Light and Radiation Techniques for Airbag System Testing

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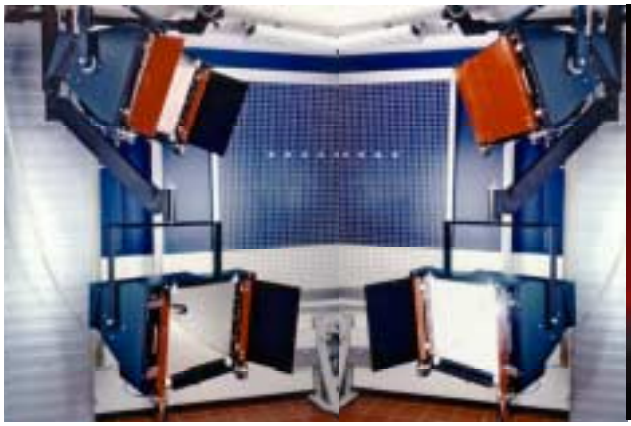


1. Introduction

Tests to accomplish accelerated ageing effects on automotive components are performed since many decades within the automotive industry. The change in material properties, like fading, cracking, distortion has been in the limelight. So the main importance was an acceptable look even after many service years. For Airbag modules, especially here the exposed cover, we have to face an important difference. Also here the look is the obvious feature, but the relevant feature is the occupant safety. Will the aged airbag module still perform within the tight limits of the specification so to ensure the safety functions.
The following paper will focus on two procedures of the **International Standard ISO 12097-2 "Road Vehicles – Airbag Components Part 2 Testing of Airbag Modules",** that require the application of light and radiation techniques.
The **Solar Radiation Simulation Tests** as part of the environmental test programme and the **Static Deployment Test** at extreme temperature conditions.

2. Environmental Testing - Solar Radiation Simulation Test

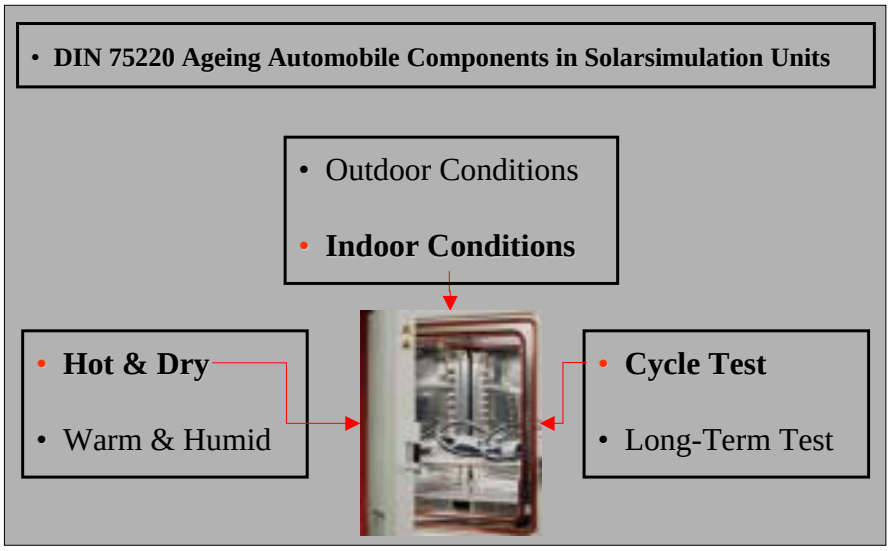
Basic for the Solar Radiation Simulation Test of **ISO 12097-2** is the **DIN 75220 "Ageing of Automobile Components in Solarsimulation Units"**.
Acquired by a VDA (German Car Industry Association) committee consisting of representatives out of the automotive industry, their suppliers and manufacturer of test systems, this regulation was published in November 1992.
Solar Simulation Systems are today a well known and accepted tool within the automotive industry.

They offer reproducible and accelerated tests to determine and to improve the ageing behaviour of automotive components.

The essential factors for this kind of tests are - the solar radiation (defined as "**Global or Total Radiation**") - the ambient temperature - the relative humidity - Radiation is considered the most important factor.

