FIRE PROTECTION FOR NUCLEAR FACILITIES
Worcester Polytechnic Institute
Spring Semester, 2013

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Goal

In nuclear facilities, fire is often a dominant cause of risk to the public and to workers. A fire at a facility containing substantial quantities of radioactive materials can, if uncontrolled, cause extensive property damage and expose both workers and the public to unacceptable levels of radiation. The goal of this course is to give the student an understanding of these unique hazards and the methods by which they can be controlled.

Objectives

Give the student a solid grasp of ten subjects:

1. The history of the nuclear industry in the United States and worldwide, with special emphasis on major nuclear (commercial nuclear and defense) facility fires.
2. The regulatory framework imposed by the Atomic Energy Act of 1954 and applied by the Nuclear Regulatory Commission, Department of Energy, and Defense Nuclear Facilities Safety Board.
3. The basic physics of radioactive and fissionable materials.
4. The design and operation of power reactors and other types of nuclear facilities.
5. Fire protection requirements and standards used in the nuclear industry (civilian and defense).
6. Nuclear fire protection programs and supporting documents
7. Methods of preventing, detecting and mitigating fires in nuclear facilities.
8. Unique systems requirements for fire protection equipment in nuclear applications.
9. Use of fire modeling in nuclear applications.
10. Safety analysis and probabilistic risk analysis.

Class Setup

The class will consist of 14 weeks beginning on January 10th, 2013, and ending on April 29th, 2013. Classes will consist of a mixture of lectures, online discussions of the readings, a mid-term and a final examination. Much of the student's time will be devoted to reading the references covered in the lectures. One three-hour session is planned to take place on the WPI campus rather than online. This session will be devoted to a free-wheeling discussion of topics (including general career information) requested in advance by students or designated by the instructors. A class lunch or dinner will also be planned.

The table below shows how the ten subjects will be dealt with over the 14 weeks of the class.

Week	Topic
1 - Jan. 10	Historical Background and Fires
2 - Jan. 17	Regulatory Framework
3 - Jan. 24	Atomic Physics, Radiation, Criticality
4 - Jan. 31	Reactor and Nonreactor Facilities
5 - Feb. 7	Requirements and Standards
6 - Feb. 14	Fire Protection Program
7 - Feb. 21	Preventing Fires
8 - Feb. 28	Detecting Fires **(Mid-Term Exam Due)**
9 - March 14	Mitigating Fires
10 - March 25	Session at WPI
11 - March 28	Safety-Class Systems
12 - April 4	Fire Modeling and Post-Fire Safe Shutdown
13 - April 11	Safety Analysis and Probabilistic Risk Analysis
14 - April 18	**Final Examination**

Highlighting indicates classes that will be held on-campus.

Grading

Grades will be calculated based on this breakdown:

Mid-Term Examination	30%
Final Examination	50%
Class discussion/Participation	20%

The class discussion grade will be assigned according to the number and technical depth of online postings, questions, and responses. Large numbers of postings will not be given preference over a smaller number of postings with significant technical or regulatory content. The class discussion board should be confined to topics under discussion and review.

Graded Assignments

The student's grade will be determined by class discussion and by two written graded examinations, a midterm due February 28 and a final examination due April 18. In each case, the student will be asked to submit an analytical written document on topics covered in the lectures and readings. The midterm will be slightly less complex and demanding than the final, but otherwise the format of the tests will be the same. For each test, the student will be given several options to choose from. In designing the questions, the instructors will take into account the possibility that some students in the class will be fire protection engineers and others will be pursuing the Nuclear Science and Engineering curriculum. The mid-term exam will be given out three days before the filing deadline; the final exam five days before the filing deadline. Students will be given direct comments on their work as well as a letter grade, which will be decided by all three instructors.

Class Teaching Assistant

The class teaching assistant is _____. Her email address is _____.

Academic Honesty Policy: Please refer to the WPI Academic Honesty Policy, located at http://www.wpi.edu/Pubs/Policies/Honesty/policy.html.

