Determining Visible Opacity of Emissions Using the Digital Opacity Compliance System II

Look Out EPA Method 9, Here Comes the Digital Equivalent (Finally)

E2S2 Conference Denver

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TECHNICAL APROACH

- DoD Recognition of the Costs and Subjectivity of Method 9 Monitoring Motivated Development of an Alternative Means of Measuring Visible Opacity.
- The DOCS II Technology Rapidly Characterizes Emissions Using:
  - Commercial-Off-The-Shelf Digital Camera
  - Standard Computer
  - DOCS II Emission Characterization Software

DOCS II is Nuisance Characterization

Is The Emission a Problem? Quantitative

Quantitative verses Qualitative

Emission T1

DOCS II is an easy inexpensive tool for **Quantitative Measurement**

Emission Tn

Opacity

% ODR

Nuisance Enforcement

Gather Soil Data

Add PM Monitors

Health Effect

Env. Impact

Impact Enforcement

What is the Problem Qualitative

Required Mitigation

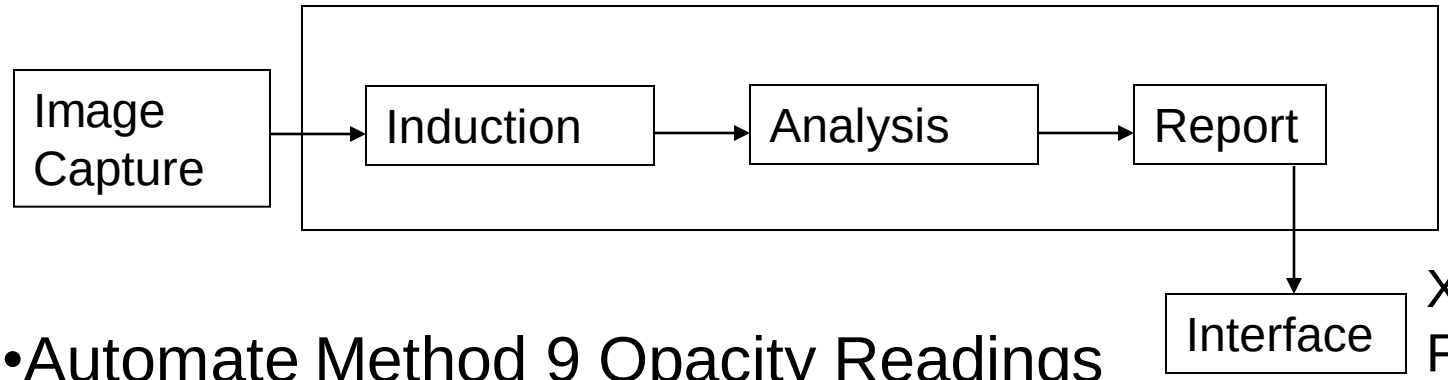
Other Projects are tools for Qualitative Measurement

Nuisance Characterization of Visible Emissions for Compliance and Permitting

EPA's Method 9 is used to Quantitatively Assess Visible Emissions

TECHNICAL APROACH

DOCS II Flow

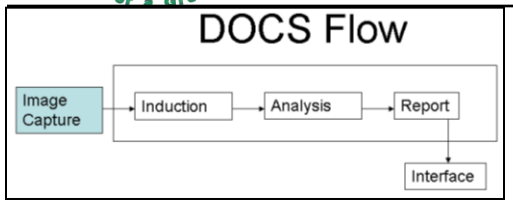


- Automate Method 9 Opacity Readings
- Provide Compliance Records
- Maintain Credible Evidence

Fast, Easy, Reliable, Repeatable, Nuisance Characterization of Visible Emissions

TECHNICAL APROACH

Image Capture



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- **Camera**
  - Min Specifications 2 Mega Pixel (“off the shelf”)
  - Refresh Rate Less Than 5 sec.
  - All Brand Specific Features (off)
- **Image, JPG Standard (ISO/IEC IS 10918-1)**
  - Images from Cameras (EXIF)
  - Meta-Data Attributes Identify Camera Settings
  - Pixel Values Set, JPG Compressed
- **Center Plume in Frame with Background**

JPG EXIF Example

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[Nikon3.Focus                   ] = AF-S
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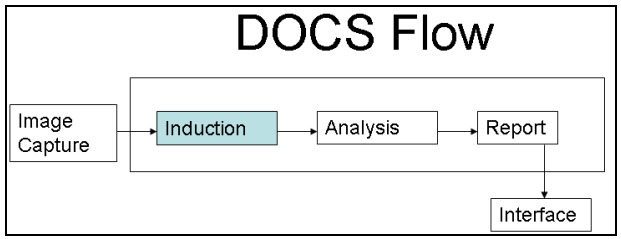
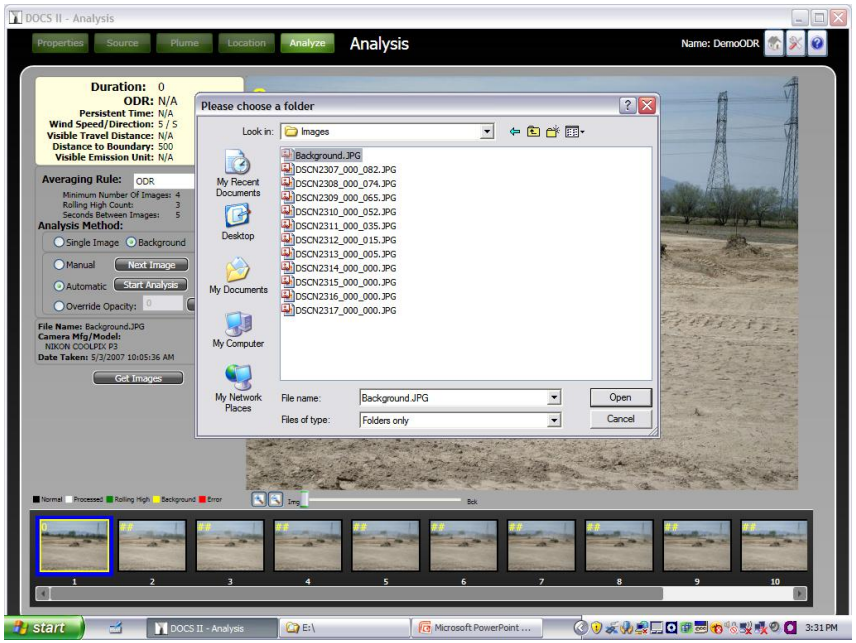
Images From a Safe Distance Capture The Plume and Background

TECHNICAL APROACH

Induction



- Method 9, 24 Image Minimum
- Dust Opacity, 2 Image Min.
- Opacity Dissipation Rate, 4 Image Min.



- Registration Method
  - Minimization of Variance
    - Same Camera Angle
    - Same Basic Image
    - Difference is Emission
  - EXIF Meta Data Cross Check
    - Same Camera
    - Same Settings
    - Checks “Rule” Tolerances

Minimization of Variance Method
(registration algorithm +/- .5 pixel)

Background Effects Neutralized and Emission Isolated

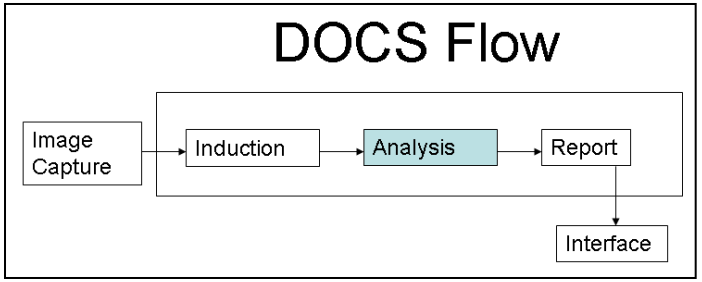
TECHNICAL APROACH

Analysis Theory

Opacity Causes:

- Loss of color
- Loss of detail

Must Quantify both for a valid automated opacity determination



Heavy Dust
Little detail
Little color

Time

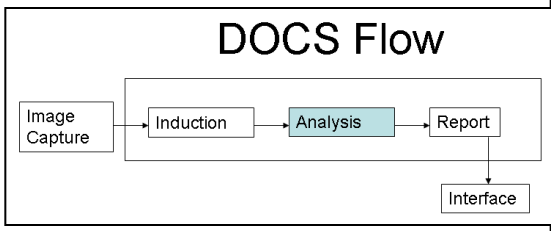
Dissipating Dust
More detail
More color

TECHNICAL APROACH

Testing and Validating DOCS

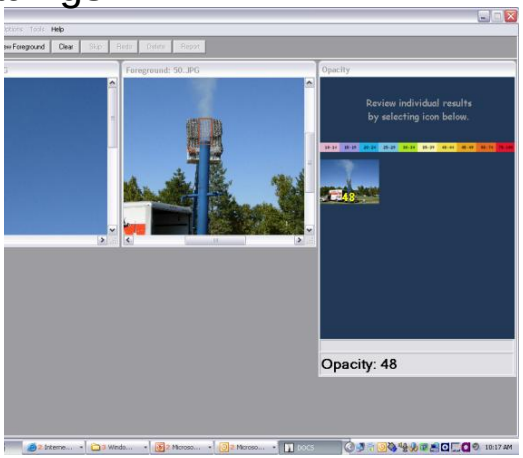
Analysis Controlled

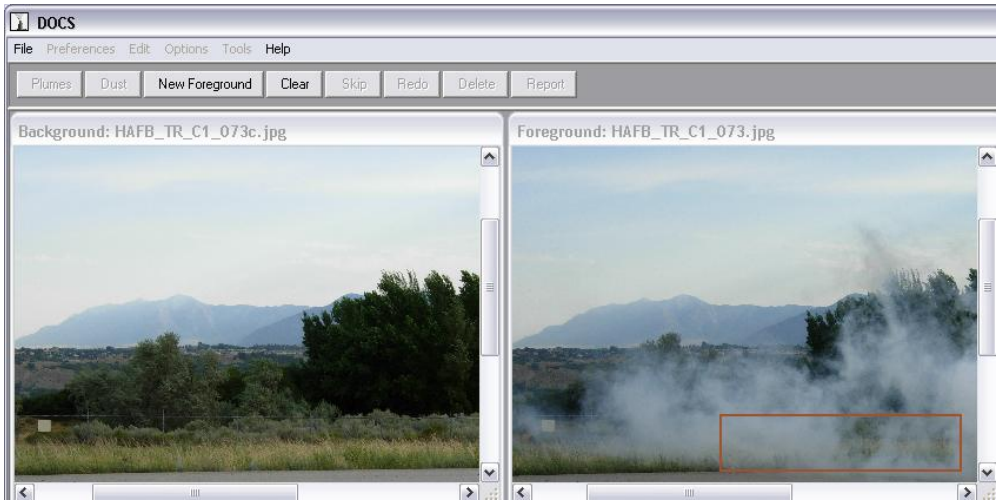
Compared to Certified Opacity Readers
Varying Light and Wind
Precision Variance Within Method:
Multiple DOCS Readings
Multiple Certified Reader Readings
Same Source at Same Time



Analysis Controlled

Using Transmisometer Metered Emissions
Smoke School gave Insight Into Accuracy(+/-5%)





Analysis Field

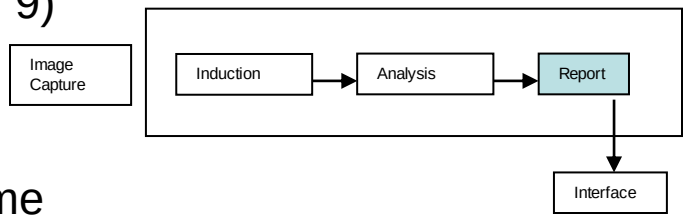
Compared to Certified Opacity Readers
Precision Variance Within Method:
Multiple DOCS Readings
Multiple Certified Reader Readings
Same Source at Same Time

TECHNICAL APROACH

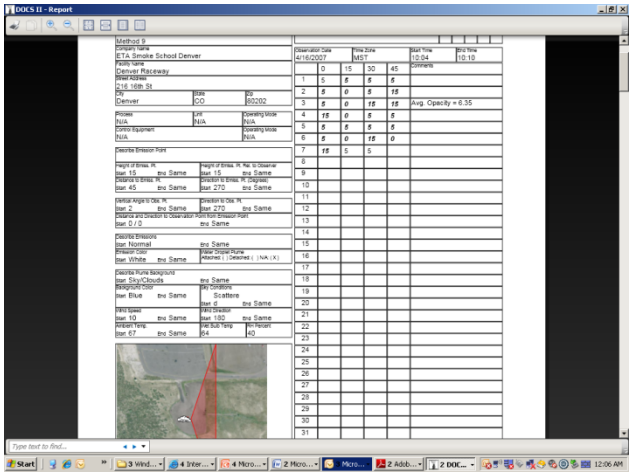
Reports

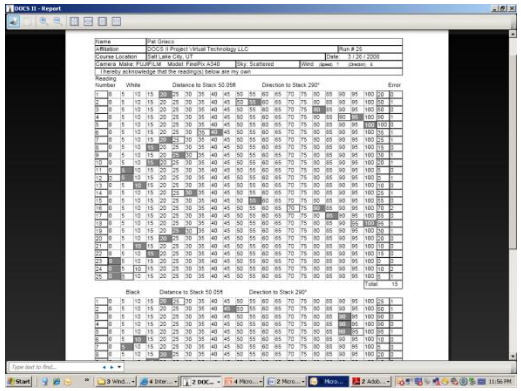
DOCS II Emissions Reports

- DOCS II Output Characterization For Visible Emission Sources:
  - Opacity of Image Being Reviewed and Site Field Report (Method 9 Format)
  - Average Opacity Over a Series of Images (Method 9)
  - Opacity Change Over a Series of Images
  - Time Change over a Series of Images
  - Opacity Rate of Change Over Series of Images/Time
  - (Future VEU) “Risk of Nuisance Visibility at a Boundary”
    Requires: Wind Direction and Speed, Location Relative to Boundary



