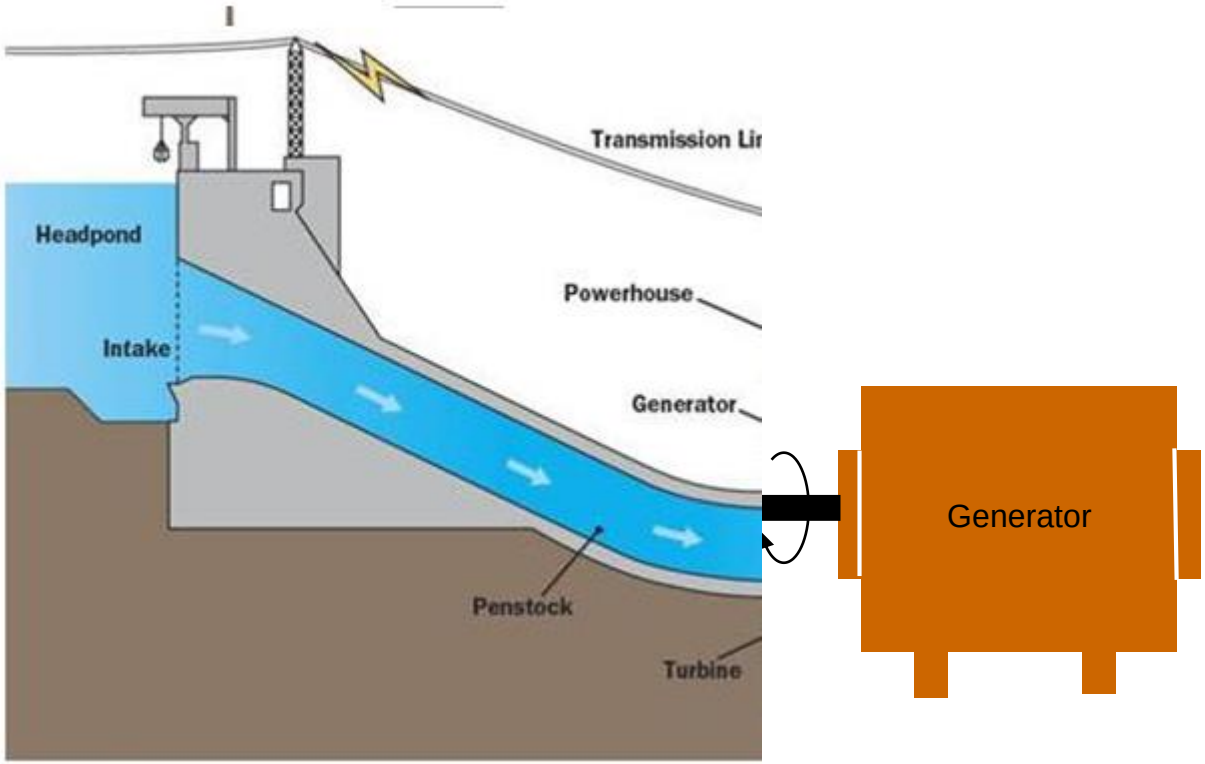
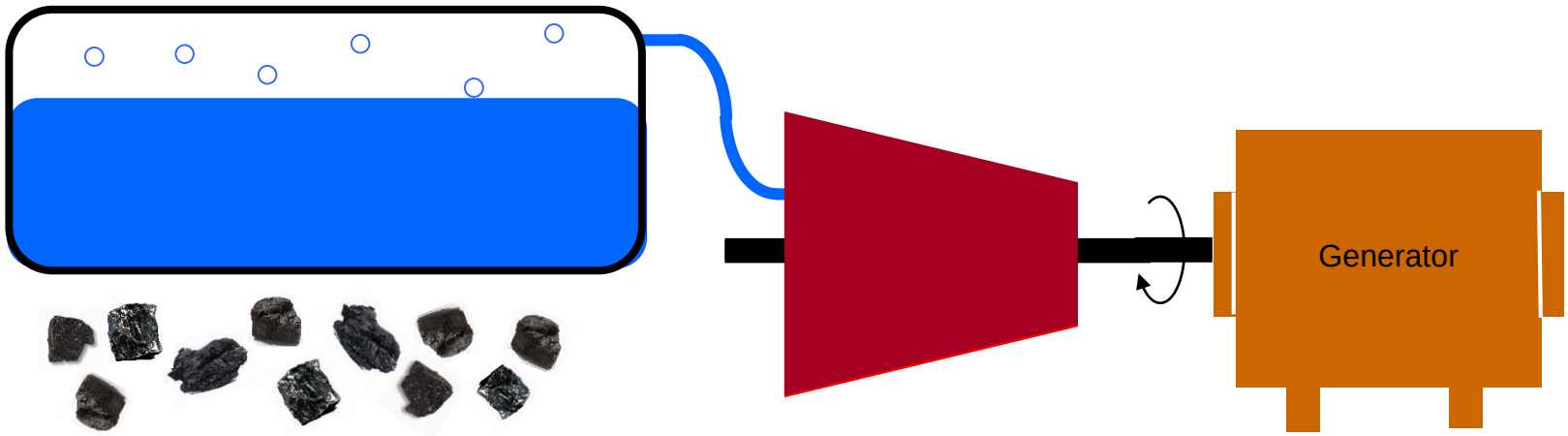
Nuclear Power