Students with Disabilities: If you need course adaptations or accommodations because of a disability, or if you have medical information to discuss, please contact the Disability Services Office (DSO) at 508-831-5235 as soon as possible to ensure that accommodations are implemented in a timely fashion.

Reading Assignments

1) The reading assignments for the semester are stated in the week-by-week syllabus below. The references should be obtained by each student before Week 1. Only Reference # 28 needs to be purchased. Used copies of Shultis and Faw are available in the $70 range; new price is $95.
All other references are available online or will be posted in "Course Materials" on Blackboard.

2) Some readings are listed for more than one lecture. In these cases, you should read the reference for the first module using it, and thereafter refer back to it as needed.

3) Minimal readings are assigned in some modules, a great deal more in others. The instructors suggest looking ahead at future readings to balance out the weekly reading load.

4) Some readings are fairly short (<30 pages) while others may exceed 100 pages or more. For the longer readings, you should scan the text but not necessarily read and comprehend every word. At minimum you should gain an understanding of each reading's purpose and scope, but detailed and complete understanding of references such as NFPA codes is not expected. With that said, it is expected that you have the knowledge of where to extract information/requirements/criteria from the various references.

5) An asterisk means this reference will be posted to the Blackboard for the course. Contact the instructors if you have trouble accessing any reference.

References

1. DOE/NE-0088, *The History of Nuclear Energy*, http://www.ne.doe.gov/pdfFiles/History.pdf.
2. Fehner & Holl, *Department of Energy Summary History 1977-1994*, November 1994, http://energy.gov/sites/prod/files/maprod/documents/Summary_History.pdf
3. DOE-HDBK-1081-94, *Primer on Spontaneous Heating and Pyrophoricity* (1994), http://www.hss.doe.gov/nuclearsafety/techstds/docs/handbook/hdbk1081.pdf
4. *Closing the Circle on the Splitting of the Atom*, U.S. Department of Energy, Office of Environmental Management, http://www.em.doe.gov/Publications/splitatom.aspx
*5. DOE Order 420.1C, "Facility Safety"
*6. DOE Standard 1066-2012, "Fire Protection"
7. DOE Orders (Archived) 5480.7, 5480.7A, http://www.tvsfpe.org/images/54807.pdf, http://www.hss.doe.gov/nuclearsafety/nfsp/fire/orders/o54807a.pdf
8. *DOE Fundamentals Handbook: Nuclear Physics and Reactor Theory*, Volumes 1 and 2, DOE-HDBK-1019, January 1993. http://www.hss.doe.gov/nuclearsafety/techstds/docs/handbook/h1019v1.pdf http://www.hss.doe.gov/nuclearsafety/techstds/docs/handbook/h1019v2.pdf
9. NUREG/BR-0175, *A Short History of Nuclear Regulation, 1946–2009*, http://www.nrc.gov/reading-rm/doc-collections/nuregs/brochures/br0175/br0175.pdf

