Flange consolidation for ultrahigh vacuum systems used in the temperature range 1.5-600K

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Analyses the shortcomings of flange consolidations type "Conflate", which is not always appear tight in the field of ultrahigh vacuum, especially after their warming-up to 600K, and also cooling from room temperature to temperatures of liquid nitrogen and helium.

Designs of flanges are shown with metal consolidation from O.D. 10 to O.D. 700, developed in the laboratory are made of stainless steel and titanium are used in warming up to 600K ultrahigh vacuum chambers with working pressure up to 10^{-10} Pa and in ultrahigh vacuum cryogenic pumps and cryostats, cooled by liquid N_2 and He.

Experience of laboratory using flange consolidations under the international standard type "Conflate" has revealed some lacks of their work, especially in warmed up ultra high vacuum chambers at achievement in them pressure 10^{-8} – 10^{-10} Pa. In the majority of them through 2–4 cycles of warming up to 300°C and cooling to room temperature appears leakage which does not manage to be eliminated by additional squeezing. This analysis has shown their disadvantages (Fig. 1):

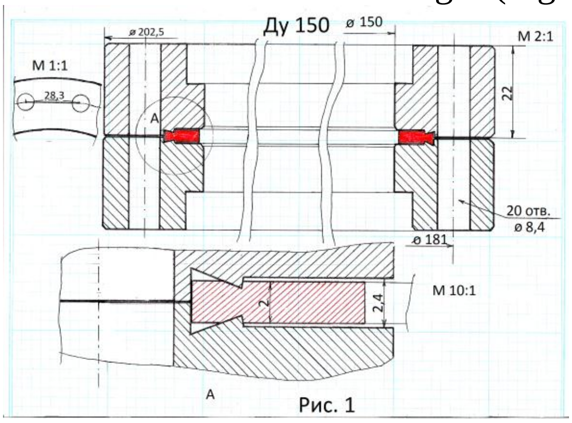

Fig. 1

1. The thickness of a copper lining (gasket) equal under the standard of 2 mm (according to some information 2,2 mm) obviously is not enough. At compression of flanges to full contact of their parts (under the standard) it is impossible to make additional squeeze pair of flanges. Besides thus the lining is suitable only for disposable use. Sometimes these lacks were partially eliminated by using of linings with thickness from 2,5 to 3 mm.

2. Because of the construction of flanges condensing part in the form of inclined at an angle 20° tooth planes occurs insufficiently strong squeezing linings, and its surface at warming up is sometimes loosened, as though "floating" on a plane of tooth towards smaller squeezing.

3. Distances from a plane of a flange to an edge of tooth and from it to a plane at the basis of tooth, which under the standard are equal 0,6 mm, at a thickness of a lining of 2 mm appear insufficient. At full contact of planes of flanges around condensing spikes with screw nuts it is formed almost full contact of the planes of an internal part of a copper lining to a flange plane. It leads to occurrence of extended flat capillary space by thickness of 0,2-0,1 mm and more thin, which essentially increases time of achievement of limiting pressure after warming up. Then we have increased this size to 1 – 1,2 mm in place of 0,6 mm.

4. Experience of using flange consolidations type "Conflate" at their cooling to temperatures liquid N_2 and He also has shown their leakage. Especially it was appreciable at temperatures of liquid helium, when the ultrahigh vacuum should be supported outside, and liquid helium should be inside, or on the contrary as it is necessary in some cry pumps or cryostats constructions.

For elimination this specified lacks in our laboratory about 30 years ago have been developed, tested and started flange connections with metal consolidation with trapezoid form of condensing tooth (Fig. 2).

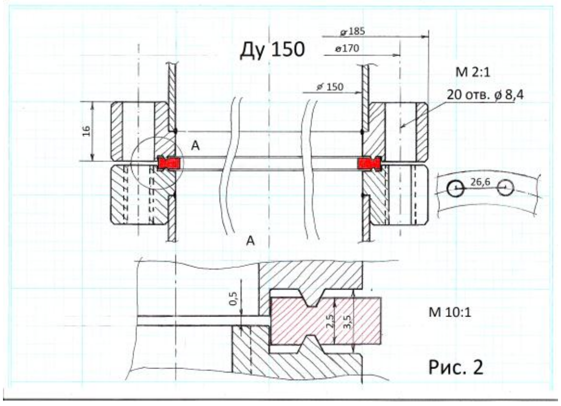

Fig. 2

In all developed flange consolidations from O.D.10 to O.D.700 condensing tooth in section represents a trapeze with 1 mm height, with width of the smaller (condensing) part 0,5 mm and width of the basis 1,5 mm.

