LIMITED LIABILITY COMPANY
"Ural Gas and Fire Fighting Equipment Factory"

APPROVED
General Director
of "Ural Gas and Fire
Fighting Equipment Factory" LLC
_____N. V. Kovalev
"05" August 2020

SMALL AND MEDIUM VOLUME STEEL CYLINDERS FOR Pp <= 19.6 MPa (200 kgf/cm^2)

SAFETY CASE

INTRODUCTION

Code OKP 14 1100, 14 1200

Code TN VED TS 7311 00 110 0, 7311 00 130 0, 7311 00 300 0

The present Safety Case covers the carbon and alloy steel cylinders of small volume below 12 liters and medium volume of 20 to 50 liters with a working pressure below 19.6 MPa (200 kgf/cm^2) manufactured by "UZGPO" LLC according to GOST 949-73 (hereinafter — cylinders) made of seamless pipes and intended for storage and transportation of compressed, liquefied and dissolved gases at temperatures of minus 50 to plus 60 °C.

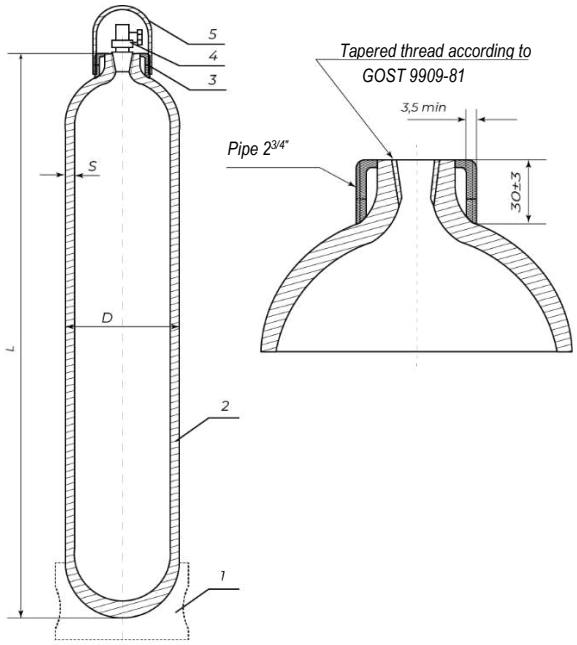
Considered pressure equipment is the object of increased hazard and shall be designed, manufactured, monitored, equipped and installed in such a way that to ensure the safety of its operation during the entire service life.

1. BASIC PARAMETERS AND CHARACTERISTICS OF CYLINDERS

1.1. Nomenclature of Cylinders.

The basic parameters and dimensions of the cylinders shall comply with those indicated in drawing and Table 1.1. The size of neck bevel is 1.5x45°.

Cylinder Cylinder neck



1 — shoe; 2 — cylinder body; 3 — neck ring; 4 — valve; 5 — safety cap

Table 1.1. Dimensions of cylinders

Cylinder capacity, liters	Cylinder diameter	Cylinder wall thickness for pressure					Cylinder body length for pressure MPa (kgf/cm^2)				
		carbon steel			alloy steel		carbon steel			alloy steel	
		9.8 (100)	14.7 (150)	19.6 (200)	14.7 (150)	19.6 (200)	9.8 (100)	14.7 (150)	19.6 (200)	14.7 (150)	19.6 (200)
0.4	70	1.6	2.2	2.9	1.6	1.9	165	170	175	165	165
0.7							255	260	270	255	255
1.0	89	1.9	2.8	3.6	1.9	2.5	240	250	255	240	245
1.3							295	305	315	295	300
2.0							425	440	455	425	435
2.0	108	2.4	3.4	4.4	2.4	3.0	320	330	340	320	325
3.0							445	460	480	445	455
3.0	140	3.1	4.4	5.7	3.1	3.9	310	325	335	310	320
4.0							385	400	415	385	395
5.0							460	475	495	460	470
6.0							535	555	575	535	550
7.0							610	630	660	610	625
8.0							680	710	740	680	700
10.0							830	865	900	830	850
12.0							975	1020	1060	975	1005
20.0	219	5.2	6.8	8.9	5.2	6.0	730	740	770	730	
25.0							890	900	935	890	
32.0							1105	1120	1165	1105	
40.0							1350	1370	1430	1350	
50.0							1660	1685	1755	1660	

Cylinders are manufactured using carbon and alloy steel with mechanical properties as per Table 1.2

Table 1.2.

Property	Out of carbon steel	Out of alloy steel
Yield strength σ_5, N/mm (kgf/mm^2), min	373 (38)	687 (70)
Elongation δ_5, %, min	15	10
Impact toughness KCU, J/cm^2(kgf·m/cm^2), min, at 20 °C	29.4 (3)	98.1 (10)

Thread of cylinder neck complies with GOST 9909, at that:

- outer diameter of the thread in the main plane:
- for small capacity cylinders 19.2 mm,
- for medium capacity cylinders 27.8 mm,
- for acetylene cylinders 30.3 mm;
- the number of threads with complete profile shall be minimum 8, and for small capacity cylinders 7 minimum in succession from neck end;
- 2–5 spare threads remain on the valve screwed into the cylinder neck. The cylinders are made from pipes (or cylinder blank) past the ultrasonic inspection of the metal integrity.

1.2. Identification of Cylinders.

For identification one shall use marking applied to the spherical portion near the cylinder neck, it contains the following information:

- product name;
- parameters and characteristics affecting safety;
- working pressure and test hydraulic pressure;
- grade of material used for the cylinder manufacturing;
- trade mark of the manufacturer;
- serial No.;
- date of manufacture;
- date of the next examination;
- capacity;
- actual weight;
- type of heat treatment.

The cylinders painting and text applying to them are made in accordance with the Table 1.3. (for flammable and explosive gases), Appendix 3 to the Technical Regulation of Customs Union "On Safety of Equipment Under Overpressure”.

Table 1.3. Painting and marking of cylinders for flammable and explosive gases

Gas	Color of painting	Text	Text color	Strip color
Acetylene	White	Acetylene	Red	-
Butylene	Red	Butylene	Yellow	Black
Oil gas	Gray	Oil gas	Red	-
Butane	Red	Butane	White	-
Hydrogen	Dark green	Hydrogen	Red	-
Cyclopropane	Orange	Cyclopropane	Black	-
Ethylene	Violet	Ethylene	Red	-
All other flammable gases	Red	Name	White	-

1.3. List of national standards and other documents according to which cylinders are designed and tested.

GOST 949-73 Small and medium volume steel cylinders for gases for Pp < 19.6 MPa (200 kgf/cm^2). Specifications.

GOST 14249-89 Vessels and apparatus. Norms and methods of strength calculation.

2. GENERAL PRINCIPLES OF ENSURING SAFETY

2.1. At the design and production phase the following general safety principles are implemented:

a) principle of passive safety;

b) principle of environmental safety;

c) analysis of possible predicted risks and the available experience of similar objects;

d) consideration of the unacceptable risk of the products operation;

e) principle of ergonomics;

f) principle of the use of raw materials and substances not threatening the life safety or health of citizens, property of physical or the legal entities, state or municipal property, life or health of fauna and flora;

g) principle of ensuring the necessary and sufficient level of product reliability.

2.2. At commissioning, operation and disposal phases the following general safety principles are implemented:

a) principle of defense-in-depth ensuring products safety;

b) principle of individual approach to the responsibility for the safety assurance;

c) principle of possible errors exclusion during steam superheater assembly, which can be sources of danger;

d) principle of maintenance provision without risk to humans;

e) consideration of the hazards associated with the phenomena of fatigue, aging, corrosion and wear;

f) principle of personnel reliability provision and check;

g) principle of quality management during operation;

i) principle of environmental protection management;

j) information acquisition and analysis on product failures and personnel errors.

3. REQUIREMENTS TO EQUIPMENT RELIABILITY

3.1. The practical way to ensure reliability is to provide a safety factor that ensures fault-free operation of the cylinders under loads applied to them during the entire service life.

3.2. Reliability indicators.

The list of indicators designed to ensure the product safety due to timely routine technical examination, repair and decommissioning is given in the Table 3.1

Table 3.1. Reliability indicators.

Indicator	Value
Reliability index	
Average time to failure, number of filling cycles	10,000
Life ratio	
Full service life, years	40
Shelf life index	
Average shelf life, years	2

3.3. Indicators characterizing safety.

The indicators characterizing the safety are set for the product failures relating any dangers which are critical. The list of indicators characterizing safety is given in Table 3.2.

Table 3.2. Indicators characterizing safety.

Indicator	Value
Assigned life time, years*	10
The probability of fault-free operation during the assigned life time in relation to critical failures	10^{-4}-9.5*10^{-3}
* until technical examination	

The assigned indicators are established to ensure the timely termination of the product operation in order to execute its industrial safety examination in terms of durability indicators.

Upon reaching the assigned indicators the product operation shall be terminated regardless of its technical condition. Further product operation is available only under the decision of the organization performed the expert examination as per the established procedure.

The probability of fault-free operation in relation to critical failures is considered by the industrial facility designed in the declaration of industrial safety in assessing the risk of production processes which use the product.

3.4. Limit state and failure criteria are shown in Table 3.3.

Table 3.3. Limit state and failure criteria.

