbon Footprint measured on an aggregate "well to wheel" or "well to wire" basis, from production through to consumption, on grams of CO_2 equivalent per megajoule of energy products consumed; chemicals + lubricants products are excluded. Carbon Footprint of the energy system is modelled using Shell methodology aggregating lifecycle emissions of energy products on a fossil-equivalence basis. The methodology will be further reviewed and validated in collaboration with external experts.

2: Potential society trajectory includes analysis from Shell scenarios estimate of Net Zero Emissions by 2070 and IEA Energy Technology Perspectives 2017; Potential illustrative Shell trajectory

GHG TARGETS -SHELL NET CARBON FOOTPRINT AMBITION 2035

- Flexibility and mix of options to achieve ambition
- Allows for oil and gas production growth offset by evolving product mix
- Changing product mix gives greatest opportunity
- Top-quartile scope 1 + 2 emissions has limited overall impact



Scope1: direct emissions

Scope2: indirect emissions

Scope 3: emissions related to use of product by end user

Existing examples:

Flare reduction | Increased LNG | Wind power | Raìzen biofuels | Shell Recharge + New Motion | Quest CCS | Nature based offsets

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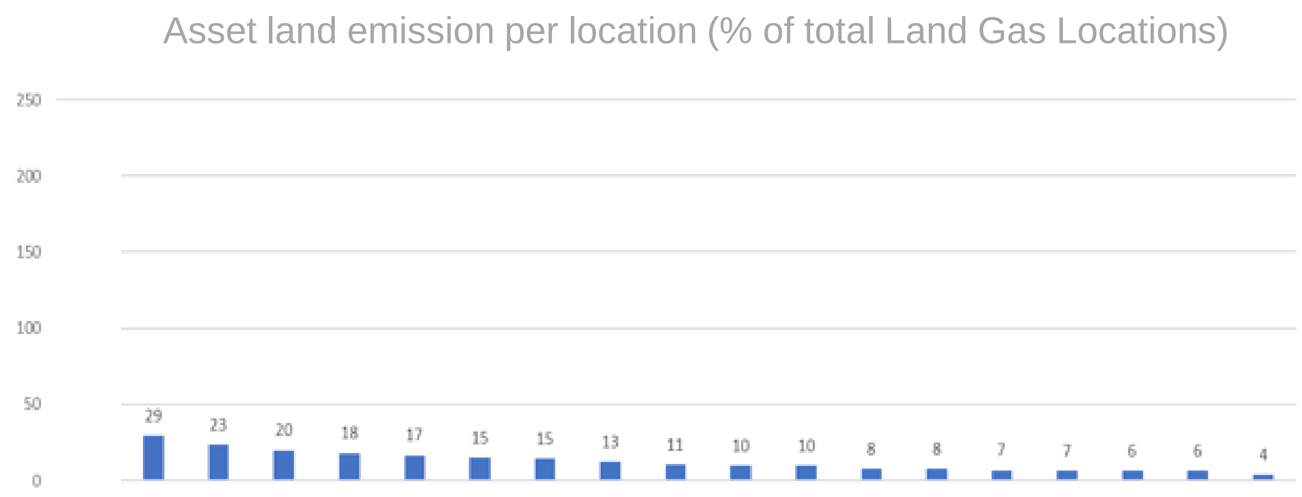
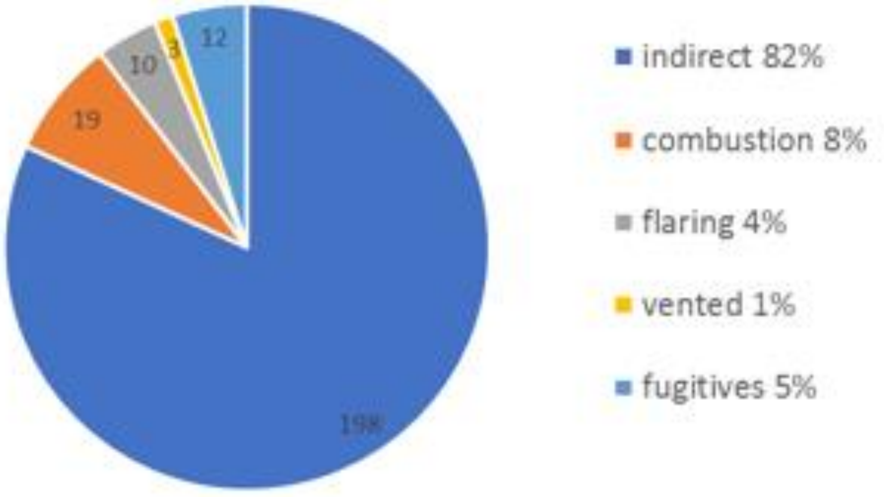
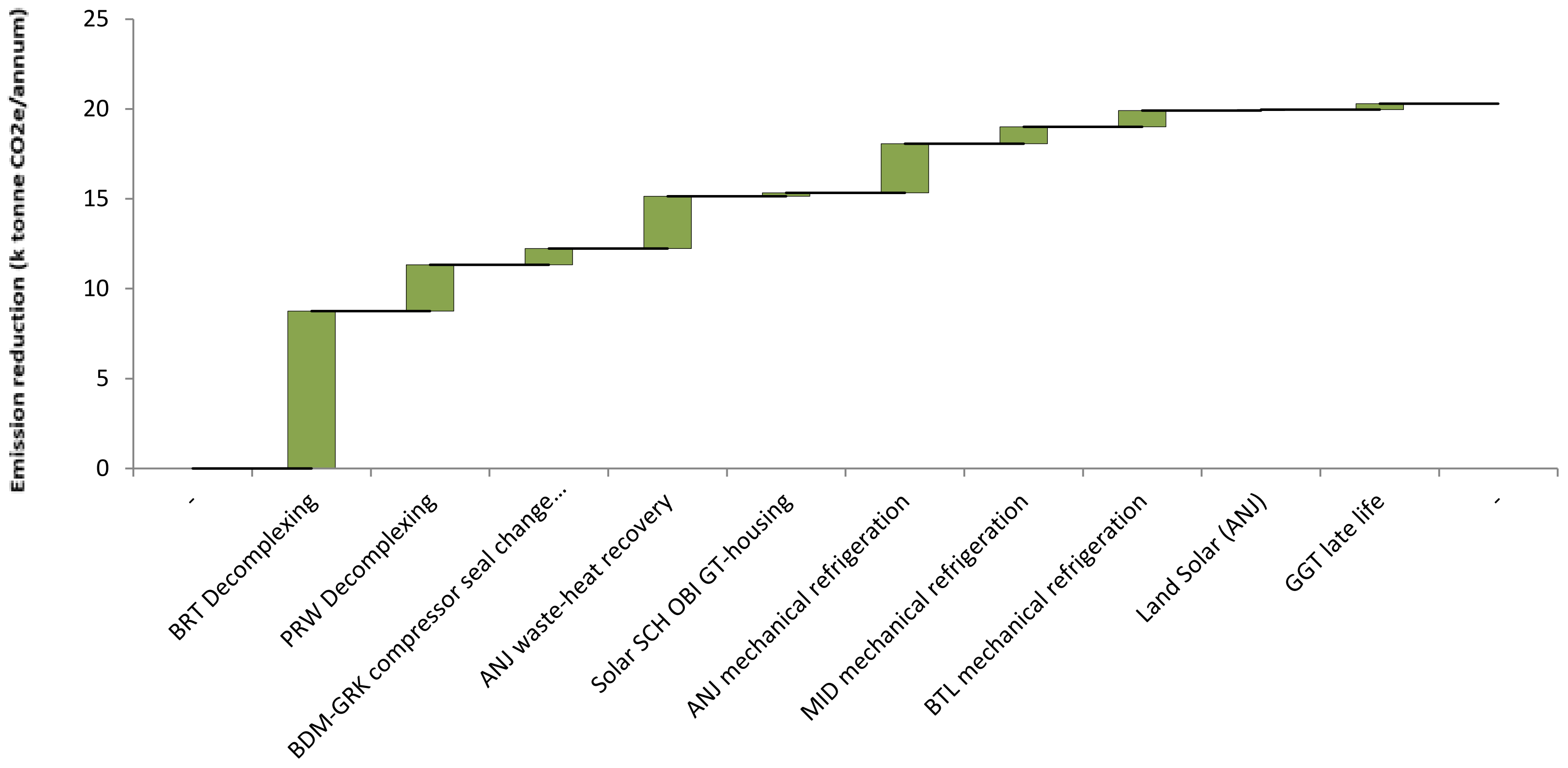
2018 GHG EMISSIONS ASSET LAND