10. Code of Federal Regulations: Title 10, Part 50, Section 50.48, "Fire Protection"; Appendix R to Part 50, "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979"; Part 50, Appendix A, General Design Criterion #3.
11. NRC Regulatory Guide 1.189, Rev. 2, "Fire Protection."
http://pbadupws.nrc.gov/docs/ML0925/ML092580550.pdf
12. NRC Regulatory Guide 1.205, Rev.1, "Risk-Informed, Performance-Based Fire Protection for Existing Light-Water Nuclear Power Plants."
http://pbadupws.nrc.gov/docs/ML0927/ML092730314.pdf
13. NUREG-0800, "NRC Standard Review Plan" (SRP), Section 9.5.1.1. (Feb. 2009)
http://pbadupws.nrc.gov/docs/ML0905/ML090510170.pdf
14. NUREG-0050, "Recommendations Related to Browns Ferry Fire," Feb. 1976
http://pbadupws.nrc.gov/docs/ML0705/ML070520452.pdf
15. NUREG-1778, "Knowledge Base for Post-Fire Safe-Shutdown Analysis - Draft Report for Comment" (in two parts) http://pbadupws.nrc.gov/docs/ML0402/ML040210151.pdf
16. NUREG-1805, "Fire Dynamics Tools (FDTs) Quantitative Fire Hazard Analysis Methods for the U. S. Nuclear Regulatory Commission Fire Protection Inspection Program"
http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1805/
17. BTP 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants Docketed Prior to July 1, 1976." http://pbadupws.nrc.gov/docs/ML0706/ML070660454.pdf
18. Safety Evaluation of Shearon Harris Request for Amendment, (approx. 54 MB)
http://pbadupws.nrc.gov/docs/ML1017/ML101750604.html
19. IAEA Safety Guide NS-G-1.7, *Protection Against Internal Fires and Explosions in the Design of Nuclear Power Plants,*
http://www-pub.iaea.org/MTCD/publications/PDF/Pub1186_web.pdf
20. IAEA Safety Guide NS-G-2.1, *Fire Safety in the Operation of Nuclear Power Plants,*
http://www-pub.iaea.org/mtcd/publications/pdf/pub1091_web.pdf
21. NFPA Code 801
22. NFPA Code 802
23. NFPA Code 803
24. NFPA Code 804
25. NFPA Code 805
26. NFPA Code 806
27. NFPA Code 1710
28. Shultis and Faw, *Fundamentals of Nuclear Science and Engineering*, Decker, New York, 2002.
29. Department of the Air Force, Engineering Technical Letter 11-7: *Nuclear Weapons-Capable Maintenance and Storage Facilities* (2011), http://www.wbdg.org/ccb/AF/AFETL/etl_11_7.pdf
30. Nuclear Energy Institute, NEI-00-01, Revision 3, "Guidance for Post-Fire Safe Shutdown Analysis," http://pbadupws.nrc.gov/docs/ML1026/ML102670556.pdf
31. Unclassified Film; U.S. Nuclear Test Film #72,
http://www.youtube.com/watch?v=RlH7OuWiPb4
*32. Fire Technology, August 1991, page 204, *Evaluation of Duct Opening Protection in Two-hour Fire Walls and Partitions,* R. Gewain, J. Shanley, P. DiNenno, J. Scheffey, and B. Campbell
*33. *Protection of Duct Openings in Two-Hour Fire Resistant Walls and Partitions,* ASHRE Journal, by Richard G. Gewain, Bruce G. Campbell, James H. Shanley Jr. and Joseph L. Scheffey, P.E.
*34. P. Andrew Karam, "Nuclear Energy," from EOLSS Database.
*35. R.A. Chaplin, "Nuclear Reactor Configuration," from EOLSS Database.
*36. W. Shields, "The Fire at Browns Ferry: Enhanced Safety from Near-Catastrophe," (Powerpoint file), 2010.