Indicator	Value
Failure criterion	The presence of a leak, sweating of the cylinder during a hydraulic test
Limit state criterion	- Cracks, slivers, dents, bulges, blowholes and scratch marks with depth over 10% of the nominal wall thickness on the outer and inner surface; - Tears and chipping. - Wear of the neck thread. - Weight reduction by 7.5% and more, increasing from 12 to 50 liters - Lack of any data in the applied marking

3.5. Design features of reliability improvement.

Strength calculations of cylinders are made according to GOST 14249. Allowable internal overpressure is calculated by the formula:

$[p] = (2 \times [\sigma] \times (s-c))/(D + (s-c))$

where D is the inner diameter (considering the minus tolerance);

s is wall thickness (minimum);

c is addition to the design thickness (c = 1 for non-corrosive mediums);

[Ơ] is allowable stress during the calculation based on the limit loads of equipment operating under static loads.

In accordance with TR TSCU 032/2013:

$[Ơ] = \min \{R_{e/t} / 1.5; R_m/2.4\}$

where $R_{e/t}$ is minimum value yield strength at the maximum permissible temperature;

R_m is minimum tensile strength at temperature of 20 °C.

The calculation results of the allowable internal overpressure are presented in Table 3.4.

Table 3.4. Allowable internal overpressure

Cylinder capacity, l	ID of cylinders for pressure, MPa (kgf/cm²), min					Wall thickness of cylinders for pressure, MPa (kgf/cm²), min					Allowable stress for cylinders		Allowable internal overpressure for cylinders for pressure, MPa				
	carbon steel			alloy steel		carbon steel			alloy steel		carbon steel	alloy steel	carbon steel			alloy steel	
	9.8 (100)	14.7 (150)	19.6 (200)	14.7 (150)	19.6 (200)	9.8 (100)	14.7 (150)	19.6 (200)	14.7 (150)	19.6 (200)			9.8 (100)	14.7 (150)	19.6 (200)	14.7 (150)	19.6 (200)
0.4	66.80	65.60	64.20	66.80	66.20	1.6	2.2	2.9	1.6	1.9	265.83	367.92	12.44	17.25	22.98	17.21	20.53
0.7	66.10	64.90	63.50	65.75	65.15								12.57	17.43	23.22	17.48	20.85
1.0	85.20	83.40	81.80	85.20	84.00	1.9	2.8	3.6	1.9	2.5			11.60	17.27	22.41	16.05	21.27
1.3	84.31	82.51	80.91	83.87	82.67								11.72	17.45	22.65	16.30	21.60
2.0																	
2.0	103.20	101.20	99.20	103.20	102.00	2.4	3.4	4.4	2.4	3.0			12.08	17.28	22.58	16.72	21.02
3.0	102.12	100.12	98.12	101.58	100.38								12.21	17.46	22.82	16.98	21.35
3.0 4.0 5.0 6.0	133.80	131.20	128.60	133.80	132.20	3.1	4.4	5.7	3.1	3.9			12.04	17.25 17.43	22.57 22.80	16.66 16.92	21.01
7.0 10.0 12.0	132.40	129.80	127.20	131.70	130.10						265.83	367.92	12.16				21.4
20.0 25.0 32.0 40.0 50.0	208.60 206.41	205.40 203.21	201.20 199.01	208.60 205.32	207.00 203.72	5.2	6.8	8.9	5.2	6			12.93 13.06	17.04 17.22	22.52 22.76	17.90 18.18	20.70 21.01

Note: The values in the upper and lower part of the fraction are shown for cylinders of common and increased manufacturing accuracy, respectively.

The fracture pressure safety factor of the cylinder for the initial stage of operation (initial strength) shall be at least 2.4.

The cylinder shall be strong under the proof (hydraulic) pressure equal to at least 1.5 of the working pressure.

The cylinder after strength testing shall be tight under pneumatic pressure equal to the working pressure.

3.6. Technological (production) ways to ensure reliability.

The technological ways to ensure reliability and safety of the product include the requirements to the manufacturing process, they are presented in Table 3.5.

Table 3.5. Requirements for manufacturing process.

Technological/Inspection operation	Inspected parameter	Responsible for inspection	Scope and/or interval of inspection			Registration method
			as per RD	Person in charge	QCD/ laboratory	
INCOMING INSPECTION						
Pipe inspection	Steel grade (spark method)	QCD	-	-	100%	Registration in the logbook of workpieces acceptance (form UTK-1650)
Cutting to workpieces	External and internal surface quality	QCD			100%	
	Geometric dimensions: - OD wall - thickness length	QCD			100%	
	Metal integrity (UI)	QCD	100%	-	100%	As per pipe quality document
Valve inspection	-	-	-	-	-	As per Certificate of Compliance
TECHNOLOGICAL INSPECTION						
Dishing Necking-in	Furnace temperature	Person in charge	-	in-process inspection	-	Registration in form of diagrams
Heat treatment (normalization) (for carbon steels)	Furnace temperature	Person in charge	-	in-process inspection	-	Registration in form of diagrams
	Issue range	Automatic inspection	-	-	-	-
Heat treatment (quenching tempering) (for alloy steels)	- Furnace temperature - Time of being in furnace	Person in charge		in-process inspection		Registration as diagrams, in logbook of quenching (form F.2241), in logbook of tempering (form F.2-242)
	Hardness	QCD	-	-	100%	Registration in logbook of hardness testing
Cooling	-	-	-	-	-	-
Quality control of the outer surface (for medium volume cylinders)	Outer surface quality	QCD			100%	Registration in logbook (form UTK-1654) of noncompliance types
Thread cutting	-	-	-	-	-	-
Stamping	Marking content	Person in charge	-	100%	-	-

Grit blasting / sand blasting of internal surface	-	-	-	-	-	-
Surface chemical treatment	Chemical composition of baths	Person in charge/CPL		Inspection of CPL reports to correct bath composition	once per 3 days	CPL — registration in the form of reports (form F.19-1235). Executor — registration in the logbook of chemical analysis
	Bath temperature	Person in charge	-	in-process inspection	-	Registration in logbook
Rings packing	-	-	-	-	-	-
Valves installation	Quality of fastening	Person in charge	-	-	100%	No registration
Contamination inspection	Air on fat contaminants and moisture	CPL			2 cylinders once per week	Registration in form of results analysis (form F.19-1235)
Shoe installation (for medium volume cylinders)						
ACCEPTANCE INSPECTION						
Cap tightening	Tightening quality	Executor	-	-	100%	No registration
Painting	-	-	-	-	-	-
Drying	-	-	-	-	-	-
Marking (gas designation)	-	-		-	-	-
Inspection after heat treatment (normalization)	Mechanical properties	Executor / QCD/CTL	2 cylinders from lot	2 cylinders from lot	2 cylinders from lot + coercimeter setting as per reference / 2 cylinders per each 10th lot	Executor — registration in the logbook (form F.2-241.A) of furnace modes, measurement results of demagnetization current and the relevant mechanical properties. CTL Registration in form of reports
Inspection after heat treatment (quenching + annealing)	Mechanical properties	CTL	2 cylinders from lot		2 cylinders of lot with maximum and minimum hardness values	Registration in form of reports
Thread inspection on neck after cutting	Thread quality Thread parameters Geometric dimensions of neck	QCD	100%		100%	Registration in logbook (form UTK-1653) of noncompliance types
Surfaces inspection after grit blasting/sand blasting	External and internal surface quality Geometric dimensions: OD wall thickness length Weight	QCD	100%		100%	Registration in the logbook of external visual inspection (form UTK-1651), the logbook of internal examination (form UTK-1652) of nonconformance types
Hydraulic tests	Strength	Executor / QCD	100%	100%	100%	Executor stamp QCD — registration in the logbook (form UTK-1656) of the pressure value, types of leaks

Pneumatic tests	Tightness	Executor / QCD	100%	100%	100%	Registration in the logbook (form UTK-1655) of the pressure value, types of leaks
Capacity testing (for medium volume cylinders)	Capacity	Person in charge	100%	100%		Mark on cylinder

4. REQUIREMENTS FOR PERSONNEL

The employees working with the cylinders shall pass training, instructed and have certificate of admission to independent work, issued as per the established order.

Periodic knowledge examination of staff (workers) working with the pressure equipment shall be carried out once per 12 months.

5. RISK ANALYSIS

This section deals with identification of hazards and calculation of the risk degree of the product operation in accordance with GOST R 54124-2010.

The important step in evaluating the probability of dangerous event occurrence in the equipment that is carried out after the determination of the operation limits is the systematic identification of predicted sources of danger and hazardous events that may occur during the entire life cycle of products, but as the TR CU 032/2013 covers only the design and manufacturing phases, then only they will be calculated and analyzed.

The first stage is the identification of hazards that may arise at the design and production phase considering the requirements for equipment safety from Appendix 2 to TR CU 032/2013.

The risk concept is based on postulate that the danger cannot make harm to the object of exposure (people, property, environment) until the sequence of events or accidental circumstances will lead to a dangerous situation. At this stage the risk can be assessed by determining the occurrence probability and probability of non-detection.

The dangerous situationы are specified that result in danger:

- loss of strength of the material;
- loss of strength when operating conditions are violated.

The likelihood of dangerous situation is calculated on the basis of statistical data and an expert method.

Regarding the current dangerous situation, the following assumptions, reflecting its possible cause were formulated.

The probability reflects the risk magnitude of the hazardous situation occurrence, considering the measures taken by the manufacturer. The measures preventing and detecting the danger are presented in form of the scope of monitoring carried out by the manufacturer.

Probability of non-detection is calculated on the basis of statistical data and by expert estimations.

