State of California
AIR RESOURCES BOARD

Appendix C

Additional Information

Cool Car Standards and Test Procedures

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This report has been reviewed by the staff of the California Air Resources Board and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Air Resources Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Appendix C

ADDITIONAL INFORMATION IN SUPPORT OF PROPOSED COOL CAR STANDARDS AND TEST PROCEDURES

Air conditioners and air conditioner use increases greenhouse gas emissions. Recognition of the benefits of reducing the air conditioner load was previously acknowledged by the California Air Resources Board (ARB) in its Assembly Bill 1493 regulation. Staff is proposing a regulation that will reduce the air conditioner load in light- and medium-duty vehicles. This document provides additional information to support that contained in the Staff Report.

I. SOLAR REFLECTIVE PAINT

As originally envisioned, the proposed regulation focused on solar reflective paints, with solar management glazing added to the proposal during the regulatory development process. However, the final proposal does not include solar reflective paint. Although staff believes that these paints should be developed and used, the timeframe of this regulation is too short to ensure that pigments for all desired colors can be developed. This is because developing new colors or new paints is a time-consuming process. New color development begins with color shows, where the automotive stylists discuss their desired color options with the paint manufacturers, who then put together their offerings. Color masters are developed and released to all suppliers for matching. Engineering evaluations of the color masters, including a two-year Florida weathering test, chip resistance, humidity resistance, intercoat adhesion, windshield adhesion, etc. are completed, followed by an application simulation for each plant. After in-plant line trials, the production launch and ramp-up begins. This is a long process. Generally, assuming pigments have been verified for automotive use, it takes around five years from color selection to application on a vehicle for sale.

This five year process assumes that the pigments used in the paints are verified for automotive use. The automotive paint requirements are rigorous, and many new pigments may not prove to have acceptable performance. Pigment verification can take an additional 1-2 years. It is uncertain whether any of the very dark pigments with higher reflectivity developed to date are suitable for automotive use. Pigments currently in the verification process are unable to generate a true “jet black”. They tend to have brown or blue undertones resulting in a somewhat “muddy” appearance that may not be visually appealing. However, staff is aware of some pigments being developed now that may overcome this issue.

II. SOLAR CONTROL GLAZING

Solar control window glazing includes solar reflective glazing and solar absorbing glazing. Solar reflective glazing is produced by a number of glass companies. Most solar reflective glazing involves the use of silver oxides, but non-metallic products are also available. Although there are solar reflective films that can be applied to the exposed glass surfaces, weatherability and durability may be an issue. Therefore, use of solar reflective glazing will generally require laminated glass. The solar reflective glazing available has significant benefits in terms of solar control compared to the best solar absorbing glazing currently available. The five percent of vehicles that currently have laminated glass are well-positioned to utilize solar reflective glazing.

Solar absorbing glazing is made by adding solar absorbing components to the molten glass. Most solar control in the United States is currently achieved with solar absorbing glazing. In Europe, solar reflective glazing has greater acceptance.

A. Effect of Solar Control Glazing on Vehicle Interior Temperatures

How much temperature reduction is possible with the use of solar control glazing? The National Renewable Energy Laboratory (NREL) and other institutions have investigated the effectiveness of various solar control products. Typical research results are summarized in Table C-1. The upper bound of potential control can be determined by efforts such as those at the Fiat Research Center, where shielding vehicle glazing with aluminum film resulted in cabin air temperature reductions of up to 20°C.[1] Similar NREL tests resulted in breath air temperatures only 10°C above ambient.[2] (Breath air temperature is the air temperature at the location of a typical driver's face.) Although the foil would allow some heat transfer, these reductions are likely near the theoretical maximum. A more practical glazing application, however, would require the transmittance of at least some visible light even for privacy glazing.