Generating Electricity

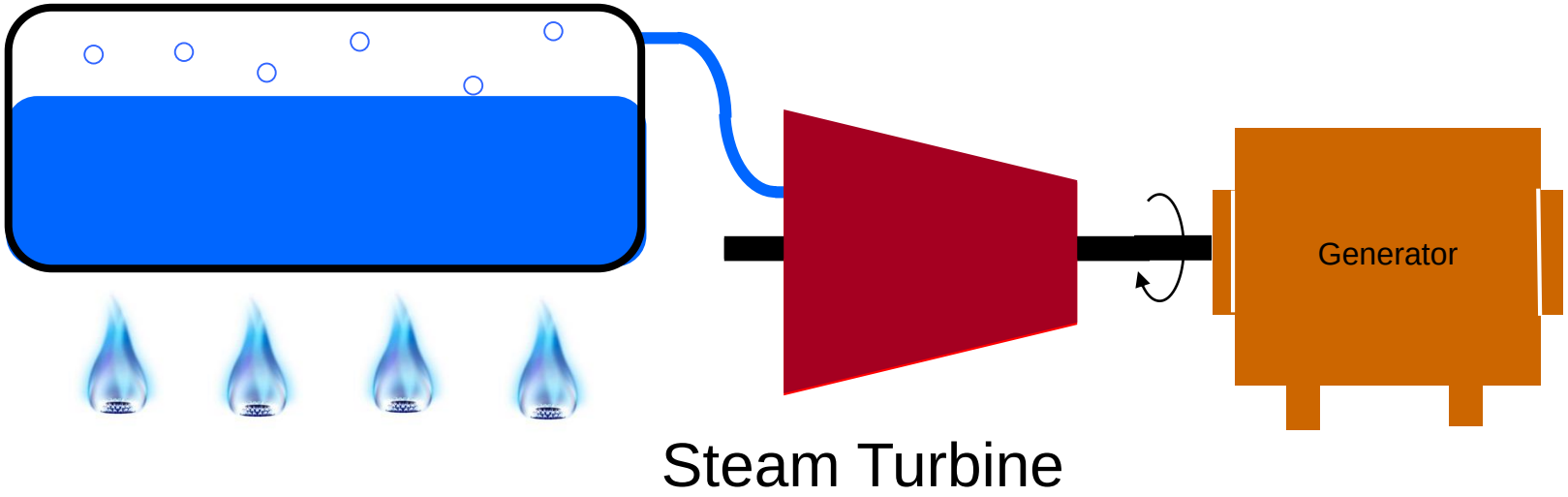


Burn Coal



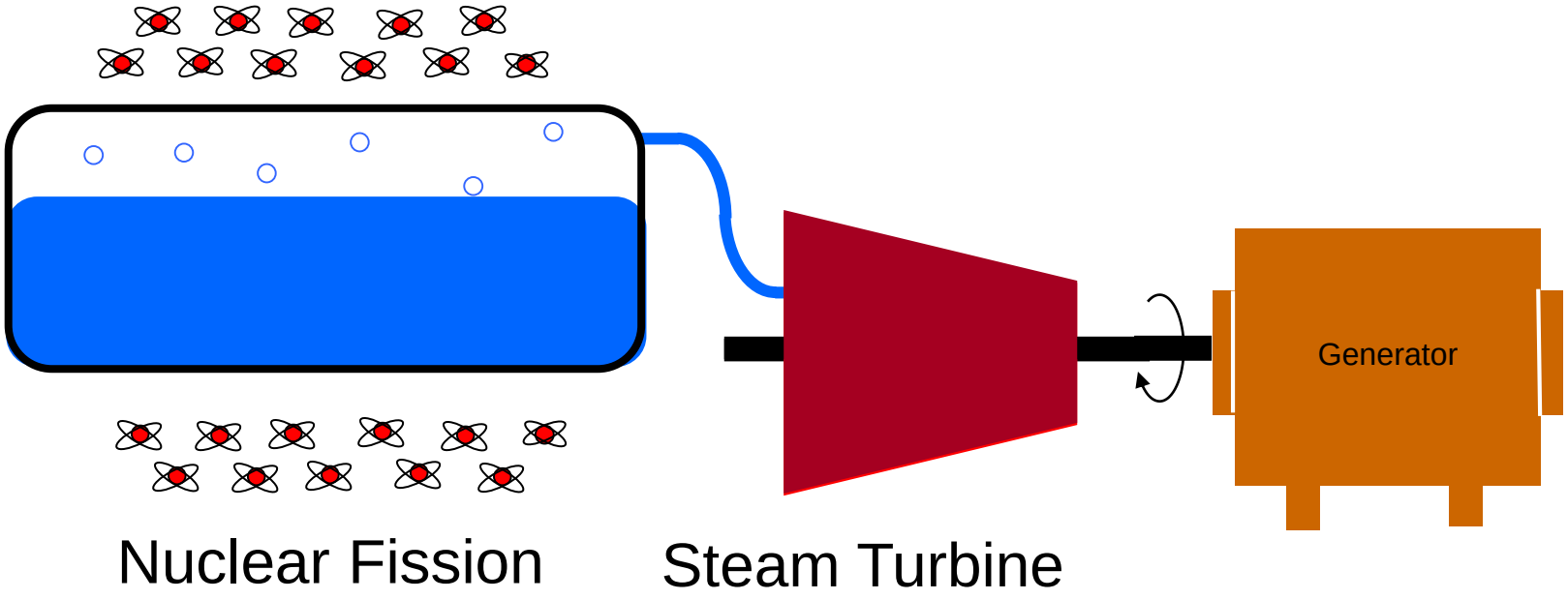
Steam Turbine