Opacity Observation XML with Images & all Reference Data



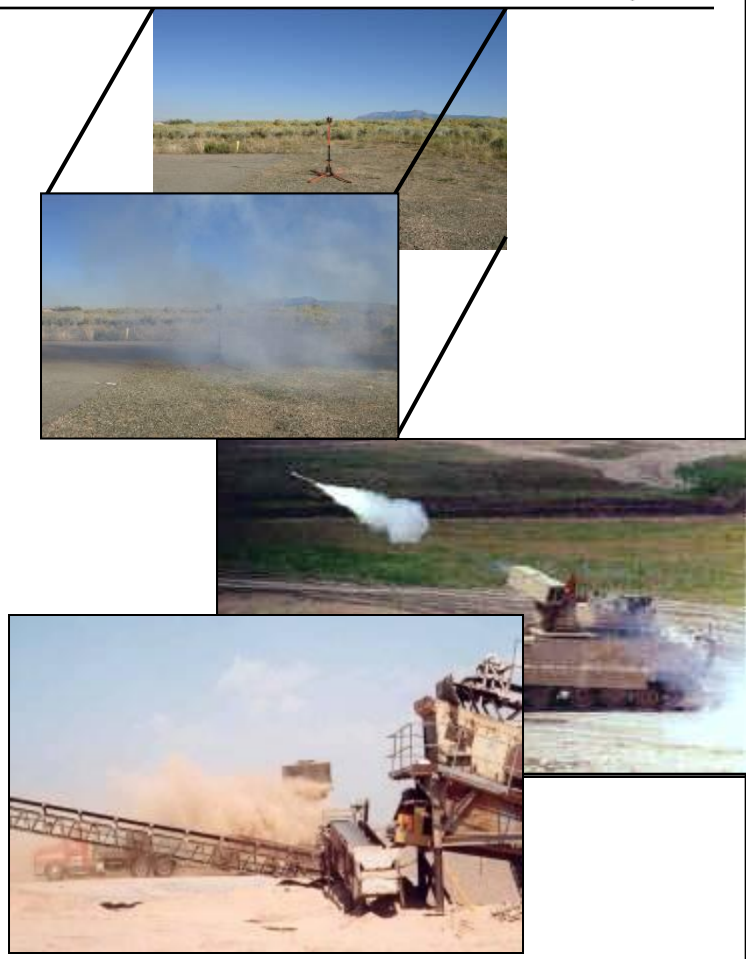


Certification Report

Monitoring & Screening Tool, Supporting Compliance & Permitting

DOCS II Enhancements for Fugitive Emissions

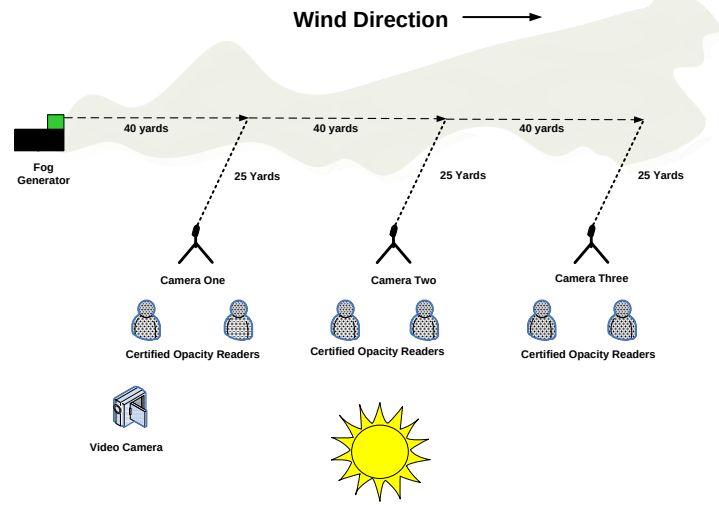
- **Fugitive Emissions Have Varying Background**
- Address Background Difference
  - Before and After Image Alignment
  - Isolation of Emission Plume
  - Registration of Plume to Background
- **Fugitive Emission Characterization Requirements**
  - Transient Nature
  - Opacity Compliance Regulations
  - Visibility Compliance Regulations
  - Boundary Visibility “Nuisance” Regulation
- **DOCS Comparison to Known Requirements**
  - Transient Nature Addressed
  - Opacity Compliance Requirement Addressed
  - Visibility Compliance Requirement Addressed (ODR)
  - Boundary Visibility Requirement Addressed



Worked with Multiple Agencies to Identify Required Capability

DOCS II Fugitive Emissions Demonstrations and Validation

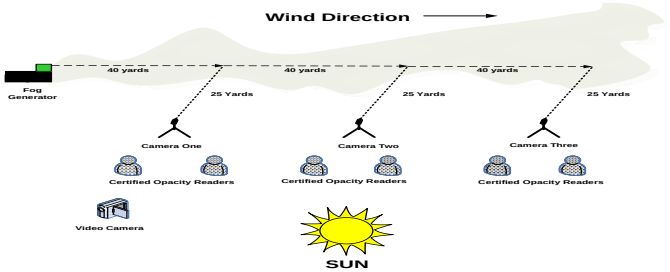
- Review of Requirements
  - Technical Interchange Outcome
    - Change Requirements
      - Like Existing Method
      - Easy to Adopt
      - Adopted in Permits
    - Boundary Requirements Require
      - Persistence Measurement

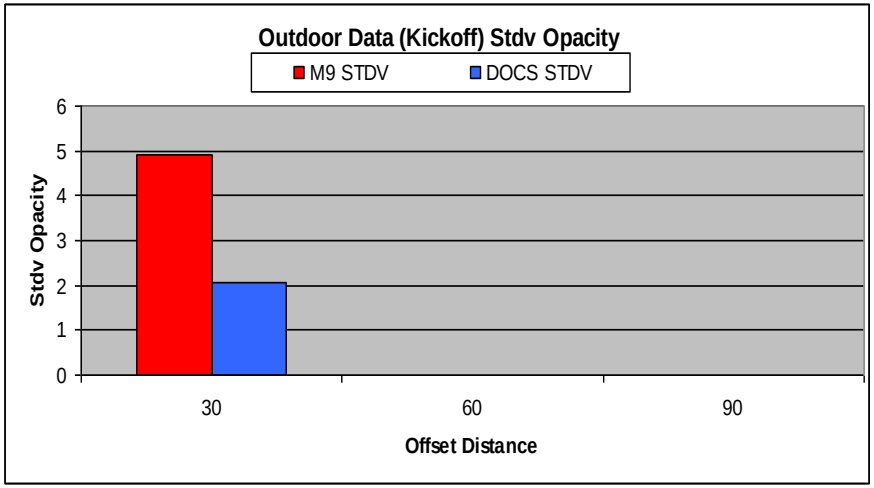


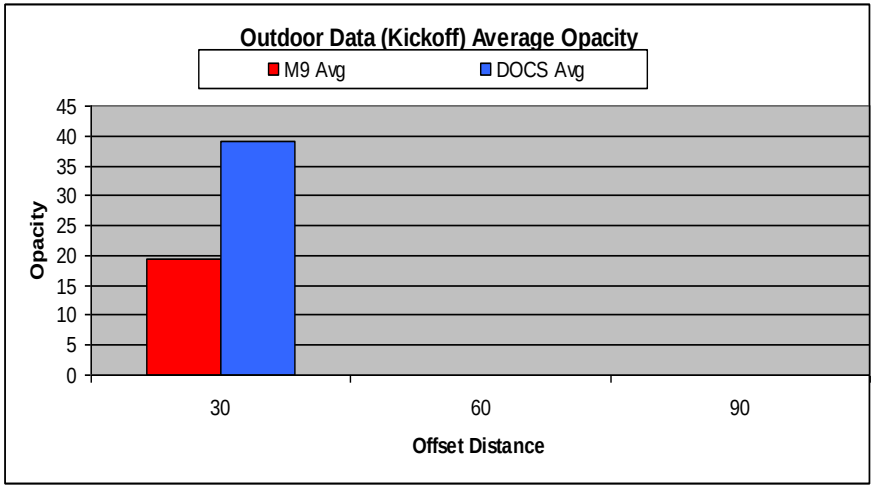
Validate DOCS for Regulatory Acceptance

DOCS II Emissions
Hill Outdoor 1 Analysis 08 15 06

- Generated Plume Not in Line With Targets Resulting in:
  - Inability to Cross Check Method 9 Readings
    - Where Was the M9 Reading Taken?
    - Relative to Where DOCS Reading Taken?
  - Wind Blew Smoke Beyond Targets at 60, 90, ft No Opacity Recorded
  - Inability to Establish limits of Light or Wind







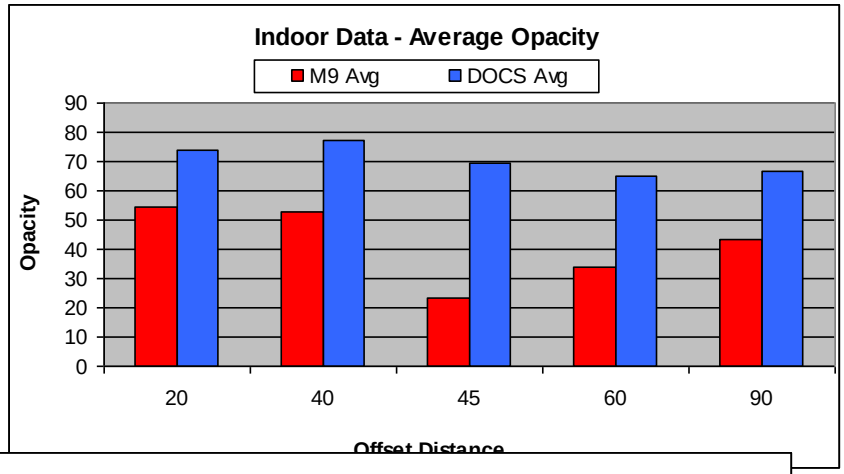
Validate DOCS II for Regulatory Acceptance

