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Austro Energy Systems Int. AG

Gas purification unit AES3000

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Gas-piston power plant AES with a preparation and purification of associated gas and converting it into a methane

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The Austrian Energy Systems offer unique equipment for generating electricity and heat with the use of associated gas of oil fields and convert it into methane-based gas-piston power plants AES in container design.

Modular design for temperatures from -50 to +40°C with two units of type AES 908 G/C with a total capacity of 8.6 MW "turnkey" with heat recovery from the cooling circuit of motors, oil heat and exhaust heat to produce steam or hot water.

The Austrian Energy System is one of the leading manufacturers of co-generation systems in Europe, and in the past 15 years have implemented numerous projects with a total capacity of more than 500 MW on the territory of the CEE, CIS and the Russian Federation. Our company provides comprehensive solution of all issues in the field of energy and offers not only first class equipment but also a range of services such as: design, installation and commissioning, comprehensive staff training, maintenance, spare parts supply and custom services.

Gas purification unit AES 3000

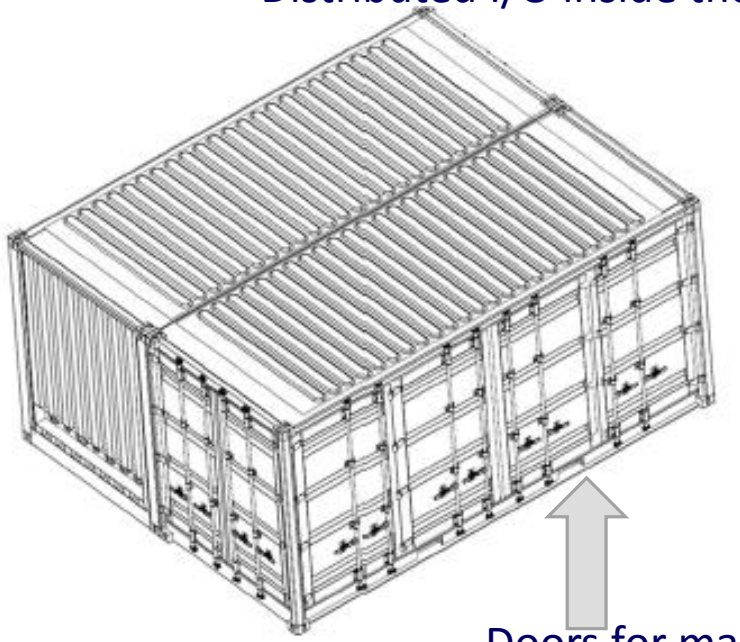
- Purification of associated gas from the hydrogen sulfide and high hydrocarbons and conversion of its qualities into similar properties of natural gas.
- Use of Gas purification unit AES improves increases performance of AES gas engines for work on associated and other gases with low methane number.
- Volume of gas preparation is 1700 Nm3 / hour (the volume of prepared gas of 2700 Nm3 / hour sufficient to generate min 10 MW of electricity per hour).

Gas purification unit AES 3000

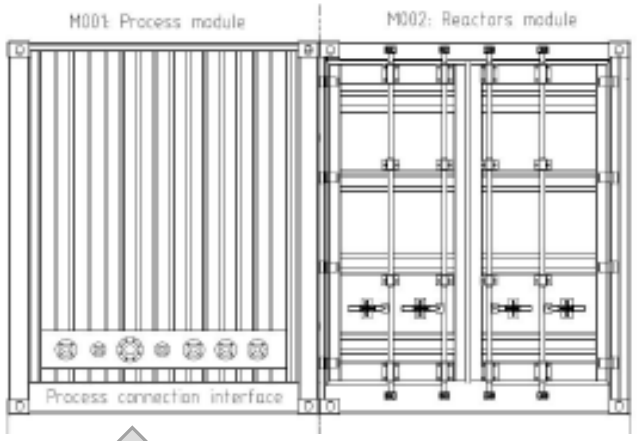
2 x 20” High Cube containers

- **Weight 25 000 kg**
- **Height 2896 mm**
- **Width 2 x 2438 mm**
- **Lenght 6058 mm**

The enclosed unit is equipped with ventilation. (Hazardous zone 1)
Separte control panel in safe area.
Distributed I/O inside the container.