- 2018 GHG Emissions Gas Locations Asset Land
- Total 448 kt CO2e in 2018 (direct + indirect)





VISUALISATION OF PROJECT PORTFOLIO 2018



STATUS OF 2018 ABATEMENT OPPORTUNITIES

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PU	title	status description
N	ANJ JT to chiller	part of PU-N re-routing study
N	ANJ waist heat recovery	No progress; was handed over to NE
N	ANJ warehouse solar panels	under construction
N	BDM K-4 compressor seal replacement	WO in place, but seals were not available
N	GGT rerouing / MWHC	MWHC is leading concept
N	GRK K-370 Compressor seal	waiting for TA; check availability of seal.
N	GRK K-470 Compressor seal	waiting for TA; check availability of seal.
O	SCH447 decomplexing	under construction
SCH	SCH zonnepanelen	concept changed from roof to ground
W	BRTP decomplexing	dig-up ongoing for inspection verification
W	BTL Botlek 3rd st compr / JT to chiller	JT installation followed by 3rd stage compression is leading concept
W	MID JT to chiller	No progress. JT is still of interest after MID compression.
W	PRW decomplexing	under construction

Projects with Rotating Equipment involved

BENZENE EMMISION REDUCTION

Natural gas is a complex mixture of methane, carbon dioxide, ethane, hydrocarbons, hydrogen sulfide, inert gases, and trace components of many other compounds, such as BTEX (**benzene**, toluene, ethylbenzene, and xylenes)

What benzene is:

- Benzene is a chemical that is a colorless or light yellow liquid at room temperature. It has a sweet odor and is highly flammable.

Long-term health effects of exposure to benzene:

- Benzene causes cancer in humans. Long-term exposure to high levels of benzene in the air can cause leukemia, cancer of the blood-forming organs.

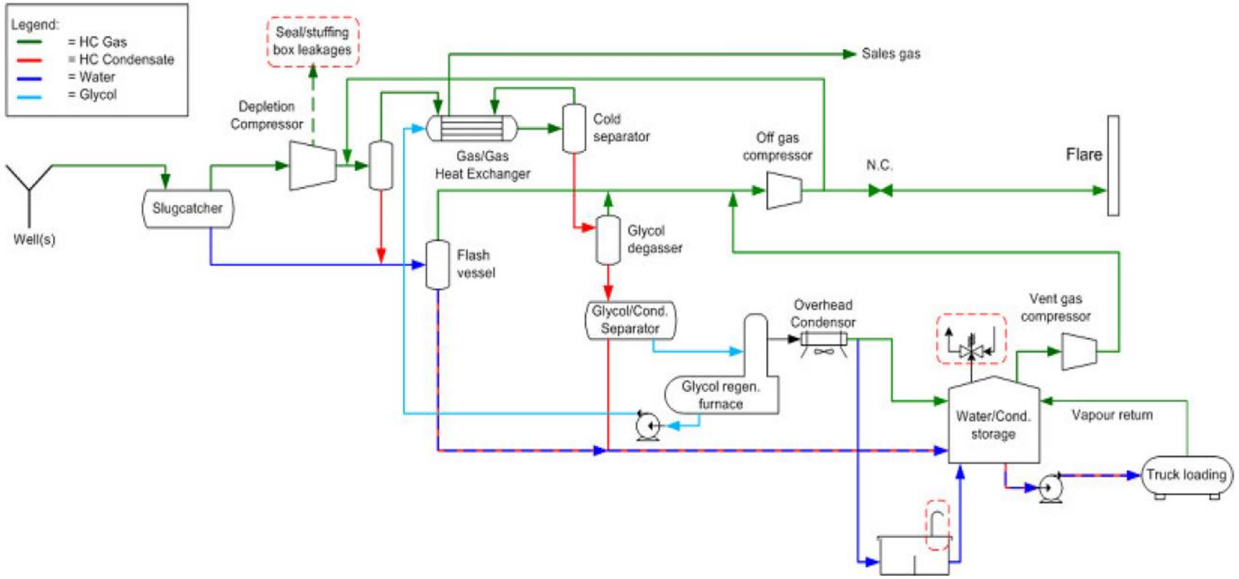
Emissions and Benzene:

- Legislation of Benzene Emission is more stringent than the GHG Emission reduction legislation/goals. With the executed/initiated NAM projects to reduce/eliminate the Benzene emmissions the GHG emissions reduction will follow as a result.

BENZENE EMMISION REDUCTION

Specific examples of applied measures in LAND to reduce the Benzene Emissions:

- Off gas rerouting / usage offgas compressoren (re-compression) and improve the availability and reliability of the compressor systems.
- Pressure vacuum valves (PVV's): review PVV performance data and adjust to accurate settings.
- Canalise Compressor seals gas to re-compress or reduce the sealgas by usage of other type of seals.



BENZENE EMMISION REDUCTION ASSUMPTIONS

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Excluded:

- Fugitive emissions.
- Combustion emissions.
- Burned emissions.
- Gas leakages to adjacent compartments can be deemed as ‘’fugitive’’ and are canalized for integrity reasons, to the atmosphere.

Included:

- **Canalized point Sources. For example ; Stuffingbox Vents (recips) or Dry Gas Seal vents (turbo’s) .**

BENZENE-CURRENT LEGISLATION -ACTIVITEITENBESLUIT (ART 2.5)

In a very high level, Dutch Legislation is concerned about:

Emissions – Rate

First: Demonstrate Emissions < 2,5 g/h (Boundary Mass Flow)

Second: If Emmissions > 2,5 g/h, then meet Immissions < 1 mg/m^3 for every indivual emission point.

