Fire Safety in a Laser Lab

DOE LSO Workshop Sep 10-12, 2013

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Info

Began working in the Laser and Radiation Safety field in 1987, after leaving the US Navy.

Past Experience:

- NASA-Ames Research Center
- UC Berkeley
- University of Cincinnati
- DOE
- Honeywell

Laser Program Extremes

Police State

Lockdown!!

Laser Program Extremes

Bon Jovi Program

Living on a Prayer

Topics

- Fire Safety Objectives
- Fire hazard and Ignition Hazards
- Standards
- Laser Barriers
- Observations

Fire Safety Objectives

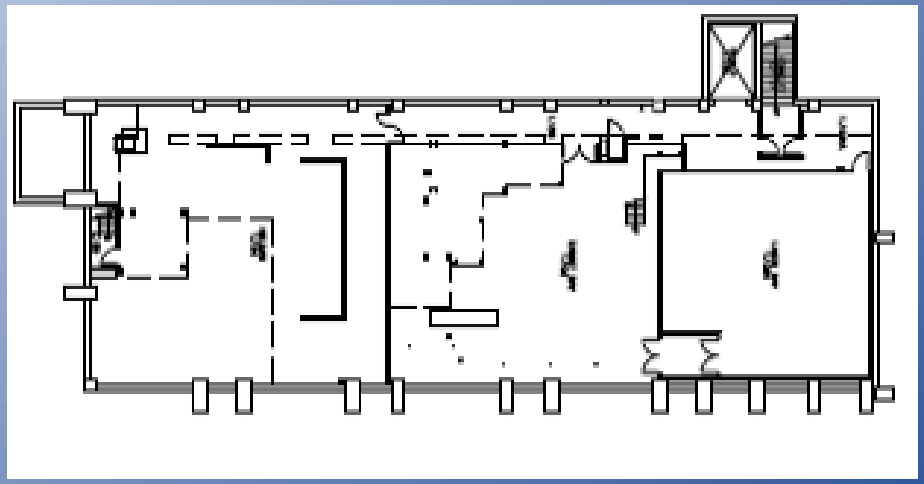
Avoiding hazardous conditions from fire in:

- **Laser components, Optical Path, target, lab materials**
- **Clothing of persons near lab**
- **Building materials**
- **Ignition of Flammable chemicals and gases**
- **Production of smoke, irritants, toxins**

Fire Safety Objectives

Life Safety

- Access into lab during an emergency
  - Medical
  - Fire
  - Other crisis
- Egress from Lab to hallways and exits
  - Primary and Secondary exits
  - Lab equipment / pathways
  - Laser Curtains, barriers



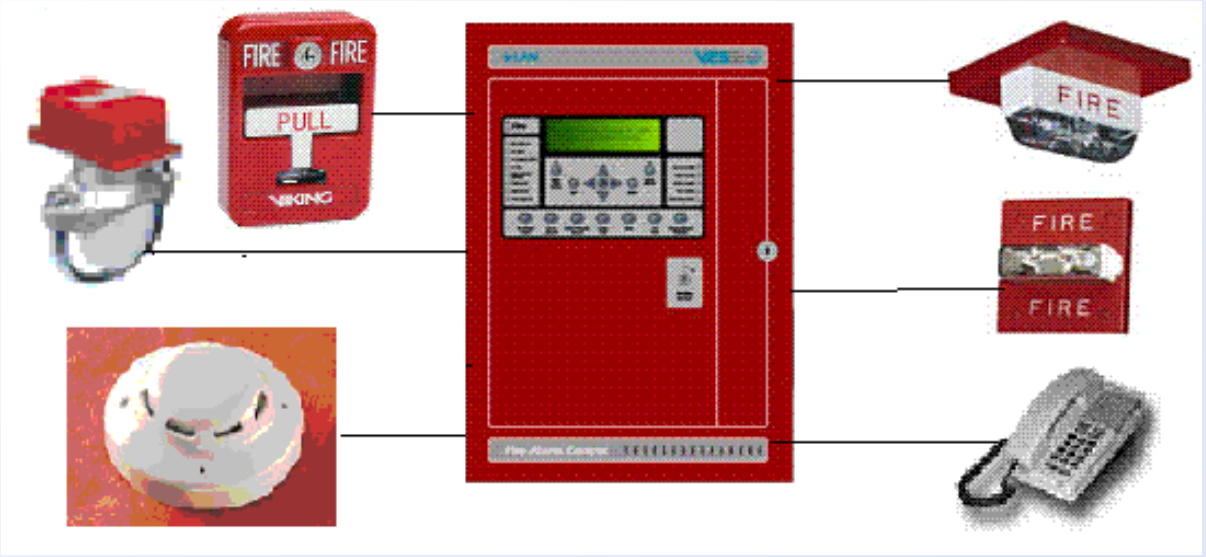
Fire Safety Objectives

Life Safety

- Work Environment
  - Property Access
  - Facility/Building Access
  - Population on premises

