



# Optical Gas Imaging For SF6 Leak Detection



Rob Raymer  
Business Development Manager  
FLIR Commercial Systems  
866-309-4981  
[rob.raymer@flir.com](mailto:rob.raymer@flir.com)

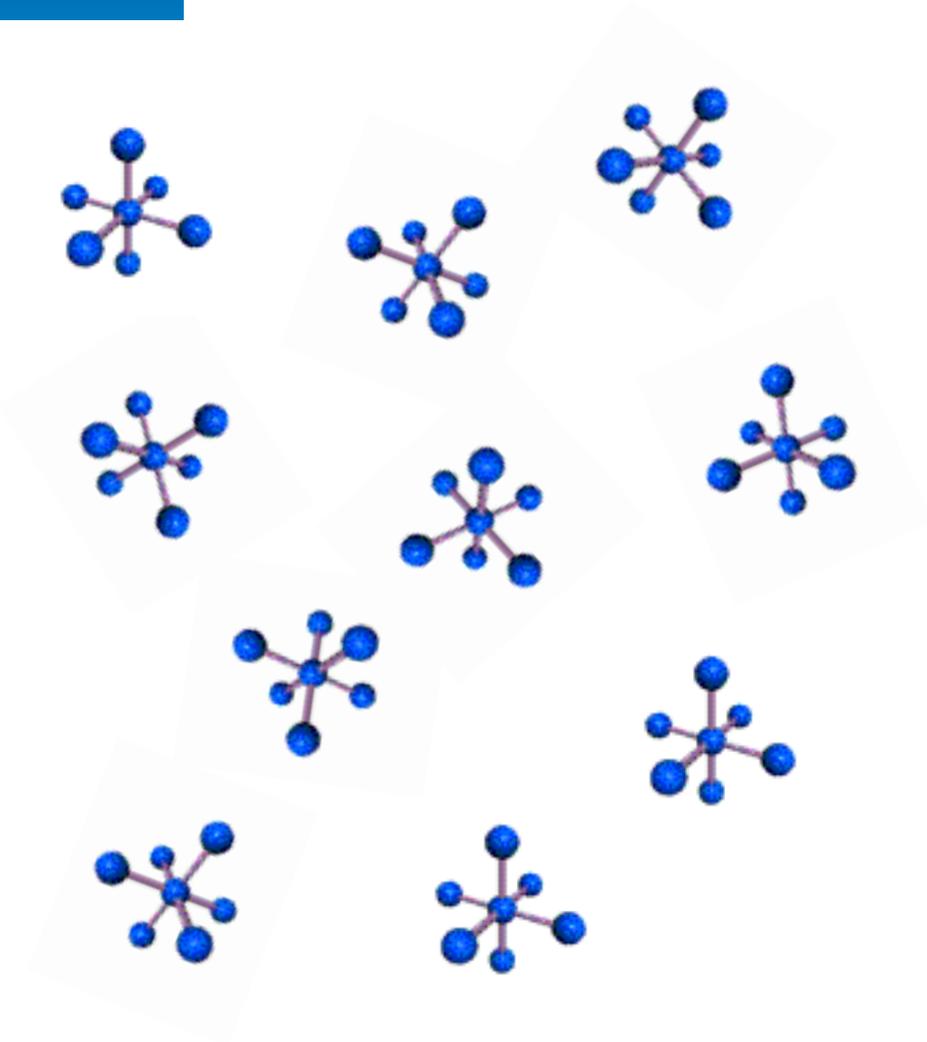
## A Quick Review...

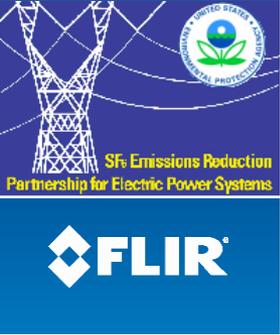
### SF<sub>6</sub>

- An excellent dielectric gas
  - Insulates 2.5x better than air
  - 100x better at arc quenching than air
  - Replaces PCB containing Oil
- Non-toxic
- Chemically neutral (non-reactive)
- Non-flammable
- Doesn't deplete the ozone



If SF<sub>6</sub> is so great, why are we concerned?





