ISO Solar Loading Background

June 8, 2016

Mark Polster
**Presentation Overview**

- This presentation is a comprehensive review of the background and data that went into the definition of heating radiator in ISO 12219-1, 4.2.

**Heating radiator**

- Infrared radiator, halogen radiator or other radiators (simulating sun light) (wave length <300 nm shall be filtered out). The heating radiators used shall be powered to create a radiation density at the reference measurement point in the middle of the roof surface of the test vehicle of 350 W/m² to 450 W/m² (400 W/m² ±50 W/m²).

- The heating area shall cover at least the area of the test vehicle cabin and an additional 0.5 m more to each side of the lower part of the glazing (footprint) (see Figure 1). The heating radiators are positioned at the roof with a shining angle of 90° to the heating area. There are no heating radiators shining from the side. The heating area shall be calibrated in squares of 25 cm x 25 cm with a radiation density of 400 W/m² ±50 W/m². The required radiation density shall be available directly after the lamps are switched-on (within a few min).

- The irradiation shall be measured in accordance with ISO 9060.
Background

- ISO/TC22-ISO/TC146/SC6 WG13
  - TC22: Road Vehicles
  - TC146: Air Quality
  - SC6: Indoor Air
  - WG13: Joint working group for vehicle level VOC test procedures
- The first meeting was in Berlin, Germany and there have been a total of 8 meetings.
- The 9th meeting is in Burlington, Vermont (US) September 28, 2016.
- To date there are over 277 committee documents and 9 test methods at various stages.
## ISO Committee Members

- Members include 10 countries and 32 representatives
  - US, UK, Germany, Japan, Korea, France, Belgium, Italy, Russia, Switzerland

<table>
<thead>
<tr>
<th><strong>Automotive</strong></th>
<th><strong>Research Institutes and Universities</strong></th>
<th><strong>Test Laboratories</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford (US)</td>
<td>The University of Tokyo (Japan)</td>
<td>BRE (UK)</td>
</tr>
<tr>
<td>Toyota (Japan)</td>
<td>Waseda University (Japan)</td>
<td>Markes (UK)</td>
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<td>Honda (Japan)</td>
<td>Kyushu University (Japan)</td>
<td>TUV Nord (Germany)</td>
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<td>Isuzu (Japan)</td>
<td>Society of Automotive Engineers of Japan (Japan)</td>
<td>Fraunhofer (Germany)</td>
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<td>GM (Germany)</td>
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<td>Hyundai (Germany)</td>
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<td>VW (Germany)</td>
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<td>Fiat (Italy)</td>
<td>Kongju National University (Korea)</td>
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<td></td>
<td>Kangwon National University (South Korea)</td>
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</table>
The original ISO proposal was to maintain a constant temperature within the vehicle like the JAMA method.

The JAMA method did not include an ambient mode but the Korean and China method did.

The JAMA method only required the measurement of Formaldehyde during the elevated “parking mode.”

There were other methods considered, see next slide.
**VIAQ Procedures back in 2008**

<table>
<thead>
<tr>
<th>Test Conditions</th>
<th>Regulations</th>
<th>Voluntary/Recommended Guidelines</th>
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<tbody>
<tr>
<td>Criteria</td>
<td><strong>HJ</strong> China HJ/T (Draft)</td>
<td><strong>Russian Federation</strong> Russia GOST R 51206-04</td>
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<tr>
<td>VOC's &amp; Aldehydes</td>
<td><strong>Vehicle Level</strong> 25°C ± 1°C for 16hrs; 15 types of aldehyde-ketone constituents (specific VOCs undefined)</td>
<td><strong>Vehicle Level</strong> Ambient; Engine idle &amp; vehicle stationary and at 50 km/h or max veh speed. CO, NOx, VOCs, form. limits.</td>
</tr>
<tr>
<td>Planned Effective Date</td>
<td>2010; China may consider adopting ISO in place of HJ.</td>
<td>Mandatory 1/1/06. Pollutant content in cabin resulting from fuel combustion in the engine and evap of fuel, etc.</td>
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<tr>
<td>ISO International Standard</td>
<td>ISO TC 146/SC 6 N (Draft)</td>
<td>JAMA JASO M361 (Draft)</td>
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<tr>
<td>3rd Party Cert.</td>
<td><strong>TÜV</strong></td>
<td><strong>KAIDA</strong> Korea MOTC Not. (Draft)</td>
</tr>
</tbody>
</table>

**Joint ISO/TC 22-ISO/TC 146/SC6/WG 13**
VIAQ Procedures back in 2008

- **Korea**
  - 2h Soak
    - Ambient 25°C
    - Ventilation off

- **China**
  - 16h Soak
    - Ambient 25°C
    - Ventilation off

- **JAMA**
  - No Soak
    - Elevated 40°C
      - Ventilation off
      - Ventilation on
Harmonization of VIAQ Procedures back in 2008

ISO 12219-1

Harmonized Procedure - 16h Soak

Ambient 25°C
Ventilation off

Elevated 50°C
Ventilation off
Ventilation on
Overview of the Draft ISO 12219-1 Procedure

- **Preconditioning**
  - Vent vehicle for 4 hours with doors and windows open

- **Test**
  - Standard driving mode
    - Soak 15 hrs; sample 1 hr

- **Closed uninfluenced mode**
  - Control cabin air to 50°C ± 2°C
  - Control hat rack, IP, headliner to 65°C ± 2°C
  - Hold temperatures for 3 hrs
  - Radiators are positioned on top and sides of vehicle.