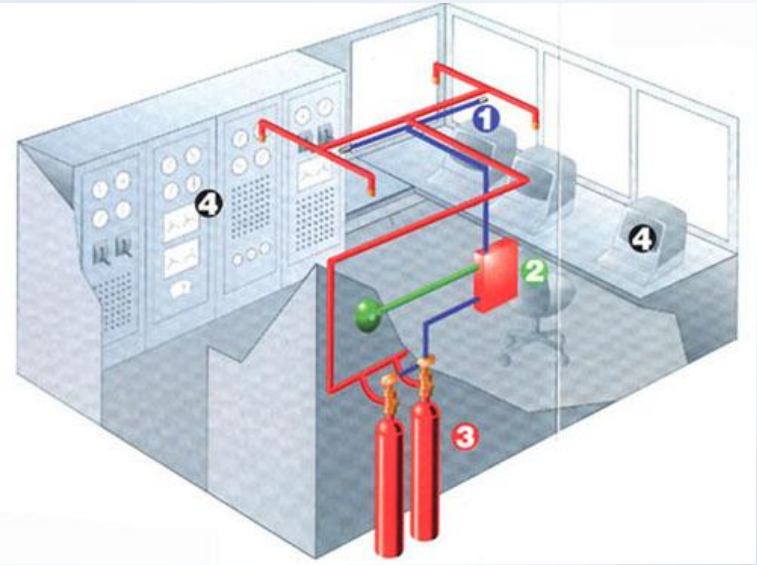
Fire Safety

- Fire Codes / Institutional Policies
- Fire Prevention Control Systems
  - Smoke Detection
  - Heat Detection
  - Alarms



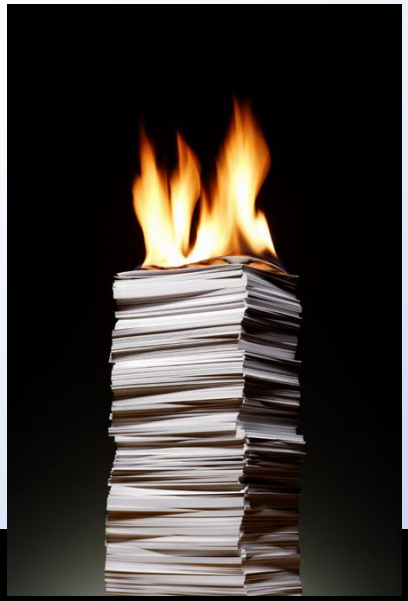
Fire Safety

- **Fire Suppression Equipment**
  - **Automated – Local or General**
  - **manual**



Fire and Ignition Hazards

- General Laser Fire Hazards
  - Class 4 Lasers
  - Lab and building materials
  - Combustible materials



Fire and Ignition Hazards

Specific Fire Hazards

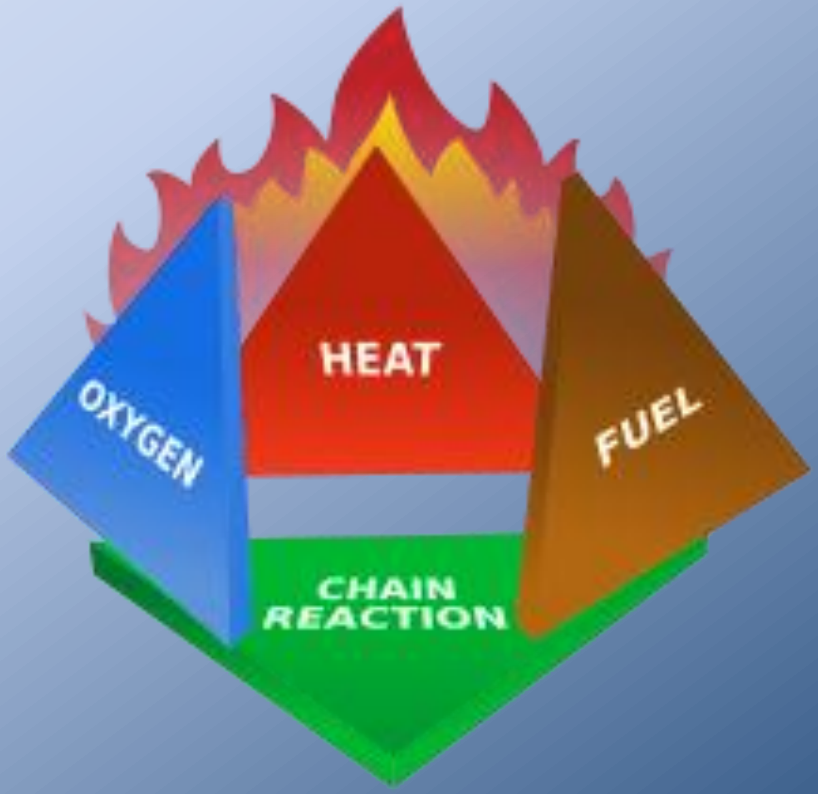
- Ignitable chemicals
- Flammable gases and vapors
- Toxic smoke or fumes
- Unusual target / samples
- Lower power laser ignition

Fire and Ignition Hazards

- Ignition issues in Labs
  - Flammable chemicals / materials
  - Ignition sources
- Combustible materials in lab
  - Room, building, construction
  - Laser table, barriers, curtains

Fire and Ignition Basics

- Fuel, Oxygen, Heat, Reaction
- Temperature of flammable substance
- Lower/Upper Limit for Flammable Atmosphere
- Flash, Fire, Boiling, Auto-ignition points



