The Tenacity of Gelatine.

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Some years ago the author called attention to the fact that the cohesive forces of gelatine must be considerably greater than those of glass in order that a single drop of gelatine in drying and contracting on a glass plate may pull a ring or disk of glass from the plate.[1] The forces here exhibited are apparently greater than shown in the common, though not well known, process of producing chipped glass by flowing a pane of glass with gelatine and allowing the gelatine to dry. Inasmuch as the author could not find in any of the literature at hand any recorded values of the tensile strength of gelatine, he requested one of his students to attempt to determine its value. Several plans were tried, the one giving the best results being as follows:

Gelatine threads were drawn out between the ends of small wooden sticks (about the size of a match) after dipping one end of each in melted gelatine. The diameter of a thread was varied by varying the size and temperature of the gelatine drop, the thickness of the fluid, the length of the thread and the time spent in drawing it. To the other end of the wooden sticks there had been attached previously small wire hooks for suspending the upper end of the threads and for attaching a small cloth sack to the lower end. Into this sack dust shot were slowly run until the thread broke. The cross-section of the thread was then measured at the point of break.

When the section of a thread was regular its cross-section was calculated from the diameters measured by a micrometer microscope. Threads of irregular cross-section were placed under a microscope with a camera lucida attachment and a tracing made of the perimeter. The area of the tracing was measured with a planimeter and the area of the section of the thread itself calculated from the known magnifying power of the microscope and attachment.

When glass threads are drawn they are usually almost cylindrical. Gelatine threads also are probably approximately cylindrical at the time

[1] Note on the Molecular Forces in Gelatine. Science, Vol. 23, p. 790, May 18, 1906.

of drawing, but they are not so after hardening and drying. The cross-section usually becomes quite irregular. This indicates a condition of internal strain which acts to lower the breaking strength of the thread. Coarse threads would be subject to greater strains than fine threads, and therefore we should expect them to show a smaller tensile strength than the fine threads. This is in accord with the results of experiment as shown by the data of Table I.

TABLE 1.

Cross Section in sq. mm.	Breaking Strength in grams.	Tensile Strength in Kgm. per sq. cm.
.000835	27.6	3,305
.000919	21.5	2,340
.001002	21.1	2,106
.001334	37.2	2,778
.001670	35.0	2,096
.002610	58.2	2,230
.004524	96.5	2,133
.006729	138.1	2,052
.013920	211.4	1,519
.035900	400.1	1,114
.130300	800.0	614
.264900	2,850.0	1,076
.608900	5,600.0	919
1.709200	6,100.0	357

Inasmuch as the error in measuring the breaking strength of any particular thread was relatively small and all strains tended to decrease that strength as measured, I have included in Table I only maximum readings; that is, readings which gave the greatest values of the tensile strength for the several sizes of threads. Average readings gave results some twenty per cent lower.

Curve A of Fig. 1 is a plot of some of the individual maximum readings of Table I. It will be observed that the measured tensile strength increases very rapidly as the threads are made thinner. A similar increase takes place in wires and glass threads, and is attributed to a "skin effect." This increase is shown in Curve B, Fig. 1, which represents the results ob-

tained by drawing out glass threads and determining their tensile strength by the method already described. That the increase in the case of glass threads was due in part only to the "skin effect" was indicated by the fact that the tensile strength measurements for threads of different sizes were made more nearly uniform by carefully annealing the threads. This was done by hanging the threads in a vertical iron tube with a small weight attached to the lower end of each thread to keep it straight. The entire tube was then brought to a temperature slightly below the melting point of glass and maintained at that temperature for one hour, after which it was allowed to cool slowly in the asbestos jacket surrounding it.