# Global Warming Potential

U.S. Environmental Protection Agency

## Non-CO2 Gases Economic Analysis and Inventory

Contact Us | Print Version Search:  **GO**  
[EPA Home](#) > [Climate Change](#) > [Non-CO2 Gases Economic Analysis and Inventory](#) > Global Warming Potentials and Atmospheric Lifetimes (Years)

### Global Warming Potentials and Atmospheric Lifetimes (Years)

Gas	Atmospheric Lifetime	GWP <sup>a</sup>
Carbon dioxide (CO <sub>2</sub> )	50-200	1
Methane (CH <sub>4</sub> ) <sup>b</sup>	12±3	21
Nitrous oxide (N <sub>2</sub> O)	120	310
HFC-23	264	11,700
HFC-32	5.6	650
HFC-125	32.6	2,800
HFC-134a	14.6	1,300
HFC-143a	48.3	3,800
HFC-152a	1.5	140
HFC-227ea	36.5	2,900
HFC-236fa	209	6,300
HFC-4310mee	17.1	1,300
CF <sub>4</sub>	50,000	6,500
C <sub>2</sub> F <sub>6</sub>	10,000	9,200
C <sub>4</sub> F <sub>10</sub>	2,600	7,000
C <sub>6</sub> F <sub>14</sub>	3,200	7,400
SF <sub>6</sub>	3,200	23,900



**CO2 is the baseline (GWP = 1)**

**SF6 is a potent greenhouse gas!**

<sup>a</sup> 100 year time horizon

<sup>b</sup> The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO<sub>2</sub> is not included.

-  Climate Change Home
- Non-CO<sub>2</sub> Gases Economic Analysis & Inventory Home
- Sources & Emissions
- Projections & Mitigation Costs
- International Analyses
- Links & Resources

# SF<sub>6</sub> Emission Reduction Programs

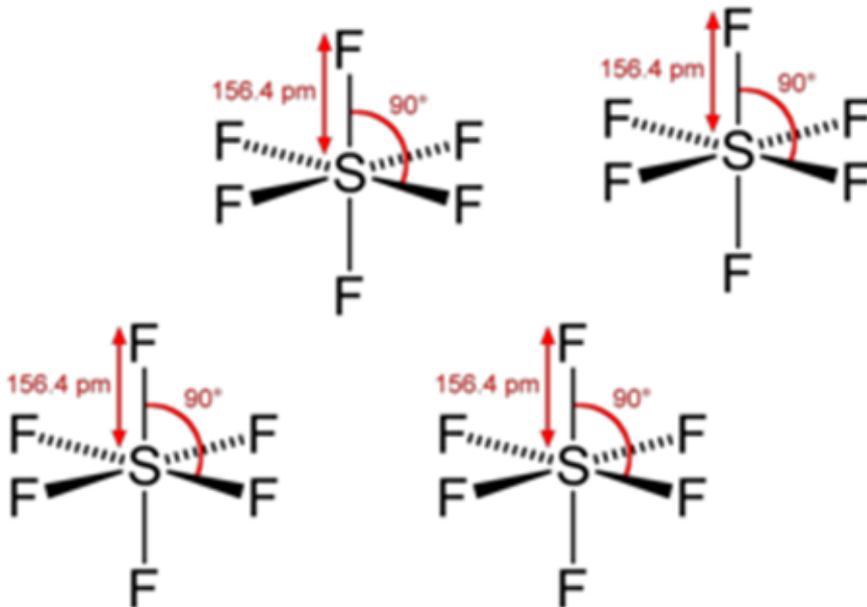
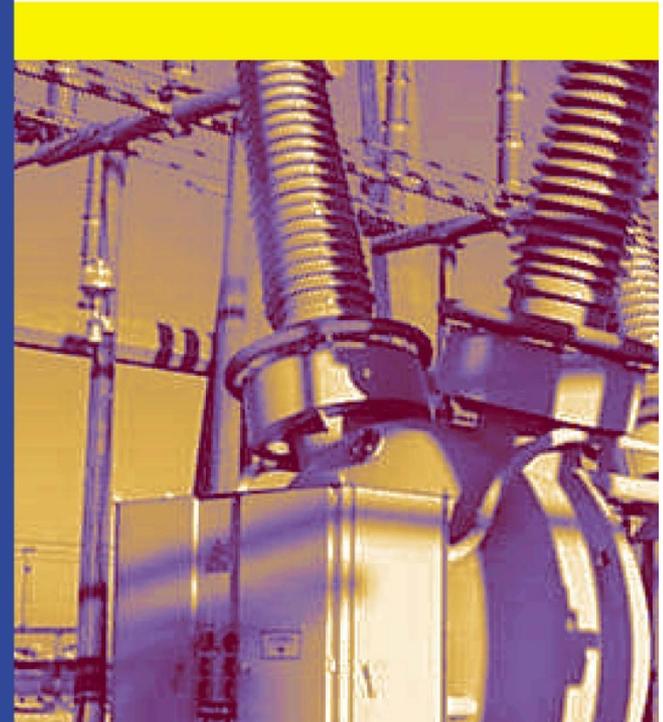
- In 1999, the EPA and members of the electric power industry created the "SF<sub>6</sub> Emissions Reduction Partnership for Electric Power Systems"

United States  
Environmental  
Protection Agency

Office of Air and  
Radiation (6202J)

EPA430-F-000-19  
March 2002

 **SF<sub>6</sub> Emissions Reduction  
Partnership for Electric  
Power Systems:**  
An Opportunity for Industry





# The EPA's Greenhouse Gas Rule

Greenhouse Gas Reporting Rule | Regulatory Initiatives | Climate Change | U.S. EPA - Windows Internet Explorer