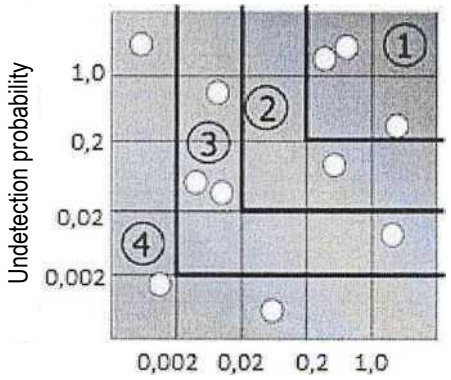
The calculations of the occurrence probability of hazardous event use two parameters:

1. probability of occurrence of imperfection leading to the hazardous situation P1;
2. probability of non-detection of imperfection leading to the hazardous situation P2.

The harm-dong probability P is calculated according to the formula 5.1:

$$P = P1 \times P2 \qquad (5.1)$$

Ranking the risks by assigning a priority number was carried out on the basis of estimates of the occurrence probability and the undetection probability using the risk matrix (Fig. 5.1). The risk matrix shows the risk, corresponding to every danger. The risk matrix provides a visual representation of the situation considering the assumptions used.



Occurrence probability

Fig. 5.1 Risk matrix

The higher in the matrix risk is the hazardous situation located, the higher its non-detection probability is, the more right it is located the higher probability is of hazardous situation causes. The hazardous situation in the upper right corner of the risk matrix correspond to the highest occurrence probability and undetection probability. Rank 1 corresponds to them. The hazardous situations in the lower left corner of the matrix correspond to the lowest occurrence probability and undetection probability. The minimum rank 4 corresponds to them.

The resulting risk priority values reflect sufficiency of the taken measures.

As a result of the evaluations made the sequences of hazardous events were obtained, their prevention requires the protection measures on the side of the manufacturer and operator in accordance with Table 5.1.

Table 5.1.

Brief name of the hazardous situation and its description	Occurrence probability	Assumptions about the probability (the hazardous situation reason)	Undetection probability	Assumptions about probability (protective measures taken during design, manufacturing and operation)	Risk priority	Recommended measures
Harm when the parts destruction due strength loss of product	OD	unacceptable deviations of cylinder parameters (41/032): - ID - wall thickness of body	0.001	- incoming inspection (validation) - 100% hydraulic tests - periodic technical examination	4	Technical examination during operation
		- defects on external and internal surface of body		- 100% incoming inspection - 100% hydraulic tests - periodic technical examination		
		- metal integrity of body		- incoming inspection (verification) – 100% pneumatic tests		
		- quality of the thread surface of the neck		- 100% visual inspection - 100% pneumatic test		-
		- parameters of the neck thread		- 100% inspection by gauges		
	OD	erroneous strength calculation (13–14, 16, 17, 19–20/032): incorrectly set safety factor	0.01	calculations check	4	Technical examination during operation
	OD	use in the manufacturing of the materials with inconsistent characteristics (34, 38/032): mechanical properties	0.001	-mechanical tests - 100% hydraulic tests	4	
	0.01	the absence of marking ensuring identification with data in manufacturer's documentation (35/032)	0.001	incoming inspection (validation)	4	
	0.95	no manufacturer's marking in the workpiece relating its cutting to parts (36/032)	0.01	marking duplication	3	Enhanced inspection of the duplicate marking application

Harm during parts destruction due to strength loss upon operation modes violation	0.001	combination of simultaneous occurrence of loads (15/032)	OD	operation conditions monitoring	4	- Personnel briefing

6. SAFETY REQUIREMENTS FOR COMMISSIONING

6.1. The products shall be commissioned by the personnel, trained and instructed in accordance with Section 4 herein.

6.2. For cylinders supplied without valves, the opening in the neck is tightly closed with a threaded plug for the period of transportation and storage. The plug position is locked with mutually perpendicular marks made with red paint on the end of the neck and plug. No special measures are required for the cylinder depreservation.

6.3. Before operation a pressure reducer, pressure gauge, and valve shall be installed on the cylinders.

6.4. The materials of the cylinder valve bodies depending on the gas to be filled, as well as the thread direction of the side union are shown in Table 6.1. The side unions of the valves shall be provided with plugs.

Table 6.1. Materials of valve body of cylinders and thread direction of side union.

Gas	Valve body material	Thread direction of side union
Butane	Brass or steel	Left-hand
Butylene	Brass	Left-hand
Hydrogen	Brass	Left-hand
Methane	Brass	Left-hand
Propane and other flammable gases	Steel or brass	Left-hand
Ethylene	Brass	Left-hand
Incombustible and inert gases	Brass	Right-hand

6.5. When the cylinders are delivered without valves the inner surface of the cylinders shall be cleaned from the chips and the delaminating scale, cylinders for hydrogen shall be degreased before installation of the valves.

6.6. Cylinders for dissolved acetylene shall be filled with appropriate amount of porous mass and solvent. The organization filling the cylinder with the porous mass is responsible for the quality of porous mass and the correct filling of the cylinders. The organization filling the cylinders with solvent is responsible for the solvent quality and proper dosing.

After filling the cylinders with porous mass and solvent the container weight (cylinder weight without cap, but with porous mass and solvent, shoe, ring and valve) is stamped on the neck.

6.7. The cylinders are not allowed for operation, if the pressure reducer has the following failures:

- with fully screwed out adjusting screw gas does not pass into the work chamber;
- captive nut thread is damaged;
- failure of one or both pressure gauges;
- pressure in the work chamber increases after gas supply termination;
- failure of safety valve.

6.8. The cylinders are not allowed for operation, if the pressure gauge has the following failures:

- there is no verification sign;
- expired verification period;
- when pressure gauge is disconnected, the pointer does not return to zero by value exceeding half of the allowable error;
- broken glass or presence of other damages, which may affect the correct readings.

6.9. The cylinders are not allowed for operation, if the valve has the following failures:

- there is no union plug;
- there are traces of oil, grease, dust;
- valve handwheel does not rotate;
- a gas leak is noted.

6.10. Oxygen storage cylinders shall be degreased. Cylinder degreasing is carried out with solvents or hot aqueous detergent, use of alcohol is strictly forbidden.

6.11. To exclude the possibility of explosion during filling the cylinder is heated, as the gas in it is compressed, after filling it is cooled to ambient temperature, at that the oxygen pressure in it reduces correspondingly. The pressure to which the cylinders shall be charged, shall be such that at 20 °C pressure in the cylinder will be 34.3 MPa maximum. When filling the cylinder its heating degree is checked. If the cylinder wall becomes so hot that it cannot be touched, then filling shall be immediately stopped, and the cylinder shall be disconnected from the ramp.

6.12. When filling the cylinder, rupture of pipes connecting it to the ramp is possible. The reason for the rupture is presence of cracks and other defects on the pipes. Therefore, before connecting pipes shall be carefully inspected and replaced, if defects are identified. If leaks are identified through the

captive nut attaching the pipe to the cylinder, disconnect the pipe from the ramp and the cylinder, and only after that tighten the nut. It is strictly forbidden to repair gas leaks under pressure. To connect the cylinders to the charging ramps it is desirable to use semi-automatic clips.

6.13. To avoid injuries associated with cylinder falling in the course of filling with gas, the cylinders shall be attached to the rack.

6.14. When filling cylinders, gas may leak into the room. So, the rooms, where the charging ramps are located, shall be thoroughly vented, the oxygen content in air shall be checked on a regular basis, the rooms shall be equipped with water baths or shower cabins.

Persons who contact with oxygen cylinders shall always have clean hands, special clothing and tools. It is forbidden to bring matches, fire, oiled rags into the room.

7. REQUIREMENTS FOR SAFETY CONTROL DURING OPERATION

7.1. Cylinder operation.

7.1.1. Operation (filling, storage, transportation and use) of the cylinders shall be carried out in accordance with the requirements of the manual provided by the organization (individual entrepreneur) executing the specified activity, approved in accordance with the established procedure.

7.1.2. When using and storing cylinders their installation in the places of people and vehicle passage and movement of goods is prohibited.

7.1.3. Cylinders shall be at a distance of at least 1 m from heating radiators and other heating devices, furnaces and at least 5 m from heat sources with open flame.

7.1.4. Cylinders shall be charged according to the manuals, developed and approved by the filling organization (individual entrepreneur) in the prescribed manner, considering properties of the gas, local conditions and requirements of Operation Manual (Instruction) and other documentation of the cylinder manufacturer.

7.1.5. When working with the cylinders, the gas charged into them shall not be spent completely. The residual pressure in the cylinder shall be at least 0.05 MPa.

7.1.6. The gas release (supply) from cylinders to vessel and to process equipment with a lower working pressure shall be made through pressure reducer designed for this gas and painted in the appropriate color. A pressure gauge with measuring scale ensuring the possibility of measuring the maximum working pressure in the cylinder shall be installed at the inlet to the pressure reducer; a spring safety valve shall be installed on the low-pressure chamber of the pressure reducer, the valve is set to the appropriate allowed pressure in the vessel or process equipment, into which gas is delivered, and the pressure gauge corresponding to this pressure shall be installed. The type of pressure gauge and safety valve is determined by the project designer and the pressure reducer manufacturer.

7.1.7. Upon impossibility to release nas from the cylinders at the place of use due to valves malfunction, the cylinders shall be returned to the filling station separately from the empty cylinders, the corresponding temporary text (marking) shall be placed on them by any available method not damaging the cylinder body integrity. Gas release from such cylinders at the filling station shall be done in accordance with the manual approved in the prescribed manner.

