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# 1. Introduction

Tempered glass shower screens were introduced in Housing & Development Board (HDB) premium flats in 1999. Since then, 18,000 premium flats has been installed with tempered shower screen of which 14,000 flats completed installation and 4,000 flats are under construction.

HDB follows the prevailing industry practice and standards in using tempered glass for shower screens in their flats. During the construction stage, thorough building checks were conducted to ensure that the fixtures and the fittings are properly installed.

However in 2002', the shattering of the tempered glass shower screens has generated much media publicity as some of the incidents had resulted in minor injuries to the residents. There were a total of 60 breakage incidents and in almost all cases; the residents reported that the glass panels had shattered spontaneously on their own.

Although tempered glass is able to withstand stronger impact than normal glass, it is susceptible to breakage due to factors such as rough usage, shoddy renovation work and/or the presence of a minute impurity, called Nickel Sulphide. As the breakage of the glass shower screen is often due to combination of the above factors, it is difficult to pinpoint the actual cause of the breakage after the incidents.

Therefore, the objective of this assignment is to study the measures that the HDB has taken to minimize this phenomenon.



## 2. Types of Shower Screens In HDB

There are two types of shower screen installed by HDB, mainly Framed Types and Frameless Types. The photos below elaborate the types of shower screen used by HDB.



**Framed with Sliding Door**



**Framed; with pivoted and framed swing door**



**Framed; with pivoted and frameless swing door**



**Framed: with frameless sliding door panel**



**Framed; the fixed panel**



**Frameless fixed panel**



**Frameless; swing door fixed to wall to fixed panel**



# 3. Tempered Glass Shattered Records

As in Jun 2002', HDB has reported that 45 cases of shattered shower screen occurred in Choa Chu Kang (CK), Sengkang (SK), Jurong West (UW) and Woodlands (WL) estates as shown in the table below. The table below shown that most of shattered shower screen occurred on Frameless swing type panels and mainly in Master Bedroom.

BO	No of Cases	No. of Cases Reported to Press	Type of Tempered Glass			Location of Incident	
			Swing	Sliding	Fixed	Master Bedroom Bath-room	Common Bath-room
<b>CK</b>	12	-	12	-	-	12	-
<b>SK</b>	22	2	11	9	2	12	10
<b>UW</b>	10	-	7	2	1	8	2
<b>WL</b>	1	1	1	-	-	1	-
<b>Total</b>	45	3	31	11	3	33	12

The incidents of shattered tempered glass shower screens in HDB flats constitute less than 0.3% of the total number of the shower screen installed. Nevertheless as a precautionary measure, HDB has carried out some improvement works on the fixtures selectively to reinforce the durability of the shower screens. This include the replacement of the rollers and sliders of the shower screens and the replacement of the existing hinged swing doors with new framed doors and new hinges.

To contain the negative publicity, a Standard Operating Operation (SOP) was established to respond to all breakage cases. As long as the breakage is not caused by the residents themselves, HDB will ask the contractors to provide the replacement, even if the one-year maintenance period has already expired. In some cases, though there were signs that the breakage could be due to usage, the evidence was normally conclusive enough to counter the claim of spontaneous breakage made by the residents.

# 4. Possible Causes Of Shattering

During the investigation, HDB found that there are few factors that caused the shattering of shower screen and the breakage may due to the following factors:

- a. Inherent glass imperfection
  - Nickel sulfide (NiS) impurity
  - Expansion of volume under room temperature
  - About 0.1% to 0.5% glass formed with impurity
- b. Improper installation and handling
  - Chip or crack due to knocking
- c. Support system and fixing details
  - Poor hinges, handles and catches
  - Contact with metal part of hinge/slider/handle
- d. Renovation works by residents
  - Improper re-installation
- e. Rough usage of residents
  - Collision with shower head, pedestal and toilet doors, etc.

# 5. Tempered Glass Breakage Investigation

In the event of shattering shower screens, Technical Officer (TO) from Branch Office (BO) where the flats occurred, will attend to the cases. Basically, the initial stage is to interview the lessees to collate information on when the incident happen, if anyone injured due to the shattering of the shower screen, what time the incident happen, what the lessees are doing when the incident happen and so on. Then the TO will check visually to gather evidence by checking:-

- parts and accessories of the shower screen
- tell-tail signs of tempering and/or dismantling
- changes made by alteration/modification
- foreign objects that can damage the glass panel.

