香港工程監督學會
The Hong Kong Institute of Clerks of Works

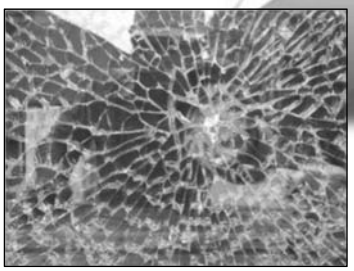
# Safety & QC of Tempered Glass and Latest Heat Soak Process to BS EN 14179-1: 2016

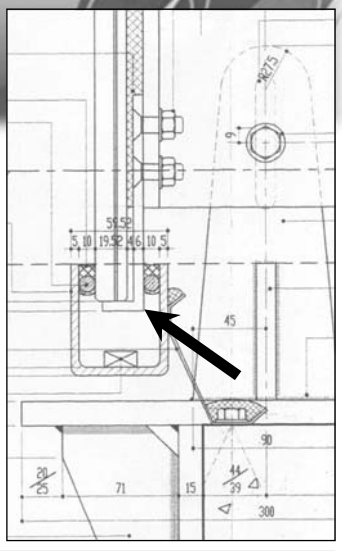
Ir Dr. Dominic YU

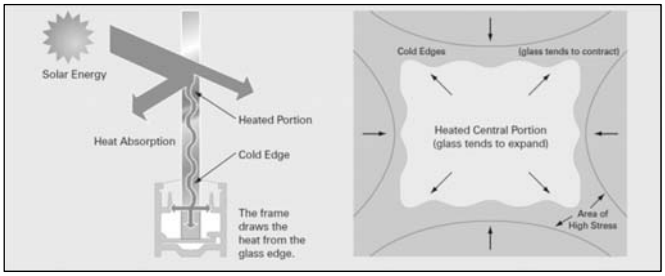
23 May 2017

## Causes of Glass Breakage

- External Impact Force
- Bad Glazing Practice
- Edge Damage
- Thermal Stress Breakage
- Spontaneous Breakage in Tempered Glass

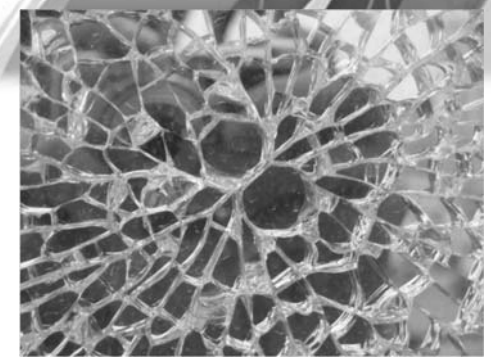





*Thermal stress breakage [Saragossi, 2000]*

# Spontaneous Breakage in Tempered Glass



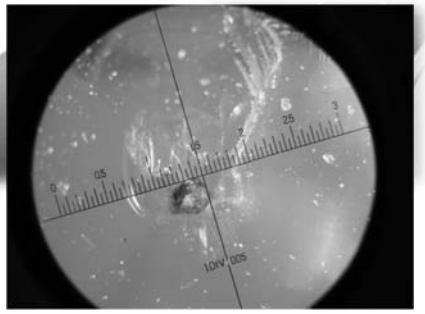
## *Breakage caused by Nickel Sulphide (NiS)*

**What is NiS?**

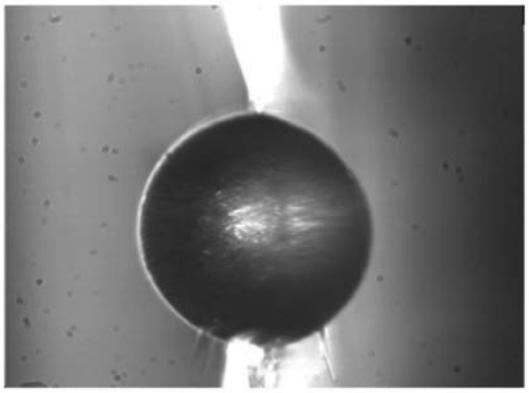
- Residual inclusion during manufacturing.
- Expand at room temperature and cause spontaneous breakage.
- The smallest theoretical inclusion that could cause a fracture in tempered glass is 50μm in diameter.



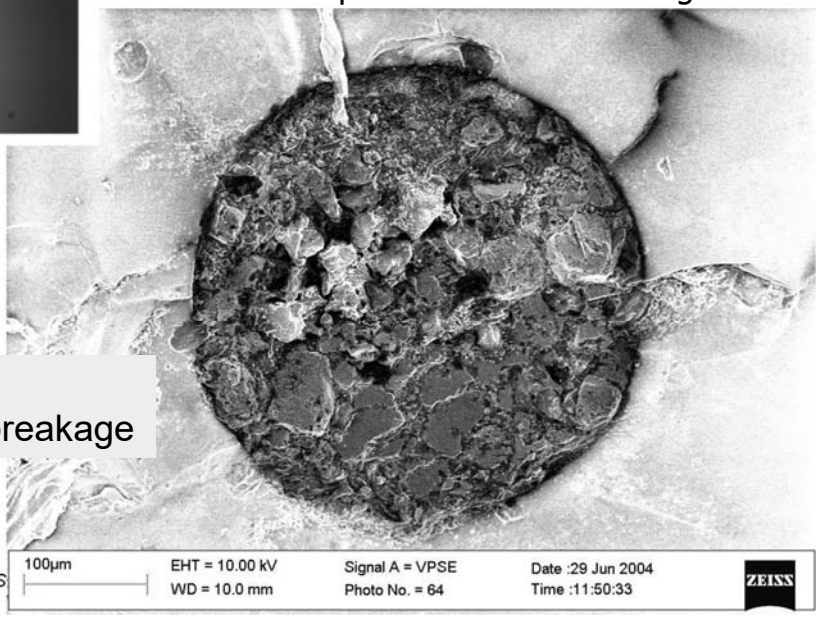
# Nickel Sulphide (NiS)



Microscopic Cross-sectional Image of NiS



Microscopic view of NiS inclusion




NiS inclusion > 50μm dia.
may cause spontaneous breakage

# Spontaneous Breakage in Tempered Glass

## Where Nickel Sulphide comes from?

- The Sulphur in the Nickel Sulphide is added to the glass as a fining agent in the form of sodium sulphate.
- There are three possible sources how nickel is introduced.
  - Raw material contamination
  - Contamination of materials used in storage/handling of the raw materials
  - Contamination in the furnace via fire bricks or gas burners



# Spontaneous Breakage in Tempered Glass

## Transformation of NiS from α phase to β phase?

- When temperature ranges between 260°C ~ 320°C, Nickel Sulphide is stable in the β-phase (low temperature) form, the volume is 2% to 4% larger than α-phase (high temperature) form).
- Beyond 320°C, NiS is stable in the α-phase form (smaller volume).
- α-NiS is not stable around 260°C, tends to transform to β-NiS.
- During manufacturing of tempered glass, the glass was heated at around 620°C followed by rapid cooling on the surface of heated glass.
- NiS inclusion would be in α-phase form. Upon rapid cooling, α-NiS does not have enough time to transform to β-NiS.
- Therefore, α-NiS was “trapped” inside the glass panel.

# Spontaneous Breakage in Tempered Glass

## Cause of spontaneous breakage

- The “trapped” $\alpha$-NiS will transform to $\beta$-NiS at the room temperature. However, this transformation takes from months to years to complete.
- Due to the fact that the volume of NiS from $\alpha$-phase to $\beta$-phase increases by 2% to 4%, this will exert localized expansion stress around the NiS.
- In compression zones, the stress is not a concern due to its extreme localization.
- However, in the core tension zone of the glass, the stress can cause micro-crack at the glass-NiS interaction surface. These micro-cracks are propagated by stress concentrations at the tip of the crack until the structure of the glass is undermined completely.
- Causes spontaneous breakage.



# Spontaneous Breakage in Tempered Glass

## Preventive Measure to reduce the risk spontaneous breakage:

- Controlling of NiS in manufacturing process
  - *It is costly and not practical to eliminate the NiS inclusion in the manufacturing process.*
- Reduce the use of tempered glass
  - *In term of strength, breakage characteristic, post-failure behaviour and safety, laminated glass is a good alternative to tempered glass. However, this may be expensive to the owner.*
- Heat Soak Process
  - *Up-to-now, the most effective and efficient way to minimize the risk spontaneous breakage.*

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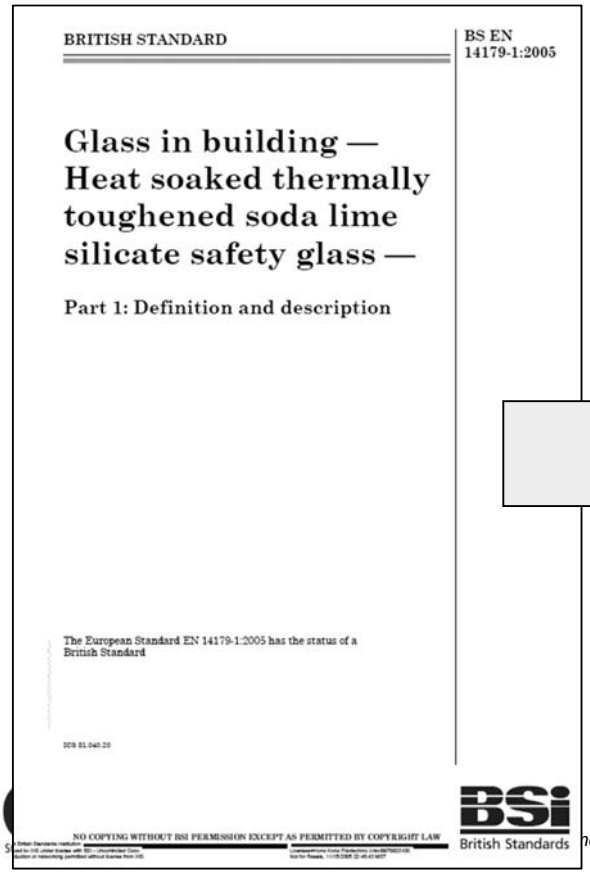
# Quality Control of Tempered Glass

# Heat Soak Process
# BS EN 14179-1: 2016

## Heat Soak Process


BRITISH STANDARD

BS EN 14179-1:2005

Glass in building — Heat soaked thermally toughened soda lime silicate safety glass —

Part 1: Definition and description

The European Standard EN 14179-1:2005 has the status of a British Standard

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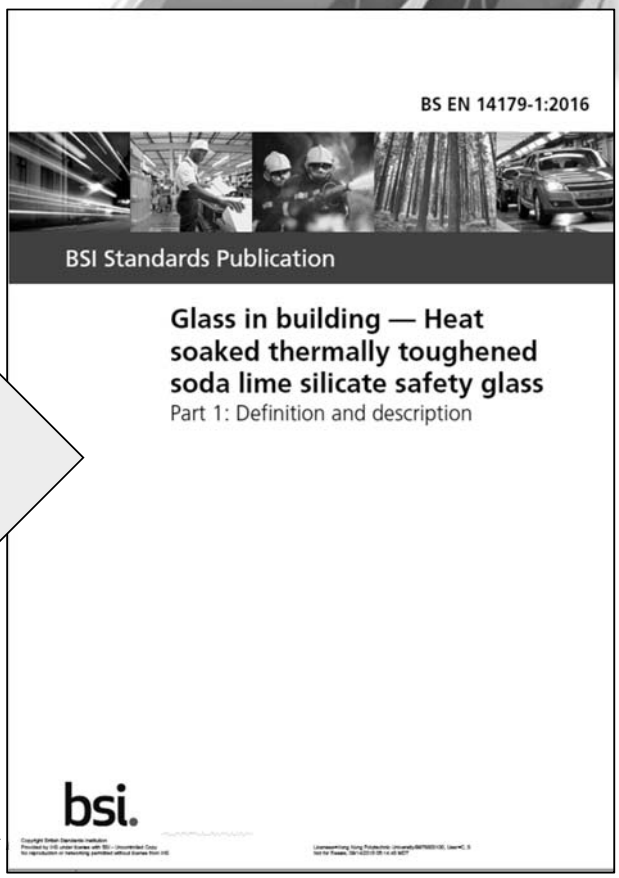
BSI British Standards


BS EN 14179-1:2016

BSI Standards Publication

Glass in building — Heat soaked thermally toughened soda lime silicate safety glass

Part 1: Definition and description

bsi.

*ment to BS*

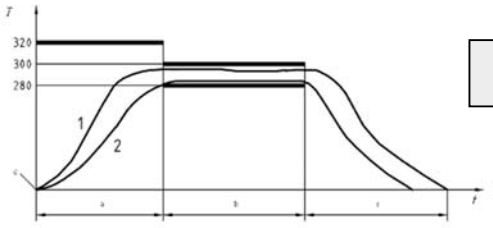
# Heat Soak Process

EN 14179-1:2005 (E)

**5.3 Heat soak process cycle**

**5.3.1 General**

The heat soak process cycle consists of a heating phase, a holding phase and a cooling phase (see Figure 1).




Key

| | | | |
|---|---|---|---|
| $T$ | glass temperature at any point, °C | d | ambient temperature |
| $t$ | time, h | a | heating phase |
| 1 | first glass to reach 280 °C | b | holding phase |
| 2 | last glass to reach 280 °C | c | cooling phase |

Figure 1 — Heat soak process cycle

BS EN 14179-1:2016
EN 14179-1:2016 (E)

**5.2 Toughening process**

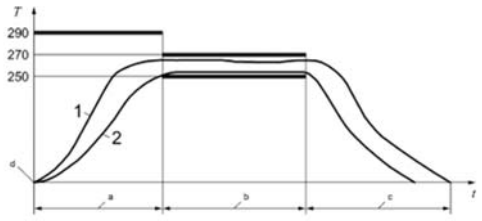
The cut, shaped and edgeworked glasses are toughened. The glasses toughened by the horizontal or air cushion or vertical process shall comply with the flatness criteria (see 8.3).

The thermally toughened soda lime silicate safety glass shall have a level of fragmentation that will ensure that after the glass has been through the heat soak process, and subsequently tested to the fragmentation test (see Clause 10), it shall comply with 10.5.

**5.3 Heat soak process cycle**

**5.3.1 General**

The heat soak process cycle consists of a heating phase, a holding phase and a cooling phase (see Figure 1).




Key

| | | | |
|---|---|---|---|
| $T$ | glass temperature at any point, °C | d | ambient temperature |
| $t$ | time, h | a | heating phase |
| 1 | first glass to reach 250 °C | b | holding phase |
| 2 | last glass to reach 250 °C | c | cooling phase |

Figure 1 — Heat soak process cycle

280°C - 300°C, 320°C

250°C - 270°C, 290°C



# Heat Soak Oven

# Heating Phase

EN 14179-1:2005 (E)

**5.3.2 Heating phase**

The heating phase commences with all the glasses at ambient temperature and concludes when the surface temperature of the last glass reaches 280 °C. The time to reach this temperature is defined in the calibration process. This time will be dependent on the size of the oven, the amount of glass to be treated, the separation between glasses and the heating system capacity.

NOTE 1 The glass separation and rate of heating should be controlled to minimise the risk of glass breakage as a result of thermal stress.