*37. Robert Sawyer and James Elsner,"Cable Fire at Browns Ferry Nuclear Power Plant," *Fire Journal*, July 1976.
*38. Andrew J. Pryor, "The Browns Ferry Nuclear Plant Fire," SFPE Technical Report 77-2.
39. Brian Metzger, "Achieving Compliance – Fire Protection at U.S. Nuclear Power Plants," *Fire Protection Engineering*, Issue No. 55 (3rd Quarter 2012).
40. "The Nuclear Regulatory Process," NEI 07-06, Nuclear Energy Institute 2007.
http://www.new.ans.org/standards/resources/toolkit/docs/nei-nuclear-regulatory-process-ans-posting1.pdf
41. (not used)
42. DNFSB Recommendation 2008-1, "Safety Classification of Fire Protection Systems," 2008.
http://www.dnfsb.gov/sites/default/files/Board%20Activities/Recommendations/rec_2008-1_36.pdf
43. DNFSB/TECH-27, "Fire Protection at Defense Nuclear Facilities," 2000.
http://www.dnfsb.gov/sites/default/files/Board%20Activities/Reports/Technical%20Reports/TECH-27_0.pdf
43. DOE-STD-3009-94, "Preparation Guide for U.S. Department Of Energy Nonreactor Nuclear Facility Documented Safety Analyses."
http://www.hss.doe.gov/nuclearsafety/techstds/docs/standard/doe-std-3009-94_cn3_3-30-06.pdf
44. IAEA Specific Safety Guide SSG-2, "Deterministic Safety Analysis for Nuclear Power Plants," 2009.
http://www-pub.iaea.org/MTCD/publications/PDF/Pub1428_web.pdf
*45. "Combustible Contents in Buildings", United States of Commerce, National Bureau of Standards, Building Materials and Structures Report, No. 149, July 25, 1957.
*46. "Analysis of Flashover Potential, Room 3501, Building 371, Rocky Flats CO", Harold E. Nelson, Senior Research Engineer, Hughes Associates, Inc., July 26, 1997.
*47. "Plutonium Fire Experiments", Presented at the DOE/ANL Training Course on Prevention of Significant Safety-Related Events in the Operation of DOE Nuclear Facilities, Rowland E. Felt, PhD. (Date not known)
48. NFPA 72, National Fire Alarm and Signaling Code, 2010 Edition.
49. National Fire Alarm and Signaling Code Handbook, 6th edition
50. NUREG/CR-3656, "Evaluation of Suppression Methods for Electrical Cable Fires," J.M. Chavez, L.D. Lambert, October 1986.
http://adamswebsearch.nrc.gov/idmws/ViewDocByAccession.asp?AccessionNumber=ML010090361
51. NUREG/CR-3192, "Investigation of Twenty-Foot Separation Distance as a Fire Protection Method as Specified in 10 CFR 50, Appendix R," D.D. Cline, W.A. von Riesemann, J.M. Chavez, October 1983.
http://adamswebsearch.nrc.gov/idmws/ViewDocByAccession.asp?AccessionNumber=ML062260282
52. NUREG/CR-4680 "Heat and Mass Release for Some Transient Fuel Sources Fires: A Test Report," S.P. Nowlen, October 1986.
http://adamswebsearch.nrc.gov/idmws/ViewDocByAccession.asp?AccessionNumber=ML062260161
53. NUREG/CR-5580 "Evaluation of Generic Issue 57: Effects of Fire Protection System Actuation on Safety-Related Equipment," J. Lambright, J. Lynch, M. Bohn, S. Ross, D. Brosseau, December 1992.
http://adamswebsearch.nrc.gov/idmws/ViewDocByAccession.asp?AccessionNumber=ML062260355

54. NUREG/CR-6738 "Risk Methods Insights Gained from Fire Incidents," S.P. Nowlen, Dr. M. Kazarians, F. Wyant, September 2001.
http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6738/cr6738.pdf
55. NUREG-1552, "Fire Barrier Penetration Seals in Nuclear Power Plants," C. S. Bajwa, K. S. West, July 1996.
http://adamswebsearch.nrc.gov/idmws/ViewDocByAccession.asp?AccessionNumber=ML070600315
56. NUREG-1552, Supplement 1, "Fire Barrier Penetration Seals in Nuclear Power Plants," C. S. Bajwa, K. S. West, January 1999.
http://adamswebsearch.nrc.gov/idmws/ViewDocByAccession.asp?AccessionNumber=ML070600313
57. NRC Information Notice 2002-27: "Recent Fires at Commercial Nuclear Power Plants in the United States"
http://pbadupws.nrc.gov/docs/ML0226/ML022630147.pdf
58. NRC Information Notice 2007-17: "Fires At Nuclear Power Plants Involving Inadequate Fire Protection Administrative And Design Controls"
http://pbadupws.nrc.gov/docs/ML0712/ML071220351.pdf
59. NRC Regulatory Issue Summary 2004-03: "Risk-Informed Approach For Post-Fire Safe-Shutdown Associated Circuit Inspections"
http://pbadupws.nrc.gov/docs/ML0406/ML040620400.pdf
60. NRC Regulatory Issue Summary 2005-30: "Clarification Of Post-Fire Safe-Shutdown Circuit Regulatory Requirements"
http://www.nrc.gov/reading-rm/doc-collections/gen-comm/reg-issues/2005/ri200530.pdf
61. NEI 00–01, Revision 3, "Guidance for Post-Fire Safe Shutdown Circuit Analysis," Oct. 2011
http://pbadupws.nrc.gov/docs/ML1129/ML112910147.pdf
62. NUREG/CR-6850, "Fire PRA Methodology for Nuclear Power Facilities," Volumes 1, 2, and Errata Sheet, September 2005
http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6850/v2/cr6850v1.pdf
http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6850/v2/cr6850v2.pdf
http://pbadupws.nrc.gov/docs/ML0616/ML061630360.pdf
63. NUREG/CR-6850 Supplement 1: "Fire Probabilistic Risk Assessment Methods Enhancements," September 2010.
http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6850/s1/cr6850s1.pdf

