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Infrared Thermal Imaging of Automobiles

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INFRARED THERMAL IMAGING OF AUTOMOBILES:

Identification of Cold Start Vehicles

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Introduction

•On-road studies identify cold start vehicles as high emitters, even thought they have no repairable fault. This study investigates the use of thermal infrared imaging to identify vehicles that are high emitting because they are "cold."

•Cold vehicles can be differentiated from hot vehicles by infrared imaging, which can distinguish between:

- •Hot and cold exhaust system metal parts
- •Hot and cold reflections of the underbody of the vehicle from the road surface
- •Tires that have a uniform and bright IR emission identify hot vehicles, contrasting with cold tires, or tires that are non-uniformly hot, mostly due to solar warming.

•A FLIR A20V Infrared Camera was used to look at the infrared image from an automobile.

•The camera was set up with a FEAT 3000 unit to compare emissions vs. the reflected heat to detect if the vehicle was hot or cold.

- •Study at a Denver high school in which the vehicles are known to be cold
- •Parking lot study on vehicle warm up emissions and IR image

Cold Start Emissions

•Vehicles emit higher amounts of CO and hydrocarbons (HC) right after the vehicle has been started because the vehicle is running rich. Extra fuel is added to the combustion chamber in order to ensure ignition. Therefore a vehicle that is cold, with high emissions, has no repairable fault, while a hot vehicle with high emissions does have repairable fault.

•Fuel enrichment causes incomplete combustion and results in increased unburned HC and CO in the exhaust before catalyst light-off.

•As the vehicle's oxygen sensor and catalyst heat up, CO and HC concentrations decrease.

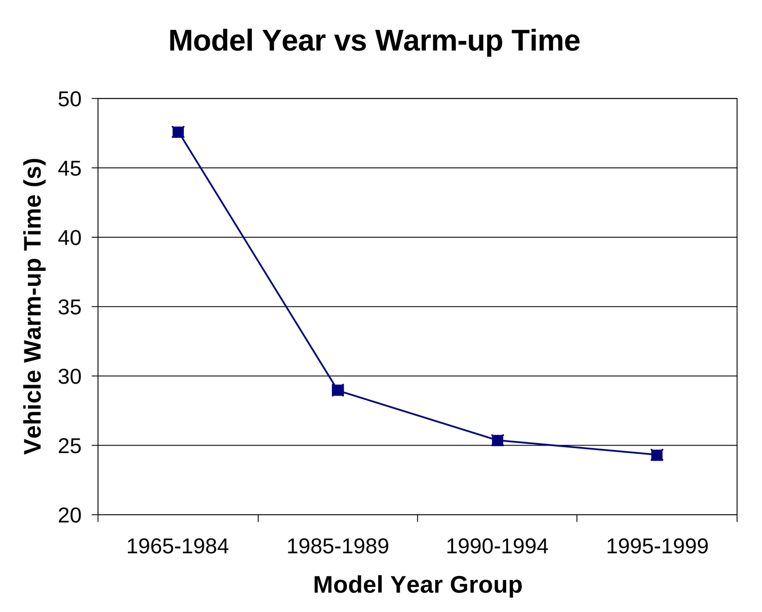
Analysis of CE-CERT FTP Data

•FTP vehicle data with MY 1965-1999 were obtained from Barth, *et al.* 2000.

•This FTP vehicle data were plotted as a function of time versus (CO/CO_2). The resulting graph was then used to determine 90% emissions recovery, i.e. the time it took for the vehicle emissions to return from the maximum to within 90%, for each vehicle in the data set. The time was then plotted against the age of the vehicle.

•Based on this data treatment, the average catalyst-light off time was less than 30 seconds.

•Vehicles produced after 1999 would be expected to display even shorter light-off times based on newer technology.



•The above graph is of the FTP data put into five year MY bins, with the exception of 1965-1984, comparing catalyst light-off times vs. MY. These data are in agreement with Younglove, *et al.* 1999, who state that "…light-off times were found to be decreasing with newer model years."

FLIR Thermovision A20V Infrared Camera

•Field of View: 25 °

•Spectral Range: 7.5-13 ì m

•Detector: Focal Point Array, Uncooled microbolometer

•Thermal Sensitivity: 90-120 mK at 25° C

References:

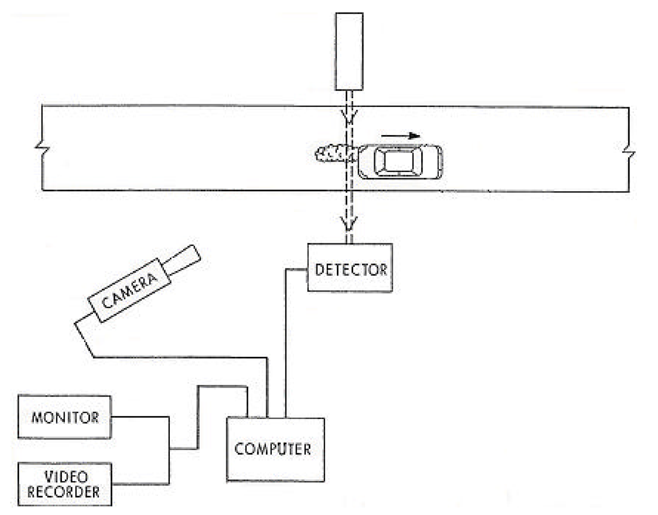
Younglove, T.; Levine, C.; Barth, M. J.;Scora, G.; Norbeck, J. M. In *Analysis of Catalyst Efficiency Differences Observed in an In-Use Light Duty Vehicle Test Fleet*, Proceedings of the CRC, San Diego, CA, April 19-21, 1999.

