# WP6.
# Design Parameters and Costs of Onshore and Off-Shore Loading/Unloading Systems.

## General Report.

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| Type of Deliverable | | |
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| **R** | Document, Report | [X] |
| **DEM** | Demonstrator, pilot, prototype | |
| **DEC** | Websites, patent filings, videos, etc. | |
| **OTHER** | | |
| **ETHICS** | Ethics requirements | |
| **ORDP** | Open Research Data Pilot | |
| | | |
| **Dissemination Level** | | |
| PU | Public | [X] |
| CO | Confidential, only for Members of the Consortium (including the EU Commission Services) | [ ] |

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## A. Introduction

This report VTG offers for coordination with the Consortium participants the optimal technical parameters for the operation of the GASVESSEL loading/unloading systems.

In addition to the technical aspects, the VTG will consider an assessment of the cost of building the infrastructure of the terminals. Determining and estimating the cost of systems will help further to clarify the benefits of Gas transporting from different regions, as well as precise the Gas supply tariffs. With the further development of the Project and the real construction of the terminals, these materials can be used as basic materials for optimizing technical and commercial Gas supply solutions.

### A.1. Glossary, abbreviations, and acronyms

In this report, the Glossary, abbreviations, and acronyms will be applied to each element of the infrastructure of the GASVESSEL loading and unloading systems.

In general, it is possible to use such abbreviations and acronyms in the text of the report in any chapter or section:

| | |
|---|---|
| **EU** | The European Commission or in general Europe |
| **INEA** | Innovation and Networks Executive Agency of the European Commission |
| **PO** | Project Officer assigned by INEA to GASVESSEL Project |
| **Partner** | Company member of the GASVESSEL Project Consortium |
| **Project** | The GASVESSEL no. 723030 Project |
| **CNG** | Compressed Natural Gas |
| **GA** | Grant Agreement |
| **CA** | Consortium Agreement |
| **PMS** | Project Management System |
| **PM** | Project Management |
| **TM** | Team Management |
| **PA** | Project Administration |
| **P&C** | Planning and Controls |
| **PR** | Project Reporting |
| **DC** | Document Control |
| **HSEQ** | Health, Safety, Environment and Quality  controls and assurance |
| **PRM** | Procurement Management |
| **MM** | Materials Management |
| **WP** | Work Package |
| **NP** | Navalprogetti Srl – Trieste – Italy – The Coordinator – Partner -Lead Beneficiary of WP1 and WP5 |
| **DOW** | Dow Deutschland Anlaghengesellschaft mbH - Partner |
| **DOWA** | DowAksa Deutschland GMBH - Partner |
| **PNO** | PNO INNOVATION – Belgium – Partner – Lead Beneficiary WP9 |
| **VTG** | VNIPITTRANSGAZ – Kyiv – Ukraine – Partner – Lead Beneficiary WP6 |
| **SINTEF** | SINTEF OCEAN AS – Trondheim – Norway – Partner – Lead Beneficiary WP7 |
| **BMP** | BM Plus Srl – Buttrio – Italy – Partner – Lead Beneficiary WP4 |
| **CNGV** | CNGV d.o.o. – Izola – Slovenia – Partner – Lead Beneficiary WP3 |
| **CEN** | CENERGY Srl – Trieste – Italy - Partner |
| **HLL** | Hanseatic Lloyd Schiffahrt GMBH & Co – Bremen – Germany - Partner |
| **CHC** | Cyprus Hydrocarbon Company – Nicosia – Cyprus – Partner – Lead Beneficiary of WP2 |
| **EST** | ESTECO S.p.A. – Trieste – Italy - Partner |
| **ABS** | American Bureau of Shipping (Hellenic) – Athens – Greece – Partner – Lead Beneficiary |

| | WP8 |
|---|---|
| **O&G** | Oil and Gas |
| **WP1** | Project Management |
| **WP2** | Scenario analyses |
| **WP3** | Prototyping activities, the design of pressure cylinders and prototyping pilot line |
| **WP4** | Prototyping of pressure cylinders. Procurement/construction/arrangement of prototyping pilot line |
| **WP5** | Ship Design |
| **WP6** | Offshore & Onshore Gas loading/unloading systems |
| **WP7** | Costs and Benefits Analysis |
| **WP8** | Class Design Review – Safety Assessments |
| **WP9** | Dissemination and Exploitation |
| **QA** | Quality Assurance |
| **QC** | Quality Control |
| **CBA** | Costs Benefits Analysis |
| **Work Plan** | Planning of Activities in Attachment 1 of Project Management Plan D1.2 |
| **WBS** | Work Breakdown Structure |

**Table 1. Glossary, abbreviations, and acronyms.**

### A.2. Units of measurement[1].

The Units of measurement are accepted in the International System of Units (SI) and the tables of accepted units for convenience are duplicated in each section. The table of units of measurement contains the general units of measurement adopted in the SI system, as well as units of measurement of other systems, but which are allowed to be used in accordance with traditions.

| **SI base units** | | | |
|---|---|---|---|
| ***Base quantity*** | | ***SI base unit*** | |
| ***Name*** | ***Symbol*** | ***Name*** | ***Symbol*** |
| length | $l, x, r, etc.$ | meter | $m$ |
| mass | $M$ | kilogram | $kg$ |
| time, duration | $t$ | second | $s$ |
| electric current | $I, i$ | ampere | $A$ |
| thermodynamic temperature | $T$ | kelvin | $K$ |
| amount of substance | $n$ | mole | $mol$ |
| luminous intensity | $I_v$ | candela | $cd$ |
| **Coherent derived units in the SI expressed in terms of base** | | | |
| ***Base quantity*** | | ***SI base unit*** | |
| ***Name*** | ***Symbol*** | ***Name*** | ***Symbol*** |
| area | $A$ | square meter | $m^2$ (m^2) |
| volume | $V$ | cubic meter | $m^3$ (m^3) |
| Volume under Standard conditions | $V$ | cubic meter under Standard conditions | $scm$ |
| speed, velocity | $v$ | meter per second | $m/s$ |
| acceleration | $a$ | meter per second squared | $m/s^2$ (m/s^2) |
| wavenumber | $\sigma, \tilde{V}$ | reciprocal meter | $m^{-1}$ |

| | | | | |
|---|---|---|---|---|
| | | | | *(m^-1)* |
| density, mass density | $\rho$ | kilogram per cubic meter | | $kg/m^3$ *(kg/m^3)* |
| density under Standard conditions | $\rho$ | kilogram per cubic meter under Standard conditions | | *kg/scm* |
| surface density | $\rho_A$ | kilogram per square meter | | $kg/m^2$ *(kg/m^2)* |
| specific volume | $v$ | cubic meter per kilogram | | $m^3/kg$ *(m^3/kg)* |
| current density | $j$ | ampere per square meter | | $A/m^2$ *(A/m^2)* |
| magnetic field strength | $H$ | ampere per meter | | *A/m* |
| amount concentration, concentration | $c$ | mole per cubic meter | | $mol/m^3$ *(mol/m^3)* |
| mass concentration | $\rho, \gamma$ | kilogram per cubic meter | | $kg/m^3$ *(kg/m^3)* |
| concentration mass | $\rho$ | parts per million | | *ppm* |
| concentration volume | $\rho$ | parts per million, volume | | *ppmv* |
| luminance | $L_v$ | candela per square meter | | $cd/m^2$ *(cd/m^2)* |
| refractive index | $n$ | one | | *1* |
| relative permeability | $\mu_r$ | one | | *1* |
| **Coherent derived units in the SI with special names and symbols** | | | | |
| ***Derived quantity*** | ***SI coherent derived unit*** | | | |
| | ***Symbol*** | ***Name*** | ***Expressed in terms of other SI units*** | ***Expressed in terms of SI base units*** |
| plane angle | *rad* | radian | 1 | m/m |
| solid angle | *sr* | steradian | 1 | $m^2/m^2$ (m^2/m^2) |
| frequency | *Hz* | hertz | | $s^{-1}$ s^-1 |
| force | *N* | newton | | M kg $s^{-2}$ (M kg s^-2) |
| pressure, stress | *Pa* | pascal | $N/m^2$ | $m^{-1}$ kg $s^{-2}$ (m^-1 kg s^-2) |
| energy, work amount of heat | *J* | joule | N/m | $m^2$ kg $s^{-2}$ (m^2 kg s^-2) |
| power, radiant flux | *W* | watt | J/s | $m^2$ kg $s^{-3}$ (m^2 kg s^-3) |
| the electric potential difference, electromotive force | *V* | volt | W/A | $m^2$ kg $s^{-3}$ $A^{-1}$ (m^2 kg s^-3 A^-1) |
| electric resistance | $\Omega$ | ohm | V/A | $m^2$ kg $s^{-3}$ $A^{-2}$ (m^2 kg s^-3 A^-2) |
| Celsius temperature | $^0C$ | degree Celsius | | K+273 |
| luminous flux | *lm* | lumen | cd sr | cd |
| illuminance | *lx* | lux | $lm/m^2$ | $m^{-2}$ cd (m^-2 cd) |
| **SI coherent derived units whose names and symbols include SI coherent derived units with special names and symbols** | | | | |
| ***SI coherent derived unit*** | | | | |
| ***Derived quantity*** | ***Symbol*** | ***Name*** | | ***Expressed in*** |

| | | | *terms of SI base units* |
|---|---|---|---|
| dynamic viscosity | *Pa s* | pascal second | $m^{-1}$ kg $s^{-1}$ (m^-1 kg s^-1) |
| moment of force | *Nm* | newton meter | $m^{2}$ kg $s^{-2}$ (m^2 kg s^-2) |
| surface tension | *N/m* | newton per meter | kg $s^{-2}$ (kg s^-2) |
| angular velocity | *rad/s* | radian per second | m $m^{-1}$ $s^{-1}$= $s^{-1}$ (m m^-1 s^-1 = s^-1) |
| angular acceleration | *rad/s*$^2$ | radian per second squared | m $m^{-1}$ $s^{-2}$= $s^{-2}$ (m m^-1 s^-2 = s^-2) |
| heat flux density irradiance | *W/m*$^2$ | watt per square meter | kg $s^{-3}$ (kg s^-3) |
| heat capacity, entropy | *J/K* | joule per kelvin | $m^{2}$ kg $s^{-2}$ $K^{-1}$ (m^2 kg s^-2 K^-1) |
| specific heat capacity, specific entropy | *J/(kg K)* | joule per kilogram kelvin | $m^{2}$ $s^{-2}$ $K^{-1}$ (m^2 s^-2 K^-1) |
| specific energy | *J/kg* | joule per kilogram | $m^{2}$ $s^{-2}$ (m^2 s^-2) |
| thermal conductivity | *W/(m K)* | watt per meter kelvin | m kg $s^{-3}$ $K^{-1}$ (m kg s^-3 K^-1) |
| energy density | *J/m*$^3$ | joule per cubic meter | $m^{-1}$ kg $s^{-2}$ (m^-1 kg s^-2) |
| molar energy | *J/mol* | joule per mole | $m^{2}$ kg $s^{-2}$ $mol^{-1}$ (m^2 kg s^-2 mol^-1) |
| molar entropy<br>molar heat capacity | *J/(mol K)* | joule per mole kelvin | $m^{2}$ kg $s^{-2}$ $K^{-1}$ $mol^{-1}$ (m^2 kg s^-2 K mol^-1) |
| **Non-SI units accepted for use with the International System of Units** | | | |
| ***Quantity*** | ***Symbol*** | ***Name*** | ***The value in SI units*** |
| time | *min* | minute | 1 min = 60 s |
| | *h* | hour | 1 h = 60 min = 3600 s |
| | *d* | day | 1 d = 24 h = 86 400 s |
| plane angle | $^{0}$ | degree | $1^{0}$ = (π/180) rad |
| | *'* | minute | 1'=$(1/60)^{0}$=(π/10 800) rad |
| | *''* | second | 1''=(1/60)' =(π/648 000) rad |
| area | *ha* | hectare | 1ha = 1 $hm^{2}$ = $10^{4}$ $m^{2}$ |
| volume | *L* | liter | 1L = 1 $dm^{3}$ = $10^{3}$ $cm^{3}$ = $10^{-3}$ $m^{3}$ |
| mass | *t* | metric ton | 1t = $10^{3}$ kg |
| **Other non-SI units** | | | |
| ***Quantity*** | ***Symbol*** | ***Name*** | ***The value in SI units*** |
| pressure | *bar* | bar | 1bar=0.1 MPa=100 kPa= $10^{5}$ Pa |
| | *mmHg* | millimeter of mercury | 1 mmHg ≈ 133.322 Pa |
| length | *Å* | ångström | 1 Å = 0.1 nm = 100 pm = $10^{-10}$ m |
| distance | *M* | nautical mile | 1 M = 1852 m |
| speed | *kn* | knot | 1 kn = (1852/3600) m/s |
| **Non-SI units associated with the CGS and the CGS-Gaussian system of units** | | | |
| ***Quantity*** | ***Symbol*** | ***Name*** | ***The value in SI units*** |
| energy | *erg* | erg | 1 erg = $10^{-7}$ J |
| force | *dyn* | dyne | 1 dyn = $10^{-5}$ N |
| dynamic viscosity | *P* | poise | 1 P = 1 dyn s $cm^{-2}$ = 0.1 Pa s |

| | | | |
|---|---|---|---|
| kinematic viscosity | *St* | stokes | 1 St = 1 $cm^2$ $s^{-1}$ = $10^{-4}$ $m^2$ $s^{-1}$ |
| luminance | *sb* | stilb | 1 sb = 1 cd $cm^{-2}$ = $10^4$ cd $m^{-2}$ |
| illuminance | *ph* | phot | 1 ph = 1 cd sr $cm^{-2}$ = $10^4$ lx |
| acceleration | *Gal* | gal | 1 Gal = 1 cm $s^{-2}$ = $10^{-2}$ m $s^{-2}$ |

**Other units using in the text of Report**

| ***Derived quantity*** | ***Name*** | ***Expressed in terms of base units*** |
|---|---|---|
| Concentration, mass [2] | parts per million | *ppm* |
| Concentration, volume [3] | parts per million, volume | *ppmv* |
| Liquid flow rate (volume) | Million Standard cubic feet per day | *mscfd* |
| Liquid flow rate (volume) | Million Standard cubic meter per day | *mscmd* |
| Heat | kilocalorie,<br>British Thermal Units | *kcal,*<br>*Btu* |
| Heat flow rate | kilocalories per hour | *kcal/h* |
| Molecular weight | kilogram per kilogram mole | *kg/kg mol* |
| Noise | Decibel A-weighting | *dBA* |
| Piping nominal diameter | inches | *inch* |
| Thermal conductivity | kilocalories per meter degree C hour | *kcal/h m °C* |
| Speed rotating | revolutions per minute | *rpm* |
| Consumption | kilomole per hour<br>kilogram per hour | *kmol/h*<br>*kg/h* |
| The average linear coefficient of the heat transfer | Watt per meter square per degree Celsius | $W/m^2/C$<br>$W/m^2/K$ |
| Enthalpy | kilojoule per kilomole<br>kilojoule per hour | *kJ/kmol*<br>*kJ/h* |

**SI prefixes**

| ***Factor*** | ***Name*** | ***Symbol*** | ***Factor*** | ***Name*** | ***Symbol*** |
|---|---|---|---|---|---|
| $10^1$ | deka | *da* | $10^1$ | deci | *d* |
| $10^2$ | hecto | *h* | $10^2$ | centi | *c* |
| $10^3$ | kilo | *K* | $10^3$ | milli | *m* |
| $10^6$ | mega | *M* | $10^6$ | micro | *μ* |
| $10^9$ | giga | *G* | $10^9$ | nano | *n* |
| $10^{12}$ | tera | *T* | $10^{12}$ | pico | *p* |
| $10^{15}$ | peta | *P* | $10^{15}$ | femto | *f* |
| $10^{18}$ | exa | *E* | $10^{18}$ | atto | *a* |
| $10^{21}$ | zetta | *Z* | $10^{21}$ | zepto | *z* |
| $10^{24}$ | yotta | *Y* | $10^{24}$ | yocto | *y* |

Table 2. The system of units.

### A.3. Codes and Standards

The Codes and Standards used to build the infrastructure of the terminals for Gas loading and unloading of GASVESSEL must meet the Standards used in the best practice of international Engineering taking into account the national Standards of the countries where these terminals will be implemented.

In view of the large list of Codes and Standards applicable to each of the elements of the infrastructure of the GASVESSEL loading and unloading systems, we will indicate only the most important ones in each section describing the respective infrastructure.

**B. General philosophy and description of GASVESSEL loading and unloading systems**

In this section, we will consider the possible volumes of Gas for CNG ship loading and the amount of Gas demand in each region. Such an analysis should be done to determine the productivity of universal process modules as part of the Gas loading terminals.

Table 52 shows the cost of the infrastructure elements of the CNG ship loading/unloading terminals. The process code number approved in accordance with the following classification:

1. **Mediterranean Sea:**

**L1. Gas loading process**

- **L1.1** - Onshore Gas loading terminal facilities near the Vasilikos Energy hub – direction to Crete (the port of Linoperamata);
- **L1.2** - Onshore Gas loading terminal facilities near the Vasilikos Energy hub – direction to Lebanon (the port of Zouk);
- **L1.3** - Onshore Gas loading terminal facilities near the Vasilikos Energy hub – direction to Egypt (the port of Alexandria);
- **L1.4** - Offshore Gas loading terminal facilities near the Cyprus offshore Gas production platforms – direction to the port of Linoperamata (Crete);
- **L1.5** - Offshore Gas loading terminal facilities near the Cyprus offshore Gas production platforms – direction to the port of Zouk (Lebanon);
- **L1.6** - Offshore Gas loading terminal facilities near the Cyprus offshore Gas production platforms – direction to the port of Alexandria (Egypt);

**U1. Gas unloading process**

- **U1.1** - Onshore Gas unloading terminal facilities on Crete Island;
- **U1.2** - Onshore Gas unloading terminal facilities near the port of Zouk;
- **U1.3** - Onshore Gas unloading terminal facilities near the port of Alexandria;

2. **Barents Sea:**

**L2. Gas loading process**

- **L2.1** - Offshore Gas loading terminal facilities near the Alke Gas production platforms – direction to the Nyhamna Gas treatment plant;
- **L2.2** - Offshore Gas loading terminal facilities near the Alke Gas production platforms – direction to Aasta Hansteen Gas production platforms (enter to the Polarled underwater Gas pipeline);
- **L2.3** - Offshore Gas loading terminal facilities near the Johan Castberg Gas production platforms – direction to the Nyhamna Gas treatment plant;
- **L2.4** - Offshore Gas loading terminal facilities near the Johan Castberg Gas production platforms – direction to Aasta Hansteen Gas production platforms (enter to the Polarled underwater Gas pipeline);

**U2. Gas unloading process**

- **U2.1** - Onshore Gas unloading terminal facilities on the Nyhamna Gas treatment plant;
- **U2.2** - Offshore Gas unloading terminal facilities near the Aasta Hansteen Gas production platforms (enter to the Polarled underwater Gas pipeline);

3. **Black Sea:**

**L3. Gas loading process**

- **L3.1** – Onshore Gas loading terminal facilities near the port of Poti (Georgia);

**U3. Gas unloading process**

- **U3.1** – Onshore Gas unloading terminal facilities near the port of Yuzne (Ukraine);

4. **Out of Scope of Project in the Black Sea Region:**

- **O4.1 –** Head Gas compressor station of the Gas interconnector SCP - Gas loading terminal near the port of Poti (Georgia);
- **O4.2 -** Gas interconnector SCP - Gas loading terminal near the port of Poti (Georgia);
- **O4.3 -** Gas interconnector onshore unloading terminal near the Port of Yuzne (Ukraine) - point of connection on the CS Berezivka.

## B.1. East Mediterranean

In the work D2.1, carried out by the Consortium participants in 2018, were considered the markets of the Mediterranean.

According to the scenario of Gas delivery in the Mediterranean region, the Gas consumers market was designated by the following countries: Cyprus, Greece (islands), Lebanon, Jordan, Israel, Italy and France (Corsica). Egypt was also indicated as a potential Gas market. But, according to the latest reports from the official persons of Egypt, the country stops importing Liquefied Gas [4].

### B.1.1. East Mediterranean analysis of required Gas volumes

In our case, the thermal power plants have been selected as the main consumers of Gas. Also, the Gas loading/unloading terminal as part of the future Vasilikos Energy hub (Cyprus) can be operated in the loading mode and be used as a regional Gas hub: receiving Gas from EEZ Cyprus Gas production platforms through the offshore pipeline, as well as Gas export and in the intermediate storage mode for smoothing the peaks of Gas consumption. In a Table below we can see the list of Gas consumers in different countries in the eastern Mediterranean which are related to the Energy sector.

The main Gas consumers in the East Mediterranean are:

| No | Country | Consumer | Capacity, | Notes |
|---|---|---|---|---|
| 1.1 | **Cyprus (Island)** | Moni Power Station | 11.464 mscmd; 324.00 mscfd | Existing turbines cannot operate on Gas; no Gas pipeline network; no nearby port. |
| 1.2 | **Cyprus (Island)** | Vasilikos Power Plant | 71.079 mscmd; 2008.00 mscfd | Possibility for Natural Gas Conversion; no Gas pipeline network; no nearby port. |
| 1.3 | **Cyprus (Island)** | Dhekelia Power Plant | 37.668 mscmd; 1064.00 mscfd | Possibility for Natural Gas Conversion; no Gas pipeline network; no nearby port. |
| | **Cyprus** | **Total** | **120.211 mscmd; 3396.00 mscfd** | |
| 2.1 | **Greece (Island)** | Chios Extension Power Plant | 1.212 mscmd 34.00 mscfd | Possibility for Natural Gas Conversion; no Gas pipeline network; no nearby port. |
| 2.2 | **Greece (Island)** | Soroni Rodos Power Plant | 6.879 mscmd 194.00 mscfd | Possibility for Natural Gas Conversion; no Gas pipeline network; no nearby port. |
| 2.3 | **Greece (Island)** | Chania Power Plant Crete | 28.25 mscmd 798.00 mscfd | Possibility for Natural Gas Conversion; no Gas pipeline network; no nearby port. |
| 2.4 | **Greece (Island)** | Linoperamata Power Plant Crete | 22.27 mscmd 629.00 mscfd | Possibility for Natural Gas Conversion; no Gas pipeline network; no nearby port. |
| 2.5 | **Greece (Island)** | Atherinolakkos IC Power Plant | 15.97 mscmd 451.00 mscfd | Possibility for Natural Gas Conversion; no Gas pipeline network; no nearby port. |
| | **Greece** | **Total** | **74.581 mscmd; 2106.00 mscfd** | |
| 3.1 | **Italy (Mainland)** | ENEL Porto Tolle Thermal Power Plant | 216.184 mscmd 6108.00 mscfd | Possibility for Natural Gas Conversion; available Gas pipeline network; nearby port. |
| 3.2 | **Italy (Mainland)** | ENIPOWER S.P.A. Stabil. di Brindisi | 108.174 mscmd 3056.00 mscfd | Possibility for Natural Gas Conversion; available Gas pipeline network; |

| | | | | |
|---|---|---|---|---|
| | | | | nearby port. |
| 3.3 | **Italy (Mainland)** | Enel Marzocco Oil Power Plant | 25.385 mscmd<br>717.00 mscfd | Possibility for Natural Gas Conversion;<br>available Gas pipeline network;<br>nearby port. |
| 3.4 | **Italy (Mainland)** | ENEL Piombino Thermal Power Plant | 78.61 mscmd<br>2220.00 mscfd | Possibility for Natural Gas Conversion;<br>available Gas pipeline network;<br>nearby port. |
| 3.5 | **Italy (Island)** | Sarlux (Cagliari) IGCC Power Plant | 45.038 mscmd<br>1272.00 mscfd | Possibility for Natural Gas Conversion;<br>available Gas pipeline network;<br>nearby port. |
| 3.6 | **Italy (Island)** | Ottana Oil CHP Power Plant | 11.464 mscmd<br>324.00 mscfd | Possibility for Natural Gas Conversion;<br>available Gas pipeline network;<br>nearby port. |
| 3.7 | **Italy (Island)** | Edipower San Filippo del Mela Thermal Power Plant | 104.817 mscmd<br>2961.00 mscfd | Possibility for Natural Gas Conversion;<br>available Gas pipeline network;<br>nearby port. |
| 3.8 | **Italy (Mainland)** | ISAB Priolo Gargallo IGCC Power Plant | 216.184 mscmd<br>6108.00 mscfd | Possibility for Natural Gas Conversion;<br>available Gas pipeline network;<br>nearby port. |
| | **Italy** | **Total** | **806.856 mscmd**<br>**22766.97 mscfd** | |
| 4.1 | **France, Corsica (Island)** | Lucciana Thermal Power Plant | 10.727 mscmd<br>303.00 mscfd | Possibility for Natural Gas Conversion;<br>no available Gas pipeline network;<br>nearby port. |
| 4.2 | **France, Corsica (Island)** | Vazzio Thermal Power Plant | 11.096 mscmd<br>313.00 mscfd | Possibility for Natural Gas Conversion;<br>no available Gas pipeline network;<br>nearby port. |
| | **France** | **Total** | **21.823 mscmd**<br>**616.00 mscfd** | |
| 5.1 | **Lebanon (Mainland)** | Deir-Ammar CCGT Power Plant | 38.487 mscmd<br>1087.00 mscfd | Possibility for Natural Gas Conversion;<br>available Gas pipeline network;<br>nearby port. |
| 5.2 | **Lebanon (Mainland)** | Al-Hreesha (Hreishi) Thermal Power Plant | 6.142 mscmd<br>174.00 mscfd | Possibility for Natural Gas Conversion;<br>available Gas pipeline network;<br>nearby port. |
| 5.3 | **Lebanon (Mainland)** | Zouk Thermal Power Plant | 49.706 mscmd<br>1404.00 mscfd | Possibility for Natural Gas Conversion;<br>no available Gas pipeline network;<br>nearby port. |
| 5.4 | **Lebanon (Mainland)** | Jieh Thermal Power Plant | 28.333 mscmd<br>800.00 mscfd | Possibility for Natural Gas Conversion;<br>no available Gas pipeline network;<br>nearby port. |
| 5.5 | **Lebanon (Mainland)** | Zahrani CCGT Power Plant | 38.487 mscmd<br>1087.00 mscfd | Possibility for Natural Gas Conversion;<br>no available Gas pipeline network;<br>nearby port. |
| 5.6 | **Lebanon (Mainland)** | Tyre (Sour) Thermal Power Plant | 5.732 mscmd | Possibility for Natural Gas Conversion;<br>no available Gas pipeline |

| | | | | |
|---|---|---|---|---|
| | | | 162.00 mscfd | network;<br>nearby port. |
| | **Lebanon** | **Total** | **166.887 mscmd**<br>**4714.00 mscfd** | |
| | | **Lump-Sum** | **1190.358 mscmd**<br>**33598.97 mscfd** | |

Table 3. The GASVESSEL main Gas consumers in East Mediterranean

Thus, we see that the total required volume of Gas supply at the offshore field is 12.0956 billion cubic meters per year. In the future, these numbers may be considered as a potential for calculating the efficiency of the GASVESSEL Project.

#### B.1.1.1. Gas to Cyprus

Gas supply to the island of Cyprus is possible using two Gas supply options:

- Deliveries of the Gas from an offshore field in Cyprus EEZ to the Energy hub near the port of Vasilikos via an offshore Gas pipeline;
- Deliveries of the Gas from an offshore field in Cyprus EEZ to the Energy hub near the port of Vasilikos using the CNG ship.

The option of Gas supply through an offshore Gas pipeline is not considered.
According to the forecasted Gas consumption in Cyprus, the required amount of Gas for transshipment to the Energy hub near the port of Vasilikos will be of **4,2 mscmd** by Underwater Gas pipeline. The Cyprus Gas demand is **2,8 mscmd** and **1,4 mscmd** by the CNG ship must be transferred to Crete Island. The conception of Gas supply to Crete provides for the loading operation of the Gas loading terminal near the port of Vasilikos:

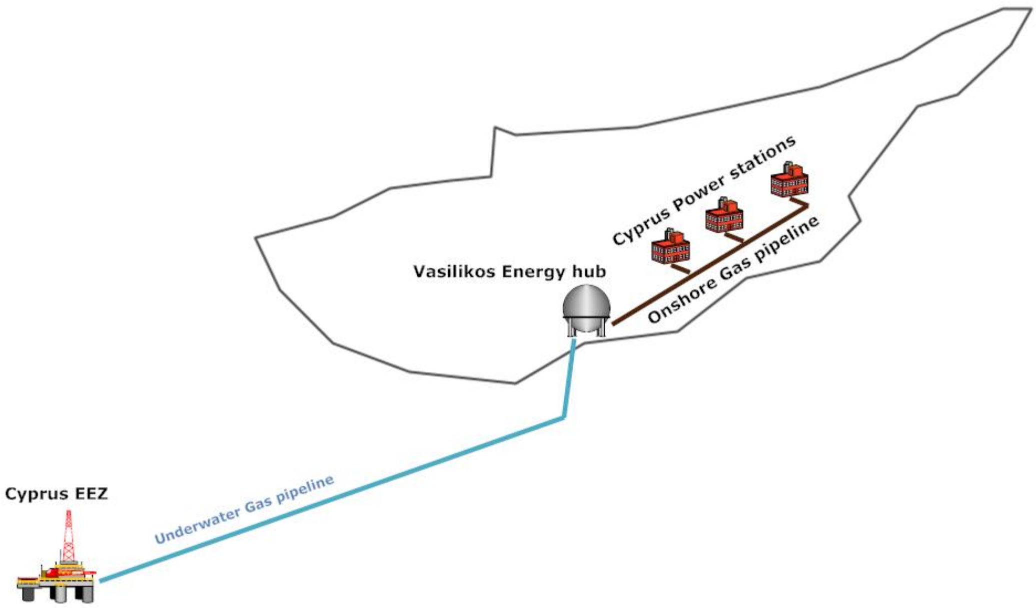



Figure 1. Gas delivery to Cyprus Energy hub (near the port of Vasilikos) using the underwater Gas pipeline.

Figure 1 above shows the Gas delivery to the Vasilikos Energy hub via the Underwater Gas pipeline from the Cyprus EEZ offshore Gas production platforms.

#### B.1.1.2. Gas to Greece

Figure 2 below shows the Gas delivery to Crete from the Cyprus EEZ offshore Gas production platforms via the underwater Gas pipeline and then using the GASVESSEL system.

For more details on the list of modules and systems of Gas loading and unloading terminals in the Mediterranean Sea, we can see in section B.1.3.

The total Gas volume parameters of Gas supplying to Cyprus are shown in Table 4.

The Gas consumption in Greece (the Energy sector of Crete) required the number of Gas for transshipment from the Vasilikos Energy hub is about **1,4 mscmd**. The Conception of Gas delivery to Greece provides the variants of delivery from Vasilikos Energy hub or Cyprus EEZ directly.

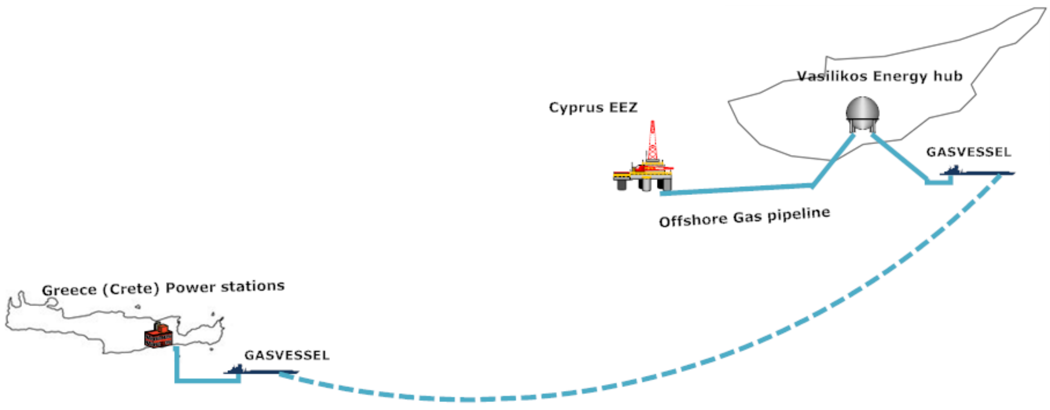



Figure 2. Gas delivery to Crete Power stations from Vasilikos Energy hub using the GASVESSEL system

Figure 3 below shows the option of Gas delivery to Greece (Crete) Power stations directly from the Cyprus EEZ offshore Gas production platforms using the GASVESSEL infrastructure.

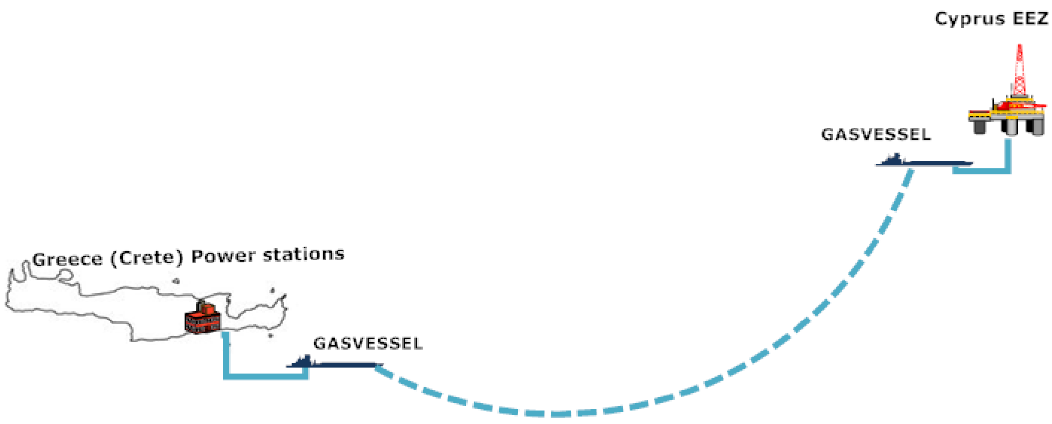



Figure 3. Gas delivery to Crete Power stations from Cyprus EEZ offshore platforms using the GASVESSEL system

The total Gas volume parameters of Gas supplying to Crete are shown in Table 4.

#### B.1.1.3. Gas to Lebanon

The Gas consumption in Lebanon (the Energy sector) is required the amount of **3.70 mscmd**. The Conception of Gas delivery to Lebanon provides the variants of delivery from Vasilikos Energy hub or Cyprus EEZ directly.


Figure 4. Gas delivery to Lebanon from the Vasilikos Energy hub using the GASVESSEL system.

Figure 4 above shows the Gas delivery to Lebanon from the proposed new Energy hub near the port of Vasilikos using the GASVESSEL system.

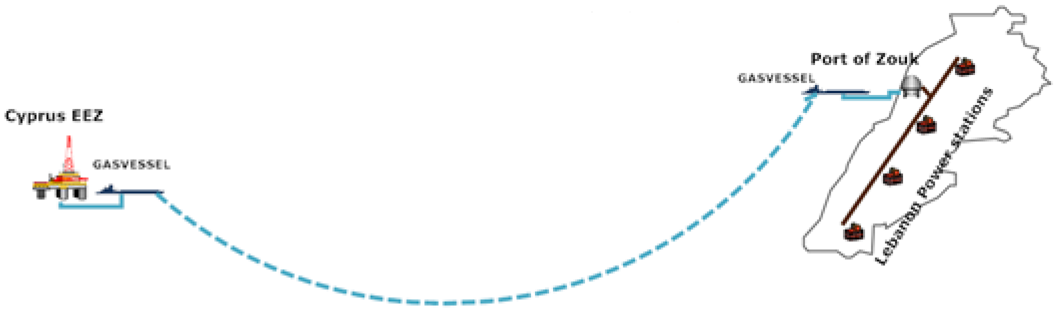



Figure 5. Gas delivery to Lebanon from the Cyprus EEZ offshore platforms using the GASVESSEL system.

Figure 5 above shows the Option of the gas delivery to Lebanon from the offshore platforms on Cyprus EEZ using the GASVESSEL infrastructure.
The total gas volume parameters of gas supplying of Lebanon are shown in Table 4.
The gas supply to the other countries (Italy, France) is not presented in this analysis, because at this stage it is difficult to determine the volumes of gas supply at a competitive price, and therefore the parameters of the process modules of the loading/unloading terminals cannot be correctly determined. In the subsequent stages of the Project, when compiling the Feasibility Study for the construction of gas terminals and gas Interconnectors, such parameters can be determined to take into account the linkage to a specific location of the terminal or interconnector and to take into account the required volume of gas supply.

#### B.1.1.4. Gas to Egypt

Gas supply to Egypt is possible using such gas supply options:

- Deliveries of the gas from the Energy hub near the port of Vasilikos using the GASVESSEL system to the points of gas unloading in the port of Alexandria;
- Deliveries of the gas from an offshore gas field in Cyprus EEZ using CNG ship directly to the port of Alexandria.

The gas consumption in Egypt (the Energy sector) is required the amount of **17.00 mscmd**.

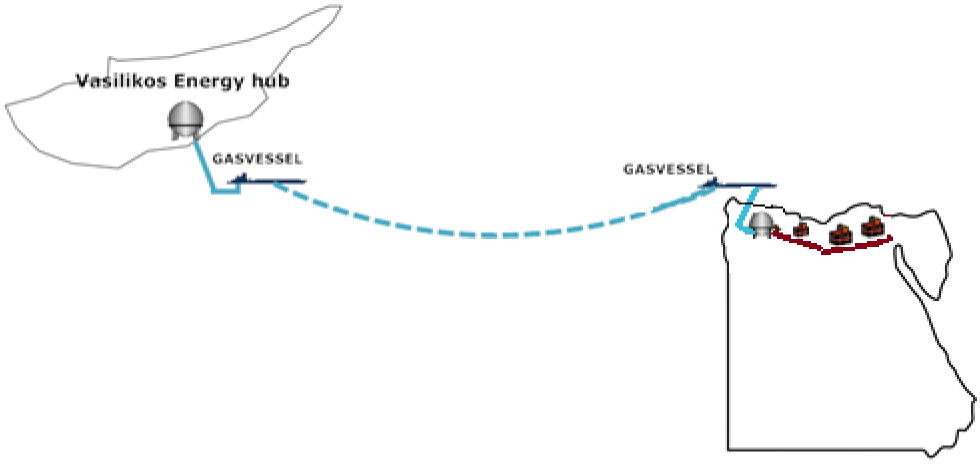



Figure 6. Gas delivery to the port of Alexandria (Egypt) from Vasilikos Energy hub using the GASVESSEL system.

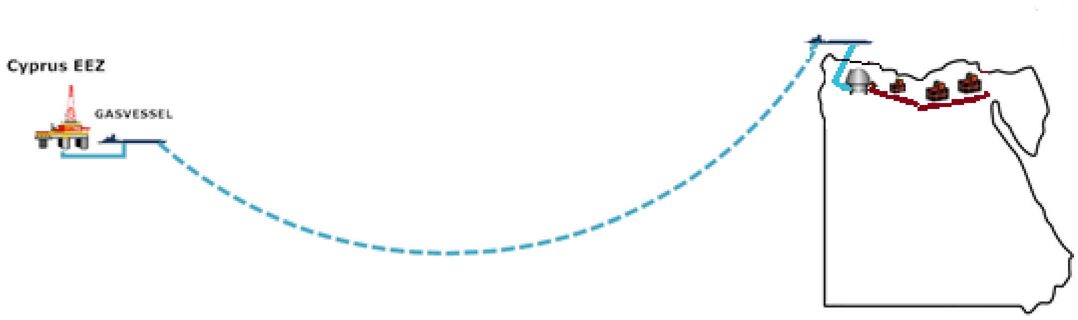



Figure 7. Gas delivery to the port of Alexandria (Egypt) from the Cyprus EEZ offshore platforms using the GASVESSEL system.

Figure 7 above shows, the Option of the gas delivery to Egypt from the offshore platforms on Cyprus EEZ using the GASVESSEL system.
The total gas volume parameters of gas supplying of Egypt are shown in Table 4.
The gas supply to the other countries (Italy, France) is not presented in this analysis, because at this stage it is difficult to determine the volumes of gas supply at a competitive price, and therefore the parameters of the process modules of the loading/unloading terminals cannot be correctly determined. In the subsequent stages of the Project, when compiling the Feasibility Study for the construction of gas terminals and Gas Interconnectors, such parameters can be determined to take into account the linkage to a specific location of the terminal or interconnector and to take into account the required volume of gas supply.

#### B.1.2. Conclusions on the Mediterranean loading/unloading parameters

Based on the above analyses, the main parameters of the CNG ship loading/unloading are determined:

Table 4 gives a view of the required Gas transfer capacity at the points of Gas loading and unloading both at offshore fields and at onshore terminals near the ports.
Thus, we can see that the productive capacity of the CNG ship loading/unloading terminals differs both depending on the sources of Gas supply and in Gas consumption mode and the updated technical parameters of loading and unloading capacity of modules will be presented in the relevant sections of this Report.

| No | Source | Loading Volume | Loading point | Unloading Volume | Unloading point | Estimated Gas volume | Transfer type | Consumer | Notes |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Offshore Gas fields on Cyprus EEZ | 24,88 mscmd, | Cyprus EEZ Offshore Gas loading terminal | 24,88 mscmd, | Vasilikos Energy hub | 24,88 mscmd, | Underwater Gas pipeline | Vasilikos Energy hub | Gas for Cyprus Power stations |
| 2 | Offshore Gas fields on Cyprus EEZ | 1,40 mscmd | Vasilikos Energy hub Gas loading terminal | 1,40 mscmd | Linoperamata Onshore Gas unloading terminal in Greece (Crete) | 1,40 mscmd | GASVESSEL | Crete Power station | Gas for Crete Power stations |
| 3 | Offshore Gas fields on Cyprus EEZ | 3,70 mscmd | Vasilikos Energy hub Gas loading terminal | 3,70 mscmd | Onshore Gas unloading terminal near the port of Zouk (Lebanon) | 3,70 mscmd | GASVESSEL | Lebanon Power station | Gas for Lebanon Power stations |
| 4 | Offshore Gas fields on Cyprus EEZ | 17,00 mscmd | Vasilikos Energy hub Gas loading terminal | 17,00 mscmd | Onshore Gas unloading terminal near the port of Alexandria (Egypt) | 17,00 mscmd | GASVESSEL | Egypt Power station | Gas for Egypt Power stations |

**Table 4. The Gas volume parameters of the loading/unloading terminals in the Mediterranean Sea.**

### B.1.3. The infrastructure of the terminals

In this section of the Report, we set out a vision of the VTG on the arrangement of loading and unloading Gas terminals for loading/unloading service during the gas supplying in the Mediterranean Sea region.

The modules of equipment and systems are necessary for the realization of the tasks of gas loading and unloading for the GASVESSEL system. The Gas loading terminals in the water area of the Mediterranean Sea can be divided into offshore and onshore.

The offshore loading terminals are located near the offshore gas production platforms and have the structures, modules, and systems, depending on the possibilities of mutual using the existing infrastructure or systems of the gas production platforms.

#### B.1.3.1. Onshore Gas loading terminal near the Vasilikos Energy hub on Cyprus

In the development up of a list of the necessary processes for CNG ship loading, we will make several assumptions. These assumptions can be adjusted at further stages of the Project's development in accordance with local conditions, such as gas loading pressure, actual gas flow for loading, the necessary equipment on the loading terminal to perform the loading process and other factors. The list of assumptions is given below (also see Table 5):

- The CNG ship capacity (12,00 mscm or 9,00 mscm according to the scenarios);
- The loading time is determined by Consortium based on the technical capabilities of the CNG ships, (it is 48 hours or 32 hours);
- It is assumed that the volume of intermediate Gas storage during loading of the CNG ship must be at least the volume of the CNG ship (according to the scenarios);
- The gas temperature during the CNG ship loading must not exceed 40 $^{0}$C;
- The loading gas from the Vasilikos Energy hub is supplied cleaned in accordance with the applicable Quality Standards.
- The piping diameter should be selected from the condition of the gas velocity inside of the pipes within 5 to 20 m/s.

In addition to the above assumptions, the Initial Data received from the cEnergy company were used for calculations.

All modules and systems can be divided by:

- **Main process facilities** (modules) of the Onshore gas loading terminal (the main facilities necessary for the loading process);
- **Auxiliary process facilities** (modules) of the Onshore gas loading terminal (the auxiliary facilities to ensure the work of the Main process facilities);
- **Life support facilities** (modules) of the Onshore gas loading terminal (the facilities that ensure and support the operation of the entire terminal).

Below is shown the composition of the gas loading terminal near the Vasilikos Energy hub in Cyprus, which consist the modules and systems and the connection pipelines or part of pipelines:

| **Facilities in the scope of the Project** |
|---|
| **Onshore Gas loading terminal** |
| ***Main process facilities (modules) of Onshore Gas loading terminal*** |
| Gas compressor module |
| Gas cooling module |
| Gas storage module |
| Gas measuring module |
| ***Auxiliary process facilities (modules) of Onshore Gas loading terminal*** |

| |
|---|
| Process automation and signaling system |
| Instrument and Plant Air System |
| Nitrogen Generation and Distribution System |
| Vent/Flare System |
| Power supply and Distribution System |
| Electrochemical anti-corrosion protection System |
| Diesel generator module |
| Diesel Fuel System |
| Communication, alarm, fire alarm system |
| Overhead transmission line (V=10 kV), (if any) |
| Power, control and signaling cables |
| Auxiliary site pipelines |
| ***Life support facilities (modules) of Onshore Gas loading terminal*** |
| Water and sewage system |
| Firewater and fire-fighting system |
| Evaporation pond |
| Ancillary buildings and structures, site improvements |
| **Connection pipelines** |
| Pipeline 2 (Onshore Gas pipeline,  D=14 inches) |
| Pipeline 3 (Underwater Gas pipeline,  D=14 inches) |
| PLEM1, (D=14 inches) |
| Pipeline 4 (Flexible connection,  D=3x7 inches) |
| **Facilities out of the scope of the Project** |
| Gas Storage on Vasilikos Energy hub |
| Pipeline1 (Onshore Gas pipeline, D=14 inches) |

The composition of modules and systems is determined according to the position that in GASVESSEL Project we focused only on the gas transportation systems and necessity of loading and unloading system for CNG ships. Gas delivery to loading terminals or from unloading terminals to consumers is also described and evaluated the cost but is not included in the cost of tariffs. It is assumed that this will be solved in each particular case of the construction of loading/unloading Gas terminals, where the existing infrastructure facilities of enterprises located in the construction area, as well as local taxes will be taken into account.
The Gas loading terminal near the Vasilikos Energy hub load CNG ships transporting the gas to Crete Island, as well as to the ports of Lebanon and Egypt.

#### B.1.3.2. Onshore Gas unloading terminal near the port of Linoperamata, the ports of Zouk and Alexandria

In development up of a list of the necessary processes for CNG ship unloading we will make also such assumptions (also see Table 7):

- The CNG ship capacity ( 12,00 mscm or 9,00 mscm according to the scenarios);
- The unloading time is determined by Consortium based on the technical capabilities of the CNG ships (it is 71hours or 54);
- It is assumed that the volume of intermediate Gas storage during unloading of the CNG ship must be at least the volume of the CNG ship (according to the scenarios);

- During the unloading process, the gas is released into a connecting pipeline at the pressure of 80 bar. In the process of unloading of the GASVESSEL cylinders about halfway, the compressor on the shipboard is turned on and pumps the gas to a minimum volume with a residual pressure of about 20 bar;
- The gas temperature during the CNG ship unloading must be not less than 10 $^0$C and no more than 40 $^0$C;
- The piping diameter should be selected from the condition of the gas velocity inside of the pipes within 5 to 20 m/s.

All modules, systems can be divided by:

- **Main process facilities** (modules) of Onshore Gas loading terminal (the main facilities necessary for the loading process);
- **Auxiliary process facilities** (modules) of Onshore Gas loading terminal (the auxiliary facilities to ensure the work of the Main process facilities);
- **Life support facilities** (modules) of the Onshore Gas loading terminal (the facilities that ensure and support the operation of the entire terminal).

The list of facilities below shows the structures of the onshore Gas unloading terminal facilities near the port on the Crete Island (Greece) and the ports of Lebanon and Egypt.

| **Facilities in the scope of the Project** |
|---|
| **Onshore Gas unloading terminal** |
| ***Main process facilities (modules) of Onshore Gas unloading terminal*** |
| Gas storage module |
| Gas pressure reducing module |
| Gas heating module |
| Gas measuring module |
| ***Auxiliary process facilities (modules) of Onshore Gas unloading terminal*** |
| Process automation and signaling system |
| Instrument and Plant Air System |
| Nitrogen Generation and Distribution System |
| Vent/Flare System |
| Power supply and Distribution System |
| Electrochemical anti-corrosion protection System |
| Diesel generator module |
| Diesel Fuel System |
| Communication, alarm, fire alarm system |
| Overhead transmission line (V=10 kV), (if any) |
| Power, control and signaling cables |
| Auxiliary site pipelines |
| ***Life support facilities (modules) of Onshore Gas unloading terminal*** |
| Water and sewage system |
| Firewater and fire-fighting system |
| Evaporation pond |
| Ancillary buildings and structures, site improvements |
| **Connection pipelines** |
| Pipeline 1 (Flexible connection, D=3x7 inches) |

| |
|---|
| PLEM1, (D=14 inches) |
| Pipeline 2 (Underwater Gas pipeline, D=14 inches) |
| PLEM 2, (D=14 inches) |
| Pipeline 3 (Onshore Gas pipeline, D=14 inches) |
| Tie in point to the existing Gas network |
| **Facilities out of the scope of the Project** |
| Pipeline 4 (Onshore Gas pipeline, to the existing Gas network, D=14 inches) |

#### B.1.3.3. Diagrams and parameters of the CNG ship loading/unloading process in the Mediterranean Sea

The processes of loading and unloading performed at the terminals of CNG ships loading/unloading were calculated in two different ways on different programs Aspen HYSYS and GasCondOil.

##### B.1.3.3.1. *Processes L1.1, 1.2, 1.3.* The parameters and Diagram of the CNG ship loading process for gas supplies to Crete, Lebanon, and Egypt

Below are shown the initial data for calculating the loading diagram for gas delivery from Vasilikos Energy hub to the ports of Linoperamata, Zouk and Alexandria in delivery volumes of a 1,4, 3,7 and 17 mscmd. The list of facilities on the loading diagram is formed taking into account the loading process from the onshore terminal.

| Name of Data | The direction of delivery, to: | | |
|---|---|---|---|
| | **Crete, Process L1.1** | **Lebanon, Process L1.2** | **Egypt, Process L1.3** |
| The ship net capacity, $Nm^3$; | 12 000 000 | 9 000 000 | 12 000 000 |
| Updated loading time, hours; | 48 | 32 | 48 |
| Loading pressure, bar; | 240 | 240 | 240 |
| The Maximum Gas temperature during loading, $^0C$; | 25 | 25 | 25 |
| Average Gas flow rate, $Nm^3/d$; | 6.122 | 6.122 | 6.122 |
| Maximum Gas flow rate, $Nm^3/d$; | 15.286 | 15.286 | 15.286 |
| Ships loading frequency, days; | 6.4 | 3.75 | 5.76 |
| Quantity of CNG ships, pcs | 1 | 2 | 8 |
| Gas storage volume, $Nm^3$ | 9 000 000 | 13 900 000 | 14 500 000 |
| Storage Gas Temperature, $^0C$; | 25 | 25 | 25 |
| Air temperature, $^0C$; | 20 | 20 | 20 |
| Seawater temperature, $^0C$; | 20 | 20 | 20 |

**Table 5. List of initial data for calculating the process of Gas loading from the onshore terminal near the Vasilikos Energy hub.**

**L1.1**
**CNG ship loading from Vasilikos Energy hub (direction to Crete)**
**G=1,4 mscmd**

| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.54 | C |
| Feed Pressure | 120.0 | bar |
| Product Pressure | 118.5 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 500.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 12.87 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.82 | C |
| Feed Pressure | 239.0 | bar |
| Product Pressure | 237.4 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 6.608 | m/s |

| Compressor | | |
|---|---|---|
| Feed Pressure | 118.5 | bar |
| Product Pressure | 240.0 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Energy | 1.510e+004 | kW |

| Pipeline3 | | |
|---|---|---|
| Feed Temperature | 24.82 | C |
| Feed Pressure | 237.4 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_4) | 6.625 | m/s |

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 24.64 | C |
| Feed Pressure | 235.8 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_5) | 6.640 | m/s |

| Cooler | | |
|---|---|---|
| Feed Temperature | 85.41 | C |
| Product Temperature | 25.00 | C |
| Duty | 2.472e+004 | kW |

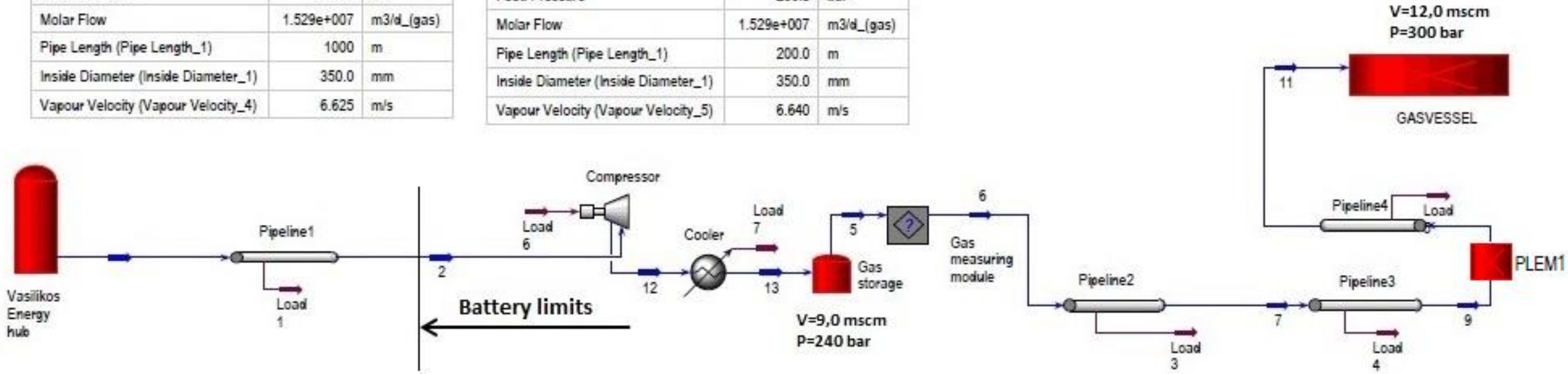
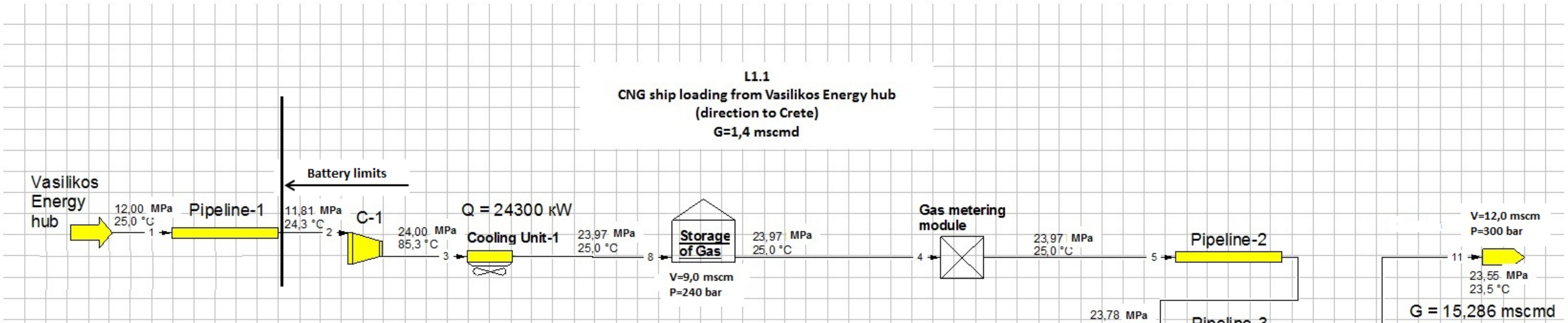



**Figure 8. Technical parameters of Gas loading terminal near the Vasilikos Energy hub - direction to Crete. (HYSYS).**




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 |
|---|---|---|---|---|
| L, m | 500 | 1000 | 1000 | 200 |
| D, mm | 350 | 350 | 350 | 350 |
| V, m/sec | 13,0 | 6,8 | 6,8 | 6,85 |

| C-1 | | |
|---|---|---|
| Pin | 11,8 | (MPa) |
| Pout | 24,0 | |
| E = | 14854 | (кW) |

**Figure 9. Technical parameters of Gas loading terminal near the Vasilikos Energy hub - direction to Crete. (GasCondOil).**

**L1.2**
**CNG ship loading from Vasilikos Energy hub (direction to Lebanon)**
**G=3,7 mscmd**

| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.54 | C |
| Feed Pressure | 120.0 | bar |
| Product Pressure | 118.5 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 500.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 12.87 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.82 | C |
| Feed Pressure | 239.0 | bar |
| Product Pressure | 237.4 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 6.608 | m/s |

| Compressor | | |
|---|---|---|
| Feed Pressure | 118.5 | bar |
| Product Pressure | 240.0 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Energy | 1.510e+004 | kW |

| Cooler | | |
|---|---|---|
| Feed Temperature | 85.41 | C |
| Product Temperature | 25.00 | C |
| Duty | 2.472e+004 | kW |

| Pipeline3 | | |
|---|---|---|
| Feed Temperature | 24.82 | C |
| Feed Pressure | 237.4 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_4) | 6.625 | m/s |

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 24.64 | C |
| Feed Pressure | 235.8 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_5) | 6.640 | m/s |

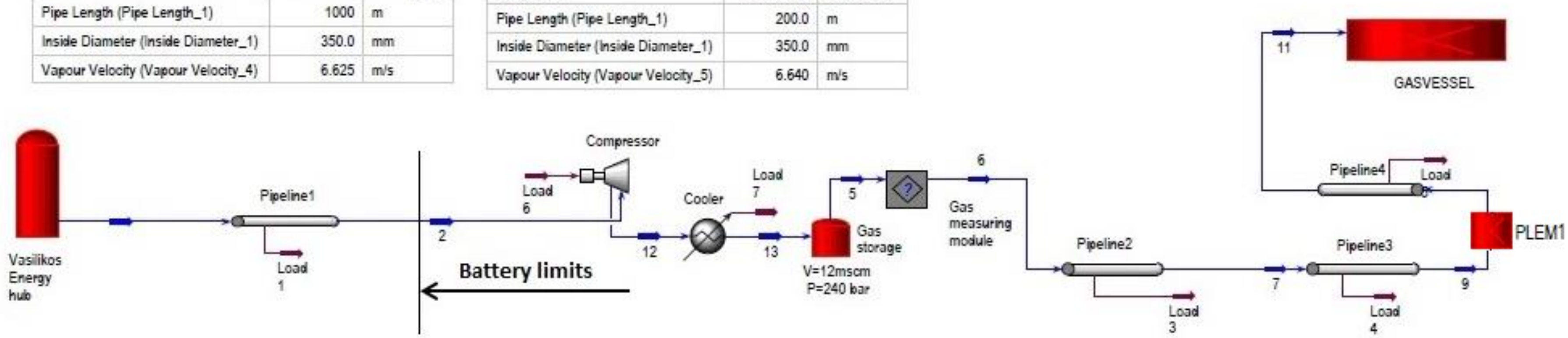



**Figure 10. Technical parameters of Gas loading terminal near the Vasilikos Energy hub - direction to Lebanon. (HYSYS).**

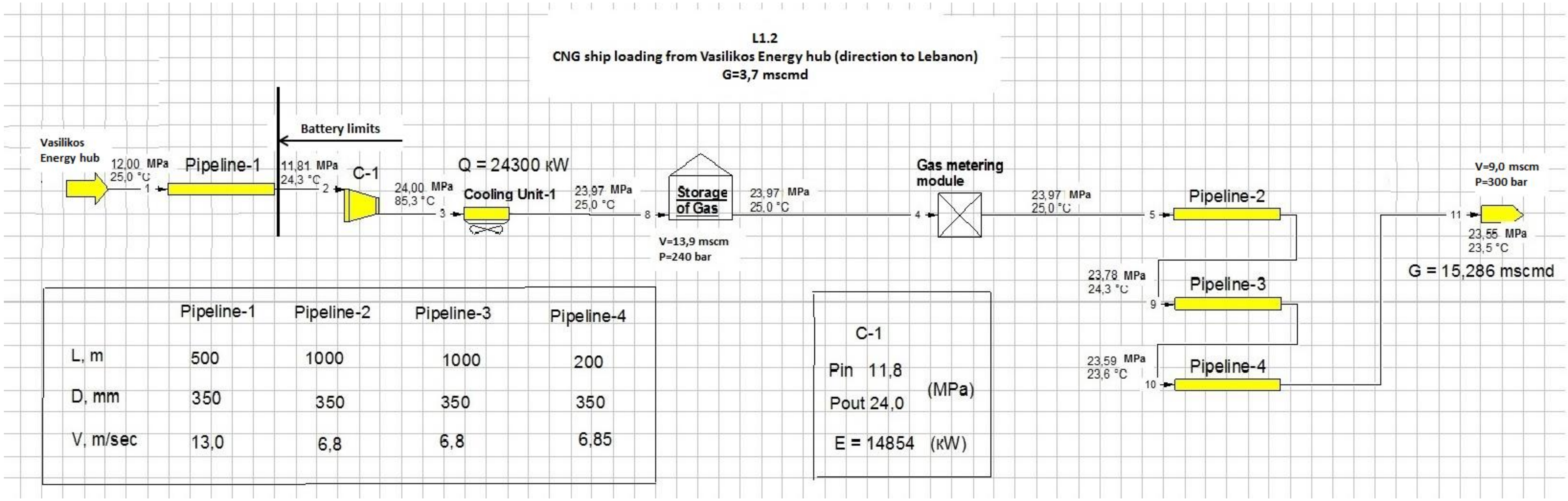



**Figure 11. Technical parameters of Gas loading terminal near the Vasilikos Energy hub - direction to Lebanon. (GasCondOil).**

**L1.3**
**CNG ship loading from Vasilikos Energy hub (direction to Egypt)**
**G=17,0 mscmd**

| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.54 | C |
| Feed Pressure | 120.0 | bar |
| Product Pressure | 118.5 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 500.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 12.87 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.82 | C |
| Feed Pressure | 239.0 | bar |
| Product Pressure | 237.4 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 6.608 | m/s |

| Compressor | | |
|---|---|---|
| Feed Pressure | 118.5 | bar |
| Product Pressure | 240.0 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Energy | 1.510e+004 | kW |

| Pipeline3 | | |
|---|---|---|
| Feed Temperature | 24.82 | C |
| Feed Pressure | 237.4 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_4) | 6.625 | m/s |

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 24.64 | C |
| Feed Pressure | 235.8 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_5) | 6.640 | m/s |

| Cooler | | |
|---|---|---|
| Feed Temperature | 85.41 | C |
| Product Temperature | 25.00 | C |
| Duty | 2.472e+004 | kW |

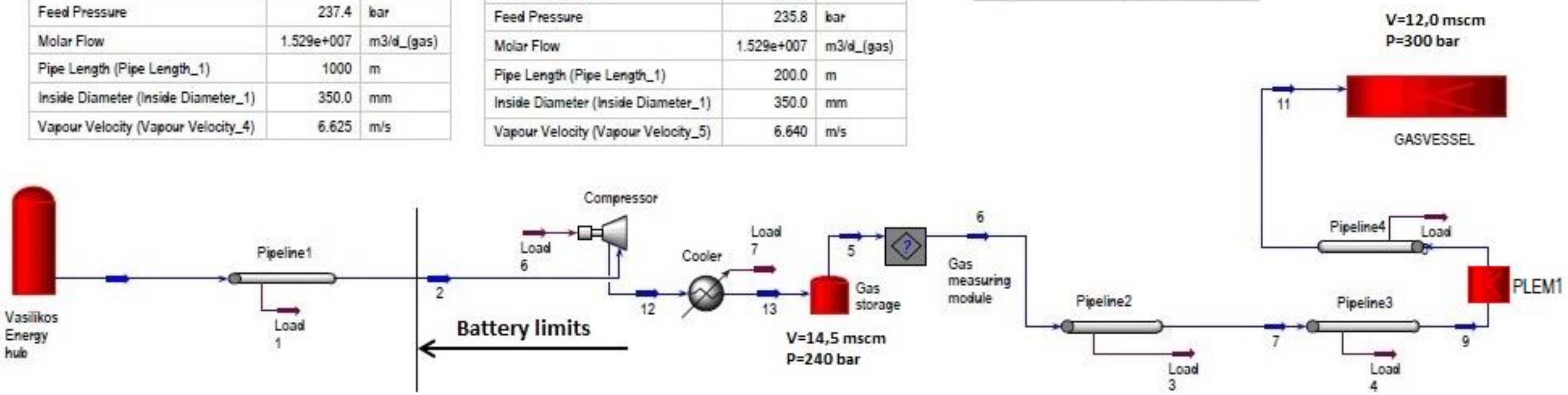



**Figure 12. Technical parameters of Gas loading terminal near the Vasilikos Energy hub - direction to Egypt. (HYSYS).**

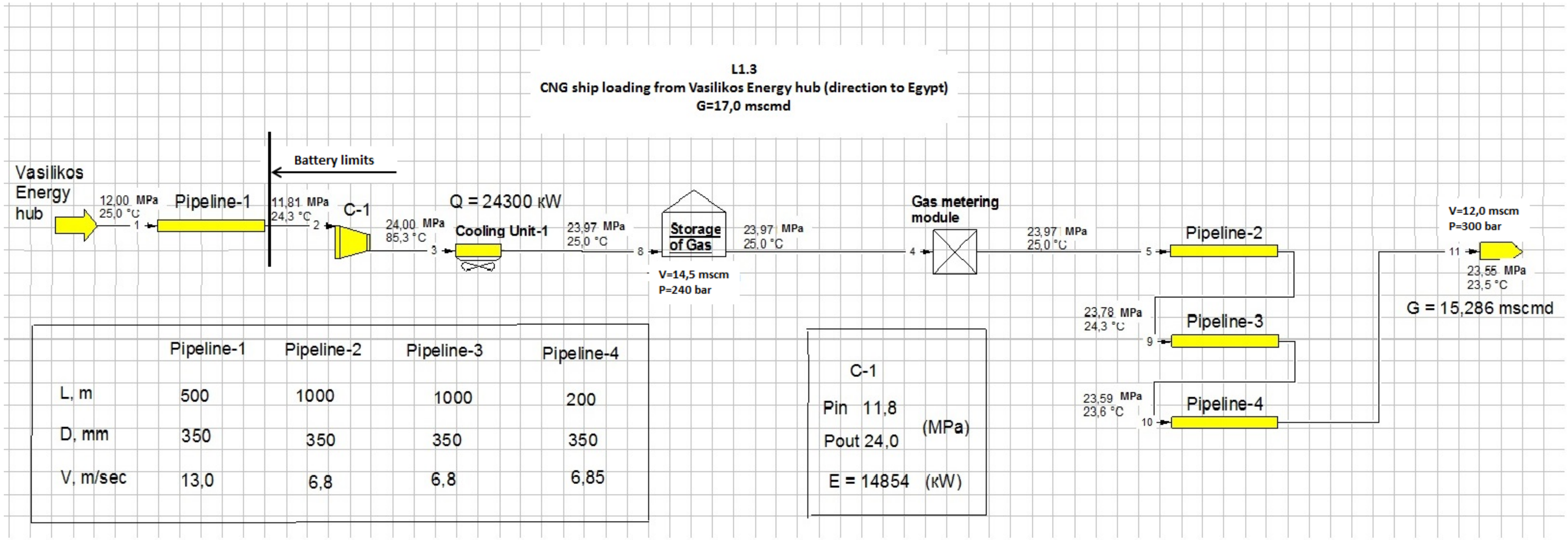



**Figure 13.Technical parameters of Gas loading terminal near the Vasilikos Energy hub - direction to Egypt. (GasCondOil).**

### B.1.3.3.2. *Processes L1.4, 1.5, 1.6.* The Parameters and Diagram of the CNG ship loading process for Gas supplies to Crete, Lebanon, and Egypt

Below are shown the initial data for calculating the loading diagram for Gas delivery from Cyprus EEZ offshore Gas production platforms to the ports of Linoperamata, Zouk and Alexandria in delivery volumes of a 1,4, 3,7 and 17 mscmd. The list of facilities on the loading diagram is formed taking into account the loading process from the offshore terminal.

| Name of Data | The direction of delivery, to: | | |
|---|---|---|---|
| | Crete, Process L1.4 | Lebanon, Process L1.5 | Egypt, Process L1.6 |
| The ship net capacity, $Nm^3$; | 12 000 000 | 9 000 000 | 12 000 000 |
| Updated loading time, hours; | 48 | 32 | 48 |
| Loading pressure, bar; | 240 | 240 | 240 |
| The Maximum Gas temperature during loading, $^0C$; | 25 | 25 | 25 |
| Average Gas flow rate, $Nm^3/d$; | 6.122 | 6.122 | 6.122 |
| Maximum Gas flow rate, $Nm^3/d$; | 15.286 | 15.286 | 15.286 |
| Ships loading frequency, days; | 6.4 | 3.75 | 5.76 |
| Quantity of CNG ships, pcs | 1 | 2 | 8 |
| Gas storage volume, $Nm^3$ | 9 000 000 | 13 900 000 | 14 500 000 |
| Storage Gas Temperature, $^0C$; | 25 | 25 | 25 |
| Air temperature, $^0C$; | 20 | 20 | 20 |
| Seawater temperature, $^0C$; | 20 | 20 | 20 |

Table 6. List of initial data for calculating the process of Gas loading from the offshore terminal near the Cyprus Gas production platforms.

**L1.4**
**CNG ship loading from Cyprus EEZ offshore Gas production platforms (direction to Crete)**
**G=1,4 mscmd**

| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.72 | C |
| Feed Pressure | 120.0 | bar |
| Product Pressure | 119.1 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 300.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 13.01 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 24.72 | C |
| Product Temperature | 15.02 | C |
| Feed Pressure | 119.1 | bar |
| Product Pressure | 118.2 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 300.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 12.57 | m/s |

1.529e+007

| Pipeline3 | | |
|---|---|---|
| Feed Temperature | 15.02 | C |
| Product Temperature | 14.95 | C |
| Feed Pressure | 118.2 | bar |
| Product Pressure | 117.6 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 12.35 | m/s |

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.96 | C |
| Feed Pressure | 239.0 | bar |
| Product Pressure | 238.7 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 6.665 | m/s |

| Gas riser1 | | |
|---|---|---|
| Temperature | 25.00 | C |
| Pressure | 120.0 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |

| Compressor | | |
|---|---|---|
| Feed Pressure | 117.6 | bar |
| Product Pressure | 240.0 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Energy | 1.556e+004 | kW |

| Cooler | | |
|---|---|---|
| Feed Temperature | 76.66 | C |
| Product Temperature | 25.00 | C |
| Duty | 2.152e+004 | kW |

| Gas2 | | |
|---|---|---|
| Temperature | 24.96 | C |
| Pressure | 238.7 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |

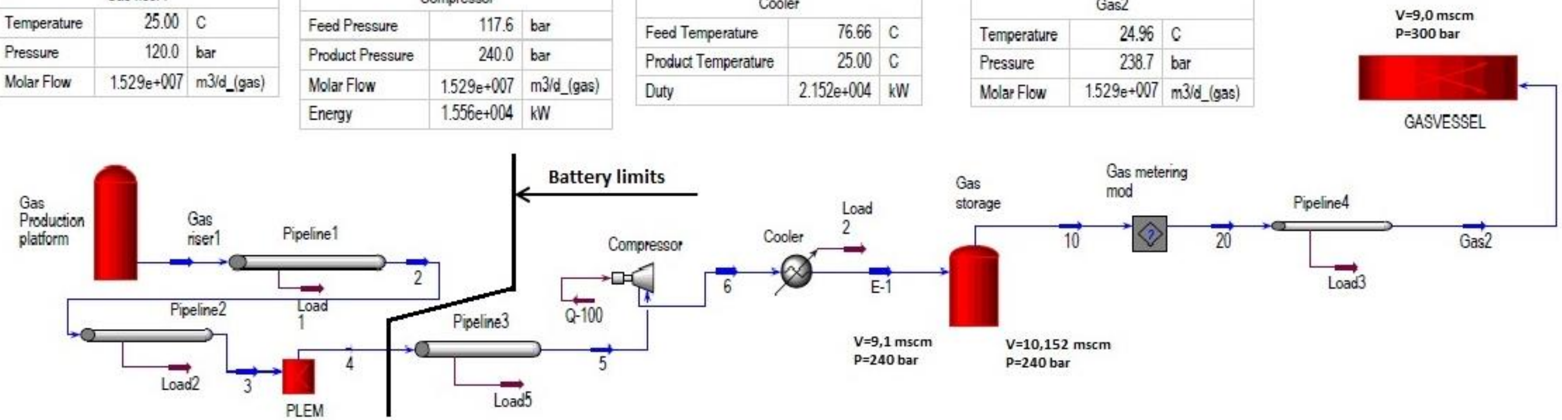
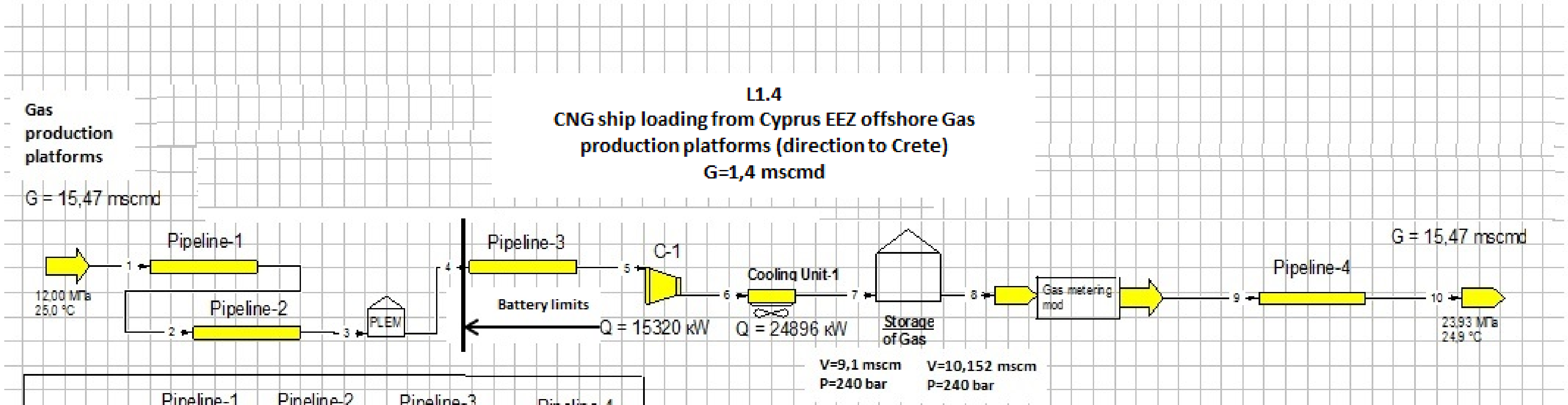


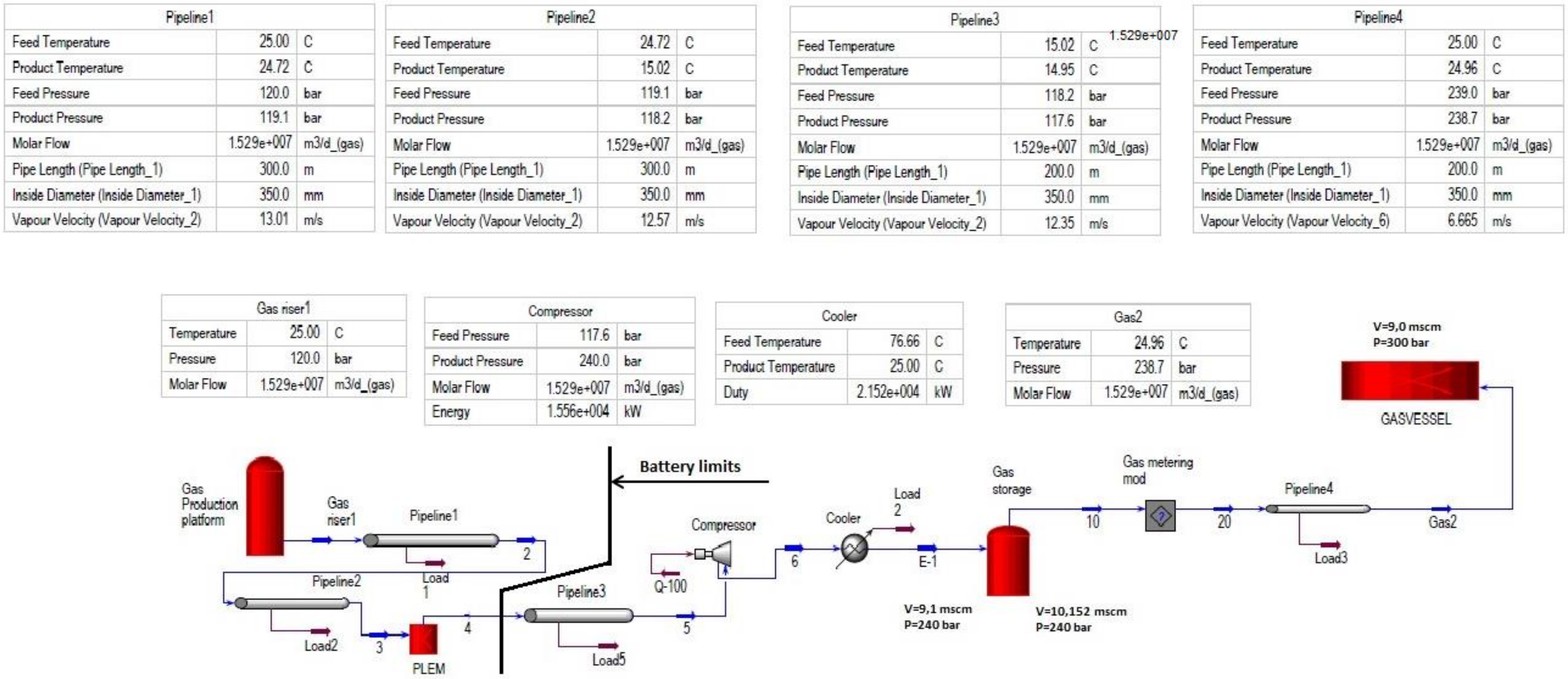

**Figure 14. Technical parameters of Gas loading terminal near the Cyprus EEZ - direction to Crete. (HYSYS).**




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 |
|---|---|---|---|---|
| L, m | 300 | 300 | 200 | 200 |
| D, mm | 350 | 350 | 350 | 350 |
| V, m/sec | 13,37 | 13,5 | 13,57 | 6,9 |

**Figure 15. Technical parameters of Gas loading terminal near the Cyprus EEZ - direction to Crete. (GasCondOil).**

**L1.5**
**CNG ship loading from Cyprus EEZ offshore Gas production platforms**
**(direction to Lebanon)**
**G=3,7 mscmd**



| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.72 | C |
| Feed Pressure | 120.0 | bar |
| Product Pressure | 119.1 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 300.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 13.01 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 24.72 | C |
| Product Temperature | 15.02 | C |
| Feed Pressure | 119.1 | bar |
| Product Pressure | 118.2 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 300.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 12.57 | m/s |

| Pipeline3 | | |
|---|---|---|
| Feed Temperature | 15.02 | C |
| Product Temperature | 14.95 | C |
| Feed Pressure | 118.2 | bar |
| Product Pressure | 117.6 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 12.35 | m/s |

1.529e+007

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.96 | C |
| Feed Pressure | 239.0 | bar |
| Product Pressure | 238.7 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 6.665 | m/s |

| Gas riser1 | | |
|---|---|---|
| Temperature | 25.00 | C |
| Pressure | 120.0 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |

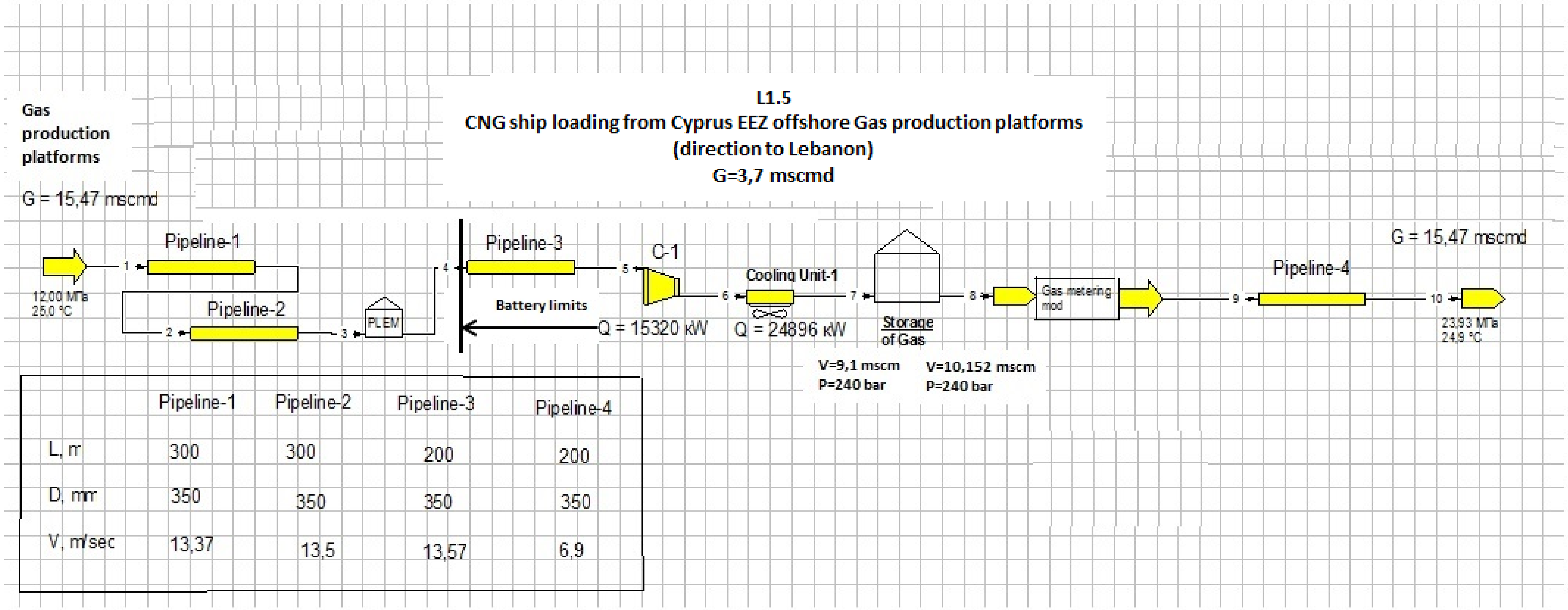
| Compressor | | |
|---|---|---|
| Feed Pressure | 117.6 | bar |
| Product Pressure | 240.0 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Energy | 1.556e+004 | kW |

| Cooler | | |
|---|---|---|
| Feed Temperature | 76.66 | C |
| Product Temperature | 25.00 | C |
| Duty | 2.152e+004 | kW |

| Gas2 | | |
|---|---|---|
| Temperature | 24.96 | C |
| Pressure | 238.7 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |



**Figure 16. Technical parameters of Gas loading terminal near the Cyprus EEZ - direction to Lebanon. (HYSYS).**




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 |
|---|---|---|---|---|
| L, m | 300 | 300 | 200 | 200 |
| D, mm | 350 | 350 | 350 | 350 |
| V, m/sec | 13,37 | 13,5 | 13,57 | 6,9 |

**Figure 17. Technical parameters of Gas loading terminal near the Cyprus EEZ - direction to Lebanon. (GasCond Oil).**

**L1.6**
**CNG ship loading from Cyprus EEZ offshore Gas production platforms**
**(direction to Egypt)**
**G=17 mscmd**

| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.72 | C |
| Feed Pressure | 120.0 | bar |
| Product Pressure | 119.1 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 300.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 13.01 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 24.72 | C |
| Product Temperature | 15.02 | C |
| Feed Pressure | 119.1 | bar |
| Product Pressure | 118.2 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 300.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 12.57 | m/s |

| Pipeline3 | | |
|---|---|---|
| Feed Temperature | 15.02 | C |
| Product Temperature | 14.95 | C |
| Feed Pressure | 118.2 | bar |
| Product Pressure | 117.6 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 12.35 | m/s |

1.529e+007

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.96 | C |
| Feed Pressure | 239.0 | bar |
| Product Pressure | 238.7 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 6.665 | m/s |

| Gas riser1 | | |
|---|---|---|
| Temperature | 25.00 | C |
| Pressure | 120.0 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |

| Compressor | | |
|---|---|---|
| Feed Pressure | 117.6 | bar |
| Product Pressure | 240.0 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |
| Energy | 1.556e+004 | kW |

| Cooler | | |
|---|---|---|
| Feed Temperature | 76.66 | C |
| Product Temperature | 25.00 | C |
| Duty | 2.152e+004 | kW |

| Gas2 | | |
|---|---|---|
| Temperature | 24.96 | C |
| Pressure | 238.7 | bar |
| Molar Flow | 1.529e+007 | m3/d_(gas) |

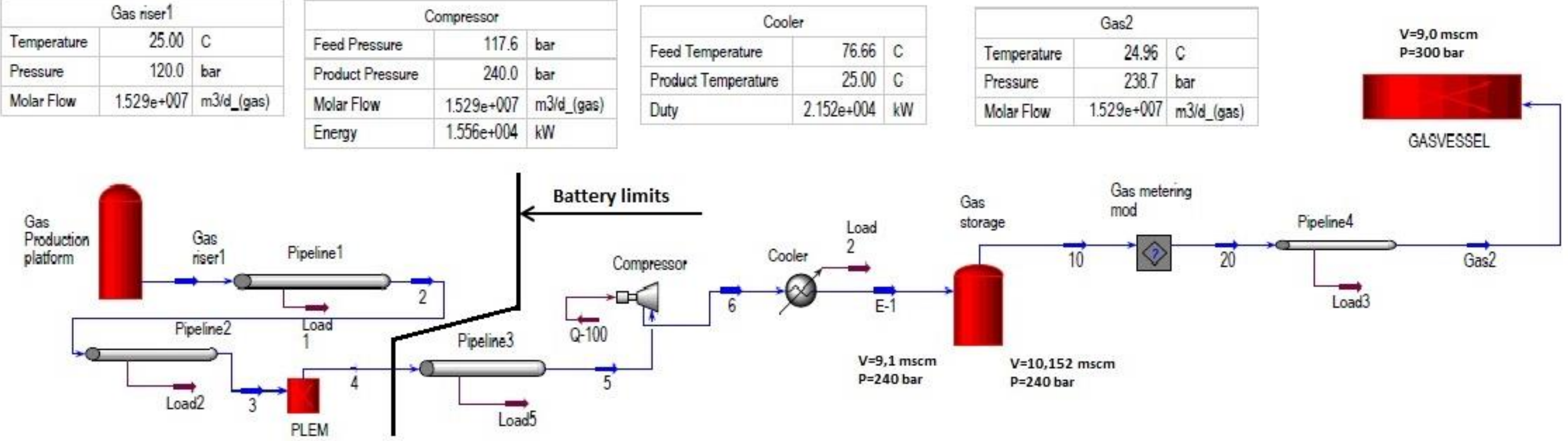
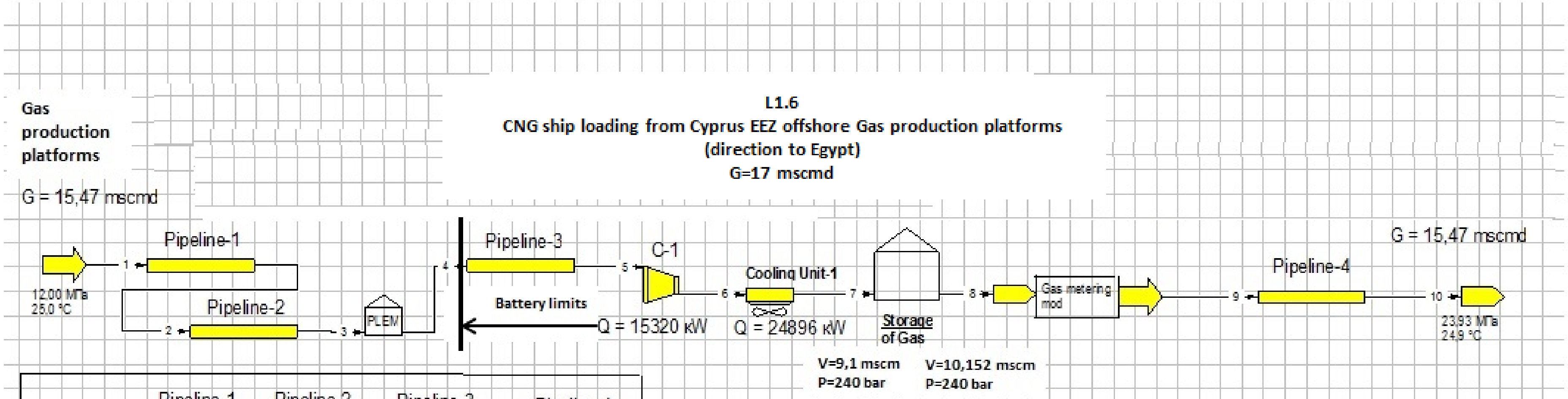



**Figure 18. Technical parameters of Gas loading terminal near the Cyprus EEZ - direction to Egypt. (HYSYS).**




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 |
|---|---|---|---|---|
| L, m | 300 | 300 | 200 | 200 |
| D, mm | 350 | 350 | 350 | 350 |
| V, m/sec | 13,37 | 13,5 | 13,57 | 6,9 |

**Figure 19. Technical parameters of Gas loading terminal near the Cyprus EEZ - direction to Egypt. (GasCondOil).**

### B.1.3.3.4. *Processes U1.1, U1.2, U1.3.* The parameters and Diagram of the CNG ship unloading process in the ports of Linoperamata, Zouk, and Alexandria

Below are shown the initial data for calculating the gas unloading diagram in the ports of Linoperamata, Zouk and Alexandria in delivery volumes of a 1,4, 3,7 and 17,0 mscmd. The list of facilities on the unloading diagram is formed taking into account the unloading process.

| Name of Data | Ports of delivery | | |
|---|---|---|---|
| | Linoperamata, Process U1.1 | Zouk, Process U1.2 | Alexandria, Process U1.3 |
| The ship net capacity, $Nm^3$; | 12 000 000 | 9 000 000 | 12 000 000 |
| Updated unloading time, hours; | 71 | 54 | 71 |
| Unloading pressure, bar; | 80 | 80 | 80 |
| The Maximum Gas temperature during unloading, $^0C$; | 32 | 32 | 32 |
| Average Gas flow rate, $Nm^3/d$; | 4.158 | 4.158 | 4.158 |
| Maximum Gas flow rate, $Nm^3/d$; | 10.472 | 10.472 | 10.472 |
| Ships loading frequency, days; | 6.4 | 3.75 | 5.76 |
| Quantity of CNG ships, pcs | 1 | 2 | 8 |
| Gas storage volume, $Nm^3$ | 9 000 000 | 13 900 000 | 14 500 000 |
| Storage Gas Temperature, $^0C$; | 25 | 25 | 25 |
| Air temperature, $^0C$; | 20 | 20 | 20 |
| Seawater temperature, $^0C$; | 20 | 20 | 20 |

**Table 7. List of initial data for calculating the process of Gas unloading on the onshore terminal near the ports of Linoperamata, Zouk, and Alexandria.**

**U1.1**
**CNG ship unloading to the port of Linoperamata**
**(direction to Crete)**
**G=1,4 mscmd**

| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 32.00 | C |
| Product Temperature | 31.82 | C |
| Feed Pressure | 80.00 | bar |
| Product Pressure | 79.53 | bar |
| Molar Flow | 1.047e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 14.48 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 31.82 | C |
| Product Temperature | 14.94 | C |
| Feed Pressure | 79.53 | bar |
| Product Pressure | 77.32 | bar |
| Molar Flow | 1.047e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 13.32 | m/s |

| Pipeline3 | | |
|---|---|---|
| Feed Temperature | 14.94 | C |
| Product Temperature | 14.94 | C |
| Feed Pressure | 77.28 | bar |
| Product Pressure | 75.02 | bar |
| Molar Flow | 1.047e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 13.73 | m/s |

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 10.00 | C |
| Product Temperature | 9.970 | C |
| Feed Pressure | 56.02 | bar |
| Product Pressure | 55.96 | bar |
| Molar Flow | 1.400e+006 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 2.569 | m/s |

| VLV-1 | | |
|---|---|---|
| Feed Pressure | 75.02 | bar |
| Product Pressure | 57.02 | bar |
| Molar Flow | 1.400e+006 | m3/d_(gas) |
| Feed Temperature | 14.94 | C |
| Product Temperature | 6.631 | C |

| T-100 | | |
|---|---|---|
| Feed Temperature | 6.631 | C |
| Product Temperature | 10.00 | C |
| Molar Flow | 1.400e+006 | m3/d_(gas) |
| Duty | 118.2 | kW |

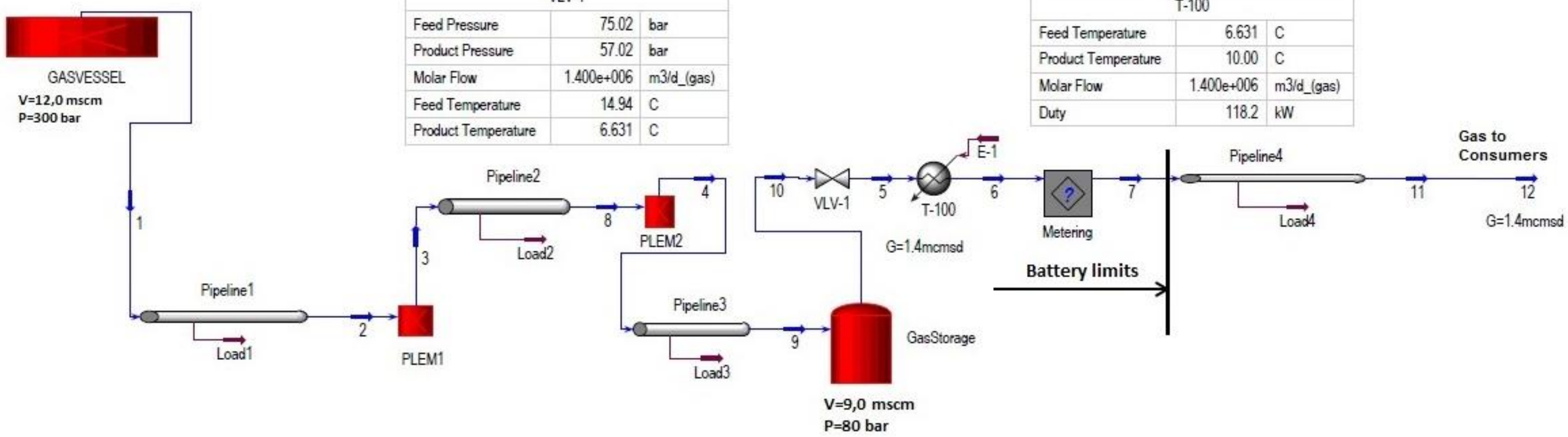
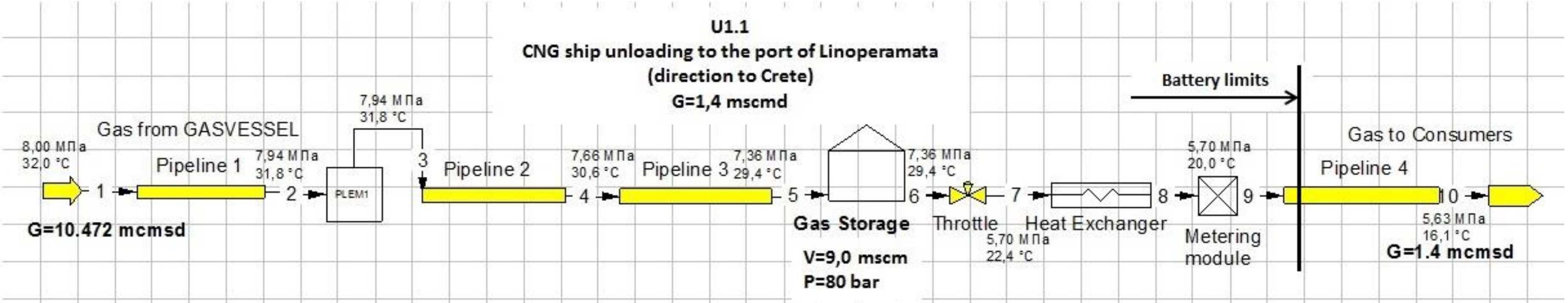



**Figure 20. Technical parameters of Gas unloading terminal near the port of Linoperamata in Crete. (HYSYS).**




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 |
|---|---|---|---|---|
| L, m | 200 | 1000 | 1000 | 1000 |
| D, mm | 350 | 350 | 350 | 350 |
| V, m/sec | 14,8 | 15,2 | 15,8 | 2,65 |

**Figure 21. Technical parameters of Gas unloading terminal near the port of Linoperamata in Crete. (GasCondOil).**

**U1.2**
**CNG ship unloading to the port of Zouk**
**(direction to Lebanon)**
**G=3,7 mscmd**

| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 32.00 | C |
| Product Temperature | 31.82 | C |
| Feed Pressure | 80.00 | bar |
| Product Pressure | 79.53 | bar |
| Molar Flow | 1.047e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 14.48 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 31.82 | C |
| Product Temperature | 14.94 | C |
| Feed Pressure | 79.53 | bar |
| Product Pressure | 77.32 | bar |
| Molar Flow | 1.047e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 13.32 | m/s |

| Pipeline3 | | |
|---|---|---|
| Feed Temperature | 14.94 | C |
| Product Temperature | 14.94 | C |
| Feed Pressure | 77.28 | bar |
| Product Pressure | 75.02 | bar |
| Molar Flow | 1.047e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 13.73 | m/s |

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 10.00 | C |
| Product Temperature | 9.806 | C |
| Feed Pressure | 56.02 | bar |
| Product Pressure | 55.62 | bar |
| Molar Flow | 3.700e+006 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 6.831 | m/s |

| VLV-1 | | |
|---|---|---|
| Feed Pressure | 75.02 | bar |
| Product Pressure | 57.02 | bar |
| Molar Flow | 3.700e+006 | m3/d_(gas) |
| Feed Temperature | 14.94 | C |
| Product Temperature | 6.631 | C |

| T-100 | | |
|---|---|---|
| Feed Temperature | 6.631 | C |
| Product Temperature | 10.00 | C |
| Molar Flow | 3.700e+006 | m3/d_(gas) |
| Duty | 312.3 | kW |

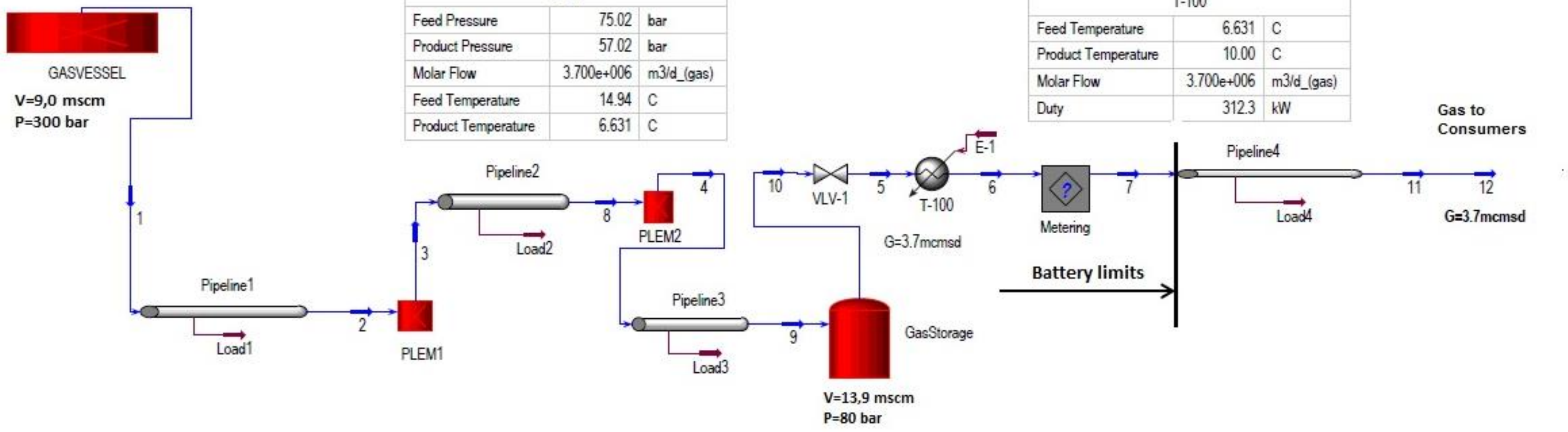
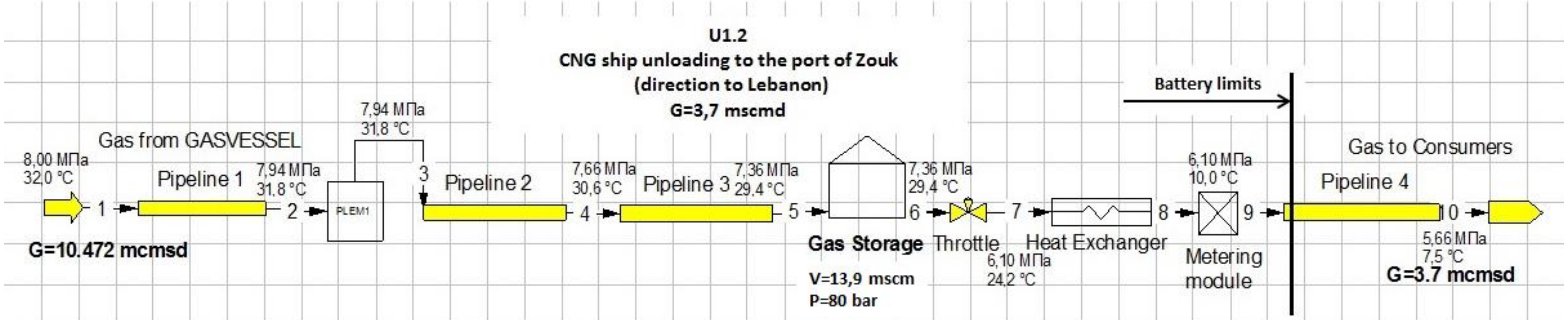



**Figure 22. Technical parameters of Gas unloading terminal near the port of Zouk in Lebanon. (HYSYS).**




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 |
|---|---|---|---|---|
| L, m | 200 | 1000 | 1000 | 1000 |
| D, mm | 350 | 350 | 350 | 350 |
| V, m/sec | 14,7 | 15,22 | 15.8 | 6,63 |

**Figure 23. Technical parameters of Gas unloading terminal near the port of Zouk in Lebanon. (GasCondOil).**

**U1.3**
**CNG ship unloading to the port of Alexandria**
**(direction to Egypt)**
**G=17 mscmd**

| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 32.00 | C |
| Product Temperature | 31.82 | C |
| Feed Pressure | 80.00 | bar |
| Product Pressure | 79.53 | bar |
| Molar Flow | 1.047e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 14.48 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 31.82 | C |
| Product Temperature | 19.94 | C |
| Feed Pressure | 79.53 | bar |
| Product Pressure | 77.25 | bar |
| Molar Flow | 1.047e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 13.72 | m/s |

| Pipeline3 | | |
|---|---|---|
| Feed Temperature | 19.94 | C |
| Product Temperature | 14.94 | C |
| Feed Pressure | 77.25 | bar |
| Product Pressure | 74.98 | bar |
| Molar Flow | 1.047e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 13.75 | m/s |

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 10.00 | C |
| Product Temperature | 9.356 | C |
| Feed Pressure | 55.98 | bar |
| Product Pressure | 54.67 | bar |
| Molar Flow | 1.700e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 500.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 15.65 | m/s |

| VLV-1 | | |
|---|---|---|
| Feed Pressure | 74.98 | bar |
| Product Pressure | 56.98 | bar |
| Molar Flow | 1.700e+007 | m3/d_(gas) |
| Feed Temperature | 14.94 | C |
| Product Temperature | 6.629 | C |

| T-100 | | |
|---|---|---|
| Feed Temperature | 6.629 | C |
| Product Temperature | 10.00 | C |
| Molar Flow | 1.700e+007 | m3/d_(gas) |
| Duty | 1435 | kW |

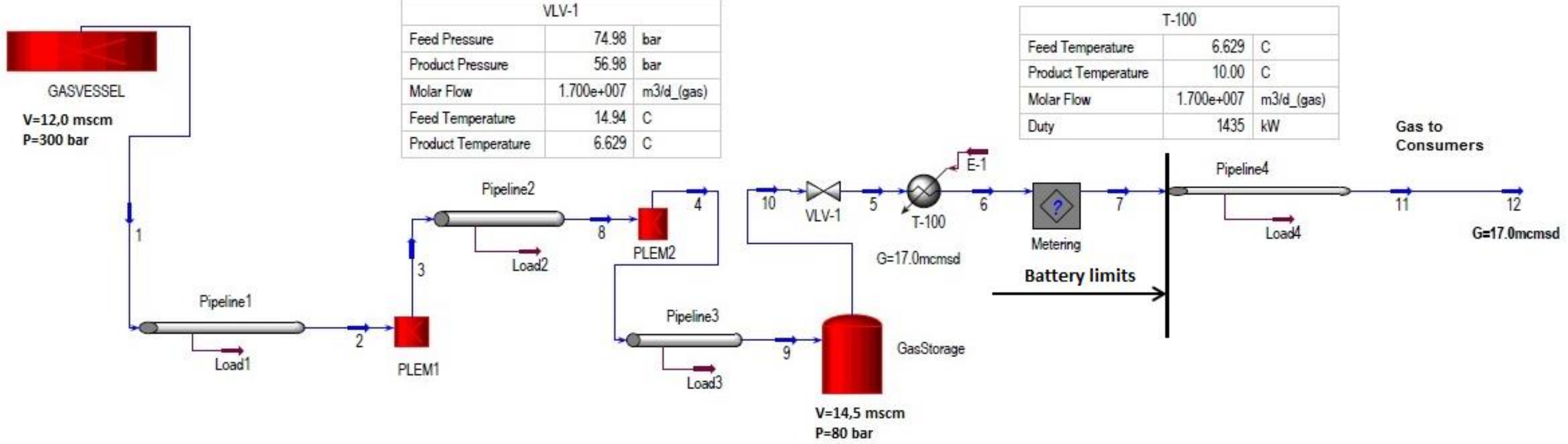
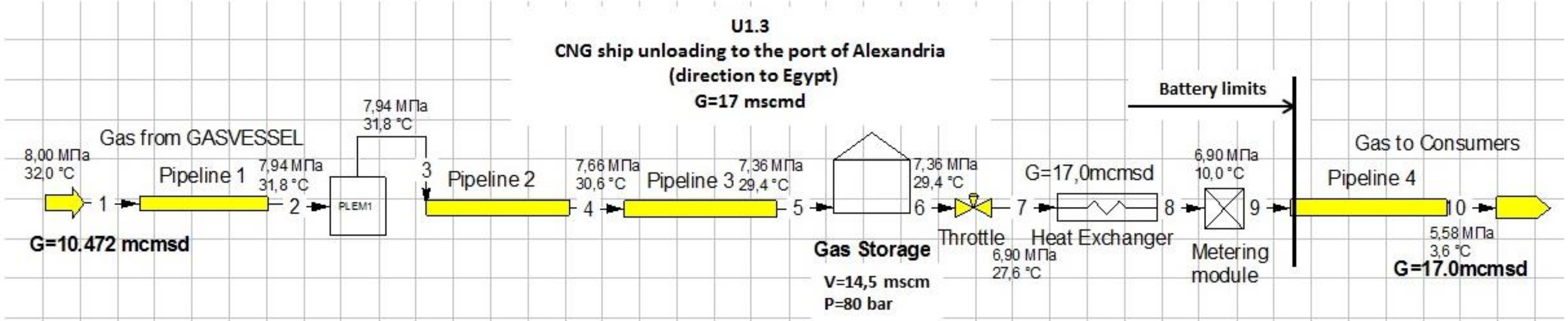



**Figure 24. Technical parameters of Gas unloading terminal near the port of Alexandria in Egypt. (HYSYS).**




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 |
|---|---|---|---|---|
| L, m | 200 | 1000 | 1000 | 1000 |
| D, mm | 350 | 350 | 350 | 500 |
| V, m/sec | 14,7 | 15,22 | 15.8 | 14,86 |

**Figure 25. Technical parameters of Gas unloading terminal near the port of Alexandria in Egypt. (GasCond Oil).**

## B.2. Barents Sea

In the D2.1 delivery carried out by the Consortium participants in 2018, was considered the markets of the North of Europe.

The study of potential gas loading and unloading points, as well as gas consumption markets in the North Europe region, was conducted by the Consortium partner, the company SINTEF OCEAN AS. After discussing the results, gas loading points were identified, the offshore fields of Alke and Johan Castberg. Gas unloading points also were identified as Nyhamna Gas treatment plant and point of entry into the underwater Gas pipeline near the Aasta Hansteen offshore gas field.

### B.2.1. Barents Sea analysis of required Gas volumes

According to the scenario of gas delivery in the North Europe region, there have been considered a lot of gas consumers.

For the market served by the offshore pipeline, the potential quantity of gas to be delivered at entry point has not been based on market demand forecast, but rather, calibrated by pipeline capacity and estimated daily production rate. The estimated daily production at the two fields Alke and Johan Castberg is **1,18 mscmd** and **1,29 mscmd** respectively. This corresponds to approximately 2% of Polarled and Langeled pipeline capacity each.

the main gas consumers in Norway:

| No | Country | Consumer | Capacity, | Notes |
|---|---|---|---|---|
| 1.1 | **Norway** | Nyhamna (Gas treatment plant) | 11.464 mscfd; 324.00 mscmd | After Quality control on the Nyhamna Gas treatment plant, the Gas will be transported via the existing underwater Langeled North Pipeline to the Easington, UK. |
| 1.2 | **Norway** | Nyhamna (Aasta Hansteen) | 71.079 mscfd; 2008.00 mscmd | Underwater Gas Pipeline from Aasta Hansteen to Nyhamna |
| | **Norway** | **Total** | **120.211 mscfd; 3396.00 mscmd** | |

Table 8. The GASVESSEL Consumers in the North Europe region.

#### B.2.1.1. Gas to the United Kingdom

In the Barents Sea region, we have two points of gas loading: Alke and Johan Castberg offshore fields. Also, we have two points of unloading:

- the offshore platforms of Aasta Hansteen fields (entry point of the Polarled underwater Gas pipeline) and
- Gas treatment plant Nyhamna.

The ways to Gas delivery to the unloading points are shown in the Figures below.

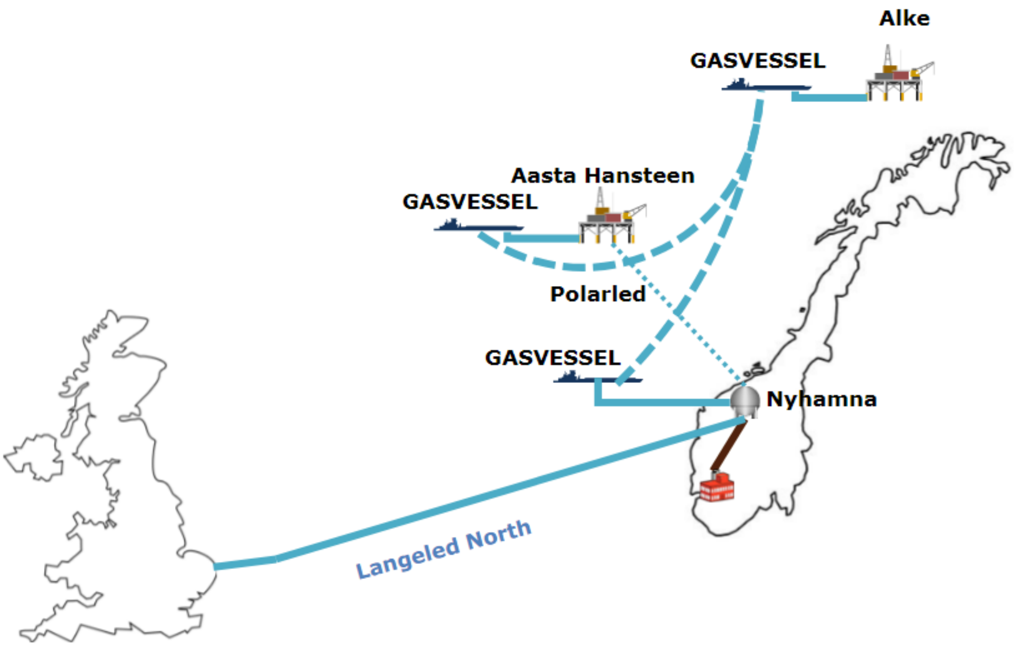



Figure 26. Gas delivery from Alke Gas fields to Nyhamna and Aasta Hansteen.

Figure 26 above shows the gas delivery to the potential unloading point – Nyhamna Gas treatment plant from Alke offshore Gas production platform.

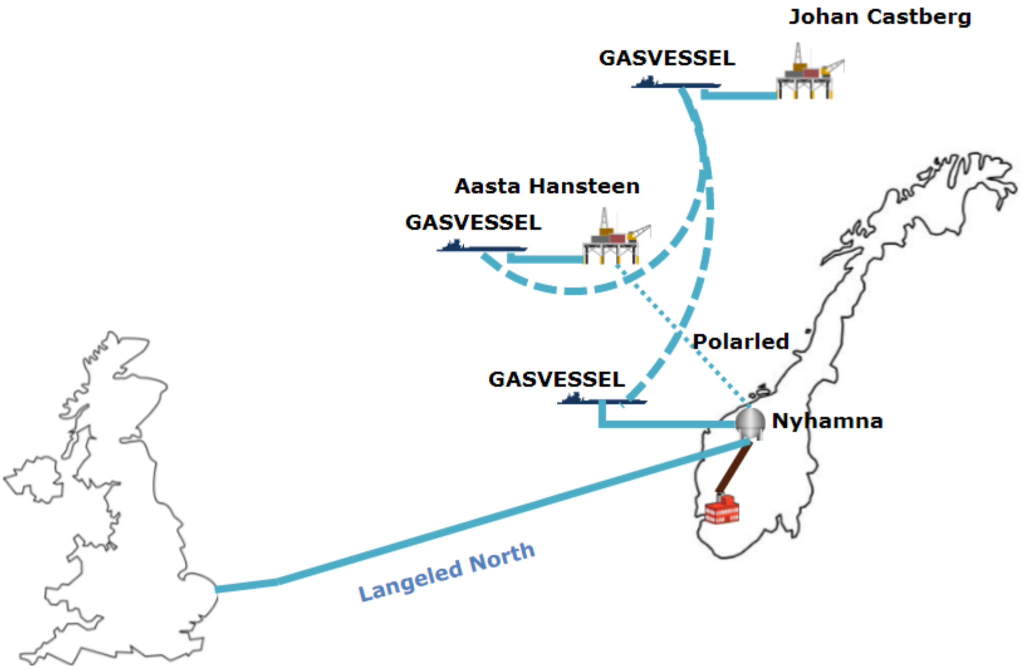



Figure 27. Gas delivery from Johan Castberg Gas fields to Nyhamna and Aasta Hansteen.

Figure 27 above shows the Variant 2 of gas delivery to the potential unloading point – Nyhamna Gas treatment plant.
For more details on the list of modules and systems of Gas loading and unloading terminals in the Barents Sea, we can see in section B.2.3.
The total gas volume parameters of gas supplying of loading and unloading terminals in the Barents Sea are shown in Table 9.

The total gas loading/unloading flow to the entry point of Polarled from Alke is **1,18 mscmd** and from Johan Castberg is **1,29 mscmd** both are via GASVESSEL system.

### B.2.2. Conclusions on the Barents Sea loading/unloading parameters

Based on the above Data, the main parameters of the CNG ship loading/unloading systems are determined:

| No | Source | Loading Volume | Loading point | Unloading Volume | Unloading point | Estimated Gas volume | Transfer type | Consumer | Notes |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Alke Offshore Gas fields | 1,18 mscmd | Alke Offshore Gas loading terminal | 1,18 mscmd | Offshore Gas unloading terminal near Gas production platforms Aasta Hansteen | 1,18 mscmd | GASVESSEL | Easington, UK | The entry point of underwater Gas pipeline Polarled |
| 2 | Johan Castberg Offshore Gas fields | 1.29 mscmd | Johan Castberg Offshore Gas loading terminal | 1.29 mscmd | | 1.29 mscmd | | | |
| 3 | Alke Offshore Gas fields | 1,18 mscmd | Alke Offshore Gas loading terminal | 1,18 mscmd | Onshore Gas unloading terminal near the Nyhamna Gas treatment plant | 1,18 mscmd | GASVESSEL | Nyhamna Gas treatment plant or Easington, UK | The entry point of underwater Gas pipeline Langeled North |
| 4 | Johan Castberg Offshore Gas fields | 1.29 mscmd | Johan Castberg Offshore Gas loading terminal | 1.29 mscmd | | 1.29 mscmd | | | |

**Table 9. The loading and unloading points and supply gas volumes in the North of Europe.**

Table 9 gives a view of the required gas transfer capacity at the points of gas loading in the gas offshore fields Alke and Johan Castberg and unloading both at the offshore Entry point of underwater Gas pipeline Polarled and the future unloading terminal near Nyhamna Gas treatment plant.
Then, after the Quality control on the Nyhamna Gas treatment plant, the gas will be transported via the existing underwater Langeled North Gas Pipeline to the Easington, UK.

### B.2.3. The infrastructure of the terminals

Here we set out a vision of the VTG on the arrangement of loading and unloading Gas terminals for loading/unloading service during the Gas supplying in the region of Barents Sea. Just as in the section describing loading and unloading systems in the Mediterranean Sea, we can see the same division into terminal types.
The section describes and structure of the CNG ship loading/unloading terminals in relation to the Barents Sea water area.
The modules of equipment and systems are necessary for the realization of the tasks of gas loading and unloading for the GASVESSEL system. The Gas loading terminals in the water area of the Barents Sea are offshore.
They are located near the offshore gas production platforms and have the structure, modules, and systems, depending on the possibilities of mutual using the existing infrastructure or systems of the gas production platforms.

#### B.2.3.1. Offshore Gas loading terminal near the offshore Gas production platforms (Alke and Johan Castberg)

VTG proposes to use the same approach as in the Mediterranean Sea to formulate assumptions and limitations when developing the list of modules for Gas loading and unloading terminals.
These assumptions can be adjusted at further stages of the Project's development in accordance with local conditions, such as gas loading pressure, actual gas flow for loading, the necessary equipment on the loading terminal to perform the loading process and other factors. The list of assumptions is given below (also see Table 10, Table 11):

- The CNG ship capacity is of 9,00 mscm according to the scenarios;
- The loading time is determined by Consortium based on the technical capabilities of the CNG ships is 44 hours;
- It is assumed that the volume of intermediate gas storage during loading of the CNG ship must be at least the volume of the CNG ship;
- The gas temperature during the CNG ship loading must not exceed 40 $^{0}$C;
- The loading gas from the offshore gas production platforms is supplied cleaned in accordance with the applicable Quality Standards.
- The piping diameter should be selected from the condition of the gas velocity inside of the pipes within 5 to 20 m/s.

All modules, systems on the Gas loading terminal can be divided by:

- **Main process facilities;**
- **Auxiliary process facilities;**
- **Life support facilities.**

Below is shown the composition of the floating Gas loading terminal near the Alke and Johan Castberg Gas production platforms:

| **Facilities in the scope of the Project** |
|---|
| **Connection pipelines** |
| Pipeline 2 (Flexible connection,  D=3x7 inches) |
| **Offshore Gas loading terminal** |
| ***Main process facilities (modules) of Offshore floating Gas loading terminal*** |
| Gas compressor module |
| Gas Air cooling module |
| Gas storage module |
| Gas measuring module |
| ***Auxiliary  process facilities (modules) of Offshore floating Gas loading terminal*** |
| Process automation and signaling system |
| Instrument and Plant Air System |
| Nitrogen Generation and Distribution System |
| Vent/Flare System |
| Power supply and Distribution System |
| Electrochemical anti-corrosion protection System |
| Diesel generator module |
| Diesel Fuel System |
| Power, control and signaling cables |
| Auxiliary site pipelines |
| ***Life support facilities (modules) of Offshore floating Gas loading terminal*** |
| Water and sewage system |
| Firewater and fire-fighting system |
| **Connection pipelines** |
| Pipeline 3 (Flexible connection,  D=3x7 inches) |
| Pipeline 4 (Flexible connection,  D=3x7 inches) |
| **Facilities out of the scope of the Project** |
| Pipeline 1 (Gas Riser,  D=14 inches) |
| Pipeline 2 (Underwater Gas pipeline,  D=14 inches) |
| PLEM1, (D=14 inches) |

The diagrams of the processes and parameters of terminals see Figure 28…Figure 31.

#### B.2.3.2. Onshore Gas unloading terminal facilities near the Nyhamna Gas treatment plant

At the list of the necessary processes for CNG ship unloading into the onshore Gas unloading terminal near the Nyhamna Gas treatment plant, we will make several assumptions (also see Table 12):

- The CNG ship capacity of 9,00 mscm according to the scenarios;
- The unloading time is determined by Consortium based on the technical capabilities of the CNG ships is 70 hours);
- It is assumed that the volume of intermediate gas storage during unloading of the CNG ship must be at least the volume of the CNG ship;
- During the unloading process, the gas is released into a connecting pipeline at the pressure of 80 bar. In the process of unloading of the GASVESSEL cylinders about halfway, the compressor on the shipboard is turned on and pumps the gas to a minimum volume with a residual pressure of about 20 bar;
- The Gas temperature during the CNG ship unloading must be not less than 10 $^0$C and no more than 32 $^0$C;
- The piping diameter should be selected from the condition of the gas velocity inside of the pipes within 5 to 20 m/s.

All modules, systems can be divided by:

- **Main process facilities;**
- **Auxiliary process facilities;**
- **Life support facilities.**

The list of facilities below shows the structures of the onshore Gas unloading terminal facilities near the Nyhamna Gas treatment plant.

| Facilities in the scope of the Project |
|---|
| **Onshore Gas unloading terminal** |
| ***Main process facilities (modules) of Onshore Gas unloading terminal*** |
| Gas storage module |
| A Gas pressure reducing module |
| Gas heating module |
| Gas measuring module |
| ***Auxiliary process facilities (modules) of Onshore Gas unloading terminal*** |
| Process automation and signaling system |
| Instrument and Plant Air System |
| Nitrogen Generation and Distribution System |
| Vent/Flare System |
| Power supply and Distribution System |
| Electrochemical anti-corrosion protection System |
| Diesel generator module |
| Diesel Fuel System |
| Communication, alarm, fire alarm system |
| Overhead transmission line (V=10 kV), (if any) |
| Power, control and signaling cables |
| Auxiliary site pipelines |

| *Life support facilities (modules) of Onshore Gas unloading terminal* |
|---|
| Water and sewage system (if any) |
| Firewater and fire-fighting system |
| Evaporation pond |
| Ancillary buildings and structures, site improvements |
| **Connection pipelines** |
| Pipeline 1 (Flexible connection, D=3x7 inches) |
| PLEM1, (D=14 inches) |
| Pipeline 2 (Underwater Gas pipeline, D=14 inches) |
| Pipeline 3 (Onshore Gas pipeline, D=14 inches) |
| Tie in point to the existing Nyhamna Gas treatment plant |
| **Facilities out of the scope of the Project** |
| Pipeline 4 (Onshore Gas pipeline, connecting the Onshore Gas unloading terminal and the existing Gas network, D=14 inches) |

#### B.2.3.3. Offshore Gas unloading terminal facilities near the Aasta Hansteen Gas production platform, enter to the Polarled underwater Gas pipeline

At the list of the necessary processes for CNG ship unloading into the existing underwater Gas pipeline Polarled, we will make several assumptions:

- The CNG ship capacity of 9,00 mscm according to the scenarios;
- The unloading time is determined by Consortium based on the technical capabilities of the CNG ships;
- It is assumed that the volume of intermediate Gas storage during unloading of the CNG ship must be at least the volume of the CNG ship;
- During the unloading process, the gas is released into a pipeline at the pressure of 80 bar. In the process of unloading of the GASVESSEL cylinders about halfway, the compressor on the shipboard is turned on and pumps the gas to a minimum volume with a residual pressure of about 20 bar;
- The gas temperature during the CNG ship unloading must be not less than 10 $^0$C and no more than 40 $^0$C;
- The piping diameter should be selected from the condition of the gas velocity inside of the pipes within 5 to 20 m/s.

All modules, systems can be divided by:

- **Main process facilities;**
- **Auxiliary process facilities;**
- **Life support facilities.**

The list of facilities below shows the structures of the onshore Gas unloading terminal facilities near the Aasta Hansteen Gas producing platform.

| **Facilities in the scope of the Project** |
|---|
| **Onshore Gas unloading terminal** |
| ***Main process facilities (modules) of Onshore Gas unloading terminal*** |
| Gas storage module |
| A Gas pressure reducing module |
| Gas heating module |

| |
|---|
| Gas measuring module |
| ***Auxiliary process facilities (modules) of Onshore Gas unloading terminal*** |
| Process automation and signaling system |
| Instrument and Plant Air System |
| Nitrogen Generation and Distribution System |
| Vent/Flare System |
| Power supply and Distribution System |
| Electrochemical anti-corrosion protection System |
| Diesel generator module |
| Diesel Fuel System |
| Communication, alarm, fire alarm system |
| Overhead transmission line (V=10 kV), (if any) |
| Power, control and signaling cables |
| Auxiliary site pipelines |
| ***Life support facilities (modules) of Onshore Gas unloading terminal*** |
| Water and sewage system (if any) |
| Firewater and fire-fighting system |
| Evaporation pond |
| Ancillary buildings and structures, site improvements |
| **Connection pipelines** |
| Pipeline 1 (Flexible connection, D=3x7 inches) |
| PLEM1, (D=14 inches) |
| Pipeline 2 (Underwater Gas pipeline, D=14 inches) |
| PLEM2, (D=14 inches) |
| Pipeline 3 (Flexible connection, D=3x7 inches) |
| **Facilities out of the scope of the Project** |
| Pipeline 4 (Flexible connection, D=3x7 inches, connecting the Offshore Gas unloading terminal and the existing underwater Gas pipeline Polarled, D=14 inches) |
| Tie in point to the existing Gas pipeline |

The Figures below show the diagrams and the calculating results for Gas loading at the Alke and Johann Castberg Gas fields.

#### B.2.3.4. Diagrams and parameters of the CNG ship loading/unloading process in the Barents Sea

The processes of loading and unloading performed at the terminals of CNG ships loading/unloading were calculated in two different ways on different programs Aspen HYSYS and GasCondOil.

##### B.2.3.4.1. *Processes L2.1, L2.3.* The parameters and Diagram of the CNG ship loading process for gas supplies to the Nyhamna gas treatment plant

Below are shown the initial Data for calculating the loading diagram for gas delivery from Alke and Johann Castberg gas production fields to the Nyhamna Gas treatment plant in delivery volumes of a **1,18 and 1,29 mscmd** respectively. The list of facilities on the loading diagram is formed taking into account the loading process from the offshore terminal.

| Name of Data | Gas loading terminal | |
|---|---|---|
| | Alke, Process L2.1 | Johan Castberg, Process L2.3 |
| The ship net capacity, $Nm^3$; | 9 000 000 | 9 000 000 |
| Updated loading time, hours; | 44 | 44 |
| Loading pressure, bar; | 240 | 240 |
| The Maximum Gas temperature during loading, $^0C$; | 25 | 25 |
| Average Gas flow rate, $Nm^3/d$; | 6.76 | 6.76 |
| Maximum Gas flow rate, $Nm^3/d$; | 15.47 | 15.47 |
| Ships loading frequency, days; | 7.65 | 7.87 |
| Quantity of CNG ships, pcs | 1 | 2 |
| Gas storage volume, $Nm^3$ | 9 100 000 | 10 152 000 |
| Storage Gas Temperature, $^0C$; | 25 | 25 |
| Air temperature, $^0C$; | 4 | 4 |
| Seawater temperature, $^0C$; | 7.8 | 7.8 |

**Table 10. List of initial Data for calculating the process of gas loading from the offshore terminal near the Alke and Johan Castberg Gas production platforms (Direction to Nyhamna).**

**L2.1**
**CNG ship loading from Alke Gas production platform**
**(direction to Nyhamna Gas treatment plant)**
**G=1,18 mscmd**

**L2.3**
**CNG ship loading from Johan Castberg Gas production platform**
**(direction to Nyhamna Gas treatment plant)**
**G=1,29 mscmd**

| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.72 | C |
| Feed Pressure | 120.0 | bar |
| Product Pressure | 119.1 | bar |
| Molar Flow | 1.547e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 300.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 13.01 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 24.72 | C |
| Product Temperature | 15.02 | C |
| Feed Pressure | 119.1 | bar |
| Product Pressure | 118.2 | bar |
| Molar Flow | 1.547e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 300.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 12.57 | m/s |

| Pipeline3 | | |
|---|---|---|
| Feed Temperature | 15.02 | C |
| Product Temperature | 14.95 | C |
| Feed Pressure | 118.2 | bar |
| Product Pressure | 117.6 | bar |
| Molar Flow | 1.547e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 12.35 | m/s |

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.96 | C |
| Feed Pressure | 239.0 | bar |
| Product Pressure | 238.7 | bar |
| Molar Flow | 1.547e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 6.665 | m/s |

| Gas riser1 | | |
|---|---|---|
| Temperature | 25.00 | C |
| Pressure | 120.0 | bar |
| Molar Flow | 1.547e+007 | m3/d_(gas) |

| Compressor | | |
|---|---|---|
| Feed Pressure | 117.6 | bar |
| Product Pressure | 240.0 | bar |
| Molar Flow | 1.547e+007 | m3/d_(gas) |
| Energy | 1.556e+004 | kW |

| Cooler | | |
|---|---|---|
| Feed Temperature | 76.66 | C |
| Product Temperature | 25.00 | C |
| Duty | 2.152e+004 | kW |

| Gas2 | | |
|---|---|---|
| Temperature | 24.96 | C |
| Pressure | 238.7 | bar |
| Molar Flow | 1.547e+007 | m3/d_(gas) |

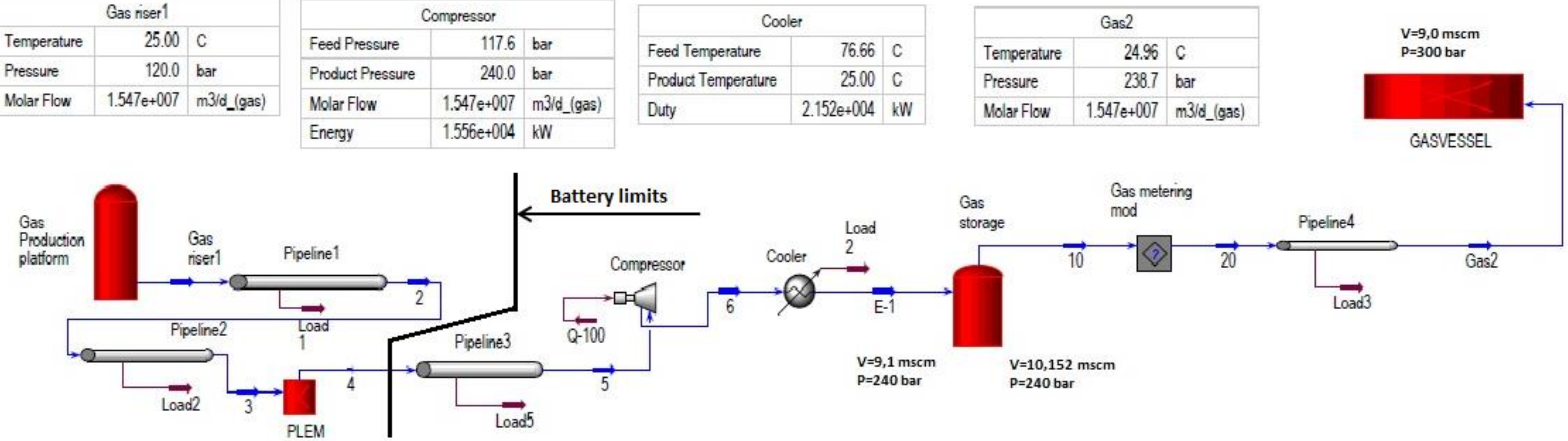
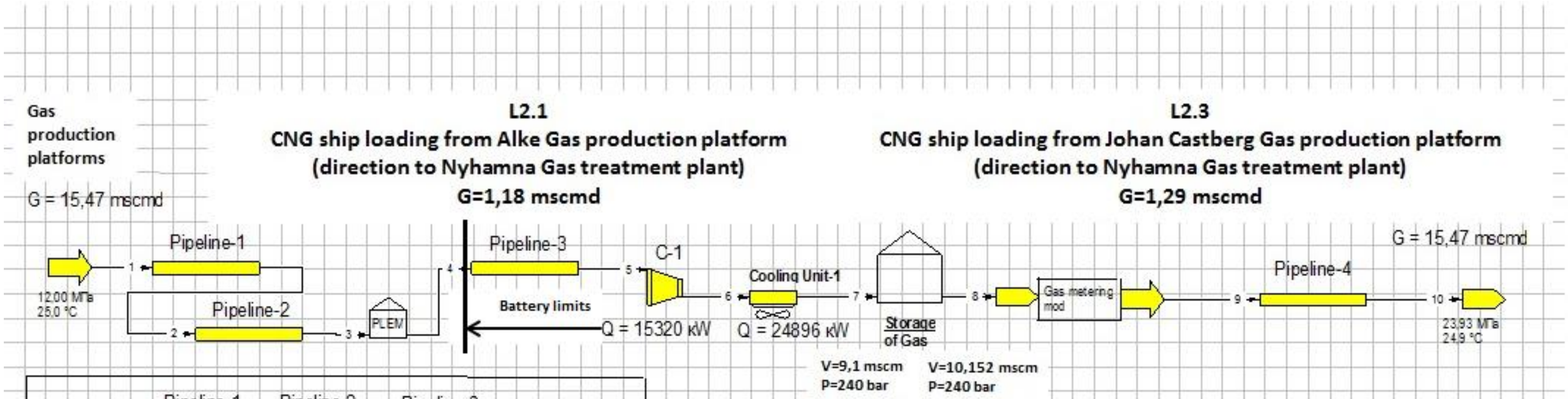



**Figure 28. Technical parameters of Gas loading terminal on Alke and Johan Castberg Gas production platform (direction to Nyhamna Gas treatment plant). (HYSYS).**




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 |
|---|---|---|---|---|
| L, m | 300 | 300 | 200 | 200 |
| D, mm | 350 | 350 | 350 | 350 |
| V, m/sec | 13,37 | 13,5 | 13,57 | 6,9 |

**Figure 29. Technical parameters of Gas loading terminal on Alke and Johan Castberg Gas production platform (direction to Nyhamna Gas treatment plant). (GasCondOil).**

#### B.2.3.4.2. *Processes L2.2, L2.4.* The parameters and Diagram of the CNG ship loading process for gas supplies to Aasta Hansteen Gas production platform

Below are shown the initial Data for calculating the loading diagram for gas delivery from Alke and Johann Castberg Gas production fields to the Aasta Hansteen Gas production platform (enter of the underwater Gas pipeline Polarled) in delivery volumes of a 1**,18 and 1,29 mscmd** respectively. The list of facilities on the loading diagram is formed taking into account the loading process from the offshore terminal.

| Name of Data | Gas loading terminal | |
|---|---|---|
| | **Alke, Process L2.2** | **Johan Castberg, Process L2.4** |
| The ship net capacity, $Nm^3$; | 9 000 000 | 9 000 000 |
| Updated loading time, hours; | 44 | 44 |
| Loading pressure, bar; | 240 | 240 |
| The Maximum Gas temperature during loading, $^0C$; | 25 | 25 |
| Average Gas flow rate, $Nm^3/d$; | 6.76 | 6.76 |
| Maximum Gas flow rate, $Nm^3/d$; | 15.47 | 15.47 |
| Ships loading frequency, days; | 6.26 | 6.49 |
| Quantity of CNG ships, pcs | 1 | 1 |
| Gas storage volume, $Nm^3$ | 7 390 000 | 8 372 000 |
| Storage Gas Temperature, $^0C$; | 25 | 25 |
| Air temperature, $^0C$; | 4 | 4 |
| Seawater temperature, $^0C$; | 7.8 | 7.8 |

**Table 11. List of initial Data for calculating the process of gas loading from the offshore terminal near the Alke and Johan Castberg Gas production platforms (Direction to Aasta Hansteen).**

**L2.2**
**CNG ship loading from Alke Gas production platform**
**(direction Aasta Hansteen Gas production platform,**
**enter to the underwater Gas pipeline Polarled )**
**G=1,18 mscmd**

**L2.4**
**CNG ship loading from Johan Castberg Gas production platform**
**(direction Aasta Hansteen Gas production platform,**
**enter to the underwater Gas pipeline Polarled )**
**G=1,29 mscmd**

| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.72 | C |
| Feed Pressure | 120.0 | bar |
| Product Pressure | 119.1 | bar |
| Molar Flow | 1.547e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 300.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 13.01 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 24.72 | C |
| Product Temperature | 24.94 | C |
| Feed Pressure | 119.1 | bar |
| Product Pressure | 118.1 | bar |
| Molar Flow | 1.547e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 300.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 13.12 | m/s |

| Pipeline3 | | |
|---|---|---|
| Feed Temperature | 24.94 | C |
| Product Temperature | 15.30 | C |
| Feed Pressure | 118.1 | bar |
| Product Pressure | 117.5 | bar |
| Molar Flow | 1.547e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 12.81 | m/s |

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 25.00 | C |
| Product Temperature | 24.96 | C |
| Feed Pressure | 239.0 | bar |
| Product Pressure | 238.7 | bar |
| Molar Flow | 1.547e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 6.665 | m/s |

| Gas riser1 | | |
|---|---|---|
| Temperature | 25.00 | C |
| Pressure | 120.0 | bar |
| Molar Flow | 1.547e+007 | m3/d_(gas) |

| Compressor | | |
|---|---|---|
| Feed Pressure | 117.5 | bar |
| Product Pressure | 240.0 | bar |
| Molar Flow | 1.547e+007 | m3/d_(gas) |
| Energy | 1.561e+004 | kW |

| Cooler | | |
|---|---|---|
| Feed Temperature | 77.16 | C |
| Product Temperature | 25.00 | C |
| Duty | 2.172e+004 | kW |

| Gas2 | | |
|---|---|---|
| Temperature | 24.96 | C |
| Pressure | 238.7 | bar |
| Molar Flow | 1.547e+007 | m3/d_(gas) |

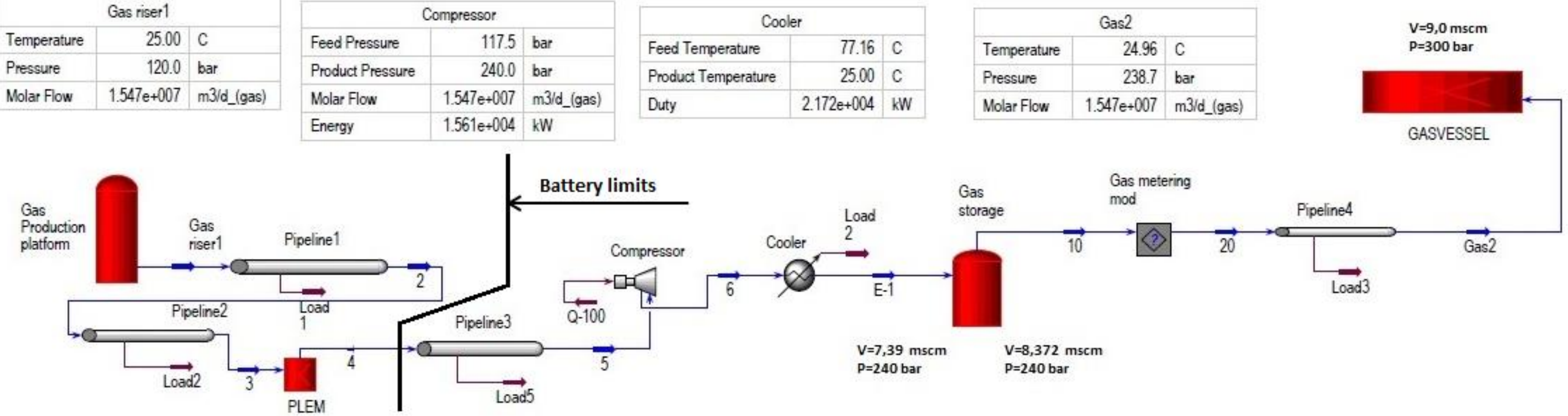
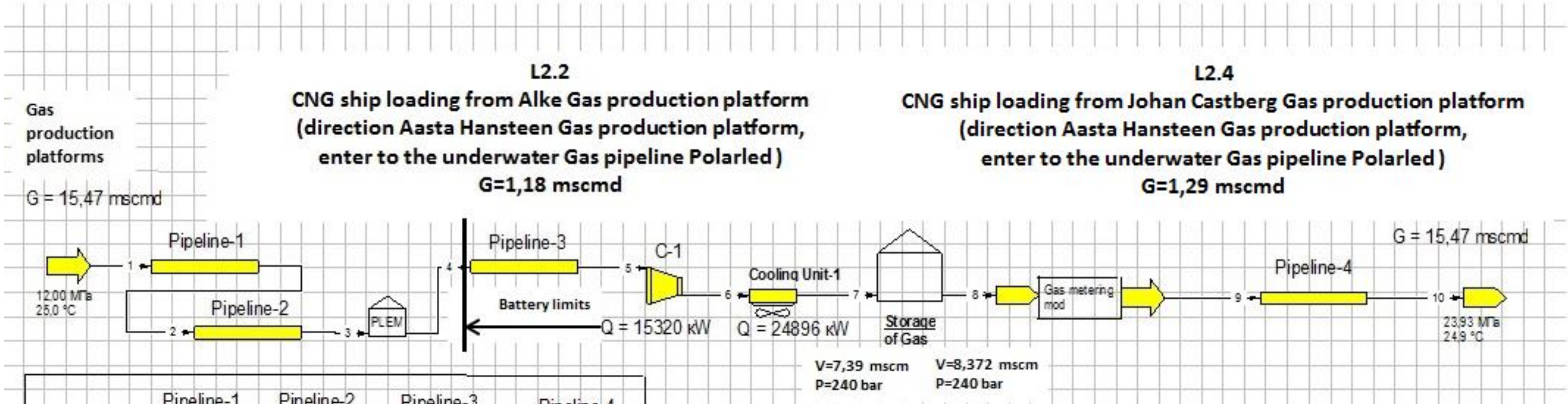



**Figure 30. Technical parameters of Gas loading terminal on Alke and Johan Castberg Gas production platform (direction to the Aasta Hansteen). (HYSYS).**




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 |
|---|---|---|---|---|
| L, m | 300 | 300 | 200 | 200 |
| D, mm | 350 | 350 | 350 | 350 |
| V, m/sec | 13,37 | 13,5 | 13,57 | 6,9 |

**Figure 31.Technical parameters of Gas loading terminal on Alke and Johan Castberg Gas production platform (direction to the Aasta Hansteen). (GasCondOil).**

#### B.2.3.4.3. *Processes U2.1 and U2.2.* The parameters and Diagram of the CNG ship unloading process for gas supplies to Nyhamna Gas treatment plant and Aasta Hansteen Gas production platform

Below are shown the initial Data for calculating the gas unloading diagram in the onshore Gas unloading terminal near the Nyhamna Gas treatment plant and the offshore Gas unloading terminal near the Aasta Hansteen Gas production platform (enter to the underwater Gas pipeline Polarled) in delivery volumes of a **1,18 and 1,29 mscmd** respectively. The list of facilities on the unloading diagram is formed taking into account the unloading process.

| Name of Data | Point of delivery | |
|---|---|---|
| | Nyhamna Gas treatment plant, Process U2.1 | Aasta Hansteen Gas production platform, Process U2.2 |
| The ship net capacity, $Nm^3$; | 9 000 000 | 9 000 000 |
| Updated unloading time, hours; | 70 | 70 |
| Unloading pressure, bar; | 80 | 80 |
| The Maximum Gas temperature during unloading, $^0C$; | 32 | 32 |
| Average Gas flow rate, $Nm^3/d$; | 4.25 | 4.25 |
| Maximum Gas flow rate, $Nm^3/d$; | 10.35 | 10.35 |
| Ships loading frequency, days; | 7.65 | 3.75 |
| Quantity of CNG ships, pcs | 1 | 2 |
| Gas storage volume, $Nm^3$ | | |
| Gas from Alke | 9 100 000 | 7 390 000 |
| Gas from Johan Castberg | 10 152 000 | 8 372 000 |
| Storage Gas Temperature, $^0C$; | | |
| Air temperature, $^0C$; | 4 | 4 |
| Seawater temperature, $^0C$; | 7.8 | 7.8 |

**Table 12. List of initial Data for calculating the process of gas unloading to the terminals near the Nyhamna Gas treatment plant and Aasta Hansteen gas production platform.**

**U2.1**
**CNG ship unloading from Alke and Johan Castberg Gas production platforms to Nyhamna**
**G=1,29 mscmd**

| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 32.00 | C |
| Product Temperature | 31.83 | C |
| Feed Pressure | 80.00 | bar |
| Product Pressure | 79.54 | bar |
| Molar Flow | 1.035e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 14.31 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 31.61 | C |
| Product Temperature | 24.99 | C |
| Feed Pressure | 78.97 | bar |
| Product Pressure | 78.61 | bar |
| Molar Flow | 1.035e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 500.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 6.871 | m/s |

| Pipeline3 | | |
|---|---|---|
| Feed Temperature | 24.99 | C |
| Product Temperature | 19.99 | C |
| Feed Pressure | 78.61 | bar |
| Product Pressure | 78.26 | bar |
| Molar Flow | 1.035e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 500.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 6.704 | m/s |

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 10.00 | C |
| Product Temperature | 9.999 | C |
| Feed Pressure | 58.37 | bar |
| Product Pressure | 58.36 | bar |
| Molar Flow | 1.290e+006 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 300.0 | m |
| Vapour Velocity (Vapour Velocity_6) | 2.257 | m/s |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |

| VLV-1 | | |
|---|---|---|
| Feed Pressure | 76.37 | bar |
| Product Pressure | 59.37 | bar |
| Molar Flow | 1.290e+006 | m3/d_(gas) |
| Feed Temperature | 19.95 | C |
| Product Temperature | 12.45 | C |

| T-100 | | |
|---|---|---|
| Feed Temperature | 12.45 | C |
| Product Temperature | 10.00 | C |
| Molar Flow | 1.290e+006 | m3/d_(gas) |
| Duty | -55.86 | kW |

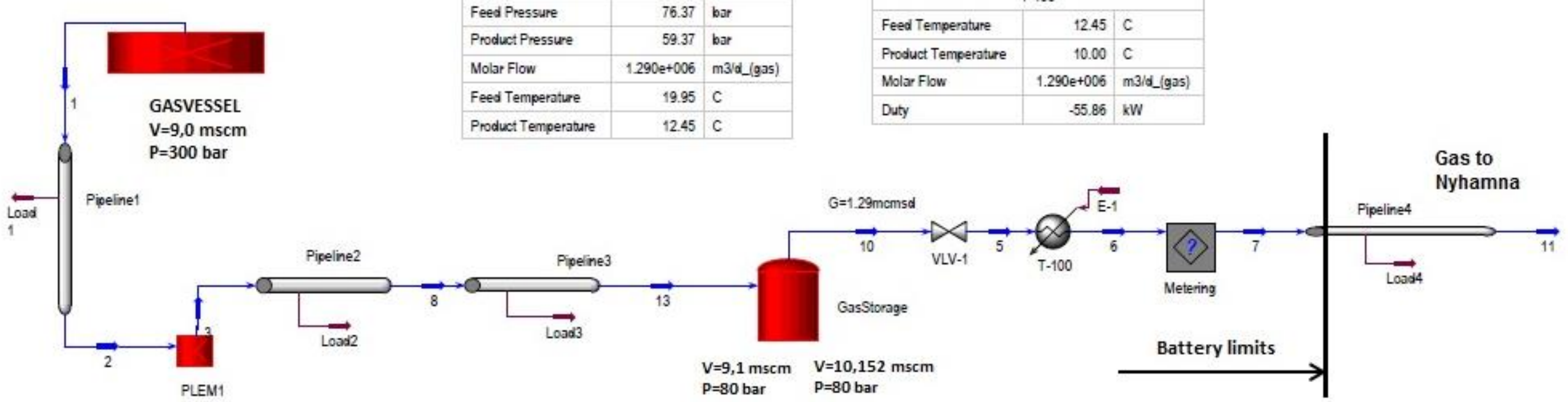
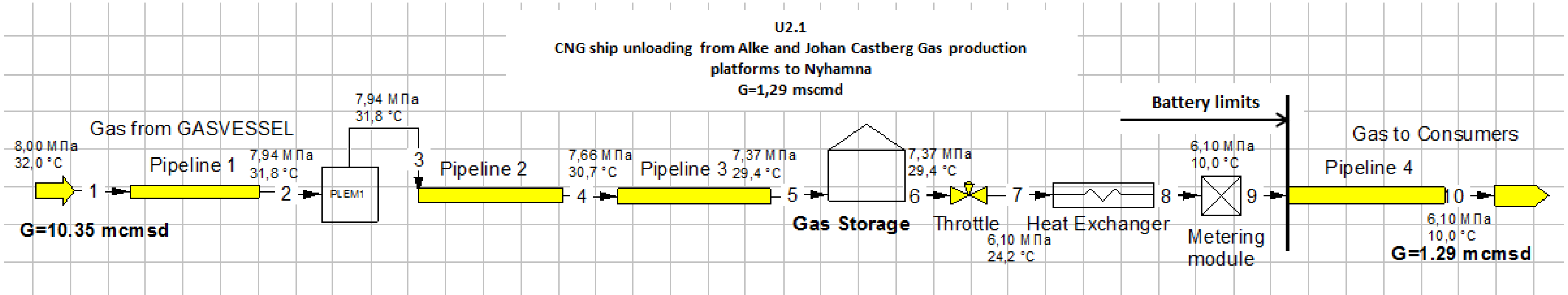



**Figure 32. Technical parameters of Gas unloading terminal near the Nyhamna Gas treatment plant. (HYSYS).**




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 |
|---|---|---|---|---|
| L, m | 200 | 1000 | 1000 | 300 |
| D, mm | 350 | 350 | 350 | 350 |
| V, m/sec | 14,5 | 15,0 | 15.6 | 2,2 |

**Figure 33. Technical parameters of Gas unloading terminal near the Nyhamna Gas treatment plant. (GasCondOil).**

**U2.2**
**CNG ship unloading from Alke and Johan Castberg Gas production platforms to Aasta Hansteen (enter to Polarled)**
**G=1,29 mscmd**

| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 32.00 | C |
| Product Temperature | 31.83 | C |
| Feed Pressure | 80.00 | bar |
| Product Pressure | 79.54 | bar |
| Molar Flow | 1.035e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 14.31 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 31.83 | C |
| Product Temperature | 31.47 | C |
| Feed Pressure | 79.54 | bar |
| Product Pressure | 78.72 | bar |
| Molar Flow | 1.035e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 350.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 14.40 | m/s |

| Pipeline3 | | |
|---|---|---|
| Product Temperature | 20.09 | C |
| Feed Pressure | 78.72 | bar |
| Product Pressure | 77.72 | bar |
| Molar Flow | 1.035e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 14.40 | m/s |

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 10.00 | C |
| Product Temperature | 9.998 | C |
| Feed Pressure | 75.02 | bar |
| Product Pressure | 75.00 | bar |
| Molar Flow | 1.290e+006 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 2.294 | m/s |

| VLV-1 | | |
|---|---|---|
| Feed Pressure | 77.72 | bar |
| Product Pressure | 75.42 | bar |
| Molar Flow | 1.290e+006 | m3/d_(gas) |
| Feed Temperature | 20.00 | C |
| Product Temperature | 19.05 | C |

| T-100 | | |
|---|---|---|
| Feed Temperature | 19.05 | C |
| Product Temperature | 10.00 | C |
| Molar Flow | 1.290e+006 | m3/d_(gas) |
| Duty | -267.0 | kW |

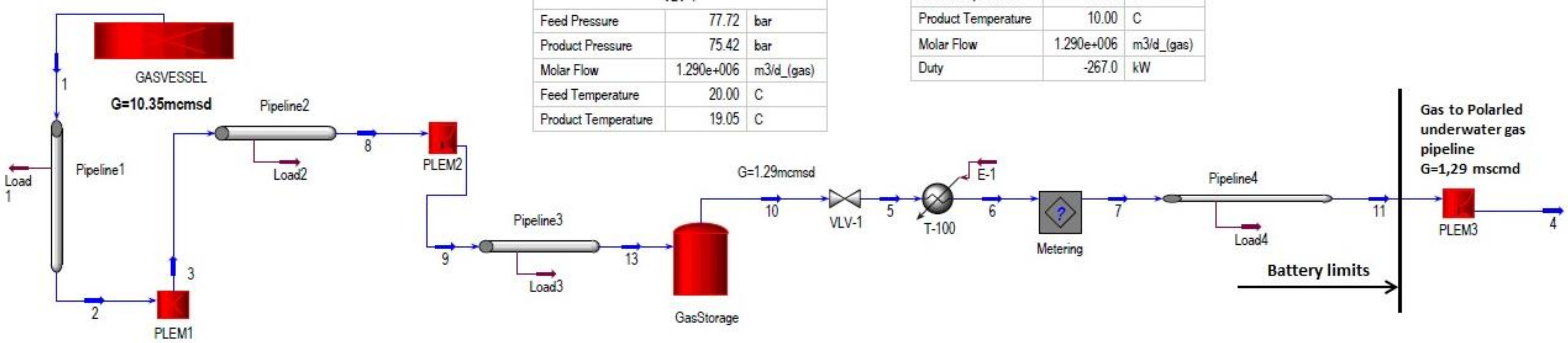
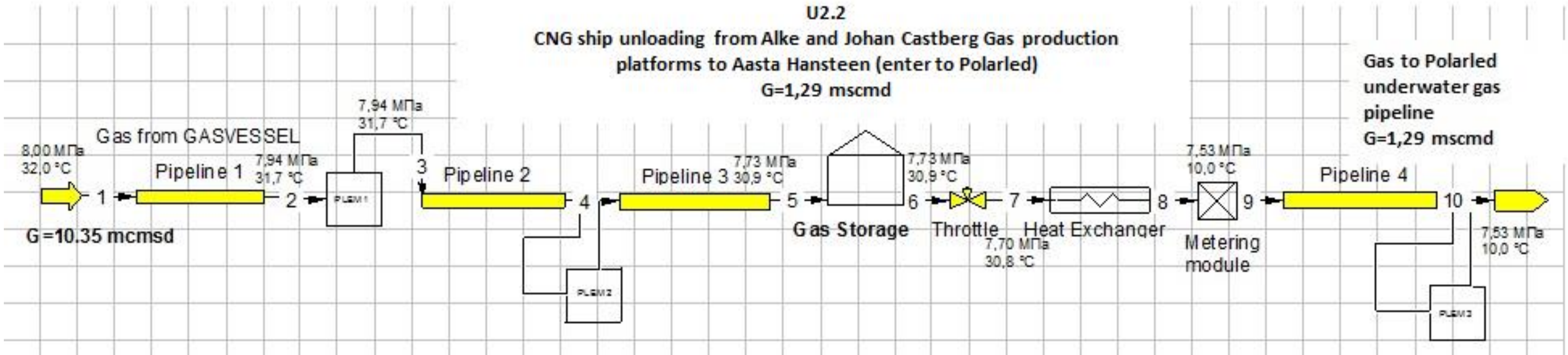



Figure 34. Technical parameters of Gas unloading terminal on the Aasta Hansteen Gas production platform. (HYSYS).




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 |
|---|---|---|---|---|
| L, m | 200 | 300 | 200 | 200 |
| D, mm | 350 | 350 | 350 | 350 |
| V, m/sec | 14,5 | 14,67 | 14,67 | 2,3 |

Figure 35. Technical parameters of Gas unloading terminal on the Aasta Hansteen Gas production platform. (GasCondOil).

### B.3. Black Sea

In the D2.1, were considered the market of the Ukraine gas consumers.

The study of potential gas loading and unloading points, as well as gas consumption markets in Ukraine, were realized by VTG. After discussing the preview results, the gas loading point was identified in Georgia with the allocation of Gas loading terminal near the port of Poti, accordingly, the Gas unloading terminal location will take a place near the port of Yuzne in Ukraine. The gas source planned as Shah-Deniz Gas fields in Azerbaijan.

#### B.3.1. Black Sea analysis of required Gas volumes

According to the Gas delivery scenarios to Ukraine, there have been considered the delivery of 6,30 mscmd.

At the 4th GASVESSEL Consortium General Assembly, NAVALPROGETTI specified the volume of CNG ship will be of 12,00 mscm of the gas.

##### B.3.1.1. Gas to Ukraine

In the Black Sea region, after discussion, we have one point of gas loading: the onshore Gas loading terminal near the port of Poti in Georgia.

In the D2.1 Delivery was considered the gas market in Ukraine as a main gas consumer in the Black Sea region.

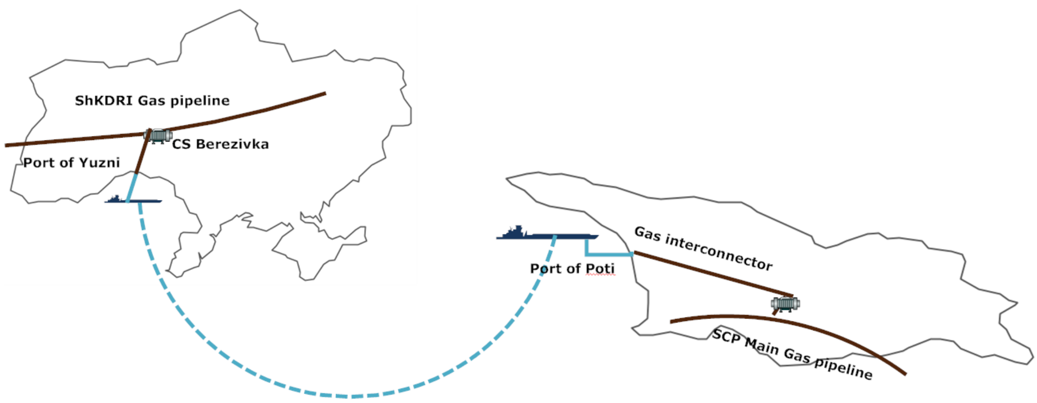



Figure 36. Gas delivery from the loading terminal in Georgia to unloading terminal in Ukraine.

Figure 36 above shows the diagram of gas delivery from Georgia to Ukraine.

The maximum total gas loading/unloading flow to Ukraine will be 6**.30 mscmd**.

#### B.3.2. Conclusions on the Black Sea loading/unloading parameters

The source and volumes of Gas supplies to Ukraine are shown in the table below.

| Source | Loading point | Unloading point | Estimated Gas volume | Notes |
|---|---|---|---|---|
| Shah-Deniz Gas fields, Azerbaijan | Onshore loading terminal near the port of Poti, Georgia | Onshore unloading terminal near the port of Yuzne, Ukraine | 6,30 mscmd | Gas for different Consumers, which are connected to the Ukrainian gas network |

Table 13. Gas transferring volumes on Gas loading/unloading points in a Black Sea region.

#### B.3.3. The infrastructure of the terminals

In this section of the Report, we set out a vision of the VTG on the arrangement of loading and unloading gas terminals for loading/unloading service during the gas supplying to Ukraine.

The structure of the Gas loading terminal facilities is the full independent infrastructure.

The modules of equipment and systems are necessary for the realization of the tasks of gas loading and unloading for the GASVESSEL system.

#### B.3.3.1. Onshore Gas loading terminal facilities near the port of Poti (Georgia)

In the development up of a list of the necessary processes for CNG ship loading, as well as in the Mediterranean and Barents Sea Region, we will make several assumptions. These assumptions can be adjusted at further stages of the Project's development in accordance with local conditions, such as gas loading pressure, actual gas flow for loading, the necessary equipment on the loading terminal to perform the loading process and other factors. The list of assumptions is given below (also see Table 14):

- The CNG ship capacity is of 12,00 mscm (according to the scenarios);
- The loading time is determined by Consortium based on the technical capabilities of the CNG ship is 47 hours;
- It is assumed that the volume of intermediate Gas storage during loading of the CNG ship must be at least the volume of the CNG ship;
- The gas temperature during the CNG ship loading must not exceed 25 $^{0}$C;
- The loading gas from the Gas interconnector is supplied cleaned in accordance with the applicable Quality Standards.
- The piping diameter should be selected from the condition of the gas velocity inside of the pipes within 5 to 20 m/s.

All modules, systems can be divided by:

- **Main process facilities**;
- **Auxiliary process facilities**;
- **Life support facilities**.

Below is shown the composition of the Gas loading terminal near the port of Poti in Georgia, which consist the modules and systems and the connection pipelines or part of pipelines:

| **Facilities in the scope of the Project** |
|---|
| **Onshore Gas loading terminal** |
| Tie-in point to the Gas interconnector (D=28") |
| ***Main process facilities (modules) of Onshore Gas loading terminal*** |
| Gas compressor module |
| Gas cooling module |
| Gas storage module |
| Gas measuring module |
| ***Auxiliary process facilities (modules) of Onshore Gas loading terminal*** |
| Process automation and signaling system |
| Instrument and Plant Air System |
| Nitrogen Generation and Distribution System |
| Vent/Flare System |
| Power supply and Distribution System |
| Electrochemical anti-corrosion protection System |
| Diesel generator module |
| Diesel Fuel System |
| Communication, alarm, fire alarm system |

| |
|---|
| Overhead transmission line (V=10 kV), (if any) |
| Power, control and signaling cables |
| Auxiliary site pipelines |
| ***Life support facilities (modules) of Onshore Gas loading terminal*** |
| Water and sewage system (if any) |
| Firewater and fire-fighting system |
| Evaporation pond |
| Ancillary buildings and structures, site improvements |
| **Connection pipelines** |
| Pipeline1 (Onshore Gas pipeline, D=28 inches) |
| Pipeline 2 (Onshore Gas pipeline,  D=14 inches) |
| Pipeline 3 (Underwater Gas pipeline,  D=14 inches) |
| PLEM1, (D=14 inches) |
| Pipeline 4 (Flexible connection,  D=3x7 inches) |
| **Facilities out of the scope of the Project** |
| **N/A** |

#### B.3.3.2. Gas unloading terminal facilities near the port of Yuzne (Ukraine)

In development up of a list of the necessary processes for CNG ship unloading we will make also such assumptions (also see Table 15):

- The CNG ship capacity is of 12,00 mscm (according to the scenarios);
- The unloading Time is determined by Consortium based on the technical capabilities of the CNG ship is of 69 hours;
- It is assumed that the volume of intermediate Gas storage during unloading of the CNG ship must be at least the volume of the CNG ship;
- During the unloading process, the gas is released into a pipeline at the pressure of 80 bar. In the process of unloading of the GASVESSEL cylinders about halfway, the compressor on board the ship is turned on and pumps gas to a minimum volume with a residual pressure of about 20 bar;
- The gas temperature during the CNG ship unloading must be not less than 10 $^0$C and no more than 40 $^0$C;
- The piping diameter should be selected from the condition of the Gas velocity inside of the pipes within 5 to 20 m/s).

All modules, systems can be divided by:

- **Main process facilities;**
- **Auxiliary process facilities;**
- **Life support facilities.**

The list of facilities below shows the structures of the onshore Gas unloading terminal facilities near the port of Yuzne in Ukraine.

| **Facilities in the scope of the Project** |
|---|
| **Onshore Gas unloading terminal** |
| ***Main process facilities (modules) of Onshore Gas unloading terminal*** |
| Gas storage module |
| Gas pressure reducing module |

| |
|---|
| Gas heating module |
| Gas measuring module |
| ***Auxiliary process facilities (modules) of Onshore Gas unloading terminal*** |
| Process automation and signaling system |
| Instrument and Plant Air System |
| Nitrogen Generation and Distribution System |
| Vent/Flare System |
| Power supply and Distribution System |
| Electrochemical anti-corrosion protection System |
| Diesel generator module |
| Diesel Fuel System |
| Communication, alarm, fire alarm system |
| Overhead transmission line (V=10 kV), (if any) |
| Power, control and signaling cables |
| Auxiliary site pipelines |
| ***Life support facilities (modules) of Onshore Gas unloading terminal*** |
| Water and sewage system (if any) |
| Firewater and fire-fighting system |
| Evaporation pond |
| Ancillary buildings and structures, site improvements |
| **Connection pipelines** |
| Pipeline 1 (Flexible connection, D=3x7 inches) |
| PLEM1, (D=14 inches) |
| Pipeline 2 (Underwater Gas pipeline, D=14 inches) |
| Pipeline 3 (Onshore Gas pipeline, D=14 inches) |
| Tie in point to the new Gas interconnector pipeline |
| **Facilities out of the scope of the Project** |
| Pipeline 4 (Onshore Gas pipeline, connecting the new Gas interconnector pipeline, D=14 inches) |

According to the VTG point of view, the infrastructure of the onshore unloading terminal near the port of Yuzne should contain the maximum number of systems and modules that will make CNG ship unloading processes independent of the external infrastructure.

