Invited ; Recent Developments in Reducing Bulkiness of CRT Glass Bulbs

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Abstract

Several innovations for reducing the bulkiness of glass bulbs for flat and large CRTs have been made and further technologies are being developed by using material and structural approaches. The integrated glass technology based on these innovations will provide a lightweight shallow glass bulb for the realization of a half- depth CRT.

1. Introduction

In the display market, a competition has made the reduction of the spacing and weight of large CRTs as one of the prerequisite for keeping the display in its leading position. If a new CRT challenges half the depth of an existing CRT with a 110° deflection angle by only conventional glass technologies, the weight of the glass bulb reaches roughly twice that of a conventional glass bulb. It is not realistic. In other words, some innovative efforts for reducing the bulkiness of glass bulbs are required to break through the current deadlock.

In fact, a lot of material and structural approaches have already been investigated individually to make glass bulbs strong.

In the material approach, it has been considered that there is no room for enhancing the usable strength by modifying the composition itself based on the required characteristics of glasses for CRTs. Therefore, this application is actually limited to solder glasses. Furthermore, besides exploiting current approaches, there are potential possibilities by the healing effect and the new material approaches; the former is to fill up fine surface flaws by coating some material with an elastic modulus comparable to that of glass; the latter refers to making a glass bulb by a composite of glass and a relevant plastic material. However, the costs may be expensive. And, another approach involves compressive pre-stressing of surfaces by thermal tempering or chemical tempering.

On the other hand, in the structural approach, FEM is very useful for reducing the weight of glass bulbs. In view of the current lightweight technologies by the FEM method, most have gotten only a minor result compared to material approaches mentioned above because the traditional shape of glass bulbs has not been innovatively changed; it is mainly caused by limitations on the CRT structure and some difficulties on making a glass bulb. Recently, we have succeeded in breaking through the traditional shape of a glass bulb, and also developed sophisticated concepts, which could attain dramatically a lightweight glass bulb.

However, the sole application of these approaches to a very shallow glass bulb may not be sufficient to attain a weight comparably light enough to that of an existing 110° deflection glass bulb. [1]

2. Strengthening Glass Bulbs

2.1 Thermal Tempering

The practical strength of glass is very low compared to its theoretical strength. The disadvantage of adopting glass for industrial use comes from two sources; one is that surface flaws will act as stress concentrators, magnifying the nominal stress corresponding to the applied load, and the other involves the static fatigue caused by the interaction of water and glass under stress.

The most fundamental thing for improvement is to raise the intrinsic strength of the glass. However, as mentioned above, there is no room for raising it modifying the composition.

On the other hand, pre-compression of the surface allows a larger external load to be borne before the tensile strength is exceeded. It is the only approach widely used in practice to enhance the strength of bulky glass. In the middle of 1990s, we developed a thermal tempering glass panel, "TLIPRED"; it can be used to reduce the weight of a tempered glass panel by 20% compared to that of a non-tempered glass panel. [2], [3]

In thermal tempering, the quenching of the glass starts at a high temperature above the transformation range, and develops a large temperature difference between the surface layer and the interior under stress-free conditions; in the transformation range, even though the surface solidifies, the interior is still relatively fluid. Since the interior cools through a larger temperature interval than the surfaces during the process, this put the surfaces under compression and the interior under tension. [4]

However, it is difficult to quench uniformly all the exterior of a glass panel because of its three dimensional structure. As a result, such non-uniform quenching creates an undesired tensile membrane stress; it is different from ordinary tempering stress as it weakens the effect of compressive pre-stressing. The tempering process that we have developed is effective for minimizing the membrane stress in a glass panel. First of all, as shown in Fig.1, it is cooled in the first stage at around the transformation range to a temperature lower than the strain point in the second stage. At the beginning of the first process, the glass is quenched to develop a large temperature difference between the surface and the interior. Then, at the end of the process, it is cooled slowly to minimize temperature differences among each portion of the panel glass. While the former operation originates both of the transient tempering stress and the transient membrane stresses, the latter operation mainly serves to reduce the transient membrane stresses.