Currently available solar management products have been tested and the results reported in the literature. Typical research results are reported in this section. NREL tested 3M polymeric solar reflective film (nonmetallic) on identical minivans, finding a 4.6°C reduction in maximum breath temperature with the use of the 3M glazing on all windows, while modifying only the windshield reduced the breath temperature by 2.5°C.[3] This is consistent with indications that about half the solar radiation enters the vehicle through the windshield (for vehicles without rooflites). The nonmetallic films are generally not as effective as metal-based products, but do not have issues with electromagnetic attenuation. The 4.6°C temperature reduction was associated with a reduction in time to 25°C by 3.75 minutes, from about 20 minutes to 16.25 minutes. This means that the air conditioning system could operate at a reduced energy level with use of the film and provide the same comfort level. To cool at the same rate as the vehicle with production glazing, a vehicle using this film would require an air conditioner with about 19% less power.[4]

Southwall Technology's XIR® film was tested on a luxury sedan. Interior temperatures were reduced by 10°C when the vehicle was equipped with XIR film compared to the standard solar tint glass. In addition, subjective passenger feedback indicated a reduction of 25% in “time to comfort” --16 minutes in the XIR vehicle compared to 21 minutes for the control.[5]

Pittsburgh Glass Works’ Sungate solar reflective glass was tested in two identical white Ford Explorers, one with production glazing and the other with modified glazing. Use of Sungate glazing in the windshield resulted in temperature reductions of 2.2°C.[6] The relatively modest result is likely due to the fact that the production windshield used solar absorbing glass. Thus, this is actually a comparison of solar absorbing to solar reflective glazing, and is consistent with other published and nonpublished results indicating a difference of around 2°C for the two solar control approaches. For example, Fiat completed a 2-hour soak testing of a Punto, which showed internal air temperatures of 65°C for standard glazing, compared to 60°C for absorbing, and 58°C for infrared reflective glazing. This shows a 2°C difference in soak temperature between a solar reflective and a solar absorbing glazing.[7]

Sungate was also tested in a Plymouth Breeze. In this test, NREL examined the effect of a Sungate windshield compared to Solex (U.S. standard), and Solar Green (European standard). With the Sungate windshield, the cabin was 9°C cooler than with standard windows under the existing test conditions. The Sungate windshield permits a compressor reduction of about 400 watts, which could reduce fuel use by 3.4 percent (0.7 miles per gallon) over the SC03 cycle, according to NREL’s ADVISOR simulations.[8]

In 2006, NREL tested solar reflective paint and glazing on a Cadillac STS.[9] This glazing was PGW’s improved Sungate EP, which has been fully developed but is not currently in production. Solar reflective glass (all locations) and solar-reflective paint resulted in a reduced breath air temperature of 9.7°C. Solar reflective glass on the windshield only resulted in reduced breath air temperature of 6.7°C. The paint and glazing were not assessed separately, but the solar reflective paint was only slightly more reflective than the standard paint (18% reflectivity compared to 11% for the standard paint). Based on Hoke’s analysis, staff estimates that about 0.7°C of the benefit would be derived from this level of solar control for the paint.[10]

Table C-1 summarizes these data, and shows an average breath air temperature reduction of 6.4°C, with a range of 1.8°C to 10°C.

B. Costs of Solar Control Glazing

1. Glazing Costs

Current glazing ranges from clear glass (i.e., no solar control) for inexpensive vehicles to all-around solar reflective glazing on more expensive European models. The proposed regulation does not require the use of solar reflective glazing. An earlier draft proposal included the use of all-around solar reflective glazing requirements. While the benefits to be obtained from this approach were greater than those from the proposed regulation, as discussed in the Staff Report, the use of all-around solar reflective glazing would substantially increase the cost of the

Table C- 1. Summary of typical research on solar reflective paints and coatings.

Source	Vehicle type	Treatment	Breath air temp red'n
NREL[11]		Aluminum foil	10°C (18 F)
Fiat[12]	Punto	Aluminum film	20°C
Fiat[13]	Punto	SR Film	7°C
NREL[14]	minivan	3M nonmetallic	4.6°C
NREL[15]	Luxury sedan	XIR	10°C
NREL[16]	Plymouth Breeze	Sungate	9°C
NREL[17]	Ford Explorer	Sungate	2.7°C
NREL[18]	Cadillac STS	Sungate EP	9.7°C*

*Note that the test vehicle also included a slightly more reflective paint than the control vehicle (0.18 versus 0.11), which was not independently assessed.

