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PRODUCTION OF PIPES AND ASSEMBLY OF PIPELINES AND PIPE SYSTEMS --ETC(U)
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PRODUCTION OF PIPES AND ASSEMBLY OF PIPELINES AND PIPE SYSTEMS ON SHIPS

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MATERIAL FOR PIPELINES AND PIPE SYSTEMS /5*

1. Requirements to Materials Used for Pipe Systems

Depending on application, steel, copper, brass and copper-nickel pipes are used on ships and in ship's power systems (SPS). In addition, pipes made of aluminum and titanium alloys, as well as bimetallic and plastic pipes are also used in many instances. Valves, fittings, mountings, gaskets, sealers, etc. are also used in pipe systems in addition to pipes.

Requirements put toward various pipe systems are dictated by application, environmental factors, class of ships and others. Among the most common requirements are the necessary mechanical strength, long service life, easiness in handling (machining assembly) and low cost. The mechanical strength is determined by various properties which are revealed during testing of samples, or the testing of individual pipes under laboratory conditions of the plant-supplier. The service life is determined by the stability of pipes against corrosion, erosion, aging and other destructive environmental forces.

Economic considerations also occupy an important place in the selection of material for pipe systems. As a result the majority of the pipelines are built of inexpensive carbon steel pipes, regardless of their comparatively short service life. Table 1 presents comparative wholesale prices of pipes having different diameter.

Zinc-plated carbon steel pipes are also frequently used on ships for various hold systems (drainage, water removal, by-passing, etc.). Pipes of copper and copper-nickel alloys are used for critical systems,

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* Numbers in the right-hand margin indicate pagination in the original text

Table 1. Wholesale prices for pipes of different metals (ruble/ton)

/6

Pipes	Pipe size, mm	
	38 x 2.5	108 x 4
Steel for water and gas (standard)	151	148
Steel zinc-plated for water and gas	264	259
Steel, seamless	238	181
Steel, seamless for shipbuilding	450	-
Stainless steel 1Kh18N9T	1610	1375
Bimetallic	2059	-
Steel, with polyethylene lining	881	428
Copper (soft)	1170	1100
Copper-nickel MNZh-5-1	1330	1350
Brass L-62 (soft)	1015	980
Aluminum-magnesium, AMG-6 alloy	2030	2400

Wholesale prices are given according to price lists No. 02-06 and 01-L4, Moscow, Preyskurantgiz, 1967

such as fire-extinquishing, cooling of power units, etc.

Cast iron pipes, with a spheroidal graphite structure, are used often in foreign countries on special tankers. These pipes are characterized by high mechanical strength and plasticity in comparison with the grey cast iron pipes, in addition to their high resistance to corrosion. However, their application on a much broader scale is limited by their excessive weight.

Regardless of material, all pipes are tested for expansion, flanging, flattening, bending and welding under conditions resembling those encountered during their production. For example, steel pipes are tested for exapansion, using a mandrel with 1:10 taper. The extent of expansion is determined from

$$x=\frac{d_1-d}{d}\cdot 100\%,$$

where d and d_1 represent the diameter of the pipe end prior and after expansion, respectively. /6

A power press (Figure 1a) is used for the flattening tests. The quality of pipes is considered to be good if they do not rupture during the flattening, provided an allowable clearance is maintained for pipes made of different material.

(a)

(b)

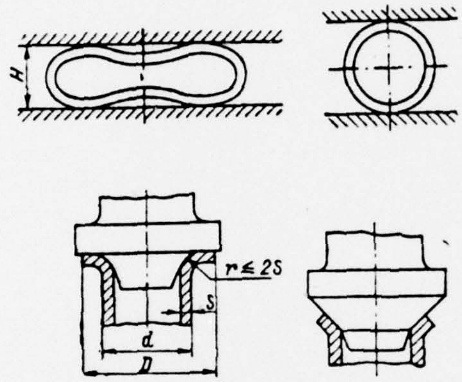

Figure 1.

Testing of pipes

A special device is used for the flanging tests (Figure 1b). The flanging angle for pipes made of soft steel and copper is 90°, and for pipes made of other steels, 60°. /7

Bending tests are performed with cold and heated pipes. The mandrel radius for these tests must equal to six external diameters for cold pipes, and to three diameters for heated pipes. The quality of pipes is judged from the absence or presence of small ruptures, cracks and openings along a seam after bending tests.

Every plant-supplier is required to test pipes for mechanical strength and density by hydraulic pressure.

Chemical composition and mechanical properties of manufactured pipes must satisfy the requirements of the USSR Registry.

2. Pipes for Various Systems

Steel pipes. Depending on the production method, all steel pipes are grouped into seamless or welded . Steel seamless pipes are produced either by cold drawing or hot rolling. For pipelines on ships pipes are made of steel types 10 and 20 (GOST 1050-60), VM St. 2sp,

Table 2. Mechanical properties of steel pipes /7

Steel	Yield point, MN/m^2 (kg/mm^2)	Ultimate resistance, MN/m^2 (kg/mm^2)	Relative elongation, %	Brinell hardness, wall thickness exceeds 10 mm	
				Indentation diam., mm not less than	Coeff. of hardness, not more than
	not less than				
10	206 (21)	333 (34)	24	5,1	137
20	246 (25)	413 (42)	21	4,8	156
35	295 (30)	510 (52)	16	4,4	187
45	324 (33)	588 (60)	14	4,2	207
10G2	265 (27)	471 (48)	21	4,3	197
20Kh	—	432 (44)	16	—	—
40 Kh	—	658 (67)	9	3,7	269
30 GSA	—	686 (70)	11	—	—
15 KhM	226 (23)	432 (44)	21	—	—
30 KhMA	393 (40)	588 (60)	13	—	—
12 KhN2	393 (40)	540 (55)	14	—	—
0Kh18N10T	—	530 (54)	37	—	—
VMSt. 4sp	245 (25)	413 (42)	20	—	—
VMst. 5sp	265 (27)	490 (50)	17	—	—

VM St. 3sp. VM St. 4sp (GOST 380-71), and also of alloyed ateels. Table 2 presents mechanical properties of steel seamless pipes.