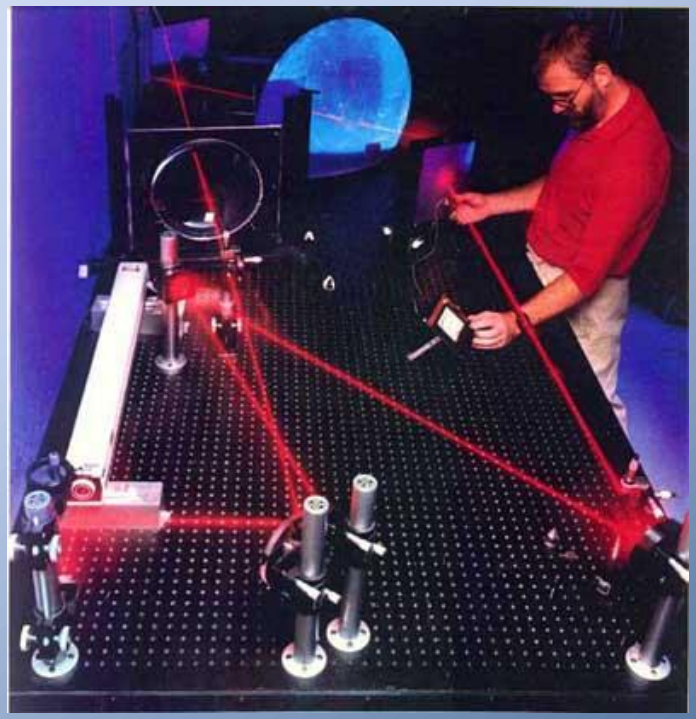
Fire and Ignition Hazards

Fire Basics Temperature Points

- Flash Point: Temporary flash flame from ignition
- Fire Point: Sustained burning from Ignition - > 5 sec
- Boiling Point: Liquid vapor pressure > air
- Auto-ignition: Vapors ignite without ignition source

Fire and Ignition - Lasers

- Combustible materials
  - Class 4 lasers
  - 10 W/cm2 or 0.5 W (ANSI)
  - Typical office, lab, building materials
- Flammable materials
  - Class 3B lasers
  - 0.5 W/cm2 (NFPA)
  - Create flammable atmosphere
  - Small ignition source needed



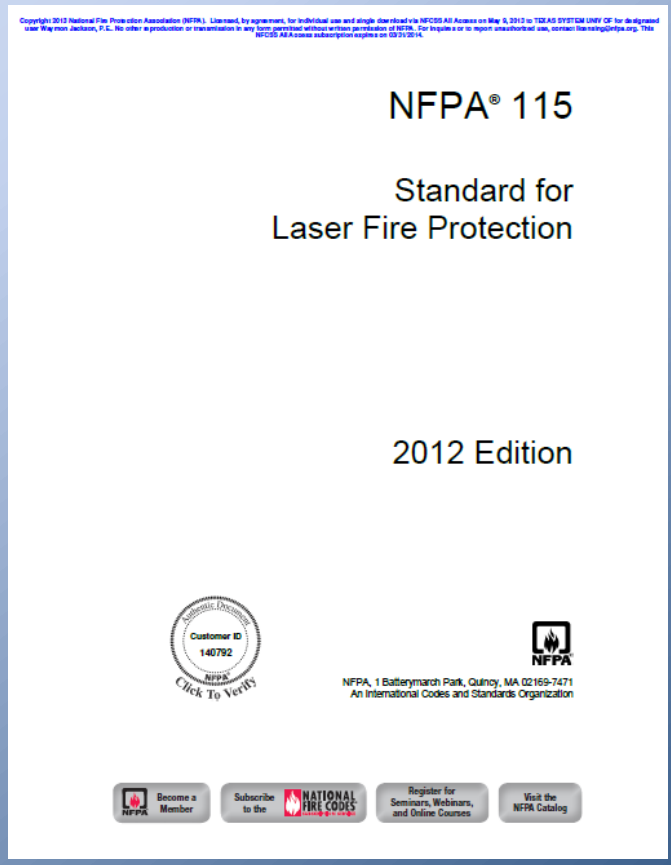
Standards/Guides

- **ANSI Z136.1 --Part 7.2.3**
  - Class 4 lasers
  - 10 W/cm^2 or 0.5 W are hazards
  - 3B lasers as Flammable Gas ignition source
  - Most barriers have limited protection times
  - References NFPA 115

Standards/Guides

NFPA 115 (1989)