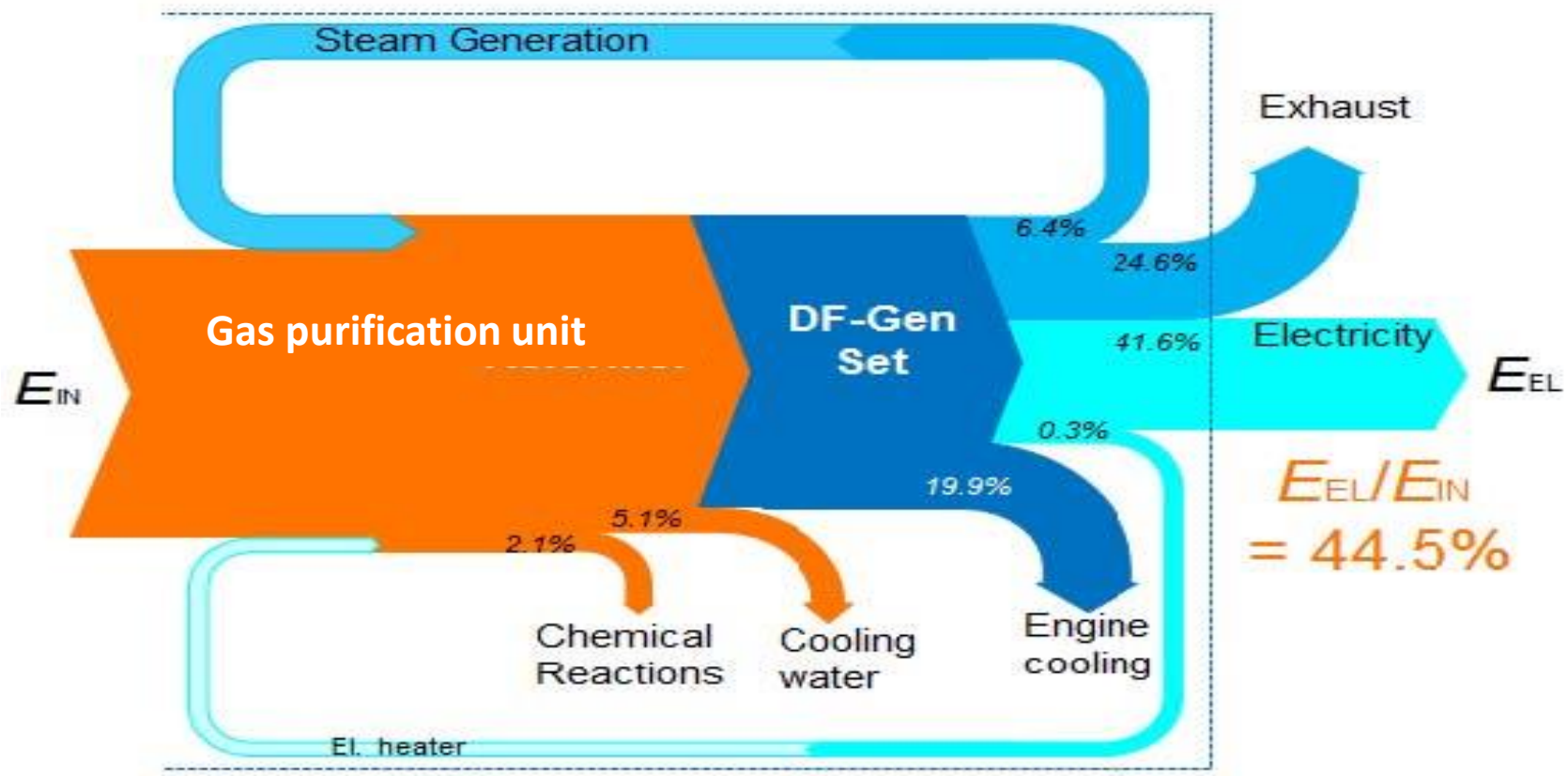


Doors for maintenance.
No operation inside the unit during normal operation.



Process connection interface

Energy balance scheme Gas purification unit AES 3000



Methane number

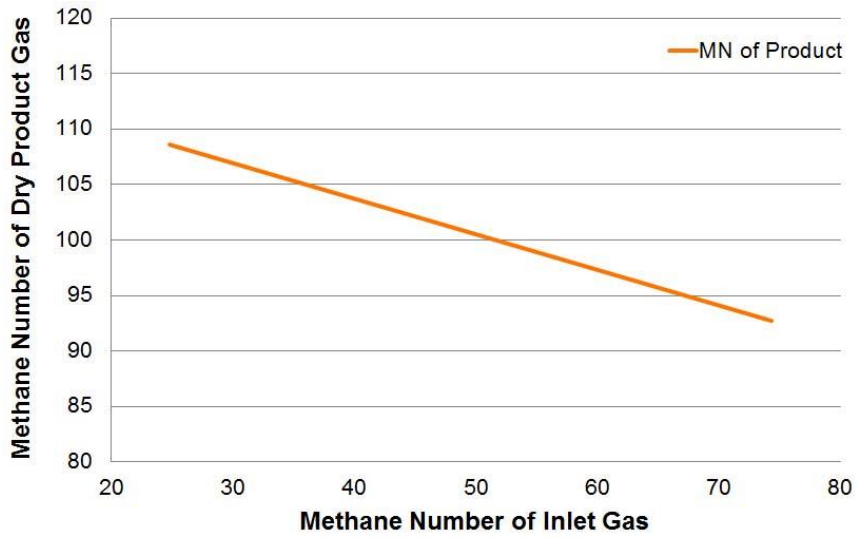
- Compressibility of the gas is measured by "methane number." The higher methane number, the better the fuel gas compressibility.
- Pure methane number is 100, but the presence of higher hydrocarbons in the gas significantly reduces this number.
- When the methane number of the fuel gas is 80 or lower, the engine must be used with a reduced nominal power in order to prevent knocking and engine damage.
- At high methane number, on the other hand, the engine can be operated with the highest efficiency.
- Methane number of individual components:

Composition	Meth. number	Composition	Meth. number	Composition	Meth. number
Methane	100	I-pentane	10	H_2S	10
Ethane	43	N-gexane	10	H_2	0
Propane	34	N-geptane	10	N_2	200
N-butane	10	H2O	100	O_2	200
I-butane	10	CO	73	Argon	200
N-pentane	10	CO2	200	Helium	200

Methane number after installation of Gas purification unit AES 3000

In the Gas purification unit the MN of any fuel gas is improved up to 100±5 by converting the non-methane hydrocarbons (NMHCs) to synthesis gas (H2 + CO) and finally to methane (CH4).

The Gas purification unit process is based on known steam reforming technology, where the hydrocarbons (alkanes) are reacted with steam in optimized conditions in the presence of a catalyst. This Ni-based catalyst is very sensitive to sulfur compounds, which need to be removed from the gas with a desulfurization absorbent upstream the unit. Excess steam is separated from the product gas by condensing and recycled back to steam generation thus minimizing the need of fresh water. The dry product gas (50 °C) is then fed through the Gas Valve Unit (GVU) to the Dual Fuel engine.