### B.3.4. Diagrams and parameters of the GASVESSEL loading/unloading process in the Black Sea region

The preliminary parameters of the processes of loading and unloading performed at the terminals of loading/unloading of CNG ship were calculated in two different ways on different programs Aspen HYSYS and GasCondOil. The calculating results are shown below.

#### B.3.4.1.1. *Process L3.1.* The parameters and Diagram of the CNG ship loading process in the port of Poti

Below are shown the initial Data for calculating the loading diagram for gas delivery from the Gas loading terminal near the port of Poti to the Gas unloading terminal near the port of Yuzne in delivery volumes of a 6**,3 mscmd**. The list of facilities on the loading diagram is formed taking into account the loading process from the onshore terminal.

| Name of Data | Gas loading terminal Poti, Process L2.1 |
|---|---|
| The ship net capacity, $Nm^3$; | 12 000 000 |
| Updated loading time, hours; | 47 |
| Loading pressure, bar; | 240 |
| The Maximum Gas temperature during loading, $^0C$; | 25 |
| Average Gas flow rate, $Nm^3/d$; | 6.29 |
| Maximum Gas flow rate, $Nm^3/d$; | 15.37 |
| Ships loading frequency, days; | 7.30 |
| Quantity of CNG ships, pcs | 4 |
| Gas storage volume, $Nm^3$ | 45 990 000 |
| Storage Gas Temperature, $^0C$; | 25 |
| Air temperature, $^0C$; | 12,2 |
| Seawater temperature, $^0C$; | 14,9 |

**Table 14. List of initial Data for calculating the process of gas loading from the onshore terminal near the port of Poti (Direction to Yuzne).**

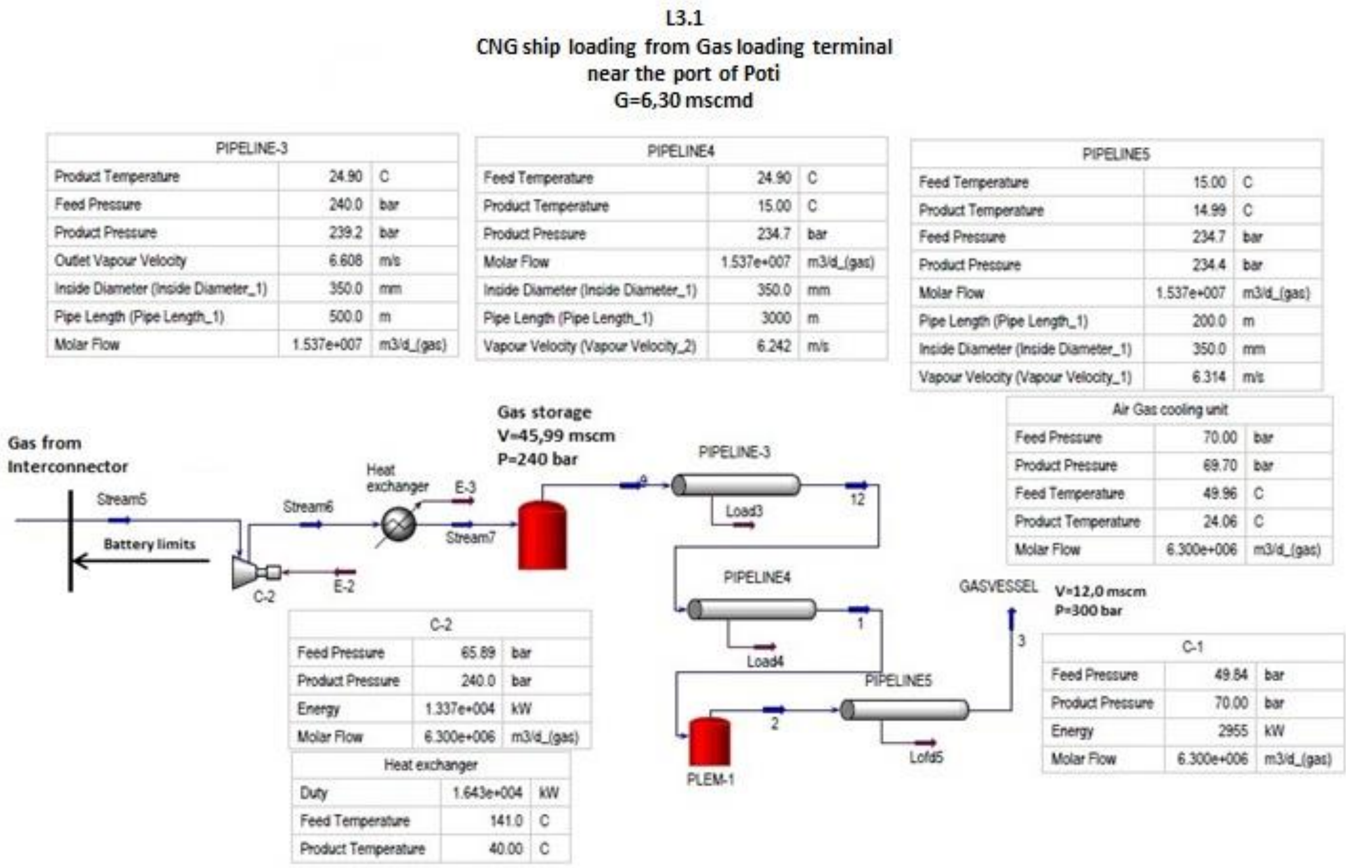
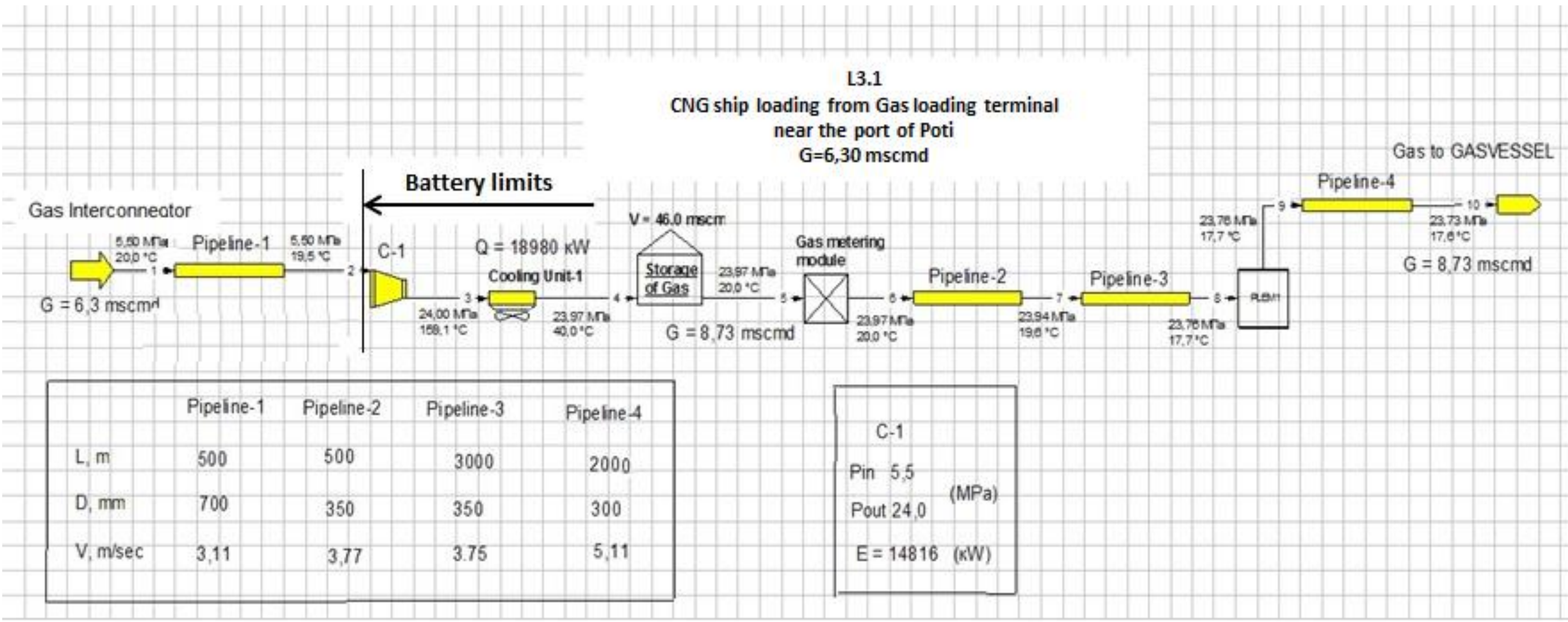



**Figure 37. Technical parameters of Gas loading terminal near the port of Poti. (HYSYS).**




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 |
|---|---|---|---|---|
| L, m | 500 | 500 | 3000 | 2000 |
| D, mm | 700 | 350 | 350 | 300 |
| V, m/sec | 3,11 | 3,77 | 3.75 | 5,11 |

**Figure 38. Technical parameters of Gas loading terminal near the port of Poti. (GasCondOil)**

### B.3.4.1.2. *Process U3.1.* The parameters and Diagram of the CNG ship unloading process in the port of Yuzne

Below are shown the initial Data for calculating the gas unloading diagram into the onshore Gas unloading terminal near the port of Yuzne in delivery volumes of a 6**,30 mscmd**. The list of facilities on the unloading diagram is formed taking into account the unloading process.

| Name of Data | Point of delivery<br>Port of Yuzne, Process U3.1 |
|---|---|
| The ship net capacity,<br>$Nm^3$; | 12 000 000 |
| Updated unloading time,<br>hours; | 69 |
| Unloading pressure,<br>bar; | 80 |
| The Maximum Gas temperature during unloading,<br>$^0C$; | 32 |
| Average Gas flow rate,<br>$Nm^3/d$; | 4.28 |
| Maximum Gas flow rate,<br>$Nm^3/d$; | 10.35 |
| Ships loading frequency,<br>days; | 7.30 |
| Quantity of CNG ships,<br>pcs | 4 |
| Gas storage volume,<br>$Nm^3$ | 45 990 000 |
| Storage Gas Temperature,<br>$^0C$; | 25 |
| Air temperature,<br>$^0C$; | 12,2 |
| Seawater temperature,<br>$^0C$; | 14,9 |

Table 15. List of initial Data for calculating the process of gas unloading to the terminals near the port of Yuzne.

**U3.1**
**CNG ship unloading to the Gas unloading terminal near the port of Yuzne**
**G=6,30 mscmd**

| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 32.00 | C |
| Product Temperature | 12.83 | C |
| Feed Pressure | 80.00 | bar |
| Product Pressure | 79.57 | bar |
| Molar Flow | 1.035e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_1) | 14.90 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 12.35 | C |
| Product Temperature | 10.01 | C |
| Feed Pressure | 79.04 | bar |
| Product Pressure | 73.66 | bar |
| Molar Flow | 1.035e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 2500 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 13.08 | m/s |

| Pipeline3 | | |
|---|---|---|
| Feed Temperature | 10.01 | C |
| Product Temperature | 19.94 | C |
| Feed Pressure | 73.66 | bar |
| Product Pressure | 71.26 | bar |
| Molar Flow | 1.035e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_1) | 13.81 | m/s |

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 10.00 | C |
| Product Temperature | 9.984 | C |
| Feed Pressure | 56.26 | bar |
| Product Pressure | 56.23 | bar |
| Molar Flow | 6.300e+006 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 700.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 2.875 | m/s |

| T-100 | | |
|---|---|---|
| Feed Temperature | 13.68 | C |
| Product Temperature | 10.00 | C |
| Molar Flow | 6.300e+006 | m3/d_(gas) |
| Duty | -438.2 | kW |

| VLV-1 | | |
|---|---|---|
| Feed Pressure | 71.26 | bar |
| Product Pressure | 57.26 | bar |
| Molar Flow | 6.300e+006 | m3/d_(gas) |
| Feed Temperature | 19.94 | C |
| Product Temperature | 13.68 | C |

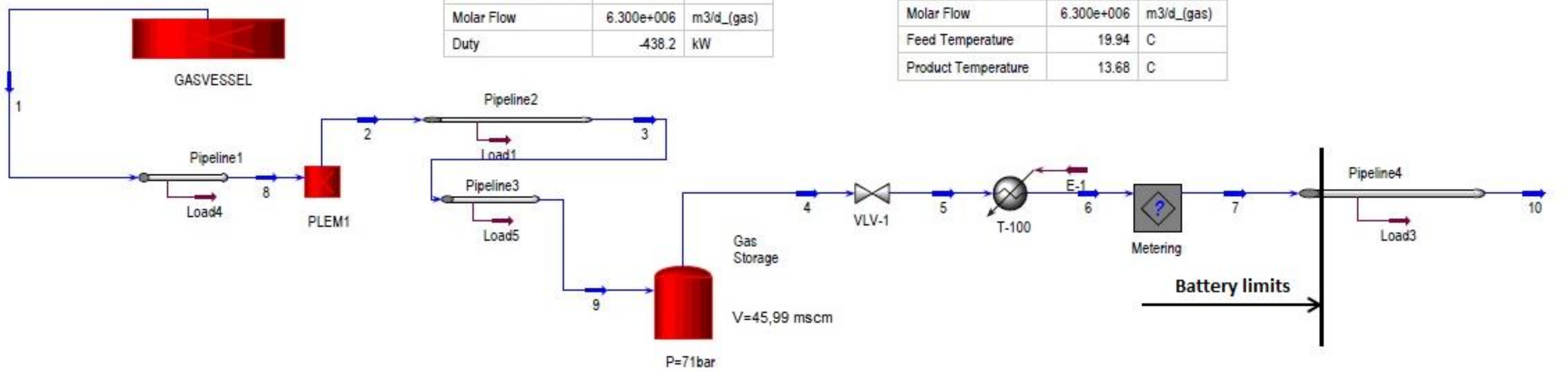
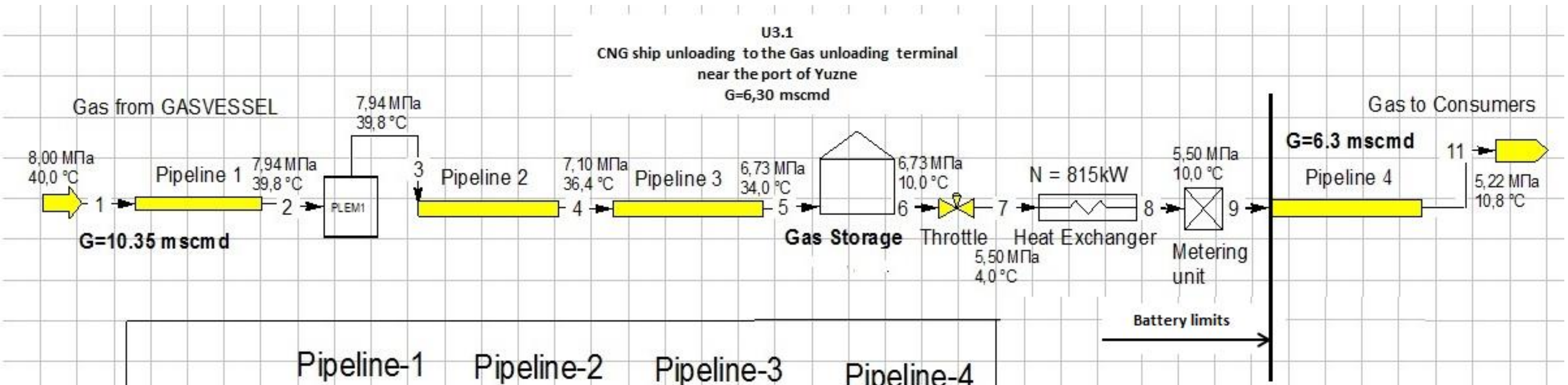



**Figure 39. Technical parameters of Gas unloading terminal near the port of Yuzne. (HYSYS).**




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 |
|---|---|---|---|---|
| L, m | 200 | 2500 | 1000 | 1000 |
| D, mm | 350 | 350 | 350 | 700 |
| V, m/sec | 15,1 | 16,8 | 17.6 | 2,97 |

**Figure 40. Technical parameters of Gas unloading terminal near the port of Yuzne. (GasCondOil).**

The Gas storage shown in the Figure can be located both in the location on the shore or in the version of the floating Gas storage.

For a more complete understanding of the process of loading and unloading a CNG ship, we also give a general diagram of a CNG ship loading. The diagram is given for an example of loading in the Black Sea region. It includes the parameters of all loading processes starting from the point of connection to the SCP to the ship loading near the port of Poti.
A similar diagram of a CNG ship unloading is given for the processes of unloading of a CNG ship in Ukraine. The diagram shows the parameters of all processes of unloading of a CNG ship, starting from a CNG ship and ending with the point of connection of the Gas interconnector to the existing in Ukraine Gas transmission network.

## C. The onshore GASVESSEL loading system (in the Black Sea region)

In this section of the report, we consider the loading of CNG SHIP ***using the example of an onshore loading system near the port of Poti in Georgia***.

As mentioned earlier, the entire loading system will consist of a source of Gas, a Gas transportation system from the source to the Gas loading terminal and the Gas loading terminal itself. Below we will look at the elements of the Gas loading system infrastructure.

### C.1. Head Compressor Station of the Gas interconnector: SCP - Loading terminal in the Poti port area (Georgia).

#### C.1.1. Introduction

In this section, VTG addresses the Technical issues of the construction of the Head compressor station of the Gas Interconnector SCP - the Gas loading terminal in the area of the port of Poti (Georgia) as a first stage of the Gas transport system. The cost of the Compressor station is not included in the cost of the system, but its cost is calculated and shown in Table 52. The Head compressor station will transport the Natural Gas from the source of the SCP main Gas pipeline to the Gas loading terminal near the port of Poti.

#### C.1.2. Purpose of the Head compressor station

The Gas to the Head compressor station is supplied from the point of connection to the SCP via a 3 km long Gas pipeline. The connection point is situated in the area of the Gas measurement station (District 81) near the village of Vale in Georgia nearby the Georgian-Turkey boarder.

Since the Gas pressure at the interconnector to the SCP connection point of the will not exceed 55 bar, and the Gas will be transported to the loading terminal through the Gas pipeline 140 km long, it is clear that the construction of the head compressor station is necessary.

The main productivity parameters of the Head Gas compressor station are harmonized with the work productivity of the Gas interconnector and belong to different scenarios of Gas delivery is **6,30 mscmd.**:

#### C.1.3. Glossary, abbreviations, and acronyms

In this section, such abbreviations and acronyms were used:

| **Abbreviation** | **Description** |
|---|---|
| **ALS** | accidental limit state |
| **AR** | an additional requirement to the stated ISO Standard |
| **API** | American Petroleum Institute |
| **ASME** | American Society of Mechanical Engineers |
| **ASTM** | American Society for Testing and Materials |
| **BM** | base material |
| **BS** | British Standard |
| **CP** | cathodic protection |
| **MAOP** | maximum allowable operating pressure |
| **MR** | the modified requirement to the stated ISO Standard |
| **N** | normalized |
| **NACE** | national association of corrosion engineers |
| **NDT** | non-destructive testing |
| **QA** | Quality assurance |
| **QC** | Quality control |
| **SC** | Safety class |
| **SCP** | South Caucasus Gas Pipeline |
| **UT** | Ultrasonic testing |
| **ACU** | Gas Air Cooling Unit; |
| **OACU** | Oil Air Cooling Unit; |

| | |
|---|---|
| **GTU** | Gas Turbine Unit; |
| **GPU** | Gas Pumping Unit; |
| **GCS** | Gas Compressor Station; |
| **GCC** | Gas Compressor Shop |

Table 16.Glossary, abbreviations, and acronyms.

### C.1.4. Units of measurement.

The Units of measurement which are used in this section are shown in Table 2.

### C.1.5. Climate data

The construction site of the Head compressor station is characterized by the following climatic characteristics which are shown in Table 17 and are corresponding with Georgian Standard SNiP 23-01[5].

| The Environmental parameters | Data |
|---|---|
| *Temperature:* | |
| - Average air temperature in January, $^0$C | minus 6,6 |
| - Average air temperature in July, $^0$C | 15,8 |
| - Average annual air temperature, $^0$C | 5,2 |
| - Absolute minimum air temperature, $^0$C | minus 38 |
| - Absolute maximum air temperature, $^0$C | 37 |
| - Average maximum temperature of the hottest month, $^0$C | 21,7 |
| - Average air temperature of the coldest five-day week with a rated of 0.92 $^0$C, | minus 15 |
| Maximum depth of soil freezing, cm | 63 |
| *Wind:* | |
| Prevailing wind direction in January | East |
| Prevailing wind direction in July | North |
| Average wind speed in January in the prevailing direction, m/s | 5,1 |
| Average wind speed in July in the prevailing direction, m/s | 5,8 |
| Wind velocity, kPa | 0,48 |
| *Precipitation:* | |
| Rainfall per year, mm | 621 |
| Daily maximum, mm | 63 |
| The average height of snow cover, cm | 68 |
| Snow cover weight per 1 $m^2$ of a horizontal surface, kPa | 1,0 |
| Seismicity of the CS area (on the MSK-64 scale) | grade 8 |
| Average monthly relative humidity of air at 13 hours,%:<br>- the hottest month;<br>- the coldest month | <br>72<br>61 |

Table 17.Environmental parameters of the area of the Gas interconnector (pipeline start).

### C.1.6. Codes and Standards

The Codes and Standards used for design and build the Head gas compressor station must meet the Standards used in the best practice of international Engineering taking into account the Georgian national Standards.

| Standard, Code | Description | Notes |
|---|---|---|
| ***ASME, ANSI, ASTM Standards*** | | |
| ASME B 16.5 | Pipes, Flanges and Flanged Fittings | |
| ASME B 19.3 | Safety Standards for Compressors for Process Industries | |
| ASME B 16.11 | Forged Steel Fittings, Socket Welding and Threaded. | |

| | | |
|---|---|---|
| ASME B16.34 | Steel Valves, Flanged threaded and welded. | |
| ASME B 19.3 | Safety Standards for Compressors for Process Industries | |
| ASME B 16.5 | Steel Pipe Flanges and Pipe Fittings | |
| ASME B 16.9 | Factory-Made Wrought Steel Butt-Welding Fittings | |
| ASME B 31.8 | Gas Transmission and Distribution Piping Systems | |
| ASME B 36.10 M | Welded and Seamless Wrought Steel Pipe | |
| ASME B31.8 | Gas Transmission and Distribution Piping Systems | |
| ASME | Performance Test Codes | |
| ASME B31.9 | Working Pressure and Temperature Limits | |
| ASME/ANSI B16 | Standards for Pipes and Fittings | |
| ASME/ANSI ASME B36.10/19 | Carbon, Alloy and Stainless Steel Pipes - Dimensions - Metric Units | |
| ASTM | ASTM International - Standards for Steel Pipes, Tubes and Fittings | |
| ASTM | ASTM International - Volume 01.01 Steel - Piping, Tubing, Fittings | |
| ***API Standards*** | | |
| API 521 | Pressure-Relieving and Depressurizing Systems | |
| API 2000: | Venting Atmospheric and low-pressure storage tanks | |
| API 537: | Flare Details for General Refinery and Petrochemical Service | |
| API 616: | Gas Turbines for the Petroleum, Chemical, and Gas Industry Services | |
| API 617: | Axial and Centrifugal Compressors and Expander-compressors for Petroleum, Chemical, and Gas Industry Services. | |
| API 661: | Air-Cooled Heat Exchangers for General Refinery Service | |
| API 676: | Positive Displacement Pumps - Rotary | |
| API RP 526 | Flanged Steel Safety Relief Valve | |
| API 619 | Rotary-Type Positive Displacement Compressors for General Refinery Service | |
| API RP 521 | Guide for Pressure-Relieving and Depressuring System | |
| API RP 526 | Flanged Steel Safety Relief Valve | |
| API STD 594 | Check Valves: Wafer, Wafer-Lug, and Double Flanged Type | |
| API STD 599 | Metal Plug Valves - Flanged and Welding Ends | |
| API STD 602 | Compact Steel Gate Valves-Flanged, Threaded, Welding, and Extended-Body Ends | |
| API STD 608 | Metal Ball Valves Flanged and Butt-Welding Ends | |
| API STD 609 | Butterfly Valves: Double Flanged, Lug- and Wafer-Type Fifth Edition | |
| API RP 520 | API RP 520 Sizing, Selection, and Installation of Pressure-Relieving Devices in Refineries | |
| API RP 521 | API RP 521 Guide for Pressure-Relieving and Depressurising Systems | |
| ***BS Standards*** | | |
| BS 1868 | Steel Check Valves | |
| BS 1873 | Steel Globe Valves | |
| BS 5146 | Inspection and Testing of Valves | |
| BS 5351 | Steel Ball Valves for the Petroleum, Petrochemical and Allied Industries | |
| BS 5352 | Steel Wedge Gate, Globe and Check Valves 50mm and | |

| | | |
|---|---|---|
| | smaller | |
| BS 6755 Part 2 | Testing of Valves Part 2: Specification for Fire Type-Testing Requirements | |
| IP6 | Institute of Petroleum Model Code of Safe Practice Part 6, Pipeline Safety Code | |
| BS 8010 | Code of Practice for Pipelines | |
| BS 5308 | Instrumentation Cables. | |
| BS 5514 | Reciprocating Internal Combustion Engines. | |
| BS 6121 | Cable Glands. | |
| BS 6231 | Specification for PVC Insulated Cables for Switchgear and Control gear wiring. | |
| BS 7671 | Requirements for Electrical Installations, IEE Wiring Regulations, Sixteenth Edition. | |
| ***Other Standards*** | | |
| ISO 10440-2 | Rotary type positive displacement packaged air compressors (Oil-Free) | |
| ISO | Pipe, Tube and Fittings Standards and Specifications | |
| ISO 2372 | Mechanical Vibration of Machines with operating speeds from 10 to 200 rpm. | |
| ISO 3046 | Reciprocating Internal Combustion Engines. | |
| ISO 8528 | Reciprocating Internal Combustion Engine drove Alternating Current Generating Sets. | |
| | National Georgian Codes and Standards | |
| IEC 34 | Rotating Electrical Machines. | |
| IEC 51-2 | Direct Acting Indicating Electrical Measuring Instruments and their Accessories. | |
| IEC 255 | Electrical Relays | |
| IEC 269 | Low Voltage Fuses. | |
| IEC 439 | Low Voltage Assemblies. | |
| IEC 529 | Classification of Degrees of Protection Provided by Enclosures (IP Code). | |
| IEC 664-1 | Insulation Co-ordination for equipment with Low-Voltage Systems – Part-1: Principles, Requirements, and Tests. | |
| IEC 947-1 | Low Voltage Switchgear and Control Gear, Part 1: General. | |
| IEC 947-2 | Low Voltage Switchgear and Control Gear, Part 2: Circuit Breakers. | |
| IEC 947-3 | Part 3: Switches, Disconnectors, Switch Disconnectors, and Fuse Combination Units. | |
| IEC 947-4-1 | Part 4: Contactors and Motor Starters, Section 1 – Electromechanical Contactors and Motor Starters. | |
| IEC-51 | IEC-51 Recommendations for direct-acting indicating electrical measuring instruments and their accessories. | |
| IEC-144 | IEC-144 Degree of protection of enclosures for low voltage switchgear and control gear | |
| IEC-157 | IEC-157 Low voltage switchgear and control gear | |
| IEC-158 | IEC-158 Low voltage control gear | |
| IEC-185 | IEC-185 Current transformers | |
| IEC-186 | IEC-186 Voltage transformers | |
| IEC-255 | IEC-255 Electrical relays | |
| IEC-269 | IEC-269 Low voltage fuses | |
| IEC-292 | IEC-292 Low voltage motor starters | |

| | | |
|---|---|---|
| IEC-337 | IEC-337 Control Switches | |
| IEC-408 | IEC-408 Low voltage air break switches, air break disconnectors, air break switch disconnectors and fuse combination units. | |
| IEC-439 | IEC-439 Factory-built assemblies of low voltage switchgear and control gear. | |
| IEC 60056 | High-Voltage Circuit Breakers of Rated Voltage of 1kV and above. | |
| IEC 60129 | AC Disconnections (Isolators) and Earthing Switches of Rated Voltage above 1kV.' | |
| IEC 60044 | Instrument Transformers | |
| IEC 60185 | Current Transformers'. | |
| IEC 60186 | Voltage Transformers'. | |
| IEC 60265 | High-Voltage switches. | |
| IEC 60298. | AC metal-enclosed switchgear and control gear of rated voltage above 1kV and up to and including 72.5kV. | |
| IEC 60470 | High-voltage alternating current contractors. | |
| IEC 60529 | Classification of degrees of protection provided by enclosures. | |
| IEC 60632 | High-voltage motor starters. | |

Table 18. List of applicable Codes and Standards.

#### C.1.7. Gas parameters

The accepted gas parameters are:

- *$CH_4$>87%;*
- *0.5%<$C_2H_6$<6%;*
- *$H_2S$, $CO_2$, Hg – are absent.*

At once for the calculations were accepted such gas parameters:

Flow 1 Gas composition

| | | | |
|---|---|---|---|
| Pressure | 50,99 ata | Temperature | 293,15 K |
| | 5,000 MPa | | 20,00 °C |

| | mol/mol | kmol/h | kg/kg | kg/h |
|---|---|---|---|---|
| Nitrogen | 0,0157515 | 616,6145 | 0,0261360 | 17271,3727 |
| Methane | 0,9428681 | 36909,8918 | 0,8958998 | 592034,6643 |
| Carbon dioxide | 0,0025606 | 100,2383 | 0,0066757 | 4411,4863 |
| Ethane | 0,0369656 | 1447,0702 | 0,0658469 | 43513,3998 |
| Propane | 0,0015031 | 58,8410 | 0,0039258 | 2594,2977 |
| i-Butane | 0,0000055 | 0,2153 | 0,0000189 | 12,5135 |
| n-Butane | 0,0000094 | 0,3680 | 0,0000324 | 21,3868 |
| neopentane | 0,0000009 | 0,0352 | 0,0000038 | 2,5420 |
| i-Pentane | 0,0001093 | 4,2787 | 0,0004672 | 308,7083 |
| n-Pentane | 0,0001065 | 4,1691 | 0,0004552 | 300,8000 |
| n-Hexane | 0,0000795 | 3,1121 | 0,0004059 | 268,2041 |
| n-Heptane | 0,0000122 | 0,4776 | 0,0000724 | 47,8541 |
| n-Octane | 0,0000014 | 0,0548 | 0,0000095 | 6,2598 |
| H-Nonane | 0,0000001 | 0,0039 | 0,0000008 | 0,5021 |
| Methanol | 0,0000261 | 1,0217 | 0,0000495 | 32,7359 |
| Water | 0,0000002 | 0,0078 | 0,0000002 | 0,1411 |
| Total | | 39146,4000 | | 660826,8552 |

Phase shares mol. share — Gas: 1,00000 — Water solution: 0,00000 — Hydrocarb. fluid: 0,00000

| | | | |
|---|---|---|---|
| Mol. mass | 16,8809 | Density kg/m3 | 38,351 |
| Enthalpy kJ/kmol | 8916,02 | Enthalpy kJ/h | 349029900,00 |
| Entropy kJ/(kg.K) | 9,468 | | |
| Volume Consumption scm/h (20°C, 0.1013 MPa) | | | 941666,65 |
| Volume Consumpt. m^3/h | 17231,0202 | Heat conductivity.W/(m·K) | 0,0358 |
| Therm.heat cap. kJ/(kg·K) | 2,551 | Dynamic viscosity MPa·c | 0,0122 |
| Calor. value low. kJ/kg | 48221,0 | Calor. value up. kJ/kg | 53452,5 |
| Compressibility factor | 0,90293 | Adiabatic Coefficient | 1,369 |

**Table 19. Accepted Gas parameters.**

### C.1.8. Description of the process diagram of the Head Compressor station

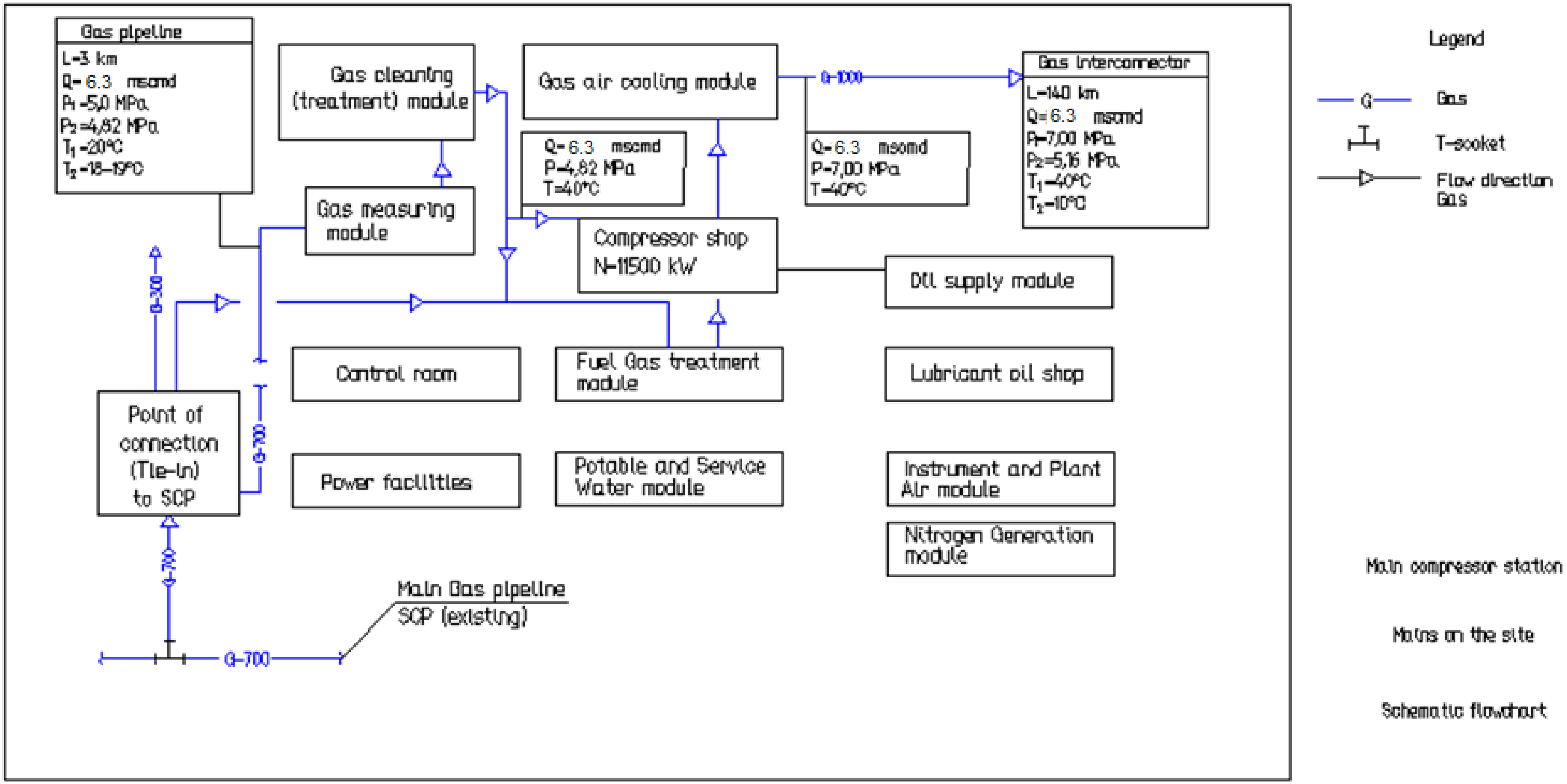



**Figure 41. Head compressor station process diagram.**

At the Head compressor station of the gas, the interconnector will be provided the main and auxiliary operations (a technological measurement of gas flow at the inlet of the CS (Gas measuring module, Gas purification from mechanical impurities and liquids, Gas compression, Gas cooling).

The list of facilities and systems for the operation of the Head compressor Station will consist of:

| |
|---|
| **Connection pipelines** |
| Onshore Gas pipeline  (D=28 inches) |
| Tie-in point to the existing Main Gas pipeline SCP  (D=28 inches) |
| **Head Gas compressor station** |
| ***Main process facilities (modules) of the Head compressor station*** |
| Gas cleaning module |
| Compressor shop-gas compressor modules |
| Gas Air cooling module |
| Gas measuring module |
| Auxiliary site pipelines |
| ***Auxiliary process facilities (modules) of the Head compressor station*** |
| Fuel gas treatment module |
| Lubricant module (Oil cleaning module) |
| Process automation and signaling system |
| Instrument and Plant Air System |
| Nitrogen Generation and Distribution System |
| Vent/Flare System |
| Power supply and Distribution System |
| Electrochemical anti-corrosion protection System |
| Diesel generator module |
| Diesel Fuel System |
| Communication, alarm, fire alarm system |
| Overhead transmission line (V=10 kV) |
| Power, control and signaling cables |
| Auxiliary site pipelines |
| ***Life support facilities (modules) of the Head compressor station*** |
| Water and sewage system |
| Firewater and fire-fighting system |
| Evaporation pond |
| Backup water line with water intake facility (D= 8 inches) |
| Ancillary buildings and structures, site improvements |

In addition, the site of the Compressor station will be provided with the ancillary facilities, which are supporting the life process of CS: mechanical workshop as part of the care and maintenance service and Chemical laboratory as part of the Service/Operation Building.

Gas at the Compressor Station (CS) comes from the SCP (South Caucasus Gas Pipeline). The tie-in point to the SCP Gas pipeline is located near the village of Vale in Georgia. The pressure at the tie-in point is not more than 5.0 MPa.

Then, the Gas in the amount of **6,30 mscmd** through the Gas Pipeline 1 (see Figure 101) with parameters L=3 km; DN 700 mm enters into the CS.

Before entering the facilities of CS, the gas passes through the Gas metering module, and then it enters the entering collector of the Compressor shop, after which separate pipelines are fed to 4 compressor units (3 works + 1 reserve). After compression, the gas enters into the Air cooling unit (ACU). After ACU the Gas with parameters: Q =6,30 mscmd; P =7.0 MPa; T=40 0C is sent via the outlet header to the point of connection with the Gas pipeline-interconnector.

#### C.1.8.1. Tie-in point to the SCP Pipeline

The tie-in point to the SCP 56 inches Main gas pipeline is described in detail in Section C.2.7.5.1 and C.2.7.5.2.
On the Point of connection, there are provided shut-off valves, equipped with a common line for filling the Compressor station with gas.
The intercepting cranes and the purging to the flare can be manually controlled locally, remotely from the Control room, and are also included in the Automatic Emergency Stop System of the Compressor Station.
Gas transportation in the event of Compressor Station stop is carried out by the Compressor Station bypass with a valve equipped with a bypass and a purge Flare DN 100 with a valve.
The drives of these valves can be manually controlled locally, remotely from the Control room, and also included in the Automatic Emergency Stop System of the Compressor Station.
On all pipelines entering and leaving of the Compressor Station, it is provided installation of the electrical insulating joint.

#### C.1.8.2. Description of the Main process facilities (modules) of the Head compressor station

##### C.1.8.2.1. Gas cleaning module

The Gas cleaning module (GCM) is meant to clean the pumped gas from mechanical impurities, water, hydrocarbon condensate, etc. in accordance with the requirements of the technical specifications of gas compressors in order to prevent contamination and erosion of equipment and CS internal pipelines.
It is envisaged to clean the gas in the apparatus of two-stage gas cleaning - the first stage in dust collectors (DC), the second stage in filter separators (FS). DC and FS should be set to the same performance, ensuring the possibility of their serial connection, without intermediate headers and valves. Optimal placement of PU and FS can be in the same package.
The number of GCM must be determined in accord with the condition for ensuring the maximum throughput mode - when withdrawing one of them for maintenance, the remaining ones must ensure that the CS operates at the design capacity for the gas to be cleaned.
The process working indicators and characteristics of the module of the two-stage cleaning apparatus are presented in the table below.

| No | Parameters | | Value |
|---|---|---|---|
| 1 | The capacity of the Gas cleaning module, mscmd, equivalent to the conditions: t = 20 $^0$C, P = 1,013 bar | | 6,3 |
| 2 | Manometric Gas pressure, MPa | | |
| | -highest primary Gas pressure, MPa | | 5,0 |
| | -minimal primary Gas pressure, MPa | | 4,8 |
| | -calculated Gas pressurte, MPa | | 7,35 (5,40) |
| 3 | Inlet Gas temperature, $^0$C, | | 20 - 40 |
| 4 | Fluid content | inlet | Maximum of 3,5 - 4 g/s m^3 |
| | | outlet | Maximum of 0,001 g/s m^3 |
| 5 | Mechanical impurity level | inlet | Maximum of 50,0 mg/m^3<br>When the CS is started up, short-term (up to |

| | | | |
|---|---|---|---|
| | | | two hours) the level of mechanical impurities in Gas can be allowed up to 200 is.mg/m^3 |
| | | outlet | Purification efficiency of particles larger than 10 mkm -99,9%<br>5-3 mkm - 99,0% |
| 6 | Gas density equivalent to the conditions: t = 20 $^0$C,<br>P = 1,013 bar, kg/m^3 | | 0,7347 |
| 7 | The density of solids, kg/m^3 | | 2500÷3000 |
| 8 | Fluid density under operating conditions, kg/m^3 | | 600-900 |
| 9 | The surface tension of the fluid under operating conditions, Nm | | 0.0357 |
| 10 | Quantity of compressors | | 4 |
| 11 | Supply type: package/not package | | supply |
| 12 | Required product life, years | | minimum of 30 |
| 13 | Package location of the product (indoors/outdoors) | | outdoors |
| 14 | Absolute minimum air temperature, $^0$C;<br>Average air temperature of the coldest five-day week with a rated of 0.92 $^0$C<br>Absolute maximum air temperature, $^o$C, | | minus 38<br><br>minus 15<br>37 |
| 15 | Seismicity of the CS area (on the MSK-64 scale) | | grade 8 |

**Table 20. Technical parameters and characteristics of Gas cleaning module.**

The units of the two-stage Gas cleaning module are equipped with inlet and outlet valves with bypass for filling pipelines with gas, spacers, and blinds (set for hydro testing).
The module is a complete element of the installation and consists of a separator placed on the frame and equipped with pipelines, shut-off and control valves on the liquid discharge line, foundation bolts, fasteners and fittings, counter flanges, and service platforms. The unit of the two-stage Gas cleaning module is equipped with instrumentation and automation equipment.
The module consists of a vertical cylindrical apparatus equipped with nozzles for connecting process piping, instrumentation and automation equipment, manholes to provide access to column internals during periodic inspection and repair.
The module of two-stage gas cleaning consists of a separate nozzle and coalescers combined in one apparatus.
A mini-cyclone assembly is located sequentially inside the apparatus, which has increased mechanical strength and is equipped with quick-release lids for access to all internal cavities and a plate with filter-coalescing elements. For pressure testing and hydraulic testing, removable blinds are provided in the block to cut off the apparatus from the process piping.
Untreated natural gas through the nozzle enters the bump stop, in which takes place the primary separation of dirt and salvo liquid intakes, then gas enters to the next gas purification section consisting of a separation nozzle, where the centrifugal forces separate the Gas from the mechanical impurities and the dripping liquid.
Separated mechanical impurities and liquid are collected in the collection section. From the collection section, the liquid goes through the fitting and the automatic condensate discharge system to the process pipe DN 4” and then goes to the condensate collector DN 6”, through which it is directed to the existing condensate collection unit. Mechanical impurities with accumulation periodically removed by blowing through the drainage fitting.
From the separation nozzle, the gas enters the upper part of the apparatus containing the filter elements, coalescers, in which takes place the final gas cleaning.
From the coalescer section, the liquid enters the condensate process pipe through a nozzle and an automatic condensate discharge system.

The schematic flowchart of Gas cleaning module connection is shown in the figure below.

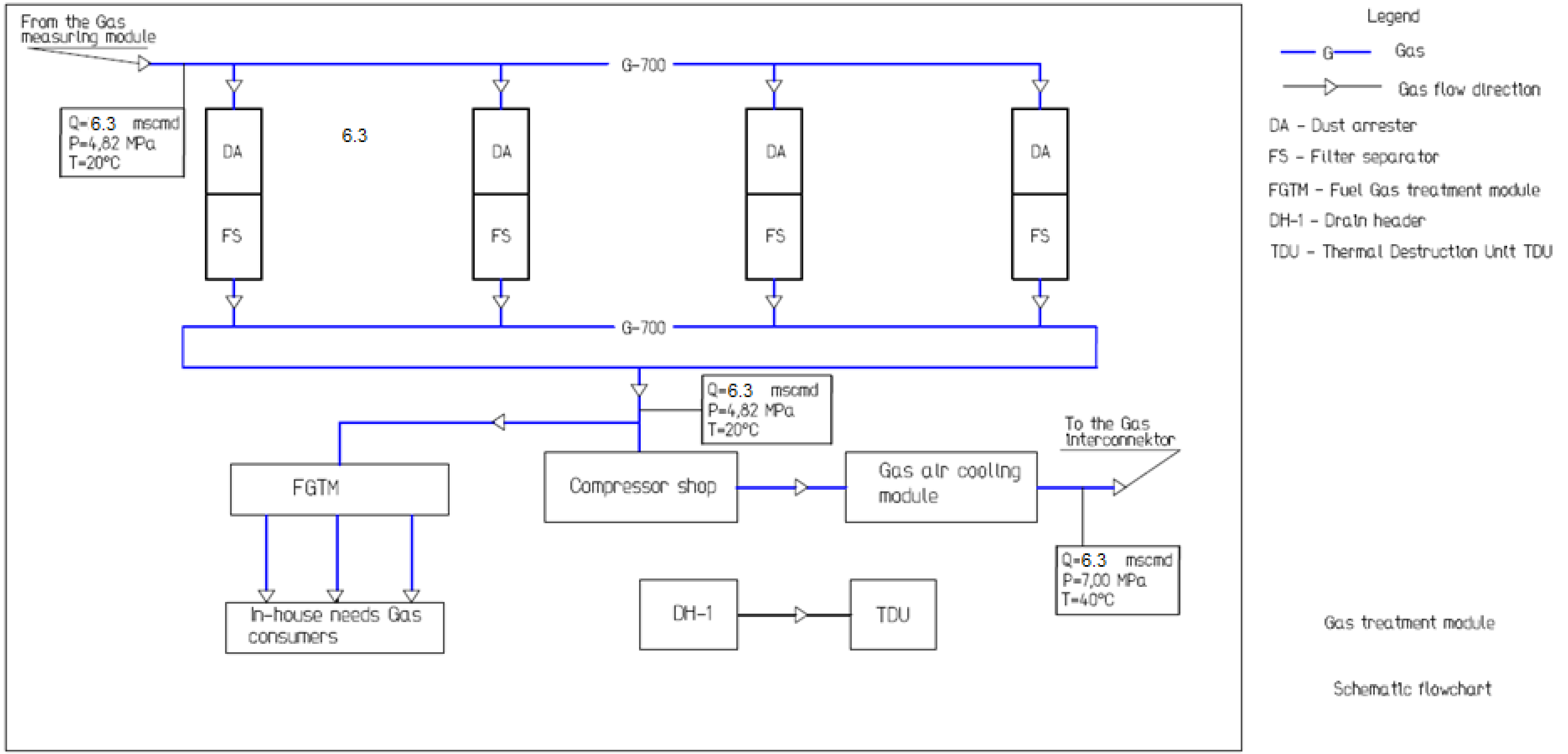



**Figure 42. Gas cleaning module connection schematic flowchart.**

#### C.1.8.2.2. Gas Compressor shop-

The compressor shop consists of 4 compressor modules (3 workings + 1 reserve), Each of which consists of a centrifugal supercharger and a 4.0 MW Gas turbine engine, with "dry" Gas dynamic seals. Each compressor module is located in an individual shelter, equipped with a 16 t electric crane.

- The individual Gas piping of Gas compressor units with the pipelines and shut-off valves, ensuring start, operation, and shutdown of units;
- The shop piping system of gas pipes and valves, ensuring the operation of the units in the large ring gas pipeline and start-up circuit (for starting the units in the mode when the compressor shop is running);
- The shop and individual systems of pipelines fuel Gas and fittings.

The design of the compressors provides the ability to remote start, stop, setting in the reserve without the presence of staff.

The system of electric heating of the oil and the heating system of the unit ensure that the compressors are changed the mode from the cold standby to the readiness for start-up mode in a time not exceed 2 hours.

Disconnection of each Gas compressor module from workshop Gas pipelines is ensured by means of shut-off valves (valve DN 40" on suction, DN 40" on discharge) installed outside the shelter.

The schematic flowchart of Gas compressor shop is shown in the figure below.

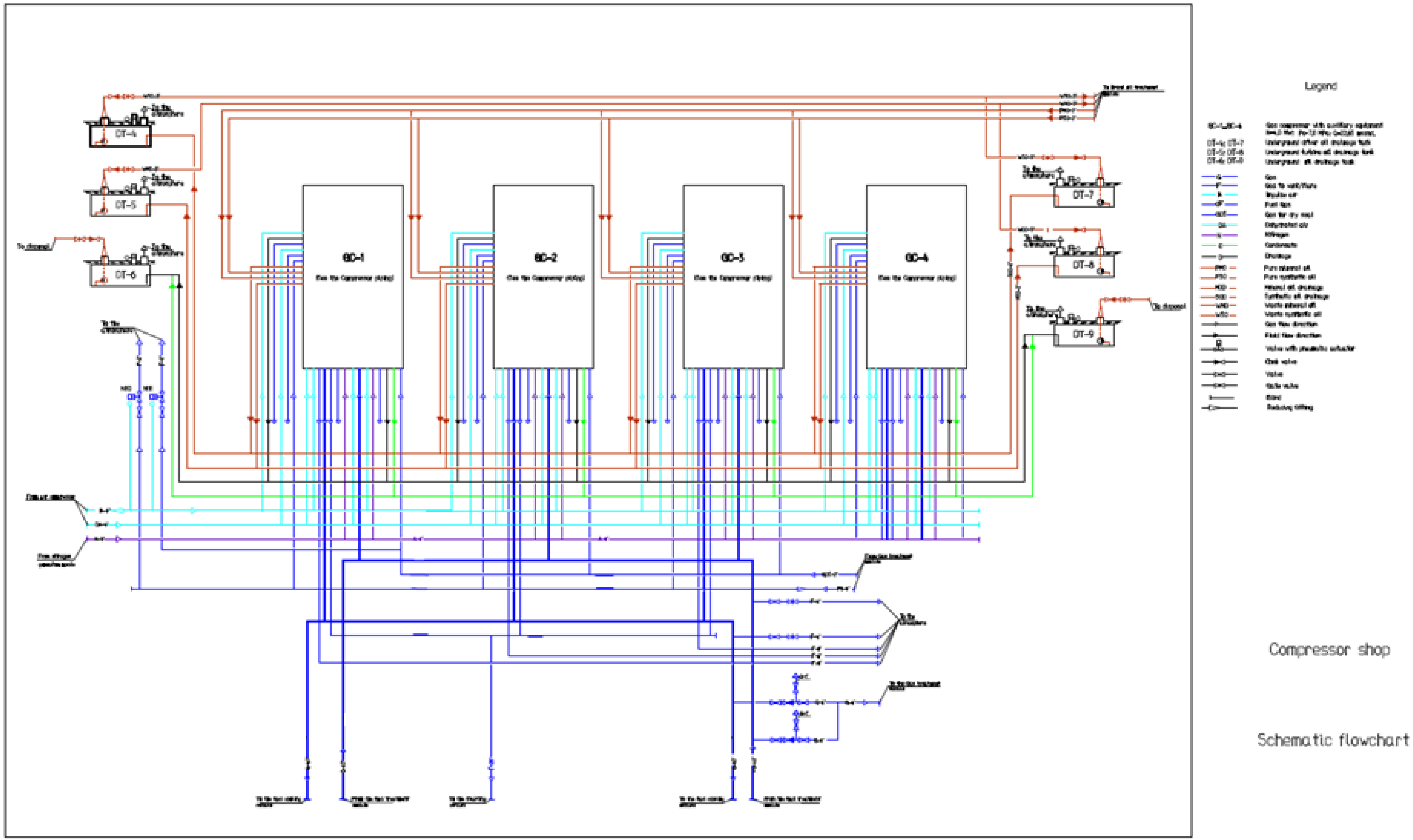



**Figure 43. Compressor shop schematic flowchart.**

On the gas inlet and outlet pipelines, there are manholes. A removable protective grid is installed on the Gas inlet pipeline, the loss pressure of which does not exceed 0.01 MPa.
To prevent counterflow on the discharge line of the turbocharger to the output shut-off valve is installed a check valve.
On the filling line of the supercharger with gas (bypass of the crane), two shut-off parts are provided: a hand-operated valve DN 4" and a pneumatic actuator DN 4", as well as a throttle washer. The schematic flowchart of compressor piping is shown in the figure below.

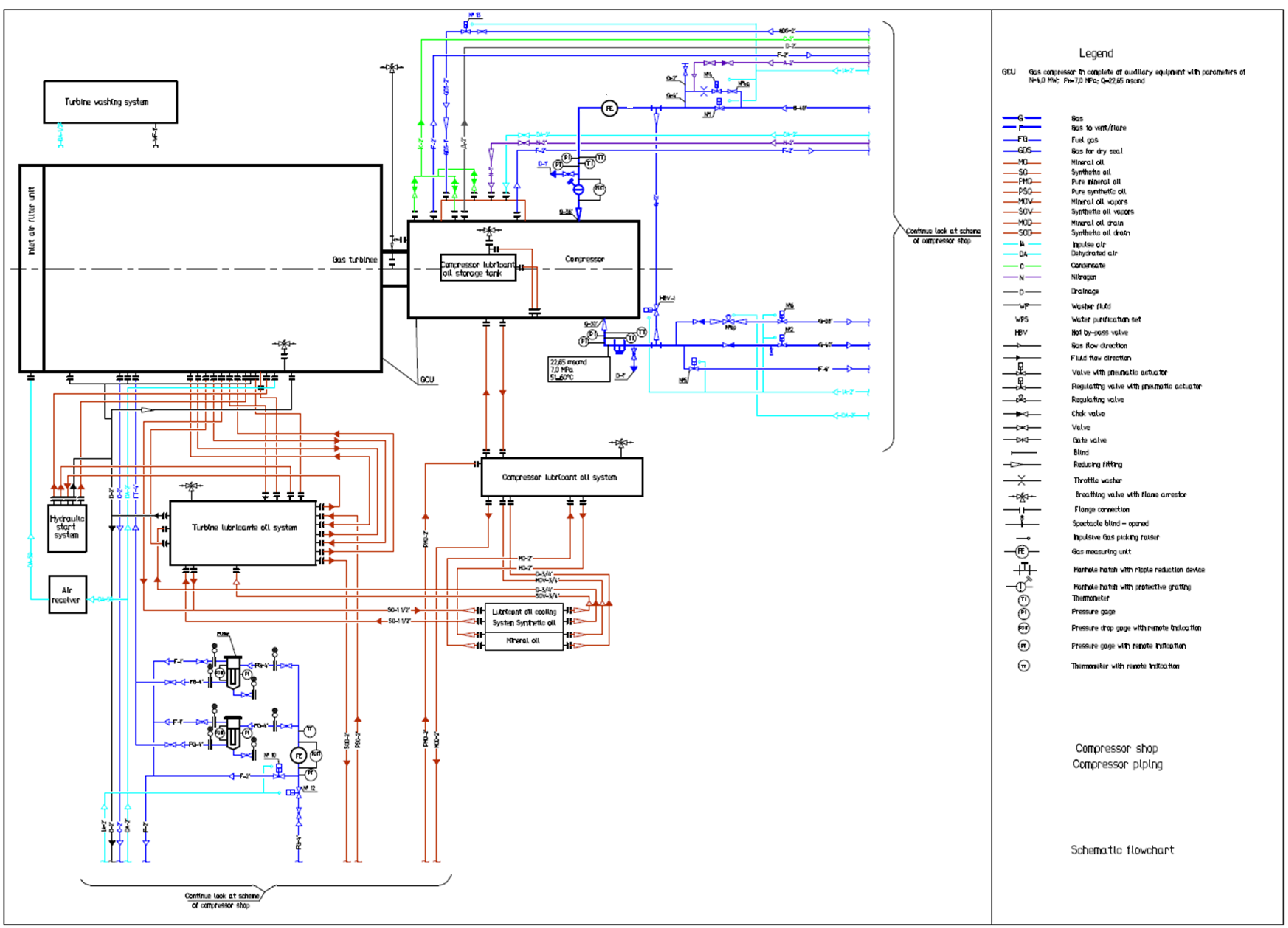



Figure 44. Gas air cooling modules schematic flowchart.

Between the suction and discharge pipelines after the cranes along with the gas flow, DN 12" pipeline with the quick-acting valve on the “hot” DN12" bypass is provided. The aggregate line of the starting circuit provides for the installation of a check valve, a control valve with an axisymmetric direction of gas flow and a pneumatic (shut-off) valve (along with the gas flow - successively behind the control valve). The piping of a centrifugal supercharger provides for the discharge of gas from all its sections. The pneumatic purge valve DN 6" is controlled manually, remotely or locally, as well as by means of the Emergency Stop Station key (ESS). The ESS signal opens this valve and takes precedence over any manual signal. The compressor fuel supply control system contains a shut-off valve that ensures the absence of the gas leaks, does not open until conditions are reached under which ignition can be made and closed at all types of shutdowns, including the loss of a control signal, including when power is lost to the stop valve. On the line for fuel gas supplying and dumping it to the candle, cranes DN4", DN2" are provided, respectively. As a buffer gas for the operation of gas-dynamic seals (GDS) of compressors, the process gas previously purified (at the Gas treatment module) gas from the common delivery manifold is used. The cyclic air heating system prevents icing when a signal is received from the automatic Control system to activate the anti-icing system. The key indicators and characteristics of the gas pumping unit module are presented in the table below.

| No | Parameters | Value | |
|---|---|---|---|
| 1 | Gas compressor (complete with all accessories) | Compressor Model | |
| 2 | Type of centrifugal supercharger seals | "Dry" Gas-dynamic | |
| 3 | Volumetric capacity per compressor (at a temperature of + 20 $^0$C and a pressure of 0,1013 MPa), mscmd, not less | 2.6 | |
| 4 | Polytropic efficiency coefficient of the compressor, not less | 0,80 | |
| 5 | Inlet gas operating pressure, MPa, | 4,82 | |
| 6 | Outlet gas operating pressure, MPa, | 7,0 | |
| 7 | Inlet gas temperature, $^0$C | 5-20 | |
| 8 | Outlet max. gas temperature, $^0$C | 52 | |
| 9 | Gas turbine (complete with all accessories) | | |
| 10 | Rated power, MW | 4,0 | |
| 11 | Fuel gas consumption, smc/h | 865 | |
| 12 | Launch system | Electro-hydraulic | |
| 13 | Efficiency coefficient of Gas turbine<br>ISO<br>under the terms of the CS | Mineral | |
| 14 | Lubricant oil type | Mineral<br>ISO VG 46 | Synthetic<br>MIL-L-7808 |
| 15 | Irretrievable loss of lubricant oil, kg/h, not more | 0,2 | |
| 16 | The content of harmful substances in exhaust gases, mg/m^3, not more than:<br>NOx<br>CO | <br><br>50<br>80 | |
| 17 | Noise level | On distance R = 3m - ≤ 80 dBa | |
| 18 | GPA reliability indicators:<br>• time between failures<br>• Availability factor<br>• The coefficient of technical use<br>• Full resource<br>• Average resource before overhaul | <br>Not less 3500 h<br>Not less 0,98<br>Not less 0,91<br>Not less 100 thousand hours<br>Not less 25000 h | |

**Table 21. Performance data and technical characteristics of the gas compressor.**

#### C.1.8.2.3. Gas air cooling module

After compression, the gas enters the Gas air cooling module.
The Gas air cooling module is intended to cool the gas to a temperature no higher than +40 $^{0}$C in order to increase the durability of the linear part of the pipeline, improve the working conditions of anti-corrosion insulation and increase the productivity of the Gas interconnector.

The Gas air cooling module consists of:

- 6 air-cooled Gas coolers connected in parallel (the single capacity of the apparatus for heat load must be at least 6 (5 workings + 1 reserve).
- pipelines of a binding and fittings (for shutdown and purge of the Gas air cooling module).

The number of air coolers is selected on the basis of hydraulic and thermal calculations of the CS from the conditions for ensuring the allowable loss of Gas pressure in the discharge and gas temperature at the exit of the CS.
Parameters and a brief description of the Gas air cooling module are presented in the table below.

| No | Parameters | Value |
|---|---|---|
| 1 | Cooled medium | Natural Gas, low corrosion, non-toxic |
| 2 | Module capacity, mscmd, (t=20 $^{0}$C, P=1,013 bar) | 3,53 |
| 3 | Density, (t=20 0C, P=1,013 bar) | 0,694 |
| 4 | Hazardous Class<br>(Standard Article 500, NEC – 1990);<br>(Standard IEC/ATEX) | <br>1, Division 2, Group D;<br>Zone 0 |
| 5 | Hazardous material<br>(Standard Article 500, NEC – 1990);<br>Temperature Class<br>Ex Class | <br>IIA<br>T1<br>2 |
| 6 | Operating gas pressure, MPa | 7,0 |
| 7 | Design gas pressure, MPa | 8,0 |
| 8 | Inlet gas temperature, $^{0}$C | 52 |
| 9 | Outlet gas temperature, $^{0}$C | 40 |
| 10 | Design gas temperature, $^{0}$C | +100 |
| 11 | Allowable gas pressure drop, bar | 0,3 |
| 12 | The quantity of Gas air cooling modules | 6 (5 workings + 1 reserve) |
| 13 | Number of air cooling sections in the module, pcs | 3 |
| 14 | Type of fan drive | electric |
| 15 | Number of electro motors per 1 Gas air cooling module, pcs | 2 |
| 16 | Motor power, kW | 37 |
| 17 | Minimum margin of heat exchange surface, % | 20 |
| 18 | Coefficient of fins | 20 |
| 19 | Seismicity of the CS area (on the MSK-64 scale) | grade 8 |

**Table 22. Performance data and technical characteristics of the Gas air cooling module.**

The schematic flowchart of the gas-air cooling module is shown in the figure below.

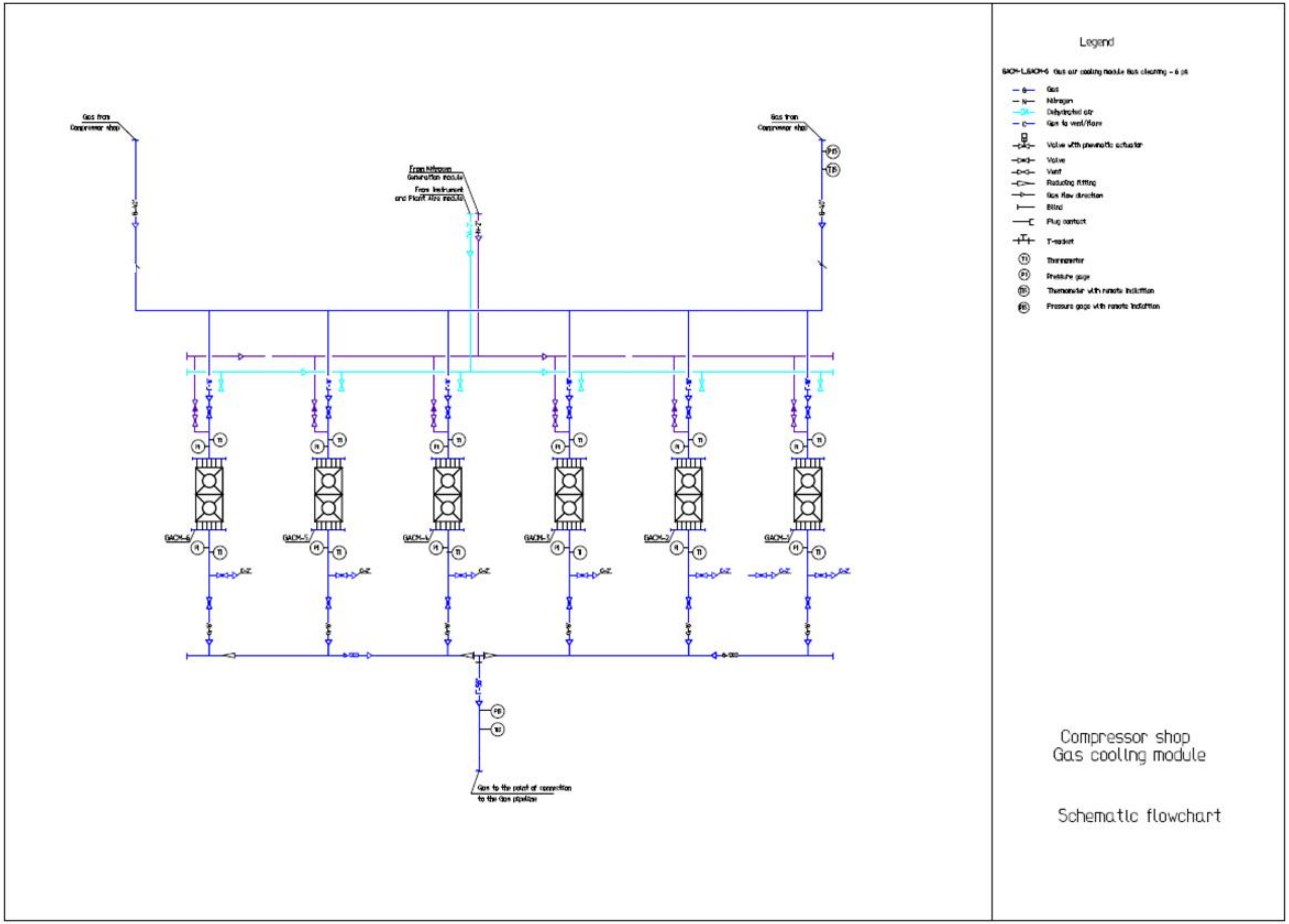



Figure 45. Gas air cooling modules schematic flowchart

#### C.1.8.2.4. Gas measuring module

From the tie-in point, the gas enters into the Gas measuring module through the DN700 pipeline.

The gas measuring module will be constructed on the site of the Head compressor station.

The gas measuring module will be designed as a station of commercial measuring of gas flow during the gas transmission to the Gas loading terminal near the port of Poti.

The scope of automation and technical measuring means of gas flow is chosen so as to ensure metering module operation in automatic unattended mode. All calculations of gas flow and also module equipment control will be made with the aid of technical means of the module, this will ensure autonomous module work when communicating with external systems is lost. For monitoring of module condition, the transmission of results of gas flow measurements and fulfillment of certain commands from the Central dispatching office, the metering module will have informational access to the SCADA system. The metering module will be equipped with surveillance (SS) and an ecological monitoring system.

The measuring module will be installed inside the fenced area.

The Ultrasonic meters are used as primary instruments for measuring gas flow, which should meet the following requirements:

- technical data of the meters should conform to project requirements;
- working scales of the instruments cover the range from maximum and minimum Gas pipeline flow conditions;
- in normal operation mode the meter should cover the range from 20% to 80% of minimum gas pipeline flow;
- the capacity of each of the two measuring lines will be such as to ensure normal module operation when turning off one of them.

Electronic measuring and alarm devices are powered with 24V direct current voltage and will provide the possibility to turn off any of them for maintenance or replacement without interruption of power supply on other devices. All wires will be supplied with tags bearing written permanent marking. Control and warning system wires will be laid separately from wires with alternating voltage. For warning systems, cables with twisted screened pairs will be used.

Electronic monitoring and measuring instruments will be equipped with electronic protection and isolated from the ground.

On the lead-ins of control and warning system dischargers for lightning protection are installed.

All information and control systems will have a 20% reserve. A reserve of a minimum of two strands are provided in each cable.

Contacts of warning system should react to “break in-circuit”, that is contact separation when the warning system operates.

Each measuring run is equipped with its individual Gas flow calculator.

The calculators are mutually redundant and failure of one of them will not result in loss of measurement results. All calculators will have interface communication with the SCADA system.

Calculators will receive the following signals:

- Gas flow through measuring pipeline;
- the pressure in measuring pipeline;
- the temperature in measuring pipeline;
- Gas composition;
- Gas energy content (calorific power);
- Gas compressibility.

Calculators will receive data on the composition, calorific power and gas compressibility from gas chromatograph through the serial data transmission channel. For the execution of gas flow calculation functions and compiling reports, calculators will support the following types of signals:

- analog 4-20 mA;
- discrete signals (“dry contact” type);
- pulsed signals;
- serial channels RS 232;
- duplex channels RS 485.

The final configuration of calculators and the scope of received information will be finally accepted during detailed designing.
Inputs and outputs of calculators will be physically isolated from inner protection systems.
Gas flow calculation algorithms will conform to the Standard and stored in hard disk memory. When calculating gas flow, current data on gas compressibility and energy content, full gas composition, whose value will be updated every 10-15 seconds.
MMI will comprise the alpha-numeric keyboard and monitor. The keyboard is used for entering parameters and modifying the calculator configuration. In so doing, the calculator will have protection from unauthorized access. Results of gas flow calculation, used in
calculations of data and also condition and configuration of the calculator will be displayed on the monitor.
The calculator will issue the following reports:

- current operational report;
- daily itemized invoice;
- weekly itemized invoice;
- flow calculator configuration report;
- report of the alarm system (will be formed automatically, on their occurrence).

The final list of reports will be formed during detailed design.

#### C.1.8.2.5. Fuel Gas treatment module

The Fuel Gas treatment module (hereinafter referred to as GTM) is intended to treat the part of the pumped Natural gas in order to provide Gas with the required characteristics and Quality of the consumers located on the CS site. The GTM should provide:

- preparation of the fuel Gas (FG) for the turbine engine;
- Gas preparation for "dry" seals of compressors;
- fuel Gas for own needs of the compressor station (boiler house, Gas turbine power station and own Gas treatment unit needs).

The Gas side stream for the Fuel Gas treatment module is provided from the three points of CS site:

- from the node connecting the compressor station to the main Gas pipeline (before and after the bypass valve of the station);
- after Gas cleaning (treatment) module;
- after Gas compression before the Gas cooling unit.

The Fuel Gas treatment module performs the following functions:

- cleaning of the gas supplied to the unit from mechanical impurities and liquid;
- the measurement of total gas consumption;
- heating, reducing and measuring the flow of fuel gas for the gas compressor;
- reduction and measurement of fuel gas supplied to the boiler house;

- reduction and measurement of fuel gas supplied to the Gas turbine power station;
- reduction and measurement of fuel gas for the own needs of the Gas cleaning (treatment) module;
- measurement and control of air parameters, gas contamination inside of the shelter with the issuance of parameters to the dispatcher's automated workplace;
- automatic control of engineering systems, fire alarm systems and access control to the shelter with the issuance of a parameter to the dispatcher's automated workplace.

All metering units in the Fuel gas treatment module (input and output) should be provided as a process, not a commercial.
The Gas cleaning (treatment) module includes:

- cleaning unit;
- heating block;
- blocks for the reduction of fuel gas to the turbine engine, fuel gas for their own needs;
- metering units;
- ventilation system, heating, and air conditioning;
- a block of the automatic control system;
- the system of power electrical equipment and electric lighting with output to the terminal boxes for power supply from external sources;
- Gas contamination monitoring system, fire protection, and Gas cleaning (treatment) module security alarm system.

The gas reduction system must be provided with 100% redundancy of the reducing valves (redundant reduction line).
The switching system of pressure regulators must ensure the guaranteed shutdown of one valve with the inclusion of another in operation when they switch from working to standby mode.
The regulator outlet pressure should be maintained with an accuracy of ± 1.5%.
The inlet Gas pipeline of the Fuel gas treatment module provides for shut-off and exhaust valves with remote control.
The connection diagram of the Fuel Gas treatment module is shown in the figure below.

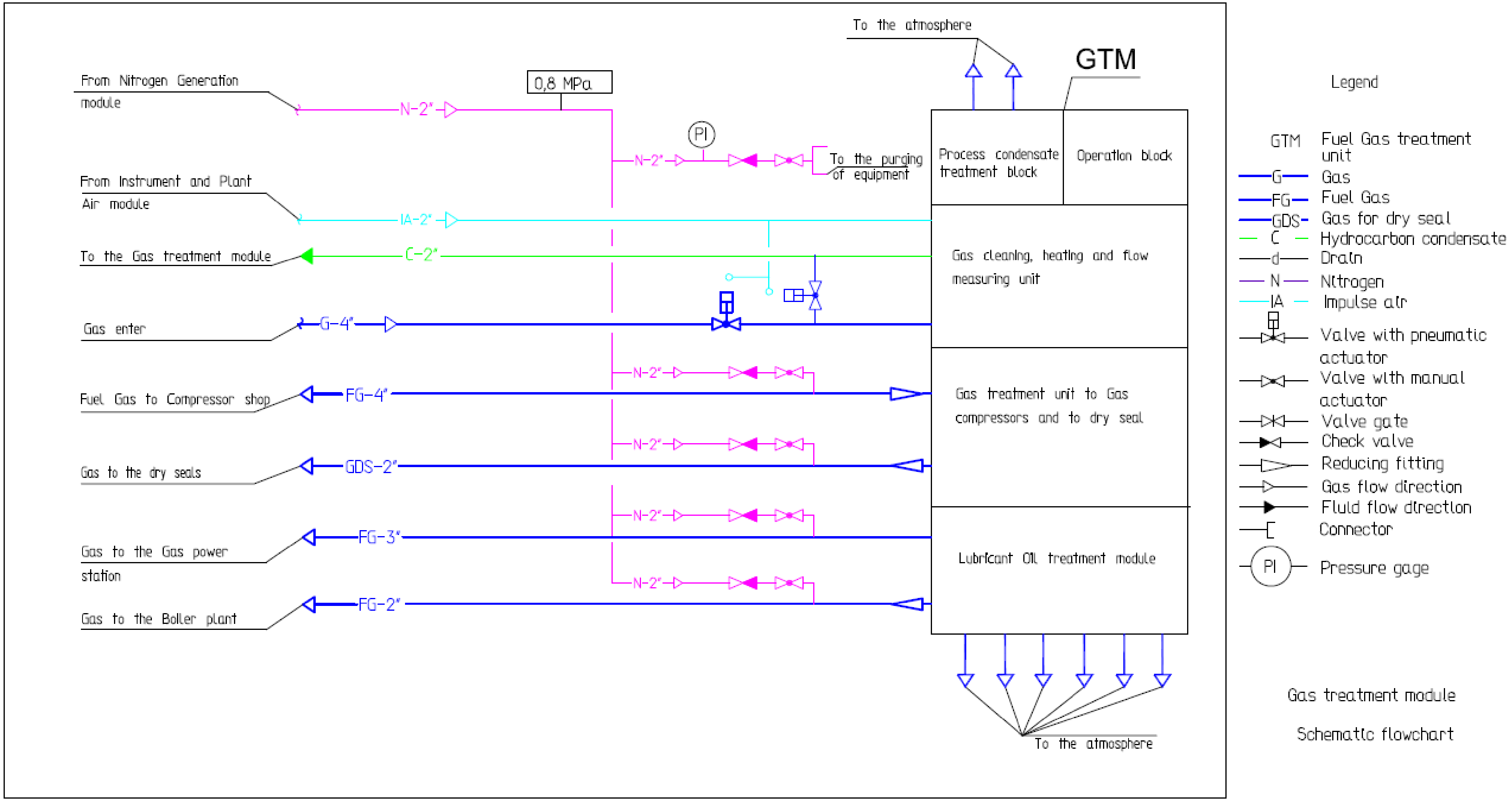



**Figure 46. Gas cleaning (treatment) module connection diagram.**

The Gas cleaning (treatment) module is a single building, which consists of four combined block-boxes with a total dimension of 13.2 x8.0 m and is divided into three rooms – process room, operator room, and preparation of the coolant room. The enclosing structures of the block building are made of three-layer panels with non-combustible insulation. The rooms have separate outside entrances.
The technical characteristics of the Gas cleaning (treatment) module for the preparation of fuel Gas and Gas of own needs are given in the table below.

| No | Parameters | Characteristics | | |
|---|---|---|---|---|
| 1 | Type of building | Shelter full factory readiness with all life support systems: lighting, ventilation, air conditioning, heating | | |
| 2 | Inlet Gas pressure, MPa | 52 ÷ 75 | | |
| 3 | Inlet Gas temperature, $^{0}$C | 20 ÷ 40 | | |
| 4 | Outlet Gas purification, mkm | 10, (Gas for "dry seals" – 3) | | |
| 5 | Capacity, m^3/h (at P = 0,1013 MPa, t = 20 $^{0}$C) | Minimum | Nominal | Maximum |
| | • Overall capacity | will be indicated when ordering | | |
| | • Outlet 1 – fuel Gas for the compressor | will be indicated when ordering | will be indicated when ordering | will be indicated when ordering |
| | • Outlet 2 – Gas for "dry seals" | will be indicated when ordering | will be indicated when ordering | will be indicated when ordering |
| | • Outlet 3 – Gas for power Gas turbine power station | will be indicated when ordering | will be indicated when ordering | will be indicated when ordering |
| | • Outlet 4 – Gas for the boiler house | will be indicated when ordering | will be indicated when ordering | will be indicated when ordering |
| | • Outlet 5 – Gas for Gas cleaning (treatment) module own needs | determined by the manufacturer | | |
| 6 | Outlet Gas pressure, MPa | Minimum | Nominal | Maximum |
| | • Outlet 1 – fuel Gas for the compressor | will be indicated when ordering | will be indicated when ordering | will be indicated when ordering |
| | • Outlet 2 – Gas for "dry seals" | will be indicated when ordering | will be indicated when ordering | will be indicated when ordering |
| | • Outlet 3 – Gas for power Gas turbine power station | will be indicated when ordering | will be indicated when ordering | will be indicated when ordering |
| | • Outlet 4 – Gas for the boiler house | will be indicated when ordering | will be indicated when ordering | will be indicated when ordering |
| | • Outlet 5 – Gas for Gas cleaning (treatment) module own needs | determined by the manufacturer | | |
| 7 | Outlet Gas temperature, $^{0}$C | Minimum | Nominal | Maximum |
| | • Outlet 1 – fuel Gas for the compressor | will be indicated when ordering | will be indicated when ordering | will be indicated when ordering |
| | • Outlet 2 – Gas for "dry seals" | will be indicated when ordering | will be indicated when ordering | will be indicated when ordering |
| | • Outlet 3 – Gas for power Gas turbine power station | will be indicated when ordering | will be indicated when ordering | will be indicated when ordering |
| | • Outlet 4 – Gas for the boiler house | will be indicated when ordering | will be indicated when ordering | will be indicated when ordering |
| | • Outlet 5 – Gas for Gas cleaning (treatment) module own needs | determined by the manufacturer | | |
| | The values of parameters according to points 5,6,7 are determined by the manufacturer | | | |
| 8 | The need for Gas metering: Yes, No | Yes (with redundancy Gas cleaning (treatment) module) | | |

**Table 23. The technical parameters required for the manufacturing of gas cleaning (treatment) module.**

The Gas cleaning (treatment) module has a design, arrangement of equipment and pipelines that provide comfortable conditions for the maintenance personnel in accordance with the applicable rules, labor protection, and ergonomic Standards.

#### C.1.8.2.6. Oil cleaning module

The oil cleaning module with the oil recovery system is designed to receive, store and supply pure mineral oil for compressors and synthetic oil for drivers of the Gas compressors, receiving waste oils from the Gas compressors through stationary pipelines. It is envisaged to clean the oil before use in an oil cleaning machine.

The module of oil supply consists of two rooms:

- oil pumps room;
- oil filter regeneration room.

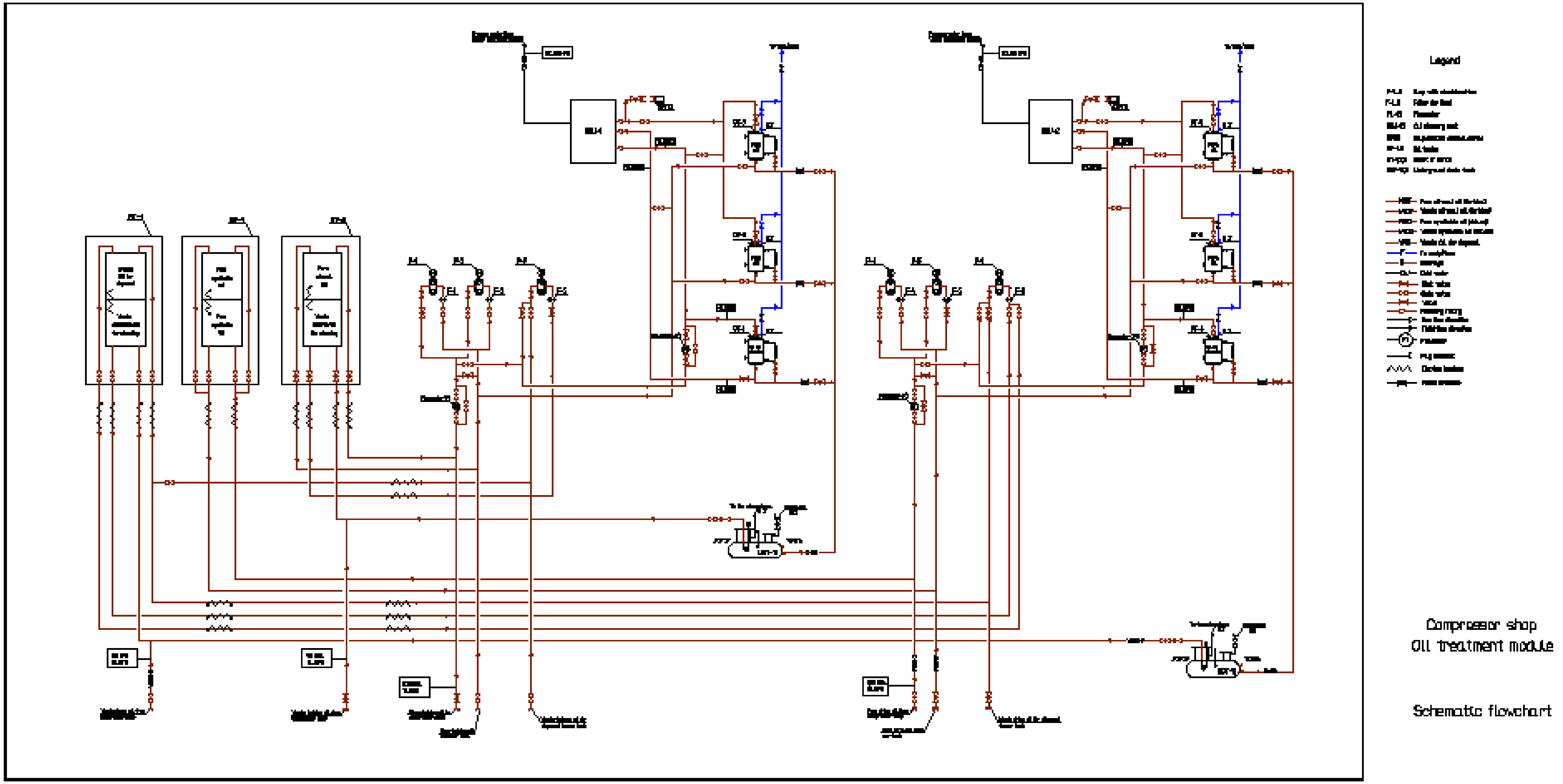



Figure 47. Oil supply and oil cleaning module.