BS EN 14179-1:2016
EN 14179-1:2016 (E)

**5.3.2 Heating phase**

The heating phase commences with all the glasses at ambient temperature and concludes when the surface temperature of the last glass reaches 250 °C. The maximum heating rate is 3° C per minute. The time to reach this temperature is defined in the calibration process. This time will be dependent on the size of the oven, the amount of glass to be treated, the separation between glasses and the heating system capacity.

NOTE 1 The glass separation and rate of heating should be controlled to minimize the risk of glass breakage as a result of thermal stress.

- Conclude when last glass surface temperature reach 250°C.
- Maximum heating rate is 3°C per minute.



# Heating Phas

Product Conformity Certification Scheme for Heat Soaked Tempered Glass - Technical Requirements

香港鋼結構學會 Hong Kong Institute of Steel Construction

Façade Group

PRODUCT CONFORMITY CERTIFICATION SCHEME

FOR

HEAT SOAKED TEMPERED GLASS

TECHNICAL REQUIREMENTS

FaG-TG 002

*JANUARY 2006*

The Facade Group, The Hong Kong Institute of Steel Construction *FaG-TG002*

**Product Conformity Certification Scheme for Heat Soaked Tempered Glass - Technical Requirements**

chamber/ furnace under the Scheme. The Participant shall carry out routine inspection and monitoring of the equipment and machinery at least at weekly intervals to ensure the production consistency. These quality records shall be maintained for three years.

8.2 Calibration of the heat soak chamber/ furnace

(a) The furnace shall be calibrated at least once a year.
(b) The thermocouples used for the temperature monitoring shall be calibrated at a minimum of every six months.
(c) A minimum no.of 8 monitoring points on the glass surface are required, including the positions where the minimum and maximum surface temperatures for each side stillage during the calibration. Take the case for 2 double side stillages as an example (refer to figure A.6 of BS EN 14179-1: 2005), the choice of the 8 monitoring points shall be those where the maximum and minimum surface temperatures for positions 1 – 5, 6 – 10, 11 – 15 and 16 – 20 respectively.
(d) The rate of heating shall be steadily increased. After an initial 15 minutes of heating, the rate of heating of all glass panels shall be less than 3 °C / min.

8.3 The Participant shall establish and implement systematic controls on the heat soak process at the plant in accordance with Clause 5.3 and Clause 6 of BS EN 14179-1: 2005 and this Scheme.

8.2(a) to 8.2(c) were incorporated in PNAP APP37 May 2012.
8.2(d) is a recommendation which not stipulated in BS EN 14179-1: 2005 and PNAP APP37.

# Heating Phase

EN 14179-1:2005 (E)

To facilitate economic heating, the air temperature within the oven may exceed 320 °C. However, the glass surface temperature shall not be allowed to exceed 320 °C. The period of glass surface temperature in excess of 300 °C shall be minimised.

NOTE 2 When the temperature of the glass exceeds 300 °C, care should be taken to ensure that the properties of the heat soaked thermally toughened soda lime silicate safety glass are not significantly altered i.e. they continue to meet Clause 10.

BS EN 14179-1:2016
EN 14179-1:2016 (E)

To facilitate economic heating, the air temperature within the oven may exceed 290 °C. However, the glass surface temperature shall not be allowed to exceed 290 °C. The period of glass surface temperature in excess of 270 °C shall be minimized.

NOTE 2 Care should be taken to ensure the maximum temperature of the glass does not exceed 270° C as there is a possibility of the nickel sulphide inclusion reconverting.

Research Finding: Nickel Sulphide phase transformation around 260°C



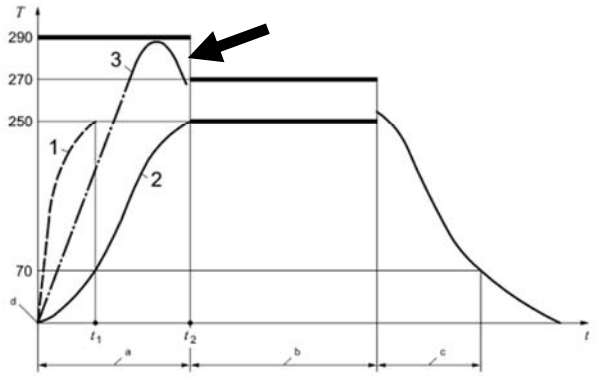
BS EN 14179-1:2016
EN 14179-1:2016 (E)

**Annex A**
(normative)

**Heat soak process system calibration test**

**A.1 Calibration criteria**

The heat soak process system shall comply with the time / temperature regime as shown in Figure A.1. The system shall be capable of meeting in the regime at both maximum and minimum load.




Key

| | | | |
|---|---|---|---|
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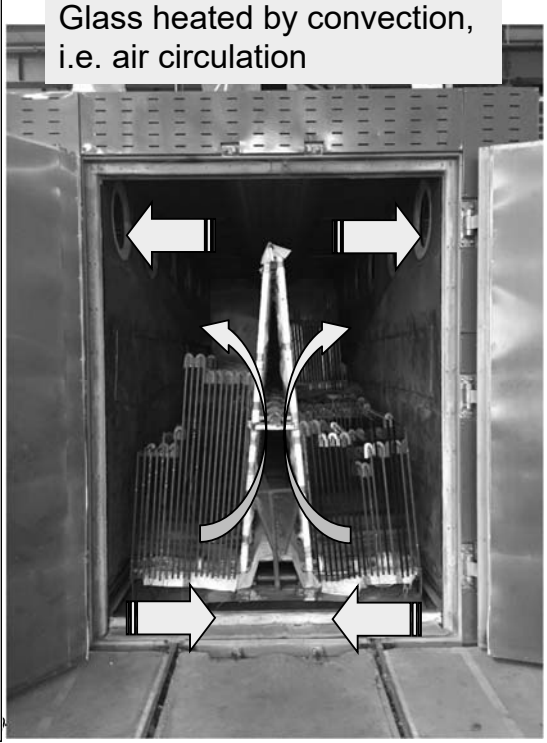
| *t* | time, h | *d* | ambient temperature |
| *t1* | time for the first glass to reach 250 °C | *a* | heating phase |
| *t2* | time for the last glass to reach 250 °C | *b* | holding phase |
| *1* | first glass to reach 250 °C | *c* | cooling phase |
| *2* | last glass to reach 250 °C | | |

**Figure A.1 — Time / temperature regime as calibration criteria**

Allowed, but should minimize the period of temperature exceed 270°C

Glass heated by convection, i.e. air circulation



# Holding Phase

EN 14179-1:2005 (E)

**5.3.3 Holding phase**

The holding phase commences when the surface temperature of all the glasses has reached a temperature of 280 °C. The duration of the holding phase is 2 h.

Precise oven control is necessary in order to ensure that the glass surface temperature shall be maintained in the range of 290 °C ± 10 °C during the holding phase.

BS EN 14179-1:2016
EN 14179-1:2016 (E)

**5.3.3 Holding phase**

The holding phase commences when the surface temperature of all the glasses has reached a temperature of 250 °C. The minimum duration of the holding phase is 2 hours.

Precise oven control is necessary in order to ensure that the glass surface temperature shall be maintained in the range of 260 °C ± 10 °C during the holding phase.

- Start when all glass surface temperature reached 250°C.
- Min. duration 2 hours
- 260°C ± 10°C



# Cooling Phase

EN 14179-1:2005 (E)

**5.3.4 Cooling phase**

The cooling phase commences when the last glass to reach 280 °C has completed its holding phase, i.e. been held for two hours at 290 °C ± 10 °C. During this phase the glass temperature shall be brought down to ambient temperature.

The cooling phase can be concluded when the air temperature in the oven reaches 70 °C.

NOTE The rate of cooling should be controlled to minimise the risk of glass breakage as a result of thermal stress.

BS EN 14179-1:2016
EN 14179-1:2016 (E)

**5.3.4 Cooling phase**

The cooling phase commences when the last glass to reach 250 °C has completed its holding phase, i.e. been held for minimum 2 hours at 260 °C ± 10 °C. During this phase the glass temperature shall be brought down to ambient temperature.

The cooling phase can be concluded when the air temperature in the oven reaches 70 °C.

The rate of cooling should be controlled to minimize the risk of glass breakage as a result of thermal stress.

- Conclude when air temperature in the oven reaches 70°C

# Glass Support & Spacing

***Same requirement in both 2005 and 2016 versions.***

EN 14179-1:2005 (E)

BS EN 14179-1:2016
EN 14179-1:2016 (E)

### 6.2 Oven

The oven shall be heated by convection and shall allow an unhindered air circulation around each glass pane. In the event of glass breakage the airflow shall not be hindered. The airflow in the oven shall be led parallel to the glass surfaces.

The openings in the oven for the air ingress / egress should be designed to ensure that fragments of broken glass do not cause blockages.

### 6.3 Glass support

Glasses may be supported vertically or horizontally. The glasses shall not be fixed or clamped, they have to be supported to allow free movement.

NOTE Vertically means true vertical or up to 15° either side of true vertical.

The distance between glasses affects the airflow, heat exchange and the heating time. Glass to glass contact shall not be allowed.



# Glass Separation

***Same requirement in both 2005 and 2016 versions.***

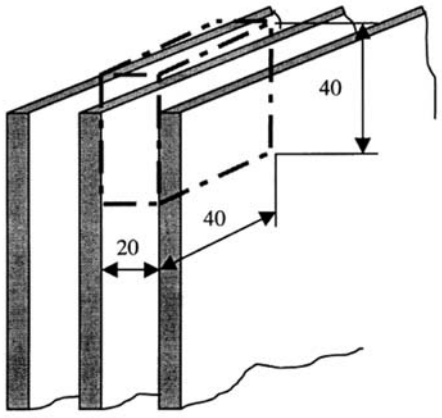
EN 14179-1:2005 (E)

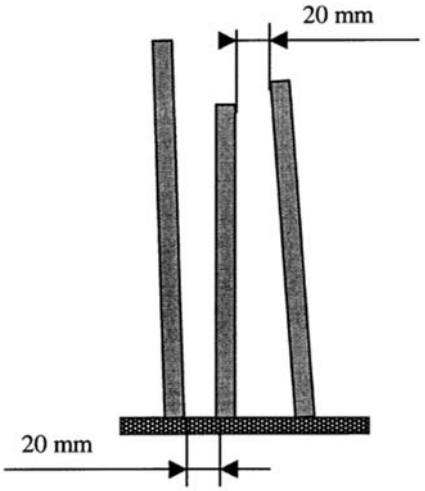
BS EN 14179-1:2016
EN 14179-1:2016 (E)

### 6.4 Glass separation

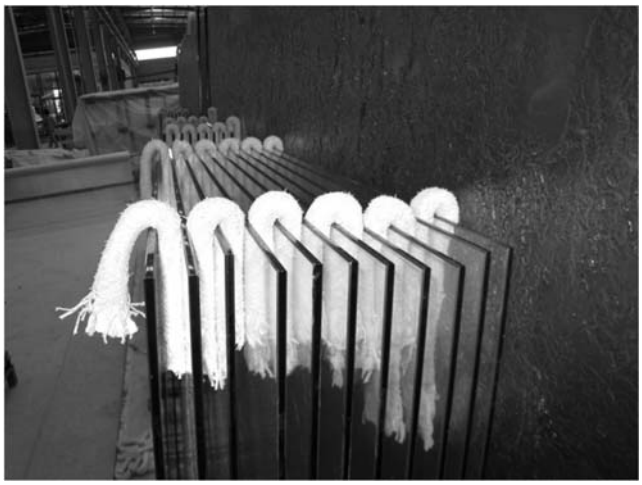
The glasses shall be separated in a manner that does not hinder the airflow. The separators shall also not hinder the airflow e.g. see Figure 2.

Dimensions in millimetres



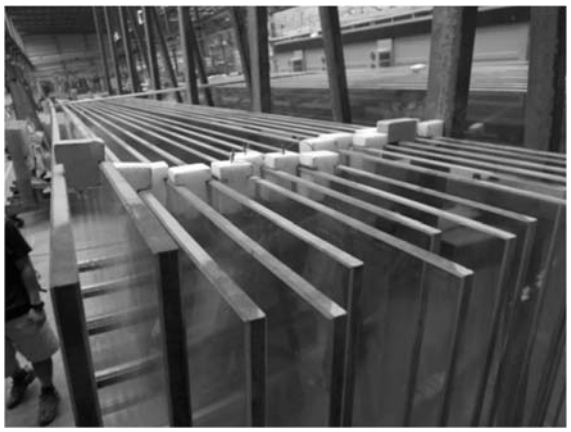



# Glass Separation – Spacer

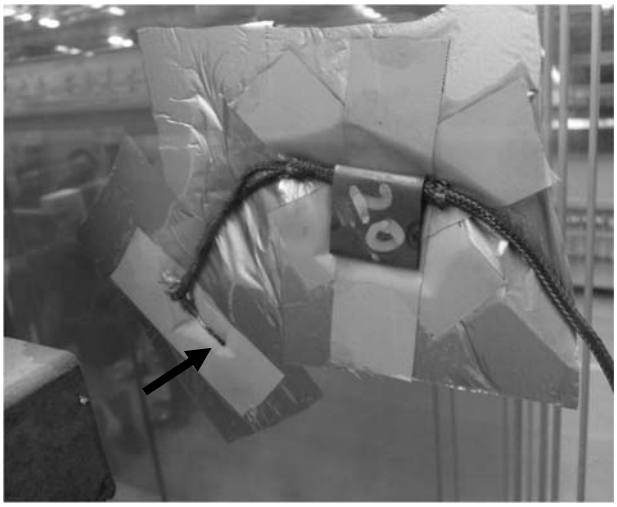




# Glass Support & Spacer



# Thermocouple – Good Practice



**TC simply installed**

**TC installed with insulation pad**



# Oven Calibration

### 6.5 Calibration

The heat soak system, e.g. oven, glass separation, separators, etc., shall be calibrated, see Annex A.

The calibration shall determine the heating phase of the process, glass separation distance, the positioning, material and shape of separators, the type and positioning of stillage(s) and define the operating conditions for use during manufacture.

***Clause 6.5 is same in both 2005 and 2016 versions.***

***But the calibration method is updated.***
***From "100% Load" & "10% Load" to one "Full Load".***

# Oven Calibration – BS EN 14179-1: 2005

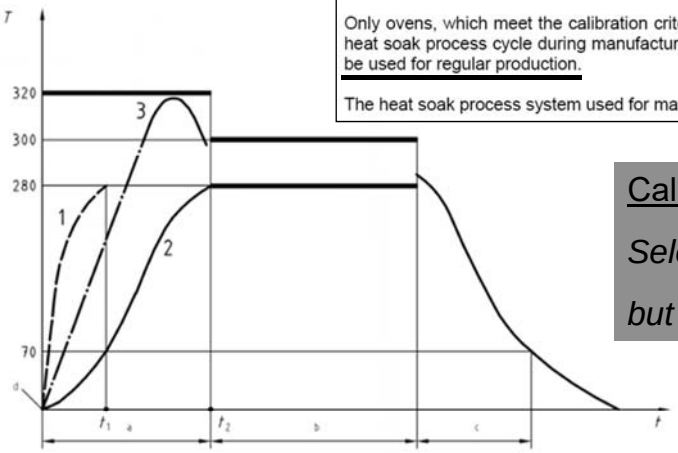


**A.5 Interpretation of the calibration test**

If the conditions for temperatures laid down in A.1 are not met then the oven shall not be regarded as calibrated.