From the surveys HDB collected from Branch Offices, shattering of shower screen in HDB flats can be categories or due to four probably causes, mainly:-

- Rough usage
- Poor workmanship
- Renovation
- Impurities

## 5.1 Rough Usage

Glass can break as a result of several types of impact or rough usage, which can be categorized as accidental or deliberate (vandalism). A strong impact almost always causes glass breakage to glass. HDB investigated that rough usage and impact has occurred on the following situation:-

- glass panel; glass is chipped at the crack initiating point.
- glass panel; has concaved
- hanging rollers and/or sliding guide; has dislodged, damaged or missing.
- flipper weather strip, door stopper; are missing, damaged or dislodged.
- brackets; has cracked, dislodged or missing.
- door hinges; the pivot is in 'close' position but the door panel debris indicate it was open during the incident.
- Pivot hinges; has cracked or dislodge.
- foreign objects; with the means to cause damage.



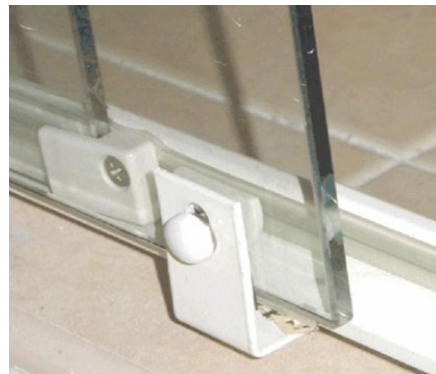
**glass panel; glass is chipped at the crack initiating point.**



**glass panel; has concave**



**hanging rollers and/or sliding guide; has dislodged, damaged or missing.**



**hanging rollers and/or sliding guide; has dislodged, damaged or missing.**





**door stopper, flipper weather strip; are missing, damaged or dislodged**



**brackets; has cracked, dislodged or missing.**



**door hinges; the pivot is in 'close' position but the door panel debris indicates it was open during the incident.**



**Pivot hinges; has cracked or dislodged.**



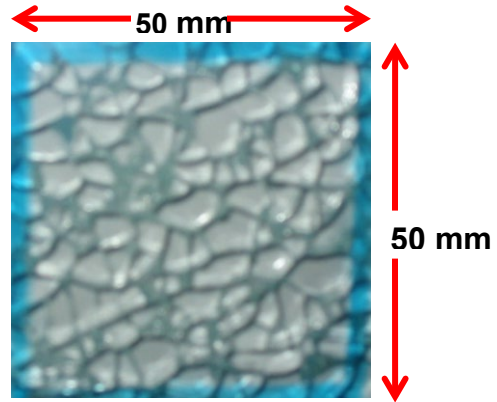
**foreign objects; with the means to cause damage.**

## 5.2 Poor Workmanship

Poor workmanship may occur during the installation stages when the installers do not follow the proper method or requirement in fixing examples the hinges or brackets. In long run it may effects or damage the fitting accessories, such as the hinges or sliders, which may cause the glass panel to detach and break.

- glass panel; large and shard-like glass fragment were presence.
- door hinges; stainless steel casing has cracked apart.
- door hinges; the pair were not in alignment with each other.
- bracket; stainless steel casing has cracked apart.
- separator between glass and metal parts; missing or out of position.
- insulating sleeve around openings; missing or out of position.

### Material problem



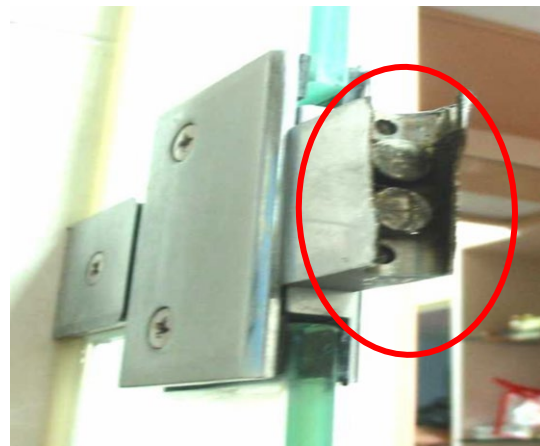
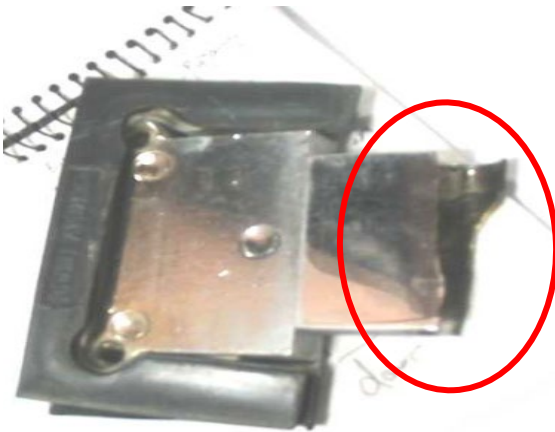
glass panel; large and shard-like glass fragment were presence.