- **Driving mode after parking**
  - Lights off, A/C on 23°C; sample 1 hr
First Meeting - Resolution 3

Unattended driving mode at 40°C accepted for HCHO sampling only

- **Position**
  - Closed mode only for HCHO
  - Values are high – 10 times
  - Low cost to include and satisfies JAMA

- **Test Plan**
  - Assess variability
  - Assess levels at 40 °C vs. 50°C
First Meeting - Resolution 6

**Real life data – component temperature profiles**

### Position
- Draft is unrealistic
  - 65°C at headliner, IP, and hat rack; and 50°C at center of vehicle is unrepresentative

### Test Plan
- Gather real life data
  - Different locations
  - Vehicle size (mass)
  - Angle of glass
  - Glass emissivity
- Note need for real life conditions
- Study constant uniform solar load centered over vehicle.
First Meeting - Resolution 7

Study temperature profile of the vehicle during heating in chamber
Lamp orientation, Exterior/Interior/Component temp, Lamp profile

- **Position**
  - Study the use of SCO3 site
    - No additional cost for some labs
    - Good at simulating sun
  - ISO Site
    - Low added cost
    - Fair at simulating sun
    - Allow different light sources per a specification

- **Test Plan**
  - Record orientation, profile, temperatures
    - SCO3 site
    - ISO site
    - Different vehicles
First meeting summary

- After the first meeting the WG agreed to investigate the heating method
  - Investigate different methods to apply a solar load to the vehicle like the sun.
  - Investigate different global locations for solar load
  - Investigate different vehicle sizes and angle of glass
  - Investigate different glass emissivity
  - Investigate different light technologies, first ISO 12219-1 method used halogen lights.
  - Start with reviewing other methods that apply a solar load to vehicles.
Indicial review of methods that currently apply solar loads

- A US EPA test method for vehicle air conditioning in the US was looked at for solar load definitions.
- SCOC test method included a general approach is to apply a solar load in watts/meter square.
- Review other methods and collect data for:
  - Type of lights
  - Level of the solar load
  - Duration of the load.
Solar Energy Distribution

Source: http://www.lbl.gov/Science-Articles/Archive/sb/Aug-2004/3_coolroofs-2.html
Spectral Adsorption vs. Color
- Paper states, “Solar lamps are used to simulate the sun”
Solar Energy Penetration

Diagram showing the flow of solar energy through a glazing system, including total solar energy entering the vehicle, reflected energy, absorbed and re-radiated out, and absorbed and re-radiated inward.
Total of Absorbed Radiation - 1 of 2

ARIZONA

MHG-SYSTEM

MH-SYSTEM
Total of Absorbed Radiation - 2 of 2
Spectral Transmission of Automotive Glass
Total of Absorbed Radiation Through Clear Glass
Total of Absorbed Radiation Through Clear Glass

ARIZONA

Quartz/Halogen

IR-SYSTEM

23%  100%  100%

31%  100%

100%

77%  69%  67%

75%  66%  65%

17%  19%  19%

48%  30%  25%
Total of Absorbed Radiation Through Tinted Glass
Total of Absorbed Radiation Through Tinted Glass
Total of Absorbed Radiation Through Thermal Glass
Total of Absorbed Radiation Through Thermal Glass
Ford Edge with Different Glass Technologies
- October 3, 4, & 5 2009 at Ford RIC
**IRR Film on Glass**

- **Effect of Intermittent Afternoon Clouds**

*October 3 Weather*

![Graph showing temperature, wind speed, and solar radiation over the day.](image)
**IRR Film on Glass**

- **Effect of Intermittent Afternoon Clouds on Breath Temp**

Driver Breath Level Measurements:
South Vehicle with Gila Light All Front Glass, Oct. 3

![Graph showing breath temperature with and without IRR film on glass over time. Temperatures are plotted against time in seconds.]
**IRR Film on Glass**  
- **Effect of Surface Temperatures**

Armrest Surface Measurements:  
South Vehicle with Gila Light All Front Glass, Oct. 3

Vehicle Pillars Block Solar Load but does not change breath temperature

*see previous slide*
**IRR Film on Glass**

- **Effect of Many Afternoon Clouds**

**October 4 Weather**

![Graph showing temperature, wind speed, and solar radiation over the day.]
**IRR Film on Glass**

- Effect of Many Afternoon Clouds

Driver Breath Level Measurements:
South Vehicle with Gila Light All Front Glass

Note: Sept. 2008 testing in AZ six week delay to Hybrid testing due to poor weather

- Breath Temp Without IRR
- Breath Temp With IRR
- Ambient Temp

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IRR Film on Glass
- Effect of Many Afternoon Clouds