In the second process, the glass panel is heated up to a temperature closed to, and lower than the strain point. Thirdly, the glass is maintained at the temperature at the third stage for several minutes.

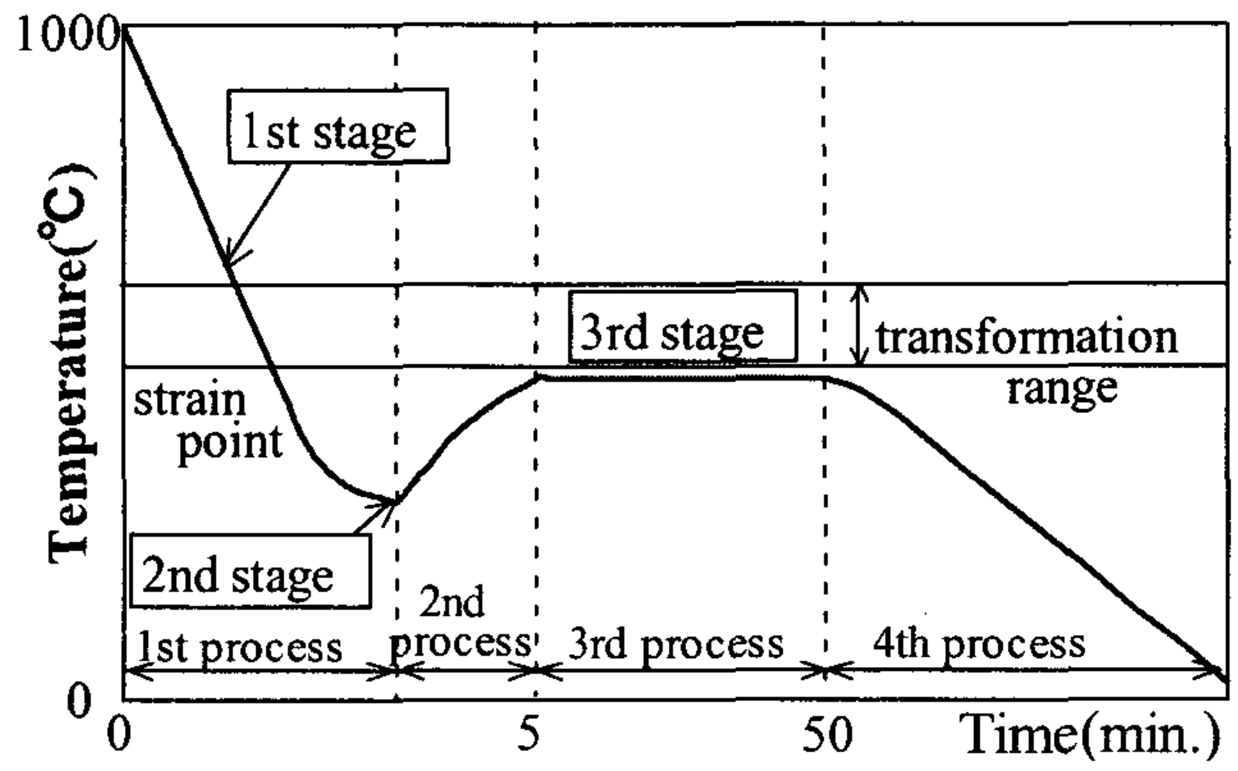
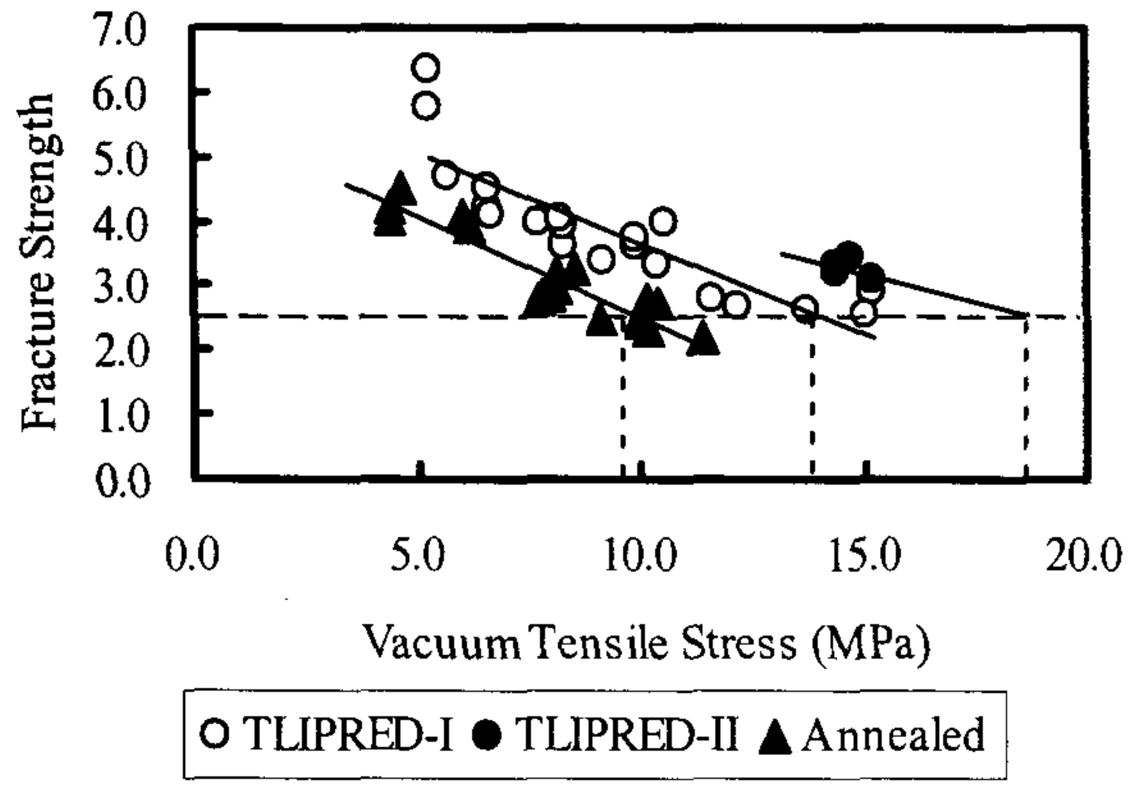