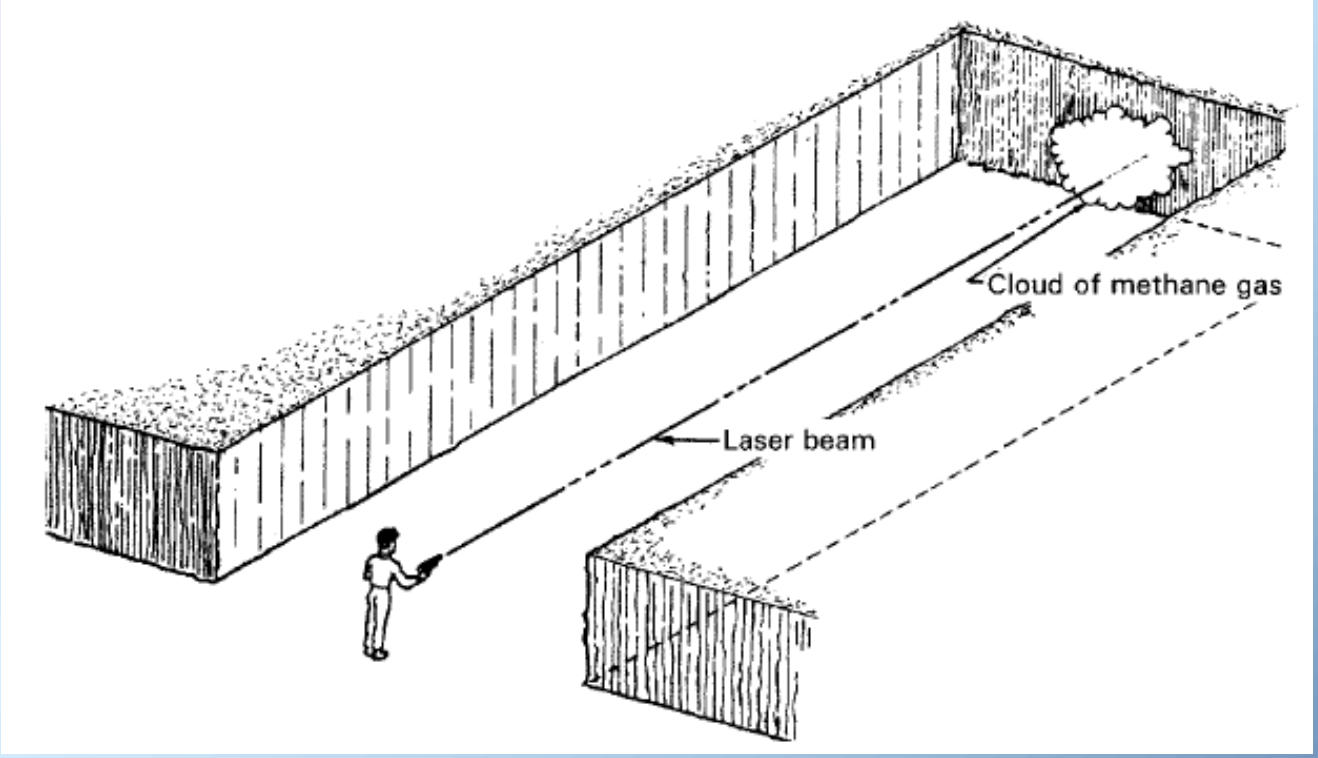
- Chapter 5 – Laser Beam Potential Eval
  - Class 4 laser
  - 0.5 W/cm^2
  - List of factors
- Chapter 6 – Laser Beam Ignition
  - Refers to ANSI Z136.1
  - "Appropriate" beam stop
  - Beam intensity profile
- Chapter 7 – Laser Equipment
- Chapter 8 – Flammable Gases

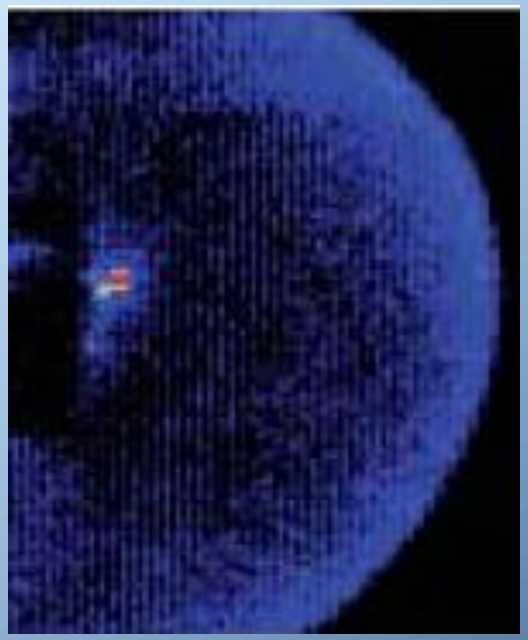


Standards/Guides

Study of Flammable Gas Ignition

- NIOSH Methane/Particle Study ~1999
- EU IEC TC31/WG8 study ~2000





Standards/Guides

IEC 60079-28

Ignition Risk due to Optical Radiation (2006)

- Laser induced ignition above 50mW
- Set 35mW limit for flammable atmosphere
- 5mW/mm^2 for beams < 7mm diameter
- Explosion groups

Explosion group	I	IIA	IIA	IIIB	IIC	
Temperature class		T3	T4	T4	T4	T6
Surface temperature (°C)	<150	<200	<135	<135	<135	<85
Power (mW)	150	150	35	35	35	15
Irradiance (mW/mm^2) (surface area not exceeding 400 mm^2)	20*	20*	5	5	5	5
* For irradiated areas greater than 30 mm^2, where combustible materials may intercept the beam, the 5 mW/mm^2 irradiation limit applies						

Table 1: Safe optical power and irradiance for hazardous areas categorized by apparatus group and temperature class

Standards/Guides

IEC 60079-28 (continued) (2006)