Example of increasing methane number of associated gas via Gas purification unit AES 3000

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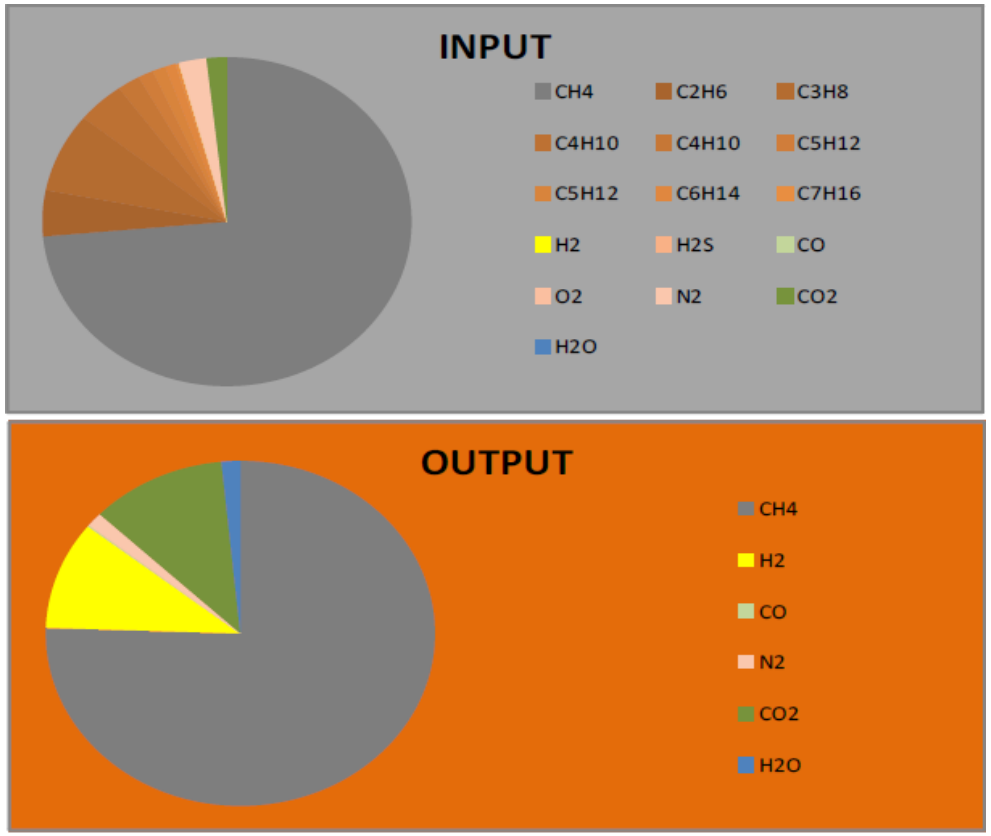
Substance	Formula	Inlet, mol %	Outlet, mol %
methane	CH4	**73,6**	**75,5**
ethane	C2H6	**4,5**	**0,0**
Propane	C3H8	**7,8**	**0,0**
n-butane	C4H10	**4,2**	**0,0**
i-butane	C4H10	**2,0**	**0,0**
n-pentane	C5H12	**1,3**	**0,0**
i-pentane	C5H12	**1,2**	**0,0**
n-hexane	C6H14	**0,9**	**0,0**
n-heptane	C7H16	**0,3**	**0,0**
n-oktane	C8H18	**0,0**	**0,0**
n-nonane	C9H20	**0,0**	**0,0**
n-dekane up to C20	C10H22-C20	**0,0**	**0,0**
hydrogen	H2	**0,0**	**10,1**
Hydrogen sulfide	H2S	**0,0**	**0,0**
Carbon monoxide	CO	**0,0**	**0,1**
Oxygen	O2	**0,0**	**0,0**
nidrogen	N2	**2,4**	**1,4**
Carbon dioxide	CO2	**1,8**	**11,3**
water	H2O	**0,0**	**1,6**
helium	He	**0,0**	**0,0**
argon	Ar	**0,0**	**0,0**
Total		**100**	**100**
Methan number		**42**	**100**

Parameters of Gas purification unit AES 3000



Reforming parameters

Temperature	383 °C
Pressure	7,6 barg
Oxygen / carbon	1,00 mol / 1,00 mol

Note:

Pressure of inlet gas is 8 barg

Comparison of preparation of fuel gas from associated gas using the Converter of AES compared with existing membrane technology.

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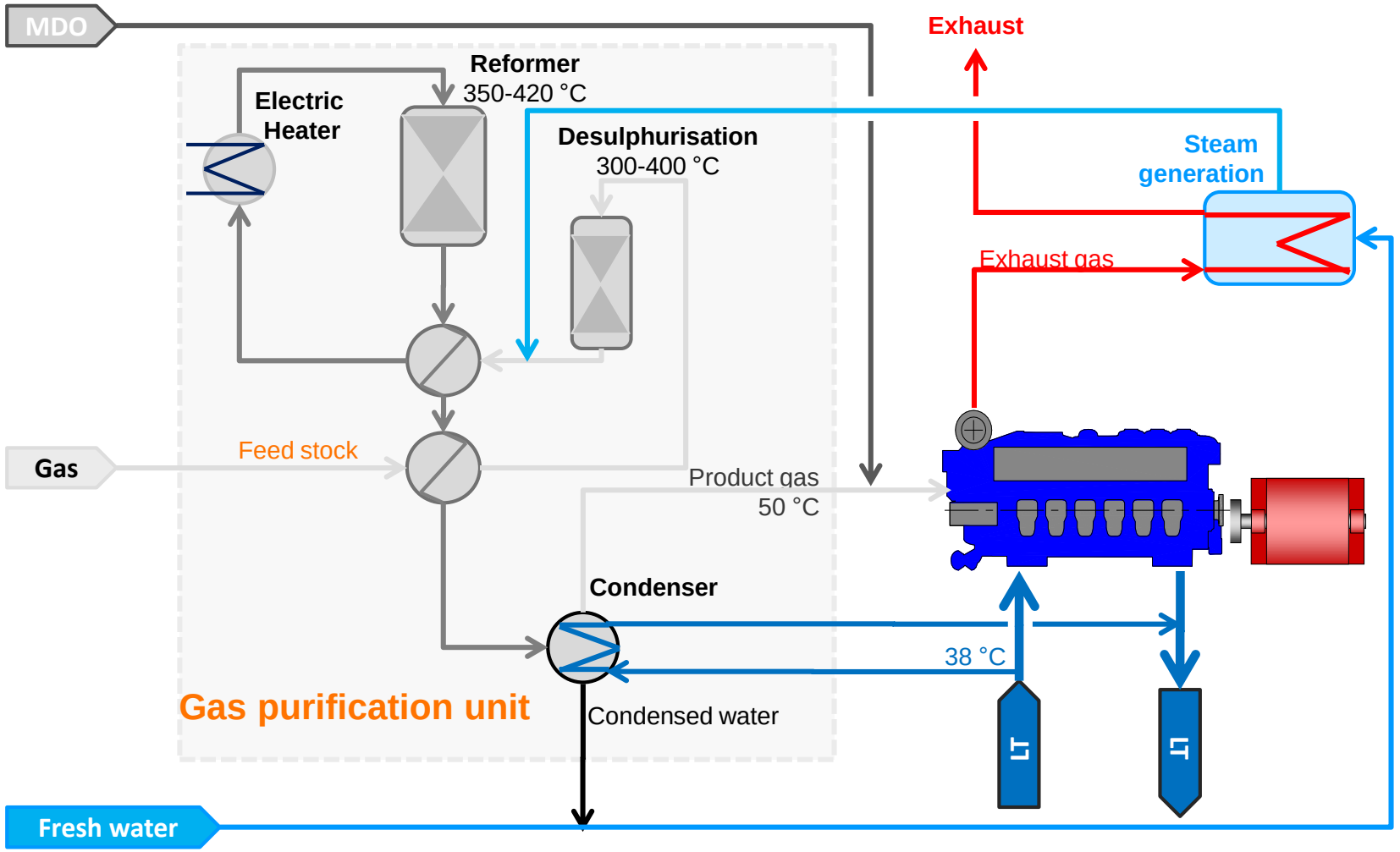
Name	APG	Membrane technology Prepared when gas coeff. Selection			Technology AES Converter AES 3000
		0,15	0,25	0,40	
Flow rate, cubic meters/h	1700	1445	1275	1020	2700
Volume concentration, %					
CH4	70,4	75,7	79,9	83,8	78,0
C4+	8,4	5,5	3,45	1,75	0,0
C8+	0,7	0,35	0,14	0,03	0,0
CO2	4,1	3,8	3,5	3,0	12,4
S	2,0	2,0	2,0	2,0	-*
Methane number	49,1	56,0	63,4	72,7	103
Lower heating value, MJ/cubic meters	49,1	40,8	37,7	34,8	29
Molecular weight	24,71	22,62	21,0	19,59	18,42