General: Even if Emmission < 2,5 g/h and Immissions < 1 mg/m^3, then it’s needed to reduce emmissions to ALARP (“if we can, we must”)

Immisions – Concentration in air at certain point (outside the fence).

Immissions requirements: 5 micrograms/m^3 outside our fence.

PROPOSED LEGISLATION -ACTIVITEITENBESLUIT

BAL (besluit activiteiten leefomgeving 2021, stb 2018 293)

Emissions – Rate

First: Demonstrate Emissions **1 mg/Nm^3** (Boundary Mass Flow)

Second: If Emmissions > **1,25 kg/y** **(art 5.30 MVP2)**

Immisions – Concentration in air at certain point (outside the fence).

Immissions requirements: 5 micrograms/m^3 at places “where people live”

(Same threshold but location where the applies is unclear)

This is a work in progress by the Legislator. It’s still uncertain/unclear

CASE 1 BENZENE EMISSION REDUCTION BOTLEK K-720 RE-ROUTE STUFFING BOX VENT

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- Gas — Natural Gas
- Type — Reciprocating 2 stage
- Cylinder Bore — 1^{st} /2^{nd} Stage
- Inlet — 1.3 bar
- Discharge — 10 bar
- Speed — 594 rpm
- Flow — 9500 Nm3/d

- General The BTL installation comprises one producing well BTL-1, separation facilities, an LTS unit for gas treatment, condensate stabilisation, and storage facilities for both condensate and produced water
- The facility also receives separated wet gas from Pernis West

CASE 1 BENZENE EMISSION REDUCTION BOTLEK K-720 RE-ROUTE STUFFING BOX VENT

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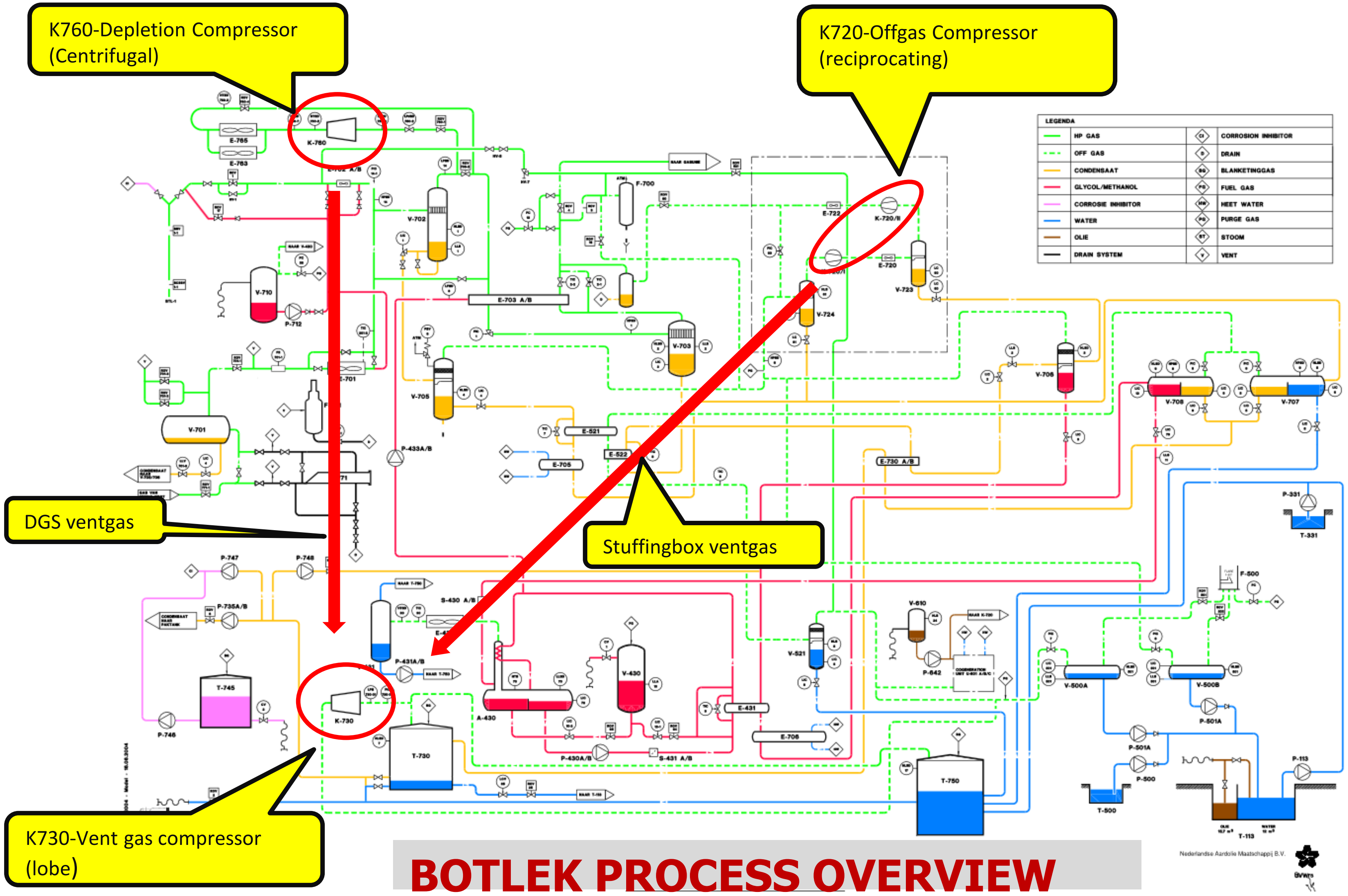

BOTLEK PROCESS OVERVIEW

CASE 1 BENZENE EMISSION REDUCTION BOTLEK K-720 RE-ROUTE STUFFING BOX VENT

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Reason for change:

- The BTL K-720 offgas compressor distant-piece emissions are currently vented to atmosphere resulting in benzene emissions among others.

Purpose:

- As the legal limit for benzene to air emissions is 2.5g/hr, reducing or eliminating any contribution from the stuffing box emissions is necessary in meeting this legal requirement.

Findings:

- Stuffing box emissions are calculated based on vendor data model to be between 7.5 to 75 Nm^3/d of gas. A field measurement shows approximately 10 m^3h actual as a ballpark figure. Based on UniSim model, this potentially results in benzene emissions between 0.8 and 8 g/hr.