Figure 1 Cooling Profile at the Tempering Process of a Glass Panel

It can be easily seen that both temperatures in the second process and the third process are closely related to the functionality of the tempering process. If the temperature at the second stage is too high, the transient membrane stresses cannot be effectively reduced and the tempering transient stress will not be sufficient. On the contrary, if it is too low, the membrane stresses still be frozen through the next process. In addition, when the sustaining temperature is too high, the transient tempering stress will almost be released. On the other hand, if it is too low, the transient tempering stress and most of the transient membrane stresses will coexist. In such an operation, there is a risk to introduce a self-implosion of the glass panel after tempering.

Finally, the glass panel is cooled down until the glass panel reaches isothermal conditions at room temperature.

Recently, a new tempering panel glass based on the above concept, "TLIPRED II" has been developed; it has a surface compression which is 50% higher compared to a conventional tempering glass panel, and it displays superior strength compared to other kinds of glass panels, as shown in Fig.2. This advantage will be useful for reducing the weight of a very shallow glass bulb.



Note) Fracture Strength Relative Value

Figure 2 Fracture Strength vs. Vacuum Tensile Stress on glass bulbs by hydrostatic pressure test

Moving on to the application to a glass funnel, the fracture strength of an annealed funnel glass is 40% lower than that of a tempered glass. Thus, it is expected to be considerably improved by thermal tempering. However, in view of the glass funnel structure, some controllable thermal tempering on all the exterior of the bulk glass is rather difficult because the maximum thickness at the sealing portion of the glass panel is most likely at least 4 or 5 times thicker than the minimum thickness at the end of the yoke area. Consequently, large membrane stresses will be inevitable.