7.1.8. Cleaning and painting of cylinders charged with gas is prohibited.

7.1.9. The combustible gases leak from the cylinders can result in formation of explosive gas mixture with air, only a small amount of energy is needed for this mixture to explode. Explosion can result in serious injury, death of people and destruction of buildings. In case of leakage of toxic and poisonous gases from the cylinders then in poorly ventilated premises poisoning of people present in it can occur.

7.1.10. Safety requirements for handling pure gaseous hydrogen as specified in GOST R 51673-

2000 and for technical hydrogen in accordance with GOST 3022-80.

7.1.10.1. Hydrogen is colorless, odorless, flammable gas. Hydrogen density under normal conditions is 0.0899 kg/m^3, density relative to air is 0.0695. Hydrogen is physiologically inert, may cause suffocation at high concentrations; it is corrosion inactive, diffuses through the heated metals and dissolves in them; under normal conditions it is chemically low-active, thermally stable. Chemical activity of hydrogen increases with temperature rise, under the influence of ultraviolet and radioactive radiation.

7.1.10.2. In mixture with air and oxygen the hydrogen is flammable and explosive, which is due to the low minimum ignition energy of hydrogen/air mixture (0.017 mJ), the high value of the minimum heat of combustion (121,000 kJ/kg) and a wide area of combustion and detonation.

Concentration limits of flame propagation for hydrogen and air mixture 4.12% are 75% vol., for hydrogen-oxygen mixture 4.1% are 96% vol.

The self-ignition temperature of the hydrogen/air mixture is 510 °C. Mixtures of hydrogen with air belong to explosive hazard category IIC, group T1 according to GOST R 51330.11-99; GOST R 51330.19-99.

7.1.10.3. The indicators of the fire and explosion hazard of hydrogen are determined in accordance with GOST 12.1.044-89.

7.1.10.4. Explosion safety of the production processes, including transporting and storage is as per GOST 12.1.010-76.

7.1.10.5. Fire safety of the processes of production, processing, storage and transportation is as per GOST 12.1.004-91.

7.1.10.6. Electrical safety of production processes is as per GOST R 12.1.019-2009.

7.1.10.7. Fire and explosion safety of static electricity is as per GOST 12.1.018-93.

7.1.10.8. Static electricity protection equipment is as per GOST 12.4.124-83.

7.1.11. Safety requirements for handling the acetylene, dissolved and gaseous, technical are specified in GOST 5457-75.

7.1.11.1. Acetylene is explosive gas. With air it forms explosive mixture with a lower explosive limit at atmospheric pressure, reduced to temperature of 25 °C, 2.5% (by volume) in accordance with GOST 12.1.004-91. The self-ignition temperature of acetylene is 335 °C.

7.1.11.2. As per categories and groups of explosive hazard the acetylene belongs to category and group IIC-T2 according to GOST P 51330.11-99; GOST R 51330.19-99.

7.1.11.3. The acetylene content in the air of the working area shall be monitored by continuous operation automatic devices, informing about the exceedance of the permissible nonexplosive concentration of acetylene in the air, and by using indication tubes on a regular basis in accordance with GOST 12.1.014-84.

7.1.11.4. Acetylene production in terms of fire hazard relates to category A, and in terms of classes

of explosive zones to classes V1; V1a; V16; V1g.

7.1.11.5. The acetylene production premises shall be equipped with supply and exhaust ventilation.

7.1.11.6. All works related to production and use of acetylene shall be carried out in accordance with the safety rules for the acetylene production approved by Rostekhnadzor.

7.1.11.7. Compressed nitrogen, carbon dioxide fire extinguishers, asbestos cloth, sand shall be used as fire extinguishing means.

7.1.12. Safety requirements for handling the liquefied hydrocarbon gases are as per GOST R 51104-97, liquefied hydrocarbon gases as per GOST 21443-75, fuel liquefied hydrocarbon gases as per GOST R 52087-2003:

7.1.12.1. Liquefied gases are fire and explosive hazardous, have low toxicity and specific characteristic odor. In terms of the health effects the gases relate to IV hazard class according to GOST 12.1.007.

7.1.12.2. Liquefied gases combine with forming explosive mixtures with concentration of propane equal to 2.1 to 9.5%, normal butane of 1.5 to 8.5% (by volume) at a pressure of 98,066 Pa (1 atm) and temperature 15–20 °C.

For monitoring of the explosive concentrations of liquefied gases in the production premises the annunciators are used with the operating level set-point of 20% of the lower limit of explosiveness, general technical requirements of the annunciators are specified in GOST 27540-87.

7.1.12.3. The self-ignition temperature of propane in air at pressure of 0.1 MPa (760 mmHg) is 466 °C, of normal butane 405 °C, of isobutane 462 °C.

7.1.12.4. Maximum permissible concentration in the air of the working zone (in carbon equivalent) of saturated hydrocarbon (propane, normal butane) is 300 mg/m^3.

7.1.12.5. Liquefied gases can exhibit properties that are dangerous to humans:

- products of incomplete combustion of gases are toxic;
- asphyxiation effect of gases, if the oxygen content is below the permissible value;
- strong cooling effect of the liquid phase causing severe frostbite.

7.1.12.6. First aid measures:

In case of intoxication- move the injured to the fresh air (or give oxygen), provide for warming, smelling ammonia swab.

To restore the injured hot drink is used, and artificial respiration, if necessary.

If the liquid phase remains on the clothes, it must be removed.

In case of frostbite first aid is similar to that provided for the burns, i.e., abundant water washing and lubrication of affected skin areas with fat-based creams and pastes.

When handling the liquefied gases eyes shall be protected with glasses with side shields, as the drops ingress into the eyes may cause loss of vision.

7.1.12.7. Personal protection equipment should be applied according to safety rules for the gas facilities approved as per the established procedure.

7.1.12.8. In case of high concentrations of liquefied gases, it is necessary to use airline insulating pressure demand respirators. For small concentrations -filtering protective respirators grade A (brown box), grade BKF (khaki box).

7.1.12.9. The production premises shall comply with the requirements of sanitary hygiene in accordance with GOST 12.1.005. All explosive premises shall be equipped with supply and exhaust ventilation ensuring ten air exchanges per 1 hour and air purity in the working area of industrial premises.

7.1.12.10. To monitor the hydrocarbons content in the production premises (in the air of the working area) the analyzers IBP, STT-2U, STT-4M etc. or automatic protection and alarm systems of "AZIZ" or "Logic" types are used.

7.1.12.11. In the premises for production, storage and pumping of the liquefied gases use of open fire is prohibited, artificial lighting shall be of explosion-proof design, all works shall be executed using spark-free tools.

The equipment protection against secondary effects of lightning and static electricity shall comply with the rules of protection against static electricity employed in the chemical, petrochemical and refinery industries.

7.1.12.12. In case of ignition the following fire extinguishing equipment is used: carbon dioxide, powder, water-dispersed and foam fire extinguishers; water steam, nitrogen and other inert gases; water in the form of compact and sprayed jets, dry sand, water steam, asbestos cloth.

7.1.13. Requirements for safety when handling flammable natural gases for industrial and household use in are accordance with GOST 5542-87.

7.1.13.1. According to their toxicological characteristics the natural flammable gases are classified as substances of IV hazard class in accordance with GOST 12.1.007-76.

7.1.13.2. Natural flammable gases belong to the group of substances capable to form the explosive mixtures with air.

The ignition concentration limit (by methane) in mixture with air, percent by volume: lower- 5, upper-15, for natural gas of specific composition the ignition concentration limits are determined in accordance with GOST 12.1.044-89.

Explosive hazard mixture category is 11A-T1.

7.1.13.3. Maximum permissible concentration of natural gas hydrocarbons in the air of the working zone is 300 mg/m^3 in carbon equivalent (GOST 12.1.005-88).

The maximum permissible concentration of hydrogen sulfide in the air of the working area is 10 mg/m^3, hydrogen sulfide in mixture with C1–C5 hydrocarbons is 3 mg/m^3.

7.1.14. Cylinders can be stored both in specific areas, and outdoors, in the latter case they shall be protected against precipitation and direct sunlight.

7.1.15. Before use at the site the cylinder with gas shall be installed in the vertical position and securely fastened against falling in the manner prescribed by the operation manual.

7.1.16. Filled cylinders with shoes fitted on them shall be stored in the upright position. To protect against falling the cylinders shall be installed in specially equipped seats, cages or shall be fenced.

7.1.17. The cylinders can be stored in the horizontal position on wooden frames or racks. When stored at open sites the cylinders can be laid in the stack with the spacers made of rope, wooden bars, rubber or other non-metal materials having shock-absorbing properties installed between the horizontal rows.

7.1.18. When stacking cylinders, the stack height shall not exceed 1.5 meters, the cylinder valves shall look in one and the same direction.

7.1.19. The cylinders at the sites of use (work places) shall be moved on a special trolley or using other devices to ensure the transportation safety.

7.1.20. Transportation of the cylinders filled with gases on the territory of the dangerous production facility, production site of the enterprise and other facilities of the installation and repair works shall be conducted on spring transport or electric trucks in horizontal position with the spacers between the cylinders. As spacers one shall use wooden bars with cut out seats for cylinders, as well as rope or rubber rings with minimum thickness of 25 mm (two rings per the cylinder) or other gaskets protecting the cylinders against impacts. All cylinders during transportation shall be laid with valves looking in one and the same direction.

7.1.21. Transportation of the cylinders filled with gas on the public roads by road (rail) transport is performed in accordance with the requirements of the normative legal acts valid in the Russian Federation.