Only ovens, which meet the calibration criteria as laid down in A.1 at full and 10 % load may be used for the heat soak process cycle during manufacture. The longer of the two times $t_{2,1}$ (full load) or $t_{2,2}$ (10 % load) shall be used for regular production.

The heat soak process system used for manufacture shall comply with the details of the system as calibrated.




Calibration to BS EN 14179-1

*Selection from Heating Phase* ✓

*but not Holding Phase*

Key

| | | | |
|---|---|---|---|
| $T$ | Glass temperature at any point, °C | 3 | glass temperature |
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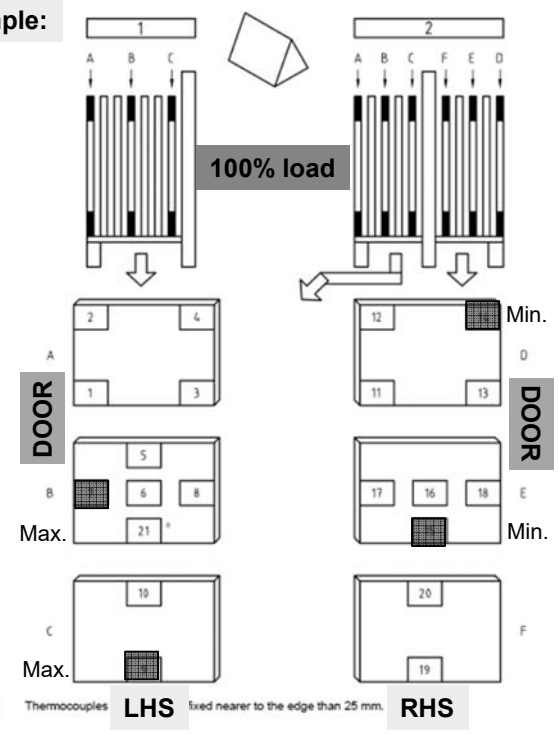
| $t_2$ | time for the last glass to reach 280 °C | b | holding phase |
| 1 | first glass to reach 280 °C | c | cooling phase |
| 2 | last glass to reach 280 °C | | |

**Figure A.1 — Time/temperature regime as calibration criteria**



DWKY

**Example:**

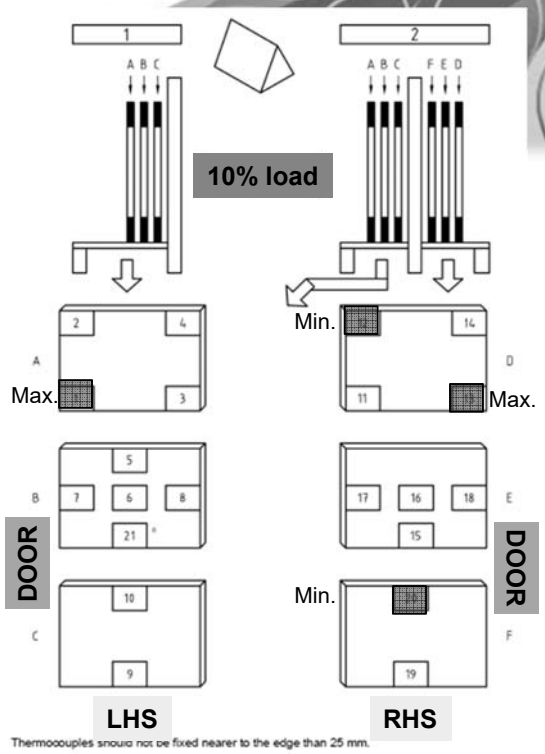



NOTE Thermocouples fixed nearer to the edge than 25 mm.

Key

a is only used for mono side stillages
1 mono side stillage
2 double sided stillage

**Figure A.2 — 1st category – 1 stillage – full load**



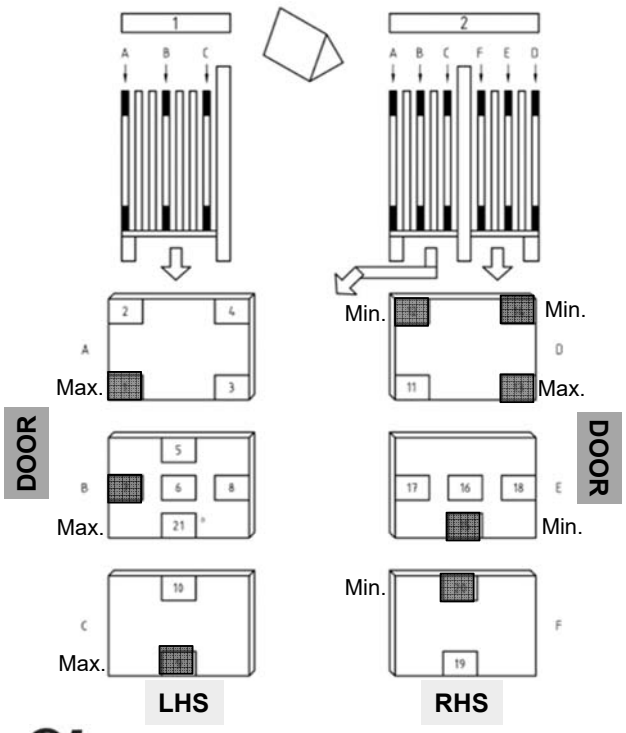

NOTE Thermocouples should not be fixed nearer to the edge than 25 mm.

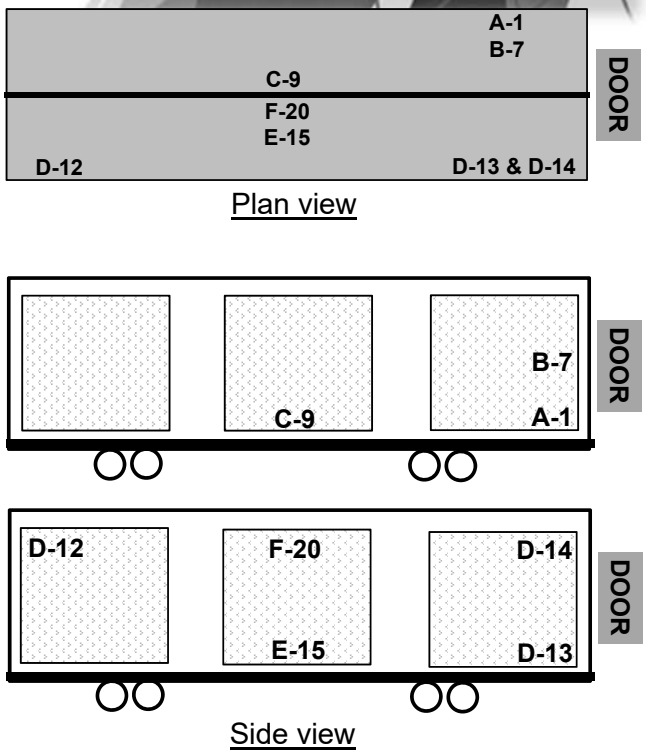
Key

a is only used for mono side stillages
1 mono side stillage
2 double sided stillage
3 on the stillage: minimum 3 glasses in parallel side by side

**Figure A.3 — 1st category – 1 stillage – 10 % load**

# Thermocouples Locations




Plan view

Side view



# Oven Calibration – BS EN 14179-1: 2016

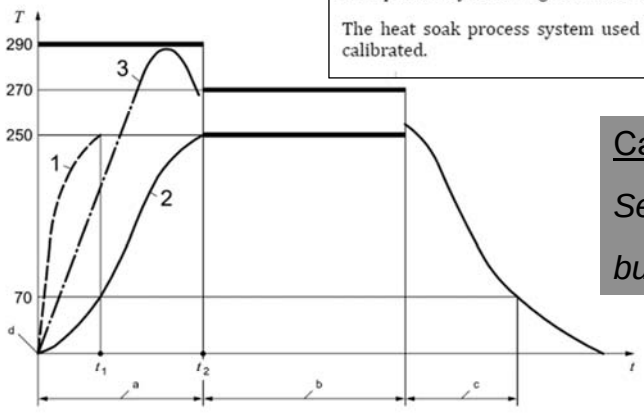
BS EN 14179-1:2016
EN 14179-1:2016 (E)

**A.5 Interpretation of the calibration test**

If the conditions for temperatures laid down in A.1 are not met then the oven shall not be regarded as calibrated.

Only ovens, which meet the calibration criteria as laid down in A.1 at full load may be used for the heat soak process cycle during manufacture. The time $t_2$ shall be used for regular production.

The heat soak process system used for manufacture shall comply with the details of the system as calibrated.

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| *1* | first glass to reach 250 °C | *c* | cooling phase |
| *2* | last glass to reach 250 °C | | |

Figure A.1 — Time / temperature regime as calibration criteria

Calibration to BS EN 14179-1

*Selection from Heating Phase* ✓

*but not Holding Phase*

8 monitoring thermocouples to be selected in "Full Load" calibration:
- 4 highest & 4 lowest during heating phase

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# Quality Control of Tempered Glass

# Residual Risk

## Level of Residual Risk

**Same Level of Residual Risk in 2016 version**

BS EN 14179-1:2016
EN 14179-1:2016 (E)

3.2
**level of residual risk**
risk of spontaneous breakage of heat soaked thermally toughened soda lime silicate safety glass, on a statistical basis, due to the presence of critical nickel sulphide inclusions, is no more than one breakage per 400 t of heat soaked thermally toughened soda lime silicate safety glass

- Since spontaneous glass breakage in tempered glass cannot be eliminated, an effective and trust-worthy heat soak process should be able to screen out glass containing NiS inclusion.

**To reduce, not to eliminate!!**

# Level of Residual Risk

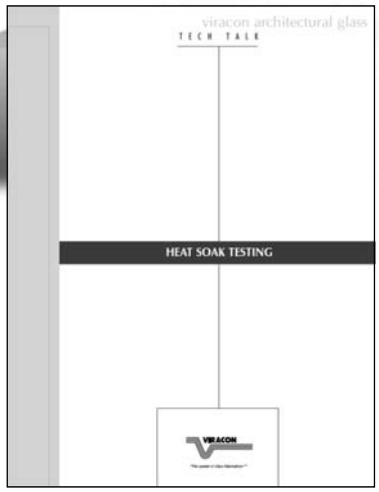
- One breakage per 400,000 kg of heat soaked glass.

| Thickness | Equivalent surface area of 400,000 kg |
|---|---|
| 6 mm | 26,667 $m^2$ |
| 8 mm | 20,000 $m^2$ (4,000 nos. of 5$m^2$) |
| 10 mm | 16,000 $m^2$ (3,200 nos. of 5$m^2$) |
| 12 mm | 13,333 $m^2$ |
| 15 mm | 10,667 $m^2$ |
| 19 mm | 8,421 $m^2$ |
| 22 mm | 7,273 $m^2$ |

- Same thickness? Same batch? Traceable?



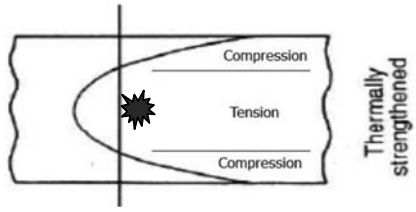
# Level of Residual Risk

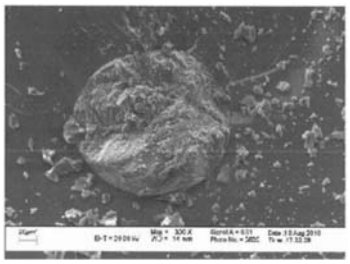



- Heat soak test at Viracon (US) since 1984.
- With two hours holding time, Viracon is confident that to minimize the potential spontaneous breakage to its lowest level.
- Viracon offers heat soaked tempered glass warranty for spontaneous breakage 5 Lites per 1000 (i.e. 0.5%).
- *Example:*
  *For a project used 40,000 glass panels, it may occur 200 spontaneous breakage incidents.*

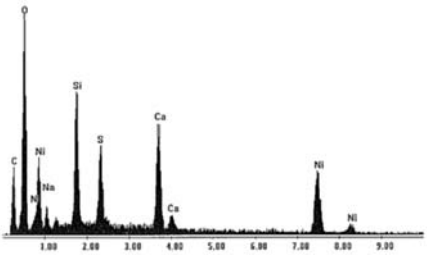
# Breakage Frequency and Timeline

- Many factors influence the fracture rate of tempered glass with NiS inclusion.
- The time to fracture is dependent on numerous factors:
  - Glass panel size – membrane stress developed in the glass panel
  - Location of the inclusion within the tensile zone of the tempered glass
  - Environmental conditions – temperature and wind pressure
  - Magnitude of the tensile stress within the tempered glass
  - Purity of the inclusion



Diameter > 50μm




energy dispersive spectroscopic

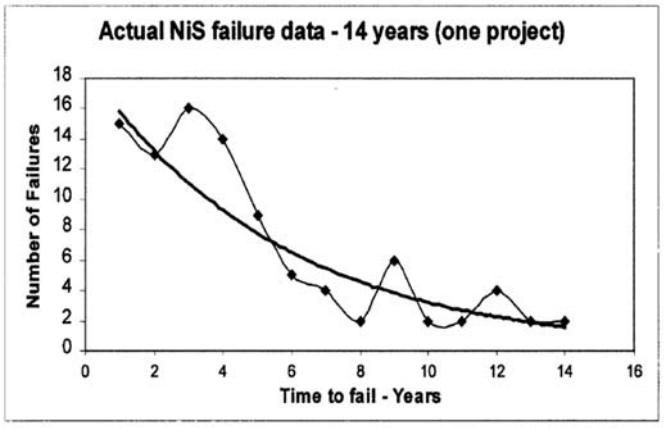


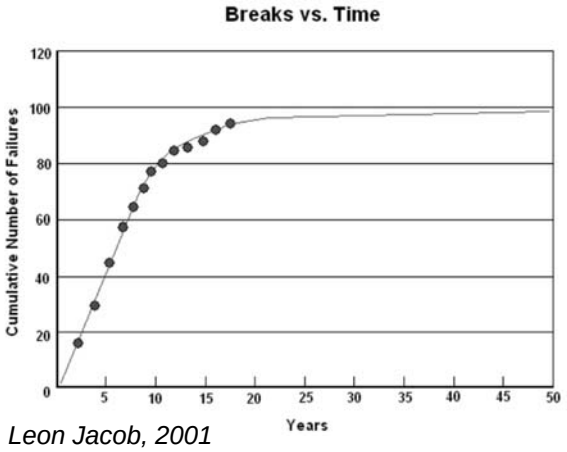
# Level of Residual Risk – Probability without Replacement

- Assume screen out 99.5% in heat soak process.
- Assume 5 possible cases in 1000 tempered glass panes
  - *1st breakage in 2nd year = 5/1000*
  - *2nd breakage in 2nd year = 4/999*
  - *3rd breakage in 3rd year = 3/998*
  - *Is there 4th or 5th breakage? may be…*
- *What if replacement of all glass panes after 3 nos. of breakage?*
- *Suffer the spontaneous breakage (Re-count the risk from 1st) again.*

# Breakage Frequency and Timeline

- The overwhelming trend is that **most panels break in the first 2 to 7 years**, after which the number of breakages tapers off with what is commonly considered a logarithmic decay.