The distance from external edge of a condensing plane of tooth to the surface of a flange covering an external part of a copper lining, in flanges O.D.10 and O.D.16 which spikes M4, and also in flanges of O.D.40 with spikes M6, is accepted 1,0 mm. In flanges from O.D.63 to O.D.250 with spikes M8, and from O.D.400 to O.D.700 with spikes M10, this size is 1,5 mm.

As a condensing element for flanges is used copper lining with thickness from 2,5 to 3 mm depending on O.D.. Distance from a condensing plane of tooth to an internal horizontal surface of a flange from O.D.10 to O.D.700 of mm is 1 mm.

Advantages of the developed type of flange consolidations in compare with "Conflate" have appeared in the following (Fig. 3):

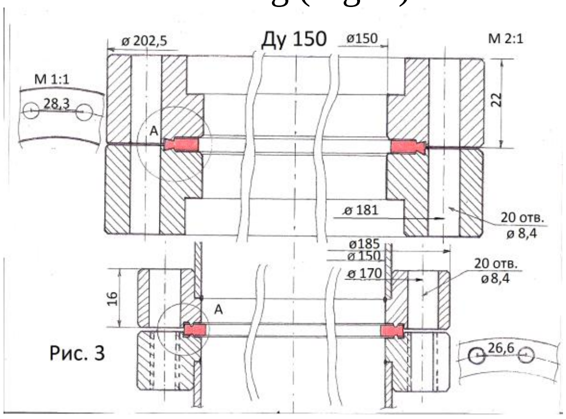

Fig. 3

1. The horizontal and parallel arrangement of condensing planes of teethes, and also their small width (0,5 mm) gives the chance to create stronger specific pressure upon unit of the area of a condensing surface. It is necessary to notice that during tests after check of the condensed pair of flanges using leak detector, warming up and repeated tightness check, at their disengagement it has appeared that on surfaces of horizontal parts of condensed teethes there are hardly appreciable traces from a copper lining. It possibly can be depend on that pressure upon lining planes was such strong that has occurred

some kind of cold welding between planes of teethes and linings. Apparently, in place of consolidation of teethes the lining material during squeezing "floats" basically in its volume part, and its planes, contacting to surfaces of teethes with width 0,5 mm, practically do not move in a horizontal direction. And it promotes reliable consolidation of flanges at higher specific pressure upon lining surfaces.

2. Tooth height in 1 mm, thickness of a lining in 2,5 mm and more, and also distance from a plane of tooth to an external plane of a flange 0,5 mm, first, give the chance more deep and stronger squeezing of a lining, secondly, to use a lining 2 - 4 times, and, thirdly, to increase a capillary backlash between a plane of a lining of its internal part and a plane of a flange up to 0,5 - 0,3 mm.

3. Besides, at same O.D. of a flange (for example, O.D.150, as it is shown on Fig. 3) it is possible to reduce essentially external diameter of flanges to 185 mm instead of 202,5 as "Conflate" has, a thickness - to 16 mm instead of 22 mm, and also to reduce diameter of apertures to 170 mm instead of 181 mm. So it gives the ability with the same quantity of apertures under spikes (20 pieces) to reduce distances between apertures centre to 26,6 mm instead of 28,3 mm, and to increase specific pressure upon a lining at tightening of flanges.

On Fig. 4 the flange O.D. 630 with trapezoid form of condensing tooth is shown. It has external diameter 690 mm, internal – 630 mm, and has 60 carving apertures M10. On Fig. 5 is shown the part of this flange in an enlarged view where the width of a condensing part of tooth is 0,5 mm and distance from its external edge to a plane to which the external part of a copper lining – 1,5 mm adjoins.

Fig. 4

Fig. 5

The flange is made with titanium mark BT-1 and has been made for ultra high vacuum cryogenic pump cooled by liquid helium, with pumping out speed 10 m^3 per sec, shown on Fig. 6. One pump of this construction has been given about 20 years ago to the «State Space Research-and-Production Centre of a name of M.V. Hrunichev» in Khimki, Moscow Region, for pumping out the space simulator chamber in volume nearby 200 $м^3$. The second pump has been started 2 years ago in branch of State National Scientific Research Institute "Kometa" in St. Petersburg for pumping out the chamber in volume nearby 60 $м^3$, intended for optical systems tests, intended for work in space.

Fig. 6

On Fig. 7 is shown in an enlarged view the pipe with a flange made with stainless steel, connected to a titanium cover of the pump body. The thin-walled corrosion-proof tube on which the vessel for liquid helium hangs is welded on the top part of this pipe.