7.1.22. Storage of filled cylinders until their handing over to the consumers can be executed without safety caps.

7.1.23. During storage it is strongly prohibited:

- to place flammable and combustible materials within the area of the cylinder storage;
- to allow for cylinder contact with electrical wires;
- to store cylinders in basement rooms and in the attic.

7.1.24. When loading or unloading gas cylinders, it is prohibited:

- to work alone (at least 2 people shall participate);

- to work in oiled overalls, gloves with traces of oil, fat;
- to carry cylinders by the hands or on the shoulder;
- to roll cylinders on the ground;
- to drop cylinders and handle in the manner that they hit one other;
- to hand over or hold the cylinders with the valve downward;
- to load and unload cylinders without safety caps or plugs.

7.2. Damage evaluation

7.2.1. Evaluation (testing) of cylinders is carried out by manufacturers, as well as duly authorized special organizations with the filling stations and (or) and test stations if they have:

a) production facilities, as well as technical means ensuring the possibility to inspect the cylinders;

b) persons appointed by the order and responsible for examination, from the number of specialists certified in the prescribed manner, and workers of appropriate qualification;

c) stamps with individual code;

d) production manual for technical evaluation of cylinders, which specifies the scope and procedure of work, drawn up on the basis of the procedures provided by the project designer and (or) the manufacturer of a specific type of cylinders.

7.2.2. Evaluation of the cylinders with the exception of acetylene cylinders includes:

a) inspection of the inner and outer surfaces of the cylinders;

b) checking the weight and capacity of the cylinders (for cylinders with volume of 12 to 50 liters);

c) hydraulic testing of cylinders.

7.2.3. If satisfactory results are obtained the examination organization stamps (applies) on the cylinder its stamp of round shape with a diameter of 12 mm, date of performed and the next examination (in the same line with the stamp).

7.2.4. Hydraulic tests of cylinders shall be carried out on specially equipped test stands ensuring test safety. The test pressure value and the test holding time of the cylinders shall be set by the manufacturer, in this the test pressure shall be at least 1.5 of working pressure.

7.2.5. The actual capacity of the cylinder shall be determined: by the difference between the weight of the cylinder charged with water and the empty cylinder weight; with the help of measuring tanks or in another manner that provides for the required measurement accuracy.

7.2.6. For internal inspection of cylinders, it is allowed to use portable source (12 V maximum) of electric lighting and other devices ensuring the possibility of visual inspection.

Before inspection the cylinders shall be thoroughly rinsed with an appropriate solvent or degassed.

7.2.7. Evaluation of the acetylene cylinders shall be performed at the acetylene filling stations at least every 5 years and include:

a) outer surface inspection;

b) porous mass examination;

c) pneumatic test.

7.2.8. The state of the porous mass in the cylinders for dissolved acetylene shall be checked at acetylene filling stations at least every 24 months.

7.2.9. Acetylene cylinders filled with porous mass during examination shall be tested with nitrogen under pressure of 3.5 MPa.

7.2.10. The ring loosening on the cylinder neck cannot be reason for the cylinder rejection. In this case the cylinder may be accepted for further examination after ring fastening or replacement by new one.

Cylinders, where oblique or weak attachment of the shoe is identified, are not allowed for the next examination without the shoe re-installation.

Fastening or replacement of the loose ring on the neck or the shoe shall be done prior to cylinder examination.

7.2.11. Re-installation of shoes and rings for caps, valves replacement, cleaning, restoration of paint and text on cylinders shall be carried out at the examination sites.

The valve after repair associated with its disassembly shall be leak tested at work pressure.

7.2.12. The cylinders filled with gas arranged for long-term storage in warehouse, when the next periodic examination date is achieved, are subjected to examination in a selective manner in maximum quantity of 5 pieces per lot of 100 cylinders, 10 pieces per batch of 500 cylinders and 20 pieces per the batch over 500 cylinders.

If satisfactory results are obtained the shelf life of the cylinders shall be specified by the person who performed the evaluation, however, not more than two years. The results of the selective examination are entered into the respective report issued for that purpose.

If unsatisfactory results are obtained the cylinders are re-evaluated in same quantity.

In the case of unsatisfactory results during re-evaluation further storage of the entire batch of cylinders is not allowed, the gas from the cylinders shall be released within the period specified by person who performed evaluation, after which each of the cylinders shall be evaluated for damage on individual basis.

7.3. Limit state criteria.

7.3.1. Criteria for rejecting the cylinders are given in Table 3.3. herein.

8. REQUIREMENTS FOR QUALITY MANAGEMENT TO ENSURE SAFETY DURING OPERATION

8.1. Table 8.1. and clauses 8.2–8.7 specify requirements for ensuring the quality of work and services affecting safety of products during their life cycle in accordance with GOST R 51901.3-2007. Task numbers missing in the Table mean that these tasks are omitted as not related to products, without changing the numbering in order to maintain a link with the original source.

Table 8.1. Connection of the stages of the product life cycle with the applied elements and tasks of reliability and safety.

Elements and tasks of reliability and safety	Stages of product life cycle					
	C&D	D&E	MNF	INST	OPER	DISP
Element 1. Management						
Task 1. Reliability and safety program	XXX	XXX	XXX	XXX	XXX	XXX
Task 2. Reliability and safety requirements		XXX	XXX	XXX		
Task 3. Processes management		XXX	XXX	XXX	XXX	
Task 4.Design management		XXX	XXX	XXX		
Task 5. Monitoring and analysis		XXX	XXX	XXX	XXX	XXX
Task 6. Supplies chain management			XXX	XXX	XXX	XXX
Task 7. Product commissioning				XXX	XXX	
Element 2. Reliability disciplines						
Task 8.Fail-free operation assurance	XXX	XXX	XXX			
Task 9. Repairability assurance	XXX	XXX	XXX	XXX		
Task 11. Standardization		XXX	XXX	XXX	XXX	
Task 12. Human factor	XXX	XXX	XXX	XXX	XXX	XXX
Element 3. Analysis and evaluation						
Task 13. Environment conditions analysis	XXX	XXX	XXX			
Task 14. Fail-free operation modeling	XXX	XXX	XXX			
Task 15. Parts estimation and management		XXX	XXX			
Task 16. Project analysis and product evaluation		XXX	XXX			
Task 17. Analysis of risk and cause-and-effect relationships		XXX	XXX	XXX	XXX	XXX
Task 18. Forecast	XXX	XXX	XXX			
Task 19. Analysis of compromise solutions	XXX	XXX	XXX			XXX

Task 20. Estimation of life cycle cost	XXX	XXX	XXX	XXX	XXX	XXX
Task 21. Reliability improvement				XXX	XXX	
Element 4. Verification and validation						
Task 22. Strategy of verification and validation		XXX	XXX	XXX		
Task 23. Safety demonstration				XXX	XXX	
Task 24. Sorting by reliability			XXX			
Element 5. Knowledge base						
Task 25. Knowledge base creation		XXX	XXX	XXX	XXX	XXX
Task 26. Data analysis		XXX	XXX	XXX	XXX	XXX
Task 27. Data acquisition and distribution of data		XXX	XXX	XXX	XXX	XXX
Task 28. Reliability and safety records		XXX	XXX	XXX	XXX	XXX
Element 6. Enhancement						
Task 29. Preventive and corrective actions		XXX	XXX	XXX	XXX	
Task 30. Enhancement and modification				XXX	XXX	
Task 31. Improving the personnel competence	XXX	XXX	XXX	XXX	XXX	
Task 32. Improvement of reliability and safety management system	XXX	XXX	XXX	XXX	XXX	
Abbreviations used in Table: C&D — concept and determination; D&E — design and engineering; MNF — manufacturing; INST — installation (erection, mounting); OPER — operation and maintenance DISP — disposal.						

8.2. Management – element 1

Management is a key element of the safety and security program. Planning defines the goals and capabilities of the project, identifies project activities, and establishes phased schedule of works and deliveries. Management applies appropriate business and technical strategies, provides management functions, and distributes the necessary resources to facilitate effective execution of tasks to achieve planned project objectives. The main management tasks are described in 8.2.1–8.2.7. Management is achieved through the appointment of technical managers ensuring reliability and safety objectives execution.

Duties of the technical manager responsible for the reliability and safety include the formation of working group, responsibilities distribution respectively between the group members, ensuring the information exchange with customers and vendors on reliability issues and the key technical communication during management of the supply chain on problems of reliability and safety. In order to increase customers loyalty the after sales information exchange shall be maintained.

8.2.1 Reliability and safety program (Task 1).

The reliability and safety program requires adequate planning and involvement of senior management. The reliability and safety plan is the basis for the management, planning, inspection of the documentation, and management of the reliability and safety program. Reliable and safety plan of products shall be integrated into the general plan of the project. It shall be reviewed by top management and approved by the head of the organization. The reliability and safety plan can cover product at one, several or all stages of its life cycle. The plan shall identify the reliability and safety program objectives applicable to the product and monitoring of its key characteristics. The reliability and safety plan shall specify the technical leader responsible for the program implementation and, if necessary, management representative. Objectives of the reliability program shall be determined in accordance with phased schedule of works and deliveries.