*Leon Jacob, 2001*



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# Quality Control of Tempered Glass

# BD PNAP APP-37

# Heat Strengthened and Tempered Glass

- Surface compressive stress:
  > 69 MPa for Tempered glass
  24-52 MPa for Heat Strengthened glass
  0 MPa for Annealed glass
- Non-destructive photoelastic measurement of surface stresses in flat glass to ASTM C1279 & C1048 should be conducted.



# Local Requirements – Practice Note

- It is widely recognized that heat soak process accelerates the expulsion of the Nickel Sulphide inclusions in tempered glass and that heat soak process is the most effective means of eliminating tempered glass with Nickel Sulphide.
- Therefore, in the absence of other recognized quality control methods, heat soaking conforming to BS EN 14179-1: 2005 or other equivalent international standards should be carried out as it is part of the quality control measures for tempered glass used in curtain wall, window and window wall works.

# Development of Tempered Glass Heat Soak Requirements

| Version | | Requirements |
|---|---|---|
| 1999 | PNAP 106 | • **No** heat soak requirement was imposed to Curtain Wall |
| 2000 | PNAP 239 | • Heat soak test (min. **One** hour holding time)<br>• Tempered glass used in Window and Window Wall |
| 2006 | PNAP 106 | • Heat soak test (min. **Two** hour holding time)<br>• **ALL** tempered glass used in Curtain Wall, Window and Window Wall Systems. |
| 2009 | PNAP 106 | • Heat soak test (min. **Two** hour holding time)<br>• *Comply with BS EN 14179-1: 2005*<br>• **ALL** tempered glass used in Curtain Wall, Window and Window Wall Systems. |
| 2010 | PNAP APP-37 | • Same as PNAP 106 – 2009 |
| 2012 | PNAP APP-37 | • ***Additional Quality Assurance Scheme*** |
| Upcoming practice… | | • *Temperatures in line with BS EN 14179-1:* ***2016*** |



# Temperature Control

| | Temperature Control |
|---|---|
| BS EN 14179-1 | During the calibration, the oven temperature (***air temp.***) was co-related to the glass surface temperature.<br>During normal usage of the oven, this 'air temp.' will be use as a reference to determine the 'holding phase'.<br>**2005:** The longer of the two times $t_{2,1}$ (100% load) or $t_{2,2}$ (10% load) shall be used for regular production.<br><br>**2016:** The time $t_2$ shall be used for regular production. |
| PNAP APP-37 | 8 monitoring thermocouples (***glass surface temp.***) were required by the APP-37 to determine the 'holding phase'. The locations of these thermocouple were determined during the calibration of the oven. |

# Calibration

| | Calibration Period |
|---|---|
| BS EN 14179-1 | Calibration period is not specified. |
| PNAP APP-37 | The oven(s) are calibrated at one-year intervals.<br>The thermocouple are calibrated at six-month intervals. |



# Third Party Inspection

| | Third Party Inspection |
|---|---|
| BS EN 14179-1 | Not required. |
| PNAP APP-37 | RC: QC supervisor(s) to provide full time continuous supervision of the heat soak process of all tempered glass.<br>RC: Have to provide his own data logger to record the surface temperature of the glass panel.<br><br>RSE: QC supervisor(s) should cover at least 30% of the tempered glass used in the project.<br><br>***Both have Legal Liability*** |

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# Quality Control of Tempered Glass

# Quality Assurance Supervision

## PNAP APP-37 (2012)
### - Quality Assurance Scheme

16. The **Quality Assurance Scheme** should include the following items:

(a) Heat soak process to all tempered glass panes;

(b) Calibration of heat soak oven and laboratory equipment for quality control tests;

(c) Residual surface compressive stress measurement of glass[1];

(d) Testing procedures and requirements; and

(e) Frequency and extent of inspection and audit by in-house staff of the manufacturer, and independent parties.

---

[1] Note
Residual surface compressive stress measured to ASTM C1279 for different types of glass are as follows:
a) > 69 MPa for tempered glass
b) 24-52 MPa for heat-strengthened glass
c) 0 MPa for annealed glass

# PNAP APP-37 (2012)
## - Quality Assurance Scheme

We are sending you herewith the following:

| Copies | Ref No. | Description |
|---|---|---|
| Re: Quality Assurance Scheme Submission | | |
| 1 set (A4 size) | 1. | Glass Impact Test Report |
| | 2. | IGCC Certificate |
| | 3. | Quality Plan of Glass Fabricate |
| | 4. | Heat Soak Process Oven (Serial No. HGM-2011 132) |
| | 5. | Report R13H46A On Calibration of Oven HSTO-2550 |
| | 6. | Report R13H46B On Calibration of Oven HSTO-2560 |
| | 7. | Surface Compression Measurement Report to ASTM C1279 |
| | 8. | Surface Compression Measurement Report to ASTM C1048 |
| | 9. | 24Nos. Of Thermal Couples Calbiration Certificate |
| | 10. | ISO9001-2014 Certificate |



# PNAP APP-37 (2012)
## - Quality Assurance Scheme

Good Example

**INDEX**

# PNAP APP-37 (2012)
## - Quality Assurance Scheme

INTRODUCTION

The proposed Composite Development at [redacted]. The development consists of 5 nos. of 16 to 19 stories residential towers, two levels of podium which including first floor & ground floor comprising clubhouse, landscaped garden & M/E rooms. Curtain wall system will be adopted for tower portion.

Project info.

The Quality Assurance Scheme for Tempered Glass is prepared with reference to the condition imposed under BD approval letter dated 8 August 2013 for Superstructure Curtain Wall. Total Area of Curtain Wall approximately is 7,000 m2 of which approximately 5116 m2 is Tempered Glass.

Approx. Area

All tempered glass will be manufactured by [redacted] with ISO 9001 quality assurance certification and IGCC/IGMA Program Certification (Section A refers).

Glass Manufacturer

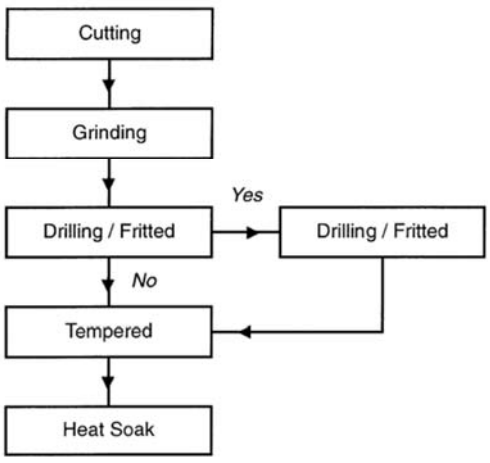
The related production flowchart and the control standard are shown as page 2 & page 3.



# PNAP APP-37 (2012)
## - Quality Assurance Scheme

Quality Assurance Scheme for Tempered Glass
By [redacted]

1. Production Flowchart




ALPHA Steel Structure & Façade Specialist 20170523 ICWCI - Latest Heat Soak Requirement to BS EN 14179-1: 2016 DWKY

# PNAP APP-37 (2012)
## - Quality Assurance Scheme

2. Tempered Glass

| Item | Control Standard | Inspection Frequency | Inspection Equipment | Responsible Staff | Inspection Record | Remark |
|---|---|---|---|---|---|---|
| Surface Stress | ASTM C1048 or according to specification | Random check 1 piece per hour | Grazing angle surface polarimeter | Quality inspector & Heat oven operator | Tempered glass quality control record | Measurement as ASTM C1279 |
| Fragmentation | 4-12mm > 40 pcs<br>Other thickness > 30 pcs | | Pointed steel tool & Ruler | | | |
| Roller Wave | ASTM C1048 or according to specification | Random check 1 piece per order batch | 300mm guide rail & Feeler gauge | | | |
| Bow | ASTM C1048 or according to specification | | Steel ruler & Thread | | | |

3. Heat Soak Process

| Item | Control Standard | Inspection Frequency | Inspection Equipment | Responsible Staff | Inspection Record | Remark |
|---|---|---|---|---|---|---|
| Tempered Glass | EN 14179-1:2005 | 100% | Heat Soak Oven | Heat oven operator | Heat soak report | Comply with APP37 |



# PNAP APP-37 (2012)
## - Quality Assurance Scheme

**B.) Frequency and extent of inspection and audit by in-house staff of the manufacturer, and independent parties**



ALPHA Steel Structure & Façade Specialist
*20170523 ICWCI - Latest Heat Soak Requirement to BS EN 14179-1: 2016*
DWKY

# PNAP APP-37 (2012)

## Heat Soak Process

17. All tempered glass panes should be heat soak treated. It is widely recognized that heat soak process[2] accelerates the expulsion of the nickel sulphide inclusions in tempered glass and that heat soak process is the most effective means of eliminating tempered glass with nickel sulphide. It is therefore required that heat soak process conforming to BS EN 14179-1:2005 or other equivalent international standards should be carried out to all tempered glass panes, as one of the quality control measures for tempered glass used in curtain wall, window and window wall works.

[2] Note

Heat soak process that significantly reduces the risk of damaging nickel sulphide usually includes, inter alia, an oven of taking the glass panes through three phases of the process. The heating phase commences with all the glass panes at ambient temperature and concludes when the surface temperature of the last glass pane reaches 280°C. The holding phase commences when the surface temperature of all the glass panes has reached a temperature of 280°C. The duration of the holding phase is 2 hours minimum. The surface temperature of the glass panes shall be maintained in the range of 290°C±10°C during the holding phase. The cooling phase commences when the last glass pane to reach 280°C has completed its holding phase. The cooling phase can be concluded when the air temperature in the oven reaches 70°C.



# PNAP APP-37 (2012)

## Compliance Report for Heat Soak Process

18. Under Regulation 10 of the B(A)R, a requirement will be imposed, when giving approval of plans, to require the compliance reports for heat soak process issued by the glass manufacturers and endorsed by the RSE to be submitted prior to the application for occupation permit. The compliance report should contain the following information:

(a) Name of the tempered glass manufacturer;

(b) Name of the project using the manufacturer's tempered glass;

(c) Total number and surface area of tempered glass panes used in the project;

(d) Location and identity number of the ovens, in which the heat soak process of the glass panes in (c) was conducted;

(e) Calibration report[3] of the ovens in accordance with BS EN 14179-1:2005 or equivalent;

# PNAP APP-37 (2012)

(f) Quantity and configuration of thermocouples used to measure the glass surface temperatures in the oven. A minimum of 8 thermocouples[4] shall be used. The location of these thermocouples shall be determined from the calibration report of the oven;

(g) Recorded temperature versus time graphs for each of the 8 thermocouples during heating phase, holding phase and cooling phase of the heat soak process;

(h) Quantity, dimensions and thickness of the tempered glass panes conforming to BS EN 14179-1:2005 or other equivalent international standards, and the record of breakages of panes in each heat soak process with corresponding oven number; and

(i) Date of carrying out the heat soak process.



# PNAP APP-37 (2012)

[3] Note
The oven should be calibrated at regular intervals in order to ensure the accuracy in achieving the correct temperature during heat soak process. Usually, the calibration period for oven is set at one-year interval.

[4] Note
Thermocouples are used to monitor the highest and lowest temperatures on the glass surfaces. For the 10% loaded oven, 2 locations for the 2 highest temperatures and 2 locations for the 2 lowest temperatures should be identified. For the 100% loaded oven, 2 locations for the 2 highest temperatures and 2 locations for the 2 lowest temperatures should similarly be identified. Hence, a minimum of 8 thermocouples should be used for monitoring glass surface temperatures in the oven. The thermocouples are calibrated at 6-month intervals as recommended in the HOKLAS Supplementary Criteria No. 2.

- Fastest ≠ Highest
- Select from Heating Phase not Holding Phase

# PNAP APP-37 (2012)

## Quality Supervision

20. Under item 6 in Section 17(1) of the BO, a condition will be imposed, when giving approval of plans, to require the submission of a quality supervision plan by the RSE and the RC for the quality supervision of manufacturer's heat soak process of the tempered glass to be used in the works shown in the approved plans.

21. The **RSE** should assign a quality control supervisor to supervise a certain number of tempered glass panes undergoing the heat soak process. The RSE should determine the necessary frequency of supervision, which should cover **at least 30%** of the tempered glass panes used in the project. The minimum qualifications and experience of the quality control supervisor are to be the same as **grade T3** technically competent person (TCP) under the RSE's stream, as stipulated in the Code of Practice for Site Supervision.



# PNAP APP-37 (2012)

22. The **RC** should assign a quality control supervisor to provide **full time continuous supervision** of the heat soak process of all tempered glass panes in the factory. The minimum qualifications and experience of the quality control supervisor are to be the same as **grade T1** – TCP under the RC's stream, as stipulated in the Code of Practice for Site Supervision 2009. To ensure the heat soak process is properly conducted by the glass manufacturer, the quality control supervisor should **measure the glass surface temperature independently by using his/her own data logger**. The information recorded by the data logger should be set at one-minute intervals and kept in the factory.

23. The names and qualifications of the quality control supervisors of the RSE and the RC respectively should be recorded in an inspection log book. The details of heat soak process for tempered glass panes should be recorded in the log book and kept in the factory.

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# Quality Control of Tempered Glass

# Tempered Glass is Safety Glass

## BD PNAP APP-110

**Appendix A**
**(PNAP APP-110)**

**Recommendations on the Salient Aspects of the Design and Construction of Glass Protective Barriers**

**Types of Glass for Protective Barriers**

1. Glass types considered suitable for use in protective barriers (barriers) are as follows :

(a) **Laminated glass** is a safety glass suitable for barriers where the glass is fully framed. It is subject to measures being taken to ensure the glass edges are protected from direct exposure to moisture and compressive forces that can cause delamination.

(b) **Tempered glass** is a safety glass suitable for barriers where the glass is fully or partially framed or is free-standing. The configuration of any opening in this type of glass should be agreed with the manufacturer and the fabricator. Due to the possibility of spontaneous breakage in tempered glass, AP/RSE should ensure that an acceptable method of quality control (such as infrared photography, laser photography or heat soaking) has been adopted in order to prevent the debris of glass formed due to the spontaneous breakage of tempered glass from falling to the lower levels.

Steel Struc

OWKY

# Safety Glass

- Tempered glass is classified as “Safety Glass” because of its *higher ultimate bending strength* and its *fracture pattern*.
- The high stresses in the tempered glass lead it to fracture into *small, relatively smooth cube-like pieces* (referred to as fracture dice) upon breaking which *reduce the risk of injury*.
- For protective barriers, glass should comply with the impact test requirements (Class A) as stipulated in BS 6206: “Impact performance requirements for flat safety glass and safety plastics for use in buildings”.



# Impact Test to BS 6206: 1981

BS 6206:1981

- With the specimen mounted vertically.
- Raise the soft body impactor (45 kg) to a drop height of 305 mm and hold it at that position.
- Release the impactor so that it swings in a pendulum arc and strike onto the specimen.
- Inspect the test piece after impact.
- Repeat the test with a drop height of 457 mm and 1219 mm.