Burn Natural Gas



Steam Turbine

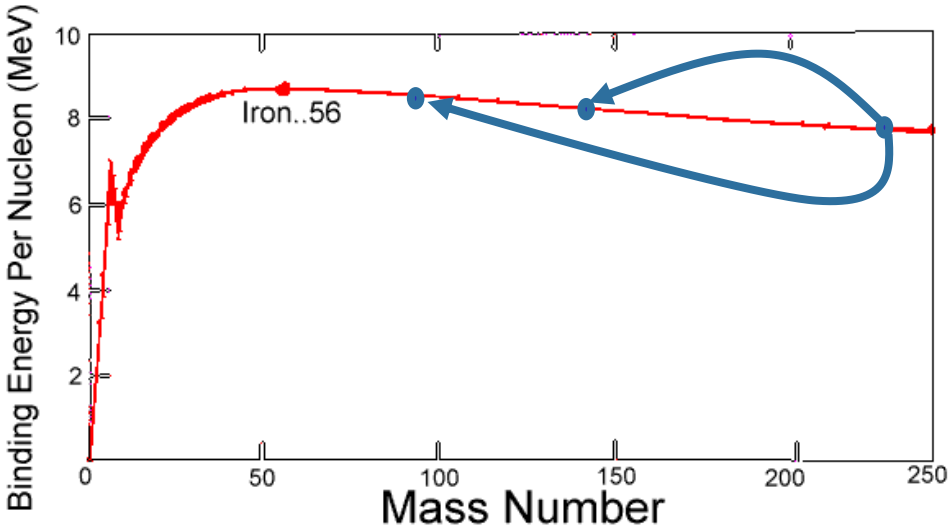
Nuclear Fission



Where does heat come from?

