"Reflective distortion Issue reported on D471 Rear Doors and Front Doors Tempered Glass"

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Reflective Distortion Issue reported on D471 Rear Doors and Front Doors Tempered Glass

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Ingeniero Industrial en Procesos y Servicios

Presenta

Efrain Madrid Carrillo

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INDICE GENERAL

I. PLANTEAMIENTO DEL PROBLEMA

La presente investigación fue realizada sobre un caso práctico en la empresa Vitro Flex S.A. de C.V. en donde se fabrica vidrio automotriz.

La investigación fue realizada con respecto a una reclamación por parte de uno de los Clientes de Vitro (FORD) contra el desempeño óptico de unos productos Templados que se estaban desarrollando para una nueva plataforma identificada como Programa D471.

El problema reportado por la Planta de Ensamble de FORD fue el que las piezas ensambladas en varias unidades presentaban una serie de Distorsiones ópticas a reflejo en el vidrio que no fueron aceptadas e inmediatamente se generó una reclamación oficial departe de dicha planta.

La metodología que se siguió para resolver el problema es una técnica llamada DMAIC utilizada por los japoneses y que actualmente es solicitada a todos los proveedores de FORD cuando se requiere darle solución a un problema.

Por cuestiones de Confidencialidad de la Información se evitaron ciertos detalles en cuanto a Nombres y Descripciones por lo que se notará durante el transcurso del reporte Nombres Generales para describir una Planta Armadora, etc.

II. JUSTIFICACIÓN

La presente investigación se escogió debido a la importancia e impacto que representa un producto nuevo en desarrollo dentro de la Industria Automotriz.

La complejidad de la problemática fue tal que la decisión de la aprobación del Cliente para la liberación de este producto a producción normal para Vitro Flex dependía de la respuesta y solución que se le diera a la reclamación impuesta.

Cabe destacar que todo producto en desarrollo cuenta con un Programa dentro del cual se tienen toda una serie de distintas Fases. La reclamación se presentó dentro de la Fase TT a 6 meses de que el producto en desarrollo iniciara dentro del Programa su Fase de producción en serie.

Al contar con dicha reclamación en puerta, la aprobación del PPAP por parte del Cliente, sufrió un significativo retraso debido a que uno de los requerimientos de dicha aprobación (Master de apariencia) no se liberaría sino hasta darle la solución pertinente.

Dicho retraso generó gran nerviosismo dentro de todos los Ingenieros de FORD encargados del desarrollo de esta nueva plataforma lo que a su vez provocó que el problema se escalara hasta las más altas esferas de los departamentos de Ingeniería de FORD.

Cabe destacar que el Impacto económico de que un proveedor

II. JUSTIFICACIÓN

de cualquier parte de una nueva unidad se retrase en la aprobación para producción en serie es alto para cualquier Compañía Automotriz (FORD, GM, CHRYSLER, etc.), lo cual genera que los proveedores sean altamente penalizados por no cumplir las Fases del Programa en Tiempo.

III. OBJETIVOS

Objetivo General

La presente investigación tiene como objetivo el lograr la aprobación del Cliente de los productos templados para el programa en desarrollo D471 a través de una serie de mejoras ya sean en el proceso, diseño o en el producto.

Objetivos particulares

- Obtener valores numéricos que permitan medir el nivel de distorsión en las piezas actuales, aún cuando la distorsión es una característica cualitativa

- Realizar posibles mejoras en el proceso de curvado que permitan disminuir la distorsión con respecto a los grados actuales presentados.

- Obtener cambios en las tolerancias actuales del diseño de estas piezas que permitan mejorar el nivel de distorsión.

- Definir una metodología para la inspección de distorsión en conjunto con el Cliente ya que la norma actual presenta brechas muy grandes con respecto a este defecto.

- Obtener la aprobación del Cliente con respecto a las mejoras que se logren mediante un MASTER de apariencia firmado.

IV. MARCO TEÓRICO

Automotive glass

Car drivers should see the real world as if there were no glazing – independent of the complex geometrical shape of modern car glazing design. However, the physics behind an ideal bent parallel glass pane shows up the difficulty, limitation or even the impossibility of such performance. We report on the dependence of optical properties of automotive glazing such as light transmittance, colour of glass or coating, secondary image angle separation and distortion with respect to design demands and technical realization. The gap between existing regulations and standards on the one hand and the increasing quality requirements on the other hand is pinpointed. Both, the challenging car design and the demanding needs of the driver (our customer) must be implemented.

The principle task of a modern glazing is to provide the driver with a high visibility and an undistorted view of the traffic scene ahead. Visual orientation is essential for safe driving. 90 % of the necessary information for safe driving is noticed visually. Thus, optical properties of a glazing
are distinguished in safety-relevant properties and others, which describe aesthetic features like colour impression
and reflection waviness of the glass or the thermal transmissivity, which governs the thermal interior comfort.
The visible properties of a glazing can be directly valued by the driver. He or she can easily recognized how the glazing effects

his or her view of the outside world. Therefore, this visual impression is a measure for the driver, our customer, about the quality of a glazing.

For the driver, the optical impression when looking through the pane (i.e. in transmission) is relevant for all possible viewing directions. This is contrary to existing regulations. Customers will also value the optical impression from the outside, particularly with regard to colour and refl ectivity behaviour. Standing in front of a vehicle, the windscreen behaves like a curved mirror. These features are not part of a regulation, but can be a signifi cant point for a purchase decision.

Tempered glass

Tempered glass is one of two kinds of safety glass regularly used in applications in which standard glass could pose a potential danger. Tempered glass is four to five times stronger than standard glass and does not break into sharp shards when it fails. Tempered glass is manufactured through a process of extreme heating and rapid cooling, making it harder than normal glass.

The brittle nature of tempered glass causes it to shatter into small oval-shaped pebbles when broken. This eliminates the danger of sharp edges. Due to this property, along with its strength, tempered glass is often referred to as safety glass.

IV. MARCO TEÓRICO

The thermal process that cures tempered glass also makes it heat resistant. Tempered glass is used to make the carafes in automatic coffee makers and the windows in ovens. Computer screens, skylights, door windows, tub enclosures and shower doors are more examples of places you will find tempered glass.

Tempered glass breaks in a unique way. If any part of the glass fails, the entire panel shatters at once. This distinguishes it from normal glass, which might experience a small crack or localized breakage from an isolated impact. Tempered glass might also fail long after the event that caused the failure. Stresses continue to play until the defect erupts, triggering breakage of the entire panel.

Tempered glass cannot be altered in any way after tempering- if glass is too big or has been fabricated wrong, it cannot be cut- as part of the safety feature of this glass- if it is "broken" (ie. "cut") it will break into hundreds of smaller pieces. glass tempering is done at a tempering plant and is not an item that can be simply "prepaired", as such there is often a longer wait for this type of glass. glass may also become somewhat "distorted" when tempered due to the extream heat the glass exposed to during the process- often tempered glass will have a "wavy" appearance when viewed at certain angles.

IV. MARCO TEÓRICO

Distortion

Distortion is a deviation from rectilinear projection, a projection in which straight lines in a scene remain straight in an image. It is a form of optical aberration.

The five basic types of aberration which are due to the geometry of lenses or mirrors, and which are applicable to systems dealing with monochromatic light, are known as Seidel aberrations, from an 1857 paper by Ludwig von Seidel. These are the aberrations that become evident in third-order optics, also known as Seidel optics.

The last of the Seidel aberrations, **distortion** is the most easily recognized aberration as it deforms the image as whole. Since straight lines in the object space are rendered as curved lines on the sensor, the name curvilinear distortion is frequently encountered. Fig. 1 shows the two fundamental manifestations of the aberration, barrel and pincushion distortion. Straight lines in the undistorted subject (left grid) bulge in the characteristic barrel fashion (middle grid) or bend inward in the pincushion representation (right grid). Straight lines running through the image center remain straight and a circle concentric with the image center remains a circle, although its radius is affected.

IV. MARCO TEÓRICO

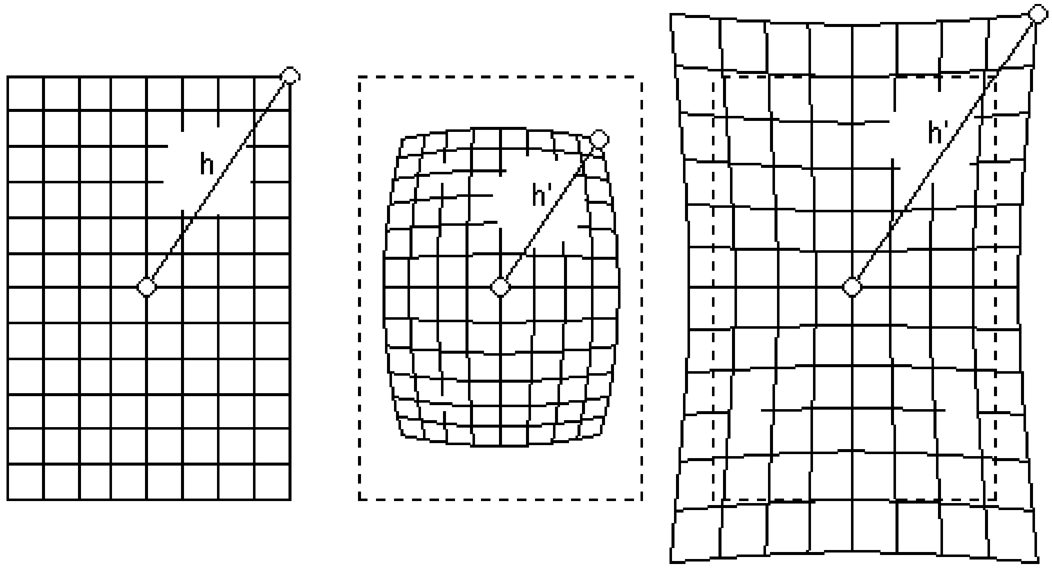


Figure 1. Distortion of a rectangular grid. Left: undistorted grid. Middle grid: barrel distortion. Right grid: pincushion distortion.

Six Sigma

Six Sigma is a business management strategy, initially implemented by Motorola, that today enjoys widespread application in many sectors of industry.

Six Sigma seeks to identify and remove the causes of defects and errors in manufacturing and business processes. It uses a set of quality management methods, including statistical methods, and creates a special infrastructure of people within the organization ("Black Belts" etc.) who are experts in these methods. Each Six Sigma project carried out within an organization follows a defined sequence of steps.

IV. MARCO TEÓRICO

Historical overview

Six Sigma was originally developed as a set of practices designed to improve manufacturing processes and eliminate defects, but its application was subsequently extended to other types of business processes as well. In Six Sigma, a defect is defined as anything that could lead to customer dissatisfaction.

The particulars of the methodology were first formulated by Bill Smith at Motorola in 1986. Six Sigma was heavily inspired by six preceding decades of quality improvement methodologies such as quality control, TQM, and Zero Defects, based on the work of pioneers such as Shewhart, Deming, Juran, Ishikawa, Taguchi and others.

Like its predecessors, Six Sigma asserts that:

- Continuous efforts to achieve stable and predictable process results (i.e. reduce process variation) are of vital importance to business success.
- Manufacturing and business processes have characteristics that can be measured, analyzed, improved and controlled.
- Achieving sustained quality improvement requires commitment from the entire organization, particularly from top-level management.

The term "Six Sigma" is derived from a field of statistics

IV. MARCO TEÓRICO

known as process capability studies. Originally, it referred to the ability of manufacturing processes to produce a very high proportion of output within specification. Processes that operate with "six sigma quality" over the short term are assumed to produce long-term defect levels below 3.4 defects per million opportunities (DPMO). Six Sigma's implicit goal is to improve all processes to that level of quality or better.

Six Sigma is a registered service mark and trademark of Motorola, Inc. Motorola has reported over US$17 billion in savings from Six Sigma as of 2006.

Other early adopters of Six Sigma who achieved well-publicized success include Honeywell (previously known as AlliedSignal) and General Electric, where the method was introduced by Jack Welch. By the late 1990s, about two-thirds of the Fortune 500 organizations had begun Six Sigma initiatives with the aim of reducing costs and improving quality.

In recent years, Six Sigma has sometimes been combined with lean manufacturing to yield a methodology named Lean Six Sigma.

Origin and meaning of the term "six sigma process"

Graph of the normal distribution, which underlies the statistical assumptions of the Six Sigma model. The Greek letter σ marks curve's inflection point. The greater this distance is, the greater is the spread of values encountered. For the curve shown in red above, $\mu = 0$ and $\sigma = 1$. The other curves illustrate different values of μ and σ.

Sigma (the lower-case Greek letter σ) is used to represent the standard deviation (a measure of variation) of a statistical population. The term "six sigma process" comes from the notion that if one has six standard deviations between the process mean and the nearest specification limit, there will be practically no items that fail to meet specifications. This is based on the calculation method employed in process capability studies.

In a capability study, the number of standard deviations between the process mean and the nearest specification limit is given in sigma units. As process standard deviation goes up, or the mean of the process moves away from the center of the tolerance, fewer standard deviations will fit between the mean and the nearest specification limit, decreasing the sigma number and increasing the likelihood of items outside specification.

Experience has shown that in the long term, processes usually do not perform as well as they do in the short. As a result, the number of sigmas that will fit between the process mean and the nearest specification limit is likely to drop over time,

IV. MARCO TEÓRICO

compared to an initial short-term study. To account for this real-life increase in process variation over time, an empirically-based 1.5 sigma shift is introduced into the calculation. According to this idea, a process that fits six sigmas between the process mean and the nearest specification limit in a short-term study will in the long term only fit 4.5 sigmas – either because the process mean will move over time, or because the long-term standard deviation of the process will be greater than that observed in the short term, or both.

Hence the widely accepted definition of a six sigma process is one that produces 3.4 defective parts per million opportunities (DPMO). This is based on the fact that a process that is normally distributed will have 3.4 parts per million beyond a point that is 4.5 standard deviations above or below the mean (one-sided capability study) So the 3.4 DPMO of a "Six Sigma" process in fact corresponds to 4.5 sigmas, namely 6 sigmas minus the 1.5 sigma shift introduced to account for long-term variation. This is designed to prevent underestimation of the defect levels likely to be encountered in real-life operation.[5]

Sigma levels

Taking the 1.5 sigma shift into account, short-term sigma levels correspond to the following long-term DPMO values (one-sided):

IV. MARCO TEÓRICO

- One Sigma = 690,000 DPMO = 68.26% efficiency
- Two Sigma = 308,000 DPMO = 95.24% efficiency
- Three Sigma = 66,800 DPMO = 99.73% efficiency
- Six Sigma = 3.4 DPMO = 99.9997% efficiency

DMAIC

Six Sigma has two key methods: DMAIC and DMADV, both inspired by Deming's Plan-Do-Check-Act Cycle. DMAIC is used to improve an existing business process; DMADV is used to create new product or process designs.

The basic method consists of the following five steps:

- ***D**efine* high-level project goals and the current process.
- ***M**easure* key aspects of the current process and collect relevant data.
- ***A**nalyze* the data to verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered.
- ***I**mprove* or optimize the process based upon data analysis using techniques like Design of experiments.
- ***C**ontrol* to ensure that any deviations from target are corrected before they result in defects. Set up pilot runs to establish process capability, move on to production, set up control mechanisms and continuously monitor the process.

V. DESARROLLO

Como se mencionó anteriormente la investigación fue realizada sobre una reclamación contra el desempeño óptico de Puertas Traseras y Delanteras Templadas que se estaban desarrollando para una nueva plataforma identificada como Programa D471.

Los productos que se fabrican en la empresa se dividen en dos: Vidrio Templado (Puertas Delanteras, Puertas Traseras, Quemacocos, Cuartos, Aletas, etc.) así como también Vidrio Laminado (Parabrisas y Quemacocos)

Es importante mencionar que el problema de Distorsión a reflejo ha sido un tema de mucha polémica entre los fabricantes de vidrio y las plantas armadoras de diversas Compañías Automotrices. Esto debido a que se trata de una característica cualitativa de la cual no se ha podido desarrollar un sistema de medición aprobado que permita tener datos concretos con respecto a este tema. Aunado a esto, las normas existentes para la inspección y medición de esta característica son muy vagas y escuetas.

Para el análisis de esta reclamación se integró el siguiente equipo multidisciplinario:

V. DESARROLLO

Project Leader: Efrain Madrid (Product Engineer)

Project Champion: Alejandro Zárate (Project Manager)

Process Owner: Francisco Palacios (Process Engineer)

Organization: Vitroflex S.A. de C.V.

Project Location: Monterrey, México

Teniéndose en cuenta para la selección de dichos integrantes únicamente el personal especializados en los procesos y productos Templados.

La metodología DMAIC se llevó a cabo paso a paso tratando de cumplir con cada uno de los requerimientos de manera que se pudieran obtener los mejores resultados y se pudiera dar una respuesta inmediata a corto plazo a la reclamación oficial del Cliente y trabajar para encontrar soluciones que permitiera obtener nuevamente la satisfacción del Cliente.

DMAIC

D	PROBLEM DESCRIPTION
M	MEASURE
A	ACTION
I	IMPROVEMENT
C	CONTROL

6-PANEL

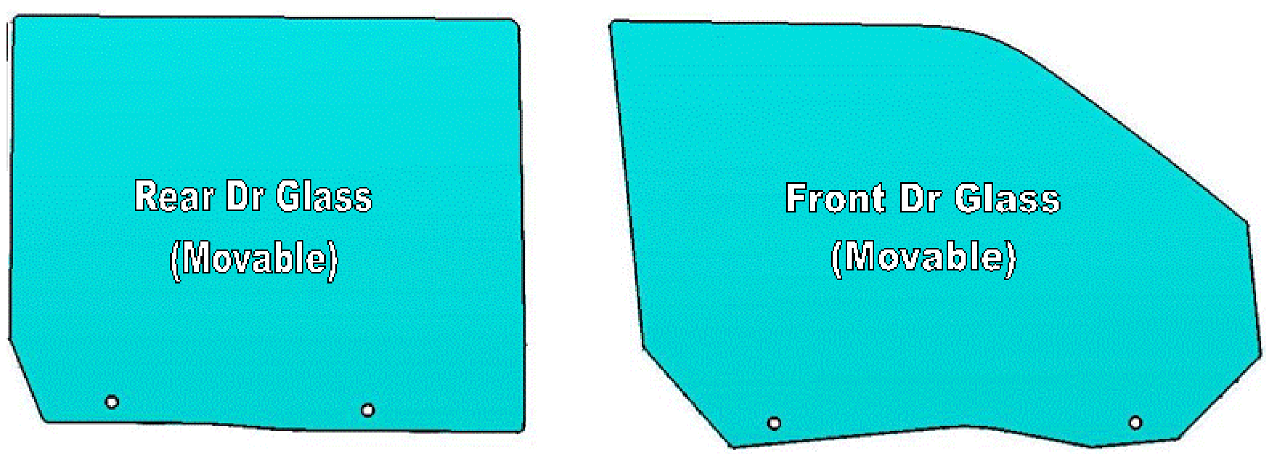
D — M — A — I — C

PROBLEM DESCRIPTION

REFLECTIVE DISTORTION

Vitro Flex was penalized by a Ford Assembly Plant because during TT BUILD of New Project D471 Rear Doors and Front Doors they appeared wavy/distorted during final inspection on units.

The D471 Rear Door and Front Door developed at VFX are the following:



6-PANEL

D – M – A – I – C

PROBLEM DESCRIPTION

REFLECTIVE DISTORTION REPORTED

6-PANEL

D – M – A – I – C

PROBLEM DESCRIPTION

The specification for Distortion Evaluation is described o in a FORD standard WSS-M28P1-B as Drawing mentioned:

MATERIAL:

FOR ∇8A83-7421410-1-A
∇WSS-M28P1-B4
GLASS, SAFETY, HEAT TREATED FLOAT
SOLAR TINT
4.7 +/-0.1MM THICK

According to this norm the inspection method for Distortion Analysis is described as follows:

∇ WSS-M28P1-B1/B5

3.12 INSPECTION METHOD for determining appearance flaws

The glass shall be examined in true view position under diffuse lighting conditions with 270 +/- 50 lux illumination measured facing the center of the white grid board at a distance of 20 +/- 2.5 cm. The part shall be examined by looking through the part with it positioned 50 - 90 cm from the observer (arms length). The observer's eye shall be level with the center and perpendicular to the part (see Figure 6).

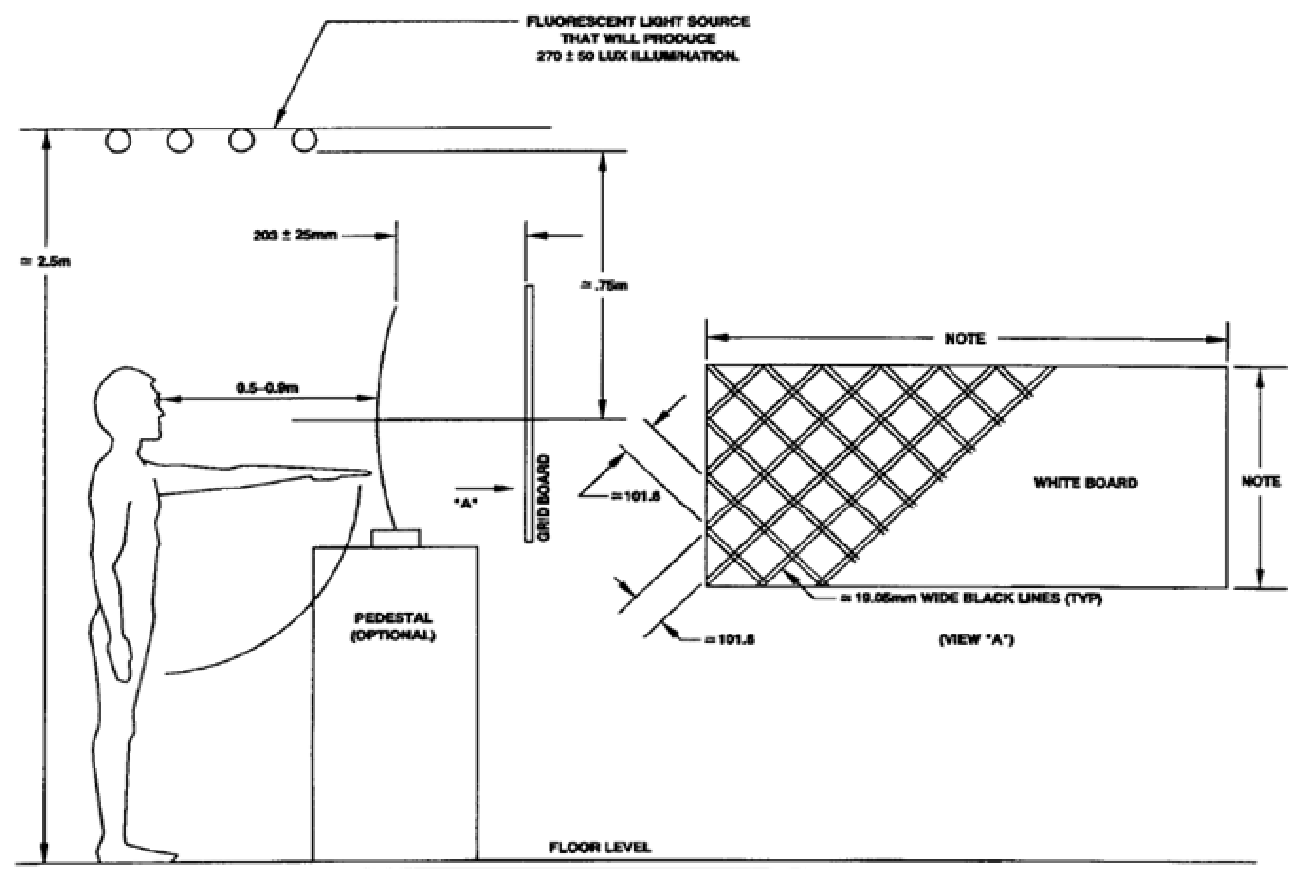
6-PANEL

D M A I C

PROBLEM DESCRIPTION

∇ WSS-M28P1-B1/B5

GLASS INSPECTION METHOD



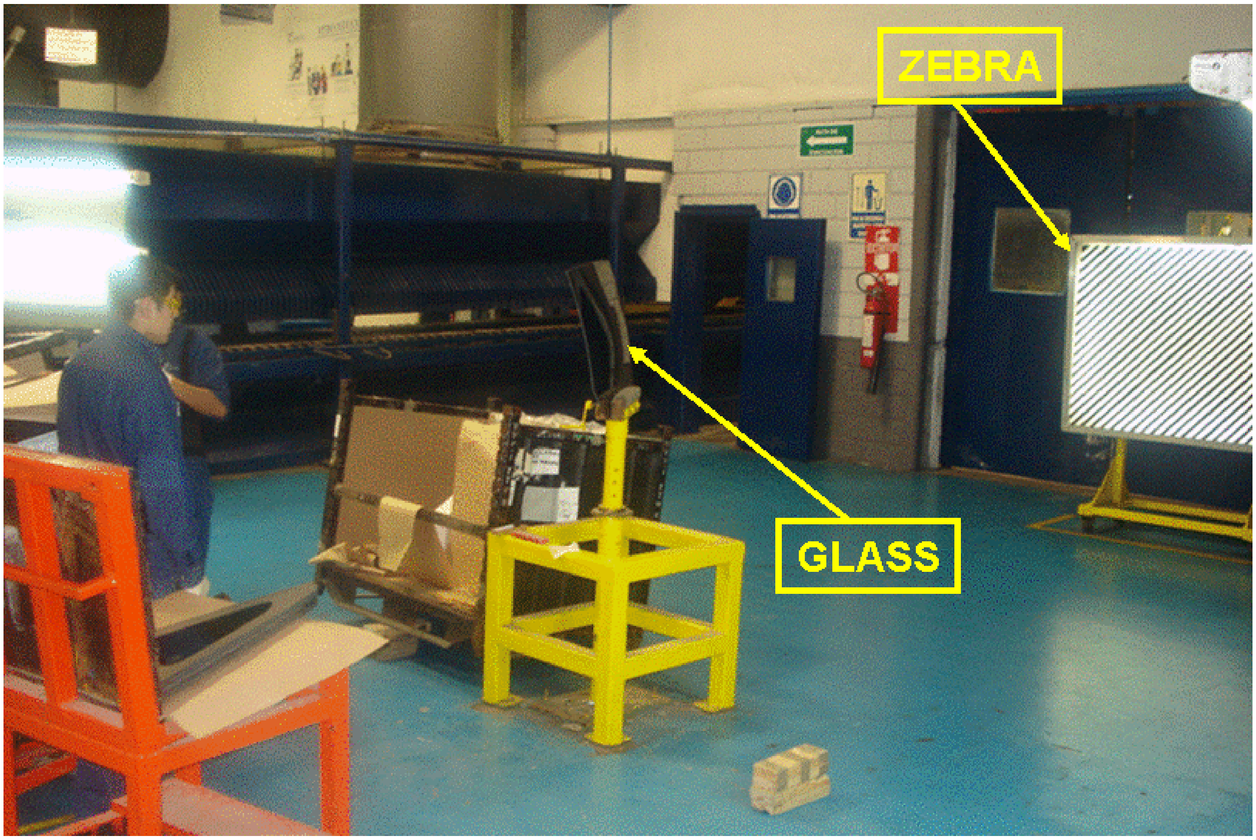
NOTES:

1. BOARD SIZE MUST COVER MAXIMUM LENGTH AND HEIGHT OF PART TO BE INSPECTED.
2. GLASS PART TO BE PLACED IN "TRUE VIEW" (PART PRINT) POSITION.