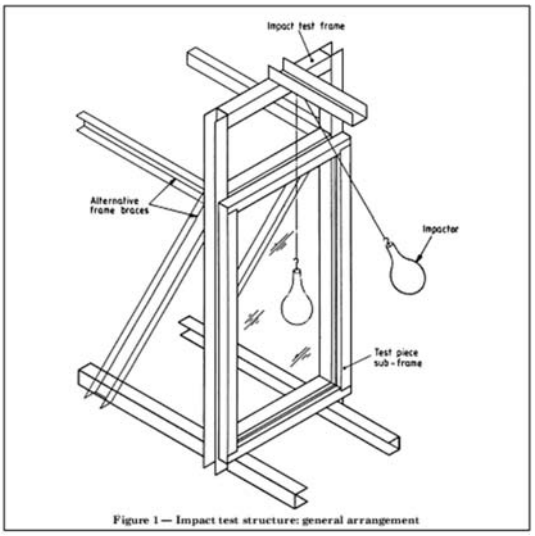

Figure 1 — Impact test structure: general arrangement

BS 6206:1981 may likely be replaced by BS EN 12600:2002

# Test Reports submitted in Quality Assurance Scheme

- Impact test reports and Surface Stress Measurement reports are commonly included in the Quality Assurance Scheme for consent application.
- Is it HOKLAS endorsed test report?
- or just a Reference Report?
- or just a Witness Report!!!
- One report cover all glass thicknesses? (and tested on same date) !!!
- Is the glass batch for your project?



# BS 6206 Classification

| Class | Behaviour on impact | | |
|---|---|---|---|
| | Drop height 305 mm | Drop height 457 mm | Drop height 1 219 mm |
| A | No breakage, or breaks safely | No breakage, or breaks safely | No breakage, or breaks safely |
| B | No breakage, or breaks safely | No breakage, or breaks safely | No requirement |
| C | No breakage, or breaks safely | No requirement | No requirement |

[*Extracted from BS 6206: 1981*]



Min. 10mm tempered glass >> No Breakage
6mm or 8mm tempered glass >> Break Safety

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# Quality Control of Tempered Glass

# Notes to T1 & T3 Inspection

## T1 & T3 Inspection Basic Check List

1. The oven has been calibrated (within calibration period).
2. The total weight of glass panels is within the oven capacity (< 100% load of the calibration).
3. The sizes of panels are less than those used in the calibration.
4. Check spacing of glass panel > 20 mm.
5. Refer to the eight monitoring thermocouples selected from the calibration report (4 from 100% load and 4 from 10% load).
6. Check the glass surface temperature within the range (280°C - 300°C) during holding phase.
7. The working thermocouples should be either internal or external calibrated. For internal calibration, the comparison shall be against a reference thermocouple (external calibrated).
8. The use of a checking thermocouple with data-logger at 1-minute interval.

# EL-USB-TC-LCD

## Thermocouple Data Logger with LCD and USB Interface

| ORDERING INFORMATION | |
|---|---|
| Standard Data Logger (Data Logger, Measurement Leads, Software on CD and Battery) | EL-USB-TC-LCD |
| Replacement Battery | BAT 3V6 1/2AA |
| K-type Probe | K-TYPE PROBE 1M5 |

FEATURES

- -200 to +1350°C (-328 to +2462°F) K-type measurement range
- -200 to +1190°C (-328 to +2174°F) J-type measurement range
- -200 to +390°C (-328 to +734°F) T-type measurement range
- High contrast LCD, with four digit temperature display
- USB Interface for set-up and data download
- User-programmable alarm thresholds
- Status indication via red and green LEDs
- Immediate, delayed and push-to-start logging
- Supplied with basic K-type thermocouple rated from 0 to 400°C (32 to 752°F)
- Supplied complete with replaceable internal lithium battery and Windows control software


Unit Price HK$770
http://hongkong01.rs-online.com/web/p/data-loggers/6668160/



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# Quality Control of Tempered Glass

# Heat Soak - FAQ

# FAQ:
# Glass thickness

- Somebody suggests include all different glass thicknesses in oven calibration?
- *Some calibration reports include all thickness range in calibration and measure different thickness (eg. 8mm, 10mm, … 22mm) !?*
  *>> Disturb the temperature data (Max. & Min.) to 280℃*

- *Recommend to use two consecutive glass thicknesses (eg. 6mm & 8mm or 8mm & 10mm) in calibration.*



# FAQ:
# 100% & 10% Loading

- Somebody comments glass weight in 10% loading must be exactly 0.1 x glass weight of 100% loading?!
- 100% load (Full load) = Full capacity of the Oven?? ✘
  ⇒ *Should be max. loading in daily operation* ✓
- 10% load = 0.1 x 100% load ??**???**
  ⇒ *Should be min. loading in daily operation* ✓

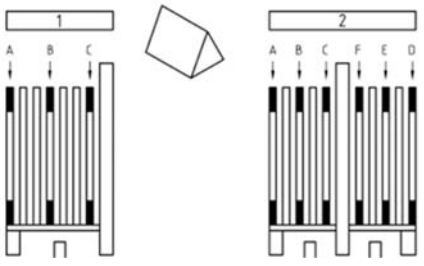


Figure A.2 — 1st category – 1 stillage – full load

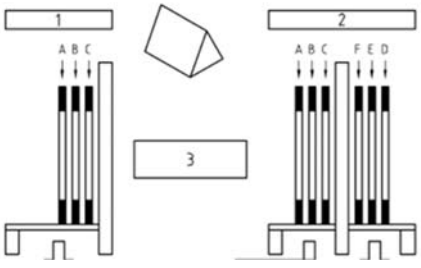


Figure A.3 — 1st category – 1 stillage – 10 % load

# FAQ: (BS EN 14179-1: 2016) Only Maximum Load

- Maximum Load (Full load)
  ⇒ *Maximum loading in daily operation*
- Eg. Oven capacity is 10 tons, but calibrated to 8.5 tons for daily operation.

- Controlling parameters in daily operation:

| Daily Operation | | Calibration |
|---|---|---|
| Total glass weight | ≤ | Max. capacity (Full load) |
| Largest glass panel size (Glass height in oven) | ≤ | Largest glass panel size (relative Height in the oven) |
| Thicker glass pane, longer heating time | ≠ | Thickest glass pane in oven |



# FAQ: Selection of 8 Monitoring Thermocouples

(e) Calibration report[3] of the ovens in accordance with BS EN 14179-1:2005 or equivalent;

(f) Quantity and configuration of thermocouples used to measure the glass surface temperatures in the oven. A minimum of 8 thermocouples[4] shall be used. The location of these thermocouples shall be determined from the calibration report of the oven;

(g) Recorded temperature versus time graphs for each of the 8 thermocouples during the heating phase, holding phase and cooling phase of the heat soak process;

(h) Quantity, dimensions and thickness of the tempered glass panes conforming to BS EN 14179-1:2005 or other equivalent international standards, and the record of breakages of panes in each heat soak process with corresponding oven number; and

(i) Date of carrying out the heat soak process.

19. Technology is constantly changing. In order not to preclude new quality control methods that are innovative and economical, APs and RSEs are encouraged to

[3] Note
The oven should be calibrated at regular intervals in order to ensure the accuracy in achieving the correct temperature during heat soak process. Usually, the calibration period for oven is set at one-year interval.
[4] Note
Thermocouples are used to monitor the highest and lowest temperatures on the glass surfaces. For the 10% loaded oven, 2 locations for the 2 highest temperatures and 2 locations for the 2 lowest temperatures should be identified. For the 100% loaded oven, 2 locations for the 2 highest temperatures and 2 locations for the 2 lowest temperatures should similarly be identified. Hence, a minimum of 8 thermocouples should be used for monitoring glass surface temperatures in the oven. The thermocouples are calibrated at 6-month intervals as recommended in the HOKLAS Supplementary Criteria No. 2.

Calibration report to BS EN 14179-1

Location of thermocouples determined from calibration report.

Calibration to BS EN 14179-1
A.5 Interpretation of the calibration test
⇒ *Selection of $t_2$ for regular production*

*Somebody wrongly interprets selection from holding phase!*

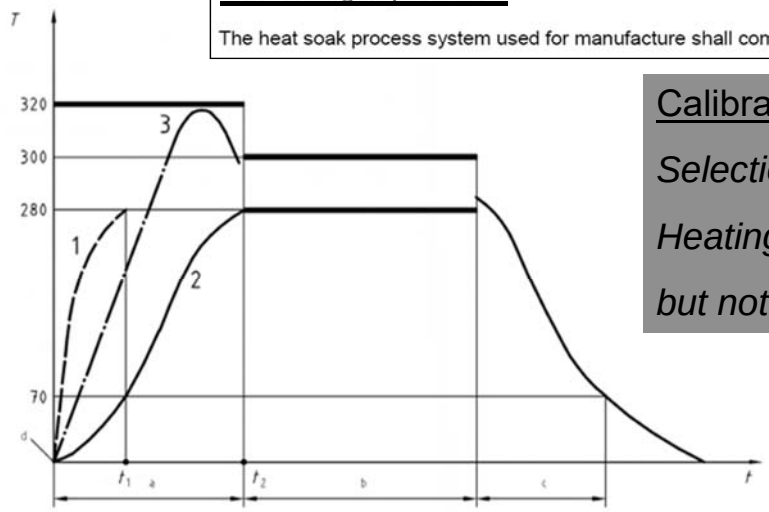
# FAQ: Se

**A.5 Interpretation of the calibration test**

If the conditions for temperatures laid down in A.1 are not met then the oven shall not be regarded as calibrated.

Only ovens, which meet the calibration criteria as laid down in A.1 at full and 10 % load may be used for the heat soak process cycle during manufacture. The longer of the two times $t_{2,1}$ (full load) or $t_{2,2}$ (10 % load) shall be used for regular production.

The heat soak process system used for manufacture shall comply with the details of the system as calibrated.




Key

| | | | |
|---|---|---|---|
| $T$ | Glass temperature at any point, °C | 3 | glass temperature |
| $t$ | time, h | d | ambient temperature |
| $t_1$ | time for the first glass to reach 280 °C | a | heating phase |
| $t_2$ | time for the last glass to reach 280 °C | b | holding phase |
| 1 | first glass to reach 280 °C | c | cooling phase |
| 2 | last glass to reach 280 °C | | |

**Figure A.1 — Time/temperature regime as calibration criteria**

Calibration to BS EN 14179-1

*Selection from*

*Heating Phase* ✓

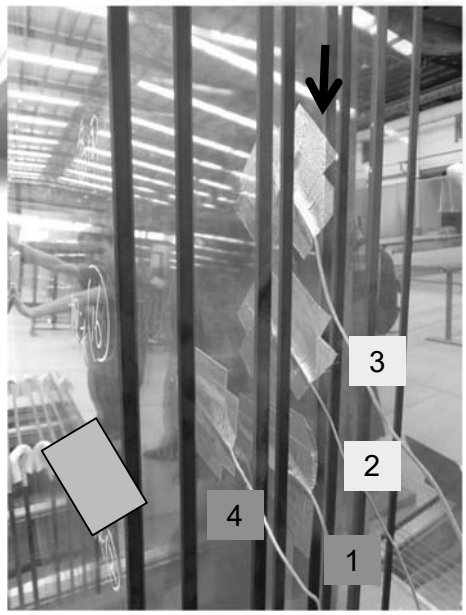
*but not Holding Phase*



# FAQ: Why so many TC?

- 3 nos. TC on same panel refer to Location #16 ?
  - Glass Manufacturer (#1)
  - Sub-Contractor (#2)
  - Main Contractor (#3)
  - **Spare (#4)** from Glass Manufacturer ??
- Another 4 nos. TC put on another monitoring TC Location#.

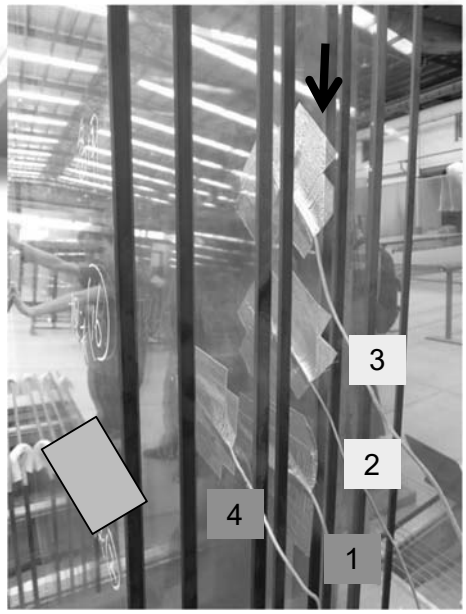
# FAQ:
# T1's Thermocouple




- Can the T1's TC put on other glass panel, that is not on the same panel with the 8 monitoring TC?
- ***NO!***
- *T1's TC is used to counter check / monitor the 8 monitoring TC by glass manufacturer.*
- *Different glass panel, different measured temperature.*
- *Recommend T1/T3 put their TC to the pre-arranged thickest and largest glass panel that with the monitoring thermocouple in regular/daily operation.*



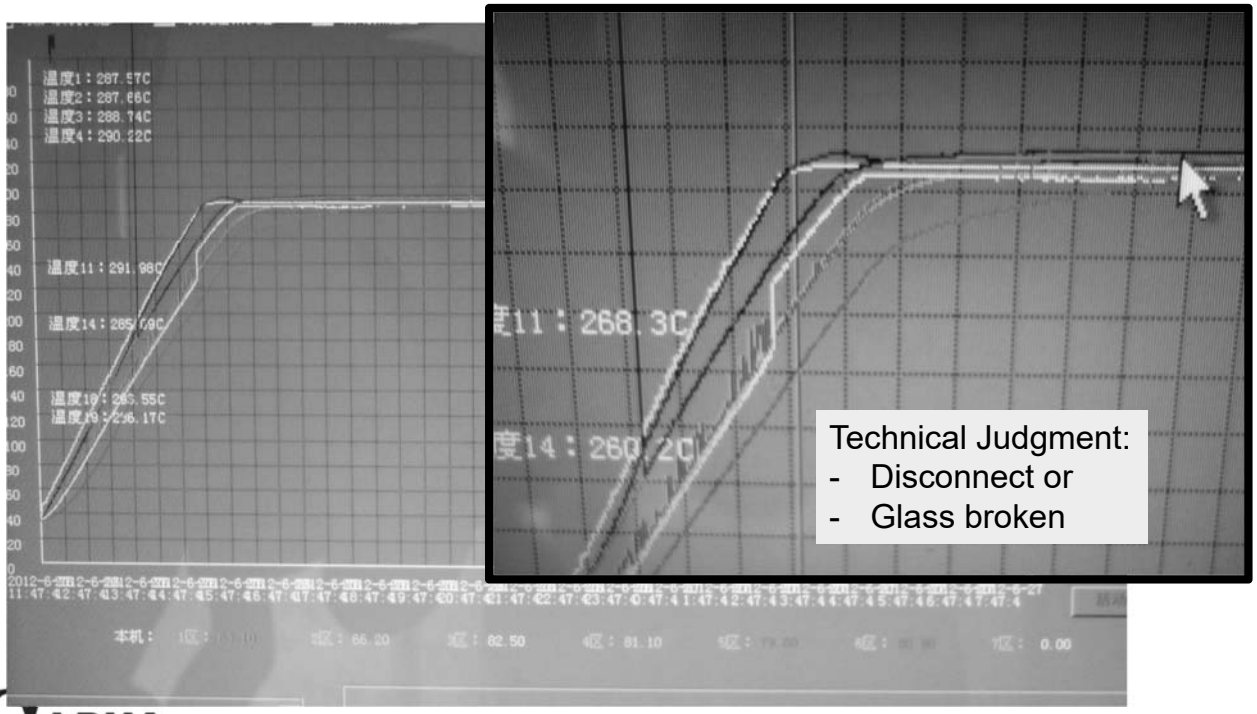
# FAQ:
# T1's Thermocouple




- Somebody interprets the 8 thermocouples is a must without technical consideration!!
- Failure of any one of the 8 thermocouples is not allowed???