*S needs to be removed to the ppm level before the Converter

Process of gas purification unit and connection with engine



Main components of Gas purification unit AES 3000

TAG	Equipment	Specification
Heat Exchangers and Heaters		
E100	Plate Heat Exchanger	
E200	Plate Heat Exchanger	
E300	Plate Heat Exchanger	Location different in GasReformer unit
E400	Plate Heat Exchanger (Condenser)	
Reactors, Vessels, and Drums		
R101	Desulfurization Vessel 1	
R102	Desulfurization Vessel 2	
R103	Reformer Vessel	Parallel R103a & R103b used for AES 3000
D101	Condensate Separator Drum	
D102	De-aeration Vessel for Condensate Water	
D501	Condensate Pot	Venting line
Other Components		
B101	Gas Filter	
B102	Steam Strainer	
B102	Ejector	
P401	Circulation Blower	

Heat Exchangers and Heaters

Heat Exchangers E100 and E200

The Gas purification unit has two integrated plate heat exchangers E100 and E200. These heat exchangers are responsible for the heating of the feed streams to desulfurization (250-350 °C) and reformer (350-420 °C) vessels and responsible for cooling of the reformer product gas before entering the Condenser (E400).

Electrical heater E300

The electrical heater E300 upstream the unit vessel is used to control the reformer vessel inlet and outlet temperatures. The set-point temperature for reformer vessel inlet depends on the hydrocarbon composition of the feed gas and thus varies by case. However, the minimum temperature of reformer feed is always 350 °C.

Heat Exchanger E400 (Condenser)

In the Gas purification unit unit product gas line, three plate heat exchangers (E200, E100, and E400) operate in cascade. These heat exchangers take care of the required cooling of the product gas from 350-450 °C to final 50 °C. The plate heat exchangers E200 and E100 are integrated into the Gas purification unit process, whereas the condenser E400 has low temperature cooling water on its cold side. The last heat exchanger (E400) not only cools down the product gas to 50 °C but also condensates all excess steam.

Reactors, Vessels, and Drums 1

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Condensate Separator Drum D101

The excess steam is condensed in the plate heat exchanger E400 and separated from the product gas in the separator drum D101 downstream. The condensed water is collected in the separator drum D101 and recycled to the Steam Generation unit (external). By recycling, the need for fresh water is minimized.

The product gas is now considered as dry product, still containing 1-2 mol-% of moisture. This cooling and the separation of condensates are sufficient to prevent condensate formation in the Gas Valve Unit (GVU) downstream.

De-aeration Vessel for Condensate Water D102

The condensate line from the Separator drum (D101) is equipped with a de-aeration vessel D102 to ensure that gaseous compounds do not end up in the recycled water and the Steam Generation unit that are located outside Hazardous area Zone 2. In case, gaseous compounds are detected in the de-aeration vessel D102, these indicate of process operation failure or leakage and an emergency shut-down (ESD) is automatically activated.

Condensate Pot D501 in Venting Line

The gas venting line is equipped with a condensate pot D501 to remove condensate and prevent possible obstructions for normal operation of venting line. The venting line is open to atmosphere and is only used during equipment shut-down or failure mode, such as pressure safety valve opening. Condensate can accumulate in the piping during periods of inactivity.

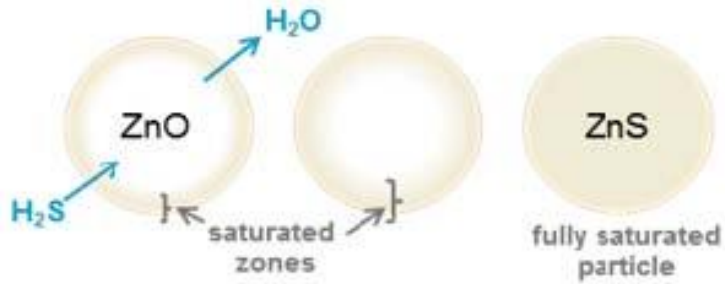
Reactors, Vessels, and Drums 2

Desulfurization Vessels R101 and R102

In the desulfurization vessels R101 and R102 all hydrogen sulfide (H2S) from the feed gas is removed by absorbing H2S into a ZnO absorbent: **ZnO + H (1) 2S = ZnS + H2O (200–400 °C)**

The desulfurization is designed to be a 2-bed system, where the first vessel R101 consist the main sulfur removal bed. The second vessel R102 acts as guard. The ZnO absorbent bed is saturated in gradients, as presented in Figure below, and the sulfur level measured from first desulfurization vessel R101 outlet indicates of absorbent replacement needs.