For storage of oil, there are provided 3 block tanks (BT) of 2x25 $m^3$ for oil products, of which 1 tank V=25 $m^3$ for storing pure mineral oil, 1 tank of volume 25 $m^3$ for waste but the oil to be cleaned on an oil cleaning mineral oil machine, 2 tanks of volume 25 $m^3$ for storage of pure synthetic oil, 1 tank of volume 25 $m^3$ for waste mineral and synthetic oil that cannot be cleaned and intended for disposal for recycling.
In the oil pumps room, oil recovery units and pumps are installed for receiving (delivering) and pumping of mineral oil and synthetic oil from (to) a tank truck or in an oil storage tank.
The cleaning machine must ensure oil cleaning grade not lower than 9 and with a capacity of at least 3,0 $m^3$/hour.
Oil storage tanks are equipped with electric heaters. Oil pipelines from pumps to tanks are laid with electrical heating.

***Oil and air filters cleaning unit***

To clean the oil filters of the oil system of Gas turbines and its drives from the contaminations accumulated during the operation of the compressors, as well as to clean the air filters of the compressors, a filter cleaning unit was installed. Such a filter cleaning unit can be located in an oil cleaning module, in an oil warehouse, or it can be separately allocated into a stand-alone unit.
The ultrasonic cleaning equipment for cleaning and degreasing of filters and filter packages of oil, hydraulic and pneumatic systems of Gas turbine engines, is installed in the regeneration filter room.
The figure below shows the schematic flowchart of filter regeneration unit piping.

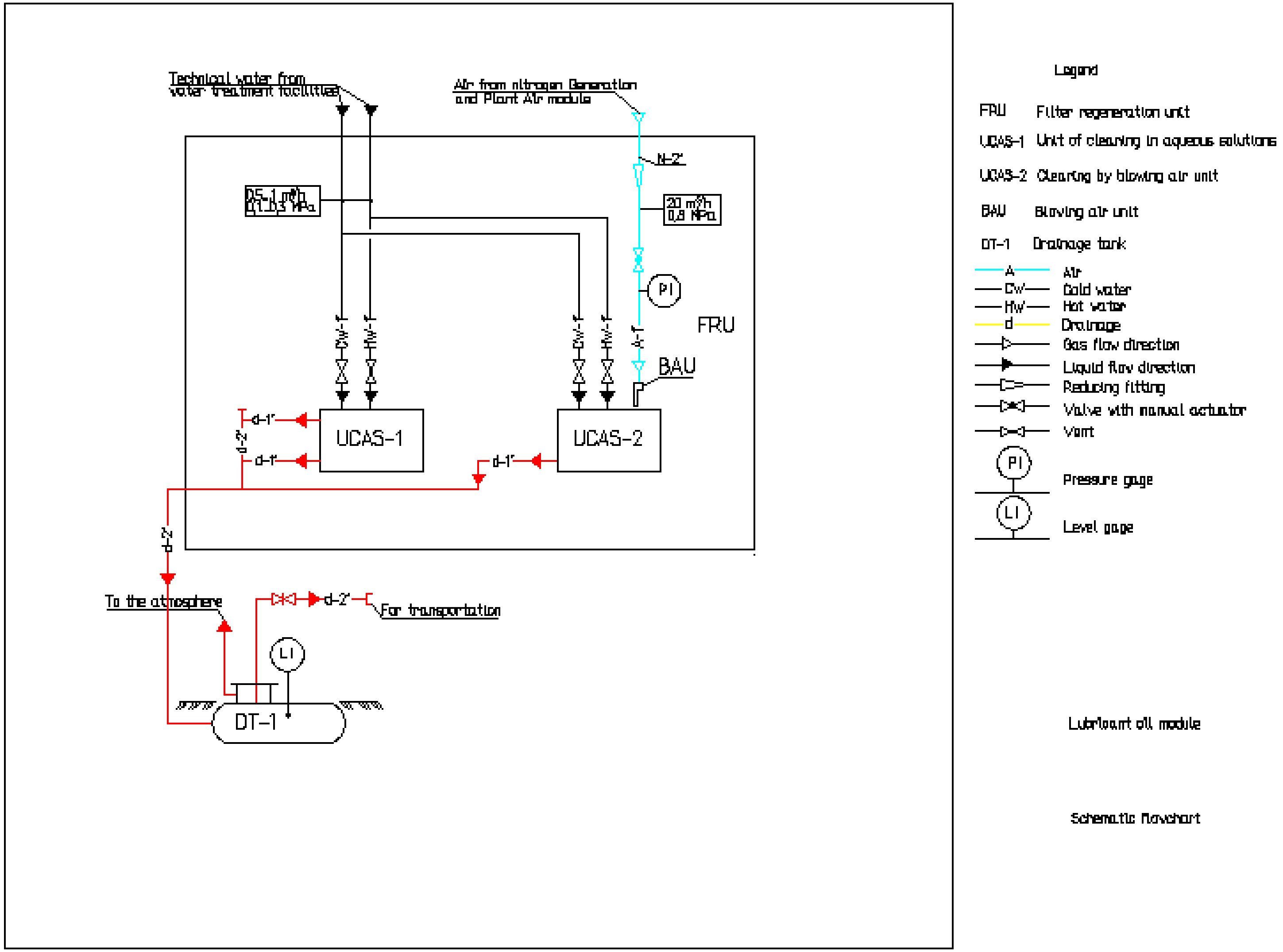



**Figure 48. Filter regeneration unit.**

Cleaning filter elements and filter packages used in the hydraulic, oil and fuel systems of Gas compressor turbine engines are intended in aqueous solutions of technical detergents using ultrasound.
Filter elements are cleaned in the bath using the ultrasound. Ultrasound turns off automatically at the end of the set time. During cleaning, the filter element is rotated. The temperature of the solution is maintained automatically around the set range.
The technical characteristics of the oil filter cleaner (as for an example) are given in the table below.

| No | Parameters | Value |
|---|---|---|
| 1 | Power consumption, kW, not more | 2,3 |
| 2 | Heater power, kW | 1,0 |
| 3 | Power Supply:<br>• voltage, V;<br>• frequency Hz | <br>220 ± 10%<br>50 ± 2% |
| 4 | Cleaning solution operating temperature, $^0$C | (60 – 70) ± 3 |
| 5 | The ultrasonic power output of the bath, VA, not less | 500 |
| 6 | Operating frequency of ultrasound, kHz | 44 ± 4,4 |
| 7 | Duration of cleaning in the ultrasonic bath (discrete steps of 2 min), minimum | (1 – 60) ± 2% |
| 8 | The rotation velocity of filter elements, rpm | 3 - 5 |
| 9 | Duration of continuous work in cyclic mode (16 minutes with an interval between switching on and off 10 minutes), hour | 16 |
| 10 | Bath volume, liter, not more | 18 |
| 11 | Overall dimensions (length X depth X height), mm, not more | 815x425x510 |
| 12 | Mass of cleaner, kg, not more. | 55 |

**Table 24. Basic parameters of the oil filter cleaning unit.**

The combined air filter cleaning unit is designed to clean the filters from operational contaminants (dust, fibrous inclusions from the surrounding air environment and other contaminants loosely connected to the filter base material) air filters used in the air inlet chambers of the Gas compressors in aqueous solutions of technical detergent using ultrasound and activators.
The unit provides such functions:

- soaking products in a hot solution of technical detergent (cleaning agents);
- ultrasonic cleaning of products in a hot detergent solution;
- detergent activators cleaning in a hot detergent solution;
- drying of filters with compressed air.

Soaking, ultrasonic cleaning and detergent activators cleaning of filters in a hot solution of detergent is performed in a combined bath. Filters washing in a flowing main-water are produced in a bath with detergent activators. Drying is carried out by filter blowing with compressed air using an air pistol in the drying chamber manually. Ultrasound, detergent activators in the baths are turned off automatically after the set time. Heating of the detergent solution is performed in the tank, the temperature is maintained automatically. The supply of washing liquid from the tank to the bath is made by the pump in the recirculation mode. Flowing main-water is supplied from the workshop water system through a mixer.
The technical characteristics of the cleaner (as for an example) are given in the table below.

| No | Parameters | Value |
|---|---|---|
| 1 | Maximum power consumption, kW, not more | 22,0 |
| 2 | Heater power, kW | 1,0 |
| 3 | Power Supply:<br>• voltage, V;<br>• frequency Hz | <br>380 ± 10%<br>50 ± 2% |
| 4 | Operating temperature, $^{0}C$<br>• cleaning solution (technical detergent)<br>• flowing main-water | <br>60 – 80<br>20 – 50 |
| 5 | The ultrasonic power output of the bath, kW, not less | 1,4 |
| 6 | Operating frequency of ultrasound, kHz | 44 ± 4,4 |
| 7 | Cleaning capacity of filters, pcs/hour, not less | 6 |
| 8 | Pump capacity, $m^3$/hour, not less | 1,0 |
| 9 | Pump outlet pressure, m, not less | 10,0 |
| 10 | Combined bath volume, liter, not more | 160,0 |
| 11 | Activators bath volume, liter, not more | 115,0 |
| 12 | Cold and hot main-water consumption, $m^3$/h, not more | 0,6 |
| 13 | Compressed air consumption at a pressure of 0,4-0,6 MPa, $m^3$/hour, not more | 20,0 |
| 14 | Overall dimensions (length depth height), mm, not more<br>• cleaning devices<br>• tank with heating and submersible pump<br>• control devices | <br>1700X1050X1350<br>1170X950X700<br>550X650X1250 |
| 15 | Mass of installation and its components, kg, not more:<br>• cleaning devices<br>• tank with heating and submersible pump<br>• control devices | 565,0<br>330,0<br>110,0<br>125,0 |

Table 25. Basic parameters of an air filter cleaning unit.

#### C.1.8.2.7. Site piping

All piping, fittings, flanges and valves design within the facilities of the Head compressor station will be carried out in accordance with codes as follows:-

- ASME B31.4 for pipelines.
- ASME B31.8 for the fuel Gas main system.
- ASME B31.3 for process piping, all plant utilities like plant air, instrument air, nitrogen, all types of water piping, diesel, chemicals, lubricating oil, etc.

The above basis takes into account the saving of material in case of using the B31.4/B31.8 code for compressor station piping allowed in accordance with para 400.1.1 and Fig. 400.1.1-1 of ASME B31.4 and para 802.1(4) of ASME B31.8. However, when it can be proved that ASME B31.3 will yield overall savings in terms of pressure testing, radiographic testing, Post Weld Heat Treatment (PWHT), support design, stress analysis, etc. or where it is essential from other considerations like limits of temperature, ASME B31.3 will be followed.

### C.1.8.3. Description of Auxiliary process facilities (modules) of the Head compressor station

#### C.1.8.3.1. Process automation and signal system

All facilities and modules on the Head compressor station site and Gas interconnector to the site of Gas loading terminal near the port of Poti to be designed/engineered and will be supervised and controlled by the Master Control Room (MCR) located at Head compressor station.
Systems of automatic control are necessary for the following functions:

a) the automatic control of compressor station and auxiliary equipment of compressor station from operators' room;
b) division of control functions between the system of the compressor station and actuating systems;
c) ensuring of the possibility of manual loading of control programs in the case of their damage;
d) supply with the system of load distribution between working Gas-pumping units;
e) maintenance of set by operator pressure values at the exit of compressor station;
f) protection of compressor station equipment in emergency and irregular situations.

The operators' room of compressor station will be designed for the permanent presence of personnel having a possibility to control CS operation manually and maintain optimum parameters of the process in the case of failure of station control system equipment.
Control systems will be highly reliable and trouble-free, however in the case of loss of control signal, CS equipment will be automatically switched over into a safe position.
Local pneumatic control chains will be used if necessary, but only on the condition that their reliability will be the same or higher of electrical circuits' reliability.
Both systems, station and actuation units, will be based on identical logical elements using identical software and operating systems.
Technical means of control systems will be assembled on sides of instrument panels to enable free access to them during their maintenance. Cable feeding-in to the instrument panels will be made from below, while access to the panels – from behind.
The CS control system will consist of a few subsystems.

***Subsystem of Station Control***

The subsystem of station control is intended for control of the main and auxiliary CS equipment, maintenance of set pressure at CS exit, distribution of loads between working Gas pumping unit.
The subsystem of Gas compressor station control will maintain permanent communication with:

- CS operator's interface;
- the subsystem of the emergency stop;
- Gas pumping unit control subsystems.

***Subsystem of Gas-Pumping Unit Control***

Gas-pumping units will be supplied complete with control subsystems. The subsystem will consist of PLC with corresponding input/output means, screen terminal of operator's interface, an alpha-numeric keyboard, a regulator of speed and surge prevention (both regulators are microprocessor-based) and hardware for engine and supercharger vibration control.
The system is supplied with requisite software for monitoring and control purposes.
Information confirming identity in the approach to software, both in respect of unit control subsystem and station control subsystem, will also be submitted.
Technical vibration control means will control all mechanic vibrations and clearance between bearings and shafts, provide unit control subsystem with data of measurements and generate command on emergency shut down of Gas-pumping units at high vibration values.

Emergency shut down buttons will be provided on each panel of Gas compressor subsystem control and in certain places of compressor building.

***Emergency Shut Down Subsystem (ES)***

Gas compressor station ES subsystem will perform the following functions:

- control and monitoring of position (open-shut) of station valves taking part in algorithms of emergency CS shut down;
- automatic monitoring of emergency shut down circuits integrity;
- fire detection;
- Gas leakage detection;
- too high temperatures detection;
- monitoring manual emergency shut down stations and critical station variable parameters;
- permanent communication with subsystems of units control;
- permanent communication with station local network for detection of emergency signals and read-out of information on equipment condition;
- monitoring of the processors of station PLC (watch timer);
- ensuring of hard (physical channel) connection with all emergency shut down systems and facilities.

Emergency shut down buttons will be provided at each gate along the station perimeter,
neat each main entrance in the aggregate shelter, near the main entrance to the auxiliary building and on the station control panel.

***Monitoring Condition of the Process Equipment***

A system of monitoring conditions of process equipment will be provided at the compressor station. It will perform the following functions:

- a permanent monitoring of equipment condition in real-time and recording of monitoring data;
- forming of files on equipment condition and drawing up necessary schedules;
- storage of data on equipment condition received from electronic devices manually, using an operator interface;
- defining of functional capabilities and calculation of productivity of Gas pumping unit.

***Engines Control Center***

Engines control signals will come to intermediate relays installed in MMS and has a 24V DC power supply. Feedback signals on the fulfillment of engine start/stop commands will be connected to the station or unit control system, depending on the functional designation of the engine.
Station and unit control systems will have technical means of permanent automatic control of engine control circuit integrity.

***Requirements to Operators' Room***

The following main equipment will be installed in the operators' room:

- units control panel;
- station control panel;
- emergency shut down system panel;
- operator's interface equipment;
- system of technological equipment condition visual monitoring;
- fire-prevention system panel;
- printers rack.

Reserve place will be provided in operators' room for placement of technical means during compressor station expansion.

#### C.1.8.3.2. Instrument and Plant Air System, Nitrogen Generation, and Distribution System

To provide the compressor station with compressed nitrogen, a nitrogen membrane-type station is provided in a container version. For the storage of an instrument (control) air, a 25 $m^3$ receiver is installed.

To provide the compressor station with instrument air, the block compressor station with a capacity of 300 s $m^3$/h of prepared air with a dew point temperature of minus 40 $^0$C and with an output pressure of 75 bar is used. The station is made with 100% redundancy of compressor equipment, an adsorption dryer, and filter elements. For the storage of instrument air, a 5 $m^3$ receiver (R-2) is installed.

To provide compressed dry air to the Gas compressor station the air block compressor station (BKS-2) with a capacity of 150 s $m^3$/h of prepared air with and a dew point temperature of -40 $^0$C and with an output pressure of 8 bar is used. For storage of compressed dried air, 3 receivers of the volume of 25 $m^3$ each are installed:

- receiver (P-3) for compressed air used for receiving an instrument air,
- receiver (P-4) - for storing air used to control pneumatic actuators,
- receiver (P-5) –for storage of repair air.

All equipment is mounted in a 3 pcs of 12-meter all-metal insulated block container.

Each container is equipped with automatic fire extinguishing systems, fire alarms, supply, and exhaust ventilation, heating, and air conditioning, main and emergency lighting.

The technical characteristics of the instrument air module are given in the table below.

| No | Parameters | Value |
|---|---|---|
| Parameters of produced nitrogen | | |
| 1 | Nitrogen productivity, s $m^3$/hour | 300,0 |
| 2 | Nitrogen concentration in the produced Gas,%, not less than | 98,0 |
| 3 | Oxygen concentration in produced Gas,%, not more than | 2,0 |
| 4 | The dew-point temperature of nitrogen at the outlet of the block, $^0$C | Minus 55 |
| 5 | The pressure of nitrogen at the outlet of the block, bar | 7,0 – 10,0 |
| Parameters of produced dry compressed air | | |
| 6 | Compressed air productivity, s $m^3$/hour | 150,0 |
| 7 | The pressure of compressed air at the outlet of the block, bar | 7,0 – 10,0 |
| 8 | The dew-point temperature of compressed air at the outlet of the block, $^0$C | Minus 40 |
| 9 | Dirty air pollution class according to GOST 17433-80 | 1 |
| Parameters of produced instrument air | | |
| 10 | Instrument air productivity, s $m^3$/hour | 300,0 |
| 11 | The pressure of instrument air at the outlet of the block, bar | 75,0 |
| 12 | The dew-point temperature of instrument air at the outlet of the block, $^0$C | Minus 40 |
| 13 | Dirty air pollution class according to GOST | |

| | | |
|---|---|---|
| | 17433-80 | 1 |
| Electrical parameters of the block | | |
| 14 | Power Supply:<br>• voltage, V;<br>• frequency Hz | <br>380 ± 10%<br>50 ± 2% |
| 15 | Installed power, kW, not more | 310,0 |

**Table 26. The technical parameters of instrument air and nitrogen generator module.**

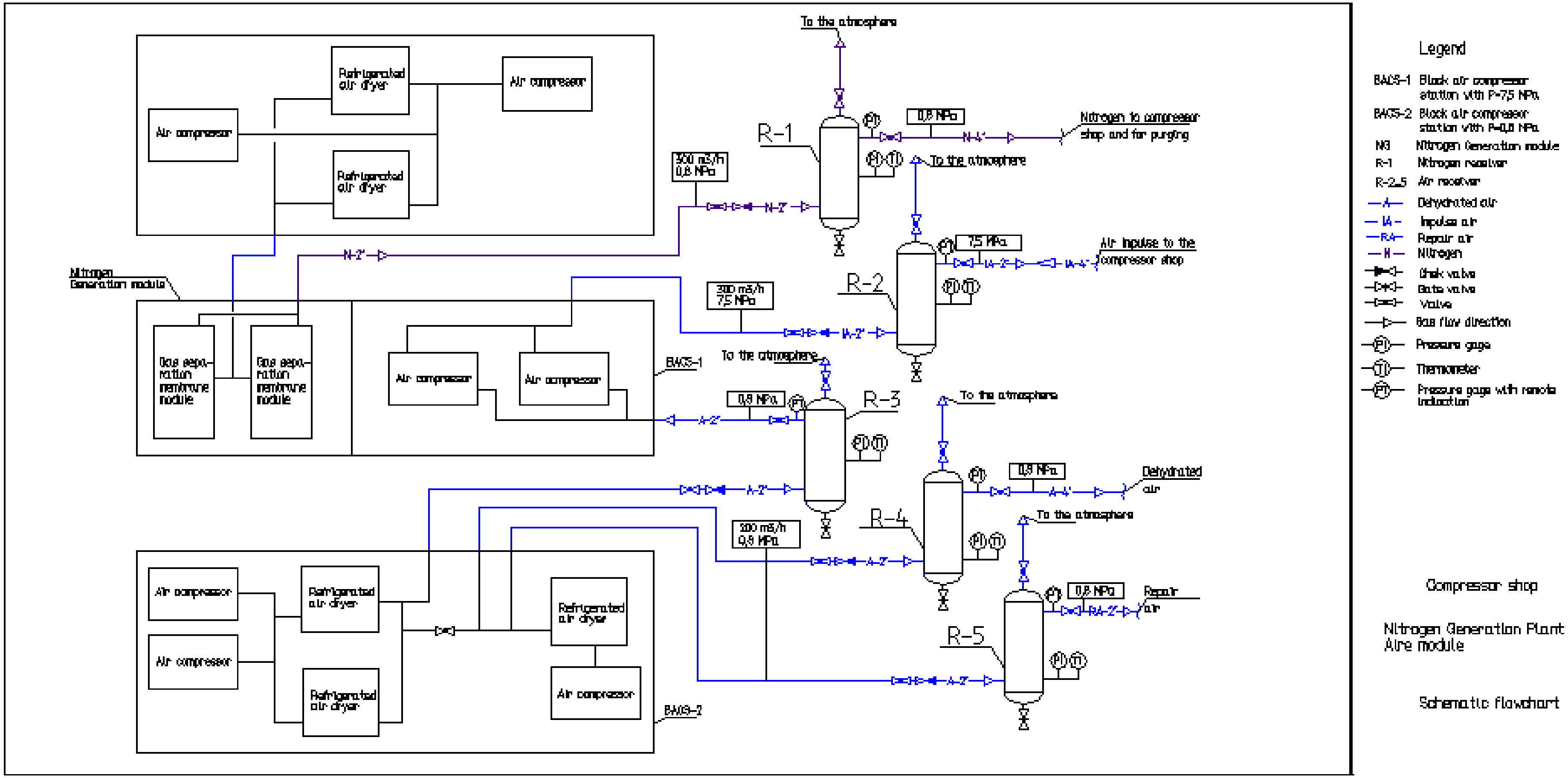



Figure 49.Instrument air and nitrogen generator module flowchart.

#### C.1.8.3.3. Vent/Flare System

The pressure-relieving and emergency depressurizing systems are required to protect the equipment when, in abnormal conditions, the internal pressure could rise above the design value. All relief and emergency depressurizing systems will be designed in accordance with API STD 520 (Part I) and API STD 521.
The relief flow rate is calculated for each of the following cases:

- Protection against overpressure;
- Protection against excessive temperature.

The vent stack designed considering potential ignition by a spark or lightning strike. The total permissible radiation intensity for the design of the sterile area radius around the vent stack is 6.31 kW/m² at the outer boundary of the sterile area according to API 521.

#### C.1.8.3.4. Power supply and power distribution system, Diesel generator module

The electrical part (Power supply and power distribution system) of the Head compressor station includes the system of external and internal power generation, power supply, power distribution, electric lighting, lightning protection and grounding of buildings and facilities of the compressor station.
The power supply system, the choice of electrical equipment will be made on the basis of international and European Standards.

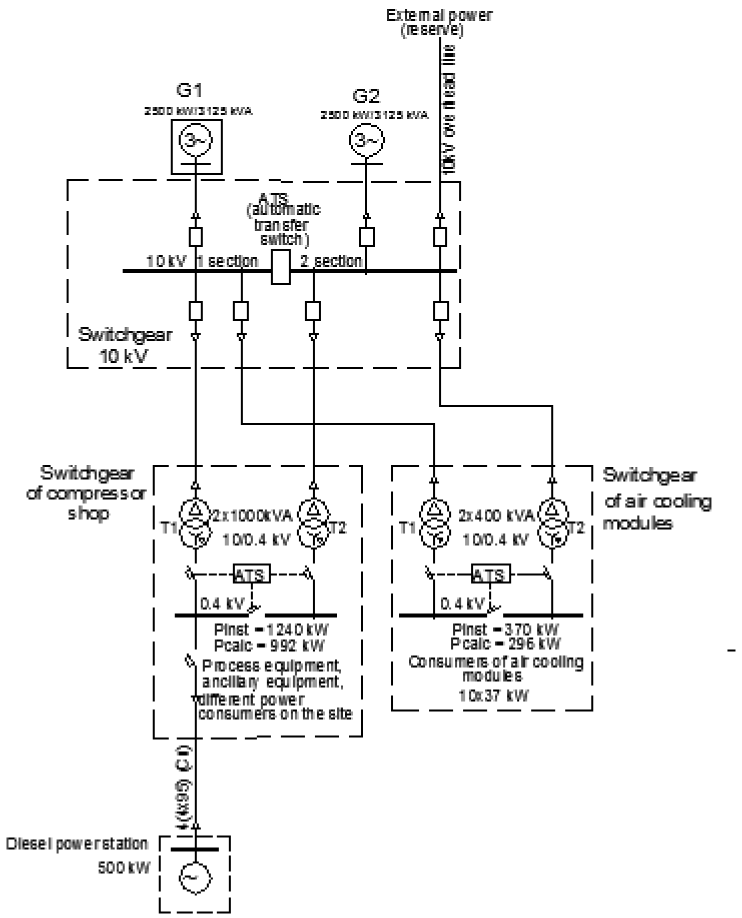



**Figure 50. Block diagram of power supply at the Head compressor station site.**

The power supply of the CS will be performed from its own Gas turbine power station (GTPS) consisting of two blocks of 2.5 MVA each (each of which is loaded in normal mode by about

50%) with a voltage of 10 kV and from a backup power source, the local connection to the power supplying of Gas metering station via overhead transmission line of 10 kV.
The power supply scheme provides for the supply and construction of the following main power supply facilities:

- Gas turbine power station (G1 and G2) with a capacity of 2x2500 kVA, the voltage of 10 kV (one working and 1 in reserve) installed in individual all-weather modules of full factory readiness;
- 10kV closed switchgear in the block-modular building of full factory readiness 10 kV indoor switchgear is provided using 10 kV SF6 or vacuum circuit breakers;
- a two-transformer power substation 10/0.4 kV, with dry transformers rated at 2x1000 kVA for power supply of the compressor shop in a block-modular building of maximum prefabrication mode, for power supply of Gas turbines, process, and infrastructure facilities (repair shops, warehouses, canteen, service and maintenance rooms);
- a two-transformer substation 10/0.4 kV, with dry transformers with a power of 2x400 kVA for power supply to Gas air cooling modules in a block-modular building of maximum factory readiness;
- diesel power unit 0.4 kV with a power of 500 kW, connected to a 0.4 kV switchgear in a block-modular building of maximum prefabrication, for reserve power supplying of a special group of electrical consumers (fire pump, boiler room, equipment for automated process control systems, alarm, ventilation, lighting and etc.);
- overhead power transmission line (10kV overhead line) approximately up to 5 km long;
- 380V power supply without failures units with 110V batteries;
- systems of lightning protection and grounding;
- cables with a voltage of 0.4 kV and 10 kV of various sections with copper conductors, armored and unarmored with PVC sheath and insulation;
- various low-voltage equipment (switchboards 0,4/0,23 kV, buttons, actuators, terminal boxes, electrical installation products, etc.);
- lighting fixtures exterior and interior lighting.

The capacities of power transformers, emergency diesel power units, and Gas turbine power stations will be refined at subsequent design stages, taking into account the actual loads of electrical consumers.

#### C.1.8.3.5. Electrochemical anti-corrosion protection System

The means of active protection are used in the electrochemical anti-corrosion protection system of the site and equipment of the Head compressor station. The protective potential of isolated steel underground units should be in the limits between -0.95 V and -1.2V.

***Protectors.***
The essence of the protectors' usage lies in the creation of manufactured electric circuit, made from more electronegative material than the object itself. To protect the equipment and steel underground pipelines from corrosion, it is proposed to install the protector units with the group of protectors from magnesium alloy.
They will be installed at the depth of 1.5m. The protectors are connected to the pipeline by means of distribution panel via a resistor. To measure the potential, the point is equipped with the long-acting copper-sulfate reference electrode.

***Bussing.***
Cable bussing is provided for the 48V circuit from the constant-potential transformer to sacrificial anode and drainage points.

The cables should be copper, isolated by PVC for the voltage up to 1000V.
The cables are laid at the depth of 1.0 m on sifted or sand soil layer of 10cm, after this they are covered with the 15cm layer of the same soil, from above the trench is covered with the soil that was taken out earlier.
The connection of the cable to the pipeline is made by means of aluminothermic welding.

***Measuring points.***
To control the state of the cathode protection, the installation of the following measuring points is provided:

***The measuring point of "pipe-ground" potential.***
It is installed in the drainage point. The point is equipped with a box where the copper cables with a section view of 1x10 mm² from pipeline and reference electrode are placed.
In order to automatically maintain the potential of the transformer, the installation of the long-acting copper-sulfate reference electrode in the drainage point is provided for.
The potential control point for the places where the pipeline crosses other underground metal communications.
It is installed in places where the Gas pipeline crosses other metal pipelines. The construction of the point on crossings eliminates the mutual negative influence of the crossing communications, compensates the protection potentials.
The point is equipped with a box where the copper cables with a section view of 1x10 mm² from crossing pipeline are placed. For protective voltage regulation, a resistor is provided. To measure the potential, the point is equipped with the long-acting copper-sulfate reference electrode for each pipe.

***Insulating flange point.***
The point is designed for measuring and regulating of the potentials, as well as for the control of the flange effectiveness.
The point is equipped with a box containing the contacts, adjustable resistor and discharger.
All the measuring points are installed on a concrete foundation 300x300x300 mm.

##### C.1.8.3.6. Diesel Fuel System

The Diesel fuel will be supplied by a car tanker and will be stored in a diesel fuel storage tank. Diesel will be required to fuel the emergency diesel power station day tank, fire water pumps, and fixed foam system. The main fuel storage tank has 4 days of storage capacity (100 cub m).
The emergency diesel power station with a capacity of 500 kVA is adopted in a noise-absorbing all-weather container in the concrete foundation.
The diesel fuel storage tank will be placed inside a concrete dike wall. Diesel fuel transfer pumps will pump the diesel fuel to consumers through diesel fuel filters. The pressure drop across filters will be monitored and changeover of the filter will be made when the pressure drop is high which shows plugging of the filter. A low level in the storage will alarm the operating personnel to re-fill the tank. The storage tank will be re-filled from a diesel fuel road tanker through unloading connections provided for this purpose.

##### C.1.8.3.7. Communication, alarm system

The telecommunication system will provide reliable communication inside various Head compressor station facilities and modules as well as between all locations along the Gas interconnector pipeline that are relevant for station operation, management, administration, and maintenance. For cybersecurity reasons, the networks of the production and security facilities will be separated from office networks and the communication networks for inhabitants of the accommodation areas, having only a minimum number of secured interfaces, if necessary.
Single-mode fiber optic cable-based communication network between all the Block valve stations will be designed as a redundant direct path structure installed along the Gas pipeline

interconnector. The network will link all manned and unmanned Block valve stations to tie-in the RTU/ICSS, CCTV, PA/GA, Telephone and IPABX, Security systems, Radio systems, office LAN/WAN and monitoring systems at all locations of the Gas loading system.
The active access node must have a high add-drop capability (2,5 Gb/s) and the transmission system must be available with STM-4 and STM-16 backbone capacity.
As the transmission system will be used as a backbone network, the system will have the following characteristics:

- High Availability;
- High Reliability;
- Dual ring configuration (by others);
- Easy to install and operate;
- Scalable;
- The high degree of flexibility with respect to the type of interfaces.

The following telecommunication services will be provided for facilities, and modules and security facilities:

- Provide voice communication with VoIP office system;
- In addition, security staff at the station will have an independent UHF radio system for mobile voice communication in and around the stations;
- Provide RADAR, CCTV, Fence mounted Perimeter intrusion detection, Access control system. All cameras will be the high-resolution type with a manual zoom, pan, and tilt and wash/wipe facilities. The CCTV System will be automatically triggered by the Intrusion Detection system;
- Provide video stream data transmission for the video surveillance system along the pipeline i.e. in Block valve stations and Gas metering stations;
- Provide PAGA (Public Address and General Alarm) system;
- Provide sufficient remaining bandwidth available that could be later leased by the facility owner to other third-party telecommunication companies if required;
- The following telecommunication services will be provided for the buildings at Gas compressor station and Gas loading terminal;
- Provide voice communication with VoIP office system and interconnection to the Public telephone network;
- Provide office data network application and access to the public internet at all locations.
- Provide satellite TV at all locations;
- Provide backup communication using wireless microwave system for critical applications only;
- Provide hotline telephone systems;
- Provide VHF Radio system;
- Provide Video conference system at Gas compressor station and Gas loading terminal.
- Meteorological systems will be installed to provide real-time site climate conditions at the Gas compressor station and Gas load terminal.

The communication system equipment is connected to protective grounding facilities.

#### C.1.8.3.8. Power, control and signal cables

The electric power supply of the equipment will be carried out by means of copper cables, isolated by thermoplastic PVC, with PVC electron outer shell. Cabling methods, types, and length of cables will be indicated during detailed Design work.

### C.1.8.4. Description of life support facilities (modules) of the Head compressor station

#### C.1.8.4.1. Water and sewage system

***Water supply***

The source of water supply for the Head Compressor station site provides for the water intake. There are two options of the arrangement of water intake:

- The arrangement of underground water supply (in case there is groundwater resource in the area);
- The surface water intake from a lake which is located at a distance of 1,3 km from the site, water will be supplied to the water purification facilities through the water conduit.

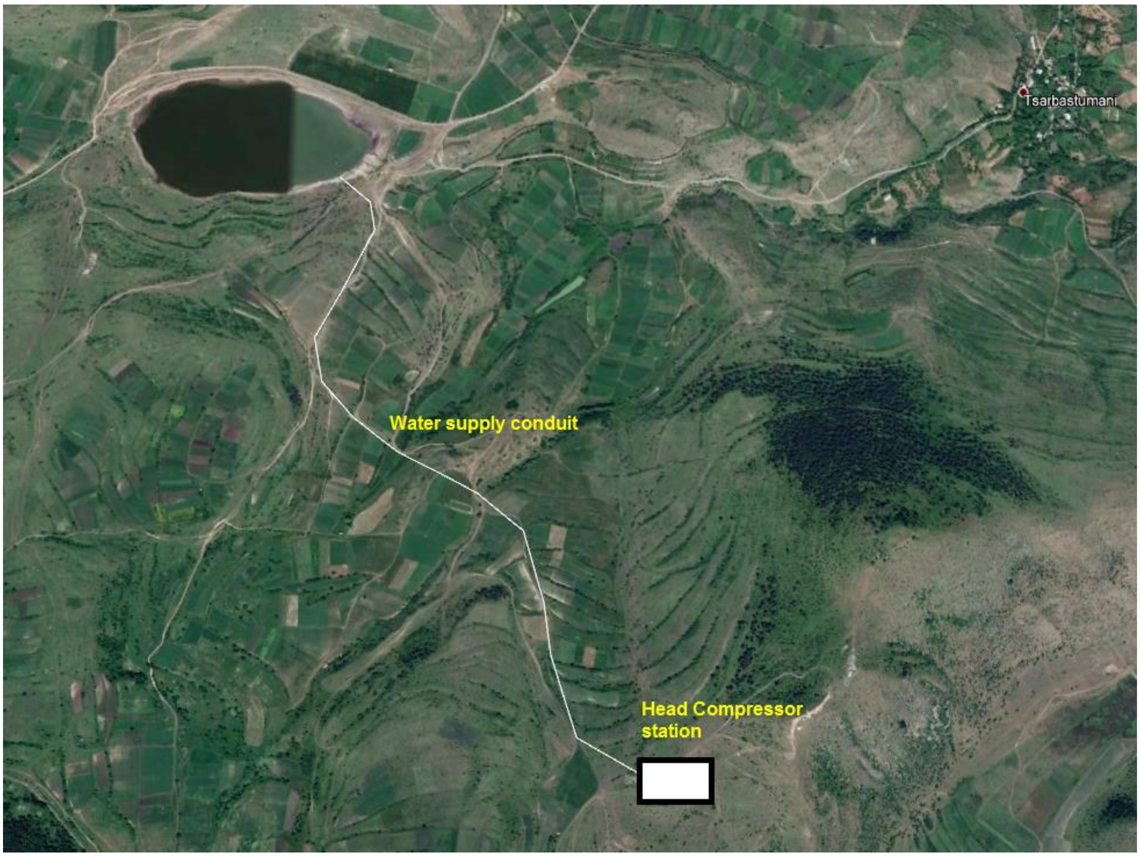



Figure 51. The map of the water supply conduit.

***Water supply schemes and systems***

The water at the site of the Head CS is consumed for household and drinking, fire fighting, production needs and irrigation of greenery.

There are adopts two separate water supply systems: for drinking, production and fire protection.

On the Head CS site are provided such water facilities:

- for drinking water supply system:
  - the drinking water tank with a capacity of 50 $m^3$ (1 pc.);
  - water purification facilities for drinking water treatment;
- for the production and fire water supply system:
  - fire pumping station;
  - tanks of firewater reserve with a capacity of 300 $m^3$ (2 pcs.)

***Scheme and system of drinking water supply***

The drinking water supply system belongs to the second category of water supply reliability. The water from the water conduit is supplied to the water purification facilities for the preparation of drinking water and after that enters the reservoir of drinking water.
The reservoir of the drinking water reserve is made from corrosion-resistant steel AISI 430, of 50 m³, factory-made. The tank is designed above ground type with external thermal insulation and heating by electric resistance cables.
The Quality of water for drinking (domestic) needs should be guaranteed by chemical and bacteriological composition. Therefore, at the site of the Head CS provides the water purification facilities of water treatment to improve the Quality of drinking water. The water purification facilities must be modular and include the following equipment:

- carbon filters (1 working + 1 reserve);
- sorption filters (1 working + 1 reserve);
- ultraviolet disinfection installation (1 working + 1 reserve).

After purification, the water will meet the requirements of SanPiN "Drinking water. Hygienic requirements for water quality of centralized drinking water supply systems. Quality Control" the Standard that is valid in the territory of Georgia.
Estimated water consumption for drinking needs is accepted in accordance with the "Internal water supply and sewerage of buildings" Standard in Georgia and is 150 liters per day per worker.
The water supply from the water conduit to the drinking water tank is carried out automatically, depending on the water levels in the tank.
Water is supplied to consumers by a pump, which is located in the water treatment plant. To account for the flow of water for drinking needs in the water treatment room equipped with a flow meter.

***Scheme and system of industrial and fire water supply***

The fire water supply system belongs to the first category of water supply security.
The water from the supply conduit from the water intake enters the firewater tanks (2 pcs.). Fire suppression will be provided by the pumping equipment of the fire pumping station. External fire extinguishing will be carried out of fire hydrants, the internal fire water line is of fire valves. On the site of the CS will be provided an external fire water ring. The pressure in the network will be provided up to 0,4 MPa, the pressure in case of fire - up to 0,7 MPa.
The industrial and fire fighting water line will be provided in the following structures:

- Shelter of the compressor shop (four buildings);
- Oil cleaning module;
- Engine and spare parts warehouse;
- Ancillary buildings and structures (production and energy unit, repair and maintenance unit, fire station garage for 2 fire trucks; service and maintenance unit with a communication center, a checkpoint, a chemical laboratory).

Water for fire needs consumption is assumed for the building requiring the highest water consumption. The maximal building volume is about 7700,0 $m^3$, the category of the building for explosive and fire danger is "A", the degree of fire resistance is III-a. Water consumption for external fire water line is 15 l/s, for internal fire extinguishing - 2 × 5 l/s = 10 l/s. The total consumption for fire fighting is about 25 l/s for 3 hours will be 270 $m^3$.
It will be provided the automatic foam fire fighting in the shelters of compressor shop.
The installation of the fire fighting system is planned in the premises of the fire pumping station. Pipelines of the foaming agent solution are provided to each building of the shelters of the units and are equipped with firewater sprinklers.
In connection with the seismicity of 8 points, the necessary fire supply of water for the external and internal fire fighting system is provided twice volume as much as calculated and will be

$270x2=540\ m^3$. There are two tanks (2 pcs.) of fire fighting water. The volume of tanks will be provided by 300 $m^3$. The tanks are provided for above-ground steel with external thermal insulation and heating.

#### C.1.8.4.2. Firewater and fire-fighting system

***Automatic foam fire fighting system in compressor shelters***

The shelter's system of automatic foam fire fighting will be provided in the shelter buildings of the CS. The work of the drencher system should provide simultaneous fire fighting with the air-mechanical foam of low multiplicity of two zones of oil blocks in the shelter of the CS:

- the console of lubricating oil of a compressor of square size 8.2x5.1 = 41.82 $m^2$;
- the console of lubricating oil of the turbine of square size 1.9 x1.5 = 2.85 $m^2$.

The duration of the working of the foam fire fighting system for premises of category "A" for explosion and fire hazard is 15 minutes.

The estimated consumption of the foaming agent solution when the automatic fire fighting system is triggered is taken at 0,15 l/s per $m^2$. The estimated flow rate of the solution for the foam fire fighting system of both consoles in the same shelter of the CS is 6,7 l/s for 15 minutes:

$$Q = 44{,}67\ m^2 x0{,}15x15x60 = 6{,}03\ m^3.$$

The volume of solution for foam extinguishing, taking into account the capacity of pipelines and facilities is 7,24 $m^3$.

The estimated water consumption when automatic fire fighting system is triggered and the external and internal water fire fighting system of the CS shelter (15,0 l/s) is provided with a fire pump during one fire and will be:

15,0 l/s + 6,7 l/s=21,7 l/s – for 17 min (2 min - for filling the system).

***Description of the Deluge System***

A deluge system is an empty pipe system that is used in high-hazard areas or in areas where fire may spread rapidly. In this type of application, open sprinklers or spray nozzles are employed for water distribution. The deluge valve is activated by a release system (fixed-temperature, rate-of-temperature rise, radiation, smoke, or combustion Gases, hazardous vapors, pressure increase). When the system is tripped, water flows through all spray nozzles or sprinklers simultaneously. The deluge system will be activated by a hydraulic, pneumatic, electric, or manual release system or any combination of these release systems.

When a releasing device operates, pressure escapes in the pneumatic release system causing alarms controlled by air supervisory transmitter to activate and the pneumatic actuator opens. When the pneumatic actuator opens, the pressure is released from the priming chamber gaster than it is supplied through a restricted orifice. The deluge valve clapper opens to allow water to flow into the system piping and alarm devices, causing water motor alarm and water flow alarms connected to the alarm pressure transmitter to activate. Water will flow from any open sprinklers and/or spray nozzles on the system.

The Deluge System will be provided to Gas Compressors and Flare Knockout drums and pumps.

Each deluge system will be fed from the firewater ring main connected with an automatic deluge valve. Isolation of automatic deluge systems will be possible by means of manual block valves, locked open in normal service. The deluge valve will be a specific quick opening automatic valve energized by the firewater pressure. The local manual release will also be possible for the deluge valve.

***Description of the Sprinkler System***

In a normal set condition, the system piping is filled with water. When a fire occurs, the heat operates a sprinkler allowing the water to flow. The alarm valve clapper is opened by a flow of water allowing pressurized water to enter the alarm port to activate the connected alarm device.

The following process areas and buildings at CS will be protected with automatic sprinkler systems (wet pipe sprinkler system) in accordance with NFPA 13.

Upon operation, the sprinklers distribute the water over a specific area to control or extinguish the fire. As the water flows through the system, an alarm is activated to indicate the system is operating. Only those sprinklers immediately over or adjacent to the fire operate, minimizing water damage. The facilities to be protected by the Sprinkler System:

- Administration building;
- Warehouse building;
- Chemical storage shelter;
- Power generation shelter;
- Workshop;
- Control room.

***Fire pumping station***

Firewater pumping station will be provided of the modular design and includes the following equipment:

- fire pump unit Q=160 $m^3$/h; P=0,70 MPa; (pumps - 2 pcs, 1 work, 1 reserve);
- fire pump unit Q=10$m^3$/h; P=0,40 MPa; (pumps - 2 pcs, 1 working, 1 reserve) with a pneumatic tank of volume V=35,0 l to maintain the pressure in the ring fire net. The maintenance pressure pump in the ring fire net is automatically activated.

For automatic foam fire fighting facilities will be provided the following equipment:

- vertical dosing system of volume 400 l with foam concentrate with an inside membrane, equipped with fittings and a concentration control valve;
- mixer for a dosing system of 3 inches;
- drencher valve;
- 24V solenoid valves in the harness of the deluge valve and concentrate control valve.

There are two facilities of fire pumping station - one working and one reserved.

***Description of automation of the fire water supply system***

When a fire occurs on the site, the first fire pump will be activated. The activation of a fire pump provided by:

- In automatic mode by the fire alarm (“Fire” signal) system of automatic foam system in the shelters of the CS;
- remote, at the “Fire” signal with the buttons at fire hydrants for external fire fighting system,
- in buildings - from buttons at fire hydrants;
- remote, from the operator's console;
- local, with buttons at the pumps in the fire pumping station.

If a second fire occurs on the site, a second fire pump will be activated. At the same time, simultaneously with the activation of the fire pumps, the pressure maintenance pump should automatically shut off, and the blockage automatically prohibiting the drawdown of the firewater volume should be automatically removed.
Provision will be made for automatic activation of backup pumps in case of malfunction of main pumps.

***Sewage water system***

Characterization of wastewater, and its treatment.
The following categories of wastewater are generated at the projected site:

- household;
- rain sewage from the territory.

***Household wastewater***

Domestic wastewater from buildings and structures, collected by sewage networks, flows by gravity to the sewage pumping station, and the pressure pipe is fed to a sewage treatment unit, which is prefabricated and packaged. Treated effluents are sent to a reservoir tank or discharged into an evaporation pond for further evaporation.
The consumption of domestic wastewater is determined from the condition that the norms for water disposal are equal to the norms for water consumption.

***Rainwater wastewater***

The project provides for the installation of rain sewers. Rainwater flows through the collectors are fed to the treatment plant.
Contamination indicators of surface wastewater from the site do not exceed:

- suspended solids up to 500 mg/l;
- for oil products up to 30 mg/l.

In the project, rainwater is scheduled to be collected only from road sections and sites where the project provides for improvement.
Provides gravity rainwater collection in storage tanks, equipped with submersible pumps, and with the subsequent transfer to wastewater treatment plants sewage treatment. This project provides for the mechanical cleaning of rainwater runoff. At the sewage treatment plant, the sedimentation of large suspended solids takes place and, with subsequent incubation, the removal of the bulk of undissolved impurities from the runoff. Due to the fact that the project made a decision to use the cleaned rain drain for watering and washing the roads, watering the lawns, and dumping the surplus to the relief, deep purification is envisaged. After treatment is provided by a sorbent charge, which detains fine contaminants and oil products. This ensures the purification of water by 99.5%. Purified rainwater flows by gravity into an underground steel horizontal tank with a capacity of 100 $m^3$, from where they are pumped to watering green spaces, washing roads and driveways. The parameters of treated rainwater are:

- suspended substances – 10,0 mg/l;
- petroleum products - less than 0,3 mg/l.

The project provides for sending a surplus of treated rainwater to the evaporator pond via the waste collector.

***Industrial waste***

Industrial effluents that are generated at the oil supply installation do not flow into the sewer network but are collected in process tanks for export for further disposal.

#### C.1.8.4.3. Evaporation pond

The evaporation pond will be designed with enough surface area to efficiently evaporate water by sunlight and exposure to ambient temperatures. The pond allows the water to evaporate, leaving the waste behind.

#### C.1.8.4.4. Backup water line with water intake facility

As a backup source of water supply, it is planned to build a conduit from a nearby pond (see Figure 51), which is located at a distance of 1,3 km from the CS site. The calculated diameter of the conduit is 8 inches.

***Underground water intake***

There are envisaged the drilling of artesian wells and the arrangement of block boxes above wells with pumping equipment, automation, and fittings. The sanitary protection zone (SPZ) of a fence is arranged around each artesian well.

***Surface water intake***

The surface water intake is provided for onshore type, recessed water intake sump with two pumping units. The water intake from the lake is provided by two separate pipelines with mesh tips. A sanitary protection zone (SPZ) with a fence is arranged around the water intake structures.

#### C.1.8.5. Ancillary buildings and structures, site improvements

##### C.1.8.5.1. Head compressor station plot plan

Plot plan of Head compressor station to be developed based on the following requirements:

- Safety distances;
- Prevailing wind direction;
- Accessibility and Constructability;
- Process requirement of equipment sequencing;
- Pipeline entry and exit points;
- Availability of utilities e.g. water, electricity, manpower, etc., and entry and exit points of utilities;
- The proximity of manned and unmanned area;
- The proximity to an environmentally sensitive area;
- Soil characteristics;
- Terrain;
- Space provision for future expansion;
- Minimum 10% green plot;
- QRA findings and recommendations;
- Loss prevention philosophy.

The figure below shows the master plan diagram of the Head compressor station.

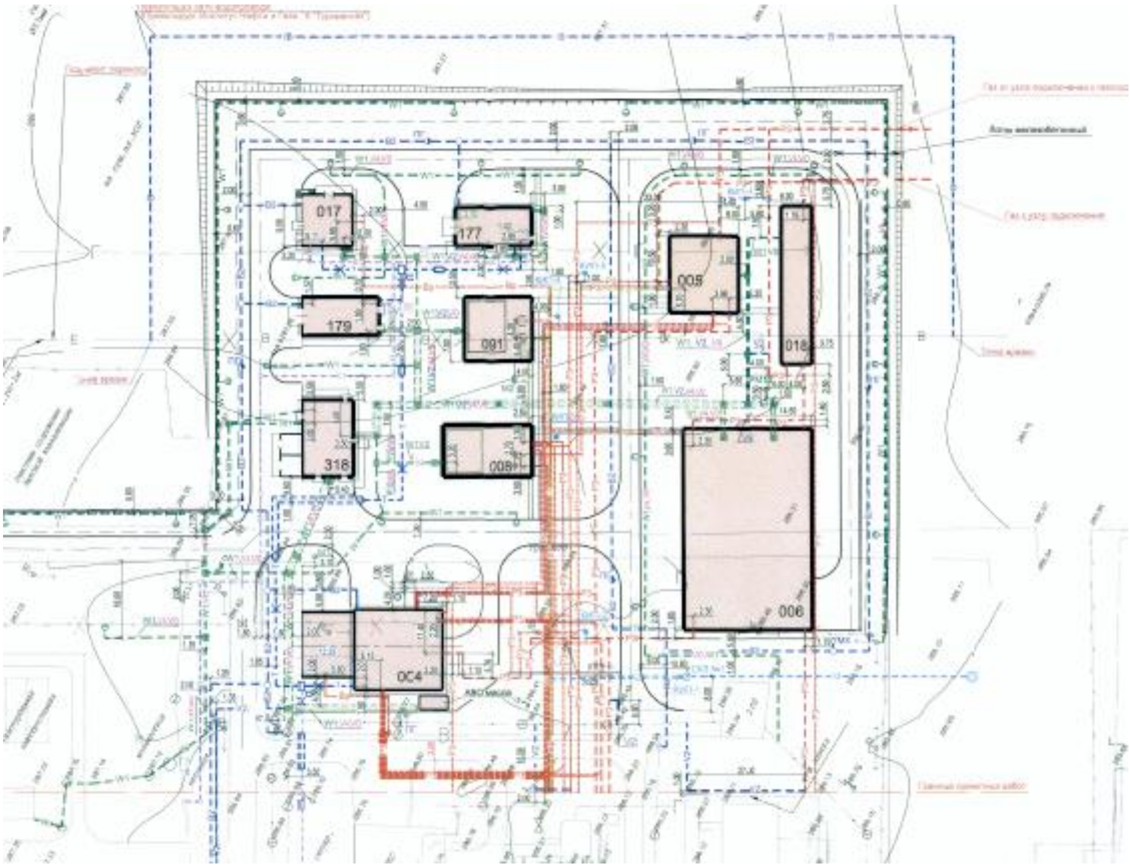



**Figure 52. Example of process facilities of Head gas compressor station Plot plan.**

***Motor roads***

Motor roads in the area of the Head compressor station will be designed taking into account the outward and inner traffic and firefighting service as well. They provide reliable connecting of buildings and constructions. Motor roads, foreseen to be the ring, are reliably satisfying the demands of processes.

The driveways are intended to be in the embankment of not less than 0,3 m higher than plan ground elevation.

Cross profile of road is intended to be with roadsides. The width of the traffic way of the main roads is to be 4,5 m, roadsides – 1,5 m.

Covering of the inner roads is intended to be from one-layer asphalt concrete with a bed of gravel-sand mixture.

For the protection of road pavement from subsidence, there is projected to install a protective shield from loam with thickness 0,15 m.

All main technical parameters for motor roads are to be of V technical category. Traffic road width is to be 4,5 m, roadsides width – 1,5 m, ground bed width – 7,5 m.

Road pavement consists of asphalt concrete with a bed of gravel-sand mixture.

For the protection of road pavement against subsidence, there is projected to install a protective shield from loam with thickness 0,15 m.

## C.2. Gas interconnector: SCP - Loading terminal in the Poti port area (Georgia).

### C.2.1. Introduction

This section addresses the Technical and Commercial issues of the construction of the Gas Interconnector SCP - The loading terminal in the area of the port of Poti (Georgia). The interconnector will be the source of the delivery of Gas to the loading CNG ship terminal.
In this section, VTG addresses the Technical issues of the construction of the Head compressor station of the Gas Interconnector SCP - The loading terminal in the area of the port of Poti (Georgia). The Head compressor station will transfer the Natural Gas from the source of the SCP main Gas pipeline to the Gas loading terminal.

### C.2.2. Purpose of the Gas interconnector to the loading terminal

Gas Interconnector SCP - the loading terminal in the area of the port of Poti (Georgia) is intended for Gas transporting from the main Gas pipeline SCP (South Caucasus Gas Pipeline) to the loading Gas terminal in the area of the port of Poti. Connection point - in the area of the Gas measurement station (District 81) near the village of Vale in Georgia nearby the Georgian-Turkey boarder. Structurally, the Gas interconnector is located after the Head compressor station.
The main productivity parameters of the Gas interconnector belong to scenarios of Gas delivery is **6,30 mscmd.**:

### C.2.3. Glossary, abbreviations, and acronyms

In this Report, such abbreviations and acronyms were used:

| Abbreviation | Description |
|---|---|
| **ALS** | accidental limit state |
| **AR** | an additional requirement to the stated ISO Standard |
| **API** | American Petroleum Institute |
| **ASME** | American Society of Mechanical Engineers |
| **ASTM** | American Society for Testing and Materials |
| **BM** | base material |
| **BS** | British Standard |
| **CP** | cathodic protection |
| **MAOP** | maximum allowable operating pressure |
| **MR** | the modified requirement to the stated ISO Standard |
| **N** | normalized |
| **NACE** | national association of corrosion engineers |
| **NDT** | non-destructive testing |
| **QA** | Quality assurance |
| **QC** | Quality control |
| **SC** | Safety class |
| **UT** | Ultrasonic testing |

Table 27. Glossary, abbreviations, and acronyms.

### C.2.4. Units of measurement.

The Units of measurement which are used in this section are shown in Table 2.

### C.2.5. Climate data

The area of the proposed construction of the Gas interconnector is characterized by the following climatic characteristics (Standard SNiP 23-01), similar to the Environmental parameters of the Head CS (at the beginning of the interconnector, see Table 17).
At the end of the interconnector, the Environmental parameters are the same as Gas loading terminal near the port of Poti (see Table 36).

| **The Environmental parameters** | **Data** |
|---|---|
| *Temperature:* | |
| - Average air temperature in January, $^0$C | 5,7 |
| - Average air temperature in July, $^0$C | 23,1 |
| - Average annual air temperature, $^0$C | 14,4 |
| - Absolute minimum air temperature, $^0$C | minus 11 |
| - Absolute maximum air temperature, $^0$C | 41 |
| - The average maximum temperature of the hottest month, $^0$C | 26,9 |
| - The average air temperature of the coldest five-day week with a rated of 0.92 $^0$C, | 3 |
| Maximum depth of soil freezing, cm | 40 |
| *Wind:* | |
| Prevailing wind direction in January | East |
| Prevailing wind direction in July | South-West |
| Average wind speed in January in the prevailing direction, m/s | 5,1 |
| Average wind speed in July in the prevailing direction, m/s | 3,5 |
| Wind velocity, kPa | 0,38 |
| *Precipitation:* | |
| Rainfall per year, mm | 1831 |
| Daily maximum, mm | 268 |
| The average height of snow cover, cm | 14 |
| Snow cover weight per 1 m$^2$ of a horizontal surface, kPa | 0,8 |
| Seismicity of the CS area (on the MSK-64 scale) | grade 8 |
| Average monthly relative humidity of air at 13 hours,%:<br>- the hottest month;<br>- the coldest month | <br>73<br>65 |

Table 28. Environmental parameters of the area of the Gas interconnector (pipeline end).

### C.2.6. Codes and Standards

The Codes and Standards used for design and build the Gas interconnector for connecting the SCP and the Gas loading terminal near the port of Poti must meet the Standards used in the best practice of international Engineering taking into account the Georgian national Standards.

| **Standard, Code** | **Description** | **Notes** |
|---|---|---|
| ***ASME, ANSI, ASTM Standards*** | | |
| ASME B 16.5 | Pipes, Flanges and Flanged Fittings | |
| ASME B 16.9 | Factory-Made Wrought Steel Butt-Welding Fittings | |
| ASME B 31.8 | Gas Transmission and Distribution Piping Systems | |
| ASME B 36.10 M | Welded and Seamless Wrought Steel Pipe | |
| B31.8 - 2012 | Gas Transmission and Distribution Piping Systems | |
| ASME | Performance Test Codes | |
| ASME B31.9 | Working Pressure and Temperature Limits | |
| ASME/ANSI B16 | Standards for Pipes and Fittings | |
| ASME/ANSI | Carbon, Alloy and Stainless Steel Pipes - Dimensions - | |

| | | |
|---|---|---|
| B36.10/19 | Metric Units | |
| ASTM | ASTM International - Standards for Steel Pipes, Tubes and Fittings | |
| ASTM | ASTM International - Volume 01.01 Steel - Piping, Tubing, Fittings | |
| ***API Standards*** | | |
| API SPEC 5 L | Line Pipe Specification | |
| API SPEC 6 A | Specification for Wellhead & Christmas Tree Equipment | |
| API SPEC 6 D | ISO 14313:1999, Petroleum and Natural Gas Industries-Pipeline Transportation Systems-Pipeline Valves | |
| API STD 594 | Check Valves: Wafer, Wafer-Lug, and Double Flanged Type | |
| API STD 598 | Valve Inspection and Testing | |
| API STD 599 | Metal Plug Valves - Flanged and Welding Ends | |
| API STD 602 | Compact Steel Gate Valves-Flanged, Threaded, Welding, and Extended-Body Ends | |
| API STD 608 | Metal Ball Valves Flanged and Butt-Welding Ends | |
| API STD 609 | Butterfly Valves: Double Flanged, Lug- and Wafer-Type Fifth Edition | |
| API RP 1102 | Steel Pipelines Crossing Railroads and Highways | |
| API STD 1104 | Welding of Pipelines and Related Facilities | |
| ***BS Standards*** | | |
| BS 1868 | Steel Check Valves | |
| BS 1873 | Steel Globe Valves | |
| BS 5146 | Inspection and Testing of Valves | |
| BS 5351 | Steel Ball Valves for the Petroleum, Petrochemical and Allied Industries | |
| BS 5352 | Steel Wedge Gate, Globe and Check Valves 50mm and smaller | |
| BS 6755 Part 2 | Testing of Valves Part 2: Specification for Fire Type-Testing Requirements | |
| IP6 | Institute of Petroleum Model Code of Safe Practice Part 6, Pipeline Safety Code | |
| BS 8010 | Code of Practice for Pipelines | |
| ***Other Standards*** | | |
| ISO 13623 | Petroleum and natural Gas industries - Pipeline transportation systems | |
| ISO | Pipe, Tube and Fittings Standards and Specifications | |
| DIN | Pipe, Tube and Fittings Standards and Specifications | |
| | National Georgian Codes and Standards | |

**Table 29. List of applicable Codes and Standards.**

### C.2.7. Description of the Route of Gas interconnector

#### C.2.7.1. Geographic conditions of the interconnector passage

The Gas pipeline route begins in the mountainous part of the Little Caucasus in South-West Georgia, in the point of 2,3 km from the border with Turkey and 2,6 km to the West of the town of Vale. The general direction of the route is North-West. The route crosses the ridge of the Meskheti Range of mountains and goes to the Colchis Lowland in the valley of the Rioni River (on the left bank) between Sajavakho and Vazisubani. Then crosses the river Rioni and goes along the Colchis Lowland in the direction to the West. The total length of the pipeline is

140 km. Of these, the length of the mountain site is 81 km, the length of the site in the Colchis Lowland is 59 km.

#### C.2.7.2. Interconnector route plan and profile

The pipeline route plan is shown in Figure 53, the initial part of the route and Section 1 on a larger scale is shown in Figure 54. The plans show the placement of the block of valves units and compressor stations (BVS and CS). The length of the Gas pipeline route from the point of connection to the SCP Main Gas pipeline to the loading terminal site in the area of Poti is 140 km. The route profile is shown in Figure 53. The beginning of the route is at a height point of 1235 m. The maximum mark on the route is a height point of 2293 m.

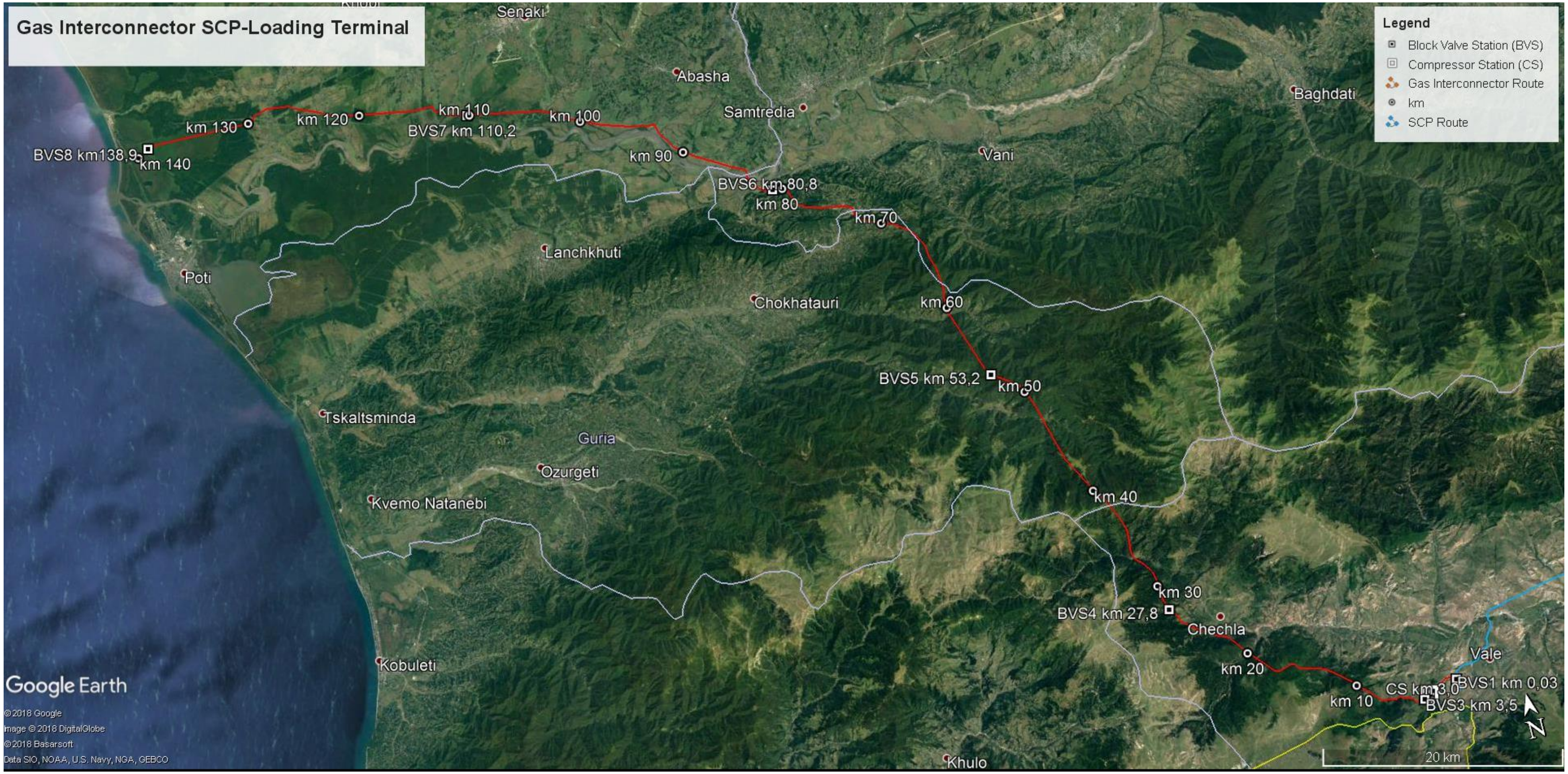



**Figure 53. Gas interconnector route with Block valve stations.**


Figure 54. Section 1 of the Gas interconnector.


**Figure 55.Gas interconnector profile.**

### C.2.7.3. Characteristics of natural and topographical obstacles along the route of the interconnector

The table below is shown the list of the topographical obstacles along the route of the interconnector.

| Type of Crossing | Km | Notes |
|---|---|---|
| Overhead transmission line | 0,8 | OTL 400 kV |
| Motor road | 9,8 | dirt |
| River | 9,7 | river width 18 m |
| Motor road | 13 | Adigeni-Ijareti-Triala |
| River | 19,7 | Dzinzusu, river width 8 m |
| Motor road | 19,9 | Batumi- Akhaltsikhe, asphalt pavement |
| River | 27,5 | Tskali |
| River | 33 | kablninichay, river width 13 m |
| River | 47 | Hanis Tskali |
| River | 59,3 | Supsa, river width 15 m |
| Motor road | 59,4 | Zemo –Surebi |
| Watercourse | 61 | Marde Tskali |
| Watercourse | 72,5 | Hepir Tskali |
| Motor road | 78,4 | dirt |
| Motor road | 80,8 | Sajavakho-Chokhatauri-Ozurgeti-Kobuleti, asphalt pavement |
| Railroad | 82 | - |
| Highway | 82 | E692, asphalt pavement |
| River | 82,2 | Rioni (river width 417 m) |
| Channel | 85 | channel width 4 m |
| Motor road | 85,2 | asphalt pavement |
| Motor road | 90,4 | dirt |
| Channel | 92 | channel width 4 m |
| River | 92,5 | Nogela, river width 5 m |
| Channel | 93,5 | channel width 14 m |
| Channel | 94 | channel width 9 m |
| Motor road | 98 | dirt |
| Motor road | 101 | Abasha-Gaghma Kodori-Guleiskiri-Japana, asphalt pavement |
| Channel | 101,2 | channel width 7 m |
| Channel network | 101,4-103 | 6 channels |
| River | 103 | Abasha, river width 80 m |
| Motor road | 104,4 | asphalt pavement |
| Channel | 108,5 | channel width 4 m |
| Motor road | 109,2 | asphalt pavement |
| Motor road | 109,6. | asphalt pavement |
| Channel | 109,64 | Mtavari-Arhvi, channel width 12 m |
| Motor road | 111 | asphalt pavement |
| River | 111,2 | Tsivi, ширина 40м |
| Motor road | 111,3 | asphalt pavement |
| Motor road, channel | 112,2 | |
| Channel | 112,5 | channel width 12 m |
| Motor road | 113,6 | slab |
| Channel network | 114-117 | 18 channels |
| Motor road, channel | 119,6 | slab, channel width 5 m |
| Channel network | 120-122 | 6 channels |
| Motor road | 122 | E60, asphalt pavement |
| Channel network | 122-124,5 | 4 channels |

| | | |
|---|---|---|
| Channel | 124,7 | Tsivi, channel width 13 m |
| Motor road | 126,6 | Chaladidi-Khorga-Khobi, asphalt pavement |
| Channel | 128,5 | Tsivi, channel width 32 m |
| Channel | 129,3 | channel width 5 m |
| Channel | 138,1 | Tsivi, channel width 32 m |
| Channel | 138,3 | channel width 4 m |

**Table 30. List of natural and topographical obstacles of the interconnector.**

### C.2.7.4. The Gas interconnector process diagram

The route of the Gas interconnector can be represented as a diagram below.

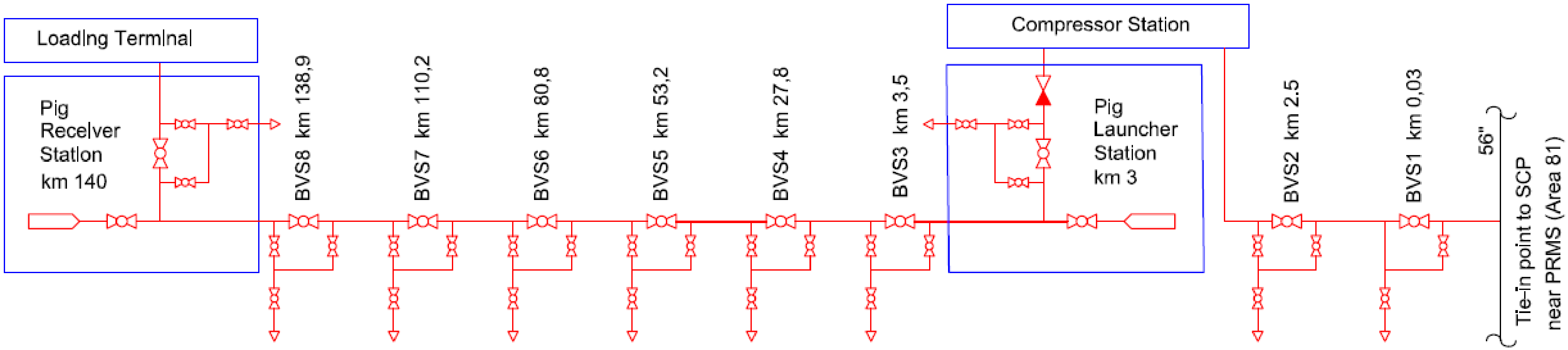



Figure 56. The interconnector process flow diagram.

### C.2.7.5. The main facilities on the Gas interconnector

#### C.2.7.5.1. Tie-in point of the interconnector to SCP Gas main pipeline

A tie-in to the SCP 56 inches Main Gas pipeline is envisaged in the area of the existing Gas Metering Station (upstream along the Gas line). Connection to the existing Gas pipeline is provided by tapping under pressure according to the technology of the company T.D. Williamson. At a distance of 30 m from the tie-in point, there is a ball valve unit BVS1 with a non-return valve. The location of the tie-in point is shown in the plan in Figure 54.

#### C.2.7.5.2. Point of connection to the Head compressor station

The compressor station is located about 3 km from the tie-in point to the SCP Gas pipeline. The connection point of the CS is combined with the pig launcher unit in the pipeline. A check valve and a two-sided blow-down valve are provided on the discharge apron. The CS site is cut-off from the linear part of the pipeline by insulating monoblocks (monolithic isolating joint), which are installed on the suction and discharge aprons. The shutdown safety valves of CS - BVS2 and BVS3 are located at a distance of 500 m from the point of connection. The location of the connection point to the CS, the pig launcher unit and security valves are shown in the diagram in Figure 56.

#### C.2.7.5.3. Loading terminal connection point

The loading terminal is located at the endpoint of the Gas interconnector near the point of 140 km. The terminal connection unit is combined with the pig receiving unit (of cleaning and diagnostic devices). The input apron to the terminal is the bypass line of the pig receiving unit. In front of the terminal site, an insulating monoblock is provided on the input loop. The shutdown valve of the loading terminal is located at the point of km 138.9 of the interconnector.

#### C.2.7.5.4. A pig launcher/receiving units

The pig launcher/receiving units are used to periodically clean the internal cavity during the operation of the Gas pipeline and pass the ultrasonic cavity detector without stopping of Gas supplying.

In accordance with the interconnector process diagram (Figure 56), the installation of the pig launcher unit combined with the connection point to the compressor station is provided on km 3 and the pig receiving unit at the end of the Gas pipeline in the area of the loading terminal site.

At the pig launcher/receiving units are provided:

- *chamber of the launcher and receiving with fast-opening end shutter;*
- *piping for purging and filling the launching and receiving chamber with natural Gas;*
- *strapping pipelines and shut-off valves, which ensure the start, passage, and adjustment of the speed of the cleaning device, as well as provide the reduction and adjustment of the speed of movement of the cleaning device at receiving;*
- *the drainage system on the receiving chamber and the condensate trap;*
- *signaling sensors of the passage of cleaning devices;*
- *lifting equipment and handling trolley.*

Launching and receiving chambers are equipped with fast-opening end shutters (End Closures) and are supplied complete with spare parts or retrieval of cleaning devices, lifting it to transport (lifting equipment and handling trolley). The fast-opening end shutters are equipped with safety mechanisms that prevent their opening while the chambers are under pressure.

The internal diameter of the receiving and launching chambers is taken larger than the diameter of the Gas pipeline to ensure the kicking of pig and retrieval of pig and diagnostic devices. The receiving and launching chambers are equipped with pressure gauges and signaling sensors for cleaning and diagnostic devices. The passage detectors are also installed.

The piping and the condensate trap are provided for underground performance, the chambers are installed above ground on supports. The pig launcher/receiving units are separated from the linear part of the pipeline by insulating monoblocks.

Anchoring flanges and anchor blocks are provided for the limitation of the movements of the pig launcher/receiving units under the action of the temperature difference and internal pressure.

The vent stack is located at a distance of 50 m from the site of pig launcher/receiving units.

For the normal passage of the cleaning devices (pig), the full-bore valves, bends of radius not less than 5D, tees with grids on the branches with a branch diameter equal to or more than 30% of the main diameter are provided.

Valves with a Gas/hydraulic actuator and a pneumatic actuator are equipped with an electro-pneumatic control unit, with a manual backup. Valves overweigh more than 150 kg are mounted on a support.

Figure 57. General view on pig launcher/receiving unit.

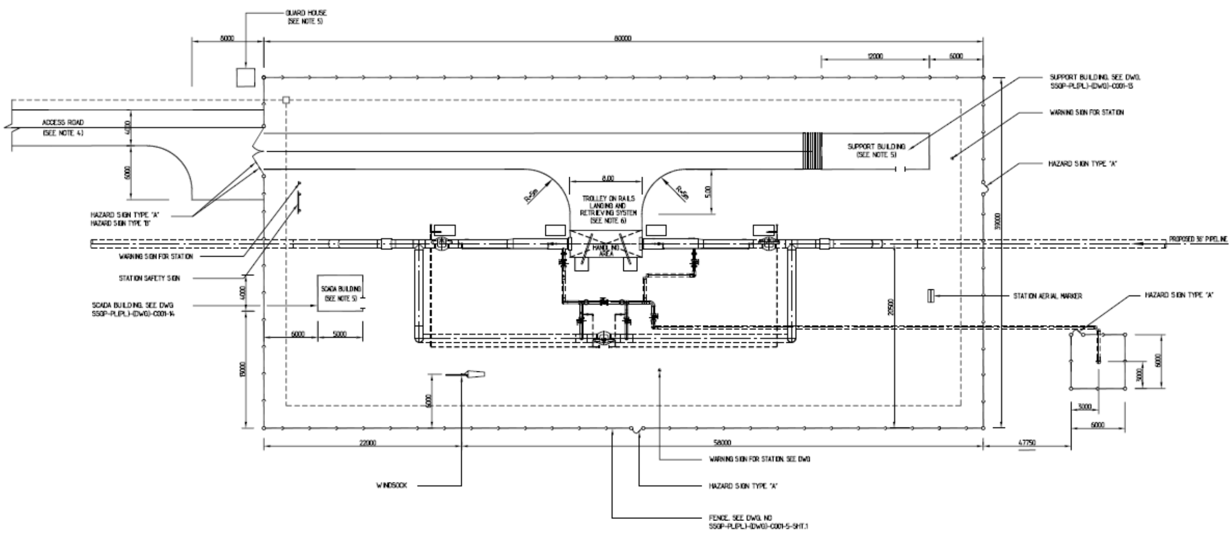


Figure 58. Plot plan of pig launcher/receiving unit.

#### C.2.7.5.5. Block valve stations

Block valve stations are designed to shut off and purge the relevant sections of the pipeline through the purge vent stack. The vent stack is situated at a distance of 15m from the block valve station on the site.

Block valve stations are located along the pipeline at a distance of no more than 30 km from each other. Structurally the valve units are provided in the underground option. The diameter of the main BVS1 and BVS2 valves is 28”, the diameter of the piping and valves is 8”. The diameter of the main valves is BVS3-BVS8 36”, the diameter of the piping and valves is 12”.

Valves are provided with a Gas/hydraulic actuator, equipped with an electro-pneumatic control unit and a manual backup.

On the block valve stations are provided with the fittings for the installation of monitoring and measuring gauges.

Figure 59. General view on linear block valve station.

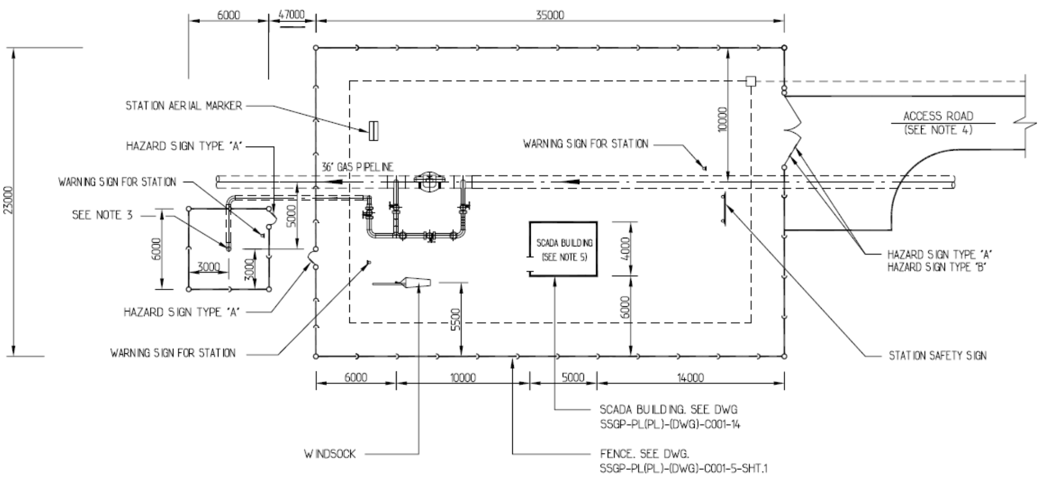



Figure 60. Plot plan of a linear block valve station.

### C.2.7.5.6. Crossings through natural and manmade obstructions

***Road crossings***

The Gas interconnector route in its length crosses the main road, local roads with bituminous pavement (asphalt) or slab (concrete) surface and rural dirt roads.
Construction of crossings on the main road and the local roads are provided in accordance with the recommendations of API RP 1102. The Gas interconnector crosses all roads at an angle close to $90^0$ but not less than $70^0$. The pipeline is lower into the case at the intersection mainly by the method of horizontal directional drilling (HDD) or using other special equipment.
At the crossing with dirt roads, the pipeline is laid without a case using the open trench method.
In the crossing roads, the Gas pipeline is laid to a depth minimum of the 1.5 m from the surface of the embankment.
On the road crossing the warning signs are placed.

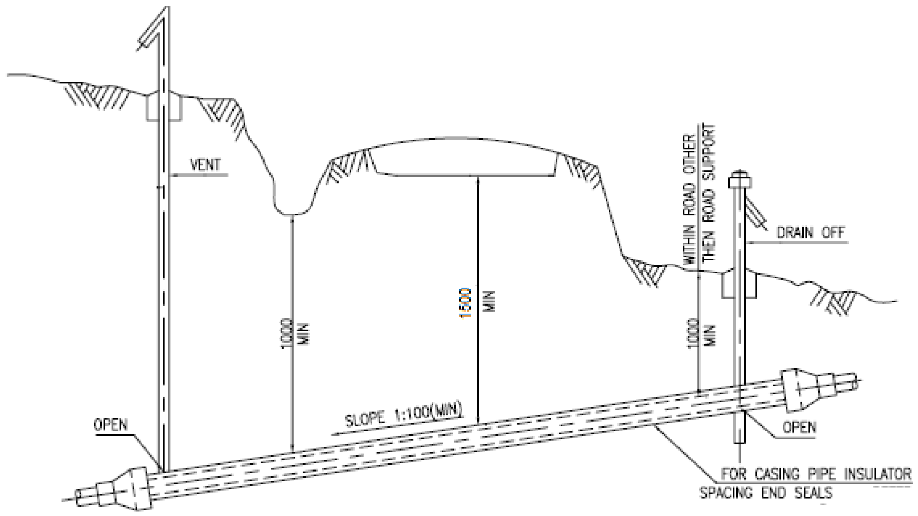



Figure 61. Typical road/highway cased crossing (scheme).

***Railway crossings***

The pipeline route crosses one railroad.
The construction of the railroad crossing is provided in accordance with API RP 1102 recommendations. The Gas interconnector crosses all roads at an angle close to $90^0$ but not less than $70^0$. The pipeline is lower into the case at the intersection mainly by the method of horizontal directional drilling or using other special equipment.
Under the embankment of the railway, the Gas pipeline is laid straight line. The minimum distance from the bottom of the rail to the top of the case is at least 3 m.
A warning sign is placed at the intersection with the railway on both sides.

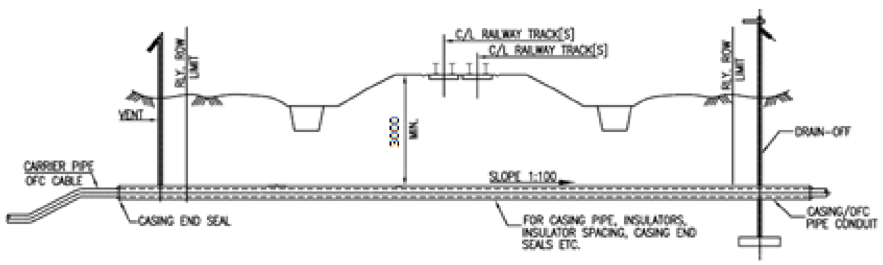



Figure 62. Typical detail of railway crossing.

