NDOT Research Report

Report No: RDT04-044

INVESTIGATION OF TEMPERATURE SEGREGATION IN THE STATE OF NEVADA

March 2004

Prepared by Research Division
Nevada Department of Transportation
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Carson City, Nevada 89712

NEVADA DOT

TECHNICAL REPORT DOCUMENTATION PAGE

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16. Abstract

This report details the results of an investigation of temperature segregation, performed by the Nevada Department of Transportation. An Infrared Camera was used to review paving operations across the state. The results are accompanied by IR Images.

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INTRODUCTION

In 2001, the Nevada Department of Transportation (NDOT) purchased an Infrared Camera for the purpose of analyzing roads constructed by the State for evidence of Temperature Segregation. Temperature segregation exists in a hot-mix asphalt pavement when a portion of the pavement mat is a different temperature than the rest of the mat. These portions can be large or small areas, or streaks in the uncompacted hot-mix asphalt. Temperature segregation may be caused by several specific paving practices, including but not limited to transport of the material and the lay down process. This type of segregation will have an adverse effect on the final hot-mix asphalt by causing differences in compaction and decreasing smoothness.

BACKGROUND

Studies performed by the State of Washington and others, using the infrared camera, have shown that temperature differentials in the hot-mix asphalt pavement during placement cause an adverse effect on the final pavement. These effects include non-uniform compaction, reduction of smoothness and early raveling due to high air void content. NDOT initiated a research project to determine if temperature segregation exists in the State of Nevada. This scope was reduced from the original scope. The original scope included identifying sources of segregation, developing specifications to eliminate segregation and constructing test section to measure the impact of the specifications changes. The scope was reduced to avoid overlap with other studies being performed by other Agencies. The cost and project time length was reduced accordingly.

FIELD RESEARCH

NDOT selected four projects to analyze with the infrared camera. The first project was Contract 3140 in Elko County. The scope of Contract 3140 was a one-inch coldmill with a two-inch dense-graded plantmix bituminous surface overlay and a three quarter-inch open-graded friction course. The total length of this project was twenty miles with an additional haul distance of approximately three miles on a gravel road from the hot plant to the nearest point of the project. In this contract, the Contractor was required to use a Material Transfer Vehicle (MTV). Included with this report are images taken from the paving operation. Images were analyzed to evaluate the performance of the Contractor's material transfer vehicle (MTV).

Images #1 through #4 were taken with the pick-up machine attached to the conveyor belt unit and the conveyor belt unit feeding into the insert in the hopper of the paver. Image #1 shows some end-of-load temperature segregation that was not entirely eliminated by the MTV. This temperature differential (19.3°F) is within limits adopted by other states. Image #2 shows a good mat with very little temperature differential. Image #3 shows the effects of stopping the paver. Regardless of the type of MTV, stopping the paver for any reason will cause a sudden change in the temperature of the mat, possibly affecting compaction and profile. Image #4 shows some end-of-load temperature segregation not entirely eliminated by the MTV followed by the introduction of a hotter load of material. Again, this change in temperatures of the mat may lead to problems with compaction and profile.

Images #5 through #11 were taken with the pick-up machine dumping directly into the insert in the hopper of the paver. This change was made to analyze the performance of the paving set-up without the conveyor belt unit in the operation. It was suggested by the contractor at an earlier field review of his equipment that this set up might generate the same results as with the conveyor belt unit in place. Image #5 shows end-of-load temperature segregation (28.7°F) that was not within the limits adopted by other states. Image #6 shows some areas of temperature segregation that were less severe, but illustrate the problems that may be eliminated by the proper use of a MTV. Image #7 shows the distinct change from a cold load of material to a hot load. This change may be made more gradual by the use of a MTV. Images #8 through #11 show transverse temperature differentials in the mat. Passing the material through a MTV might also eliminate these differentials.

Based on the images seen in the field and the images analyzed back in the Lab, the Materials Division recommended the use of all of the components of the material transfer vehicle provided by the contractor for the best protection against temperature segregation. The system without the conveyor belt unit did not protect against temperature segregation.

The second project was Contract 3127 in Clark County. The portion of Contract 3127 that was analyzed was construction of a new roadway with a five-inch dense-graded plantmix bituminous surface overlay and a three quarter-inch open-graded friction

course. The project was investigated during placement of the second lift of dense-grade. In this contract, the contractor was required to use a MTV.

Images #1 through #6 show a paving operation with minimal temperature segregation. The temperature differentials ranged from 10.7°F to 17.8°F. The MTV appeared to be functioning as intended. Image #1 shows a view of the mat behind the paver. White spots on the left and right sides of the screed were hand propane torches being used to heat the screed extensions. In the foreground of the picture, the marks from the roller can be seen, outlined by cooler lines on the mat. This cooling is normal as the roller compacts the plantmix. In the area outlined by the white line, an acceptable temperature differential of 14.8°F occurred across the mat. Images #2 through #5 show some streaking in the mat, most likely due to differential heating of the screed. The most common form of this streaking appears as a cold streak down the center of the mat, in the vicinity of the gear box, and a hot streak on either side, probably due to the main screed heaters. If the temperature of the mix is uniform and the screed heaters are not set too hot, this will not adversely affect the mat. Image #6 was taken near the paver, looking back at the breakdown roller. The color change and the line graph show the uniform cooling of the mat as expected.

Images #7 and #8 show two problems that cannot be solved with a MTV. Image #7 shows the result of a "hot" load of plantmix following a "cold" load of plantmix. When there is a delay in the delivery of the plantmix from the hot-plant, the truck that arrived before the delay may wait at the paver for an extended period of time. When a load of

plantmix arrives after the delay, even the MTV cannot blend the two different loads to prevent a temperature differential. This situation can be remedied by supplying a constant flow of plantmix to the paver. This may be accomplished by paving at a slower rate, the end result will be better compaction and a better profile. Image #8 shows the temperature result of stopping the paver. When the paver stops, not only does the screed settle into the mix, but also the paver insulating the mix underneath it causes a temperature differential. Then when the paver starts again, the screed will rise up until it settles to the proper height. This will also cause a problem with compaction and profile. This situation can be remedied by supplying a constant flow of plantmix to the paver.

Based on the images seen in the field and the images analyzed in the Lab, the Materials Division recommended the continued use of the Material Transfer Vehicle. The equipment seemed to be working as demonstrated in other studies.

The third project was Contract 3162 in Washoe County. The portion of Contract 3162 that was analyzed was the inlay of a one and one-half-inch stress relief layer, a three-inch dense-graded plantmix bituminous layer and a three-quarter inch open-graded friction course. The project was investigated during placement of the three-inch lift of dense-grade. In this contract, the contractor was **not** required to use a Material Transfer Vehicle (MTV).

Images #1 through #5 show temperature differentials ranging from 16.5°F to 92.4°F. These numbers may be compared to a limit found to be acceptable by the Washington

DOT of 25°F. This comparison would reveal that, if a similar specification were implemented in Nevada, the current paving operation would not satisfy specifications.

Images #6 through #12 show uneven, blotchy mats behind the paver. These areas of temperature differential may be due to several causes. The cooling of the plantmix in the delivery truck will form a "crust" on the load of mix. As the mix is windrowed on the roadway, this cooler mix will stay relatively grouped together through the paver and become evident in the mat behind the paver. Another cause of cooler spots in the images may be dumping the wings of the paver and "broadcasting" or throwing shovels full of plantmix out across the mat behind the paver. These areas of cooler plantmix will affect compaction and profile as described above.

The fourth project was Contract 3164 in Churchill County. The portion of Contract 3164 that was analyzed was a two-inch dense-graded plantmix bituminous overlay and a three-quarter inch open-graded friction course. The project was investigated during placement of the two-inch lift of dense-grade. In this contract, the contractor was required to use a Material Transfer Vehicle (MTV). This particular paving operation included a Roadtec Shuttle Buggy, SB-2500. The results of the investigation of this project revealed two facts. One, the material transfer vehicle was operating effectively. The mat behind the paver was relatively uniform in temperature. Two, the only problem with this paving operation was the regular interval at which the paver had to be stopped. This stopping of the paver resulted in temperature differentials across the mat. These differentials may cause "bumps" in the surface that may require profile grinding after compaction is

complete. This project was evidence that the use of a material transfer vehicle is only one part of a good paving operation.

CONCLUSIONS AND RECOMMENDATIONS

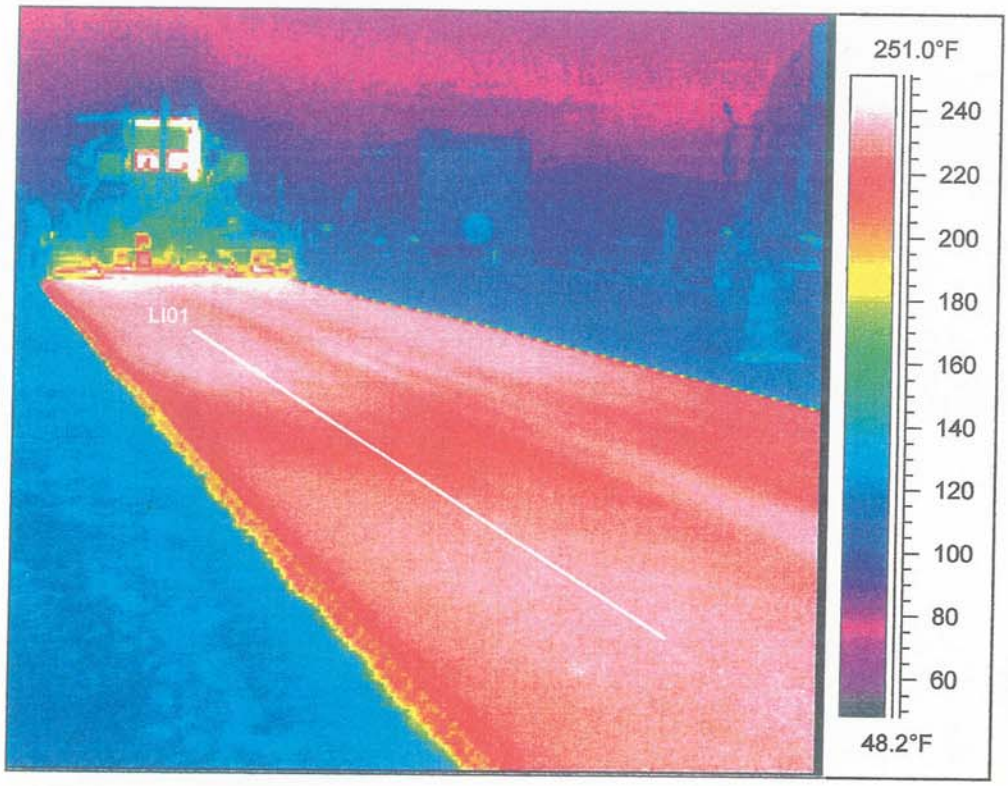
The results of this investigation have shown that temperature segregation does exist on plantmix paving projects in Nevada. The results also show that when used properly, the materials transfer vehicle is an effective tool for prevention of temperature segregation. Problems with transport and delivery of plantmix bituminous material can be remedied by the use of the MTV. In addition to the use of a MTV, this investigation revealed that good paving practices also have a beneficial effect on the paving process. As noted in more than one case, supplying a constant flow of plantmix to the paver and not starting and stopping the paver will also aid in obtaining a better-compacted plantmix surface.

It is recommended that NDOT continue to use the infrared camera on projects without a MTV, to identify sources of temperature segregation. Once sources are identified, appropriate specification changes can be made. It is also recommended that NDOT monitor low volume projects for sources of temperature segregation in the other types of plantmix gradations.

As referred to several times in this report, the State of Washington has implemented a specification limiting the magnitude of the temperature differential behind the paver. This limit is currently 25° F. If a specification for the State of Nevada were implemented, a similar temperature would seem to be appropriate. If NDOT implements a

specification based on maximum temperature differential, a measuring device for acceptance would have to be purchased and calibrated against the infrared camera.

NDOT Materials Division
Temperature Segregation Report
Contract 3140
May 29, 2003
Image #1



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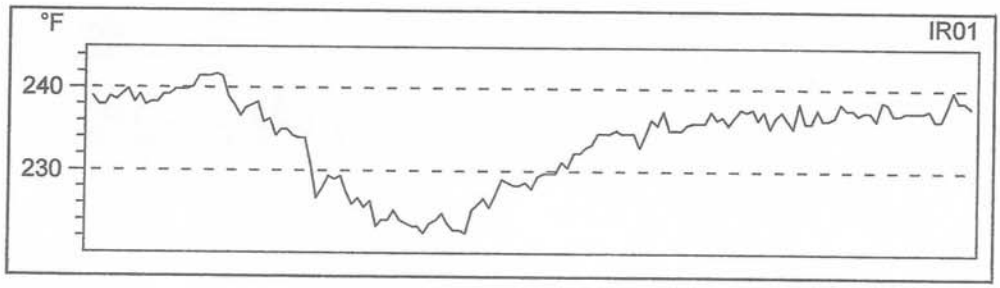
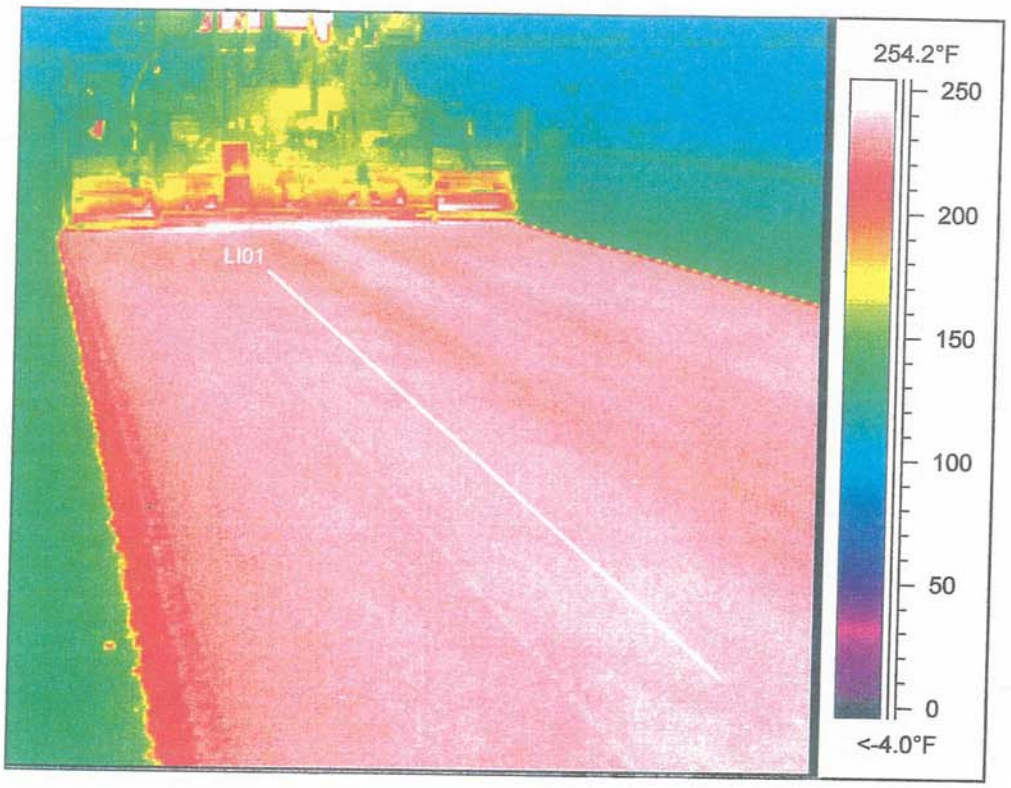
LI01 : min	222.4°F
LI01 : max-min	19.3°F



NDOT Materials Division
Temperature Segregation Report
Contract 3140
May 29, 2003
Image #2



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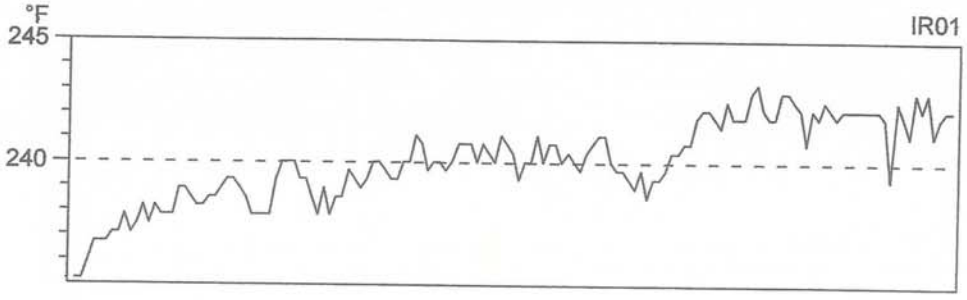
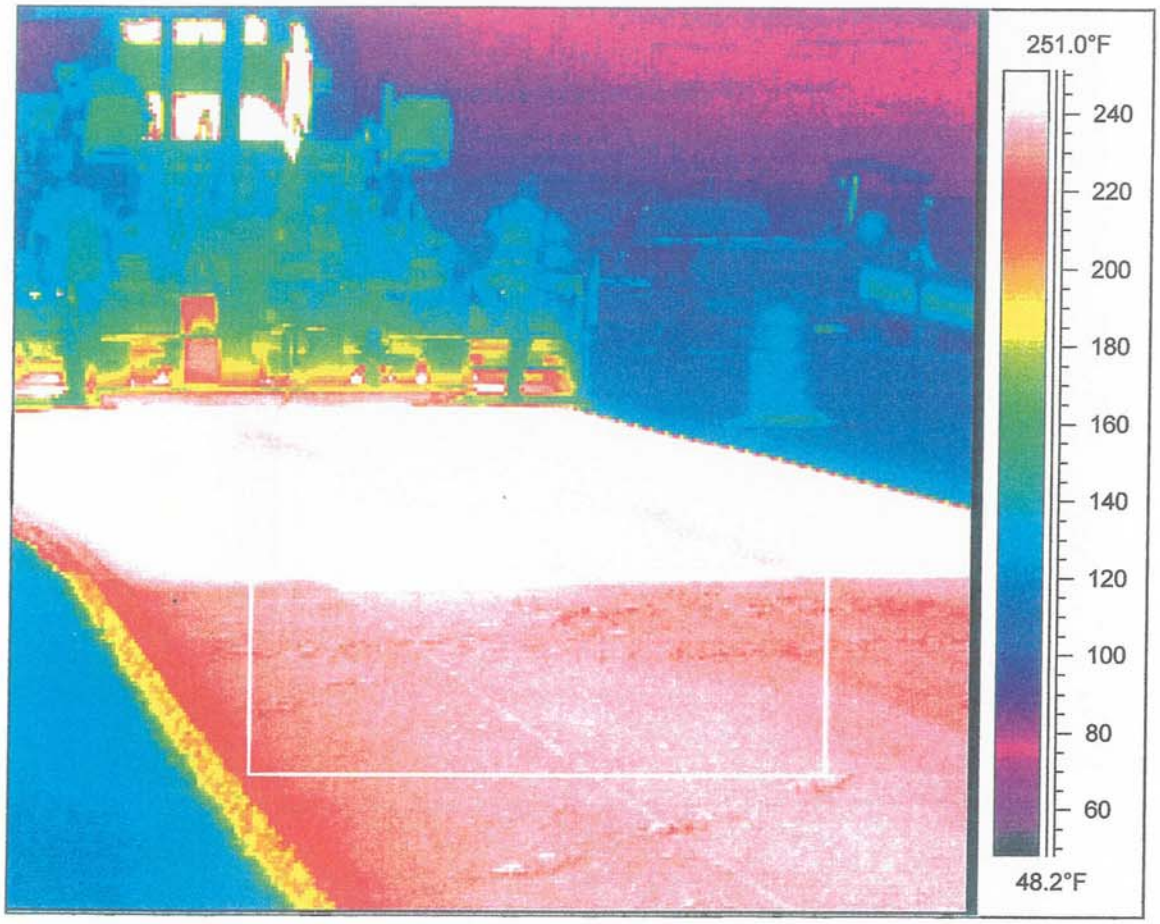
LI01 : max-min	8.0°F



NDOT Materials Division
Temperature Segregation Report
Contract 3140
May 29, 2003
Image #3



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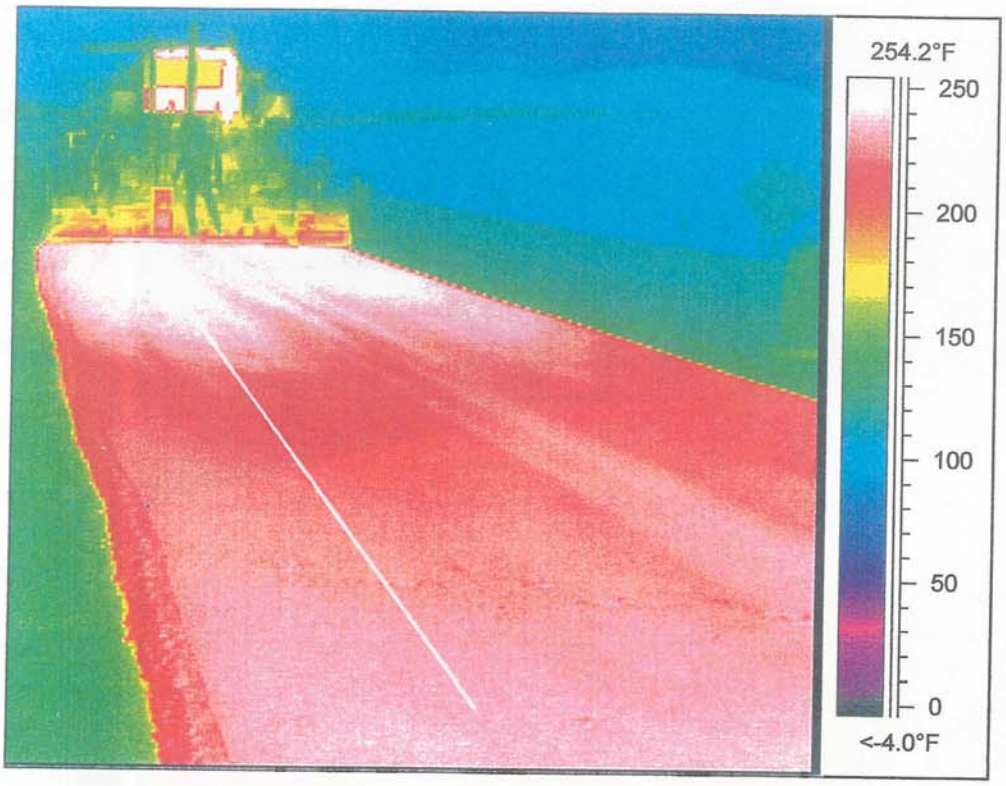
AR01 : min	211.4°F
AR01 : max-min	>39.6°F

