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Title: Godiva-IV Critical Assembly

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Godiva-IV Critical Assembly

Advanced Nuclear Technology, NEN-2

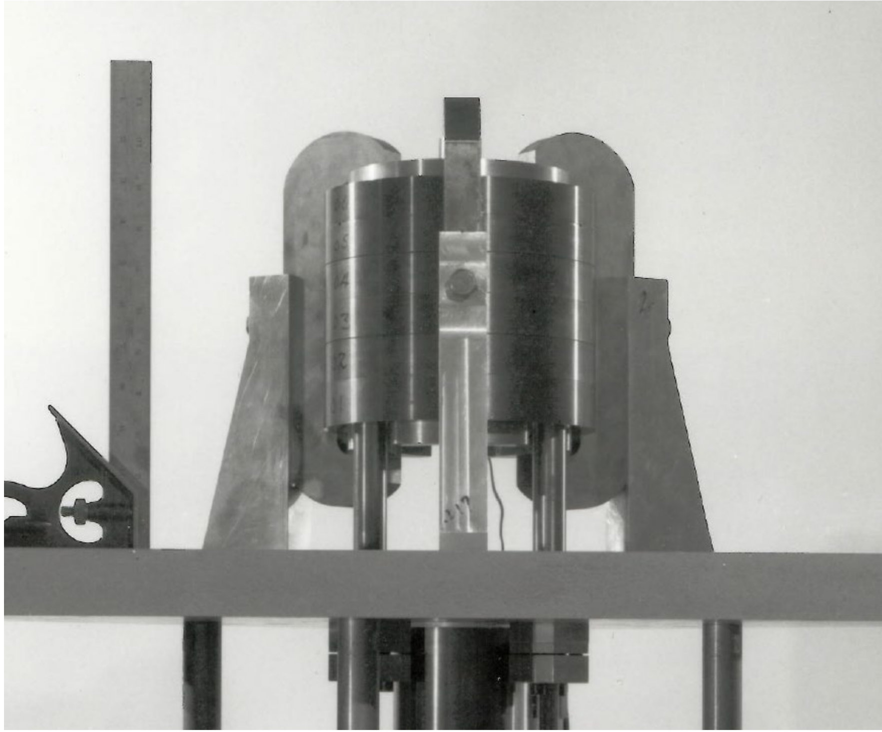
LA-UR-24-

Objectives

- Familiarization of the Godiva-IV assembly.
- Understand the criticality safety parameters that effect Godiva IV
- Understand the differences between subcritical, delayed-critical, and prompt-critical operations.
- Understand the concept of temperature-dependent reactivity feedback

What is Godiva-IV?

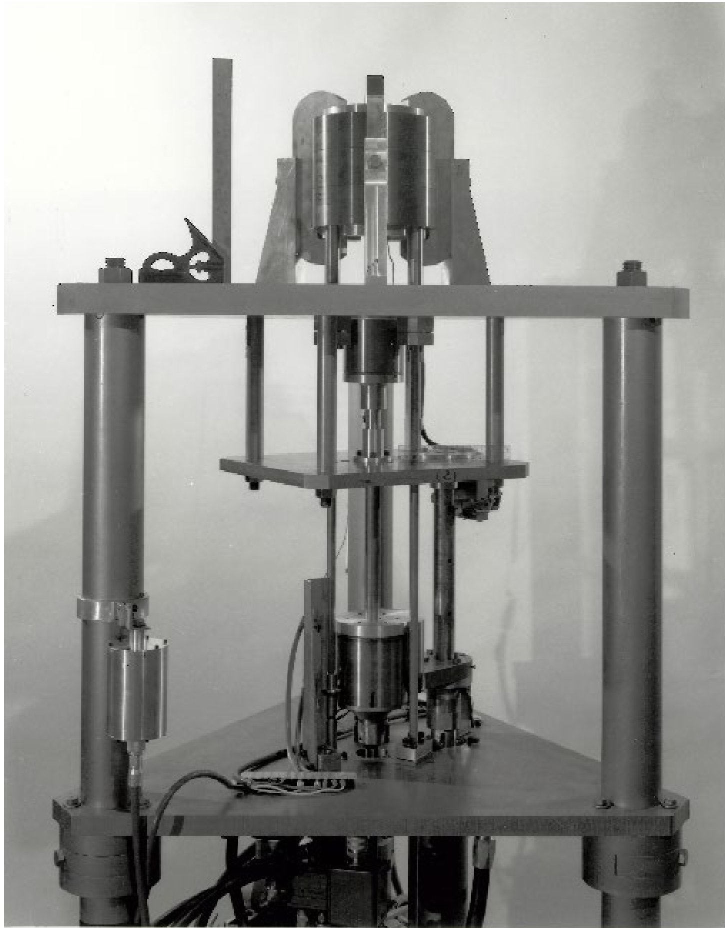
- Godiva-IV is a critical assembly
- Godiva-IV is special – can operate outside of the delayed critical window,
  - i.e., above prompt critical
- A Godiva-IV operation above prompt critical is called a Godiva Burst