Pipes produced by the cold drawing could be from 6 to 160 mm /8 in outside diam., with the wall thickness of 1.6-7.0 mm; and those produced by the hot rolling, 25-426 mm in outside diam., with the wall thickness of 2.5-14 mm and higher. In both instances pipes are from 4 to 12.5 m long and they are supplied after heat treatment.

All pipes carry certain designations on blueprints and in accompanying certificates. For example, a steel seamless pipe 25 mm in O. D. 2 mm thick wall and 4 m long is designated as: pipe 25x2x4000 (GOST 1060-53).

Pipes of low carbon steel with up to 63.5 mm in O.D. and up to 2.5 mm wall thickness are produced by drawing or by other methods, and those of other sizes, by other methods than the drawing.

All pipe rolling plants test pipes for exploratory pressure. This pressure for steel seamless pipes is

$$P_{ex} = \frac{20.0\ s\sigma_a}{d_{in}}\ MN/m^2$$

where s is the wall thickness, mm; σ_a is the allowable material stress, MN/m²; d_{in} is the internal diam. of pipes, mm. /8

Water and gas -conducting pipes are produced by electric arc welding from low carbon steel. They could be either zinc-plated or standard (black). With respect to wall thickness they are divided into standard, strong and light, either with or without treads. Some pipes are supplied with sleeves.

The water-gas conducting pipes can be from 17 to 88.5 mm in O.D., with 2.2-4.0 mm wall thickness. The strengthened pipes carry the letter "U" after the word "pipe" in designations; and for light pipes the letter "L" is used. Some pipes carry the letter "P" to designate pipes of high precision.

Stainless steel seamless pipes can be either cold drawn or hot rolled, with 6-110 mm in O.D. for the cold drawn, and 76-219 mm in O.D. for hot rolled. Different stainless steel is used for these pipes but for shipbuilding the 0Kh18N10T steel is preferred (with 18 and 10% of Cr and Ni, respectively). Bimetallic pipes have the outside layer made of 12Kh3A, 10 and 20 steels, while inside layer could be of M3r copper (GOST 10192 - 62 and GOST 51210 - 72). The O.D. of bimetallic pipes could be 6-370 mm, with 1.5 - 5 mm wall thickness. The copper layer amounts to 0.4-1.4 mm, depending on the total pipe wall thickness.

P i p e s o f c o p p e r a n d c o p p e r a l l o y s. Copper pipes are produced either by the cold drawing (soft annealed; hard unannealed), /9
or by pressing, with O.D. 6-360 mm, wall thickness of 1.0-10 mm and 1-6 m long.

According to the regulation ON9-398-66 pipes for pipelines on ships are made of copper M3r containing not more than 0.01% of oxygen. Mechanical properties of copper pipes are shown in Table 3.

The drawn and cold rolled pipes 30 mm and higher in I.D. should withstand cold flanging equaling 90°, with the flange width amounting to 25% of the I.D. but not more than 25 mm. Soft pipes must satisfy requirements according to accompanying certificates.

Copper pipes after annealing should be subjected to cold flattening until opposite walls come into contact, with a clearance at edges equaling the pipe wall thickness.

Table 3. Mechanical properties of pipes of nonferrous metals and alloys

Pipes	Ultimate resistance to rupture $MN/m^2 (kg/mm^2)$	Relative elongation, %
	not less than	
Copper:		
drawn and cold-rolled (soft)	206(21)	35
pierced	186(10)	30
Copper-nickel alloy MNKh5-1	255(26)	30
Brass:		
L-62	294(30)	30
L-68	294(30)	40
Aluminum alloys		
AD-1	108(11)	28
AMG-5	265(27)	15-12
D-16	422-393(43-40)	7-5
Titanium:		
VT1-1	442-590 (45-60)	25
VT1-2	540-686 (55-70)	20
Titanium alloys:		
VT-5	785-935 (80-95)	12-25
VT-6	885-981 (90-100)	8-13

Drawn, cold rolled and pressed pipes are tested by hydraulic pressure which is calculated from

$$p_{pr} = \frac{110.0s}{din} \; MN/m^2$$

where s is the wall thickness, mm.

Copper pipes on ships are used for different purposes. The total weight of copper pipes amounts to 10-25 tons on diesel boats of average tonnage, and to 80 tons on large boats. This is due mostly to a high

Table 4. Chemical composition of copper-nickel pipes /10

Type of alloy	Chemical composition, %							
	basic components				impurities (not more than)			
	Ni + Co	Fe	Mn	Co	Pb	C	Zn	Total
MNZh5-1	5.0-6.5	1-1.4	0.3-0.8	remaining	0.005	0.03	0.5	0.7

corrosion resistance of copper pipes in sea water.

Copper-nickel pipes. The copper-nickel pipes are made of the MNZh5-1 alloy according to requirements MRTU5.962-3777-62 either by drawing or cold rolling. The O.D. of these pipes is 6-258 mm, with the wall thickness of 1.5-7 mm. Table 4 presents the chemical composition of copper-nickel pipes. Mechanical properties of annealed pipes made MNZh5-1 alloy are shown in Table 3.

The copper-nickel pipes must withstand the flattening test in a cold state, without producing any cracks and ruptures, provided the clearance equaling two wall thicknesses is observed. Requirements for hydraulic pressure tests are indicated by a customer. This pressure shouldnot exceed that calculated from the formula

$$p_{pr} = \frac{140.0s}{d_{in}} \text{ MN/m}^2$$

where s is the wall thickness, cm.

Brass pipes. These pipes (copper-zinc) are produced either by cold rolling or by drawing (GOST 494 - 69). L-62 and L-68 brass is used in shipbuilding for speaking tupes and for heat exchange devices operating in fresh waters. The L-62 and L-68 brass contains 60.5-63.5 and 67-70% of copper, respectively, with remaining percentage of zinc.

The drawn brass pipes produced from 5 to 100 mm in O.D., with 0.5-6 mm wall thickness. Soft (annealed) pipes are designated by the

letter "M", and semihard pipes (low-temperature annealing) by letters /10
"PT".