- Ignition graph of power and beam area
- Large disparity of ignition points

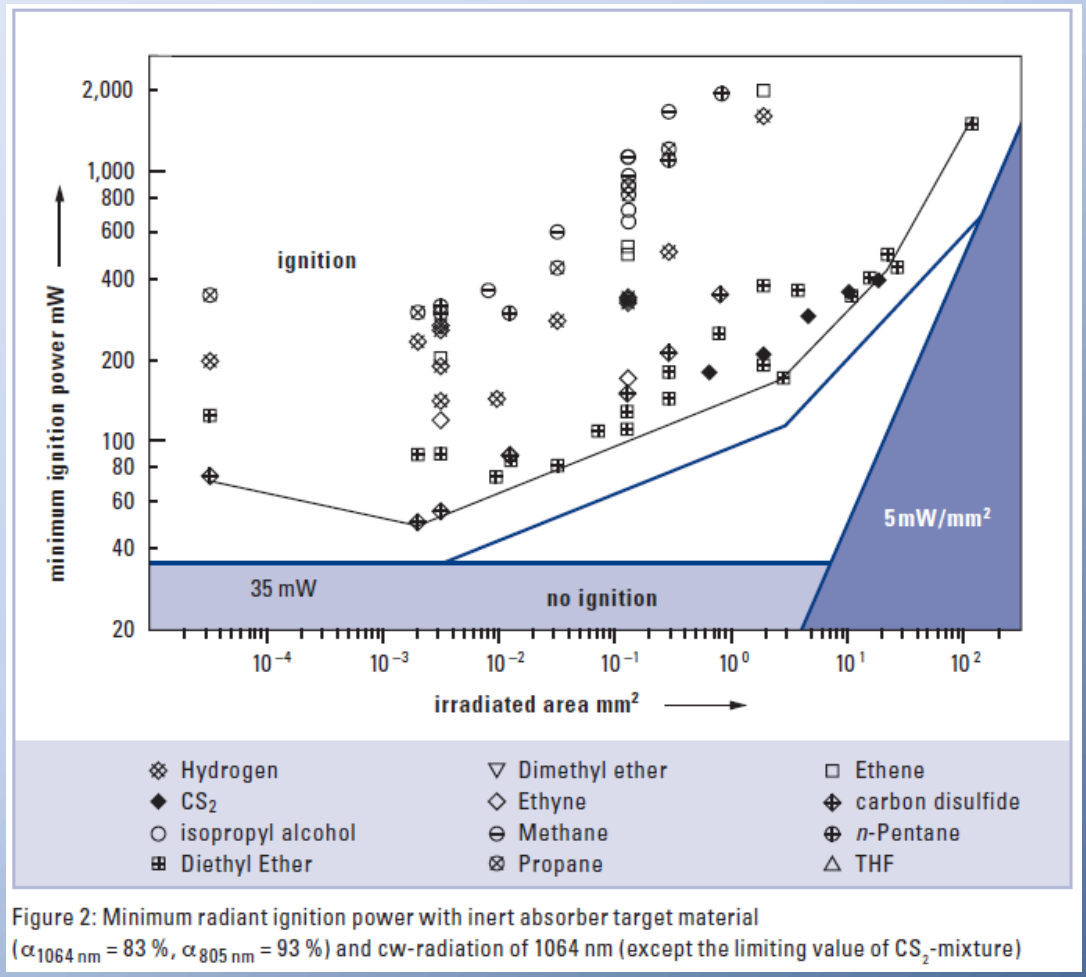


Figure 2: Minimum radiant ignition power with inert absorber target material ($\alpha_{1064\,nm}$ = 83 %, $\alpha_{805\,nm}$ = 93 %) and cw-radiation of 1064 nm (except the limiting value of CS_2-mixture)

Laser Barriers

- Commercial products
  - Specific for laser controls
  - Laser Tested and Certified
  - Large selection

- Alternate materials
  - Not specific to Laser use
  - Not tested or certified
  - May have great properties
  - Availability / Cost effective

Gypsum (Calcium Sulfate Di-hydrate)

Laser Barrier Standards

- **ANSI Z136.7 Laser Protective Equipment**
  3.6, 4.4.5, 6.3 (2008)
  - Focus is absorber OD and eyewear
  - 100 sec protection, 3mm to 10mm beam
  - Barrier labeling requirements
  - Appendix F testing details
  - Rating = highest irradiance w/o breakthrough

Laser Barriers

- **EU 12254 Screens for Laser Workplaces ~1999**
  - **Based on 100 sec with 1mm beam**
  - **Types of exposure categorized Table 1**

Table 1 — Duration of test applicable to screens for laser working places

Test condition (corresponding laser designation)	Pulse duration s	Number of pulses
D (continuous wave (CW) laser)	100	1
I (pulsed laser)	10^{-6} to 10^{-2}	1 000
R (Giant pulsed laser)	10^{-9} to 10^{-6}	1 000
M (Mode-coupled pulsed laser)	$\leq 10^{-9}$	100 000
NOTE The listed pulse durations are values of typical lasers. A laser with a pulse length in this range of values is recommended for testing. Total exposure time for each test should be about 100 s.		

Laser Barriers

- **EU 12254 (Continued)**
  - **Rating in Tiers (decades) in Table 2**

Table 2 — Scale numbers of screens for laser working places (maximum spectral transmittance and resistance to laser radiation)

Scale number	Maximum spectral transmittance at the laser wavelength $\tau(\lambda)$	Mean power (E) and single pulse energy density (H) for testing protective properties and resistance to laser radiation in the wavelength range									
		180 nm to 315 nm			> 315 nm to 1 050 nm	> 1 050 nm to 1 400 nm	> 315 nm to 1 400 nm		> 1 400 nm to 10^6 nm		
		For test condition/pulse duration in s (see Table 1)									
		D	I, R	M	D	D	I, R	M	D	I, R	M
		> 0,25	> 10^{-9} to 0,25	≤ 10^{-9}	> $5 \cdot 10^{-3}$	> $2 \cdot 10^{-3}$	> 10^{-9} to 0,01	≤ 10^{-9}	> 0,1	> 10^{-9} to 0,1	≤ 10^{-9}
		E_D W/m²	$H_{I,R}$ J/m²	E_M W/m²	E_D W/m²	E_D W/m²	$H_{I,R}$ J/m²	H_M J/m²	E_D W/m²	$H_{I,R}$ J/m²	E_M W/m²
AB1	10^{-1}	0,01	$3 \cdot 10^2$	$3 \cdot 10^{11}$	10	$2{,}5 \cdot 10^2$	0,05	0,0015	10^4	10^3	10^{12}
AB2	10^{-2}	0,1	$3 \cdot 10^3$	$3 \cdot 10^{12}$	10^2	$2{,}5 \cdot 10^3$	0,5	0,015	10^5	10^4	10^{13}
AB3	10^{-3}	1	$3 \cdot 10^4$	$3 \cdot 10^{13}$	10^3	$2{,}5 \cdot 10^4$	5	0,15	10^6	10^5	10^{14}
AB4	10^{-4}	10	$3 \cdot 10^5$	$3 \cdot 10^{14}$	10^4	$2{,}5 \cdot 10^5$	50	1,5	10^7	10^6	10^{15}
AB5	10^{-5}	10^2	$3 \cdot 10^6$	$3 \cdot 10^{15}$	10^5	$2{,}5 \cdot 10^6$	$5 \cdot 10^2$	15	10^8	10^7	10^{16}
AB6	10^{-6}	10^3	$3 \cdot 10^7$	$3 \cdot 10^{16}$	10^6	$2{,}5 \cdot 10^7$	$5 \cdot 10^3$	$1{,}5 \cdot 10^2$	10^9	10^8	10^{17}
AB7	10^{-7}	10^4	$3 \cdot 10^8$	$3 \cdot 10^{17}$	10^7	$2{,}5 \cdot 10^8$	$5 \cdot 10^4$	$1{,}5 \cdot 10^3$	10^{10}	10^9	10^{18}
AB8	10^{-8}	10^5	$3 \cdot 10^9$	$3 \cdot 10^{18}$	10^8	$2{,}5 \cdot 10^9$	$5 \cdot 10^5$	$1{,}5 \cdot 10^4$	10^{11}	10^{10}	10^{19}
AB9	10^{-9}	10^6	$3 \cdot 10^{10}$	$3 \cdot 10^{19}$	10^9	$2{,}5 \cdot 10^{10}$	$5 \cdot 10^6$	$1{,}5 \cdot 10^5$	10^{12}	10^{11}	10^{20}
AB10	10^{-10}	10^7	$3 \cdot 10^{11}$	$3 \cdot 10^{20}$	10^{10}	$2{,}5 \cdot 10^{11}$	$5 \cdot 10^7$	$1{,}5 \cdot 10^6$	10^{13}	10^{12}	10^{21}