CASE 1 BENZENE EMISSION REDUCTION BOTLEK K-720 RE-ROUTE STUFFING BOX VENT

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K720- 4x main leak paths for recips:

1. The vent/drain line of the stuffing box.
2. The line from distance piece/box.
3. The leakage down the rod into the crankcase
4. Unloader Vents

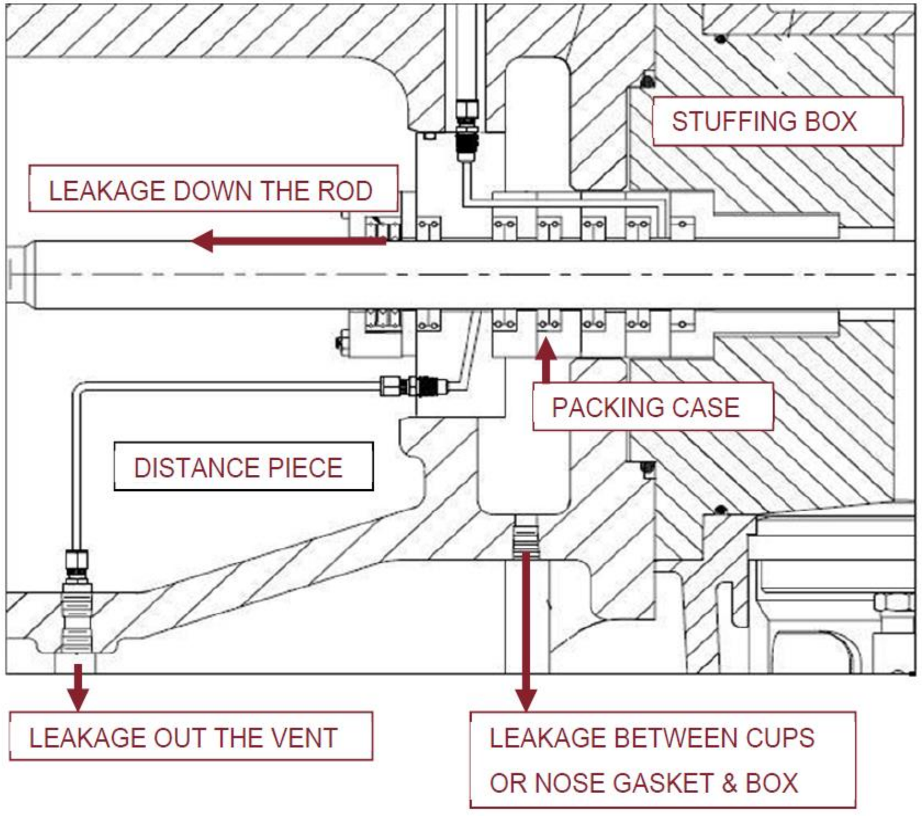


Figure 1. Sources of leakage in a compressor packing case

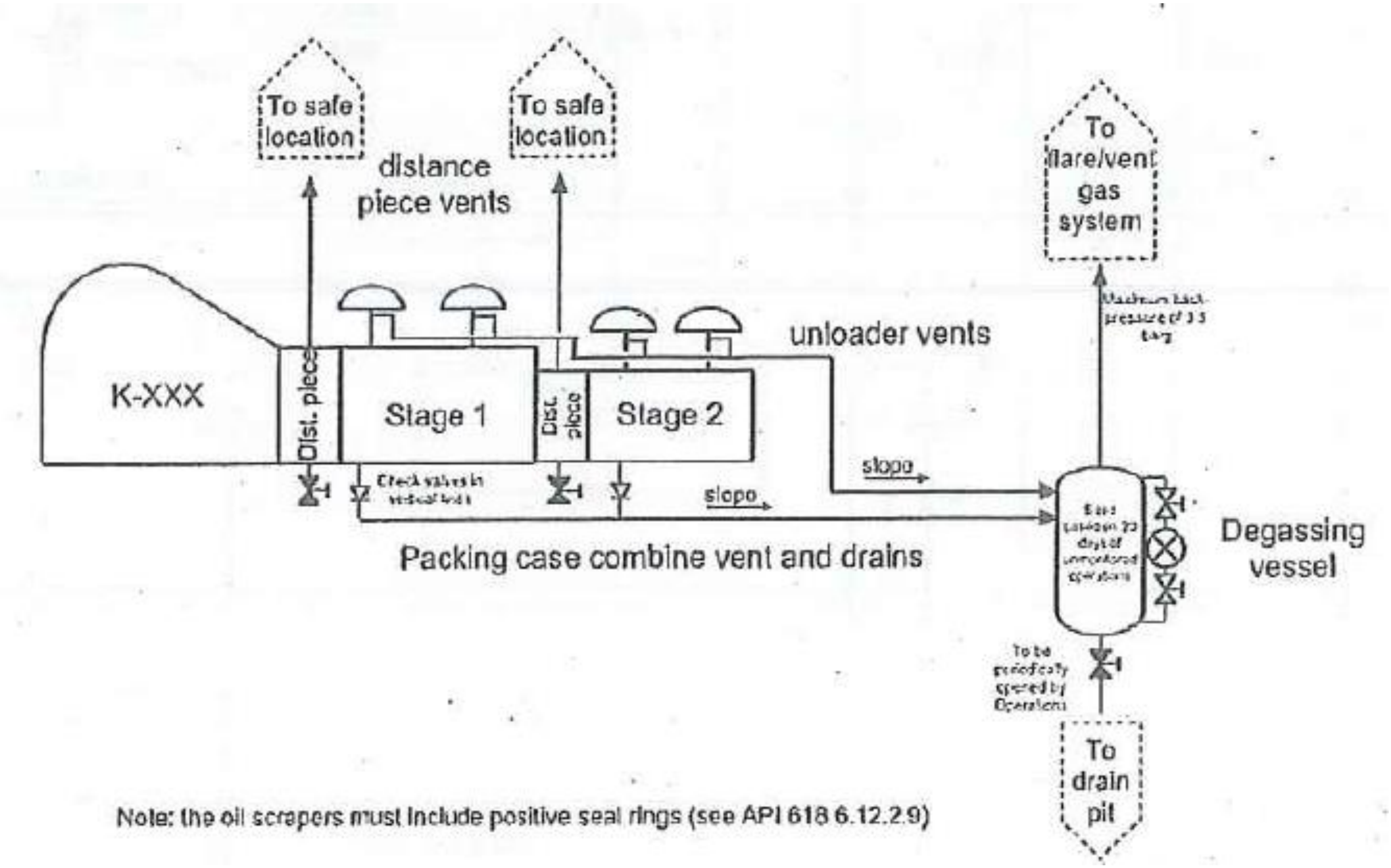
CASE 1 BENZENE EMISSION REDUCTION BOTLEK K-720 RE-ROUTE STUFFING BOX VENT

As per API 618, 5TH Edition:

- **1.**No matter how the packing performs, some gas will eventually escape towards the distance piece. To prevent this gas from leaking into the compressor frame, it is customary to vent the distance piece. The lower the backpressure of this vent is, the lesser the amount likely to leak to the frame.
- Distance piece should be vented to atmosphere, with the smallest pressure loss possible (min. 1” as per API 618 (1)):
- API 618 7.7.7.2 *Drain and vent piping serving individual cylinders shall not be less than DN 25 (NPS 1) or 20 mm (3/4 in.) outside diameter if tubing is used. Drain and vent headers shall not be less than DN 50 (NPS 2).*
- Drains from the distance pieces should not be connected to any pressurized system, even through a normally closed valve. Indeed this means filling the distance piece with gas every time it is drained.
- **2.**The pressure packing at the stem of a valve unloader might leak overtime and requires a vent to direct this leakage to safe location. (See API 618 (1) Annex I.5 g) This vent can be shared with the packing case vent.