NDOT Materials Division
Temperature Segregation Report
Contract 3140
May 29, 2003
Image #4



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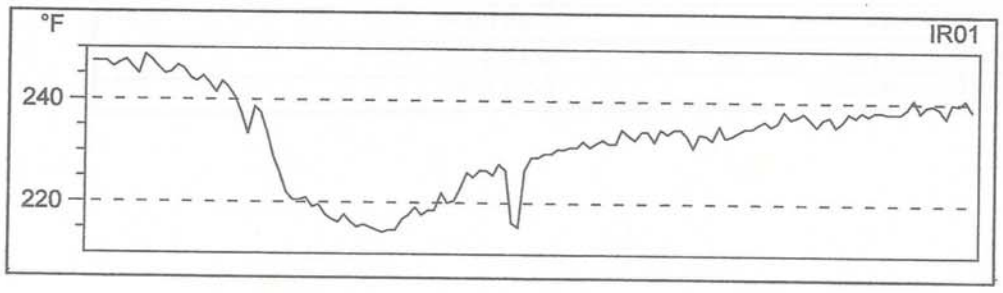
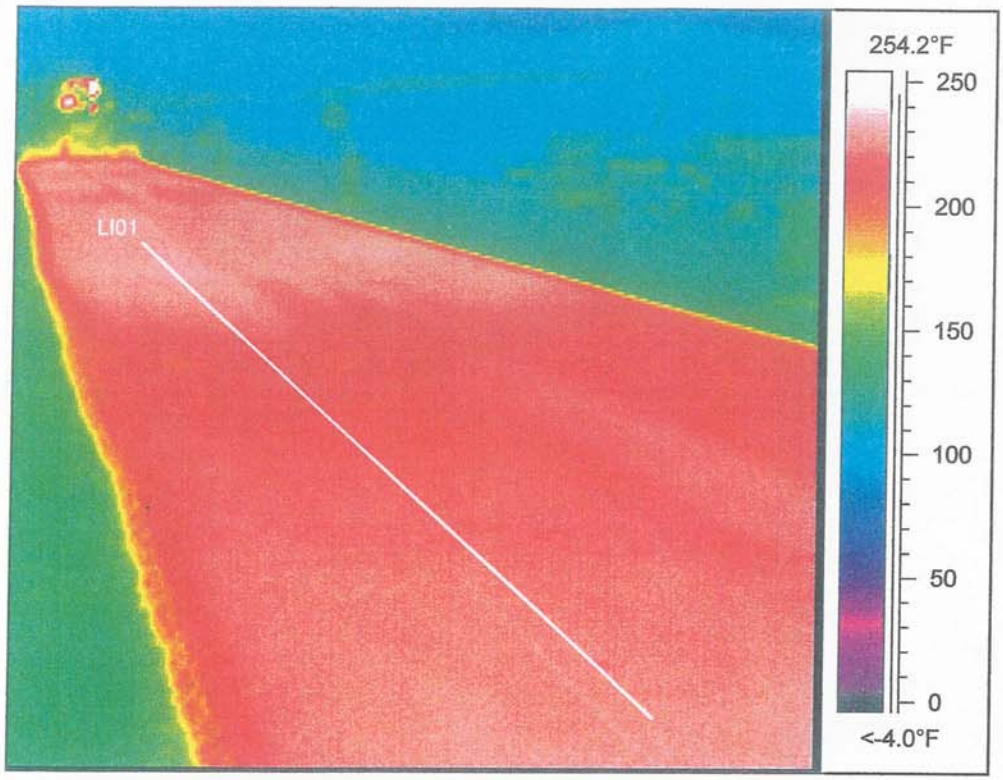


NDOT Materials Division
Temperature Segregation Report
Contract 3140
May 29, 2003
Image #5



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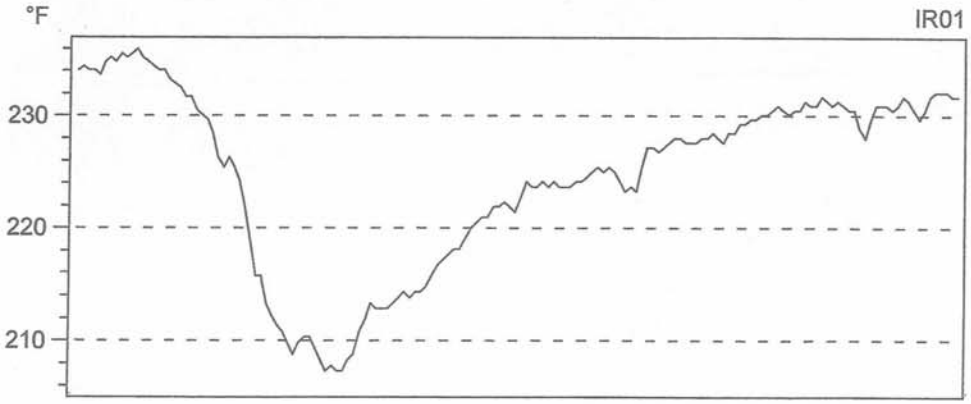
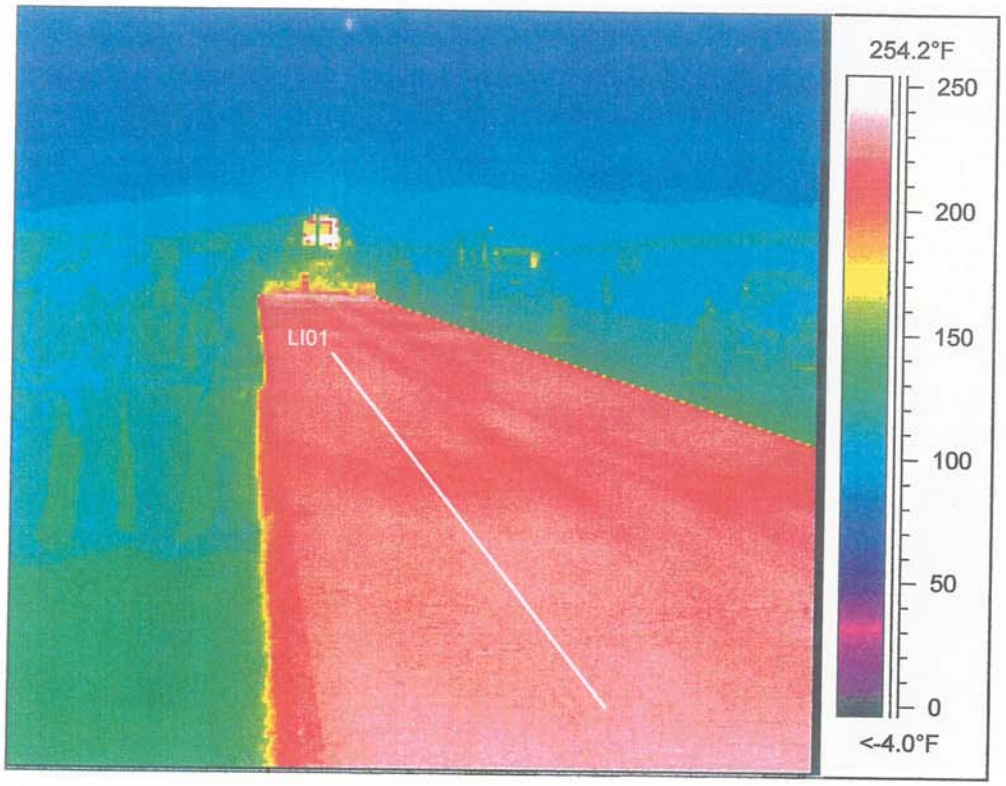


NDOT Materials Division
Temperature Segregation Report
Contract 3140
May 29, 2003
Image #6



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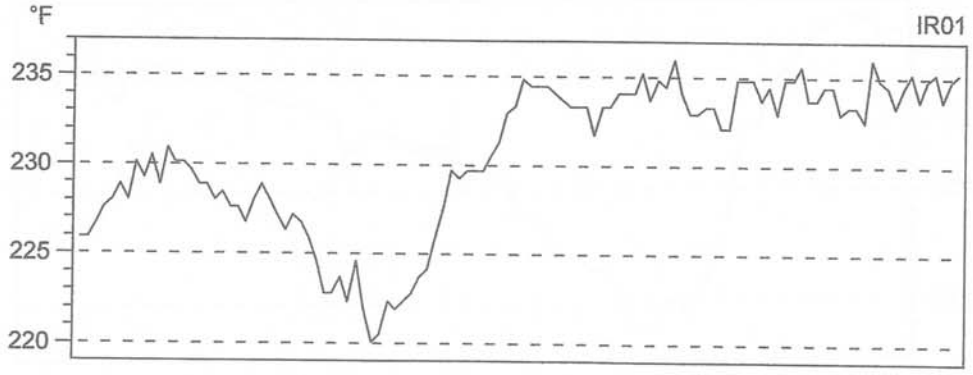
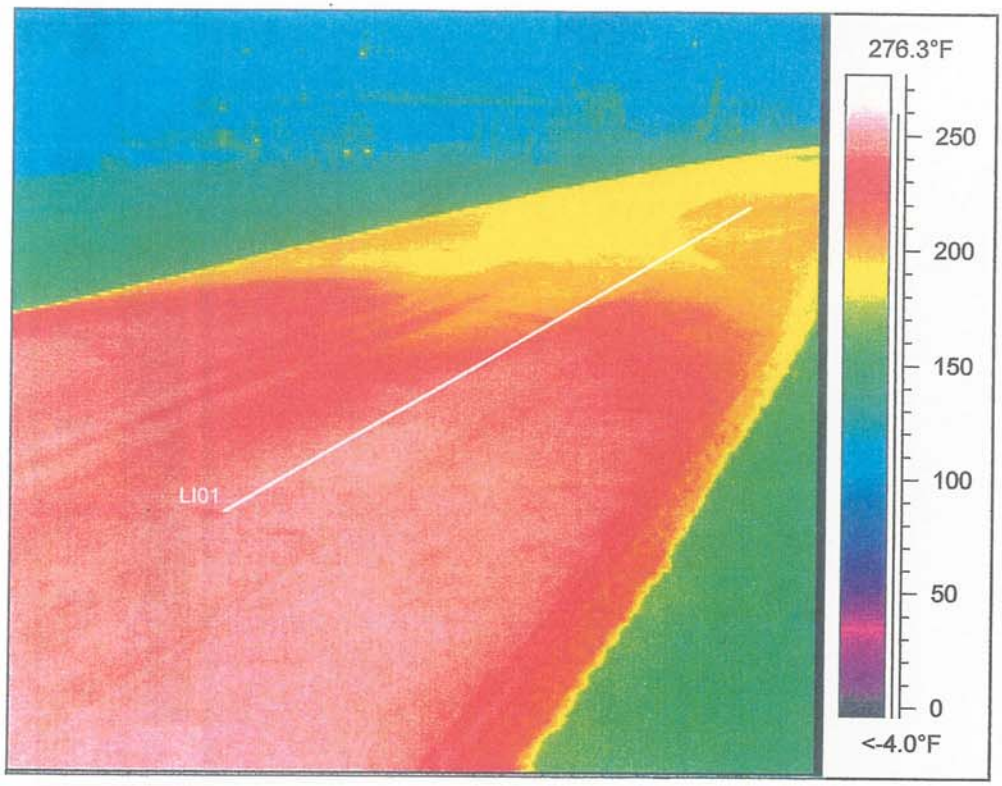
LI01 : min	220.0°F
LI01 : max-min	15.9°F



NDOT Materials Division
Temperature Segregation Report
Contract 3140
May 29, 2003
Image #7



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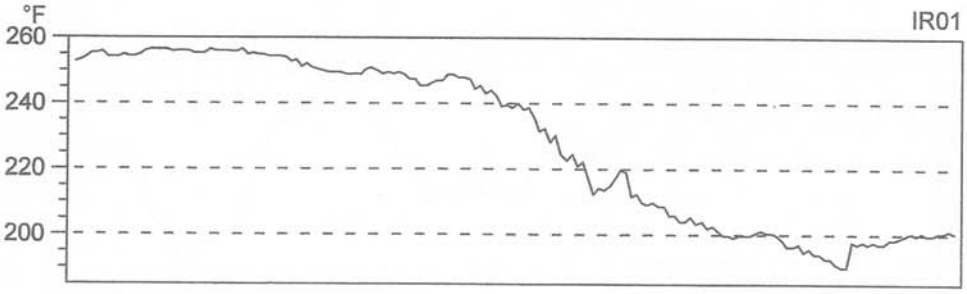
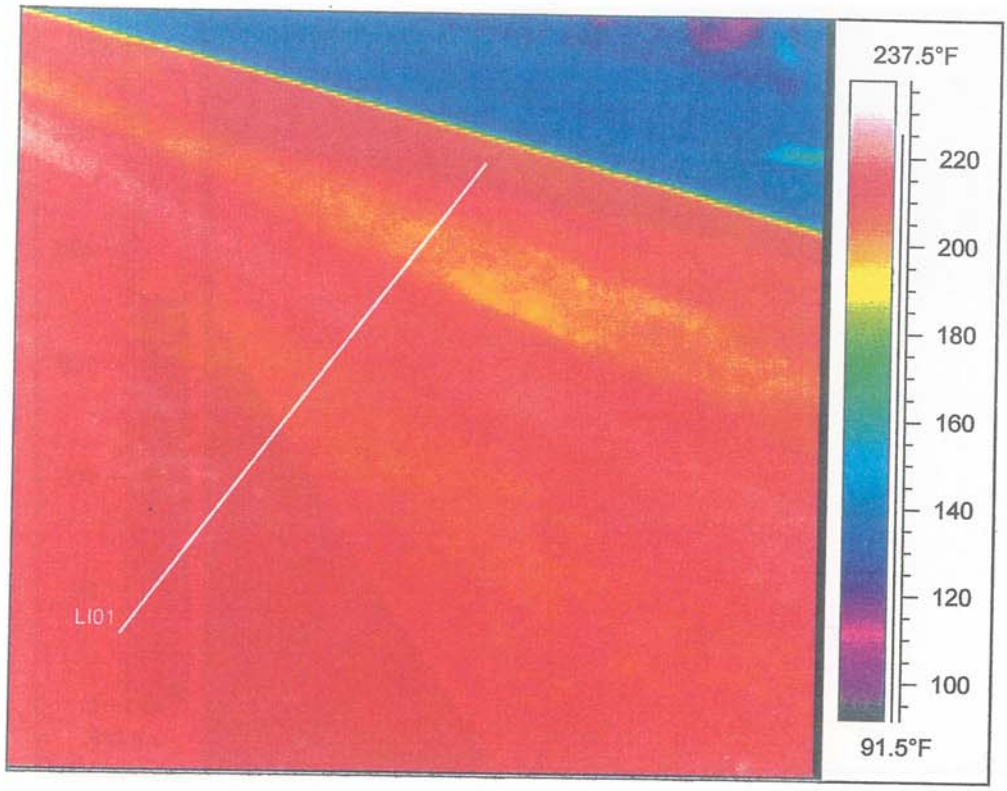
LI01 : min	190.2°F
LI01 : max-min	66.3°F



NDOT Materials Division
Temperature Segregation Report
Contract 3140
May 29, 2003
Image #8



Label	Value
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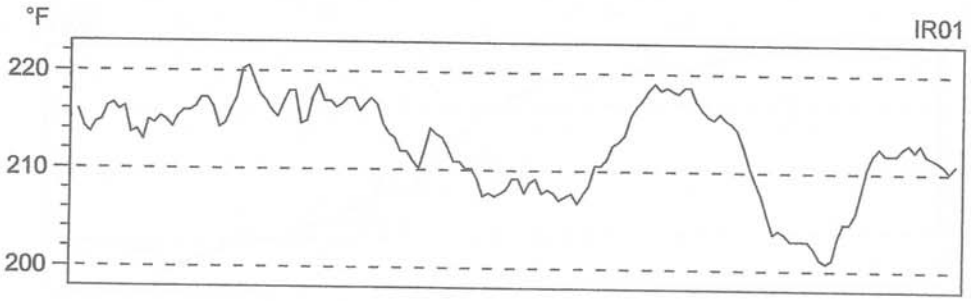
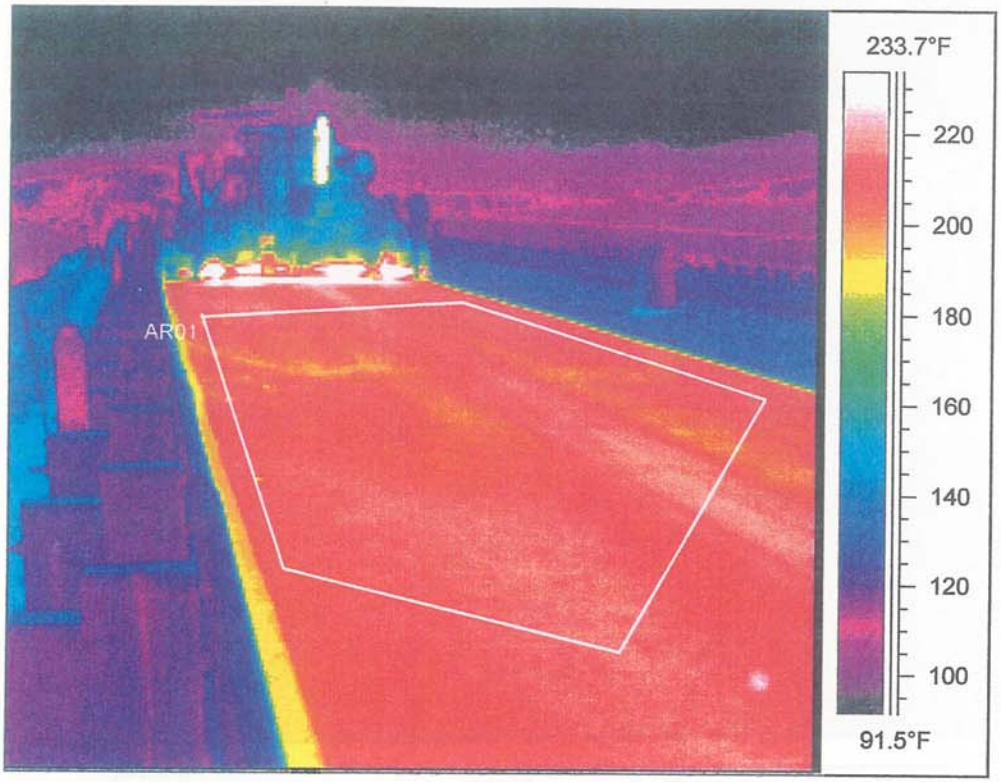
LI01 : min	200.8°F
LI01 : max-min	19.8°F

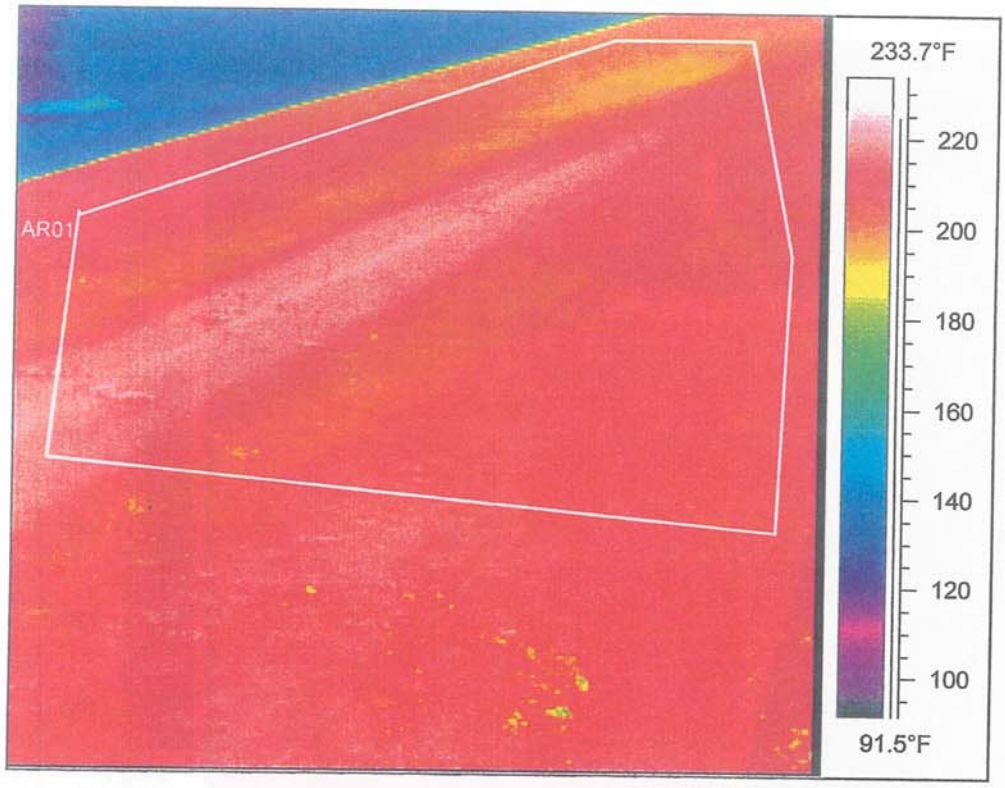


NDOT Materials Division
Temperature Segregation Report
Contract 3140
May 29, 2003
Image #9