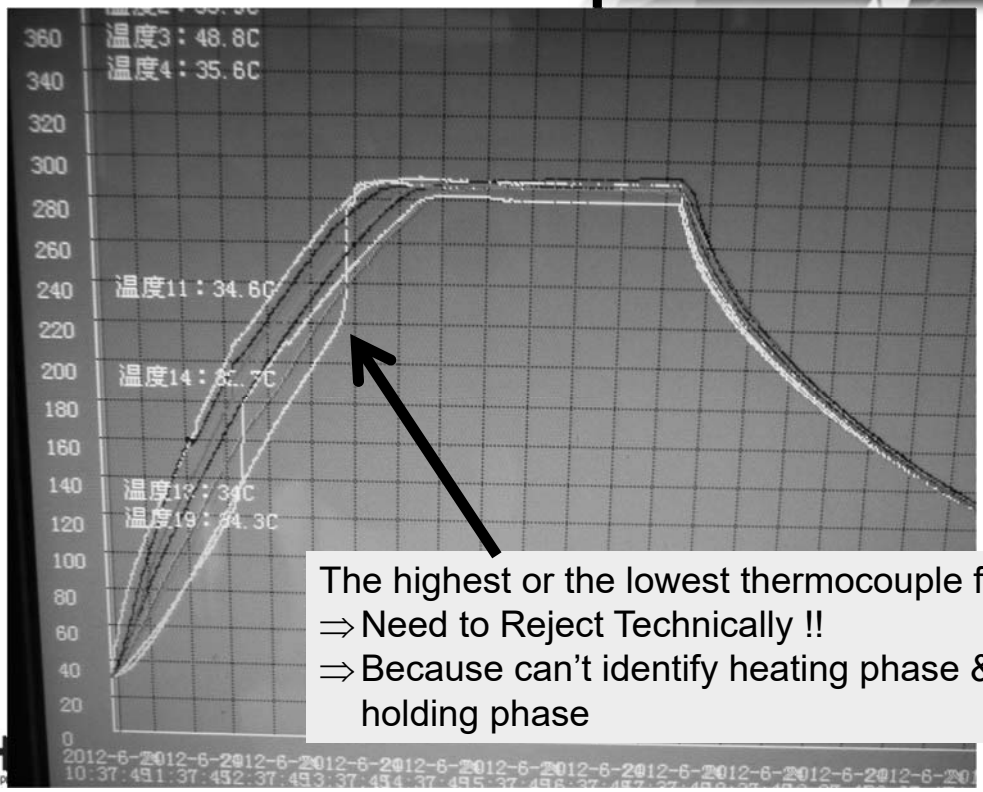
- *Disengagement of adhesive tape*
  *⇒ Disconnect due to poor workmanship?!*
- *How about spontaneous breakage happened on measuring glass panel during heat soak?*

# FAQ:
# Temperature Fluctuation



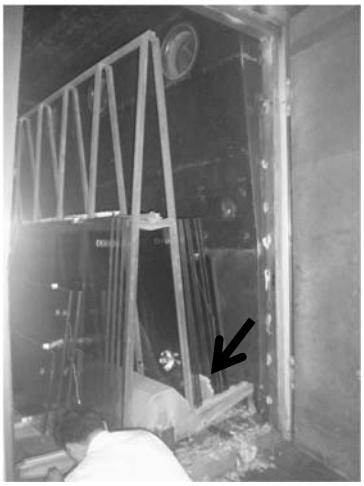



# FAQ:
# Failure of Thermocouple



# FAQ:
# Is it necessary?

- *Failure of one temperature data (not the highest / lowest) due to spontaneous breakage during heat soak process, but "**Somebody**" rejected the whole completed heat soak process !?*
- *Because of only remaining 7 temperature data! OMG!*



ALPHA
Steel Structure & Façade Specialist

# FAQ:
# T1's Thermocouple


- The spare TC #4 on the next glass pane which refer to same Location 16?
- *It is the 9th TC and/or 10th TC provided by the Glass Manufacturer.*
- *Glass Manufacturer tries to provide additional temperature data in case of anyone of the 8 monitoring TC failure during heat soak process.*
- *With reference to this arrangement, spare TC #4 can be used for the replacement of TC #1 in case of TC #1 failure. How about T1's TC, i.e. #2 as shown in Figure?*

# FAQ:
# How many T1's TC?


- *Recommend T1 to use at least 2 nos. of TC next to the GM's TC.*

*Recommended locations:*

- *1 @ the highest temperature*
  *1 @ the lowest temperature*
  *of the 8 monitoring TC selected from calibration.*
- *If the thickest and largest glass pane is arranged with monitoring thermocouple in regular/daily operation, then T1's TC is recommended to put on this pane.*



# FAQ:
# Heating Phase

- Somebody comments the heating phase cannot exceed 300°C???

**5.3.2 Heating phase**

The heating phase commences with all the glasses at ambient temperature and concludes when the surface temperature of the last glass reaches 280 °C. The time to reach this temperature is defined in the calibration process. This time will be dependent on the size of the oven, the amount of glass to be treated, the separation between glasses and the heating system capacity.

NOTE 1 The glass separation and rate of heating should be controlled to minimise the risk of glass breakage as a result of thermal stress.

To facilitate economic heating, the air temperature within the oven may exceed 320 °C. However, the glass surface temperature shall not be allowed to exceed 320 °C. The period of glass surface temperature in excess of 300 °C shall be minimised.

NOTE 2 When the temperature of the glass exceeds 300 °C, care should be taken to ensure that the properties of the heat soaked thermally toughened soda lime silicate safety glass are not significantly altered i.e. they continue to meet Clause 10.

# FAQ:
# Heating Phase (2016)

- Will Somebody comments the heating phase cannot exceed 270°C???

**5.3.2 Heating phase**

The heating phase commences with all the glasses at ambient temperature and concludes when the surface temperature of the last glass reaches 250 °C. The maximum heating rate is 3° C per minute. The time to reach this temperature is defined in the calibration process. This time will be dependent on the size of the oven, the amount of glass to be treated, the separation between glasses and the heating system capacity.

NOTE 1 The glass separation and rate of heating should be controlled to minimize the risk of glass breakage as a result of thermal stress.

To facilitate economic heating, the air temperature within the oven may exceed 290 °C. However, the glass surface temperature shall not be allowed to exceed 290 °C. The period of glass surface temperature in excess of 270 °C shall be minimized.

NOTE 2 Care should be taken to ensure the maximum temperature of the glass does not exceed 270° C as there is a possibility of the nickel sulphide inclusion reconverting.



# FAQ:
# Heating Rate?

- Somebody says the heating rate cannot faster than 3°C/minute.

**5.3.2 Heating phase**

The heating phase commences with all the glasses at ambient temperature and concludes when the surface temperature of the last glass reaches 280 °C. The time to reach this temperature is defined in the calibration process. This time will be dependent on the size of the oven, the amount of glass to be treated, the separation between glasses and the heating system capacity.

NOTE 1 The glass separation and rate of heating should be controlled to minimise the risk of glass breakage as a result of thermal stress.

To facilitate economic heating, the air temperature within the oven may exceed 320 °C. However, the glass surface temperature shall not be allowed to exceed 320 °C. The period of glass surface temperature in excess of 300 °C shall be minimised.

NOTE 2 When the temperature of the glass exceeds 300 °C, care should be taken to ensure that the properties of the heat soaked thermally toughened soda lime silicate safety glass are not significantly altered i.e. they continue to meet Clause 10.

# FAQ:
# Heating Rate (2016)

- In future, the heating rate ≤ 3°C/minute.

**5.3.2 Heating phase**

The heating phase commences with all the glasses at ambient temperature and concludes when the surface temperature of the last glass reaches 250 °C. The maximum heating rate is 3° C per minute. The time to reach this temperature is defined in the calibration process. This time will be dependent on the size of the oven, the amount of glass to be treated, the separation between glasses and the heating system capacity.

NOTE 1 The glass separation and rate of heating should be controlled to minimize the risk of glass breakage as a result of thermal stress.

To facilitate economic heating, the air temperature within the oven may exceed 290 °C. However, the glass surface temperature shall not be allowed to exceed 290 °C. The period of glass surface temperature in excess of 270 °C shall be minimized.

NOTE 2 Care should be taken to ensure the maximum temperature of the glass does not exceed 270° C as there is a possibility of the nickel sulphide inclusion reconverting.



# FAQ:
# Holding Phase 290°C±10°C

- How if Glass Manufacturer's temperature (GM) not satisfy the Holding Phase requirement?

- *Holding Phase 290℃±10℃*
  *⇒ You should reject it, if GM's T < 280℃ or T > 300℃*

- *But not applicable in Heating Phase.*
  *Not mentioned this in both BS EN 14179-1: 2005 and PNAP APP-37.*

# FAQ:
# Cooling Phase

- Somebody claims the cooling phase stop when "glass surface temperature" less than 70°C??

**5.3.4 Cooling phase**

The cooling phase commences when the last glass to reach 280 °C has completed its holding phase, i.e. been held for two hours at 290 °C ± 10 °C. During this phase the glass temperature shall be brought down to ambient temperature.

The cooling phase can be concluded when the air temperature in the oven reaches 70 °C.

NOTE The rate of cooling should be controlled to minimise the risk of glass breakage as a result of thermal stress.

- *It should be oven air temperature but not glass surface temperature.*



# FAQ:
# Oven Air Temperature?

- If calibration to BS EN 14179-1, oven air temperature is monitored which used for future operation.

**A.3 Procedure**

The measurements of the air temperature in the oven and the glass surface temperatures shall be carried out when the furnace is fully loaded. They shall be repeated for a 10 % loading.

The oven air temperature is monitored by a control element, which is located near the air egress. The measurement of the glass surface temperatures is carried out by thermocouples that are stuck, with good thermal contact, to the glass surfaces.

At the beginning of the calibration, the air temperature in the oven shall not exceed 35 °C.

- *PNAP APP-37 introduced additional requirement for daily operation which monitoring the glass surface temperature instead of oven air temperature.*

# FAQ:
# Oven Calibration to…

- If oven calibration to BS EN 14179-1…

> **A.5 Interpretation of the calibration test**
>
> If the conditions for temperatures laid down in A.1 are not met then the oven shall not be regarded as calibrated.
>
> Only ovens, which meet the calibration criteria as laid down in A.1 at full and 10 % load may be used for the heat soak process cycle during manufacture. The longer of the two times $t_{2.1}$ (full load) or $t_{2.2}$ (10 % load) shall be used for regular production.
>
> The heat soak process system used for manufacture shall comply with the details of the system as calibrated.

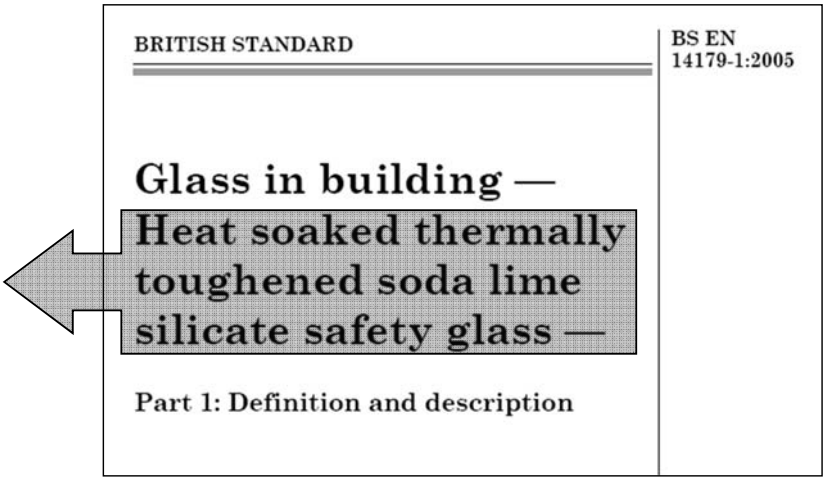
- *For new type heat soak oven, the heating time can be controlled by the monitoring thermocouple.*
- *So recently, the oven is calibrated to "BS EN 14179-1 and fulfilling PNAP APP-37 requirement".*
- *But not calibrated to PNAP APP-37.*



# FAQ:
# Heat Soak to HS Glass?

- Somebody requests sub-contractor to carry heat soak process to heat strengthen glass?!

- ***Tempered Glass***



# FAQ:
# Oven Calibration by…

- PNAP APP-37 para. 18 (e):

> (e) Calibration report[3] of the ovens in accordance with BS EN 14179-1:2005 or equivalent;
>
> [3] Note
> The oven should be calibrated at regular intervals in order to ensure the accuracy in achieving the correct temperature during heat soak process. Usually, the calibration period for oven is set at one-year interval.

- *Require HOKLAS accredited laboratory or calibration laboratory **?***
- *With this scope in HKAS accreditation or calibration **?***

- *Most common before 2012: **JAS** and **RED***
- *Newly jointed: CASTCO and Leading Edge*
- *may be more in future…*



# FAQ:
# Compliance Report by GM

> - 6 -
>
> 18. Under Regulation 10 of the B(A)R, a requirement will be imposed, when giving approval of plans, to require the compliance reports for heat soak process issued by the glass manufacturers and endorsed by the RSE to be submitted prior to the application for occupation permit. The compliance report should contain the following information:

- *Compliance reports should be prepared and issued by the glass manufacturer and endorsed by RSE.*
- *Therefore, the temperature records should be referred to GM's TC for compliance of the heat soak process.*

# FAQ:
# T3 - 30% Frequency

21. The RSE should assign a quality control supervisor to supervise a certain number of tempered glass panes undergoing the heat soak process. The RSE should determine the necessary frequency of supervision, which should cover at least 30% of the tempered glass panes used in the project. The minimum qualifications and experience of the quality control supervisor are to be the same as grade T3 technically competent person (TCP) under the RSE's stream, as stipulated in the Code of Practice for Site Supervision 2009.

- **30% in quantity? 30% in area? 30% in weight?**
- **30% of total Heat Soak Process?**
- ***Recommend RSE to assign T3 heat soak inspection regularly and evenly distributed. (Review the planning of glass production and Agree the acceptable criteria prior to mass production)***



# FAQ:
# Full time inspection

22. The RC should assign a quality control supervisor to provide full time continuous supervision of the heat soak process of all tempered glass panes in the factory. The minimum qualifications and experience of the quality control supervisor are to be the same as grade T1 – TCP under the RC's stream, as stipulated in the Code of Practice for Site Supervision 2009. To ensure the heat soak process is properly conducted by the glass manufacturer, the quality control supervisor should measure the glass surface temperature independently by using his/her own data logger. The information recorded by the data logger should be set at one-minute intervals and kept in the factory.