6-PANEL

D ✓ – M – A – I – C

PROBLEM DESCRIPTION



Using the Norm WSS-M28P1-B the parts were inspected according to VFX's Control Plan frequency giving us all parts under specification no detecting any Distortion through the Glass.

6-PANEL

D – M – A – I – C

PROBLEM DESCRIPTION

However the Distortion ISSUE reported by Ford Plant is been inspected by a completely different method than the one specified by the Norm. They are inspecting the parts using a Reflective Distortion without having any parameter to compare.

The Reflective Distortion is a characteristic that at this time there isn’t a Norm as WSS-M28P1-B does. This makes the supplier not to inspect the parts for this kind of Distortion and moreover the Product Drawing requirements never establishes anything about it, just what we already mentioned before.

It’s important to mention that because of the current method for Distortion evaluation this characteristic is fully qualitative which means there won’t be any data to compare.

For Reflective Distortion evaluation the results will depend on several variables like:

- Operator height
- Angle of vision
- Illumination
- Angle of glass installation
- Etc.

6-PANEL

D M A I C

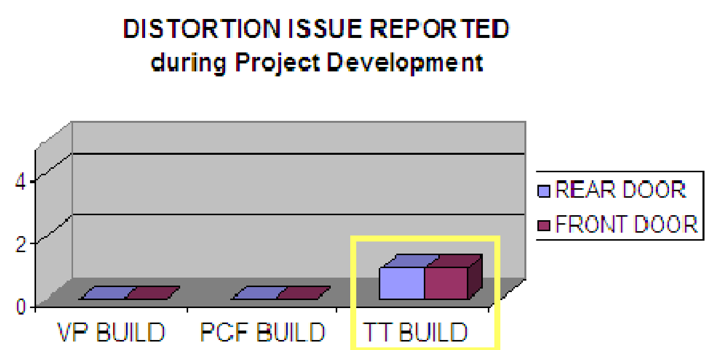
PROBLEM DESCRIPTION

Business Unit Name XXXX	Functional Area Name XXXX	Customer **FORD**
Vehicle Name & Model Year or Product / Process Name	**2008**	Part / Process Name & Number XXX

PROJECT CLASSIFICATION:
SAQ, QSF, High Mileage, etc.

Vitro has been required to eliminate wavy /distortion issue on Rear and Front Doors by Ford Assembly Plant

TREND CHARTS and BREAKDOWN OF ISSUE:



VOICE OF THE CUSTOMER:
Ford Assembly Plant reported all door glass appears wavy/distorted

CTQ STATEMENT (Customer Requirement):
Eliminating wavy / distortion on D471 Rear Doors and Front Doors

DEFECT DEFINITION for Y (Engineering Metric):
Pieces complied according to what Ford Assembly Plant is requesting

COST OF POOR QUALITY:
Ford Assembly Plant rejected the parts and approval of the appearance for PPAP purposes.

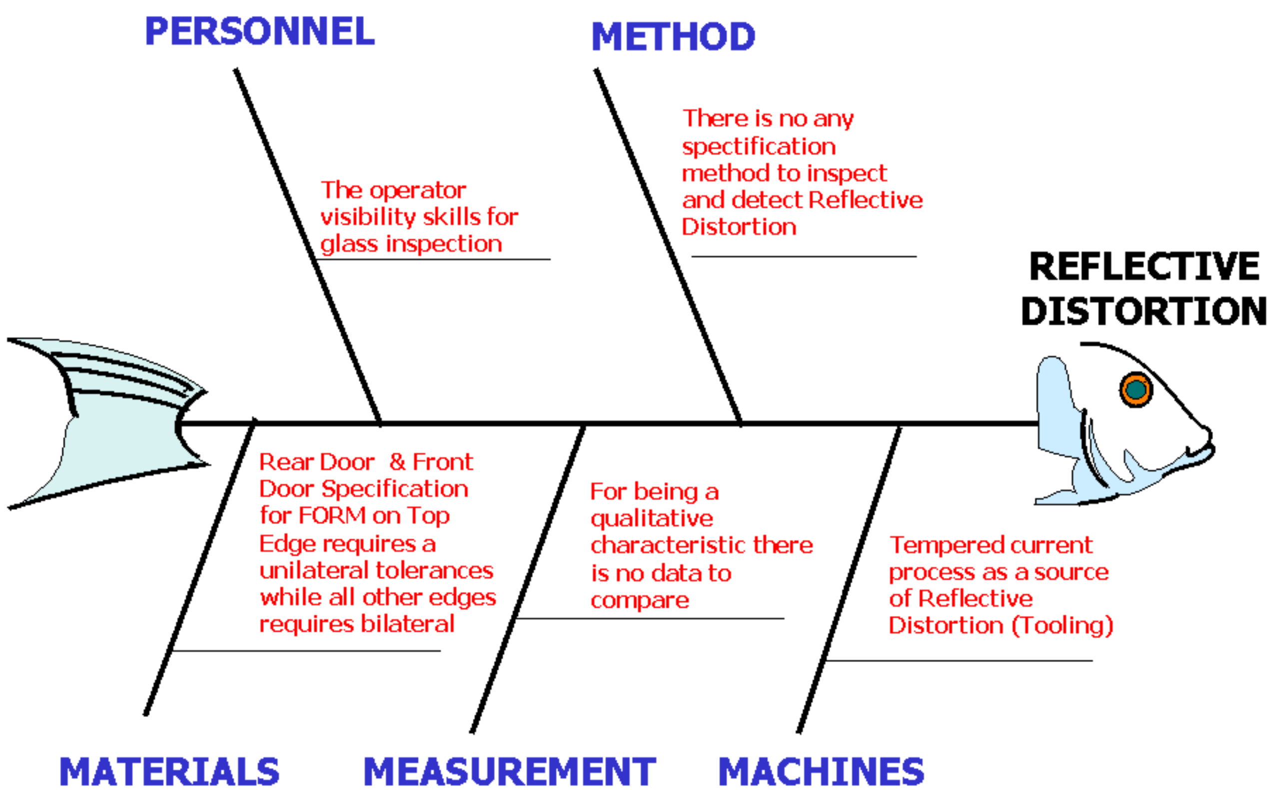
PROBLEM STATEMENT, SCOPE, AND GOAL
Rear Doors and Front Doors must have appearance approval before JOB 1

6-PANEL

D – M – A – I – C

MEASURE

ISHIKAWA FISHBONE

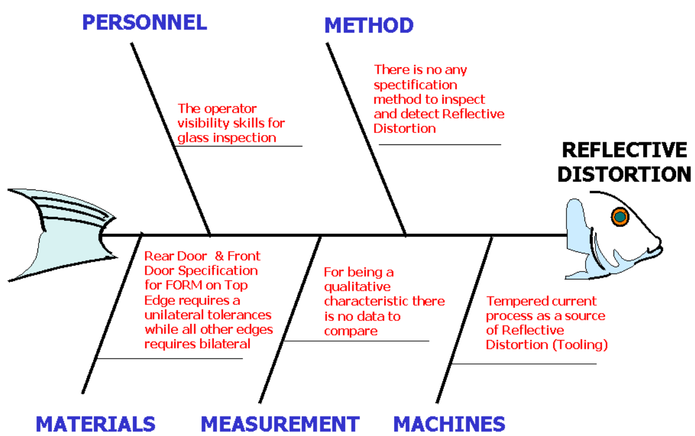


6-PANEL

D – M ✓ – A – I – C

MEASURE

Cause & Effect Diagram w/ Ranking:



Cause and Effect Matrix

X's	
Operator visibility skills	10.0%
Unilateral tolerances on top edge	40.0%
No method define for inspection	15.0%
Tooling adjustments	25.0%
No data avalability	10.0%
TOTAL	100.0%

Cause and Effect Matrix

X's	
Operator visibility skills	10.0%
Unilateral tolerances on top edge	40.0%
No method define for inspection	15.0%
Tooling adjustments	25.0%
No data avalability	10.0%
TOTAL	100.0%

6-PANEL

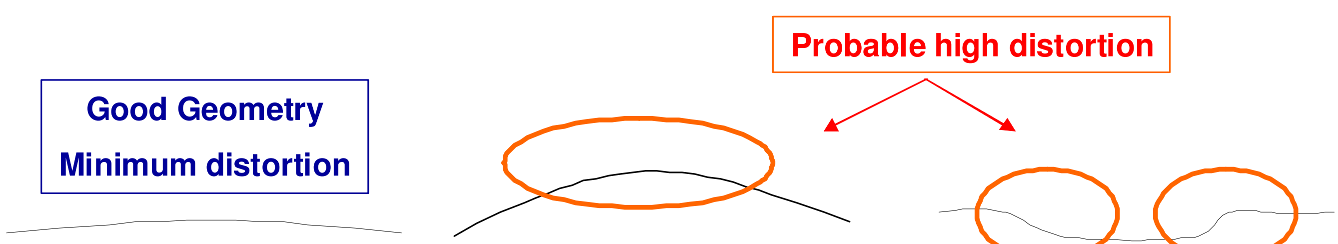
D – M – A – I – C

MEASURE

Unilateral tolerances on top edge

This cause is considered the mainly contributor of Reflective Distortion on the D471 Rear Door and Front Door. The reason is that according to Drawing the FORM tolerances for top edge is +0/-2mm and for all other edges the tolerance is +/-1.0 mm. This means that we can have a glass on the maximum tolerance +1.0 mm on each of the pillars and then a transition to the top edge to the minimum -2 mm a whole of 3.0 mm of distance between pillars and top edge.

The glass tends to reflect distortion on areas where there is an irregular surface/geometry:

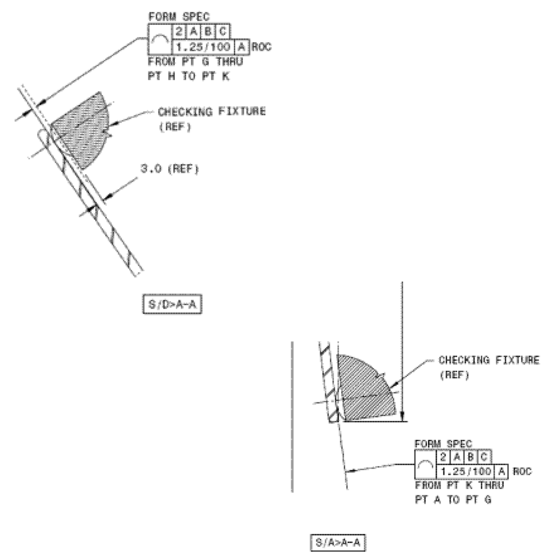


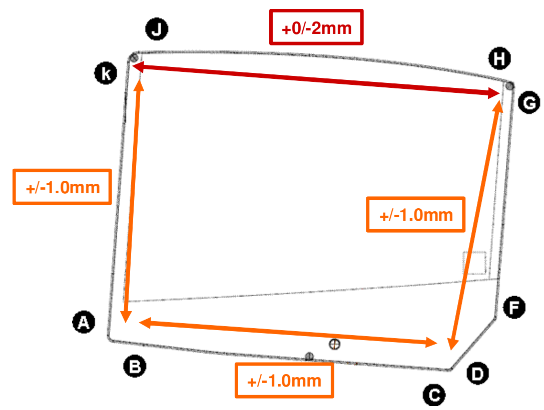
6-PANEL

D – M – A – I – C

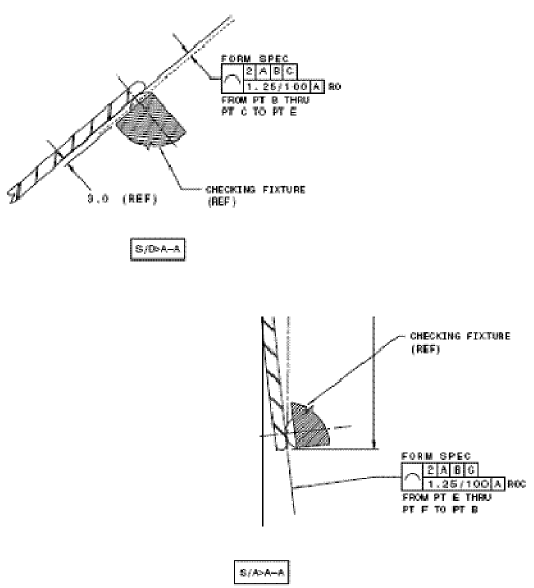
MEASURE

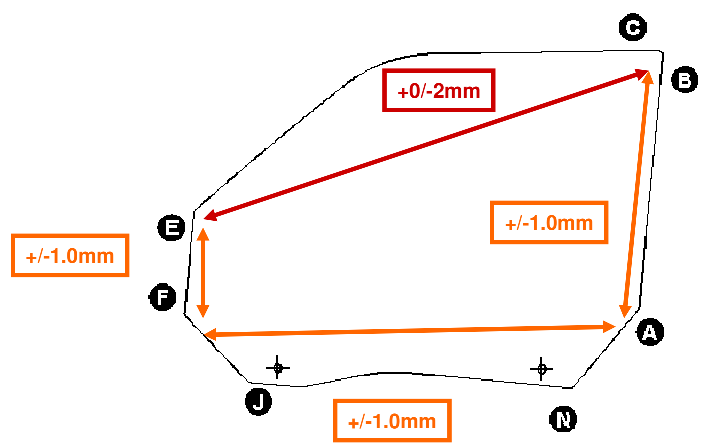
REAR DOOR GLASS: FORM SPECIFICATION





FRONT DOOR GLASS: FORM SPECIFICATION



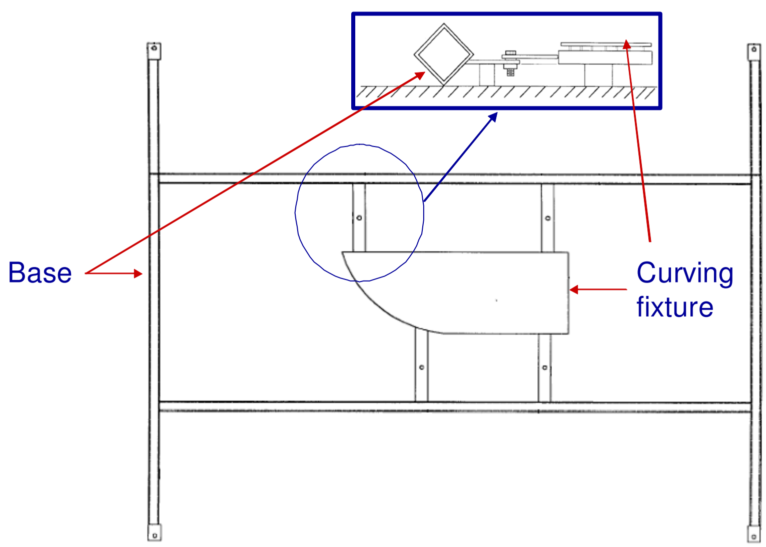


Bending tooling

In order to improve transition between bilateral tolerances zones into top edge unilateral zone a proposal was made by doing some modifications on bending tooling adding more screws along the periphery.

Current tooling has a screw every 2” distance. The proposal is to add a screw between the current ones every 1”.

The target for doing these changes is to avoid having a big transition into unilateral edge by controlling a Rate of change every 1” instead of 2” that originally had, resulting in a smooth curved along the top edge periphery.

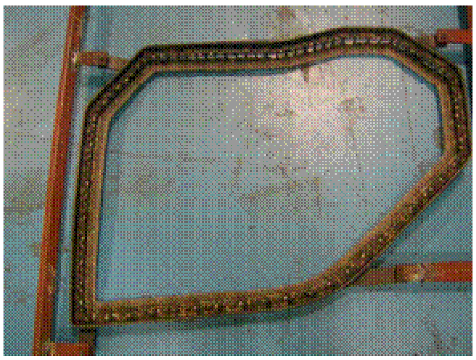


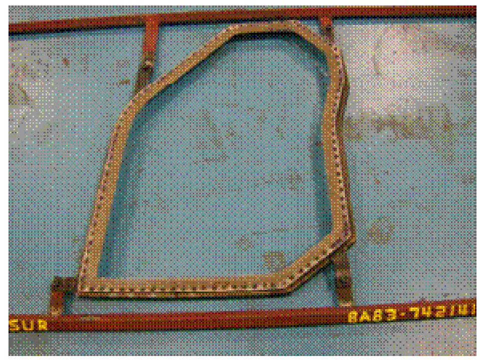
6-PANEL

D – M ✓ – A – I – C

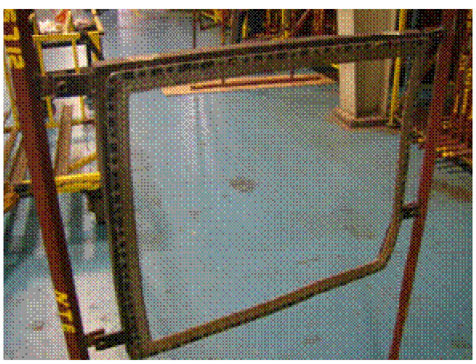
MEASURE

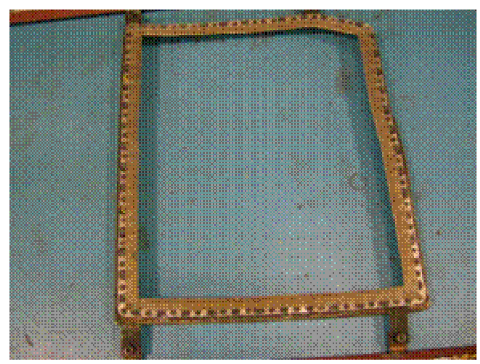
FRONT DOOR BENDING TOOL

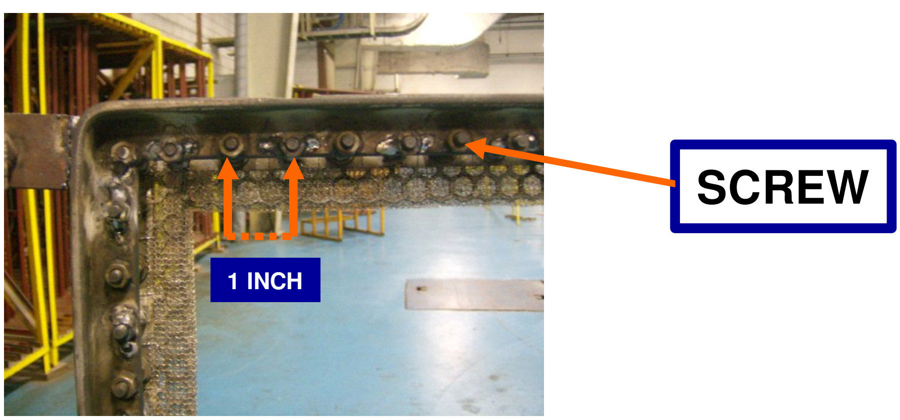




REAR DOOR BENDING TOOL





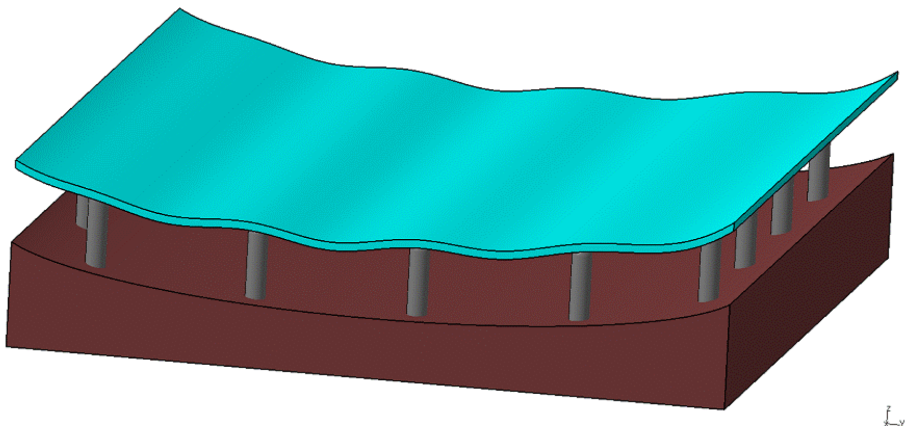


6-PANEL

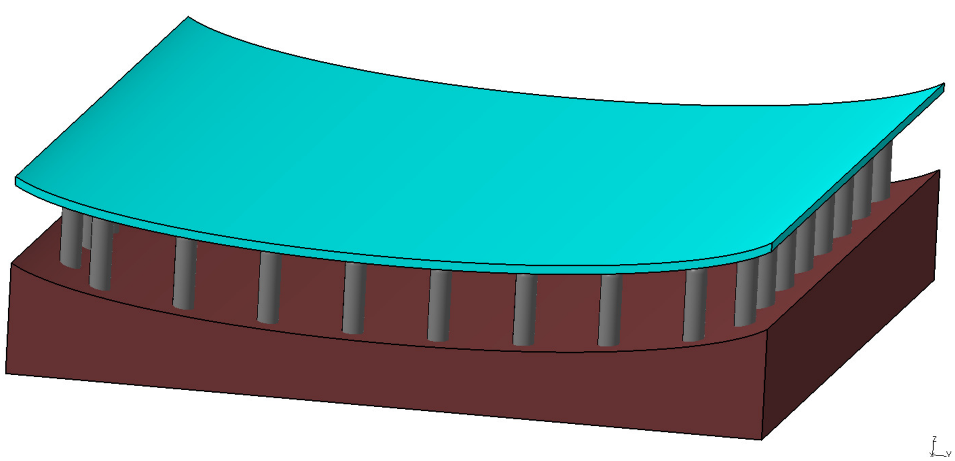
D – M – A – I – C

MEASURE

Next image simulates the glass being curved on a bending fixture with screws every 2”:



The result we want to have by adding screws every 1” can be seen on next image. The glass is been curved softly so curvature can be controlled with more precision.



6-PANEL

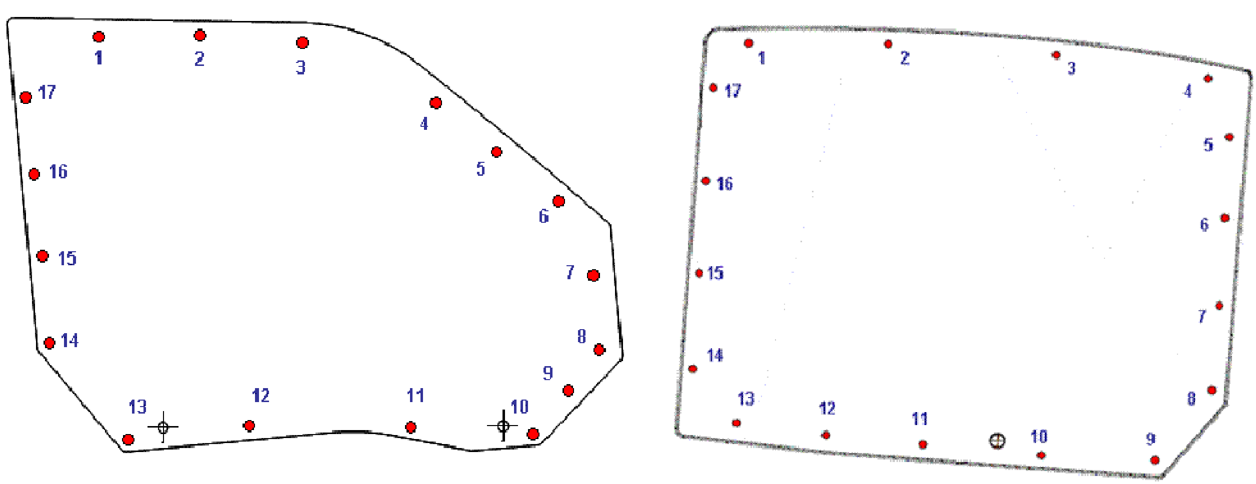
D – M – A – I – C

MEASURE

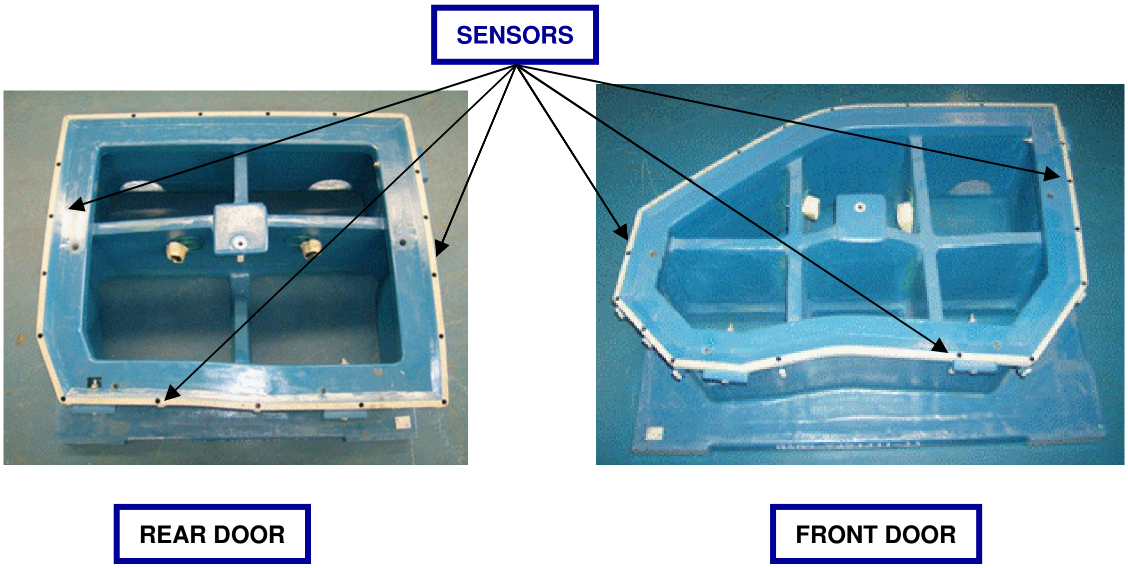
The checking fixtures to inspect the parts once they have been curved, have sensors along the periphery so FORM and Central SAG can be measured and Data can be collected every time the operator inspects the parts from a production run.