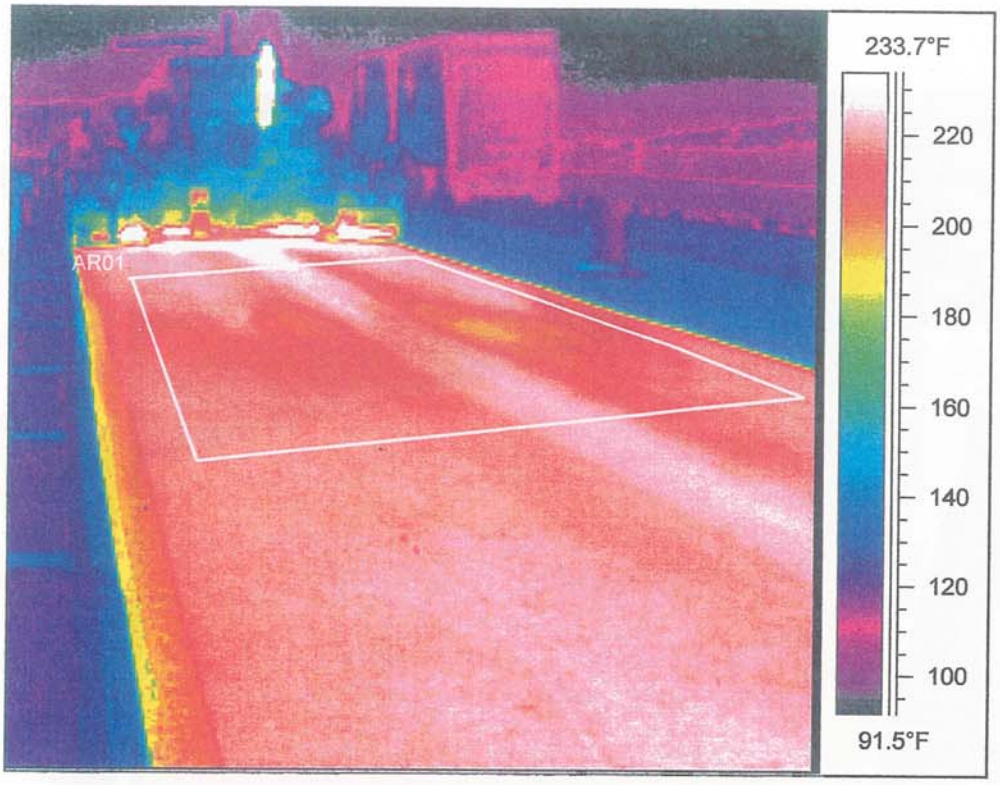
Label	Value
AR01 : max	223.4°F
AR01 : min	191.7°F
AR01 : max-min	31.7°F

NDOT Materials Division
Temperature Segregation Report
Contract 3140
May 29, 2003
Image #10



Label	Value
AR01 : max	226.8°F
AR01 : min	190.0°F
AR01 : max-min	36.8°F

NDOT Materials Division
Temperature Segregation Report
Contract 3140
May 29, 2003
Image #11



Label	Value
AR01 : max	229.8°F
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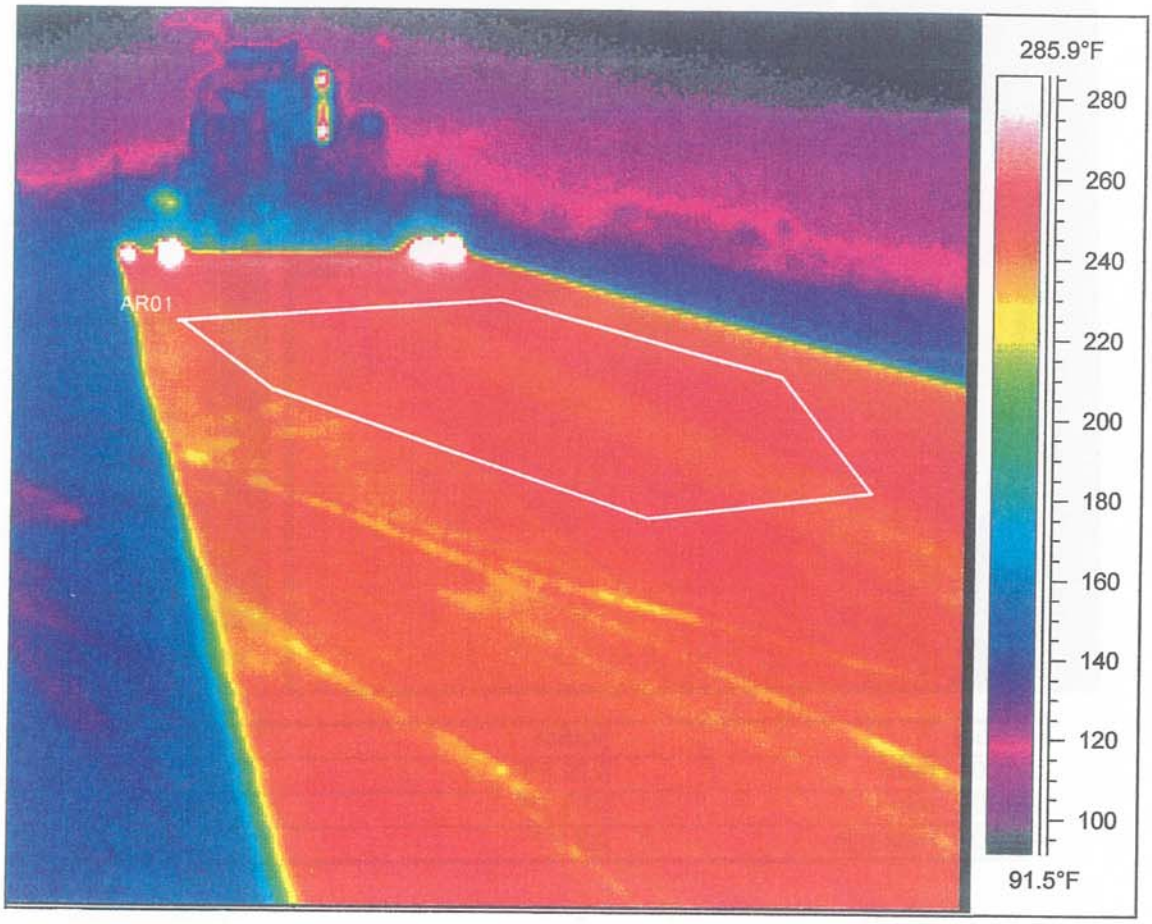
AR01 : max-min	33.1°F

NDOT Materials Division
Temperature Segregation Report
Contract 3127
September 12, 2003
Image #1



Label	Value
AR01 : max	255.6°F
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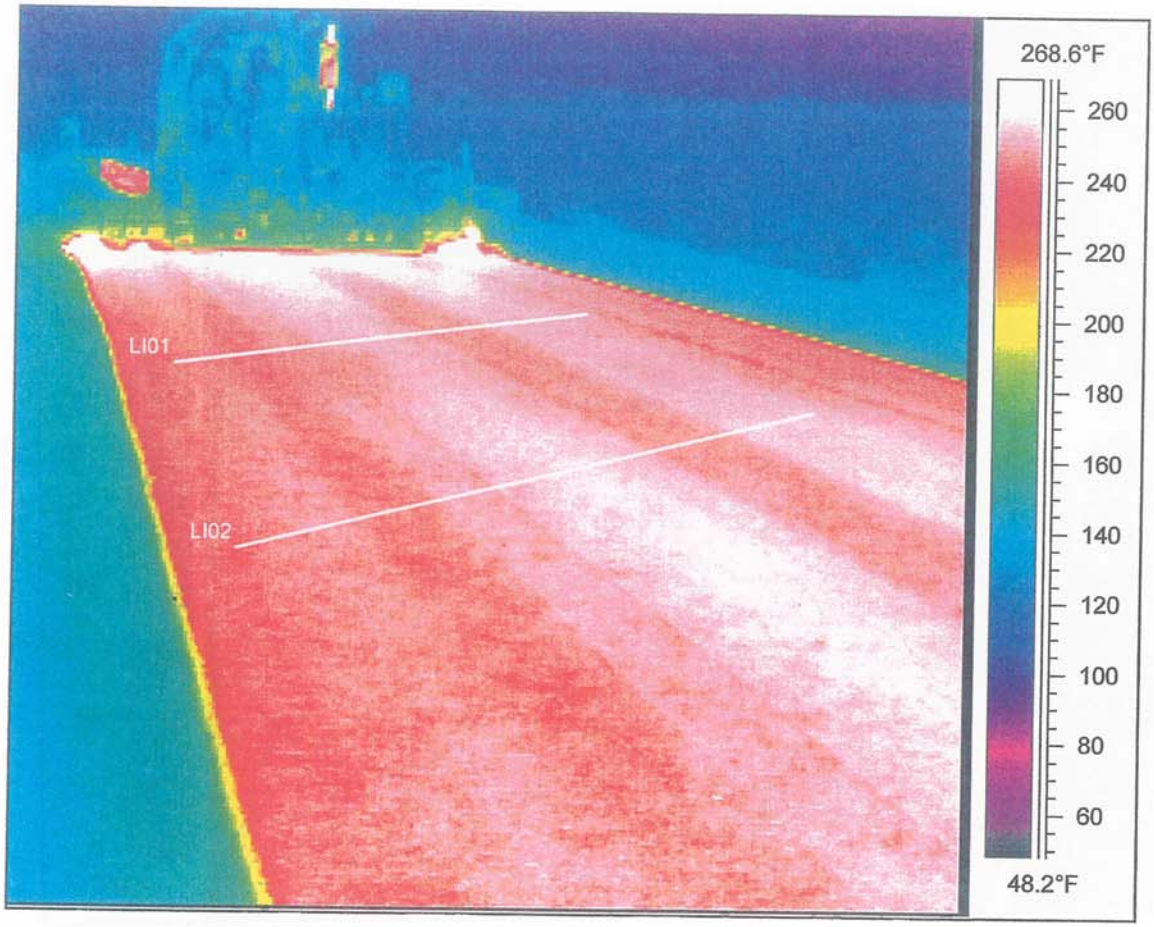
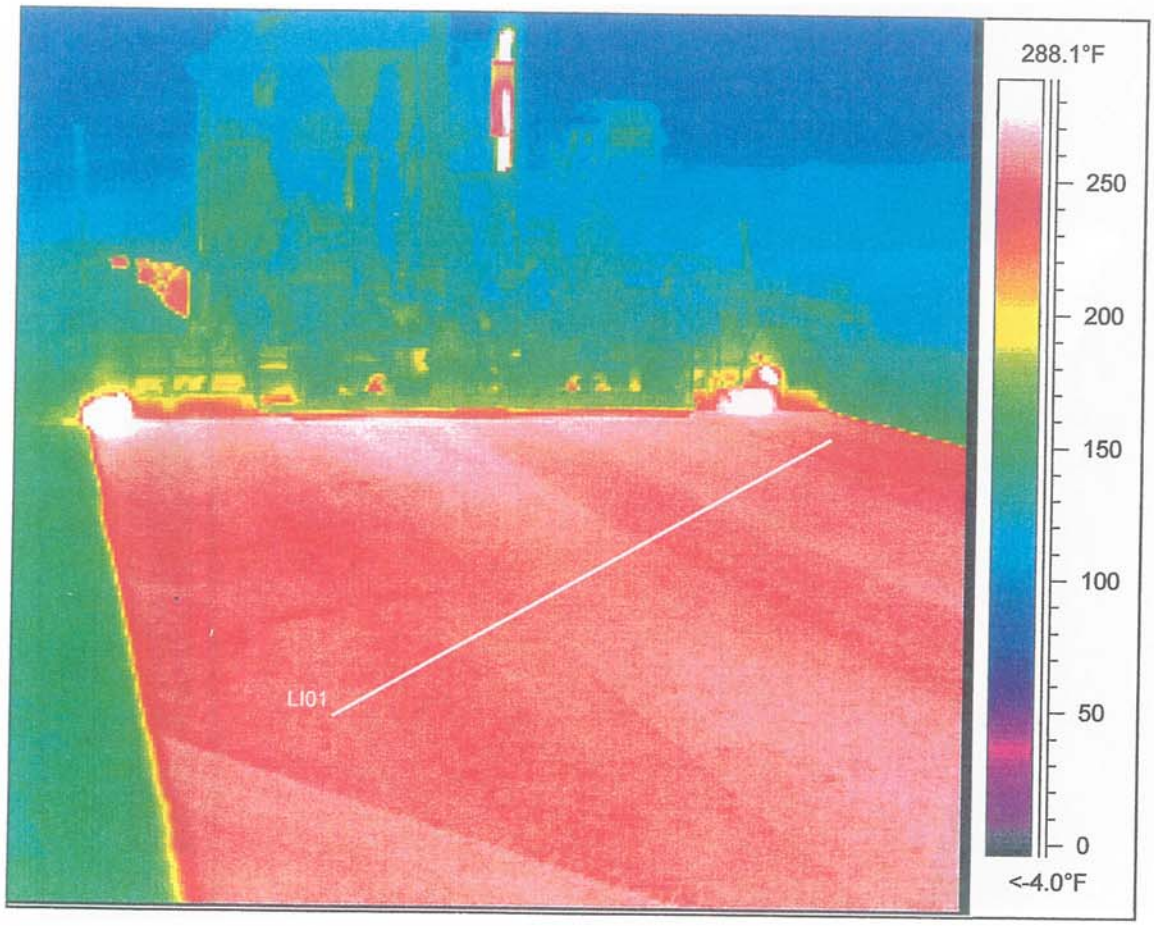
NDOT Materials Division
Temperature Segregation Report
Contract 3127
September 12, 2003
Image #2



Label	Value
LI01 : max	256.3°F
LI01 : min	244.6°F
LI01 : max-min	11.7°F
LI02 : max	260.0°F
LI02 : min	242.3°F
LI02 : max-min	17.8°F

NDOT Materials Division
Temperature Segregation Report
Contract 3127
September 12, 2003
Image #3



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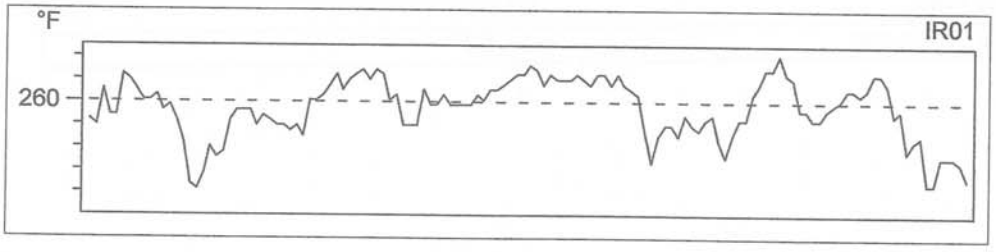
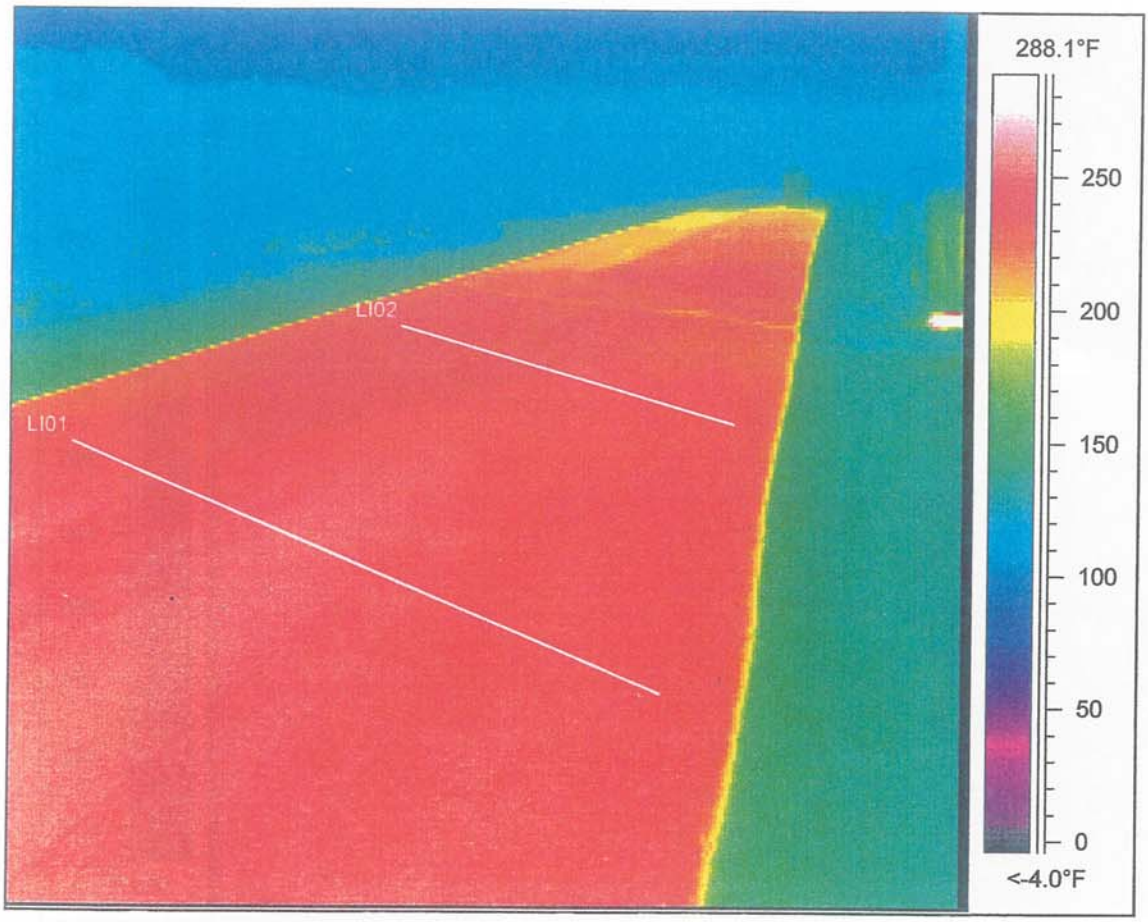
LI01 : max-min	11.9°F



NDOT Materials Division
Temperature Segregation Report
Contract 3127
September 12, 2003
Image #4



Label	Value
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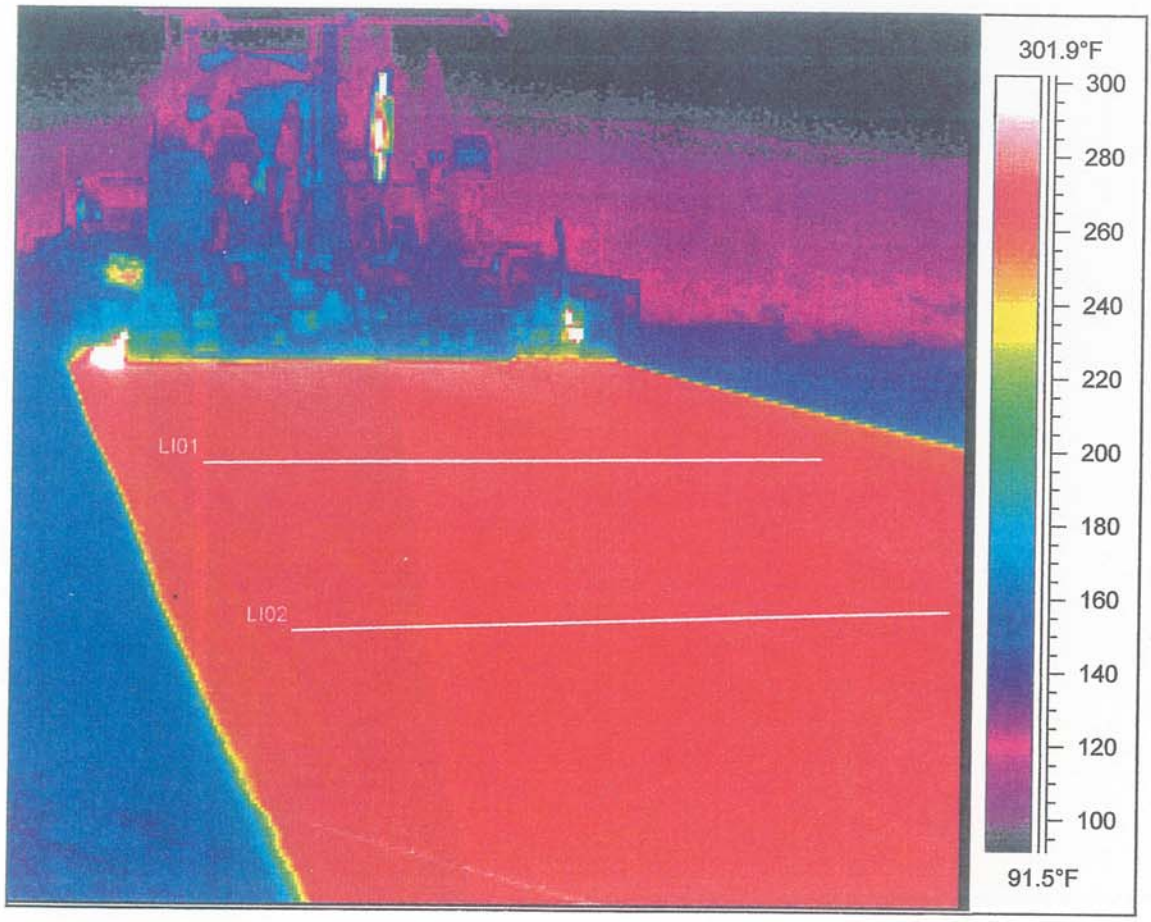
LI01 : min	242.7°F
LI01 : max-min	16.1°F
LI02 : max	245.3°F
LI02 : min	234.5°F
LI02 : max-min	10.8°F

NDOT Materials Division
Temperature Segregation Report
Contract 3127
September 12, 2003
Image #5