As a result, the resultant stress of the tempering compression and the membrane stresses become tensile, so the effect of tempering may be negated. Fig.3 shows such an example caused by tempering on the surface at the short axis of a glass funnel.

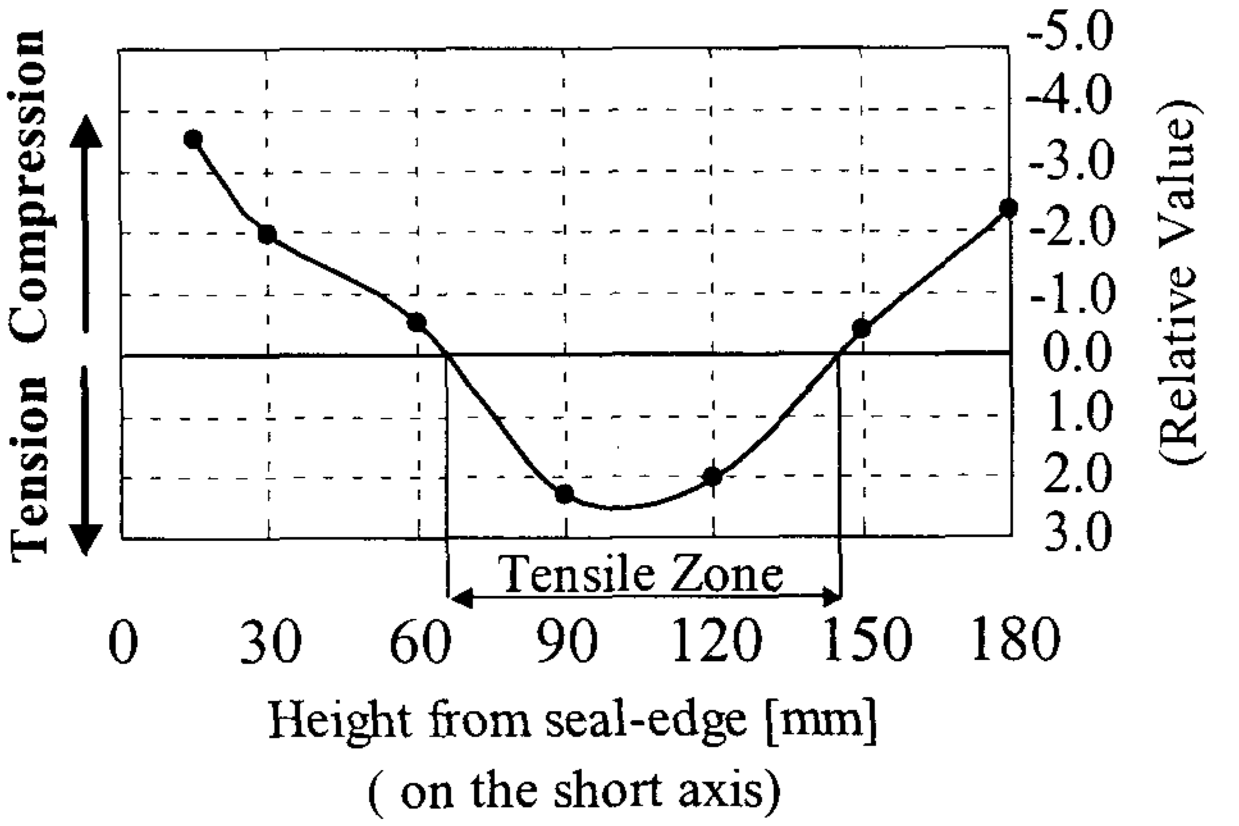


Figure 3 Resultant Stress of Tempering Stress and Membrane Stress

2.2 Highly strengthened Solder Glass

With superiority in its mechanical and thermal performance, a crystalline solder glass, such as ASF-1307R, is generally used for CRTs. [6]

In general, three actions are simultaneously required to improve the fracture strength of the sealing portion between a glass panel and a glass funnel

The first action is to strengthen the baked solder glass, which is effective for reducing the breakage originated in the baked solder glass. The second is to get an excellent wettability to the glass bulb in order to avoid cracking on the surface boundaries between the baked solder glass and the glass bulb; they act as stress concentrators. In addition, the third is to enhance the reaction between the baked solder glass and the glass bulb to prevent cracking at the interface.