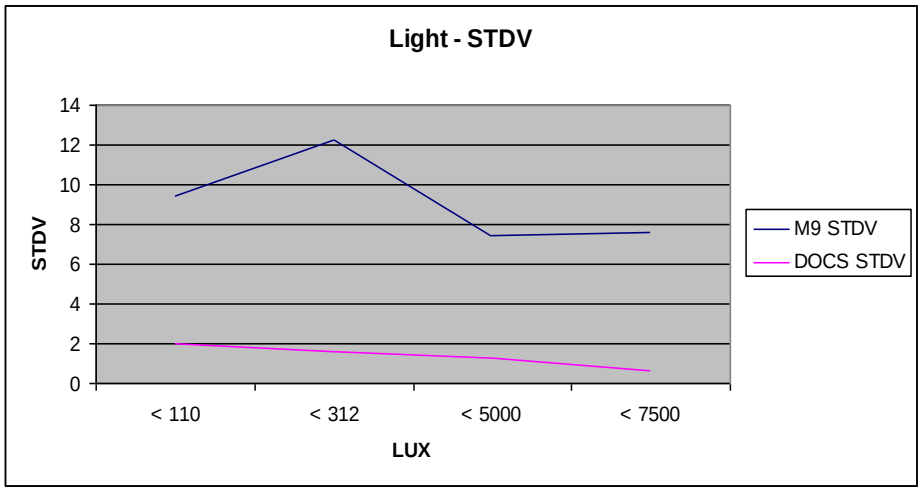
Requested to Find Light and Wind Limits

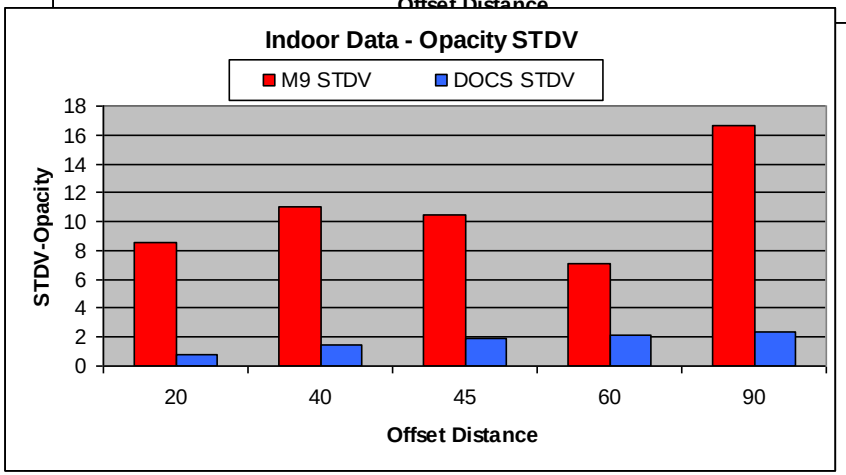
Requested to Define Persistence of Emission

DOCS II Fugitive Emissions
Hill Indoor Analysis 09 01 06, 11 09 06

- Light Limit >200 LUX
- Wind Limit Between 1 and 15 mph
- Higher Light Less Variance
- Accuracy Could not be Determined
  - Even With Targets In Place Readers Eyes Follow Plume







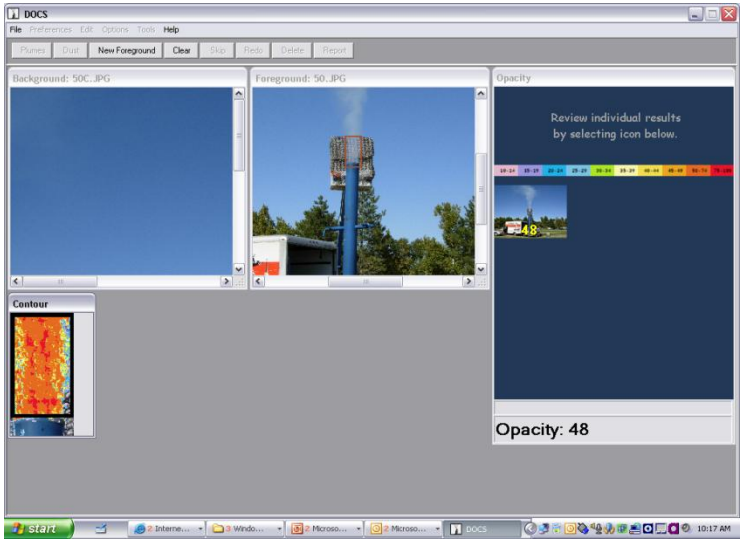
Validate DOCS II for Regulatory Acceptance

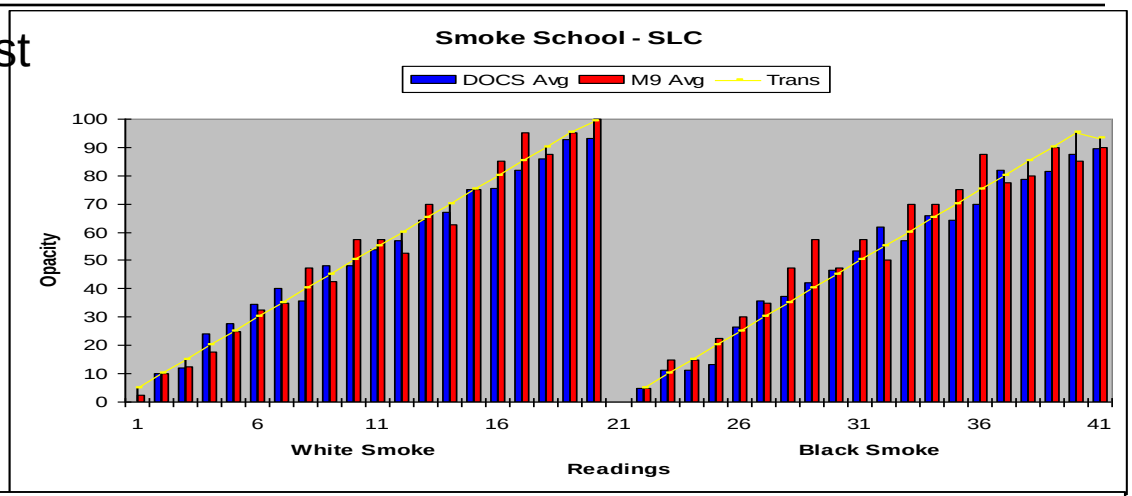
Defined Light and Wind Limits

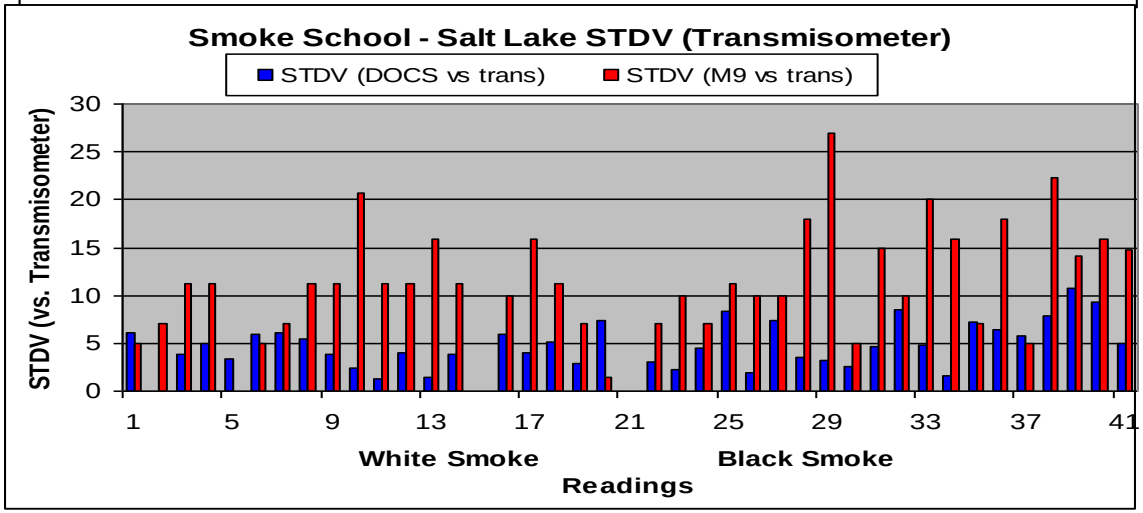
Precision Validated

DOCS II Fugitive Emissions
Smoke School Hill Test 10 19 06

- DOCS II Compared to M9 Against Transmissomitor
- Accuracy Established
- Method 9 Certification Distance
  - 45 Feet From Source
- Used Camouflage to Simulate Background of Fugitive Environment





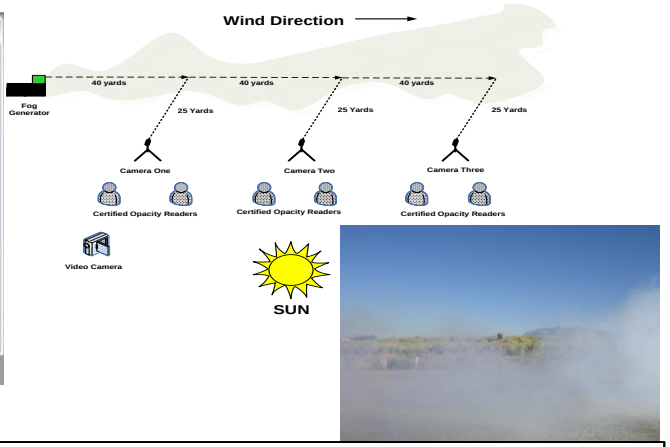


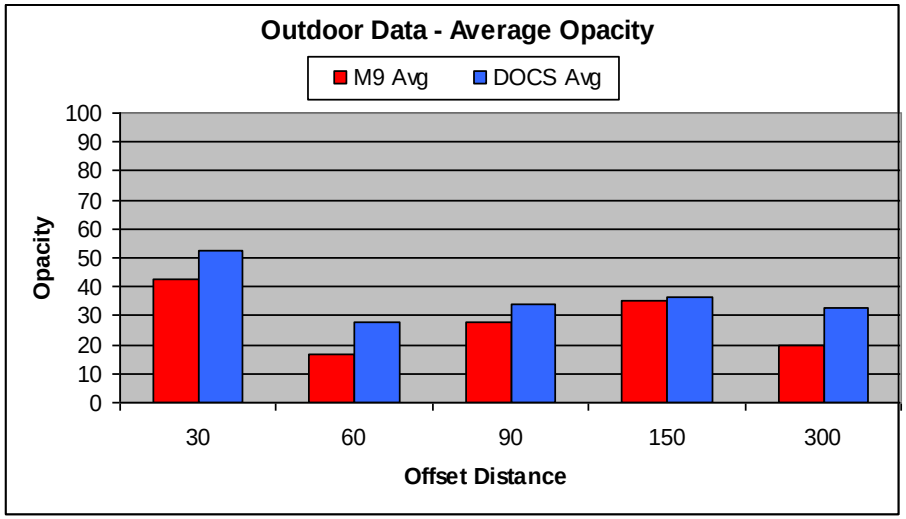
Validate DOCS II for Regulatory Acceptance