Label	Value
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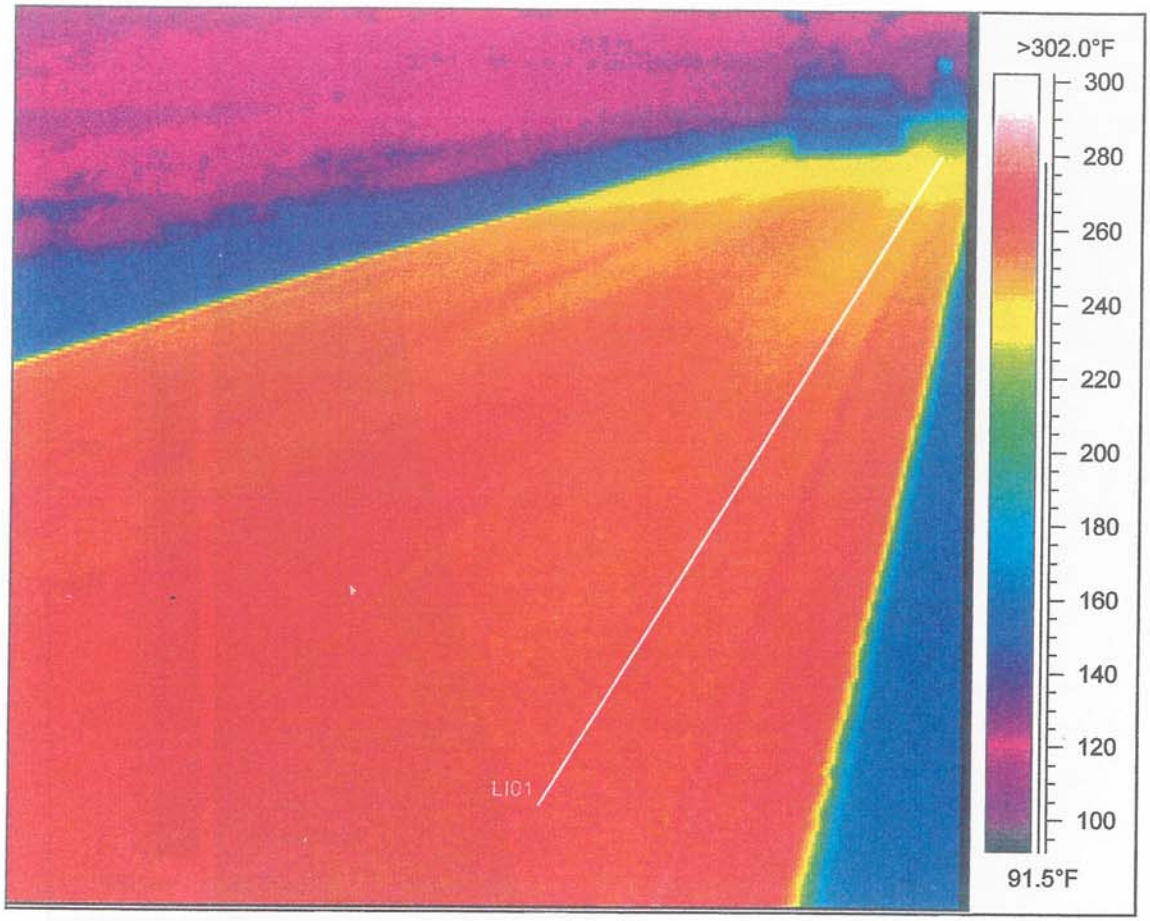
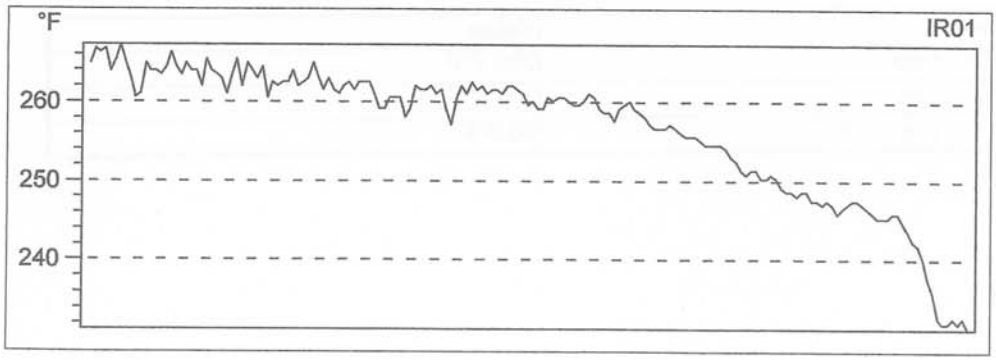
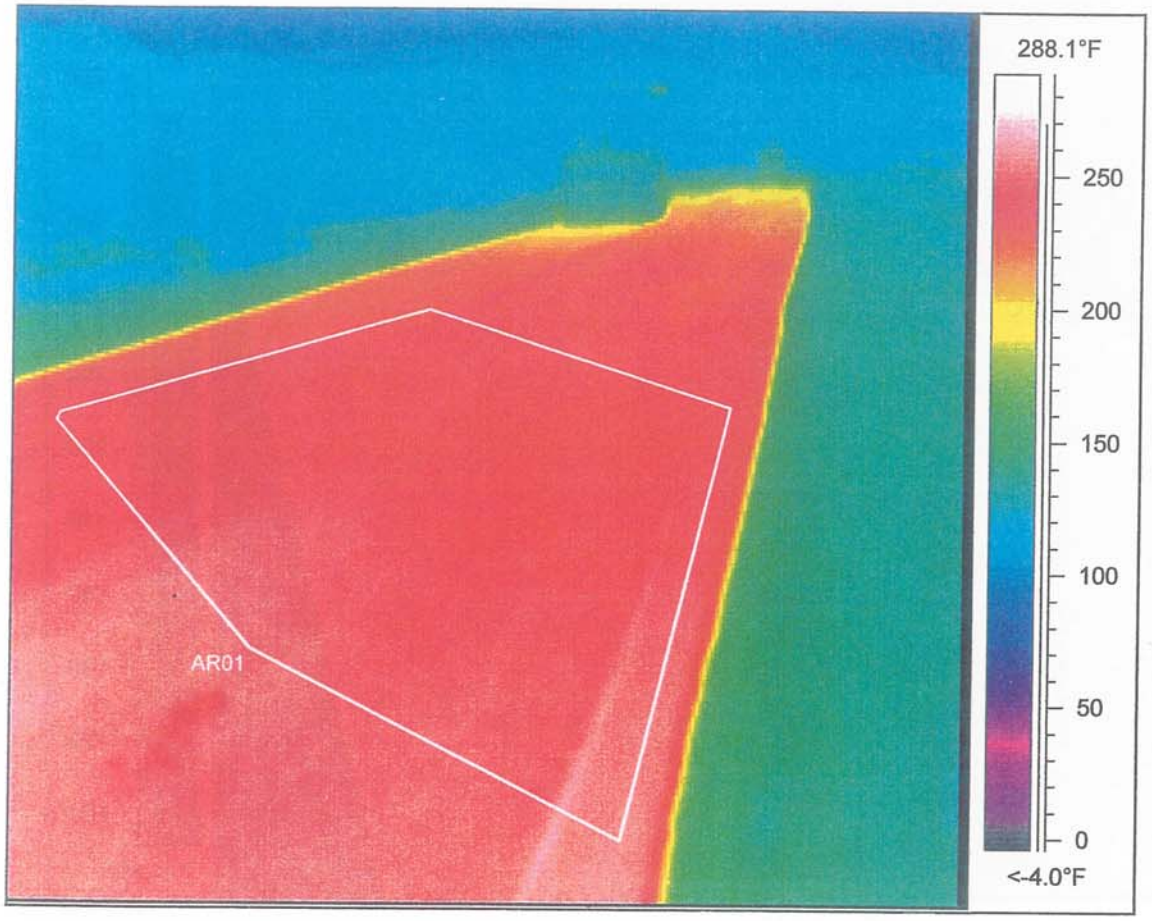
LI01 : min	264.0°F
LI01 : max-min	10.7°F
LI02 : max	274.7°F
LI02 : min	261.1°F
LI02 : max-min	13.6°F

NDOT Materials Division
Temperature Segregation Report
Contract 3127
September 12, 2003
Image #6





NDOT Materials Division
Temperature Segregation Report
Contract 3127
September 12, 2003
Image #7



Label	Value
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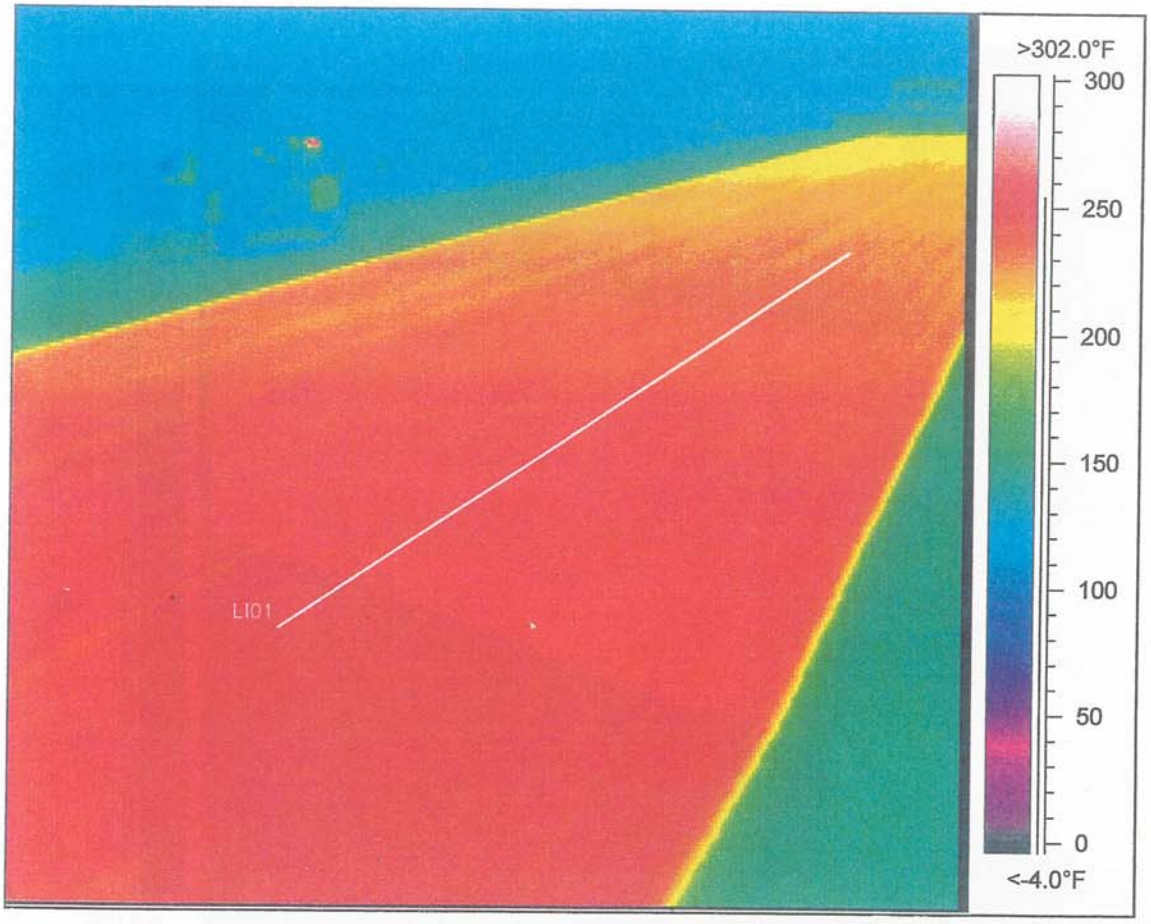
AR01 : min	232.1°F
AR01 : max-min	36.6°F

NDOT Materials Division
Temperature Segregation Report
Contract 3127
September 12, 2003
Image #8



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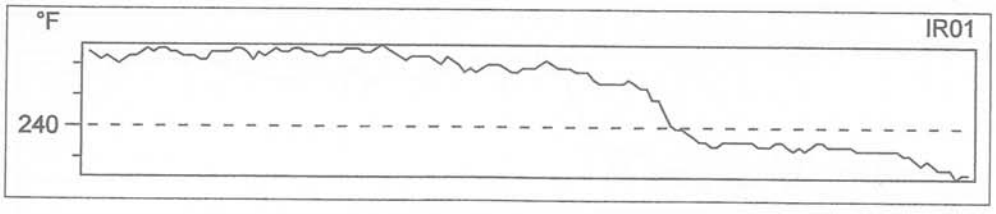
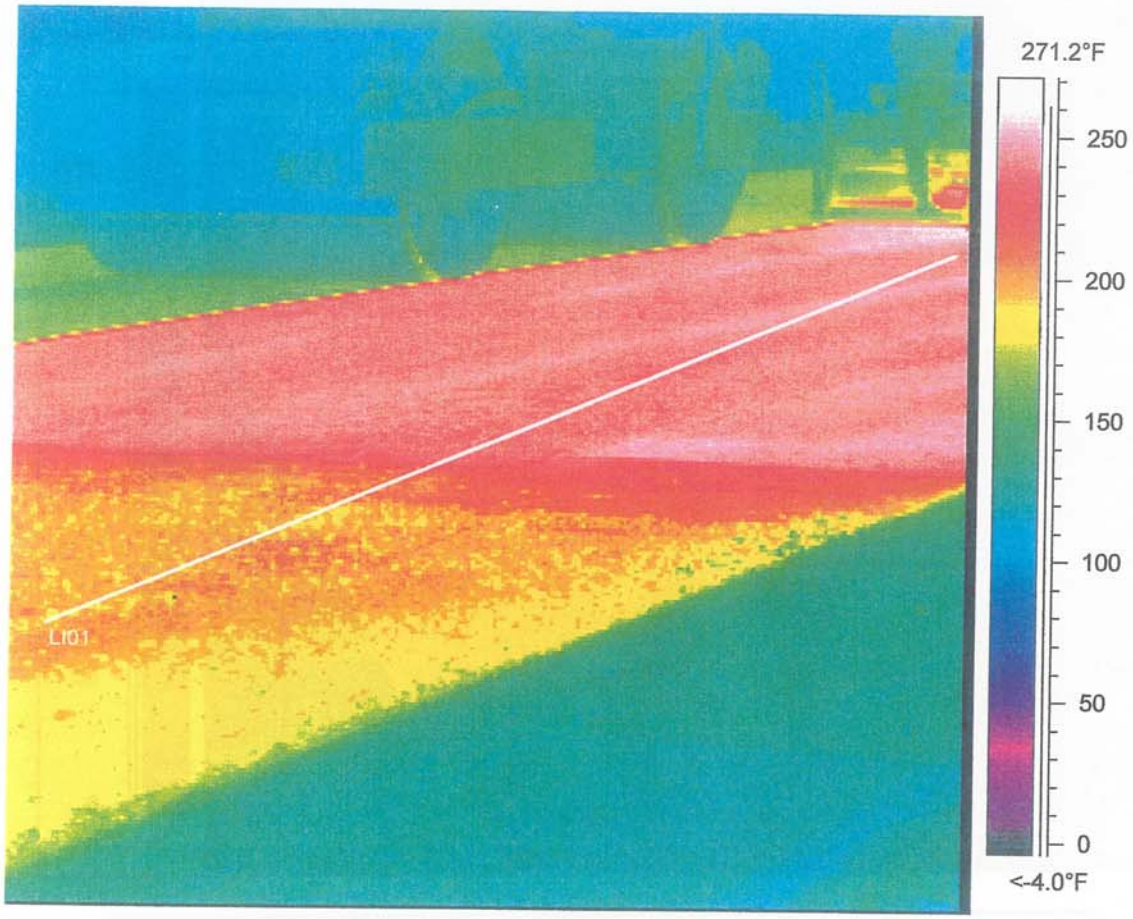
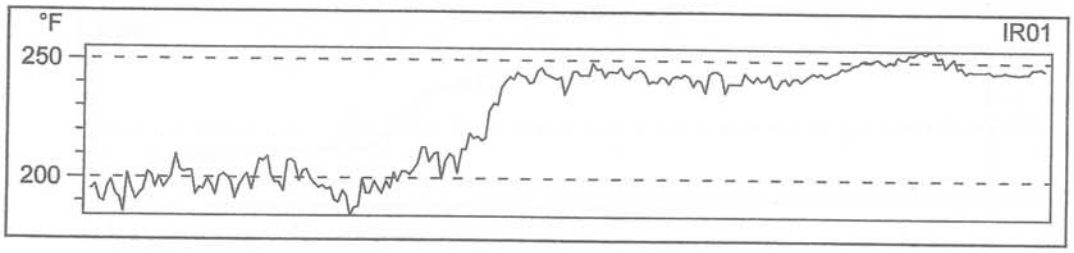
LI01 : min	231.9°F
LI01 : max-min	21.3°F



NDOT Materials Division
Temperature Segregation Report
Contract 3162
September 30, 2003
Image #1



Label	Value
LI01 : max	254.7°F
LI01 : min	184.0°F
LI01 : max-min	70.7°F



NDOT Materials Division
Temperature Segregation Report
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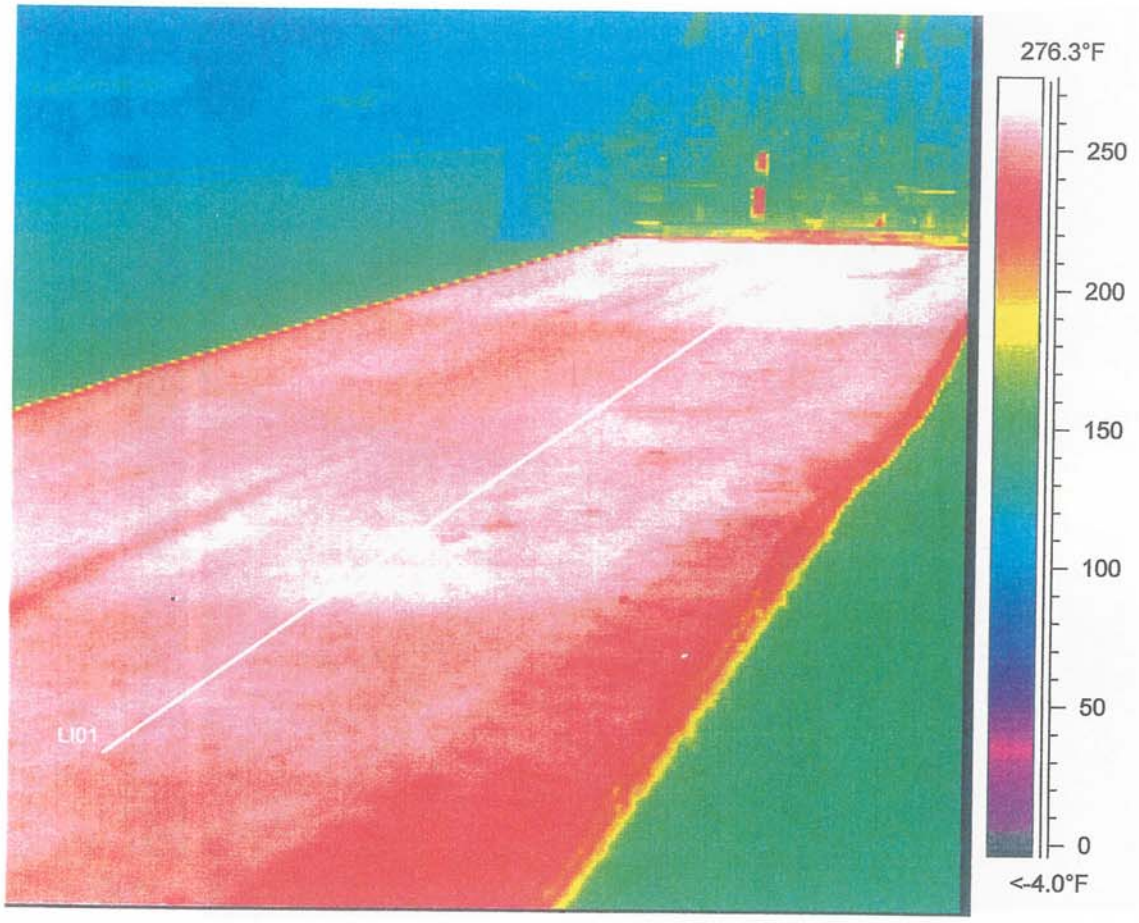
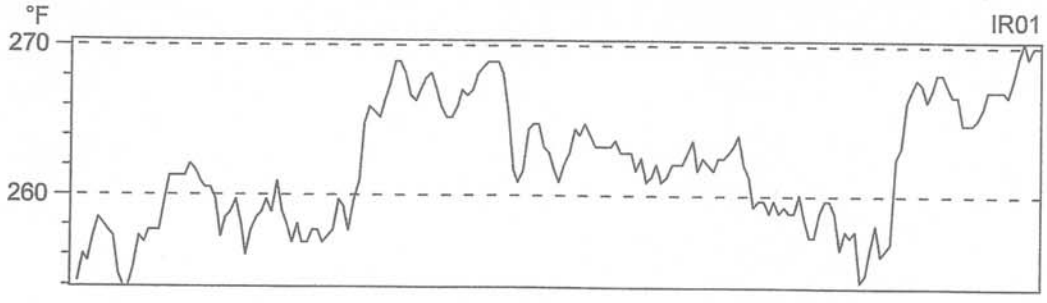
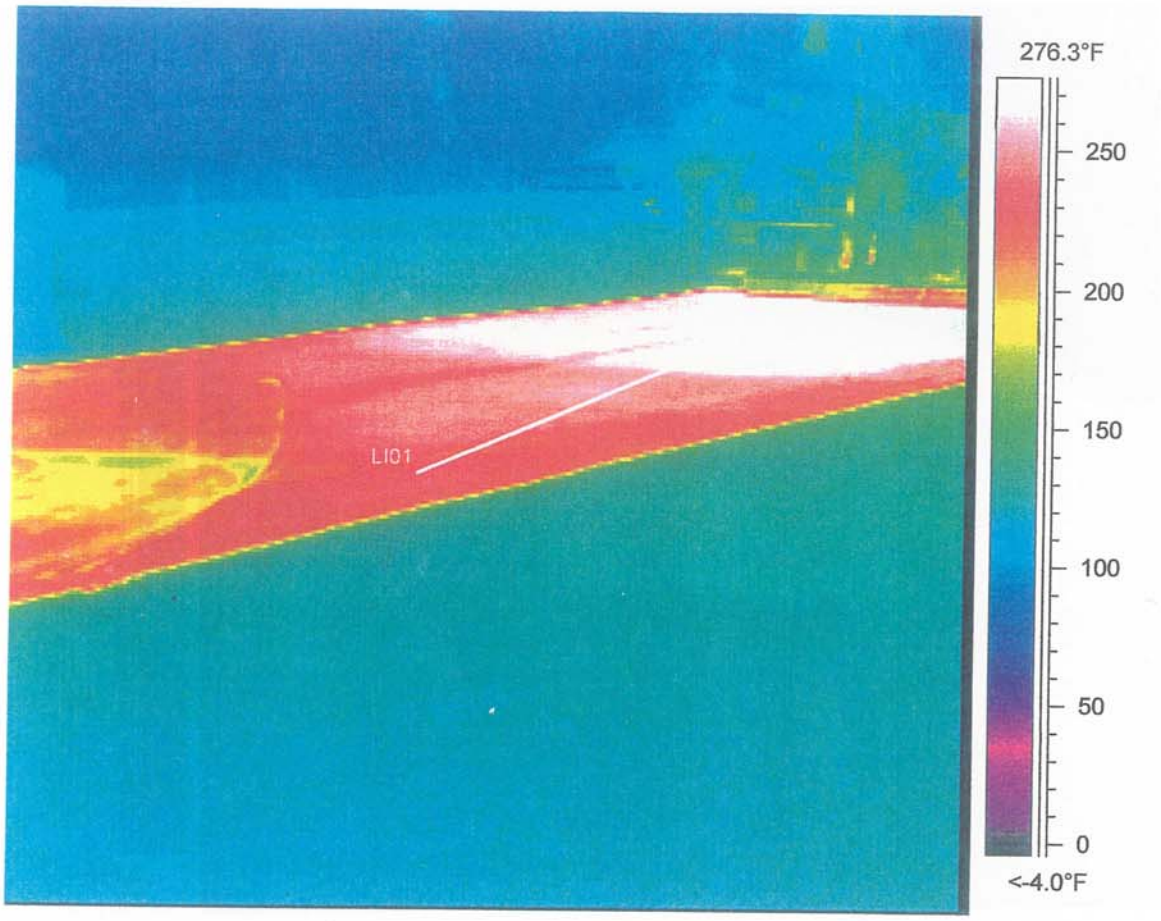
September 30, 2003
Image #2



