THE RESISTANCE TO DEFORMATION AND FAILURE
OF CYLINDRICAL TUBULAR ELEMENTS OF INDUSTRIAL
GLASS UNDER THE ACTION OF EXTERNAL AND
INTERNAL PRESSURE

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Earlier [1, 2] it has been shown that in biaxial compression of plastic samples the strength of industrial
glasses is very high, its particular values have little dispersion, and the conditions of failure of the given
materials are determined by the first theory of strength. There is significant interest in comparison of the
values of strength obtained under the conditions of the uniform stressed condition with the value of the maxi-
mum failure stresses of the elements of casings characterized by a nonuniform field of stresses.

The purpose of our work was a study of the rules of the resistance to deformation and failure of the ele-
ments of glass casings under the action of external and internal pressure under conditions of the nonuniform
plane-stressed condition characteristics of actual engineering parts.

During the course of the investigations, a test method and special experimental means were developed
and some basic problems in the design of highly stressed elements of cylindrical glass casings, particularly
a device for connecting them with metal end plugs capable of sustaining a high external pressure, were
solved.

As a test object a design element having a uniform cross section working area with a thickness of \( h \) and
gradually changing to the thickened ends was chosen. In the region of the support zones the thickness of the
element is twice the thickness of the working area (Fig. 1), which makes it possible to substantially reduce
the level of axial contact loads on the support surfaces and to eliminate the possibility of their failure.

For the purpose of increasing the supporting capacity of the support portions and providing sealing of the
internal cavity under the action of an external pressure the ends of the element were cemented into the cir-
cular grooves of the flat rigid metal plugs 3 with the inserts 5 (Fig. 2). At the same time the recommenda-
tions of [3] were used. The depth of the groove was equal to three times the thickness of the face zone.

The length of the working area \( l \) (Fig. 1) was chosen based on the condition of providing its rigidity as
a cylindrical casing loaded with an external pressure \( q \) according to Papkovich's equation [4]:

\[
l \leq \frac{2\pi h^2}{3 \sqrt{6} (1 - \mu^2) R_{av}^2} \sqrt{\frac{h}{R_{av}}}.
\]  
(1)

According to the condition of Eq. (1), for an element of 13c glass (\( E = 1.00 \cdot 10^4 \) kgf/mm\(^2\), Poisson's
ratio \( \mu = 0.22 \) [5]) with \( R_{av} = 11.5 \) \( h \) and \( q = 2500 \) kgf/cm\(^2\), the allowable length of working area
\[
l \leq 9.75h.
\]  
(2)

Taking into consideration Eq. (2) it may be accepted that \( l = 8.6h \). The relative length \( \rho \) and also the param-
eter \( x \) found from the equations of [4]

\[
\rho = \frac{l}{R_{av}}; \quad x = \frac{4}{3} \sqrt{\frac{1}{(1 - \mu^2)}} \sqrt{\frac{R_{av}}{h}},
\]

for the working area of the element are 0.76 and 4.43, respectively. At the same time the criterion condition
To produce the elements, tubular blanks of 13c glass obtained by the drawing method were used. The mechanical working was done with a diamond tool with abundant cooling.

The points where the portions of different thickness meet were rounded to a smooth radius of $R = 3h$ and the sharp boundaries were blunted with $0.2h \times 45^\circ$ bevels, which aided in reducing stress concentration.

The method chosen for producing the elements provided high accuracy. The difference in wall thickness of the working portion did not exceed $0.017h$ and the out-of-perpendicularity of the support surfaces to the axis of the tubular element was not more than $0.05 \text{ mm}$ in a length of $100 \text{ mm}$.

For the purpose of measuring the axial and tangential deformations, type 2PKB-5-100GV strain gauges were cemented to the outer and inner surfaces of the working portion. The order of calibration and preparation of the strain gauges, the composition of the cement used, and the heat treatment corresponded to that described in [1].

Type-PÉLSh0-0.2 conductors from the outer strain gauges passed through the cemented joint 4 into the element 1 and then they were led through the hole in the plunger 2 (Fig. 2) together with the conductors from the inner gauges outside to the SD-1 static deformation gauge.

The cemented joints made for testing the elements were heat-treated at 65-75°C for 75 h. This made it possible to increase the strength of the cemented joint and to prevent cracks in the glass elements which had occurred at higher hardening temperatures.

The elements were tested in a special unit (Fig. 3) consisting of a loading unit, a high-pressure hydraulic system, and a deformation measuring and recording system. The elements assembled in the chamber were loaded with an external hydrostatic pressure in steps of 100-150 kgf/cm². At the same time the deformations in the working zone were measured using the strain gauges T and the SD-1 instrument.

In the NSVD-2500 pump station there is only a single working plunger. In addition, it was not able to control the consumption of the liquid delivered, which with the small volume of the chamber caused large pulsations in pressure. To eliminate this disadvantage the pressure increase regulator R (Fig. 4), which is a variable hydraulic resistance unit [6] was used. The amount of the hydrostatic resistance of the regulator may be varied within the limits of 0 to 300 kgf/cm² by screwing in the rubber plug to a different depth in the hole in the casing. This permits a smooth increase in pressure in the working chamber and also changing the rate of drop in pressure in cyclic tests. In addition, the regulator serves as a protective filter interrupting the path of fine abrasive particles between glass elements which have failed in the chamber and the check valve of the NSVD-2500 pump station, which increases its service life.

In determining strength under conditions of long-term action of a load two elements with close $R_{AV}/h$ ratios are placed in the chamber simultaneously and loaded with the specified pressure. The manometer readings are observed at least once per day. If necessary the pressure is corrected to compensate for the effect of temperature variations.