The checking fixture simulates the sheet metal shape where the glass will be installed so that supplier can ensure if the part will be functional or not.

This sketch shows the sensors location on the checking fixture and are related to the SC point from the next charts.



6-PANEL



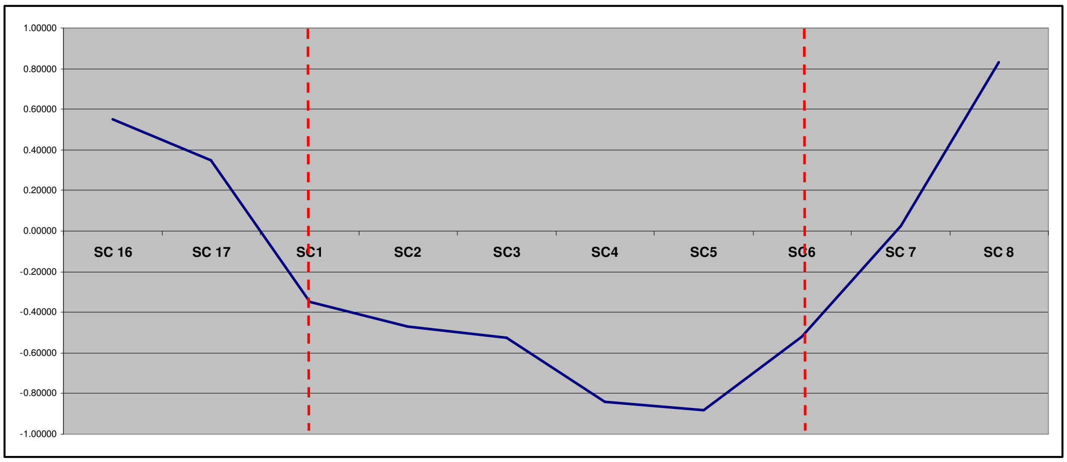
The next charts shows the behavior of transition between Bilateral tolerances to Unilateral for Front Doors Left hand and Right hand and Rear Doors as well.

Charts were created with an historical data from sample production runs (Average from a total of 100 samples).

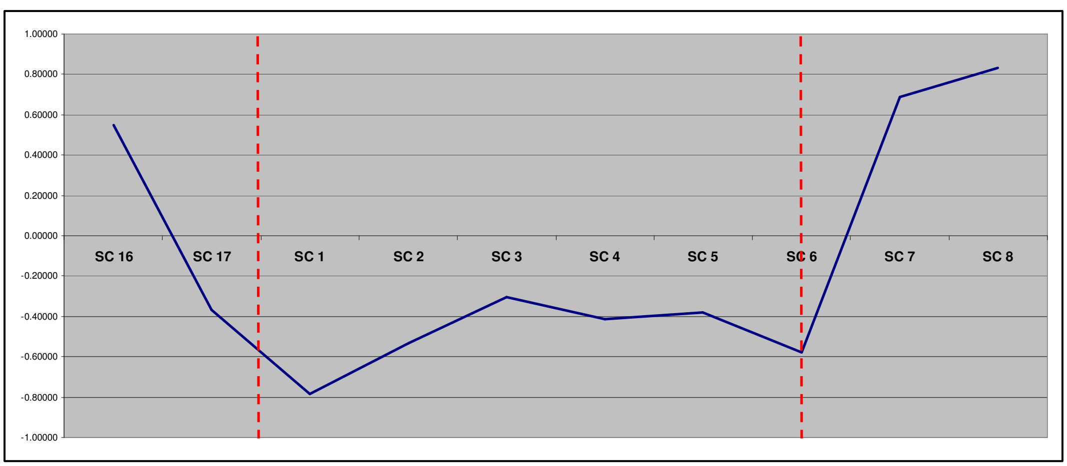
6-PANEL

D M A I C
MEASURE

D471 FRONT DOOR RIGHT HAND (TOP EDGE)



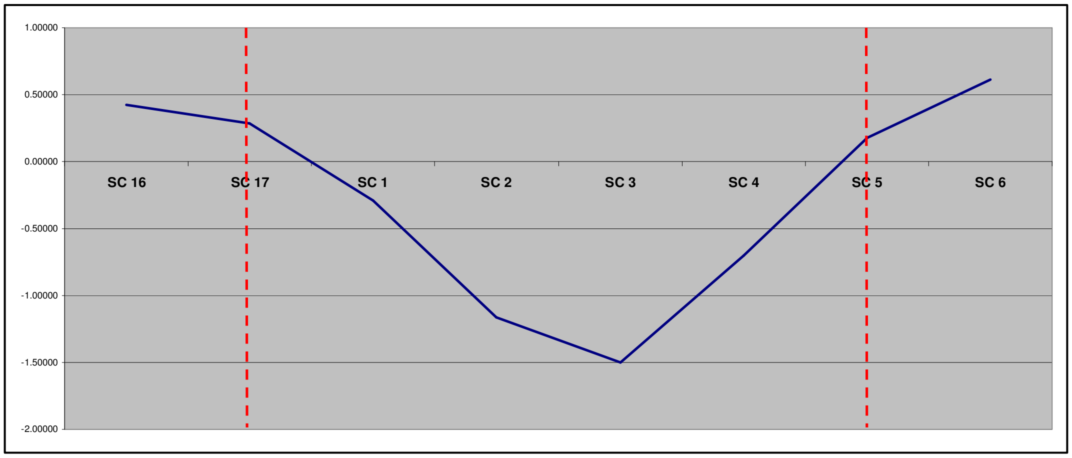
D471 FRONT DOOR LEFT HAND (TOP EDGE)



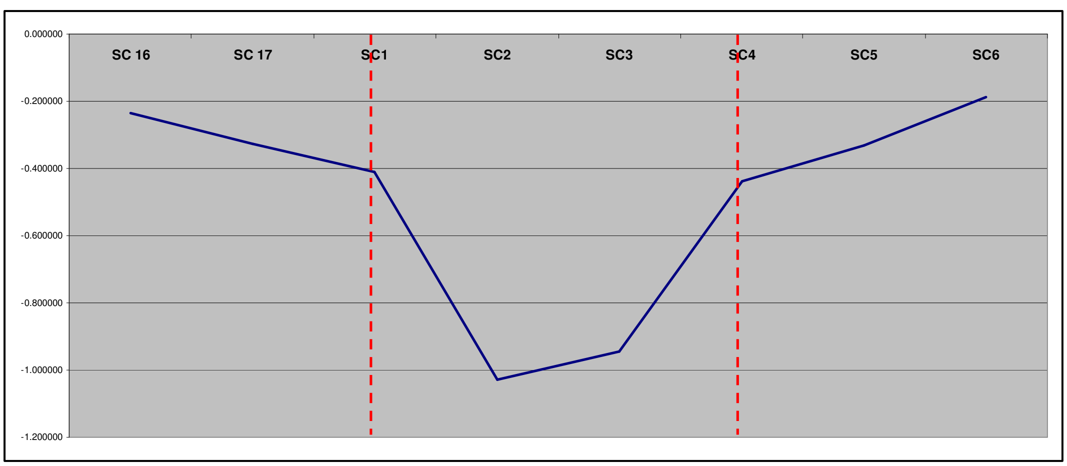
6-PANEL

D M A I C
MEASURE

D471 REAR DOOR RIGHT HAND (TOP EDGE)



D471 REAR DOOR LEFT HAND (TOP EDGE)

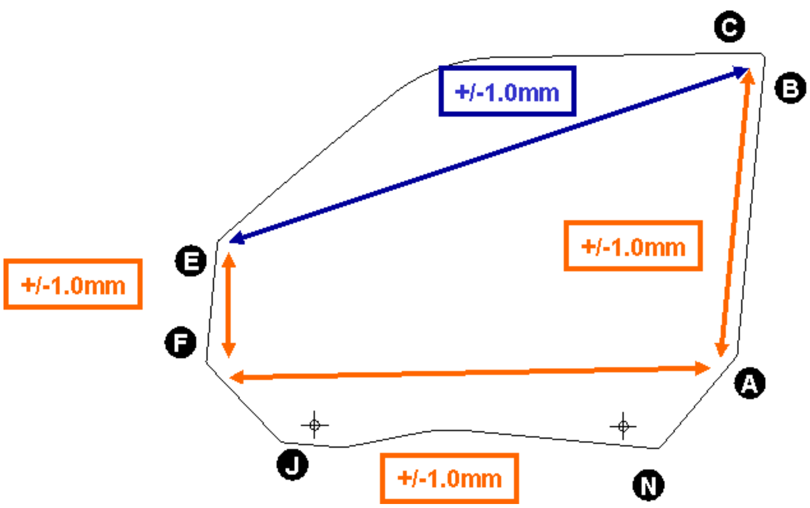


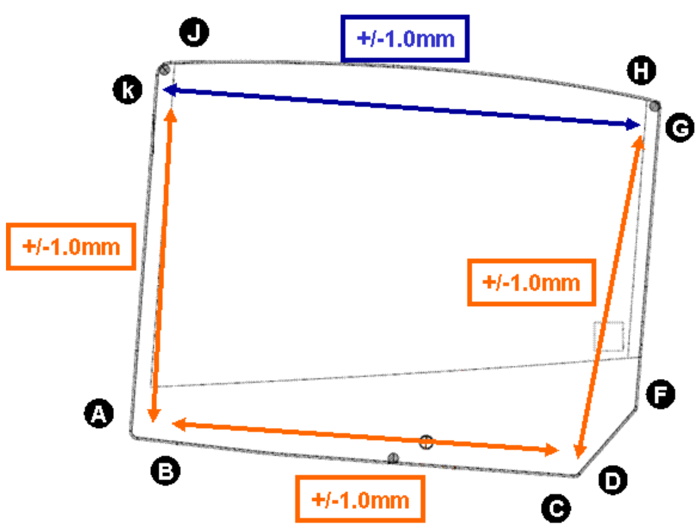
6-PANEL

D – M – A – I – C

MEASURE

A second proposal for avoiding reflective distortion is to change top edge to Bilateral tolerances so we can eliminate transition between pillars to top edge unilaterally.





6-PANEL

To get these 2 proposals approved it's necessary validate the next:

- Reflective distortion is eliminated or considerable reduced so that Ford Plant approves it.

- An assembly trial must be performed at Ford Plant to validate that there won't be any ISSUE when glass goes upwards through the run channels.

A CMM study is performed to analyze the part geometry to get a better perspective of what is happening that is probably causing a reflective distortion ISSUE

The CMM study consists on measuring the parts surface in reference to the Math Data as nominal.

The parts measured was done on parts with 4 different conditions as follows:

Condition 1

- Glass with the original design **(unilateral tolerances +0/-2mm upper edge)**

6-PANEL

D – M – A – I – C

ACTION

Condition 2

- Glass with bilateral tolerances +/- 1mm all periphery.

Condition 3

- Glass with the original design plus Fixtures modifications.

Condition 4

- Glass with bilateral tolerances plus Fixtures modifications.

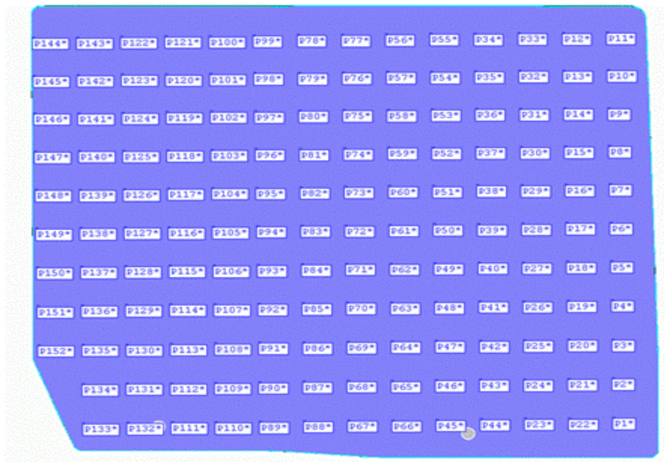
The Rear Door CMM study had 152 points of measurement on the whole surface as you can see on the following image.

All the points were put on a graphic so a surface can be simulated.

6-PANEL

D – M – A – I – C

ACTION



CMM RAW DATA

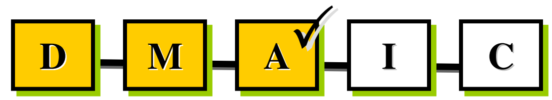
D471 REAR DOOR LH - CMM EVALUATION

	PIECE 1	PIECE 3	PIECE 2	PIECE 4
#	C1	C3	C2	C4
P1	-0.866	-0.552	-0.488	-0.492
P2	-0.967	-0.471	-0.488	-0.483
P3	-0.787	-0.233	-0.261	-0.250
P4	-0.598	-0.022	0.006	0.013
P5	-0.529	0.004	0.103	0.091
P6	-0.601	-0.130	-0.007	0.041
P7	-0.757	-0.256	-0.221	-0.006
P8	-0.962	-0.374	-0.497	-0.106
P9	-1.195	-0.572	-0.836	-0.339
P10	-1.274	-0.719	-1.064	-0.570
P11	-0.874	-0.561	-0.916	-0.523
P12	-1.168	-0.422	-1.359	-0.470
P13	-1.614	-0.740	-1.542	-0.683

D471 REAR DOOR RH - CMM EVALUATION

	PIECE 1	PIECE 3	PIECE 2	PIECE 4
#	C1	C3	C2	C4
P1	-0.424	-0.257	-0.292	-0.404
P2	-0.177	-0.238	-0.251	-0.374
P3	0.342	-0.077	-0.070	-0.196
P4	0.780	0.003	0.012	-0.117
P5	1.044	-0.007	-0.001	-0.141
P6	1.124	0.018	0.042	-0.120
P7	0.932	-0.020	0.045	-0.106
P8	0.661	-0.223	-0.074	-0.195
P9	0.281	-0.594	-0.306	-0.418
P10	-0.133	-0.886	-0.488	-0.587
P11	-0.248	-0.821	-0.361	-0.424
P12	-0.376	-1.429	-0.456	-0.543
P13	-0.325	-1.368	-0.639	-0.742

6-PANEL



ACTION

The Front Door CMM study had 174 points of measurement on the whole surface as you can see on image.

All the points were put on a graphic so a surface can be simulated.

6-PANEL

D – M – A – I – C

ACTION

CMM RAW DATA

D471 FRONT DOOR LH - CMM EVALUATION

	PZA 1	PZA 3	PZA 2	PZA 4
#	C1	C3	C2	C4
P1	-0.791	-0.608	-0.637	-0.648
P2	-0.670	-0.749	-0.554	-0.763
P3	-0.350	-0.615	-0.333	-0.604
P4	-0.111	-0.258	-0.129	-0.236
P5	-0.664	-0.282	-0.387	-0.200
P6	-0.818	-0.877	-0.593	-0.740
P7	-0.876	-1.136	-0.663	-0.993
P8	-0.961	-1.205	-0.738	-1.064
P9	-0.926	-1.057	-0.743	-0.937
P10	-0.591	-0.576	-0.500	-0.520
P11	-0.354	-0.447	-0.363	-0.297
P12	-0.729	-1.019	-0.670	-0.799
P13	-0.907	-1.267	-0.682	-1.003

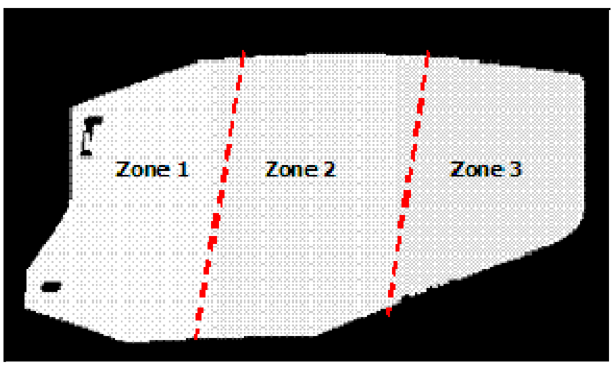
D471 FRONT DOOR RH - CMM EVALUATION

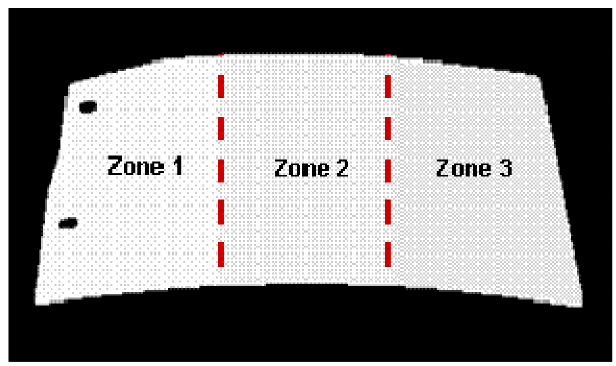
	PZA 1	PZA 3	PZA 2	PZA 4
#	C1	C3	C2	C4
P1	-0.459	-0.066	-0.024	-0.009
P2	-0.389	-0.287	-0.044	-0.258
P3	-0.192	-0.285	0.003	-0.233
P4	-0.059	-0.152	-0.001	0.000
P5	-0.571	-0.283	-0.511	-0.123
P6	-0.844	-0.745	-0.574	-0.703
P7	-0.842	-0.877	-0.516	-0.932
P8	-0.854	-0.883	-0.501	-0.975
P9	-0.851	-0.724	-0.459	-0.793
P10	-0.512	-0.288	-0.233	-0.300
P11	-0.455	-0.444	-0.340	-0.351
P12	-0.940	-0.931	-0.638	-1.001
P13	-1.059	-1.093	-0.634	-1.259

In order to measure reflective distortion, it was decided to divide the glass into 3 zones trying to see which zones are affected.

6-PANEL

According to the pictures from Issue reported by Ford Plant, the zone 3 seems to be the one with Reflective Distortion issues, so it should reflects the highest value on all studies.