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{236}_{92}U^{*} \longrightarrow ^{94}_{38}Sr + ^{140}_{54}Xe + ^{1}_{0}n + ^{1}_{0}n$$

Most of the energy goes here
~ 3%c



Speed of outgoing neutrons

	Slow neutrons	Medium neutrons	Fast neutrons
$^{235}_{93}U$	fission	fission	fission
$^{238}_{93}U$	nothing	capture	fission

$^{235}_{92}U$ is ***fissile*** (hit with anything, it splits)

$^{238}_{92}U$ is ***fissionable*** (hit hard enough, it splits)

is also ***fertile*** (can capture neutrons and turn into something that's fissile)

$^{238}_{94}Pu$

"Going Critical"

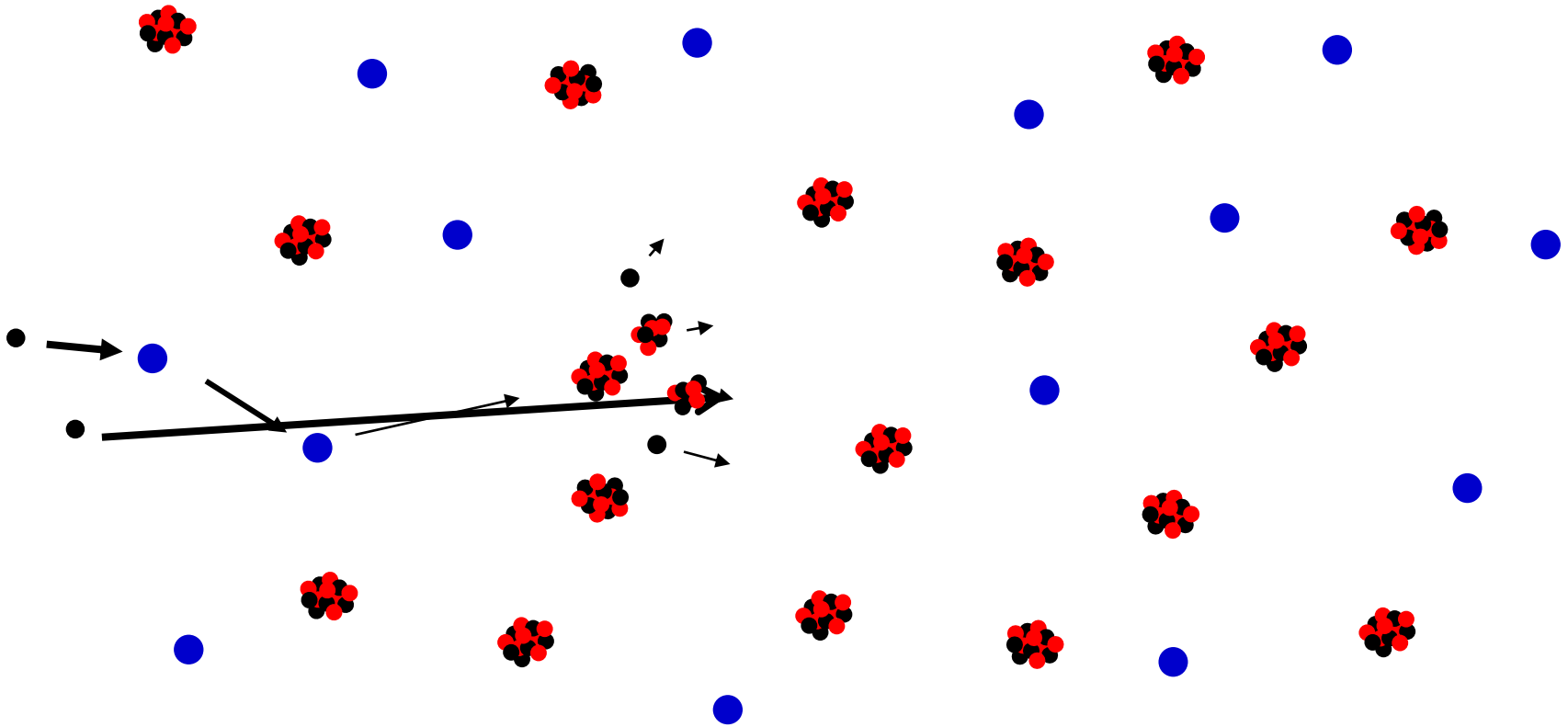
- Not all neutrons go on to cause fission
  - Some are "captured"
  - Some just escape the fuel

- If, on average, one neutron from each fission causes another fission (k=1), reactor is "critical"

- Neutrons are immediate ("prompt"), some are delays by fraction of a second.

- **Reactor can not have nuclear explosion!** Fuel not enriched enough. (Can have other types of explosions.)