Aluminum alloy pipes. Pipes from aluminum alloys are produced either by drawing (cold drawing and cold rolling) or by piercing. AD and AD-1 alloys are used for the production of annealed pipes by drawing. Among other alloys, AMG-2, AMG-3, AMG-5 and AMG-61 are used for pipes (aluminum-magnesium alloys). The AD alloy contains 98.8% of Al, 0.5% of Fe and 0.5% of Si; while the AD-1 alloy contains 93.9, 0.3 and 0.3% of Al, Fe and Si, respectively. In addition to Al the AMG-5 alloy contains 0.3-0.6% of Mn and 4.8-5.5% of Mg. /11
Aluminum alloy pipes are supplied in 6-110 mm O.D., 1-5 mm thick walls and in 2 to 5.5 m long sections.

Pipes of titanium and titanium alloys. Titanium and titanium alloys are comparatively new structural metals which are used for the production of pipes along with other parts and accessories. Titanium alloys are two-three times stronger than the aluminum and are even stronger than the alloyed steel. At the same time they are not as dense and weight less (γ = 44200 N/m^3 = 4.5 g/cm^3).

Titanium is distinquished by high resistance to corrosion in sea water, which exceeds the stability of all known industrial metals. Titanium pipes could find a broad application in shipbuilding. However, they use is limited by high cost.

Table 3 presents mechanical properties of pipes made of titanium and titanium alloys.

Nonmetallic pipes. Pipes made of polyethylene P404-O, P200ZK and P2006T-Sh are used extensively in shipbuilding.

The following types of pipes are produced from polyethylene (Table 5): light (L) for pressures up to 0.25 MN/m^2 (2.5 kg/cm^2; average-light for pressures up to 0.4 MN/m^2 (4.0 kg/cm^2; of average weight for pressure up to 0.6 MN/m^2 (6.0 kg/cm^2); of heavy weight for pressures up to 1.0 MN/m^2 (10 kg/cm^2).

A max. diameter of polyethylene pipes reaches 160-315 mm. Their operation temperature should not exceed 50°C.

Table 5. Basic properties of plastic pipes /11

Material	Density, N/m^3 (g/cm^3)	Heat resistance, ^oC
Polyethylene:		
low specific weight	8900-9100 (0.91-0.925)	100-120
average sp. weight	9100-9200 (0.926-0.940)	Operation temperatures from (-45 ÷ 52) to (-60 ÷ 100)^oC
high sp. weight	9200-9500 (0.941-0.965)	
Polypropylene	8850-8900 (0.90-0.91)	140-150 m.p. 170^oC

/12

As compared with the steel pipes, the polyethylene pipes have a low resistance to hydraulic pressure, they do not sweat, or require any grounding or insulation.

32. Controlling the quality and assembly of pipes /84

All pipes after assembly must pass the quality control tests. Formen and shop heads must check the quality of production and treatment of pipes. Pipes intended for steam and outside water must be subjected to checking by representatives of the Quality Control Department (QCD). First of all the external appearance of each pipe is checked. Cracks, ruptures, blisters, pits, rolling laps and other defects should be absent on the pipe surface.

The external pipe surface is checked by a naked eye, or with 5-10 magnifying glass for critical pipes (main and auxiliary steam lines). A low-voltage lamp, mirror or a periscope is used for checking the internal pipe surface, both of straight and bent segments. After the external checking, the pipe configuration is compared with the blueprint dimensions or with a standard.

Deviation from sizes indicated on blueprints should be not more that ± 3 mm for straight segments and ± 10 mm for bent sections with a diameter of up to 100 mm and ± 15 mm for pipes not exceeding 100 mm in diameter. The flanges planes should not deviate more than ± 0.5 mm with respect to a plate parallel to it. Side arms should not deviate by more than ± 10 mm with respec to the pipe length and not more than ± 3 mm with respect to the side arm length. Pipe connections and side arms should not deviate by more than ± 1 mm with respect to the inclination angle to a pipe for up to 100 mm of side arms and not more than ± 5 mm for side arms exceeding 100 in diam. Accuracy in bending works should agree with the standard requirements.

33. Hydraulic shop testing of pipes and their markings

The hydraulic testing of pipes is needed to check the quality of /85 welded elements to pipes (connections, side arms, flanges, lugs, etc.) and bent sections. For this purpose, ends of pies and side arms are closed with plugs and water is supplied through one opening. The air is released from pipes by means of valves in plugs. The pressure produced by a pump is measured by a manometer attached to a pipeline or to a pump.

Good quality pipes should withstand the test pressure which could vary from 1.5 to 2.5 of operating pressure, depending on the pipeline purpose.

One or several test stands are installed in a shop, with all necessary equipment for testing (Figure 67).

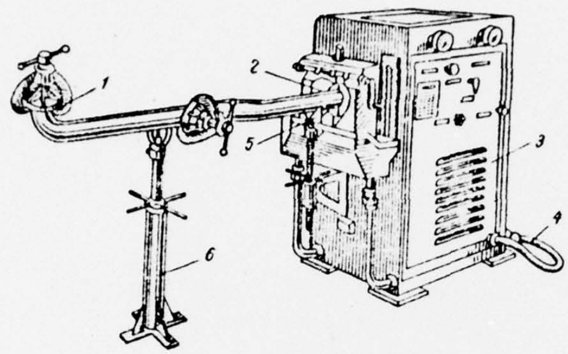

Figure 67. Stand for hydraulic testing of pipes

A pipe is inserted into the opening (5) and supported by the adjustable stand (6). The hydraulic lock (2) clamps the pipe end, while all other pipe opening are closed by plugs (1). The water is supplied by the hose (4) and the necessary pressure is maintained by a pump located inside of the stand body (3).

In order to accelerate the testing procedures, different devices and approaches are used. For example, manual pumps are substituted with a pneumatic attachment; plugs with grips are used. Collets are used for pipes without flanges, etc.

The hydraulic tests are used to check the strength of pipes and their watertightness. In those cases when these tests are insufficient, pipes and fixtures are subjected to vacuum helium testing. There are different approaches how to conduct the tests with the use of helium.

All pipes must be marked before they are delivered to a shipyard or to a warehouse.

Chapter 7. WELDING OF PIPES

34. Welding methods, weld joints and welding materials

All permanent connections in a pipeline are completed with the electric arc, using consumable or nonconsumable electrodes. In some instance the resistance welding is used. The gas welding is use only for pipes of small diameter (less than 26 mm) and for accessories made of sheet metal not exceeding 2mm in thickness (air-conditioning ducts). /86

The gas welding permits to control the amount of heat supplied to the base metal, weld bath and filler metal. Therefore, it is easier to avoid burns with the gas welding of thin metal pieces, as compared with the electric arc welding. On the other hand, the quality of the weld metal is very often unsatisfactory because of overheating and oxidation.