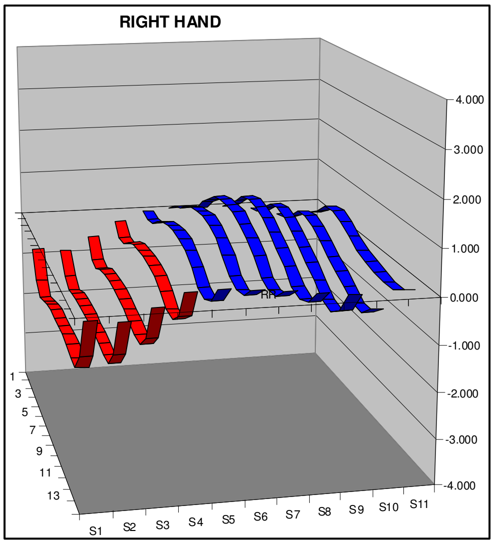


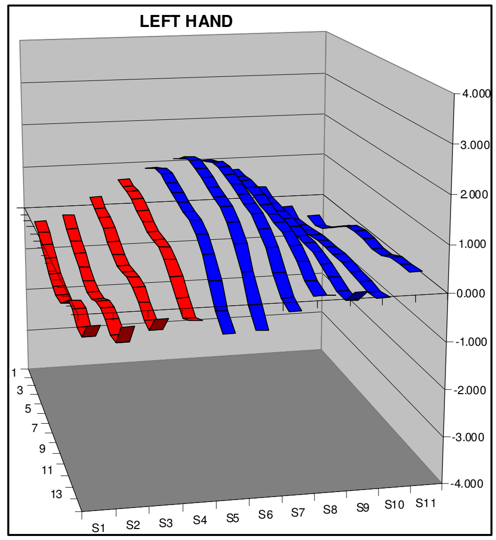
6-PANEL

D - M - A - I - C
IMPROVEMENT

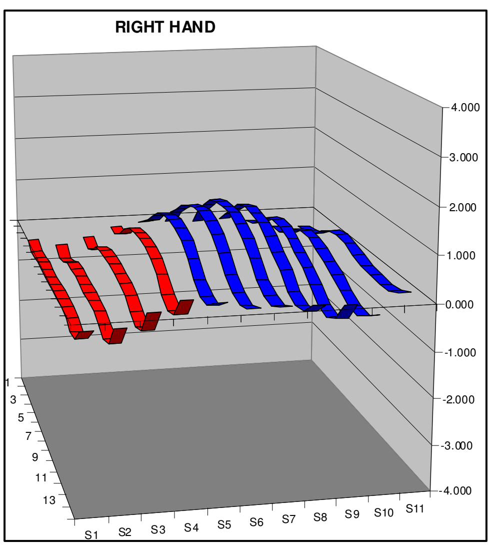
REAR DOOR

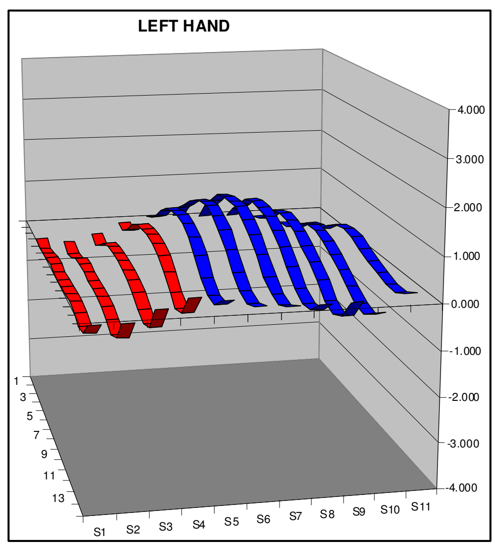
CONDITION #1





CONDITION #2



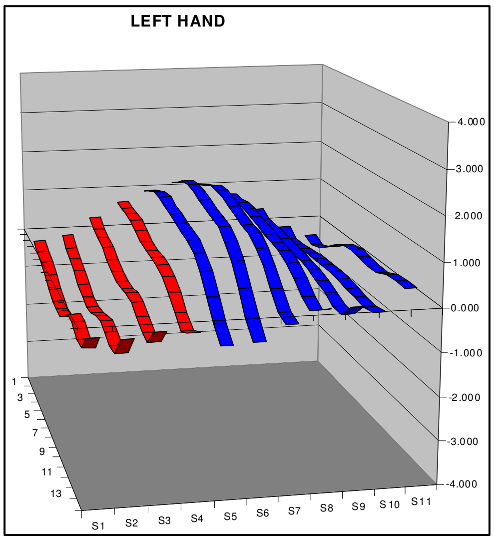


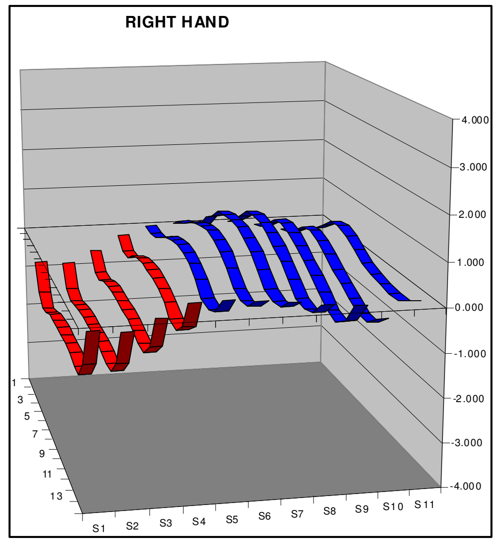
6-PANEL

D – M – A – I – C
IMPROVEMENT

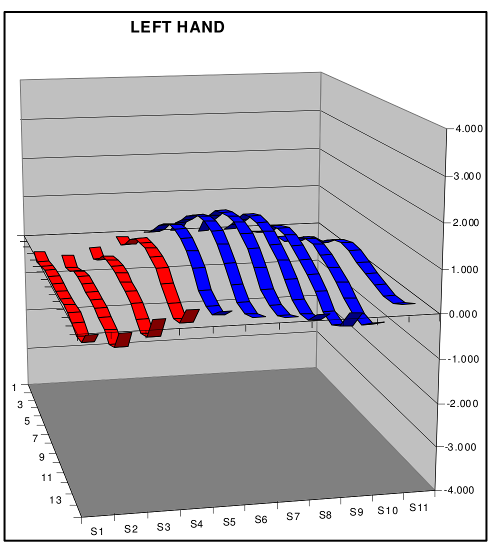
REAR DOOR

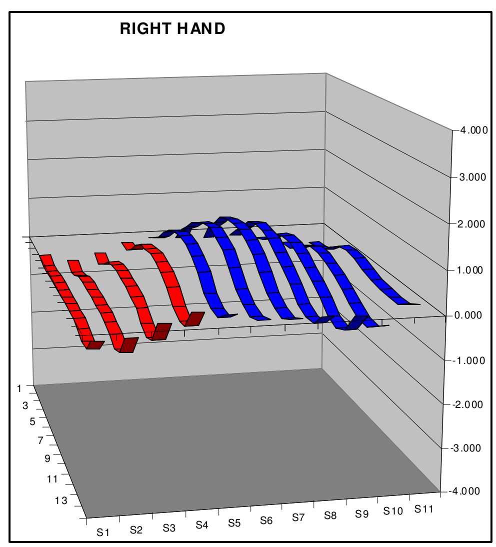
CONDITION #3





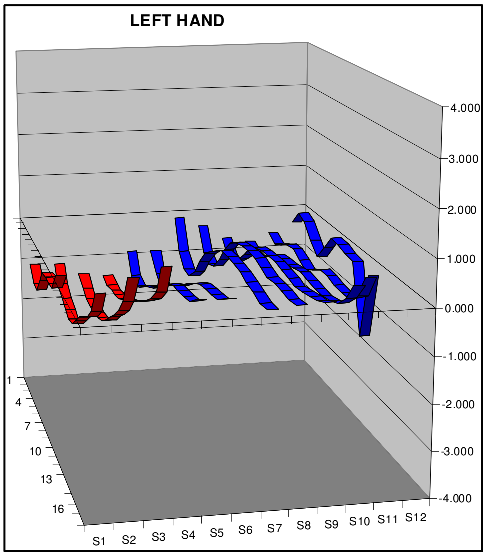
CONDITION #4

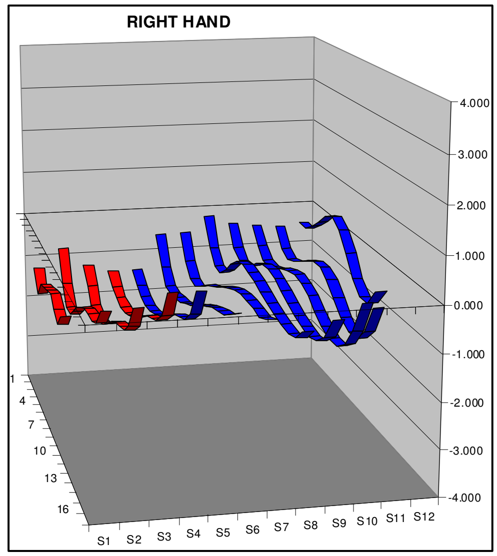




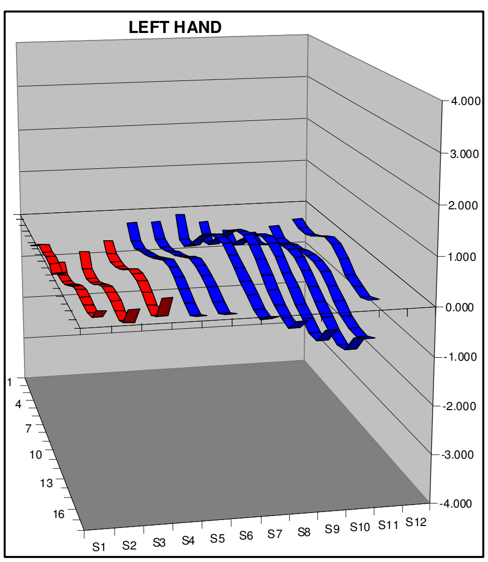
FRONT DOOR

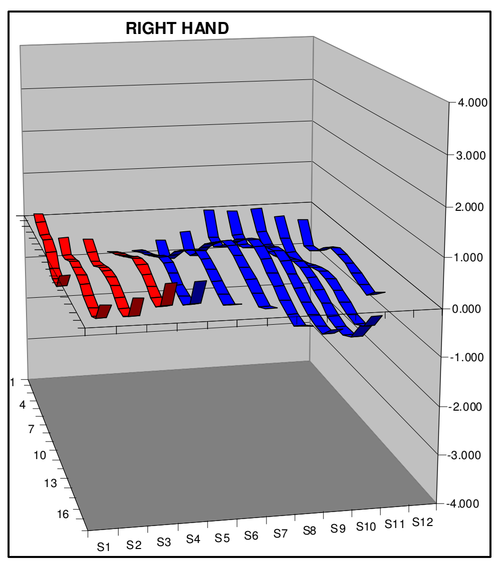
CONDITION #1





CONDITION #2



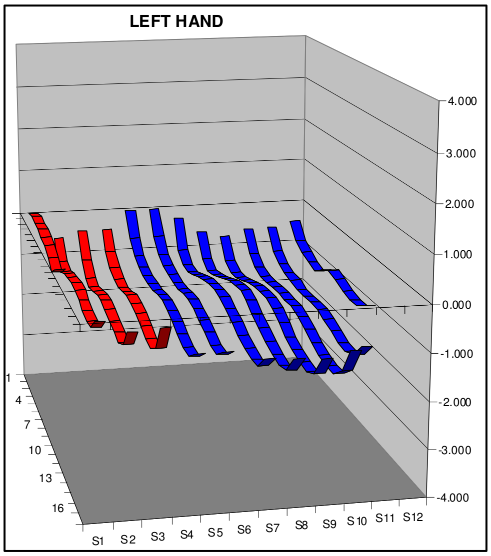


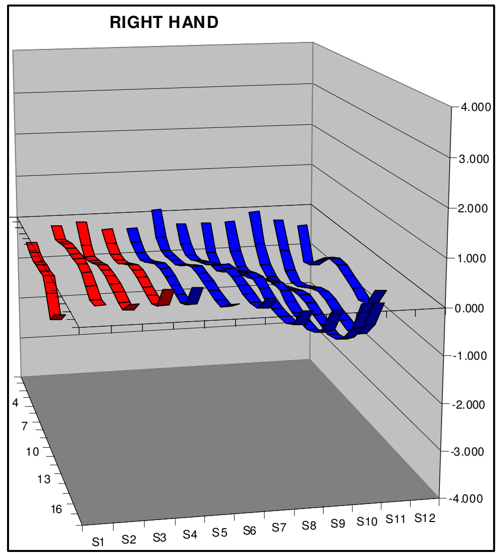
6-PANEL

D – M – A – I – C
IMPROVEMENT

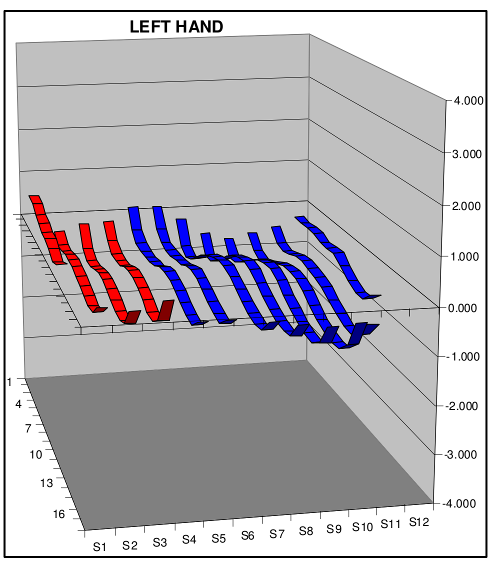
FRONT DOOR

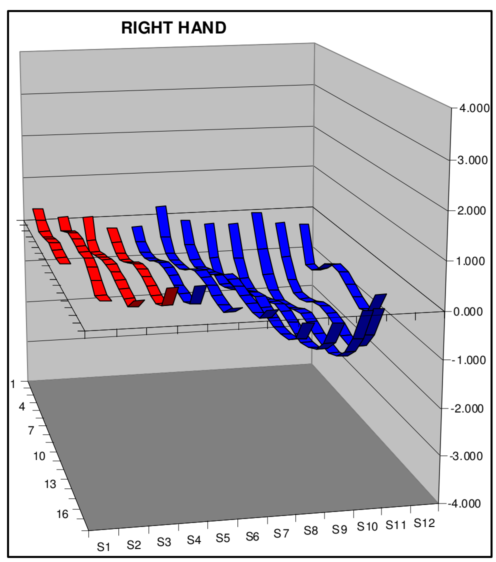
CONDITION #3





CONDITION #4





6-PANEL

D – M – A ✓ – I – C

ACTION

Because there is no method established to measure reflective distortion as already mentioned before, a study was performed trying to get same angle as pictures taken from Issue reported. All Reflective measurements done during this study were performed trying to quantify distortion and getting a picture to visualize it.

A quantity of 3 samples for Front Doors and Rear Doors of each condition were measured through an ANALYZER and results were expressed on a graphic.

In order to measure reflective distortion, a DISTORTION ANALYZER was used to get some data readings.

The DISTORTION ANALYZER shows results expressed in standard deviations. These values are the results of comparing a nominal value (straight lines: Zebra) against what is reflected on the glass.

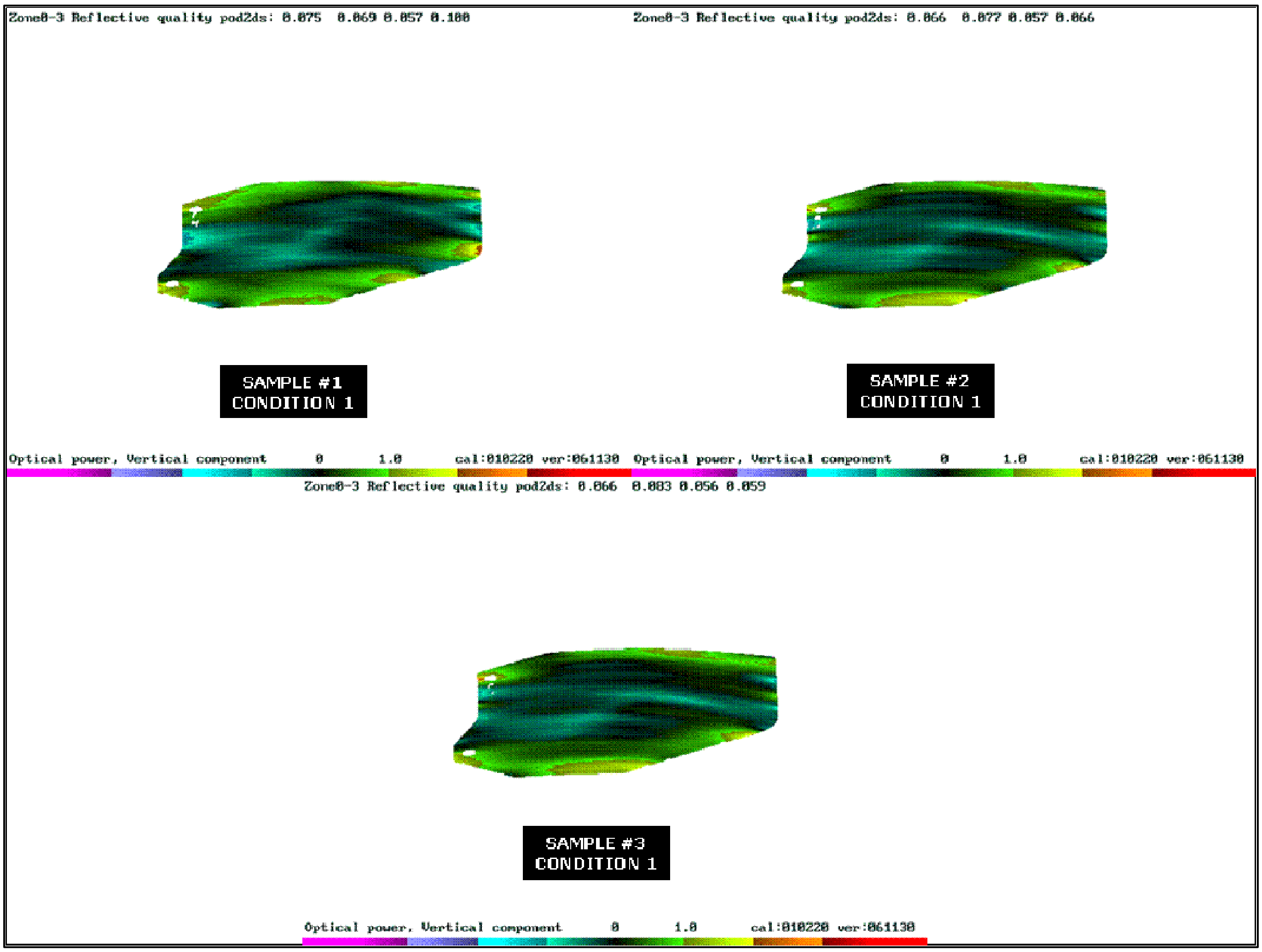
The 4 conditions mentioned before were the samples for this study.

6-PANEL

D – M – A – I ✓ – C
IMPROVEMENT

FRONT DOOR

DISTORSION ANALYSIS READINGS



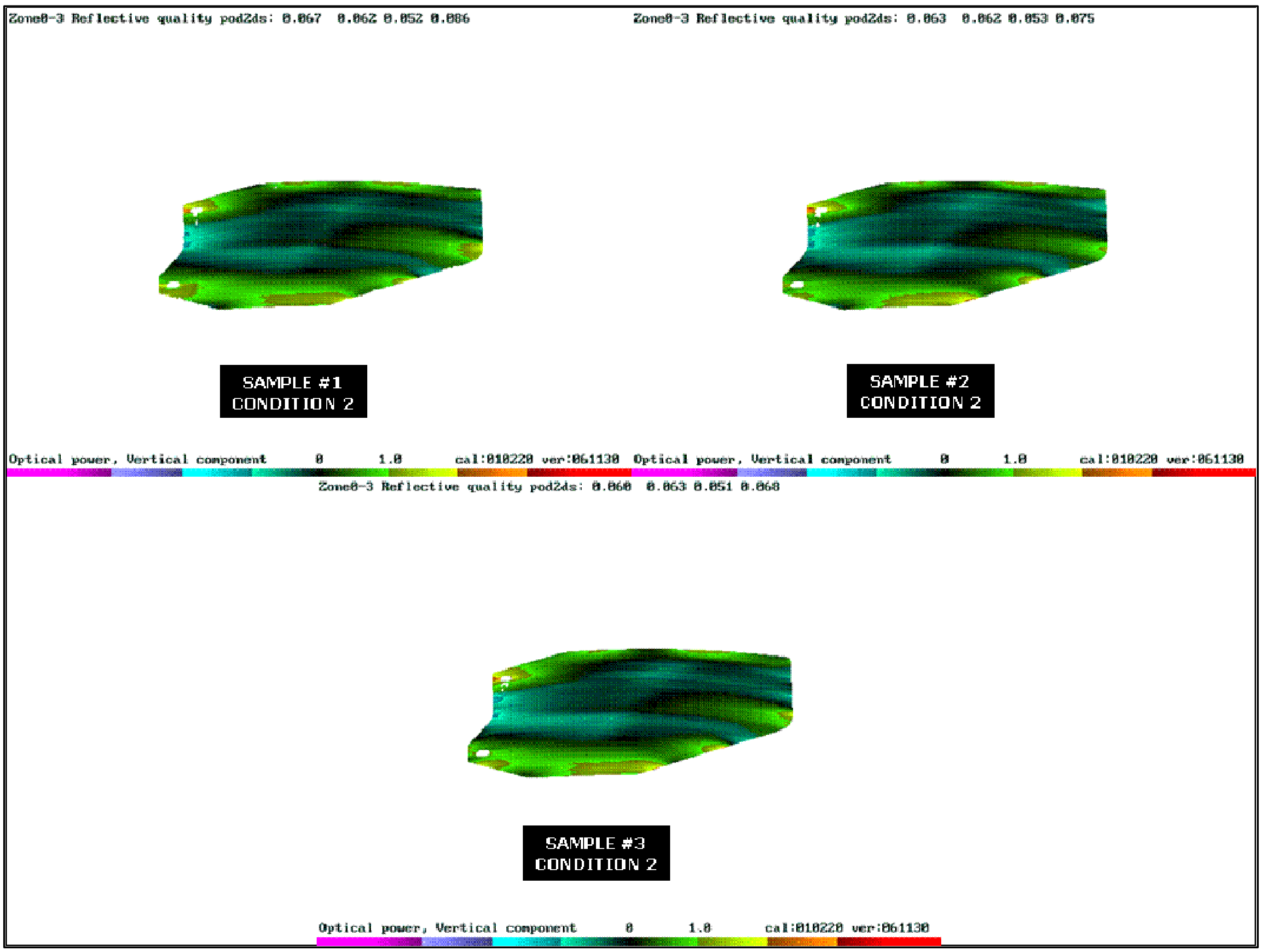
6-PANEL

D – M – A – I – C

IMPROVEMENT

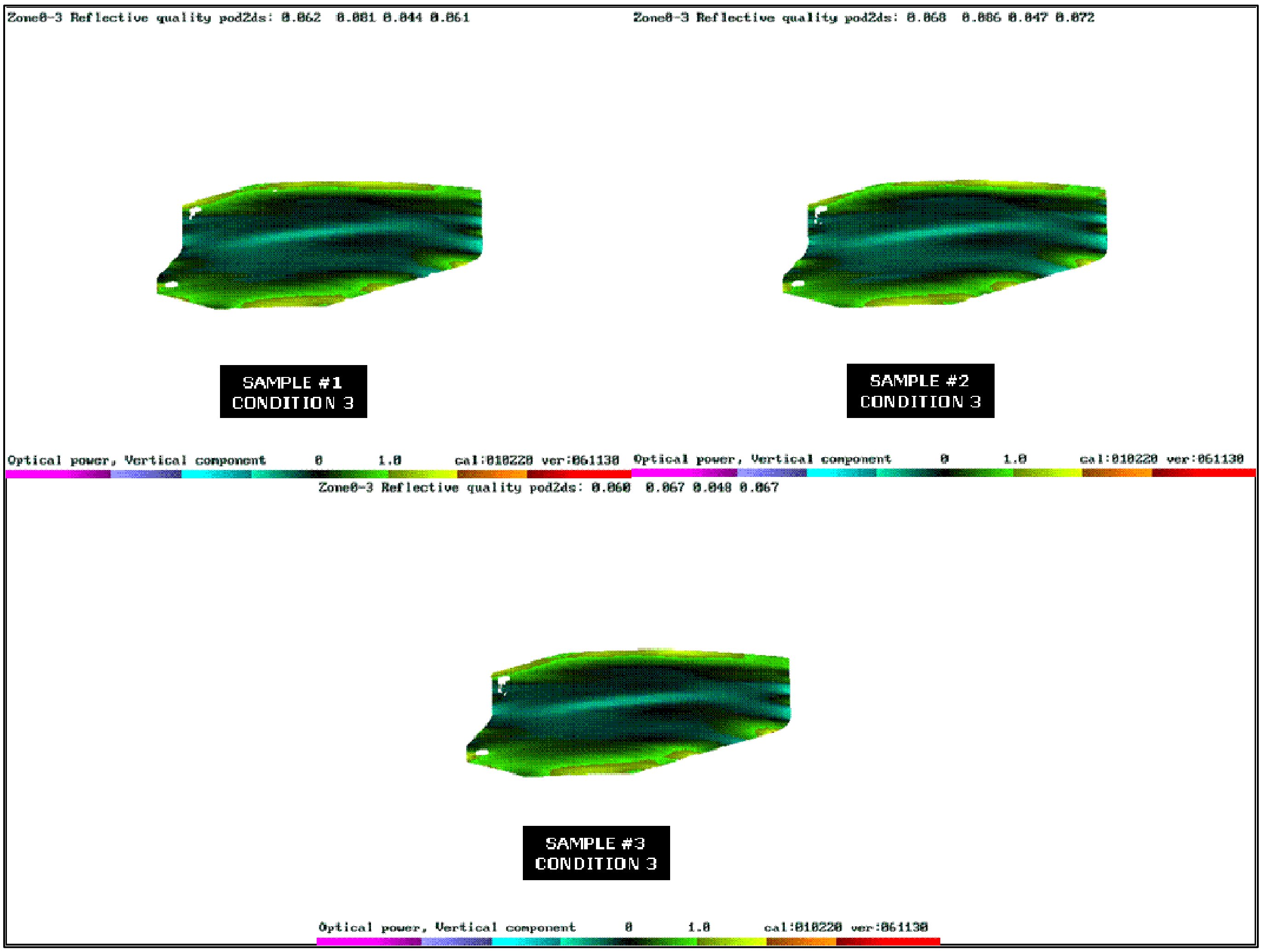
FRONT DOOR

DISTORSION ANALYSIS READINGS



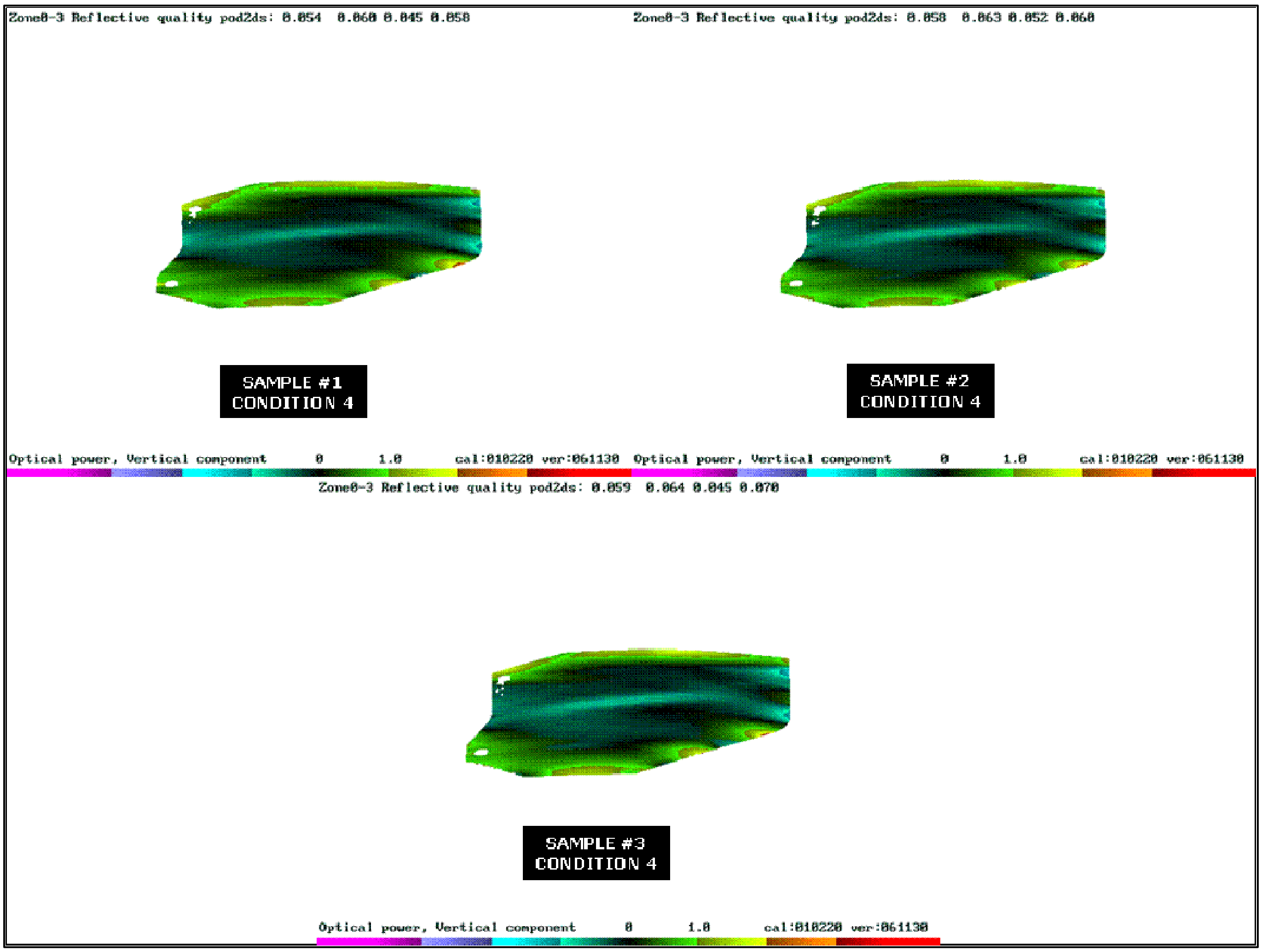
FRONT DOOR

DISTORSION ANALYSIS READINGS



FRONT DOOR

DISTORSION ANALYSIS READINGS



6-PANEL

D – M – A – I ✓ – C

IMPROVEMENT

Summarizing the DA readings on chart, the results are as follows:

FRONT DOOR

DISTORSION ANALYSIS READINGS

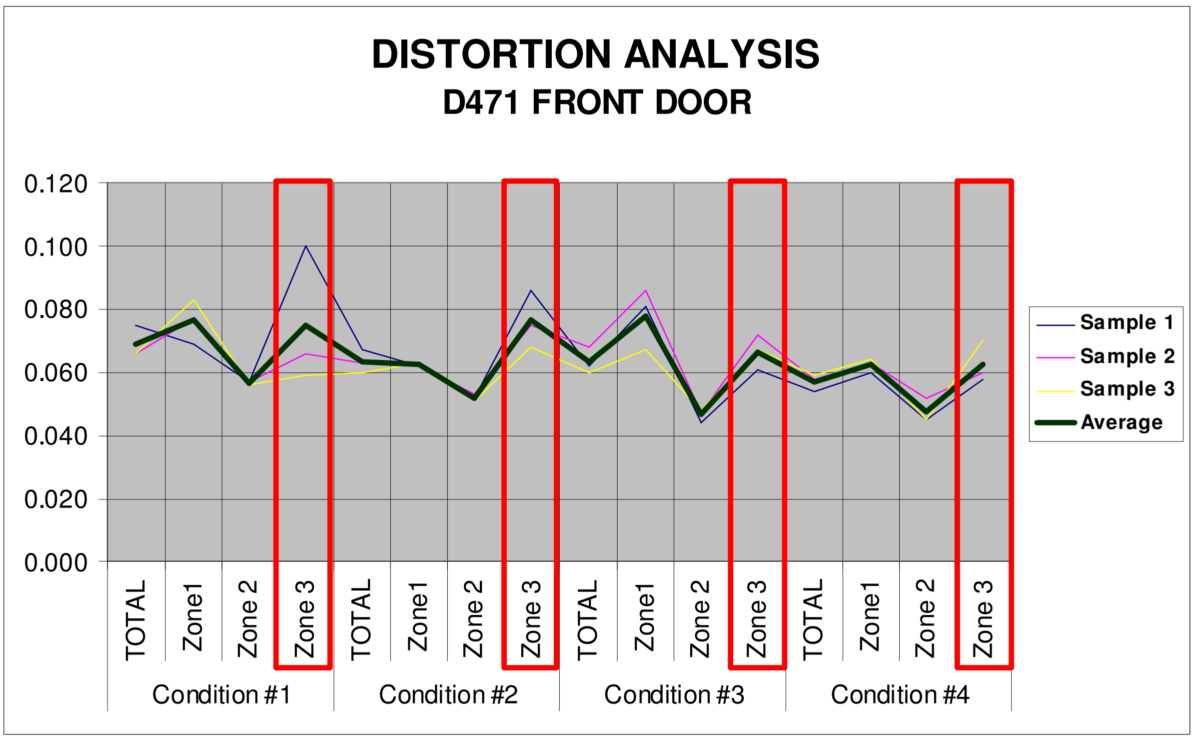
	Condition #1			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.075	0.069	0.057	0.100
Sample 2	0.066	0.077	0.057	0.066
Sample 3	0.066	0.083	0.056	0.059
Average	0.069	0.076	0.057	0.075

	Condition #2			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.067	0.062	0.052	0.086
Sample 2	0.063	0.062	0.053	0.075
Sample 3	0.060	0.063	0.051	0.068
Average	0.063	0.062	0.052	0.076

	Condition #3			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.062	0.081	0.044	0.061
Sample 2	0.068	0.086	0.047	0.072
Sample 3	0.060	0.067	0.048	0.067
Average	0.063	0.078	0.046	0.067

	Condition #4			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.054	0.060	0.045	0.058
Sample 2	0.058	0.063	0.052	0.060
Sample 3	0.059	0.064	0.045	0.070
Average	0.057	0.062	0.047	0.063

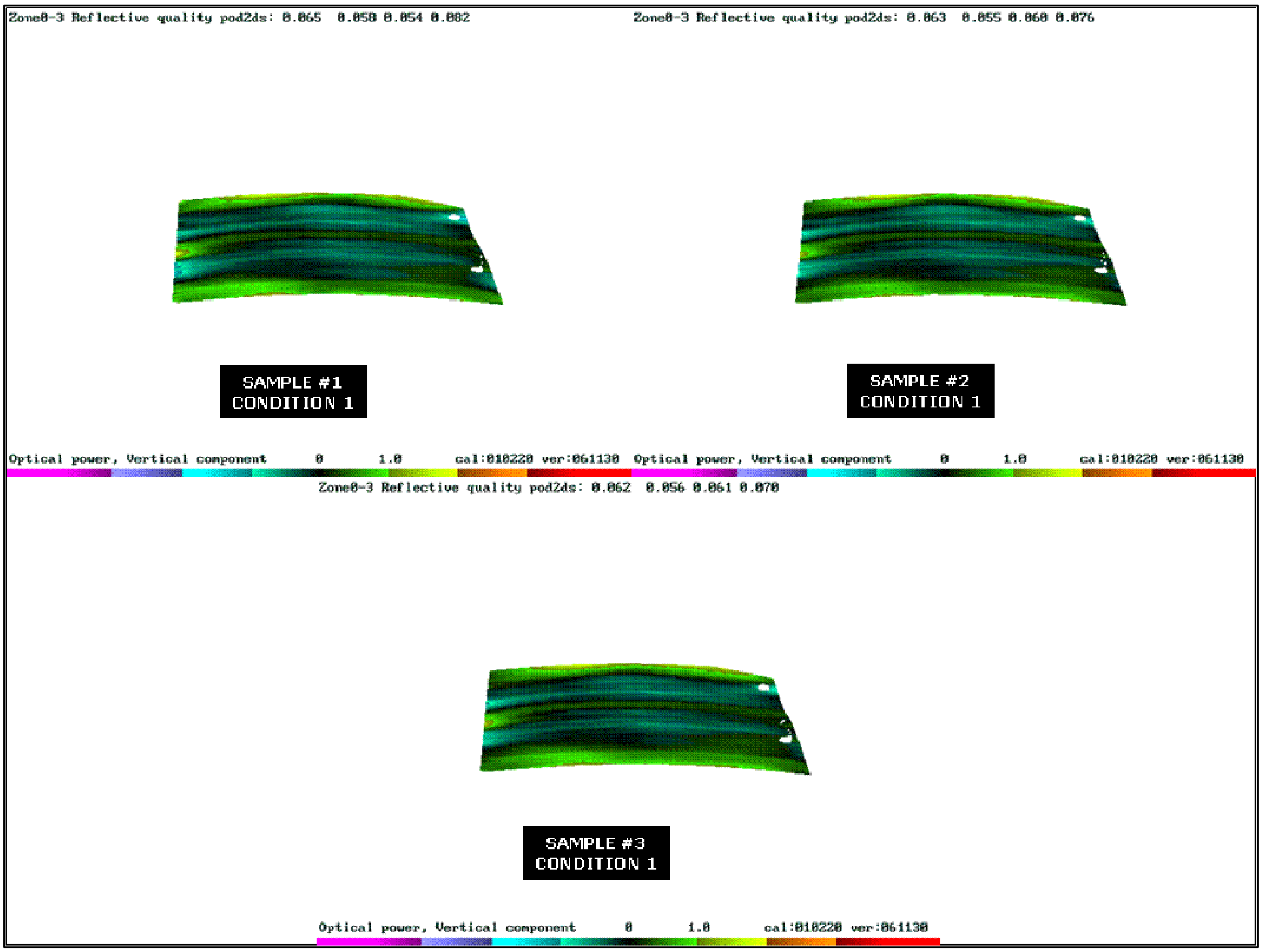
Summarizing the DA readings on chart, the results are as follows:



The samples under conditions 3 & 4 are the ones that gives the best distortion results, which also is shown on the images generated from the CMM data, seen before.

REAR DOOR

DISTORSION ANALYSIS READINGS

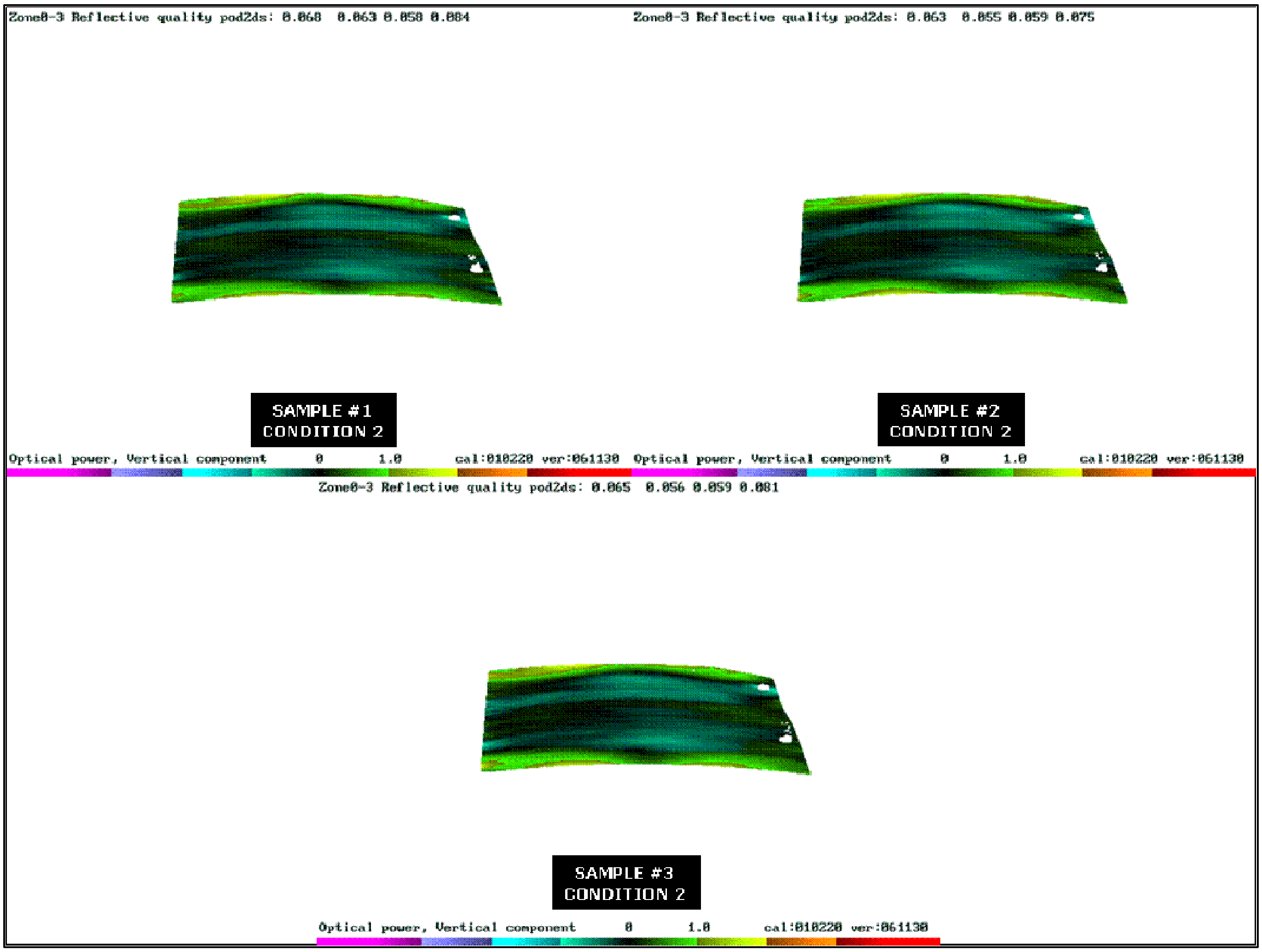


6-PANEL

D – M – A – I – C
IMPROVEMENT

REAR DOOR

DISTORSION ANALYSIS READINGS

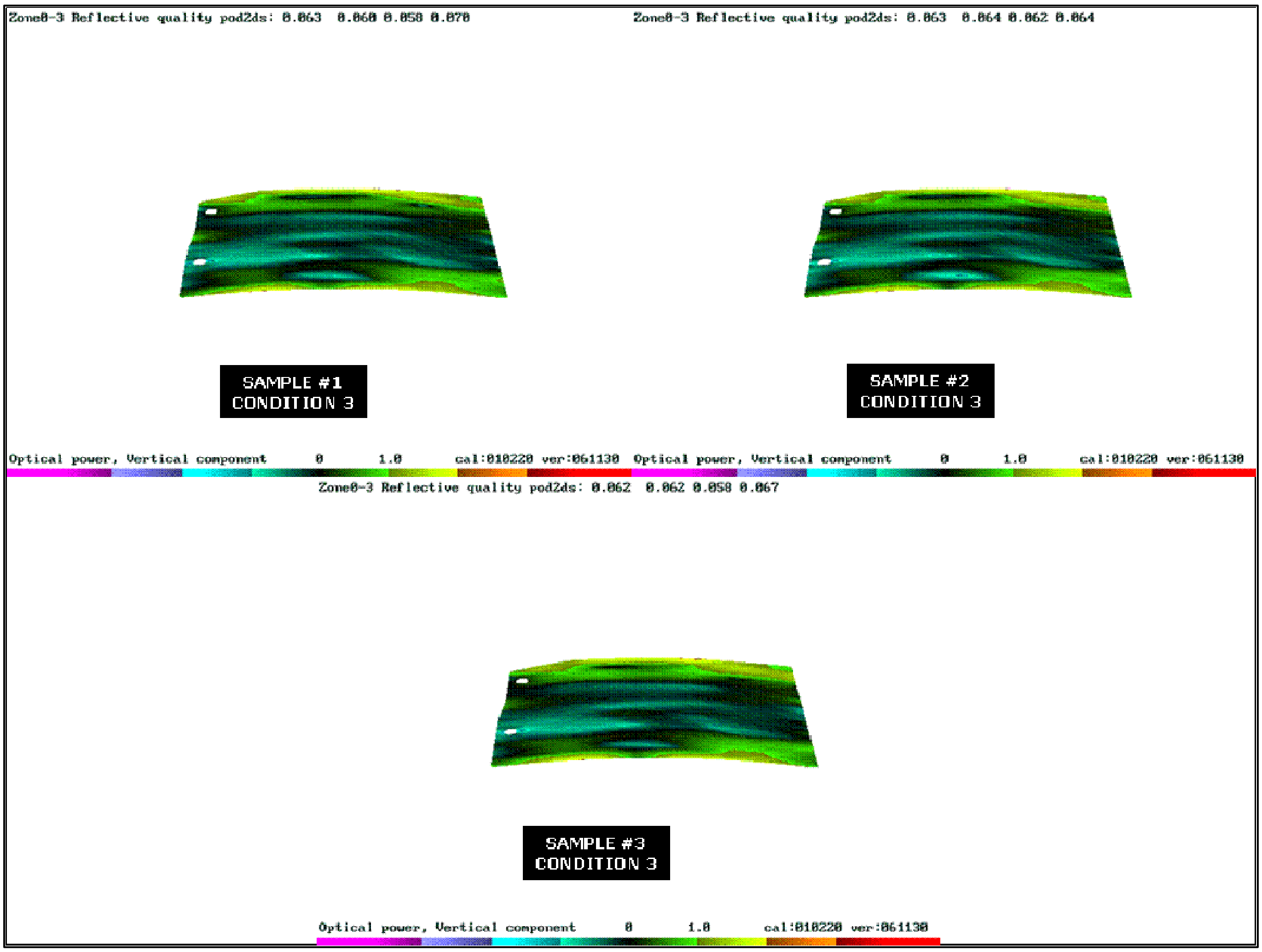


6-PANEL

D – M – A – I – C
IMPROVEMENT

REAR DOOR

DISTORSION ANALYSIS READINGS

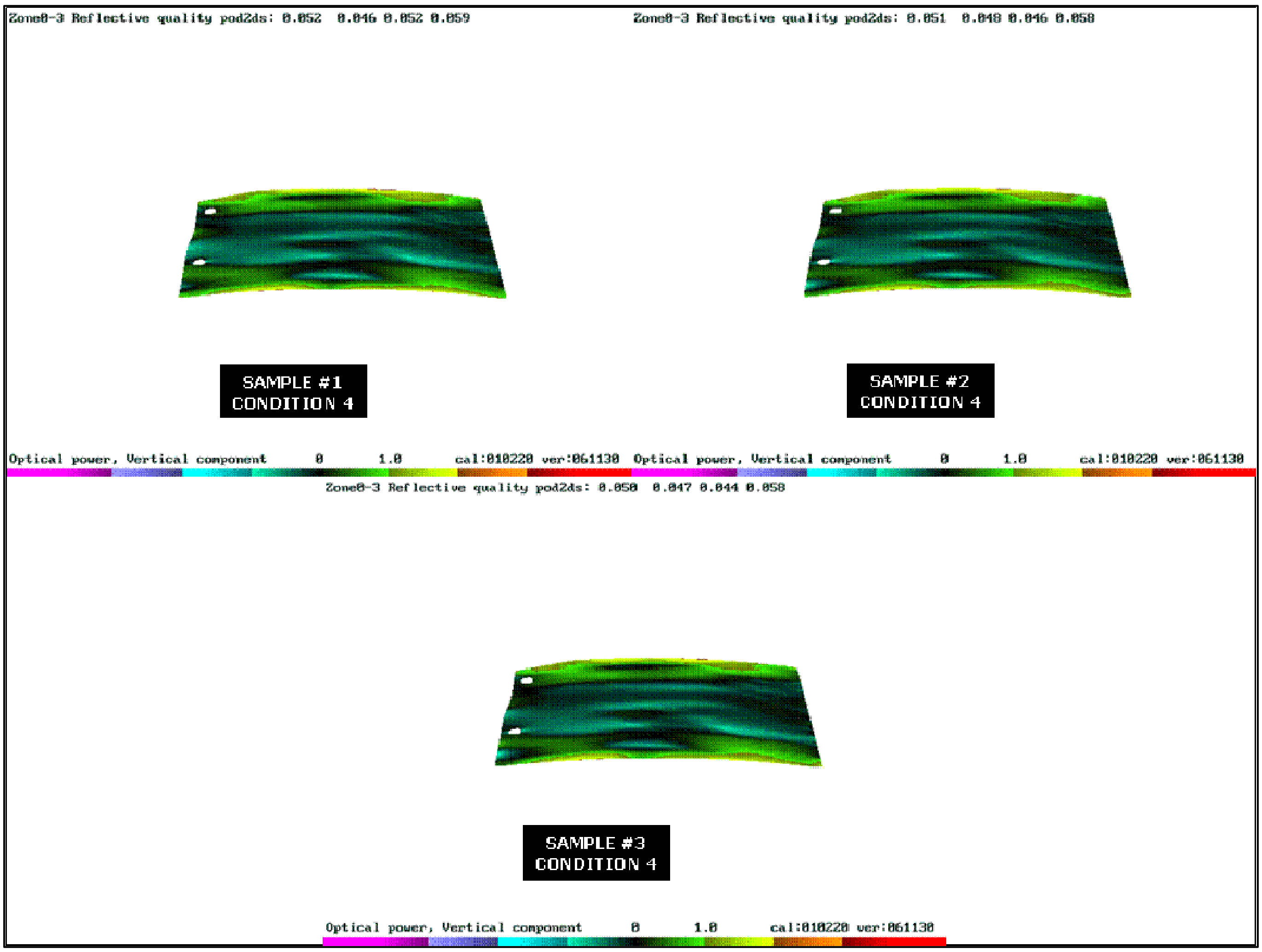


6-PANEL

D M A I C
IMPROVEMENT

REAR DOOR

DISTORSION ANALYSIS READINGS



Summarizing the DA readings on chart, the results are as follows:

REAR DOOR

DISTORSION ANALYSIS READINGS

	Condition #1			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.065	0.058	0.054	0.082
Sample 2	0.063	0.055	0.060	0.076
Sample 3	0.062	0.056	0.061	0.070
Average	0.063	0.056	0.058	0.076

	Condition #2			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.068	0.063	0.058	0.084
Sample 2	0.063	0.055	0.059	0.075
Sample 3	0.065	0.056	0.059	0.081
Average	0.065	0.058	0.059	0.080

	Condition #3			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.063	0.060	0.058	0.070
Sample 2	0.063	0.064	0.062	0.064
Sample 3	0.062	0.062	0.058	0.067
Average	0.063	0.062	0.059	0.067

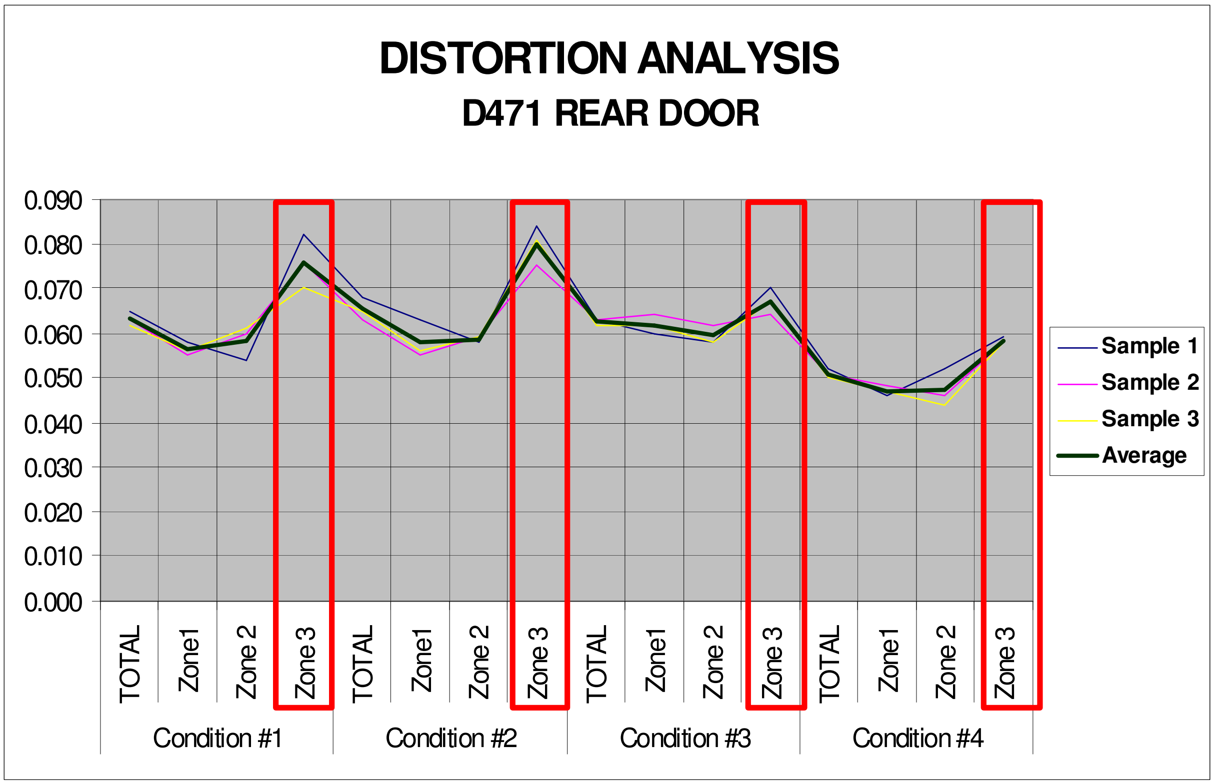
	Condition #4			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.052	0.046	0.052	0.059
Sample 2	0.051	0.048	0.046	0.058
Sample 3	0.050	0.047	0.044	0.058
Average	0.051	0.047	0.047	0.058

6-PANEL

D – M – A – I – C

IMPROVEMENT

Summarizing the DA readings on chart, the results are as follows:



The samples under conditions 3 & 4 are the ones that gives the best distortion results, same that happened on D471 Front Door, which also is shown on the images generated from the CMM data, seen before.

6-PANEL

D – M – A – I ✓ – C
IMPROVEMENT

Additional to the measurements done through the Distortion Analyzer, an evaluation using a Digital Camera was also performed by taking a picture to 4 pieces of each condition.

The angle and distance were established trying to capture the Reflective Distortion just like the pictures showed it.

A Zebra was placed so the image could be reflected on the glass. The lines in the Zebra should not have any variation once they are reflected on the glass.

With that method we can have now a perspective of what the Customer is detecting and claiming.

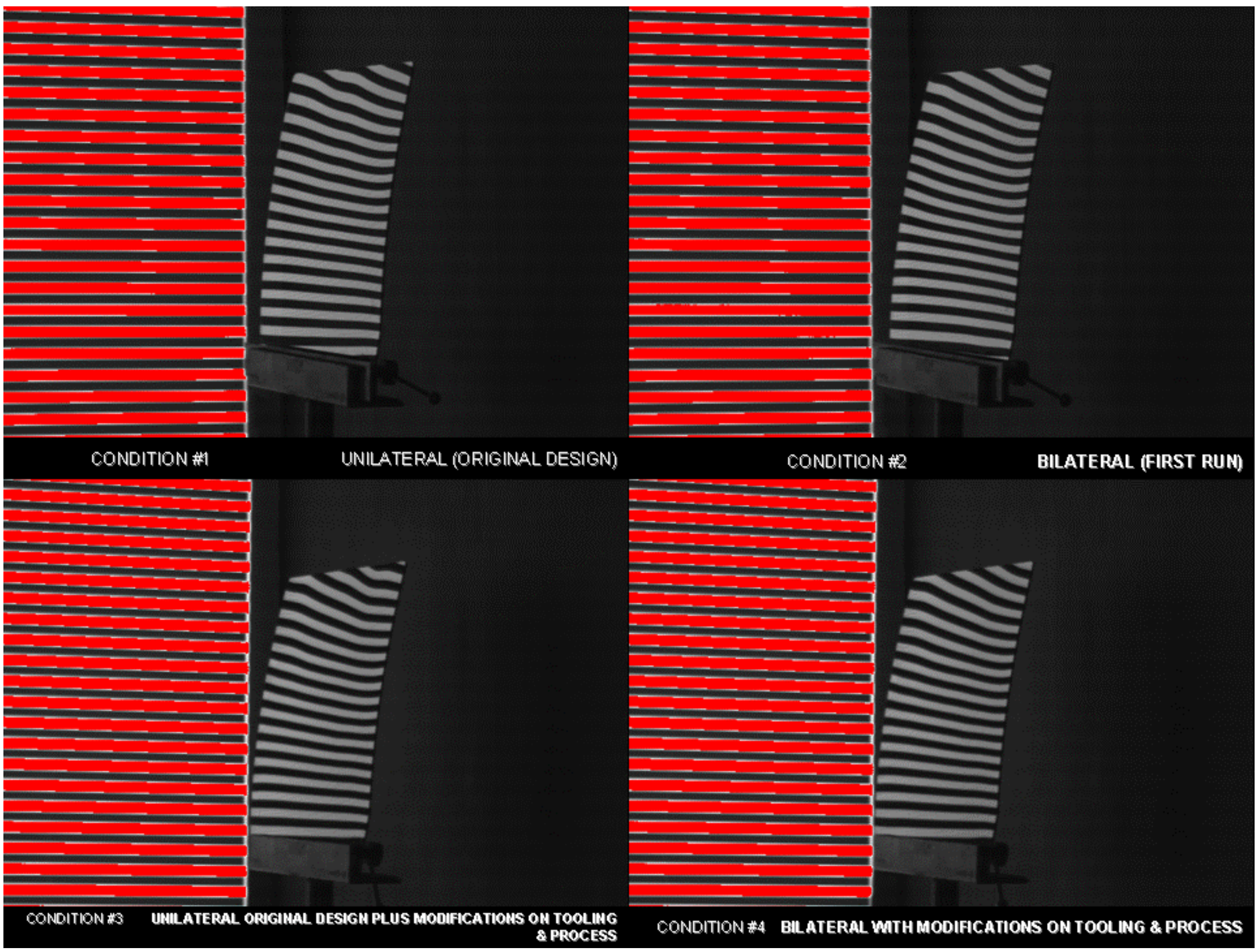
The four conditions will also evaluated in order to see if an improvement has been reached on any of the 3 conditions modified versus the original glass.