Label	Value
LI01 : max	270.4°F
LI01 : min	253.9°F
LI01 : max-min	16.5°F



NDOT Materials Division
Temperature Segregation Report
Contract 3162
September 30, 2003
Image #3



Label	Value
LI01 : max	275.3°F
LI01 : min	218.1°F
LI01 : max-min	57.2°F

NDOT Materials Division
Temperature Segregation Report
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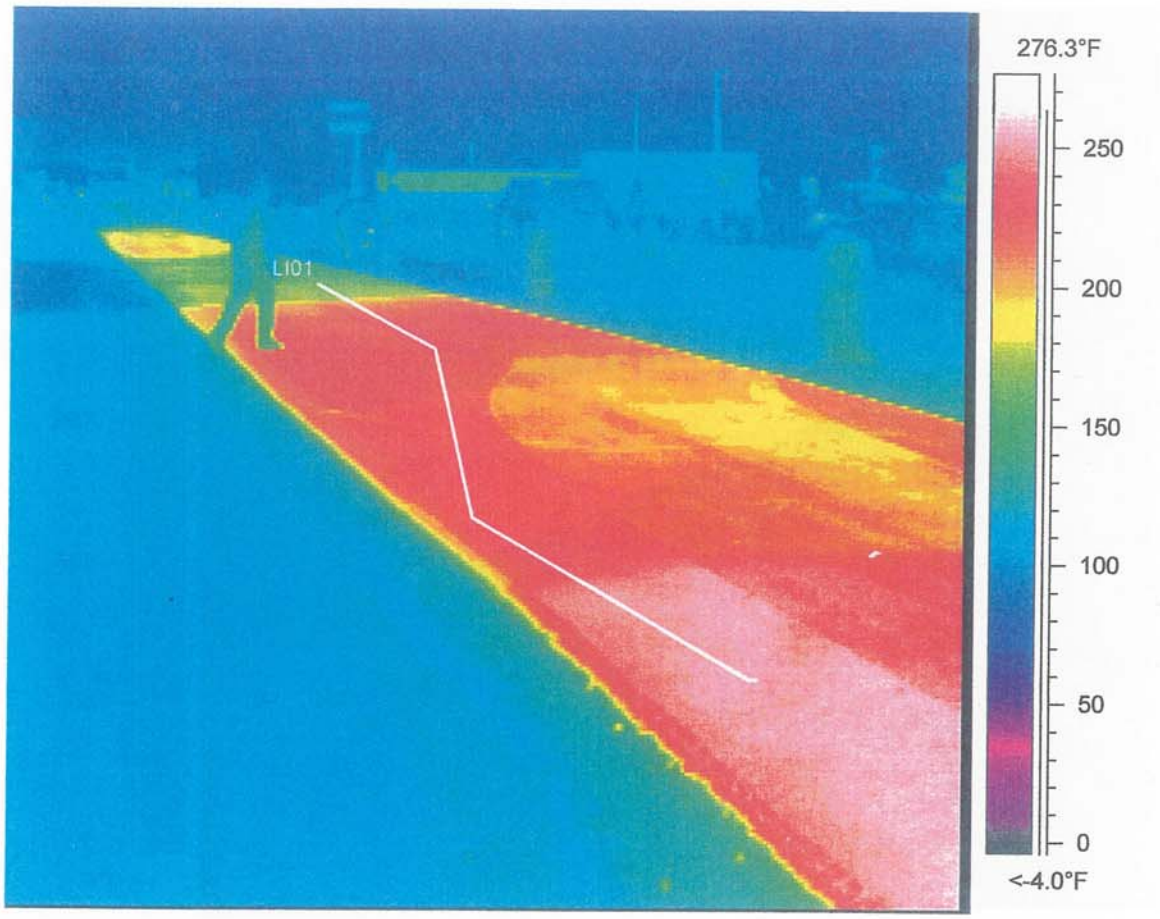
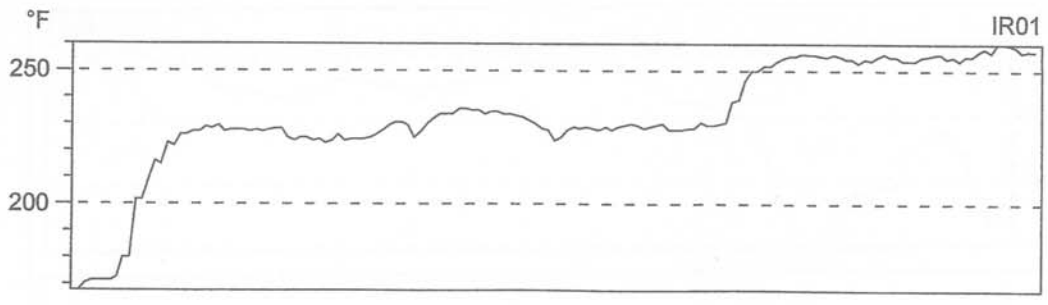
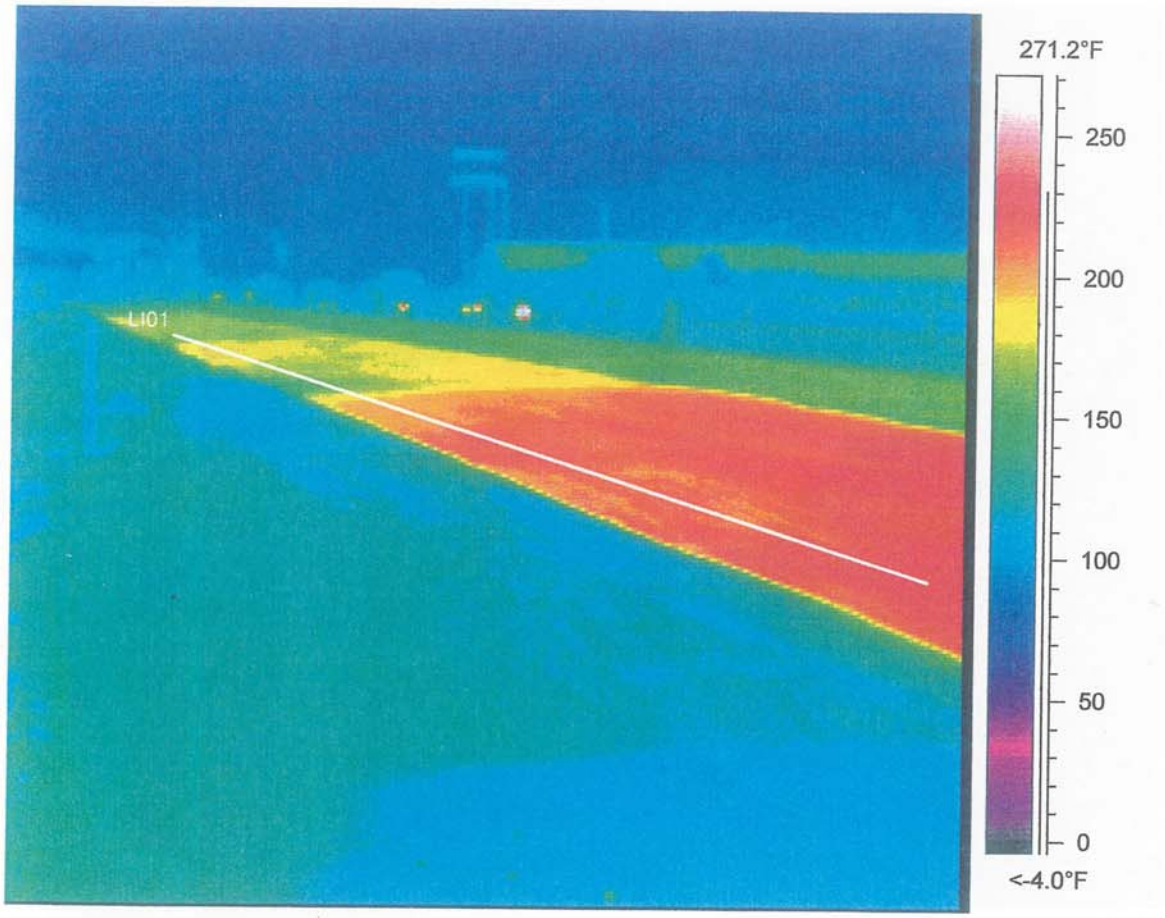
September 30, 2003
Image #4



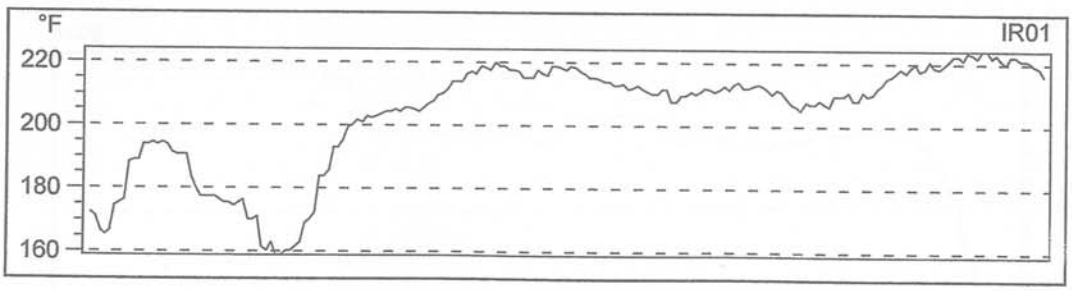
Label	Value
LI01 : max	260.1°F
LI01 : min	167.7°F
LI01 : max-min	92.4°F



NDOT Materials Division
Temperature Segregation Report
Contract 3162
September 30, 2003
Image #5



Label	Value
LI01 : max	224.1°F
LI01 : min	158.9°F
LI01 : max-min	65.3°F



NDOT Materials Division
Temperature Segregation Report
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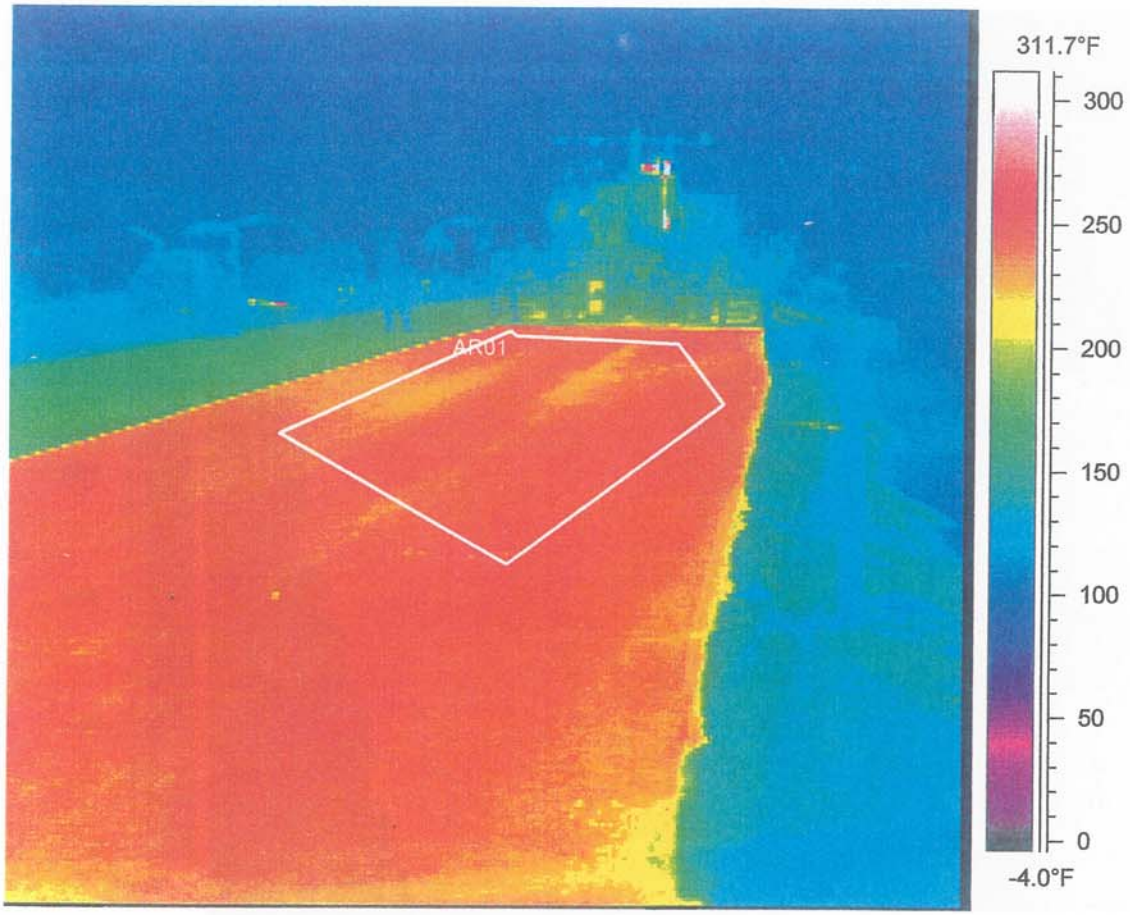
September 30, 2003
Image #6



Label	Value
AR01 : max	253.0°F
AR01 : min	222.9°F
AR01 : max-min	30.1°F

NDOT Materials Division
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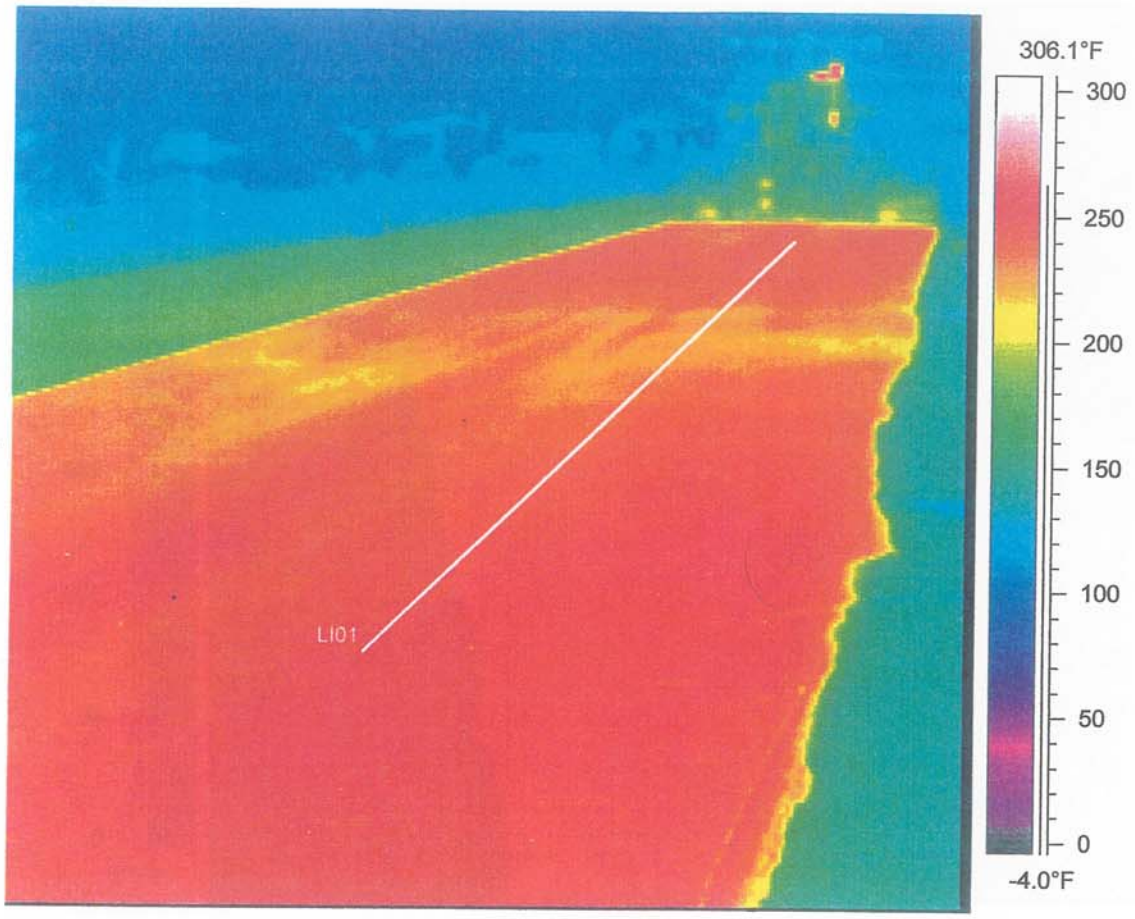
September 30, 2003
Image #7



Label	Value
LI01 : max	253.9°F
LI01 : min	222.9°F
LI01 : max-min	31.0°F

NDOT Materials Division
Temperature Segregation Report
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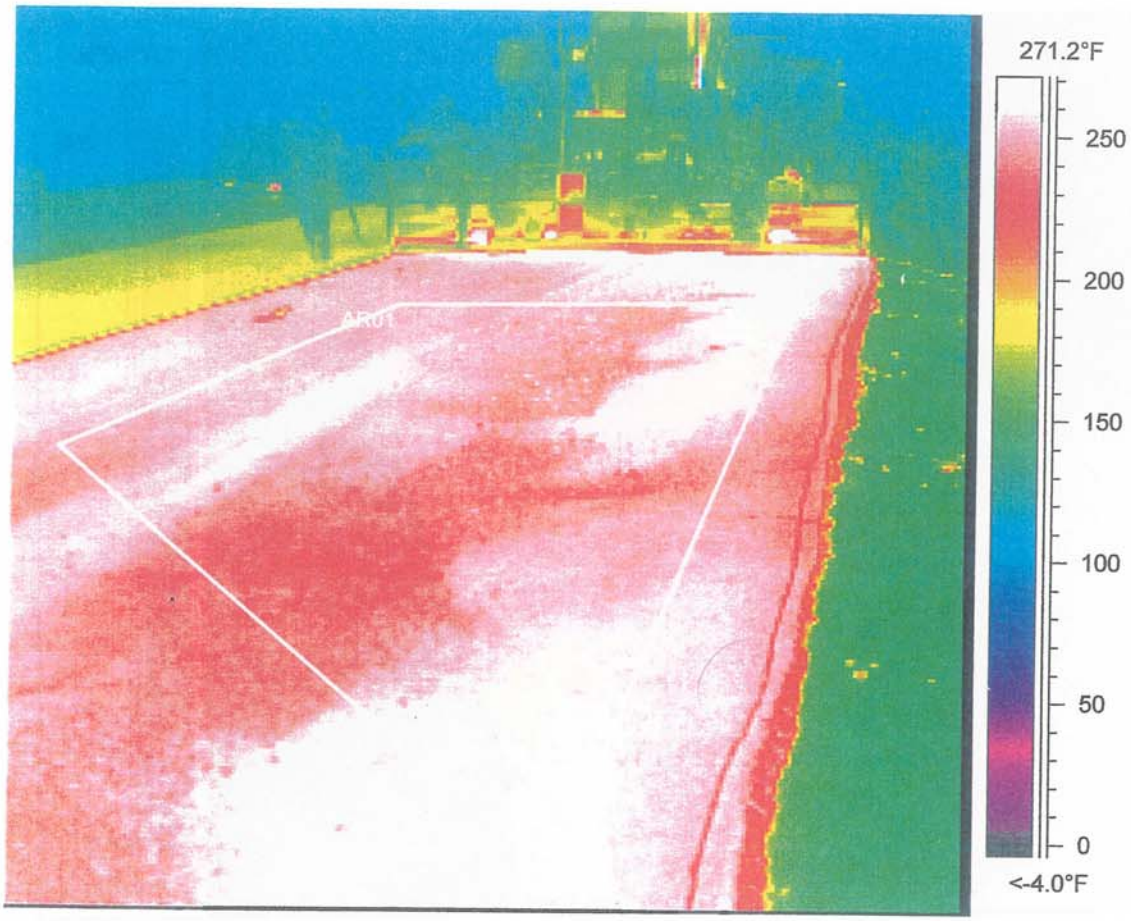
Image #8