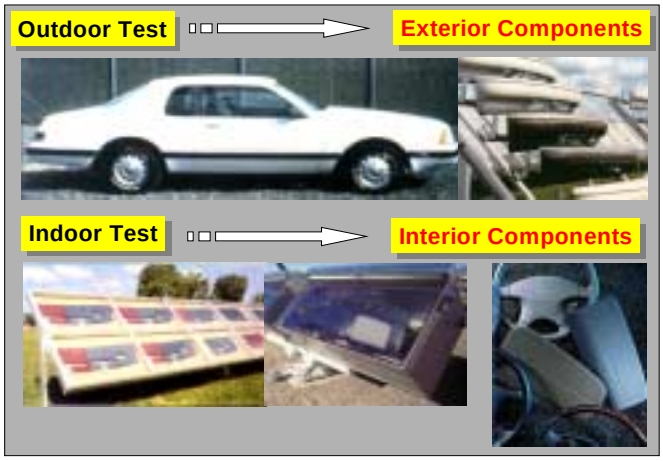
2.1 Solar Radiation Simulation Test – DIN 75220

It needs to be understood that the specification gives some guidelines on the performance of the test, but some critical aspects need to be considered carefully as there is still room for interpretation and also some lacks of definition.
For the solar radiation simulation test on airbag modules the selected parameters are shown in the following graph.



There are two different environments selected to offer severe weathering effects on automotive components. The **Hot and Dry** and the **Warm and Humid** climates.
One reason for the selection of those climates is also the long time experience and the existence of reference data by performing natural weathering tests in location like **Arizona** (hot&dry) and **Florida** (warm&humid). One can still find those names as “Arizona-Test” or “Florida-Test” in specifications for solar simulation test of the automotive industry.

The most important point that often creates some confusion, is the distinction of the so-called **Outdoor-** and **Indoor Test Conditions**.

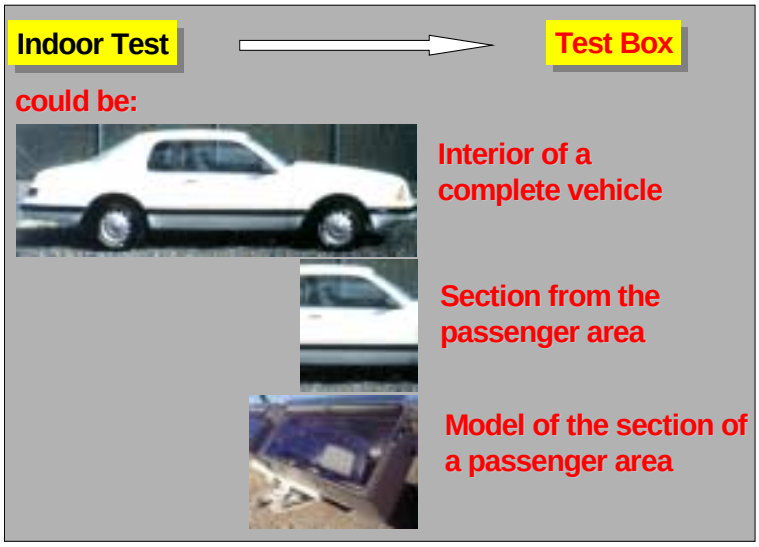


Fundamental we can say, "**Outdoor**" means the climate conditions that need to be simulated on the external surfaces of a vehicle and "**Indoor**" means to simulate the climate conditions found in an enclosed car interior when exposed to the "**Outdoor Conditions".**
The confusion mainly arises at the "Indoor Conditions" due to a lack on definitions in the DIN 75220 standard and the design of the solar simulation systems.

Irradiance, spectral radiation distribution and the ambient temperature are the essential differences between "Outdoor" and "Indoor".

The **Outdoor Test** is performed within a large climatic chamber where complete vehicles, but also exterior components are exposed to direct sunlight. Irradiance, spectral power distribution and ambient temperature are selected to be close to the terrestrial extremes so to achieve accelerated effects.

For the **Indoor Test** the specification gives different options.



Definitions of DIN 75220

Test Box *"The test box is a device in which the climatic conditions found in an enclosed car interior are simulated: indoor conditions"*

- This means, that if the climate conditions are kept, the "Test Box" could be designed in any way - Different from that you also find under "Test Equipment" -

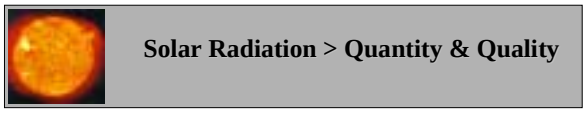
Test Box "*The test box, which is made from a vehicle, a section from the passenger area or a model of this, is used to simulate the internal conditions in different models of vehicles."*

- This gives at least a hint, that the geometrical design of the test box should take the passenger cabin as a model, but a detailed specification is not defined.