Barth, M.; AN, F.; Younglove, T.; Scora, G.; Levine,C.; Ross, M.; Wenzel, T. *Development of a Comprehensive Modal Emissions Model.* Final Report NCHRP Project 25-11, April, 2000.

Camera Setup

First the camera is set to a black and white color scale, with white being the hottest color; this is done because it is an intuitive color scheme and is easy for everyone to interpret. The camera is focused, set to the manual mode and is calibrated by holding down the SEL button on the top of the camera. This is done while aiming the camera at a known hot vehicle with the road surface in the FOV. For this setting we ensure that the hot exhaust system or underbody of the vehicle cannot be seen. The temperature scale is adjusted by changing the level and span scale on the camera in order to see small changes in reflected energy off the road surface. The level and scan can be likened to brightness and contrast respectively, which sets the scale of reflected energy between which the camera recognizes. While the above guidelines are specific to the FLIR A20V, other types of camera's should be set up similarly.

On-Road Setup with FEAT 3000 Unit



Regis High School

•An underclassmen parking lot, in which most of the vehicles had been sitting since the morning had been chosen.

•FEAT 3000 unit was set up across parking lot access road to measure the emissions of vehicles entering and leaving the lot. Most of the vehicle entering the lot should be hot, while those leaving the lot should be cold.

•332 vehicles were measured on two consecutive days.

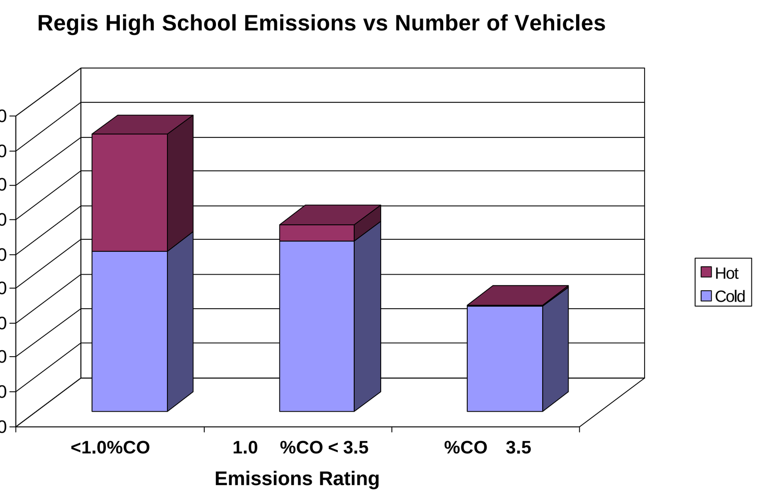
Analysis of Data

•Emissions data from the FEAT 3000 unit is extracted from computer, and the invalid vehicles removed.

•The video tape of recorded IR images are watched, and it is decided if the vehicle is hot or cold based on heat signatures that are emitted and reflected from the vehicle.

- •Bright reflections off road surface
- •Very hot tailpipes
- •Uniform heat emitted from tire treads.

•The vehicle is noted as either hot or cold in a spreadsheet.



This graph shows the number of vehicles that received a GOOD, FAIR, or POOR rating, as well as if the vehicle was a cold or hot vehicle. Only one vehicle received both a POOR rating and was a hot vehicle from both days of measuring vehicles at the high school.

	<1.0%CO	1.0 %CO < 3.5	%CO 3.5
Cold	93	99	61
Hot	68	10	1
Percent	48.5	32.8	18.7

Time: 09:29.16

%CO: 2.83

Time: 09:31.39

%CO: 2.07

Time: 09:34.27

%CO: 0.14

Time: 09:35.41

%CO: 0.19

•One vehicle from cold start to beyond catalyst light-off time. CO emissions are from 2.87% at cold start to 0.19% after warming up. Emissions of CO decrease with rising exhaust temperatures. In little over 5 minutes, this 1986 Chevy Celebrity (Blue) has warmed up enough to control its emissions.

Snow on Road Surfaces

•Snow is a mostly absorbing surface in the infrared, however liquid water is very reflective in the infrared.

•Breckenridge Ski Area patrol SUV had very little reflection on the snow covered parking lot surface.

•Tire treads are also cooled in the snow, and therefore are not emitting higher IR and appear to be cold, even if the vehicle had been driving around.

•Both of the vehicles in the IR images above are hot, however because snow does not reflect IR radiation, there is no reflection on the road from the underbody of the vehicles.

Conclusions

•An infrared camera can be used to differentiate between hot and cold cars on the road based on the thermal reflection that radiates from the underbody of automobiles.
•Cold cars will have the same IR reflection as the road, or only a slightly "brighter" reflection than the road. Hot vehicles will have a very intense, bright reflection off the road surface.
•When combined with a FEAT unit, vehicles can be correctly identified as gross emitters of pollution. Cold vehicles will be higher emitters, and previous to incorporating an infrared camera with a FEAT unit, these vehicles would be given a POOR rating.
•Snow is not a good surface for observing infrared images of vehicles because it is not very reflective, and also cools tires so that the heat being emitted from the tires cannot be seen in the IR.

Future Work

•Using the IR camera determine hot and cold vehicle signatures on hot road surfaces. (Las Vegas, May 2004)
•Software still need to be written in order to incorporate the infrared camera with the visual camera and the FEAT.

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