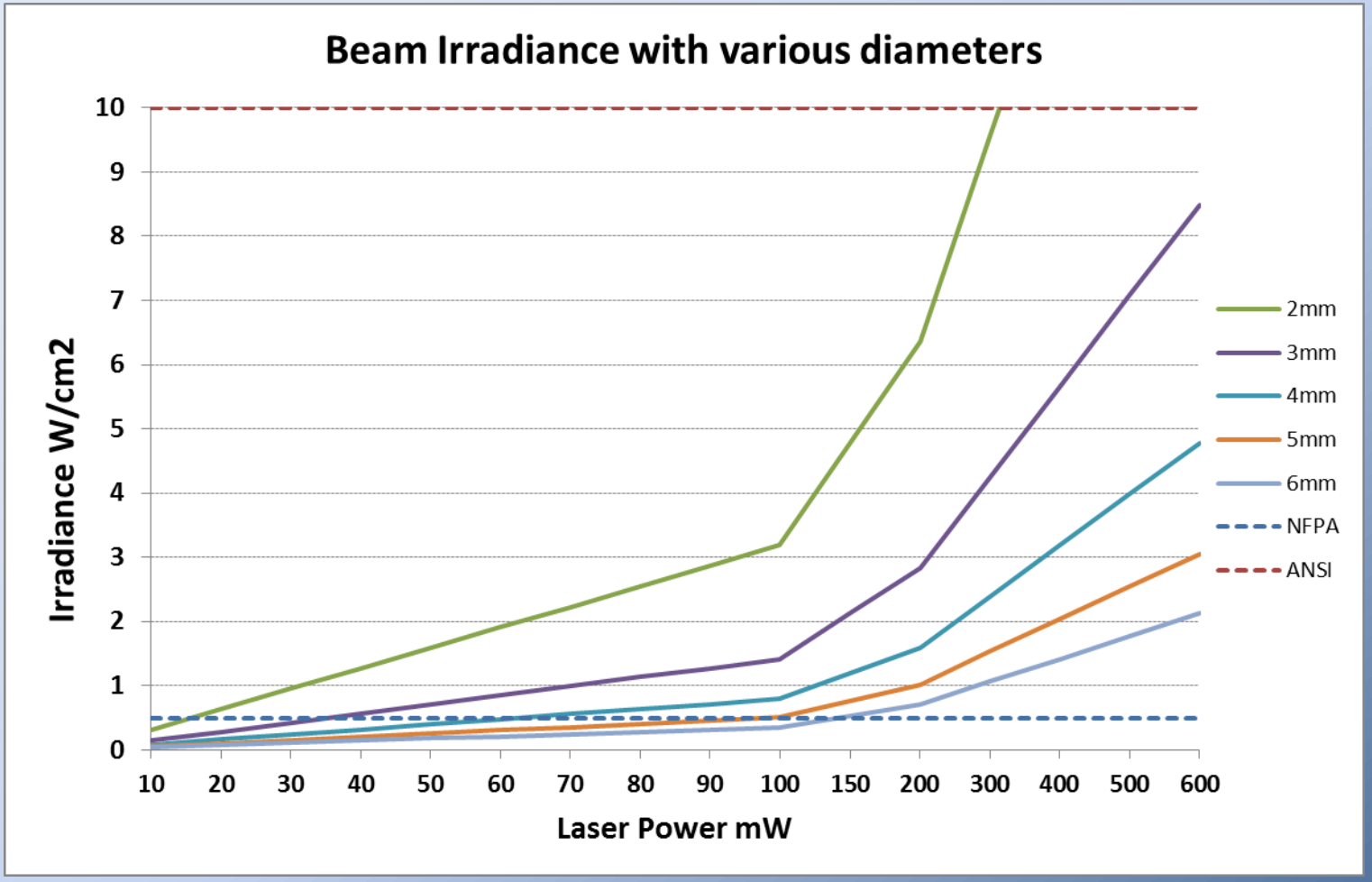
Barrier Standards Comparison

- ANSI Z136.7 and EU 12254
  - 3mm-10mm vs 1mm beam diameter
  - Power Rating actual vs tiered
  - MFG rating specs vs listing preset specs
  - Both use units of irradiance