proposal, as windows not currently laminated would need to be upgraded. Most vehicle manufacturers indicated a 5-fold increase in cost from tempered glazing to solar reflective laminated glazing. At the May 15, 2008 workshop, General Motors indicated that laminated glass would cost an additional $45-50 per piece of glass. Glass manufacturers have put the cost estimate significantly lower, around a 1.5 to 2-fold increase, or, around $150-300 for the entire vehicle. This is still a significant investment. Glass manufacturers have estimated direct cost increases from laminated to solar reflective laminated of around $1.50 per square foot; for glass not currently laminated, the cost is higher, at around $2.50 per square foot, to go from current tempered glass to solar reflective laminated glass.[a] These costs are based on a five percent penetration rate, and may be expected to decline with higher volumes.

Concern about these costs led staff to assess the potential benefits from allowing solar absorbing glazing on some window positions. Solar absorbing glazing generally has a small cost premium over current light-tinted glass, ranging from $0 to $25 for all the vehicle's sidelites and backlite. This direct cost will be the cost to move from the current level of solar control (none, light green tinting, solar absorbing glazing) to a glazing that transmits no more than 60 percent of the total solar energy. Based on staff's assessments of the current level of solar control in sidelites and backlites, staff determined that direct costs for sidelites and backlites will increase by around $11 for the typical vehicle. Rooflites currently use some level of solar control for the comfort of the passengers. Staff estimates an increased direct cost for rooflites of $7, based on the average size and solar performance of current rooflites.

To meet the proposed windshield requirements with current technology, a solar reflective approach is likely. While solar reflective glazing generally requires the use

[a] One glass manufacturer provided specific estimates of the cost to move from a laminated to a solar reflective laminated windshield. The solar reflective product was projected to cost around $25 for the typical windshield. Going from current tempered glazing to laminated solar reflective glazing was projected to cost $26 for a backlite, $105 for the 4 door glass panes, and another $52 for the quarter panels, for a total for all-around solar reflective laminated glazing of $208.

of laminated glass, all windshields currently use laminated glass. Thus, the direct cost for a solar reflective windshield would only reflect the additional cost of the film or coating. For a windshield, which has a large surface area, the direct incremental cost between the current laminated windshield and a solar reflective model is around $25 to $35, when customer options are considered. Higher levels of solar control tend to be slightly more expensive.

In these direct cost estimates, staff has considered anticipated cost increases suggested by both glazing and vehicle manufacturers. For the first tier (2012) windshield requirement, direct cost estimates provided to staff range from $15 to $110 over current glazing, with the typical estimated direct cost of around $35. Staff used the typical cost of $35 for our analyses.[b] For the second tier (2014), anticipated cost increases provided by glazing manufacturers indicate an additional $10 to $15 would be expected, for a total increased direct cost from today's baseline direct cost of up to $50 for the windshield. Depending on current control levels, cost increases for the other glazing ranges from $0 to $33, with an anticipated average cost of $18 per vehicle. This results in a total direct cost to the vehicle manufacturer of $68 ($50+$18) for the tier 2 (2014) requirements.

This $68 estimated direct cost increase for the solar management glazing reflects the costs that the glass suppliers charge the automobile manufacturers. But there are also indirect costs that the automobile manufacturers may encounter. The automotive industry applies scaling factors to predict the full impact vehicle modifications have on the selling price. A commonly used scaling factor is the retail price equivalent (RPE) multiplier. This RPE multiplier includes both direct and indirect costs. In a recent EPA report,[19] an indirect cost multiplier which specifically evaluates the components of indirect costs likely to be affected by vehicle modifications associated with environmental regulation was developed. A range of multipliers accounts for the differences in the technical complexity of the change, and adjusts over time as new technology becomes assimilated into the automotive production process. The underlying concept is that regulations requiring major changes in materials or manufacturing processes, or significant invention of new technology, will likely have a significant impact on indirect costs. In contrast, regulations requiring simple technology modifications may have negligible impacts on indirect costs.

The EPA report presents three multipliers, based on the level of complexity of the suggested change. A change to a hybrid electric vehicle would have high complexity. A transmission change might be a medium level of complexity, because associated components might need modification to properly mesh with the new component. A change to low rolling resistance tires would have a low technical complexity.