Issue #1: Neutrons move too fast

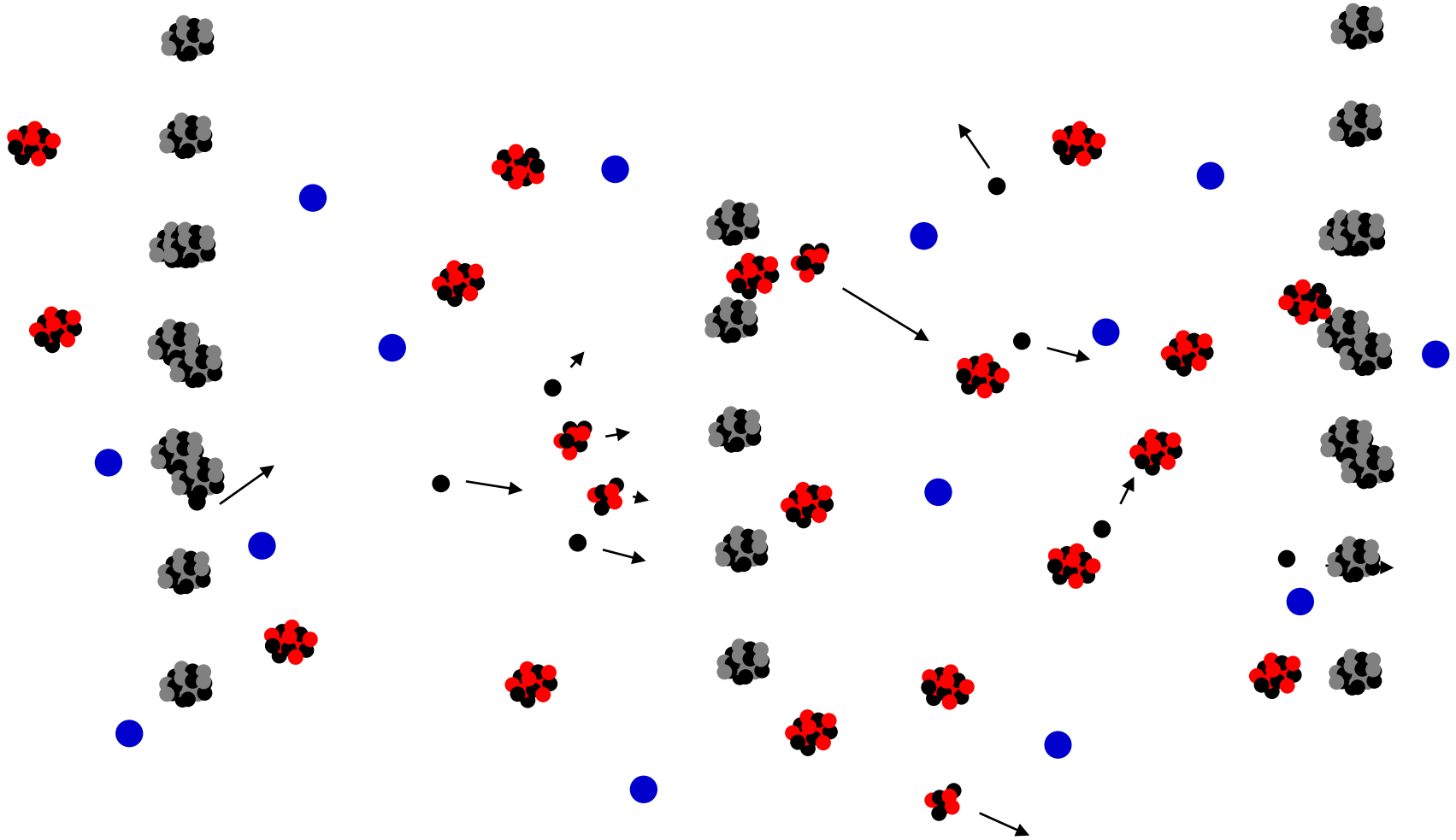


Neutrons have *too much* energy

Solution is "moderation"

(allow collisions to slow down neutrons)

Issue #2: Controlling Reaction



Solution: Insert material which is very good a *capturing* neutrons

(Boron Control Rods)