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**IRR Film on Glass**

- **Effect of No Clouds until Late Afternoon**

October 5 Weather

![Graph showing temperature, wind speed, and solar radiation over time](image)
**IRR Film on Glass**
- **Effect of No Clouds until Late Afternoon**

Driver Breath Level Measurements:
South Vehicle with Gila Light All Front Glass

- Breath Temp Without IRR
- Breath Temp With IRR
- Ambient Temp

**Graph Details:**
- X-axis: Time in seconds (8:00 AM to 12:00 AM)
- Y-axis: Temperature in °C

- Pink line: Breath Lvl South
- Cyan line: Pave Und South
- Red line: Breath Lvl North
- Blue line: Wheelwell North

Effect of No Clouds until Late Afternoon
Mean Sky Cover (MSC) - Varies Greatly Based on Location and Time of Year

Note: No US location as less than 46% MSC
Conclusions on Outdoor Solar Loads and glass technology

- Interior temperature were impacted by glass technologies
- Solar load changes and varies greatly with:
  - Geographic location
  - Clouds
  - Vehicle direction
  - Solar path
  - Time of day/calendar day
  - Sudden wind gusts.
Different Solar Testing Sites

- Metal Halide
- Outdoor
- Halogen
Response to ISO VOC draft site design
ISO Interior Air Quality Test Site
EPA Solar Loading Procedure – SC03
Federal Code of Register

- § 86.161–00 Air conditioning environmental test facility ambient requirements.

- The goal of an air conditioning test facility is to simulate the impact of an ambient heat load on the power requirements of the vehicle’s air conditioning compressor while operating on a specific driving cycle.

**SC03 Solar Load represents WORST CASE for US.**

*This emissions test was designed to find defeat devises related to AC usage not A/C efficiency.*
(3) Radiant energy specifications. (i) Simulated solar radiant energy intensity is determined as an average of the two points measured at: (A) Centerline of the test vehicle at the base of the windshield. (B) Centerline of the vehicle at the base of the rear window (truck and van location defined as bottom of vertical window or where an optional window would be located). (ii) The radiant energy intensity set point is $850 \pm 45$ watts/square meter. (iii) The definition of an acceptable spectral distribution is contained in the following table:

### DEFINITION OF THE SPECTRAL DISTRIBUTION

<table>
<thead>
<tr>
<th>Band width (nanometers)</th>
<th>Percent of total spectrum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower limit (percent)</td>
</tr>
<tr>
<td>&lt;320</td>
<td>0</td>
</tr>
<tr>
<td>320–400</td>
<td>0</td>
</tr>
<tr>
<td>400–780</td>
<td>45</td>
</tr>
<tr>
<td>&gt;780</td>
<td>35</td>
</tr>
</tbody>
</table>

(iv) The angle of incidence of radiant energy is defined as 90 degrees from the test cell floor.
(d) Solar heat loading.

(1)(i) Acceptable types of radiant energy emitters that may be used for simulating solar heat load are: (A) Metal halide; (B) Quartz halogen with dichroic mirrors; and (C) Sodium iodide. (ii) The Administrator will approve other types of radiant energy emitters if the manufacturer can show they satisfy the requirements of this section.

(2) The height of the minimal cell size will dictate the type of radiant energy source that will satisfy the spectral distribution and uniformity definitions of this section. (v) The requirements for measuring the uniformity of radiant energy are: (A) The radiant energy uniformity tolerance is ±15 percent of the radiant energy intensity set point of 850 watts/square meter. (B) The uniformity of radiant energy intensity is measured at each point of a 0.5 meter grid over the entire footprint of the test vehicle at the elevation of one meter including the footprint edges. (C) Radiant energy uniformity must be checked at least every 500 hours of emitter usage or every six months depending on which covers the shorter time period; and every time major changes in the solar simulation hardware occur. (vi) The radiant energy intensity measurement instrument specifications (minimum) are: (A) Sensitivity of 9 microvolts per watt/square meter; (B) Response time of 1 second; (C) Linearity of ±0.5 percent; and (D) Cosine of ±1 percent from normalization 0–70 degree zenith angle.
SCO3 Site with Metal Halide Lights and Pyranometer
Ford SC03 Site
- As measured at APTL SC03 Site

Spectral Measurements of Solar Simulator at Ford Allen Park Test Laboratory
Eppley Precision Spectral Pyranometer (PSP)

- This radiometer measures sun and sky irradiance in the range of wavelengths 0.285 to 2.8 microns, including most of the solar spectrum. The PSP is intended to weight the energy flux in all wavelengths equally. It is a “hemispheric receiver” intended to approximate the cosine response for oblique rays.