CASE 1 BENZENE EMISSION REDUCTION BOTLEK K-720 RE-ROUTE STUFFING BOX VENT

- As per API 618, 5th edition



CASE 1 BENZENE EMISSION REDUCTION BOTLEK K-720 RE-ROUTE STUFFING BOX VENT

- A pressure release pipe from a packing case will be carrying a mixture of liquid and gas.
- This means that the system should be designed to separate these phases to avoid liquid blockage of the vent system. (See API 618 (1) Annex I.5 f.)
- Packing vents/drains should be directed to a degassing pot periodically drained by Operations. This vessel should be sized based on 2 weeks of unmonitored operations.
- No matter their nature, connections to drains and blowoffs from other equipments should be avoided. (API 618 (1) Annex I.5 k)
- Pipe slope should not allow liquid accumulation.
- Degassing pot can be connected to a vent gas system. A normal packing case backpressure of 5 psig is recommended but the maximum backpressure is 50 psig (3.4 barg) for conventional packing cases. Higher backpressure requires two rings passed the vent.
- The degassing pot being a pressure containing vessel, no valve is allowed between it and the first PSV in the line routed to the vent gas system. The PSV should be sized to handle the maximum flow of a leaking packing case.
- Check valves are to be fitted in the individual packing case vent lines not to avoid backflow from the vent gas system (the low differential pressure will generally not close the check valve) but to avoid a leaking packing case to leak towards a healthy one.
- Check-valves should be in the vertical part of the drain line for liquids to easily go through.

CASE 1 BENZENE EMISSION REDUCTION BOTLEK K-720 RE-ROUTE STUFFING BOX VENT

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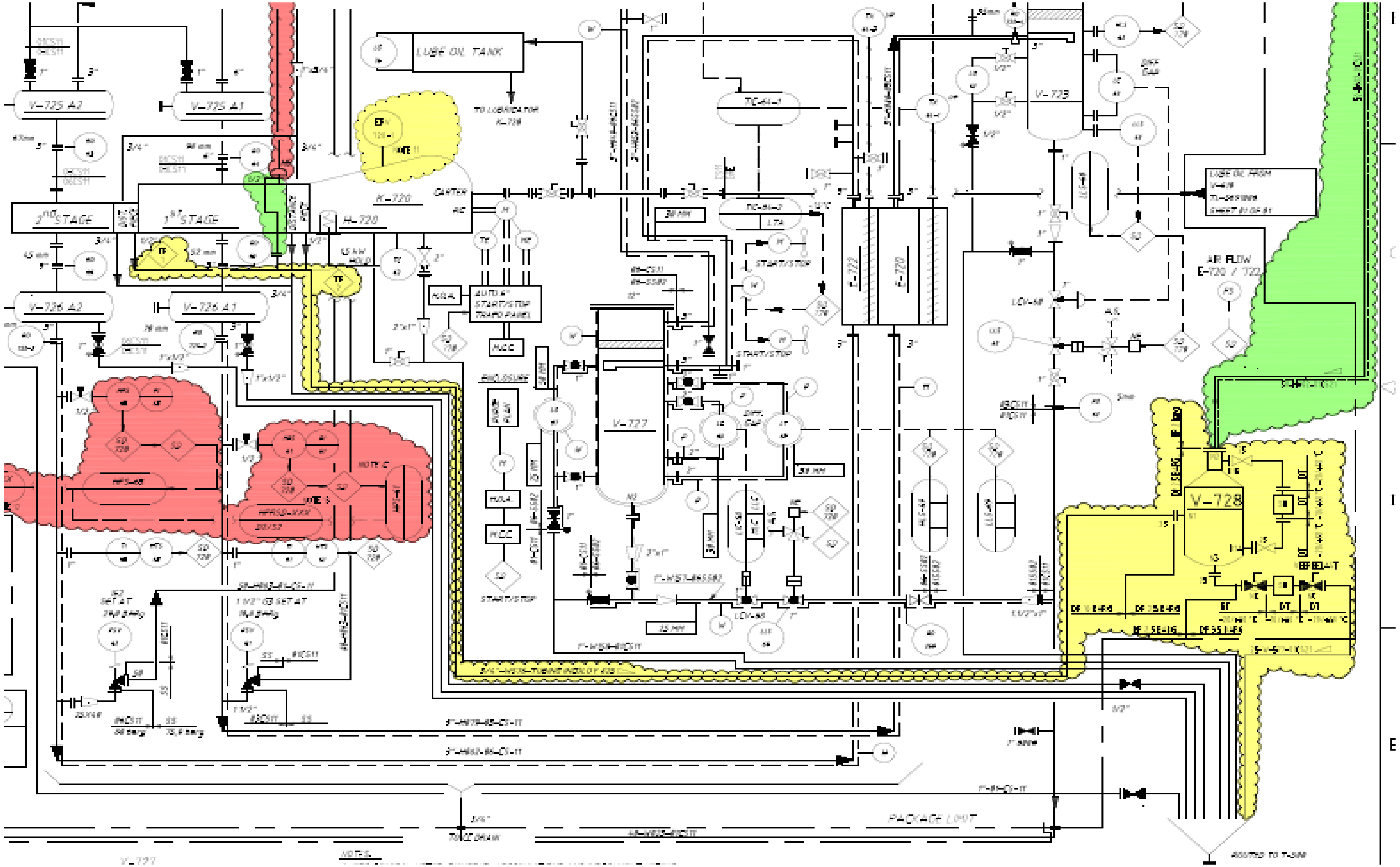
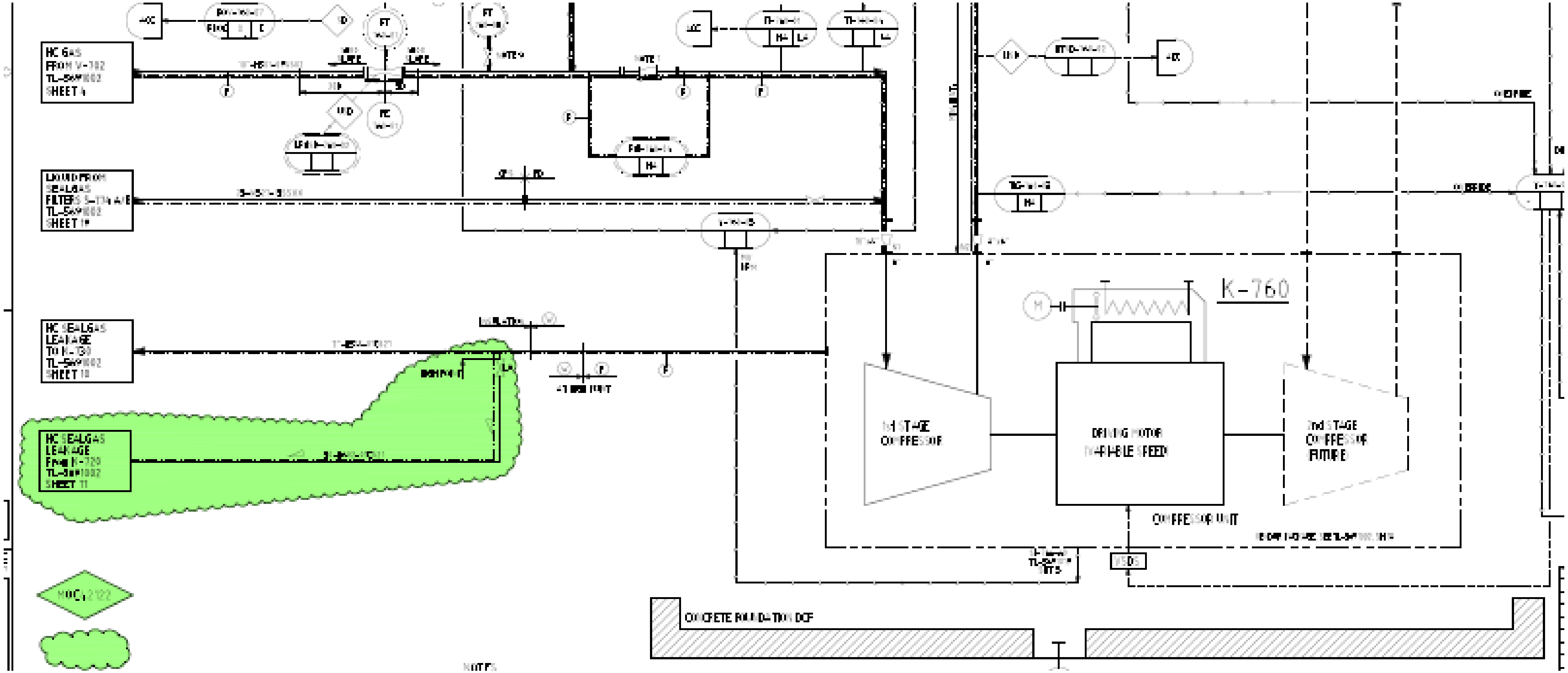