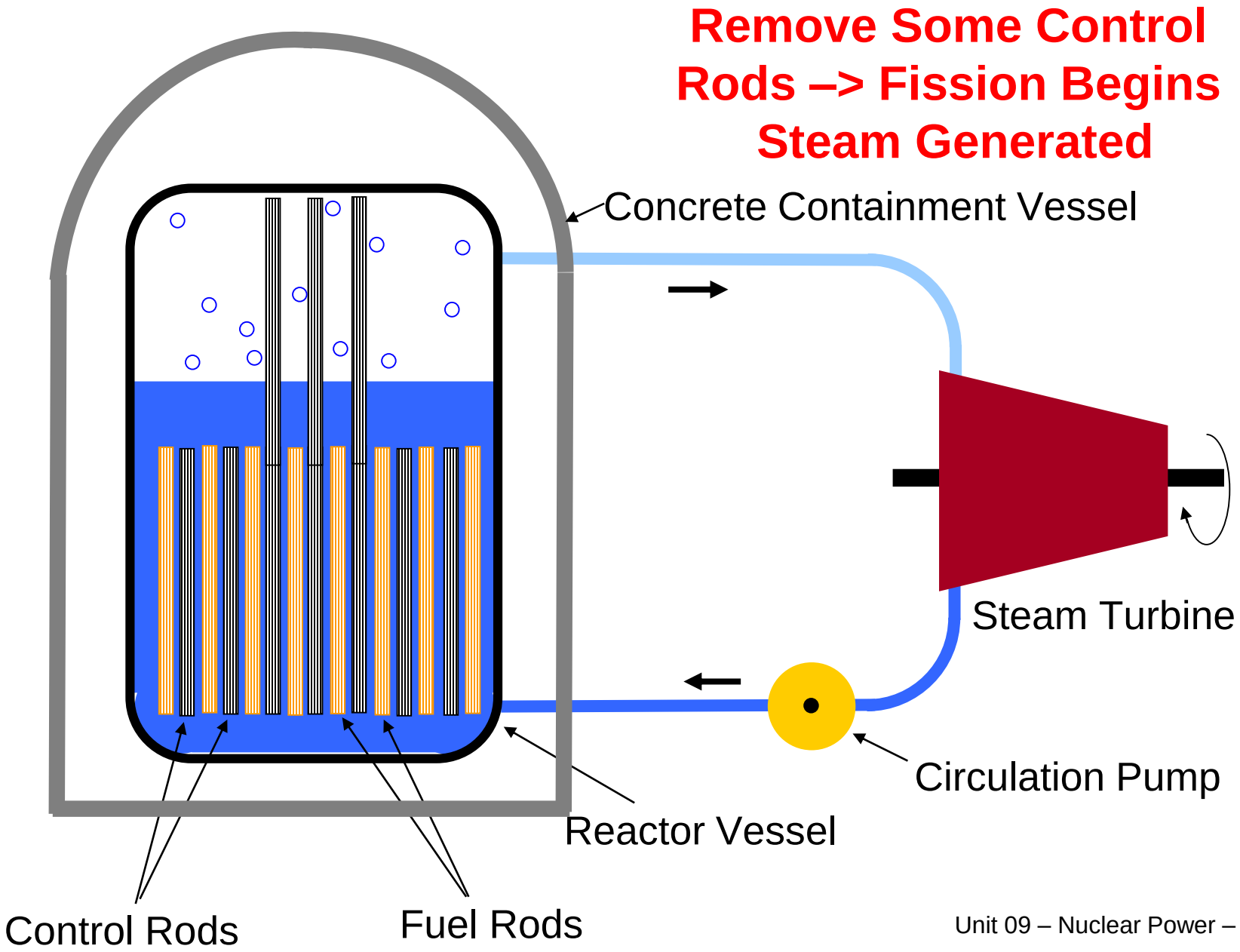
Key Point:

H_20 has have two different effects

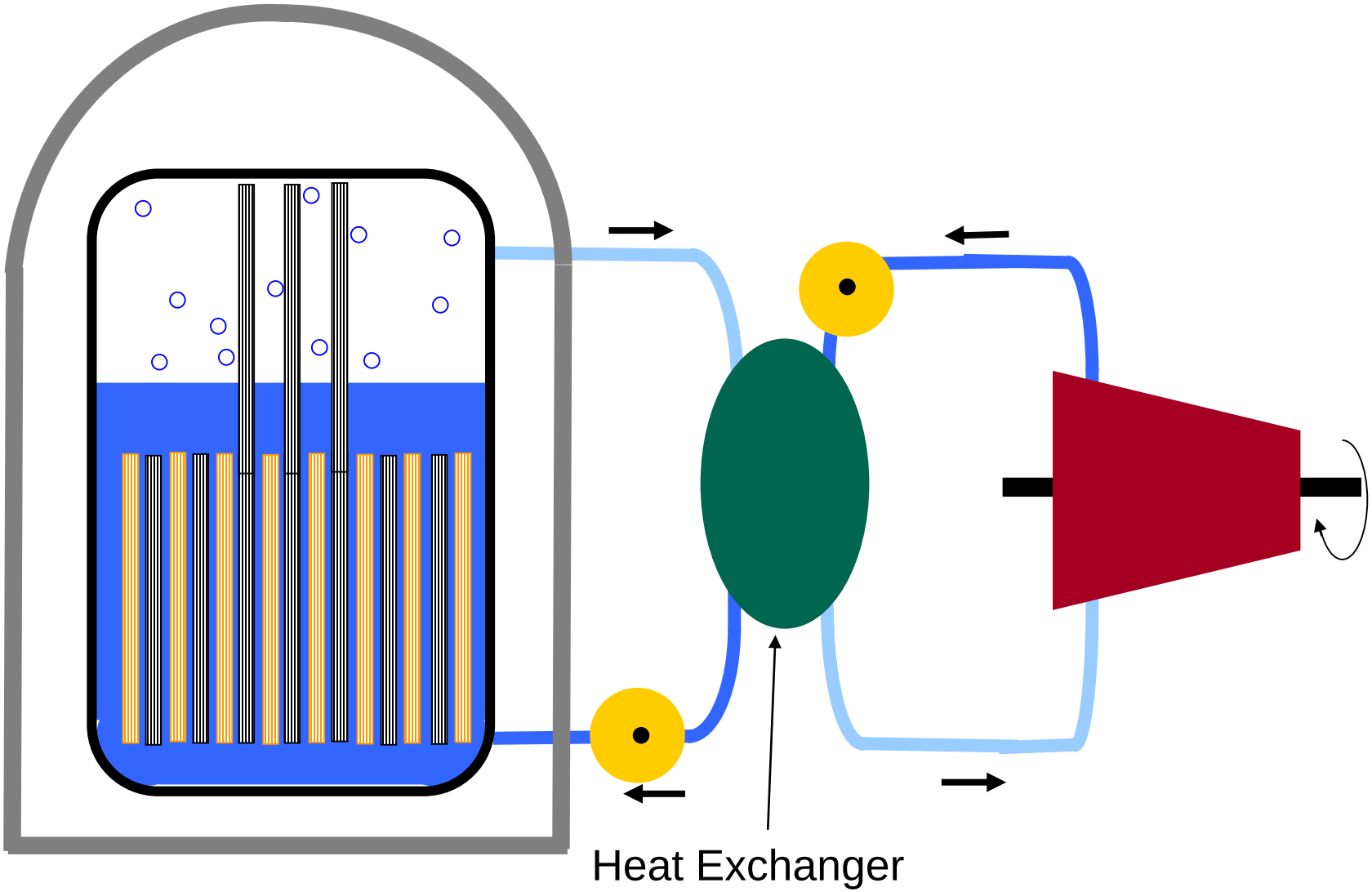
1) Act as coolant (carry heat away)
2) Act as moderator (increase rate of fission)

Also act as “poison” (capture neutrons and decrease rate of fission)