Label	Value
AR01 : max	268.2°F
AR01 : min	217.1°F
AR01 : max-min	51.1°F

NDOT Materials Division
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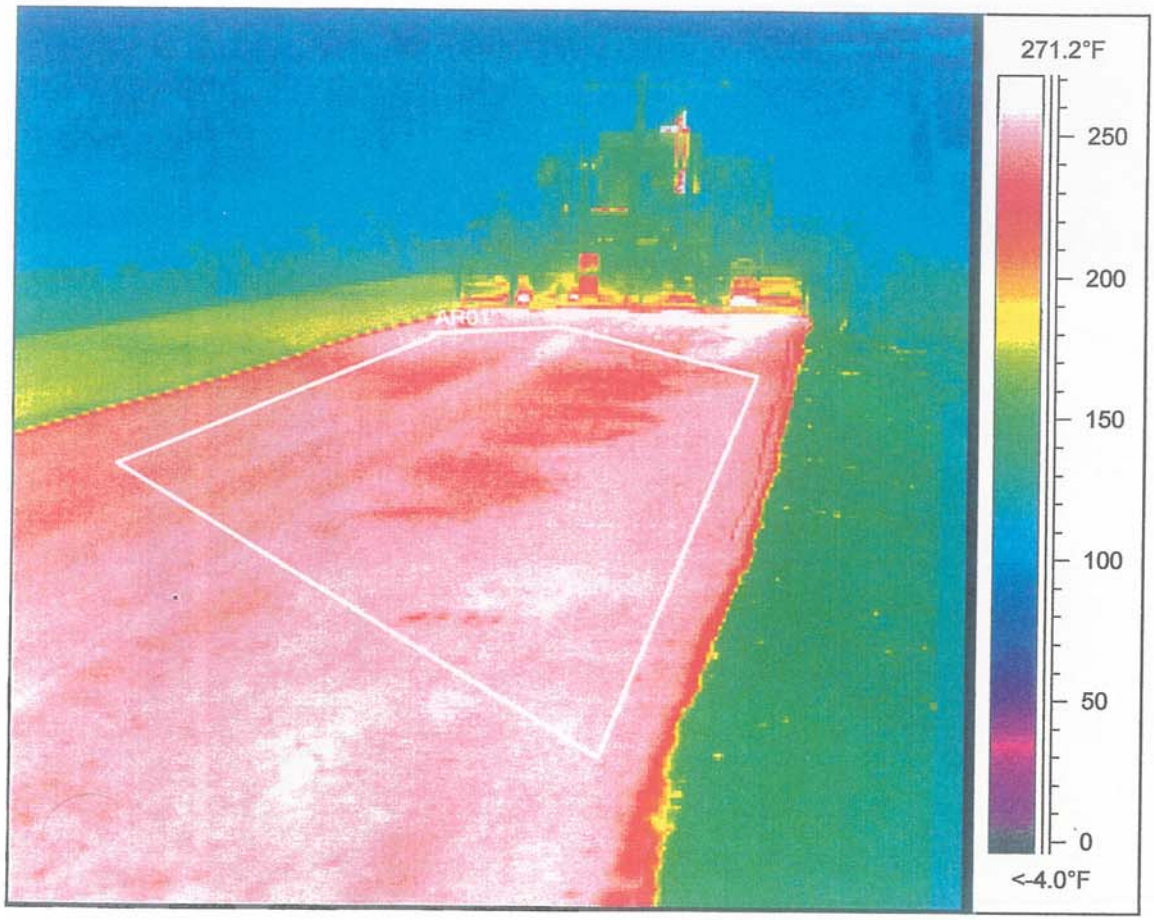
Image #9



Label	Value
AR01 : max	263.2°F
AR01 : min	229.5°F
AR01 : max-min	33.6°F

NDOT Materials Division
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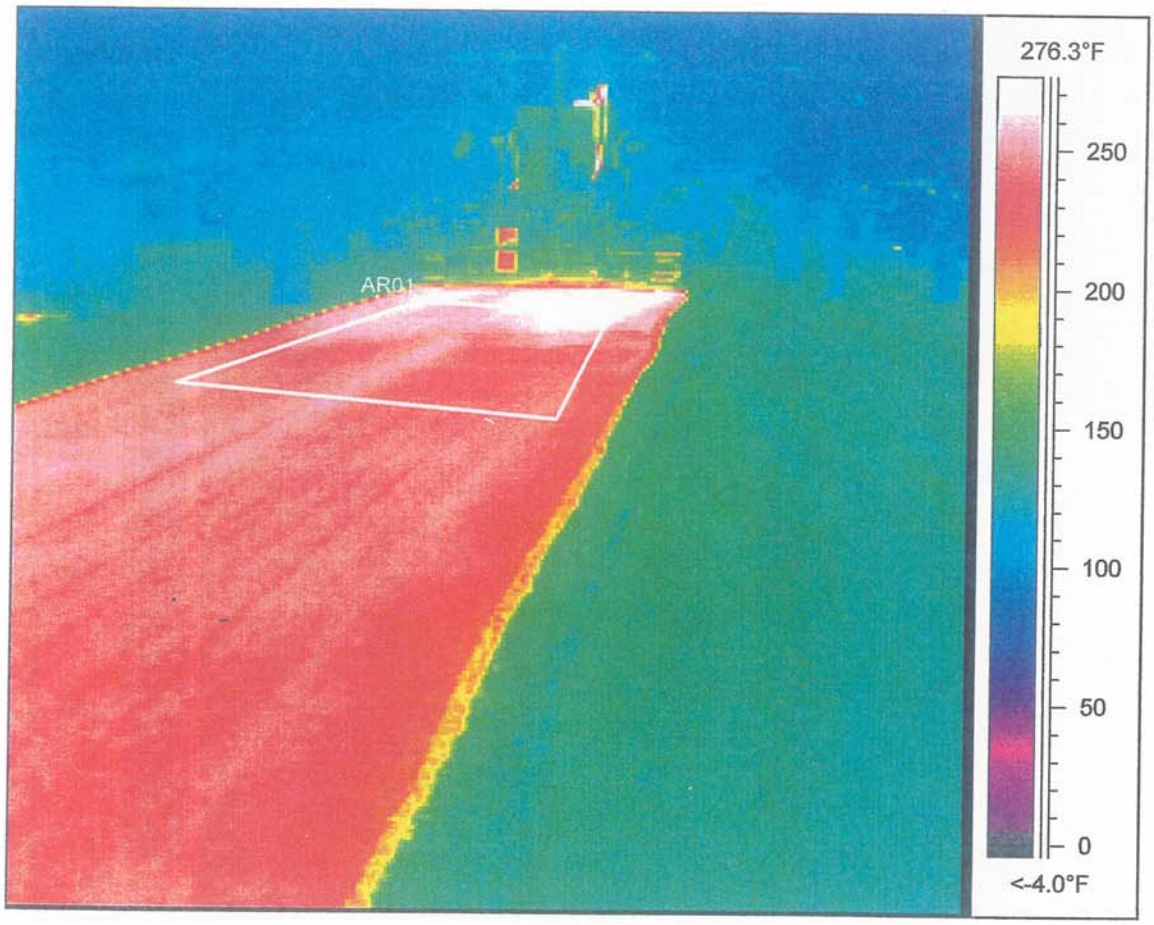
Image #10



Label	Value
AR01 : max	271.5°F
AR01 : min	215.5°F
AR01 : max-min	56.0°F

NDOT Materials Division
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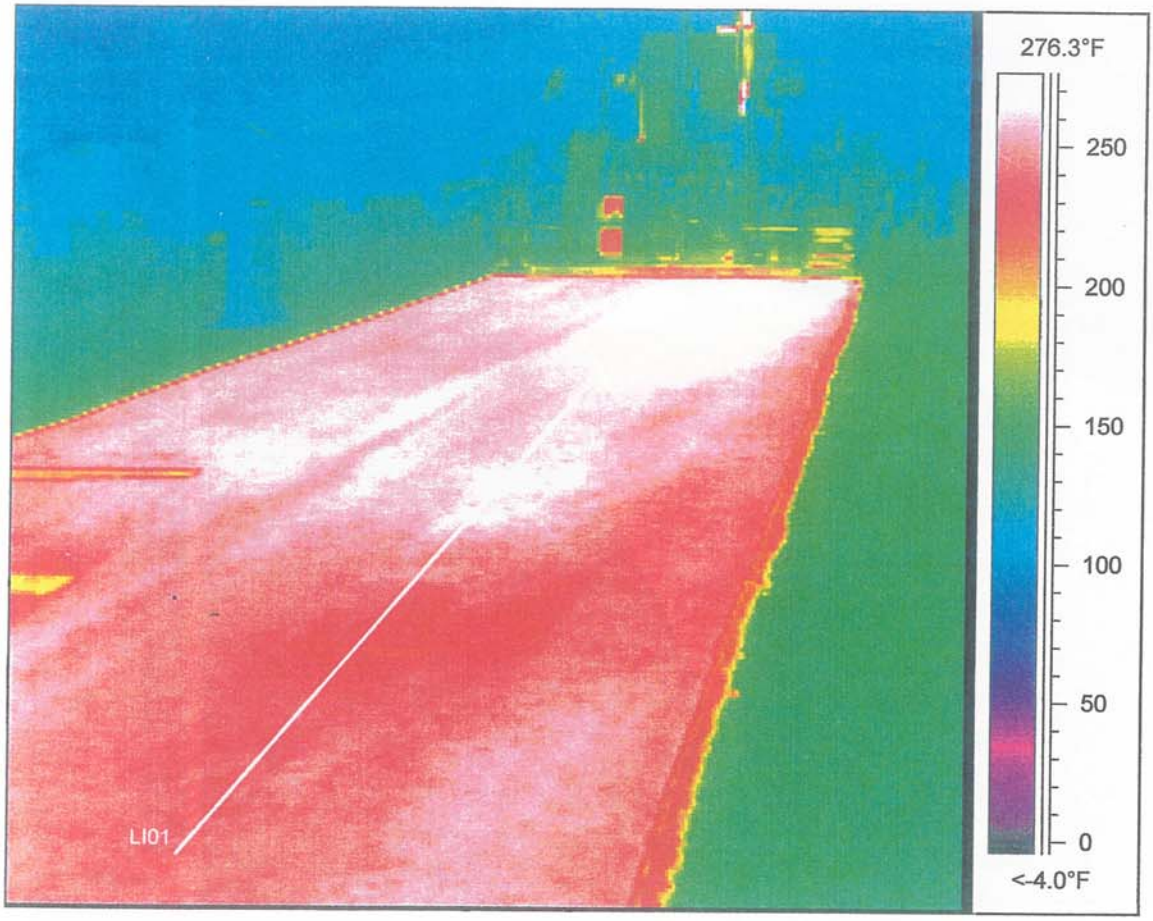
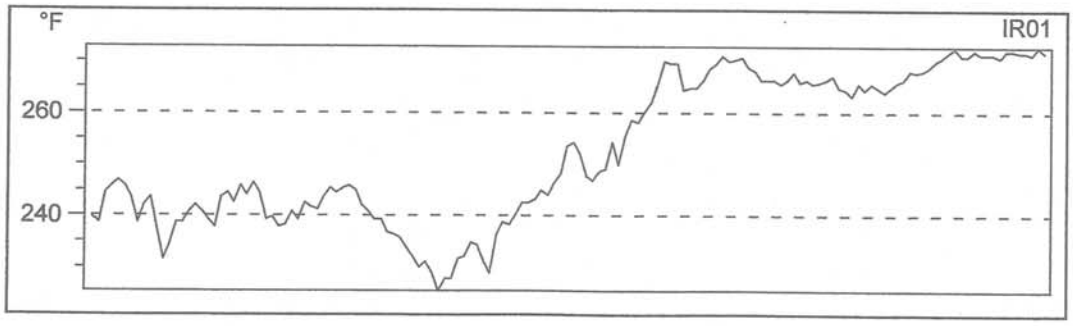
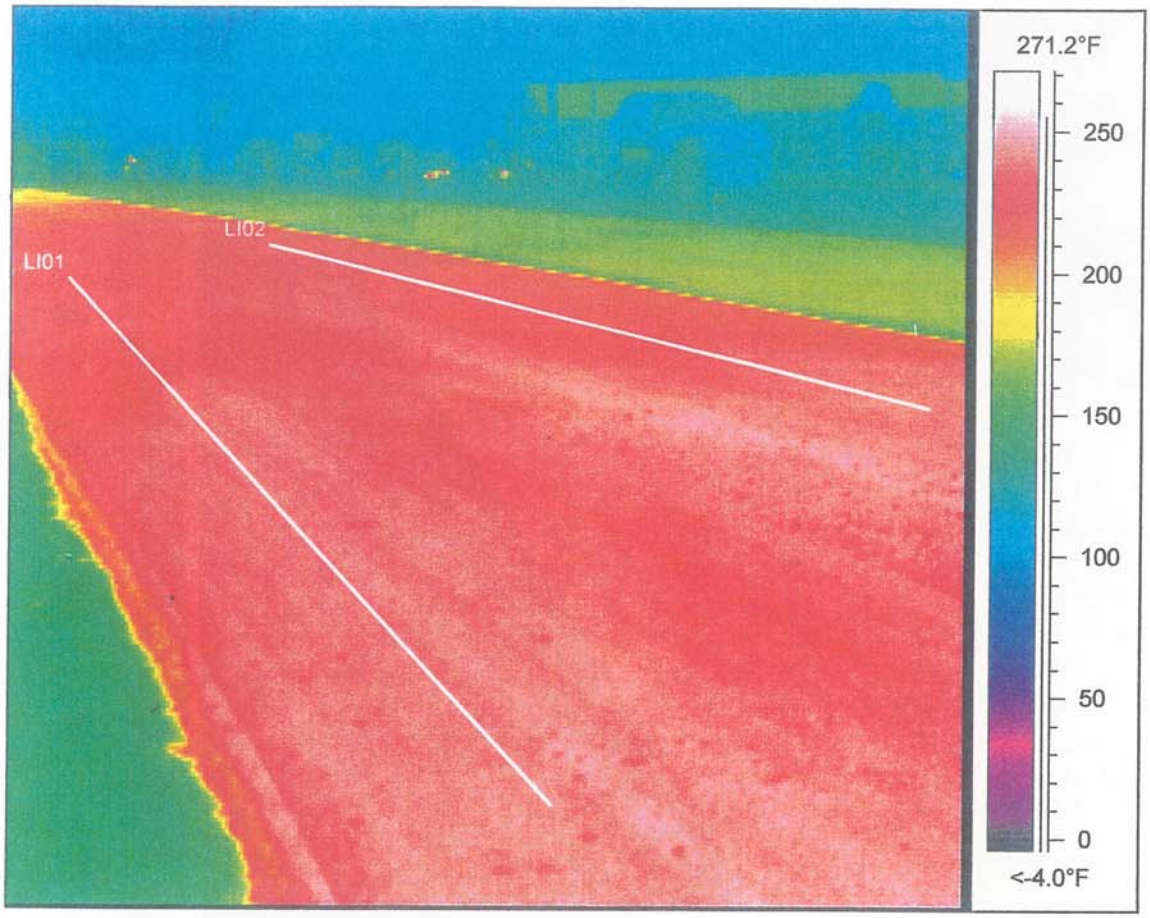
Image #11



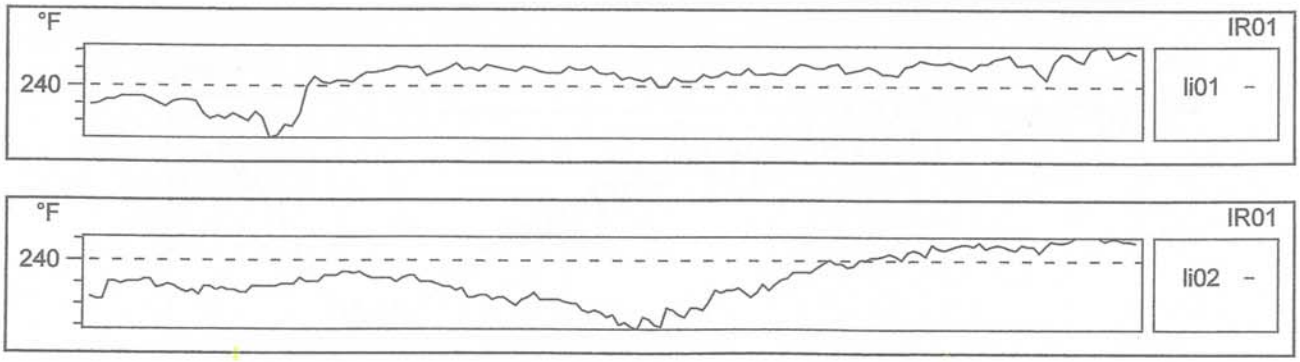
Label	Value
LI01 : max	272.9°F
LI01 : min	225.4°F
LI01 : max-min	47.4°F



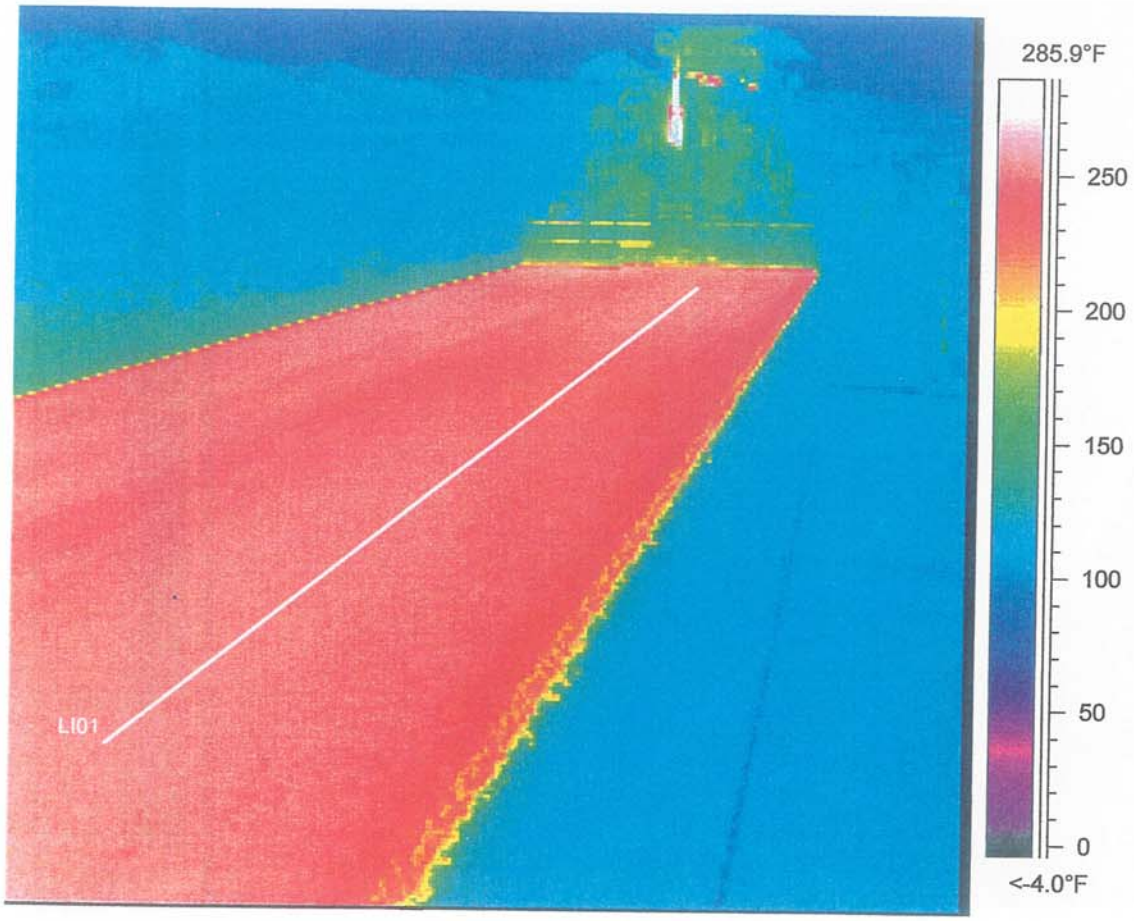
NDOT Materials Division
Temperature Segregation Report
Contract 3162
September 30, 2003
Image #12



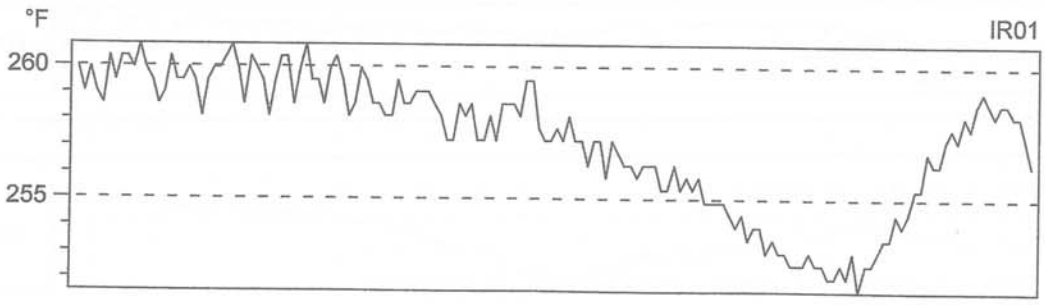
Label	Value
LI01 : max-min	26.2°F
LI02 : max-min	21.4°F



