Nuclear Power Safety

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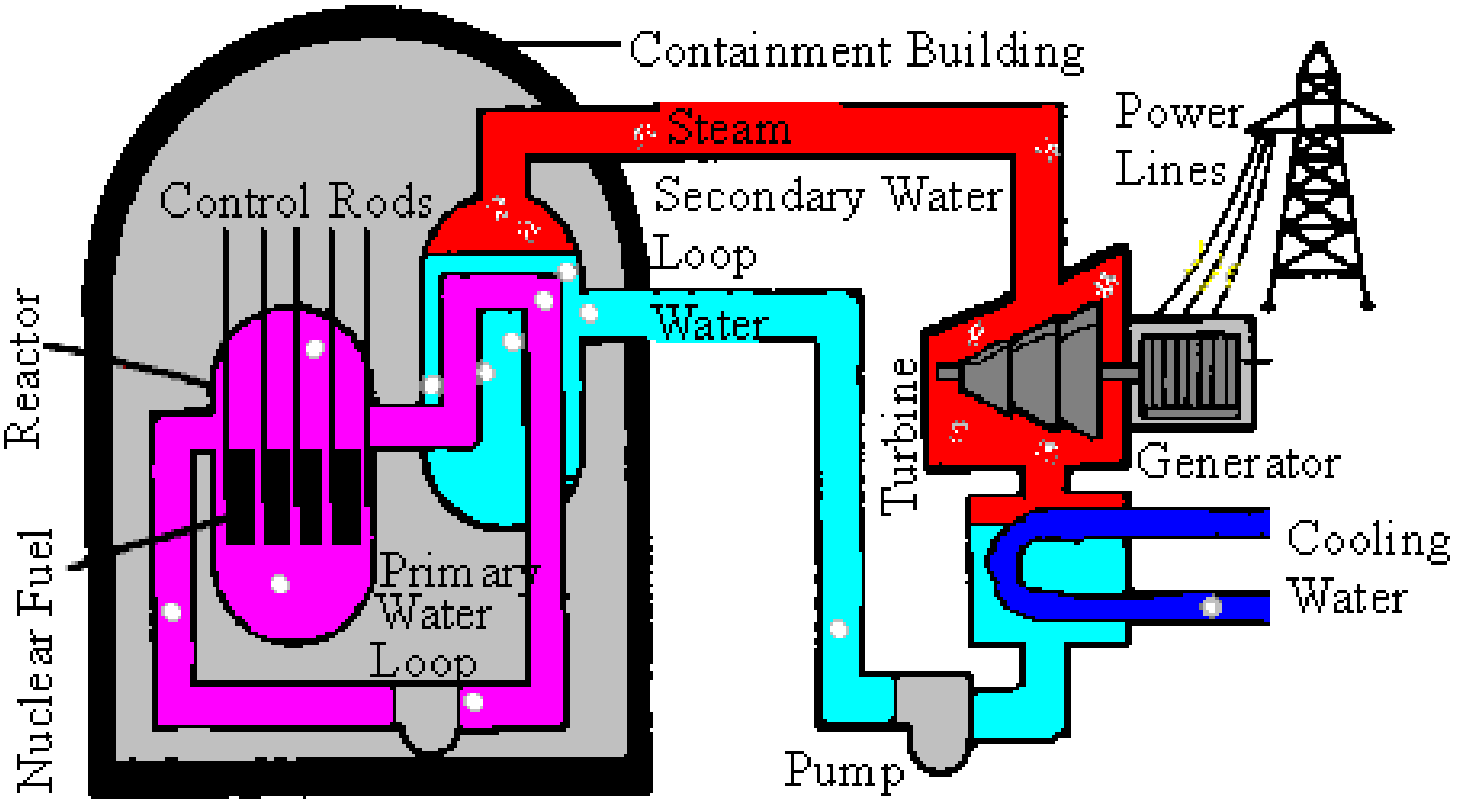
Pressurized Water Reactor

(http://reactor.engr.wisc.edu/power.html)