US EPA http://www.epa.gov/climatechange/emissions/ghgrulemaking.html

U.S. ENVIRONMENTAL PROTECTION AGENCY

## Climate Change - Regulatory Initiatives

Contact Us Search:  All EPA  This Area

You are here: [EPA Home](#) » [Climate Change](#) » [Regulatory Initiatives](#) » Final Mandatory Reporting of Greenhouse Gases Rule

### Final Mandatory Reporting of Greenhouse Gases Rule

**← FINAL RULE**

Final Mandatory Reporting of Greenhouse Gases Rule | Resources and Tools | Training Opportunities | Background | Rule Help Center

In response to the FY2008 [Consolidated Appropriations Act](#) (H.R. 2764; Public Law 110-161), EPA has issued the Final Mandatory Reporting of Greenhouse Gases Rule. The rule requires reporting of greenhouse gas (GHG) emissions from large sources and suppliers in the United States, and is intended to collect accurate and timely emissions data to inform future policy decisions.

Under the rule, suppliers of fossil fuels or industrial greenhouse gases, manufacturers of vehicles and engines, and facilities that emit 25,000 metric tons or more per year of GHG emissions are required to submit annual reports to EPA. The gases covered by the proposed rule are carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulfur hexafluoride (SF<sub>6</sub>), and other fluorinated gases including nitrogen trifluoride (NF<sub>3</sub>) and hydrofluorinated ethers (HFE).

The final rule was signed by the Administrator on September 22, 2009.

EPA's new reporting system will provide a better understanding of where GHGs are coming from and will guide development of the best possible policies and programs to reduce emissions.

This comprehensive, nationwide emissions data will help in the fight against climate change.

- [Press Release](#)
- [Final Mandatory GHG Reporting Preamble \(full version\) \(PDF\)](#) (591 pp, 4.67 MB, [About PDF](#))
  - [Preamble Sec. I - II, p. 1-150 \(Introduction, Background, General Requirements of the Rule\) \(PDF\)](#) (150 pp, 567 KB, [About PDF](#))
  - [Preamble Sec. III.A - III.S, p. 151-300 \(Overview and Electricity Purchases through Lime Manufacturing\) \(PDF\)](#) (150 pp, 558 KB, [About PDF](#))
  - [Preamble Sec. III.T - III.PP, p. 301-489 \(Magnesium Production through Suppliers of Carbon Dioxide\) \(PDF\)](#) (189 pp, 629 KB, [About PDF](#))
  - [Preamble Sec. IV - VIII, p. 489-591 \(Mobile Sources through Statutory and Executive Order Reviews\) \(PDF\)](#) (103 pp, 537 KB, [About PDF](#))
- [Final Mandatory GHG Reporting Rule Text \(full version\) \(PDF\)](#) (711 pp, 2.11 MB, [About PDF](#))
  - [Rule Parts 86-94, p. 592-600 \(Mobile Sources\) \(PDF\)](#) (9 pp, 548 KB, [About PDF](#))
  - [Rule Part 98, subparts A, C, & G, 608-701 \(General Provisions through General Stationary Fuel Combustion Sources\) \(PDF\)](#)

**What's New**

- EPA Offers Training on GHG Reporting Applicability Tool
- EPA Administrator Lisa Jackson Signs Final Mandatory Reporting of Greenhouse Gases Rule

**Resources and Tools**

- Press Release
- Frequently Asked Questions
- General Fact Sheet (PDF) (3 pp., 35 KB, [About PDF](#))
- Power Point Presentation of the Mandatory Reporting of GHG Rule (PDF) (26 pp., 258 KB, [About PDF](#))
- Major Changes to the Rule Since Proposal (PDF) (1 p, 46 KB, [About PDF](#))
- Applicability Tool
- Information Sheets/Checklists for Source Categories
- Technical Support Documents

You will need Adobe Reader to view some of the files on this page. See [EPA's PDF page](#) to learn more.

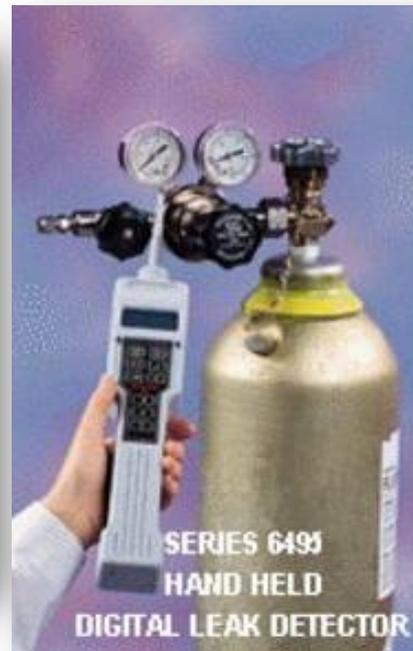
# How do you find these SF<sub>6</sub> leaks?