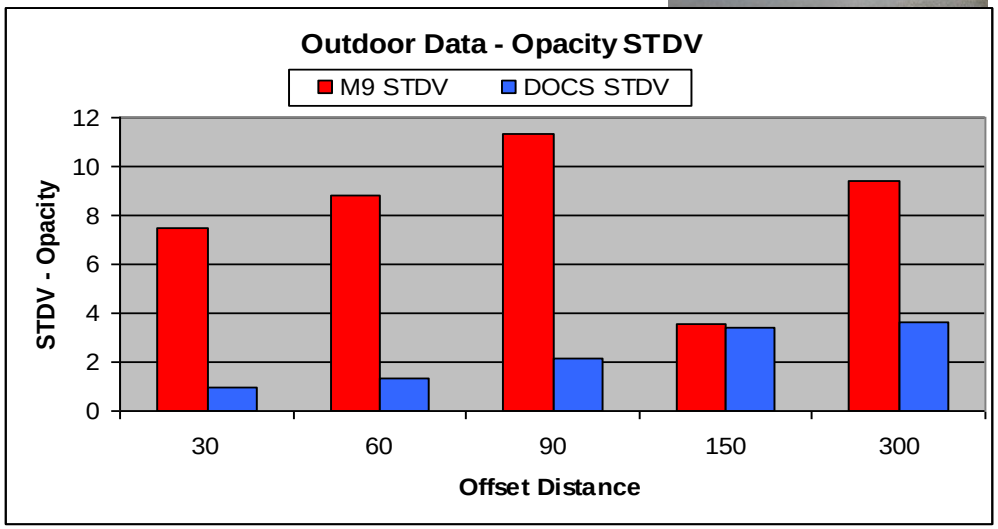
DOCS II Accuracy Validated

DOCS II Fugitive Emissions
Hill Outdoor 9 25 06, 11 02 06

- Compare DOCS II with Method 9 Compliance Conditions
- Constant Source
  - Fog Generator
  - Extreme Distance





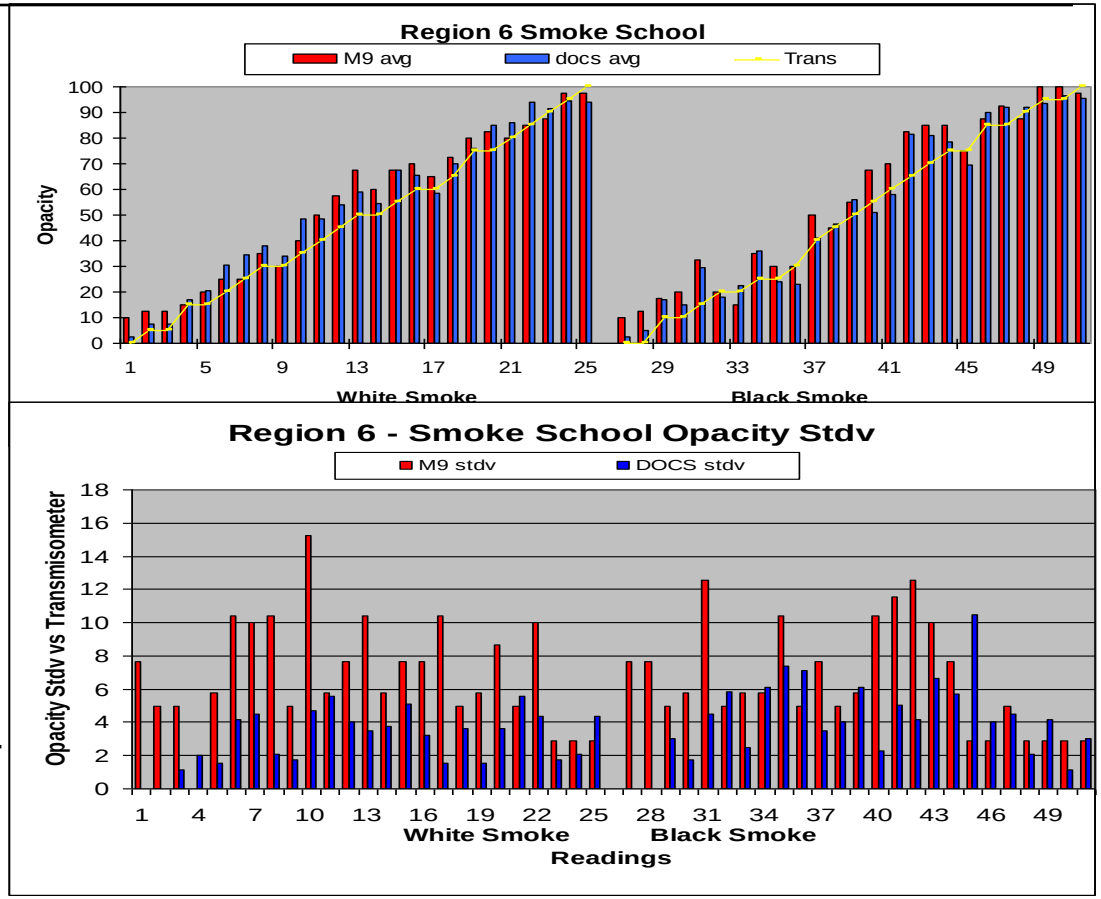


Validate DOCS II for Regulatory Acceptance

DOCS II Just as Reliable In Compliance Conditions as Method 9

DOCS II Fugitive Emissions
Smoke School Region 6 Test 02 20 07

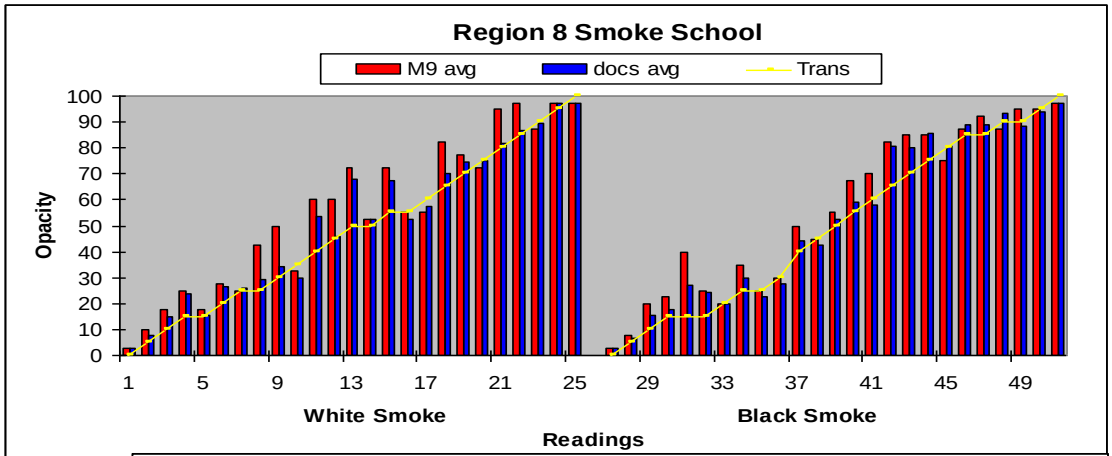
- DOCS II Compared to Known Transmissomitor
  - 45 and 90 feet
  - Software Distributed to All Participants
- Validation for TCEQ
  - Revise Ft Hood Tile V to Include DOCS II Implementation and Training
    - Implementation through use of Method 9 users first year DOCS school after that.
    - DOCS School currently under development