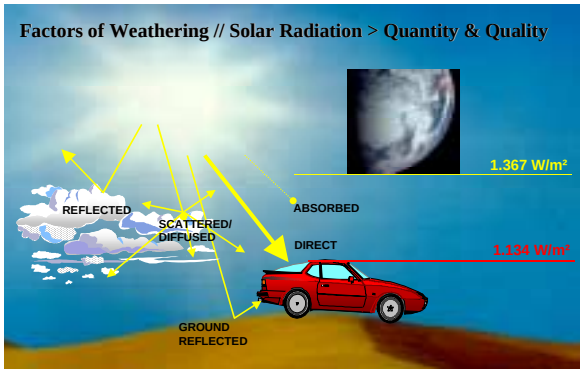
The ISO 12097-2 gives even more room on the design.

The different design of “Indoor Test Boxes” is mainly critical in respect of the sample surface temperature. This problem will be addressed later on.

2.2 Solar Radiation Simulation Test – DIN 75220 – Factors of Weathering

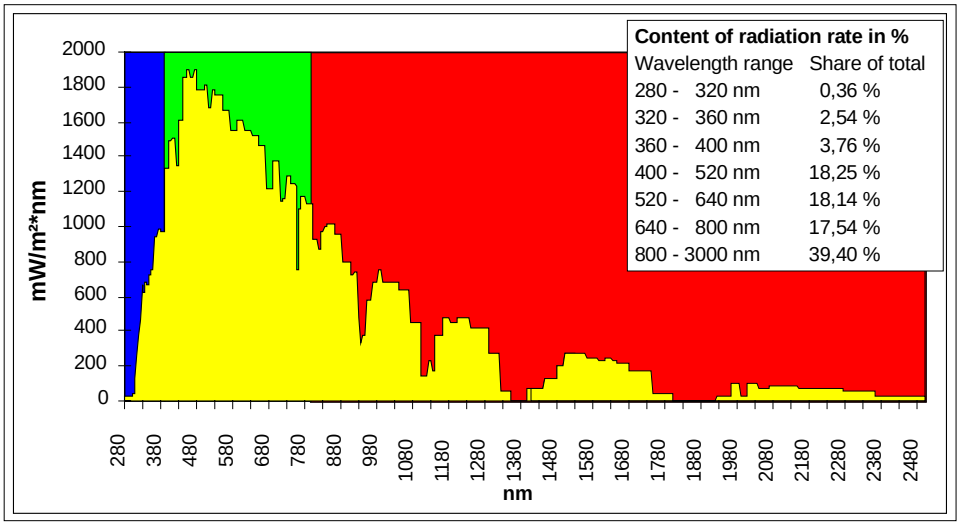


The Global Solar Radiation is the sum of direct and diffuse solar radiation received on a horizontal plane on earth surface.
The reference for the Global Radiation in respect of spectral radiation distribution and irradiance is shown in the CIE Publication No.85 "Solar Spectral Irradiance" at Table 4.



The following diagram shows the spectral radiation distribution.

Global Radiation to CIE Publ. 85 Tabel 4



Outdoor Test

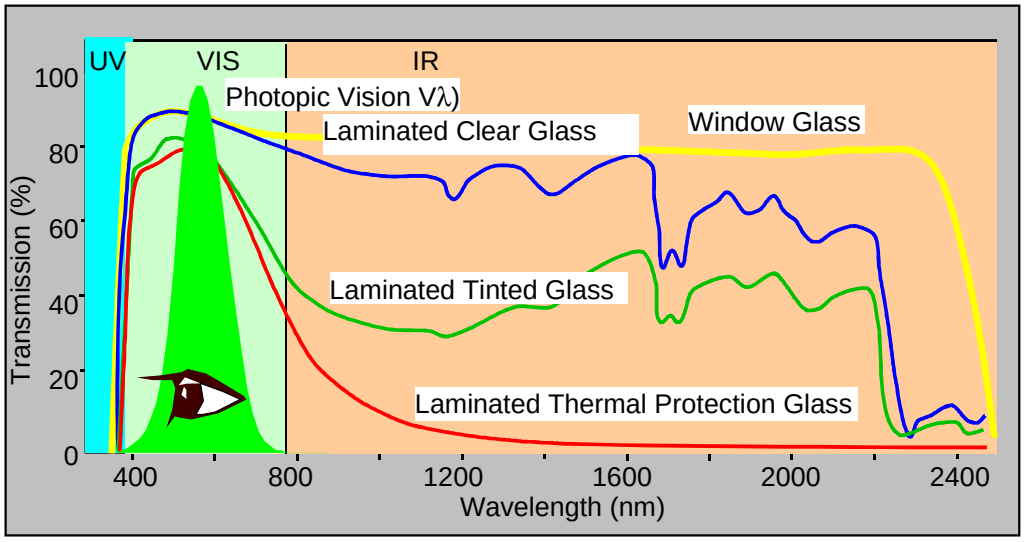
For the simulation of the Global Radiation the following conditions had been specified:
Irradiance of 1.000W/m² +/-100W/m² in the spectral range from 280-3.000nm.
The Spectral Power Distribution