***Waterway crossings***

Interconnector crossing through the water barriers is performed in an open trench method. If the geological conditions are permits, can be used the HDD method.

During the construction by the open trench method, one of the following manners can be applied:

1. With a partial overlap of the channel dumping temporary mounds of imported coarse-grained soil;
2. With a temporary metal or wooden bridge arrangement.

Prior to the arrangement of the underwater trench, the following work is performed:

1. Secure project directions and rappers;
2. The depth of the watercourse is measured and the correspondence of the actual bottom profile to the design one is determined;
3. A survey of the river section at the design width of the underwater trench is carried out to identify random obstacles.

Excavated soil which is suitable for backfilling a trench, is stored in a channel so as not to block the flow of water.

If the excavated soil is not suitable for backfilling the trench, then it is removed to the designated storage areas, and the trench is filled with imported soil.

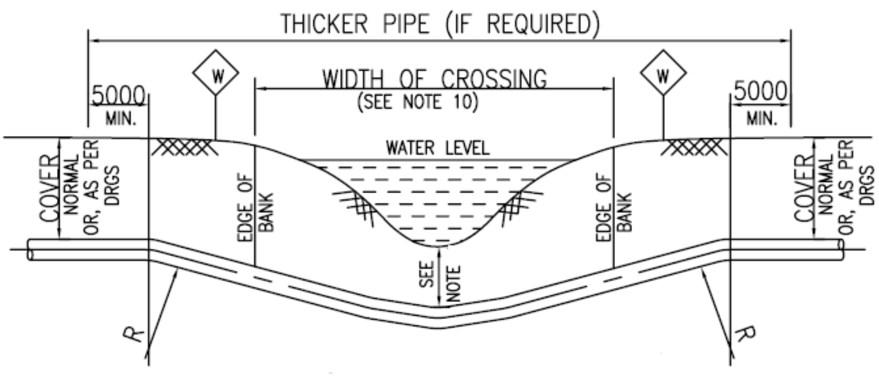
The pipeline against the ascent is loaded by concrete coating or by reinforced concrete ring weights consisting of two parts (halves) bolted together.

The pipe is laid at a depth below the possible changing of the river bed.

All major river and channel crossings, which are built by open trench method, and all HDD crossings will be pre-tested for a minimum period of two (2) hours without a loss of pressure. This pre-test shall be carried out prior to the installation of the pipes into the trench or pulling the pipes in the bore.

This pipe section shall be hydrostatically tested to the minimum test pressure for that test section.

On crossings through channels made by open trench methods, strengthening of banks by gabions to prevent their collapse is to be performed.




THE MINIMUM COVER OVER THE PIPE MEASURED BELOW THE MAXIMUM SCOUR DEPTH SHALL BE
(a) 1500 FOR EARTH STREAM BOTTOM.
(b) 1000 FOR ROCKY STREAM BOTTOM.

**Figure 63. Typical detail of water stream crossing.**

***Underground services crossings (including the different pipelines)***

When crossing the pipeline with existing communication cables, electrical cables, existing different pipelines also, the clear distance of at least 0.6 m between the pipeline and the existing communication is maintained. Basically, the Gas pipeline will be laid under the existing communications. If the existing communication is laid deep and it is possible to maintain a clear distance of at least 0.6 m with the Gas pipeline, then a Gas pipeline can be laid under the communication.

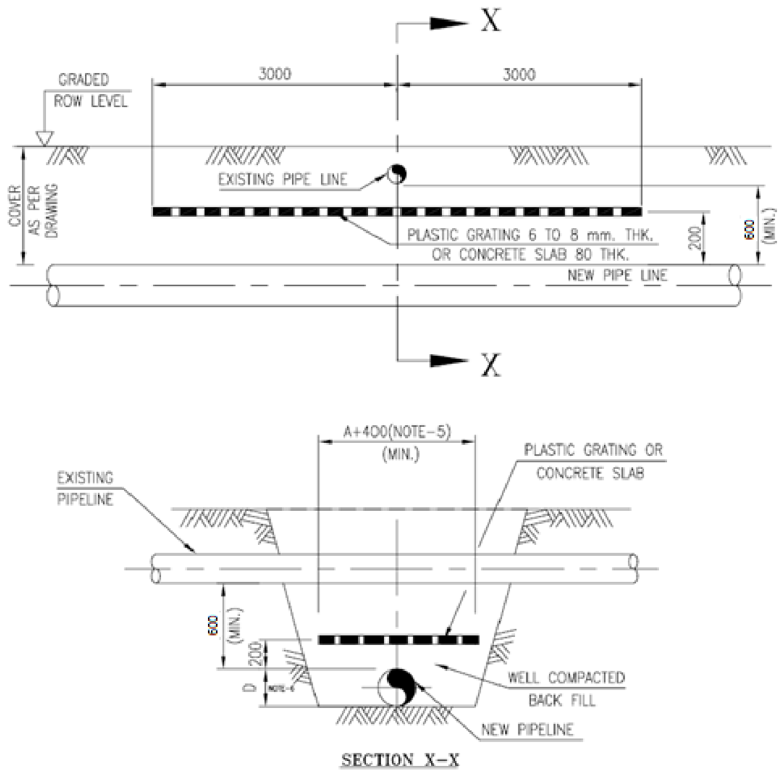



Figure 64. Typical underground pipeline crossing.

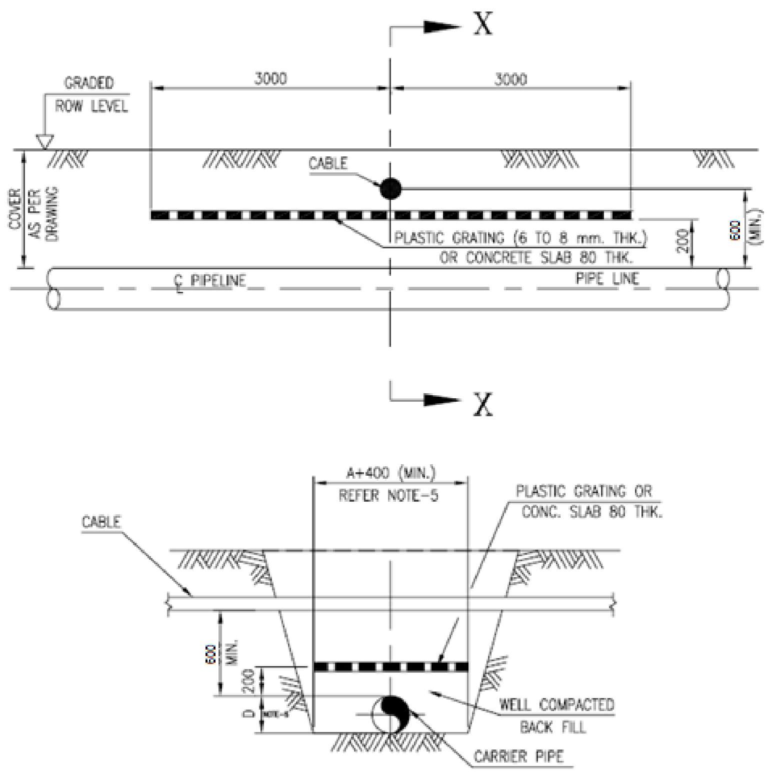



Figure 65. Typical underground cable crossing.

### *Electrical high voltage transmission line crossings*

A minimum distance between Gas the pipeline and tower footings and its grounding elements shall be 10 m, otherwise, effective measures such as the following shall be provided to mitigate any adverse effects:

- *addition of pipeline grounding with polarization cells to prevent CP current leakage,*
- *equipotential mats and gratings at aboveground facilities to protect operators, and*
- *an extra coating of the pipeline near the tower.*

The pipeline intersection with electric power lines to be maintained if the distance between the lowest wireline and ground level is less than 8 meters at least.

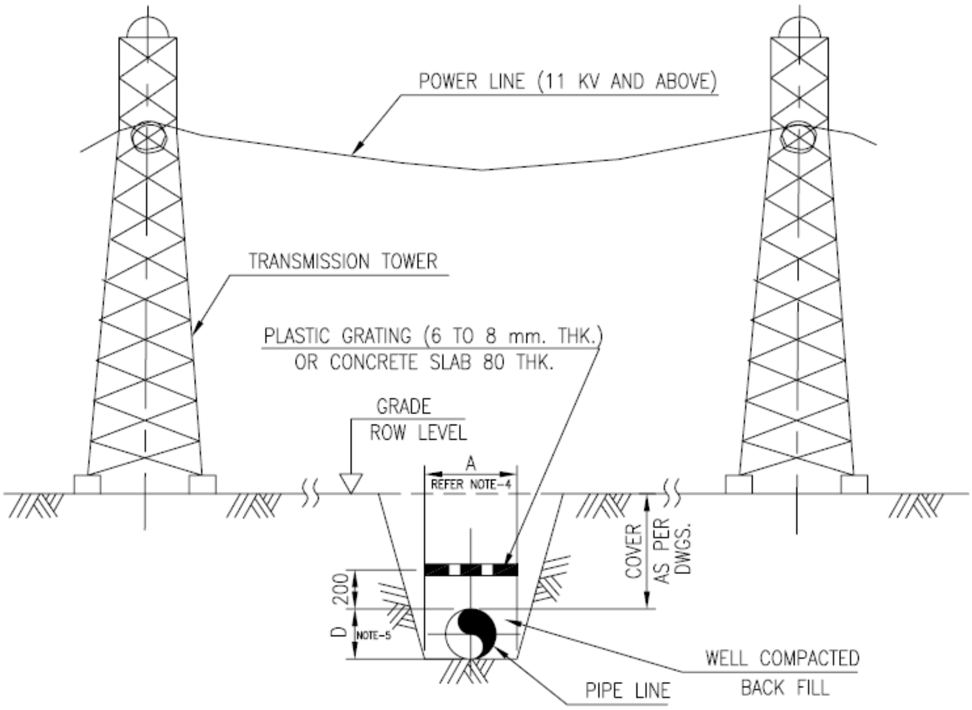



**Figure 66. Above-ground power line crossing.**

### *Buoyancy control*

The stability of the Gas pipeline position (against ascent) laid on the flooded sections of the pipeline route must be checked for each section (depending on the construction conditions).
The choice of design and methods of the Gas pipeline fixing is made depending on the specific conditions or method of construction, data of engineering surveys and design loads that act on the pipeline.
The following options of design to be provided:

1. Concrete coating.

The concrete coating will carry out in the factory. The concrete coating may be used where it is required. It can be applied to an individual coating thickness with reinforcement concrete. The ends of each joint shall be bare to make a welding operation.

2. Set-on the pipe weights.

This type of weight is used for pipe loading only in a free water trench.

3. Bolt-on weights consisting of two semi-weights connected with bolts and nuts.

Under the weights on the pipe are mounted the protective mats that prevent the sliding of weights on the pipe and damage to the anticorrosive insulation.

#### C.2.7.6. The initial Data and Technical parameters of the Gas interconnector

In this section, we will describe the Initial data for the calculation and the possible Technical solutions of the design of Gas interconnector between the tie-in point of SCP and Gas loading terminal.

##### C.2.7.6.1. Technical parameters of the Gas interconnector

In agreement with the Consortium partners, the following parameters of the Gas interconnector were accepted:

- *The pressure at the tie-in point to the SCP is 5,0 MPa;*
- *The pressure at the outlet of the compressor station is calculated (*Table 21*);*

The diagram below shows the whole process of CNG ship loading using the onshore terminal in the version with the Gas source as SCP. Data and calculations are made for the maximum scenario of Gas supply to Ukraine equal to 6,30 mscmd.

Structurally, the Gas interconnector consists of Section 1 - Gas transmission pipeline from the tie-in point in the SCP to the Main Compressor Station, in Figure 101 is marked as Pipeline 1 and Section 2 between the Head compressor station and the onshore Gas loading terminal in the port area of Poti, in the diagram, marked as Pipeline 2.

##### C.2.7.6.2. Process and strength characteristics calculations

The thermo-hydraulic calculations of the Gas interconnector are presented in the tables below. As mentioned above in Figure 53, the whole Gas interconnector was divided into two sections. Section 1 (on Figure 101– Pipeline 1 with a length of 3,0 km) and Section 2 (Pipeline 2 with a length of 140,0 km).

```
= HYDRAULIC AND THERMAL CALCULATION OF PIPELINE =
----------------------------------------------------------------------
 Pipeline Inlet flow - 4      ---------> 5      -    Outlet Flow.
----------------------------------------------------------------------
= INITIAL DATA =
----------------------------------------------------------------------
 Flow                                              kg/h        184212.800
                                                   scm/h       262500.0
 (t=20 C,P=0.1013 Mpa)                             mscmd            6.300
 Initial Pressure                                  MPa              6.971
                                                   barg            71.08
 Initial Temperature                               C               40.00
                                                   K              313.15
 Pipeline Length                                   m           140000.0
----------------------------------------------------------------------
 Absolute roughness                                mm                .10
----------------------------------------------------------------------
 No of   Sect.   Height  External Pipe    Heat    Ambien  Num.   Sect.
 sect.   Length  differ. pipe     thickn. transf. Temp.   step   effic.
                         Diam.            coef.           calcul.
                                          W/(m^2K)
         m        m       mm       mm             C
----------------------------------------------------------------------
 1    140000.     0.    720.0    10.0     2.80    10.0    25     1.00
----------------------------------------------------------------------

THERMAL CONDITIONS

Section  1
  Pipeline Location - Underground
  Depth of cover (to the top of the pipe), m          0.8
  Thermal conductivity coefficient of the soil, W/(m*K) 2.00

= CALCULATION RESULTS =
----------------------------------------------------------------------
 Initial characteristics :                Volume gas fraction    1.000000
 Velocity             2.656 m/s           Flow Mode - Single Phase

 Characteristics at the end of the section (pipeline):
----------------------------------------------------------------------
 No of   Volume      Velocity  Flow          Pressure       Temperature
 section gas                   mode
         fraction     m/s                  Mpa      barg    C      K
----------------------------------------------------------------------
 1       1.000000     2.433   Single      6.531   66.59     9.6   282.8
                               Phase
----------------------------------------------------------------------

 18-Jul-19
```

**Table 31. Thermo-hydraulic calculation of Section 2 of the Gas interconnector**

Also, the pipe strength calculations were made for these sections.

**PIPE WALL THICKNESS CALCULATION**

Version 1.0

| | | | |
|---|---|---|---|
| Project Name | Gas Interconnector Pipeline | By | FIV |
| Project Number | | Chkd by | YMN |
| | | Appd by | KVI |

Design Pressure (P): 55 bar g — 797,71 psi g

SMYS (psi):

| | | | | | |
|---|---|---|---|---|---|
| 35000 | for pipe Gr. B | 42000 | for pipe X42 | 46000 | for pipe X46 |
| 52000 | for pipe X52 | 56000 | for pipe X56 | 60000 | for pipe X60 |
| 65000 | for pipe X65 | 70000 | for pipe X70 | 80000 | for pipe X80 |

Joint factor (E): 1

Corrosion Allowance: 2 mm

Temperature derating factor (T): 1

Design code: ASME B31.8

Formula used :

t = P x D / (2 x F x SMYS x E x T) + Corrosion allowance

| No | Outside Dia. (D) | Design Factor (F) | SMYS | Grade | Wall thickness Calculated | Wall thickness Calculated | Wall thickness Available |
|---|---|---|---|---|---|---|---|
| | inch | | psi | | inch | mm | inch |
| 1 | 28 | 0,72 | 70000 | X70 | 0,300 | 9,63 | 0,312 |
| 2 | 28 | 0,6 | 70000 | X70 | 0,345 | 10,75 | 0,375 |
| 3 | 28 | 0,5 | 70000 | X70 | 0,398 | 12,10 | 0,406 |

Table 32.Pipe wall thickness calculation of Section 1 of the Gas interconnector

**PIPE WALL THICKNESS CALCULATION**

Version 1.0

| | | | |
|---|---|---|---|
| Project Name | Gas Interconnector Pipeline | By | FIV |
| Project Number | | Chkd by | YMN |
| | | Appd by | KVI |

Design Pressure (P): 71,1 bar g — 1031,22 psi g

SMYS (psi):

| | | | | | |
|---|---|---|---|---|---|
| 35000 | for pipe Gr. B | 42000 | for pipe X42 | 46000 | for pipe X46 |
| 52000 | for pipe X52 | 56000 | for pipe X56 | 60000 | for pipe X60 |
| 65000 | for pipe X65 | 70000 | for pipe X70 | 80000 | for pipe X80 |

Joint factor (E): 1

Corrosion Allowance: 2 mm

Temperature derating factor (T): 1

Design code: ASME B31.8

Formula used :

t = P x D / (2 x F x SMYS x E x T) + Corrosion allowance

| No | Outside Dia. (D) | Design Factor (F) | SMYS | Grade | Wall thickness Calculated | Wall thickness Calculated | Wall thickness Available |
|---|---|---|---|---|---|---|---|
| | inch | | psi | | inch | mm | inch |
| 1 | 28 | 0,72 | 70000 | X70 | 0,365 | 11,28 | 0,469 |
| 2 | 28 | 0,6 | 70000 | X70 | 0,422 | 12,73 | 0,562 |
| 3 | 28 | 0,5 | 70000 | X70 | 0,491 | 14,48 | 0,625 |

Table 33. Pipe wall thickness calculation of Section 2 of the Gas interconnector

The pipes wall thickness was calculated depending on the class of terrain (location class) in accordance with ASME B31.8 with corrosion allowance adopted as 2,0 mm.
The results of strength calculations of the Gas interconnector pipeline are summarized in Table 34. The specified pipeline parameters will be taken into account in a cost calculation of Gas interconnector construction.

| Location Class | Outside Diameter, inch | Design Factor | SMYS | Grade | Calculated WT, inch | Calculated WT plus corrosion allowance, mm | Specified WT, mm |
|---|---|---|---|---|---|---|---|
| 1 | 28 | 0,72 | 70000 | X70 | 0.300 | 9.63 | 0.312 |
| 2 | 28 | 0,6 | 70000 | X70 | 0.345 | 10.75 | 0.375 |
| 3 | 28 | 0,5 | 70000 | X70 | 0.398 | 12.10 | 0.406 |
| 1 | 28 | 0,72 | 70000 | X70 | 0,365 | 11,28 | 0,469 |
| 2 | 28 | 0,6 | 70000 | X70 | 0,422 | 12,73 | 0,562 |
| 3 | 28 | 0,5 | 70000 | X70 | 0,491 | 14,48 | 0,625 |

Table 34. Pipes wall thickness calculation results.

#### C.2.7.6.3. Technical and design parameters of the interconnector

##### C.2.7.6.3.A. Pipes and fittings

***Pipes***

For the construction of the linear part of the Gas pipeline, pipes are provided in accordance with ISO 3183 with a diameter of 28”x0.582.

The basic requirements for pipes are:

- *the level of requirements PSL-2;*
- *type of pipe SAWL with one longitudinal seam;*
- *strength group L485M (X70M);*
- *length of pipes 10.5 m - 12 m.*

For pipelines with a diameter of 16” and less for piping of pig receiving/launching units and valve units, to be provided with the seamless pipes (SMLS) according to ISO 3183, PSL2, strength group L290 (X42). The wall thickness for pipelines is calculated according to ASME B31.8 (design factor 0.5, corrosion allowance 2,0 mm).

***Fittings***

Tees, elbows and reducing fittings with a diameter of 16” and more are provided according to the Standard MSS-SP-75, less than 16” - according to ASME B16.9. Tees with a diameter of 36" with branches with a diameter of 30% or more of the main diameter will be provided with grids.

##### C.2.7.6.3.B. Anticorrosive protection

Protection of the Gas pipeline against corrosion is provided by an anti-corrosion coating and facilities of electrochemical protection.

Pipes for the construction of the linear part of the Gas interconnector will be supplied with factory-made insulation of three-layer polyethylene coating of 2.5 mm thickness for pipes with a diameter of 28”.

Insulation of welded joints of the underground Gas pipeline with a factory coating is provided for with heat-shrinking sleeves with a minimum width of 450mm, which are completely supplied with a separate lock and primer.

In areas of horizontal drilling or HDD at the intersections of the pipeline with roads and rivers, the insulation of welds is provided for with special heat-shrinkable cuffs for HDD crossings.

Induction taps for underground Gas pipelines are provided with a factory outer polyurethane coating of 1.5 mm thickness.
To protect against corrosion of the underground part of valves, fittings, and pipelines of valve units and pig receiving and launching units, a polyurethane coating with a thickness of 1.5 mm is provided.
For the protection of aboveground sections of pipelines and equipment from atmospheric corrosion, protective paint and varnish coating are provided in accordance with № A 4.09 of table A.4 of ISO 12944-5[6] NDFT of at least with a thickness not less than 280 microns.

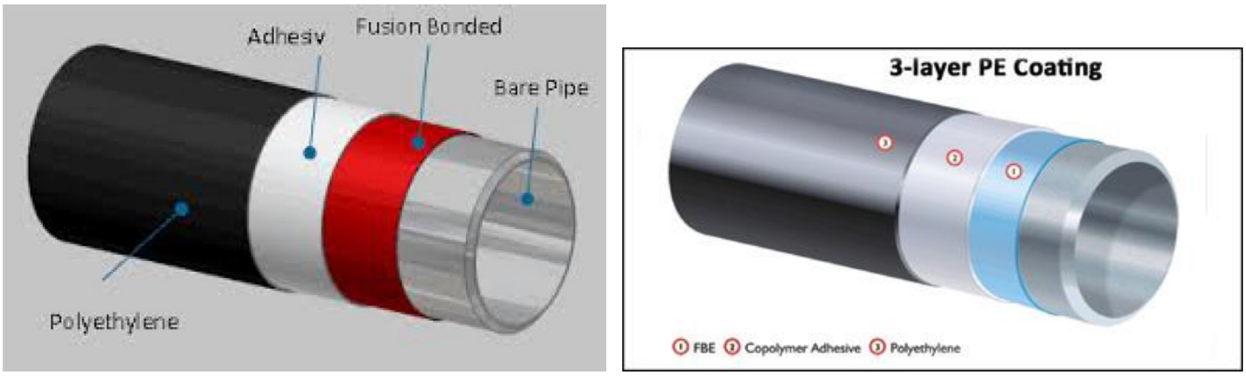



Figure 67.3 layer polyethylene anti-corrosion coating.

### C.2.7.7. Construction method statement

#### C.2.7.7.1. Depth of cover

The pipeline is mainly laid at a depth not less than 1,0 m from the ground surface (depth of cover). When passing through irrigated fields, the Gas pipeline must be laid to a depth of not less than 1.5 m from the ground surface. When the Gas pipeline is crossing the roads, it must be laid at a depth not less than 1.5 m from the ground surface of the embankment, railways - 3 m from the rail foot, on small streams - 1.5 m, on large ones - 2.0 m.

#### C.2.7.7.2. Bending

The pipeline is laid mostly parallel to the terrain.
The pipeline is laid in horizontal and vertical planes by elastic bending with a bending radius of at least 1000 m.
Bends with a radius of curvature of 40D are made on the highway by cold bending from pipes supplied for the construction of a Gas pipeline.
For pipe bends of 15” or more, induction taps with a factory-made 5D radius according to ISO 15590-1 are used. Induction taps for underground Gas pipelines are provided with a factory outer polyurethane coating.

#### C.2.7.7.3. Joining

The connection of pipes among themselves and with other components is provided by butt-welding (semi-automatic or manual).
Quality control of all-welded joints of the pipeline and structures (assemblies) is provided by the radiographic method (radiographic inspection). Welds made by semi-automatic welding are additionally controlled by a mechanized ultrasonic inspection system.

#### C.2.7.7.4. Soil erosion protection

To protect against erosion of the Gas pipeline trench and to reduce damage to the environment caused by the construction of the Gas pipeline, the following protective measures are provided.

- *The jumpers arrangement in the trench of the bags filled with the sand-cement mixture.*

- *The arrangement of drainage ditches, fixed with monolithic concrete, and rollers of local soil with the enforcement of slopes.*
- *Protection of slope plots from erosion is carried out by retaining the drain and discharging it to a safe place with the help of highland ditches and rollers.*
- *Fastening of ravines is carried out by arranging interfacing hydraulic structures – water speeds, water check drops. The drops are arranged in the form of retaining walls made of concrete or masonry on cement mortar.*
- *Stability of slopes with a sloping grade of more than $35^0$ and more is provided by the arrangement of retaining walls of gabions.*
- *Collapsing shores of watercourses are secured with gabion boxes or stone sketches. The thickness of the rough gravel filter in each case is determined by calculation depending on the geological and hydrological characteristics of the watercourse.*

### C.2.7.7.5. Passage of the Gas pipeline on the hillsides

When laying a Gas pipeline on hillsides with the slope grade of more than $8^0$, the constant passage for the period of construction and installation works and the subsequent operation of the pipeline is ensured by installing a 14 m wide shelf embedded in the slope Figure 68. Depending on the angle of inclination, the following shelves are available.

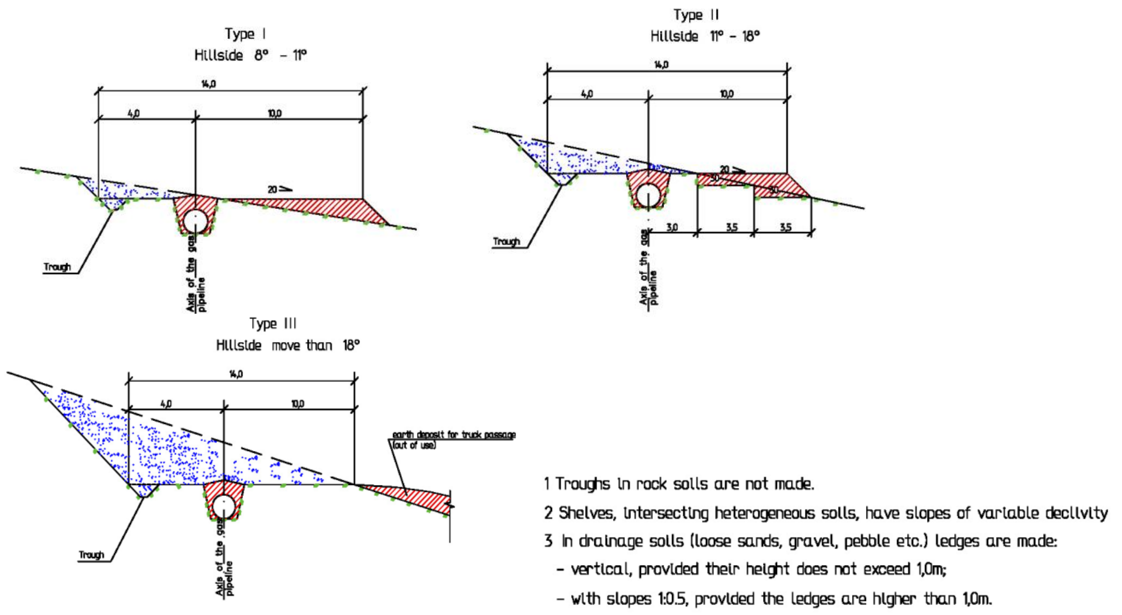



**Figure 68. Arrangement of passages along the pipeline in a different hillside.**

When laying the pipeline on slopes with the slope grade from above $8^0$ to $11^0$ inclusive (Figure above, Type I), cutting and filling of soil is provided in order to build a working strip (shelf).
The shelf arrangement, in this case, is provided by dumping embankment directly on the slope.
With a transverse slope of the slope grade above $11^0$ to $18^0$ inclusive, taking into account the properties of the soil, ledges are provided to prevent the soil from sliding along the slope (Figure above, Type II).
On slopes with the slope grade above $18^0$, shelves are provided only by cutting the soil (Figure above, Type III).
A pipeline trench is provided in the continental soil near the foot of the slope at a distance that ensures the normal operation of the earthmoving equipment and transport machines.

In order to prevent the destruction of the shelves by storm waters, an arrangement of upland ditches and longitudinal trays is envisaged, the dimensions and stabilization of which is depending on the size of the longitudinal slope.
Highland ditches are arranged above the shelves up to the relief in places of possible runoff of surface water in the direction of the shelf.
For removal of the storm (surface) water at the bottom of the shelf-slope, a longitudinal chute with a longitudinal slope of at least 0.2% is provided. The shelf is given a slope of 2% in both directions from the axis of the trench.

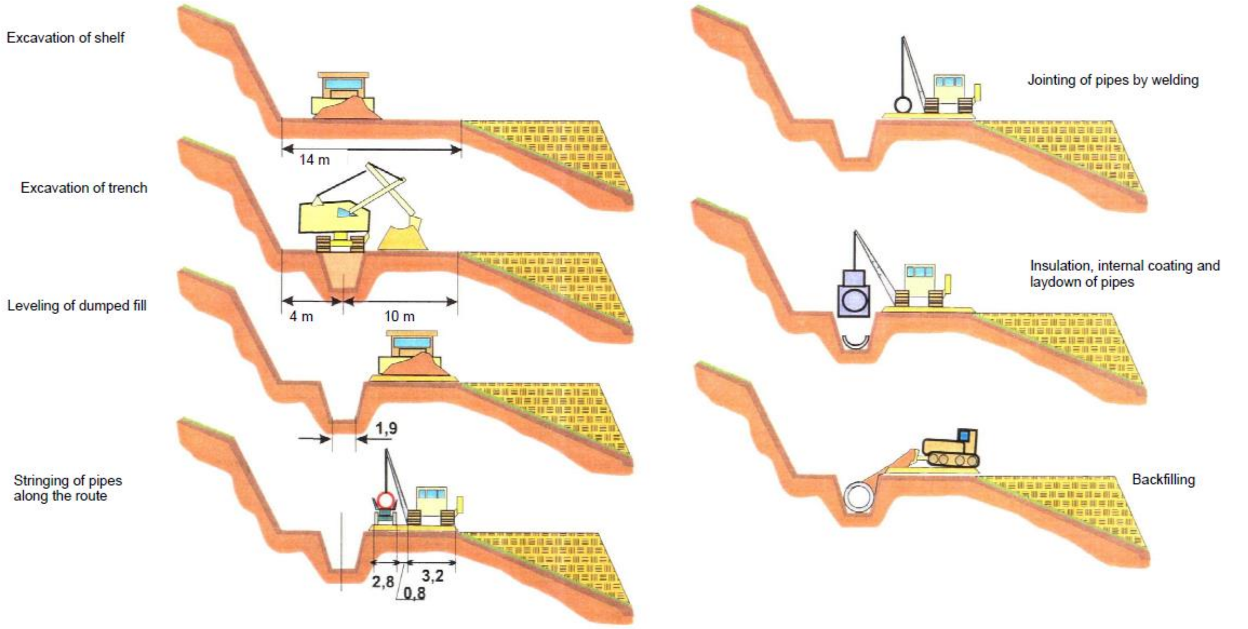



Figure 69. Shelf arrangement on the slopes.

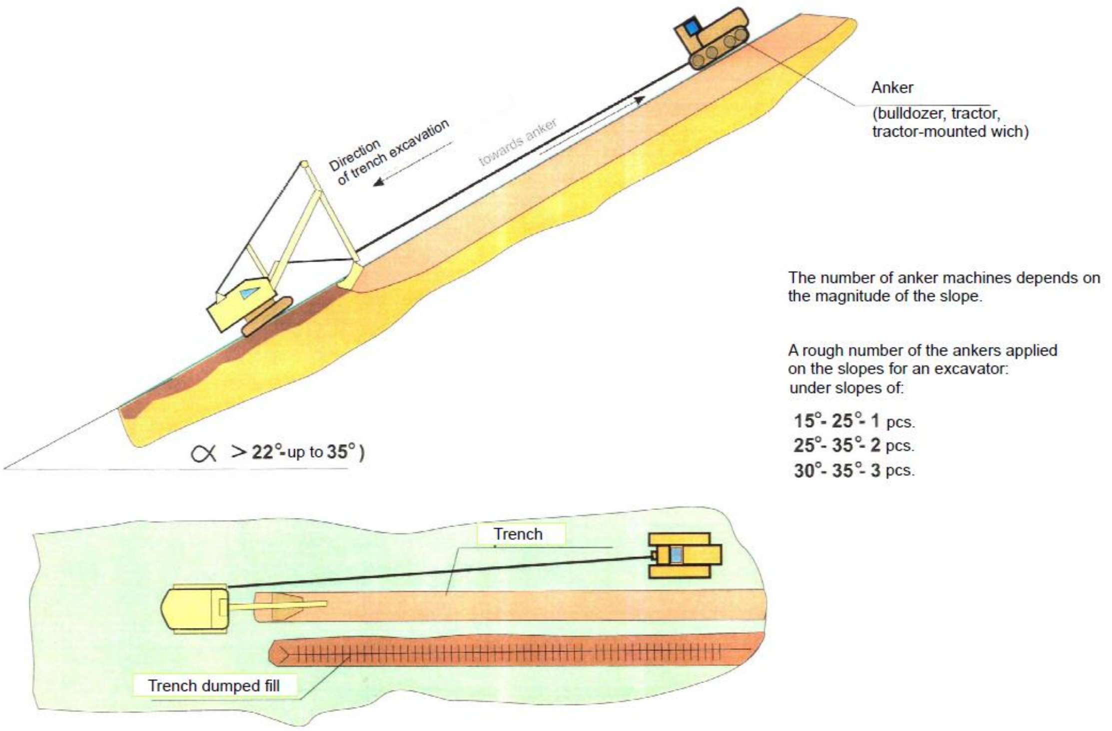



Figure 70. Excavation of trenches on inclines from 22 grade to 35 grade.

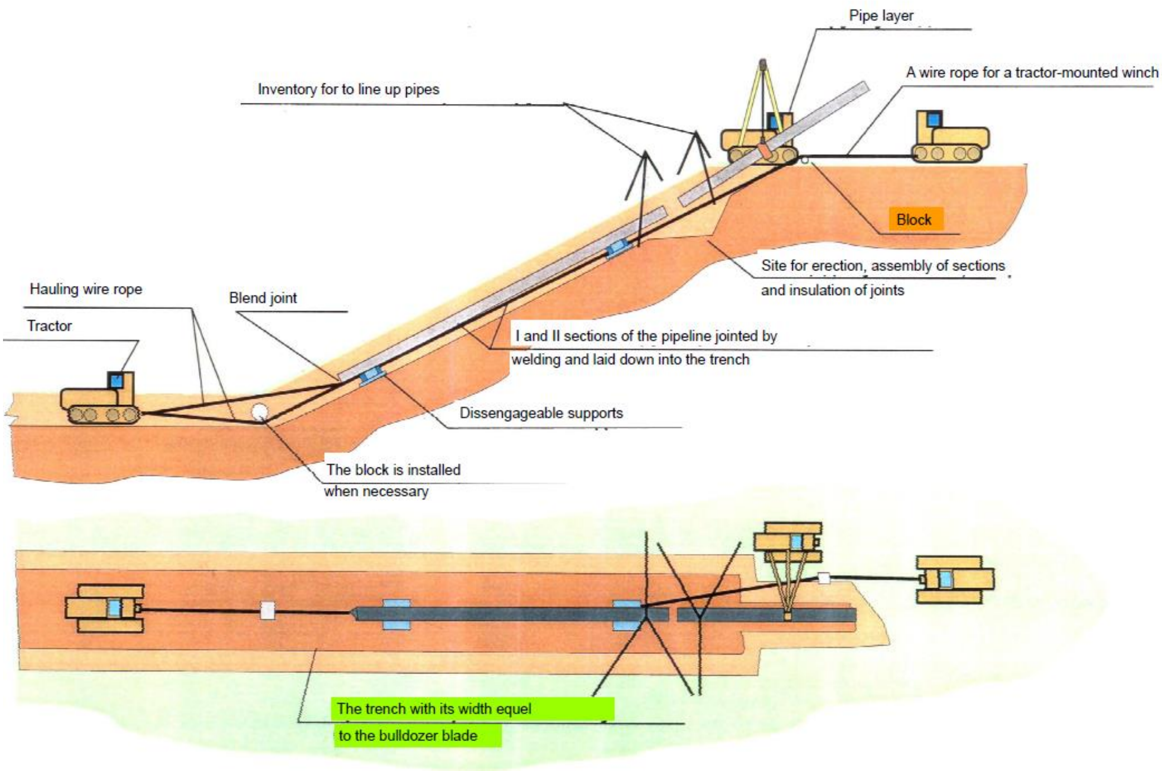



Figure 71. Work on longitudinal inclines over 30 grade.

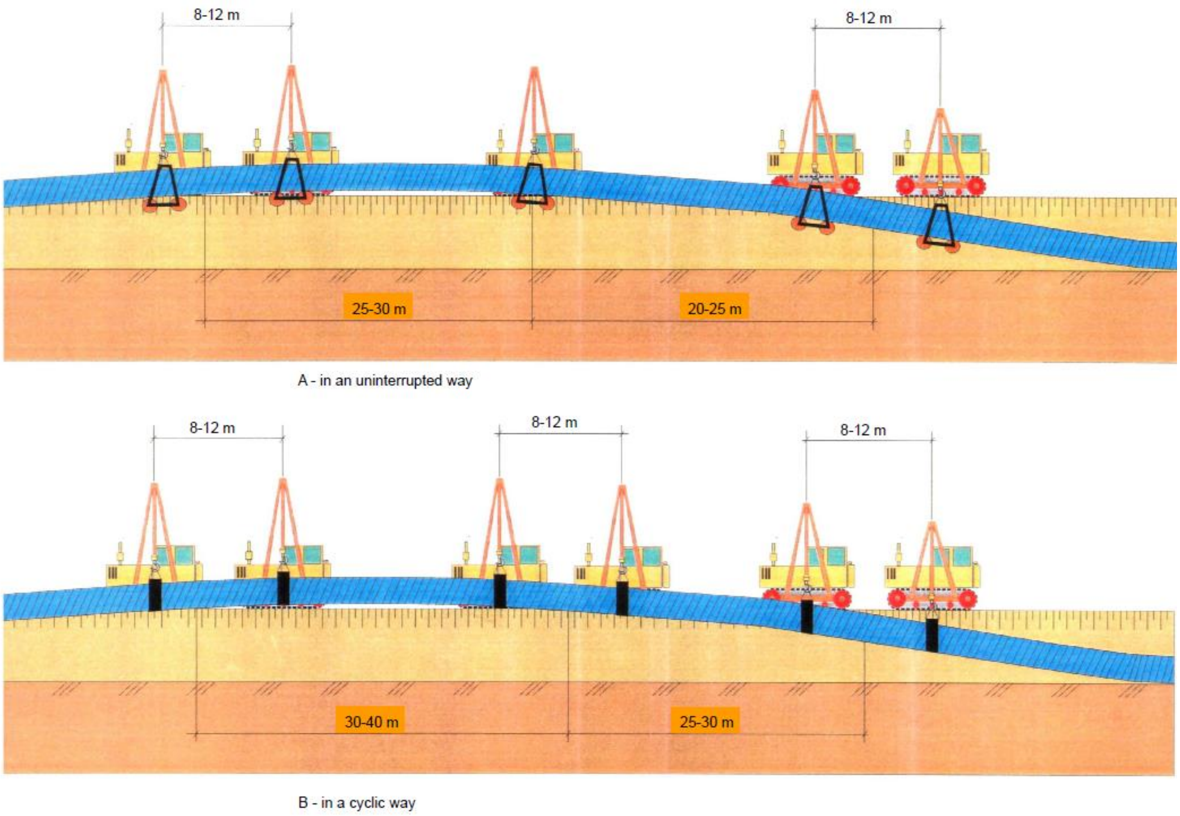



Figure 72. Scheme for laying down an insulated pipeline.

#### C.2.7.8. Quality control

The system of the Quality audit will guarantee the essential audit and tests for all the works concerning materials Qualities, works execution Quality and functioning Quality to confirm the Standards and the local lows and Detailed Construction Design.
The Detailed Design will pay maximum attention to the detection and elimination or minimization of operational risks, and Project aims will be achieved through a flexible management structure, trying to improve performance and raise Quality indexes.
The system of Quality Control organization and implementation is the tool that allows them and the Customer to evaluate the Quality of construction at any time and to interfere, if necessary.
This System consists of the following elements and stages:
The arrangement of the Quality Control service whose director is responsible for:

- *all the measures necessary to achieve the Quality of works;*
- *all Quality control procedures and orders at, and outside the sites are followed;*
- *adoption of technical logbooks and organizing Quality control;*
- *all Quality control process documents including inspections and reports;*
- *supervision of staff training.*
- *creation of the corresponding working conditions and adequate reward for employees involved in construction, encouragement of collective work, initiative and pride for participation in the Project.*

The pipeline construction will be accompanied by an incoming, operative and acceptance inspection.
The incoming control will include the Detailed Design check-up for the completeness and corresponding Standards, and also check-up of the incoming equipment: pipes, materials and structures and their conformity to the Standards and Detailed Design Documents, certificates and passports.
The operative inspection will attend the construction and erection works, providing for the prompt defects exposure and elimination. The operation control will include inspection of construction works technique and works conformity to the Project Documentation and Standards. Operational inspection is executed by the foremen, construction supervisors, and special Quality control services.
The Acceptance control will include the inspection of the construction and erection works Quality and drawing up the relevant documentation. Special defect eliminating measures will be developed according to the inspection results taking into account the supervision.
It comprises inspection of all delivered materials, devices and equipment to ensure their high-Quality condition before delivering them to the site. The respective certificates are an integral part of the supporting documents delivered together with materials, devices, and equipment.
These inspections determine:

- *possible beginning and finish of construction and erection works and their conditions;*
- *check-up of works which are performed in this way for the first time at the site and control of their progress.*

The Quality control plan has been submitted. This plan consists of a minimum of:

- *Quality control directions;*
- *certifying group of the Quality control staff;*
- *responsibilities of each controller;*
- *the Quality control inspections and measures plan including for the Subcontractor (if anyhow what and where);*

- *the preliminary list of necessary inspections for the first stage of the construction;*
- *Quality control record keeping, a copy of the operational instructions for the controlling staff indicating their responsibilities;*
- *general explanatory note on the Project Quality control measures;*
- *the list of Acts of Concealed Works.*

The Contractor cannot perform construction and erection works if he has not submitted the Quality control plan to Customer for approval or has not received such approval.
In the context of the Quality control System, the Contractor submits the following Quality control Data:

Daily:

- *directions for necessary inspection, 24 hours before the inspection;*
- *inspection results.*

Monthly:

- *a complete summary of the most important Quality control measures, completed items of Quality control measures, deadlines for the elimination of defects and imperfections left at the end of the month according to previous inspections.*

On coordination with Customer, the Contractor (represented by the Quality control Manager) holds regular meetings on construction Quality control issues.
The Contractor (represented by the Quality control Manager) runs a separate territory on the site, where he keeps all materials, devices, and equipment that failed the qualitative and quantitative acceptance tests till the Customer agrees to further use and/or repair them.
The Contractor constantly informs the Customer about such works.
The Contractor (represented by the Quality control Manager) attaches the necessary Quality control Documents to the Acceptance and Turn-In Inspections Documents.
After the equipment pieces have been erected and revised, they are tested in an idle mode which is followed by the Serviceability and Integrity Report.
The Contractor should equip a construction laboratory and provide its operation no later than 30 days after the construction start.
The laboratory should consist of:

- *premises;*
- *all equipment necessary for its efficient operation;*
- *laboratory equipment;*
- *additional testing instruments;*
- *qualified laboratory engineers, technicians, assistants and supporting staff.*

The Customer is responsible for maintaining the laboratory in its working condition during all construction period.
In addition, within the framework of their responsibilities as to Quality control, the Contractor's laboratory staff has to be equipped with devices allowing the following tests on:

- *electrical operations;*
- *works on-field part of the pipeline;*
- *works on-site facilities;*
- *welding including steel structures' joints and reinforcement welded joints.*

Before starting any construction, the Contractor should determine and approve with Customer the list of tests to be carried out at the construction sites.
In 14 days after the order has been received, the Contractor submits a detailed laboratory operation plan including equipment work and staff qualification. Besides, he submits a list of

organizations that will carry out the tests, which cannot be performed by the construction laboratory.

After pipelines and site equipment have been erected, they should be tested in accordance with the Detailed Design, flow charts, current Standards, technical requirements and instructions for the assembled equipment, pipelines, and pipeline fittings.

The Quality control Service will strictly control that the environmental protection requirements are observed, maintaining environmental balance on every stage of construction.

## C.3. Gas loading terminal in the area of the port of Poti (Georgia).

### C.3.1. Introduction

This section addresses the Technical issues of the construction of the onshore Gas loading terminal near the port of Poti.
The Gas loading terminal is one of the links in the general Gas transportation system for loading of CNG ship for the Gas transport to Ukraine.
The loading terminal will be situated in the free lands near the port of Poti.

### C.3.2. Purpose of the Gas loading terminal

The Gas loading terminal is meant to load the CNG ship in the volumes necessary for carrying out Gas transportation in the Black Sea region. The Gas loading terminal is connected to the source of Natural Gas – the existing SCP Main Gas pipeline.
Structurally, the Gas interconnector is located after the Head compressor station and the Gas interconnector.
The main productivity parameters of the gas loading terminal are harmonized with the work productivity of the Head CS and Gas interconnector belongs to the scenario of Gas delivery of 6,30 mscmd.

### C.3.3. Glossary, abbreviations, and acronyms

In this Report, such abbreviations and acronyms were used:

| Abbreviation | Description |
|---|---|
| **ALS** | accidental limit state |
| **AR** | an additional requirement to the stated ISO Standard |
| **API** | American Petroleum Institute |
| **ASME** | American Society of Mechanical Engineers |
| **ASTM** | American Society for Testing and Materials |
| **BM** | base material |
| **BS** | British Standard |
| **CP** | cathodic protection |
| **MAOP** | maximum allowable operating pressure |
| **MR** | the modified requirement to the stated ISO Standard |
| **N** | normalized |
| **NACE** | national association of corrosion engineers |
| **NDT** | non-destructive testing |
| **QA** | Quality assurance |
| **QC** | Quality control |
| **SC** | Safety class |
| **SCP** | South Caucasus Gas Pipeline |
| **UT** | Ultrasonic testing |

Table 35. Glossary, abbreviations, and acronyms.

### C.3.4. Units of measurement.

The Units of measurement which are used in this section are shown in Table 2.

### C.3.5. Climate data and Geographic conditions of the Gas loading terminal

The area of the proposed construction of the Gas loading terminal is characterized by the following climatic characteristics (Standard SNiP 23-01).

| The Environmental parameters | Data |
|---|---|
| *Temperature:* | |
| - Average air temperature in January, $^{0}$C | 5,7 |

| | |
|---|---|
| - Average air temperature in July, $^0$C | 23,1 |
| - Average annual air temperature, $^0$C | 14,4 |
| - Absolute minimum air temperature, $^0$C | minus 11 |
| - Absolute maximum air temperature, $^0$C | 41 |
| - The average maximum temperature of the hottest month, $^0$C | 26,9 |
| - The average air temperature of the coldest five-day week with a rated of 0.92 $^0$C, | 3 |
| Maximum depth of soil freezing, cm | 40 |
| *Wind:* | |
| Prevailing wind direction in January | East |
| Prevailing wind direction in July | South-West |
| Average wind speed in January in the prevailing direction, m/s | 5,1 |
| Average wind speed in July in the prevailing direction, m/s | 3,5 |
| Wind velocity, kPa | 0,38 |
| *Precipitation:* | |
| Rainfall per year, mm | 1831 |
| Daily maximum, mm | 268 |
| The average height of snow cover, cm | 14 |
| Snow cover weight per 1 $m^2$ of a horizontal surface, kPa | 0,8 |
| Seismicity of the CS area (on the MSK-64 scale) | grade 8 |
| Average monthly relative humidity of air at 13 hours,%:<br>- the hottest month;<br>- the coldest month | <br>73<br>65 |

Table 36. Environmental parameters of the area of the Gas interconnector (pipeline end).

### C.3.6. Codes and Standards

The Codes and Standards used for design and build the Gas loading terminal near the port of Poti must meet the Standards used in the best practice of international Engineering taking into account the Georgian national Standards.

| Standard, Code | Description | Notes |
|---|---|---|
| ***ASME, ANSI, ASTM Standards*** | | |
| ASME B 16.5 | Pipes, Flanges and Flanged Fittings | |
| ASME B 16.9 | Factory-Made Wrought Steel Butt-Welding Fittings | |
| ASME B 31.8 | Gas Transmission and Distribution Piping Systems | |
| ASME B 36.10 M | Welded and Seamless Wrought Steel Pipe | |
| B31.8 - 2012 | Gas Transmission and Distribution Piping Systems | |
| ASME | Performance Test Codes | |
| ASME B31.9 | Working Pressure and Temperature Limits | |
| ASME/ANSI B16 | Standards for Pipes and Fittings | |
| ASME/ANSI B36.10/19 | Carbon, Alloy and Stainless Steel Pipes - Dimensions - Metric Units | |
| ASTM | ASTM International - Standards for Steel Pipes, Tubes and Fittings | |
| ASTM | ASTM International - Volume 01.01 Steel - Piping, Tubing, Fittings | |
| ***API Standards*** | | |
| API SPEC 5 L | Line Pipe Specification | |
| API SPEC 6 A | Specification for Wellhead & Christmas Tree Equipment | |
| API SPEC 6 D | ISO 14313:1999, Petroleum and Natural Gas Industries-Pipeline Transportation Systems-Pipeline Valves | |

| | | |
|---|---|---|
| API STD 594 | Check Valves: Wafer, Wafer-Lug, and Double Flanged Type | |
| API STD 598 | Valve Inspection and Testing | |
| API STD 599 | Metal Plug Valves - Flanged and Welding Ends | |
| API STD 602 | Compact Steel Gate Valves-Flanged, Threaded, Welding, and Extended-Body Ends | |
| API STD 608 | Metal Ball Valves Flanged and Butt-Welding Ends | |
| API STD 609 | Butterfly Valves: Double Flanged, Lug- and Wafer-Type Fifth Edition | |
| API RP 1102 | Steel Pipelines Crossing Railroads and Highways | |
| API STD 1104 | Welding of Pipelines and Related Facilities | |
| ***BS Standards*** | | |
| BS 1868 | Steel Check Valves | |
| BS 1873 | Steel Globe Valves | |
| BS 5146 | Inspection and Testing of Valves | |
| BS 5351 | Steel Ball Valves for the Petroleum, Petrochemical and Allied Industries | |
| BS 5352 | Steel Wedge Gate, Globe and Check Valves 50mm and smaller | |
| BS 6755 Part 2 | Testing of Valves Part 2: Specification for Fire Type-Testing Requirements | |
| IP6 | Institute of Petroleum Model Code of Safe Practice Part 6, Pipeline Safety Code | |
| BS 8010 | Code of Practice for Pipelines | |
| ***Other Standards*** | | |
| ISO 13623 | Petroleum and natural Gas industries - Pipeline transportation systems | |
| ISO | Pipe, Tube and Fittings Standards and Specifications | |
| DIN | Pipe, Tube and Fittings Standards and Specifications | |
| | National Georgian Codes and Standards | |

Table 37. List of applicable Codes and Standards.

### C.3.7. Description of the Gas loading terminal site

The loading terminal site will be situated on the northern territory of Poti port and Poti city (Patara Poti) because the lands to the south of the Poti seaport is mostly residential and public access area. The territory to the south of the port of Poti is densely occupied by Sanatoriums, Hotels and Private Buildings. The construction of the loading terminal will require its location at a safe distance (at least 500 m from residential buildings). In addition, the cost of land in the southern region is more expensive. The site for the Gas loading terminal allocation to the north of the port of Poti is a greenfield region and is situated near the existing railroad, this circumstance is important for the delivery of building materials and equipment during the construction of the terminal.

Although the terminal site is restrained by the Rioni river in the north, it has been decided to construct the Gas loading terminal to the north of the Poti seaport, more specifically behind the river Rioni, in which case the terminal location will be equally distanced from both Poti seaport and the Kulevi Oil terminal. Another element taken into account for the Gas loading terminal location was the directions of the underwater streams, as well as sludge from the Rioni and Khobi rivers.


Figure 73. The free lands of allocation of the Gas loading terminal near the port of Poti.

### C.3.8. Technical description of the Gas loading terminal

The Facilities, modules, and systems of the Gas loading terminal are intended to perform loading operations of CNG ship, including the management of loading, measurement of gas loading parameters, the creation of the necessary documents accompanying cargo (compressed gas). For the implementation of these processes, three groups of facilities and structures have been identified and a separate group consists of connecting pipelines to the CNG ship and a source of gas. The complex of loading terminal will be designed to the accepted volumes of gas loading, which are described in previous sections.
Technically provided the loading of one CNG ship. The average capacity of loading is 6.29 mscmd, and the maximum (gas flow rate) capacity of loading is 15,37 mscmd.

### C.3.9. The infrastructure of the terminal

In this section of the report, we set out a vision of the VTG on the arrangement of loading Gas terminal for loading service during the gas supplying to Ukraine.
The structure of the Gas loading terminal facilities is the fully independent infrastructure.
The modules of equipment and systems are necessary for the realization of the tasks of gas loading and unloading for the GASVESSEL system.

#### C.3.9.1. Gas loading terminal near the port of Poti (Georgia)

The composition of the gas loading terminal facilities is described in more detail in Section B.3.3.1. The following is a description of the terminal facilities.

##### C.3.9.1.1. Gas compressor module

The Gas compressor module at the Gas loading terminal is similar in design to the compressor shop at the Head Compressor Station of the Gas Interconnector. The purpose of the Gas compressor module is the transfer of gas coming from the Interconnector to the Gas Storage for subsequent loading into the CNG ship. The Gas compressor module has the parameters of compression: Inlet pressure is of 55 bar, Outlet pressure is of 240 bar, the gas flow is 15,37 mscmd. In the future, we propose to use compressors manufactured by Nuovo Pignone GE with the specified parameters.

#### C.3.9.1.2. Gas Air cooling module

The Gas Air cooling module at the Gas Loading terminal is similar in design to the Gas Air cooling module on the Head compressor station at the beginning of the Gas Interconnector SCP-Loading terminal. The purpose of the Gas Air cooling module is the gas cooling after compressing the loading gas into the CNG ship. It cools the gas to the maximal temperature of 25 $^0$C The Gas Air cooling module at the Gas Loading terminal is similar in design to the Gas Air cooling module on the Head compressor station at the beginning of the Gas Interconnector SCP-Loading terminal. The purpose of the Gas Air cooling module is the gas cooling after compressing the loading gas into the CNG ship. It cools the gas to the maximal temperature of 25 $^0$C based on cooling energy savings of the onboard cooling system. The temperature of 25 $^0$C is assigned the maximum based on the maximum allowable for admission to the intermediate gas storage, as well as on the basis of the material properties of the shell of the Storage tanks. For more details see Section C.1.8.2.3.

The temperature of 25 $^0$C is assigned the maximum based on the maximum allowable for admission to the intermediate gas storage, as well as on the basis of the material properties of the shell of the Storage tanks.

#### C.3.9.1.3. Gas measuring module

After all storage and other operations, immediately before the Gas is supplied from the intermediate Gas storage to the pipeline to load the CNG ship, the volume of Gas supplied for loading must be measured. The gas measuring module will be designed as a station of commercial measuring of Gas flow during the Gas transmission to the loading. For monitoring of module condition, the transmission of results of Gas flow measurements and fulfillment of certain commands from the Central dispatching office, the metering module will have informational access to the SCADA system. The metering module will be equipped with surveillance (SS) and an ecological monitoring system. For more details see Section C.1.8.2.4.

#### C.3.9.1.4. Fuel Gas treatment module

The Fuel Gas treatment module is intended to treat the part of the pumped Natural Gas in order to provide Gas with the required characteristics and Quality of the consumers located on the Compressor station of the Gas Loading terminal. The Gas treatment module should provide:

- preparation of the fuel Gas for the turbine engine, in a case of Gas compressor drive, is Gas turbine;
- Gas preparation for "dry" seals of compressors;
- fuel Gas for own needs of the compressor station (boiler house, Gas turbine power station and own Gas treatment unit needs).

For more details see Section C.1.8.2.5.

#### C.3.9.1.5. Oil cleaning module

The oil cleaning module with the oil recovery system is designed to receive, store and supply pure mineral oil for compressors and synthetic oil for drivers of the Gas compressors, receiving waste oils from the Gas compressors through stationary pipelines. It is envisaged to clean the oil before use in an oil cleaning machine. For storage of oil, there are provided 3 block tanks (BT) of 2x25 m$^3$ for oil products, of which 1 tank V=25 m$^3$ for storing pure mineral oil, 1 tank of volume 25 m$^3$ for waste but the oil to be cleaned on an oil cleaning mineral oil machine, 2 tanks of volume 25 m$^3$ for storage of pure synthetic oil, 1 tank of volume 25 m$^3$ for waste mineral and synthetic oil that cannot be cleaned and intended for disposal for recycling. For more details see Section C.1.8.2.6.

#### C.3.9.1.6. Site piping

All piping, fittings, flanges and valves design within the facilities of the Gas Loading terminal will be carried out in accordance with codes as follows:-

- ASME B31.4 for pipelines.
- ASME B31.8 for the fuel Gas main system.
- ASME B31.3 for process piping, all plant utilities like plant air, instrument air, nitrogen, all types of water piping, diesel, chemicals, lubricating oil, etc.

The above basis takes into account the saving of material in case of using the B31.4/B31.8 code for Loading terminal piping allowed in accordance with para 400.1.1 and Fig. 400.1.1-1 of ASME B31.4 and para 802.1(4) of ASME B31.8. However, when it can be proved that ASME B31.3 will yield overall savings in terms of pressure testing, radiographic testing, Post Weld Heat Treatment (PWHT), support design, stress analysis, etc. or where it is essential from other considerations like limits of temperature, ASME B31.3 will be followed. The section will be developed in more detail based on the actual Master plan and the placement of the modules at the Gas Loading terminal site.

### C.3.9.2. Auxiliary process facilities (modules) of a loading terminal

#### C.3.9.2.1. Process automation and signaling system

All facilities and modules on the Gas loading terminal site to be designed/engineered and will be supervised and controlled by the Master Control Room (MCR) located at the site of the gas loading terminal. Systems of automatic control are necessary for the following functions:

a) the automatic control of the loading process and Gas flow from Gas interconnector;

b) division of the control functions between the system of the compressor station and actuating systems;

c) the ability to control Gas transfer processes through the Gas Interconnector and control of the Head compressor station operation with the dispatcher displaying information;

d) control functions of all systems of the terminal;

e) drawing up commercial documents for loaded Gas in the CNG ship and the incoming Gas to the terminal storage.

The operators' room of Gas loading terminal will be designed for the permanent presence of personnel having a possibility to control CS operation manually and maintain optimum parameters of the loading process. Control systems will be highly reliable and trouble-free, however in the case of loss of control signal, Gas loading terminal equipment will be automatically switched over into a safe position.

Local pneumatic control chains will be used if necessary, but only on the condition that their reliability will be the same or higher of electrical circuits' reliability.

Technical means of control systems will be assembled on sides of instrument panels to enable free access to them during their maintenance. Cable feeding-in to the instrument panels will be made from below, while access to the panels – from behind.

The terminal control system will consist of a few subsystems.

***Subsystem of terminal Control***

The subsystem of terminal control will maintain permanent communication with:

- terminal operator's interface;
- the subsystem of the emergency stop;
- Gas loading control subsystems.

***Subsystem of Gas-Pumping Unit Control***

Gas-pumping units will be supplied complete with control subsystems. The subsystem will consist of PLC with corresponding input/output means, screen terminal of operator's interface, an alpha-numeric keyboard, a regulator of speed and surge prevention (both regulators are microprocessor-based) and hardware for engine and supercharger vibration control.
The system is supplied with requisite software for monitoring and control purposes.
Information confirming identity in the approach to software, both in respect of unit control subsystem and station control subsystem, will also be submitted.

***Emergency Shut Down Subsystem (ES)***

ES subsystem will perform the following functions:

- control and monitoring of position (open-shut) of terminal valves taking part in algorithms of emergency Compressor shut down;
- control of Gas parameters in the Gas storage;
- automatic monitoring of emergency shut down circuits integrity;
- fire detection;
- Gas leakage detection;
- too high temperatures detection;
- monitoring manual emergency shut down stations and critical station variable parameters;
- permanent communication with subsystems of units control;
- permanent communication with station local network for detection of emergency signals and read-out of information on equipment condition;
- monitoring of the processors of terminal PLC (watch timer);
- ensuring of hard (physical channel) connection with all emergency shut down systems and facilities.

Emergency shut down buttons will be provided at each gate along the terminal perimeter,
neat each main entrance in the aggregate shelter, Gas storage, near the main entrance to the auxiliary building and on the terminal control panel.

***Monitoring Condition of the Main equipment***

A system of monitoring condition of process equipment will perform the following functions:

- a permanent monitoring of equipment condition in real-time and recording of monitoring data;
- forming of files on equipment condition and drawing up necessary schedules;
- storage of data on equipment condition received from electronic devices manually, using an operator interface;
- defining of functional capabilities and calculation of productivity of Gas pumping unit.

***Engines Control Center***

Engines control signals will come to intermediate relays installed in MMS and has a 24V DC power supply. Feedback signals on the fulfillment of engine start/stop commands will be connected to the station or unit control system, depending on the functional designation of the engine.
Station and unit control systems will have technical means of permanent automatic control of engine control circuit integrity.

***Requirements to Operators' Room***

The following main equipment will be installed in the operators' room:

- units control panel;
- station control panel;

- emergency shut down system panel;
- operator's interface equipment;
- system of technological equipment condition visual monitoring;
- fire-prevention system panel;
- printers rack.

#### C.3.9.2.2. Instrument and Plant Air System

As described in section C.3.9.2.1 to control the drives of cranes and valves, it is necessary to supply the Loading terminal site with instrument compressed air. The block air compressor station with a capacity of 300 sm$^3$/h of prepared air with a dew point temperature of minus 40 $^0$C and with an output pressure of 75 bar is used. The station is made with 100% redundancy of compressor equipment, an adsorption dryer, and filter elements. For the storage of instrument air, a 5 m$^3$ receiver is installed. For storage of compressed dried air, 3 receivers of the volume of 25 m$^3$ each are installed:

- receiver for compressed air used for receiving an instrument air,
- receiver for storing air used to control pneumatic actuators,
- receiver for storage of repair air.

All equipment is mounted in a 3 pcs of 12-meter all-metal insulated block container.
Each container is equipped with automatic fire extinguishing systems, fire alarms, supply, and exhaust ventilation, heating, and air conditioning, main and emergency lighting.

#### C.3.9.2.3. Nitrogen generation and distribution system

To provide the Loading terminal with compressed nitrogen, a nitrogen membrane-type station is provided in a container version. When repairing and operating equipment and pipelines in order to avoid the formation of an explosive mixture, Gas is replaced by nitrogen. Nitrogen at the loading terminal site is used to purge pipelines and Gas storage. Nitrogen-expelled Gas is dumped onto the Flare system. The Technical parameters of the Nitrogen generation and distribution system are shown in the table below.

| No | Parameters | Value |
|---|---|---|
| 1 | Nitrogen productivity, m$^3$/hour | 450,0 |
| 2 | Nitrogen concentration in the produced Gas,%, not less than | 98,0 |
| 3 | Oxygen concentration in produced Gas,%, not more than | 2,0 |
| 4 | The dew-point temperature of nitrogen at the outlet of the block, $^0$C | Minus 55 |
| 5 | The pressure of nitrogen at the outlet of the block, bar | 7,0 – 12,0 |

Table 38. The Technical parameters of the Nitrogen generator module.

#### C.3.9.2.4. Vent/Flare system

For the protection against abnormal conditions, the internal pressure could rise above the design value overpressure, protection against excessive temperature and Gas replacing from Gas pipelines, Gas storage, and other equipment the pressure-relieving and emergency depressurizing systems are required. Collected Gas through the pipeline enters the flare, where it burns. Flare system is equipped with an automatic ignition system, which is triggered when a Gas appears in the supply line. The flare is set by a Ko drum tank for collecting drops of liquid. Relief and emergency depressurizing systems will be designed in accordance with API STD 520 (Part I) and API STD 521. The flare system designed considering potential ignition by a spark or lightning strike. The total permissible radiation intensity for the design of the sterile area radius around the vent stack is 6.31 kW/m² at the outer boundary of the sterile area according to API 521.

#### C.3.9.2.5. Power supply and power distribution system

The power supply and power distribution system of the Loading terminal includes the system of external and internal power generation, power supply, power distribution, electric lighting, lightning protection and grounding of buildings and facilities of the compressor station.

The power supply system, the choice of electrical equipment will be made on the basis of the International and European Standards.

The power supply of the Gas Loading terminal site will be performed from its own Gas turbine power station consisting of two blocks of 2.5 MVA each (each of which is loaded in normal mode by about 50%) with a voltage of 10 kV and from a backup power source, the local connection to the power supplying of Gas metering station via overhead transmission line of 10 kV. The Gas turbine power station is the main option of Power supply. Depending on the capacity of local electric networks to transfer the required power for the Loading terminal, the length of the transmission line may vary. For the distribution of electrical power will be used switchgear involved in the production of electricity using a Gas power plant.

The power supply scheme provides for the supply and construction of the following main power supply facilities:

- Gas turbine power station with a capacity of 2x2500 kVA, the voltage of 10 kV (one working and 1 in reserve) installed in individual all-weather modules of full factory readiness;
- 10kV closed switchgear in the block-modular building of full factory readiness 10 kV indoor switchgear is provided using 10 kV SF6 or vacuum circuit breakers;
- a two-transformer power substation 10/0.4 kV, with dry transformers rated at 2x2500 kVA for power supply of the compressors in a block-modular building of maximum prefabrication mode, for power supply of Gas turbines, process, and infrastructure facilities (repair shops, warehouses, canteen, service and maintenance rooms);
- a two-transformer substation 10/0.4 kV, with dry transformers with a power of 2x630 kVA for power supply to Gas air cooling modules in a block-modular building of maximum factory readiness;
- diesel power unit 0.4 kV with a power of 500 kW, connected to a 0.4 kV switchgear in a block-modular building of maximum prefabrication, for reserve power supplying of a special group of electrical consumers (fire pump, boiler room, equipment for automated process control systems, alarm, ventilation, lighting and etc.);
- overhead power transmission line (10kV overhead line) approximately up to 5 km long;
- 380V power supply without failures units with 110V batteries;
- systems of lightning protection and grounding;
- cables with a voltage of 0.4 kV and 10 kV of various sections with copper conductors, armored and unarmored with PVC sheath and insulation;
- various low-voltage equipment (switchboards 0,4/0,23 kV, buttons, actuators, terminal boxes, electrical installation products, etc.);
- lighting fixtures exterior and interior lighting.

The capacities of power transformers, emergency diesel power units, and Gas turbine power stations will be refined at subsequent design stages, taking into account the actual loads of electrical consumers.

#### C.3.9.2.6. Electrochemical anti-corrosion protection System

The means of active protection electrochemical anti-corrosion protection are used in the cathodic protection system of the Gas loading terminal facilities.
The protective potential of isolated steel underground units should be in the limits between -0,95 V and -1,2 V.

***Protectors.***
The essence of the protectors' usage lies in the creation of manufactured electric circuit, made from more electronegative material than the object itself. To protect steel underground pipelines from corrosion, it is proposed to install the protector units with the group of protectors from magnesium alloy.

**Bussing.**
Cable bussing is provided for the 48V circuit from the constant-potential transformer to sacrificial anode and drainage points. The cables should be copper, isolated by PVC for the voltage up to 1000V. The cables are laid at the depth of 1.0m on sifted or sand soil layer of 10cm, after this they are covered with the 15cm layer of the same soil, from above the trench is covered with the soil that was taken out earlier.
The connection of the cable to the pipeline is made by means of aluminothermic welding.

#### C.3.9.2.7. Diesel fuel system

For consumers of the first category, which include Fire fighting system and Control system, it is necessary to provide the backup power supply. For this purpose, a 500 kVA diesel power station is provided with a system for storing and supplying diesel fuel.
The Diesel fuel will be supplied by a car tanker and will be stored in a diesel fuel storage tank. Diesel will be required to fuel the emergency diesel power station day tank, fire water pumps, and fixed foam system. The main fuel storage tank has 4 days of storage capacity (100 cub m). The emergency diesel power station with a capacity of 500 kVA is adopted in a noise-absorbing all-weather container in the concrete foundation.
The diesel fuel storage tank will be placed inside a concrete dike wall. Diesel fuel transfer pumps will pump the diesel fuel to consumers through diesel fuel filters. The pressure drop across filters will be monitored and changeover of the filter will be made when the pressure drop is high which shows plugging of the filter. A low level in the storage will alarm the operating personnel to re-fill the tank. The storage tank will be re-filled from a diesel fuel road tanker through unloading connections provided for this purpose.

#### C.3.9.2.8. Communication, alarm, fire alarm system

The configuration of the Communication, alarm, and fire alarm system of the Gas loading terminal is similar to the configuration and functions of the Communication system of the Head Compressor Station described in Section C.1.8.3.7.

#### C.3.9.2.9. Power, control and signaling cables

Power electrical cables should preferably be laid on-ramps. Control and signal cables are preferably laid in special trays underground. The electric power supply of the equipment will be carried out by means of copper cables, isolated by thermoplastic PVC, with PVC electron outer shell. Cabling methods, types, and length of cables will be indicated during detailed Design work.

#### C.3.9.2.10. Auxiliary pipelines

Auxiliary pipelines are pipelines connecting auxiliary modules and auxiliary equipment, which provides the basic processes of loading and storing of Gas at the terminal. Auxiliary pipelines also include pipelines of the life support systems of the terminal. The laying of auxiliary pipelines must be carried out in accordance with the standards ASME B 16.5 and ASME B 31.8.

### C.3.9.3. Life support facilities (modules) of a loading terminal

#### C.3.9.3.1. Water and sewage system

***Water supply***

The main source of the water supply of drinking and industrial water for the loading terminal site will be underground wells. As a reserve source of water for the terminal, a water line from the river near the village of Kulevi can be laid. The inflow of water from the underground wells should be sufficient for the needs of drinking and technical water supply of the terminal site and the replenishment of water fo the fire fighting system.

***Underground water intake***

There are envisaged the drilling of underground artesian wells and the arrangement of block boxes above wells with pumping equipment, automation, and fittings. The sanitary protection zone of a fence is arranged around each artesian well or its group.

***Surface water intake***

The surface water intake is provided for onshore type, recessed water intake sump with two pumping units. The water intake from the lake is provided by two separate pipelines with mesh tips.
A sanitary protection zone with a fence is arranged around the water intake structures.

***Sewage water system***

Characterization of wastewater, and its treatment.
The following categories of wastewater are generated at the projected site:

- household;
- rain sewage from the territory.

***Household wastewater***

Domestic wastewater from buildings and structures, collected by sewage networks, flows by gravity to the sewage pumping station, and the pressure pipe is fed to a sewage treatment unit, which is prefabricated and packaged. Treated effluents are sent to a reservoir tank or discharged into an evaporation pond for further evaporation.
The consumption of domestic wastewater is determined from the condition that the norms for water disposal are equal to the norms for water consumption.

***Rainwater wastewater***

The project provides for the installation of rain sewers. Rainwater flows through the collectors are fed to the treatment plant.
Contamination indicators of surface wastewater from the site do not exceed:

- suspended solids up to 500 mg/l;
- for oil products up to 30 mg/l.

In the project, rainwater is scheduled to be collected only from road sections and sites where the project provides for improvement.
Provides gravity rainwater collection in storage tanks, equipped with submersible pumps, and with the subsequent transfer to wastewater treatment plants sewage treatment.
This project provides for the mechanical cleaning of rainwater runoff. At the sewage treatment plant, the sedimentation of large suspended solids takes place and, with subsequent incubation, the removal of the bulk of undissolved impurities from the runoff.
Due to the fact that the project made a decision to use the cleaned rain drain for watering and washing the roads, watering the lawns, and dumping the surplus to the relief, deep purification is envisaged. After treatment is provided by a sorbent charge, which detains fine contaminants and oil products. This ensures the purification of water by 99.5%.
Purified rainwater flows by gravity into an underground steel horizontal tank with a capacity of 100 $m^3$, from where they are pumped to watering green spaces, washing roads and driveways.
The parameters of treated rainwater are:

- suspended substances – 10,0 mg/l;
- petroleum products - less than 0,3 mg/l.

The project provides for sending a surplus of treated rainwater to the evaporator pond via the waste collector.

***Industrial waste***

Industrial effluents that are generated at the oil supply installation do not flow into the sewer network but are collected in process tanks for export for further disposal.

#### C.3.9.3.2. Firewater and fire-fighting system

***Automatic foam fire fighting system in compressor shelter***

The shelter's system of automatic foam fire fighting will be provided in the shelter buildings of the CS. The work of the drencher system should provide simultaneous fire fighting with the air-mechanical foam of low multiplicity of two zones of oil blocks in the shelter of the compressors:

- the console of lubricating oil of a compressor of square size 8.2x5.1 = 41.82 $m^2$;
- the console of lubricating oil of the turbine of square size 1.9 x1.5 = 2.85 $m^2$.

The duration of the working of the foam fire fighting system for premises of category "A" for explosion and fire hazard is 15 minutes.

The estimated consumption of the foaming agent solution when the automatic fire fighting system is triggered is taken at 0,15 l/s per $m^2$. The estimated flow rate of the solution for the foam fire fighting system of both consoles in the same shelter of the compressors is 6,7 l/s for 15 minutes:

$$Q = 44,67\ m^2 x0,15x15x60 = 6,03\ m^3.$$

The volume of solution for foam extinguishing, taking into account the capacity of pipelines and facilities will be determined in the next stage of Project depending on dimensions of Gas storage. The estimated water consumption when automatic fire fighting system is triggered and the external and internal water fire fighting system of the compressors shelter (15,0 l/s) is provided with a fire pump during one fire and will be:

15,0 l/s + 6,7 l/s=21,7 l/s – for 17 min (2 min - for filling the system).

***Description of the Deluge System***

A deluge system is an empty pipe system that is used in high-hazard areas or in areas where fire may spread rapidly. In this type of application, open sprinklers or spray nozzles are employed for water distribution. The deluge valve is activated by a release system (fixed-temperature, rate-of-temperature rise, radiation, smoke, or combustion Gases, hazardous vapors, pressure increase). When the system is tripped, water flows through all spray nozzles or sprinklers simultaneously. The deluge system will be activated by a hydraulic, pneumatic, electric, or manual release system or any combination of these release systems.

When a releasing device operates, pressure escapes in the pneumatic release system causing alarms controlled by air supervisory transmitter to activate and the pneumatic actuator opens. When the pneumatic actuator opens, the pressure is released from the priming chamber gaster than it is supplied through a restricted orifice. The deluge valve clapper opens to allow water to flow into the system piping and alarm devices, causing water motor alarm and water flow alarms connected to the alarm pressure transmitter to activate. Water will flow from any open sprinklers and/or spray nozzles on the system.

The Deluge System will be provided to Gas Compressors and Flare Knockout drums and pumps.

Each deluge system will be fed from the firewater ring main connected with an automatic deluge valve. Isolation of automatic deluge systems will be possible by means of manual block valves, locked open in normal service. The deluge valve will be a specific quick opening automatic valve energized by the firewater pressure. The local manual release will also be possible for the deluge valve.

***Description of the Sprinkler System***

In a normal set condition, the system piping is filled with water. When a fire occurs, the heat operates a sprinkler allowing the water to flow. The alarm valve clapper is opened by a flow of water allowing pressurized water to enter the alarm port to activate the connected alarm device.
The following process areas and buildings at the Loading terminal will be protected with automatic sprinkler systems (wet pipe sprinkler system) in accordance with NFPA 13.
Upon operation, the sprinklers distribute the water over a specific area to control or extinguish the fire. As the water flows through the system, an alarm is activated to indicate the system is operating. Only those sprinklers immediately over or adjacent to the fire operate, minimizing water damage. The facilities to be protected by the Sprinkler System:

- Terminal Administration building;
- Warehouse building;
- Chemical storage shelter;
- Power generation shelter;
- Workshop;
- Control room.

***Fire pumping station***

Firewater pumping station will be provided of the modular design and includes the following equipment:

- fire pump unit Q=160 $m^3$/h; P=0,70 MPa; (pumps - 2 pcs, 1 work, 1 reserve);
- fire pump unit Q=10$m^3$/h; P=0,40 MPa; (pumps - 2 pcs, 1 working, 1 reserve) with a pneumatic tank of volume V=35,0 l to maintain the pressure in the ring fire net. The maintenance pressure pump in the ring fire net is automatically activated.

For automatic foam fire fighting facilities will be provided the following equipment:

- vertical dosing system of volume 400 l with foam concentrate with an inside membrane, equipped with fittings and a concentration control valve;
- mixer for a dosing system of 3 inches;
- drencher valve;
- 24V solenoid valves in the harness of the deluge valve and concentrate control valve.

There are two facilities of fire pumping station - one working and one reserved.

***Description of automation of the fire water supply system***

When a fire occurs on the site, the first fire pump will be activated. The activation of a fire pump provided by:

- In automatic mode by the fire alarm (“Fire” signal) system of automatic foam system in the shelters of the CS;
- remote, at the “Fire” signal with the buttons at fire hydrants for external fire fighting system,
- in buildings - from buttons at fire hydrants;
- remote, from the operator's console;
- local, with buttons at the pumps in the fire pumping station.

If a second fire occurs on the terminal site, a second fire pump will be activated. At the same time, simultaneously with the activation of the fire pumps, the pressure maintenance pump should automatically shut off, and the blockage automatically prohibiting the drawdown of the firewater volume should be automatically removed.

#### C.3.9.3.3. Evaporation pond

The evaporation pond will be designed with enough surface area to efficiently evaporate water by sunlight and exposure to ambient temperatures. The pond allows the water to evaporate, leaving the waste behind.

#### C.3.9.3.4. Ancillary buildings and structures, site improvements

The list of auxiliary buildings and structures at the loading terminal site will be updated at the subsequent stages of the Project. In any case, such a list should include all the necessary structures and buildings to ensure the loading tasks of the CNG ship's, as well as the documentation of all processes. The list of premises for personnel should be compiled in such a way as to ensure the safety of personnel and create comfortable working conditions and create the necessary living conditions. The master plan for the loading terminal site should be designed in such a way that a clear chain of Gas loading and storage processes can be traced. At the same time, the auxiliary systems and modules must be located in close proximity, but at a safe distance. The location of the Gas storage should also be at a safe distance, but convenient for the approach of fire equipment in case of an emergency situation.
Plot plan of Gas loading terminal to be developed based on the following requirements:

- Safety distances;
- Prevailing wind direction;
- Accessibility and Constructability;
- Process requirement of equipment sequencing;
- Pipeline entry and exit pipeline;
- Availability of utilities e.g. water, electricity, manpower, etc., and entry and exit points of utilities;
- The proximity of manned and unmanned area;
- The proximity to an environmentally sensitive area;
- Soil characteristics;
- Terrain;
- Space provision for future expansion;
- Minimum 10% green plot;
- QRA (quality and reliability assurance) findings and recommendations;
- Loss prevention philosophy.

***Motor roads***

Motor roads in the area of Gas loading terminal will be designed taking into account the outward and inner traffic and firefighting service as well. They provide reliable connecting of buildings and constructions. Motor roads, foreseen to be the ring, are reliably satisfying the demands of processes. The driveways are intended to be in the embankment of not less than 0,3 m higher than plan ground elevation. Cross profile of road is intended to be with roadsides. The width of the traffic way of the main roads is to be 4,5 m, roadsides – 1,5 m.
Covering of the inner roads is intended to be from one-layer asphalt concrete with a bed of gravel-sand mixture. For the protection of road pavement from subsidence, there is projected to install a protective shield from loam with thickness 0,15 m.
All main technical parameters for motor roads are to be of V technical category. Traffic road width is to be 4,5 m, roadsides width – 1,5 m, ground bed width – 7,5 m.
Road pavement consists of asphalt concrete with a bed of gravel-sand mixture. For the protection of road pavement against subsidence, there is projected to install a protective shield from loam with thickness 0,15 m.

## C.4. Underwater Gas pipelines Loading terminal – CNG ship, and CNG ship - Unloading terminal.

### C.4.1. Introduction

This part of the Report addresses the Technical and Commercial issues of the construction of underwater Gas pipelines as part of the overall loading and unloading system of CNG ship.

### C.4.2. Purpose of the Gas underwater pipelines

The main purpose of the underwater Gas pipeline is the connection of the system of CNG ship loading/unloading with the points of shipping or receiving of Gas during the loading and unloading process of CNG ship. Underwater Gas pipelines are applicable in case of loading/unloading the CNG ship in the open sea using a floating buoy. This can be implemented if it is impossible to build a mooring extension wall for mooring a CNG ship. As an example, we can consider the method of loading from offshore Gas production platforms in the Mediterranean and the Barents Sea, as well as unloading the CNG ship when connected to the Polarled underwater Gas pipeline.

### C.4.3. Glossary, abbreviations, and acronyms

In this Report, such abbreviations and acronyms were used:

| Abbreviation | Description |
|---|---|
| **ALS** | accidental limit state |
| **AR** | an additional requirement to the stated ISO standard |
| **API** | American Petroleum Institute |
| **ASME** | American Society of Mechanical Engineers |
| **ASTM** | American Society for Testing and Materials |
| **BM** | base material |
| **BS** | British standard |
| **CP** | cathodic protection |
| **DNV** | Standard package (Det Norske Veritas, NORSOK Standards) |
| **MAOP** | maximum allowable operating pressure |
| **MR** | the modified requirement to the stated ISO standard |
| **N** | normalized |
| **NACE** | national association of corrosion engineers |
| **NDT** | non-destructive testing |
| **QA** | quality assurance |
| **QC** | quality control |
| **SC** | safety class |
| **UT** | Ultrasonic testing |

Table 39. Glossary, abbreviations, and acronyms.

### C.4.4. Units of measurement[7].

The Units of measurement which are used in this section are shown in Table 2.

### C.4.5. Climate data

In the design and construction of underwater loading/unloading Gas pipelines, climatic factors should be taken into account that will affect the processes of construction and operation of Gas pipelines. They are part of the factors in determining the loads on the Gas pipelines.

In the Final report of the work package WP2 shown the climatic characteristics of the areas of loading and unloading of GASVESSEL. These data are to be clarified and updated according to the results of Engineering surveys in the development of Project documentation at subsequent stages of Project development.

### C.4.6. Codes and Standards

The Codes and Standards used for design and build the underwater Gas pipelines for connecting the load and unload terminals must meet the Standards used in the best practice of international Engineering taking into account the national Standards of the countries where these terminals will be implemented.