Gradual saturation of ZnO particles



NOTE: Only in case, where 0 ppmv H2S is in feed, one desulfurization vessel is sufficient.

NOTE: The desulfurization reaction is an equilibrium reaction, and therefore, the feed to desulfurization should not contain moisture (H2O < 2 mol-%) that inhibits the H2S absorption. The feed gas should not contain more than 2 mol-% of H2, if CO2 is present, as these react together forming H2O + CO at this low temperature.

NOTE: Gas purification unit provides sampling points after both the desulfurization vessels, but analysis tools are not included.

Reactors, Vessels, and Drums 3

Reformer Vessel R103

The purification vessel R103 is the main module of the Gas purification unit . In the unit the methane number (MN) of the feed gas is improved by converting all higher hydrocarbons to methane, hydrogen, and carbon dioxide. The main reactions in the reformer are:

Steam reforming

$C_xH_y + n \cdot x\ H_2O \leftrightarrow (x + y/2)\ H_2 + x\ CO$ (endothermic)

$CH_4 + H_2O \leftrightarrow 3\ H_2 + CO$ (methane steam reforming)

Methanation

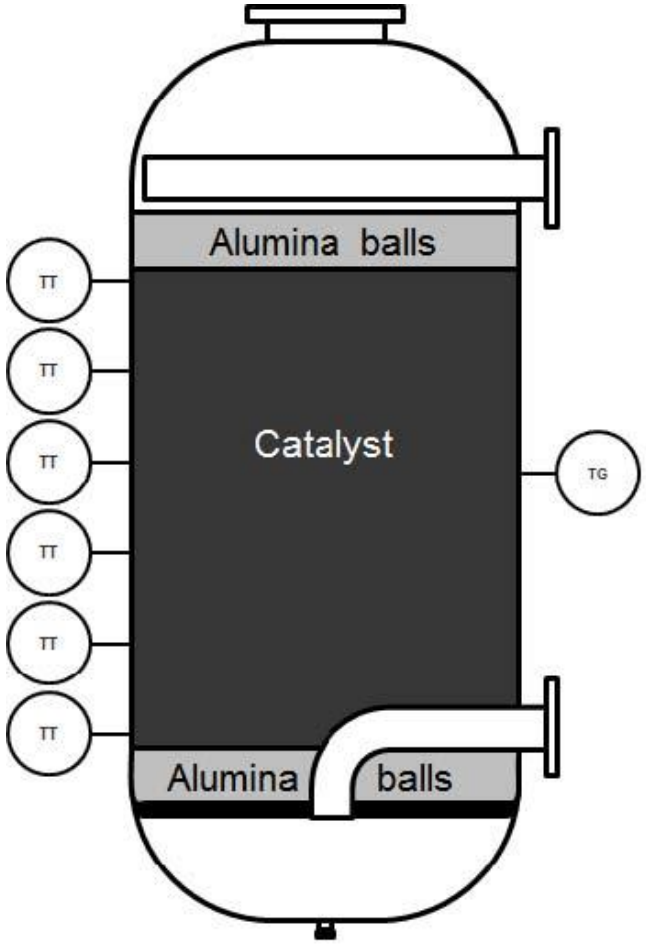
$CO + 3\ H_2 \leftrightarrow CH_4 + H_2O$ (exothermic)

Water-gas shift

$CO + H_2O \leftrightarrow H_2 + CO_2$ (endo/exothermic, depends on reaction temperature)

Cross section of the purification unit

These reactions take place on an active nickel catalyst, which is packed as a bed between layers of alumina balls. The upper alumina layer (Ø 1”) is to avoid turbulence in the top part and to help the distribution of the feed gas. The lower alumina layer (Ø ½”) is to hold back dust and particles from the catalyst bed. The
cross section of the reformer vessel is shown in Figure on the left.



Other Components

Ejector B102

To maintain high activity of the reformer catalyst the purification unit R103 feed should contain 1-2 mol-% hydrogen (H2). The small amount of hydrogen in feed keeps the nickel (Ni) sites in reduced, active state.

As pure hydrogen supply is usually not available, 10-30 % of the hot product gas from reformer vessel outlet is recycled by the ejector B102 to the purification unit feed.