# Soap Testing



# Hand-held Leak Detectors "Sniffers"



## Major Limitations ...

- It is ***DANGEROUS*** to use a “sniffer” on energized equipment.
- Equipment must be ***De-Energized*** to inspect the areas most prone to leaking.



# A Better Technology...



**Optical Gas Imaging!**

# What is Optical Gas Imaging?

- A technology that allows us to “see” invisible gases
  - *Gas looks like smoke*
- Term was coined by the US EPA in Spring of 2006
- OGI Instrument definition

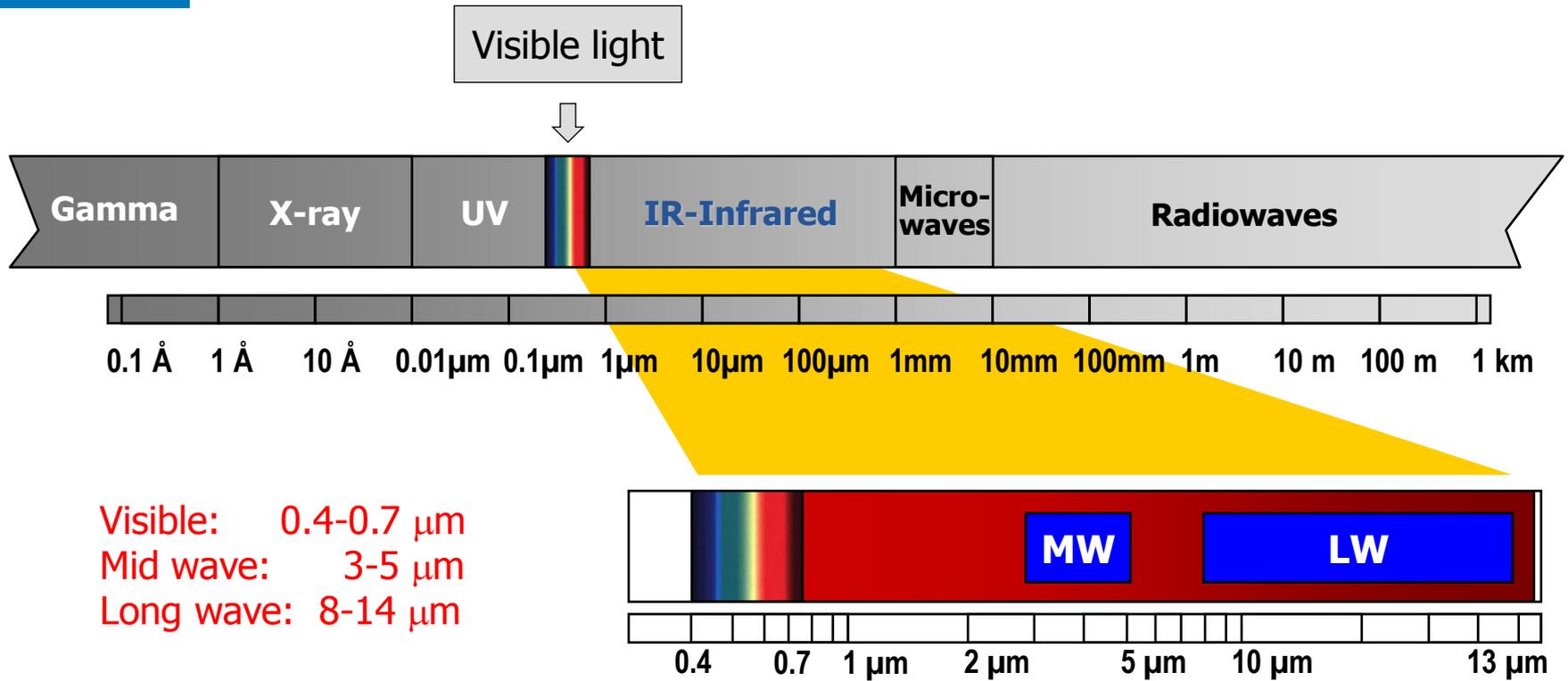
(4) Optical gas imaging instrument means an instrument that makes visible emissions that may otherwise be invisible to the naked eye.