Advantages of the electric arc welding are attributed to a high labor productivity, easiness in controlling the metal overheating, high mechanical properties of weld metal and the possibility to mechanize the welding process.

The essence of these methods of welding are presented in the book entitle "Welding in Shipbuilding" and are not given in this book.

While designing pipelines and assigning industrial processes with which it should be constructed, preference should be given to the automatic welding. And in case of its complexity, to semiautomatic, i.e., manual /87 mechanized in shielding gases .

According to existing requirements, the use of manual welding of pipelines on ships is permitted only in individual cases.

The relative cost of welding during construction of metal structures follows the ratio 4:2:1 (manual with electrodes UONI 13/45, semiautomatic in CO_2 and automatic with flux). This ratio can not be justified with respect to pipelines on ships. A length of weld joints in this case is small, preparation of edges and joints varies for the same pipeline, and much of the time is spent for preparatory works than for actual welding. Therefore, a comparative effectiveness of mechanized processes is somewhat lower on ships in comparison with welding of hulls, for example. Nevertheless, the use of mechanized welding of pipelines on ships is highly desirable.

Several welding machines are designed for the automatic welding of pipelines, such as the universal machine UAST 70-114 for welding in shielding gases of immovable butt joints 50-114 mm in diam.; machines for welding of flanges, sleeves and accessories.

The resistance welding of pipes and flanges could also be effective in shipbuilding because it requires little time and does not require expensive equipment. Table 14 presents welding conditions and the time requirements for steel pipes with falnges. /87

Table 14. Welding conditions and the time required to weld steel pipes with flanges

Pipe size, mm		Welding in CO_2			Manual welding with clad electrodes			Automatic submerged arc welding		
O. D.	Wall thickness	Current, A	Electrode diam., mm	Time per piece, min	Current, A	Electrode diam., mm	Time per piece, min	Current, A	Electrode diam., mm	Time per piece, min
22	2	80	0.8	0.74	100	3	0.71	-	-	-
70	3	100	1	2.08	100	3	1.99	260	2	0.95
125	6	125	1.0	4.03	150	4	3.33	280	2	1.63

*Welding is completed in two passes

/88

It is not recommended to use soldered joints in pipelines because of their low strength and low resistance to corrosion. Soldering is used only for brass parts and copper pipes which do not transport water.

Shape and sizes of prepared edges and of completed joints are determined by standards. There are two standards, one for steel pipes and another for copper and copper alloy pipes. Butt welding is the most commonly used type of joining pipes (Figure 68a). Depending on the thickness of pieces to be joined, edges could be prepared without bevelling, with bevelling of both edges, square edges, etc.

Pipes can be welded on one side, with or without backing rings. If accessible, two side butt welding is performed. Two-sided butt welding with a backing run is recommended for steel flanges attached to pipes, provided the length of the flange is equal or less than its I. D.

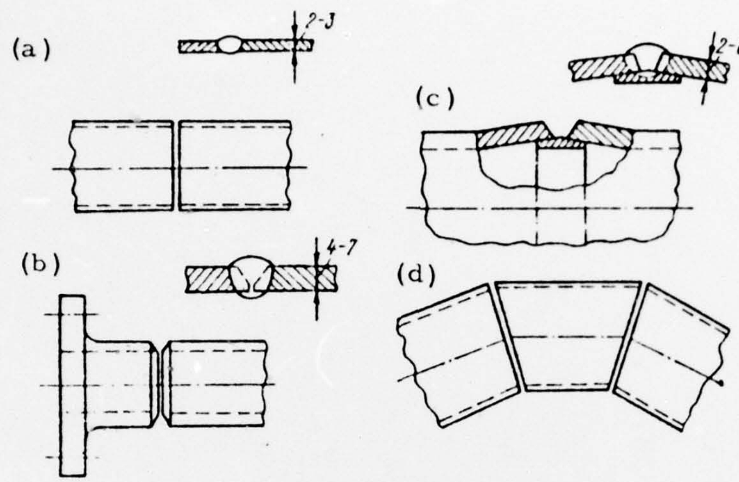

Figure 68. Butt joints of steel pipes:
(a) - pipe with another pipe;
(b) - pipe with a flange;
(c) - two pipes with backing ring;
(d) - knee segments.

The backing removable rings prevent molten metal to leak into a pipe. They could be made either of copper for steel pipes for a fast dissipation of heat, or of the same metal as pipes. After welding these rings are removed by griding. /89

Permanent rings are made of the same metal as pipes and the edges where the ring is located are expanded (Figure 68d).

A good quality butt joints require a careful fitting of pipe ends and observation of required clearances with an accuracy up to 0. 5 mm. Fusible inserts are also used in butt joints. These joints cost more but they allow freedom in dealing with clearances.

The fitting of pieces can be simplified by using lap butt welding or applying external sleeves. The overlapping welds are less reliable than the butt welds because of a possible corrosion of pipe surfaces in the place of overlapping.

In many instances flanges, sleeves and side arms are welded to pipes at angles (Figure 69). Weld joints in these cases could be two-sided if access is provided from the other side of the joint. The type of joints is dictated by a wall thickness and the diamter of pipes, as well as by material, welding method and welding conditions. For example, the down-hand welding can be performed if a pipe can be rotated; in other instances the source of heat is rotated (Figure 70).

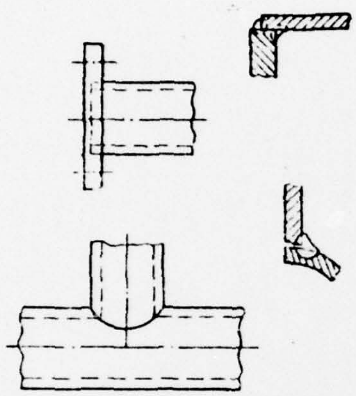

Figure 69. Angular joints of pipes with flanges (a) and pipes with side arms (b)

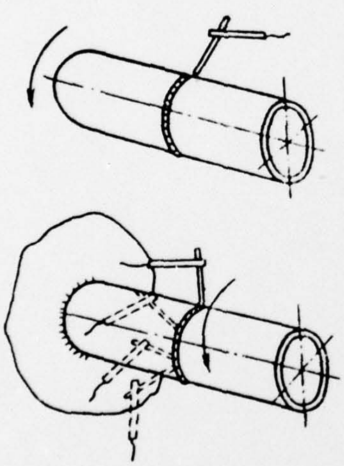

Figure 70. Butt welds when a pipe is rotated (a) and the source of heat (b).