The images taken are the following:

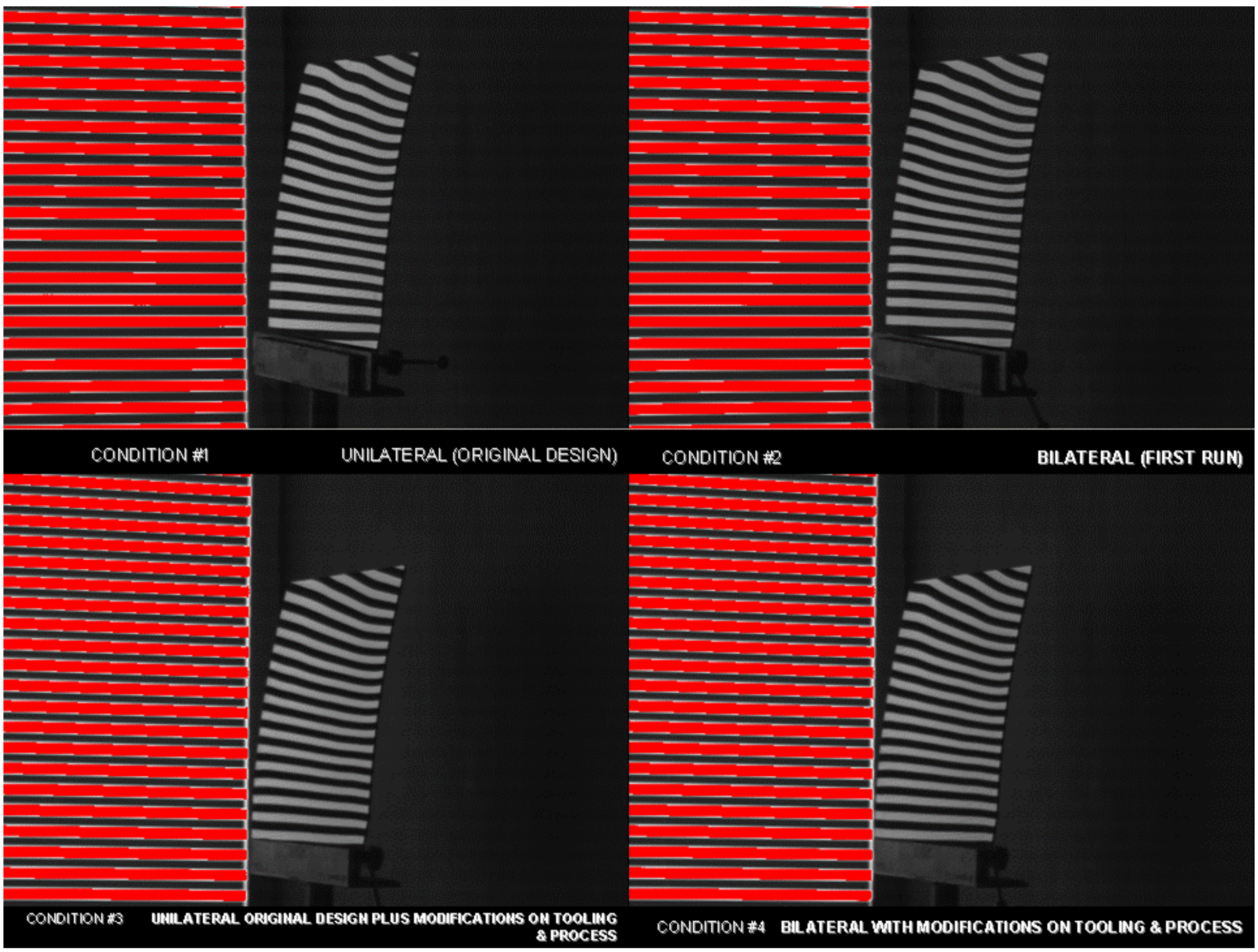
6-PANEL

D M A I C
IMPROVEMENT

D471 Rear Door
DISTORTION PICS:
LEFT HAND (First Parts)



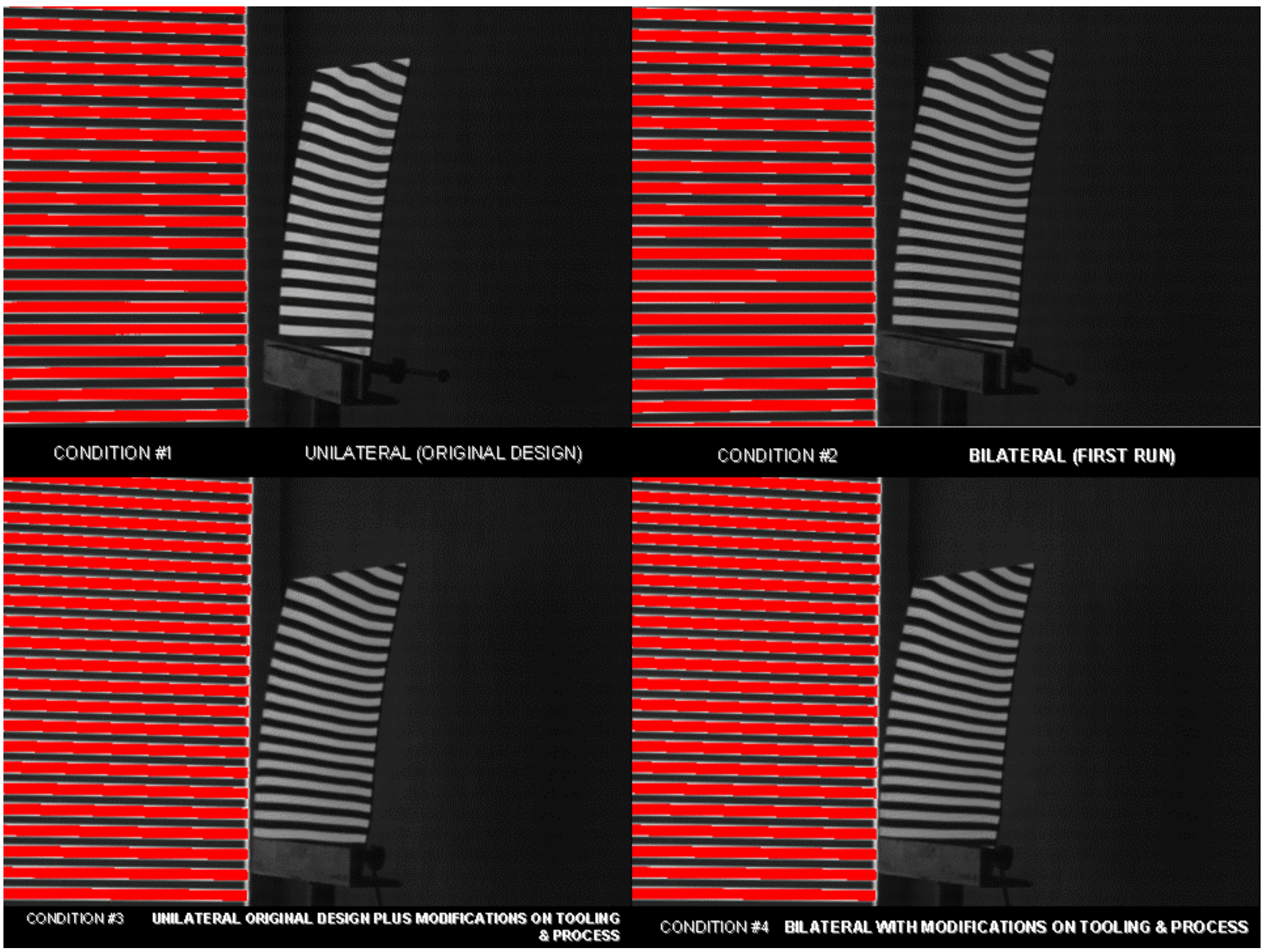
D471 Rear Door
DISTORTION PICS:
LEFT HAND (Second Parts)



6-PANEL

D – M – A – I – C
IMPROVEMENT

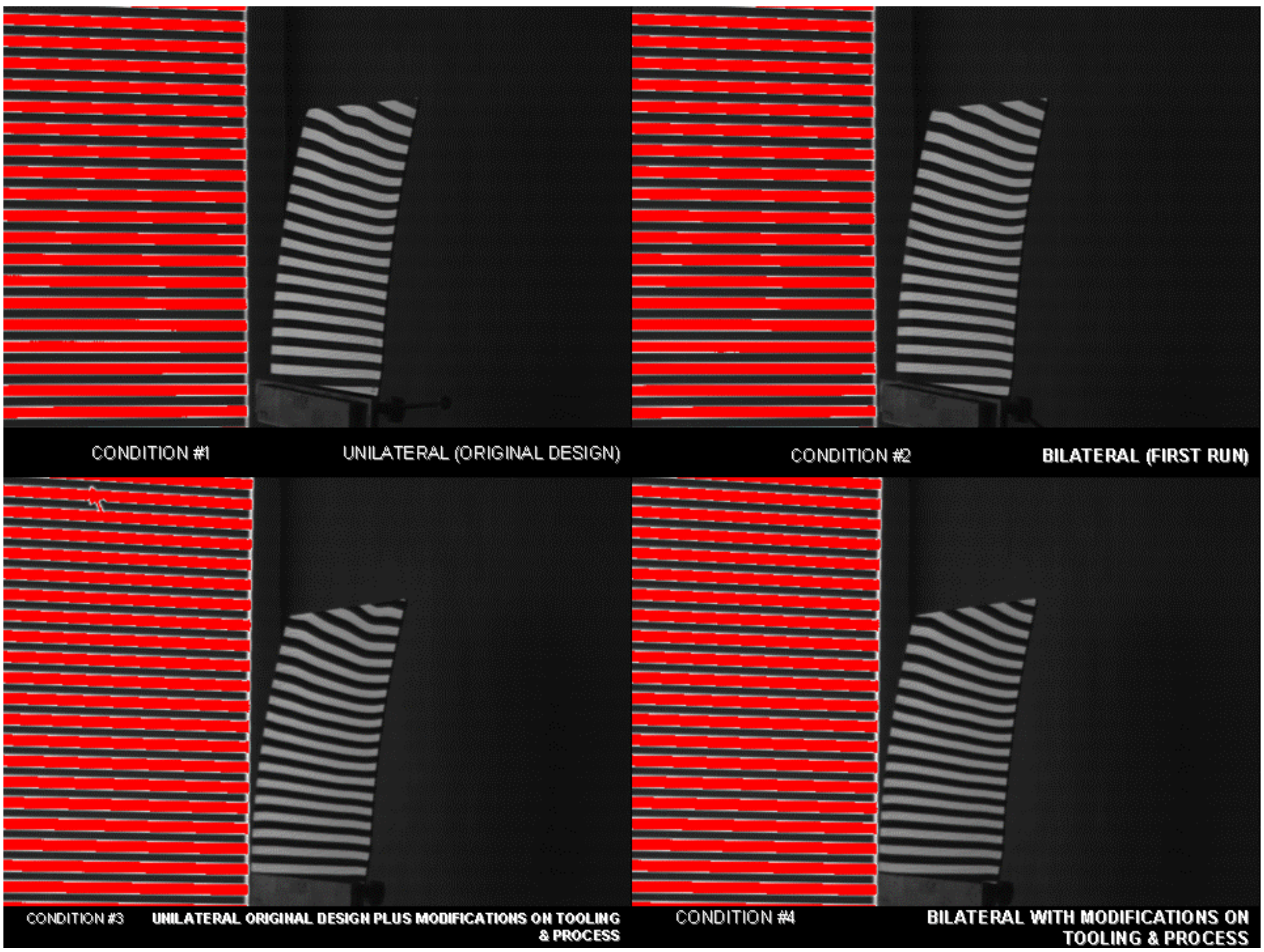
D471 Rear Door
DISTORTION PICS:
LEFT HAND (Third Parts)



6-PANEL

D M A I C
IMPROVEMENT

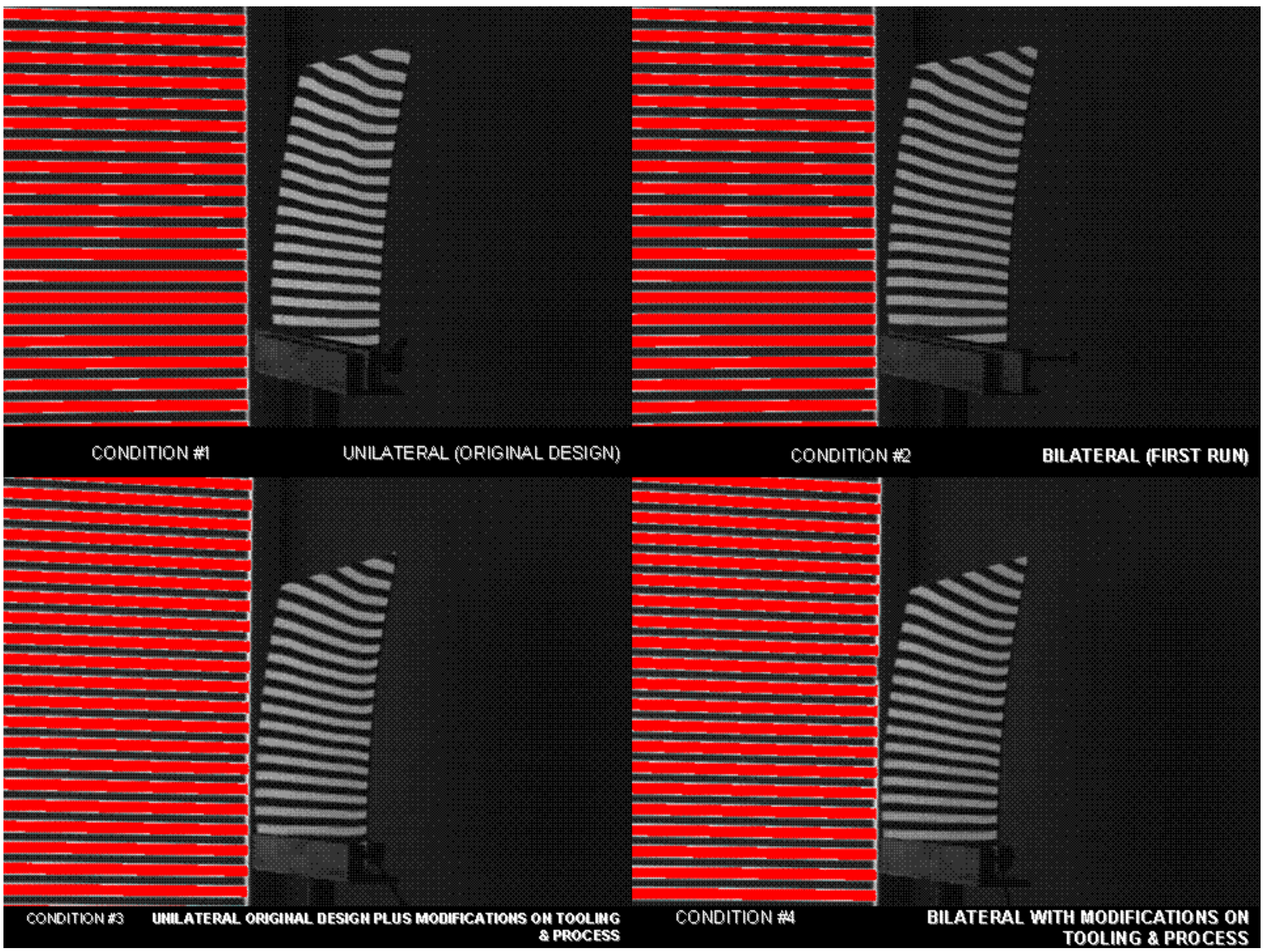
D471 Rear Door
DISTORTION PICS:
LEFT HAND (Fourth Parts)



6-PANEL

D M A I C
IMPROVEMENT

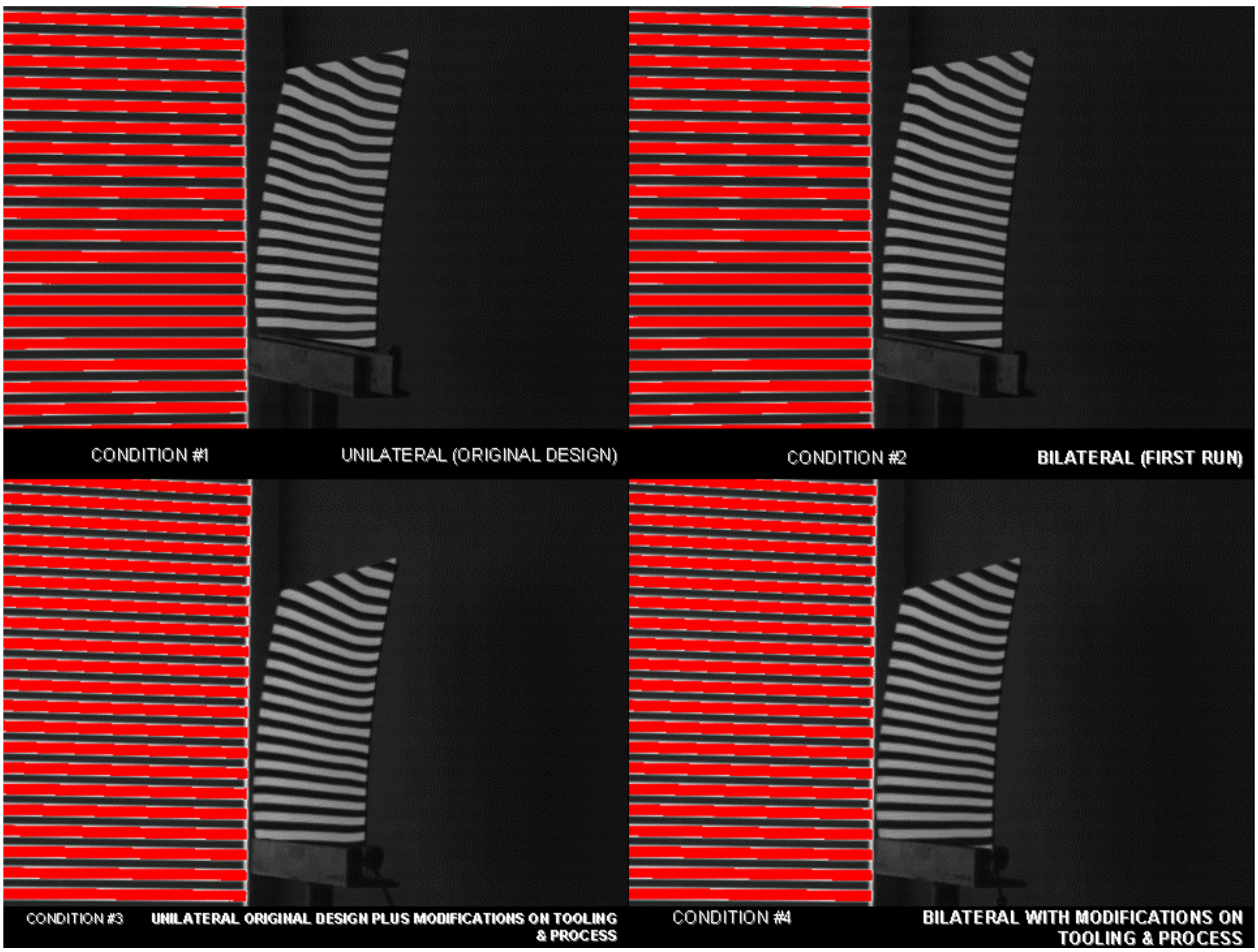
D471 Rear Door
DISTORTION PICS:
RIGHT HAND (First Parts)



6-PANEL

D - M - A - I - C
IMPROVEMENT

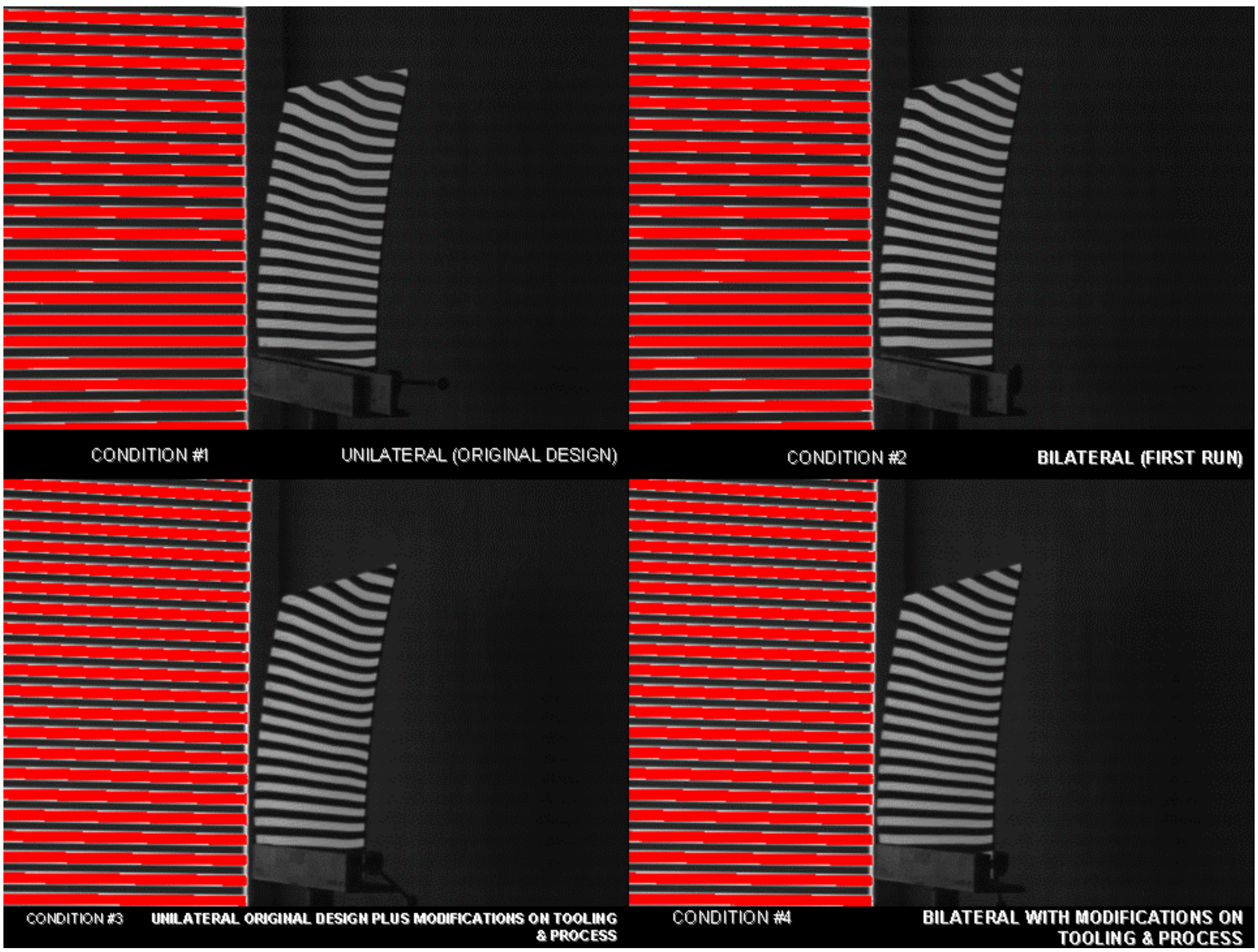
D471 Rear Door
DISTORTION PICS:
RIGHT HAND (Second Parts)