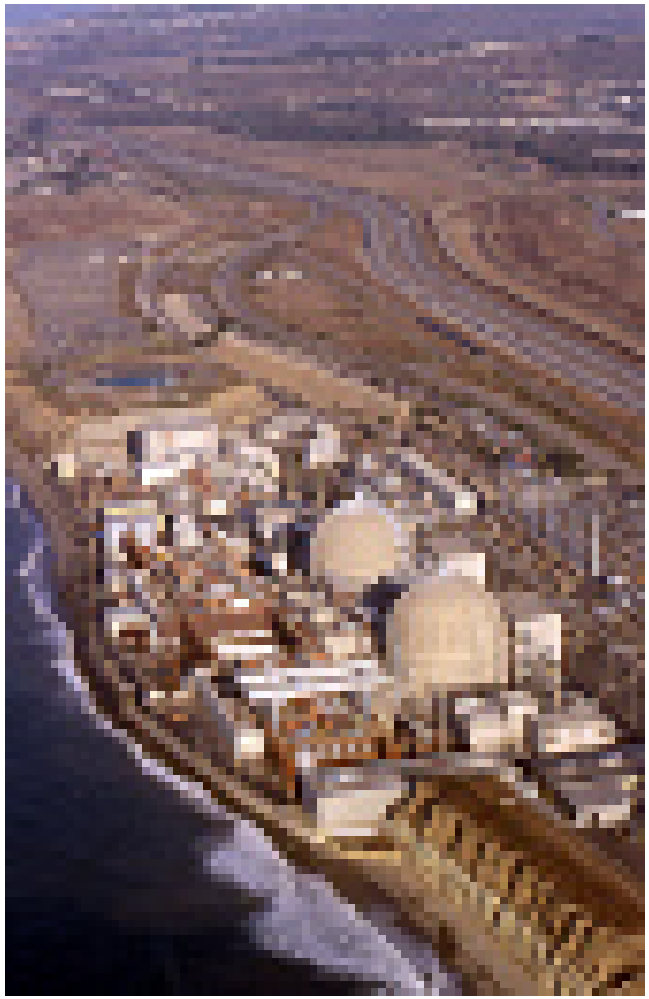
Probabilistic Risk Assessment

- PRA is a model of how a plant responds to disturbances during operations
- Provides a quantitative assessment of how often particular problems might occur
- Risk estimates vary:
  - But typical values are on the order of 10^{-4}
  - One core melt every 10,000 plant years
- Many of those core melts would not result in significant releases of radioactivity

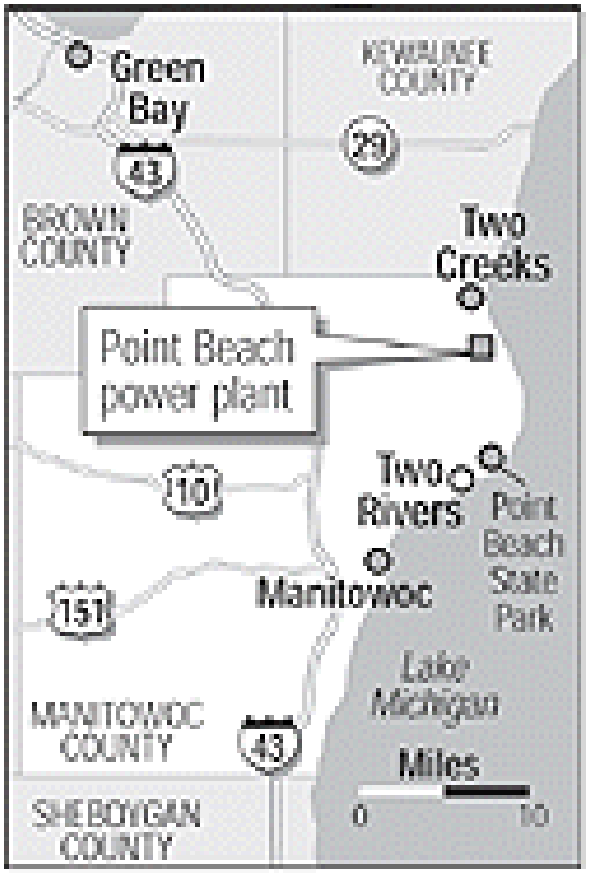
Probabilistic Risk Assessment

- **The U.S. currently has about 100 reactors**
- **At an accident rate of 10^{-4} per year:**
  - **We might expect to see one accident like Three Mile Island every 100 years**
- **Wisconsin currently has three reactors:**
  - **Point Beach (2 units), and Kewaunee (1 unit)**
  - **We might expect to see one core melt every 3,000 years**

SONGS, California



Point Beach, Wisconsin



Safety Features

- **Nuclear power plants have numerous safety features:**
  - **Redundant safety equipment**
  - **Containment buildings**
  - **Licensing and training requirements**
  - **Physical security**
  - **Remote sites, with emergency plans**
  - **Highly developed and evolving regulations (allowed outage times, required testing, etc.)**
- **Not all present in other technologies**

Safety Comparison

- **Accidents at nuclear plants can have severe offsite consequences:**
  - **But so can accidents at many other types of facilities**
- **Overall, nuclear plants are safe:**
  - **But it is important to understand the kinds of safety problems that can occur**