# What is Optical Gas Imaging?

- A technology that allows us to “see” invisible gases
  - *Gas looks like smoke*
- Term was coined by the US EPA in Spring of 2006
- OGI Instrument definition
- “Instrument” refers to a thermal imaging camera
  - An Infrared Camera

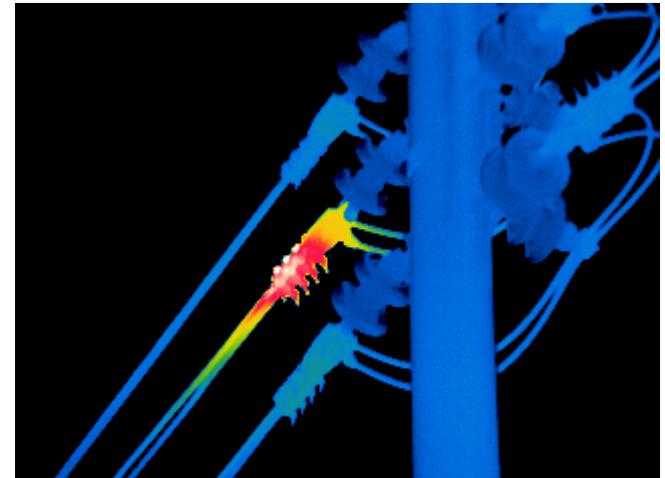


# What is Infrared?



# What is an Infrared Image?

- Image of varying colors or shades of B&W
- Each color represents an amount of detected infrared energy.
- Typically, brighter colors indicate more IR energy (hotter)



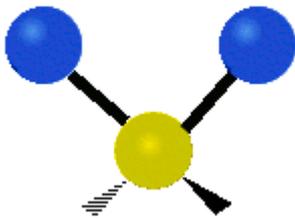
# How Does an OGI Camera See Gas?

- It's a thermal camera
- It must see the gas due to a temperature difference....Right?

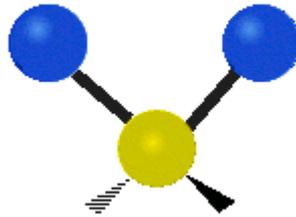


# How Does an OGI Camera See Gas?

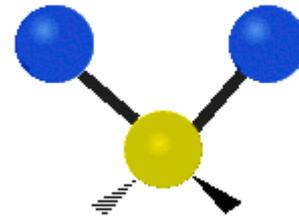
- The camera employs a spectral filter designed to transmit in a region of the IR spectrum that is coincident in wavelength with vibrational/rotational energy transitions of VOC molecular bonds.
- These transitions are typically strongly coupled to the field via dipole moment changes in the molecule, and are common to many types of gases and vapors.
- With this in mind, the camera's detection sensitivity to a wide variety of gases and vapors is extremely small.
- Thermally, the camera's sensitivity is <30mK when FLIR's adaptive temporal filter is engaged.



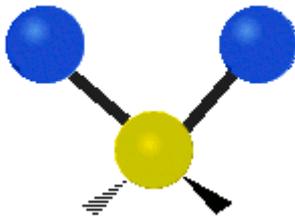
Symmetric stretch



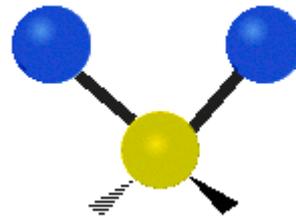
Twisting



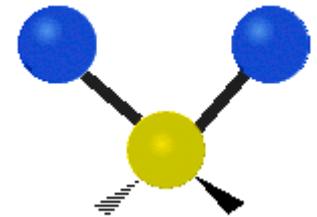
Scissoring



Asymmetric stretch



Wagging

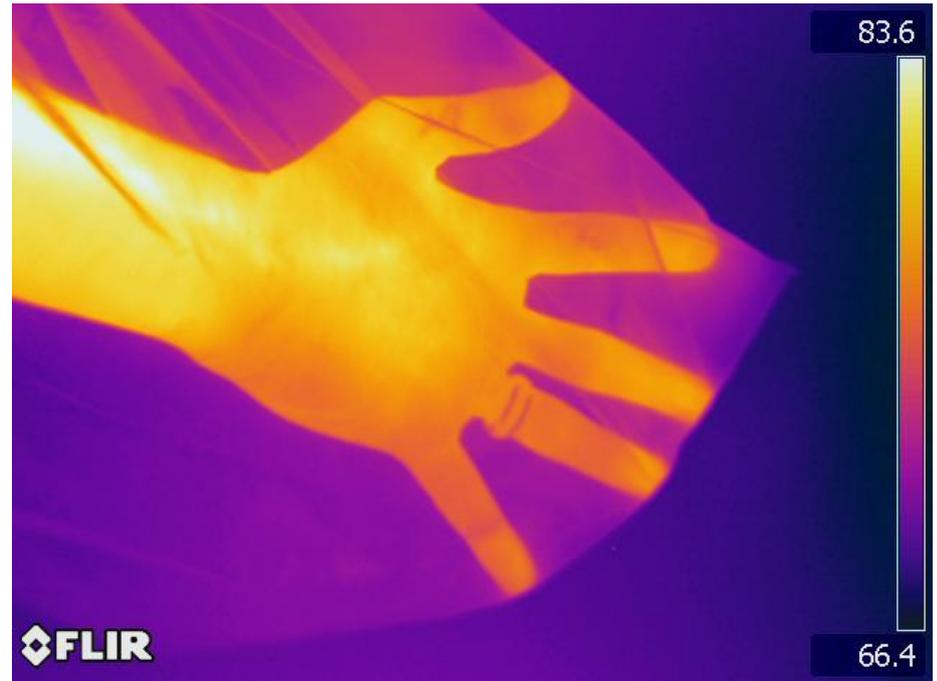


Rocking

# Visual Light Verses Infrared



Visual Light Image  
(White Trash Bag)