6-PANEL

D – M – A – I – C
IMPROVEMENT

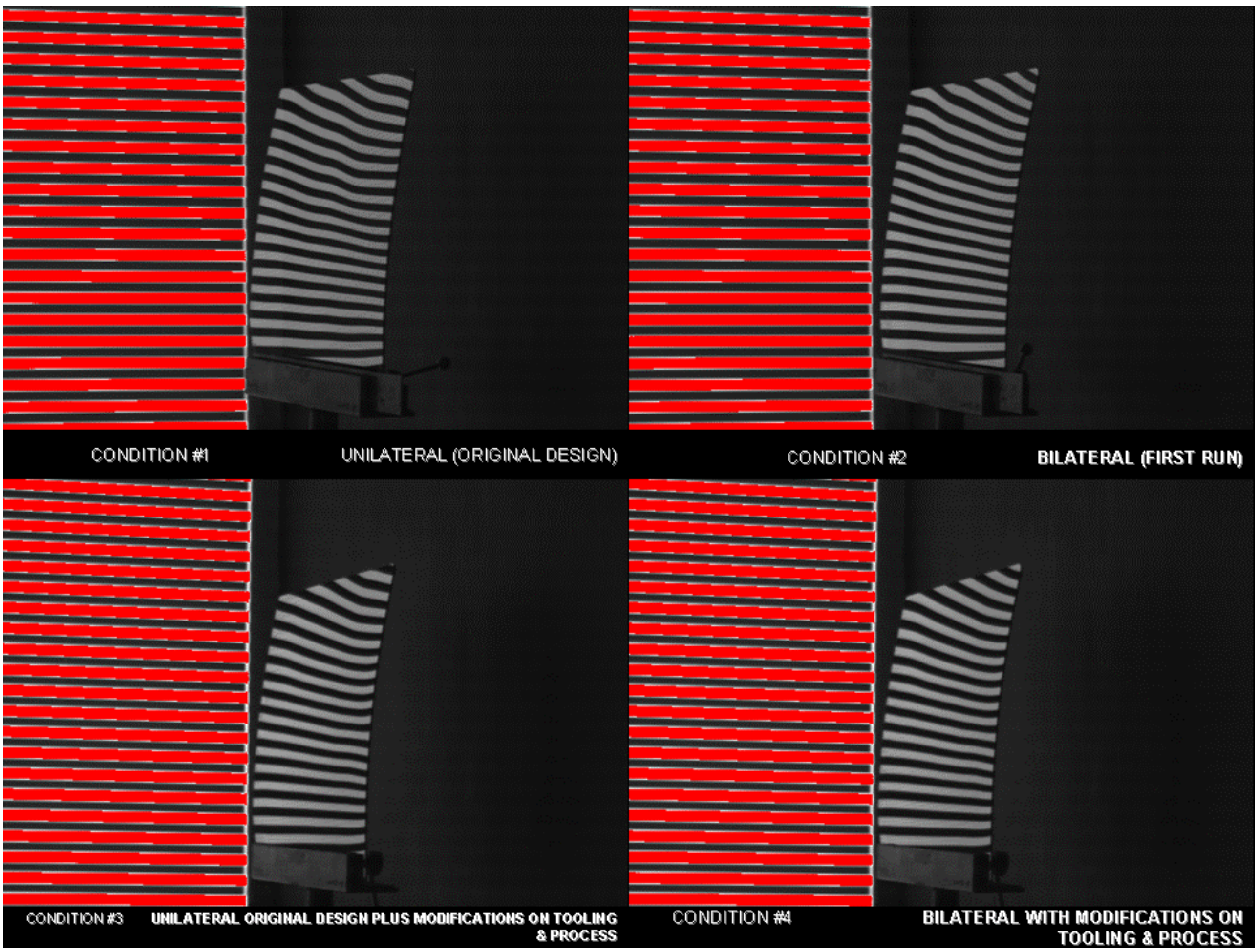
D471 Rear Door
DISTORTION PICS:
RIGHT HAND (Third Parts)



6-PANEL

D - M - A - I - C
IMPROVEMENT

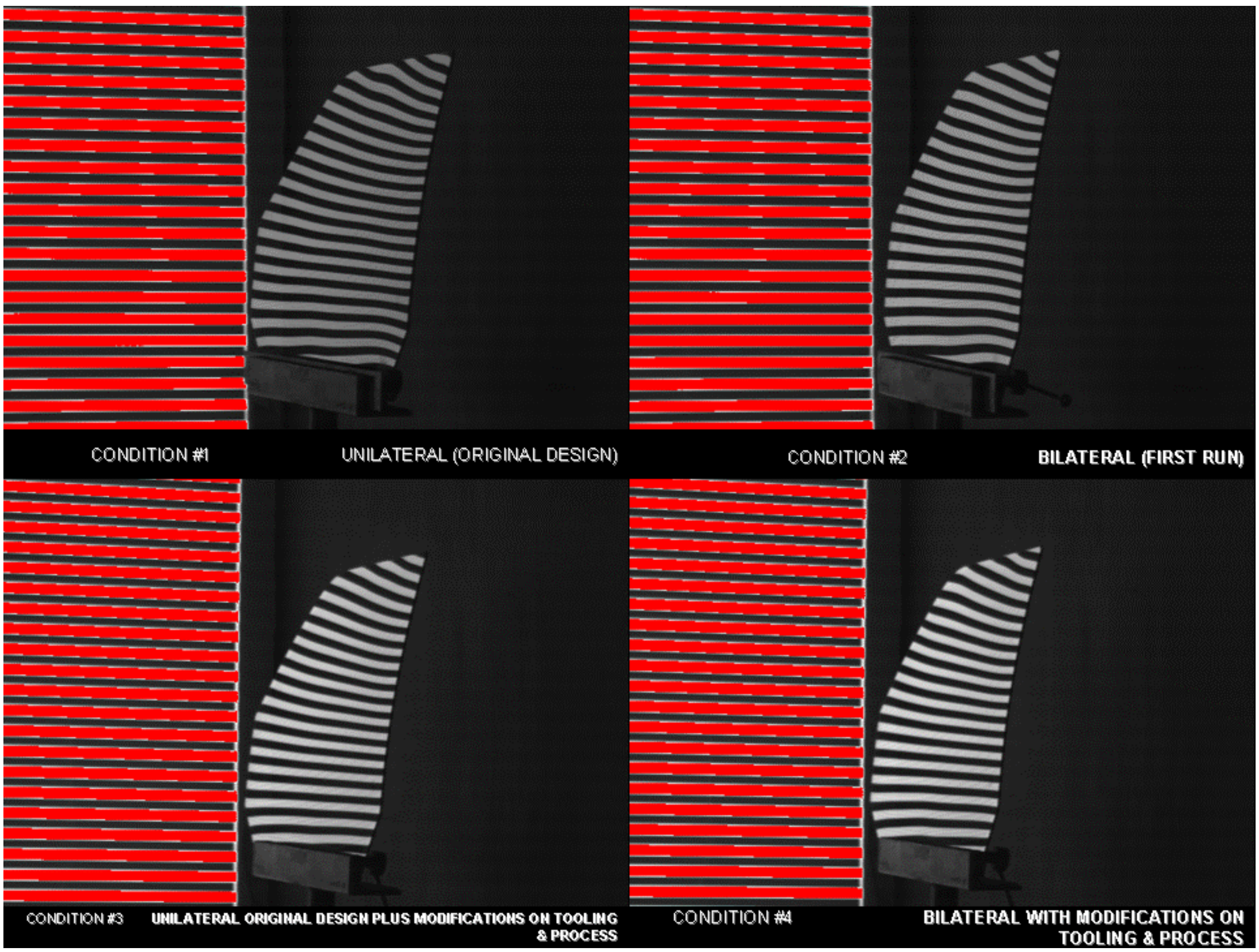
D471 Rear Door
DISTORTION PICS:
RIGHT HAND (Fourth Parts)



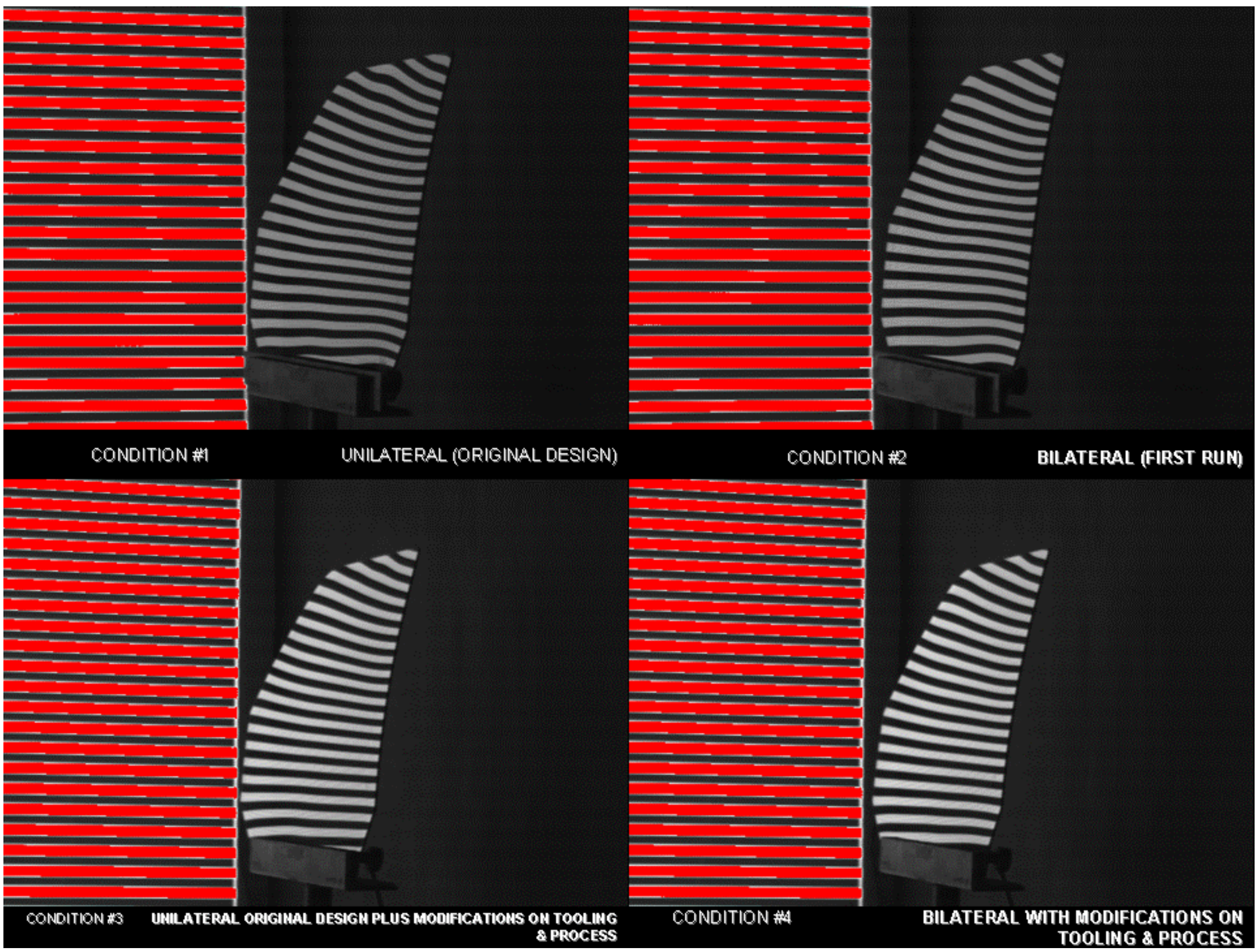
6-PANEL

D — M — A — I ✓ — C
IMPROVEMENT

D471 Front Door
DISTORTION PICS:
LEFT HAND (First Parts)



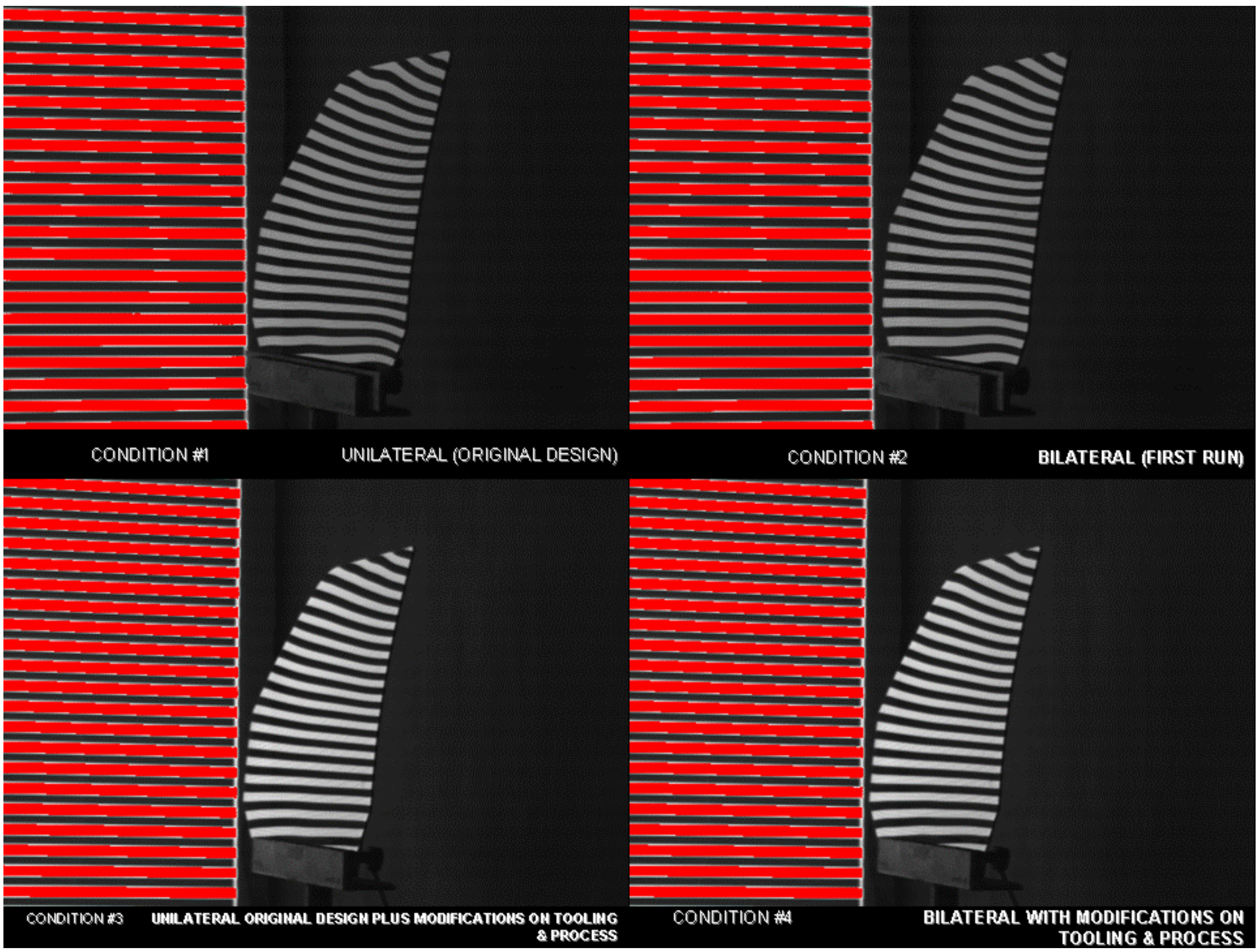
D471 Front Door
DISTORTION PICS:
LEFT HAND (Second Parts)



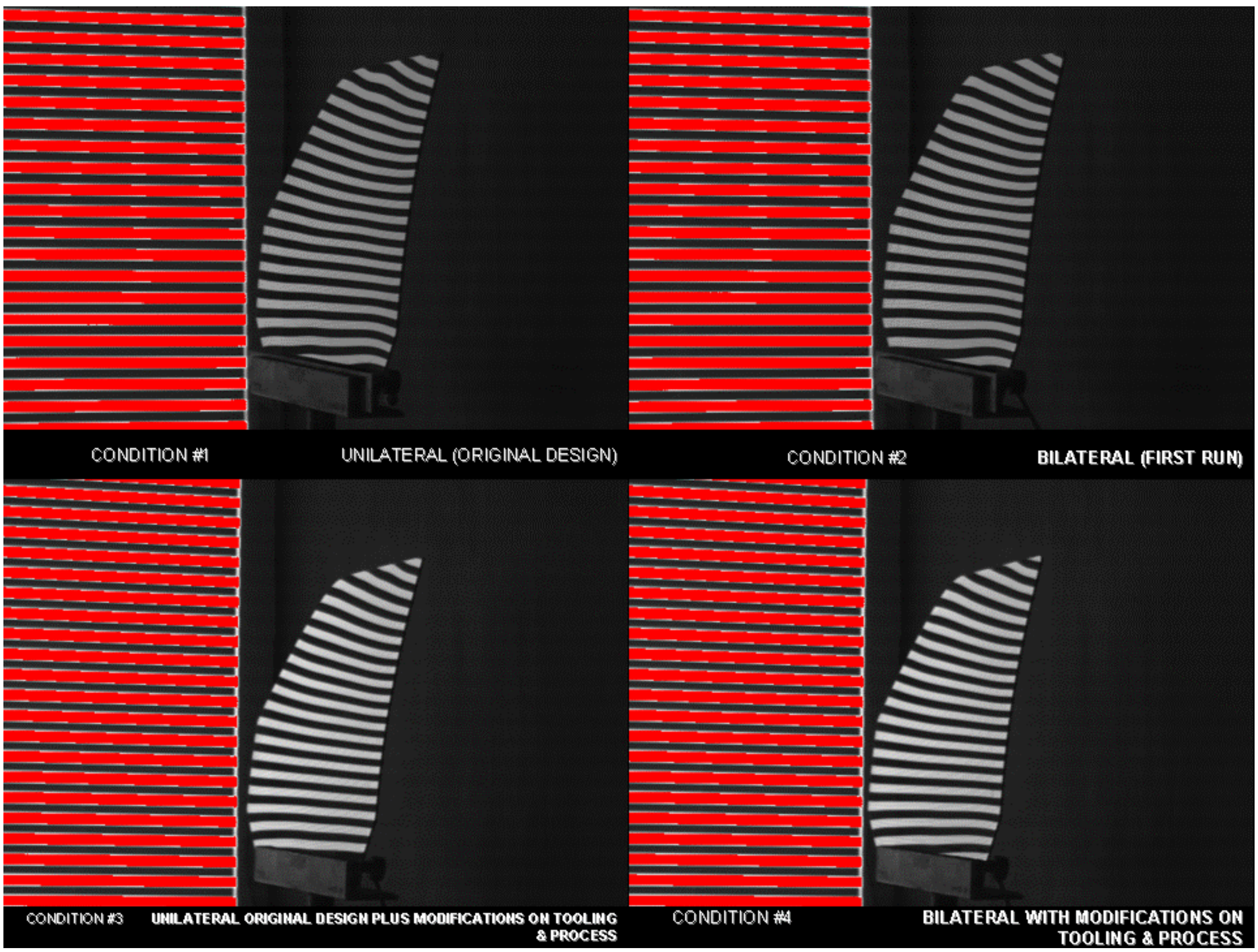
6-PANEL

D - M - A - I - C
IMPROVEMENT

D471 Front Door
DISTORTION PICS:
LEFT HAND (Third Parts)



D471 Front Door
DISTORTION PICS:
LEFT HAND (Fourth Parts)



D471 Front Door
DISTORTION PICS:
RIGHT HAND (First Parts)

6-PANEL

D – M – A – I – C
IMPROVEMENT

D471 Front Door
DISTORTION PICS:
RIGHT HAND (Second Parts)

6-PANEL

D – M – A – I ✓ – C
IMPROVEMENT

D471 Front Door
DISTORTION PICS:
RIGHT HAND (Third Parts)

6-PANEL

D – M – A – I ✓ – C
IMPROVEMENT

D471 Front Door
DISTORTION PICS:
RIGHT HAND (Fourth Parts)

6-PANEL

D - M - A - I ✓ - C

IMPROVEMENT

The lowest Reflective Distortion showed on pictures taken demonstrates again that Condition #4 are the one that reduce it considerable. Nevertheless Condition #3 even Condition #2 also gives a better Reflective Distortion reduction compare with the original design parts. These results have the same tendency for Rear Doors and Front Doors.

According to these results plus the ones already analyzed, we can have a preliminary conclusion that significant improvements have been done with all modifications to the product and process.

Nevertheless some of the modifications done on the parts tested before imply changes on Design which are not part of the Original Unit Program Plan.

To validate this changes a performance functionality validation test must be done as soon as possible so that we won't cause functionality issues.

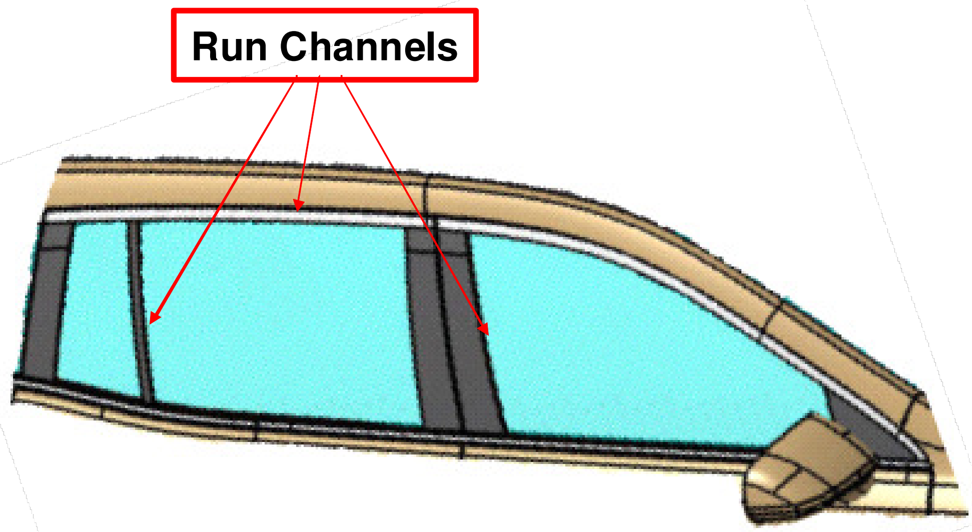
Vitro Flex requested to the Engineering Department to get permission from the FORD Assembly Plant to test a couple of sets for the condition 4 with Design changes (bilateral tolerances).

6-PANEL

D M A I C

IMPROVEMENT

A total of 5 sets of Rear doors and Front doors were sent to Ford Assembly Plant with condition 4 in order to validate there is no functionality Issues while working on run channels.

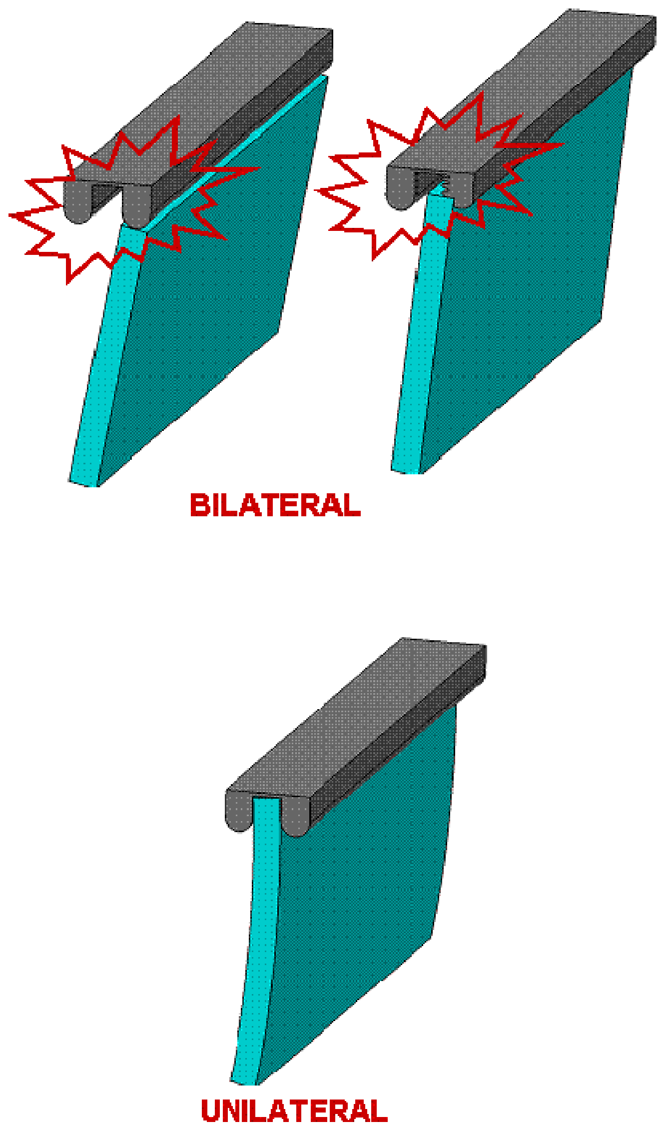


The Trial was unsuccessful because the glass at the time to go upwards trough the run channels when almost reach the Top, it got stuck with seals or fully stooped so the glass with bilateral tolerances was no functional at the time to assemble it. See next image:

6-PANEL

D – M – A – I – C

IMPROVEMENT



6-PANEL

D - M - A - I - C ✓

CONTROL

The unsuccessful TRIAL describe before automatically took out the Option of Condition number 2 and 4.

The final decision had to be made only for the Condition number 3. However, FORD did like the appearance results gotten with parts from Condition number 4.

In order to give FORD the best option to get their Approval, a combination between Condition 3 and 4 was suggested. The FORM specification on Top Edge was modified. Besides to be controlled as an unilateral tolerance the whole edge, a ROC specification was determined along the top edge having a central point classified as a SC with +0/-2 mm. This single point will remain unilaterally so that the glass ensures to have a good performance going inboard into the run channel.

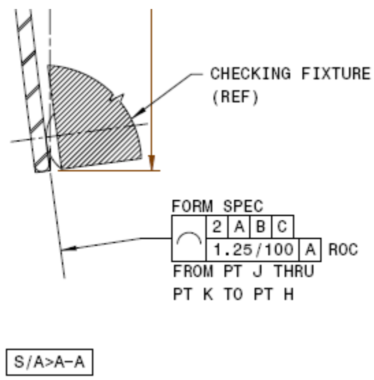
This modification will allow the part to have a softly transition from pillars to Top edge avoiding to have a critical deformation due to Unilateral Top Edge. That softness will shows a significant Reflective Distortion similar than the one resulted by parts with Condition number 4.