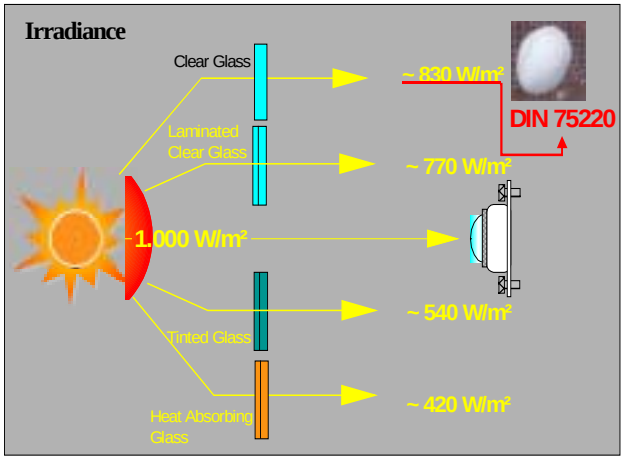
Content of radiation rate in % Wavelength range	Share of total CIE Publ.85 T4	DIN 75220
280 - 320 nm	0,36 %	0,3.....0,7%
320 - 360 nm	2,54 %	1,8.....3,0%
360 - 400 nm	3,76 %	2,4.....4,4%
400 - 520 nm	18,25 %	16,1....19,7%
520 - 640 nm	18,14 %	14,9....18,3%
640 - 800 nm	17,54 %	12,8....19,0%
800 - 3000 nm	39,41 %	33,7....50,5%

Indoor Test

Indoor Irradiation Conditions The main factor to achieve the indoor conditions is the glass cover (Filter). Specified as standard is a 4mm thick window glass. Due to its relative high transmission within the UV range it simulates the so-called *"worst case"*. Further on it is mentioned, *..."Obviously other types of glass may be used, but this shall be agreed. It should be noted that using other types of glass changes the transmittance and hence the spectral energy distribution."....*

The use of different glasses is required rather frequently. Nearly always it is a type of laminated safety glass or tempered glass - so typical automotive glass of the windshield or side and rear windows.





This glass is used as clear glass or most common today as tinted (heat absorbing or reflecting) glass. Apart from the changes on the spectral radiation distribution those different automotive glass types have a considerable influence to the irradiance. Especially the changes in the irradiance values are often not obvious.
A typical complain is "the required 830W/m² can not be reached".
Only detailed information's on the overall transmission values of the particular glass can give correct reference values on the irradiance that should be achieved.

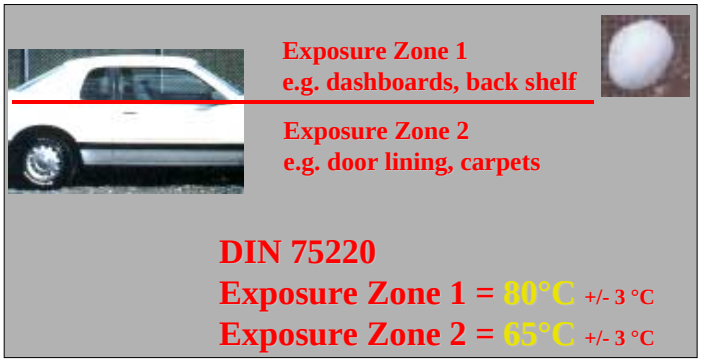
Worst case scenario – transmission of 4mm thick window glass