- Specifications:
  - Sensitivity approximately 9 microvolts per W/m². Thus an irradiance of 1000W/m² will produce a DC potential of 9 millivolts.
  - Impedance is approximately 650 Ohms. Thus, if current is drawn from the PSP, the output voltage will drop.
  - Temperature dependence is 1% over -20 to +40°C
  - Linearity is plus or minus 0.5% from 0 to 2800 W/m²
  - Response time is 1 second (for a 1/e relaxation)
  - Cosine response: 1% for 0 to 70 degrees from zenith; 3% from 70 to 80 degrees
  - Size 5.75 inches diameter; 3.75 inched high
  - Weight 7 pounds
Solar Uniformity on SC03 Site

### SITE 78 SOLAR UNIFORMITY VERIFICATION DATA

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<th>DATE:</th>
<th>2/1/2008</th>
<th>(run hours: on E1)</th>
<th>Before</th>
<th>2468</th>
<th>After</th>
<th>2756</th>
<th>Run Hours</th>
<th>288</th>
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<td>OBSERVER:</td>
<td>B. Hefferon / Cass Kemp / Jeff Smith</td>
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#### Solar Intensity Data (W/m²)

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<th>1.5</th>
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<td>802</td>
<td>782</td>
<td>742</td>
<td>692</td>
</tr>
</tbody>
</table>

**Minimum Intensity** | 692 | -14.4% |
**Maximum Intensity** | 921 | 13.9% |
**Average Intensity** | 808.8 |
**Standard Deviation** | 51.5 |

#### Percent Difference from Average Intensity

<table>
<thead>
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<th>Temp</th>
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<td>-0.8%</td>
<td>-3.3%</td>
<td>-8.3%</td>
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</table>

**Minimum Difference** | -14.4% | EPA Min Limit | -15% | Average Difference | 0.0% |
**Maximum Difference** | 13.9% | EPA Max Limit | 15% | Standard Deviation | 6.4% |
**WG Progress**

- The WG shared data for temperatures in the countries and regions they represented.
- With that was some test site and real world solar and temperature data.
- The WG also shared data on the effect the type of the light had on heating the vehicle, taking into account the type of glass technology on the vehicle.
Outdoor Testing

- Temperature - Day 1
- Temperature - Day 2
- Solar Load - Day 1
- Solar Load - Day 2
Sun and SC03 site data

Ford Fusion
Black paint and Black interior

Outside "Ambient" Temperature

<table>
<thead>
<tr>
<th>Time [h]</th>
<th>Temperature [°F]</th>
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<td>75</td>
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<tr>
<td>6</td>
<td>75</td>
</tr>
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</table>
Sun and SC03 site data

Ford Fusion
Black paint and Black interior

Solar Load

Average "Sunny Day" Solar Load
860 W/m² from 9:30AM - 3:30PM
Sun and SC03 site data

Ford Fusion
Black paint and Black interior

Interior "Breath" Temperature

Time [h]

Temperature [°F]

Sunny Day
SC03 Site

50C
Sun and SC03 site data

Temperature [°F]

Time [s] - 3600s = 1h

- Sun
- Metal Halide Lights
- Halogen Lights

Interior Breath Temperature
Sun Path and Angle of Incidence on one of the hottest days in Allen Park, MI USA

Lincoln MKZ
Black Paint and Black Interior

Interior "Breath" Temperature

Sun Path Change

Similar Results

Cloud Cover Change

Sunny Day (August 15, 2009)
SC03 site
ISO Presentation - N87

Car cabin interior air quality
(April 7th ~ 9th 2010)

Man Goo Kim
Dept. of Environmental science
Kangwon National University, Korea
ISO Presentation - N87

Outdoor exposure test conditions

Test condition

1) Test period: May 2005~Jun 2006
   (14 month)

2) Test vehicle
   ▶ Blue Body Color
   ▶ White Body Color

3) Test method
   ▶ Outdoor
   ▶ Direction: South
   ▶ Angle: 0 deg.

Vehicles under Out-Door Weathering Test
ISO Presentation - N87

The highest temp. in Cabin during test period

Test site: Seosan, Korea.
ISO Presentation - N87

The solar radiation in Seoul(1)

Current standard (800±100 W/m²)

- mean
- median
- 25~75 percentile
- 10~90 percentile
- 5 and 95 percentile

Test period
ISO Presentation - N87

The solar radiation in Seoul(2)

Current standard (800±100 W/m²)

1 hour average
ISO Presentation - N87

Chamber Test(1)

<table>
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<tr>
<th>800W/m² (4 hours)</th>
<th>Temperature[°C]</th>
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<td>Car indoor air</td>
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<tr>
<td>HATCH (360 cm x 158 cm, Silver body color)</td>
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<tr>
<td>SEDAN (480 cm x 183 cm, White body color)</td>
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<tr>
<td>SEDAN (516 cm x 190 cm, Black body color)</td>
<td>63</td>
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Test Plan with Multiple: Vehicles, Lights, Solar Loads

- Two vehicles tested both dark colors
  - Ford Fiesta (green glass)
  - Mazda 2 (combination of glass tint)
- Two light types tested
  - Halogen (500 Watt each)
  - Metal Halide (4000 Watt each) on SC03 test site (75)
- Three temperature locations
  - Breath (50 cm from top of steering wheel on a line to the bottom of headrest)
  - Top and center of headrest
  - Center of Rooftop
Pyranometer Measurement Locations

- Nine Solar load measurements were recorded at height of the roof (59 inches/150 cm) for each of the test conditions.
  - Four measurements were at the roof corners
  - One at each the center of the front, rear, driver, and passenger sides
  - One at the center of the roof
Pyranometer Measurement Locations continued...