A new crystalline solder glass system composed of PbO, ZnO, B_2O_3, BaO, and SiO_2 was investigated in ASAHI Glass.

Firstly, alumina was added as a ceramic filler to enhance the bulky strength of the baked solder glass. The amount and particle size were optimized, judging from its mechanical strength, fluidity, and crystallization time. Secondly, the composition of the base glass was modified to compensate its wettability and enhance the reaction at the interface with a glass bulb. As a result, a highly strengthened crystalline solder glass, ASF-2000 has been recently developed; its mechanical strength is 20% higher than that of a conventional solder glass. The main properties of ASF-2000 are listed in Table 1 compared to those of ASF-1307R.

However, the desirable sealing strength for a half-depth CRT is most likely to be 50% higher than that of the conventional solder glass. But, a breakthrough to get such strength has not been found out yet.

Items		ASF1307R	ASF2000
Transition Temperature ( )		320	317
Softening Point ( )		395	392
Thermal Expansion Coeff. ($x10^{-7}$/ , 20-300)		98	97
Volume Resistance log(Ω -cm)	at 150	10.1	10.2
	at 200	8.9	9.0
	at 250	8.0	8.1
MOR (MPa)		47	56
Diameter of Flow Button (mm)		21.6	21.6
Crystallization Peak Time (min.)		19	23
Thermal Shock Endurance of Glass Bulb (/min.,29")		>17	>17
Mechanical Strength of Glass Bulb (MPa,25")		4.6	5.5

Table.1 Physical properties of Solder glasses and Thermal and Mechanical Performance of the glass bulbs

3. Reducing vacuum stresses

Since an atmospheric pressure is applied to the outer surface of an evacuated glass bulb for a CRT, stresses, which are known as "vacuum stresses", are produced. The glass bulb has an asymmetric shape unlike a spherical shape, and accordingly, some regions of tensile stress and compressive stress will coexist on the surface. Generally, the maximum tensile vacuum stress allowed at each portion of a glass bulb is limited to a value, which is lower than the practical glass fracture strength, in order to ensure high reliability. Therefore, a shallow glass bulb for the half-depth CRT has a serious disadvantage on vacuum stresses compared to the existing spherical bulbs because of its asymmetrical structure.

The Fig. 4 shows the calculated maximum tensile vacuum stress versus the deflection angle relation at the three portions of the glass bulb for a CRT with an 86cm screen diameter at the diagonal.