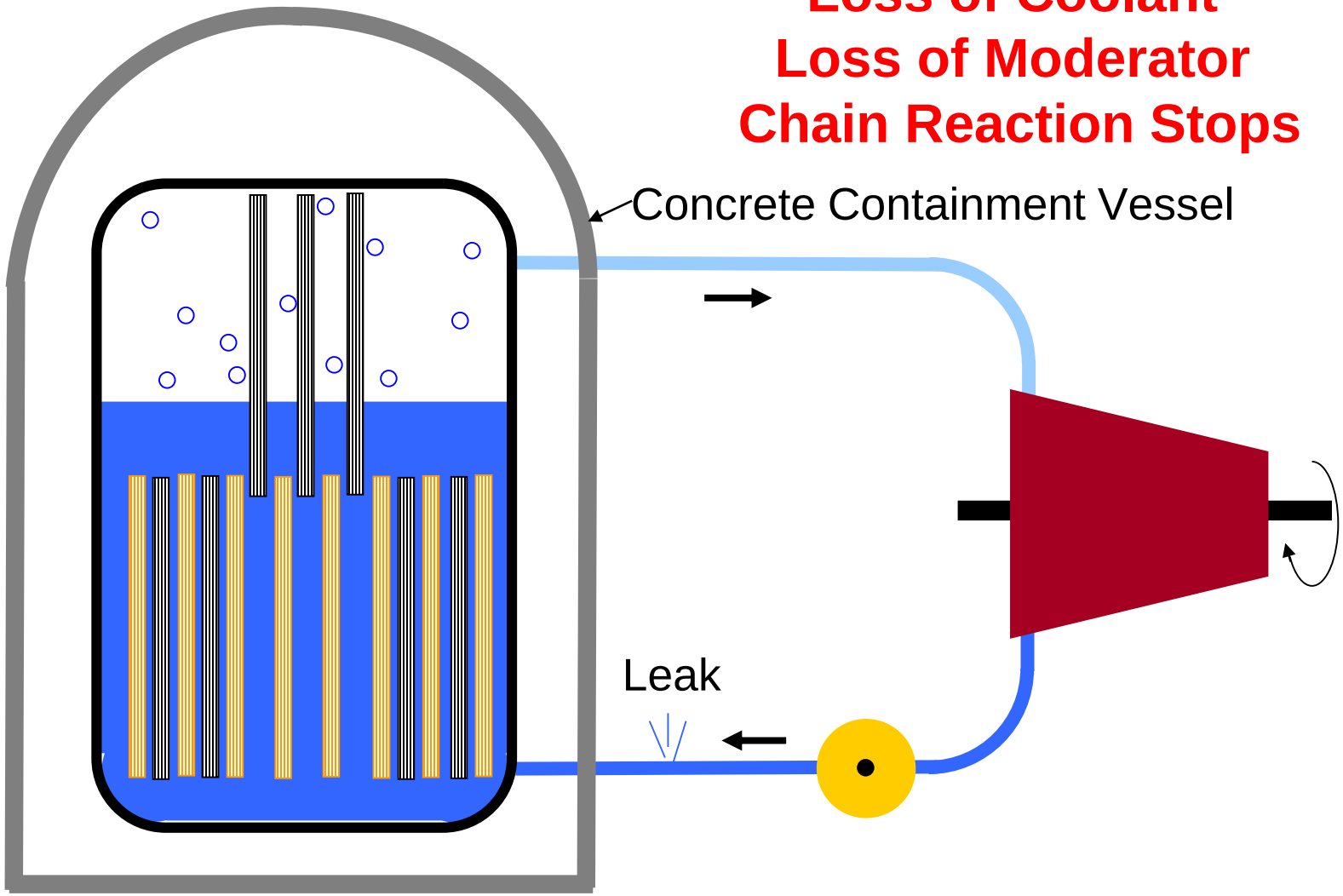
Boiling Water Reactor



Pressurized Water Reactor (PWR)



Loss of Coolant
Loss of Moderator
Chain Reaction Stops



Question

What does the “moderator” do in a nuclear power plant?

A. slows down the neutrons
B. stops or “captures” the neutrons
C. keeps the number of neutrons and uranium atoms in balance
D. Moderates the numbers of uranium-steel collisions
E. Moderates the number of uranium-uranium collisions

Question

What is the “moderator” is most current US nuclear power plants?

A. uranium

B. Boron

C. Water

D. Steel

E. concrete

Nuclear Fuel Cycle

Nuclear Fuel

- Natural Uranium 0.7% U-235
- To act as nuclear fuel, it must be enriched to around 3% - 5%

Spent Fuel

- Mixture of
  - high activity material with $T_{1/2}$ ~ decades (^{90}Sr)
  - Low activity material with $T_{1/2}$ ~ millions of years (^{129}I)

Where does waste go?

- Nowhere!
- Normally stored in pools on site.

Terms of interest

- Electrical Capacity of Nuclear Power Plant **1Gigawatt** (within factor of 2)

- Electrical Capacity of Wind Turbine **2Megawatt** (within factor of 2)

- Average use of Chicago ~ **4Gigawatt** (peak ~ five/six times greater)

- **Capacity Factor** (percentage of time producing power)
  - ~80% thermal plant
  - ~30% wind turbine

Question

About how many wind turbines would it take provide power to the city of Chicago? (You can assume the wind is blowing all the time so they're running all the time. It's the "Windy City" after all.)

A) 20

B) 2000

C) 20,0000

D) 200,0000

Things **not** to be concerned about :

- Blowing up like an atomic bomb
- General radiation from around the plant.

Things to be concerned about :

- Cost
  - General cost of the plant
  - Interest paid during time plant being build
  - Cost of decommissioning (or cleanup!)
  - Stability of the market
- Spent fuel
- Enough uranium (cheap uranium)
- How fast can you build them