<table>
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<tr>
<th>Light Type</th>
<th>Vehicle Type</th>
<th>Light Type</th>
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Pyranometer Measurement Locations continued...

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<td>337</td>
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Ford Fiesta and Halogen Solar Simulation
Ford Fiesta and Metal Halide Solar Simulation (SC03 site)
Mazda 2 and Halogen Solar Simulation
Ford Fiesta Roof
Halogen and Metal Halide Lights
Temperature vs Time

- 600-Halogen Light
- 600-Metal Halide
- 500-Halogen Light
- 400-Halogen Light
- 450-Metal Halide
- 350-Metal Halide
- 300-Halogen Light

Temperature (degrees F)
Temperature (degrees C)
Time (seconds)
Ford Fiesta Head Rest
Halogen and Metal Halide Lights
Temperature vs Time
Mazda2 Roof
Halogen and Metal Halide Lights
Temperature vs Time

Time (seconds)

Temperature (degrees F)

600(4)-Halogen
600(3)-Halogen
600(2)-Halogen
600(1)-Halogen
300-Halogen Light
450-Metal Halide
350-Metal Halide
Mazda2 Head Rest
Halogen and Metal Halide Lights
Temperature vs Time

Temperature (degrees F)

Temperature (degrees C)

Time (seconds)
Mazda2 Breath
Halogen and Metal Halide Lights
Temperature vs Time
1. Solar energy at world principal cities

Toronto, CAN: 0.318 (kW/m²)
Berlin, GER: 0.264 (kW/m²)
Moscow, RUS: 0.261 (kW/m²)
Beijing, CHN: 0.352 (kW/m²)
Phoenix, USA: 0.451 (kW/m²)
Sao Paulo, BRA: 0.460 (kW/m²)
Abu Dhabi, UAE: 0.367 (kW/m²)
Okinawa, JPN: 0.376 (kW/m²)

Our proposal of irradiation energy: 300 ± 50 W/m²

Source: NASA surface meteorology and Solar Energy
*Monthly Average from 1983 to 2005
*Time scale is standardized to GMT.
2. Study of irradiation energy effects
   2-1. Comparison study for lamp specification difference

Halogen lamp results

Infrared lamp results

<table>
<thead>
<tr>
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<th>Halogen lamp A</th>
<th>Halogen lamp B*</th>
<th>Infrared lamp</th>
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<tr>
<td>800 W/m²</td>
<td>54.5</td>
<td>49.0</td>
<td>60.0</td>
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<td>500 W/m²</td>
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<td>350 W/m²</td>
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<td>No data</td>
<td>40.0</td>
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<tr>
<td>300 W/m²</td>
<td>38.3</td>
<td>33.8</td>
<td>37.0</td>
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</tbody>
</table>

*Halogen lamp B is filtered lamp
2. Study of irradiation energy effects
   2-1. Comparison study for lamp specification difference

Lamp wavelength comparison

- Infrared lamp
- Metal halide lamp
- Standard sun light
4.1 heating lamps

The lamps should be powered to create $300 \text{ W/m}^2 \pm 50 \text{ W/m}^2$ on the roof surface of the test vehicle. Distance of the lamps to the roof of the test vehicle should be conformed to guaranteed distance of each irradiation system. The heating area covers the area of the test vehicle cabin and 1 m more to each side. There are no lamps shining from the side.

The specification of lamp should be Metal Halide, Quartz halogen with dichroic mirrors or sodium iodide.

The spectroscopic of lamps shall satisfy the following conditions.

- $<320\text{nm} : 0\%$
- $320\text{nm} ~ 400\text{nm} : 0\% ~ 7\%$
- $400\text{nm} ~ 780\text{nm} : 45\% ~ 55\%$
- $>780\text{nm} : 35\% ~ 53\%$

**NOTE** The power of lamp simulates the mean sun irradiation in Europe, Asia, North-America etc.
2. Study of irradiation energy effects

2-2. Chamber temperature influence on cabin temperature

Test conditions:
1. Irradiation energy: 270W/m²
2. Lamp: Infrared lamp
3. Distance (lamp to roof): 1.5m
2. Study of irradiation energy effects
   2-2. Chamber temperature influence on cabin temperature

6.1 Requirements for the whole vehicle test chamber

The whole vehicle test chamber with the following requirements is assembled as shown in Figures 1, 2 and 3. The following requirements shall be met:

a) The whole vehicle test chamber shall be large enough to accommodate the complete test vehicle.

b) The temperatures inside of the whole vehicle test chamber are: 23 °C ± 2 K (to be discussed) (during the heating phase the temperature in the whole vehicle test chamber is allowed to raise to 30 °C to 35 °C). A heating and ventilation system (including the adjustment of the humidity) and, if necessary a cooling system, is necessary. Sampling point for the background concentrations in the whole test chamber: more than 1 m beside the test vehicle and in the height of the lower window frame of the front door.