Gas Filter B101 and Steam Strainer B201

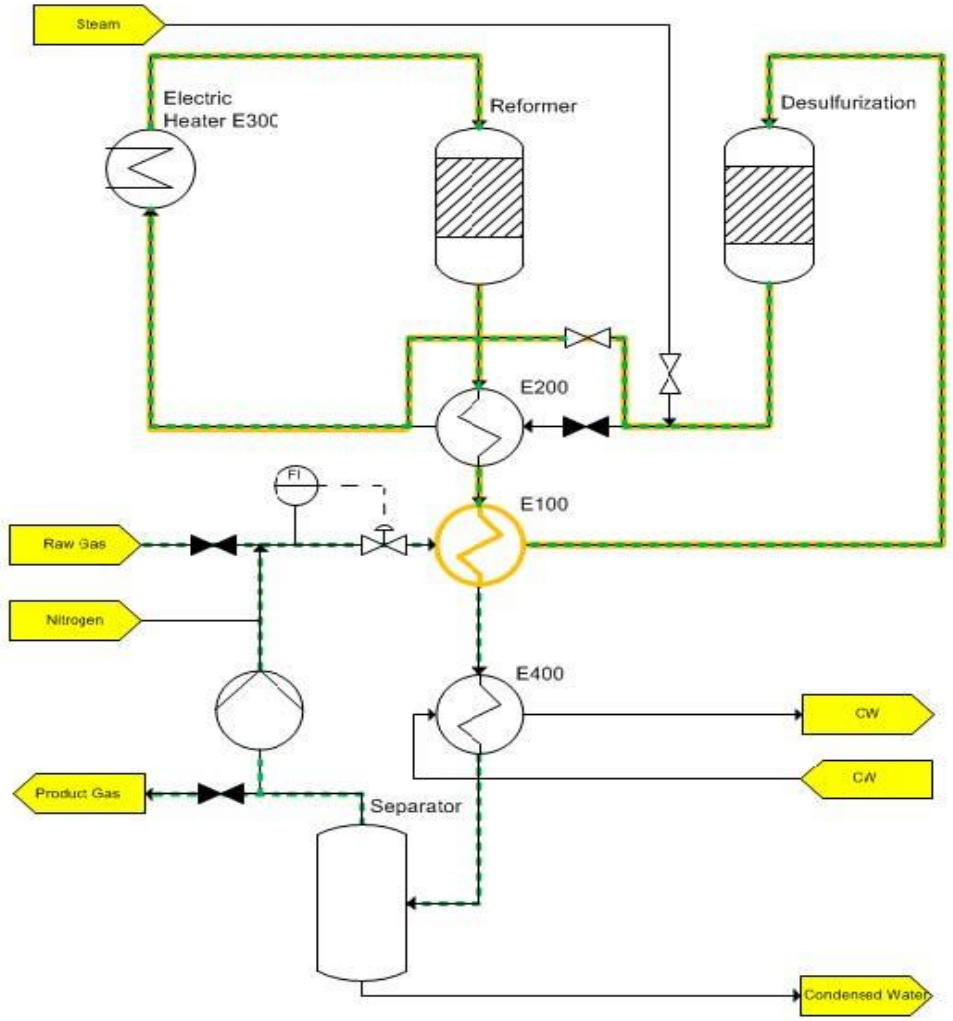
The gas filter B101 and steam strainer B201 in inlet lines take care that no impurities such as solid matter will enter the process.

Circulation Blower P401

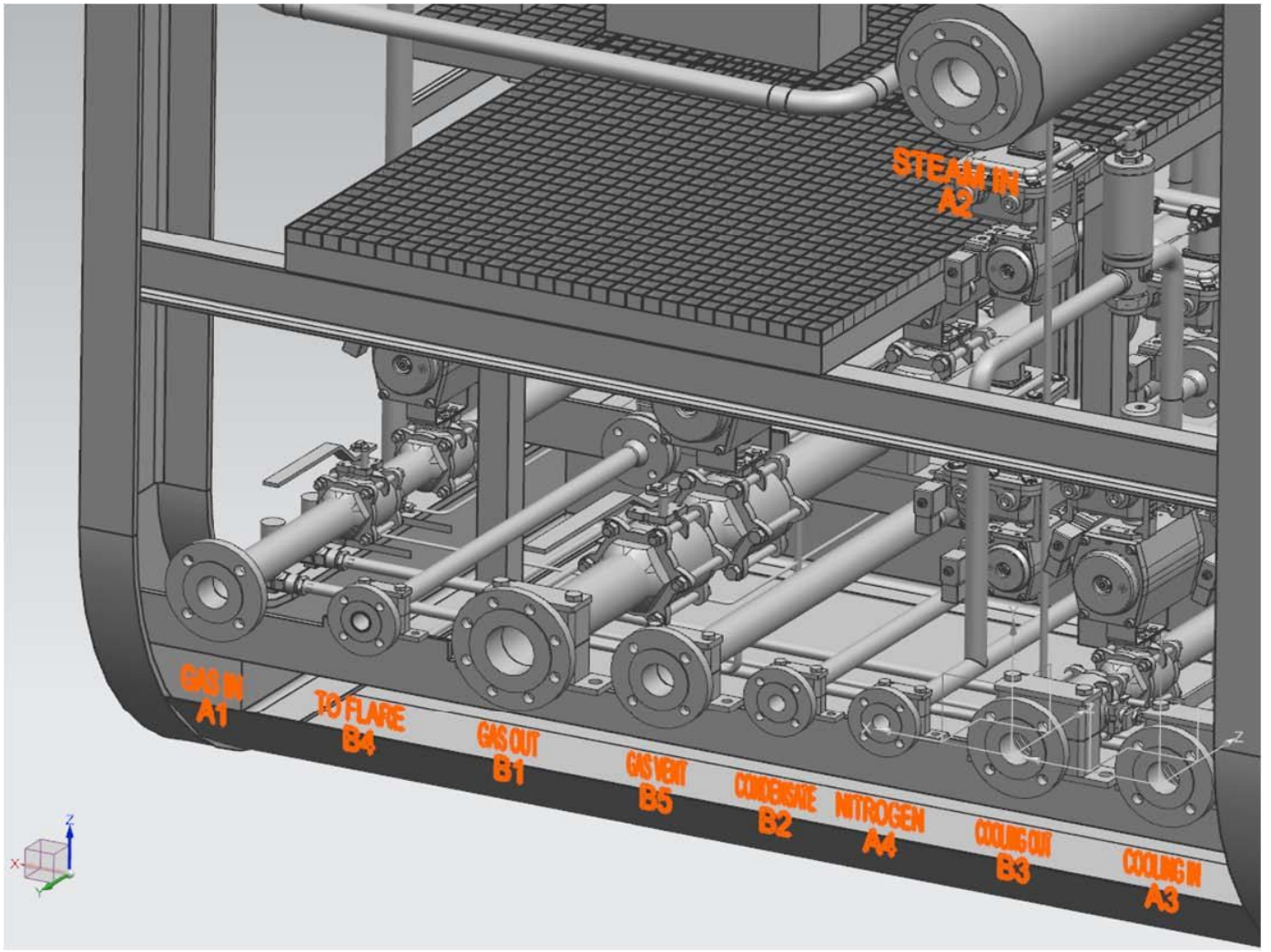
The blower P401 is used for circulating low pressure nitrogen in the process system. Nitrogen circulation is needed only for heat-up and cooling of the Gas purification unit .

Use of nitrogen

Nitrogen is consumed in start-up and shut-down of the Gas purification unit process, as well as in emergency and flushing situations. In the start-up sequence, nitrogen is circulated through the system, and an electrical heater is heating the media, see Figure on the right. Before normal operation nitrogen is vented out of the system and the unit is pressurized with feed gas.