CASE 1 BENZENE EMISSION REDUCTION BOTLEK K-720 RE-ROUTE STUFFING BOX VENT



Case 2- Botlek Chiller Project

- Currently the Botlek K760 compressor compresses the gas from BTL and PRW from a suction pressure of 7 barg to a discharge pressure of 65 barg.
- To cool the gas for low temperature separation (LTS) of liquids, a Joule-Thompson valve (JT-Valve) reduces the pressure with 25 bar.
- The aim of the mechanical refrigeration project is to replace the pressure drop caused by the Joule Thompson valve for a mechanical refrigeration system with minimal pressure drop.
- Reducing the discharge pressure of the compressor will lower the suction pressure, this will lead to incremental production as well as **a lower energy intensity per cubic meter of produced gas.**

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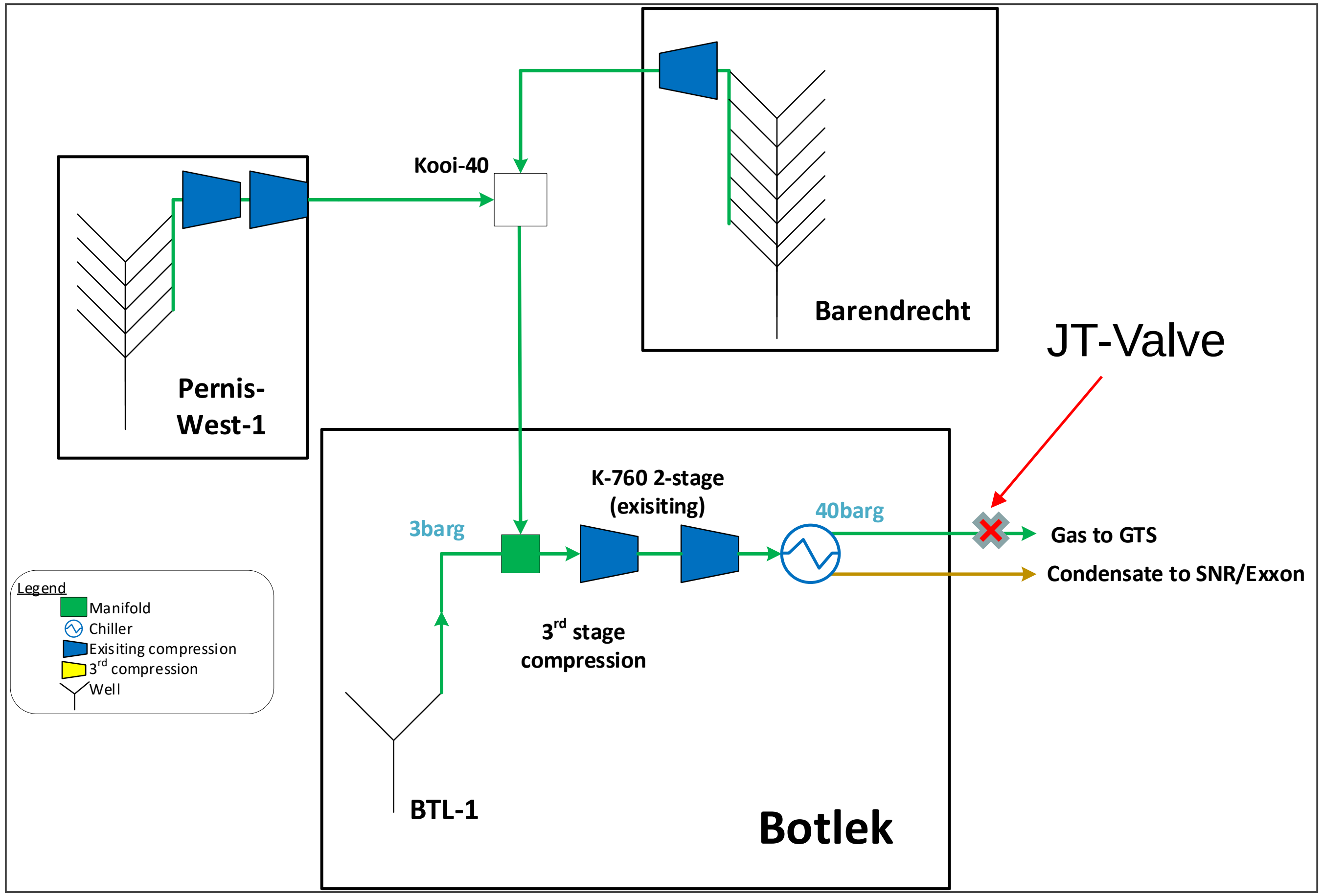
Case 2- Concept difinition Overview of Chiller



Scope overview chiller

New chiller package 2021 onstream

Site specific scope:

Bypass JT-valve

Lower discharge pressure compressor to 41barg

Operating envelope

Chiller package capacity <1mln Nm3/d

Duty 0.5MW

Key benefits

Lower net system energy intensity: increased chiller duty offset by less compression power. **Lower power consumption by at least 0.5MW. (=12000 kWh/d of electricity at 0.459 kgCO2e/kWh = 5.51 tons CO2)**