....the whole test chamber have to keep 23 °C ± 2K.
Luft - Temperatur im Fzg.-Innenraum in Kopfstützenhöhe
Vergleich Sonnensimulation 500 / 800 / 1000 W/m²

- Bei 1000 W/m²
- Bei 800 W/m²
- Bei 500 W/m²

Motor + Klima an
Car cabin air temperature with IR radiation

Lamp: IR light

<table>
<thead>
<tr>
<th>Lamp Intensity</th>
<th>300 W m⁻²</th>
<th>400 W m⁻²</th>
<th>500 W m⁻²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabin air Temperature</td>
<td>29 C</td>
<td>38 C</td>
<td>45 C</td>
</tr>
</tbody>
</table>
## Irradiation energy vs Cabin temperature

A graph showing the relationship between irradiation energy (W/m²) and cabin temperature (°C). The graph includes lines for different lamp types: IR, Halogen, and Halogen+Metal halide. The equations for each line are:

- IR: \( y = 0.0731x + 22.275 \)
- Halogen: \( y = 0.0436x + 24.191 \)
- Halogen+Metal halide: \( y = 0.0305x + 24.5 \)

### Table

| Vehicle | Category (segment) | Color     | Test chamber size (m³) | Lamp type      | Irradiation area (m²) | Cabin temperature | France/SNCF
|---------|--------------------|-----------|------------------------|-----------------|-----------------------|-------------------|----------------
| A       | B                  | black     | 52                     | IR              | 12.3                  | IR                | 243–363W/m³     
| B       | D                  | black     | 132                    | Halogen         | 12.5                  |                  |                
| C       | A                  | pink gold | 284                    | Halogen         | 13.8                  | IR                | 243–363W/m³     
| D       | C                  | silver    | 284                    | Halogen         | 13.8                  | Halogen           | 367–508W/m³     
| E       | B                  | yellow pearl | 284            | Halogen+Metal halide | 13.8                  | 15.6              |                
| F       | D                  | silver    | 284                    | Halogen+Metal halide | 13.8                  | 15.6              |                
| G       | A                  | black     | 340                    | Halogen+Metal halide | 15.6                  | 15.6              |                
| H       | A                  | black     | 340                    | Halogen+Metal halide | 15.6                  | 15.6              |                

- Cabin temperature: 40°C
- France/SNCF: 243–363W/m³, 367–508W/m³
Attached please find test results of energy.

Conclusion:

Irradiation energy should be control 350 W/m² ± 50 W/m² with lamp correlated sun light such as halogen or metal halide. 350 W/m² is a mean value of global main city. When use IR radiator, need adjust power of radiator to be same cabin temperature condition with specified radiator such as halogen or metal halide.

So we proposed in ISO describe as below,

Halogen radiators or metal halide radiators (wave length < 300 nm could be filtered out). The radiators should be powered to create 350 W/m² ± 50 W/m² on the roof surface of the test vehicle. The heating area covers the area of the test vehicle cabin and 1 m more to each side (footprint). There are no radiators shining from the side. If use infrared radiators, adjust power of radiator to reach cabin temperature as same as specified radiator such as halogen or metal halide.
Test results to verify the irradiation energy value

Working items:

Definition of the irradiation energy value for different Lamp Types.

The following Lamp Types would be tested:
- IR Lamps
- Metal-halogen-Lamps (SOLISI-Test chamber)

The Test car was a Polo (Car-class A0)

The Temperature Measurement was done in the position described in the DIS ISO 12219-1
Test results to verify the irradiation energy value

Test situation for the IR-Lamp testing:

- The side overlay of the radiation is 0.5 meter
- The radiation value was measured in the middle of the roof
- The start temperature for each measurement was 23 °C
Test results to verify the irradiation energy value

Temperature curve IR-Radiation 500 W/m²/ Measure time 5 h

end temperature 46 °C
Test results to verify the irradiation energy value

Temperature curve IR-Radiation 400 W/m²/ Measure time 5 h

Temperatureverlauf bei 400 Watt/m² IR-Strahlung

- Temperature in °C during the high-temperature application
- Measured temperature in °C

End temperature 43 °C
Test results to verify the irradiation energy value

Temperature curve IR-Radiation 300 W/m²/ Measure time 5 h

Temperaturverlauf bei 300 Watt/m² IR-Strahlung

end temperature 35 °C
Test results to verify the irradiation energy value

Test situation for the SOLISI-Lamp testing:

- The side overlay of the radiation is 1.0 meter
- The radiation value was measured in the middle of the roof
- The start temperature of the car was 23°C
- The test procedure differs between the 400/600 W/m² and the 500 W/m² test
  - by the 500 W/m² test the car was in the chamber when the lamps switch on
  - by the 400 and 600 W/m² tests, the car was driven in the chamber after the lamps are on for two hours (a metal-halogen-lamp need 1-2 hours to reach their full power)
Test results to verify the irradiation energy value

Temperature curves SOLISI-Radiation / Measure time 4 h

- End temperature:
  - 43 °C
  - 40 °C
  - 37 °C

Postulated after 5h

Temperature [°C]

- 400 W
- 500 W
- 800 W

Dauer [h:mm:ss]
Test results to verify the irradiation energy value

Conclusion:

For IR-Lamps the irradiation energy value to get an interior temperature of 40 °C is 400 +/- 25 W/m².