- Somebody requests T1/T3 to provide full time continuous supervision.
- *i.e. Stay next to the HS oven and need to have lunch box next to oven.*
- *How about go to toilet ?*

香港工程監督學會
The Hong Kong Institute of Clerks of Works

# Quality Control of Tempered Glass

# Quality Control

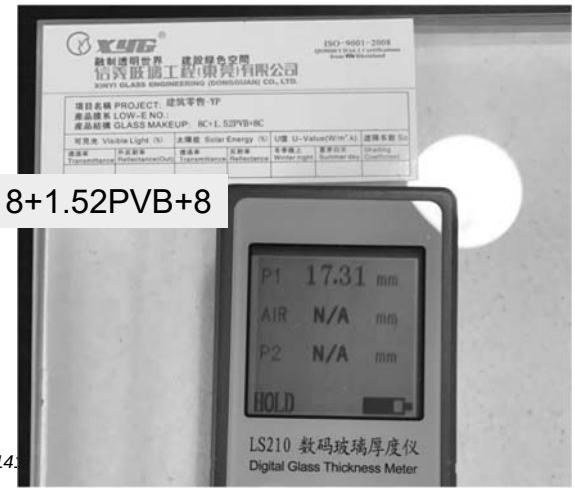
## Testing and Measurement

- Structural Test (HOKLAS)
  - Safety Test – PNAP APP37
  - Bending Test – BS EN 1288-3

- Testing and Measurement
  - Thickness Measurement – ASTM C1036 & C1048
  - Flatness & Roller Wave Measurement – ASTM C1036 & C1048
  - Surface Compressive Stress – ASTM C1279 & C1048
  - Impact Test – BS 6206, ANZI Z97.1, BS EN 12600
  - Fragmentation test – BS 6206, BS EN 14179-1
  - Heat Soak Process – BS EN 14179-1
  - Boil Test – ANSI Z97.1

# Thickness Measurement Digital Meter






*ment to BS EN 14*

# Flatness and Roller Wave Measurement

## 2: FLAT TEMPERED GLASS MATERIAL

CODES;

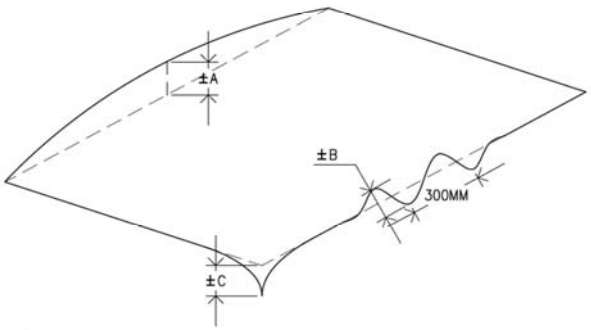
ASTM C1306-01-02
ASTM C1048-04

A) PANEL BOW = MAX. 0,1% OF PANE DIMENSION

B) DEPTH OF ROLLERWAVES = MAX. 0.20MM OVER 300MM

C) EDGE DIP < 0.25MM

D) ANISOTROPY: NO ANISOTROPY TO BE VISIBLE WHEN VIEWED AT AN ANGLE OF GREATER THAN 30° AND LESS THAN 150° TO ITS PLANE SURFACE IN SUNLIGHT CONDITIONS. SHOULD THERE BE ANY DOUBT IT IS INCUMBENT ON THE CONTRACTOR TO CALL THE OWNER AND AGREE AND INDEPENDENT INSPECTION AND SIGN-OFF




E) ALL GLASS TO BE HEATSOAKED TO BS EN 14179 AND PNAP 106 (APP-37)

F) ROLLER WAVES SHALL RUN SAME DIRECTION FOR THE ENTIRE PROJECT

# Visual Inspection

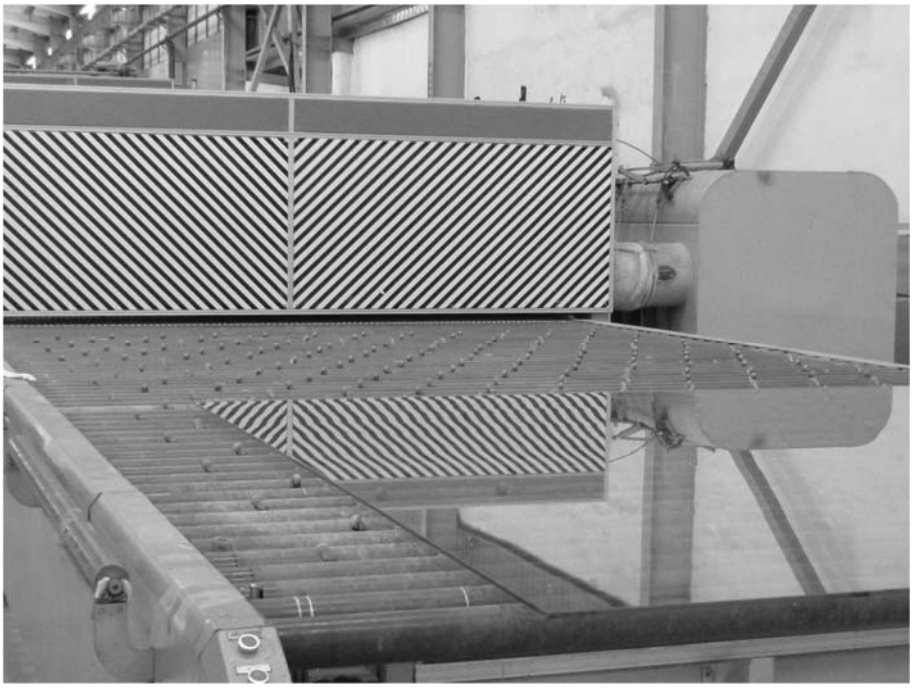
Visual Inspection:
Parallel image from
Zebra Boards

Marks to identify
glass orientation



# Visual Inspection

Parallel image
from
Zebra Boards?



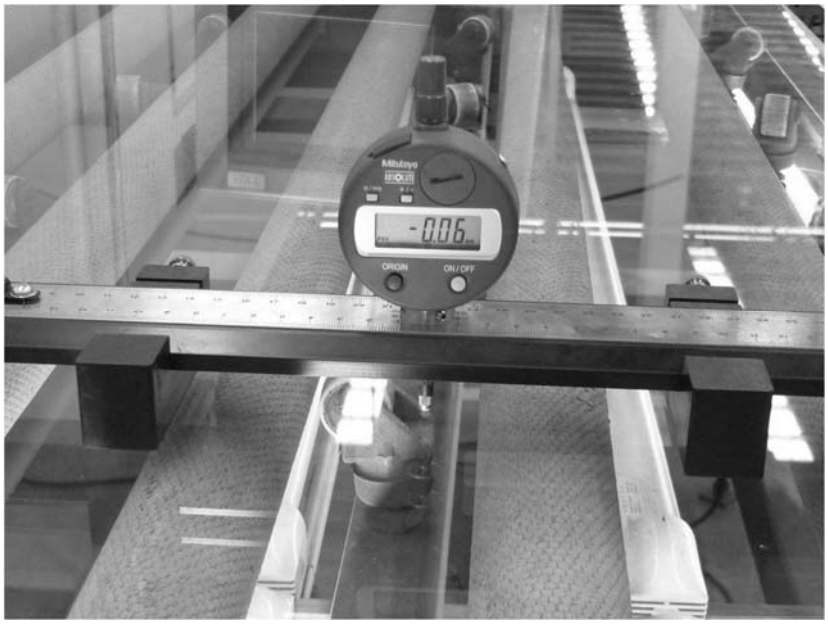
# Flatness Measurement

Flatness:
Overall Bow < 0.1% of
glass shortest dimension



# Roller Wave Measurement

Roller Wave
Measurement
to ASTM C1651



# Roller Wave Measurement

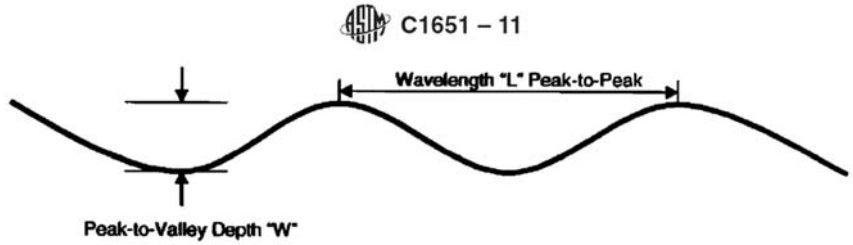



FIG. 1 Representative Roll Wave Showing *"W"* and *"L"*

Peak to Trough < 0.15mm
Different between adjacent wave < 0.08mm

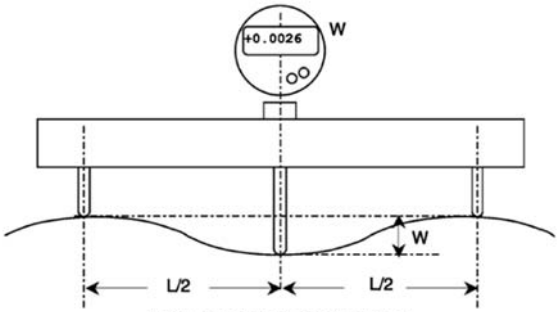



FIG. 3 "Three-Point Contact" Gauge on Valley

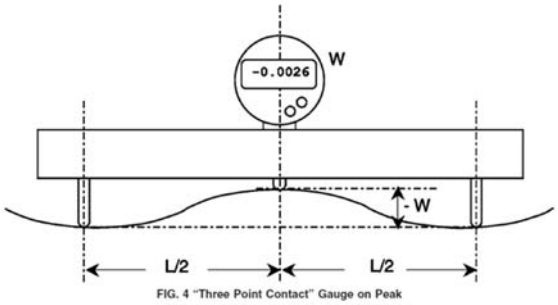
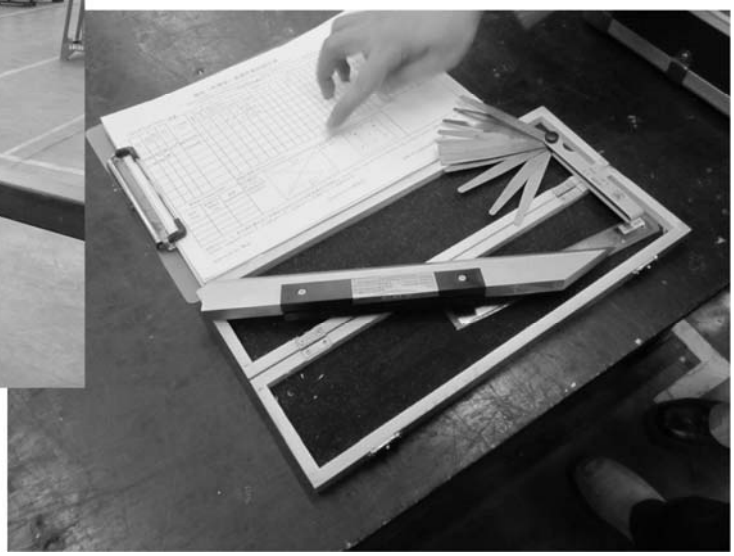



FIG. 4 "Three Point Contact" Gauge on Peak



# Roller Wave Measurement



# Surface Stress Measurement

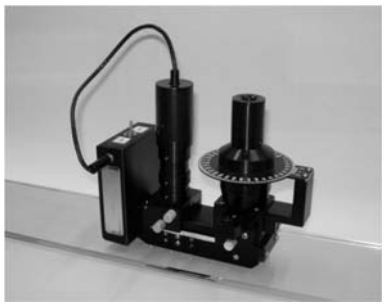
Surface Stress:
HS: 24~52 MPa
TG: >69 MPa

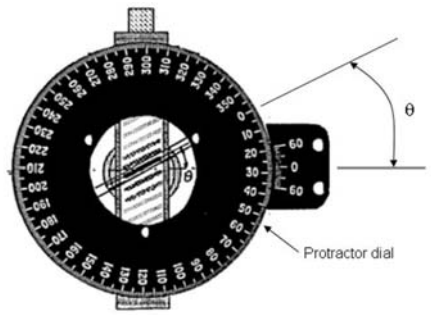
Laser GASP reading
64° ≈ 86 MPa

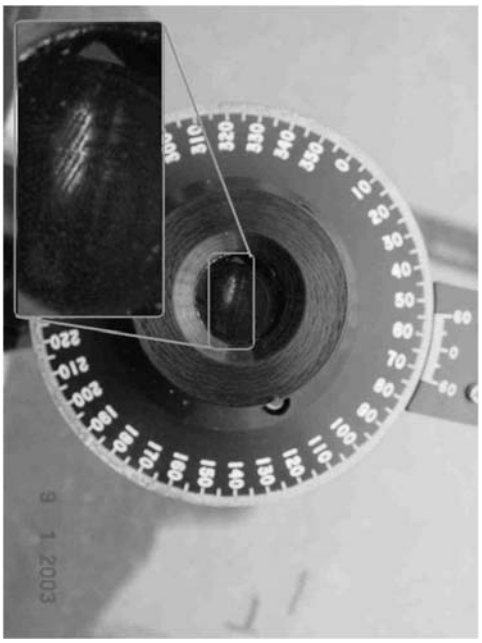
Grazing Angle Surface Polarimeter (GASP)



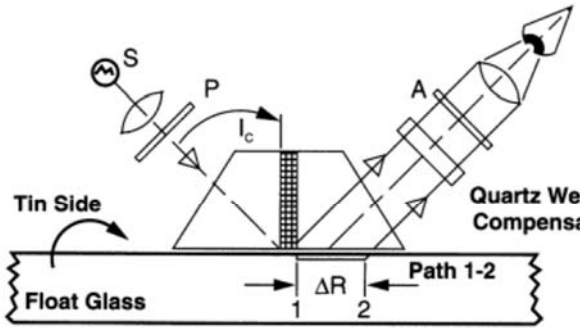
# Grazing Angle Surface Polarimeter (GASP)



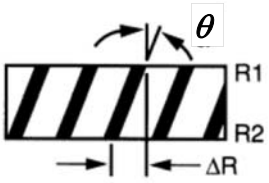


# How the GASP® Polarimeter Works




Pattern observed on a stress-free surface




Pattern observed on stressed surface. Stress is obtained from the measured angle $\theta$

$$Stress = K \cdot \tan\theta$$

STANDARD WEDGE USED IN GASP OR LASER GASP
WEDGE FACTOR = 1.00
# XXX DATE XX/XX/XX
Caution: This table is NOT valid if wedge is installed in GASP-CS model.