8.2.2. Reliability and safety requirements (Task 2).

Reliability and safety requirements include process of requirements identification and the definition of conditions for project deliveries. Requirements are formed in such a way as to ensure satisfaction of customer needs or to define criteria for choosing preferred suppliers. As a result, a formal contract agreement can be made between all the parties involved. Cooperation between the customer and supplier allows significant acceleration of the requirements preparation and facilitation of mutual understanding of the objectives and constraints of reliability and safety to reach the agreement. Reliability requirements can include the quantitative parameter values, such as the availability ratio, average life time, the maximum permissible duration of operation or characteristics of the limit state of the product. Requirements for quantitative characteristics to demonstrate and to acceptance the product shall be defined and documented. The reliability requirements shall highlight the requirements directly related to the general operability of the product and to its purpose.

8.2.3. Process management (Task 3)

The reliability and safety management system shall manage all processes affecting reliability and safety. The management function shall be activated for the processes affecting the reliability and availability of the system. Typical processes affecting reliability and safety are material selection, reliability assessment methods, product acceptance criteria, failure data logging, failure causes analysis, preventive and corrective actions. Each process owner shall be identified. Inputs and outputs of the

process shall be verified for accuracy and consistency in accordance to their purpose. The interim objectives of the project associated with reliability shall specify the coordinated set of necessary purchases and schedules of work under project, this facilitates the decisions making when analyzing by management, but also when interacting with suppliers and customers.

8.2.4. Design management (Task 4)

Design management is an essential reliability management process to ensure product development in compliance with reliability and safety objectives. Steps of design management include the establishment of rules and recommendations for design to ensure safe operation, selection of physical and functional units, ensuring modularity, facilitating assembly and disassembly, warranty servicing. These actions ensure that the product meets the mandatory requirements. Improved design results are improved product reliability and safety. Monitoring the status of product reliability and safety during design shall be integrated into the design management process. Inputs and outputs of the design management process shall be verified in terms of accuracy and completeness. The project analysis shall be aimed at assessment of compliance with the requirements for the progressive design to ensure possibility of product manufacturing of the corresponding quality. The design changes shall be carried out in accordance with the configuration management process that facilitates the traceability of modifications or modernization of the project.

8.2.5. Monitoring and analysis (task 5).

The analysis consists of contract analysis, analysis by management and technical analysis.

The contract analysis shall be carried out together with the general product analysis. Specified contract requirements related to the reliability of the procured components, during acceptance are analyzed by the customer, and by component suppliers, if necessary. When incompliances are identified, the occurred problems shall be solved, and appropriate changes shall be made to the contract. Entries for the contract analysis shall be maintained in operating condition.

Analysis of reliability and safety by management shall performed regularly.

Typically, the project technical analysis is carried out several times during the design when it is necessary. At specific stages of the project the technical analysis may include a more formal process for verifying compliance with contract or regulatory requirements. Entries for the analysis shall be maintained in operating condition. As formal project analysis manual GOST R IEC 61160 shall be used.

8.2.6. Supplies chain management (Task 6)

The organization shall develop and implement the supply chain management process. The technical leader responsible for reliability and safety shall be actively participate in the supply chain management process to ensure that reliable components are supplied and used. Dialogue with customers and suppliers shall be maintained. Information stream management shall provide quick response and security purposes. A general analysis process shall be established. Additional information on the supply chain

management related to the products sale is given in clause 7.4 GOST R 51901.3-2007.

In accordance with the reliability and security management objectives the following shall be reviewed:

- recommendations on the list of the main parts of the project and product design;
- establishing criteria for the selection of preferred suppliers;
- joint use of reliability data for critical characteristics of the product and history of their functioning;
- joint use of the estimation process data of products and output data;
- general analysis of inconsistencies and emergency failures;
- solution of general problems for continuous improvement;
- general analysis of the constraints on product resources during process change or obsolescence of market products;
- monitoring of suppliers.

8.2.7. Product commissioning (Task 7).

The organization shall ensure the products commissioning planning, as well as managing the new product transfer to operation stage. The main objectives of the reliability and safety are providing the products availability, communication with the customer in respect of claims and the product return, and the distribution of resources necessary for execution of the functions in extreme situations. The process of product commissioning shall include the customer participation in assessing the products operation and feedback from stakeholders on the product quality for the possibility of its improvement. The time of new product introduction to the market shall be coordinated with the product manufacturing, its renewal or modifications related to the product improvement, the reduction of the risk/cost, improvement of business processes. If possible, the product commissioning shall be provided in integrated process of project management to achieve full results and scope of product delivery to the customer.

8.3. Reliability disciplines – element 2.

The reliability and safety of product are achieved primarily through the application of technical knowledge and the successful use of the production methods.

To ensure the practical use of the technical solutions associated with the reliability and safety of the product, you need to know special technical disciplines. The required technical disciplines in the field of reliability are described in 8.3.1–8.3.4.

8.3.1. Fail-free operation assurance (Task 8).

Fail-free operation assurance is a technical discipline used to describe operating conditions, workloads, and establish rules and recommendations for the design and manufacture of reliable and safe

products. Fail-free operation assurance includes the development of fault-free design, fail-free operation analysis, verification to confirm the maturity and sustainability of the project and the production readiness.

8.3.2. Repairability assurance (Task 9).

Repairability assurance is intended for the products, easy and cost saving during maintenance. Repairability is achieved by ensuring the design testability, availability, interchangeability and unification of elements during design. The beginning and frequency of analysis of detailed repairability criteria are determined based on the requirements set for the product. Repairability is included in design testability. Testability is the design property to provide test and diagnostics of its elements with the help of the established means. Accordingly, the testability is characterized by the completeness of coverage by test and diagnostics of its elements in accordance with the established criteria. The purpose of test and diagnostics of products is to identify the onset of limiting states after which the operation is impossible.

8.3.3. Standardization (Task 11).

Standardization is one of the reliability disciplines and relates to the check of the project compliance with requirements to the products and the correctness of performed procedures of changes implementation in the project. Standardization of materials facilitates the selection and qualification of suppliers. The use of standards for design, manufacture, operation and maintenance minimizes the problems associated with nonconformities.

For the project the configuration management plan shall be established and implemented. This plan shall be used for identification, monitoring, status accounting, evaluation, changes management, implementation and supply of materials and documentation included in the overall project. The configuration management manual is given in GOST R ISO 10007.

8.3.4. Human factor (Task 12).

The human factor has a significant impact on the products functioning. To expand interaction "human-machine", to facilitate operation and maintenance the recommendations on design and related standards shall be used. The project shall consider anthropometric characteristics, sensory limitations and psychological parameters of the human, which affect his perception and reaction.

To ensure that all reliability and safety goals are met, the recorded precedents and diagnostic procedures shall cover human factors elements associated with the operating conditions of the products.

When designing products, one shall consider the level of human labor intensity during its operation. The potential impacts on the personnel, equipment and the environment in the event of incident with the product due to the human mistake shall be investigated.

8.4. Analysis and evaluation – element 3

Ensuring fail-free operation and repairability includes the use of various methods for reliability problem solution. Quantitative or qualitative methods, or both can be applied, but solutions shall

consider the precedents of technical solutions and use of successfully applied production methods. The most common methods used for analysis and evaluation of elements are given in 8.4.1–8.4.9.

8.4.1. Analysis of environment conditions (Task 13)

To establish requirements for products the operation modes, which will be applied, shall be clearly defined. Use conditions of product shall be defined in terms of specified performance characteristics with allowable limit values. This gives the possibility to classify operating conditions and to identify possible deviations of the environmental conditions in order to facilitate the design of products, focused on operation in certain environmental conditions and its possible changes. Typical environment impacts on the product are the impacts of mechanical stresses.

Analysis of the use conditions of products is necessary to check that the product project meets the goals and operation modes of the product.

8.4.2. Fail-free operation modeling (Task 14).

Whenever possible, the fail-free operation modeling methods shall be used to assess the products availability. Methods for the fail-free operation modeling provide an analytical approach to the determination of the expected operation modes of the product and performance under normal and adverse situations. These methods are useful for use on stage of concept and definition to identify existing technical problems, at the stage of engineering and design to study the product characteristics during changes making to the design to reduce the risk. The cost of the product life cycle during design significantly depends on product reliability predicted on the basis of performance information obtained in the early stages, and allows you to determine actions necessary to prevent unnecessary costs.

Reliability modeling and simulation modeling shall determine the cause and the effect of the product operation conditions and limitations used during modeling, determine limitations and suggestions used when designing products; assess the validity of the data used and the interpretation of the modeling results that may affect the finished product during the decisions making related to the business. Relevant guidance is given in GOST R 51901.5.

8.4.3. Evaluation and management of parts (Task 15).

Parts (components, sub-parts, items) evaluation and management during the design and assembly of product are very important to achieve the required level of product reliability and safety. The degree of parts evaluation and management shall be consistent with the project requirements. Efforts relating estimation and management are essential to ensure confidence that stored product pieces are suitable for planned application. If possible, the supply chain management process shall be implemented.

At that the following actions shall be applied:

- when selecting the components, the critical parameters and requirements to components, which may be delivered by few possible suppliers, shall be established. Monopoly suppliers or suppliers setting

limitations on deliveries shall be identified;

- the possibilities of potential suppliers of parts considering the previous business relationships shall be studied. This process is critical when purchasing materials manufactured according to customer requirements in accordance with the product purpose;

- manufacturing processes and supplier warranties shall be studied. Analysis of suppliers, if required, may ensure confidence in relations;

- the parts responsible for achievement of the assigned functional, physical, quality and fail-free operation characteristics during the product purpose use shall be identified. This is achieved by qualifying parts, verifying and validating evaluation and testing of new parts as needed. The process output is developed list of main parts with qualified suppliers. The critical parts necessary for the organization shall be identified. Parts and appropriate information shall be maintained in operation state;

- critical parts are, for example, parts with limited period of validity, the elements of a consistent chain in the reliability block diagram, parts affecting safety, responsible parts of the processes, components manufactured in accordance with the customer requirements, etc.;

- parts management comprises the working state assurance of data entries in the occurred failures and inconsistencies of parts necessary for further analysis and decisions making.