Acetylene-oxygen mixture is used for gas welding of pipelines. This type of welding allows to control the welding flame by a set of nuzzles, depending of the material thickness.

Soldering of pipes can also use the acetylene-oxygen mixture as a source of heat, with the use of different fluxes for wetting the edges.

A sample welding by the continuous flash-off method on stationary machines is desirable only when a large quantitites of pipes not less than /90 14 mm in diam. and wall thickness exceeding 2 mm are to be welded.

While designing pipelines, a minimum number of assembly joints should be planned. Weld joints should be located in accessible places. Depending on the distance A to the deckhead (above the assemble joint) the following distances to other structures on ships are established (mm):

	$A < 150$	$A < 500$
to bulkheads	100	100
to the deck below	300	120
to the board	150	120

The composition and properties of weld joints are influences by the welding gaseous media. Therefore, it is recommended to use CO_2 during semiautomatic and automatic welding of pipes of low carbon steel. Among filler wires, best results produce Sv082S and Sv08G2S (silicon-manganese) wire (GOST 2246 - 70). Pipes of alloyed steels 12MKh and 15KhM is better to weld by a manual arc welding, with UONI 13/45MKh electrodes. The semiautomatic welding of copper and copper-nickel pipes should be conducted with consumable electrodes in nitrogen or argon. The labor productivity is higher when nitrogen is used and the gas cost much less. The bronze wire BrKMts 3-1 (GOST 5222 - 50) and SvMNZhKT 5-1-0.2-0.2 is used as filler for copper (M3S) and copper-nickel pipes, respectively.

The manual gas-electric welding of copper, copper-nickel and /91 alloyed steel pipes is carried out in argon, using nonconsumable tungsten electrodes. When many identical joints are welded, the use of special machines is warranted.

35. Welding Technology and Quality Control of Weld Jonts

The welding technology of pipelines is conducted according to rules and orders accepted at a given branch of industry, type of weld joints and welding conditions. Among welding conditions, horizontal or vertical welding in a shop or outside, etc. must be considered.

After fitting, pipeline elements must be tack-welded with the same material as the base metal. /91

Movable joints, as well as other elements are welded to pipes in a downhand position by the semiautomatic welding in shielding gases. A special stand is recommended for angle joints of flanges under shop conditions. This stand consists of a table with necessary fixing devices. The table is rotated usually and a welder remains at one spot while performing the welding.

When a manual or semiautomatic welding is used for pipes less than 100 mm in diam., the flanges are attached usually to pipes by a double joint completed during two opposing passages. The first run is made from inside, the second from outside (Figure 71a).

Pipes of alloyed steels are preliminarily heated before welding up to 200-300°C, as is the case for 12MKh and 15KhM steels. The entire joint perimetry is heated either by gas or electricity.

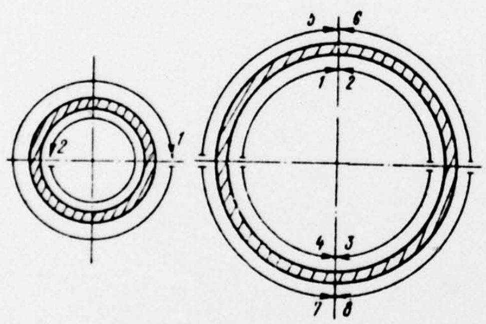

Figure 71. Welding sequences of the butt joints (marked by numbers).
(a) - pipes up to 100 mm and less;
(b) - large diam. pipes.

Weld joints of critical pipelines (steam) of 15KhM and 12KhMF steels must be tempered at 720-750°C for 5-6 min. per each mm of the /92 wall thickness. The tempering should be accomplished by an electrical heating coil wound around the joint, while the pipe at 70 - 80 mm from the joint on both sides be plugged.

The austenite stainless steel, such as 0Kh18N10G and others, should be used in pipelines on ships conducting aggressive media. Main difficulties in welding stainless steel pipes is the avoidance of crystallization cracks and elimination of the tendency to intercrystalline corrosion during operation. This can be accomplished by following strictly the welding conditions and by letting the joints to cool at a definite rate. Of importance also is the use of a special high-alloyed welding wire, special welding machines, fluxes and nonconsumable electrodes. /92

Copper pipes with the wall thickness exceeding 4 mm are welded manually, with a preliminary heating of pipes up to 300-500°C.

When welding copper, copper-nickel and steel pipes without any backings, shielding gases are used for protection of internal surfaces (nitrogen or argon for copper and copper alloys; carbon dioxide for steel pipes). In order to save the shielding gas, pipes are plugged at a certain distance from a weld joint. If rubber plugs are used, a gas-supplying tube passes through them.

Strict requirements are applied to pipelines on ships. The USSR ship building industry has its own rules and standards according to which the quality control of pipelines consists of a preliminary checking, after completion of each weld and overall checking of a completed structure.

The preliminary checking includes the quality control of pipes, pipe elements, fixtures, welding equipment and material, qualification of welders and certification procedures by process engineers.

The past-operation control includes the checking of edges, fitting of individual pieces, welding conditions and the quality of a completed joint. The quality of weld joints is checked visually, by measuring the /93
weld dimensions, for tightness by hydraulic and air pressure, for leakage with helium or halides and by penetrating radiation.

The volume of control and requirements are determined by types of pipelines, transporting media, operation pressure, etc.

Weld joints of the most critical pipelines are checked by R- or γ-rays. To critical lines belong steam pipes operating at 1.0 MN/m^2 (10 kg/cm^2) pressure and higher at temperature exceeding 250°C, as well as pipelines operating at pressures exceeding 1.6 MN/m^2 (16 kg/cm^2) and steam pilelines of alloyed steels. If pipelines are required to be resistant to corrosion, each weld joint is tested for intercrystalline corrosion. This test is accomplished with hot aggressive fluids, followed by bending, flattening and tension. Defective section are removed and replaced by new sections which are also tested for quality .