Lessons Learned

- **Many accidents (in nuclear power as well as other fields) are due to:**
  - **Systems being operated outside of their intended design envelope**
  - **Due to either approved workarounds, or unintended circumventions**
- **"Organizational culture" has at least as much effect on risk as design of components, subsystems, software!**

Pilgrim Nuclear Power Plant

- ***Wall Street Journal*, 7/28/87:**
  - **Pilgrim and Millstone, Two Nuclear Plants, Have Disparate Fates**
  - **Different Management Styles Cause the First to Be Shut Down While the Second Thrives**

Pilgrim Nuclear Power Plant

- ***Wall Street Journal*, 7/28/87:**
  - "Some of the worst mistakes at American nuclear power plants have been blamed on a series of relatively minor foul-ups that plague poorly managed plants"
  - "Badly run plants also shut down more frequently, produce more contaminated garbage, expose workers to more radiation and produce less electricity"

Pilgrim Nuclear Power Plant

- **Despite being "comparable in size, design and vintage":**
  - **"In the past 15 months, Pilgrim has generated as much power as Plymouth Rock, which is to say none"**
  - **"Millstone 1, though currently shut down for routine refueling, has generated enough to supply a city of 540,000"**

Pilgrim Nuclear Power Plant

- These two "sister plants" also exhibited major differences in:
  - Amounts of overtime worked
  - Staff turnover and qualifications
  - Lifetime capacity factor
  - Worker radiation exposure
    - (factor of 3 difference!)
  - Low-level radioactive waste produced
  - Nuclear Regulatory Commission fines
    - ($666,000 versus $0)

Pilgrim Nuclear Power Plant

- **Note that no accidents or serious safety problems ever occurred there**
- **Also, by the 1990's, the plants had changed their performance:**
  - **Millstone was the one with problems!**

Davis-Besse Nuclear Power Plant

- In March 2002, workers detected severe degradation of the reactor vessel head:
  - Which had been going on for years
- Leakage from the reactor vessel head flanges and nozzles had released boric acid to outside the reactor vessel
- A modification to improve the ability to inspect the reactor vessel head had been postponed indefinitely

Davis-Besse Cavity

Davis-Besse Nuclear Power Plant

- **Many plants experienced problems with boric acid corrosion:**
  - **The NRC required a control program**
- **Despite this, rust problems had been dismissed or ignored:**
  - **For example, rust had caused frequent problems with filter plugging**

Davis-Besse Nuclear Power Plant

- **The staff "stumbled" onto the problem in the course of another repair:**
  - **When one of the nozzles "leaned over"**
- **Corrosion of the reactor vessel head had taken place from the outside:**
  - **Stopped when it hit the stainless steel liner**
- **Degradation covered 30 square inches:**
  - **And removed about 70 pounds of material!**

Davis-Besse Nuclear Power Plant

- The original problem of nozzle cracking in the reactor vessel head was well known
- The cracking allowed corrosive boric acid to attack the vessel head from outside
- There were numerous opportunities to discover the problem:
  - But it was not discovered until it developed into a “near miss”

Safety Culture: An NRC Perspective (Meserve, 2002)

- **Plant operations were not conducted in a manner which encouraged:**
  - **A questioning attitude**
  - **A commitment to excellence**
  - **The identification and resolution of safety issues**
- **Prior to the discovery of the reactor vessel head corrosion:**
  - **The performance indicators at the Davis-Besse facility were "green"**
  - **The baseline inspections did not reveal any significant findings**

Safety Culture: An NRC Perspective (Meserve, 2002)

- **Reasons for the Commission's past decision to forego the direct regulation of safety culture:**
  - **Any attempt to regulate and evaluate safety culture is necessarily very subjective**
  - **An effort to regulate safety culture would intrude inappropriately on management prerogatives**
  - **The most effective safety cultures are ones that are generated as a result of the commitment of the organization itself**
  - **Regulatory pressure for improvements in safety culture is not necessary**

Safety Culture: An NRC Perspective (Meserve, 2002)

- **The responsibility rests on the organization's leadership:**
  - **To establish priorities,**
  - **To make the commitment to safety real**
  - **To create a climate in which such a commitment can flourish**

NRC Cross-Cutting Issues

- **Since Davis-Besse, there has been greater attention paid to the so-called "cross-cutting issues":**
  - **Human performance**
  - **Safety-conscious work environment**
  - **Problem identification and resolution**

Conclusion

- **Neuschel (1988):**
  - **Achieving safety…is a particularly demanding task that requires intensive management skill and dedication…**
  - ***Safety can be managed…***
  - **But it takes total commitment, special know-how, a highly disciplined work force and exemplary skill by management**

Conclusion

- Nuclear power plants can be managed safely
- Careful review and prioritization of observed safety problems makes it possible to minimize risk