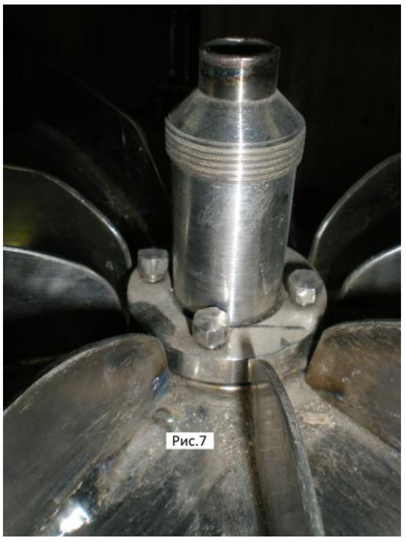

Fig. 7

On Fig. 8 the drawing of the specified connection is resulted. It is necessary to notice that consolidations of pair flanges from titanium and stainless steel remain tight not only at room, but also at low temperature when vessel filling with liquid helium and subsequent exit of its steams is made.

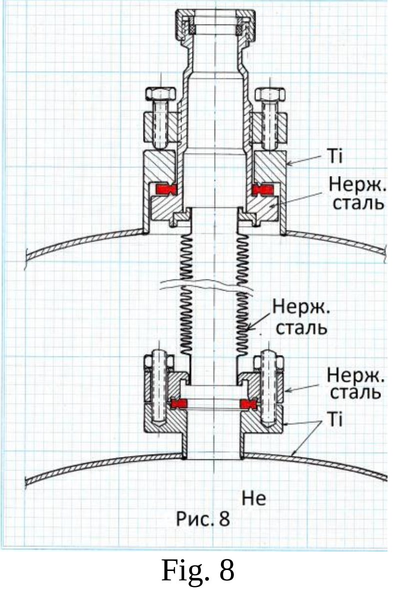

Fig. 8

On Fig. 9 is shown in an enlarged view the cryogenic pump, cooled by liquid helium, made completely non-magnetic from titanium and copper, for carrying out precision experiments.

Fig. 9

On Fig. 10 is shown the top part of this pump with folding pipes for pouring of liquid nitrogen and helium. The pump has speed of pumping out about 700 litres per sec, limited pressure 10^{-11} Pa and a resource of continuous work up to 3,5 months after unitary pouring of liquid helium in amount 8 litres. Similar pumps in the nineties have been sold to Japan (4 pieces) to the electronic accelerator in Ttsukuba, and Germany in Universities of Berlin, Mainz, Magdeburg and Saarbrucken.

Fig. 10

On Fig. 11, 12 and 13 are represented ultra high vacuum installations of physical laboratories of these Universities, pumped out by cry pumps, shown on Fig. 9.