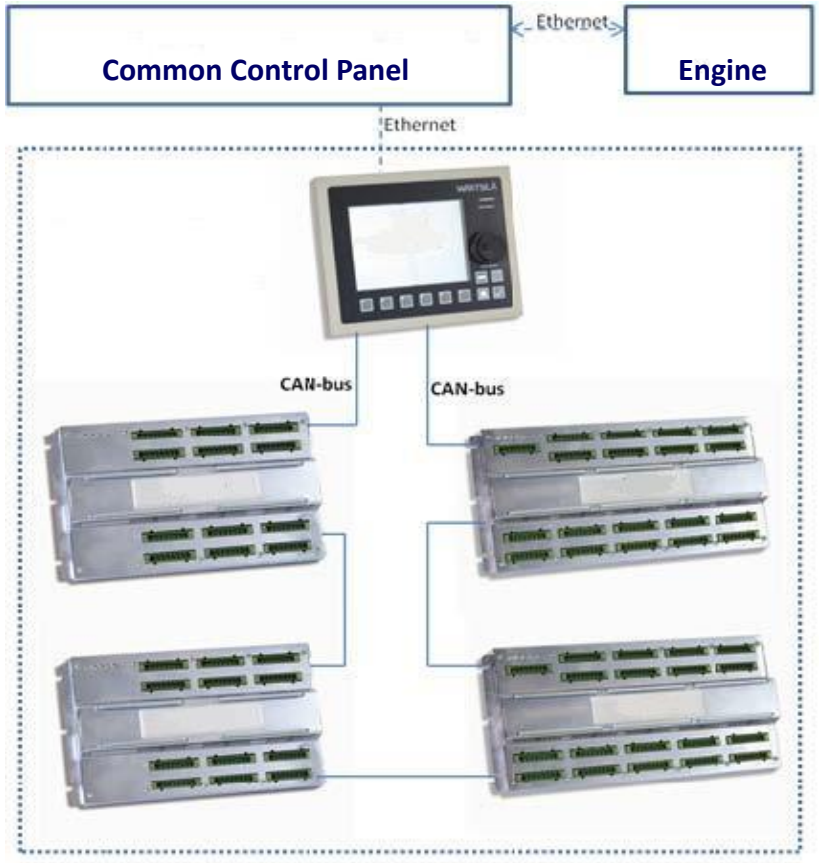


Interface of process

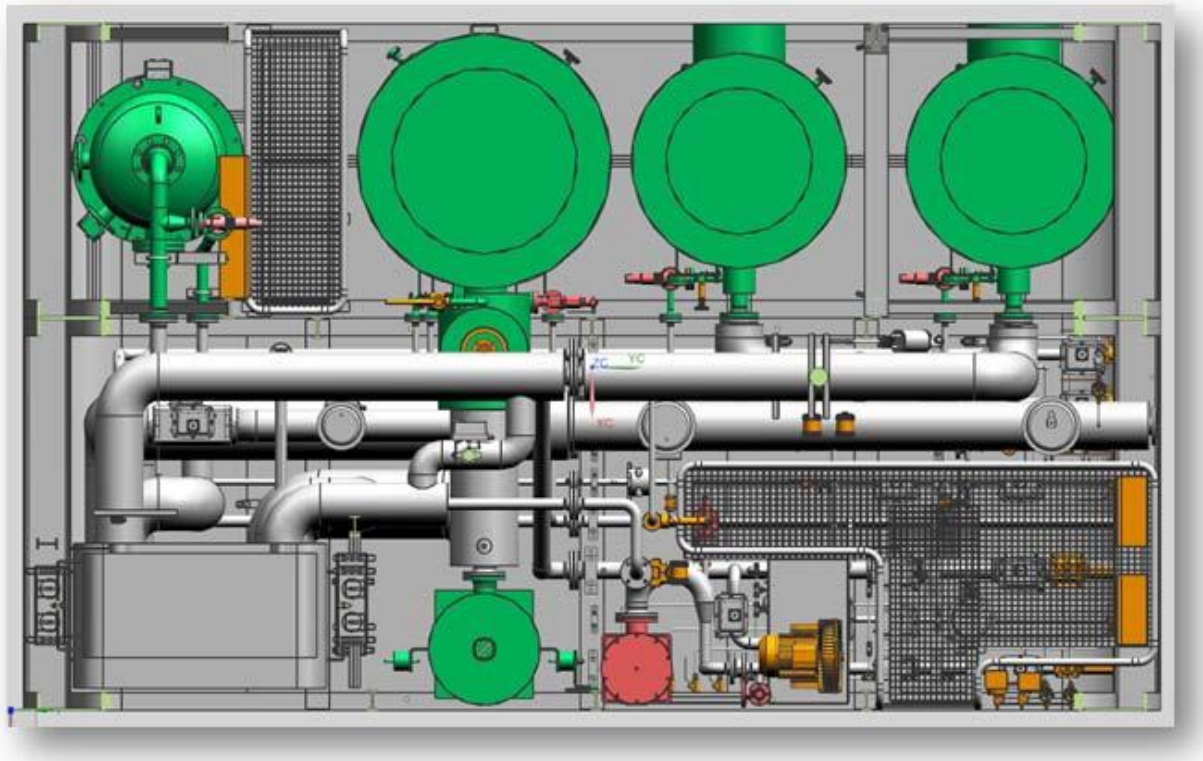


Automatic control system

Gas purification unit AES 3000 Main Control Panel



Maintenance Plan



Regular maintenance (lifetime related, inspection)

Access required (manual valves, check etc.)

Inspection

Period of operation / service costs

Reforming pressure vessel	**1 vessel**
Catalyst lifetime for full capacity	3-4 years
Volume per vessel	2.0 m3
Weight (of which catalyst) per vessel	4120 kg (2150 kg)
Replacement requires shutdown of unit.	
Desulphurization pressure vessels	**2 vessels**
Catalyst lifetime for full capacity	1 year @ 10 ppm H2S
Volume per vessel	1.0 m3
Weight (of which catalyst) per vessel	2120 kg (860 kg)
Replacement requires shutdown of unit.	