A three-point scale is used for the quality evaluation of weld joints /93 by penetrating radiation. For steel pipes those are only accepted that received 3 points evaluation. Copper and copper-nickel pipes with 2 point can also be used. Points are determined by sizes and number of defects shown on x-ray plate. For example, 3 points are assigned only to those steep pipes 35 mm in diam. that do not contain pores and slag inclusions exceeding 1.5 mm in size. For pipes larger than 35 mm in diam., inclusions up to 3 mm are permitted. Engineering specifications at each given plant or organization indicate standards and norms for steeland copper pipes differing in sizes and wall thicknesses.

38. Protection of pipes against corrosion /102

The protection of pipes against corrosion is one of the most important factors and this is done by the following methods.

Zinc-plating of pipes. Zinc coatings adhere well to steel /103 pipes and have a negative electrode potential with respect to steel. They protect steel pipes not only from mechanical but also from electrochemical corrosion. Application of zinc-plated pipes in shipbuilding is limited because they require a secondary zinc-plating after flanges and other fixtures are welded to them.

Steel pipes for shipbuilding are zinc-plated by one of the following three methods: (a) hot plating that includes dipping of pipes into molten zinc; (b) hot with ensuing heat treatment; and (c) thermal diffusion of zinc from a powdery mixture during a long heating. According to Figure 80 it follows that coating deposited during the dipping of pipes into molten zinc wear off much faster in comparison with those deposited during the thermal diffusion. However, the thermal diffusion method is not used very often in shipbuilding because of a long heating time(10-18 hr), labor-consuming (loading of pipes with a powdery mixture, unloading, etc.), complexity of mechanization tasks, and health hazards. The hot zinc-plating with ensuing heat treatment is the most often method used for steel pipe zinc coating. The strength of coatings obtained in this way approaches that of the thermal diffusion method (Figure 80a).

Regardless of the method of zinc plating, the most intensive corrosion of plated pipes takes place during the initial operation (Figure 80a).

It amounts to 60-70 µm for the hot zinc-plated pipes and to 25-30 µm for hot plated and heat treated pipes during the first 1000 hr of operation. Afte this time the wear of zinc coatings stabilizes. /103

The service life of hot zinc-plated and thermally treated pipes with 120 µm zinc coatings amounts to 3-4 and 9-13 years, respectively.

Different sea water flow influences differently the rate of corrosion (Figure 80b).

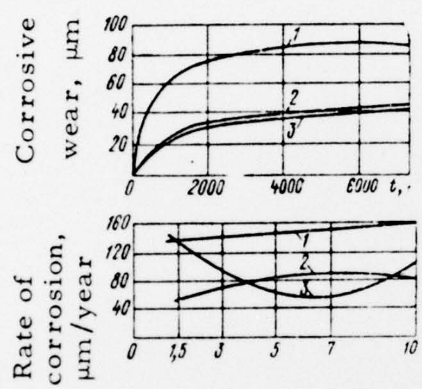

Figure 80. Effect of the methods of zinc plating on corrosion stability of zinc-plated pipes.
(a) corrosion wear as a function of time;
(b) rate of corrosion as a function of the sea water flow (for tests lasting 4,000 hr).
1 - hot zinc-plating; 2 - hot plating with heat treatment; 3 - thermodiffusion plating.

Table 16 presents thicknesses of the zinc coatings and the methods of zinc plating in line with operation requirements of pipes. /104

To avoid damaging the protective coating, only fully assembled and tested pipes according to OTK standards are subjected to zinc plating. The number of bends should be not more than three and they must be located within only two planes. A maximum bending angle shoul not exceed 90°, with the pipe internal diameter not less than 15 mm. Table 17 presents the sequence of the zinc plating processes of pipes by the methods mentioned before.

Pipes zinc plated by the hot method in horizontal tubs are subjected to a double fluxing. The first fluxing with a slightly dried flux is carried out not later that 10-15 min. after pickling by dipping the pipes into a tub with a solutions of zinc salts. This operation produces a solid crystalline flux film on a pipe surface. The second fluxing is applied simultaneously with dipping the pipes into a tub containing zinc salts on the surface of molten zinc.

Table 16. Methods of zinc plating and thickness of zinc coatings /104

Operation conditions of pipes	Pipes	Method of zinc plating		
		Hot	Hot with heat treatment	Thermo-diffusive
Very rigit (VR)	For cold and hot sea water for continuous operation	200-300 μm	–	120-200 μm
Rigit (R)	For a periodic transportation of cold sea water, or for continuous transportation of cold fresh water	120-150 μm	120-150 μm	100-120 μm
Average (A)	For a periodic transportation of fresh water on internal water ships	100-120 μm	100-120 μm	100-120 μm
Light (L)	For non-water carrying systems	100-110 μm	100-110 μm	-

Note. The hot zinc plating with heat treatment is recommended vertical tubs in which a uniform coating more than 100-120 mm thick is difficult to obtain

For pipes subjected to zinc plating in vertical tubs, only the first type of fluxing is applied.

The hot zinc plating is accomplished by dipping the pipes into molten zinc containing 0.04-0.06% aluminum. The latter is necessary for preventing the zinc against burning and for better quality of zinc plating. /105 Depending on the zinc coating thickness, the temperature of the molten zinc should be kept at 490-500°C and the pipes are dipped into it for 10-15 min. After this time they are removed from the zinc plating tub and cooled in air.