Staff believes that the sidelite, backlite, and rooflite requirements in this regulation are low complexity changes. Staff anticipates that they will introduce only minor changes to existing glazing. However, if compliance with the windshield requirements leads to

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[b] The estimated cost includes the costs for "deletion areas" in reflective coated windshields to allow the proper operation of electronic devices such as cellular telephones and global positioning systems.

the use of metallic materials that result in electromagnetic attenuation, other associated components might need to be addressed, such as the positioning of antennae and the creation of deletion areas. Therefore, staff proposes the use of a medium complexity multiplier for the windshield, and a low complexity multiplier for the balance of glazing. The low complexity multiplier suggested in the EPA analysis is 1.05 in the short term, and 1.02 in the long term. The medium complexity multiplier suggested in the EPA analysis is 1.2 for the short term, declining to 1.05 in the long term. Applying these multipliers increases the long-term cost assessment for compliant glazing at the tier 2 (2014) level to $52.50 for the windshield, and $18.36 for the balance of glazing, for a total adjusted cost to the consumer of around $71. This adjusted cost is used in the cost-effectiveness calculations.

2. Effect of State Revenues

The CO_2 benefit in this proposed regulation is due to reduced fuel use. Therefore, vehicles built to comply with the regulation, i.e., 2012 and subsequent model-year vehicles, would use less fuel. This will result in reduced state and local government revenue from the excise tax and sales tax on motor vehicle fuel. The regulation is expected to result in a reduction in fuel use of 161M gallons per year with full implementation. This reduced fuel use will result in a reduction in the excise tax and sales tax collected for motor vehicle fuel of $29M (assuming these taxes total $0.18/gallon). The loss will be offset by increased sales tax for the vehicles. At a rate of 8%, the increased sales tax would total around $12M annually at full implementation. This net revenue loss of around $17M annually at full implementation is not included in the cost-savings calculations.

III. ISSUES

Vehicles with no air conditioner. ARB was asked to consider exempting vehicles without air conditioner from these regulations. Staff has not proposed doing so, because of concerns about aftermarket addition of air conditioning, practicalities of manufacturing and enforcement, and because we believe there will be a small emissions benefit even for vehicles without air conditioners in that if the interior temperature is less hot, the occupant will be less likely to keep the windows down, and therefore the vehicle will be operated in a more aerodynamic manner. We believe that the increase in cost will be acceptable to the consumer for the benefit of cooler interiors.

Electromagnetic attenuation. Current solar reflective glazing does tend to reduce the strength of electromagnetic signals used by devices such as global positioning systems, toll passes, garage door openers, and various sensors. Staff believes that since all-around solar reflective glazing is not required in this proposal, most sensors and antennae can be placed in positions where signal strength will be adequate. Nonetheless, the regulatory proposal allows the use of deletion windows where needed, so staff does not believe that electromagnetic attenuation will be a problem.

Test Procedures. Concerns have been raised about the use of the specified test procedure, International Standards Organization's (ISO) 13837, primarily as relates to the fixed convective coefficients and secondary heat generation from absorption, and their relationship to calculation of total solar transmission. It is argued that the coefficients underestimate the secondary heat flow for dark privacy glazing and overestimate the conductive gain for reflective glazing, providing the appearance that privacy glazing performs better than reflective glazing, even though in the real world, this is not the case, because it assumes all glass is "ordinary" with an emissivity of 0.837. An alternative methodology might be ISO 15099, which is much more accurate, but is very complicated. While staff acknowledges this issue, staff believes that the additional complexity of ISO 15099 does not merit its use, given that ISO 13837 is a much more commonly used procedure.

It has also been suggested that the total solar transmission should be measured at a "more typical" angle between the sun and the glass than the normal incidence called for in ISO 13837. Some solar management materials may be particularly sensitive to the measurement angle. The concern is that these materials may not appear to meet the required total solar transmission requirements but in actual use, their performance may be equivalent to materials that do comply with the proposed limits. Staff has addressed this issue by allowing a request to be made to the Executive Officer to allow alternate test procedures so long as use of the proposed glazing results in equivalent solar control to that anticipated under the proposed glazing requirements, as demonstrated by the assessment of real-world temperature measurements on a variety of vehicles under outdoor test procedures such as those typically used by NREL.

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