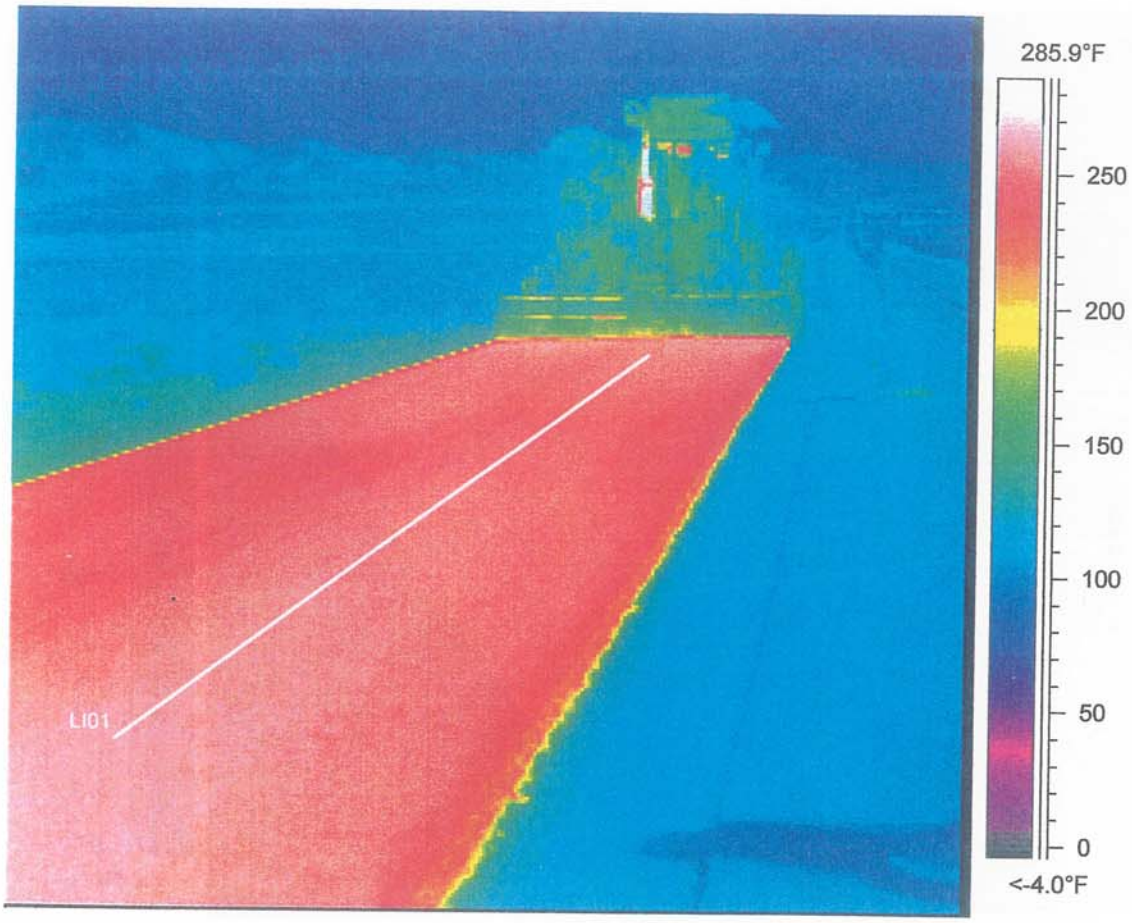
NDOT Materials Division
Temperature Segregation Report
Contract 3164
October 17, 2003
Image #1



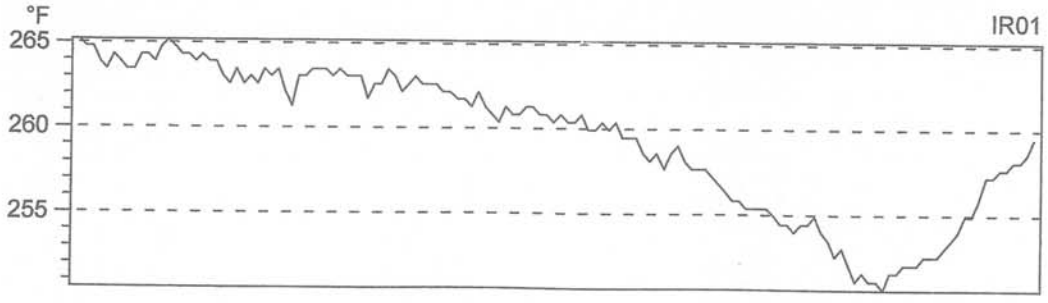
Label	Value
LI01 : max	260.8°F
LI01 : min	251.5°F
LI01 : max-min	9.3°F



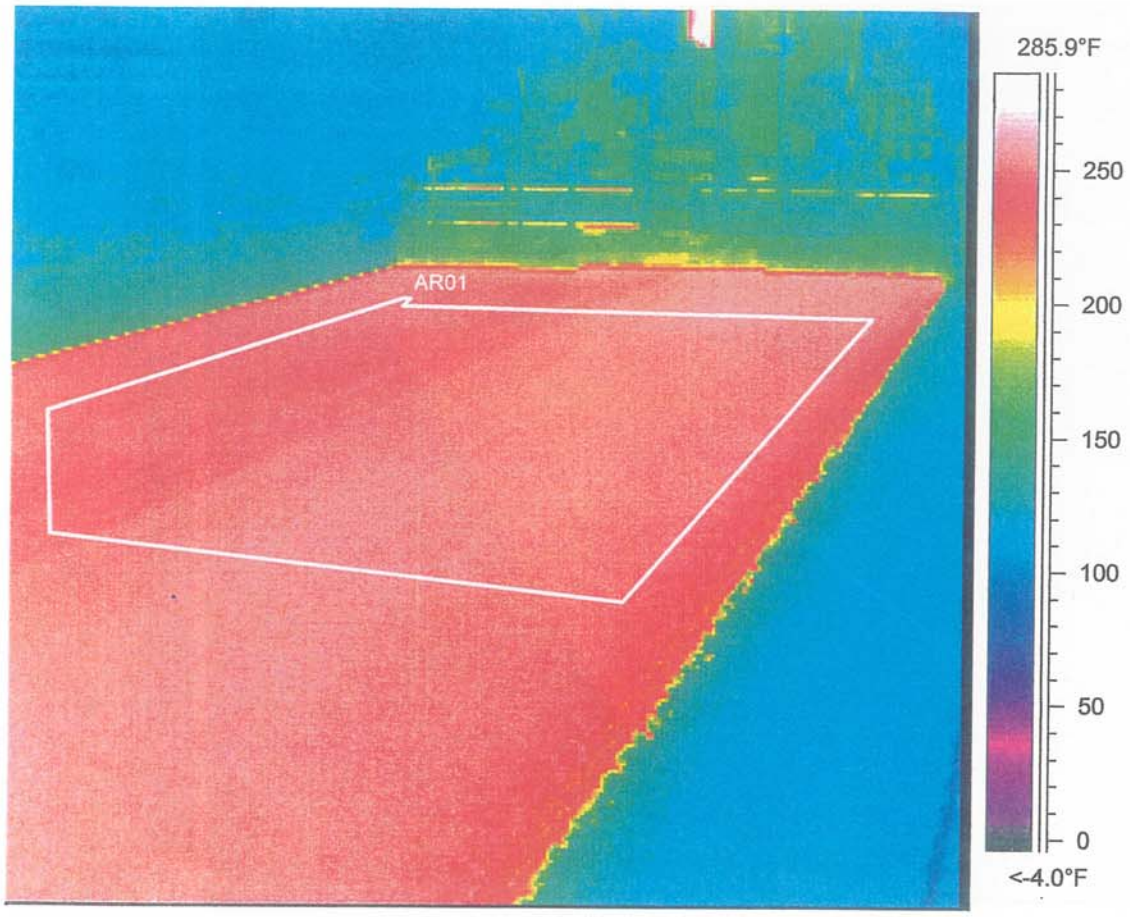
NDOT Materials Division
Temperature Segregation Report
Contract 3164
October 17, 2003
Image #2



Label	Value
LI01 : max	265.2°F
LI01 : min	250.5°F
LI01 : max-min	14.6°F



NDOT Materials Division
Temperature Segregation Report
Contract 3164
October 17, 2003
Image #3



Label	Value
AR01 : max	264.8°F
AR01 : min	249.6°F
AR01 : max-min	15.2°F

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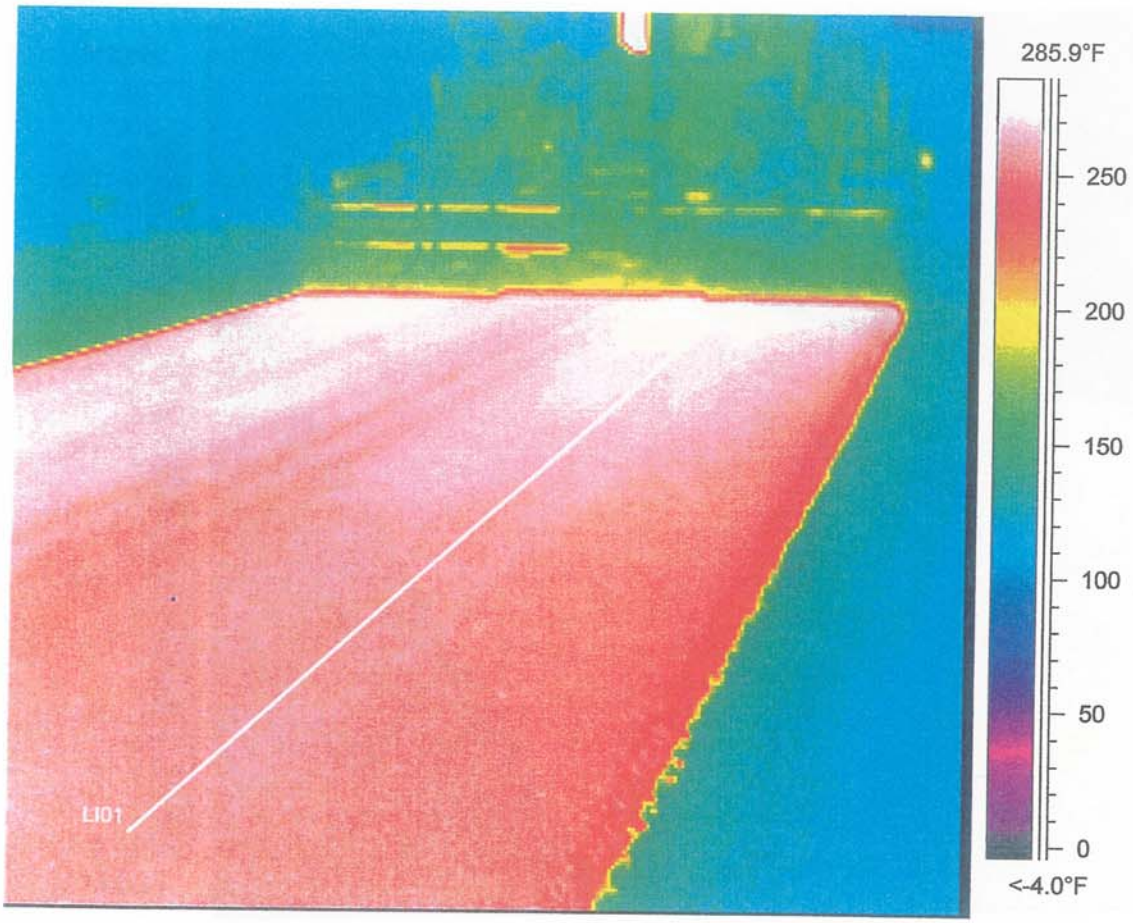
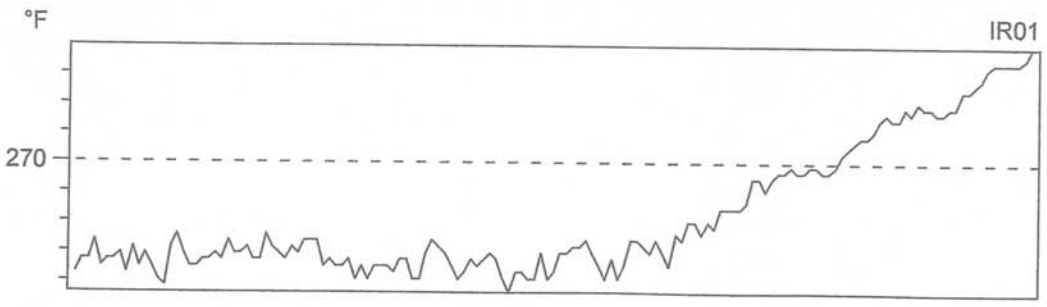
October 17, 2003
Image #4



Label	Value
LI01 : max	277.9°F
LI01 : min	261.3°F
LI01 : max-min	16.6°F



NDOT Materials Division
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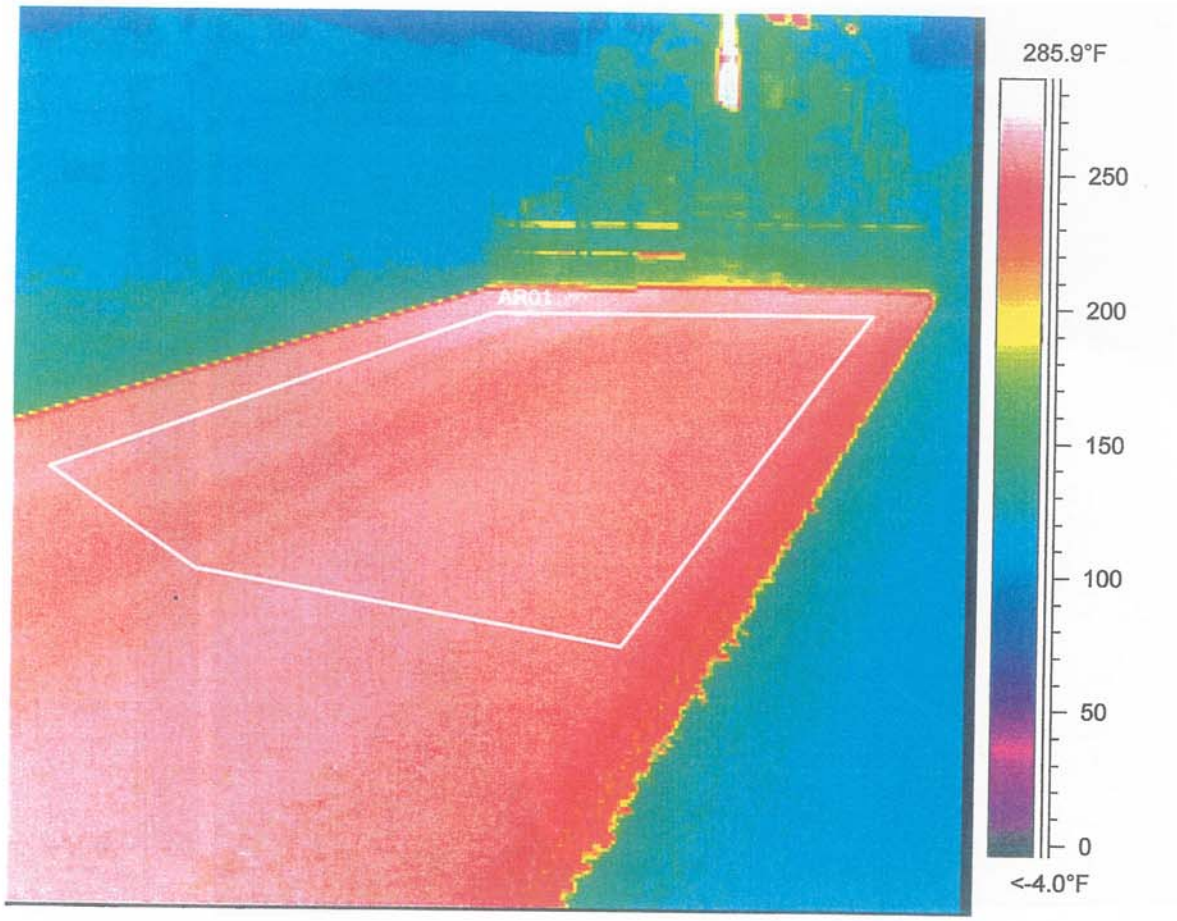
October 17, 2003
Image #5



Label	Value
AR01 : max	271.7°F
AR01 : min	254.4°F
AR01 : max-min	17.3°F

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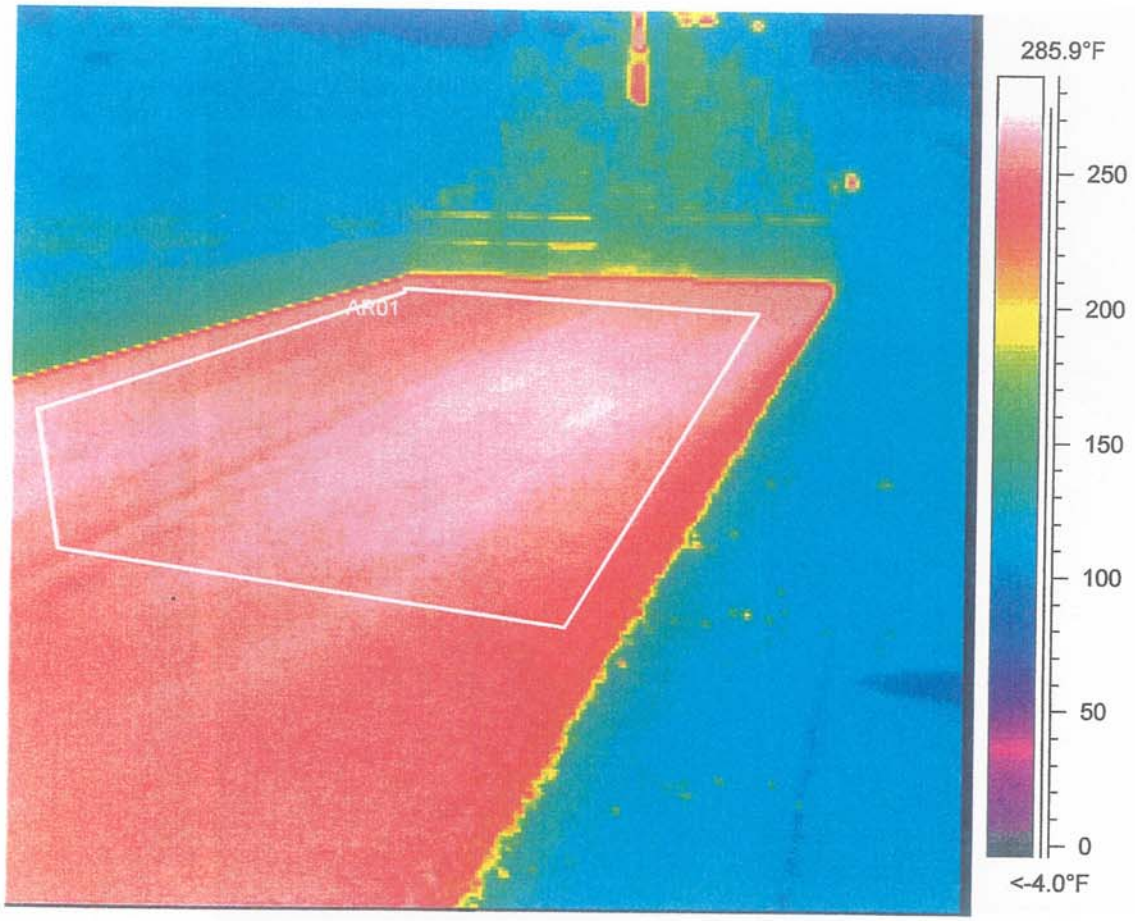
Image #6



Label	Value
AR01 : max	274.5°F
AR01 : min	246.5°F
AR01 : max-min	27.9°F

NDOT Materials Division
Temperature Segregation Report
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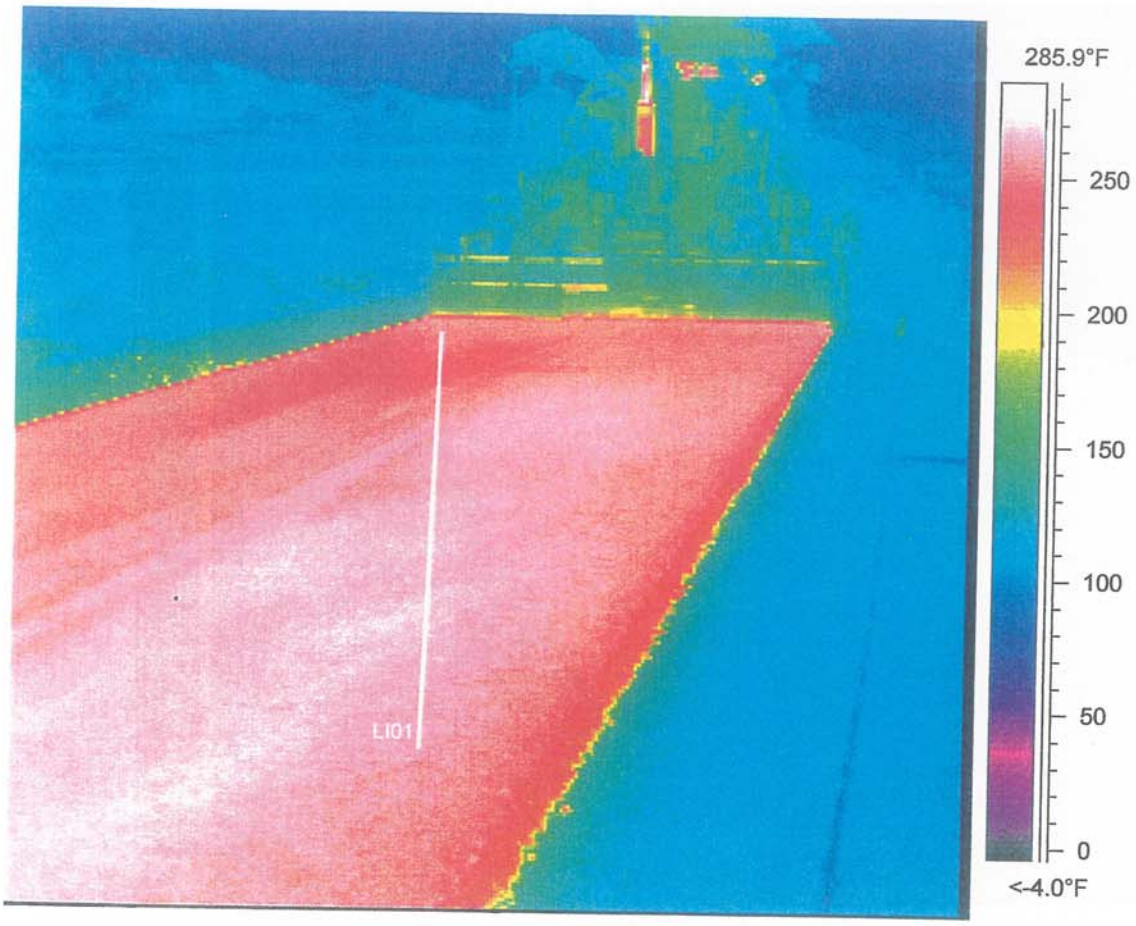
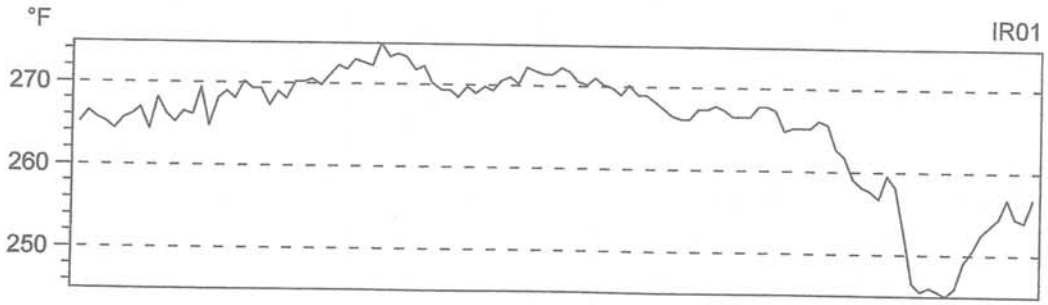
October 17, 2003
Image #7