Midwave Infrared Image  
(White Trash Bag)

# Visual Light Verses Infrared



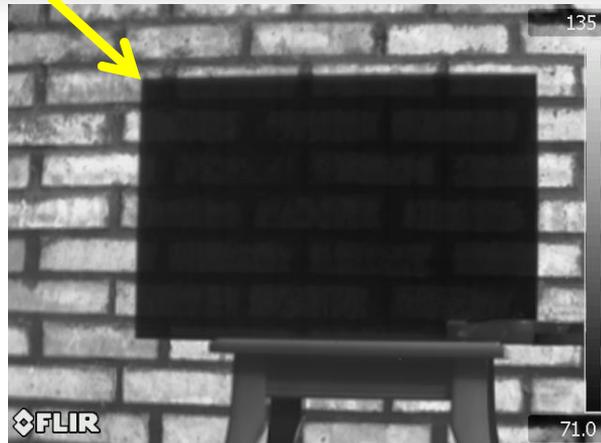
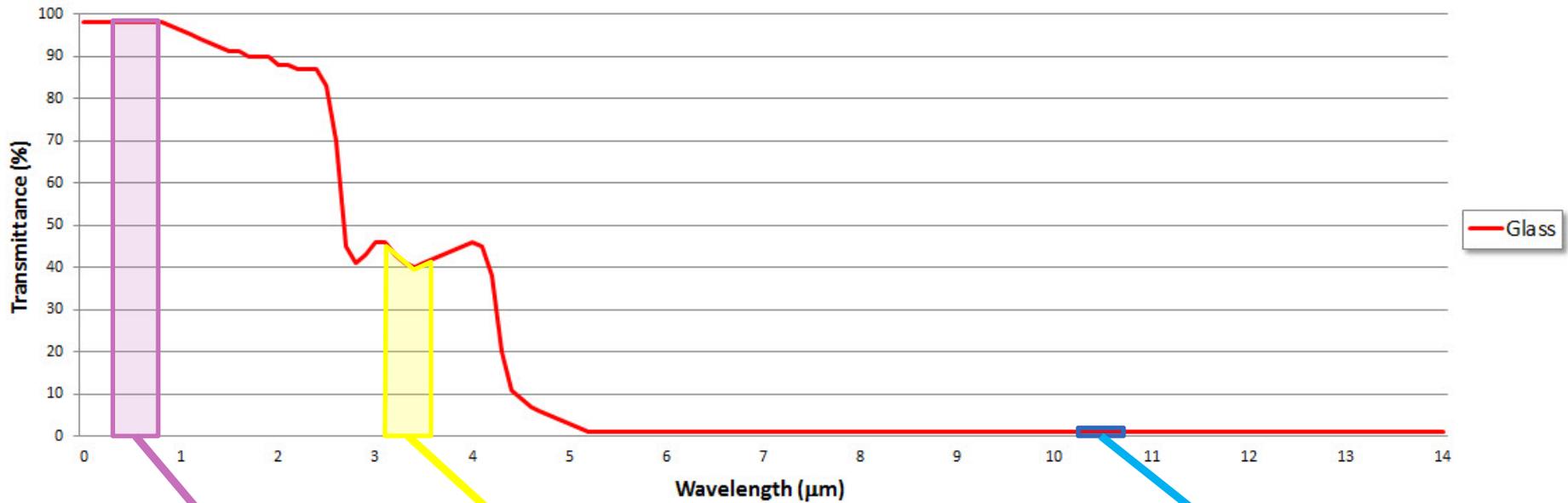
Visual Light Image  
(Plate Glass)



Midwave Infrared Image  
(Plate Glass)