Following table gives a comparison between different pipeline codes and standards with respect to **mechanical design** of pipeline:

| Code/ Standard | Geophysical | Internal Fluid | Pressure | Temperature | Approach | Material | Diameter | Thickness |
|---|---|---|---|---|---|---|---|---|
| ASME B31.8<br>ASME B31.4 | Onshore/ Offshore | Gas<br>Liquid | Any | Max: 230 °C | ASD | Steel, Ductile Iron, Plastic | External | Nominal |
| BS 8010 | Onshore/ Offshore | Any | Any | Max: 120 °C | ASD | Steel | External (1) | Minimum |
| EN 14161 | Onshore/ Offshore | Any | Any | Max: 150 °C | LSD | Steel | Note 3 | Note 4 |
| ISO 13623 | Onshore/ Offshore | Any | Any | Max: 150 °C | LSD | Steel | Note 3 | Note 4 |
| DNV OS-F101 | Offshore | Any | Any | Note 2 | LSD | Metallic | Note 3 | Note 4 |
| API RP-1111 | Offshore | Hydrocarbons | Any | Max: 230 °C | LSD | Steel | Note 3 | Nominal |

Notes:
1. BS 8010 uses thick wall equation for D/t ratio less than or equal to 20.
2. Not specified directly. But strength derating information is presented up to 200 °C.
3. Mean and outside diameters are used for burst pressure and external collapse pressure, respectively.
4. Minimum and nominal thicknesses are used for burst pressure and external collapse pressure, respectively.
5. CSA uses nominal and minimum wall thicknesses for onshore and offshore pipelines, respectively.

ASD: Allowable Strength Design LSD: Limit State Design RBD: Reliability Based Design

Table 40. The field of applicable Standards.

Maximum application extent of DNV OS-F101 :

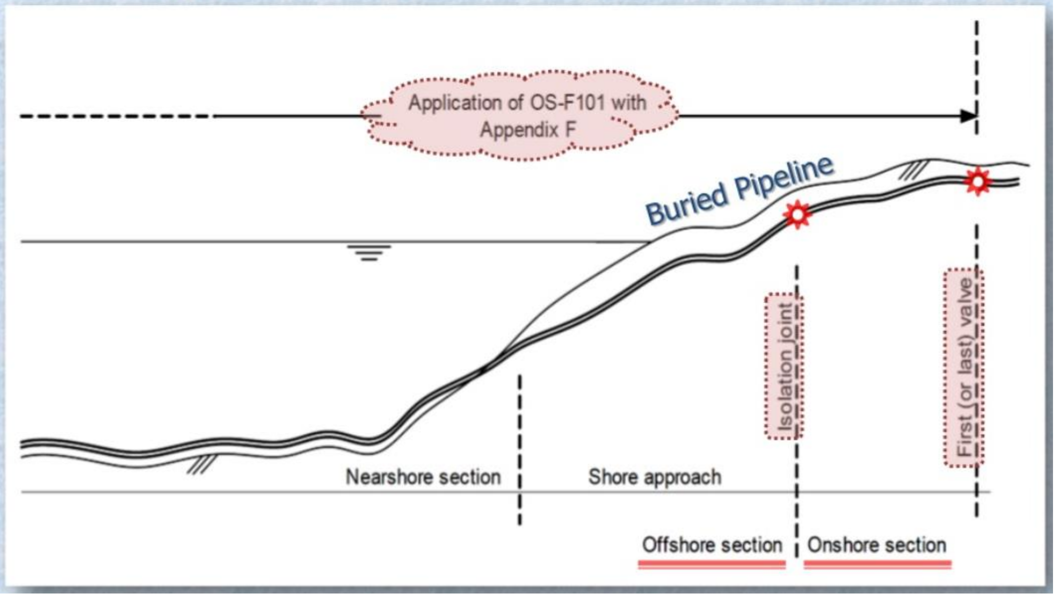



Figure 74. Division of the underwater pipeline into zones covered by the DNV Standard.

| Standard, Code | Description | Notes |
|---|---|---|
| ***NORSOK Standards*** | | |
| M-001 | Materials selection | |
| M-501 | Surface preparation and protective coating | |
| M-503 | Cathodic protection | |

| | | |
|---|---|---|
| M-601 | Welding and inspection of piping | |
| M-630 | Material data sheets and element data sheets for piping | |
| N-001 | Integrity of offshore structures | |
| N-003 | Actions and action effects | |
| N-004 | Design of steel structures | |
| P-002 | Process system design | |
| R-001 | Mechanical equipment | |
| R-004 | Piping and equipment insulation | |
| I-001 | Field instrumentation | |
| I-002 | Safety and automation system (SAS) | |
| L-001 | Piping and valves | |
| L-002 | Piping system layout, design, and structural analysis | |
| L-003 | Piping details | |
| L-004 | Piping fabrication, installation, flushing, and testing | |
| L-005 | Compact flanged connections | |
| S-001 | Technical safety | |
| S-002 | Working environment | |
| S-003 | Environmental care | |
| T-100 | Telecom subsystems | |
| E-001 | Electrical systems | |
| S-011 | Safety equipment data sheets | |
| S-012 | Health, safety, and environment (HSE) in construction-related activities | |
| U-001 | Subsea production systems | |
| U-009 | Life extension for subsea systems | |
| U-100 | Manned underwater operations | |
| I-106 | Fiscal metering systems for hydrocarbon liquid and Gas | |
| Z-003 | Technical information flow requirements | |
| Z-007 | Mechanical completion and commissioning | |
| Y-002 | Life extension for transportation systems | |
| ***DNV GL STANDARDS*** | | |
| DNVGL-OS-A101 | Safety principles and arrangements | |
| DNVGL-OS-C101 | Design of offshore steel structures, general - LRFD method | |
| DNVGL-OS-E201 | Oil and Gas processing systems | |
| DNVGL-OS-E301 | Position mooring | |
| DNVGl-ST-C501 | Composite components | |
| DNVGL-ST-F201 | Dynamic risers | |
| DNVGL-ST-N001 | Marine operations and marine warranty | |
| ***ASME, ANSI, ASTM Standards*** | | |
| ASME B31 | Pressure Piping | |
| B31.1 - 2012 | Power Piping | |
| B31.2 - 1968 | Fuel Gas Piping | |
| B31.8 - 2012 | Gas Transmission and Distribution Piping Systems | |
| ASME | Performance Test Codes | |
| ASME B31.9 | Working Pressure and Temperature Limits | |
| ASME B31.3 | Process Piping | |
| ASME/ANSI B16 | Standards for Pipes and Fittings | |
| ASME/ANSI B36.10/19 | Carbon, Alloy and Stainless Steel Pipes - Dimensions - Metric Units | |
| ASTM | ASTM International - Standards for Steel Pipes, Tubes and Fittings | |
| ASTM | ASTM International - Volume 01.01 Steel - Piping, Tubing, Fittings | |
| ***Other Standards*** | | |

| | | |
|---|---|---|
| ISO 13623 | Petroleum and natural Gas industries - Pipeline transportation systems | |
| ISO | Pipe, Tube and Fittings Standards and Specifications | |
| DIN | Pipe, Tube and Fittings Standards and Specifications | |
| API | API SPEC 5L April 2018 Line Pipe 46th Edition | |
| | National Georgian Codes and Standards | |
| | National Ukrainian Codes and Standards | |

Table 41. List of applicable Codes and Standards.

### C.4.7. Philosophy of Gas underwater pipeline for CNG ship loading/unloading

In this section, we will consider the possible Technical solutions of the design of Gas underwater pipelines for GASVESSEL loading/unloading. In this section we will describe two Options of design:

- Offshore platforms for CNG ship loading/unloading;
- Onshore terminal for CNG ship loading/unloading.

#### C.4.7.1. Technical parameters of CNG ship loading

The main Technical parameters of CNG ship are:

| Parameter | Unit | Value | Notes |
|---|---|---|---|
| CNG ship volume | mscm | 9,0 or 12,0 | |
| Gas Flow (Average value, Max. value) | mscmd | According to the loading time | See the diagrams of loading/unloading processes |
| Loading Pressure | MPa | 24,0 | |
| Temperature (Max.) | $^0$C (K) | 40 (313) | |

Table 42. The Technical parameters of CNG ship loading.

#### C.4.7.2. Technical parameters of CNG ship unloading

The main Technical parameters of CNG ship unloading are:

| Parameter | Unit | Value | Notes |
|---|---|---|---|
| CNG ship volume | mscm | 9,0 or 12,0 | |
| Gas Flow (Average value, Max. value) | mscmd | According to the unloading time | See the diagrams of loading/unloading processes |
| Unloading Pressure | MPa | 30,0 (12,0) | Initial unloading pressure is 30,0 MPa, Final unloading pressure is 12,0 MPa before the starting of ship's compressor |
| Temperature (Max.) | $^0$C (K) | 40 (313) | |

Table 43. The Technical parameters of Gas unloading.

#### C.4.7.3. Safety philosophy

The safety of the underwater Gas pipelines is ensured by the use of a safety class methodology. The pipelines are classified into one or more safety classes based on failure consequences, normally given by the content and location. For each safety class, a set of partial safety factors is assigned to each limit state.

The concept development, design, construction, operation and abandonment of the pipelines will be conducted in compliance with national legislation with respect to health, safety, and environmental aspects

The Natural Gas to be transported by the underwater pipeline shall be categorized according to their hazard potential as Category E[8] (DNVGL-ST-F101, Submarine pipeline systems, Article 2.3.2).
The pipelines system shall be classified into location class 2 as defined in Article 2.3.3 (DNVGL-ST-F101, Submarine pipeline systems).
The safety class is high (Article 2.3.4).

### C.4.8. Hydraulic analyses and flow assurance

Below shown the results of technical decisions and thermo-hydraulic calculation of the loading and unloading underwater Gas pipelines. The calculation was made for a loading Gas pipeline with a conventional length of 3000 m. In the future after updating, the results of the Engineering survey the calculation will be amended.
In the case of loading or unloading of the CNG ship near an offshore platform, the length of the underwater Gas pipeline shall be at least 500 m. Conditionally we take the length of 540 m from the connection point to the riser. The calculation accepted the length of the underwater pipeline will be at least about 3000 m.
The agreed Gas pressure at the loading process is 24,0 MPa (240 bar). Conventionally, it is assumed that the height difference between the beginning of the pipeline and its end is 0 meters, but it depends on the level of the seabed. The Underwater Gas loading pipeline on the diagram (Loading terminal in Georgia) is marked as Pipeline 4.
In Table 44 below is show the Thermo-hydraulic calculation of the loading underwater Gas pipeline. The agreed Gas pressure at the unloading process is 24,0 MPa (240 bar). The height difference between the beginning of the pipeline and its end conventionally accepted as 0 meters.

```
= HYDRAULIC AND THERMAL CALCULATION OF PIPELINE =
----------------------------------------------------------------------
 Pipeline Inlet flow - 9      ---------> 10      -   Outlet Flow.
----------------------------------------------------------------------
= INITIAL DATA =
----------------------------------------------------------------------
 Flow                                           kg/h        449420.800
                                                scm/h         640416.8
 (t=20 C,P=0.1013 Mpa)                          mscmd           15.370
 Initial Pressure                               MPa             23.896
                                                barg            243.67
 Initial Temperature                            C                19.72
                                                K               292.87
 Pipeline Length                                m               3000.0
----------------------------------------------------------------------
 Absolute roughness                             mm                 .10
----------------------------------------------------------------------
 No of    Sect.    Height   External Pipe     Heat     Ambien  Num.    Sect.
 sect.    Length   differ.  pipe     thickn.  transf.  Temp.   step    effic.
                            Diam.             coef.            calcul.
                                              W/(m^2K)
          m        m        mm       mm                C
----------------------------------------------------------------------
 1       3000.       0.   370.0    10.0      8.42      5.0     25      .95
----------------------------------------------------------------------

THERMAL CONDITIONS

  Pipeline Location - Underwater

  Thermal conductivity coefficient of the soil, W/(m*K) 2.00

= CALCULATION RESULTS =
----------------------------------------------------------------------
 Initial characteristics :              Volume gas fraction    1.000000
 velocity              6.662 m/s        Flow Mode - Single Phase

 Characteristics at the end of the section (pipeline):
----------------------------------------------------------------------
 No of    Volume      Velocity  Flow          Pressure        Temperature
 section  gas                   mode
          fraction     m/s                    Mpa      barg   C       K
----------------------------------------------------------------------
1      1.000000     6.732     Single       23.266 237.25    18.1   291.2
                              Phase
----------------------------------------------------------------------

 16-Dec-19
```

Table 44. Thermo-hydraulic calculation of underwater loading pipeline.

The agreed Gas pressure during the free unloading process is 80 bar at the beginning of the process, and then, after the pressure in the CNG ship tanks is reduced, the ship compressor will be turned on. In all time during the unloading process, the Gas is released in a pipeline at the pressure of 80 bar. The height difference between the beginning of the underwater Gas pipeline and its end is conventionally taken as 0 meters. The Gas unloading pipeline on the diagram (Unloading terminal in Ukraine) is marked as Pipeline 2.

In the Table below is show the Thermo-hydraulic calculation of the unloading underwater Gas pipeline.

```
= HYDRAULIC AND THERMAL CALCULATION OF PIPELINE =
--------------------------------------------------------------------------
 Pipeline Inlet flow - 3      ---------> 4      -    Outlet Flow.
--------------------------------------------------------------------------
= INITIAL DATA =
--------------------------------------------------------------------------
 Flow                                              kg/h       302635.400
                                                   scm/h       431250.1
 (t=20 C,P=0.1013 Mpa)                             mscmd         10.350
 Initial Pressure                                  MPa            7.936
                                                   barg           80.93
 Initial Temperature                               C              39.75
                                                   K             312.90
 Pipeline Length                                   m             2500.0
--------------------------------------------------------------------------
 Absolute roughness                                mm               .10
--------------------------------------------------------------------------
 No of   Sect.   Height  External Pipe    Heat     Ambien  Num.    Sect.
 sect.   Length  differ. pipe     thickn. transf.  Temp.   step    effic.
                         Diam.            coef.            calcul.
                                          W/(m^2K)
         m       m       mm       mm                C
--------------------------------------------------------------------------
 1      2500.       0.  370.0   10.0       .76     14.9      25       .95
--------------------------------------------------------------------------

THERMAL CONDITIONS

  Pipeline Location - Underwater

  Thermal conductivity coefficient  W/(m*K) 0.30

= CALCULATION RESULTS =
--------------------------------------------------------------------------
 Initial characteristics :              Volume gas fraction    1.000000
 velocity             15.141 m/s         Flow Mode - Single Phase

 Characteristics at the end of the section (pipeline):
--------------------------------------------------------------------------
 No of   Volume      Velocity  Flow          Pressure         Temperature
 section gas                   mode
         fraction     m/s                    Mpa      barg    C      K
--------------------------------------------------------------------------
1       1.000000   16.825     Single        7.097   72.37    36.4   309.6
                              Phase
--------------------------------------------------------------------------

 16-Dec-19
```

Table 45. Thermo-hydraulic calculation of underwater unloading pipeline.

### C.4.9. Design Loads

During the construction and operation, the underwater Gas pipelines will be subjected to various loads and impacts. These impacts can be classified in:

- *Functional loads;*
- *Environmental loads;*
- *Construction loads;*
- *Interference loads;*
- *Accidental loads;*
- *Other loads.*

The ***Functional loads*** include the loads arising from the physical existence of the Gas underwater pipelines and its intended use shall be classified as functional loads, for example, the pressure loads.

The ***Environmental loads*** are defined as those loads on the Gas underwater pipelines which are caused by the surrounding environment, and that are not otherwise classified as functional or accidental loads, for example, wind loads, hydrodynamic loads, ice loads, earthquake.

The ***Construction loads*** which arise as a result of the construction and operation of the Gas underwater pipelines shall be classified into functional and environmental loads, for example, stacking of pipes, pipe transportation, handling, lifting of pipes and pipe sections, static and dynamic installation loads, pressure testing, etc.

The ***Interference loads*** which are imposed on the Gas underwater pipelines from 3rd party activities shall be classified as Interference loads. Typical interference loads include trawl interference, anchoring, vessel impacts, and dropped objects.

The ***Accidental loads*** which are imposed on a Gas underwater pipelines under abnormal and unplanned conditions and with a probability of occurrence less than $10^{-2}$ within a year shall be classified as accidental loads, for example, extreme wave and current loads, vessel impact or other drifting items (collision, grounding, sinking, iceberg), dropped objects, infrequent internal overpressure, seabed movement and/or mudslides, explosion, fire and heat flux, accidental water filling due to wet buckle, operational malfunction, dragging anchors.

The Environmental data on the areas of the location of loading and unloading Gas terminals were given in the Report on the Work Package WP2. Other loads data will be collected and used in the development of the Basis of Design of underwater Gas pipelines at the stages of further development of the GASVESSEL Project when it is put into practice.

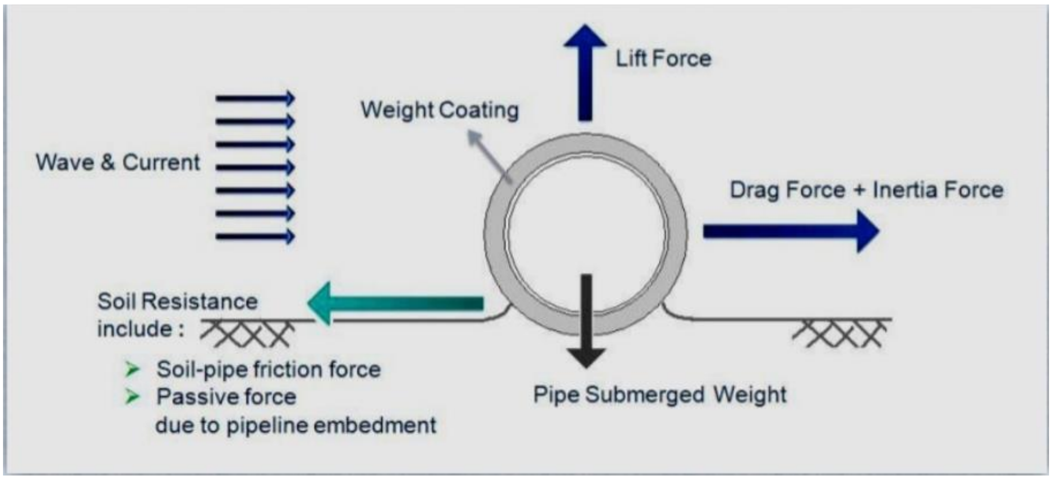



Figure 75. Loads and impacts on the underwater pipeline.

#### C.4.9.1. Pipeline route

The routes of underwater Gas pipelines for loading and unloading terminals in the Black Sea region are chosen based on the influence of the following indicators:

- Environment;
- Seabed characteristics;
- Facilities;
- Third-party activities;
- Shore crossing.

In Figure 76and Figure 77 are shown the underwater parts of the loading Gas pipelines from the loading terminal in the area of the port of Poti and the unloading terminal in the area of the port of Yuzhne.

The underwater Gas pipeline approaches the shore and goes underground to the terminals. The junction of the underwater part of the pipeline and the underground part will be described in details in the Section Construction method statement


Figure 76. The underwater part of the loading Gas pipeline in Georgia.

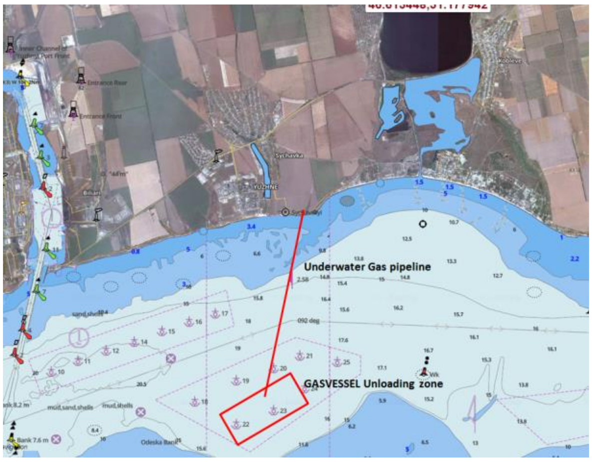



Figure 77.The underwater part of the loading Gas pipeline in Ukraine.

The direction of the laying of the underwater Gas pipelines was chosen based on the considerations given in this section, as well as reasons of sufficient depth for the CNG ship approach into the loading or unloading area.

A similar approach will be used in the construction of other underwater Gas pipelines in the areas of near-shore terminals in the Mediterranean and the Barents Sea regions.

#### C.4.9.2. Pipeline material selection

The materials for the underwater Gas pipeline are selected with due consideration of the loads, temperature and possible failure modes during installation and operation. The following material characteristics were considered:

- Mechanical properties;
- Hardness;
- Fracture toughness;
- Fatigue resistance;
- Weldability;
- Corrosion resistance.

Since the Gas transported through the underwater Gas pipeline does not contain hydrogen sulfide or sulfur impurities, no special corrosion-resistant steel is required for the pipeline material.
To determine the parameters of the underwater Gas pipeline (loading and unloading), approximate calculations were performed. The calculations were based on the MOP (maximum operation pressure) index[9].
The initial pressure for the calculation of the diameter and wall thickness of the underwater Gas pipeline is given in the table below.
The calculation did not take into account the depth of installation of the underwater Gas pipeline (to calculate the load collapse of an empty pipeline), as well as construction loads, which depend on the type of installation ship and the depth of installation of the pipeline. These calculations will be performed at the subsequent stages of the Project.
The above calculations were performed to determine the cost of the underwater pipeline.

| Process | Location | Constituent part | Maximum Pressure, MPa | Notes |
|---|---|---|---|---|
| **Loading** | **Offshore platform** | **Riser** | **24,0** | **Barents Sea**<br>(Alke, Johan Castberg);<br>**Mediterranean Sea**<br>(Cyprus EEZ, Lebanon offshore platforms); |
| | | **Underwater Pipeline** | **24,0** | |
| | **Onshore terminal** | **Underwater Pipeline** | **24,0** | **Black Sea**<br>(port of Poti); |
| **Unloading** | **Offshore platform** | **Underwater Pipeline** | **30,0** | **Barents Sea**<br>(Aasta Hansteen); |
| | **Onshore terminal** | **Underwater Pipeline** | **30,0** | **Barents Sea**<br>(Nyhamna);<br>**Mediterranean Sea**<br>(Cyprus Vasilikos, Grece Crete, Lebanon port of Zouk, Egypt);<br>**Black Sea**<br>(port of Yuzne) |

**Table 46. The initial pressure for underwater pipeline calculation.**

The calculations were performed according to the equations given in the API 1111 and DNV GL ST-F101 standards.
Were selected such requirements for the pipes:

Specification level – PSL 2 (PSL 2 pipe ordered for offshore service API 5L, Annex J);

Delivery conditions - Thermomechanical rolled or thermomechanical formed;

Pipe type SMLS;

Steel grade – X70;

The corrosion allowance was adopted as 2 mm.

The results of the calculation are given in the tables below:

### *Loading process*

**PIPE WALL THICKNESS CALCULATION**

Version 1.0

| | | | |
|---|---|---|---|
| Project Name | Gas Interconnector Pipeline | By | BS |
| Project Number | | Chkd by | VK |
| | | Appd by | VK |
| Design Pressure (Pb) | 240 bar g | 3480,90 psi g | |

SMYS (psi)

| | | | | | |
|---|---|---|---|---|---|
| 35000 | for pipe Gr. B | 42000 | for pipe X42 | 46000 | for pipe X46 |
| 52000 | for pipe X52 | 56000 | for pipe X56 | 60000 | for pipe X60 |
| 65000 | for pipe X65 | 70000 | for pipe X70 | 80000 | for pipe X80 |

| | |
|---|---|
| Joint factor (E) | 1 |
| Corrosion Allowance | 2 mm |
| Temperature derating factor (T) | 1 |
| U | 82000 |
| Design code | API RP-1111 |

Equation :

t=Pb x D/[0,90(S x F+U) x E x T+Pb]+Corrosion Allowance

| No | Outside Dia. (D) | Design Factor (F) | SMYS | Grade | Wall thickness | | |
|---|---|---|---|---|---|---|---|
| | | | | | Calculated | Calculated | Available |
| | inch | | psi | | inch | mm | inch |
| 1 | 14 | 0,72 | 70000 | X70 | 0,476 | 14,09 | 0,562 |
| 2 | 14 | 0,6 | 70000 | X70 | 0,502 | 14,76 | 0,625 |
| 3 | 14 | 0,5 | 70000 | X70 | 0,527 | 15,38 | 0,625 |

**Table 47. Calculation results of the underwater loading gas pipeline.**

### *Unloading process*

**PIPE WALL THICKNESS CALCULATION**

Version 1.0

| | | | |
|---|---|---|---|
| Project Name | Gas Interconnector Pipeline | By | BS |
| Project Number | | Chkd by | VK |
| | | Appd by | VK |
| Design Pressure (Pb) | 80 bar g | 1160,30 psi g | |

SMYS (psi)

| | | | | | |
|---|---|---|---|---|---|
| 35000 | for pipe Gr. B | 42000 | for pipe X42 | 46000 | for pipe X46 |
| 52000 | for pipe X52 | 56000 | for pipe X56 | 60000 | for pipe X60 |
| 65000 | for pipe X65 | 70000 | for pipe X70 | 80000 | for pipe X80 |

| | |
|---|---|
| Joint factor (E) | 1 |
| Corrosion Allowance | 2 mm |
| Temperature derating factor (T) | 1 |
| U | 82000 |
| Design code | API RP-1111 |

Equation :

t=Pb x D/[0,90(S x F+U) x E x T+Pb]+Corrosion Allowance

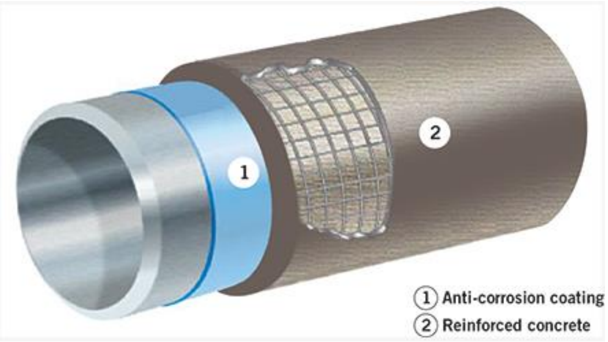
| No | Outside Dia. (D) | Design Factor (F) | SMYS | Grade | Wall thickness | | |
|---|---|---|---|---|---|---|---|
| | | | | | Calculated | Calculated | Available |
| | inch | | psi | | inch | mm | inch |
| 1 | 14 | 0,72 | 70000 | X70 | 0,214 | 7,43 | 0,219 |
| 2 | 14 | 0,6 | 70000 | X70 | 0,223 | 7,66 | 0,250 |
| 3 | 14 | 0,5 | 70000 | X70 | 0,231 | 7,88 | 0,250 |

**Table 48. Calculation results of the underwater unloading gas pipeline.**

The figure below shows the loads on the pipeline which impact affect it during operation.
To ensure the stability of the loading/unloading pipelines we take the following pipe parameters:

***Loading process:***
Pipe Specification API 5L, PSL 2, SMLS, Grade X70, Delivery conditions - Thermomechanical rolled or thermomechanical formed, Dimensions – 14x0,625", Corrosion allowance - 2 mm, Outdoor concrete coating thickness 40 mm (coverage share 2,9 t/$m^3$.

***Unloading process:***
Pipe Specification API 5L, PSL 2, SMLS, Grade X70, Delivery conditions - Thermomechanical rolled or thermomechanical formed, Dimensions – 14x0,250", Corrosion allowance - 2 mm, Outdoor concrete coating thickness 30 mm (coverage share 2,9 t/$m^3$.




or

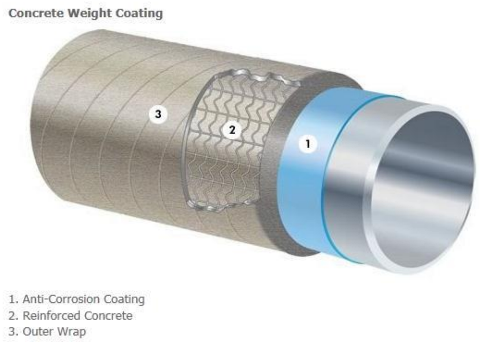
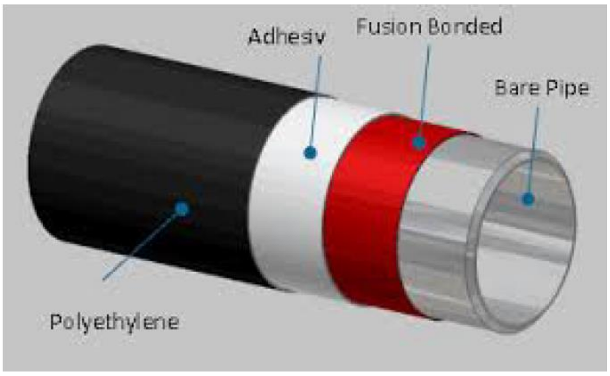



Figure 78. External concrete weight coating.

Design criteria for the calculation of the required thickness of external weight concrete coating or another method of stabilization of the pipeline use the DNV-RP-F-109 Standard.

### C.4.10. Anticorrosive protection

The Technical decisions of underwater pipeline external corrosion protection are based on a combination of anticorrosion coating and cathodic protection systems. Since the maximum temperature of the Gas during the loading of GASVESSEL will not exceed the 110 $^0$C we can propose as anticorrosion coating 3-layer polyethylene (PE) or in a case of temperature will not exceed the 140 $^0$C - 3-layer polypropylene (PP) with combination of Sacrificial anodes (Aluminium anode and Zinc anode) as cathodic protection system. Pipeline anti-corrosion coating is the first barrier of defense against corrosion due to probably damages could be made o coating, CP System will be applied in parallel. CP design uses the DNV-RP-F-103 Standard.



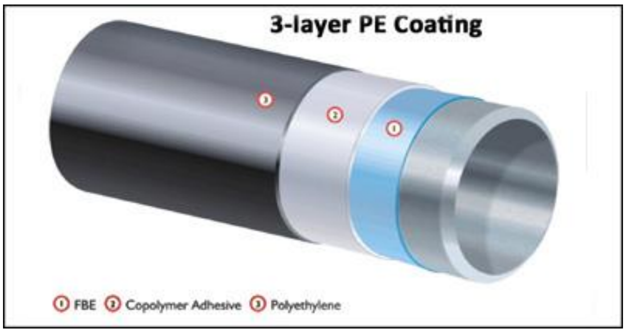




Figure 79. 3 layer polyethylene anti-corrosion coating.

The application of anti-corrosion coating on the pipes is produced in the factory. After applying anti-corrosion insulation, a concrete coating is applied to the pipes. The ends of pipes intended for welding are left uncoated. After welding the pipes into the whip and control of welds, the Thermo shrinkable films are installed at the place of welding.

### C.4.11. Riser for offshore platforms

To ensure the connection of the loading Gas pipeline that runs from the offshore platform to the horizontal underwater pipeline, a vertical pipeline (riser) is fixed to the metal structures of the platform. The lower part of the riser is fixed either to the steel structures of the platform or fixed on a special foundation. With a bend, the riser is connected to the underwater pipeline. The Figure below shows the option of fixing the riser to the platform structure.

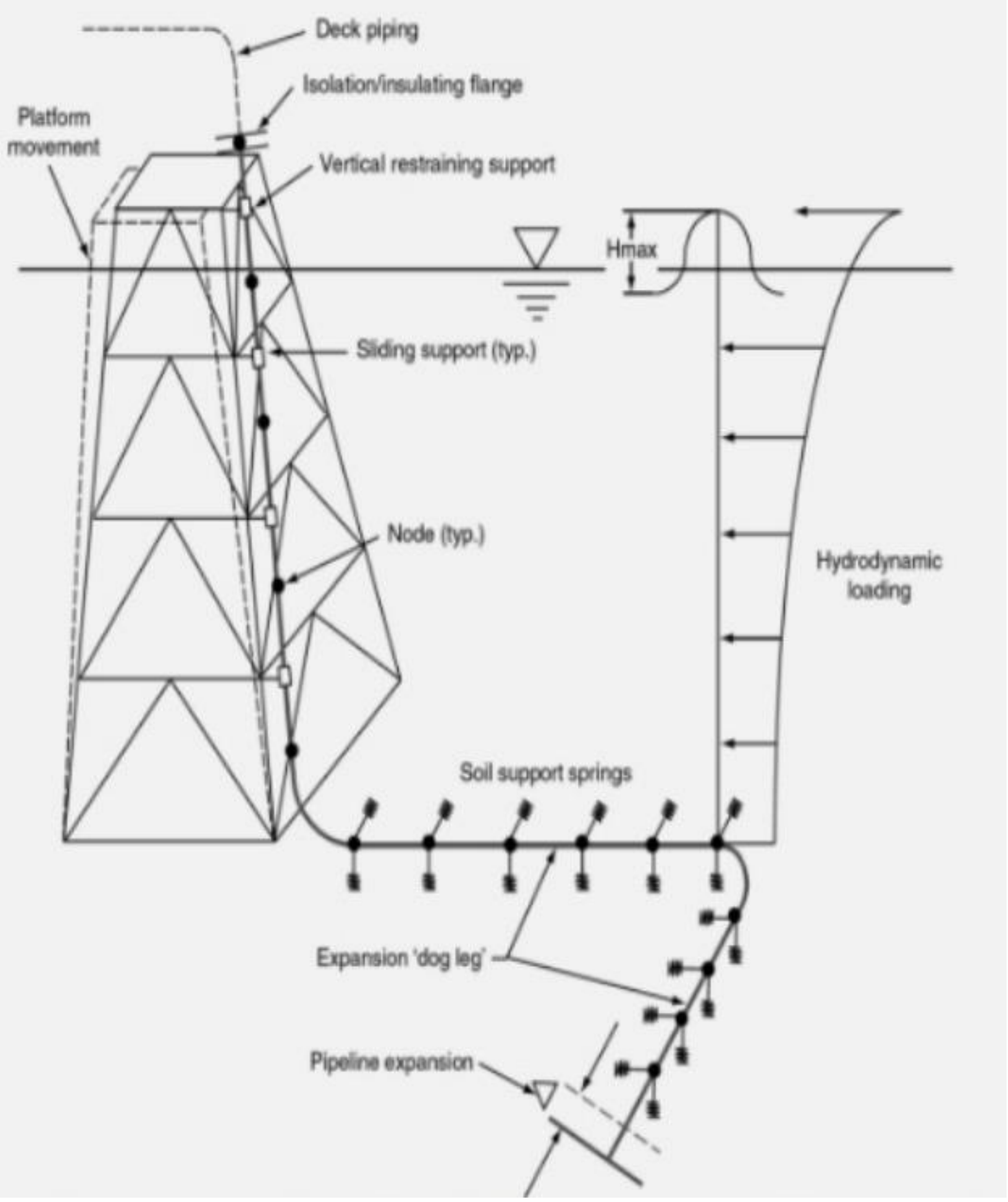



Figure 80. The option of the technical decision of riser fixing to the offshore platform.

### C.4.12. Construction method statement

The construction of the underwater Gas pipeline for loading/unloading of GASVESSEL in the area of the onshore terminals begins with the ditching of a trench on the shore and laying the pipeline towards the sea. Reaching the shoreline on the pipeline install the blind. The trench with the installed section of the pipeline does not backfill. Carry out the hydraulic testing of the pipeline section. In the sea, at a distance allowing the installation vessel to approach the shore, laying of the pipeline to the seabed begins.

Before the installation, a pipe blind and a special hook are installed on the end of the pipeline to enable attachment of traction winch wire rope. In the direction of installation of the pipeline on the seabed, a trench is laid for laying the pipeline.
From the coast, a similar trench is being built with a ditch to install a winch. After starting the installation of the pipeline from the installation vessel, the end of the pipeline with a winch is tightened into the coastal trench to the tie-in location and the pipeline joints are welded with a control seam.
To preserve the trench in the zone of transition of the coastal trench to the sea, a sheet piling (cofferdam) is arranged, inside which the soil is removed by an excavator on the shore and a special vessel at the sea.

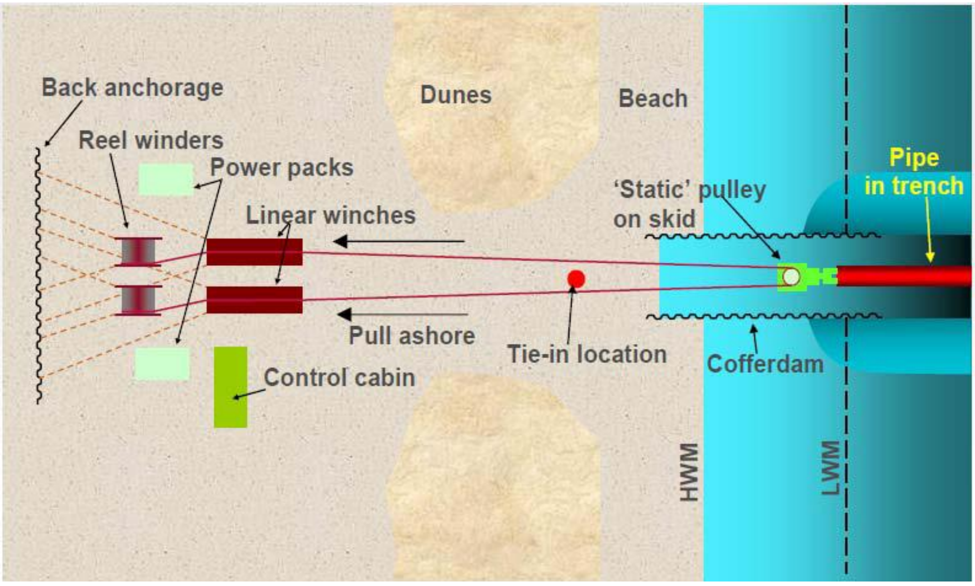



Figure 81. Scheme of tie-in the onshore and offshore parts of loading/unloading Gas pipeline.

After completing the above steps, the installation vessel begins installation the offshore section of the pipeline before docking with the PLEM.
The general scheme of the functions of the installation vessel is shown in the figure below.

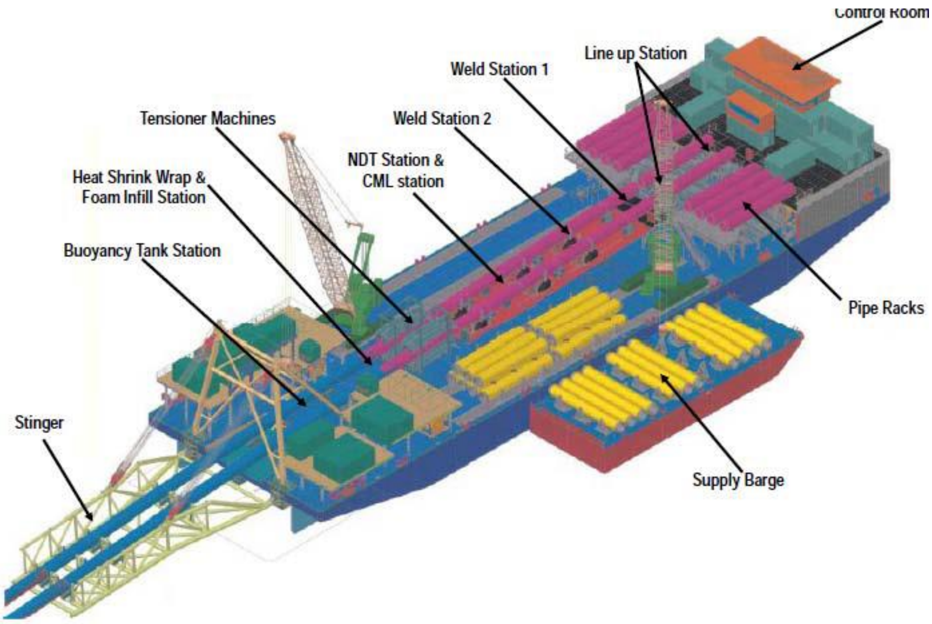



Figure 82. The complex of the installation vessel.

The scheme of pipeline laying on the installation process of installation vessel was adopted S-lay.

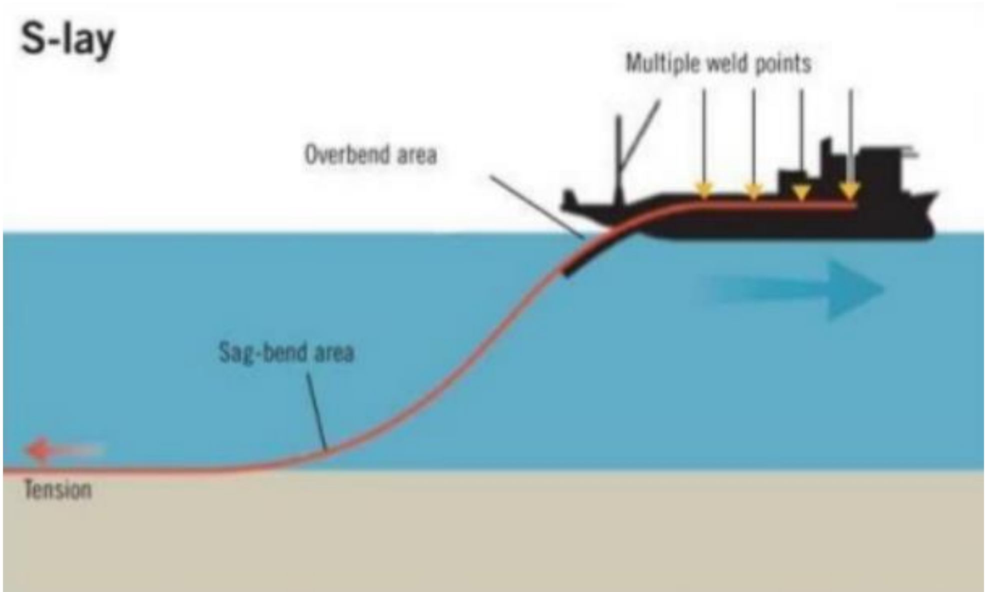



Figure 83. The option of underwater pipeline installation.

Further work of the installation vessel is reduced to the performance of such operations:

- Pre-concreted pipes on special barges are brought in and reloaded onto the installation vessel

- and move to the assembly line.

- The ends of the pipes are processed on the end seam machine.

- The pipes are moved to the lineup station.


- The surface of the pipe is prepared for welding, the guide of the semi-automatic welding machine is installed, and the root seam is welded.


- The finishing seam is imposed.

- The finished seam is cleaned and cooled.


- Automatic ultrasonic inspection of the weld and stripping with metal brushes of the zone for the application of anti-corrosion insulation.

- The primer is applied on the cleared and heated-up surface.

- Shrink sleeve is installed.

- A high-strength high-density polyurethane coupling is installed at the joint, and the joint area of the pipes is filled with a special foam or composite material.

- For the installation of the signal and control cables, special fastenings are mounted to the pipe. After that, the pipe is lowered onto the seabed along with the stinger of the installation vessel.

- Instead of a cover sleeve made of polyurethane, a sleeve made of galvanized steel can be installed, followed by filling with foam or composite material.

**Figure 84. The sequence of laying the marine part of the pipeline with the installation vessel.**

Similar technology for the construction of the offshore part of the Gas pipeline will be implemented for the Barents Sea. In the Barents Sea, installation vessels will be used for the construction of pipelines at somewhat greater depths, as well as making joints with a riser at offshore platforms will be carried out with the help of special deep-water diving bells.

### C.4.13. Quality control

The safety format requires that gross errors (human errors) shall be controlled by requirements for the organization of the work, the competence of persons performing the work, verification of the design, and quality assurance during all relevant phases.

It is assumed that the pipeline system has been constructed in high-quality fulfillment. To all the Project members shall, in both internal and external quality-related aspects, seek to achieve the quality level of products and services intended in the quality objective. Further, the Project members shall provide assurance that intended quality is being or will be, achieved ю Documented quality systems shall be applied by Project members and other parties (e.g. design contractors, manufacturers, fabricators, and installation contractors) to ensure that products, processes, and services will be in compliance with the requirements. Effective implementation of quality systems shall be documented.

The repeated occurrence of non-conformities reflecting systematic deviations from procedures and/or inadequate workmanship shall initiate:

- the investigation into the causes of the non-conformities,
- reassessment of the quality system,
- corrective action to establish the possible acceptability of products,
- preventative action to prevent the re-occurrence of similar non-conformities.

Quality surveillance in the construction phase shall be performed by the Third-party inspection or an inspectorate nominated by the operator. The extent of quality surveillance shall be sufficient to establish that specified requirements are fulfilled and that the intended quality level is maintained. For Quality Assurance, an ISO Standard package shall be applied.

### C.4.14. Health, Safety & Environment

The concept development, design, construction, operation and abandonment of the pipeline system shall be conducted in compliance with national legislation and Project members policy with respect to health, safety, and environmental aspects.
The selection of materials and processes shall be conducted with due regard to the safety of the public and employees and to the protection of the environment.

### C.4.15. Investment Value Assessment

The Calculations of the cost of underwater Gas pipelines will be included in Table 52.

## C.5. Unloading terminal in the area of the port of Yuzhny (Ukraine).

### C.5.1. Introduction

This section addresses the Technical issues of the construction of the onshore gas unloading terminal near the port of Yuzne in Ukraine.

The gas unloading terminal is one of the links in the general gas transportation system for the unloading of CNG ship for the gas transport to Ukraine.

The unloading terminal will be situated in the free lands near the port of Yuzne.

### C.5.2. Purpose of the Gas loading terminal

The gas unloading terminal is meant to unload the CNG ship in the volumes necessary for carrying out gas transportation in the Black Sea region. The gas unloading terminal is connected to the existing Ukrainian gas network via the Interconnector to the point of connection near the existing Berezivka Compressor station.

The maximum productivity parameters of gas unloading are of 10,35 mscmd.

### C.5.3. Glossary, abbreviations, and acronyms

Glossary, abbreviations, and acronyms in this Section are the same as in Section C.3.3.

### C.5.4. Units of measurement.

The Units of measurement which are used in this section are shown in Table 2.

### C.5.5. Climate data and Geographic conditions of the Gas unloading terminal

The area of the proposed construction of the gas unloading terminal is characterized by the following climatic characteristics (Standard SNiP 23-01).

| The Environmental parameters | Data |
|---|---|
| *Temperature:* | |
| - Average air temperature in January, $^0$C | minus 6,6 |
| - Average air temperature in July, $^0$C | 15,8 |
| - Average annual air temperature, $^0$C | 5,2 |
| - Absolute minimum air temperature, $^0$C | minus 38 |
| - Absolute maximum air temperature, $^0$C | 37 |
| - Average maximum temperature of the hottest month, $^0$C | 21,7 |
| - Average air temperature of the coldest five-day week with a rated of 0.92 $^0$C, | minus 15 |
| Maximum depth of soil freezing, cm | 63 |
| *Wind:* | |
| Prevailing wind direction in January | East |
| Prevailing wind direction in July | North |
| Average wind speed in January in the prevailing direction, m/s | 5,1 |
| Average wind speed in July in the prevailing direction, m/s | 5,8 |
| Wind velocity, kPa | 0,48 |
| *Precipitation:* | |
| Rainfall per year, mm | 621 |
| Daily maximum, mm | 63 |
| The average height of snow cover, cm | 68 |
| Snow cover weight per 1 $m^2$ of a horizontal surface, kPa | 1,0 |
| Seismicity of the CS area (on the MSK-64 scale) | grade 8 |
| Average monthly relative humidity of air at 13 hours,%:<br>- the hottest month;<br>- the coldest month | <br>72<br>61 |

Table 49. Environmental parameters of the area of the Gas unloading terminal.

### C.5.6. Codes and Standards

The Codes and Standards used for design and build the Gas unloading terminal near the port of Yuzne must meet the Standards used in the best practice of international Engineering taking into account the Ukrainian national Standards. The list of applicable Standards is the same as shown in Section C.3.6.

### C.5.7. Description of the Gas unloading terminal site

The Gas unloading terminal site will be situated on the East of the port of Yuzne on the free site. The construction of the unloading terminal will require its location at a safe distance (at least 500 m from residential buildings). In fact, the distance between the residual buildings of Sychavka village and the fence of the unloading terminal is 570 m, which corresponds to the standard safety distance.

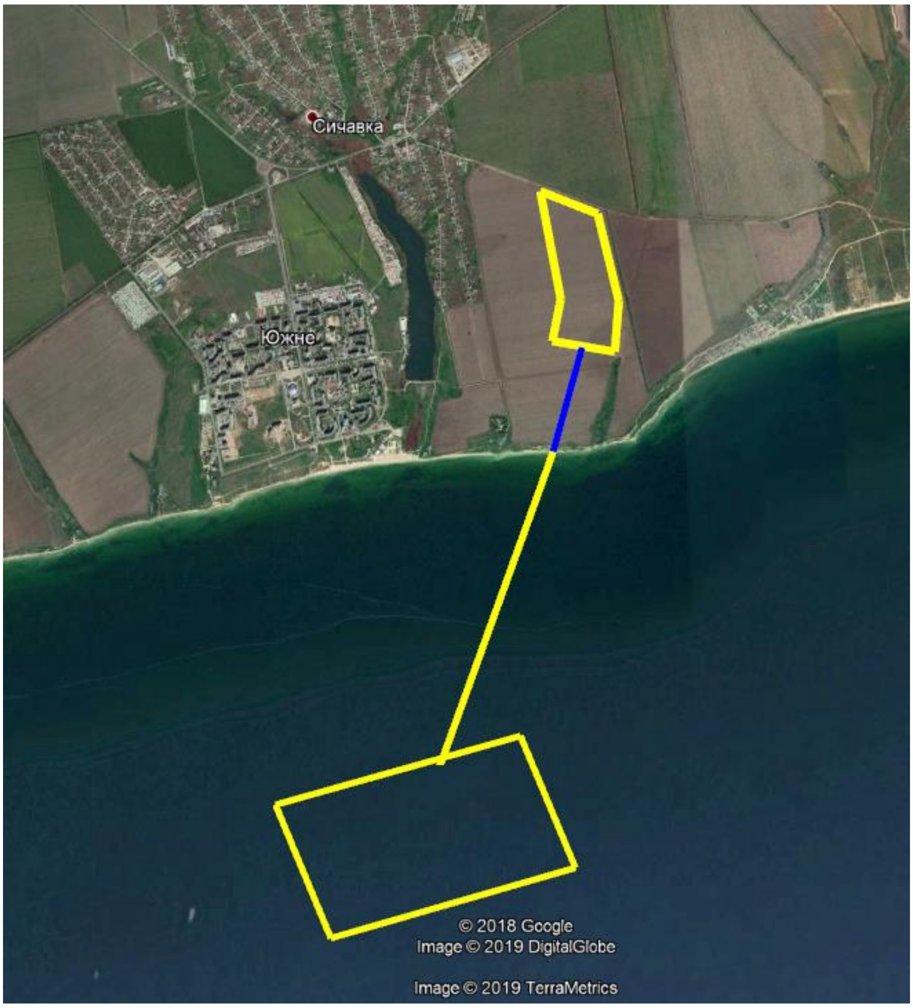



Figure 85. Allocation of the Gas unloading terminal near the port of Yuzne.

### C.5.8. Technical description of the Gas unloading terminal

The Facilities, modules, and systems of the Gas unloading terminal are intended to perform the unloading operations of CNG ship, including the management of unloading, measurement of gas unloading parameters, the creation of the necessary documents accompanying cargo (Compressed gas). For the implementation of these processes, three groups of facilities and structures have been identified and a separate group consists of connecting pipelines to the CNG ship and the Gas interconnector to existing National gas pipelines. The complex of unloading terminal will be designed to the accepted volumes of gas unloading, which are described in previous sections.

### C.5.9. The infrastructure of the terminal

In this section of the Report, we set out a vision of the VTG on the arrangement of unloading gas terminal for unloading service during the gas supplying to Ukraine.
The structure of the Gas unloading terminal facilities is the fully independent infrastructure.
The modules of equipment and systems are necessary for the realization of the tasks of gas unloading for the CNG ship. The overall diagram of the unloading process we can see in Figure 103.

#### C.5.9.1. Gas unloading terminal near the port of Yuzne (Ukraine)

The composition of the gas unloading terminal facilities is described in more detail in Section B.3.3.2. The following is a description of the terminal facilities.

#### C.5.9.2. Main process facilities (modules) of Onshore Gas unloading terminal

##### C.5.9.2.1. Gas storage module

For the Gas, storage is used FRA-CO containers with a capacity of 12,000 scm each. The same design solutions are used in the CNG ship. Depending on the required capacity of the Gas storage, the number of FRA-CO containers may vary. Each FRA-CO container consists of a cylinder made of carbon composite material and piping with valves and automation sensors. If necessary, the number of containers may be increased or decreased. All containers are connected to the binding pipeline through which the Gas storage can be loaded or unloaded. Gas storage can be built in half a pile. To reduce security risks, Gas storage should be divided into sections of 64 FRA-CO containers. Between the sections must be provided the backfilling with the loose ground, the distance between the sections is to be at least 6 meters. Gas storage should also be equipped with gas leak detection systems, security systems, and fire fighting systems. The onshore gas storage facility will be developed at subsequent stages of Project development.

##### C.5.9.2.2. Gas pressure reducing module

The aim of a pressure reducing module is to regulate the gas outlet pressure to a setting value according to norm EN 12186. The pressure-regulating unit consists of a train of the self-actuated or piloted valve, composed by a block valve and monitor fail to close the valve that gives the double barrier against overpressure as required by the latest version of European code.
The typical solution consists mainly of two reducing streams (2×100% capacity) with two regulators each: one is the main regulator and the other is used as a monitor/slam shut valve. Active and monitor pressure regulator shall be Top entry type in order to guarantee simple maintenance of the equipment. The active regulator normally assures pressure reduction to the setting value.
To assure gas supply continuity in case of failure of the active regulator a second regulator (monitor) is installed in series. The monitor regulator is normally wide open. In the event of an accidental increase of outlet pressure, the monitor regulator will take over as a control valve. During the normal operation, depending on the service, one line is working while the other line is in stand-by. Only in case of a failure of the monitor and main regulator, the standby line starts to work. An overpressure slam shut device, in the event the outlet pressure exceeds an acceptable value, protects the equipment downstream of the pressure regulators from over-pressure.
The limitation of pressure in the downstream end is supported by safety devices like Slam shut off valve, safety relief valve, creep relief valve, etc.
The pressure regulators and safety devices are powered by the gas itself so that this function does not require any external power source i.e. comp. air or electrical supply.
A Gas pressure reducing module is consist of,
***Ball valves***: to isolate the system from the mains supply or to isolate either side of PRS.

***Filtration unit***: A filter protects the rest of the system from any debris or dust that may be carried with the gas stream. Debris may, for example, consist of parts accidentally left in the pipe during construction. It could also result from swarf from drilling holes & taps or welding & sand from construction or fine iron oxide dust.

***Slam shut off Valve***: Slam shut off valves is installed after Filter & before pressure regulator. Slam shut off valve close the supply of gas when downstream pressure exceeds a pre-determined limit.

***Pressure regulator***: Pressure regulator maintains downstream pressure at a certain quantity of Gas, irrespective of variation in upstream pressure from maximum to minimum limit. Spring-loaded or Pilot operated pressure regulators are used.

***Relief valves***:

- Creep Relief Valve: A slight weeping of pressure regulator/ increase in downstream due to rise in downstream surrounding temperature result in increasing the downstream pressure to a dangerous level, such creep pressure is blown off through creep relief valve.
- Safety Relief Valve: The safety relief valve set at a higher pressure than the slam shut off valve so that the safety relief valve will operate when the slam shut off valve fails to operate.

***Pressure gauges***: To monitor upstream and downstream pressure, the pressure gauges are installed. An isolation valve is provided with each pressure gauge for easy replacement of pressure gauges in case of failure.

**Figure 86. Gas pressure reducing module in an open-air option.**

Figure 87. A Gas pressure reducing module in a container option (with the walls removed).

#### C.5.9.2.3. Gas heating module

The gas heating module is designed to heat the gas after reducing the pressure to a temperature of 10 $^{0}$C. This temperature was chosen in order to save energy for gas heating, which is quite enough to measure the Gas parameters and transfer it to existing gas networks. The main equipment of the module is the heat exchanger. The design of the heat exchanger is as described below.

***Tubes***

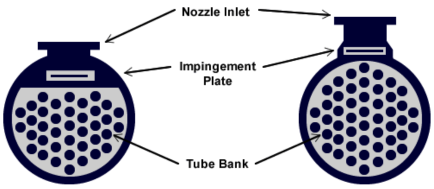
Heat exchangers with shell diameters of 20 inches are typically manufactured to industry standards. Commonly, 1.5" tubing used in exchangers is made from low carbon steel, Admiralty, copper, copper-nickel, stainless steel, Hastelloy, Inconel, or titanium.
Tubes can be drawn and thus seamless, or welded.

***Tube Sheets***

Tube sheets constructed from a round, flattened sheet of metal. Holes for the tube ends are teen drilled for the tube ends in a pattern relative to each other. The tube holes can both be drilled and reamed, this significantly increases tube joint strength.

***Shell Assembly***

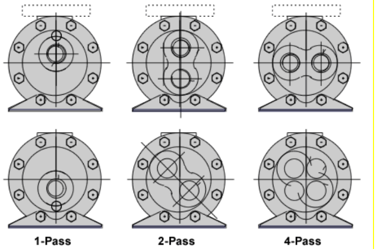
The shell is constructed either from a pipe or rolled plate metal. For economic reasons, steel is the most commonly used material.




A consistent inner shell diameter or ‘roundness’ needs to minimize the baffle spacing on the outside edge, excessive space reduces performance as the fluid tends to channel and bypasses the core. Roundness is increased typically by using a mandrel and expanding the shell around it, or by double rolling the shell after welding the longitudinal seam. In some cases, although extreme, the shell is cast and then bored out until the correct inner diameter is achieved.

***Bonnets and End Channels***

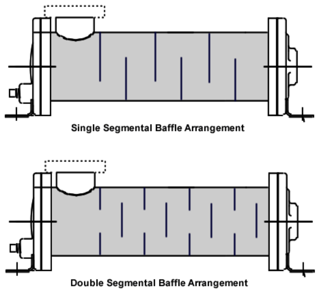
Bonnets/end channels regulate the flow of fluid in the tube-side circuit, they are typically fabricated or cast. They are mounted against the tube sheet with a bolt and Gasket assembly.




If one or more passes are intended, the head may include pass ribs that direct flow through the tube bundle. The material used in the cast bonnets/heads used in smaller diameters (ie 15" or less) are typical, poured from iron, steel, bronze, Hastelloy, nickel-plated, or stainless steel. Pipe connections are normally NPT, others including SAE, tri-clamp, ASME flanged, BSPP, and other types are available.

***Baffles***

Baffles function in two ways, during assembly they function as tube guides, in operation, they prevent vibration from flow induced eddies, last but most importantly they direct shell-side fluids across the bundle increasing velocity and turbulence effectively increasing the rate of heat transfer. In typical applications, baffles occupy with 40-45% of shell diameter are used.




Baffle placement requires an overlap at one or more tubes in a row to provide adequate tube support. Additionally, baffles are spaced evenly throughout the shell to aid in reducing pressure drop and even fluid velocity. In a 'single-segmental' configuration, baffles move fluid or Gas across the full tube count. When high-velocity Gases are present, this configuration would result in excessive pressure loss thus calling a 'double-segmental' layout. In a 'double-segmental' arrangement, structural effectiveness is retained, yet allowing Gas to flow in a straighter overall direction. While this configuration takes full advantage of the full available tube surface, a reduction in heat transfer performance should be expected.

#### C.5.9.2.4. Gas measuring module

After all storage and other operations, immediately before the Gas is supplied from the intermediate Gas storage to the pipeline to the Interconnector for Gas delivery to consumers, the volume of Gas supplied must be measured. The gas measuring module will be designed as a station of commercial measuring of Gas flow during the Gas transmission.

For monitoring of module condition, the transmission of results of Gas flow measurements and fulfillment of certain commands from the Central dispatching office, the metering module will have informational access to the SCADA system. The metering module will be equipped with surveillance (SS) and an ecological monitoring system. For more details see Section C.1.8.2.4.

Figure 88. Gas metering equipment inside the Gas metering module.

#### C.5.9.2.5. Site piping

All piping, fittings, flanges and valves design within the facilities of the Gas unloading terminal will be carried out in accordance with codes as follows:

- ASME B31.4 for pipelines.
- ASME B31.8 for the fuel Gas main system.
- ASME B31.3 for process piping, all plant utilities like plant air, instrument air, nitrogen, all types of water piping, diesel, chemicals, lubricating oil, etc.

The above basis takes into account the saving of material in case of using the B31.4/B31.8 code for Loading terminal piping allowed in accordance with para 400.1.1 and Fig. 400.1.1-1 of ASME B31.4 and para 802.1(4) of ASME B31.8. However, when it can be proved that ASME B31.3 will yield overall savings in terms of pressure testing, radiographic testing, Post Weld Heat Treatment (PWHT), support design, stress analysis, etc. or where it is essential from other considerations like limits of temperature, ASME B31.3 will be followed. The section will be developed in more detail based on the actual Master plan and the placement of the modules at the Gas unloading terminal site.

### C.5.9.3. Auxiliary process facilities (modules) of a loading terminal

#### C.5.9.3.1. Process automation and signaling system

In terms of its configuration and functions, the Automation system for the unloading process is similar to the Automation system described in the Automation Section of the Gas Loading Terminal.

All facilities and modules on the Gas unloading terminal site to be designed/engineered and will be supervised and controlled by the Master Control Room (MCR) located at the site of Gas unloading terminal. Systems of automatic control are necessary for the following functions:

a) the automatic control of the unloading process and Gas flow to the Gas interconnector;

b) the ability to control Gas transfer processes through the Gas Interconnector to the Gas consumers and control of the Pressure reducing module operation as well as parameters of Gas storage with the dispatcher displaying information;

c) control functions of all systems of the terminal;

d) drawing up commercial documents for unloaded Gas and the incoming and effluent Gas stream from the Gas storage.

Operators' room of Gas unloading terminal will be designed for the permanent presence of personnel having a possibility to control manually and maintain optimum parameters of the unloading process. Control systems will be highly reliable and trouble-free, however in the case of loss of control signal, Gas loading terminal equipment will be automatically switched over into a safe position.

Local pneumatic control chains will be used if necessary, but only on the condition that their reliability will be the same or higher of electrical circuits' reliability.

Technical means of control systems will be assembled on sides of instrument panels to enable free access to them during their maintenance. Cable feeding-in to the instrument panels will be made from below, while access to the panels – from behind.

The terminal control system will consist of a few subsystems.

***Subsystem of terminal Control***

The subsystem of terminal control will maintain permanent communication with:

- terminal operator's interface;
- the subsystem of the emergency stop;
- Gas unloading control subsystems.

***Subsystem of Gas unloading Control***

The subsystem will consist of PLC with corresponding input/output means, screen terminal of operator's interface, an alpha-numeric keyboard, a regulator of speed and surge protection (both regulators are microprocessor-based) and hardware for engine control.

The system is supplied with requisite software for monitoring and control purposes.

Information confirming identity in the approach to software, both in respect of unit control subsystem and station control subsystem, will also be submitted.

***Emergency Shut Down Subsystem (ES)***

ES subsystem will perform the following functions:

- control and monitoring of position (open-shut) of terminal valves;
- control of Gas parameters in the Gas storage;
- automatic monitoring of emergency shut down circuits integrity;
- fire detection;
- Gas leakage detection;
- too high temperatures detection;
- monitoring manual emergency shut down terminal and critical terminal variable parameters;
- permanent communication with subsystems of units control;
- permanent communication with the terminal local network for detection of emergency signals and read-out of information on equipment condition;
- monitoring of the processors of terminal PLC (watch timer);
- ensuring of hard (physical channel) connection with all emergency shut down systems and facilities.

Emergency shut down buttons will be provided at each gate along the terminal perimeter, neat each main entrance in the aggregate shelter, Gas storage, near the main entrance to the auxiliary building and on the terminal control panel.

***Monitoring Condition of the Main equipment***

A system of monitoring condition of process equipment will perform the following functions:

- a permanent monitoring of equipment condition in real-time and recording of monitoring data;
- forming of files on equipment condition and drawing up necessary schedules;
- storage of data on equipment condition received from electronic devices manually, using an operator interface;
- defining of functional capabilities and calculation of productivity of Gas flow in unloading process and Gas flow to the consumers.

***Engines Control Center***

All engine control signals will come to intermediate relays installed in MMS and has a 24V DC power supply. Feedback signals on the fulfillment of engine start/stop commands will be connected to the terminal equipment or unit control system, depending on the functional designation of the engine.

Terminal and unit control systems will have technical means of permanent automatic control of engine control circuit integrity.

***Requirements to Operators' Room***

The following main equipment will be installed in the operators' room:

- units control panel;
- terminal control panel;
- emergency shut down system panel;
- operator's interface equipment;
- system of Process equipment condition visual monitoring;
- fire-prevention system panel;
- printers rack.

#### C.5.9.3.2. Instrument and Plant Air System

The configuration and functions of the Instrument Plant Air System of the Unloading terminal are similar to the Instrument Plant Air System of the Gas Loading Terminal. As described in section C.5.9.3.1 to control the drives of cranes and valves, it is necessary to supply the unloading terminal site with instrument compressed air. The block air compressor station with a capacity of 300 $sm^3/h$ of prepared air with a dew point temperature of minus 40 $^0C$ and with an output pressure of 75 bar is used. The station is made with 100% redundancy of compressor equipment, an adsorption dryer, and filter elements. For the storage of instrument air, a 5 $m^3$ receiver is installed. For storage of compressed dried air, 3 receivers of the volume of 25 $m^3$ each are installed:

- receiver for compressed air used for receiving an instrument air,
- receiver for storing air used to control pneumatic actuators,
- receiver for storage of repair air.

All equipment is mounted in a 3 pcs of 12-meter all-metal insulated block container.

Each container is equipped with automatic fire extinguishing systems, fire alarms, supply, and exhaust ventilation, heating, and air conditioning, main and emergency lighting.

#### C.5.9.3.3. Nitrogen generation and distribution system

To provide the unloading terminal with compressed nitrogen, a nitrogen membrane-type station is provided in a container version. When repairing and operating equipment and pipelines in order to avoid the formation of an explosive mixture, Gas is replaced by nitrogen. Nitrogen at the loading terminal site is used to purge pipelines and Gas storage. Nitrogen-expelled Gas is dumped onto the Flare system. The Technical parameters of the Nitrogen generation and distribution system are shown in Table 38.

#### C.5.9.3.4. Vent/Flare system

For the protection against abnormal conditions, the internal pressure could rise above the design value overpressure, protection against excessive temperature and Gas replacing from Gas pipelines, Gas storage, and other equipment the pressure-relieving and emergency depressurizing systems are required. Collected Gas through the pipeline enters the flare, where it burns. Flare system is equipped with an automatic ignition system, which is triggered when a Gas appears in the supply line. The flare is set by a Ko drum tank for collecting drops of liquid. Relief and emergency depressurizing systems will be designed in accordance with API STD 520 (Part I) and API STD 521. The flare system designed considering potential ignition by a spark or lightning strike. The total permissible radiation intensity for the design of the sterile area radius around the vent stack is 6.31 kW/m² at the outer boundary of the sterile area according to API 521.

#### C.5.9.3.5. Power supply and power distribution system

The configuration and functions of the Instrument Plant Air System of Unloading terminal are similar to the Instrument Plant Air System of the Gas of Loading Terminal.

The power supply and power distribution system of the Unloading terminal includes the system of external and internal power generation, power supply, power distribution, electric lighting, lightning protection and grounding of buildings and facilities of the compressor station.

The power supply system, the choice of electrical equipment will be made on the basis of international and European Standards.

The power supply of the Gas Unloading terminal site will be performed from its own Gas turbine power station consisting of two blocks of 2.5 MVA each (each of which is loaded in normal mode by about 50%) with a voltage of 10 kV and from a backup power source. The Gas turbine power station is the main option of Power supply. Depending on the capacity of local electric networks to transfer the required power for the Unloading terminal, the length of the transmission line may vary. For the distribution of electrical power will be used switchgear involved in the production of electricity using a Gas power plant.

The power supply scheme provides for the supply and construction of the following main power supply facilities:

- Gas turbine power station with a capacity of 2x2500 kVA, the voltage of 10 kV (one working and 1 in reserve) installed in individual all-weather modules of full factory readiness;
- 10kV closed switchgear in the block-modular building of full factory readiness 10 kV indoor switchgear is provided using 10 kV SF6 or vacuum circuit breakers;
- a two-transformer power substation 10/0.4 kV, with dry transformers rated at 2x2500 kVA for power supply of the compressors in a block-modular building of maximum prefabrication mode, for power supply of Gas turbines, process, and infrastructure facilities (repair shops, warehouses, canteen, service and maintenance rooms);
- a two-transformer substation 10/0.4 kV, with dry transformers with a power of 2x630 kVA for power supply to Gas air cooling modules in a block-modular building of maximum factory readiness;
- diesel power unit 0.4 kV with a power of 500 kW, connected to a 0.4 kV switchgear in a block-modular building of maximum prefabrication, for reserve power supplying of a special group of electrical consumers (fire pump, boiler room, equipment for automated process control systems, alarm, ventilation, lighting and etc.);
- overhead power transmission line (10kV overhead line) approximately up to 5 km long;
- 380V power supply without failures units with 110V batteries;
- systems of lightning protection and grounding;

- cables with a voltage of 0.4 kV and 10 kV of various sections with copper conductors, armored and unarmored with PVC sheath and insulation;
- various low-voltage equipment (switchboards 0,4/0,23 kV, buttons, actuators, terminal boxes, electrical installation products, etc.);
- lighting fixtures exterior and interior lighting.

The capacities of power transformers, emergency diesel power units, and Gas turbine power stations will be refined at subsequent design stages, taking into account the actual loads of electrical consumers.

#### C.5.9.3.6. Electrochemical anti-corrosion protection System

The means of active protection electrochemical anti-corrosion protection are used in the cathodic protection system of the Gas Unloading terminal facilities.
The protective potential of isolated steel underground units should be in the limits between -0,95 V and -1,2 V.

***Protectors.***
The essence of the protectors' usage lies in the creation of manufactured electric circuit, made from more electronegative material than the object itself. To protect steel underground pipelines from corrosion, it is proposed to install the protector units with the group of protectors from magnesium alloy.

**Bussing.**
Cable bussing is provided for the 48V circuit from the constant-potential transformer to sacrificial anode and drainage points. The cables should be copper, isolated by PVC for the voltage up to 1000V. The cables are laid at the depth of 1.0m on sifted or sand soil layer of 10cm, after this they are covered with the 15cm layer of the same soil, from above the trench is covered with the soil that was taken out earlier.
The connection of the cable to the pipeline is made by means of aluminothermic welding.

#### C.5.9.3.7. Diesel fuel system

For consumers of the first category, which include Fire fighting system and Control system, it is necessary to provide the backup power supply. For this purpose, a 500 kVA diesel power station is provided with a system for storing and supplying diesel fuel.
The Diesel fuel will be supplied by a car tanker and will be stored in a diesel fuel storage tank. Diesel will be required to fuel the emergency diesel power station day tank, fire water pumps, and fixed foam system. The main fuel storage tank has 4 days of storage capacity (100 cub m).
The emergency diesel power station with a capacity of 500 kVA is adopted in a noise-absorbing all-weather container in the concrete foundation.
The diesel fuel storage tank will be placed inside a concrete dike wall. Diesel fuel transfer pumps will pump the diesel fuel to consumers through diesel fuel filters. The pressure drop across filters will be monitored and changeover of the filter will be made when the pressure drop is high which shows plugging of the filter. A low level in the storage will alarm the operating personnel to re-fill the tank. The storage tank will be re-filled from a diesel fuel road tanker through unloading connections provided for this purpose.

#### C.5.9.3.8. Communication, alarm, fire alarm system

The configuration of the Communication, alarm, and fire alarm system of the Gas Unloading terminal is similar to the configuration and functions of the Communication system of the Gas Loading terminal described in Section C.3.9.2.8.

#### C.5.9.3.9. Power, control and signaling cables

Power electrical cables should preferably be laid on-ramps. Control and signal cables are preferably laid in special trays underground. The electric power supply of the equipment will be carried out by means of copper cables, isolated by thermoplastic PVC, with PVC electron outer shell. Cabling methods, types, and length of cables will be indicated during detailed Design work.

##### C.5.9.3.10. Auxiliary pipelines

Auxiliary pipelines are pipelines connecting auxiliary modules and auxiliary equipment, which provides the basic processes of loading and storing of Gas at the terminal. Auxiliary pipelines also include pipelines of the life support systems of the terminal. The laying of auxiliary pipelines must be carried out in accordance with the standards ASME B 16.5 and ASME B 31.8.

#### C.5.9.4. Life support facilities (modules) of a loading terminal

##### C.5.9.4.1. Water and sewage system

***Water supply***

The main source of the water supply of drinking and industrial water for the loading terminal site will be underground wells. The inflow of water from the underground wells should be sufficient for the needs of the drinking and technical water supply of the terminal site and the replenishment of water for the fire fighting system.

***Underground water intake***

There are envisaged the drilling of underground artesian wells and the arrangement of block boxes above wells with pumping equipment, automation, and fittings. The sanitary protection zone of a fence is arranged around each artesian well or its group.

***Sewage water system***

Characterization of wastewater, and its treatment.
The following categories of wastewater are generated at the projected site:

- household;
- rain sewage from the territory.

***Household wastewater***

Domestic wastewater from buildings and structures, collected by sewage networks, flows by gravity to the sewage pumping station, and the pressure pipe is fed to a sewage treatment unit, which is prefabricated and packaged. Treated effluents are sent to a reservoir tank or discharged into an evaporation pond for further evaporation.
The consumption of domestic wastewater is determined from the condition that the norms for water disposal are equal to the norms for water consumption.

***Rainwater wastewater***

The project provides for the installation of rain sewers. Rainwater flows through the collectors are fed to the treatment plant.
Contamination indicators of surface wastewater from the site do not exceed:

- suspended solids up to 500 mg/l;
- for oil products up to 30 mg/l.

In the project, rainwater is scheduled to be collected only from road sections and sites where the project provides for improvement.
Provides gravity rainwater collection in storage tanks, equipped with submersible pumps, and with the subsequent transfer to wastewater treatment plants sewage treatment.
This project provides for the mechanical cleaning of rainwater runoff. At the sewage treatment plant, the sedimentation of large suspended solids takes place and, with subsequent incubation, the removal of the bulk of undissolved impurities from the runoff.
Due to the fact that the project made a decision to use the cleaned rain drain for watering and washing the roads, watering the lawns, and dumping the surplus to the relief, deep purification is envisaged. After treatment is provided by a sorbent charge, which detains fine contaminants and oil products. This ensures the purification of water by 99.5%.

Purified rainwater flows by gravity into an underground steel horizontal tank with a capacity of 100 m$^3$, from where they are pumped to watering green spaces, washing roads and driveways. The parameters of treated rainwater are:

- suspended substances – 10,0 mg/l;
- petroleum products - less than 0,3 mg/l.

The project provides for sending a surplus of treated rainwater to the evaporator pond via the waste collector.

***Industrial waste***

Industrial effluents that are generated at the oil supply installation do not flow into the sewer network but are collected in process tanks for export for further disposal.

#### C.5.9.4.2. Firewater and fire-fighting system

The configuration and functions of the Firewater and fire-fighting system of the Unloading terminal are similar to the Firewater and fire-fighting system of the Gas of Loading Terminal, exclude the system for fire-fighting of compressor shelter.

***Description of the Deluge System***

A deluge system is an empty pipe system that is used in high-hazard areas or in areas where fire may spread rapidly. In this type of application, open sprinklers or spray nozzles are employed for water distribution. The deluge valve is activated by a release system (fixed-temperature, rate-of-temperature rise, radiation, smoke, or combustion Gases, hazardous vapors, pressure increase). When the system is tripped, water flows through all spray nozzles or sprinklers simultaneously. The deluge system will be activated by a hydraulic, pneumatic, electric, or manual release system or any combination of these release systems.
When a releasing device operates, pressure escapes in the pneumatic release system causing alarms controlled by air supervisory transmitter to activate and the pneumatic actuator opens. When the pneumatic actuator opens, the pressure is released from the priming chamber gaster than it is supplied through a restricted orifice. The deluge valve clapper opens to allow water to flow into the system piping and alarm devices, causing water motor alarm and water flow alarms connected to the alarm pressure transmitter to activate. Water will flow from any open sprinklers and/or spray nozzles on the system.
The Deluge System will be provided to Gas Compressors and Flare Knockout drums and pumps.
Each deluge system will be fed from the firewater ring main connected with an automatic deluge valve. Isolation of automatic deluge systems will be possible by means of manual block valves, locked open in normal service. The deluge valve will be a specific quick opening automatic valve energized by the firewater pressure. The local manual release will also be possible for the deluge valve.

***Description of the Sprinkler System***

In a normal set condition, the system piping is filled with water. When a fire occurs, the heat operates a sprinkler allowing the water to flow. The alarm valve clapper is opened by a flow of water allowing pressurized water to enter the alarm port to activate the connected alarm device.

The following process areas and buildings at the Loading terminal will be protected with automatic sprinkler systems (wet pipe sprinkler system) in accordance with NFPA 13.
Upon operation, the sprinklers distribute the water over a specific area to control or extinguish the fire. As the water flows through the system, an alarm is activated to indicate the system is operating. Only those sprinklers immediately over or adjacent to the fire operate, minimizing water damage. The facilities to be protected by the Sprinkler System:

- Terminal Administration building;
- Warehouse building;
- Chemical storage shelter;
- Power generation shelter;

- Workshop;
- Control room.

***Fire pumping station***

Firewater pumping station will be provided of the modular design and includes the following equipment:

- fire pump unit Q=160 $m^3$/h; P=0,70 MPa; (pumps - 2 pcs, 1 work, 1 reserve);
- fire pump unit Q=10$m^3$/h; P=0,40 MPa; (pumps - 2 pcs, 1 working, 1 reserve) with a pneumatic tank of volume V=35,0 l to maintain the pressure in the ring fire net. The maintenance pressure pump in the ring fire net is automatically activated.

For automatic foam fire fighting facilities will be provided the following equipment:

- vertical dosing system of volume 400 l with foam concentrate with an inside membrane, equipped with fittings and a concentration control valve;
- mixer for a dosing system of 3 inches;
- drencher valve;
- 24V solenoid valves in the harness of the deluge valve and concentrate control valve.

There are two facilities of fire pumping station - one working and one reserved.

***Description of automation of the fire water supply system***

When a fire occurs on the site, the first fire pump will be activated. The activation of a fire pump provided by:

- remote, at the “Fire” signal with the buttons at fire hydrants for the external fire-fighting system,
- in buildings - from buttons at fire hydrants;
- remote, from the operator's console;
- local, with buttons at the pumps in the fire pumping station.

If a second fire occurs on the terminal site, a second fire pump will be activated. At the same time, simultaneously with the activation of the fire pumps, the pressure maintenance pump should automatically shut off, and the blockage automatically prohibiting the drawdown of the firewater volume should be automatically removed.

#### C.5.9.4.3. Evaporation pond

The need for construction and the location of the evaporation pond is determined at a further stage of the development of the Project. At this stage, its cost is determined. The evaporation pond will be designed with enough surface area to efficiently evaporate water by sunlight and exposure to ambient temperatures. The pond allows the water to evaporate, leaving the waste behind.

#### C.5.9.4.4. Ancillary buildings and structures, site improvements

The list of auxiliary buildings and structures at the Unloading terminal site will be updated at the subsequent stages of the Project. In any case, such a list should include all the necessary structures and buildings to ensure the loading tasks of the CNG ship’s, as well as the documentation of all processes. The list of premises for personnel should be compiled in such a way as to ensure the safety of personnel and create comfortable working conditions and create the necessary living conditions. The master plan for the unloading terminal site should be designed in such a way that a clear chain of Gas unloading and storage processes can be traced. At the same time, the auxiliary systems and modules must be located in close proximity, but at a safe distance. The location of the Gas storage should also be at a safe distance, but convenient for the approach of fire equipment in case of an emergency situation.

Plot plan of Gas unloading terminal to be developed based on the following requirements:

- Safety distances;

- Prevailing wind direction;
- Accessibility and Constructability;
- Process requirement of equipment sequencing;
- Pipeline entry and exit pipeline;
- Availability of utilities e.g. water, electricity, manpower, etc., and entry and exit points of utilities;
- The proximity of manned and unmanned area;
- The proximity to an environmentally sensitive area;
- Soil characteristics;
- Terrain;
- Space provision for future expansion;
- Minimum 10% green plot;
- QRA (quality and reliability assurance) findings and recommendations;
- Loss prevention philosophy.

***Motor roads***

Motor roads in the area of Gas unloading terminal will be designed taking into account the outward and inner traffic and firefighting service as well. They provide reliable connecting of buildings and constructions. Motor roads, foreseen to be the ring, are reliably satisfying the demands of processes. The driveways are intended to be in the embankment of not less than 0,3 m higher than plan ground elevation. Cross profile of road is intended to be with roadsides. The width of the traffic way of the main roads is to be 4,5 m, roadsides – 1,5 m.

Covering of the inner roads is intended to be from one-layer asphalt concrete with a bed of gravel-sand mixture. For the protection of road pavement from subsidence, there is projected to install a protective shield from loam with thickness 0,15 m.

All main technical parameters for motor roads are to be of V technical category. Traffic road width is to be 4,5 m, roadsides width – 1,5 m, ground bed width – 7,5 m.

Road pavement consists of asphalt concrete with a bed of gravel-sand mixture. For the protection of road pavement against subsidence, there is projected to install a protective shield from loam with thickness 0,15 m.

## C.6. Gas interconnector Unloading terminal - CS "Berezivka" (Ukraine).

### C.6.1. Introduction

This section addresses the Technical issues of the construction of the Gas Interconnector the Unloading terminal in the area of the port of Yuzne (Ukraine) – Point of connection to the main Gas pipeline ShKDRI near the Gas compressor station Berezivka.
This section shows the possible technical solutions for the process of CNG ship unloading and based on these solutions the possibility of cost calculations of the unloading process fo Gas supplying to Ukraine. Of course, these calculations will be sufficiently refined after determining the Customer for the construction work and obtaining from the local authorities the necessary technical requirements and approvals for the Gas unloading terminal construction Project.

### C.6.2. Purpose of the Gas interconnector to the unloading terminal

Gas Interconnector Gas Unloading terminal near the port of Yuzne – CS Berezivka is intended for Gas transporting from the Gas Unloading terminal to the point of connection to the existing Gas network near the CS Berezivka.
The main productivity parameters of the Gas interconnector is **6,30 mscmd.**:

### C.6.3. Glossary, abbreviations, and acronyms

The abbreviations and acronyms were used in this section are the same as described in Section A.1.