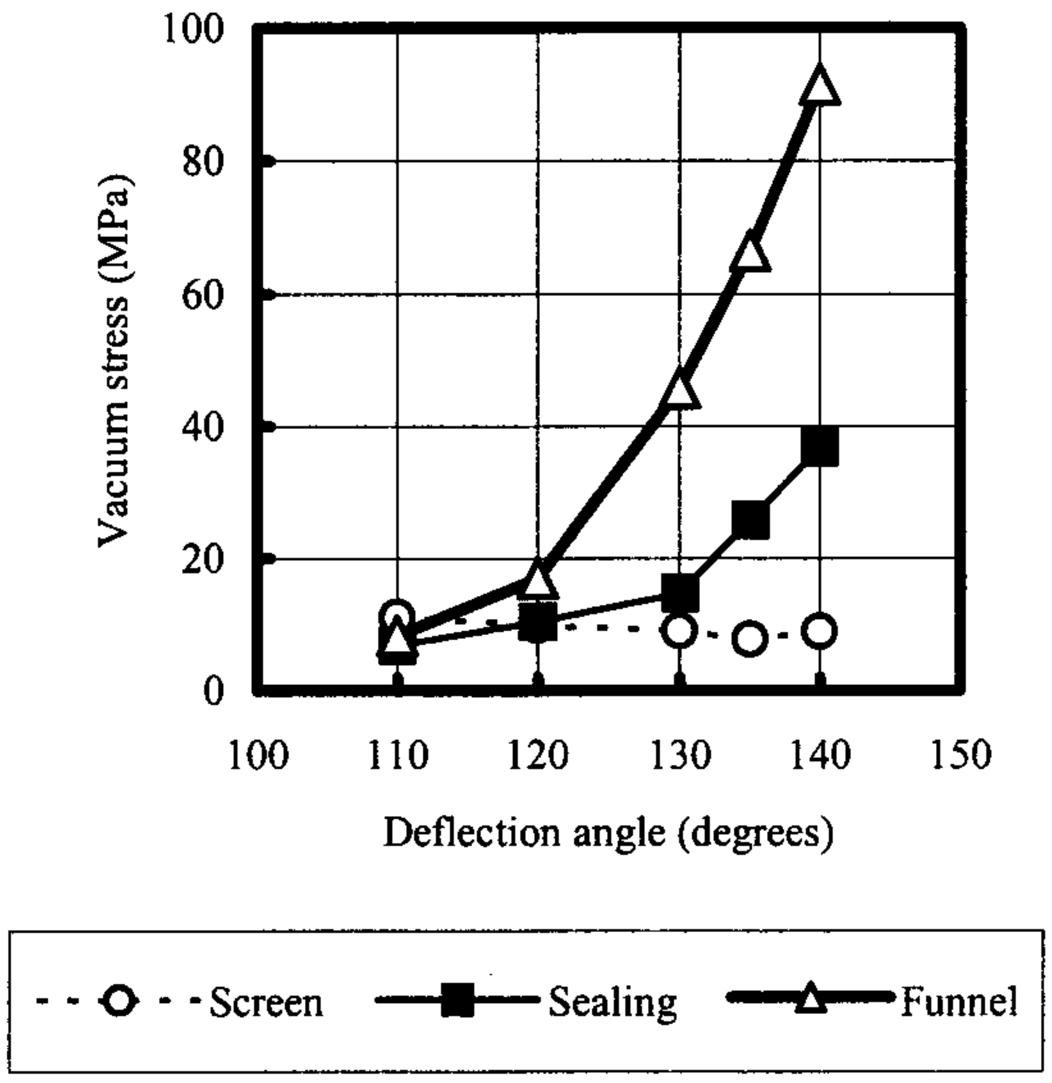


Figure 4 Calculated maximum tensile vacuum stress at each portion of the 86cm screen glass bulb as a function of deflection angle

While the maximum tensile stress at the screen edge decrease gradually with an increasing deflection angle, the maximum tensile stress at the funnel body portion and that of the sealing portion will both increase exponentially. In the case of the 135° deflection angle glass bulb, the maximum tensile stress at the funnel body portion will reach 66MPa. This is fatal because the value greatly exceeds the practical fracture strength of a funnel glass.

In our recent studies of unique structures of glass funnels by FEM, we have found out that the Canal type funnel is most effective for reducing stresses induced by the vacuum on a glass bulb for the half-depth CRT. As shown in Fig. 5, the body portion of the Canal type funnel protrudes backward and the yoke portion caves in. That is, the Canal type funnel has a groove between these portions. The concept of the Canal type funnel is to form virtually the body of a funnel with a narrow deflection angle.