The suppliers analysis shall be continuous.

8.4.4. Project analysis and product evaluation (Task 16)

The project analysis is required to meet the project requirements to the products. Methods of the project analysis associated with the reliability and safety include reliability modeling and simulation modeling (e.g., when studying load and strength),

fail-free operation prediction, analysis of the types and consequences of failure/malfunction. The product estimation includes the tests during the project verification with the working conditions modeling, as well as tests for the product validation in real operation conditions.

General methods of reliability analysis used in the design and assessment of product reliability indicators are given in GOST R 51901.5. General statistical methods for use in standards and specifications are described in R 50.1.059 and GOST R ISO/TO 10017.

8.4.5. Analysis of risk and cause-and-effect relationships (Task 17).

The analysis of the potential causes of failures and their impact on the products functioning shall be carried out to check the project safety and to minimize the risk during operation.

Type analysis methods include:

- failure modes and effects analysis (FMEA), which is the basic qualitative method of reliability analysis, especially convenient for failures studies of materials, equipment and components and their impact on the next higher functional level of the system. The FMEA method is given in GOST R 51901.12-

2007;

- failure tree analysis (FTA), which is downward method of the product reliability analysis, including the identification and analysis of states and parameters that cause or contribute to the occurrence of undesirable events and affect the functioning, safety, efficiency or other set characteristics of the product. Recommendations for FTA method use are shown in GOST R 51901.13-2005;

- Markov analysis, which allows determination of the system readiness indicators with the probability of transition from the failure state to the operable state and vice versa. Recommendations for Markov analysis use are shown in GOST R 51901.15-2005;

- risk analysis to determine the quantitative characteristics of risk and the likelihood of adverse events. Recommendations for risk analysis use are shown in GOST R 51901.1-2002;

8.4.6. Forecast (Task 18).

Forecast shall be carried out in the early stages of design and engineering of modified object as the projected progresses.

Forecast results allow us to estimate the parameters of fail-free operation of products in the form of mean time to failure, mean time between failures or failures rate. Indicators of system readiness are expressed in the percentage of calendar time of downtime for the specified period of operation.

Forecasts relating to products shall consider the conditions of use, workload, complexity of the system design and configuration, as well as empirical data used to predict the reliability parameters of the product.

8.4.7. Analysis of compromise solutions (Task 19).

The analysis of compromise solutions shall be carried out at the stage of concept and definition, at the early stages of design and engineering in order to timely provide the input data of reliability distribution problem. The analysis of compromise solutions can be carried out at any stage of the life cycle of products depending on the studied problem. The analysis shall be made also close to the end of product life cycle to determine costs for operation support or changes making. Analysis of the cost of the entire life cycle of product shall be amended with the analysis of compromise solutions.

The analysis of compromise solutions can be effectively used for selecting the project options, decisions of purchase or manufacture of components and the comparative analysis of alternative solutions. The analysis of compromise solutions shall be used when selecting the technology, design or operational methods or combined design and operation solution in the general structure of the project to achieve the required efficiency of the system and objectives of the project profitability.

8.4.8. Estimation of life cycle cost (Task 20).

Estimation of the life cycle cost of product is performed to quantify the estimation of the life cycle cost by components to estimate resource allocation and potential expenses. Quantitative assessments

are often accompanied by qualitative recommendations for changes making. Estimation of the product life cycle cost makes easier the decisions making relating the project management. Product sensitivity analysis is often done to analyze the situation using the “what if” method. Results of the analysis of the product life cycle can be used for:

- distribution and change of goals of reliability and safety;
- identification of critical factors of reliability and safety and their impact on expenses;
- selection of design options and consideration of alternative projects;
- optimization of readiness indicators under the set restrictions of the life cycle cost;
- selection of methods of product use to minimize harm to the environment and to reduce the risk within the limits of set cost. Guidance on the determination of life cycle cost is given in IEC 60300-3-3.

8.4.9. Reliability improvement (Task 21).

Reliability improvement programs shall be implemented to improve the product reliability. The process of reliability improvement includes procedures of failures identification, their causes analysis, corrective actions and verification of the effectiveness of the actions taken. If possible, the preventive measures shall be taken to ensure continuous improvement. The GOST R 51901.6 gives guidance on the development of programs for reliability improvement and the relevant procedures. Test methods for reliability improvement estimation are shown in GOST R 51901.16-2005.

8.5. Verification and validation – element 4.

The fail-free operation and repairability of the product project shall be verified for compliance with the project requirements. Validation of performance and efficiency characteristics related to reliability and safety shall be carried out during commissioning or at the early stages of product operation to confirm that the product meets the specified requirements. Verification and validation shall be part of the project analysis process. Description of the verification and validation methods are given in 8.5.1–8.5.3.

8.5.1. Strategy of verification and validation (Task 22).

Actions relating verification and validation shall be planned at early stages.

The verification strategy shall include modeling and testing of product to determine the adequacy of the functions and evaluations of limit values of reliability indicators used when designing safety and reliability, and repairability characteristics during operation in the established environment conditions. The purpose of the verification strategy is confirmation of the functional and physical efficiency of the technical models or samples used for the investigation qualification tests.

The validation strategy shall be followed for the finished product under specified operating conditions. The validation process shall be carried out together with the customer if the system is installed in accordance with customer requirements. Validation results shall be registered as a proof of the system acceptance.

8.5.2. Safety demonstration (Task 23).

Safety demonstration is one of the objectives of the acceptance test. The demonstration shall be carried out only before or during system commissioning during its acceptance by the consumer.

The purpose of these tests is to demonstrate that the set goals are met. Where it is possible and economically feasible, the demonstration tests shall be carried out together with other prescribed tests carried out under the same conditions. This provides a more realistic validation of the test results in relation to the acceptance criteria. The test procedures shall be specified in the documentation indicating the necessary measurements and test conditions. Test data shall be recorded to provide adequate information for analysis in determining the results of product acceptance.

8.5.3. Sorting by reliability (Task 24).

Products sorting by reliability under loads is process using stresses arising under the environment effect and/or work load as method of disadvantages detection. These disadvantages may occur due to poor workmanship or inaccuracies of the project or manufacturing process. Method of sorting by reliability identifies hidden defects of product and its parts facilitating the onset of failure. Recommendations relating to the sorting by reliability in conditions of actual loads are given in IEC 60300-3-7, IEC 61163-1 and IEC 61163-2.

8.6. Knowledge base – element 5.

The knowledge base in the field of reliability and safety is essential condition of the effective and efficient work of the organization.

Getting data of the reliability and safety, information and knowledge with the use of latest technologies, modernized processes and market information provides competitiveness and organization benefits in business. Supported knowledge base is important in solving management problems and selecting the strategy of products design to meet the market requirements. Knowledge shall be considered as strategic an information resource. Knowledge base items are described in 8.6.1–8.6.4.

8.6.1. Knowledge base creation (Task 25).

The organization shall establish the knowledge base in the field of reliability and safety, corresponding activities of the organization. It provides availability of adequate and timely information on the reliability and safety, this helps to maintain an active production of the manufactured range of products and new models. The knowledge base in the field of reliability and safety shall include:

- product project information related to reliability and safety;
- data of product functioning obtained through the service network;
- information from suppliers about the reliability and quality of components;
- project information about the reliability and safety of products, requirement to reliability and safety, the recommendations for the use of components, forecast of fail-free operation and repairability,

sources of models of reliability and repairability, information about the test results and, if necessary, history of product acceptance.

Product functioning data shall include the trends of product reliability improvement, information about maintenance and repair, warranty returns, messages about the incidents and further decisions, the feedback information from the customer and claims (see IEC 60300-3-2).

Information about the suppliers shall include history of reliability of the supplied components, the range of their reliability variation, data of monitoring and sorting, qualification criteria and sources of information about suppliers.

8.6.2. Data analysis (Task 26).

The data analysis is necessary to identify trends of reliability and security change, to identify abnormal changes and, if necessary, to initiate preventive or corrective actions. Analysis of test results, operation data or other sources can provide insight and information about reliability and safety changes, indication of system problems for their causes analysis. All analyzed data shall be interpreted with explanations and analysis, necessary for subsequent decision making by management and further actions of continuous improvement of the product quality.

8.6.3. Data acquisition and distribution of data (Task 27).

The data acquisition and distribution system shall focus on data acquisition from appropriate sources and information delivery to decision-makers. Fact-based data are essential for improving the reliability and safety and for making business decisions. Recommendations for investment in improvement shall be based on the data interpretation.

The data collected and distributed through the system include data relating to the functioning of the manufactured products and feedback with the customer.

The results of product evaluation, data of test, verification and validation, the results of product analysis and providers analysis shall be included as part of the data collected. The data acquisition and distribution system shall be simple and adequate to provide the data required for reliability, safety analysis and decision making. In ideal situation raw data relating to failures and procedural errors shall be easily obtainable for further analysis. Therefore, the design and development of the data acquisition and distribution system shall be investigated in terms of the feasibility and efficiency of product operation. Data acquisition and distribution system shall be also studied in terms of use for classification, keeping in archives and searching of documents, for data management, information protection and safety.