### C.6.4. Units of measurement.

The units of measurement were used in this section are the same as described in Section A.2.

### C.6.5. Climate data

The area of the proposed construction of the Gas interconnector is characterized by the following climatic characteristics (Standard SNiP 23-01), similar to the Environmental parameters of the GASVESSEL unloading terminal near the port of Yuzne in Odessa region.

### C.6.6. Codes and Standards

The Codes and Standards used for design and build the Gas interconnector for connecting the Gas unloading terminal near the port of Yuzne to the point of connection near the CS Berezivka will meet the Standards used in the best practice of international Engineering taking into account the Ukrainian national Standards. In this stage of the Project, we adopt the Codes and Standards for the construction of Gas pipelines on the coast (mainland). A list of such Standards is given in C.2.6.

### C.6.7. Description of the route of the Gas pipeline interconnector

#### C.6.7.1. Geographic conditions of the interconnector passage

The Gas interconnector route starts on the Black Sea coast at a distance of 1.35 km from the coastline and 850 m east of the Sychavka village in the Odesa region. The general direction of the route is northwest. All along the route passes through the Black Sea Lowland mainly on agricultural land. The Gas interconnector route crosses two beams and, on km 40, runs around the Petrovsky wildlife reserve on the western side. The total length of the route is about 53.6 km. Administratively, the Gas interconnector route passes through the Liman district and the Berezovka district of the Odessa region.

#### C.6.7.2. Interconnector route plan and profile

The plan of the pipeline route is shown in Figure 89. The plan shows the placement of crane sites, the unloading terminal at the beginning of the Gas pipeline and the Gas reduction and metering unit at the end of the Gas pipeline in the area of the Berezovka compressor station connection to the Shebelinka-Dykanka-Kryvyi Rih-Izmail Gas pipeline. The length of the pipeline route from the point of connection to the discharge terminal to the point of connection to the ShDKRI Gas pipeline is 53,6 km.

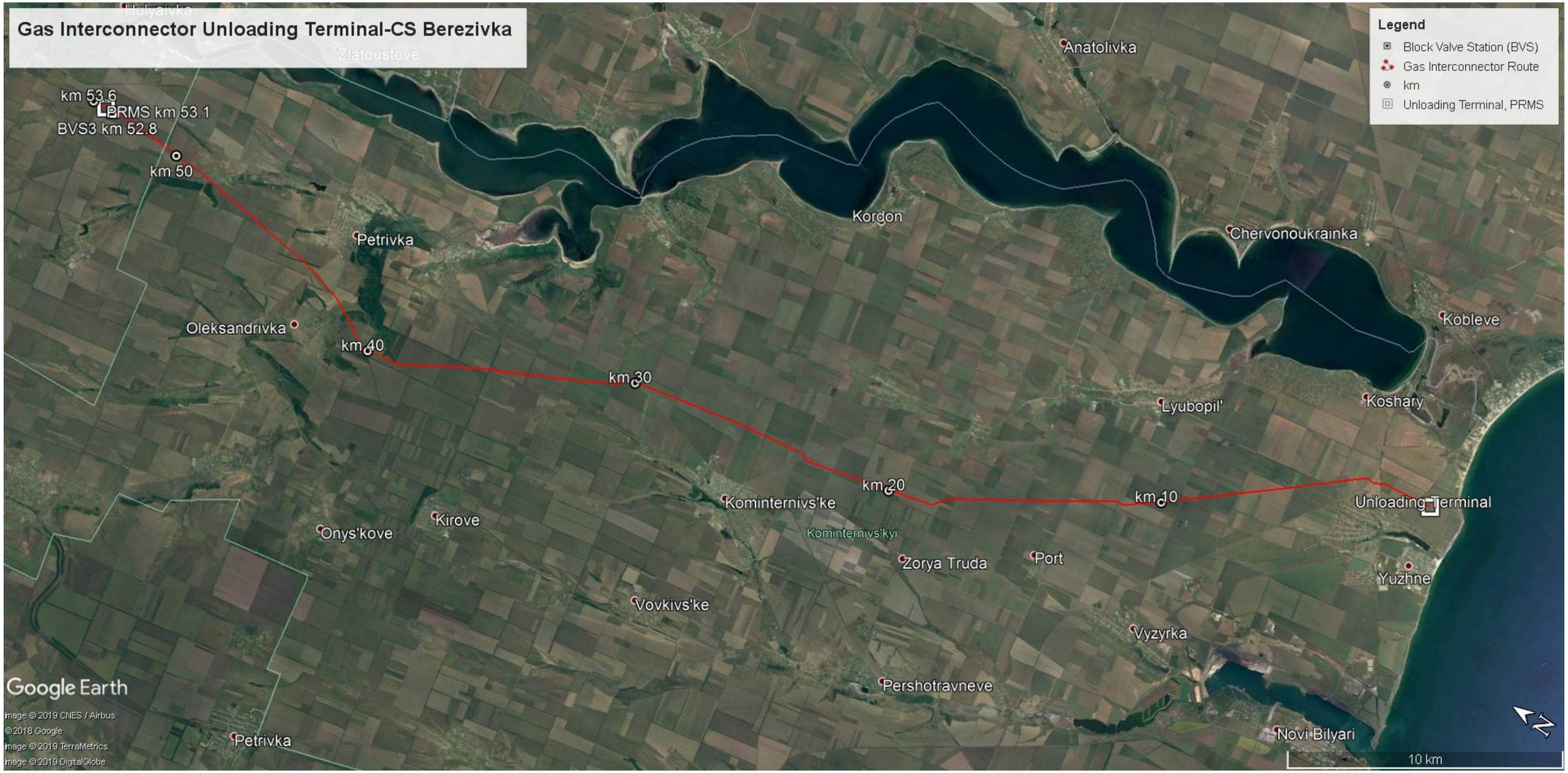



Figure 89. Overview of the route of Gas interconnector Gas Unloading terminal - CS Berezivka.

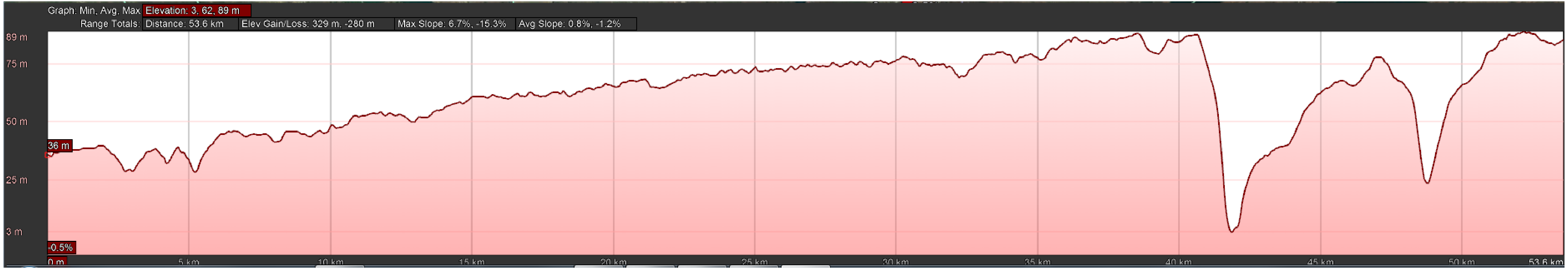



**Figure 90.** Route profile of the Gas interconnector Gas Unloading terminal - CS Berezivka

As we can see, the maximum 89 m and a minimum 3 m mark are on the Gas interconnector route profile.

#### C.6.7.3. Characteristics of natural and topographical obstacles along the route of the interconnector

The table below is shown the list of the topographical obstacles along the route of the interconnector.

| Type of Crossing | Km | Notes |
|---|---|---|
| Motor road | 1,99 | M 14, Sychavka, asphalt pavement |
| Main motor road | 2,38 | M 14, Odessa - Melitopol, asphalt pavement |
| Pipeline | 6,34 | Main Oil pipeline Odessa – Brody, DN 700 |
| Motor road | 11,5 | Vyzyrka-Lyubopil, asphalt pavement |
| Pipeline | 43,3 | ammonia pipeline DN 250 Tolyatti-Gorlovka-Odessa |
| Overhead transmission line | 22,6 | two overhead transmission lines OTL 110 kV |
| Motor road | 23,8 | Kominternivske-Dmytrivka, asphalt pavement |
| Motor road | 25,02 | Kominternivske-Kordon, asphalt pavement |
| Motor road | 30,65 | T 16 02, asphalt pavement |
| Motor road | 32,65 | T 16 02, Nove Selyshche, asphalt pavement |
| Motor road | 35,5 | T 16 02, Kirove, asphalt pavement |
| Pipeline | 37,73 | Main Oil pipeline Odessa – Brody, DN 700 |
| Gully with a river | 41,9 | Gully with a river Balay, the river dries up in summer |
| Pipeline | 43,3 | ammonia pipeline DN 250 Tolyatti-Gorlovka-Odessa |
| Motor road | 43,5 | Kapitanivka-Petrivka, asphalt pavement |
| Gully | 48,8 | gully Balaychuk |
| Pipeline | 52,59 | Main Gas pipeline DN 500 |
| Pipeline | 52,62 | Main Gas pipeline DN 500 |
| Motor road | 53,38 | T 16 02, Chornohirka, asphalt pavement |
| Pipeline | 53,41 | Main Oil pipeline Snigurivka - Odessa, DN 700 |
| | | |

Table 50. List of natural and topographical obstacles of the interconnector.

### C.6.7.4. The Gas interconnector process diagram

The route of the Gas interconnector can be represented as a diagram below.

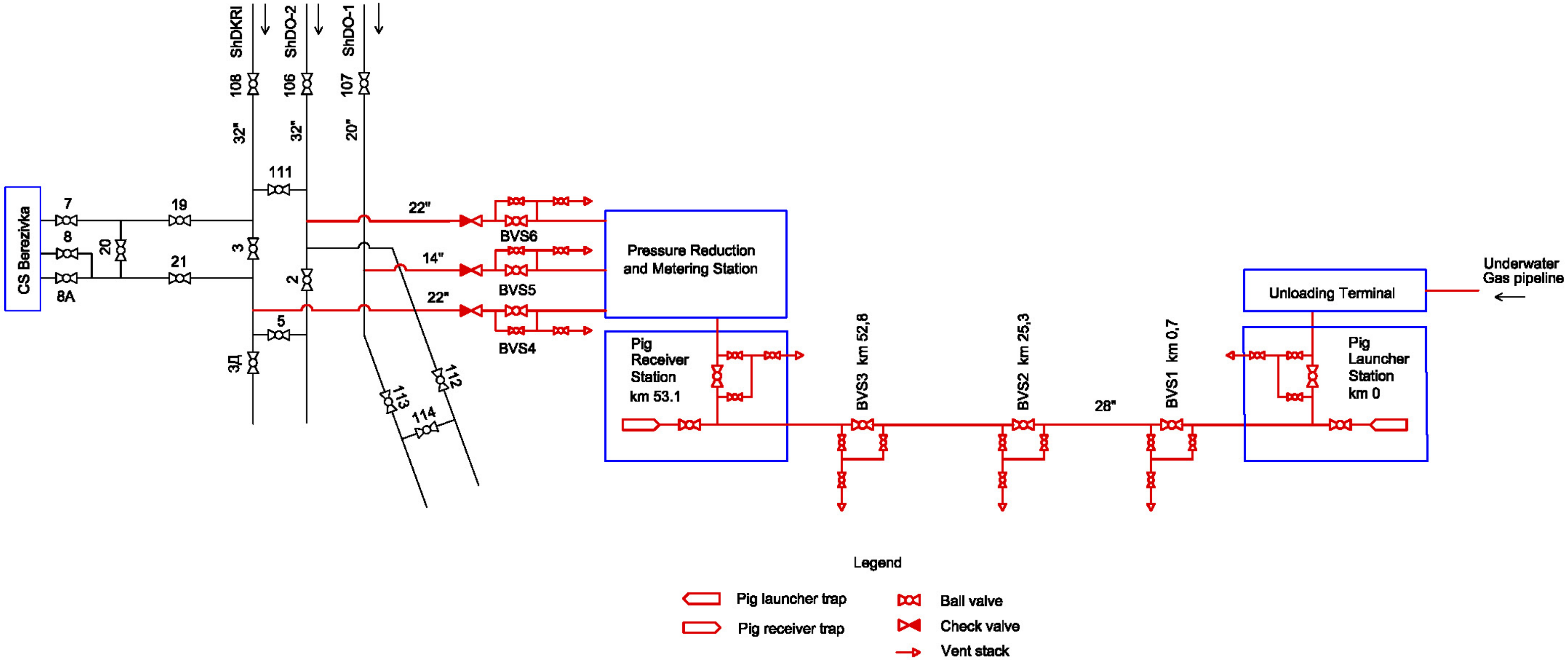



Figure 91. Process flow Diagram of the Gas interconnector Unloading terminal - CS Berezivka.

### C.6.8. The main facilities on the Gas interconnector

#### C.6.8.1. Tie-in point of the interconnector to an unloading terminal

The unloading terminal is located at the starting point of the pipeline at km 0. The unloading terminal tie0in point is combined with the launch site of cleaning and diagnostic devices. The output loop of the unloading terminal is the bypass line of the pig launcher.

The unloading terminal site is cut-off from the linear part of the interconnector by insulating monoblocks (monolithic isolating joint), which are installed on the output loop of the terminal. The shutdown safety valve BVS1 of the unloading terminal is located at km 0.7 of the interconnector.

#### C.6.8.2. Tie-in point of the interconnector to the main Gas pipeline ShKDRI

The Gas transmission from the interconnector is provided to the existing trunk and distribution Gas pipelines in the area of the connection point of the Berezivka compressor station. The interconnector connection is provided to the following Gas pipelines (see Process flow diagram, Figure 91:

- Shebelinka-Dykanka-Kryvyi Rih-Izmail (ShDKRI), DN 800 (32 ”), MAOP (maximum allowable operation pressure) 5,4 MPa. The tie-in point is provided after the output loop of the CS Berezovka along with the Gas flow;
- Shebelinka-Dykanka-Odessa -2 (ShDO-2), DN 800 (32 ”), MAOP 5.4 MPa. The tie-in point is provided before the point of connecting of trunk Gas pipeline to the Odessa portside plant along with the Gas flow;
- Shebelinka-Dykanka-Odessa -1 (ShDO-1), DN 500 (20 "), MAOP 5.4 MPa;

The tying in of the Gas interconnector provides the ability to Gas supply to regional consumers, consumers in the west of the Odessa region, Moldovan consumers connected to the ShDKRI and Razdelnaya-Izmail Gas pipelines, as well as supply Gas abroad (Romania) through the GMS Orlovka.

Connection to the existing Gas pipeline is provided by tapping under pressure according to the technology of the company T.D. Williamson.

On the Gas, pipelines connection is provided ball valve units (BVS4, BVS5, BVS6) with one-sided purge and non-return valve.

#### C.6.8.3. Pressure Reduction and Metering Station

The PRMS (pressure reduction and metering station) is located at the end of the Gas interconnector pipeline at km 53.1 (see Figure 91).

The station consists of:

- Gas metering units for commercial accounting of Gas entering to the main Gas pipelines ShDKRI, ShDO-2, and ShDO-1. The units are made on the basis of ultrasonic Gas counters;
- Gas reduction units to reduce the Gas pressure in the station's output pipelines to values not exceeding the MAOP in existing Gas pipelines. By regulating the pressure in the station’s output Gas pipelines, it is possible to distribute Gas between the ShDKRI, ShDO-2 and ShDO-1 Gas pipelines in necessary volumes. The control mode of the control valves of the reduction units is automatic with the possibility of a remote changing of the pressure (flow) setting after the valve.

The PRMS site is separated from the linear part of the interconnector by insulating monoblocks (monolithic isolating joint), which are installed at the inlet and outlet pipelines. The shutdown safety valve BVS3 is located on the inlet Gas pipeline at a distance of 300 m from the site.

The site of the diagnostic and cleaning devices receiving site adjoins the PRMS site. The bypass line of the receiving unit is the inlet Gas line of the station.

#### C.6.8.4. A pig launcher/receiving units

The pig launcher/receiving units are used to periodically clean the internal cavity during the operation of the Gas pipeline and pass the ultrasonic cavity detector without stopping of Gas supplying.

In accordance with the process flow chart, on the interconnector Gas pipeline is installed the pig launcher unit at the km 0 in the area of the unloading terminal site and a pig receiver unit is installed at the end of the pipeline at the km 53.1 in the area of the PRMS site.

At the pig launcher/receiving units are provided:

- *chamber of the launcher and receiving with fast-opening end shutter;*
- *piping for purging and filling the launching and receiving chamber with Natural Gas;*
- *strapping pipelines and shut-off valves, which ensure the start, passage, and adjustment of the speed of the cleaning device, as well as provide the reduction and adjustment of the speed of movement of the cleaning device at receiving;*
- *the drainage system on the receiving chamber and the condensate trap;*
- *signaling sensors of the passage of cleaning devices;*
- *lifting equipment and handling trolley.*

Launching and receiving chambers are equipped with fast-opening end shutters (Launcher Door, End Closures) and are supplied complete with spare parts or retrieval of cleaning devices, lifting it to transport (lifting equipment and handling trolley). The fast-opening end shutters are equipped with safety mechanisms that prevent their opening while the chambers are under pressure.

The internal diameter of the receiving and launching chambers is taken larger than the diameter of the Gas pipeline to ensure the kicking of pig and retrieval of pig and diagnostic devices. The receiving and launching chambers are equipped with pressure gauges and signaling sensors for cleaning and diagnostic devices. The passage detectors are also installed.

The piping and the condensate trap are provided for underground performance, the chambers are installed above ground on supports. The pig launcher/receiving units are separated from the linear part of the pipeline by insulating monoblocks.

Anchoring flanges and anchor blocks are provided for the limitation of the movements of the pig launcher/receiving units under the action of the temperature difference and internal pressure.

The vent stack is located at a distance of 50 m from the site of pig launcher/receiving units.

For the normal passage of the cleaning devices (pig), the full-bore valves, bends of radius not less than 5D, tees with grids on the branches with a branch diameter equal to or more than 30% of the main diameter are provided.

Valves with a Gas/hydraulic actuator and a pneumatic actuator are equipped with an electro-pneumatic control unit, with a manual backup. Valves overweigh more than 150 kg are mounted on a support.

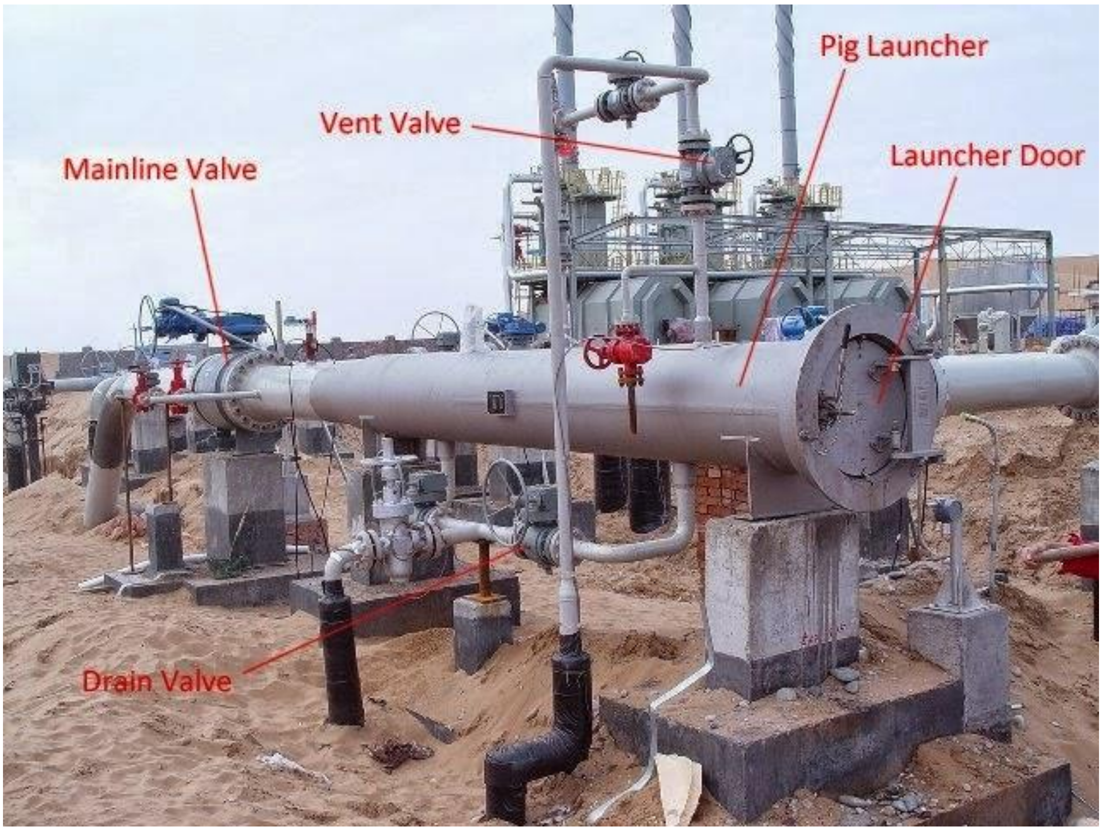



Figure 92. View on the Pig launcher unit during construction.

Smart pigging is carried in the gas interconnector pipeline to measure thickness faults and dents.
“Smart” pigs use intelligent technology such as sensors, transmitters, GPS, magnetic fields, eddy current, ultrasonic and acoustics to identify and diagnose potential problems.

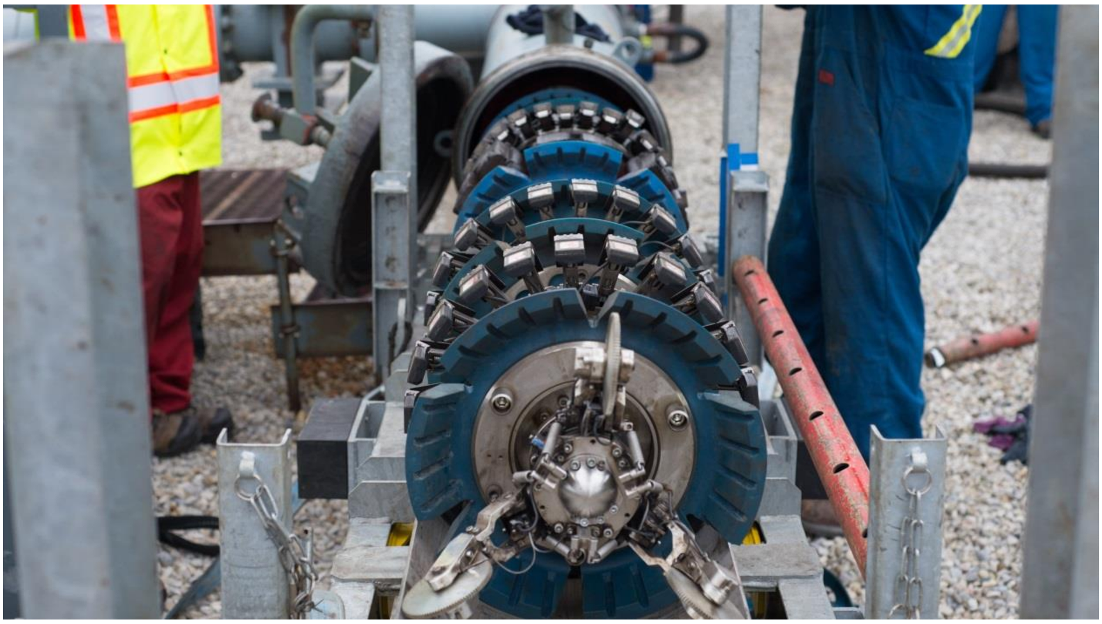


Figure 93. The smart diagnostic unit, magnetic sensors and a scrubber in the foreground are visible.

Figure 94. Pipeline cleaning pig.

Cleaning pigs provide one of the simplest, most cost-effective ways for the pipeline operator to optimize flow, reduce corrosion, and minimize the presence of foreign matter in Gas.
The pipeline cleaning pig consists of different cleaning components include brushes to remove hard, crust-like deposits; urethane blades for removing soft, gummy deposits; and scraper discs and cups to clean hard and soft internal deposits.

#### C.6.8.5. Block valve stations

Block valve stations are designed to shut off and purge the relevant sections of the pipeline through the purge vent stack. The vent stack is situated at a distance of 15m from the block valve station on the site.
Block valve stations are located along the pipeline at a distance of no more than 30 km from each other. Structurally the valve units are provided in the underground option. The diameter of the main BVS1, BVS2, and BVS3 valves are 28”, the diameter of the piping and valves is 8”.
The diameter of the BVS4-BVS6 valves is according to the diameter of the connection Gas pipelines, the diameter of the piping and valves is 6”. On the sites of valve units BVS4-BVS6, the installation of check valves after the valve along the Gas flow is provided. Check valves for the underground installation, the diameter of the valves is selected according to the diameter of Gas pipelines. Valves are provided with a pneumatic hydraulic actuator (Gas/hydraulic actuator), equipped with an electro-pneumatic control unit and a manual backup. On the block valve stations are provided with the fittings for the installation of monitoring and measuring gauges.

#### C.6.8.6. Crossing through natural and artificial obstacles

***Road crossings***

The Gas interconnector pipeline crosses one main motor road, local motor roads with asphalt pavements and rural roads.
The construction of crossings on the main motor road and covered roads is provided in accordance with the recommendations of API RP 1102.
The Gas interconnector pipeline crosses all roads at an angle close to 90° but not less than 70°, is laid at the intersection 28”, mainly by drilling method or using another special equipment.
At intersections with dirt roads, the Gas interconnector pipeline is laid without a case using an open construction method.
When crossing roads, the Gas interconnector pipeline is laid to a depth of at least 1,5 m from the surface of the embankment (depth of cover).
Warning signs are placed on the intersection with the roads.
Figure 61 shows a typical intersection of a Gas interconnector pipeline with a motorway.

***Waterway crossings***

The Gas interconnector pipeline crosses the beam with the Balay River, which is drying out in the summer. Construction of the crossing of the Gas interconnector pipeline through the river is carried out in an open mode (with laying the pipe into the developed trench) in the summer period. The pipe is laid at a depth below the possible reformation of the bottom and banks of the river.

The Gas interconnector pipeline against the ascent is loaded by continuous concrete coating or by reinforced concrete ring weights consisting of two halves bolted together.

At the crossings through watercourses performed by the open method, it is envisaged to secure the banks from their destruction (stream-bank erosion).

Figure 63shows a typical intersection of a Gas interconnector pipeline with a water stream.

***Underground services crossings (including the different pipelines)***

When crossing a Gas interconnector pipeline with existing communication cables, electrical cables, the clear distance of at least 0.6 m between the Gas interconnector pipeline and the existing communication is maintained. Basically, the Gas interconnector pipeline is laid under the existing communication. If the existing communication is laid deep and it is possible to maintain a clear distance of at least 0.6 m with the projected Gas interconnector pipeline, then a Gas interconnector pipeline can be laid over the communication.

Figure 64 and Figure 65shows a typical intersection of a Gas interconnector pipeline with existing pipelines and cables.

***Electrical high voltage transmission line crossings***

A minimum distance between Gas the pipeline and tower footings and its grounding elements shall be 10 m, otherwise, effective measures such as the following shall be provided to mitigate any adverse effects:

- *addition of pipeline grounding with polarization cells to prevent CP current leakage,*
- *equipotential mats and gratings at aboveground facilities to protect operators, and*
- *an extra coating of the pipeline near the tower.*

The pipeline intersection with electric power lines to be maintained if the distance between the lowest wireline and ground level is less than 8 meters at least see Figure 66.

***Buoyancy control***

The stability of the Gas pipeline position (against ascent) laid on the flooded sections of the pipeline route must be checked for each section (depending on the construction conditions).

The choice of design and methods of the Gas pipeline fixing is made depending on the specific conditions or method of construction, data of engineering surveys and design loads that act on the pipeline.

The following options of design to be provided:

4. Concrete coating.

The concrete coating will carry out in the factory. The concrete coating may be used where it is required. It can be applied to an individual coating thickness with reinforcement concrete. The ends of each joint shall be bare to make a welding operation.

5. Pipeline weights that are placed on top of the pipe (set-on weights).

This type of weight is used for pipe loading only in a free water trench.

6. Ring reinforced concrete weights (bolt-on weights), consisting of two half-loads connected together with bolts and nuts.

Under the weights on the pipe are mounted the protective mats that prevent the sliding of weights on the pipe and damage to the anticorrosive insulation.

### C.6.9. The initial Data and Technical parameters of the Gas interconnector

In this section, we will describe the Initial data for the calculation and the possible Technical solutions of the design of Gas interconnector between the tie-in point of unloading terminal near the port of Yuzne and tie-in point to the existing main Gas pipeline ShKDRI.

### C.6.10. Technical parameters of the Gas interconnector

In agreement with the Consortium partners, the following parameters of the Gas interconnector were accepted:

- *The pressure at the tie-in point to the unloading terminal near the port of Yuzne – the beginning of the Gas interconnector is about 5,6 MPa;*

#### C.6.10.1. Process and strength characteristics calculations

The thermo-hydraulic calculations of the Gas interconnector are presented in the tables below.

```
= HYDRAULIC AND THERMAL CALCULATION OF PIPELINE =
----------------------------------------------------------------------
 Pipeline Inlet flow - 10     ---------> 11      -    Outlet Flow.
----------------------------------------------------------------------
= INITIAL DATA =
----------------------------------------------------------------------
 Flow                                          kg/h       184212.800
                                               scm/h        262500.0
 (t=20 C,P=0.1013 Mpa)                         mscmd           6.300
 Initial Pressure                              MPa             5.478
                                               barg            55.86
 Initial Temperature                           C                1.05
                                               K              274.05
 Pipeline Length                               m             52600.0
----------------------------------------------------------------------
 Absolute roughness                            mm                .10
----------------------------------------------------------------------
 No of   Sect.   Height  External Pipe    Heat    Ambien  Num.   Sect.
 sect.   Length  differ. pipe     thickn. transf. Temp.   step   effic.
                         Diam.            coef.           calcul.
                                          W/(m^2K)
         m         m       mm       mm              C
----------------------------------------------------------------------
 1    52600.     0.    720.0    10.0       .71    15.0    25     1.00
----------------------------------------------------------------------

THERMAL CONDITIONS

Section  1
  Pipeline Location - Underground
  Depth of cover (to the top of the pipe), m            0.8
  Thermal conductivity coefficient of the soil, W/(m*K) 2.00

= CALCULATION RESULTS =
----------------------------------------------------------------------
 Initial characteristics :             Volume gas fraction    1.000000
 velocity              2.656 m/s       Flow Mode - Single Phase

 Characteristics at the end of the section (pipeline):
----------------------------------------------------------------------
 No of   Volume      Velocity  Flow          Pressure        Temperature
 section gas                   mode
         fraction     m/s                   Mpa     barg    C      K
----------------------------------------------------------------------
 1       1.000000    2.300    Single        5.361   54.67    8.4   281.6
                               Phase
----------------------------------------------------------------------

 25-Jul-19
```

Figure 95. Thermo-hydraulic calculation of Gas interconnector Gas Unloading terminal - CS Berezivka.

Also, the pipe strength calculations were made for these sections.

PIPE WALL THICKNESS CALCULATION

Version 1.0

| | | | |
|---|---|---|---|
| Project Name | Gas Interconnector Pipeline | By | FIV |
| Project Number | | Chkd by | YMN |
| | | Appd by | KVI |
| Design Pressure (P) | 56 bar g | 812,21 psi g | |

SMYS (psi)

| | | | | | |
|---|---|---|---|---|---|
| 35000 | for pipe Gr. B | 42000 | for pipe X42 | 46000 | for pipe X46 |
| 52000 | for pipe X52 | 56000 | for pipe X56 | 60000 | for pipe X60 |
| 65000 | for pipe X65 | 70000 | for pipe X70 | 80000 | for pipe X80 |

Joint factor (E): 1

Corrosion Allowance: 2 mm

Temperature derating factor (T): 1

Design code: ASME B31.8

Formula used :

t = P x D / (2 x F x SMYS x E x T) + Corrosion allowance

| No | Outside Dia. (D) | Design Factor (F) | SMYS | Grade | Wall thickness | | |
|---|---|---|---|---|---|---|---|
| | | | | | Calculated | Calculated | Available |
| | inch | | psi | | inch | mm | inch |
| 1 | 28 | 0,72 | 70000 | X70 | 0,304 | 9,73 | 0,406 |
| 2 | 28 | 0,6 | 70000 | X70 | 0,349 | 10,88 | 0,438 |
| 3 | 28 | 0,5 | 70000 | X70 | 0,404 | 12,25 | 0,500 |

Figure 96. The thickness calculation of the Gas interconnector pipeline.

The pipes wall thickness was calculated depending on the class of terrain (location class) in accordance with ASME B31.8 with corrosion allowance adopted as 2,0 mm.
The results of strength calculations of the Gas interconnector pipeline are summarized in Table 51. The specified pipeline parameters will be taken into account in a cost calculation of Gas interconnector construction.

| Location Class | Outside Diameter, inch | Design Factor | SMYS | Grade | Calculated WT, inch | Calculated WT plus corrosion allowance, mm | Specified WT, mm |
|---|---|---|---|---|---|---|---|
| 1 | 28 | 0,72 | 70000 | X70 | 0,304 | 9,73 | 10.4 |
| 2 | 28 | 0,6 | 70000 | X70 | 0,349 | 10,88 | 11,12 |
| 3 | 28 | 0,5 | 70000 | X70 | 0,404 | 12,25 | 12,7 |

Table 51. Pipes wall thickness calculation results.

### C.6.10.2. Technical and design parameters of the interconnector

#### C.6.10.2.1. Pipes and fittings

***Pipes***

For the construction of the linear part of the Gas pipeline, pipes are provided in accordance with ISO 3183 with a diameter of 28”x0.438.
The basic requirements for pipes are:

- *the level of requirements PSL-2;*
- *type of pipe SAWL with one longitudinal seam;*
- *strength group L485M (X70M);*
- *length of pipes 10.5 m - 12 m.*

For pipelines with a diameter of 16" and less for piping of pig receiving/launching units and valve units, to be provided with the seamless pipes (SMLS) according to ISO 3183, PSL2, strength group L290 (X42). The wall thickness for pipelines is calculated according to ASME B31.8 (design factor 0.5, corrosion allowance 2,0 mm).

***Fittings***

Tees, elbows and reducing fittings with a diameter of 16" and more are provided according to the Standard MSS-SP-75, less than 16" - according to ASME B16.9. Tees with a diameter of 36'' with branches with a diameter of 30% or more of the main diameter will be provided with grids.

#### C.6.10.2.2. Anticorrosive protection

Protection of the Gas pipeline against corrosion is provided by an anti-corrosion coating and facilities of electrochemical protection.

Pipes for the construction of the linear part of the Gas interconnector will be supplied with factory-made insulation of three-layer polyethylene coating of 2.5 mm thickness for pipes with a diameter of 28".

Insulation of welded joints of the underground Gas pipeline with a factory coating is provided for with heat-shrinking sleeves with a minimum width of 450mm, which are completely supplied with a separate lock and primer.

In areas of horizontal drilling or HDD at the intersections of the pipeline with roads and rivers, the insulation of welds is provided for with special heat-shrinkable cuffs for HDD crossings.

Induction taps for underground Gas pipelines are provided with a factory outer polyurethane coating of 1.5 mm thickness.

To protect against corrosion of the underground part of valves, fittings, and pipelines of valve units and pig receiving and launching units, a polyurethane coating with a thickness of 1.5 mm is provided.

For the protection of aboveground sections of pipelines and equipment from atmospheric corrosion, protective paint and varnish coating are provided in accordance with № A 4.09 of table A.4 of ISO 12944-5[10] NDFT of at least with a thickness not less than 280 microns.

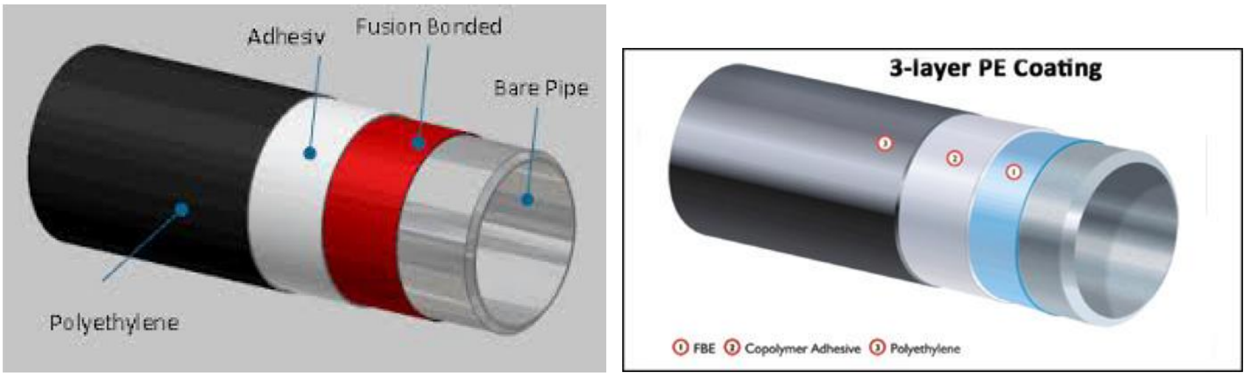



Figure 97. layer polyethylene anti-corrosion coating.

### C.6.10.3. Construction method statement

#### C.6.10.3.1. Depth of cover

The pipeline is mainly laid at a depth not less than 1,0 m from the ground surface (depth of cover). When passing through irrigated fields, the Gas pipeline must be laid to a depth of not less than 1.5 m from the ground surface. When the Gas pipeline is crossing the roads, it must be laid at a depth not less than 1.5 m from the ground surface of the embankment, railways - 3 m from the rail foot, on small streams - 1.5 m, on large ones - 2.0 m.

#### C.6.10.3.2. Bending

The pipeline is laid mostly parallel to the terrain.
The pipeline is laid in horizontal and vertical planes by elastic bending with a bending radius of at least 1000 m.
Bends with a radius of curvature of 40D are made on the method by cold bending from pipes supplied for the construction of a Gas pipeline.
For pipe bends of 15" or more, induction taps with a factory-made 5D radius according to ISO 15590-1 are used. Induction taps for underground Gas pipelines are provided with a factory outer polyurethane coating.

#### C.6.10.3.3. Joining

The connection of pipes among themselves and with other components is provided by butt-welding (semi-automatic or manual).
Quality control of all-welded joints of the pipeline and structures (assemblies) is provided by the radiographic method (radiographic inspection). Welds made by semi-automatic welding are additionally controlled by a mechanized ultrasonic inspection system.

#### C.6.10.3.4. Soil erosion protection

To protect against erosion of the Gas pipeline trench and to reduce damage to the environment caused by the construction of the Gas pipeline, the following protective measures are provided.

- *The jumpers arrangement in the trench of the bags filled with the sand-cement mixture.*
- *The arrangement of drainage ditches, fixed with monolithic concrete, and rollers of local soil with the enforcement of slopes.*
- *Protection of slope plots from erosion is carried out by retaining the drain and discharging it to a safe place with the help of highland ditches and rollers.*
- *Fastening of ravines is carried out by arranging interfacing hydraulic structures – water speeds, water check drops. The drops are arranged in the form of retaining walls made of concrete or masonry on cement mortar.*
- *Stability of slopes with a sloping grade of more than $35^0$ and more is provided by the arrangement of retaining walls of gabions.*
- *Collapsing shores of watercourses are secured with gabion boxes or stone sketches. The thickness of the rough gravel filter in each case is determined by calculation depending on the geological and hydrological characteristics of the watercourse.*

#### C.6.10.3.5. Passage of the Gas pipeline on the hillsides

When laying a Gas pipeline on hillsides with the slope grade of more than $8^0$, the constant passage for the period of construction and installation works and the subsequent operation of the pipeline is ensured by installing a 14 m wide shelf embedded in the slope Figure 69Figure 68. Depending on the angle of inclination, the following shelves are available.

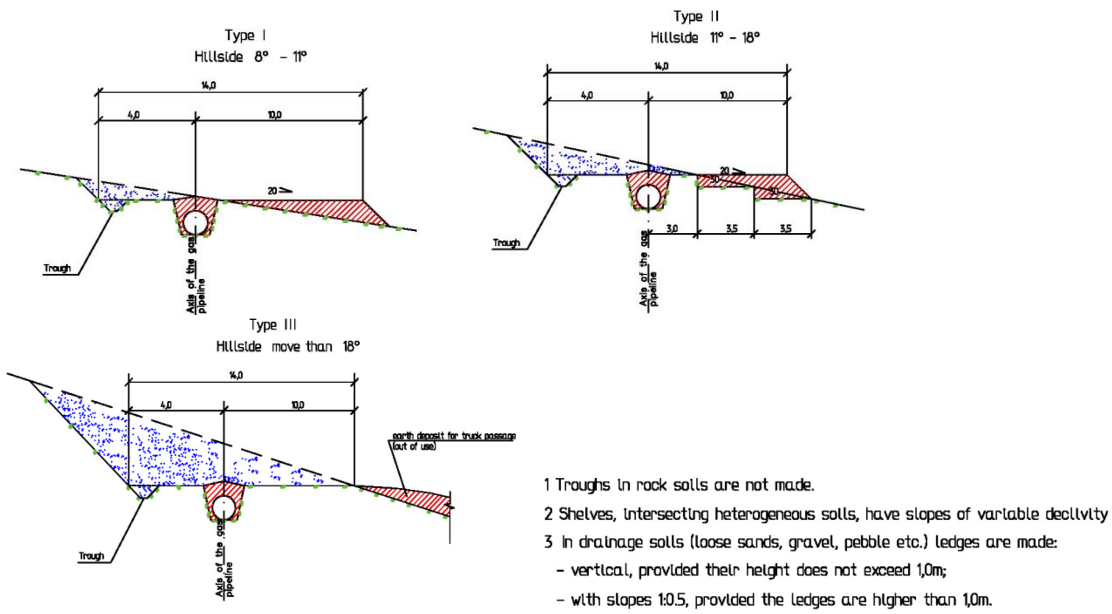



**Figure 98. Arrangement of passages along the pipeline in a different hillside.**

When laying the pipeline on slopes with the slope grade from above $8^0$ to $11^0$ inclusive (Figure above, Type I), cutting and filling of soil is provided in order to build a working strip (shelf).
The shelf arrangement, in this case, is provided by dumping embankment directly on the slope.
With a transverse slope of the slope grade above $11^0$ to $18^0$ inclusive, taking into account the properties of the soil, ledges are provided to prevent the soil from sliding along the slope (Figure above, Type II).
On slopes with the slope grade above $18^0$, shelves are provided only by cutting the soil (Figure above, Type III).
A pipeline trench is provided in the continental soil near the foot of the slope at a distance that ensures the normal operation of the earthmoving equipment and transport machines.
In order to prevent the destruction of the shelves by storm waters, an arrangement of upland ditches and longitudinal trays is envisaged, the dimensions and stabilization of which is depending on the size of the longitudinal slope.
Highland ditches are arranged above the shelves up to the relief in places of possible runoff of surface water in the direction of the shelf.
For removal of the storm (surface) water at the bottom of the shelf-slope, a longitudinal chute with a longitudinal slope of at least 0.2% is provided. The shelf is given a slope of 2% in both directions from the axis of the trench.

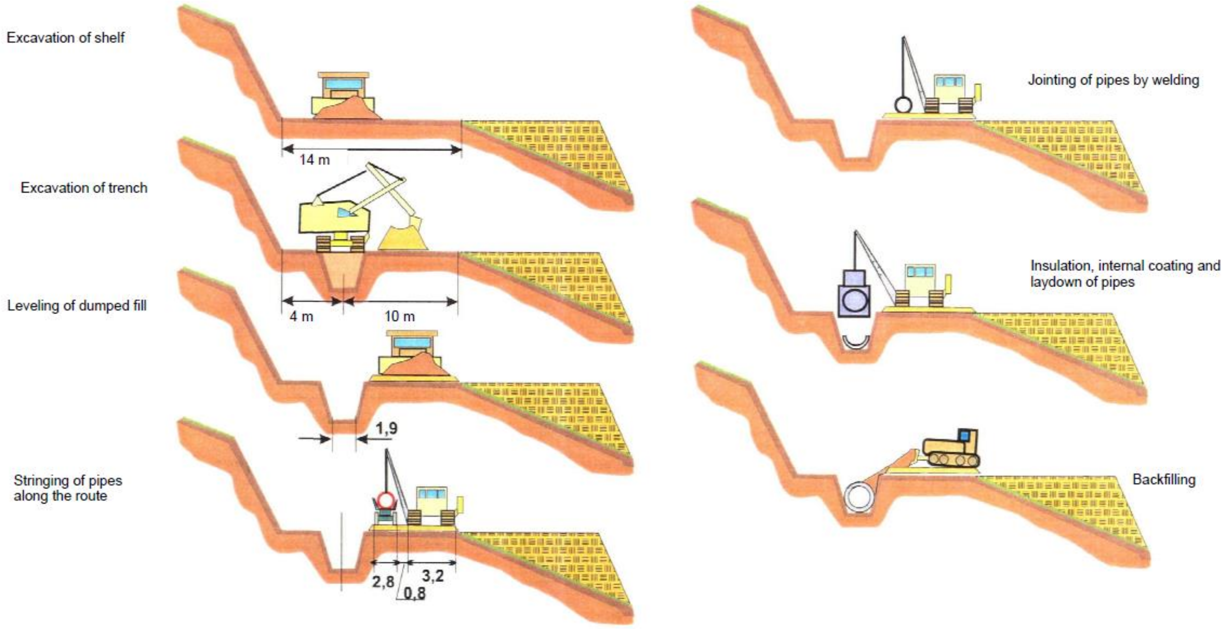



Figure 99. Shelf arrangement on the slopes.

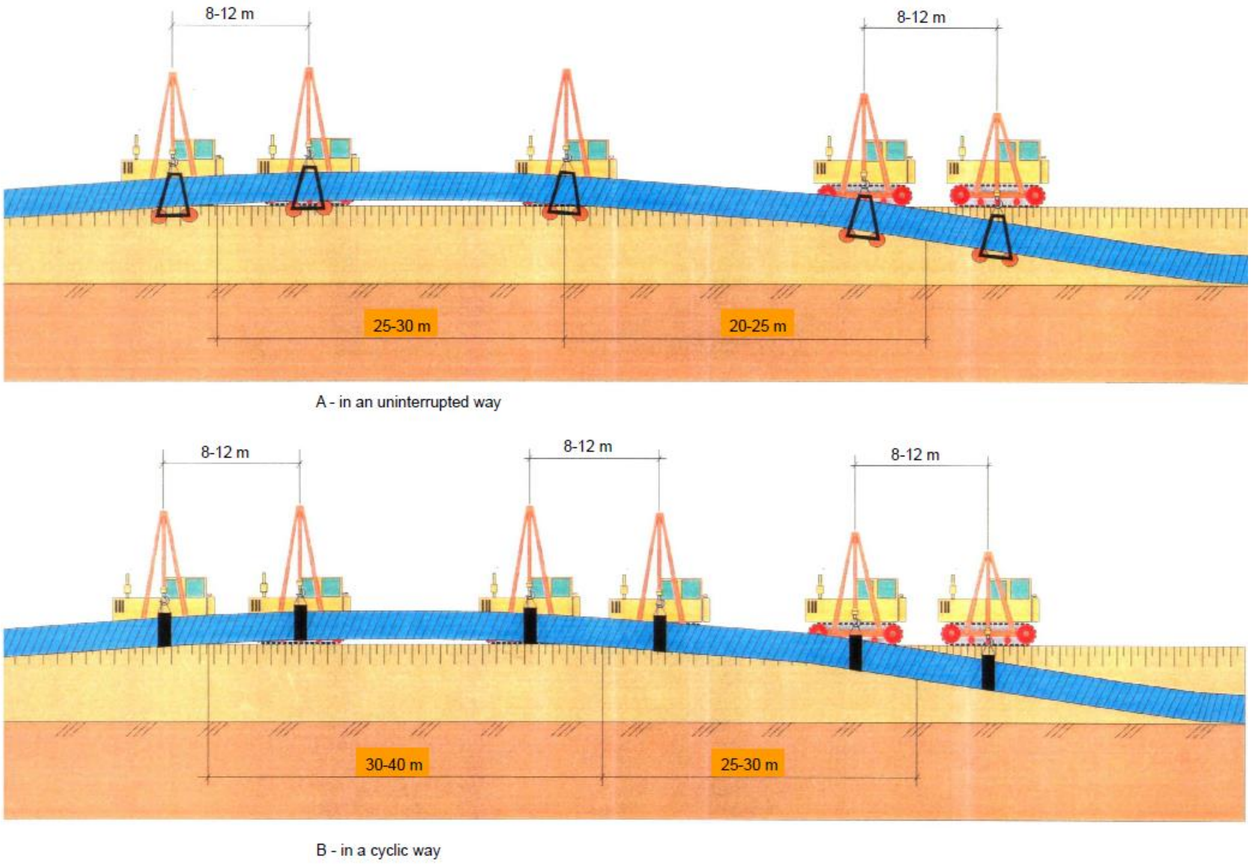



Figure 100. Scheme for laying down an insulated pipeline.

#### C.6.10.4. Quality control

The system of the Quality audit will guarantee the essential audit and tests for all the works concerning materials Qualities, works execution Quality and functioning Quality to confirm the Standards and the local lows and Detailed Construction Design.

The Detailed Design will pay maximum attention to the detection and elimination or minimization of operational risks, and Project aims will be achieved through a flexible management structure, trying to improve performance and raise Quality indexes.
The system of Quality Control organization and implementation is the tool that allows them and the Customer to evaluate the Quality of construction at any time and to interfere, if necessary.
This System consists of the following elements and stages:
The arrangement of the Quality Control service whose director is responsible for:

- *all the measures necessary to achieve the Quality of works;*
- *all Quality  control procedures and orders at, and outside the sites are followed;*
- *adoption of technical logbooks and organizing Quality control;*
- *all Quality  control process documents including inspections and reports;*
- *supervision of staff training.*
- *creation of the corresponding working conditions and adequate reward for employees involved in construction, encouragement of collective work, initiative and pride for participation in the Project.*

The pipeline construction will be accompanied by an incoming, operative and acceptance inspection.
The incoming control will include the Detailed Design check-up for the completeness and corresponding Standards, and also check-up of the incoming equipment: pipes, materials and structures and their conformity to the Standards and Detailed Design Documents, certificates and passports.
The operative inspection will attend the construction and erection works, providing for the prompt defects exposure and elimination. The operation control will include inspection of construction works technique and works conformity to the Project Documentation and Standards. Operational inspection is executed by the foremen, construction supervisors, and special Quality control services.
The Acceptance control will include the inspection of the construction and erection works Quality and drawing up the relevant documentation. Special defect eliminating measures will be developed according to the inspection results taking into account the supervision.
It comprises inspection of all delivered materials, devices and equipment to ensure their high-Quality condition before delivering them to the site. The respective certificates are an integral part of the supporting documents delivered together with materials, devices, and equipment.
These inspections determine:

- *possible beginning and finish of construction and erection works and their conditions;*
- *check-up of works which are performed in this way for the first time at the site and control of their progress.*

The Quality control plan has been submitted. This plan consists of a minimum of:

- *Quality  control directions;*
- *certifying group of the Quality  control staff;*
- *responsibilities of each controller;*
- *the Quality  control inspections and measures plan including for the Subcontractor (if anyhow what and where);*
- *the preliminary list of necessary inspections for the first stage of the construction;*
- *Quality  control record keeping, a copy of the operational instructions for the controlling staff indicating their responsibilities;*
- *general explanatory note on the Project Quality  control measures;*
- *the list of Acts of Concealed Works.*

The Contractor cannot perform construction and erection works if he has not submitted the Quality control plan to Customer for approval or has not received such approval.
In the context of the Quality control System, the Contractor submits the following Quality control Data:

Daily:

- *directions for necessary inspection, 24 hours before the inspection;*
- *inspection results.*

Monthly:

- *a complete summary of the most important Quality control measures, completed items of Quality control measures, deadlines for the elimination of defects and imperfections left at the end of the month according to previous inspections.*

On coordination with Customer, the Contractor (represented by the Quality control Manager) holds regular meetings on construction Quality control issues.
The Contractor (represented by the Quality control Manager) runs a separate territory on the site, where he keeps all materials, devices, and equipment that failed the qualitative and quantitative acceptance tests till the Customer agrees to further use and/or repair them.
The Contractor constantly informs the Customer about such works.
The Contractor (represented by the Quality control Manager) attaches the necessary Quality control Documents to the Acceptance and Turn-In Inspections Documents.
After the equipment pieces have been erected and revised, they are tested in an idle mode which is followed by the Serviceability and Integrity Report.
The Contractor should equip a construction laboratory and provide its operation no later than 30 days after the construction start.
The laboratory should consist of:

- *premises;*
- *all equipment necessary for its efficient operation;*
- *laboratory equipment;*
- *additional testing instruments;*
- *qualified laboratory engineers, technicians, assistants and supporting staff.*

The Customer is responsible for maintaining the laboratory in its working condition during all construction period.
In addition, within the framework of their responsibilities as to Quality control, the Contractor's laboratory staff has to be equipped with devices allowing the following tests on:

- *electrical operations;*
- *works on-field part of the pipeline;*
- *works on-site facilities;*
- *welding including steel structures' joints and reinforcement welded joints.*

Before starting any construction, the Contractor should determine and approve with Customer the list of tests to be carried out at the construction sites.
In 14 days after the order has been received, the Contractor submits a detailed laboratory operation plan including equipment work and staff qualification. Besides, he submits a list of organizations that will carry out the tests, which cannot be performed by the construction laboratory.
After pipelines and site equipment have been erected, they should be tested in accordance with the Detailed Design, flow charts, current Standards, technical requirements and instructions for the assembled equipment, pipelines, and pipeline fittings.

The Quality control Service will strictly control that the environmental protection requirements are observed, maintaining environmental balance on every stage of construction.

## C.7. Overall diagrams of CNG ship loading and unloading systems in the Black Sea region

### C.7.1. An overall diagram of CNG ship loading system

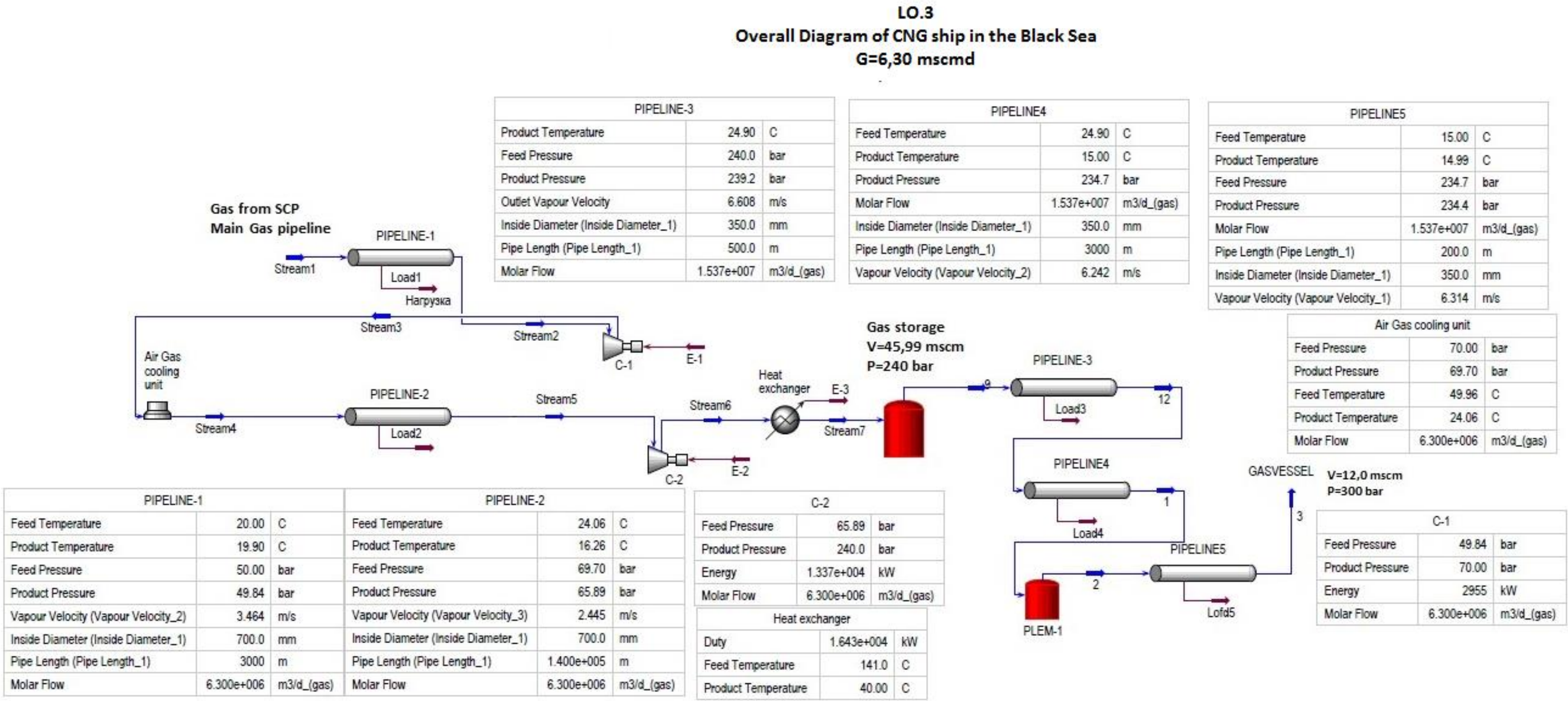
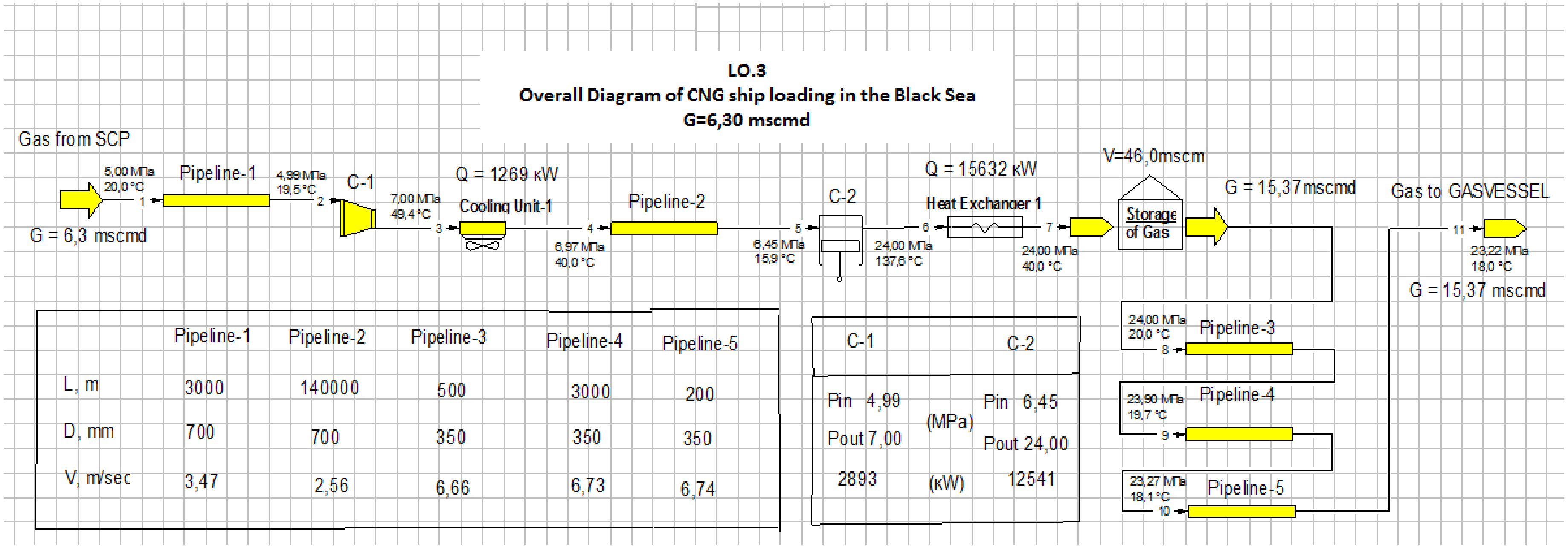



Figure 101. Loading parameters and diagram of the CNG ship loading in the Black Sea region. (HYSYS).




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 | Pipeline-5 |
|---|---|---|---|---|---|
| L, m | 3000 | 140000 | 500 | 3000 | 200 |
| D, mm | 700 | 700 | 350 | 350 | 350 |
| V, m/sec | 3,47 | 2,56 | 6,66 | 6,73 | 6,74 |

| C-1 | | C-2 |
|---|---|---|
| Pin 4,99 | (MPa) | Pin 6,45 |
| Pout 7,00 | | Pout 24,00 |
| 2893 | (kW) | 12541 |

**Figure 102. Loading parameters and diagram of the CNG ship loading in the Black Sea region. (GasCondOil).**

## C.7.2. An overall diagram of CNG ship unloading system

**UO.3**
**Overall Diagram of CNG ship unloading in the Black Sea**
**G=6,30 mscmd**

| Pipeline1 | | |
|---|---|---|
| Feed Temperature | 40.00 | C |
| Product Temperature | 12.83 | C |
| Feed Pressure | 80.00 | bar |
| Product Pressure | 79.57 | bar |
| Molar Flow | 1.035e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 200.0 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_1) | 14.90 | m/s |

| Pipeline2 | | |
|---|---|---|
| Feed Temperature | 12.35 | C |
| Product Temperature | 10.01 | C |
| Feed Pressure | 79.04 | bar |
| Product Pressure | 73.66 | bar |
| Molar Flow | 1.035e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 2500 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_2) | 13.08 | m/s |

| Pipeline3 | | |
|---|---|---|
| Feed Temperature | 10.01 | C |
| Product Temperature | 19.94 | C |
| Feed Pressure | 73.66 | bar |
| Product Pressure | 71.26 | bar |
| Molar Flow | 1.035e+007 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 350.0 | mm |
| Vapour Velocity (Vapour Velocity_1) | 13.81 | m/s |

| Pipeline4 | | |
|---|---|---|
| Feed Temperature | 10.00 | C |
| Product Temperature | 9.984 | C |
| Feed Pressure | 56.26 | bar |
| Product Pressure | 56.23 | bar |
| Molar Flow | 6.300e+006 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 1000 | m |
| Inside Diameter (Inside Diameter_1) | 700.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 2.875 | m/s |

| T-100 | | |
|---|---|---|
| Feed Temperature | 13.68 | C |
| Product Temperature | 10.00 | C |
| Molar Flow | 6.300e+006 | m3/d_(gas) |
| Duty | -438.2 | kW |

| VLV-1 | | |
|---|---|---|
| Feed Pressure | 71.26 | bar |
| Product Pressure | 57.26 | bar |
| Molar Flow | 6.300e+006 | m3/d_(gas) |
| Feed Temperature | 19.94 | C |
| Product Temperature | 13.68 | C |

| Pipeline5 | | |
|---|---|---|
| Feed Temperature | 9.984 | C |
| Product Temperature | 9.151 | C |
| Feed Pressure | 56.23 | bar |
| Product Pressure | 54.53 | bar |
| Molar Flow | 6.300e+006 | m3/d_(gas) |
| Pipe Length (Pipe Length_1) | 5.260e+004 | m |
| Inside Diameter (Inside Diameter_1) | 700.0 | mm |
| Vapour Velocity (Vapour Velocity_6) | 2.963 | m/s |

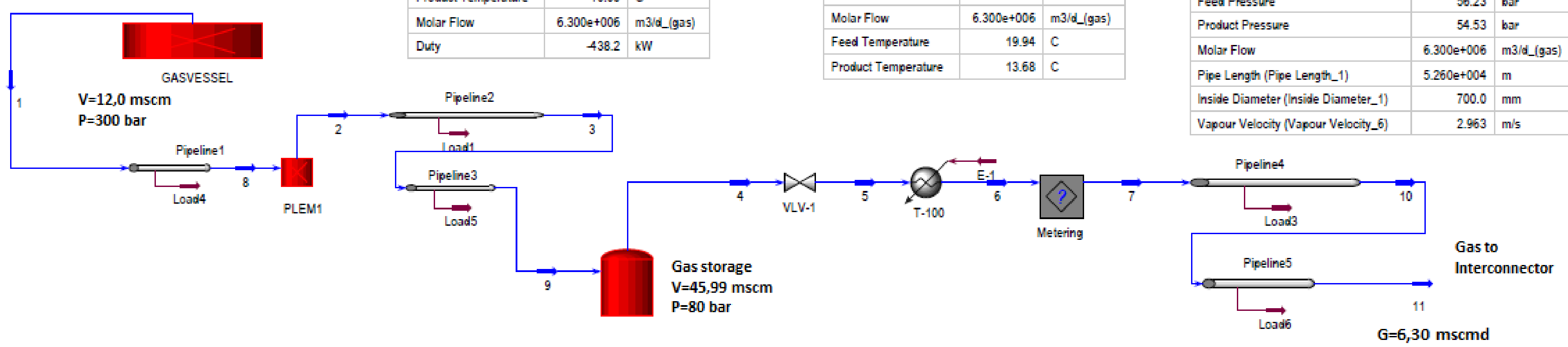
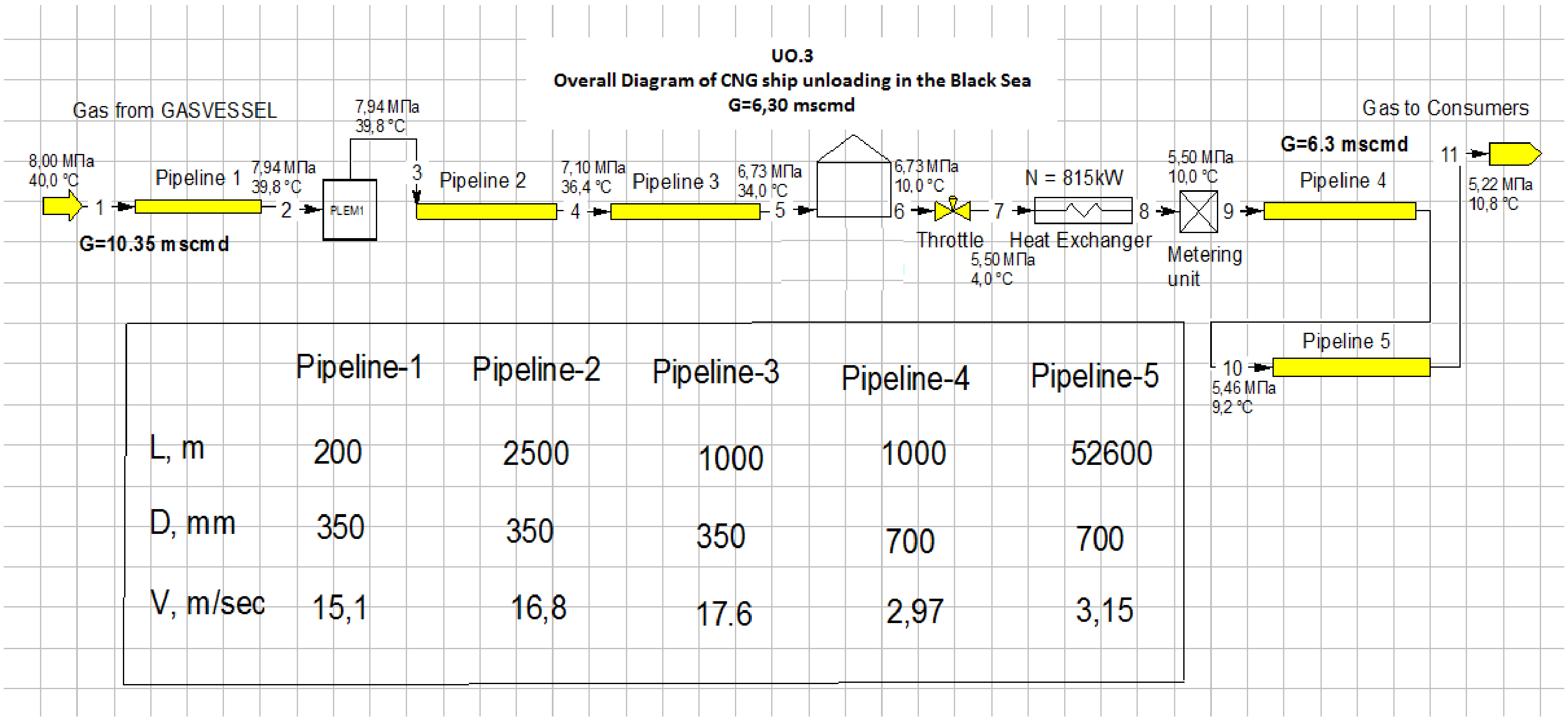



Figure 103. Unloading parameters and diagram of the CNG ship loading in the Black Sea region. (HYSYS).




| | Pipeline-1 | Pipeline-2 | Pipeline-3 | Pipeline-4 | Pipeline-5 |
|---|---|---|---|---|---|
| L, m | 200 | 2500 | 1000 | 1000 | 52600 |
| D, mm | 350 | 350 | 350 | 700 | 700 |
| V, m/sec | 15,1 | 16,8 | 17.6 | 2,97 | 3,15 |

**Figure 104. Unloading parameters and diagram of the CNG ship loading in the Black Sea region. (GasCondOil).**

**D. Cost of elements of GASVESSEL Gas loading/unloading systems**

The cost of elements of CNG ship loading/unloading systems is necessary for calculating the cost of construction of infrastructure and accounting for Gas transportation tariffs when determining the volume of investments in the GASVESSEL Project.

Based on the technical description and parameters of the infrastructure elements described in previous chapters, we made a summary table with a list of structures, their technical indicators, and cost.

According to the VTG point of view, this approach will allow determining the cost of infrastructure elements in each case, when specifying data on cargo (gas) flows, location of loading and unloading terminals, as well as at subsequent stages of the GASVESSEL Project, make a technical decisions that can change or complement the described configuration of terminals and Gas interconnectors for gas delivery from existing or planned to the construction of main gas pipelines from gas sources.

In the case of the construction of a floating Gas loading terminals at offshore Gas fields (Alke, Johan Castberg offshore platform, Norway; Cyprus EEZ offshore platform, Cyprus; Lebanon offshore platform), as well as in a case of the need to set up a floating intermediate Gas storages, the required set of modules will be maximum in accordance with B.1.3.

In the case of the construction of a floating Gas unloading terminals at offshore Gas fields (Aasta Hansteen offshore platform, Norway), as well as in a case of the need to set up floating intermediate Gas storage, the required set of modules will be maximum in accordance with B.2.3.

In any case, it is necessary, whenever possible, to use auxiliary systems of existing Gas production platforms in coordination with companies that own and operate these platforms. The table of the cost of infrastructure elements shows the cost of the main process and auxiliary modules of the terminals providing the process of loading and unloading of GASVESSEL. The cost of life support systems listed in B.1.3 and B.2.3 is not given due to the lack of specific information from platform owners.