### Particle counts:-

≥ 30 pieces for 4mm thick glass panel

≥ 40 pieces for above 4mm thick glass panel

### Defective Material



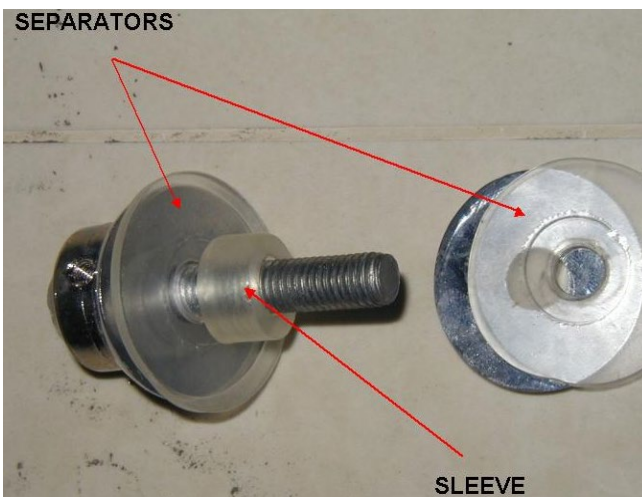
door hinges; stainless steel casing has cracked apart.



**door hinges; the pair were not in alignment with each other.**



**separator between glass and metal parts; missing or out of position.**



**insulating sleeve around openings; missing or out of position.**

## 5.3 Renovation

Renovation works that are carried out near shower screens without any precaution may cause damaged incidentally. Improper usage and renovation work can cause chipping of the glass. The glass may not break instantaneously. Over time, the chips may develop into cracks, causing the glass to break suddenly when they widen to a certain crack width. Glass panel could fall off and break if it was not properly re-installed after being removed during renovation work.

- renovation work items; were carried out at the scene of the incident.
- glass panel; was removed from the shower screen.
- shower screen; was altered or modified
- renovation work; still on-going.



**renovation work items; were carried out at the scene of the incident.**

## 5.4 Impurities

Presence of a minute impurity, called Nickel Sulphide, within the glass that renders the glass more susceptible to breakage. Based on current technology, the formation of such an impurity during the manufacturing process cannot be totally eliminated.

The breakage of glass shower screen is frequently due to a combination of the factors. It is difficult to pinpoint the actual cause of the breakage after the incident. (According to research and suppliers' feedback, there is up to a 0.5 percent chance of such formation during the manufacturing process).

As mention, in almost all cases, the residents reported that the glass panels had shattered spontaneously on their own. They only possibility of spontaneous breakage is possible for tempered due to the presence of Nickel Sulphide, which is an impurity formed within the glass during the production. It is estimated that 0.1 to 0.5% of the glass panels is likely to have inclusion of the Nickel Sulphide.

# 6 What is Nickel Sulphide (NiS)?

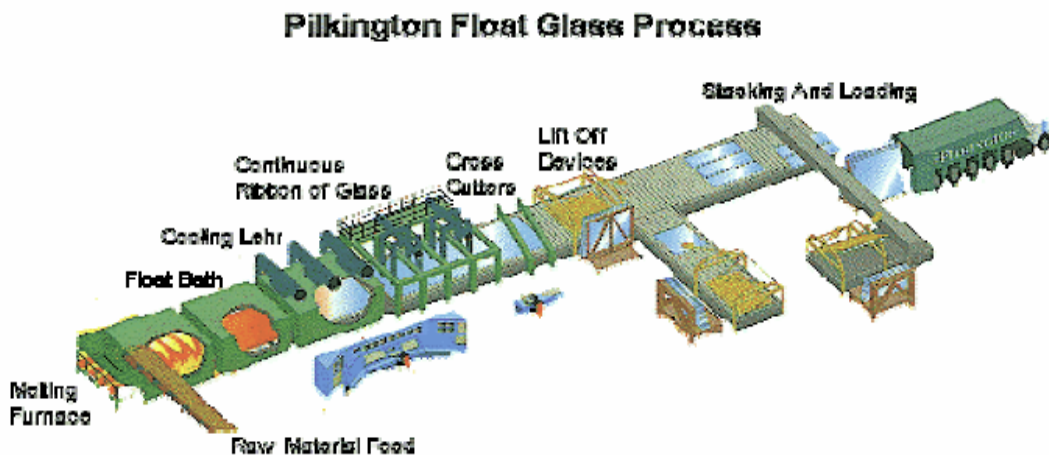
The shattering of the glass spontaneously with no apparent reasons was first thoroughly investigated as spontaneous breakage event reportedly followed the failure of glass panes installed on a building in Melbourne in later 1950's (E.R. Ballantyne, 1961). The causes of failures have been identified to be **Nickel sulfide (NiS)** inclusions.