Mercury-vapor-lamps have similar the same characteristic (70 to 80% IR value), so for them the same test value is to be used.

Metal-halogen-lamps cannot be used for heating up cars. This has two reasons:

a. This lamp type needs 1-2 hours to get there full power, and this depends on the age of the lamp

b. The IR-radiation value of this lamps where filtered out in different ways, so the value of IR-radiation differs from type to type.

ISO%2DTC146%2DSC6%2D WG13_N0115_Irradiation_energy_value_measuremen
ISO/CD 12219-1

Irradiation energy value

Please find enclosed (see Doc. N 115) the measurement results of comparative irradiation value measurements with different lamp types.

The measurements carried out by Peter Schwarzer and investigations among the suppliers/manufacturers of metal halide lamps resulted in the following fact:

Metal halide lamps should not be recommended in ISO/CD 12219-1 due to the fact that with this sort of lamps no reproducible heating can be reached within the heating cycle of 4 h.

This has two reasons:

a) The lamps require 1 h – 2 h to reach their final energy radiation. Since the energy radiation also depends on the age of the lamps no constant heating characteristic for the vehicles can be reached.

b) The IR fraction of these lamps, being an essential part of the heating process, is filtered out as far as possible as these lamps are needed primarily to simulate sunlight in the visible and UV spectrum. This filtration characteristic is mainly manufacturer-specific. Therefore the final resulting IR fraction during the heating process is not known and, thus, there is a risk of non-comparability between different lamp manufacturers.

From Peter Schwarzer's point of view this could be the reason for the different results of the tests carried out in Japan, Korea and the US.

Therefore, Peter Schwarzer proposes not to include the metal halide lamps and to refer only to IR lamps and halogen lamps with an irradiation of 400 +/- 25 W/m².
After review of N116 & N115, I have some comments.

1. Irradiation study by Japan & Germany
   I made a graph include our data & German data as attachment.
   IR's results are similar between VW's and Japanese.
   376W/m²@40C (VW)
   362W/m²@40C (Vehicle A)
   Halogen's result is similar about 400W/m² or below.
   406W/m²@40C (Vehicle C)
   Average of these results is 381W/m².

2. Outcome of the results
   Metal halide lamp makes different results.
   IR and halogen lamp makes similar results, but 400+/-25W/m² is too severe condition when considering different vehicles, test equipments and lamp arrangement etc.

Therefore I propose 400+/-50 W/m² as appropriate value.
Final Conclusions

- After much discussion the WG agreed to a solar load of 400 W/m² ± 50. This value was assumed to be a value that represented a nationalized and annualized level.
Elevated VOC Levels

- The WG shared elevated vehicle test results, both temperature and VOC levels to see the affect solar load and temperature had on VOC levels.
The final draft was submitted in January 2010

A new vehicle was tested over 38 days

The 23 page report show the results of 19 multiple phase tests

Over 200 samples were collected and analyzed
**Background**

- **Vehicle Criteria**
  - New (< 4 weeks) black exterior and black interior vehicle

- **Four procedures were evaluated**
  - A (TUV), B (JAMA), C (ISO), D (load-based)

- **Three solar load source test sites**
  - ISO site, SC03 site, sun

- **Various parameters were evaluated to determine the effect on concentration (µg/m³)**
  - Parameters: temperature, ventilation, vehicle age and solar load source
  - Compounds of interest: TVOCs and formaldehyde
    - 65+ hydrocarbons were analyzed including, benzene, toluene, ethylbenzene, m&p-xylenes, o-xylene, styrene, and tetradecane
Procedure Overview

- Procedure A (TUV)
  - Soak 8+ hr
  - 3 min door opening
  - Sample @ ambient T (A1)

- Procedure B (JAMA)
  - Sample @ ambient T (not part of original method) (B1)
  - Doors open 0.5 hr
  - Heat vehicle to 40 °C and hold for 4.5 hr then sample (B2)
  - Open driver door for 1 min and set A/C to 23 °C then sample (B3)

- Procedure C (ISO)
  - Doors open 4 hr then 15.5 hr soak (no air exchange in vehicle)
  - Sample @ ambient T (C1)
  - Heat vehicle to 50 °C and hold for 2.5 hr then sample (C2)
  - Open driver door for 1 min and set A/C to 23 °C then sample (C3)

- Procedure D (load-based)
  - Soak 8+ hr
  - Sample @ ambient T (D1)
  - Apply constant load and hold for 2.5 hr then sample (D2)
  - Open driver door for 1 min and set A/C to 23 °C then sample (D3)