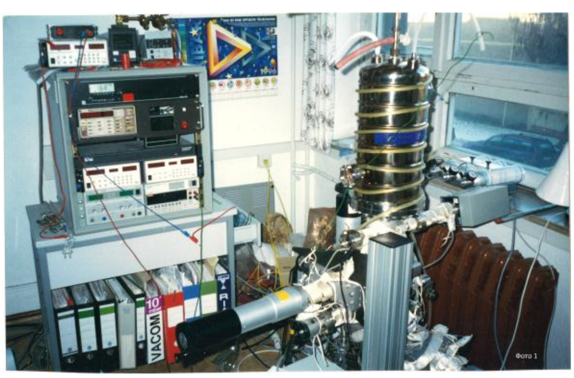

Fig. 11

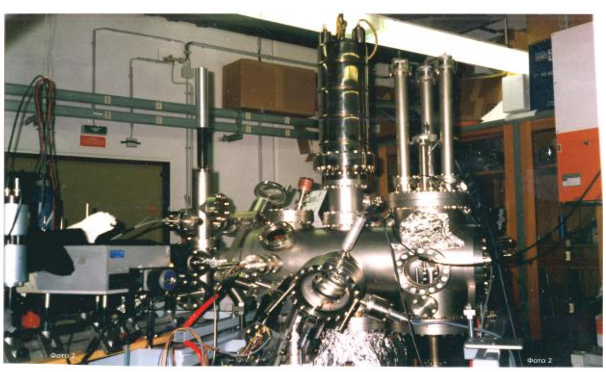

Fig. 12

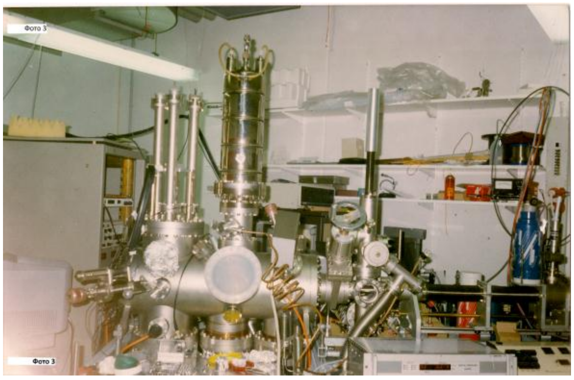

Fig. 13

The construction of the assemblage, shown on Fig. 8, has been used in technical project of cryostat cooled by liquid helium, for Moscow organizations “Central Scientific Institute of Mechanical Engineering” and “Russian Space Agency”. On Fig. 14 is shown the general view of this cryostat. It is planned for work at the International space station.

For simplification of cryostat weight its basic units will be made with titanium (the body and a vessel for liquid helium) and aluminum (the screen cooled by steams of liquid helium). Floating screens – with a corrosion-proof tape in thickness of 0,1 mm which surfaces will have aluminum coverings with high reflective ability [1,2].

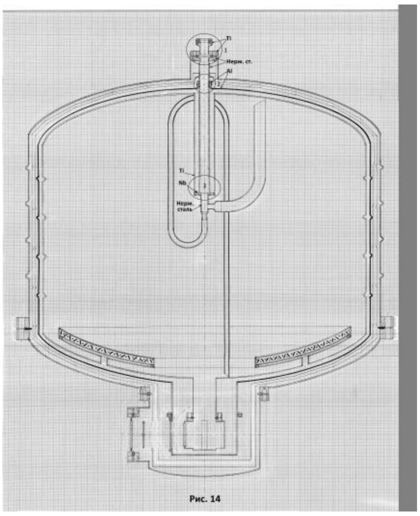

Fig. 14

The unit 1 on Fig. 15 represents consolidation through a copper lining of flanges from titanium and stainless steel as it is shown on Fig. 2. Unit 2 looks in the form of the cutted aluminum plug with the screw flute interfaced to a helicoids profile of a flexible hose from stainless steel. In working position this plug will be pulled together by strops with a surface of a flexible hose.

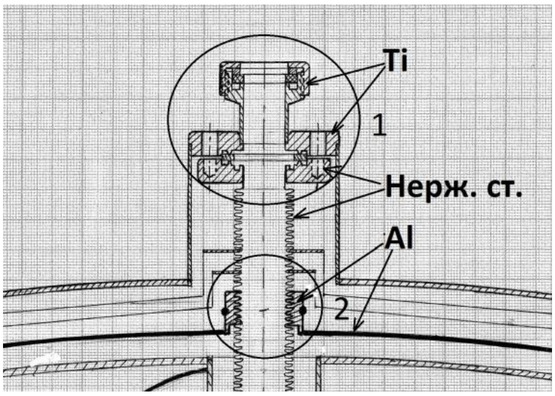

Fig. 15

In Unit 3 Fig. 16 is planned to use a ring from niobium as vacuum welded transition from stainless steel to the titanium, on the basis of our experiments it has appeared that niobium well welding both with the titanium, and with stainless steel, and even with copper.

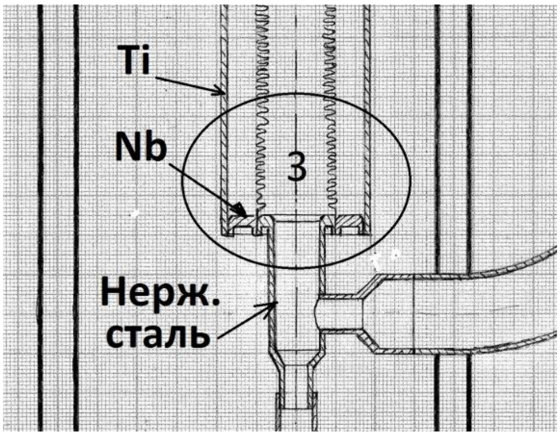

Fig. 16

In summary it is necessary to notice that developed flange with trapezoid profile of condensing tooth could be used in vacuum constructions, which do not need to be connected to the devices with flanges made according with the international standard "Conflate".

The literature:

1. M.P. Larin. To a question on a films dusting in steams of liquid helium. The electronic techniques, vol. 5, 1980.
2. M.P. Larin. Reception, measurement and use of surfaces with small degree of blackness at low temperatures. Journal of technical physics, vol. 53, № 5, 1983.