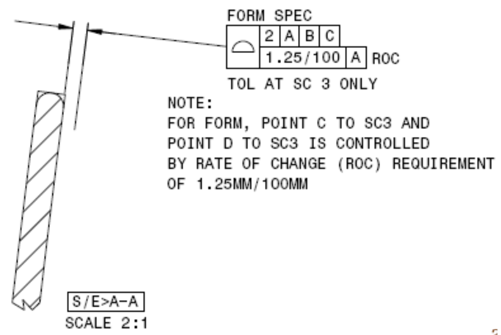
6-PANEL

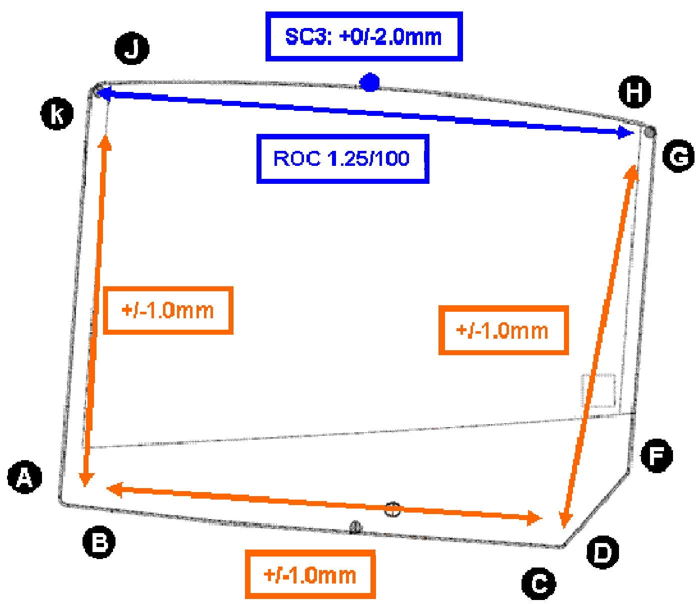
D – M – A – I – C ✓

CONTROL

REAR DOOR GLASS: NEW FORM SPECIFICATION





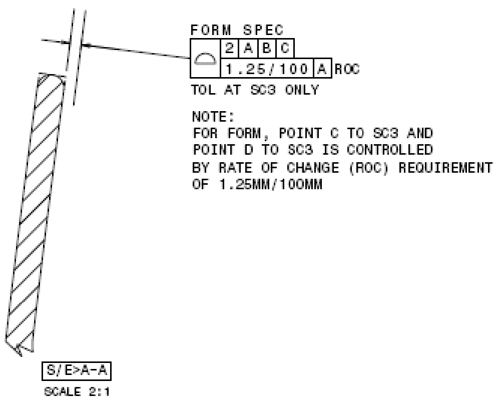


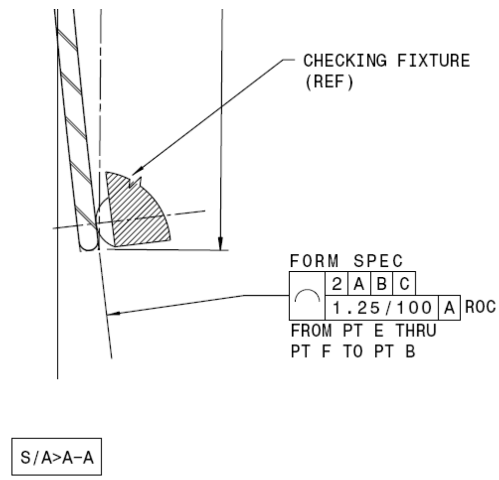
6-PANEL

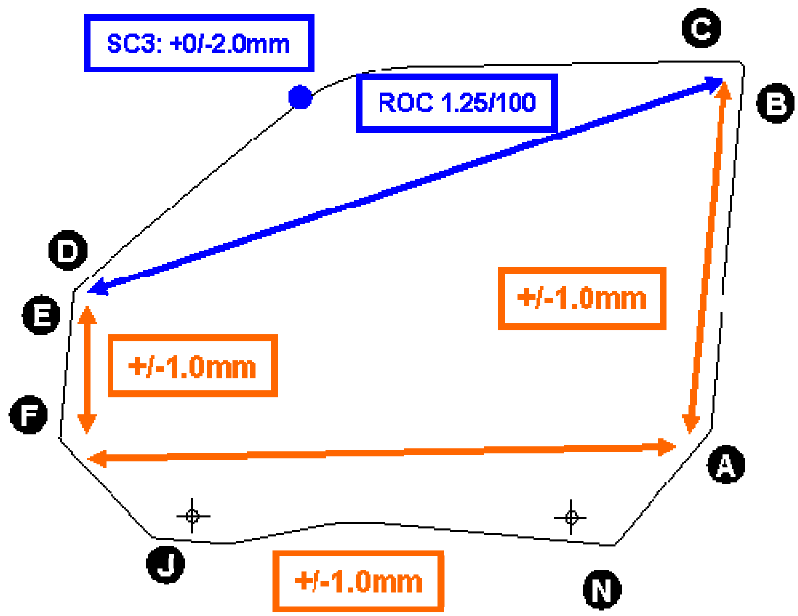
D M A I C

CONTROL

FRONT DOOR GLASS: NEW FORM SPECIFICATION







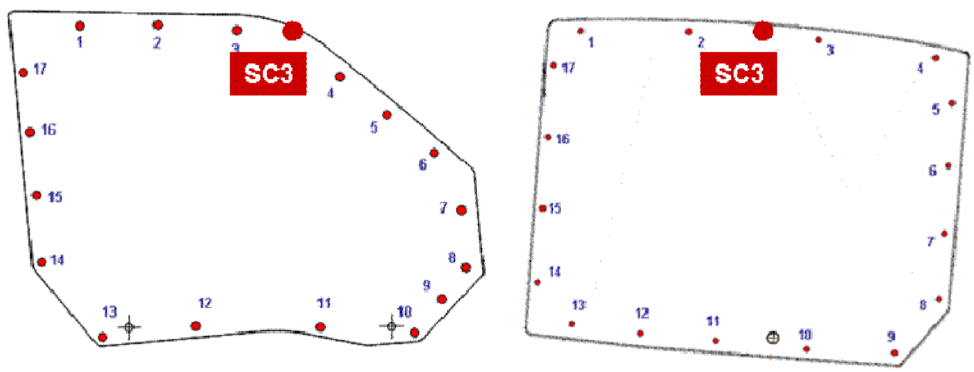
6-PANEL

D – M – A – I – C ✓

CONTROL

This modification on Drawings allowed the plant to have a single SC point to be controlled by SPC and reported to the Customer.

This also made possible to have a better Process Capability (PPk's) results below the 1.67 on the SC3 point.



6-PANEL

D M A I C

CONTROL

In order to have a parameter of Distortion level allowed. VFX sent 3 sets of Rear Doors and Front Doors as representative production parts with the new specification in top edge to be evaluated by FORD Plant

The Ford Plant evaluated the samples sent for Master & Appearance Approval and they accepted the level of Distortion as the maximum allowed.

Because the Distortion Analyzer is a Laboratory equipment that can not be used for regular production inspection, Vitro Flex implemented a Distortion Station in the production line where it allows to inspect the parts for Reflective Distortion according to a frequency determined on the Control Plan.

If there is any suspect about Reflective Distortion that could not be under spec, the master sample is placed together with the part to allow the operators evaluate the Distortion condition and decide if is a good part in a short time. If the part is still under suspect then is sent to be evaluated to the Distortion Analyzer.

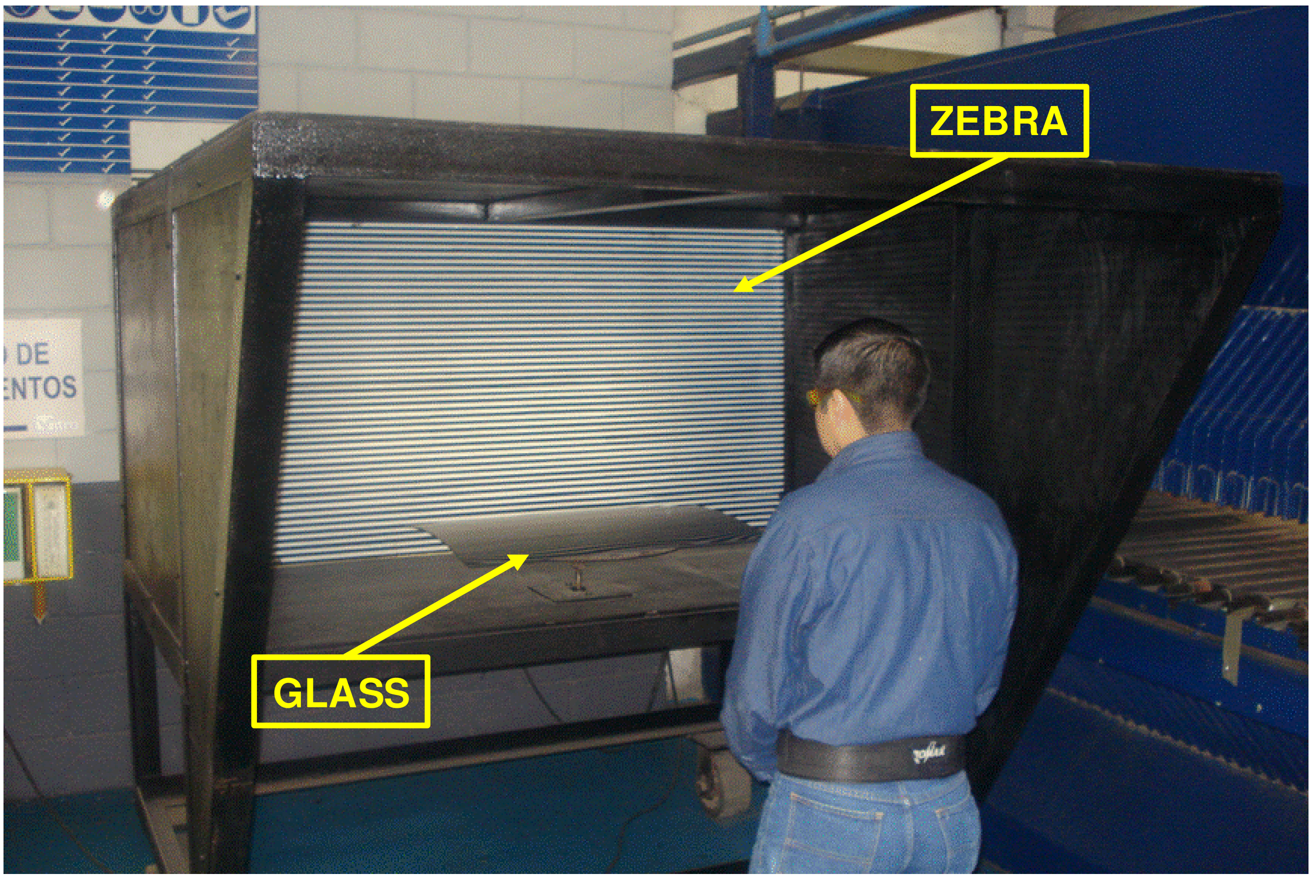
The following picture shows the Station implemented.

6-PANEL

D M A I C

CONTROL

Distortion Station on production line



VI. RESULTADOS

Las soluciones implementadas anteriormente descritos durante el Desarrollo de la investigación nos dieron los siguientes resultados que se pueden ver las siguientes tablas:

Puerta Trasera:

	Condition #1			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.065	0.058	0.054	0.082
Sample 2	0.063	0.055	0.060	0.076
Sample 3	0.062	0.056	0.061	0.070
Average	0.063	0.056	0.058	0.076

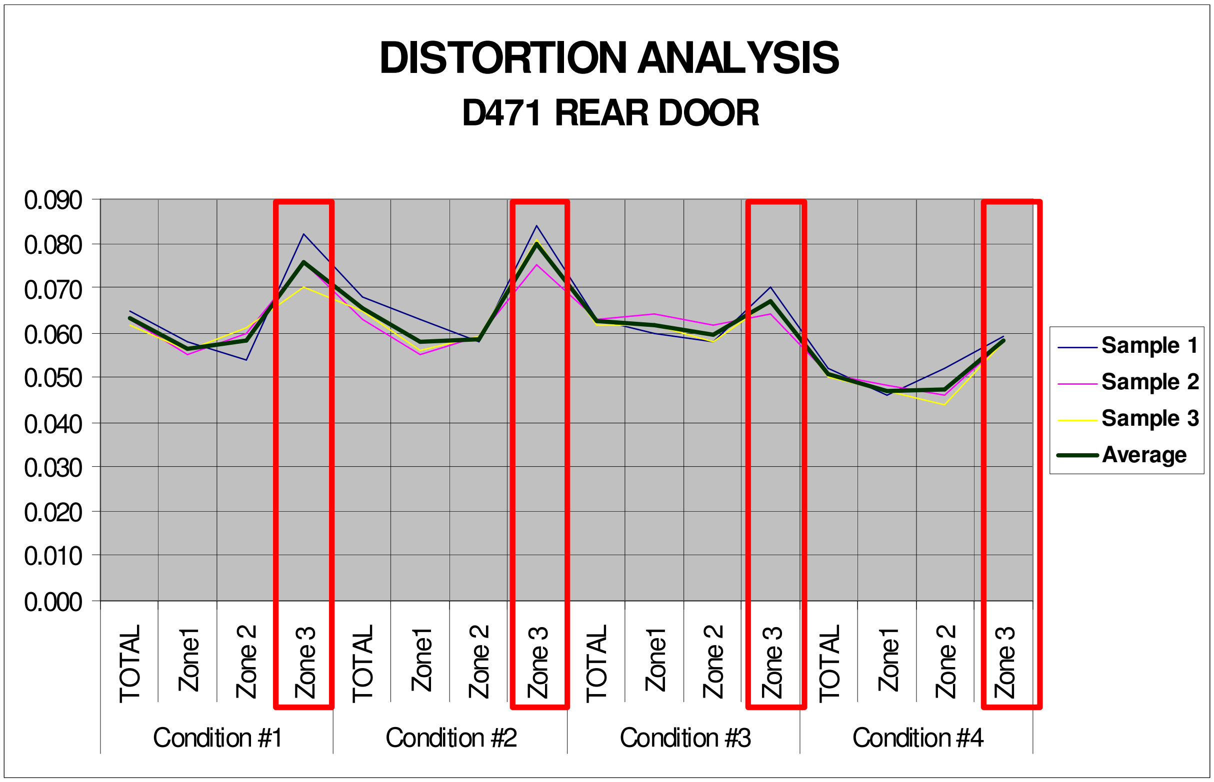
	Condition #2			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.068	0.063	0.058	0.084
Sample 2	0.063	0.055	0.059	0.075
Sample 3	0.065	0.056	0.059	0.081
Average	0.065	0.058	0.059	0.080

	Condition #3			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.063	0.060	0.058	0.070
Sample 2	0.063	0.064	0.062	0.064
Sample 3	0.062	0.062	0.058	0.067
Average	0.063	0.062	0.059	0.067

	Condition #4			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.052	0.046	0.052	0.059
Sample 2	0.051	0.048	0.046	0.058
Sample 3	0.050	0.047	0.044	0.058
Average	0.051	0.047	0.047	0.058

VI. RESULTADOS

Tales resultados fueron graficados para tener una mejor perspectiva:



Como se puede ver, con cada una de las mejoras o cambios realizados se fue obteniendo un mejor desempeño en Distorsión expresado en un valor numérico. Siendo la condición número 4 la que mejor resultados ópticos presentó en estas puertas traseras analizadas.

VI. RESULTADOS

En cuanto a las Puertas Delanteras se refiere nos dieron los siguientes resultados que se pueden ver las siguientes tablas:

Puerta Delantera:

	Condition #1			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.075	0.069	0.057	0.100
Sample 2	0.066	0.077	0.057	0.066
Sample 3	0.066	0.083	0.056	0.059
Average	0.069	0.076	0.057	0.075

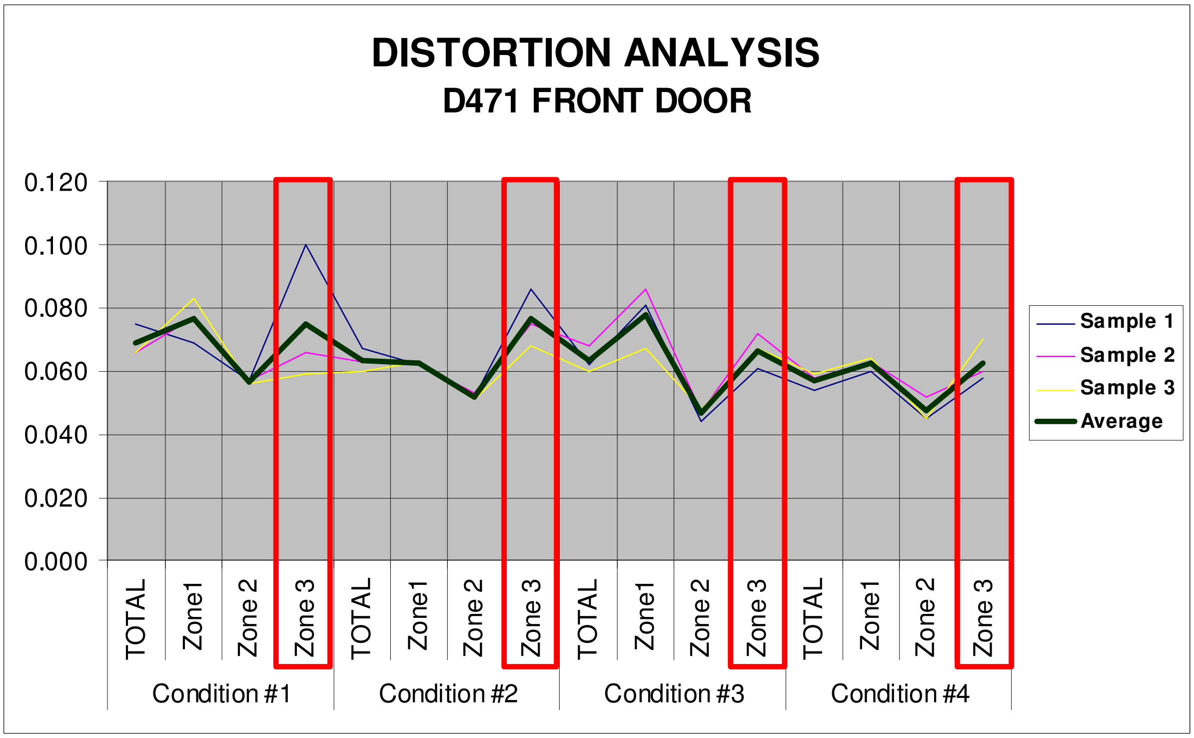
	Condition #2			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.067	0.062	0.052	0.086
Sample 2	0.063	0.062	0.053	0.075
Sample 3	0.060	0.063	0.051	0.068
Average	0.063	0.062	0.052	0.076

	Condition #3			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.062	0.081	0.044	0.061
Sample 2	0.068	0.086	0.047	0.072
Sample 3	0.060	0.067	0.048	0.067
Average	0.063	0.078	0.046	0.067

	Condition #4			
	TOTAL	Zone1	Zone 2	Zone 3
Sample 1	0.054	0.060	0.045	0.058
Sample 2	0.058	0.063	0.052	0.060
Sample 3	0.059	0.064	0.045	0.070
Average	0.057	0.062	0.047	0.063

VI. RESULTADOS

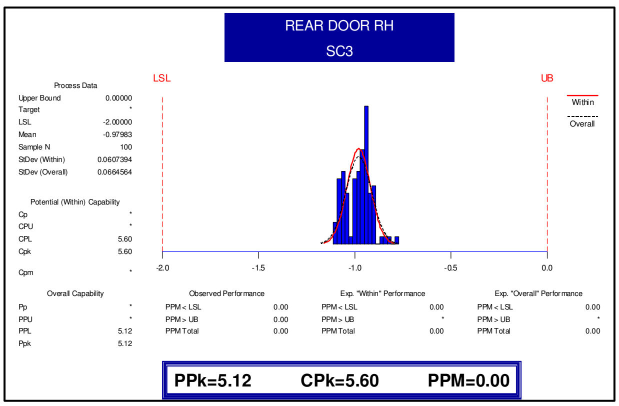
Tales resultados fueron graficados para tener una mejor perspectiva:

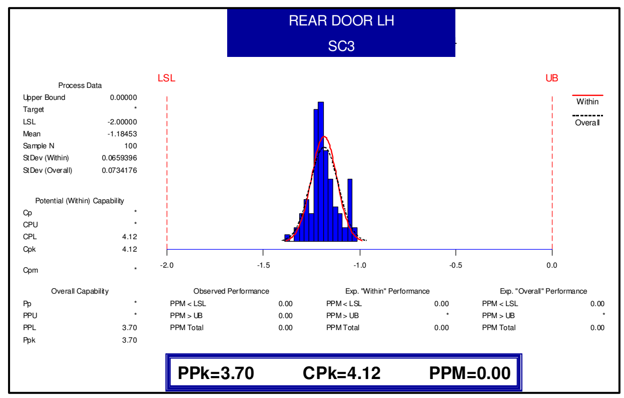


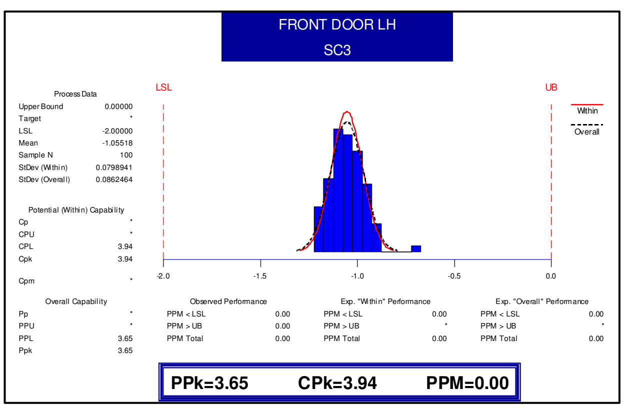
Como se puede ver, al igual que con las Puertas Traseras, con cada una de las mejoras o cambios realizados se fue obteniendo un mejor desempeño en Distorsión expresado en un valor numérico. Siendo la condición número 4 la que mejor resultados ópticos presentó.

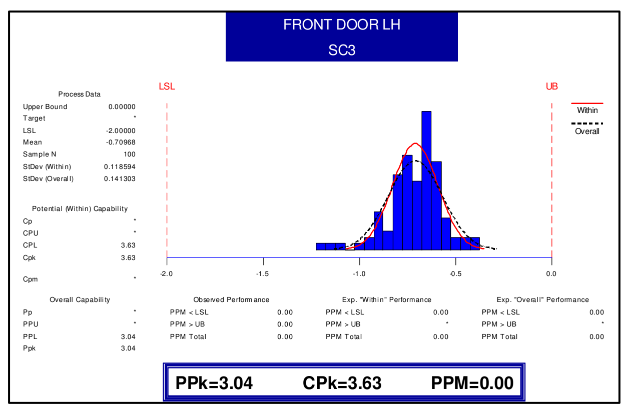
VI. RESULTADOS

Debido a que en el canto superior nuestra habilidad de proceso inicial (PPk) no cumplía por las situaciones ya mencionadas en el Capítulo de Desarrollo, al momento de obtenerse un solo punto marcado como Característica Especial a controlar estadísticamente, se lograron obtener los siguientes resultados:









Una habilidad de proceso (PPk's) muy por encima del 1.67 mínimo requerido para tener una confiabilidad en el proceso en cuanto a defectivos se refiere.

VII. CONCLUSION

La investigación realizada dio los siguientes resultados:

- El análisis del Diseño de las piezas provocaba que la Distorsión a reflejo se magnificara debido al quiebre pronunciado que se generaba para poder cumplir con las tolerancias Unilaterales que se tenían en el canto superior.

- Mediante un Analizador de Distorsión de Laboratorio, el cual solo se utilizaba para medir distorsión a través del Vidrio se lograron obtener valores numéricos de la Distorsión a Reflejo para analizar la magnitud de la misma en las piezas producidas así como también en las que presentaban mejoras tanto en proceso como en Producto.

- Mediante la modificación de los arillos de curvado, como se vio previamente, se lograron obtener mejoras en las piezas por Distorsión a reflejo con respecto a las piezas sin cambios.

- Realizando modificaciones en las tolerancias del canto superior a una bilateralidad en todo el canto se obtuvieron mejoras considerables en los resultados de Distorsión tanto numéricos como cualitativos.

VII. CONCLUSION

- La propuesta original de Cambiar las tolerancias del canto superior de Unilaterales a Bilaterales no fue productiva debido a que las piezas bajo dicha condición presentaron problemas en los ensambles.

- El cambio en el Diseño mediante una transición controlada del canto inferior al canto superior a través de un Levantamiento Gradual (ROC) permitió que el quiebre original se suavizara de tal forma que el vidrio no sufriera una deformación significativa que a su vez se reflejaba en una alta Distorsión.

- Desafortunadamente no se logró que la Norma existente en el apartado de Distorsión fuera modificada o mejorada para tomar en cuenta la Distorsión a Reflejo o detallar aún más el método de inspección para dicha característica por parte del personal de Ingeniería de FORD.

  Ante esta situación, Vitro Flex, decidió acondicionar una estación de Inspección en línea para detectar piezas con problemas de Distorsión a Reflejo, como se vió

VII. CONCLUSION

anteriormente. Dicha inspección considera las piezas Máster aprobadas por el Cliente como un comparativo en el caso de tener dudas con respecto al nivel de distorsión que estuviera presentado dicha pieza.

- Finalmente la Planta de FORD quedó complacida con el nivel de Distorsión mejorado debido a todas las mejoras en el proceso y producto accediendo a la aprobación final que permitió a Vitro Flex lograr un lanzamiento exitoso de esta nueva plataforma a producción en serie.

- Se sentaron bases importantes en cuanto al tema de Distorsión a Reflejo se refiere quedando como antecedente un estudio completo que pueda ser referente para futuros proyectos de piezas templadas principalmente tanto para la empresa como para los distintos Clientes.

VIII. GLOSARIO

- **DISTORTION:** An Optical effect what causes straight lines to look curved
- **TT BUILD:** Tooling Trial Build event on Assembly plant were first units are official built.
- **CONTROL PLAN:** Also called Inspection Plan is a Quality Document where all product & process characteristics from every single Operation according to Process Flow Diagram is necessary to inspect and control.
- **FORM:** Characteristic from the Glass which shows the Gap between checking fixture and Glass along periphery.
- **CENTRAL SAG:** Characteristic from the Glass which shows the Gap between checking fixture and Glass in the gravity center of the part.
- **SC:** Special Characteristics marked on Drawing by the Customer. Needs special attention for control.
- **CMM:** Coordinate Measuring Machine
- **ROC:** Rate of Change maximum allowed of FORM in a specific length required.

VIII. GLOSARIO

- **SPC:** Statistical Process Control
- **PPAP:** Part Production Approval Process
- **MASTER SAMPLE:** Part representative from production that is accepted and signed by the Customer as the minimum quality to be accepted.

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