Godiva-IV Assembly Description

- Cylindrical geometry core design.
  - Dimensions of 7 in. in diameter (17.8 cm) × 6 in. tall (15.2 cm).
- Core mass of ~66 kg.
  - Very close to “optimal” bare sphere critical mass of ~50 kg
- Uranium content enriched to 93.5 wt.% U-235.
- Uranium-molybdenum alloyed metal
  - 1.5 wt.% molybdenum

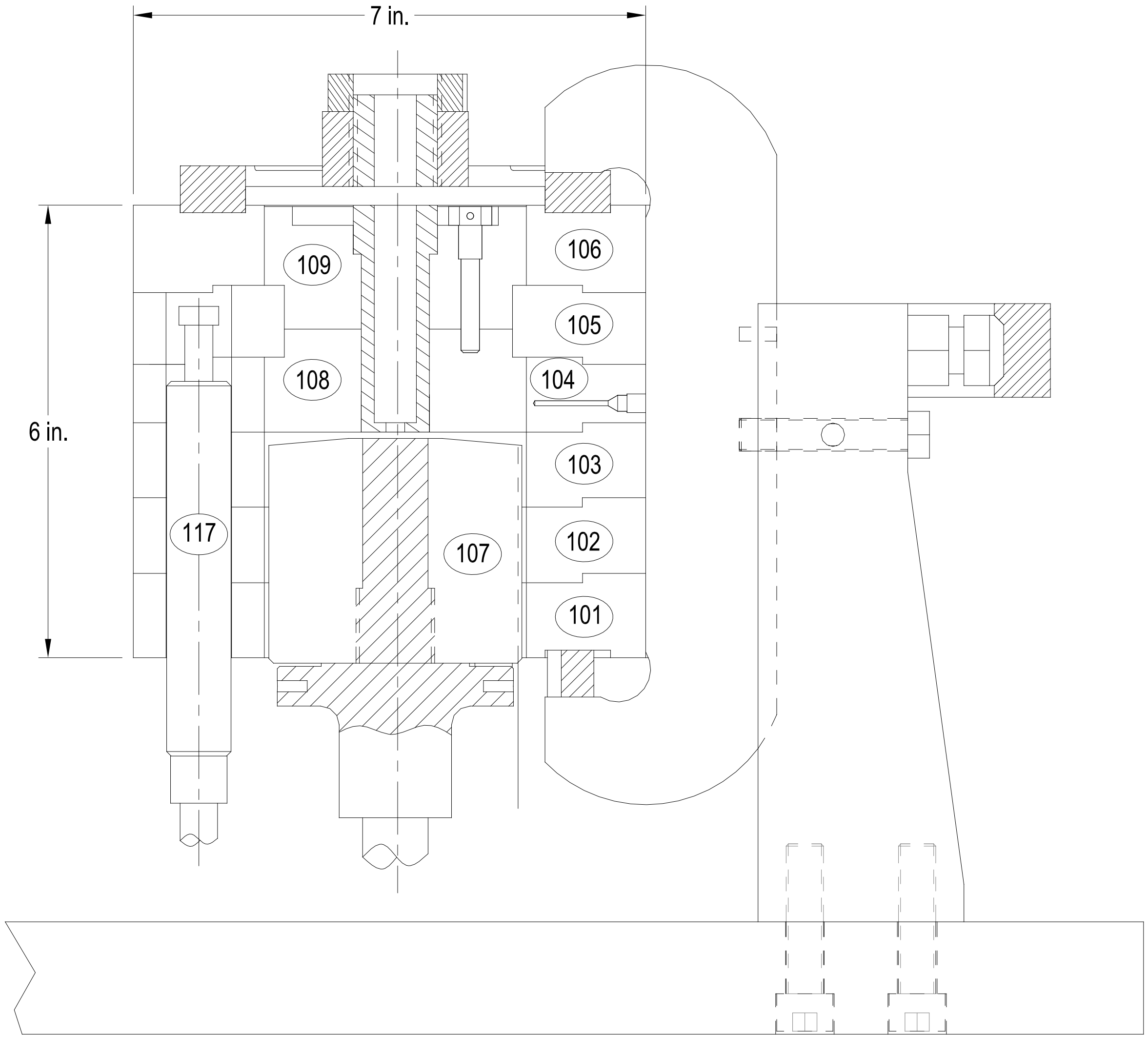
Godiva-IV assembly, circa 1967.