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **1.** | **Mediterranean Sea** | | | | | | |
| **L1.** | **Gas loading process** | | | | | | |
| **L1.1** | ***Onshore Gas loading terminal facilities near the Vasilikos Energy hub – direction to Crete (the port of Linoperamata)*** | ***Gas demand volume*** | ***1,4 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | | |
| A2 | Loading time | H, hour | 48,00 | | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | | |
| A4 | Gas temperature | T, °C | 40,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **L.1.1.1** | **Onshore Gas loading terminal** | | | | | | |
| L1.1.1.1 | Tie-in point to the Vasilikos Energy hub (D=14") | L, m | 500,00 | P=120,0 bar | **725 500,00** | | 1 205,00 |
| | ***Main process facilities (modules) of Onshore Gas loading terminal*** | | | | | | 1 205,00 |
| L1.1.1.2 | Gas compressor module | Q, mscmd | 15,29 | $P_{in}$=120,0 bar, Pout=240,0 bar | **14 840 056,43** | | |
| L1.1.1.3 | Gas cooling module | Q, mscmd | 15,29 | P=240,0 bar | **1 335 235,44** | | 970 826,67 |
| L1.1.1.4 | Gas storage module | V, mscm | 9,00 | P=240,0 bar | **150 000 000,00** | | 87 350,22 |
| L1.1.1.5 | Gas measuring module | Q, mscmd | 15,29 | P=240,0 bar | **3 070 500,00** | | 16,67 |
| | ***Auxiliary process facilities (modules) of Onshore Gas loading terminal*** | | | | | | |
| L1.1.1.6 | Process automation and signaling system | System | 1,00 | - | **1 340 000,00** | | 1 340 000,00 |
| L1.1.1.7 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| L1.1.1.8 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| L1.1.1.9 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| L1.1.1.10 | Power supply and Distribution System | N, kW | 1610,00 | - | **8 533 000,00** | | 5 300,00 |
| L1.1.1.11 | Electrochemical anti-corrosion protection System | N, kW | 25,00 | - | **370 000,00** | | 14 800,00 |
| L1.1.1.12 | Diesel generator module | N, kW | 500,00 | - | **900 000,00** | | 1 800,00 |
| L1.1.1.13 | Diesel Fuel System | V, m cubic | 100,00 | - | **54 000,00** | | 540,00 |
| L1.1.1.14 | Communication, alarm, fire alarm system | System | 1,00 | - | **680 000,00** | | 680 000,00 |
| L1.1.1.15 | Overhead transmission line (V=10 kV), (if any) | L, km | 3,00 | - | **432 000,00** | | 144 000,00 |
| L1.1.1.16 | Power, control and signaling cables | L, km | 26,00 | | **1 086 428,57** | | 41 785,71 |
| L1.1.1.17 | Auxiliary site pipelines | System | 1,00 | | **1 942 500,00** | | 1 942 500,00 |
| | ***Life support facilities (modules) of Onshore Gas loading terminal*** | | | | | | |
| L1.1.1.18 | Water and sewage system | System | 1,00 | - | **3 228 000,00** | | 3 228 000,00 |
| L1.1.1.19 | Firewater and fire-fighting system | Q, liter/sec | 25,00 | - | **3 600 000,00** | | 144 000,00 |
| L1.1.1.20 | Evaporation pond | S, sq.m | 1800,00 | - | **864 000,00** | | 480,00 |
| L1.1.1.21 | Ancillary buildings and structures, site improvements | Facilities complex | 1 | - | **6 200 000,00** | | 6 200 000,00 |
| **L1.1.2** | **Connection pipelines** | | 1,00 | - | **3 228 000,00** | | 3 228 000,00 |
| L1.1.2.1 | Pipeline 2 (Onshore Gas pipeline, D=14 inches) | L, m | 1000,00 | P=240,0 bar | **1 899 040,00** | | 1 899,04 |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| L1.1.2.2 | Pipeline 3 (Underwater Gas pipeline, D=14 inches) | L, m | 1000,00 | P=240,0 bar | **2 602 241,00** | | 2 602,24 |
| L1.1.2.3 | PLEM1, (D=14 inches) | System | 1,00 | P=240,0 bar | **740 030,77** | | 35 030,77 |
| L1.1.2.4 | Pipeline 4 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=240,0 bar | **5 760 000,00** | | 28 800,00 |
| | | **TOTAL in Scope of Project** | | | **213 601 607,21** | | |
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | Gas Storage on Vasilikos Energy hub | V, mscm | 9,00 | P=120,00 bar | **150 000 000,00** | | 16,67 |
| C2 | Pipeline1 (Onshore Gas pipeline, D=14 inches) | L, m | 500,00 | P=120,00 bar | **593 450,00** | | 1 186,90 |
| | | **TOTAL out of the scope of Project** | | | **150 593 450,00** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** <br> ***Note 2: The assumptions made to perform loading processes are given in the text in Report.*** | | | | | | |
| | | **TOTAL** | | | **364 195 057,21** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **1.** | **Mediterranean Sea** | | | | | | |
| **L1.2** | ***Onshore Gas loading terminal facilities near the Vasilikos Energy hub – direction to Lebanon (the port of Zouk)*** | ***Gas demand volume*** | ***3,7 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | | |
| A2 | Loading time | H, hour | 32,00 | | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | | |
| A4 | Gas temperature | T, °C | 40,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **L.1.2.1** | **Onshore Gas loading terminal** | | | | | | |
| L1.2.1.1 | Tie-in point to the Vasilikos Energy hub (D=14") | L, m | 500,00 | P=120,0 bar | **725 500,00** | | 1 205,00 |
| | ***Main process facilities (modules) of Onshore Gas loading terminal*** | | | | | | |
| L1.2.1.2 | Gas compressor module | Q, mscmd | 15,29 | $P_{in}$=120,0 bar, Pout=240,0 bar | **14 840 056,43** | | 970 826,67 |
| L1.2.1.3 | Gas cooling module | Q, mscmd | 15,29 | P=240,0 bar | **1 335 235,44** | | 87 350,22 |
| L1.2.1.4 | Gas storage module | V, mscm | 13,90 | P=240,0 bar | **231 666 666,67** | | 16,67 |
| L1.2.1.5 | Gas measuring module | Q, mscmd | 15,29 | P=240,0 bar | **3 070 500,00** | | 3 070 500,00 |
| *a* | ***Auxiliary process facilities (modules) of Onshore Gas loading terminal*** | | | | | | |
| L1.2.1.6 | Process automation and signaling system | System | 1,00 | - | **1 340 000,00** | | 1 340 000,00 |
| L1.2.1.7 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| L1.2.1.8 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| L1.2.1.9 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| L1.2.1.10 | Power supply and Distribution System | N, kW | 1610,00 | - | **8 533 000,00** | | 5 300,00 |
| L1.2.1.11 | Electrochemical anti-corrosion protection System | N, kW | 25,00 | - | **370 000,00** | | 14 800,00 |
| L1.2.1.12 | Diesel generator module | N, kW | 500,00 | - | **900 000,00** | | 1 800,00 |
| L1.2.1.13 | Diesel Fuel System | V, m cubic | 100,00 | - | **54 000,00** | | 540,00 |
| L1.2.1.14 | Communication, alarm, fire alarm system | System | 1,00 | - | **680 000,00** | | 680 000,00 |
| L1.2.1.15 | Overhead transmission line (V=10 kV), (if any) | L, km | 3,00 | - | **432 000,00** | | 144 000,00 |
| L1.2.1.16 | Power, control and signaling cables | L, km | 26,00 | | **1 086 428,57** | | 41 785,71 |
| L1.2.1.17 | Auxiliary site pipelines | System | 1,00 | | **1 942 500,00** | | 1 942 500,00 |
| *I* | ***Life support facilities (modules) of Onshore Gas loading terminal*** | | | | | | |
| L1.2.1.18 | Water and sewage system | System | 1,00 | - | **3 228 000,00** | | 3 228 000,00 |
| L1.2.1.19 | Firewater and fire-fighting system | Q, liter/sec | 25,00 | - | **3 600 000,00** | | 144 000,00 |
| L1.2.1.20 | Evaporation pond | S, sq.m | 1800,00 | - | **864 000,00** | | 480,00 |
| L1.2.1.21 | Ancillary buildings and structures, site improvements | Facilities complex | 1 | - | **6 200 000,00** | | 6 200 000,00 |
| **L1.2.2** | **Connection pipelines** | | | | | | |
| L1.2.2.1 | Pipeline 2 (Onshore Gas pipeline, D=14 inches) | L, m | 1000,00 | P=240,0 bar | **1 899 040,00** | | 1 899,04 |
| L1.2.2.2 | Pipeline 3 (Underwater Gas pipeline, D=14 inches) | L, m | 1000,00 | P=240,0 bar | **2 602 241,00** | | 2 602,24 |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| L1.2.2.3 | PLEM1, (D=14 inches) | System | 1,00 | P=240,0 bar | **740 030,77** | | 35 030,77 |
| L1.2.2.4 | Pipeline 4 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=240,0 bar | **5 760 000,00** | | 28 800,00 |
| | | **TOTAL in Scope of Project** | | | **295 268 273,88** | | |
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | Gas Storage on Vasilikos Energy hub | V, mscm | 9,00 | P=120,00 bar | **150 000 000,00** | | 16,67 |
| C2 | Pipeline1 (Onshore Gas pipeline, D=14 inches) | L, m | 500,00 | P=120,00 bar | **593 450,00** | | 1 186,90 |
| | | **TOTAL out of the scope of Project** | | | **150 593 450,00** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** <br> ***Note 2: The assumptions made to perform loading processes are given in the text in Report.*** | | | | | | |
| | | **TOTAL** | | | **445 861 723,88** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **1.** | **Mediterranean Sea** | | | | | | |
| **L1.3** | ***Onshore Gas loading terminal facilities near the Vasilikos Energy hub – direction to Egypt (the port of Alexandria)*** | ***Gas demand volume*** | ***17,0 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | | |
| A2 | Loading time | H, hour | 48,00 | | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | | |
| A4 | Gas temperature | T, °C | 40,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **L.1.3.1** | **Onshore Gas loading terminal** | | | | | | |
| L1.3.1.1 | Tie-in point to the Vasilikos Energy hub (D=14") | L, m | 500,00 | P=120,0 bar | **725 500,00** | | 1 205,00 |
| | ***Main process facilities (modules) of Onshore Gas loading terminal*** | | | | | | |
| L1.3.1.2 | Gas compressor module | Q, mscmd | 15,29 | $P_{in}$=120,0 bar, Pout=240,0 bar | **14 840 056,43** | | 970 826,67 |
| L1.3.1.3 | Gas cooling module | Q, mscmd | 15,29 | P=240,0 bar | **1 335 235,44** | | 87 350,22 |
| L1.3.1.4 | Gas storage module | V, mscm | 14,50 | P=240,0 bar | **241 666 666,67** | | 16,67 |
| L1.3.1.5 | Gas measuring module | Q, mscmd | 15,29 | P=240,0 bar | **3 070 500,00** | | 3 070 500,00 |
| | ***Auxiliary process facilities (modules) of Onshore Gas loading terminal*** | | | | | | |
| L1.3.1.6 | Process automation and signaling system | System | 1,00 | - | **1 340 000,00** | | 1 340 000,00 |
| L1.3.1.7 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| L1.3.1.8 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| L1.3.1.9 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| L1.3.1.10 | Power supply and Distribution System | N, kW | 1610,00 | - | **8 533 000,00** | | 5 300,00 |
| L1.3.1.11 | Electrochemical anti-corrosion protection System | N, kW | 25,00 | - | **370 000,00** | | 14 800,00 |
| L1.3.1.12 | Diesel generator module | N, kW | 500,00 | - | **900 000,00** | | 1 800,00 |
| L1.3.1.13 | Diesel Fuel System | V, m cubic | 100,00 | - | **54 000,00** | | 540,00 |
| L1.3.1.14 | Communication, alarm, fire alarm system | System | 1,00 | - | **680 000,00** | | 680 000,00 |
| L1.3.1.15 | Overhead transmission line (V=10 kV), (if any) | L, km | 3,00 | - | **432 000,00** | | 144 000,00 |
| L1.3.1.16 | Power, control and signaling cables | L, km | 26,00 | | **1 086 428,57** | | 41 785,71 |
| L1.3.1.17 | Auxiliary site pipelines | System | 1,00 | | **1 942 500,00** | | 1 942 500,00 |
| / | ***Life support facilities (modules) of Onshore Gas loading terminal*** | | | | | | |
| L1.3.1.18 | Water and sewage system | System | 1,00 | - | **3 228 000,00** | | 3 228 000,00 |
| L1.3.1.19 | Firewater and fire-fighting system | Q, liter/sec | 25,00 | - | **3 600 000,00** | | 144 000,00 |
| L1.3.1.20 | Evaporation pond | S, sq.m | 1800,00 | - | **864 000,00** | | 480,00 |
| L1.3.1.21 | Ancillary buildings and structures, site improvements | Facilities complex | 1 | - | **6 200 000,00** | | 6 200 000,00 |
| **L1.3.2** | **Connection pipelines** | | | | | | |
| L1.3.2.1 | Pipeline 2 (Onshore Gas pipeline, D=14 inches) | L, m | 1000,00 | P=240,0 bar | **1 899 040,00** | | 1 899,04 |
| L1.3.2.2 | Pipeline 3 (Underwater Gas pipeline, D=14 inches) | L, m | 1000,00 | P=240,0 bar | **2 602 241,00** | | 2 602,24 |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| L1.3.2.3 | PLEM1, (D=14 inches) | System | 1,00 | P=240,0 bar | **740 030,77** | | 35 030,77 |
| L1.3.2.4 | Pipeline 4 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=240,0 bar | **5 760 000,00** | | 28 800,00 |
| | | **TOTAL in Scope of Project** | | | **305 268 273,88** | | |
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | Gas Storage on Vasilikos Energy hub | V, mscm | 9,00 | P=120,00 bar | **150 000 000,00** | | 16,67 |
| C2 | Pipeline1 (Onshore Gas pipeline, D=14 inches) | L, m | 500,00 | P=120,00 bar | **593 450,00** | | 1 186,90 |
| | | **TOTAL out of the scope of Project** | | | **150 593 450,00** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** <br> ***Note 2: The assumptions made to perform loading processes are given in the text in Report.*** | | | | | | |
| | | **TOTAL** | | | **455 861 723,88** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **1.** | **Mediterranean Sea** | | | | | | |
| **L1.4** | ***Offshore Gas loading terminal facilities near the Cyprus offshore Gas production platforms – direction to the port of Linoperamata (Crete)*** | ***Gas demand volume*** | ***1,4 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | | |
| A2 | Loading time | H, hour | 48,00 | | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | | |
| A4 | Gas temperature | T, °C | 40,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **L.1.4.1** | **Connection pipelines** | | | | | | |
| L1.4.1.1 | Tie-in point to the Offshore platform (D=14") | L, m | 15,00 | P=120,0 bar | **145 960,95** | | 1 530,73 |
| L1.4.1.2 | **Offshore Gas loading terminal** | | | | | | |
| | ***Main process facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L1.4.1.3 | Gas compressor module | Q, mscmd | 15,29 | $P_{in}$=120,0 bar, Pout=240,0 bar | **5 437 192,76** | | 355 697,55 |
| L1.4.1.4 | Gas cooling module | Q, mscmd | 15,29 | P=240,0 bar | **1 335 235,44** | | 87 350,22 |
| L1.4.1.5 | Gas storage module | V, mscm | 9,00 | P=240,0 bar | **150 000 000,00** | | 16,67 |
| L1.4.1.6 | Gas measuring module | Q, mscmd | 15,29 | P=240,0 bar | **3 070 500,00** | | 3 070 500,00 |
| | ***Auxiliary process facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L1.4.1.7 | Process automation and signaling system | System | 1,00 | - | **1 340 000,00** | | 1 340 000,00 |
| L1.4.1.8 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| L1.4.1.9 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| L1.4.1.10 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| L1.4.1.11 | Power supply and Distribution System | N, kW | 300,00 | - | **4 440 000,00** | | 14 800,00 |
| L1.4.1.12 | Electrochemical anti-corrosion protection System | N, kW | 15,00 | - | **27 000,00** | | 1 800,00 |
| L1.4.1.13 | Diesel generator module | N, kW | 300,00 | - | **162 000,00** | | 540,00 |
| L1.4.1.14 | Diesel Fuel System | V, m cubic | 75,00 | - | **51 000 000,00** | | 680 000,00 |
| L1.4.1.15 | Power, control and signaling cables | L, km | 12,00 | | **501 428,57** | | 41 785,71 |
| L1.4.1.16 | Auxiliary site pipelines | System | 1,00 | | **892 500,00** | | 892 500,00 |
| | ***Life support facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L1.4.1.17 | Water and sewage system | System | 1,00 | - | **2 690 000,00** | | 2 690 000,00 |
| L1.4.1.18 | Firewater and fire-fighting system | Q, liter/sec | 35,00 | - | **1 890 000,00** | | 54 000,00 |
| **L1.4.2** | **Connection pipelines** | | | | | | |
| L1.4.2.1 | Pipeline 3 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=120,0 bar | **4 320 000,00** | | 21 600,00 |
| L1.4.2.2 | Pipeline 4 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=240,0 bar | **5 760 000,00** | | 28 800,00 |
| | | **TOTAL in Scope of Project** | | | **236 410 892,72** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | Pipeline 1 (Gas Riser, D=14 inches) | L, m | 300,00 | P=120,00 bar | **826 594,20** | | 2 755,31 |
| C2 | PLEM, (D=14 inches) | System | 1,00 | P=120,00 bar | **463 623,08** | | 16,67 |
| C3 | Pipeline 2 (Underwater Gas pipeline, D=14 inches) | L, m | 300,00 | P=120,00 bar | **734 750,40** | | 2 449,17 |
| | | **TOTAL out of the scope of Project** | | | **2 024 967,68** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** <br> ***Note 2: The assumptions made to perform loading processes are given in the text in Report.*** | | | | | | |
| | | **TOTAL** | | | **238 435 860,40** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **1.** | **Mediterranean Sea** | | | | | | |
| **L1.5** | ***Offshore Gas loading terminal facilities near the Cyprus offshore Gas production platforms – direction to the port of Zouk (Lebanon)*** | ***Gas demand volume*** | ***3,7 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | | |
| A2 | Loading time | H, hour | 32,00 | | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | | |
| A4 | Gas temperature | T, °C | 40,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **L.1.5.1** | **Connection pipelines** | | | | | | |
| L1.5.1.1 | Tie-in point to the Offshore platform (D=14") | L, m | 15,00 | P=120,0 bar | **35 260,95** | | 1 530,73 |
| | **Offshore Gas loading terminal** | | | | | | |
| L1.5.1.2 | ***Main process facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | 970 826,67 |
| L1.5.1.3 | Gas compressor module | Q, mscmd | 15,29 | $P_{in}$=120,0 bar, Pout=240,0 bar | **5 437 192,76** | | 355 697,55 |
| L1.5.1.4 | Gas cooling module | Q, mscmd | 15,29 | P=240,0 bar | **1 335 235,44** | | 87 350,22 |
| L1.5.1.5 | Gas storage module | V, mscm | 13,90 | P=240,0 bar | **231 666 666,67** | | 16,67 |
| L1.5.1.6 | Gas measuring module | Q, mscmd | 15,29 | P=240,0 bar | **3 070 500,00** | | 3 070 500,00 |
| | ***Auxiliary process facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L1.5.1.7 | Process automation and signaling system | System | 1,00 | - | **1 340 000,00** | | 1 340 000,00 |
| L1.5.1.8 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| L1.5.1.9 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| L1.5.1.10 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| L1.5.1.11 | Power supply and Distribution System | N, kW | 300,00 | - | **4 440 000,00** | | 14 800,00 |
| L1.5.1.12 | Electrochemical anti-corrosion protection System | N, kW | 15,00 | - | **27 000,00** | | 1 800,00 |
| L1.5.1.13 | Diesel generator module | N, kW | 300,00 | - | **162 000,00** | | 540,00 |
| L1.5.1.14 | Diesel Fuel System | V, m cubic | 75,00 | - | **158 000,00** | | 2 000,00 |
| L1.5.1.15 | Power, control and signaling cables | L, km | 12,00 | | **501 428,57** | | 41 785,71 |
| L1.5.1.16 | Auxiliary site pipelines | System | 1,00 | | **892 500,00** | | 892 500,00 |
| | ***Life support facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L1.5.1.17 | Water and sewage system | System | 1,00 | - | **2 690 000,00** | | 2 690 000,00 |
| L1.5.1.18 | Firewater and fire-fighting system | Q, liter/sec | 35,00 | - | **1 890 000,00** | | 54 000,00 |
| **L1.5.2** | **Connection pipelines** | | | | | | |
| L1.5.2.1 | Pipeline 3 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=120,0 bar | **4 320 000,00** | | 21 600,00 |
| L1.5.2.2 | Pipeline 4 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=240,0 bar | **5 760 000,00** | | 28 800,00 |
| | | | | **TOTAL in Scope of Project** | **267 124 859,39** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **C** | **Facilities out of the scope of the Project** | | | | | | 1 899,04 |
| C1 | Pipeline 1 (Gas Riser, D=14 inches) | L, m | 300,00 | P=120,00 bar | **826 594,20** | | 2 755,31 |
| C.2 | PLEM, (D=14 inches) | System | 1,00 | P=120,00 bar | **463 623,08** | | 270 018,00 |
| C3 | Pipeline 2 (Underwater Gas pipeline, D=14 inches) | L, m | 300,00 | P=120,00 bar | **734 750,40** | | 2 449,17 |
| | | **TOTAL out of the scope of Project** | | | **2 024 967,68** | | **18 228 011,27** |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** ***Note 2: The assumptions made to perform loading processes are given in the text in Report.*** | | | | | | |
| | | **TOTAL** | | | **269 149 827,07** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **1.** | **Mediterranean Sea** | | | | | | |
| **L1.6** | ***Offshore Gas loading terminal facilities near the Cyprus offshore Gas production platforms – direction to the port of Alexandria (Egypt)*** | ***Gas demand volume*** | ***17,0 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | | |
| A2 | Loading time | H, hour | 48,00 | | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | | |
| A4 | Gas temperature | T, °C | 40,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **L.1.6.1** | **Connection pipelines** | | | | | | |
| L1.6.1.1 | Tie-in point to the Offshore platform (D=14") | L, m | 15,00 | P=120,0 bar | **35 260,95** | | 1 530,73 |
| L1.6.1.2 | **Offshore Gas loading terminal** | | | | | | |
| | ***Main process facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L1.6.1.3 | Gas compressor module | Q, mscmd | 15,29 | $P_{in}$=120,0 bar, Pout=240,0 bar | **5 437 192,76** | | 355 697,55 |
| L1.6.1.4 | Gas cooling module | Q, mscmd | 15,29 | P=240,0 bar | **1 335 235,44** | | 87 350,22 |
| L1.6.1.5 | Gas storage module | V, mscm | 14,50 | P=240,0 bar | **241 666 666,67** | | 16,67 |
| L1.6.1.6 | Gas measuring module | Q, mscmd | 15,29 | P=240,0 bar | **2 670 000,00** | | 2 670 000,00 |
| | ***Auxiliary process facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L1.6.1.7 | Process automation and signaling system | System | 1,00 | - | **1 340 000,00** | | 1 340 000,00 |
| L1.6.1.8 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| L1.6.1.9 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| L1.6.1.10 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| L1.6.1.11 | Power supply and Distribution System | N, kW | 300,00 | - | **4 440 000,00** | | 14 800,00 |
| L1.6.1.12 | Electrochemical anti-corrosion protection System | N, kW | 15,00 | - | **27 000,00** | | 1 800,00 |
| L1.6.1.13 | Diesel generator module | N, kW | 300,00 | - | **162 000,00** | | 540,00 |
| L1.6.1.14 | Diesel Fuel System | V, m cubic | 75,00 | - | **158 000,00** | | 2 000,00 |
| L1.6.1.15 | Power, control and signaling cables | L, km | 12,00 | | **501 428,57** | | 41 785,71 |
| L1.6.1.16 | Auxiliary site pipelines | System | 1,00 | | **892 500,00** | | 892 500,00 |
| | ***Life support facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L1.6.1.17 | Water and sewage system | System | 1,00 | - | **2 690 000,00** | | 2 690 000,00 |
| L1.6.1.18 | Firewater and fire-fighting system | Q, liter/sec | 35,00 | - | **1 890 000,00** | | 54 000,00 |
| **L1.6.2** | **Connection pipelines** | | | | | | |
| L1.6.2.1 | Pipeline 3 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=120,0 bar | **4 320 000,00** | | 21 600,00 |
| L1.6.2.2 | Pipeline 4 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=240,0 bar | **5 760 000,00** | | 28 800,00 |
| | | | | **TOTAL in Scope of Project** | **275 832 751,89** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | Pipeline 1 (Gas Riser, D=14 inches) | L, m | 300,00 | P=1200,00 bar | **826 594,20** | | 2 755,31 |
| C2 | PLEM, (D=14 inches) | System | 1,00 | P=120,00 bar | **463 623,08** | | 16,67 |
| C3 | Pipeline 2 (Underwater Gas pipeline, D=14 inches) | L, m | 300,00 | P=120,00 bar | **734 750,40** | | 2 449,17 |
| | | **TOTAL out of the scope of Project** | | | **2 024 967,68** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** ***Note 2: The assumptions made to perform loading processes are given in the text in Report.*** | | | | | | |
| | | **TOTAL** | | | **278 749 327,07** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **1.** | **Mediterranean Sea** | | | | | | |
| **U1.** | **Gas unloading process** | | | | | | |
| **U1.1** | ***Onshore Gas unloading terminal facilities on Crete Island*** | ***Gas demand volume*** | ***1,4 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | | |
| A2 | Unloading time | H, hour | 71,00 | | | | |
| A3 | Unloading pressure | P, bar | 80,00 | | | | |
| A4 | Gas temperature | T, °C | 32,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **U1.1.2** | **Onshore Gas unloading terminal** | | | | | | |
| | ***Main process facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U1.1.2.2 | Gas storage module | V, mscm | 9,00 | P=80,0 bar | **150 000 000,00** | | 16,67 |
| U1.1.2.3 | Gas pressure reducing module | Q, mscmd | 1,40 | $P_{in}$=75,0 bar, Pout=55,0 bar | **114 450,00** | | 81 750,00 |
| U1.1.2.4 | Gas heating module | Q, mscmd | 1,40 | P=55,0 bar | **193 823,22** | | 138 445,15 |
| U1.1.2.5 | Gas measuring module | Q, mscmd | 1,40 | P=55,0 bar | **801 000,00** | | 801 000,00 |
| | ***Auxiliary process facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U1.1.2.6 | Process automation and signaling system | System | 1,00 | - | **1 200 000,00** | | 1 200 000,00 |
| U1.1.2.7 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| U1.1.2.8 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| U1.1.2.9 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| U1.1.2.10 | Power supply and Distribution System | N, kW | 1610,00 | - | **8 533 000,00** | | 5 300,00 |
| U1.1.2.11 | Electrochemical anti-corrosion protection System | N, kW | 25,00 | - | **370 000,00** | | 14 800,00 |
| U1.1.2.12 | Diesel generator module | N, kW | 500,00 | - | **270 000,00** | | 540,00 |
| U1.1.2.13 | Diesel Fuel System | V, m cubic | 100,00 | - | **208 000,00** | | 2 000,00 |
| U1.1.2.14 | Communication, alarm, fire alarm system | System | 1,00 | - | **680 000,00** | | 680 000,00 |
| U1.1.2.15 | Overhead transmission line (V=10 kV), (if any) | L, km | 3,00 | - | **432 000,00** | | 144 000,00 |
| U1.1.2.16 | Power, control and signaling cables | L, km | 26,00 | | **1 086 428,57** | | 41 785,71 |
| U1.1.2.17 | Auxiliary site pipelines | System | 1,00 | | **1 869 000,00** | | 1 869 000,00 |
| | ***Life support facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U1.1.2.18 | Water and sewage system | System | 1,00 | - | **2 959 000,00** | | 2 959 000,00 |
| U1.1.2.19 | Firewater and fire-fighting system | Q, liter/sec | 25,00 | - | **3 600 000,00** | | 144 000,00 |
| U1.1.2.20 | Evaporation pond | S, sq.m | 1800,00 | - | **864 000,00** | | 480,00 |
| U1.1.2.21 | Ancillary buildings and structures, site improvements | Facilities complex | 1 | - | **6 200 000,00** | | 6 200 000,00 |
| **U1.1.3** | **Connection pipelines** | | | | | | |
| U1.1.3.1 | Pipeline 1 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=80,0 bar | **3 360 000,00** | | 16 800,00 |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| U1.1.3.2 | PLEM1, (D=14 inches) | Q, mscmd | 1,00 | P=80,0 bar | **459 341,54** | | 9 341,54 |
| U1.1.3.3 | Pipeline 2 (Underwater Gas pipeline, D=14 inches) | L, m | 1000,00 | P=80,0 bar | **2 219 558,50** | | 2 219,56 |
| U1.1.3.4 | PLEM2, (D=14 inches) | Q, mscmd | 1,00 | P=80,0 bar | **459 341,54** | | 9 341,54 |
| U1.1.3.5 | Pipeline 3 (Onshore Gas pipeline, D=14 inches) | L, m | 1000,00 | P=80,0 bar | **1 364 935,00** | | 1 364,94 |
| | | **TOTAL in Scope of Project** | | | **190 642 953,36** | | |
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | Pipeline 4 (Onshore Gas pipeline, connecting the Onshore Gas unloading terminal and the existing Gas network, D=14 inches) | L, m | 1000,00 | P=55,00 bar | **2 296 095,00** | | 1 068,21 |
| C2 | Tie in point to the existing Gas network | L, m | 15,00 | P=55,00 bar | **36 150,00** | | 2 410,00 |
| | | **TOTAL out of the scope of Project** | | | **2 332 245,00** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** ***Note 2: The assumptions made to perform unloading processes are given in the text in Report.*** | | | | | | |
| | | **TOTAL** | | | **192 975 198,36** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **1.** | **Mediterranean Sea** | | | | | | |
| **U1.2** | ***Onshore Gas unloading terminal facilities near the port of Zouk*** | ***Gas demand volume*** | ***3,7 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | | |
| A2 | Unloading time | H, hour | 54,00 | | | | |
| A3 | Unloading pressure | P, bar | 80,00 | | | | |
| A4 | Gas temperature | T, °C | 32,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **U1.2.2** | **Onshore Gas unloading terminal** | | | | | | |
| | ***Main process facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U1.2.2.2 | Gas storage module | V, mscm | 13,90 | P=80,0 bar | **231 666 666,67** | | 16,67 |
| U1.2.2.3 | Gas pressure reducing module | Q, mscmd | 3,70 | $P_{in}$=75,0 bar, Pout=55,0 bar | **431 867,08** | | 116 720,83 |
| U1.2.2.4 | Gas heating module | Q, mscmd | 3,70 | P=55,0 bar | **567 412,14** | | 153 354,63 |
| U1.2.2.5 | Gas measuring module | Q, mscmd | 3,70 | P=55,0 bar | **1 201 500,00** | | 1 201 500,00 |
| | ***Auxiliary process facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U1.2.2.6 | Process automation and signaling system | System | 1,00 | - | **1 200 000,00** | | 1 200 000,00 |
| U1.2.2.7 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| U1.2.2.8 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| U1.2.2.9 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| U1.2.2.10 | Power supply and Distribution System | N, kW | 1610,00 | - | **8 533 000,00** | | 5 300,00 |
| U1.2.2.11 | Electrochemical anti-corrosion protection System | N, kW | 25,00 | - | **370 000,00** | | 14 800,00 |
| U1.2.2.12 | Diesel generator module | N, kW | 500,00 | - | **270 000,00** | | 540,00 |
| U1.2.2.13 | Diesel Fuel System | V, m cubic | 100,00 | - | **208 000,00** | | 2 000,00 |
| U1.2.2.14 | Communication, alarm, fire alarm system | System | 1,00 | - | **680 000,00** | | 680 000,00 |
| U1.2.2.15 | Overhead transmission line (V=10 kV), (if any) | L, km | 3,00 | - | **432 000,00** | | 144 000,00 |
| U1.2.2.16 | Power, control and signaling cables | L, km | 26,00 | | **1 086 428,57** | | 41 785,71 |
| U1.2.2.17 | Auxiliary site pipelines | System | 1,00 | | **1 869 000,00** | | 1 869 000,00 |
| | ***Life support facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U1.2.2.18 | Water and sewage system | System | 1,00 | - | **2 959 000,00** | | 2 959 000,00 |
| U1.2.2.19 | Firewater and fire-fighting system | Q, liter/sec | 25,00 | - | **3 600 000,00** | | 144 000,00 |
| U1.2.2.20 | Evaporation pond | S, sq.m | 1800,00 | - | **864 000,00** | | 480,00 |
| U1.2.2.21 | Ancillary buildings and structures, site improvements | Facilities complex | 1 | - | **6 200 000,00** | | 6 200 000,00 |
| **U1.2.3** | **Connection pipelines** | | | | | | |
| U1.2.3.1 | Pipeline 1 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=80,0 bar | **3 360 000,00** | | 16 800,00 |
| U1.2.3.2 | PLEM1, (D=14 inches) | Q, mscmd | 1,00 | P=80,0 bar | **459 341,54** | | 9 341,54 |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| U1.2.3.3 | Pipeline 2 (Underwater Gas pipeline, D=14 inches) | L, m | 1000,00 | P=80,0 bar | **2 219 558,50** | | 2 219,56 |
| U1.2.3.4 | PLEM2, (D=14 inches) | Q, mscmd | 1,00 | P=80,0 bar | **459 341,54** | | 9 341,54 |
| U1.2.3.5 | Pipeline 3 (Onshore Gas pipeline, D=14 inches) | L, m | 1000,00 | P=80,0 bar | **1 364 935,00** | | 1 364,94 |
| | | **TOTAL in Scope of Project** | | | **273 401 126,04** | | |
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | Pipeline 4 (Onshore Gas pipeline, connecting the Onshore Gas unloading terminal and the existing Gas network, D=14 inches) | L, m | 1000,00 | P=55,0 bar | **2 296 095,00** | | 1 068,21 |
| C2 | Tie in point to the existing Gas network | L, m | 15,00 | P=55,0 bar | **36 150,00** | | 2 410,00 |
| | | **TOTAL out of the scope of Project** | | | **2 332 245,00** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** <br> ***Note 2: The assumptions made to perform unloading processes are given in the text in Report.*** | | | | | | |
| | | **TOTAL** | | | **275 733 371,04** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **1.** | **Mediterranean Sea** | | | | | | |
| **U1.3** | ***Onshore Gas unloading terminal facilities near the port of Alexandria*** | ***Gas demand volume*** | ***17,00 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | | |
| A2 | Unloading time | H, hour | 71,00 | | | | |
| A3 | Unloading pressure | P, bar | 80,00 | | | | |
| A4 | Gas temperature | T, °C | 32,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **U1.3.2** | **Onshore Gas unloading terminal** | | | | | | |
| | ***Main process facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U1.3.2.2 | Gas storage module | V, mscm | 14,50 | P=80,0 bar | **241 666 666,67** | | 16,67 |
| U1.3.2.3 | Gas pressure reducing module | Q, mscmd | 17,00 | $P_{in}$=75,0 bar, Pout=55,0 bar | **1 389 750,00** | | 81 750,00 |
| U1.3.2.4 | Gas heating module | Q, mscmd | 17,00 | P=55,0 bar | **2 353 567,63** | | 138 445,15 |
| U1.3.2.5 | Gas measuring module | Q, mscmd | 17,00 | P=55,0 bar | **801 000,00** | | 801 000,00 |
| | ***Auxiliary process facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U1.3.2.6 | Process automation and signaling system | System | 1,00 | - | **1 200 000,00** | | 1 200 000,00 |
| U1.3.2.7 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| U1.3.2.8 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| U1.3.2.9 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| U1.3.2.10 | Power supply and Distribution System | N, kW | 1610,00 | - | **8 533 000,00** | | 5 300,00 |
| U1.3.2.11 | Electrochemical anti-corrosion protection System | N, kW | 25,00 | - | **370 000,00** | | 14 800,00 |
| U1.3.2.12 | Diesel generator module | N, kW | 500,00 | - | **270 000,00** | | 540,00 |
| U1.3.2.13 | Diesel Fuel System | V, m cubic | 100,00 | - | **208 000,00** | | 2 000,00 |
| U1.3.2.14 | Communication, alarm, fire alarm system | System | 1,00 | - | **680 000,00** | | 680 000,00 |
| U1.3.2.15 | Overhead transmission line (V=10 kV), (if any) | L, km | 3,00 | - | **432 000,00** | | 144 000,00 |
| U1.3.2.16 | Power, control and signaling cables | L, km | 26,00 | | **1 086 428,57** | | 41 785,71 |
| U1.3.2.17 | Auxiliary site pipelines | System | 1,00 | | **1 869 000,00** | | 1 869 000,00 |
| | ***Life support facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U1.3.2.18 | Water and sewage system | System | 1,00 | - | **2 959 000,00** | | 2 959 000,00 |
| U1.3.2.19 | Firewater and fire-fighting system | Q, liter/sec | 25,00 | - | **3 600 000,00** | | 144 000,00 |
| U1.3.2.20 | Evaporation pond | S, sq.m | 1800,00 | - | **864 000,00** | | 480,00 |
| U1.3.2.21 | Ancillary buildings and structures, site improvements | Facilities complex | 1 | - | **6 200 000,00** | | 6 200 000,00 |
| **U1.3.3** | **Connection pipelines** | | | | | | |
| U1.3.3.1 | Pipeline 1 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=80,0 bar | **3 360 000,00** | | 16 800,00 |
| U1.3.3.2 | PLEM1, (D=14 inches) | Q, mscmd | 1,00 | P=80,0 bar | **459 341,54** | | 9 341,54 |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| U1.3.3.3 | Pipeline 2 (Underwater Gas pipeline, D=14 inches) | L, m | 1000,00 | P=80,0 bar | **2 219 558,50** | | 2 219,56 |
| U1.3.3.4 | PLEM2, (D=14 inches) | Q, mscmd | 1,00 | P=80,0 bar | **459 341,54** | | 9 341,54 |
| U1.3.3.5 | Pipeline 3 (Onshore Gas pipeline, D=14 inches) | L, m | 1000,00 | P=80,0 bar | **1 364 935,00** | | 1 364,94 |
| | | **TOTAL in Scope of Project** | | | **285 744 664,44** | | |
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | Pipeline 4 (Onshore Gas pipeline, connecting the Onshore Gas unloading terminal and the existing Gas network, D=14 inches) | L, m | 1000,00 | P=55,000 bar | **2 296 095,00** | | 1 068,21 |
| C2 | Tie in point to the existing Gas network | L, m | 15,00 | P=55,0 bar | **36 150,00** | | 2 410,00 |
| | | **TOTAL out of the scope of Project** | | | **2 332 245,00** | | **2 332 245,00** |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** ***Note 2: The assumptions made to perform unloading processes are given in the text in Report.*** | | | | | | |
| | | **TOTAL** | | | **288 076 909,44** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **2.** | **Barents Sea** | | | | | | |
| **L2.** | **Gas loading terminal** | | | | | | |
| **L2.1** | ***Offshore Gas loading terminal facilities near the Alke Gas production platforms – direction to the Nyhamna Gas treatment plant*** | ***Gas demand volume*** | ***1,18 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | | |
| A2 | Loading time | H, hour | 44,00 | | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | | |
| A4 | Gas temperature | T, °C | 25,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **L2.1.1** | **Connection pipelines** | | | | | | |
| L2.1.1.1 | Tie-in point to the Offshore platform (D=14") | L, m | 15,00 | P=120,0 bar | **35 260,95** | | 1 530,73 |
| **L2.1.2** | **Offshore Gas loading terminal** | | | | | | |
| | ***Main process facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L2.1.2.1 | Gas compressor module | Q, mscmd | 15,47 | $P_{in}$=120,0 bar, Pout=240,0 bar | **15 018 688,53** | | 970 826,67 |
| L2.1.2.2 | Gas cooling module | Q, mscmd | 15,47 | P=240,0 bar | **1 351 307,88** | | 87 350,22 |
| L2.1.2.3 | Gas storage module | mscm | 10,15 | P=240,0 bar | **169 166 666,67** | | 16,67 |
| L2.1.2.4 | Gas measuring module | Q, mscmd | 15,47 | P=240,0 bar | **3 150 600,00** | | 3 150 600,00 |
| | ***Auxiliary process facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L2.1.2.5 | Process automation and signaling system | System | 1,00 | - | **1 340 000,00** | | 1 340 000,00 |
| L2.1.2.6 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| L2.1.2.7 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| L2.1.2.8 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| L2.1.2.9 | Power supply and Distribution System | N, kW | 300,00 | - | **1 590 000,00** | | 5 300,00 |
| L2.1.2.10 | Electrochemical anti-corrosion protection System | N, kW | 15,00 | - | **222 000,00** | | 14 800,00 |
| L2.1.2.11 | Diesel generator module | N, kW | 300,00 | - | **162 000,00** | | 540,00 |
| L2.1.2.12 | Diesel Fuel System | V, m cubic | 75,00 | - | **158 000,00** | | 2 000,00 |
| L2.1.2.13 | Power, control and signaling cables | L, km | 12,00 | | **501 428,57** | | 41 785,71 |
| L2.1.2.14 | Auxiliary site pipelines | System | 1,00 | | **892 500,00** | | 892 500,00 |
| | ***Life support facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L2.1.2.15 | Water and sewage system | System | 1,00 | - | **2 690 000,00** | | 2 690 000,00 |
| L2.1.2.16 | Firewater and fire-fighting system | Q, liter/sec | 35,00 | - | **1 890 000,00** | | 54 000,00 |
| **L2.1.3** | **Connection pipelines** | | | | | | |
| L2.1.3.1 | Pipeline 3 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=120,0 bar | **4 320 000,00** | | 21 600,00 |
| L2.1.3.2 | Pipeline 4 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=240,0 bar | **5 760 000,00** | | 28 800,00 |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| | | TOTAL in Scope of Project | | | **211 647 527,60** | | |
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | Pipeline 1 (Gas Riser, D=14 inches) | L, m | 300,00 | P=120,0 bar | **826 594,20** | | 2 755,31 |
| C2 | PLEM, (D=14 inches) | System | 1,00 | P=120,0 bar | **463 623,08** | | 13 623,08 |
| C3 | Pipeline 2 (Underwater Gas pipeline, D=14 inches) | L, m | 300,00 | P=120,0 bar | **734 750,40** | | 2 449,17 |
| | | TOTAL out of the scope of Project | | | **2 024 967,68** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** ***Note 2: The assumptions made to perform loading processes are given in the text in Report.*** | | | | | | |
| | | TOTAL | | | **213 672 495,28** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **2.** | **Barents Sea** | | | | | | |
| **L2.2** | ***Offshore Gas loading terminal facilities near the Alke Gas production platforms – direction to Aasta Hansteen Gas production platforms (enter to the Polarled underwater Gas pipeline)*** | ***Gas demand volume*** | ***1,18 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | | |
| A2 | Loading time | H, hour | 44,00 | | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | | |
| A4 | Gas temperature | T, °C | 25,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **L2.2.1** | **Connection pipelines** | | | | | | |
| L2.2.1.1 | Tie-in point to the Offshore platform (D=14") | L, m | 15,00 | P=120,0 bar | **35 260,95** | | 1 530,73 |
| **L2.2.2** | **Offshore Gas loading terminal** | | | | | | |
| | ***Main process facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L2.2.2.1 | Gas compressor module | Q, mscmd | 15,47 | $P_{in}$=120,0 bar, Pout=240,0 bar | **15 018 688,53** | | 970 826,67 |
| L2.2.2.2 | Gas cooling module | Q, mscmd | 15,47 | P=240,0 bar | **1 351 307,88** | | 87 350,22 |
| L2.2.2.3 | Gas storage module | mscm | 8,37 | P=240,0 bar | **139 500 000,00** | | 16,67 |
| L2.2.2.4 | Gas measuring module | Q, mscmd | 15,47 | P=240,0 bar | **3 150 600,00** | | 3 150 600,00 |
| | ***Auxiliary process facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L2.2.2.5 | Process automation and signaling system | System | | | | | |
| L2.2.2.6 | Instrument and Plant Air System | System | 1,00 | - | **1 100 000,00** | | 1 100 000,00 |
| L2.2.2.7 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| L2.2.2.8 | Vent/Flare System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| L2.2.2.9 | Power supply and Distribution System | N, kW | 1,00 | - | **504 375,00** | | 504 375,00 |
| L2.2.2.10 | Electrochemical anti-corrosion protection System | N, kW | 300,00 | - | **1 590 000,00** | | 5 300,00 |
| L2.2.2.11 | Diesel generator module | N, kW | 15,00 | - | **222 000,00** | | 14 800,00 |
| L2.2.2.12 | Diesel Fuel System | V, m cubic | 300,00 | - | **162 000,00** | | 540,00 |
| L2.2.2.13 | Power, control and signaling cables | L, km | 75,00 | - | **158 000,00** | | 2 000,00 |
| L2.2.2.14 | Auxiliary site pipelines | System | 12,00 | | **501 428,57** | | 41 785,71 |
| | ***Life support facilities (modules) of Offshore floating Gas loading terminal*** | | 1,00 | | **892 500,00** | | 892 500,00 |
| L2.2.2.15 | Water and sewage system | System | 1,00 | - | **2 690 000,00** | | 2 690 000,00 |
| L2.2.2.16 | Firewater and fire-fighting system | Q, liter/sec | 35,00 | - | **1 890 000,00** | | 54 000,00 |
| **L2.2.3** | **Connection pipelines** | | | | | | |
| L2.2.3.1 | Pipeline 3 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=240,0 bar | **5 760 000,00** | | 28 800,00 |
| L2.2.3.2 | Pipeline 4 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=240,0 bar | **5 760 000,00** | | 28 800,00 |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| | | | | **TOTAL in Scope of Project** | **183 180 860,94** | | |
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | Pipeline 1 (Gas Riser, D=14 inches) | L, m | 300,00 | P=120,00 bar | **826 594,20** | | 2 755,31 |
| C2 | PLEM1, (D=14 inches) | System | 1,00 | P=120,00 bar | **463 623,08** | | 270 018,00 |
| C3 | Pipeline 2 (Underwater Gas pipeline, D=14 inches) | L, m | 300,00 | P=120,00 bar | **734 750,40** | | 2 449,17 |
| | | | | **TOTAL out of the scope of Project** | **2 024 967,68** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** ***Note 2: The assumptions made to perform loading processes are given in the text in Report.*** | | | | | | |
| | | | | **TOTAL** | **185 205 828,61** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **2.** | **Barents Sea** | | | | | | |
| **L2.3** | ***Offshore Gas loading terminal facilities near the Johan Castberg Gas production platforms – direction to the Nyhamna Gas treatment plant*** | ***Gas demand volume*** | ***1,29 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | | |
| A2 | Loading time | H, hour | 44,00 | | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | | |
| A4 | Gas temperature | T, °C | 25,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **L2.3.1** | **Connection pipelines** | | | | | | |
| L2.3.1.1 | Tie-in point to the Offshore platform (D=14") | L, m | 15,00 | P=120,0 bar | **35 260,95** | | 1 530,73 |
| **L2.3.2** | **Offshore Gas loading terminal** | | | | | | |
| | ***Main process facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L2.3.2.1 | Gas compressor module | Q, mscmd | 15,47 | $P_{in}$=120,0 bar, Pout=240,0 bar | **15 018 688,53** | | 970 826,67 |
| L2.3.2.2 | Gas cooling module | Q, mscmd | 15,47 | P=240,0 bar | **1 351 307,88** | | 87 350,22 |
| L2.3.2.3 | Gas storage module | mscm | 10,15 | P=240,0 bar | **169 200 000,00** | | 16,67 |
| L2.3.2.4 | Gas measuring module | Q, mscmd | 15,47 | P=240,0 bar | **3 150 600,00** | | 3 150 600,00 |
| | ***Auxiliary process facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L2.3.2.5 | Process automation and signaling system | System | 1,00 | - | **1 100 000,00** | | 1 100 000,00 |
| L2.3.2.6 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| L2.3.2.7 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| L2.3.2.8 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| L2.3.2.9 | Power supply and Distribution System | N, kW | 300,00 | - | **1 590 000,00** | | 5 300,00 |
| L2.3.2.10 | Electrochemical anti-corrosion protection System | N, kW | 15,00 | - | **222 000,00** | | 14 800,00 |
| L2.3.2.11 | Diesel generator module | N, kW | 300,00 | - | **162 000,00** | | 540,00 |
| L2.3.2.12 | Diesel Fuel System | V, m cubic | 75,00 | - | **158 000,00** | | 2 000,00 |
| L2.3.2.13 | Power, control and signaling cables | L, km | 12,00 | | **501 428,57** | | 41 785,71 |
| L2.3.2.14 | Auxiliary site pipelines | System | 1,00 | | **892 500,00** | | 892 500,00 |
| | ***Life support facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L2.3.2.15 | Water and sewage system | System | 1,00 | - | **2 690 000,00** | | 2 690 000,00 |
| L2.3.2.16 | Firewater and fire-fighting system | Q, liter/sec | 35,00 | - | **1 890 000,00** | | 54 000,00 |
| **L2.3.3** | **Connection pipelines** | | | | | | |
| L2.3.3.1 | Pipeline 3 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=120,0 bar | **4 320 000,00** | | 21 600,00 |
| L2.3.3.2 | Pipeline 4 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=240,0 bar | **5 760 000,00** | | 28 800,00 |
| | | | | **TOTAL in Scope of Project** | **211 440 860,94** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | Pipeline 1 (Gas Riser, D=14 inches) | L, m | 300,00 | P=120,00 bar | **826 594,20** | | 2 755,31 |
| C2 | PLEM, (D=14 inches) | System | 1,00 | P=120,00 bar | **463 623,08** | | 270 018,00 |
| C3 | Pipeline 2 (Underwater Gas pipeline, D=14 inches) | L, m | 300,00 | P=120,00 bar | **734 750,40** | | 2 449,17 |
| | | **TOTAL out of the scope of Project** | | | **2 024 967,68** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** ***Note 2: The assumptions made to perform loading processes are given in the text in Report.*** | | | | | | |
| | | **TOTAL** | | | **213 465 828,61** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **2.** | **Barents Sea** | | | | | | |
| **L2.4** | ***Offshore Gas loading terminal facilities near the Johan Castberg Gas production platforms – direction to Aasta Hansteen Gas production platforms (enter to the Polarled underwater Gas pipeline)*** | ***Gas demand volume*** | ***1,29 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | | |
| A2 | Loading time | H, hour | 44,00 | | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | | |
| A4 | Gas temperature | T, °C | 25,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **L2.4.1** | **Connection pipelines** | | | | | | |
| L2.4.1.1 | Tie-in point to the Offshore platform (D=14") | L, m | 15,00 | P=120,0 bar | **35 260,95** | | 1 530,73 |
| **L2.4.3** | **Offshore Gas loading terminal** | | | | | | |
| | ***Main process facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L2.4.3.1 | Gas compressor module | Q, mscmd | 15,47 | $P_{in}$=120,0 bar, Pout=240,0 bar | **15 018 688,53** | | 970 826,67 |
| L2.4.3.2 | Gas cooling module | Q, mscmd | 15,47 | P=240,0 bar | **1 351 307,88** | | 87 350,22 |
| L2.4.3.3 | Gas storage module | mscm | 8,37 | P=240,0 bar | **139 500 000,00** | | 16,67 |
| L2.4.3.4 | Gas measuring module | Q, mscmd | 15,47 | P=240,0 bar | **3 150 600,00** | | 3 150 600,00 |
| | ***Auxiliary process facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L2.4.3.5 | Process automation and signaling system | System | 1,00 | - | **1 100 000,00** | | 1 100 000,00 |
| L2.4.3.6 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| L2.4.3.7 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| L2.4.3.8 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| L2.4.3.9 | Power supply and Distribution System | N, kW | 300,00 | - | **1 590 000,00** | | 5 300,00 |
| L2.4.3.10 | Electrochemical anti-corrosion protection System | N, kW | 15,00 | - | **222 000,00** | | 14 800,00 |
| L2.4.3.11 | Diesel generator module | N, kW | 300,00 | - | **162 000,00** | | 540,00 |
| L2.4.3.12 | Diesel Fuel System | V, m cubic | 75,00 | - | **158 000,00** | | 2 000,00 |
| L2.4.3.13 | Power, control and signaling cables | L, km | 12,00 | | **501 428,57** | | 41 785,71 |
| L2.4.3.14 | Auxiliary site pipelines | System | 1,00 | | **892 500,00** | | 892 500,00 |
| | ***Life support facilities (modules) of Offshore floating Gas loading terminal*** | | | | | | |
| L2.4.3.15 | Water and sewage system | System | 1,00 | - | **2 690 000,00** | | 2 690 000,00 |
| L2.4.3.16 | Firewater and fire-fighting system | Q, liter/sec | 35,00 | - | **1 890 000,00** | | 54 000,00 |
| **L2.4.4** | **Connection pipelines** | | | | | | |
| L2.4.4.1 | Pipeline 3 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=120,0 bar | **4 320 000,00** | | 21 600,00 |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| L2.4.4.2 | Pipeline 4 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=240,0 bar | **5 760 000,00** | | 28 800,00 |
| | | **TOTAL in Scope of Project** | | | **181 740 860,94** | | |
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | Pipeline 1 (Gas Riser, D=14 inches) | L, m | 200,00 | P=120,00 bar | **826 594,20** | | 2 755,31 |
| C2 | PLEM, (D=14 inches) | System | 1,00 | P=120,00 bar | **463 623,08** | | 270 018,00 |
| C3 | Pipeline 2 (Underwater Gas pipeline, D=14 inches) | L, m | 300,00 | P=120,00 bar | **734 750,40** | | 2 449,17 |
| | | **TOTAL out of the scope of Project** | | | **2 024 967,68** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** <br> ***Note 2: The assumptions made to perform loading processes are given in the text in Report.*** | | | | | | |
| | | **TOTAL** | | | **183 765 828,61** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **2.** | **Barents Sea** | | | | | | |
| **U2.** | **Onshore Gas unloading terminal** | | | | | | |
| **U2.1** | ***Onshore Gas unloading terminal facilities on the Nyhamna Gas treatment plant*** | ***Gas demand volume*** | ***1,29 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | | |
| A2 | Unloading time | H, hour | 70,00 | | | | |
| A3 | Unloading pressure | P, bar | 80,00 | | | | |
| A4 | Gas temperature | T, °C | 32,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **U2.1.1** | **Onshore Gas unloading terminal** | | | | | | |
| | ***Main process facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U2.1.1.1 | Gas storage module | V, mscm | 10,15 | P=80,0 bar | **169 166 666,67** | | 16,67 |
| U2.1.1.2 | Gas pressure reducing module | Q, mscmd | 1,29 | $P_{in}$=80,0 bar, Pout=75,0 bar | **77 921,38** | | 60 404,17 |
| U2.1.1.3 | Gas heating module | Q, mscmd | 1,29 | P=75,0 bar | **164 856,23** | | 127 795,53 |
| U2.1.1.4 | Gas measuring module | Q, mscmd | 1,29 | P=75,0 bar | **2 670 000,00** | | 2 670 000,00 |
| | ***Auxiliary process facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U2.1.1.5 | Process automation and signaling system | System | 1,00 | - | **1 200 000,00** | | 1 200 000,00 |
| U2.1.1.6 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| U2.1.1.7 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| U2.1.1.8 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| U2.1.1.9 | Power supply and Distribution System | N, kW | 1610,00 | - | **8 533 000,00** | | 5 300,00 |
| U2.1.1.10 | Electrochemical anti-corrosion protection System | N, kW | 25,00 | - | **370 000,00** | | 14 800,00 |
| U2.1.1.11 | Diesel generator module | N, kW | 500,00 | - | **270 000,00** | | 540,00 |
| U2.1.1.12 | Diesel Fuel System | V, m cubic | 100,00 | - | **208 000,00** | | 2 000,00 |
| U2.1.1.13 | Communication, alarm, fire alarm system | System | 1,00 | - | **680 000,00** | | 680 000,00 |
| U2.1.1.14 | Overhead transmission line (V=10 kV), (if any) | L, km | 3,00 | - | **432 000,00** | | 144 000,00 |
| U2.1.1.15 | Power, control and signaling cables | L, km | 26,00 | | **1 086 428,57** | | 41 785,71 |
| U2.1.1.16 | Auxiliary site pipelines | System | 1,00 | | **1 869 000,00** | | 1 869 000,00 |
| | ***Life support facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U2.1.1.17 | Water and sewage system | System | 1,00 | - | **2 959 000,00** | | 2 959 000,00 |
| U2.1.1.18 | Firewater and fire-fighting system | Q, liter/sec | 25,00 | - | **3 600 000,00** | | 144 000,00 |
| U2.1.1.19 | Evaporation pond | S, sq.m | 1800,00 | - | **864 000,00** | | 480,00 |
| U2.1.1.20 | Ancillary buildings and structures, site improvements | Facilities complex | 1 | - | **6 200 000,00** | | 6 200 000,00 |
| **U2.1.2** | **Connection pipelines** | | | | | | |
| U2.1.2.1 | Pipeline 1 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=80,0 bar | **3 360 000,00** | | 16 800,00 |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| U2.1.2.2 | PLEM1, (D=14 inches) | System | 1,00 | P=80,0 bar | **459 341,54** | | 9 341,54 |
| U2.1.2.3 | Pipeline 2 (Underwater Gas pipeline, D=14 inches) | L, m | 1000,00 | P=80,0 bar | **2 219 558,50** | | 2 219,56 |
| U2.1.2.4 | Pipeline 3 (Onshore Gas pipeline, D=14 inches) | L, m | 1000,00 | P=80,0 bar | **1 364 935,00** | | 1 364,94 |
| U2.1.2.5 | Tie in point to the existing Nyhamna Gas treatment plant | L, m | 15,00 | P=75,0 bar | **36 150,00** | | 2 410,00 |
| | | | | **TOTAL in Scope of Project** | **211 189 932,88** | | |
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | Pipeline 4 (Onshore Gas pipeline, connecting the Onshore Gas unloading terminal and the Nyhamna Gas treatment plant, D=14 inches) | L, m | 1000,00 | P=75,00 bar | **2 296 095,00** | | 1 305,59 |
| | | | | **TOTAL out of the scope of Project** | **2 296 095,00** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** ***Note 2: The assumptions made to perform unloading processes are given in the text in Report.*** | | | | | | |
| | | | | **TOTAL** | **213 486 027,88** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **2.** | **Barents Sea** | | | | | | |
| **U2.2** | ***Offshore Gas unloading terminal facilities near the Aasta Hansteen Gas production platforms (enter to the Polarled underwater Gas pipeline)*** | ***Gas demand volume*** | ***1,29 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | | |
| A2 | Unloading time | H, hour | 70,00 | | | | |
| A3 | Unloading pressure | P, bar | 80,00 | | | | |
| A4 | Gas temperature | T, °C | 32,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **U2.2.1** | **Onshore Gas unloading terminal** | | | | | | |
| | ***Main process facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U2.2.1.1 | Gas storage module | V, mscm | 8,37 | P=80,0 bar | **139 533 333,33** | | 16,67 |
| U2.2.1.2 | Gas pressure reducing module | Q, mscmd | 1,29 | $P_{in}$=80,0 bar, Pout=75,0 bar | **77 921,38** | | 60 404,17 |
| U2.2.1.3 | Gas heating module | Q, mscmd | 1,29 | P=75,0 bar | **164 856,23** | | 127 795,53 |
| U2.2.1.4 | Gas measuring module | Q, mscmd | 1,29 | P=75,0 bar | **2 670 000,00** | | 2 670 000,00 |
| | ***Auxiliary process facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U2.2.1.5 | Process automation and signaling system | System | 1,00 | - | **1 340 000,00** | | 1 340 000,00 |
| U2.2.1.6 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| U2.2.1.7 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| U2.2.1.8 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| U2.2.1.9 | Power supply and Distribution System | N, kW | 1610,00 | - | **8 533 000,00** | | 5 300,00 |
| U2.2.1.10 | Electrochemical anti-corrosion protection System | N, kW | 25,00 | - | **370 000,00** | | 14 800,00 |
| U2.2.1.11 | Diesel generator module | N, kW | 500,00 | - | **270 000,00** | | 540,00 |
| U2.2.1.12 | Diesel Fuel System | V, m cubic | 100,00 | - | **208 000,00** | | 2 000,00 |
| U2.2.1.13 | Communication, alarm, fire alarm system | System | 1,00 | - | **500 000,00** | | 500 000,00 |
| U2.2.1.14 | Overhead transmission line (V=10 kV), (if any) | L, km | 3,00 | - | **432 000,00** | | 144 000,00 |
| U2.2.1.15 | Power, control and signaling cables | L, km | 12,00 | | **501 428,57** | | 41 785,71 |
| U2.2.1.16 | Auxiliary site pipelines | System | 1,00 | | **892 500,00** | | 892 500,00 |
| | ***Life support facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U2.2.1.17 | Water and sewage system | System | 1,00 | - | **2 690 000,00** | | 2 690 000,00 |
| U2.2.1.18 | Firewater and fire-fighting system | Q, liter/sec | 25,00 | - | **1 350 000,00** | | 54 000,00 |
| U2.2.1.19 | Evaporation pond | S, sq.m | 1800,00 | - | **864 000,00** | | 480,00 |
| **U2.2.2** | **Connection pipelines** | | | | | | |
| U2.2.2.1 | Pipeline 1 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=80,0 bar | **3 360 000,00** | | 16 800,00 |
| U2.2.2.2 | PLEM1, (D=14 inches) | System | 1,00 | P=80,0 bar | **459 341,54** | | 9 341,54 |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| U2.2.2.3 | Pipeline 2 (Underwater Gas pipeline, D=14 inches) | L, m | 300,00 | P=80,0 bar | **665 867,55** | | 2 219,56 |
| U2.2.2.4 | PLEM2, (D=14 inches) | System | 1,00 | P=80,0 bar | **459 341,54** | | 9 341,54 |
| U2.2.2.5 | Pipeline 3 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=80,0 bar | **3 360 000,00** | | 16 800,00 |
| U2.2.2.6 | Pipeline 4 (Flexible connection, connecting the Offshore Gas unloading terminal and the existing Underwater Gas pipeline Polarled, D=3x7 inches) | L, m | 200,00 | P=80,0 bar | **3 360 000,00** | | 16 800,00 |
| | | **TOTAL in Scope of Project** | | | **175 460 665,14** | | |
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | PLEM3, (D=14 inches) | System | 1,00 | P=80,0 bar | **635 155,20** | | 185 155,20 |
| | | **TOTAL out of the scope of Project** | | | **635 155,20** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** ***Note 2: The assumptions made to perform unloading processes are given in the text in Report.*** | | | | | | |
| | | **TOTAL** | | | **176 095 820,34** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **3.** | **Black Sea** | | | | | | |
| **L3.** | **Gas loading terminal** | | | | | | |
| **L3.1** | ***Onshore Gas loading terminal facilities near the port of Poti (Georgia)*** | ***Gas demand volume*** | ***6,3 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | | |
| A2 | Loading time | H, hour | 47,00 | | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | | |
| A4 | Gas temperature | T, °C | 25,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **L.3.1.1** | **Onshore Gas loading terminal** | | | | | | |
| L3.1.1.1 | Tie-in point to the Gas interconnector (D=28") | L, m | 15,00 | P=55,0 bar | **141 075,00** | | 1 205,00 |
| | ***Main process facilities (modules) of Onshore Gas loading terminal*** | | | | | | |
| L3.1.1.2 | Gas compressor module | Q, mscmd | 6,30 | $P_{in}$=55,0 bar, Pout=240,0 bar | **6 116 208,00** | | 970 826,67 |
| L3.1.1.3 | Gas cooling module | Q, mscmd | 6,30 | P=240,0 bar | **550 306,38** | | 87 350,22 |
| L3.1.1.4 | Gas storage module | V, mscm | 45,99 | P=240,0 bar | **766 500 000,00** | | 16,67 |
| L3.1.1.5 | Gas measuring module | Q, mscmd | 6,30 | P=240,0 bar | **2 883 600,00** | | 2 883 600,00 |
| | ***Auxiliary process facilities (modules) of Onshore Gas loading terminal*** | | | | | | |
| L3.1.1.6 | Process automation and signaling system | System | 1,00 | - | **1 340 000,00** | | 1 340 000,00 |
| L3.1.1.7 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| L3.1.1.8 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| L3.1.1.9 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| L3.1.1.10 | Power supply and Distribution System | N, kW | 1610,00 | - | **8 533 000,00** | | 5 300,00 |
| L3.1.1.11 | Electrochemical anti-corrosion protection System | N, kW | 25,00 | - | **370 000,00** | | 14 800,00 |
| L3.1.1.12 | Diesel generator module | N, kW | 500,00 | - | **270 000,00** | | 540,00 |
| L3.1.1.13 | Diesel Fuel System | V, m cubic | 100,00 | - | **208 000,00** | | 2 000,00 |
| L3.1.1.14 | Communication, alarm, fire alarm system | System | 1,00 | - | **800 000,00** | | 800 000,00 |
| L3.1.1.15 | Overhead transmission line (V=10 kV), (if any) | L, km | 3,00 | - | **432 000,00** | | 144 000,00 |
| L3.1.1.16 | Power, control and signaling cables | L, km | 26,00 | | **1 086 428,57** | | 41 785,71 |
| L3.1.1.17 | Auxiliary site pipelines | System | 1,00 | | **1 942 500,00** | | 1 942 500,00 |
| | ***Life support facilities (modules) of Onshore Gas loading terminal*** | | | | | | |
| L3.1.1.18 | Water and sewage system | System | 1,00 | - | **3 228 000,00** | | 3 228 000,00 |
| L3.1.1.19 | Firewater and fire-fighting system | Q, liter/sec | 25,00 | - | **3 825 000,00** | | 153 000,00 |
| L3.1.1.20 | Evaporation pond | S, sq.m | 1800,00 | - | **864 000,00** | | 480,00 |
| L3.1.1.21 | Ancillary buildings and structures, site improvements | Facilities complex | 1 | - | **6 200 000,00** | | 6 200 000,00 |
| **L3.1.2** | **Connection pipelines** | | | | | | |
| L3.1.2.1 | Pipeline 3 (Onshore Gas pipeline, D=14 inches) | L, m | 500,00 | P=240,0 bar | **949 520,00** | | 1 899,04 |
| L3.1.2.2 | Pipeline 4 (Underwater Gas pipeline, D=14 inches) | L, m | 3000,00 | P=240,0 bar | **7 806 723,00** | | 2 602,24 |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| L3.1.2.3 | PLEM1, (D=14 inches) | System | 1,00 | P=240,0 bar | **740 030,77** | | 35 030,77 |
| L3.1.2.4 | Pipeline 5 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=240,0 bar | **5 760 000,00** | | 28 800,00 |
| | | **TOTAL in Scope of Project** | | | **823 945 466,72** | | |
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | N/A | | | | **0,00** | | 1,00 |
| | | **TOTAL out of the scope of Project** | | | **0,00** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.*** <br> ***Note 2: The assumptions made to perform loading processes are given in the text in Report.*** | | | | | | |
| | | **TOTAL** | | | **823 945 466,72** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **3.** | **Black Sea** | | | | | | |
| **U3.** | **Gas unloading terminal** | | | | | | |
| **U3.1** | ***Onshore Gas unloading terminal facilities near the port of Yuzne (Ukraine)*** | ***Gas demand volume*** | ***6,3 mscmd*** | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | | |
| A2 | Unloading time | H, hour | 69,00 | | | | |
| A3 | Unloading pressure | P, bar | 80,00 | | | | |
| A4 | Gas temperature | T, °C | 32,00 | | | | |
| **B** | **Facilities in the scope of the Project** | | | | | | |
| **U3.1.1** | **Onshore Gas unloading terminal** | | | | | | |
| | ***Main process facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U3.1.1.1 | Gas storage module | V, mscm | 45,99 | P=80,0 bar | **766 500 000,00** | | 16,67 |
| U3.1.1.2 | Gas pressure reducing module | Q, mscmd | 6,30 | $P_{in}$=80,0 bar, Pout=60,0 bar | **515 025,00** | | 81 750,00 |
| U3.1.1.3 | Gas heating module | Q, mscmd | 6,30 | P=75,0 bar | **872 204,47** | | 138 445,15 |
| U3.1.1.4 | Gas measuring module | Q, mscmd | 6,30 | P=75,0 bar | **2 670 000,00** | | 2 670 000,00 |
| | ***Auxiliary process facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U3.1.1.5 | Process automation and signaling system | System | 1,00 | - | **1 340 000,00** | | 1 340 000,00 |
| U3.1.1.6 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| U3.1.1.7 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| U3.1.1.8 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| U3.1.1.9 | Power supply and Distribution System | N, kW | 1610,00 | - | **8 533 000,00** | | 5 300,00 |
| U3.1.1.10 | Electrochemical anti-corrosion protection System | N, kW | 25,00 | - | **370 000,00** | | 14 800,00 |
| U3.1.1.11 | Diesel generator module | N, kW | 500,00 | - | **270 000,00** | | 540,00 |
| U3.1.1.12 | Diesel Fuel System | V, m cubic | 100,00 | - | **208 000,00** | | 2 000,00 |
| U3.1.1.13 | Communication, alarm, fire alarm system | System | 1,00 | - | **800 000,00** | | 800 000,00 |
| U3.1.1.14 | Overhead transmission line (V=10 kV), (if any) | L, km | 3,00 | - | **432 000,00** | | 144 000,00 |
| U3.1.1.15 | Power, control and signaling cables | L, km | 26,00 | | **1 086 428,57** | | 41 785,71 |
| U3.1.1.16 | Auxiliary site pipelines | System | 1,00 | | **1 869 000,00** | | 1 869 000,00 |
| | ***Life support facilities (modules) of Onshore Gas unloading terminal*** | | | | | | |
| U3.1.1.17 | Water and sewage system | System | 1,00 | - | **3 228 000,00** | | 3 228 000,00 |
| U3.1.1.18 | Firewater and fire-fighting system | Q, liter/sec | 25,00 | - | **3 600 000,00** | | 144 000,00 |
| U3.1.1.19 | Evaporation pond | S, sq.m | 1800,00 | - | **864 000,00** | | 480,00 |
| U3.1.1.20 | Ancillary buildings and structures, site improvements | Facilities complex | 1 | - | **6 200 000,00** | | 6 200 000,00 |
| **U3.1.2** | **Connection pipelines** | | | | | | |
| U3.1.2.1 | Pipeline 1 (Flexible connection, D=3x7 inches) | L, m | 200,00 | P=80,0 bar | **3 360 000,00** | | 16 800,00 |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| U3.1.2.2 | PLEM1, (D=14 inches) | Q, mscmd | 1,00 | P=80,0 bar | **459 341,54** | | 9 341,54 |
| U3.1.2.3 | Pipeline 2 (Underwater Gas pipeline, D=14 inches) | L, m | 2500,00 | P=80,0 bar | **5 548 896,25** | | 2 219,56 |
| U3.1.2.4 | Pipeline 3 (Onshore Gas pipeline, D=14 inches) | L, m | 1000,00 | P=80,0 bar | **1 364 935,00** | | 1 364,94 |
| U3.1.2.5 | Tie in point to the Gas interconnector | L, m | 15,00 | P=55,0 bar | **45 921,90** | | 3 061,46 |
| | | **TOTAL in Scope of Project** | | | **813 535 827,73** | | |
| **C** | **Facilities out of the scope of the Project** | | | | | | |
| C1 | Pipeline 4 (Onshore Gas pipeline, connecting the Onshore Gas unloading terminal and the Gas Interconnector between terminal and point of connection to the existing Gas network, D=14 inches) | L, m | 1000,00 | P=55,00 bar | **1 068 210,00** | | 1 068,21 |
| | | **TOTAL out of the scope of Project** | | | **1 068 210,00** | | |
| | ***Note 1: In the header is shown the commercial Gas flow rate. The cost of Gas terminal equipment items is given in the table depending on the Technical parameters of the equipment.***<br>***Note 2: The assumptions made to perform unloading processes are given in the text in Report.*** | | | | | | |
| | | **TOTAL** | | | **814 604 037,73** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **4.** | **Out of Scope of Project in the Black Sea Region** | | | | | | |
| **O4.1** | ***Head Gas compressor station of the Gas interconnector SCP - Gas loading terminal near the port of Poti (Georgia)*** | ***Gas demand volume*** | ***6,3 mscmd*** | | | | |
| **A** | **Process parameters** | | | | | | |
| A1 | Process capacity | Q, mscmd | 6,30 | | | | |
| A2 | Design pressure | P, bar | $P_{in}$=55,0 bar, $P_{out}$=70,0 bar | | | | |
| A3 | Gas temperature | T, °C | 40,00 | | | | |
| **O4.1.1** | **Connection pipelines** | | | | | | |
| O4.1.1.1 | Onshore Gas pipeline (D=28 inches) | L, m | 3000,00 | P=55,0 bar | **7 121 400,00** | | 2 373,80 |
| O4.1.1.2 | Tie-in point to the existing Main Gas pipeline SCP (D=28 inches) | L, m | 15,00 | P=55,0 bar | **18 075,00** | | 1 205,00 |
| **O4.1.2** | **Head Gas compressor station** | | | | | | |
| m | ***Main process facilities (modules) of the Head compressor station*** | | | | | | |
| O4.1.2.1 | Gas cleaning module | Q, mscmd | 6,30 | P=55,0 bar | **2 880 150,00** | | 457 166,67 |
| O4.1.2.2 | Compressor shop-Gas compressor modules | Q, mscmd | 6,30 | $P_{in}$=55,0 bar, Pout=70,0 bar | **8 556 293,76** | | 1 358 141,87 |
| O4.1.2.3 | Gas cooling module | Q, mscmd | 6,30 | P=70,0 bar | **550 306,38** | | 87 350,22 |
| O4.1.2.4 | Gas measuring module | Q, mscmd | 6,30 | P=70,0 bar | **2 403 000,00** | | 2 403 000,00 |
| O4.1.2.5 | Auxiliary site pipelines | System | 1,00 | P=70,0 bar | **1 050 000,00** | | 1 050 000,00 |
| | ***Auxiliary process facilities (modules) of the Head compressor station*** | | | | | | |
| O4.1.2.6 | Fuel Gas treatment module | System | 1,00 | P=55,0 bar | **890 000,00** | | 890 000,00 |
| O4.1.2.7 | Lubricant module (Oil cleaning module) | System | 1,00 | - | **212 618,40** | | 212 618,40 |
| O4.1.2.8 | Process automation and signaling system | System | 1,00 | | **1 350 000,00** | | 1 350 000,00 |
| O4.1.2.9 | Instrument and Plant Air System | System | 1,00 | - | **1 800 000,00** | | 1 800 000,00 |
| O4.1.2.10 | Nitrogen Generation and Distribution System | System | 1,00 | - | **1 094 700,00** | | 1 094 700,00 |
| O4.1.2.11 | Vent/Flare System | System | 1,00 | - | **504 375,00** | | 504 375,00 |
| O4.1.2.12 | Power supply and Distribution System | N, kW | 1610,00 | - | **8 533 000,00** | | 5 300,00 |
| O4.1.2.13 | Electrochemical anti-corrosion protection System | N, kW | 15,00 | - | **222 000,00** | | 14 800,00 |
| O4.1.2.14 | Diesel generator module | N, kW | 500,00 | - | **270 000,00** | | 540,00 |
| O4.1.2.15 | Diesel Fuel System | V, m cubic | 100,00 | - | **208 000,00** | | 2 000,00 |
| O4.1.2.16 | Communication, alarm, fire alarm system | System | 1,00 | - | **800 000,00** | | 800 000,00 |
| O4.1.2.17 | Overhead transmission line (V=10 kV) | L, km | 3,50 | - | **504 000,00** | | 144 000,00 |
| O4.1.2.18 | Power, control and signaling cables | L, km | 26,00 | - | **1 086 428,57** | | 41 785,71 |
| O4.1.2.19 | Auxiliary site pipelines | System | 1,00 | | **1 050 000,00** | | 1 050 000,00 |
| | ***Life support facilities (modules) of the Head compressor station*** | | | | | | |
| O4.1.2.20 | Water and sewage system | System | 1,00 | - | **3 228 000,00** | | 3 228 000,00 |
| O4.1.2.21 | Firewater and fire-fighting system | Q, liter/sec | 25,00 | - | **3 825 000,00** | | 153 000,00 |
| O4.1.2.22 | Evaporation pond | S, sq.m | 1800,00 | - | **864 000,00** | | 480,00 |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| O4.1.2.23 | Backup water line with water intake facility (D= 8 inches) | L, m | 1300,00 | P=10,0 bar | **390 000,00** | | 300,00 |
| O4.1.2.24 | Ancillary buildings and structures, site improvements | Facilities complex | 1,00 | - | **6 200 000,00** | | 6 200 000,00 |
| | | | | **TOTAL** | **55 611 347,11** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **4.** | **Out of Scope of Project in the Black Sea Region** | | | | | | |
| **O4.2** | ***Gas interconnector SCP - Gas loading terminal near the port of Poti (Georgia)*** | ***Gas demand volume*** | ***6,3 mscmd*** | | | | |
| **A** | **Process parameters** | | | | | | |
| A1 | Process capacity | Q, mscmd | 6,30 | | | | |
| A2 | Design pressure | P, bar | $P_{in}$=70,0 bar | | | | |
| A3 | Gas temperature | T, °C | 40,00 | | | | |
| **B** | **Gas pipeline parameters** | | | | | | |
| B1 | Gas pipeline length | L, km | 140,00 | | | | |
| B2 | Gas pipeline diameter | D, inches (mm) | 28,00 | | | | |
| B3 | Gas pipeline wall thickness | WT, inches (mm) | 0,422 (12,73) | | | | |
| **O4.2.1** | **Connection pipelines** | | | | | | |
| O4.2.1.1 | Tie-in point to the Head compressor station (D=28") | L, m | 15,00 | P=55,00 bar | **18 075,00** | | 1 205,00 |
| **O4.2.2** | **Gas interconnector** | | | | | | |
| O4.2.2.1 | Pig launcher station (D=28") | System | 1,00 | P=70,00 bar | **2 373,80** | | 2 373,80 |
| O4.2.2.2 | Block valve stations | n, pcs | 28,00 | P=70,00 bar | **424 480,00** | | 15 160,00 |
| O4.2.2.3 | Linear part of interconnector (D=28") | L, km | 140,00 | P=70,00 bar | **177 240 000,00** | | 1 266 000,00 |
| O4.2.2.4 | Pig receiver station (D=28") | System | 1,00 | P=70,00 bar | **2 373,80** | | 2 373,80 |
| O4.2.2.5 | Process automation and signaling system | System | 1,00 | - | **1 420 000,00** | | 1 420 000,00 |
| O4.2.2.6 | Electrochemical anti-corrosion protection System | N, kW | 32,00 | - | **473 600,00** | | 14 800,00 |
| O4.2.2.7 | Power supply of pipeline facilities | L, km | 140,00 | - | **694 400,00** | | 4 960,00 |
| | | | | **TOTAL** | **180 275 302,60** | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes | Cost of production index |
|---|---|---|---|---|---|---|---|
| **4.** | **Out of Scope of Project in the Black Sea Region** | | | | | | |
| **O4.3** | ***Gas interconnector onshore unloading terminal near the Port of Yuzne (Ukraine) - point of connection on the CS Berezivka*** | ***Gas demand volume*** | ***6,3 mscmd*** | | | | |
| **A** | **Process parameters** | | | | | | |
| A1 | Process capacity | Q, mscmd | 6,30 | | | | |
| A2 | Design pressure | P, bar | $P_{in}$=55,0 bar | | | | |
| A3 | Gas temperature | T, °C | 40,00 | | | | |
| **B** | **Gas pipeline parameters** | | | | | | |
| B1 | Gas pipeline length | L, km | 53,60 | | | | |
| B2 | Gas pipeline diameter | D, inches (mm) | 28 (720) | | | | |
| B3 | Gas pipeline wall thickness | WT, inches (mm) | 0,349 (11,2) | | | | |
| **O4.3.1** | **Connection pipelines** | | | | | | |
| O4.3.1.1 | Tie-in point to the Gas compressor station Berezivka (D=28") | L, m | 300,00 | P=55,00 bar | **361 500,00** | | 1 205,00 |
| O4.3.1.2 | Block valve stations (D=28") | n, pcs | 3,00 | P=55,00 bar | **90 960,00** | | 30 320,00 |
| O4.3.1.3 | Tie-in point to the Gas compressor station Berezivka (D=28") | L, m | 300,00 | P=55,00 bar | **361 500,00** | | 1 205,00 |
| **O4.3.2** | **Gas interconnector** | | | | | | |
| O4.3.2.1 | Pig launcher station (D=28") | System | 1,00 | P=55,00 bar | **1 899,04** | | 1 899,04 |
| O4.3.2.2 | Block valve stations (D=28") | n, pcs | 3,00 | P=55,00 bar | **45 480,00** | | 15 160,00 |
| O4.3.2.3 | Linear part of interconnector (D=28") | L, km | 53,60 | P=55,00 bar | **40 292 996,00** | | 751 735,00 |
| O4.3.2.4 | Pig receiver station (D=28") | System | 1,00 | P=55,00 bar | **1 899,04** | | 1 899,04 |
| O4.3.2.5 | Process automation and signaling system | System | 1,00 | - | **1 320 000,00** | | 1 320 000,00 |
| O4.3.2.6 | Electrochemical anti-corrosion protection System | L, km | 54,00 | - | **799 200,00** | | 14 800,00 |
| O4.3.2.7 | Power supply of pipeline facilities | L, km | 54,00 | - | **267 840,00** | | 4 960,00 |
| **O4.3.3** | **Tie-in point to the Gas compressor station Berezivka (D=28")** | L, m | 300,00 | P=55,00 bar | **361 500,00** | | 1 205,00 |
| | | | | **TOTAL** | **43 904 774,08** | | |
| | | | | | | | |

**Table 52. Technical parameters and cost of elements of Gas loading/unloading system.**

The Table above shows the cost of every element of the CNG ship loading and unloading systems. The table below summarizes the cost of loading and unloading facilities for CNG ships.

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes |
|---|---|---|---|---|---|---|
| **1.** | **Mediterranean Sea** | | | | | |
| **L1.** | **Gas loading process** | | | | | |
| **L1.1** | ***Onshore Gas loading terminal facilities near the Vasilikos Energy hub – direction to Crete (the port of Linoperamata)*** | ***Gas demand volume*** | ***1,4 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | |
| A2 | Loading time | H, hour | 48,00 | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | |
| A4 | Gas temperature | T, °C | 40,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **213 601 607,21** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **150 593 450,00** | |
| | | | | **TOTAL** | **364 195 057,21** | |
| **L1.2** | ***Onshore Gas loading terminal facilities near the Vasilikos Energy hub – direction to Lebanon (the port of Zouk)*** | ***Gas demand volume*** | ***3,7 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | |
| A2 | Loading time | H, hour | 32,00 | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | |
| A4 | Gas temperature | T, °C | 40,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **295 268 273,88** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **150 593 450,00** | |
| | | | | **TOTAL** | **445 861 723,88** | |
| **L1.3** | ***Onshore Gas loading terminal facilities near the Vasilikos Energy hub – direction to Egypt (the port of Alexandria)*** | ***Gas demand volume*** | ***17,0 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | |
| A2 | Loading time | H, hour | 48,00 | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | |
| A4 | Gas temperature | T, °C | 40,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **305 268 273,88** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **150 593 450,00** | |
| | | | | **TOTAL** | **455 861 723,88** | |
| **L1.4** | ***Offshore Gas loading terminal facilities near the Cyprus offshore Gas production platforms – direction to the port of Linoperamata (Crete)*** | ***Gas demand volume*** | ***1,4 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | |
| A2 | Loading time | H, hour | 48,00 | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | |
| A4 | Gas temperature | T, °C | 40,00 | | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes |
|---|---|---|---|---|---|---|
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **236 410 892,72** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **2 024 967,68** | |
| | | | | **TOTAL** | **238 435 860,40** | |
| **L1.5** | ***Offshore Gas loading terminal facilities near the Cyprus offshore Gas production platforms – direction to the port of Zouk (Lebanon)*** | ***Gas demand volume*** | ***3,7 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | |
| A2 | Loading time | H, hour | 32,00 | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | |
| A4 | Gas temperature | T, °C | 40,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **267 124 859,39** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **2 024 967,68** | |
| | | | | **TOTAL** | **269 149 827,07** | |
| **L1.6** | ***Offshore Gas loading terminal facilities near the Cyprus offshore Gas production platforms – direction to the port of Alexandria (Egypt)*** | ***Gas demand volume*** | ***17,0 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | |
| A2 | Loading time | H, hour | 48,00 | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | |
| A4 | Gas temperature | T, °C | 40,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **275 832 751,89** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **2 024 967,68** | |
| | | | | **TOTAL** | **278 749 327,07** | |
| **U1.** | **Gas unloading process** | | | | | |
| **U1.1** | ***Onshore Gas unloading terminal facilities on Crete Island*** | ***Gas demand volume*** | ***1,4 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | |
| A2 | Unloading time | H, hour | 71,00 | | | |
| A3 | Unloading pressure | P, bar | 80,00 | | | |
| A4 | Gas temperature | T, °C | 32,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **190 642 953,36** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **2 332 245,00** | |
| | | | | **TOTAL** | **192 975 198,36** | |
| **U1.2** | ***Onshore Gas unloading terminal facilities near the port of Zouk*** | ***Gas demand volume*** | ***3,7 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes |
|---|---|---|---|---|---|---|
| A2 | Unloading time | H, hour | 54,00 | | | |
| A3 | Unloading pressure | P, bar | 80,00 | | | |
| A4 | Gas temperature | T, °C | 32,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **273 401 126,04** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **2 332 245,00** | |
| | | | | **TOTAL** | **275 733 371,04** | |
| **U1.3** | ***Onshore Gas unloading terminal facilities near the port of Alexandria*** | ***Gas demand volume*** | ***17,00 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | |
| A2 | Unloading time | H, hour | 71,00 | | | |
| A3 | Unloading pressure | P, bar | 80,00 | | | |
| A4 | Gas temperature | T, °C | 32,00 | | | |
| | | | | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **285 744 664,44** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **2 332 245,00** | |
| | | | | **TOTAL** | **288 076 909,44** | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes |
|---|---|---|---|---|---|---|
| **2.** | **Barents Sea** | | | | | |
| **L2.** | **Gas loading terminal** | | | | | |
| **L2.1** | ***Offshore Gas loading terminal facilities near the Alke Gas production platforms – direction to the Nyhamna Gas treatment plant*** | ***Gas demand volume*** | ***1,18 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | |
| A2 | Loading time | H, hour | 44,00 | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | |
| A4 | Gas temperature | T, °C | 25,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **211 647 527,60** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **2 024 967,68** | |
| | | | | **TOTAL** | **213 672 495,28** | |
| **L2.2** | ***Offshore Gas loading terminal facilities near the Alke Gas production platforms – direction to Aasta Hansteen Gas production platforms (enter to the Polarled underwater Gas pipeline)*** | ***Gas demand volume*** | ***1,18 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | |
| A2 | Loading time | H, hour | 44,00 | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | |
| A4 | Gas temperature | T, °C | 25,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **183 180 860,94** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **2 024 967,68** | |
| | | | | **TOTAL** | **185 205 828,61** | |
| **L2.3** | ***Offshore Gas loading terminal facilities near the Johan Castberg Gas production platforms – direction to the Nyhamna Gas treatment plant*** | ***Gas demand volume*** | ***1,29 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | |
| A2 | Loading time | H, hour | 44,00 | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | |
| A4 | Gas temperature | T, °C | 25,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **211 440 860,94** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **2 024 967,68** | |
| | | | | **TOTAL** | **213 465 828,61** | |
| **L2.4** | ***Offshore Gas loading terminal facilities near the Johan Castberg Gas production platforms – direction to Aasta Hansteen Gas production platforms (enter to the Polarled*** | ***Gas demand volume*** | ***1,29 mscmd*** | | | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes |
|---|---|---|---|---|---|---|
| | ***underwater Gas pipeline)*** | | | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | |
| A2 | Loading time | H, hour | 44,00 | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | |
| A4 | Gas temperature | T, °C | 25,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **181 740 860,94** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **2 024 967,68** | |
| | | | | **TOTAL** | **183 765 828,61** | |
| **U2.** | **Onshore Gas unloading terminal** | | | | | |
| **U2.1** | ***Onshore Gas unloading terminal facilities on the Nyhamna Gas treatment plant*** | ***Gas demand volume*** | ***1,29 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | |
| A2 | Unloading time | H, hour | 70,00 | | | |
| A3 | Unloading pressure | P, bar | 80,00 | | | |
| A4 | Gas temperature | T, °C | 32,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **211 189 932,88** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **2 296 095,00** | |
| | | | | **TOTAL** | **213 486 027,88** | |
| **U2.2** | ***Offshore Gas unloading terminal facilities near the Aasta Hansteen Gas production platforms (enter to the Polarled underwater Gas pipeline)*** | ***Gas demand volume*** | ***1,29 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 9,00 | | | |
| A2 | Unloading time | H, hour | 70,00 | | | |
| A3 | Unloading pressure | P, bar | 80,00 | | | |
| A4 | Gas temperature | T, °C | 32,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **175 460 665,14** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **635 155,20** | |
| | | | | **TOTAL** | **176 095 820,34** | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes |
|---|---|---|---|---|---|---|
| **3.** | **Black Sea** | | | | | |
| **L3.** | **Gas loading terminal** | | | | | |
| **L3.1** | ***Onshore Gas loading terminal facilities near the port of Poti (Georgia)*** | ***Gas demand volume*** | ***6,3 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | |
| A2 | Loading time | H, hour | 47,00 | | | |
| A3 | Loading pressure | P, bar | 240,00 | | | |
| A4 | Gas temperature | T, °C | 25,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **823 945 466,72** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **0,00** | |
| | | | | **TOTAL** | **823 945 466,72** | |
| **U3.** | **Gas unloading terminal** | | | | | |
| **U3.1** | ***Onshore Gas unloading terminal facilities near the port of Yuzne (Ukraine)*** | ***Gas demand volume*** | ***6,3 mscmd*** | | | |
| **A** | **Process parameters and CNG ship characteristics** | | | | | |
| A1 | CNG ship capacity | V, mscm | 12,00 | | | |
| A2 | Unloading time | H, hour | 69,00 | | | |
| A3 | Unloading pressure | P, bar | 80,00 | | | |
| A4 | Gas temperature | T, °C | 32,00 | | | |
| **B** | **Facilities in the scope of the Project** | | | **TOTAL in Scope of Project** | **813 535 827,73** | |
| **C** | **Facilities out of the scope of the Project** | | | **TOTAL out of the scope of Project** | **1 068 210,00** | |
| | | | | **TOTAL** | **814 604 037,73** | |

| No | Name, Element of infrastructure, Facilities | Units of measure | Parameter, the Production index | Pressure | Cost of facilities | Notes |
|---|---|---|---|---|---|---|
| **4.** | **Out of Scope of Project in the Black Sea Region** | | | | | |
| **O4.1** | ***Head Gas compressor station of the Gas interconnector SCP - Gas loading terminal near the port of Poti (Georgia)*** | ***Gas demand volume*** | ***6,3 mscmd*** | | | |
| **A** | **Process parameters** | | | | | |
| A1 | Process capacity | Q, mscmd | 6,30 | | | |
| A2 | Design pressure | P, bar | $P_{in}$=55,0 bar, $P_{out}$=70,0 bar | | | |
| A3 | Gas temperature | T, °C | 40,00 | | | |
| | | | | **TOTAL** | **55 611 347,11** | |
| **O4.2** | ***Gas interconnector SCP - Gas loading terminal near the port of Poti (Georgia)*** | ***Gas demand volume*** | ***6,3 mscmd*** | | | |
| **A** | **Process parameters** | | | | | |
| A1 | Process capacity | Q, mscmd | 6,30 | | | |
| A2 | Design pressure | P, bar | $P_{in}$=70,0 bar | | | |
| A3 | Gas temperature | T, °C | 40,00 | | | |
| **B** | **Gas pipeline parameters** | | | | | |
| B1 | Gas pipeline length | L, km | 140,00 | | | |
| B2 | Gas pipeline diameter | D, inches (mm) | 28,00 | | | |
| B3 | Gas pipeline wall thickness | WT, inches (mm) | 0,422 (12,73) | | | |
| | | | | **TOTAL** | **180 275 302,60** | |
| **O4.3** | ***Gas interconnector onshore unloading terminal near the Port of Yuzne (Ukraine) - point of connection on the CS Berezivka*** | ***Gas demand volume*** | ***6,3 mscmd*** | | | |
| **A** | **Process parameters** | | | | | |
| A1 | Process capacity | Q, mscmd | 6,30 | | | |
| A2 | Design pressure | P, bar | $P_{in}$=55,0 bar | | | |
| A3 | Gas temperature | T, °C | 40,00 | | | |
| **B** | **Gas pipeline parameters** | | | | | |
| B1 | Gas pipeline length | L, km | 53,60 | | | |
| B2 | Gas pipeline diameter | D, inches (mm) | 28 (720) | | | |
| B3 | Gas pipeline wall thickness | WT, inches (mm) | 0,349 (11,2) | | | |
| | | | | **TOTAL** | **43 904 774,08** | |

**Table 53. The summary table of the cost of the elements of loading and unloading CNG ships in the Black Sea.**

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[1] https://www.nist.gov/fusion-search?s=sp330;
[2] https://chem.libretexts.org/Textbook_Maps/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Physical_Properties_of_Matter/Solutions_and_Mixtures/Solution_Basics/Units_Of_Concentration;
[3] http://www.differencebetween.net/language/difference-between-ppm-and-ppmv/;
[4] http://www.egypttoday.com/Article/3/52748/Egypt-to-stop-importing-LNG-in-Q4-Minister;
[5] http://www.eifs.ru/download/snip_23-01-99_klimat.pdf;
[6] https://www.sis.se/api/document/preview/80001357/;
[7] https://www.nist.gov/fusion-search?s=sp330
[8] https://www.dnvgl.com/oilGas/download/dnvgl-st-f101-submarine-pipeline-systems.html;
[9] API 1111 (Fourth edition). Design, Construction, Operation, and Maintenance of Offshore Hydrocarbon Pipelines;
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