Content of radiation rate in % Wavelength range	Share of total DIN 75220 Outdoor	Transmittance 4mm Window Glass	DIN 75220 Indoor
280 - 320 nm	0,3.....0,7%	7%	< 0,04%
320 - 360 nm	1,8.....3,0%	61%	1,3.....2,3%
360 - 400 nm	2,4.....4,4%	88%	2,6.....4,6%
400 - 520 nm	16,1....19,7%	89%	17,3....21,1%
520 - 640 nm	14,9....18,3%	89%	16,0....19,6%
640 - 800 nm	12,8....19,0%	83%	12,8....19,0%
800 - 3000 nm	33,7....50,5%	80%	32,4....48,6%

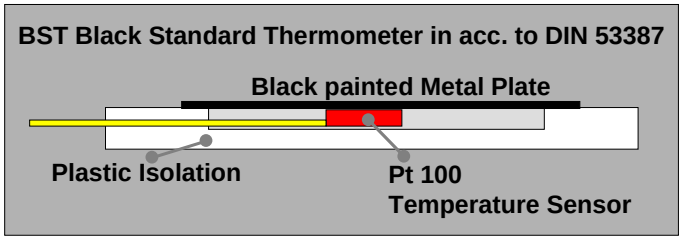
Temperature > Quantity & Cycles

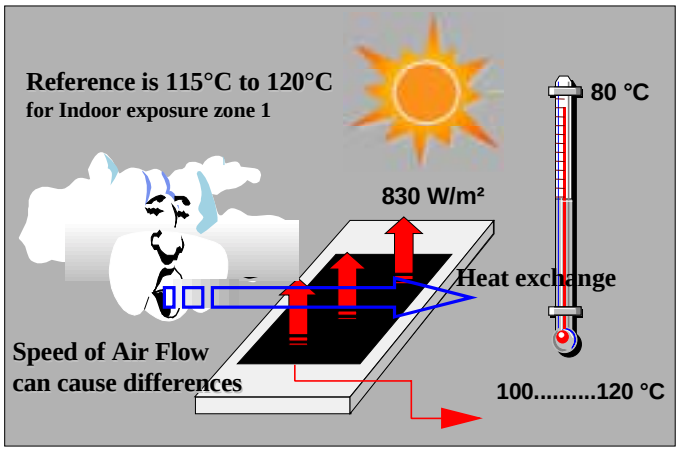
Regarding the radiation conditions “Outdoor Test” and "Indoor Test" are well specified (for Indoor only true if the recommended 4mm window glass is used).
The thermal conditions, basically also well defined, can lead to extreme differences on the results of the test.
This refers to the correlation of outdoor weathering as well as to the correlation between tests performed in different solar simulation units.

For the “Outdoor Test” this is again relative clear. An ambient temperature of **42°C** +/-3°C had been specified in accordance to temperatures found in desert conditions like Arizona or the Kalahari.
For the Indoor test two different exposure zones had been defined as shown below.
Apart from the pure thermal conditions, which are different in a quite open chamber than within a vehicle (formation of temperature layers, convection), high attention must be paid on the speed of air flow.
Even with the same irradiance and the same ambient temperature different surface temperatures will be achieved if the air flow is not specified so to offer similar conditions.

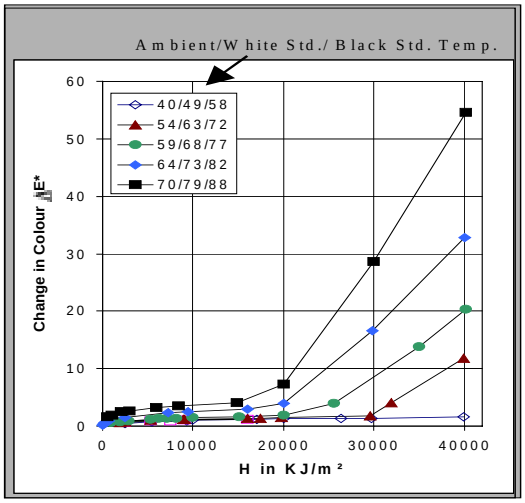


<u>Warning</u> Variations in sample surface temperatures will lead to different ageing behaviour of the tested specimens.





The measurement of the so-called "Black Standard Temperature" can function in this case as a relative good indication. The exposure conditions will influence the sensor similar to the sample.



As an example how extreme those differences could be, the graph above illustrates the change in colour for grey pigmented PVC at different temperatures. A difference of about 6°C on surface temperature will lead nearly to a double of the Δ E*.