Pipes for the thermodiffusive zinc plating are washed after scouring, dried and loaded with a charge containing 80% of zinc powder and 20% of finely ground quartz. The latter prevents the zinc from melting and sintering. If only the internal surface of pipes is zinc plated, both ends of each

Table 17. Sequence of the zinc plating industrial processes /105

Method of zinc plating	Sequence of operations
Thermodif-fusive	↑ - D-LP-Z_{td}-C_c-C_r-B_a-C_{zp}
Hot	D - R_h - C_d - P - R_c - B_a -
Hot plus heat treat-ment	-S_b- B_a - C_{cl} - Sc - R_c —— - F-D-C_f-Z_h-C_c-C_{zp} → -H_t-C_c

Designations: Sc - scouring

S_b - shot blasting

C_d, C_{cl}, C_{zp}, C_f - quality control of degreasing, cleaning, zinc plating and fluxing, respectively

LP - loading of pipes with a charge and placing of them in a steel cage

D - chemical degreasing

B_a - blowing with air

C_c - cooling

R_h, R_c - rinsing with hot (70-80°C) and cold water, respectively

D - drying

P - pickling

H_t - heat treatment

C_r - charge removal

F - fluxing

Z_h, Z_{td} - hot and thermodiffusive zinc plating, respectively

Note. Threads on pipes are protected before scouring

pipe are plugged and pipes are placed in furnaces. When two-sided coating is needed, pipes are places in a steel box covered with charge of the same composition, covered with asbestos sheets and closed with a cover. Clearances between the cover and the box are filled with fire clay and asbestos and pipes are placed into furnaces. /105

The thermodiffusive zinc plating lasts 10-18 hr at 480-500°C. After cooling, the charge is removed from pipes, air is blown into each pipe for a complete removal of the charge and the quality of the coating is checked. /106

The zinc coatings are checked by a visual examination of each pipe. The adhesion of the zinc coating to the pipe material is checked by knocking the pipes with a wooden hammer (up to 1 kg in wt.) two or three times to see if the coating can be separated from the base material. The coating on each pipe is checked for thickness.

Enameling the pipes. Enamel coatings on pipes are highly resistant to corrosion at room and high temperatures. Enameled pipes have been sufficiently tested on ships under operation conditions.

Enamel is an inorganic glass type substance which is deposited on pipes in a liquid form (the slip) and which forms a strong and thin coating.

Pipes with $D \geq 32$ mm which are bent at not more than 90°C in not more than two planes can be enameled. Their rounding radius at joints should be not less than 4 mm. The pipes are subjected to enameling in the following sequence: thermal or chemical degreasing → pickling → rinsing → neutralization → drying → enameling → drying of the deposited enamel → → firing of the enamel → quality control.

Enamaling of the internal pipe surface is done after drying by filling the pipe with a slip from the upper end, or though a hose in a plug. The external pipe surface is enameled with a sprayer. A special unit is used for a mechanized enameling of both surfaces.

The enamel coating is fired at 810-840°C for 10-15 min. in furnaces. High frequency current can be used for firing the coatings on straight pipes.

The enameled pipes cost 20-25% more than the hot zinc plated pipes. However, their service life could be 2-3 times longer.

Application of lined pipes. Steel or aluminum pipes lined with polyethylene combine a high corrosion resistance of polyethylene with a high strength of metal. The lined pipes can operate in aggressive media at high pressures and temperatures (in comparison with polyethylene pipes).

The lining of metal pipes is accomplished by two methods:

(1) With stressed polyethylene pipes which are strained by heating during a highly elastic state, followed by an intensive cooling without removing the deforming load and internal stresses ("freezing" of stresses). The second stage includes the lining process during which the polyethylene pipe is inserted into the metal pipe, with a small clearance between them. This is followed by a heating to a temperature slightly exceeding that at which the state of stress was created in the polyethylene pipe. During this heating the stressed pipe resumes its initial dimensions ("thawing" of stresses) and tightly adheres to the internal surface of the metal pipe. The cooling is accomplished in air.

(2) By a simultaneous drawing of the metal and plastic pipe. In this case the inserted plastic pipe must be smaller that the metal by 2-3 mm (Figure 81).

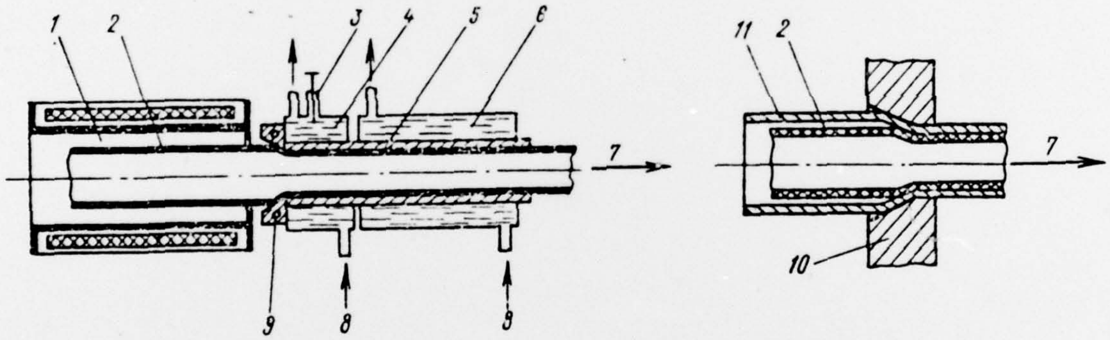

Figure 81. Lining of pipes with polyethylene: (a) stressing of the polyethylene pipe; (b) lining by a simultaneous drawing of both pipes.
1 - furnace; 2 - polyethylene pipe; 3 - heat control; 4 - preliminary cooling chamber; 5 - metal pipe with a calibrating bell;
6 - intensive cooling chamber; 7 - direction of pulling forces;
8 - cooling water; 9 - bell heating; 10 - drawing ring;
11 - metal pipe.

The steel polyethylene lined pipes can be used in media which do not destroy the polyethylene at 1.6 MN/m^2 pressure (16 kg/cm^2) and up to $60^{\circ}C$. The aluminum lined pipes, at 1.0 MH/m^2 (10 kg/cm^2) and up to $60^{\circ}C$.

The lined pipes are joined by flanges (Figure 82) or sleeves along beads. Joining of these pipes is carried out on the PG-50 press equipped with special punches. /108

Disadvantages of the lined pipes include the use of specially shaped fixtures that require many joints and the exclusion of welding of these pipes.

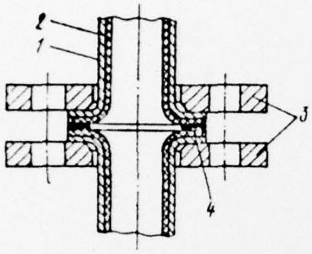

Figure 82. Flange joining of lined pipes.
1 - metal shell; 2 - lining polyethylene layer;
3 - flanges; 4 - gasket.