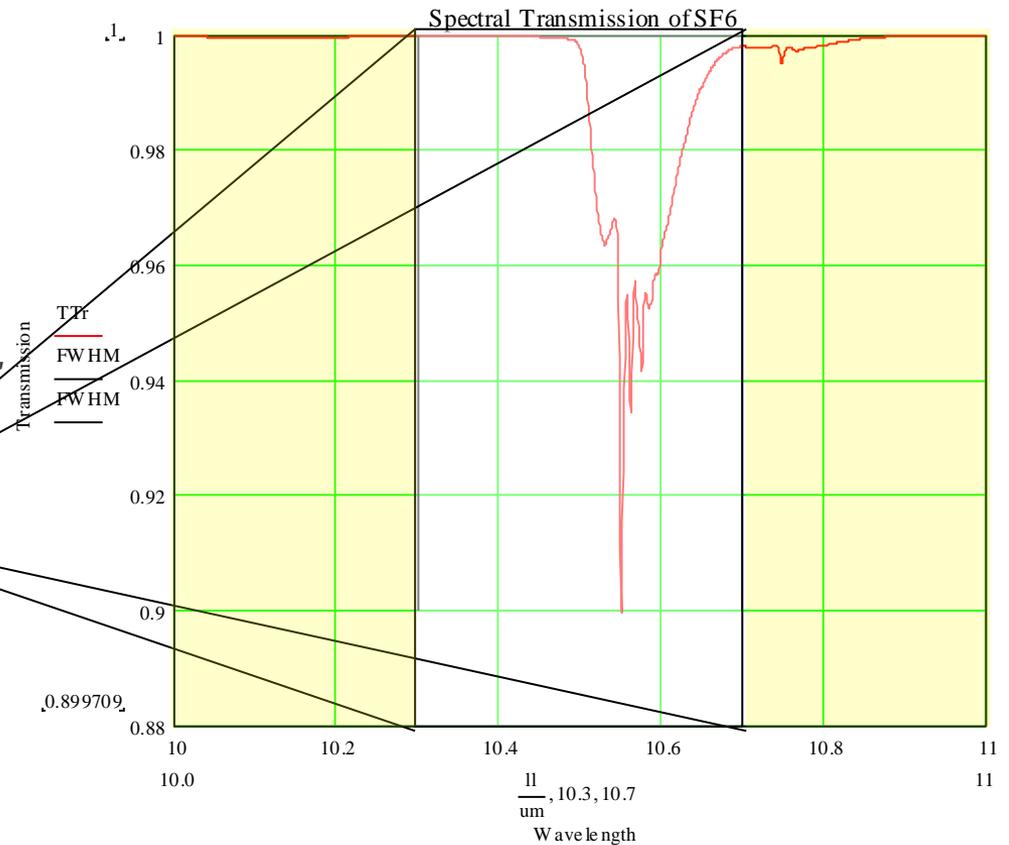
# Glass Example Again...

Infrared Transmission Spectrum - Glass



# How Do We Determine the Wavelength?

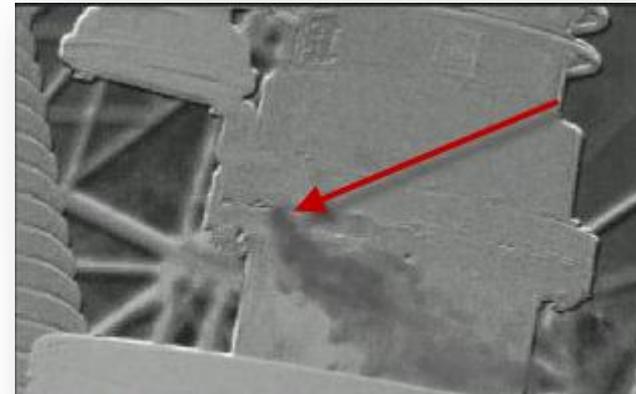
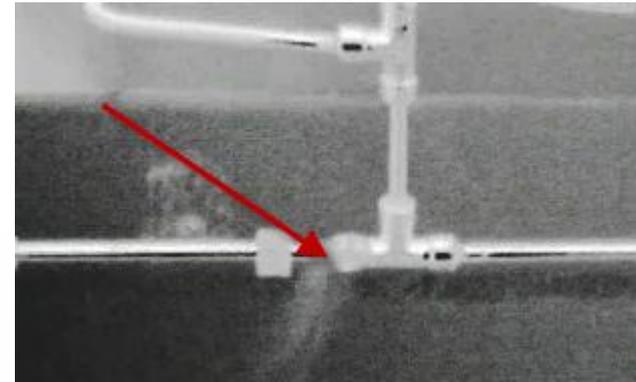
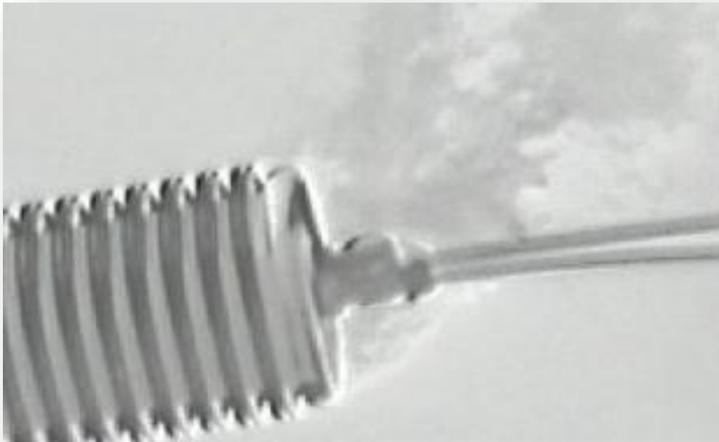
- *First, we locate the "peak" spectral absorption of the gas!*
- *Then we "match" the spectral response of the camera to that wavelength.*