Godiva-IV Operations

- Max Burst (Theoretical):
  - Temperature Rise: 525°C
  - Burst Duration: 25 μs
  - Power: 90,000 MWth
- Current applications include
  - sample reactivity worth studies
  - reactor kinetics benchmark studies
  - reactor dynamic excursion studies
  - sample neutron activation studies
  - dosimetry measurements
  - criticality alarm testing
  - critical assembly operator training
  - criticality safety training demonstrations

Detailed Design Drawing of Godiva IV Core



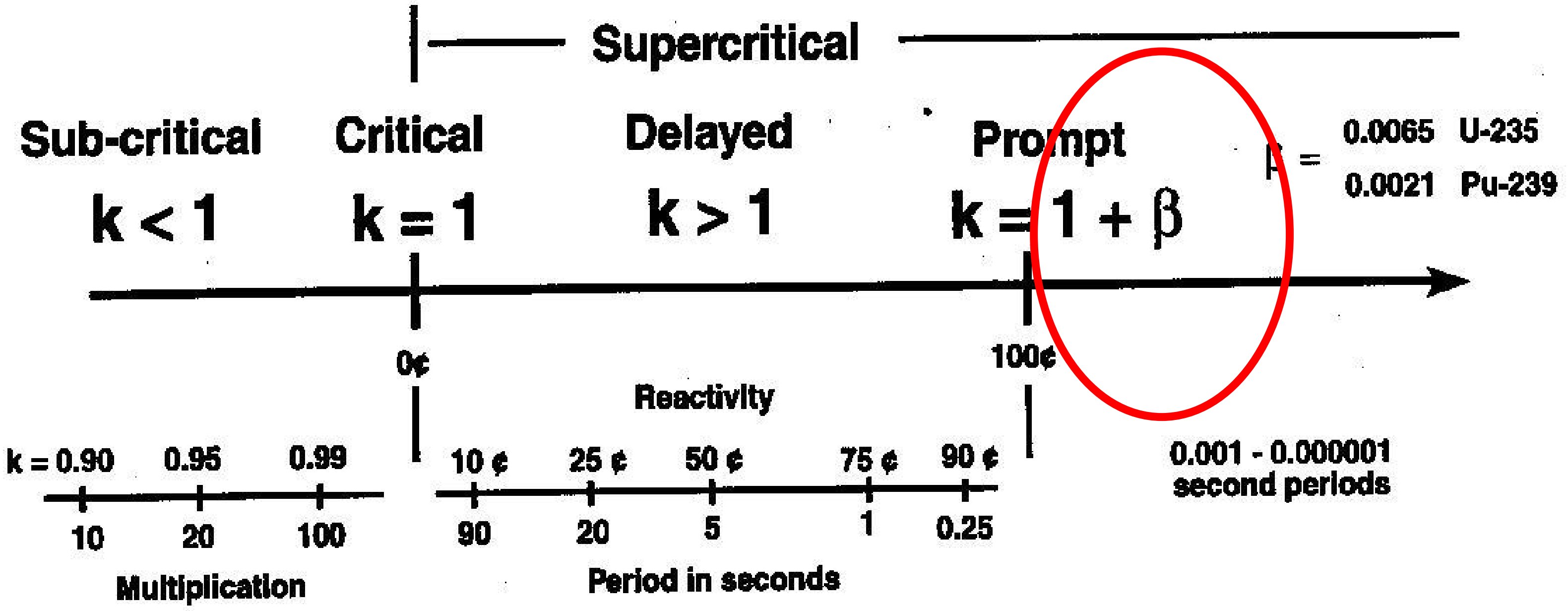
Godiva-IV and Criticality Safety Parameters

- Godiva-IV ~66 kg
- Bare HEU critical sphere ~50 kg
- Water reflected HEU critical sphere ~25 kg
- What about the criticality safety parameter Reflection?
  - Person “hugging” Godiva-IV?
  - Or tripping/falling?
  - Fire suppression leak?
  - Bulky item tipping onto Godiva-IV?
  - These were major concerns when constructing Godiva-IV after move from TA-18