The operational reliability of lined pipes is considerably higher in comparison with steel zinc plated, copper and copper-nickel pipes. The rate of a fluid flow in lined pipes is also much higher. In addition, lined pipes cost less; they are lighter by ~33% (steel) and ~62% (aluminum) in comparison with the copper-nickel pipes.

Coating-forming polymeric compounds contain resins (perchlorovinyl PSKh-S, epoxy ED-5, ED-6), fillers (iron oxide or aluminum powder), plasticizers and solvents. There are several coating compounds that have shown good experimental results. Prior to coating, pipes are cleaned from grease, scale and rust. Internal coatings are produced by filling the pipes with a suitable composition, and external by a brush. Each coating is subjected to drying at 15-20°C for 2 hr and heat treatment for 2-4 hr at 45-60°C. A minimal number of coatings to seal all possible pores is 3, and the optimal coating thickness is 300-400 μm. Pipes must not be assembled for al least three days after coating treatment. Coated pipes can be used at 60°C (sometimes at 80-100°C), provided their diam. is within 40-400 mm. The permissible rate of fluid flow through these pipes can be up to 7 m/sec.

Steam oxidation of pipes. Oxidation is used for protection of aluminum pipes of all sizes against corrosion in fresh waters. Oxidation is carried out after all other production operations of pipes are finished.

The oxidation process starts with a chemical cleaning which is conducted in the following sequence: /109

degreasing
rinsing in hot water
dipping in a bath containing nitric acid solution
rinsing in cold water
drying with compressed air
quality control.

The oxidation of pipes after cleaning is carried out on a steam stand by passing the steam through each pipe, or it can be accomplished in autoclave where both pipe sides can be oxidized simultaneously.

The aluminum oxide film, $Al_2O_3 \cdot H_2O$, is formed according to formula

$$2Al + 4H_2O \rightarrow Al_2O_3 \cdot H_2O + 3H_2.$$

The formed oxide film is 100 times thicker than the natural aluminum oxide film, and its resistance to corrosion is 10-14 times higher.

44. Testing of assembled systems and acceptance of assembled units on ships /123

The hydraulic testing of systems and pipelines for leakage is carried out after assembly and approval by the quality control section according to blueprints and acceptable specifications.

The hydraulic testing for leakage includes tests of joints, pipe sections and the whole pipeline. Individual pipe sections can be isolated by closing the end fittings located directly at apparatus, devices, or by disconecting at some joints and plugging the pipe ends. If fittings are not designed to be tested by pressure, they are disconnected and openings are plugged. /124

The feed water for hydraulic testing fills the pipe through outlets or pipe connections of small diameter which are located in the center of the section or pipeline to be tested. Faucets and valves in a pipeline should be open during tests for the air escape.

/124

The pressure in a pipeline must be increased gradually with manual portable and pneumatic pumps. A desirable pressure must be kept as long as it takes to check all joints, but not less than 10 min. Upon detecting leaking joints, they are tightened and defective joints are replaced and tested again.

After hydraulic testing and removal of water, pipelines are blown with a compressed air. For testing pipelines designed to carry other liquids than water, an appropriate liquid is used during testing procedures. Systems designated to carry a compressed air can be tested by the air under suitable pressure but only after hydraulic testing and when all leakages are fixed.

When testing with a compressed air of systems of high and average pressure, the pressure in pipelines is achived gradually, with 0.5-1.5 MN/m^2 (5-15 kg/cm^2) increments, with intervals between each pressure of not less than 10 min. Upon detection of a leakage, a further increase in pressure is resumed after fixing the faulty joint.

Any leakages are repaired only after releasing the pressure in pipes. The final tests of leaking joints after their repair should be conducted with the use of a soap lather while maintaining the test pressure for 1 hr.

Table 20 presents test pressures for different pipelines.

After testing pipelines for leakages, experimental runs are performed during mooring and sailing of ships. At this time, pipelines are tested together with all units and devices attached to them (pumps, apparatus, etc.) which serve a given system (boilers, engines, heat eachanges).

During a trial testing the performance of the following units is checked: (a) safety valves for maintaining the necessary pressure; /126
(b) safety valves which should open when the prescribed pressure exceeds by not more than 10%; (c) shut-off valves; (d) measuring and controlling devices; (e) back-up switching and pumping units; and (f) insulation of pipelines and reliability of current-conducting lines.

Tests performed during the mooring period include checking the completeness of other ship's equipment.

Pipelines which do not influence the ship performance in sea (speaking tube, scupper pipe, sewage pipe, etc.) are checked during the mooring time. Pipelines serving the power units are tested together with power installations. Many pipelines (for oil, fuel, cooling, exhaust, etc) and pipe systems (for loading of a liquid cargo while sailing, etc) are tested under different conditions while sailing in addition to tests performed during the mooring. /126

Trial tests of pipelines and pipe systems are performed before they are painted and insulated.

Table 20. Standards for hydraulic pressure tests

/125

Pipelines and pipe systems	Trial hydraulic pressure MN/m^2 (kg/cm^2)	
	Ships built aacoding to the Sea Register of the USSR	Ships built according to the River Register of the USSR
Pipelines for fresh steam and compressed air	1. 5p+0. 35 (3. 5)	
For exhaust steam, steam heating, fresh water, pumping, heating of tanks	1.25p 2p	2p, but not more than 0. 8 (8.0)
Systems: sanitary, drinking water, outside water, bilge-pumping, drainage, heeling, trim, ballast, flooding, circulatory for main and auxiliary condensers, for cooling fresh and outside waters, condensate-feeding, fuel filling	1.25p	
Systems: deck-drain and scupper fuel under pressure; gas-freeing and measuring	by filling 2p Together with tanks	not less than 0. 2 (2.0)
Pipelines: gasoline and kerosene filling and pumping; pumping under pressure; circulation exhaust	2p 0.40 (4.0) 1.25p at least 2p operational	0. 6 (6.0) 2p 2p 0. 4 (4.0)
Air pipelines, $7MN/m^2$ ($70\ kg/cm^2$) and lower	p + 7.0 (70), then with 1p of air	
" "	2p, at least 1 (10), then with 1 p air	
Manometer tubes extended to other rooms	1.25p or 1p with a medium	
Local manometer tubes	Under actual operation	

p designates the pipeline operation pressure