Detailed Syllabus with Readings
(highlighting indicates on-campus modules)

Week	Topic	Instructors	Readings
1	Mod. 1: History of the nuclear industry	Shields	Readings 1, 2, 31
1	Mod. 2: Nuclear power plant fires	March	Readings 14, 17, 34, 35, 36, 37, 38, 54, 57
1	Mod. 3: Nonreactor facility fires	Campbell	Reading 2
2	Regulatory Framework	Shields	Readings 9, 13, 30, 40
3	Physics: Radiation, Fission, Criticality	Shields	Reading 8, Volume I only; Reading 28, chapters 5, 9 and 10
4	Mod. 1: Nuclear Power Reactors	Shields/March	Readings 8, Volume 2 only; Reading 28, chapter 11; Readings 34, 35, 39
4	Mod. 2: Nonreactor Nuclear Facilities	March/Campbell	Reading 4
5	Mod. 1: NRC and DOE Regulations	Shields	Readings 10, 11
5	Mod. 2: Government and industry standards	March/Campbell	Readings 5, 6, 7, 21, 22, 23, 24, 25, 26, 27
6	Mod. 1: Fire protection program requirements	Campbell	Readings 5, 6, 21, 29,
6	Mod. 2: Fire hazards analysis	March	Readings 6, 11, 21, 52, 53
6	Mod. 3: QA, IT&M, TSRs	Campbell	Readings 32, 33, 43
7	Mod. 1: Preventing fires – ignition sources	March	Readings 3, 6, 11, 21, 47
7	Mod. 2: Preventing fires – combustible loading	Campbell	Readings 29, 45, 46
8	Mod. 1: Detecting fires – heat & smoke detectors	March	Readings 48, 49
8	Mod. 2: Detecting fires – alarms & fire watches	Campbell	Reading 48, 49
9	Mod. 1: Mitigating fires: engineered systems	March	Reading 6, 11, 21, 22, 23, 23, 24, 25, 26, 48, 49, 55, 56, 58
	(Mid-Term Exam Due)		**Email by midnight March 1**
9	Mod. 2: Mitigating fires: manual response	Campbell	Readings 21, 22, 23, 23, 24, 25, 26, 27
10	On-Campus Session March 25	All	
11	Mod. 1: Safety-class systems: regulatory overview	Shields	Reading 6 (Appendix A only), 42, 43 (Sec. 3.3)
11	Mod. 2: Suppression and detection systems	March	Readings 6, 11, 21, 50, 51
11	Mod. 3: Barriers and ventilation systems	Campbell	Reading 32, 33
12	Mod 1: Post-Fire Safe Shutdown Analysis	March/Shields	Reading 15, 59, 60, 61
12	Mod. 2: Fire Modeling	March/Campbell	Reading 16
13	Mod. 1: Safety Analysis	Shields	Reading 43, 44
13	Mod. 2: Probabilistic Risk Analysis	March	Reading 12, 62, 63
14	Final Exam	--	**Email by midnight April 30**