- Unit comparison
  - ANSI, NFPA W/cm^2
  - EU 60079-28 mW/mm^2
  - EU 12254 W/m^2
  - $10mW/mm^2 = 1\ W/cm^2 = 10^5\ W/m^2$

Barrier Standards Comparison

- **Beam Diameter and Irradiance**



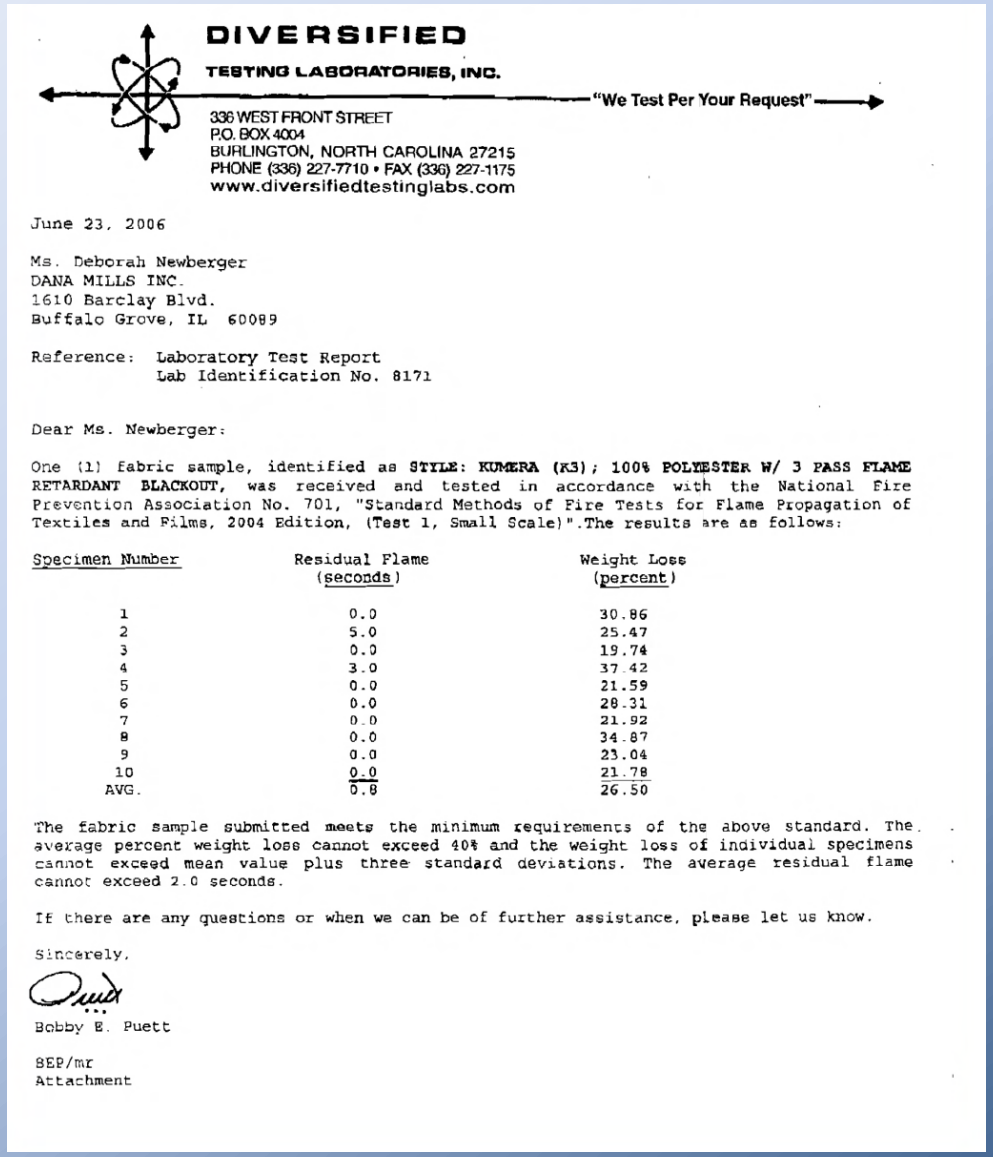
Fire Standard for Curtains

- NFPA 701 Standard Flame Tests for Textiles, Film, etc.
  - Not based on laser tests
  - Any curtain used in occupied spaces
  - Fire Safety / Fire Marshall approval
  - Mfg Certificate of Compliance / Testing

- Curtain / Barrier / Drape applications
  - Window Coverings
  - Class 3B enclosure
  - Light sensitive enclosure
  - Room delineation

Fire Standard for Curtains

- **NFPA 701 Certificate Example**



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June 23, 2006

Ms. Deborah Newberger
DANA MILLS INC.
1610 Barclay Blvd.
Buffalo Grove, IL 60089

Reference: Laboratory Test Report
Lab Identification No. 8171

Dear Ms. Newberger:

One (1) fabric sample, identified as **STYLE: KUMERA (K3); 100% POLYESTER W/ 3 PASS FLAME RETARDANT BLACKOUT,** was received and tested in accordance with the National Fire Prevention Association No. 701, "Standard Methods of Fire Tests for Flame Propagation of Textiles and Films, 2004 Edition, (Test 1, Small Scale)".The results are as follows:

Specimen Number	Residual Flame (seconds)	Weight Loss (percent)
1	0.0	30.86
2	5.0	25.47
3	0.0	19.74
4	3.0	37.42
5	0.0	21.59
6	0.0	28.31
7	0.0	21.92
8	0.0	34.87
9	0.0	23.04
10	0.0	21.78
AVG.	0.8	26.50

The fabric sample submitted meets the minimum requirements of the above standard. The average percent weight loss cannot exceed 40% and the weight loss of individual specimens cannot exceed mean value plus three standard deviations. The average residual flame cannot exceed 2.0 seconds.