Label	Value
LI01 : max	274.9°F
LI01 : min	245.0°F
LI01 : max-min	29.8°F



NDOT Materials Division
Temperature Segregation Report
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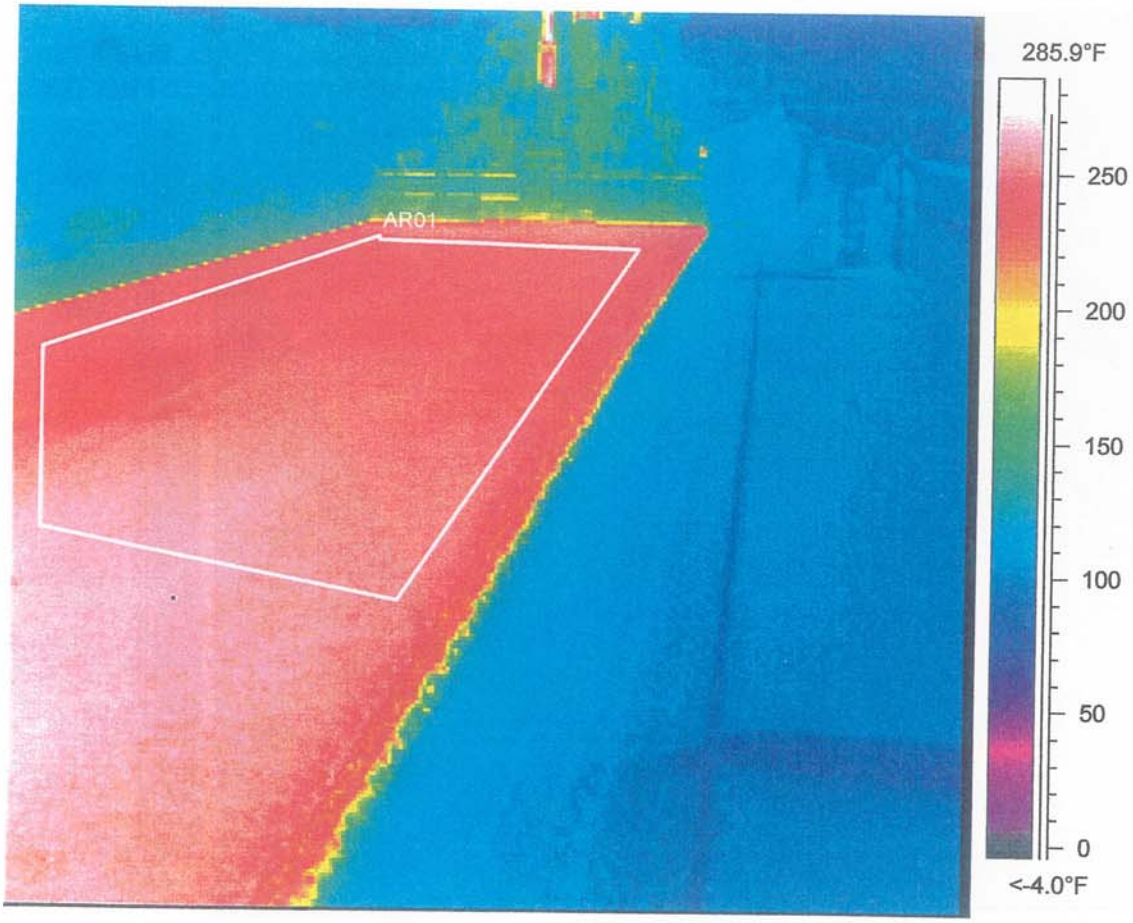
October 17, 2003
Image #8



Label	Value
AR01 : max	268.9°F
AR01 : min	229.4°F
AR01 : max-min	39.6°F

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Temperature Segregation Report
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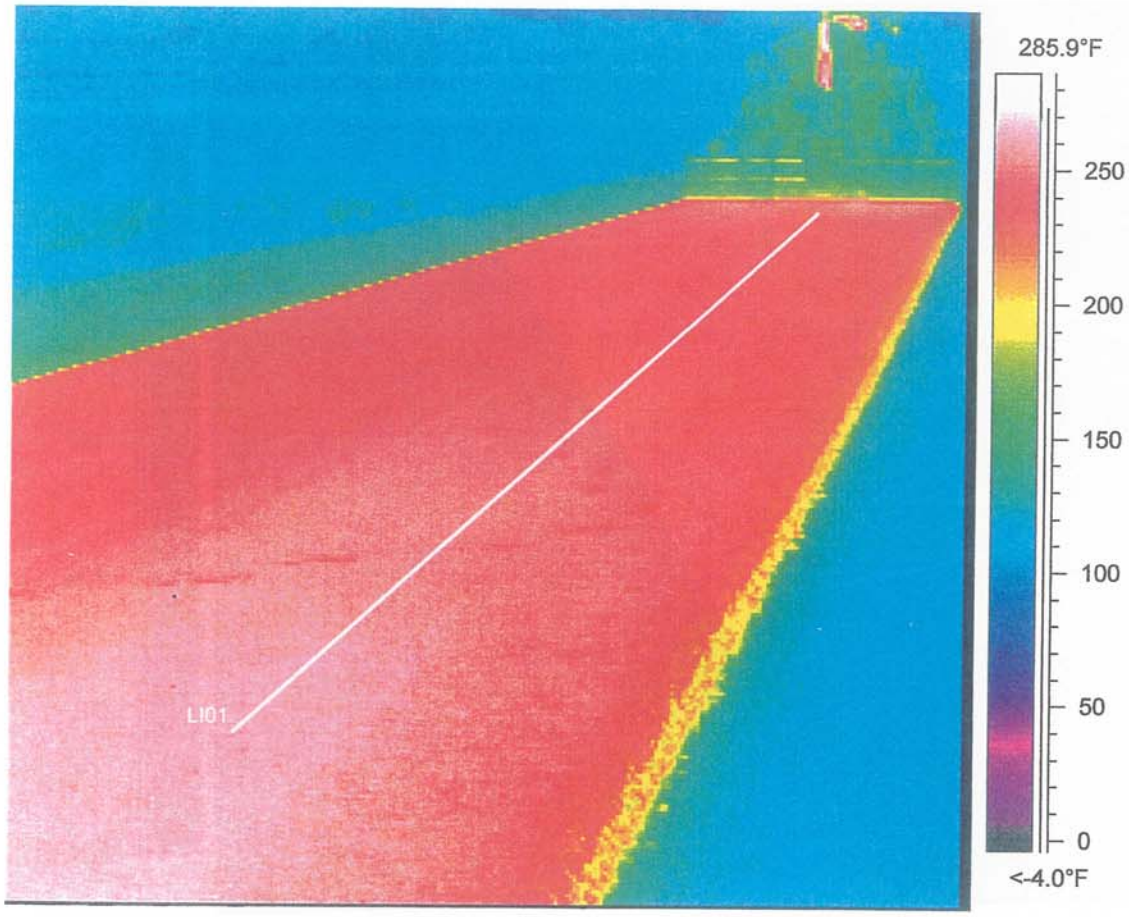
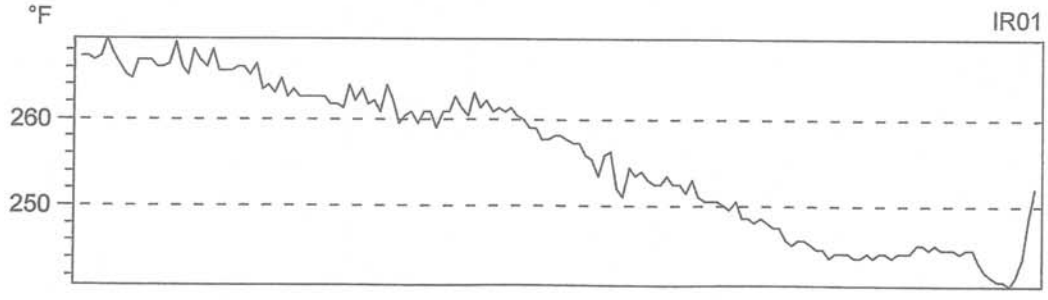
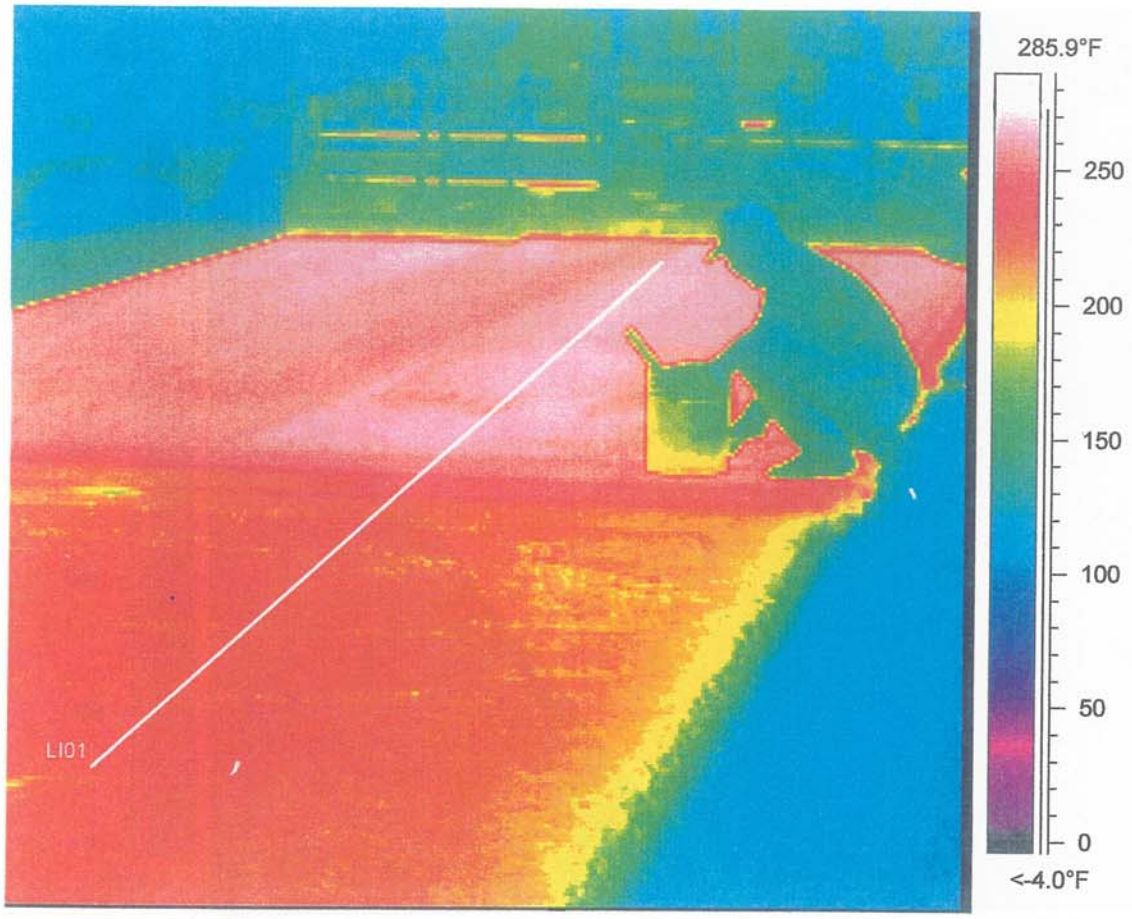
October 17, 2003
Image #9



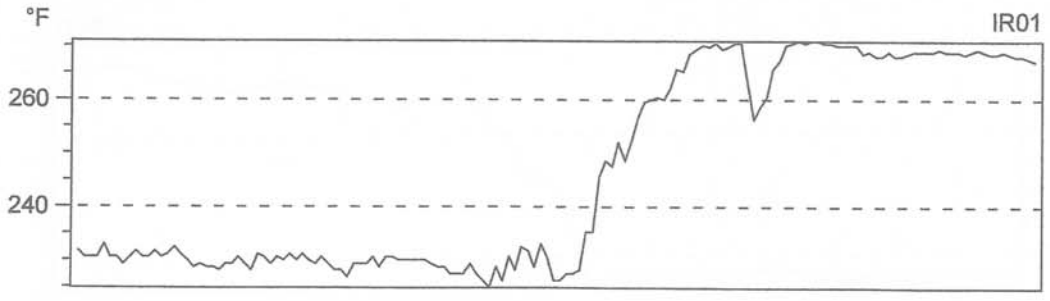
Label	Value
LI01 : max	269.3°F
LI01 : min	240.8°F
LI01 : max-min	28.5°F



NDOT Materials Division
Temperature Segregation Report
Contract 3164
October 17, 2003
Image #10



Label	Value
LI01 : max	270.9°F
LI01 : min	224.9°F
LI01 : max-min	46.1°F



NDOT Materials Division
Temperature Segregation Report
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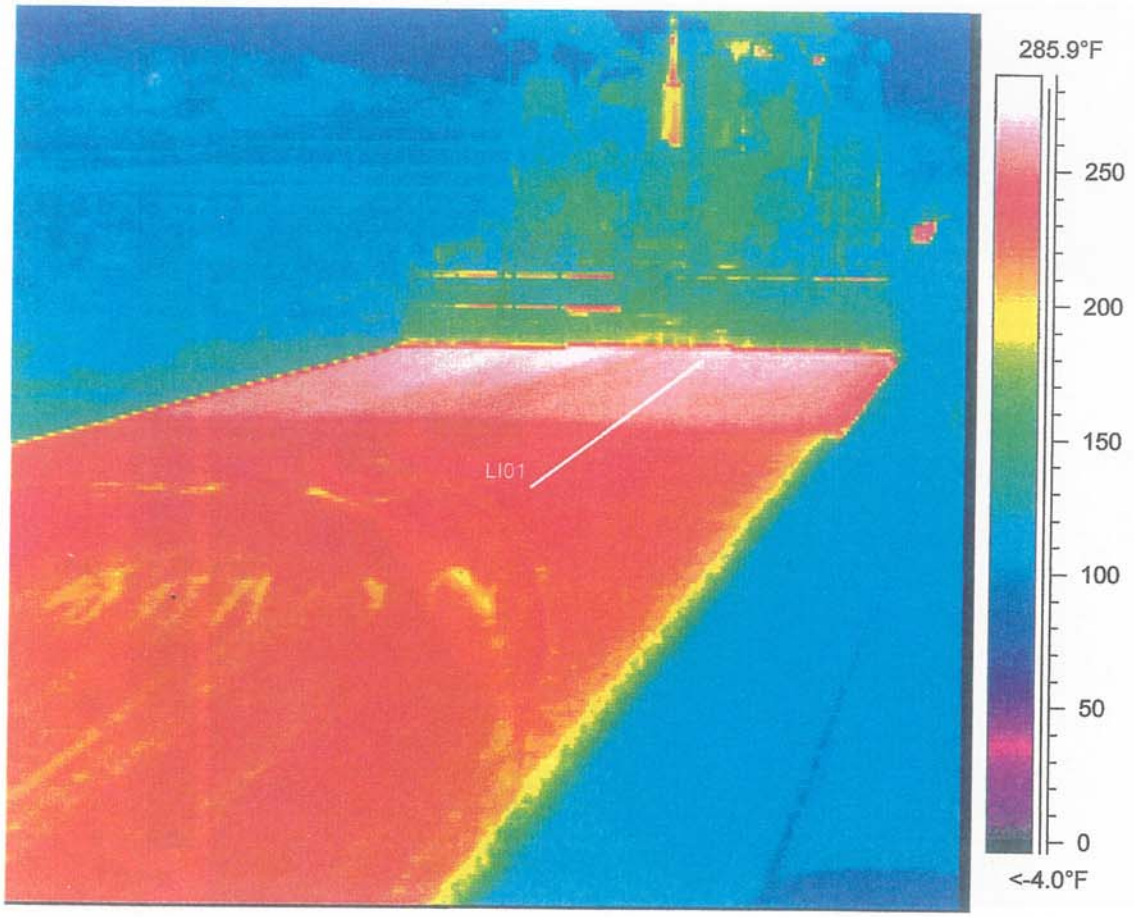
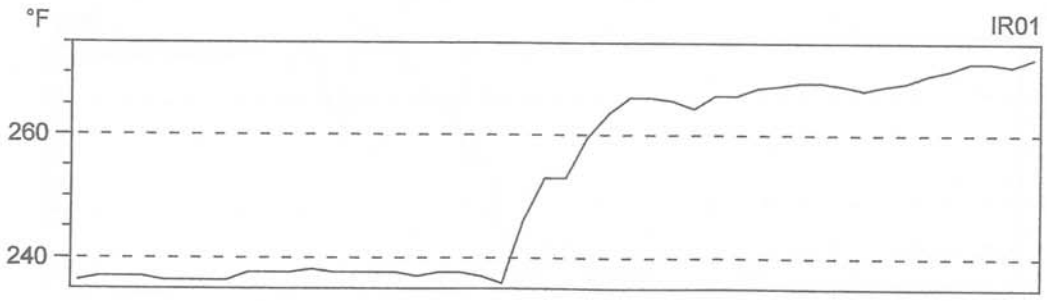
October 17, 2003
Image #11



Label	Value
LI01 : max	272.5°F
LI01 : min	235.9°F
LI01 : max-min	36.7°F



NDOT Materials Division
Temperature Segregation Report
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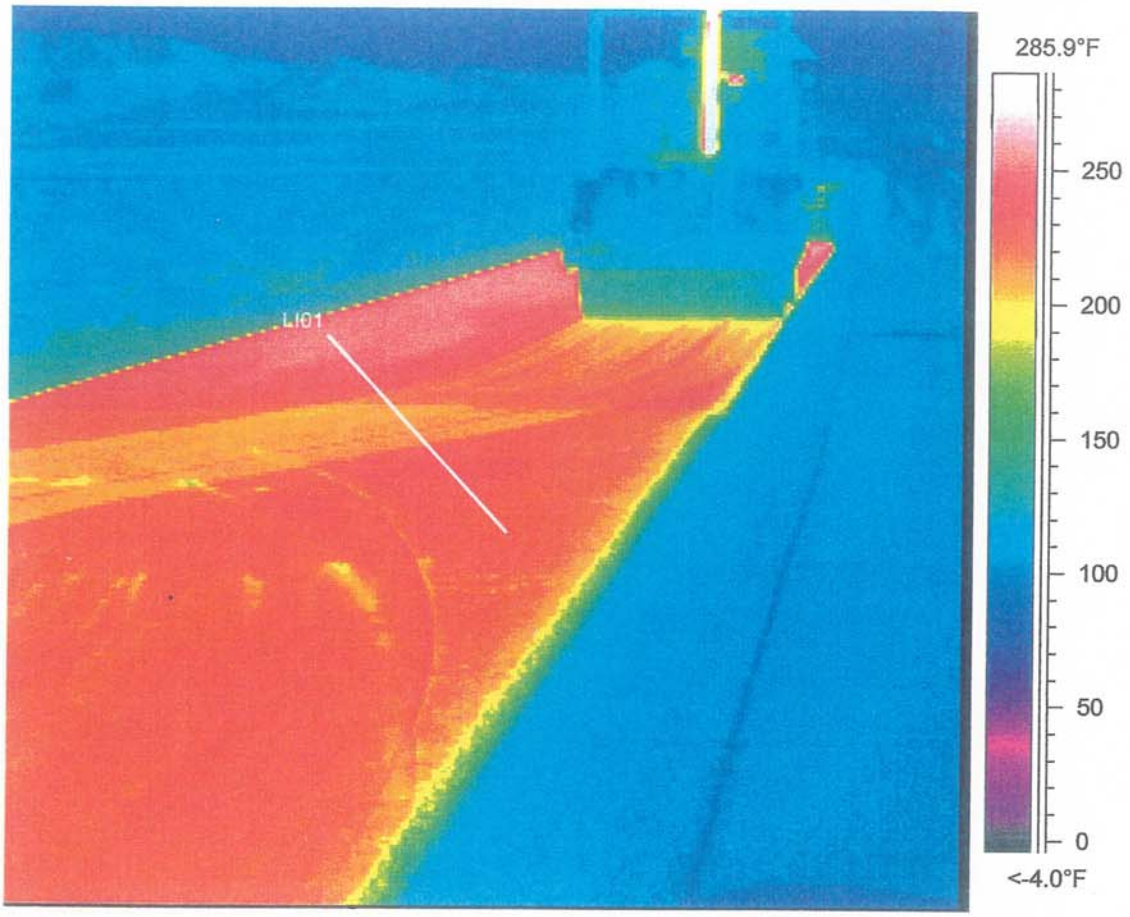
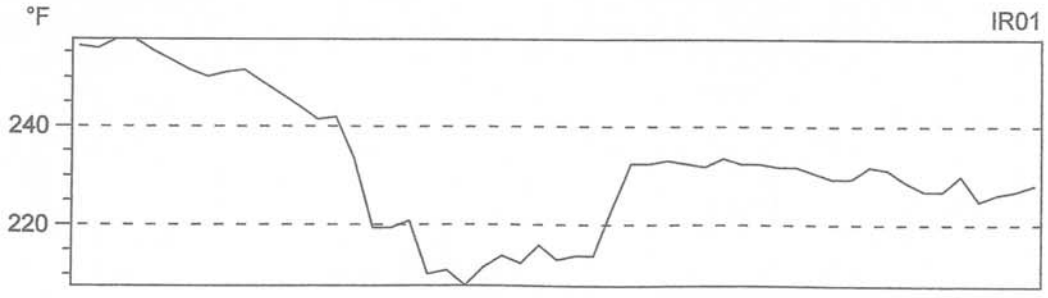
October 17, 2003
Image #12



Label	Value
LI01 : max	257.7°F
LI01 : min	207.6°F
LI01 : max-min	50.0°F



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Investigation of Temperature Segregation