Service costs for 15 years of Gas purification unit AES 3000 operation are about 120 thousand Euro per year (0.75 Euro / MW) and include the replacement of catalysts, components and working hours.

Period of operation / consumable materials

OPEX is based on following specifications:		Full load (x1.1)	Full load
GasReformer max unit capacity (MW stands for shaft power)	MW	10.0	10.0
Average load (10-100%)	%	11.0	100.0
Feed LVOC	kg/h	1660	1509
H2S in feed (10-15 ppmV used in reference case)	ppmV	10	10.00
Components and hardware service (kEUR) for 15 years lifecycle			
Pressure vessel REF (replaced every 4th year)		712	649
Pressure vessel MET (replaced every 4th year)		15	15
Pressure vessel DES1 (replaced every year)		404	370
Pressure vessel DES2 (replaced every 4th year)		137	126
Filter replacement (replaced every year)		34	31
Cumulative OPEX costs for 15 years operation (component)	kEUR/15a	1302	1191
Service costs (workhours) independent on capacity	kEUR/a	2.9	2.9
Annual OPEX costs	kEUR/a	89.7	82.3
Daily OPEX costs	EUR/d	246	226
*)incl. Replacement of pressure vessel and catalyst, recertification of pressure vessel, service margin)	OPEX/MW	9.0	8.2

Example of consumbales for a 10MW APG AES 3000

Consumables & Streams		Ref data	Unit size	
Engine shaft power		**1**	**10**	**MW**
Feed gas		166	1659	kg/h
Product gas		210	2098	kg/h
Water / Steam				
		1	**10**	**MW**
Total Steam		195	1949	kg/h
Recycled boiler water		151	1509	kg/h
Boiler water consumed		44	439	kg/h
Cooling water consumption				
Inlet temperature		38		°C
Outlet temperature		65		°C
Flow		2896	28963	kg/h
Heat value		111	1106	kW
Nitrogen (purging, start-up & shutdowns)				
Nitrogen pressure			9	barg
Nitrogen purity			99.95	%
Consumption	Start up		6	Nm3
	Purging / shutdown		27	Nm3
Electrical load				
Nominal operation		12.4	124	kW
Start up per unit			50	kW
Stand by per unit			20	kW

Contact

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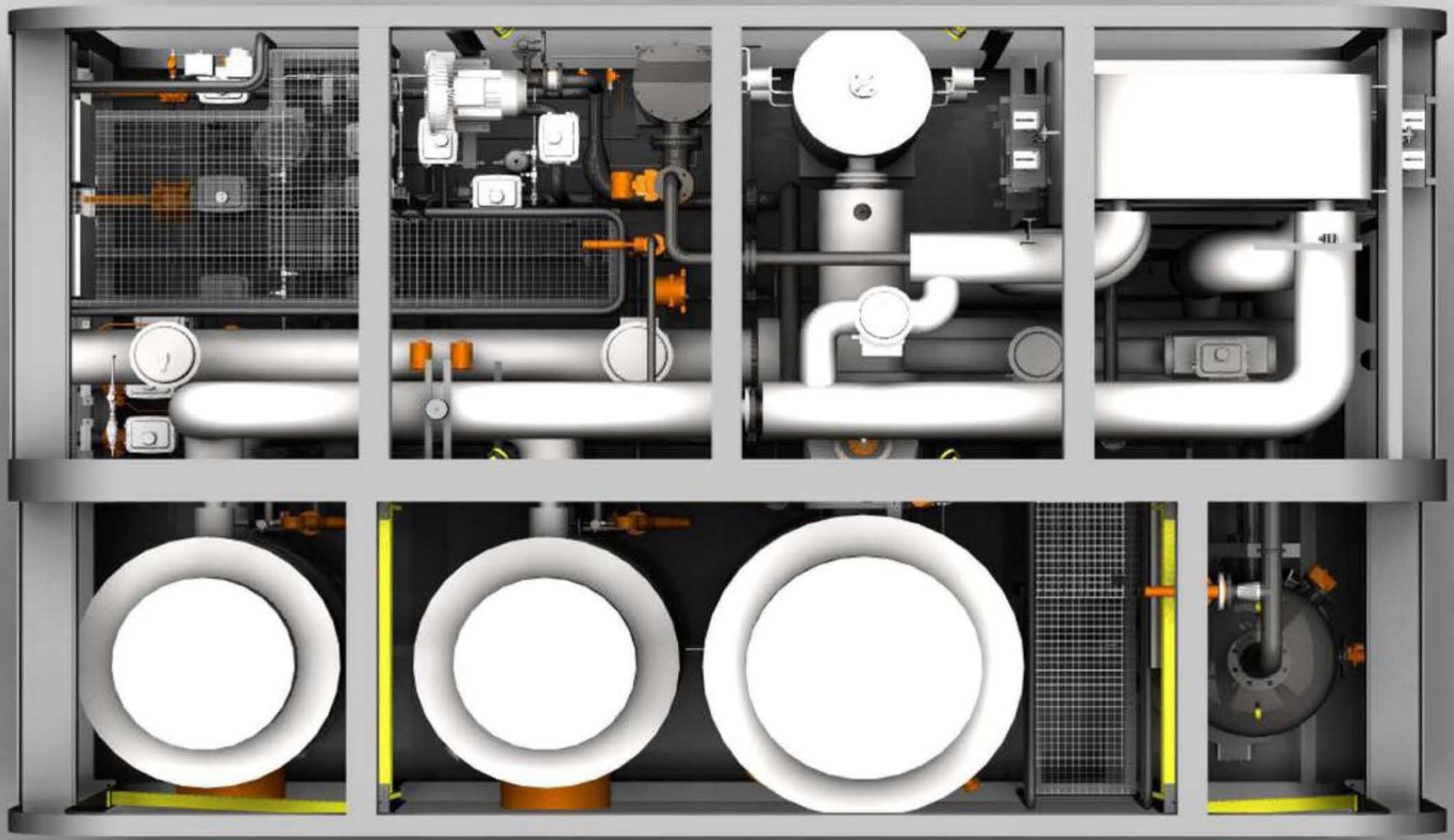

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