**Nickel sulphide** inclusion, also known as NiS, occurs during the manufacturing process for float glass. In the float glass manufacturing process, soda ash, lime, silica sand, salt cake and other ingredients are combined and melted in a furnace at temperatures near 2870°F (1576°C). After melting, the molten glass is formed by introducing it to the tin bath where it literally “floats” on top of a layer of molten tin to form the desired glass thickness.

After the float glass has been formed, it is cooled uniformly in an annealing lehr. Proper “annealing” results in uniform cooling rate of the glass surface, edges and core to reduce residual stress within the glass.

## 6.1 Float Glass Manufacturing

In 1952 Alistair Pilkington invented the float glass process. This process used a horizontal method whereby glass was drawn over top of a bath filled with molten tin. This method is still the most common method of glass manufacture today.



In the manufacture of glass, there are approximately 50 identified chemical types present. Undissolved inclusions may be incorporated within the float glass. These are broadly categorized as "*knots, dirt and stones*". Most of these are considered imperfections and do not influence the performance of the glass.

NiS is a residue in the manufacture of toughened glass panels. It exists in about 20% of toughened glass panels. At room temperature, it can expand by 4% in volume over time. An inclusion size of greater than 110µm will cause the glass to crack or shatter resulting in property damages or possible injuries.

When glass is heat-treated, the nickel sulfide inclusions are modified into a form that grows or transforms with time and temperature. Once glass is installed and the nickel sulfide inclusions are solar heated, small cracks may develop from the inclusion. If these cracks penetrate the tension layer of fully tempered glass, the resulting release of energy will cause the glass to spontaneously break.

In recent years concern has grown regarding nickel sulfide inclusions and related tempered glass breakage. The following discussion is meant to clarify the cause of nickel sulfide inclusions in glass and explain how these inclusions may cause tempered glass to break. Since these inclusions cannot be eliminated, the discussion addresses how to reduce the potential of nickel sulfide inclusion breakage through an alternative heat treating method and through statistical heat soaking.

## 7 Measure of Minimise Shattering

To minimize the shattering of shower screens HDB has inspected and carry out rectification works to all completed contracts provided with glass shower screen (sold and vacant flats) such as replacement of hinges/sliders (non-durable), inserting flexible separator, inserting flexible sleeve in handle, adding stopper and rectifying poor installation.

As for flats under construction, if the tempered glass has yet to be installed will go through heat soaked test to reduce the probability of the breakage due to NiS impurity or installation of safety film/laminating glass.

In addition during the exercise, HDB will issue a guide to flat owners on Dos & Don'ts on maintenance of shower screen. **(Annex 1)**

### 7.1 Safety Film

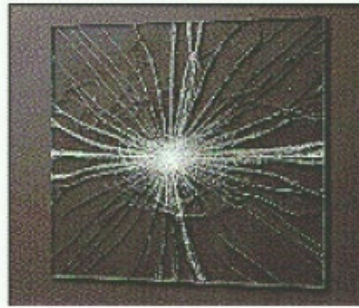
HDB has conducted several laboratory tests on the safety films and the benefits when applied, particularly to frameless glass panels of shower screens. The purpose of applying laminated safety films on the glass panels of shower screens is to enhance the strength and impart resistance of these panels.

## **Safety File / Laminated Glass**

Laminated safety glass is produced by bonding or laminating together two or more layers of glass with a layer of polymer film in between. By using heat and pressure, air bubbles are eliminated from the laminate so that it appears optically as a single sheet of glass. Mechanically, however it is more robust: If the laminate is fractured, the broken glass shards are held together and are less likely to cause injury.



Ordinary Annealed glass when broken shatters into dangerous, Razor sharp shards and splinters



Laminated Safety glass when broken adheres to a transparent layer, Guarding against injury from sharp splinters and shards.