If there are any questions or when we can be of further assistance, please let us know.

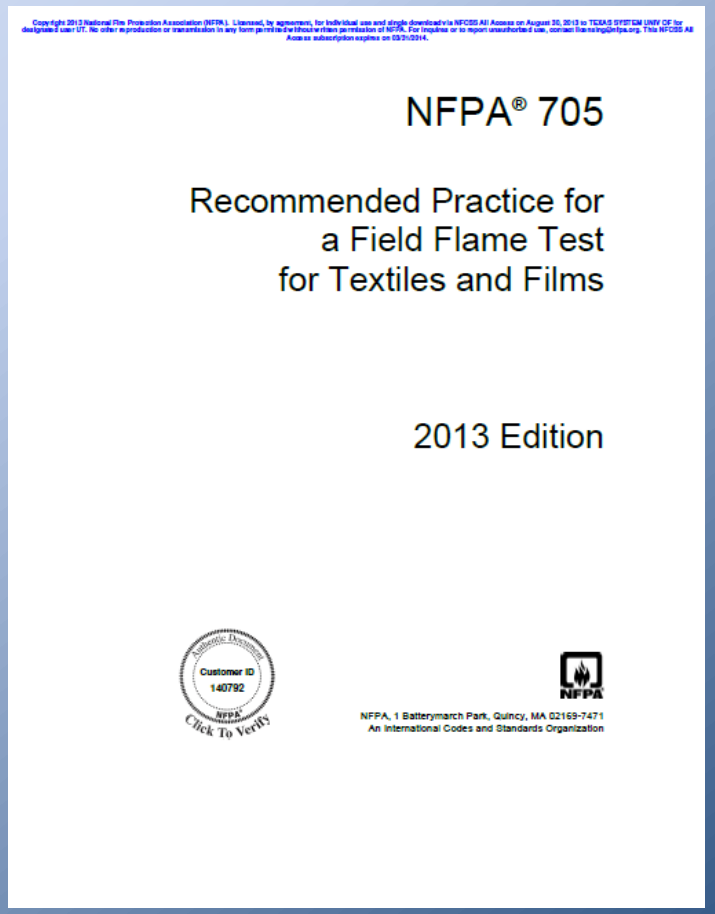
Sincerely,

Bobby E. Puett

BEP/mr
Attachment

Fire Standard for Curtains

- **NFPA 705 Field Test for Textiles, Film etc.**
  - **Is not directly linked to NFPA 701**
  - **Excellent to identify extremes of fabrics**
  - **Not a replacement for NFPA 701**
  - **Limitations of test results**



Results from Combustion tests from the Laser Curtain Samples

Result Summary

- All of the curtain samples provided were combustible and it is recommended that none of them be used .
- All samples also gave off thick combustible, choking smoke when exposed to an open flame.
- Samples B and D continued to burn when the ignition sources was removed
- It should be remembered that a relatively low temperature ignition source was used. The propane torch flame temperature is lower than a typical paper “trash can” fire
- Also remember that the materials would burn better in a lab setting due to the fact smoke and heat cannot escape

Sample A

Sample B
Not only did Sample B burn but it melted, pooled the pool continued to burn

Sample C

Sample D

- Sample D continued to burn hot once on the ground and had to be extinguished after burning for several minutes

Conclusion

- It is recommended by both the Laser Safety group and the Fire Prevention that all of these curtains be replaced and no more of this curtain material is used in any of the laser labs on campus.

Laser Curtain Test

July 16, 2004

Blue Sample

Initial Flame Exposure

Blue Sample

Burned while exposed to direct flame contact

Blue Sample

Did not sustain combustion when flame was removed

Black Sample

Initial Flame Exposure

Black Sample

Direct flame contact charred surface but material did not burn

Black Sample

Did not sustain combustion when flame was removed

Black Sample

View of surface char

Grey Sample

Initial flame exposure

Grey Sample

Flame contact charred surface slightly but material did not burn

Grey Sample

Did not sustain combustion when flame was removed

Grey Sample

Direct Flame Contact

Grey Sample

View of Surface Char

Test Summary

- Grey Sample performed very well. Sample did not burn and produced very little smoke
- Black Sample also perfomed well. Did not burn and produced mild smoke.
- Blue Sample did burn when exposed to direct flame contact but did not sustain combustion when flame was removed. Produced more smoke than other samples.

Laser Curtain Testing III

Aug 23, 2004

Black Material

- This product decomposed and off gassed when exposed to an open flame
- A large amount of smoke was produced during testing
- This product is not recommended as a laser curtain at UT

Another Black Material

- This product decomposed and off gassed when exposed to an open flame
- A large amount of smoke was produced during testing
- This product is not recommended as a laser curtain at UT

Grey Material

- This product decomposed and off gassed when exposed to an open flame
- A large amount of smoke was produced during testing
- This product **CONTINUED TO BURN** after exposure to an open flame
- This product is not recommended as a laser curtain at UT

None of the products tested are recommended by Environmental Health and Safety for laser curtain material

Special thanks to:
EHS's Fire Prevention Group