Less capex compared to new 3th stage compressor

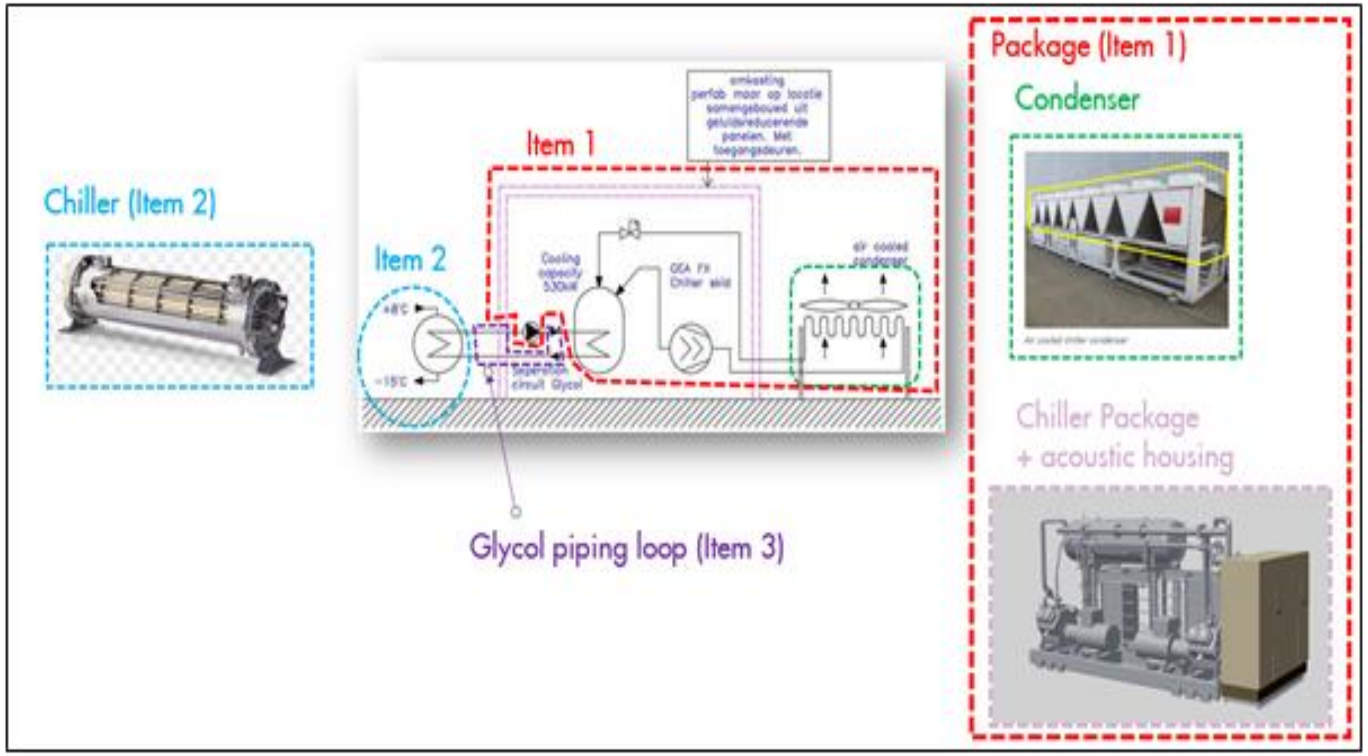
Key risks/downsides

Larger brownfield scope

Case 2- Botlek Chiller Project

The mechanical refrigeration unit will comprise of the following main equipment (but might not be limited to):

- Chiller
- Glycol loop with circulation pump
- Evaporator
- **Compressor (Type to be selected)**
- Condenser
- Buffer vessel