**Good quality of laminated glass is avoiding the bubble and delamination.**

### ***Reasons for bubble and delamination:***

- The bad roller wave of tempered glass can result in bubble and delamination.
- The moisture content of PVB may cause the delamination.
- The temperature and humidity of lamination room may not meet with the requirement.
- The cleanliness of tempered glass may cause the delamination.
- The failure in controlling the parameters of pre-press may cause the the penetration of the autoclaving medium into the edge during manufacturing.

In addition, HDB has also advised residents to periodically check their shower screens and ensure that they are properly maintained. To assist residents, HDB prepared and enclose a copy of the guide on the proper maintenance and usage of the shower screens for residents in the premium flats. The guide also includes the particulars of the original installer of the shower screens should residents require future maintenance of the shower screen. **(Annex 2)**



## **7.2 Heat Soak**

If the tempered glass has yet to be installed it will go through heat soaked test to reduce the probability of the breakage due to NiS impurity. HDB will perform a heat soak test to provide the building owner with added assurance that significant spontaneous breakage will not occur. Glass suppliers have offered heat soak tests in the past to reduce the potential for spontaneous breakage and building owners have accepted the process as a means to limit liability. HDB heat soaked tempered glass shall comply with DIN-18516 and SS341: 2001 to be used for the replacement.

### **7.2.1 The Heat Soak Process**

When glass is heat treated, these nickel sulphide inclusions undergo a phase change as a function of time and temperature. If located near the central tension core of the glass, the expansion of these inclusions may provide sufficient stresses to produce spontaneous breakage. The inclusion expands at a rate greater than the glass and literally causes the glass to break from within. When tempered glass is heat soak tested, the glass is placed in an oven and subjected to temperatures of  $550^{\circ}\text{F}\pm 50^{\circ}\text{F}$  ( $290^{\circ}\text{C}\pm 10^{\circ}\text{C}$ ).

Careful temperature controls must be enforced to establish when the hold time or dwell time begins. The dwell time at peak temperature is another critical factor in the heat soak process. It was found that two hour dwell time is capable of reducing the potential for spontaneous breakage in heat soak tested glass to 5 lites per 1000 (5/1000).

# 8 Case Study

This case was based on my own experience that I encountered in 2006. The unit is Design & Build executive apartment Block 184 in Jelebu Road. The block was handed over to HDB by the building contractor on 19 Dec 2000 and the main supplier of shower screen for this contract is Kian Gwan Engineering Pte Ltd.

In 03<sup>rd</sup> May 2006, the Lessees, Mr Ng and Mdm Teo, reported to Choa Chu Kang Branch Office (CCK BO) that their master toilet glass shower screens had shattered spontaneously. (Annex 5)

## Typical Master Toilet Shower Screen



## 8.1 Site Observation

Inspection was conducted on the same day and due to the urgency of the case, a personal from Building Technology Department was called for joint inspection. It was noted that, the swing panel of 8mm thick frameless glass was totally shattered and the fixed panel was intact. The fixed panel was intact, as it may due to the installation of quadrant piece between two fixed panels which make it more stable.

As all the tempered glass was shattered, we cannot conclude or confirm the causes of failures. Common sources of failures may due to spontaneous fracture due to NiS inclusion (as feedback by Lessees) or external induced stress due to heavy impact on the swing door.

The Lessees even feedback that they felt the handle for the shower screen is heavy. From our data on shower screen, the handle is less than 2kg. HDB has experimented and conducted on 6mm thick tempered glass with load of 200kg before fracture occurred. The tempered glass door is held to fixed panel by the hinges. The hinges will grip the tempered glass in the slot, which is precut before the tempering process. Most tempered door is supported by this method as it provides a better stress distribution all around the tempered glass. Holding in by screws will create local stress concentration which will damage the tempered glass easily. Unless the tempered glass experience heavy impact due to swing, the possibility of it fracturing at he hinge area due to its self weight is minimal. (Annex 4: Site Investigation and Procedure for Shattering Shower Screen)



# 9 Conclusion

Housing & Development Board (HDB) has followed the prevailing industry practice and standard in using tempered glass for shower screens in HDB flats. Tempered glass is known to withstand stronger impact than normal glass. However, like all glass product, it is susceptible to breakage due to factors such as rough usage, shoddy renovation work and the presence of minute impurity called Nickel Sulphide (NiS). As the shattering of the glass shower screen is often due to combination of the above factors, it is difficult to pinpoint the actual cause of the shattering after the incident.

Nevertheless, after implementation and recommendation to ensure that the new contracts are installed with frame type of shower screen for both toilets, the shattering of shower screen was tremendously reduced.