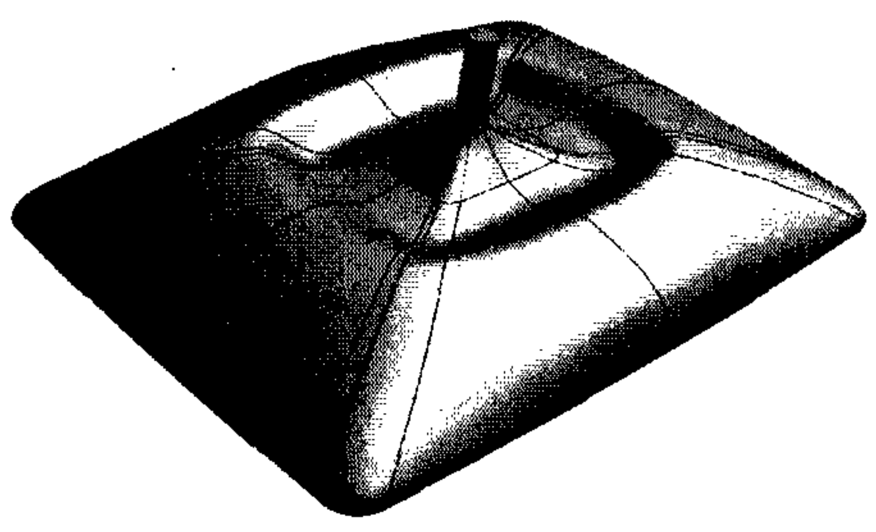


Figure 5 "Canal" Type Funnel

The maximum vacuum stress at the funnel body portion and that of the sealing portion can both be dramatically reduced owing to this structure.

This maximum tensile stress shows a strong dependency on the height from the bottom of the groove to the top of the body portion of a 135° glass bulb as shown in Fig. 6.

4. Conclusion

It has been considered that the goal for the half-depth CRT is not easy to attain because a glass bulb for such a CRT is too heavy. Nevertheless, some innovations for optimizing the glass bulb structure and strengthening the glass material have provided the impetus to achieve the goal.

For instance, firstly, a new tempering panel glass with a higher compression has been developed. In addition, some improvements in the glass funnel by tempering are also being experimented. Secondly, a highly strengthened crystalline solder glass has become available. Thirdly, the funnel glass structure has evolved.

A newly integrated technology based on these innovations will lead to a shallow and lightweight glass bulb for the half-depth CRT.

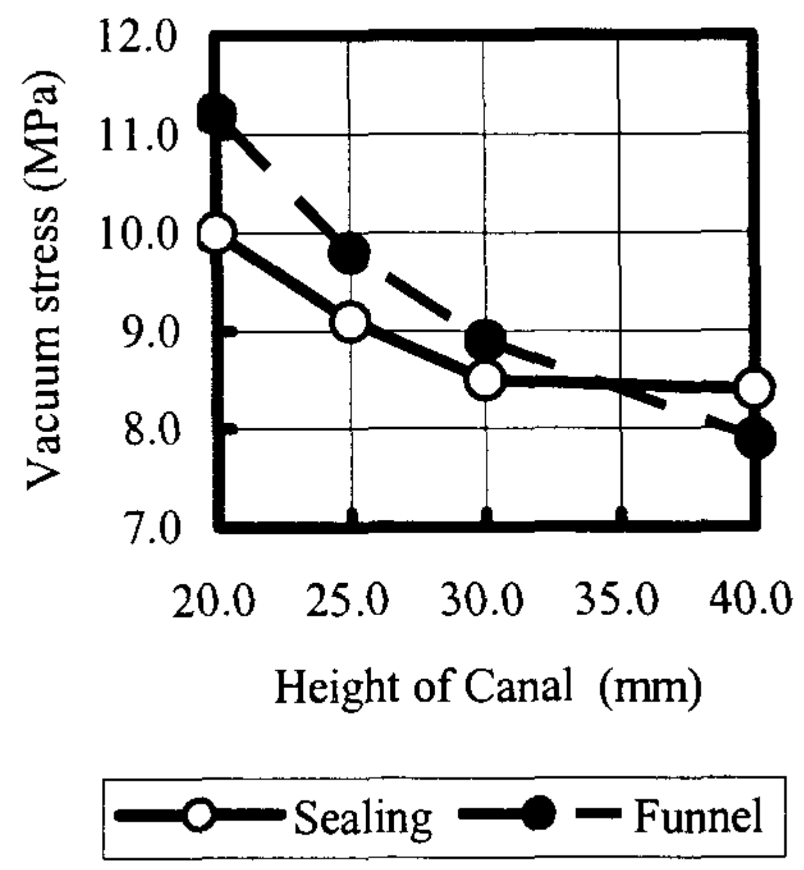


Figure 6 Dependency of the Maximum Vacuum Stresses on the height of Canal

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