Case 2- Concept Definition Overview of Chiller

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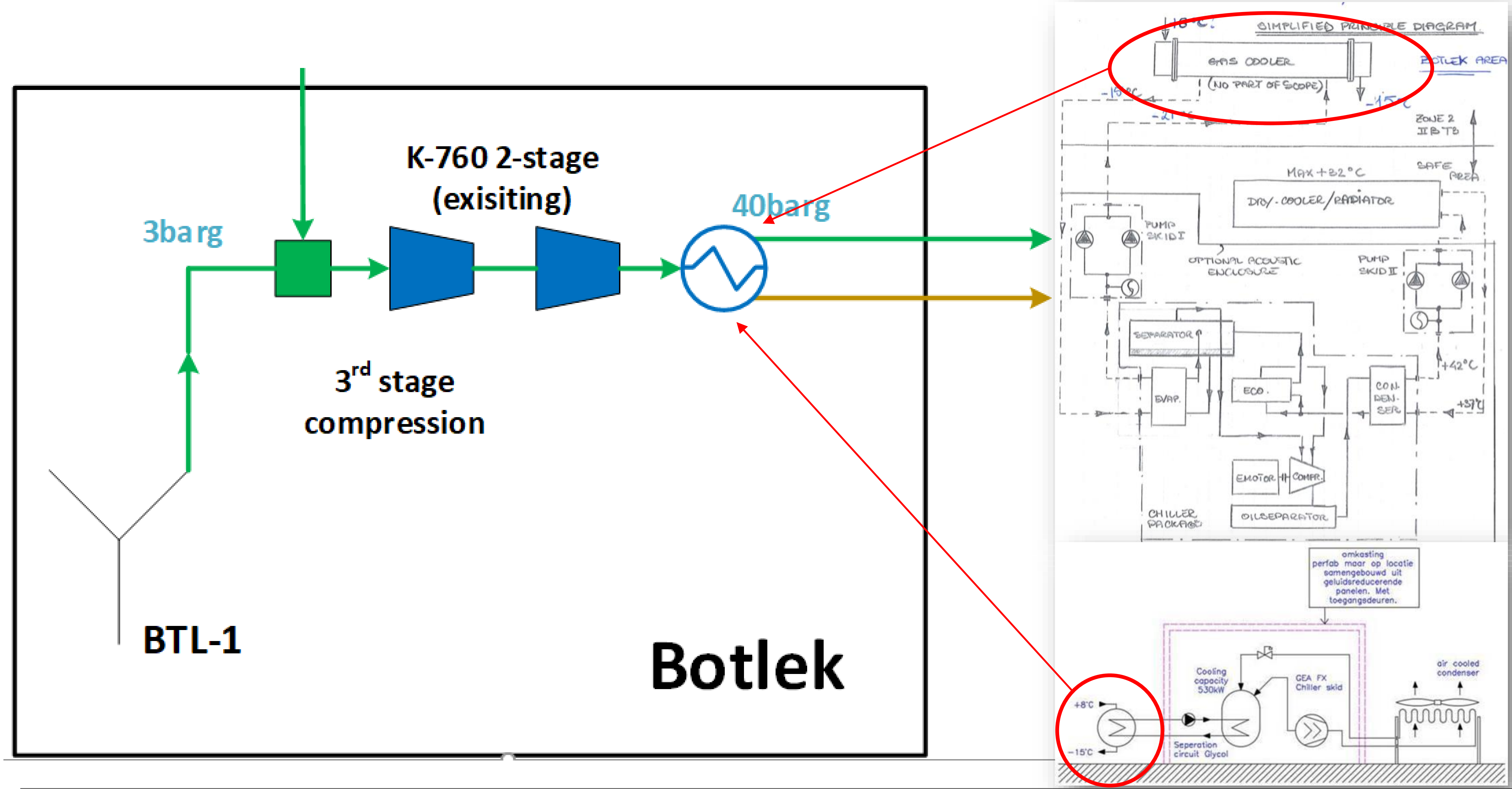
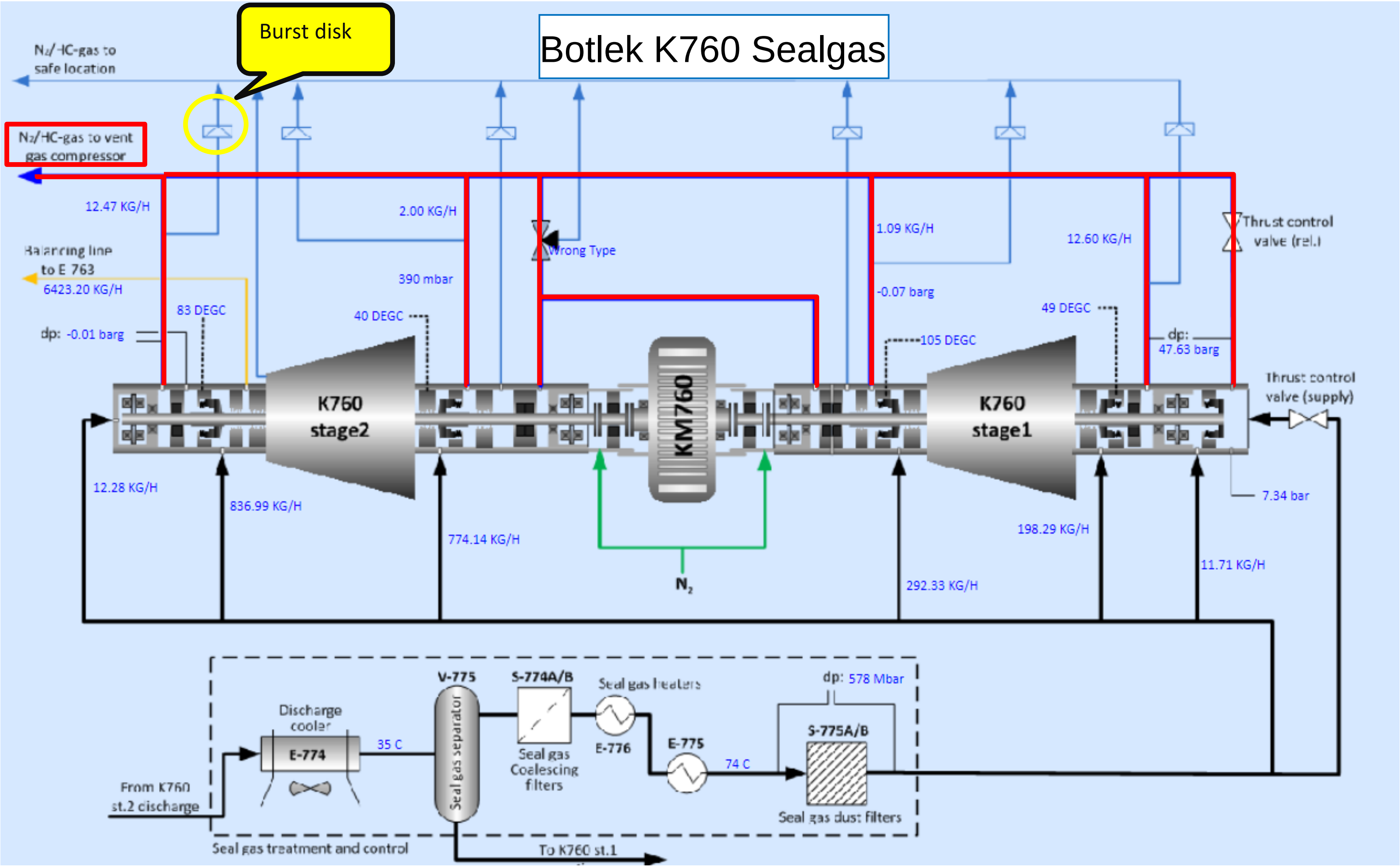


Case 3- EMISSION REDUCTION K-760 REROUTE DRY GAS SEAL VENT



- Gas: Natural Gas
- Type: Centrifugal 2-stage
- Inlet: 5.5-6.5 barg
- Discharge: 60-80 barg
- Speed: 14500 rpm
- Flow: 450.000 Nm³/d
- Bearings: Magnetic Bearings
- Sealing: Dry Gas Seals

Case 3- EMISSION REDUCTION K-760 REROUTE DRY GAS SEAL VENT

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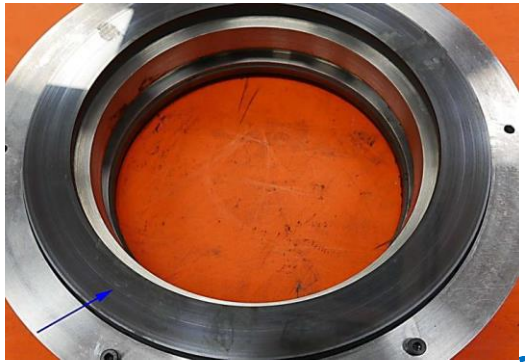
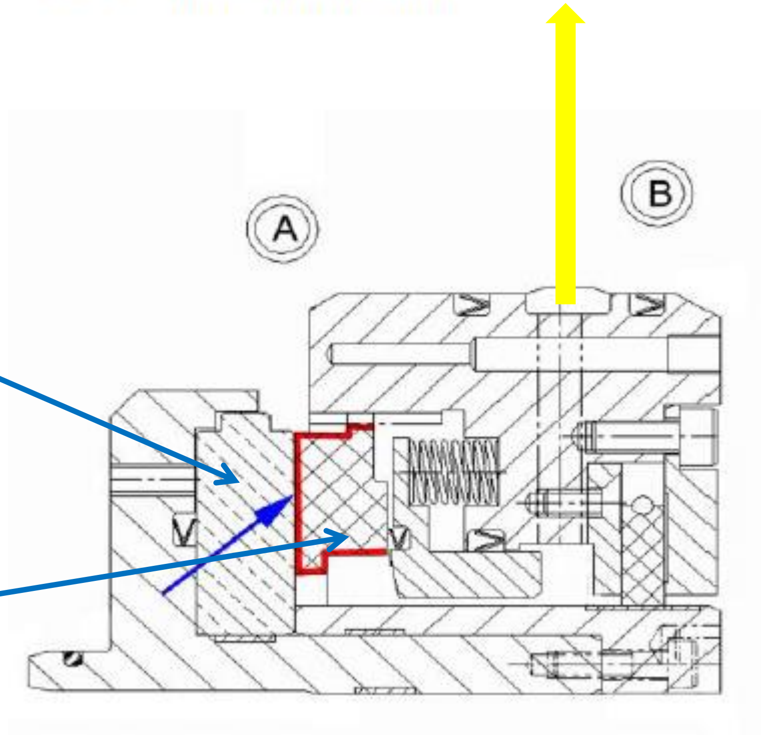


PORTING DETAILS

A = LP SEAL GAS
B = SEAL MONITORING



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Thank You for

Your Attention