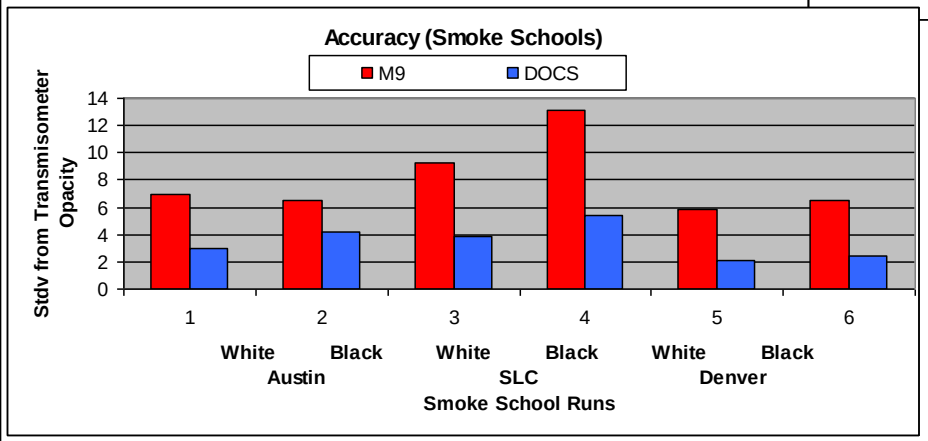


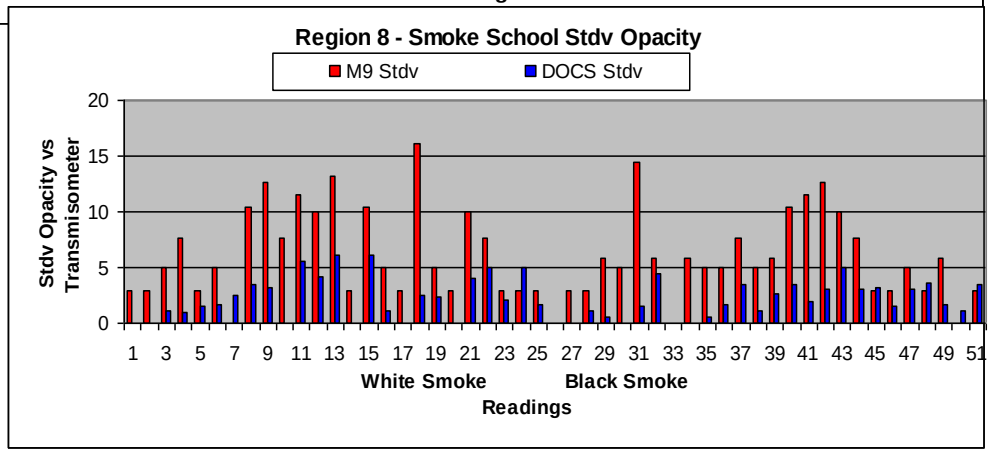
Validated DOCS II Capability Against Method 9 and Transmissometer

DOCS II Fugitive Emissions
Smoke School Region 8 Test 04 17 07

- Compare DOCS II to Method 9 With a Known Opacity Source
  - DOCS II Accuracy Better
  - DOCS II Precision Better
  - Method 9 Individual Readings
    - Much More Error Than DOCS II
    - Averaged With Multiple Readers
      - Very Close to DOCS II







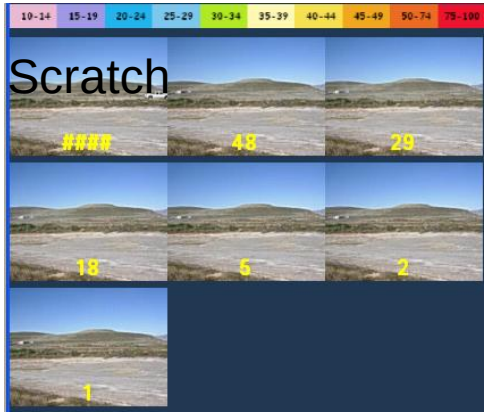
Validation of DOCS II Capability

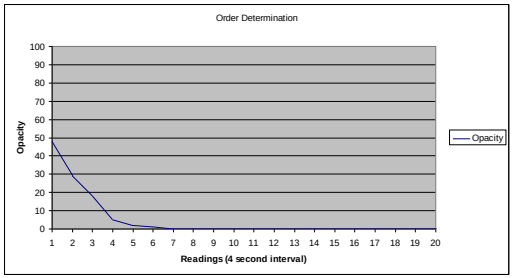
Average Accuracy Validated, Instantaneous Capability Established

DOCS II Passed Smoke School Just Like Method 9 Readers

DOCS II Fugitive Emissions ODR Test 4 13 07

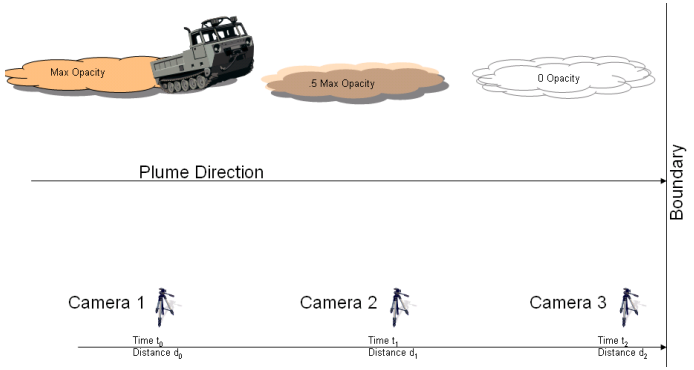
- Minimized scale of test to define better define req.
- **Identified Requirements**
  - Source Dissipates Too Fast 17 Seconds to Zero adjusted to every 4 seconds
  - Reading Every 15 Seconds for 6 Min. Like M9 Can Not Be Used
  - Event Definition Images Every 4 sec. High Opacity = Start, Below 2 opacity = End
- Opacity Decay Linear Until Very Low Visibility >3%





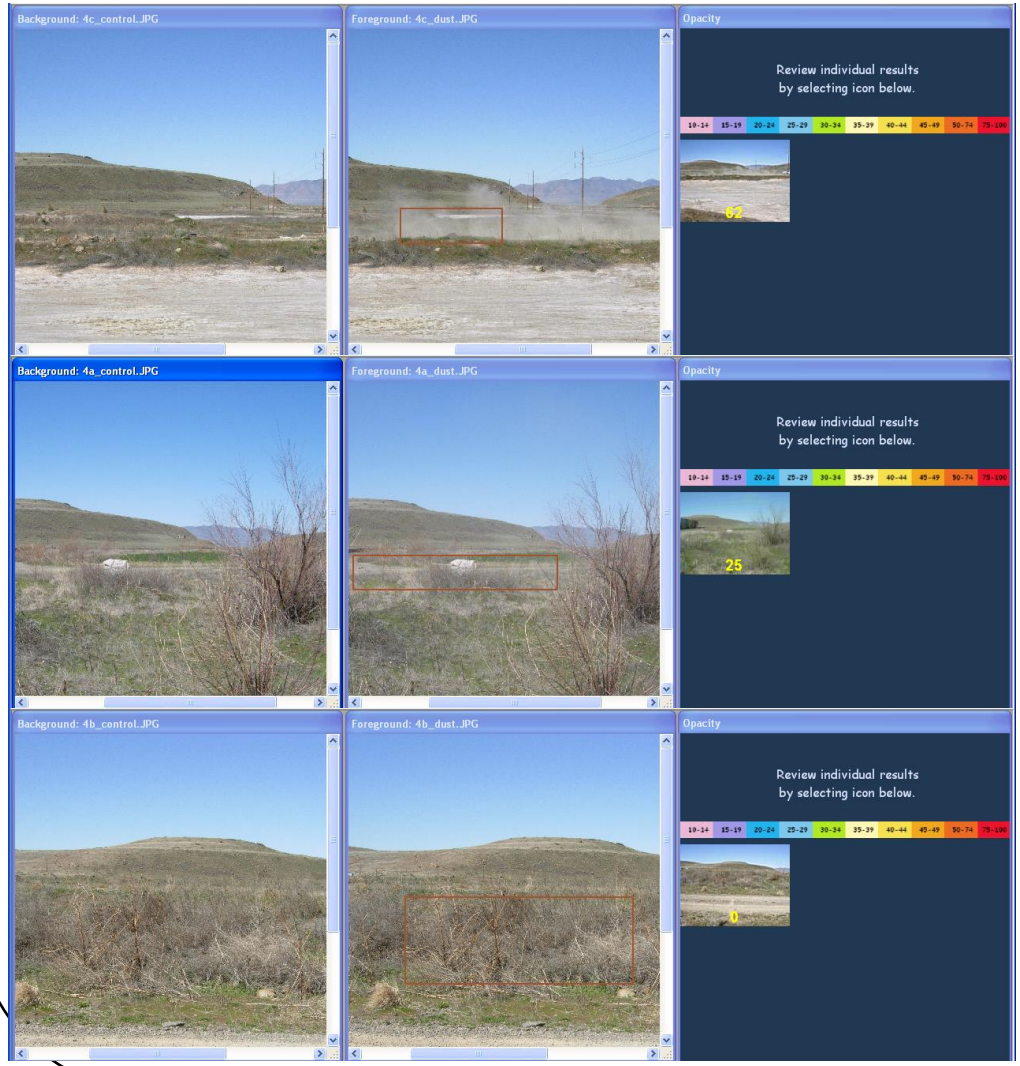
Calculated ODR Duration @ Distance:

- Half Life: 8.5 Seconds and @ 150 ft
- Life: 17 Seconds and @ 300ft

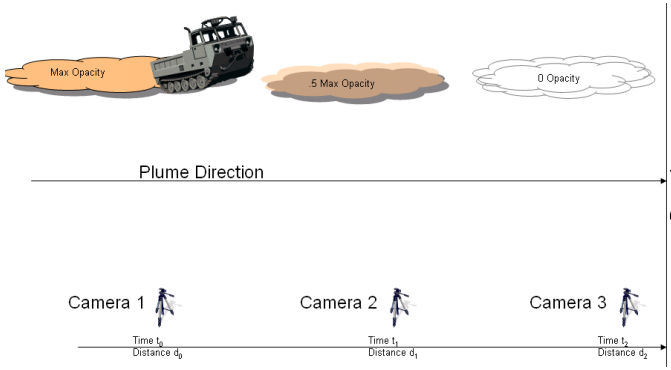


Validating Opacity Dissipation Rate Calculations

DOCS II Fugitive Emissions
ODR Test 4 13 07



Source
62%
D=0
T=0



Opacity Half
Distance 150'
Time 8.5 sec
25%

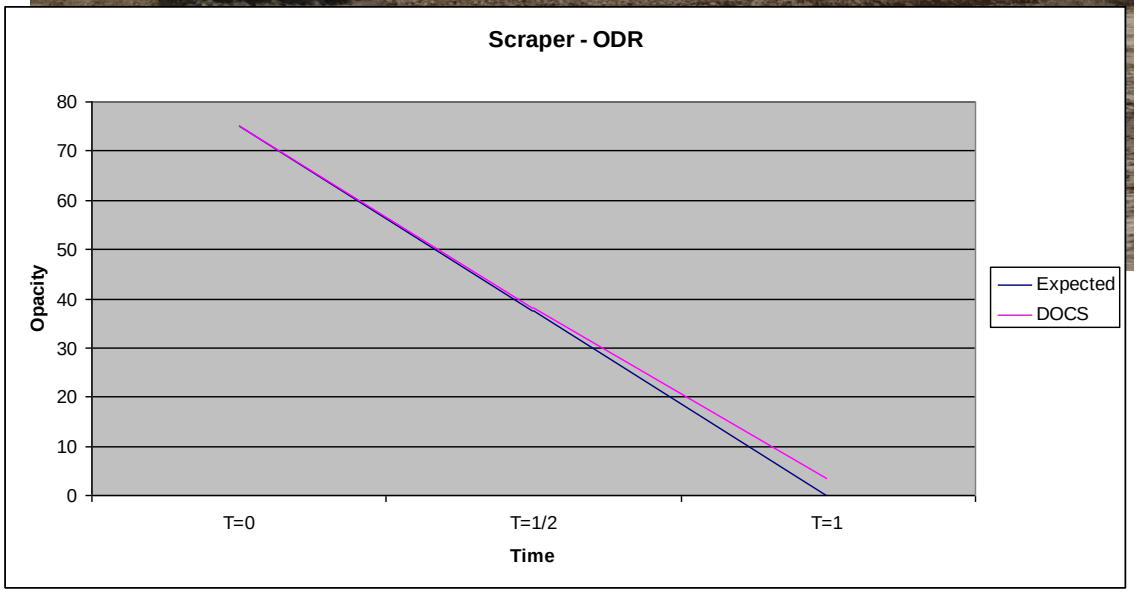
Opacity Zero
Distance 300'
Time 17 sec
0%

Conclusions:

- Linear Dissipation Valid
- Reynolds Numbers (Mixing) Not Needed
- Plan Revisions Required to Reduce Sequence to 5 sec
  Start = First Image
  End = Fourth Image

DOCS II Fugitive Emissions ODR Test 5 5 07

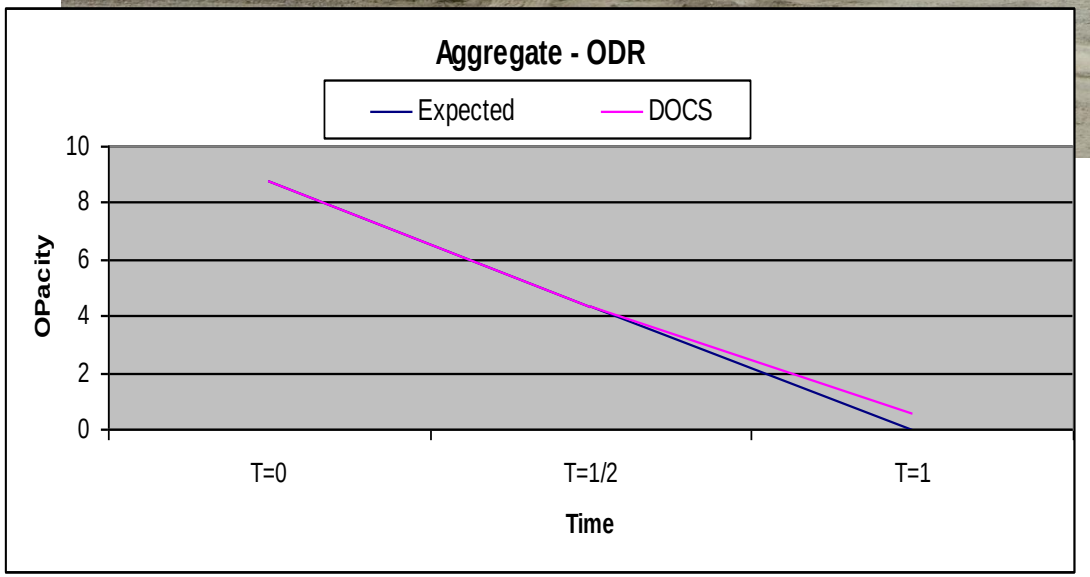
- Scraper at Hill AFB
  - 4 Images 5 sec Apart (5 in set)
  - ODR Validation
- Linear Dissipation Valid To Below Visible
- Reynolds Numbers (Mixing) Not Needed
- Can Accurately Predict how fast 'Visible Emission" will Persist



Validating Opacity Dissipation Rate Calculations

DOCS II Fugitive Emissions ODR Test 5 5 07

- Aggregate Handling Hill AFB
  - 4 Images 5 sec Apart (5 in set)
  - ODR Validation
- Linear Dissipation Valid
- Validated Capability to Accurately Determine the Persistence of Opacity

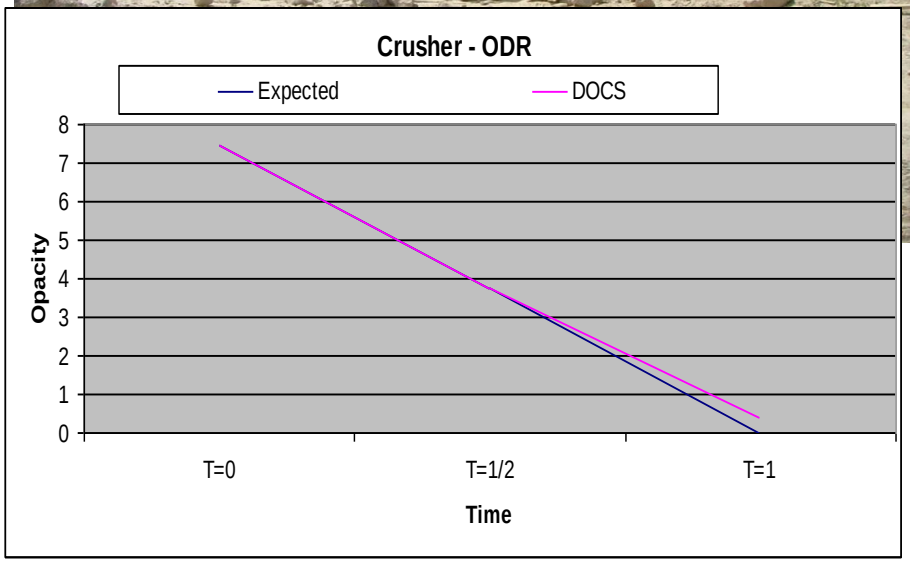


Validating Opacity Dissipation Rate Calculations

DOCS II Fugitive Emissions ODR Test 5 5 07

- Continuous Source Test To CA Rules
  - Comparison to CA Continuous Method For Continuous Sources
  - Event Start at T=0 and End T=60 min.
  - Readings Every 15 sec. for Hour
    - Average of 3 min From High Opacity