The relative atmospheric humidity is only given in very rough values like < 30% for the dry climate or > 60% for the humid one. Similar as the temperature also the humidity plays a role within the ageing process of materials. The water absorption and desorption gives stress to the different layers of the material, which will speed up the ageing processes. The large tolerances of the relative atmospheric humidity may lead again to different test results.

Test Sequences

General there are two different kind of test sequences defined. The long-term test with 240 hours of constant climatic and irradiation conditions. And a cycle test with a combination of 15x24hours dry climate cycles and 10x24hours humid climate cycles. For the test of airbag modules only the 15x24hours dry climate cycle had been selected.

Dry Climate Cycle	**8,0h**	**daytime (solar radiation cycle)**
15 Times	**3,5h**	**nighttime (dark cycle)**
	**8,0h**	**daytime (solar radiation cycle)**
	3,5h	**nighttime (dark cycle)**
	1,0h	**room conditions for inspection**

2.3 Test Equipment

In general there are various possibilities on the design of adequate test equipment. Assuming that they all have to fulfil the specification, it is mainly a question of the required test room capacity. One needs to test just a few single samples, others may have the need to test the integrated parts (e.g. a complete instrument panel) or even a complete vehicle.

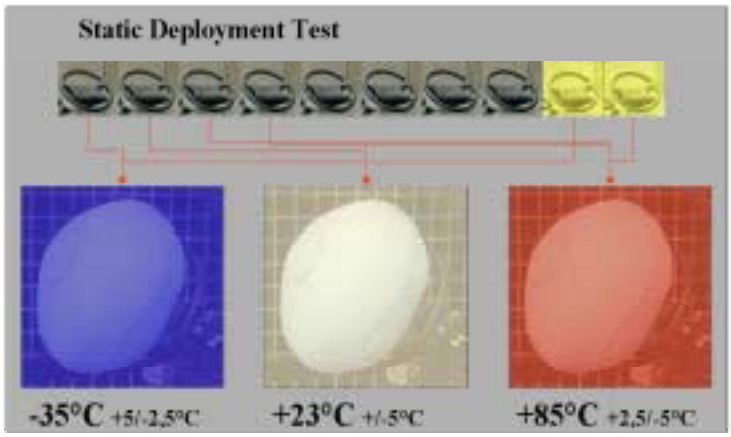
Also there is often the need to perform tests in accordance to different standards like specific ones out of the automotive industry or other organisations.
Therefore KHS offers a large variety on modular equipments that all could be designed to the individual test needs.

As one example two standard test units out of the SolarClimatic series are shown along with the important features.
Both instruments are capable to perform tests in accordance to most if not all standards for solar simulation tests on automotive components, even including the MIL-810-F standard.

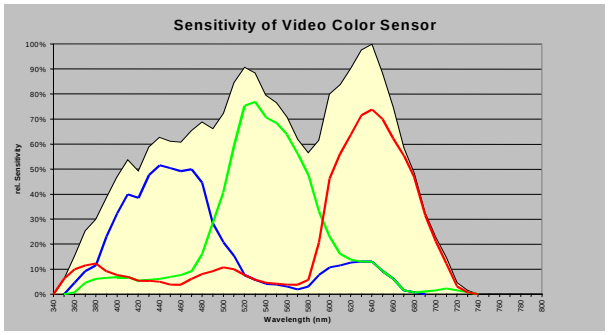
2.3.1 Features

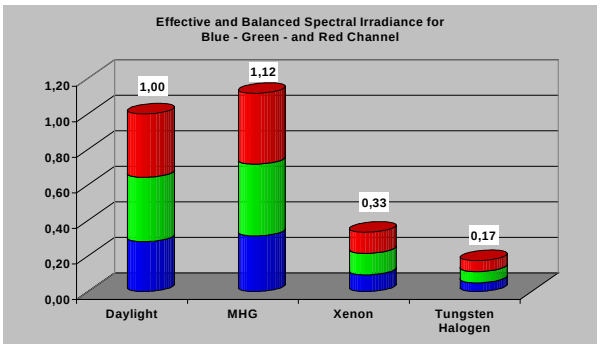
With those features precise simulation of the basic weathering factors, with good correlation to natural weathering, controlled acceleration and probably most important, reproducible test results could be achieved.