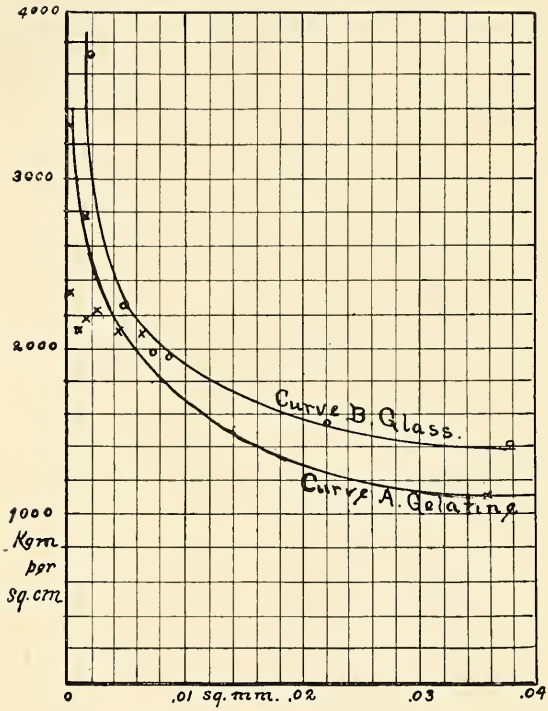

Fig. 1.

An attempt was made to anneal the gelatine threads by hanging them in a moist atmosphere in an enameling oven. Various oven temperatures were tried with little permanent effect on the threads. The author inclines to the view that the "skin effect" does not account for the larger values of the tensile strength shown by the finer gelatine threads, but that it is due chiefly to the cause already suggested—the greater uniformity in the finer threads.

The highest value of the tensile strength obtained for glass threads was 3,652 kilograms per square centimeter, while the maximum for gelatine threads was 3,305 kilograms per square centimeter. It is evident that these values cannot represent the true values or the relative values of the tenacity of glass and gelatine. It may be that the internal strains set up in the gelatine threads were such that the tensile strengths as determined in this experiment were always too low. Or it may be that the "skin effect" in glass threads gave values far beyond the tenacity of glass in a plate. Further experiments along this line are in progress.

The strength of the gelatine threads was found to increase for a few hours after drawing, and then to decrease—especially when the thread was exposed for a day or two to a dry atmosphere. Impurities tended to weaken the threads, Curve A of Fig. 2 showing the tensile strength of threads of ordinary glue. Curve B those of gelatine containing six per cent of potassium chlorate, and Curve C those of supposedly pure gelatine. Gelatine containing six per cent of potassium alum gave a curve similar to Curve B; that is, the tensile strength of the gelatine was diminished by the salt. Still it must be greater than the tenacity of the glass, for in chipping glass about six per cent of some easily crystallizable salt is mixed with the glue in order to produce the peculiar fern-

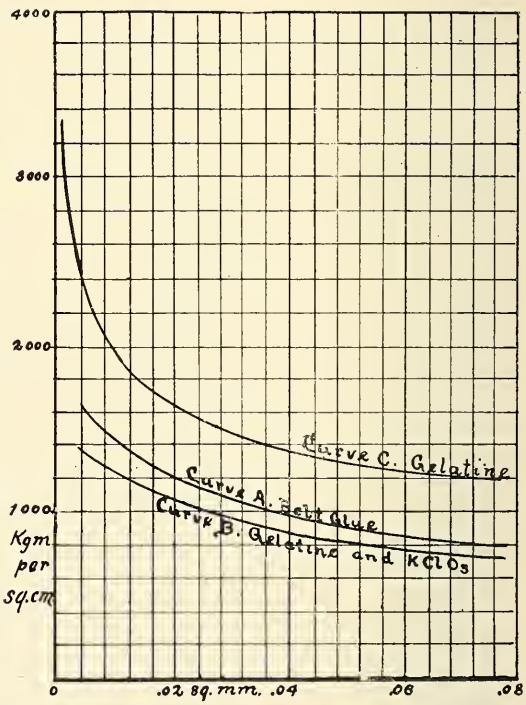

Fig. 2.

like forms which give chipped glass its decorative effect. Evidently there are forces involved here other than cohesion and adhesion, as these terms are commonly used.

Most of the experimental work of this investigation was done by Mr. Elmer J. Harrel, now of the high school of St. Paul, Minn.

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