Godiva "Burst"

- What is a Godiva Burst?
  - Sudden increase in the power/neutron population of the assembly, typically above prompt critical
  - Very, very fast, power rise happens over 10s of μs
  - Similar to Flat-Top, Godiva will naturally shutdown the burst
- Why perform a Godiva Burst?
  - Mimics a criticality accident, essentially a "controlled" criticality accident
  - Burst occurs over a very short time frame
  - Large amounts of radiation released during burst
  - Good criticality safety demonstration!
  - Good demonstration of how quick a criticality accident occurs!

Delayed Critical and Prompt Critical



Delayed Critical

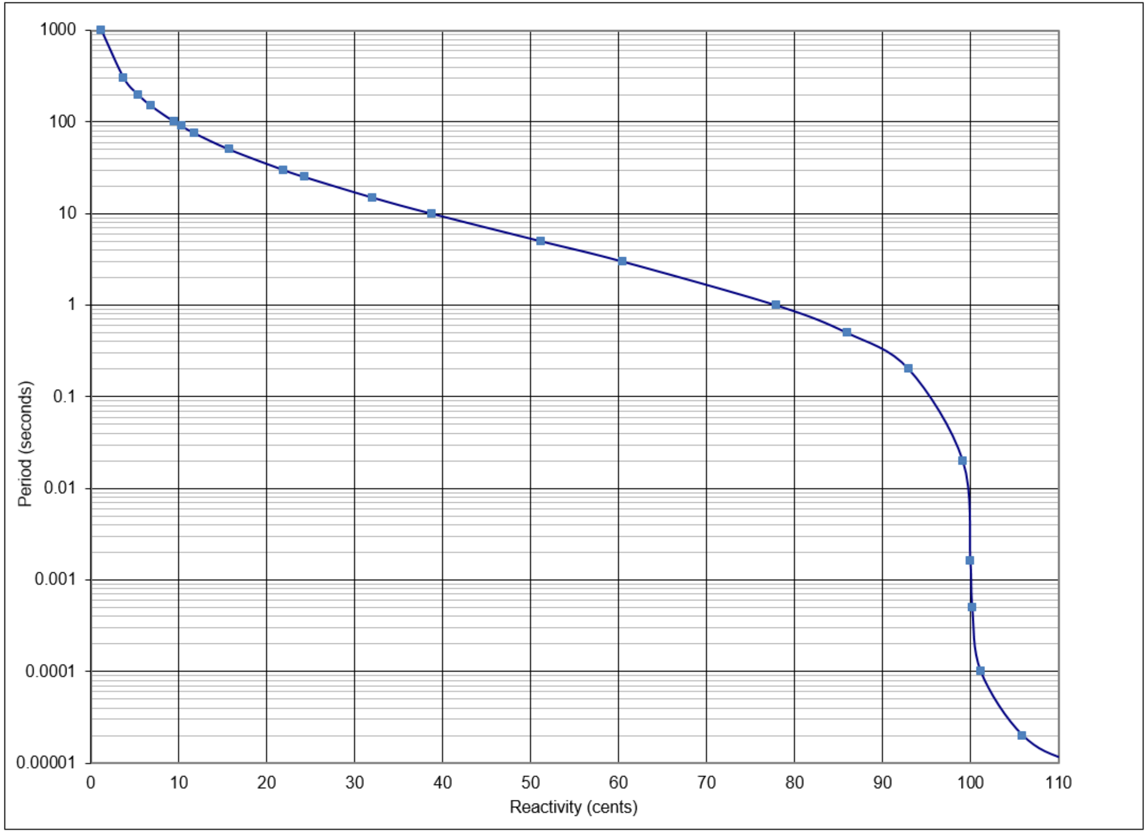
- Needs both delayed and prompt neutrons to be a self-sustaining neutron chain reacting system.
- Increase in neutron population (power) dominated by the timescales associated with the appearance of delayed neutrons
  - Neutrons from fission product decay
  - Time scale of milliseconds to minutes).
- Longer timescales **DO** allow for control mechanisms to affect the transient power behavior
  - control rods
  - mechanical safety systems
  - operator intervention

Prompt Critical

- Needs only prompt neutrons to be a self-sustaining neutron chain reacting system.
- Increase in neutron population (power) dominated by prompt neutrons
  - Time scale of nanoseconds to milliseconds

- Shorter timescales **DO NOT** allow for control mechanisms to affect the transient power behavior.