- Gas Spectra
- Filter cutoff FWHM 10.3 $\mu\text{m}$
- Filter cutoff FWHM 10.7 $\mu\text{m}$

# OGI Detection Limits

- Minimum Detectable Leak Rates (MDLR's)
  - **SF<sub>6</sub>**
    - **0.5 lb./year**
    - 2 ppm\*m

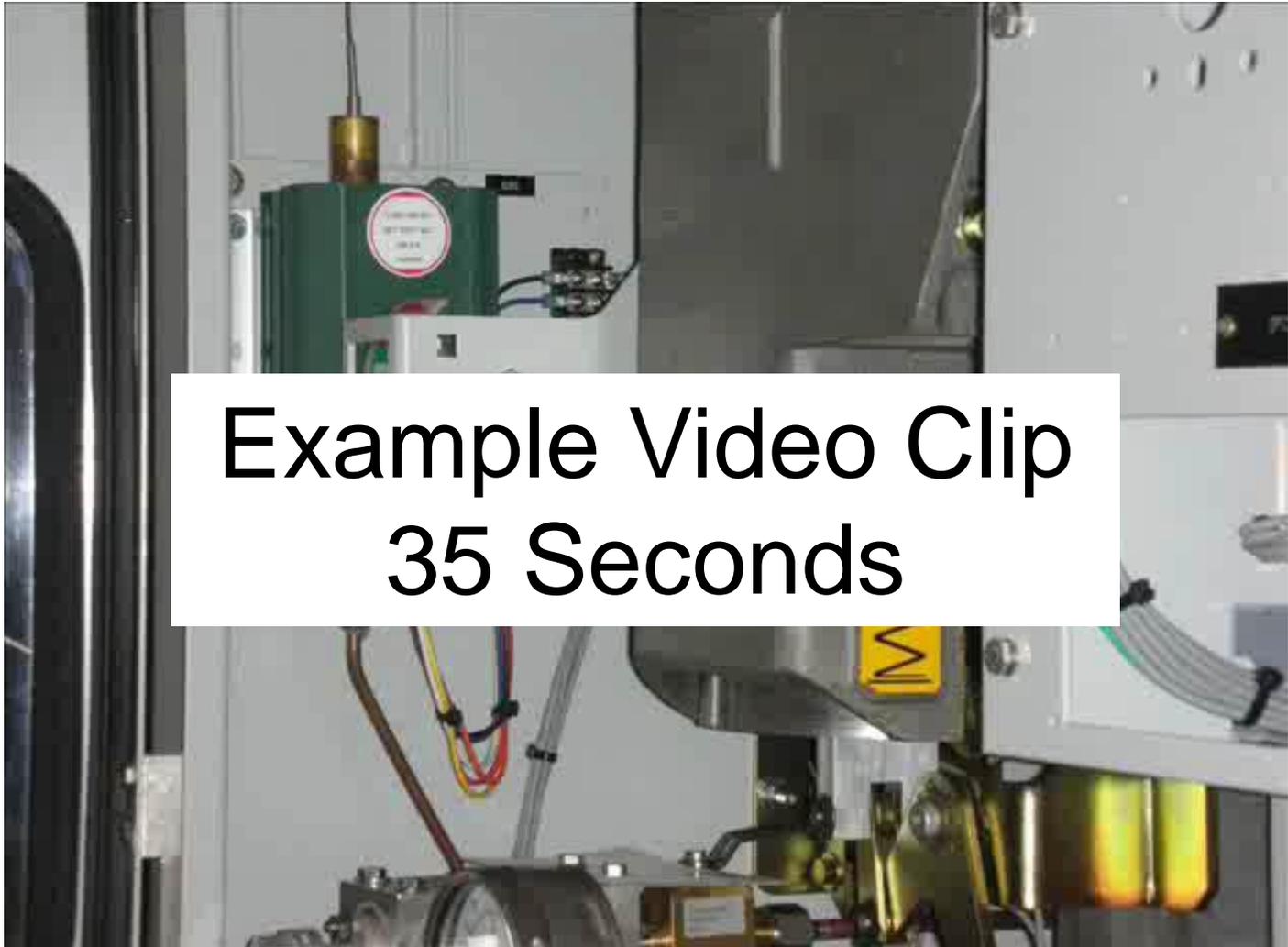




# SF6 Leak Examples

Example Video Clip  
67 Seconds

# SF<sub>6</sub> Leak Example



A world map is shown in a dark blue color with white outlines of the continents. The map is centered on the Atlantic Ocean. Overlaid on the map is the word "Questions?" in a large, bold, yellow font. The background of the entire image is a dark blue field with a pattern of small, glowing white dots, resembling a starry night sky or a digital data field.

**Questions?**