3. Performance – Static Deployment Test



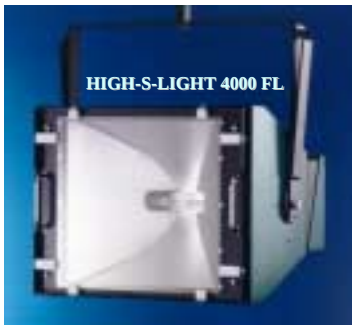
Six out of the ten airbag modules that went through the various environmental tests need to prove their function at the static deployment test. This includes also the two modules that had been exposed under solar simulation.
The deployment of the modules has to be performed under specified sample temperatures.
To maintain those temperatures is especially critical due to the necessary use of lighting systems that are needed for sufficient illumination of the event to be recorded by film or video.
For the quantity and quality of data recorded by the use of High-Speed-Photography and Videography, light plays an important role.
Beside the basic requirements concerning illuminance, spatial uniformity and light modulation, the efficiency in respect to the sensitivity of the high-speed imaging sensor needs to be considered.





Out of today's available light sources, special Metal Halide lamps had been found to be the most efficient for those applications.

Integrated into the **HIGH-S-LIGHT BOOST** technology of KHS they offer:



- **High luminous efficiency > 100lm/W**
- **Daylight Color Temperature of 5.600 - 6.000 K**
- **Matches perfectly the Sensitivity of Film & Video**
- **Flicker-free Light - Modulation < 1%**
- **High Illuminace due to the BOOST Mode**
- **Low Heat Radiation**
- **Stabilized True Power Control**
- **Optical System for Uniform Illumination**
- **Modulare Design**
- **Useful Subsystems**

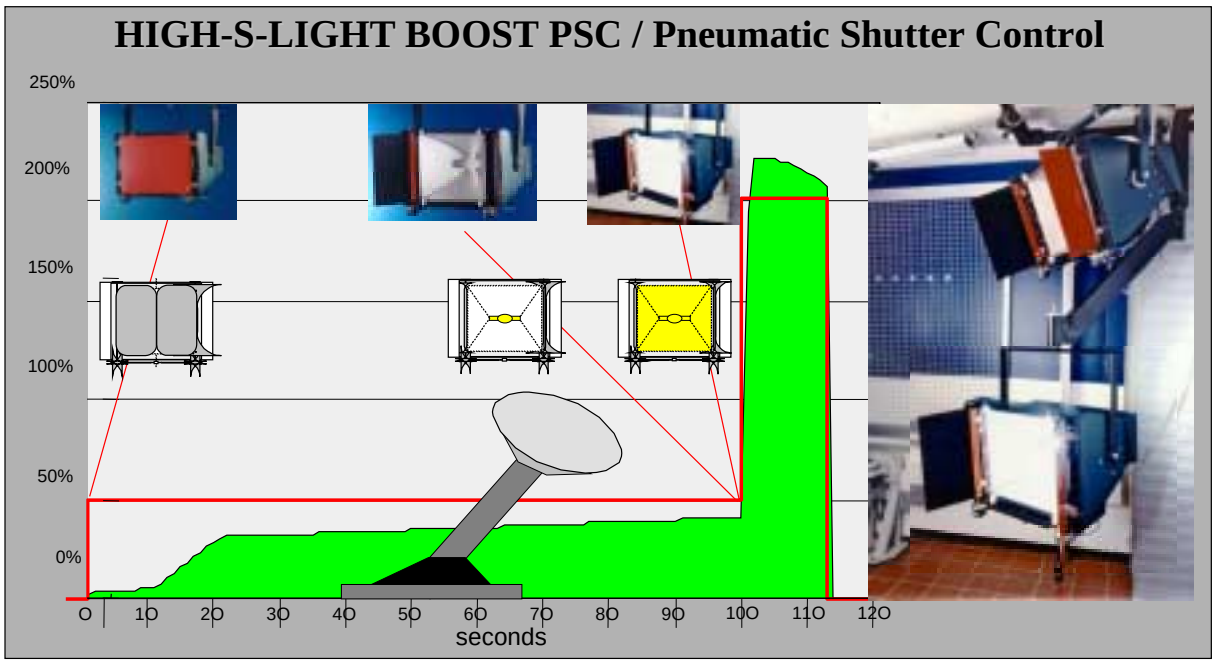
But there is also a seamy side of the picture. To get all the filling components, which are responsible for the illumination quality of the lamp, into the full operational process (vaporisation) a certain amount of time is required once the lamp had been ignited. The time depends on the type of lamp, the control gear and the ambient thermal conditions.
Normally a delay of at least 90 seconds is necessary.
Even so the lamp has relative "cold" radiation within this warm-up period especially when operated in the stand-by mode, illuminated samples will absorb the radiated energy and build up heat.