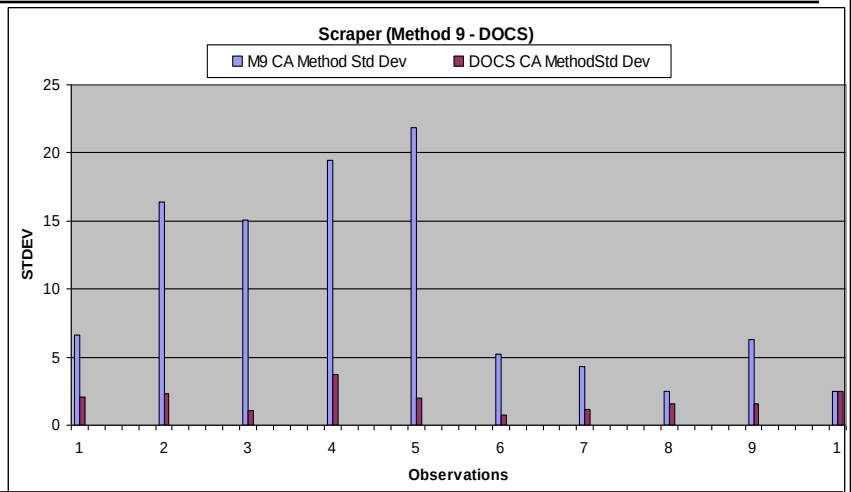
      (12 readings) = Opacity
  - Event Start at T=0 and End T=60 min, Images every 15 sec. (241 to set), High Opacity Image Plus Previous 5 and Next 6 (12 readings) to Compare to Human Readings, High Opacity Image Plus Next 6 used for ODR calc.

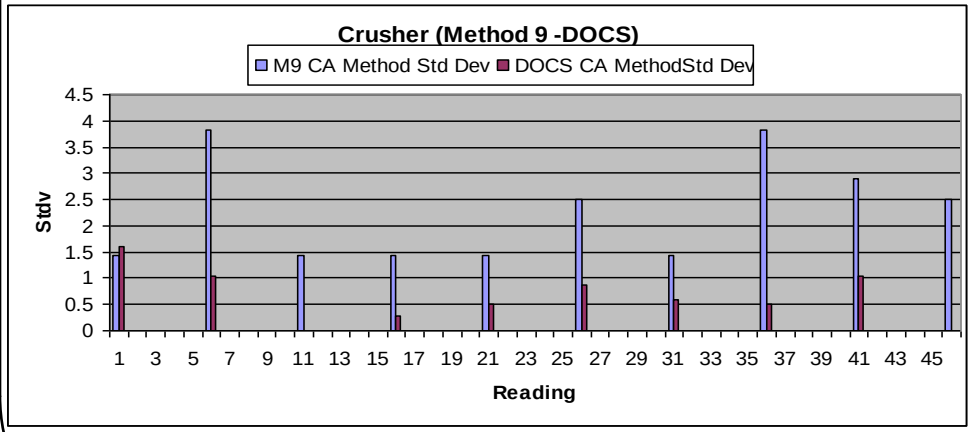


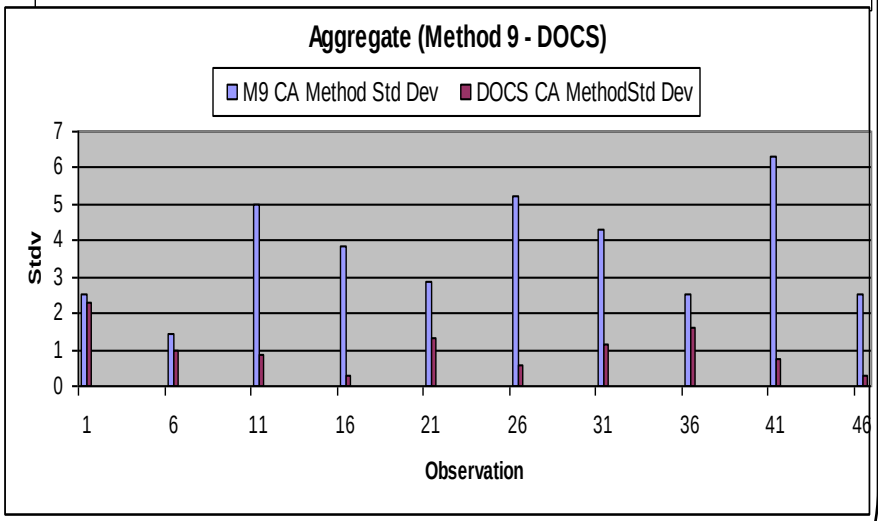
Validating Opacity Dissipation Rate Calculations

DOCS II Fugitive Emissions ODR Test 5 5 07

- Comparison, CA Road Dust Rules
  - Event Start T=0 and End T=5 sec.
  - Two Opacity Readings 0 and 5 sec
    - Average of two, equal opacity of event
  - Event Starts at T=0 and End T=15 sec. Images Every 5 sec. (4 to set), first 2 to Compare to Human Readings all 4 Used for ODR calc.







Comparing High Variable M9 to Low Variable DOCS II Using Two Readings

Human Opacity Average Higher than DOCS II Average

DOCS II
Automating Method 9

- DOCS II Released to Final Testing 5-08
  - Images Validated from Header Record EXIF
  - Integrated GPS Locations
  - Integrated NOAA ‘Weather”
  - Streamlined User Interface
  - Integrated Solar Tables
  - Generated “Most Credible Evidence” argument based on Integrated Output from DOCS II

DOCS II Validated to Determine Instantaneous Opacity and ODR

ASTM Standard D7520-09 Digital Camera Opacity Technique

- Performance Standard requiring same criteria as Method 9
- Software, Camera and Computer Model Certified in DCOT package
- Certification valid for 3.5 years (lifecycle of computer equipment)
- Operators required to know how to take images and document observation
- DCOT providers responsible for training

Lessons Learned--Risk Reduction

- Industry is significantly concerned with vetting technological solutions
- Method 9 had no perceived scale-up issues when moving from the certification platform to field application
- In contrast, tools based on the new ASTM standard require a significant body of data showing:
  - Certification success
  - Field success against in-stack transmissometers for various stack sizes and configurations

CAA 1990 Amendments, Section 113(e)(1):

Penalty calculation: “the duration of a violation is established by *any credible evidence*, including evidence other than that in the applicable test method”

Summary

- DOCS II aligns with most aspects of Method 9:
  - Smoke school certification
  - Certification records
- DOCS II certified to ASTM 7520-09 method
- DOCS II can be applied as an equivalent to Method 9
- DOCS II can be used as a field data acquisition support tool in conjunction with traditional human observations
- DOCS II sets a new standard for Credible Evidence in the Visible Emissions measurement.

CAA 1990 Amendments, Section 113(e)(1):

Penalty calculation: “the duration of a violation is established by *any credible evidence*, including evidence other than that in the applicable test method”

The Future of Visual Emissions Opacity Measurements & Data Collection

Handheld Real Time Climatic Sensor

- Handheld Data Collection Device for DOCS II Application
  - One Device Collects all Required Data
  - Error-Free Automated Data Collection

- Integrated Weather Meter, GPS, Rangefinder, & Camera
- Measures all Required Report Data including
  - Weather Conditions - Wind Speed, Wind Direction, Temperature, & Humidity
  - GPS Position Location, Sun Position, & Time
  - Distance to Target Missions Source
  - Digital Images of Visual Emissions & Source
- Creates Digital Reports in the Selected Format
- Only Works as an Upgrade with PC based DOCS II

Coming in 2011

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