All sample periods are 0.5 h
Results

- Part 1
  - Effect of temperature, ventilation, and vehicle age
- Part 2
  - Effect of solar load source
- Part 3
  - Evaluation of a load-based approach (Procedure D only)
RESULTS – Part 1

- Temperature, Ventilation, and Vehicle Age
50% reduction in TVOCs from day 12 to day 20 due to extensive testing (incl. elevated)

Increase in TVOCs from day 32 to day 39 and day 50. The vehicle was sealed between these tests and VOCs were allowed to build-up
Formaldehyde ($\mu g/m^3$)

- Reduction in formaldehyde from day 12 to day 20 due to extensive testing (incl. elevated)
- Not a significant decrease in formaldehyde from day 32 to 39 to 50 due to limited ventilation

Concentration of formaldehyde ($\mu g/m^3$) using Procedure A at ambient T
At elevated T the effect of ventilation results in a decrease of TVOCs by ~9-10x.

- At ambient T the TVOCs are half of that at an elevated T (40 °C) with no ventilation.
- At ambient T the TVOCs are 4-5x higher than at elevated T (40 °C) with ventilation.

Concentration of total VOCs (C6-C16 (µg/m³)) using Procedure B at ambient T and 40 °C.
At elevated T the effect of ventilation results in a decrease of TVOCs by ~12-13x.

At ambient T the TVOCs are half of that at an elevated T (50 °C) with no ventilation.

At ambient T the TVOCs are 4-5x higher than at elevated T (50 °C) with ventilation.

Concentration of total VOCs (C6-C16 (µg/m³)) using Procedure C at ambient T and 50 °C.
Concentration of total VOCs (C6-C16 (µg/m³)) using Procedure B (40 °C) and C (50 °C)

- Results are similar for Procedure B and C even though pre-conditioning, elevated T, and heating times are different.
Results are similar for Procedure B and C even though pre-conditioning, elevated T, and heating times are different.
On day 13 with no door opening the TVOCs were 2x that on day 12 with a 3 min door opening.

Immediately following the doors and windows were open and the TVOCs were 5x lower than with the 3 min door opening.

The TVOCs from day 16 through 19 were greatly decreased due to exercising the vehicle.
RESULTS – Part 2

- Solar Load Source
  - ISO Site
  - SC03 Site
  - Sun (back-up)
Concentration of total VOCs (C6-C16 (µg/m³)) using Procedure C and D using SC03 site
Concentration of total VOCs (C6-C16 (µg/m³)) using Procedure C and D using ISO site
RESULTS – Part 3

- Evaluation of Load-Based Approach
  - Procedure D only
Concentration of total VOCs (C6-C16 (µg/m³)) comparing Procedure D using SC03 & ISO

Concentration of formaldehyde (µg/m³) comparing Procedure D using SC03 & ISO

- D2 (SC03 + Vent OFF)
- D3 (SC03 + Vent ON)
- D2 (3-Zone, Top only + Vent OFF)
- D3 (3-Zone, Top only + Vent ON)

Formaldehyde (µg/m³)

850 W/m²

600 W/m²

Concentration of formaldehyde (µg/m³) comparing Procedure D using SC03 & ISO

Cell Temperature (°C) from Procedure D using the SC03 and ISO test site

- Temperature - Cell
- Solar Load - SC03
- Solar Load - 5-Zone

Cell Temperature (°C) from Procedure D using the SC03 and ISO test site
Breath Temperature (°C) from Procedure D using the SC03 and ISO test site

5-Zone - 600 W/m², top 3 zones
SC03 - 850 W/m²

D2  D3
Cell Temperature (°C) from Procedure C using the SC03 and ISO sites
Cell Temperature (°C) from Procedure D using the sun as a solar load test site
Top (Headliner) - TSD

- Sun - Day 20
- SC03 - C - 1100 W/m²
- 5-Zone - C - 650 W/m²
- SC03 - D - 850 W/m²
- 3-Zone - D - 600 W/m²
- Sun - Day 21
Center (Breath) - TC

- Sun - Day 20
- SC03 - C - 1100 W/m²
- 5-Zone - C - 650 W/m²
- Sun - Day 21
- SC03 - D - 850 W/m²
- 3-Zone - D - 600 W/m²
**Floor (Carpet)**

- **Sun - Day 20**
- **SC03 - C - 1100 W/m²**
- **5-Zone - C - 650 W/m²**
- **3-Zone - D - 600 W/m²**

- **Sun - Day 21**
- **SC03 - D - 850 W/m²**

Temperature (°C) vs Hours graph.
Rear (Hat rack) - TSH

- Sun - Day 20
- SC03 - C - 1100 W/m²
- 5-Zone - C - 650 W/m²
- Sun - Day 21
- SC03 - D - 850 W/m²
- 3-Zone - D - 600 W/m²
Front (Dash) - TSI
Roof (Outside)

- Sun - Day 20
- SC03 - C - 1100 W/m²
- SC03 - D - 850 W/m²
- 5-Zone - C - 650 W/m²
- 3-Zone - D - 600 W/m²

Temperature (°C) vs Hours

0 1 2 3 4