8.6.4. Reliability and safety records (Task 28).

The reliability and safety records shall include all necessary data on reliability and safety required in accordance with the contract and regulations. Typical records required for storage include:

- chronology of product reliability for the selection the preferred suppliers;

- reports on reliability, repairability and readiness;

- information on the verification and validation to ensure trends of product improvement and suitability for use;

- records of the analysis of the deviation causes for the initiation of reduction of the risk and expenses for elimination of adverse consequences;

- records on safety demonstration during product acceptance;

- records on operation and warranty maintenance for improvements and modernization.

The ability to monitor subsystems and components adds value to reliability records. The time period of records storage shall be specified in the contract.

8.7. Enhancement element 6.

Enhancement is a key process in ensuring business viability by improving the business processes and products of the enterprise. Continuous enhancement provides the necessary incentives to develop business. Investing in the latest technologies and products can improve the competitiveness of product and create organization's advantages in the market. Scheduling of the improvement actions is critical for the investments return. For descriptions of enhancement items, see 8.7.1–8.7.4.

8.7.1. Preventive and corrective actions (Task 29). Preventive actions are performed to eliminate the causes of possible undesirable situations. Corrective actions are performed to eliminate the causes of existing undesirable situations. Corrective actions shall prevent the re-occurrence of undesirable situations, and preventive action shall prevent the possibility of adverse situation.

Preventive and corrective actions are part of the improvement process. The success or effectiveness of preventive and corrective actions depends on the approach used and the methods used. An information system shall be used to facilitate the initiation of preventive and corrective actions. The responsible person shall be appointed with an indication of the date of task completion or termination. Result of actions shall be verified to determine the efficiency of the problem elimination. Preventive and corrective actions shall be specified in the documentation and be traceable.

8.7.2. Enhancement and modification (Task 30). Enhancement shall be carried out with the aim of improving the quality of product regarding the expansion of its functions and capabilities. The modification is carried out in accordance with the product improvement procedures. Enhancement and modification shall reflect the results of initiating and effective implementation of the process improvement. They shall be consistent with the configuration management process for records traceability and facilitate data analysis to identify improvement trends. The configuration management manual is given in GOST R ISO 10007.

8.7.3. Improving the personnel competence (Task 31).

Improving the personnel competence is necessary to expand the knowledge base and investment of resources with continuous improvement. Corresponding competence level is required to ensure the

ability of organization to withstand the press of modern technology, not reducing competitiveness of the product.

Knowledges and competence in the field of reliability and safety can be achieved due to basic education and training at the work place, use of counseling programs, traineeship, as well as engagement to cooperation of the scientific institutions, the regular qualification improvement at special courses.

The competence improvement shall be considered as periodic technical updating of knowledge about reliability and security. It can be achieved through the participation of a large number of personnel in technical forums, technological professional workshops on safety and security, as well as in different groups of finding solutions of problems of reliability, safety, and cross-functional groups to get the experience of application of reliability and safety methods in industry.

However, during public discussions the right for intellectual property and the rule of non-disclosure of confidential information shall be met.

8.7.4. Improvement of reliability and safety management system (Task 32).

The effectiveness of the reliability and safety management system shall be regularly evaluated. The assessment shall be initiated by the improvement process. To improve the reliability management system the following aspects shall be discussed:

- top management shall create a working environment and maintain infrastructure to encourage creativity, efficiency, expansion of business possibilities and to support the reliability improvement process;
- reliability and safety are managed by the market and new technologies. The personnel of the organization shall continuously improve their qualifications and competence and improve the knowledge base in the field of reliability and safety;
- top management shall establish achievable goals, implement the benchmarking and expand the practice to reliability and safety provision to ensure the product competitiveness;
- new ideas for improving the reliability, safety and options of cost decreasing shall be established and brought to the attention of all organization employees;
- the program of recognition the merits and awarding to encourage the achievement in continuous improvement shall be established;
- the corresponding records shall be maintained in work order as information resources for actions on improving the reliability and safety, if this is economically justified.

9. REQUIREMENTS TO ACQUISITION AND ANALYSIS OF SAFETY INFORMATION DURING COMMISSIONING, OPERATING AND DISPOSAL

9.1. Processes of monitoring, measurement, analysis and improvement needed to ensure the timely correction of system errors made during the design, manufacturing installation, operation, disposal, documentation development for the product; information acquisition on cases of harm to life and health, property, environment and estimation of amount; assurance of quality management system compliance continuous improvement of its effectiveness are given in Section 8.6 of this safety case.

9.2. Rules of action for establishment of the accident causes.

9.2.1. The procedure of the technical investigation of the causes of accidents, incidents at facilities supervised by Rostekhnadzor, and operated by organizations regardless of their organizational-legal form and form of property in the Russian Federation, including the procedure of execution, registration, accounting and analysis of materials of the executed technical investigations are given in the Order of the Federal Service for ecological, technological and nuclear supervision (Rostekhnadzor) of August 19, 2011 No. 480 "On approval of technical investigation of causes of accidents, incidents and loss of industrial explosives at objects supervised by the Federal Service for environmental, technological and nuclear supervision".

9.2.2. Activities organized and executed by the organization (its director or his deputy person) operating the facility where the accident occurred:

- immediately, in accordance with the established procedure of information transfer about such incidents (accidents, including incidents as result of the accident), informing about the accident Rostekhnadzor and its territorial body that supervises the facility, the higher level body or organization (if any), local government administration, the State Inspectorate of labor of the Russian Federation subject, trade union, insurance company, which entered into liability insurance contract for risks of harm to life, health, property of other persons and the environment in the event of accident, the territorial prosecutor's office.

In the event of incident (serious, group, with fatal outcome) occurred as a result of accident at the facility supervised by Rostekhnadzor the message includes, along with the form of operational message about accident, a form of an operational message about incident (serious, group, with fatal outcome).

The operational message about the accident is transmitted by fax or verbally by the phone, if fax transmission cannot be performed;

- taking measures protecting life and health, environment, as well as the property of organization and third parties against negative consequences of accident;

- taking measures preserving the existing situation at the accident place prior to the causes

investigation, excluding those cases when accident liquidation and the preservation of life and health shall be performed.

If it is impossible to save the situation at the accident site its documentation (photographs, video and audio recording etc.) shall be ensured until the work relating accident isolation and liquidation, ensuring the preservation and transmission of the said materials to special commission of technical investigation of accident reasons;

- implementation of measures on isolation and liquidation of accident consequences;

- the organization of technical investigation of accident reasons and taking measures for elimination and prevention of the reasons contributing to the accident occurrence;

- supporting the work of the commission on technical investigation of the accident reasons.

9.2.3. Procedure of Actions during Accident.

Accident in the production is an event with the result that insured person received injury or other damage to health when executing his obligations under the labor contract and in other cases established by Federal Law (Art. 3 of the Federal Law "On compulsory social insurance against accidents in the production and occupational diseases") cases, both in the territory of the insurer, as well as outside it or during movement to the work place or return from the work place on the transport, provided by the insurer, and which resulted in the need for insured person transfer to other work, in temporary or permanent loss of professional ability to work or his death.

Possible effects on human in case of accident, as well as methods of first aid in case of accident are given in Section 7 of the present Safety Case (clauses 7.1.10–7.1.13).

9.2.4. Responsibilities of Employer during Accident in Production.

9.2.4.1. Immediately arrange first aid to the victim and, if necessary, his/her delivery to the medical organization;

9.2.4.2. To take urgent measures for the prevention of emergency situation and the impact of traumatic factors to other persons;

9.2.4.3. Keep until start of accident investigation the situation, which was at the time of incident, if it does not threaten life and health of others and does not lead to an accident, in the case of impossibility of its keeping fix the current situation: make diagrams, take photographs, execute other measures;

9.2.4.4. Immediately inform relatives of the victim about the incident;

9.2.4.5. To notify the relevant authorities (the State Inspectorate of Labor, Prosecutor’s Office of the incident place, Executive Authorities of the Russian Federation subject, the employer sending the employer suffered from incident, territorial associations of trade union organizations, the Territorial State Supervisory Authority, if the incident took place in the organization or on the object supervised by this authority, the Insurer on issues of compulsory social insurance against incidents in the production and

occupational diseases, about cases of acute poisoning to the appropriate body of the Federal Executive Authority supervising in the sphere of sanitary and epidemiological welfare of the population):

- during serious incident, group incident, incident with fatal outcome during day;

- about incidents which after one day enter the above-mentioned categories — during 3 days after receiving the information about it;

9.2.4.6. Provide timely investigation of the incident;

9.2.4.7. Immediately create a committee comprising at least three persons.

10. SAFETY REQUIREMENTS FOR DISPOSAL

10.1. Before disposal the cylinders shall be rendered unserviceable by application of notches on the thread of the neck, or drilling holes in the body, excluding the possibility of their further use.

10.2. The recycled scrap is assigned to a legal entity or an entrepreneur carrying out this type of activity. The procedure of handling and disposal of scrap and ferrous metal waste is defined by "Regulations of handling scrap and ferrous metal waste and their disposal", approved by resolution of the Government of the Russian Federation dated 11 May 2001 No. 369.

10.3. Enterprises, organizations and commercial units gathering, handing over, recycling and remelting secondary ferrous metals, as well as exporting or reloading them at ports and other points shall check all secondary ferrous metals for explosion safety and remove from them all the components containing explosive flammable and combustible substances.

10.4. Products disposed as scrap shall be free from remaining fuels or lubricants (and in winter from ice and snow), and available for inspection of inner surface.