Godiva IV Period Versus Reactivity



Temperature Coefficient of Reactivity

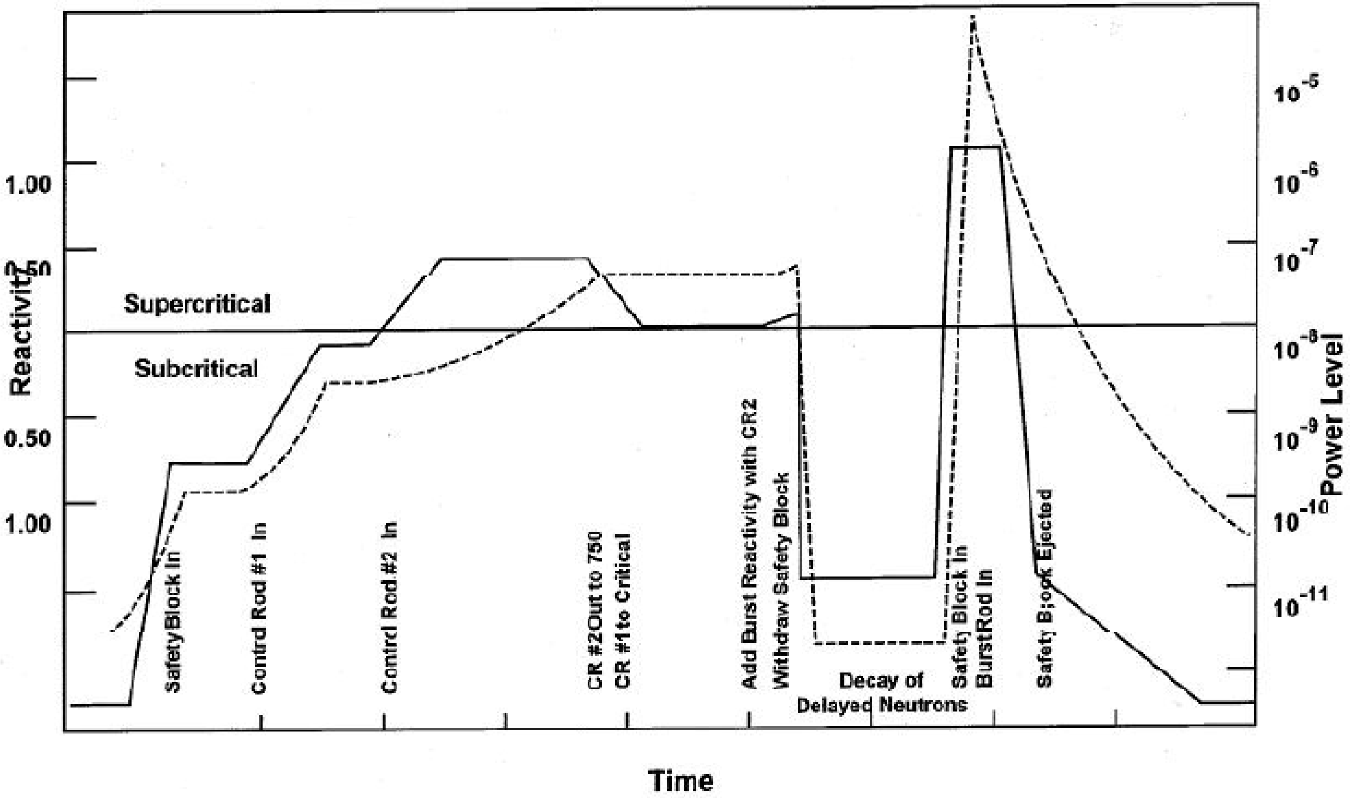
$$\frac{\Delta\rho}{\Delta T}(¢/°C)$$

Negative: increase in temperature => decrease in reactivity

Positive: increase in temperature => increase in reactivity

Assembly	Approx. Temp. Coeff.
Godiva IV, Big Ten, Flattop U	-0.3 (¢/°C)
Flattop delta-phase plutonium	-0.2(¢/°C)
SHEBA U(5) solution	-4.0 to -10.0 (¢/°C)
CNPS(U(20)O_2-C matrix	-1.2 (¢/°C)

Godiva IV Burst Operation



What Terminates the Burst?

- Expansion and Neutron Leakage
- Shock Wave Removal of Safety Block
- Trigger Module Input to Control System
- Log-N SCRAM Signal