To overcome this problem and also the general task of maintaining the required temperatures several solutions are available.

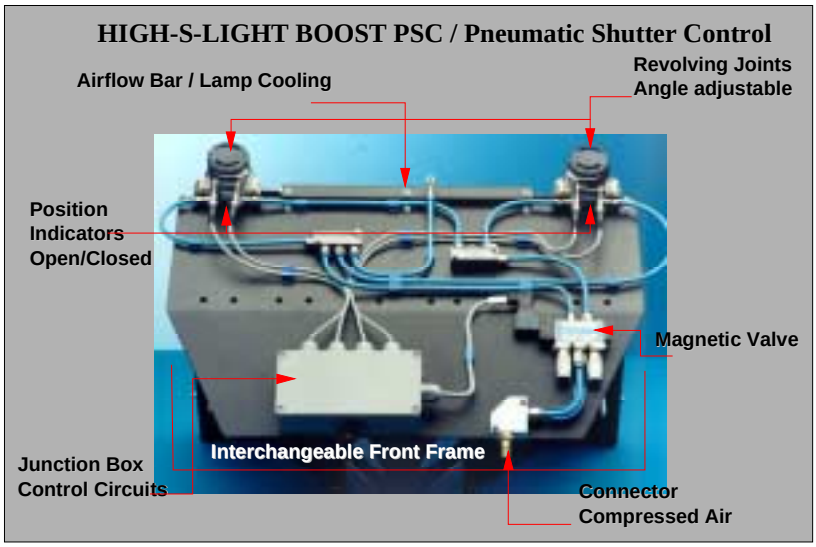
One solution offered by the manufacturers of climatic and/or temperature controlled chambers, which are needed anyway to condition the airbag modules, is a design that enables the direct performance of the static deployment test. This is achieved in general by two different constructions. One is to move the samples rapidly out of the chamber by means of a sled or by having the module mounted to the cabinet door. The other opens the chamber by about 180° so the ignition of the airbag can be performed inside the chamber.

As this is for sure a way of precise temperature control, daily series testing is most often performed in different set-ups. The preconditioned airbag modules will be rigidly mounted on fixtures in special designed test rooms. Once in place they would be subjected to the lighting system that is installed for the proper illumination of the coming event.
This would again cause the earlier mentioned problems to maintain the module temperature.

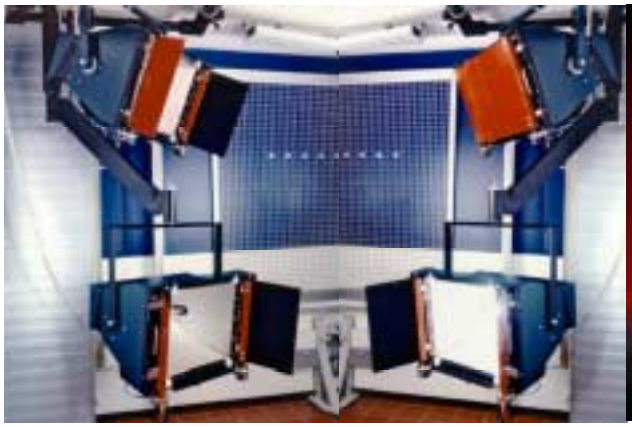
To overcome this problem and finally to avoid any radiation striking the module before the actual test is performed, KHS designed a **Pneumatic Shutter** for the luminaries of the **HIGH-S-LIGHT BOOST FL** series.



The function is internal co-ordinated with the Stand-by and BOOST mode operation and the whole sequence is integrated into the overall test control.



The complete system is mounted to the luminary front frame. So any existing system could be easily modified.
The open/close positions of the shutter is permanent controlled and a corresponding signal is provided. The compressed air is also used for lamp fixture cooling as long as the shutters are closed. This enables an unlimited operation time even when the luminary is closed.



Proposals, planing and realisation of Solar Simulation Units and Lighting Systems must be always done in a close co-operation with the customers and need to consider the technical requirements of the special application.

Even if standards give a guideline for the design, they are most often not precise enough to ensure reliable and reproducible test results. Especially the field of laboratory testing, like the solar simulation test, requires continuos verification of the correlation of natural weathering conditions and effects.