| angle o | Stress psi | Stress kgf/cm2 | Stress MPa | angle o | Stress psi | Stress kgf/cm2 | Stress MPa |
|---|---|---|---|---|---|---|---|
| 1 | 107 | 8 | 0.73 | 39 | 4944 | 348 | 34.09 |
| 2 | 213 | 15 | 1.47 | 40 | 5123 | 361 | 35.32 |
| 3 | 320 | 23 | 2.21 | 41 | 5307 | 374 | 36.59 |
| 4 | 427 | 30 | 2.94 | 42 | 5497 | 387 | 37.90 |
| 5 | 534 | 38 | 3.68 | 43 | 5693 | 401 | 39.25 |
| 6 | 642 | 45 | 4.42 | 44 | 5896 | 415 | 40.65 |
| 7 | 750 | 53 | 5.17 | 45 | 6105 | 430 | 42.09 |
| 8 | 858 | 60 | 5.92 | 46 | 6322 | 445 | 43.59 |
| 9 | 967 | 68 | 6.67 | 47 | 6547 | 461 | 45.14 |
| 10 | 1076 | 76 | 7.42 | 48 | 6780 | 477 | 46.75 |
| 11 | 1187 | 84 | 8.18 | 49 | 7023 | 495 | 48.42 |
| 12 | 1298 | 91 | 8.95 | 50 | 7276 | 512 | 50.17 |
| 13 | 1409 | 99 | 9.72 | 51 | 7539 | 531 | 51.90 |
| 14 | 1522 | 107 | 10.50 | 52 | 7814 | 550 | 53.89 |
| 15 | 1636 | 115 | 11.28 | 53 | 8102 | 571 | 55.88 |
| 16 | 1751 | 123 | 12.07 | 54 | 8403 | 592 | 57.94 |
| 17 | 1868 | 131 | 12.87 | 55 | 8719 | 614 | 60.12 |
| 18 | 1984 | 140 | 13.68 | 56 | 9051 | 637 | 62.41 |
| 19 | 2102 | 148 | 14.49 | 57 | 9401 | 662 | 64.82 |
| 20 | 2222 | 156 | 16.32 | 58 | 9770 | 688 | 67.36 |



# LCD-GASP

Designation: C1279 – 09

# Standard Test Method for Non-Destructive Photoelastic Measurement of Edge and Surface Stresses in Annealed, Heat-Strengthened, and Fully Tempered Flat Glass[1]

STANDARD WEDGE USED IN GASP OR LASER GASP
WEDGE FACTOR = 1.00
#LCD-198 DATE 01/06/12
Caution: This table is NOT valid if wedge is installed in GASP-CS model.

| angle θ | Stress psi | Stress kgf/cm2 | Stress MPa | | angle θ | Stress psi | Stress kgf/cm2 | Stress MPa |
|---|---|---|---|---|---|---|---|---|
| 1 | 107 | 8 | 0.73 | | 39 | 4944 | 348 | 34.09 |
| 2 | 213 | 15 | 1.47 | | 40 | 5123 | 361 | 35.32 |
| 3 | 320 | 23 | 2.21 | | 41 | 5307 | 374 | 36.59 |
| 4 | 427 | 30 | 2.94 | | 42 | 5497 | 387 | 37.90 |
| 5 | 534 | 38 | 3.68 | | 43 | 5693 | 401 | 39.25 |
| 6 | 642 | 45 | 4.42 | | 44 | 5896 | 415 | 40.65 |
| 7 | 750 | 53 | 5.17 | | 45 | 6105 | 430 | 42.09 |
| 8 | 858 | 60 | 5.92 | | 46 | 6322 | 445 | 43.59 |
| 9 | 967 | 68 | 6.67 | | 47 | 6547 | 461 | 45.14 |
| 10 | 1076 | 76 | 7.42 | | 48 | 6780 | 477 | 46.75 |
| 11 | 1187 | 84 | 8.18 | | 49 | 7023 | 495 | 48.42 |
| 12 | 1298 | 91 | 8.95 | | 50 | 7276 | 512 | 50.17 |
| 13 | 1409 | 99 | 9.72 | | 51 | 7539 | 531 | 51.98 |
| 14 | 1522 | 107 | 10.50 | | 52 | 7814 | 550 | 53.88 |
| 15 | 1636 | 115 | 11.28 | | 53 | 8102 | 571 | 55.86 |
| 16 | 1751 | 123 | 12.07 | | 54 | 8403 | 592 | 57.94 |
| 17 | 1866 | 131 | 12.87 | | 55 | 8719 | 614 | 60.12 |
| 18 | 1984 | 140 | 13.68 | | 56 | 9051 | 637 | 62.41 |
| 19 | 2102 | 148 | 14.49 | | 57 | 9401 | 662 | 64.82 |
| 20 | 2222 | 156 | 15.32 | | 58 | 9770 | 688 | 67.36 |
| 21 | 2343 | 165 | 16.16 | | 59 | 10160 | 716 | 70.06 |
| 22 | 2467 | 174 | 17.01 | | 60 | 10574 | 745 | 72.91 |
| 23 | 2591 | 182 | 17.87 | | 61 | 11014 | 776 | 75.94 |
| 24 | 2718 | 191 | 18.74 | | 62 | 11482 | 809 | 79.17 |
| 25 | 2847 | 200 | 19.63 | | 63 | 11982 | 844 | 82.61 |
| 26 | 2978 | 210 | 20.53 | | 64 | 12517 | 881 | 86.31 |
| 27 | 3111 | 219 | 21.45 | | 65 | 13092 | 922 | 90.27 |
| 28 | 3246 | 229 | 22.38 | | 66 | 13712 | 966 | 94.54 |
| 29 | 3384 | 238 | 23.33 | | 67 | 14382 | 1013 | 99.17 |
| 30 | 3525 | 248 | 24.30 | | 68 | 15110 | 1064 | 104.19 |
| 31 | 3668 | 258 | 25.29 | | 69 | 15904 | 1120 | 109.66 |
| 32 | 3815 | 269 | 26.30 | | 70 | 16773 | 1181 | 115.65 |
| 33 | 3965 | 279 | 27.34 | | 71 | 17730 | 1249 | 122.25 |
| 34 | 4118 | 290 | 28.39 | | 72 | 18789 | 1323 | 129.55 |
| 35 | 4275 | 301 | 29.47 | | 73 | 19969 | 1406 | 137.68 |
| 36 | 4436 | 312 | 30.58 | | 74 | 21291 | 1499 | 146.80 |
| 37 | 4600 | 324 | 31.72 | | 75 | 22784 | 1605 | 157.10 |
| 38 | 4770 | 336 | 32.89 | | 76 | 24486 | 1724 | 168.83 |

C1048 – 12$^{\varepsilon 1}$

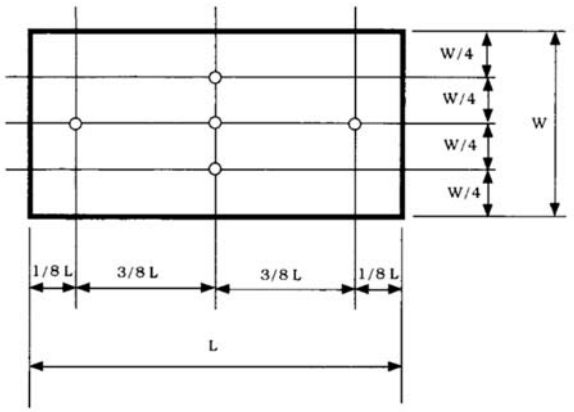



FIG. 5 Five Locations Examined

HS: 24~52MPa $\Rightarrow$ $30° \le \theta \le 51°$
TP: > 69MPa $\Rightarrow$ $\theta \ge 59°$



# Fragmentation test – BS EN 14179-1

**10.3 Test procedure**

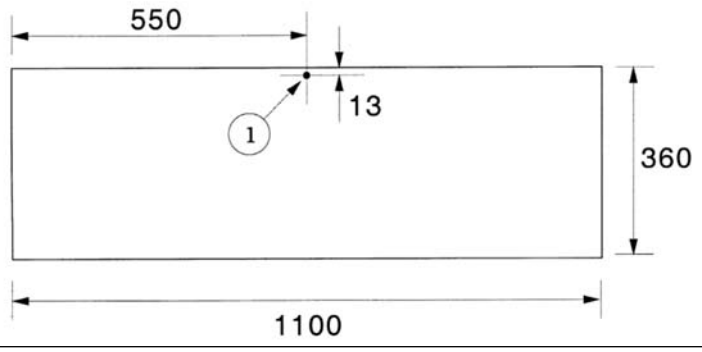
Each test specimen shall be impacted, using a pointed steel tool, at a position 13 mm in from the longest edge of the test specimen at the mid-point of that edge, until breakage occurs (see Figure 18).

NOTE The fragmentation characteristics of heat soaked heat soak thermally heat soak toughened soda lime silicate glass are unaffected by temperatures between –50 °C and +100 °C.

Examples of steel tools are a hammer of about 75 g mass, a spring loaded centre punch, or other similar appliance with a hardened point. The radius of curvature of the point should be approximately 0,2 mm.

The test specimen shall be laid flat on a table without any mechanical constraint. In order to prevent scattering of the fragments, the specimen shall be simply held at the edges, e.g. by a small frame, adhesive tape etc., so that the fragments remain interlocked after breakage yet extension of the specimen is not hindered.

Dimensions in millimetres



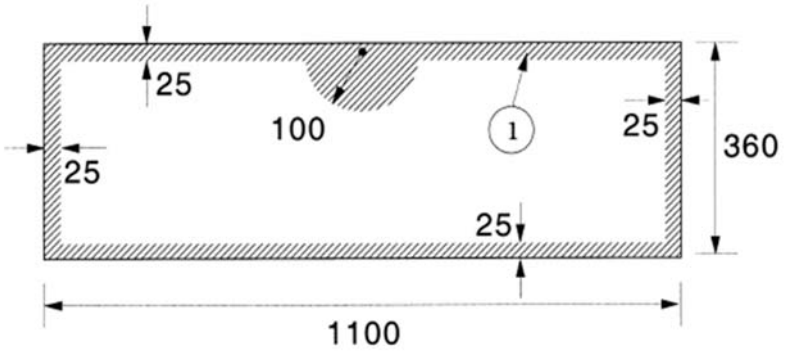
# Fragmentation test – BS EN 14179-1

**10.4 Assessment of fragmentation**

The particle count and measuring of the dimensions of the largest particle shall be made between 4 min to 5 min after fracture. An area of radius 100 mm, centred on the impact point, and a border of 25 mm, round the edge of the test specimen (see Figure 19), shall be excluded from the assessment.

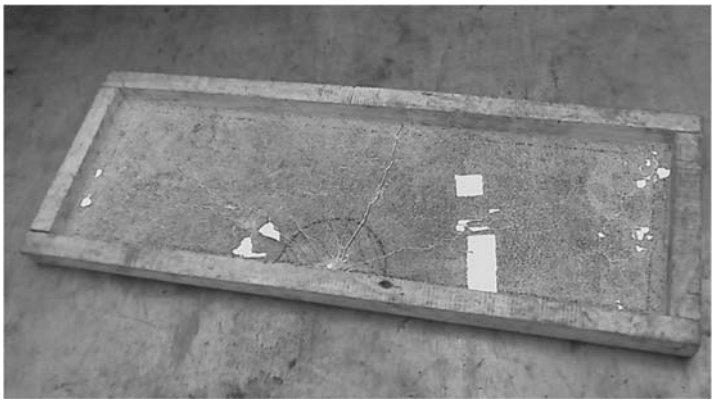
The particle count shall be made in the region of coarsest fracture (the aim being to obtain the minimum value). The particle count shall be made by placing a mask of (50 ± 1) mm × (50 ± 1) mm on the test piece (see annex C). The number of crack-free particles within the mask shall be counted. A particle is 'crack-free' if it does not contain any cracks which run from one edge to another (see Figure 20).

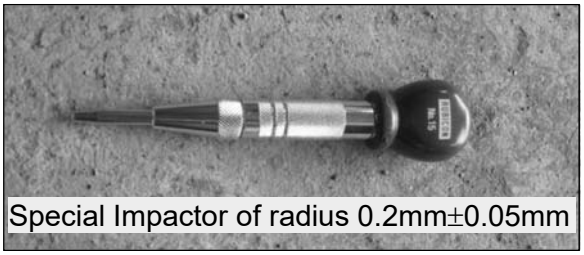
Dimensions in millimetres





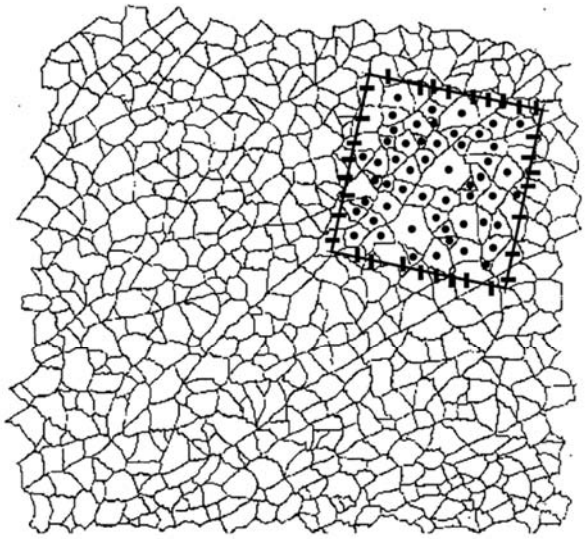

# Fragmentation test – BS EN 14179-1





Special Impactor of radius 0.2mm±0.05mm

# Particle Count



**Key**
Number of central particles = 53
Total number of particles = 16 + 53 = 69

**Figure C.3 — Mark and count the central fragments and add these to the perimeter count to obtain the particle count for the specimen**



### 10.5 Minimum values from the particle count

In order to classify a glass as a heat soaked thermally toughened soda lime silicate safety glass, the particle count of each test specimen shall not be less than the values given in Table 5.

**Table 5 — Minimum particle count values**

| Glass type | Nominal thickness ($d$) mm | Minimum particle count |
|---|---|---|
| Float and drawn sheet | 3 | 15 |
| | 4 to 12 | 40 |
| | 15 to 19 | 30 |
| Patterned | 4 to 10 | 30 |

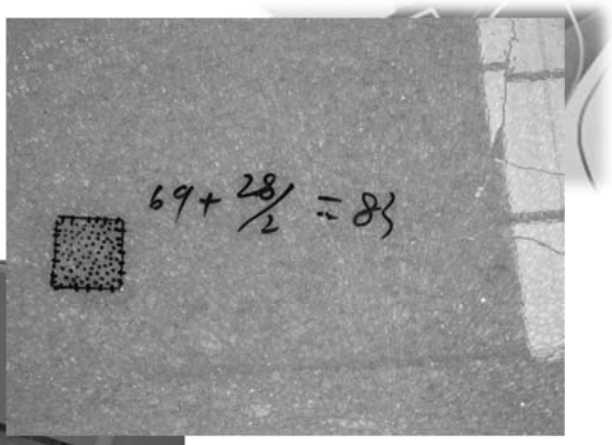
### 10.6 Selection of the longest particle

The longest particle shall be chosen from the body of the test specimen. It shall not be in the excluded area (see 10.4).

### 10.7 Maximum length of longest particle

In order to classify the glass as heat soaked thermally toughened soda lime silicate safety glass, the length of the longest particle shall not exceed 100 mm.

# Particle Count



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# THANK YOU !!

**Ir Dr. YU Wai-Kin, Dominic**
*BEng(Civil), MSc(Fire), PhD(Str.), MHKIE, MHKISC, MHKICA*

*Principal – Structural Fire and Façade*
of
Alpha Consulting Limited

*Email: dominic@alpha-c.com.hk*

ALPHA Steel Structure & Façade Specialist