Compact Water Cooled Dump Resistor

IRENG07

Wes Craddock

September 19, 2007

Dump Resistor Basic Idea

- The solenoid dump resistor, dump breaker and power supply are mounted on the detector to eliminate long runs of high current cable that must also be moveable.
- A detector mounted air cooled dump resistor such as that used for CMS is not possible.
- So the practical choice is a resistor that uses either the heat of vaporization or the sensible heat of water. The choice here is the latter.

Air Cooled Resistor

An air cooled resistor would be one half the physical volume of the CMS dump resistor.

Pressurizing reduces both water and stainless steel over a 1 atm water cooled design.

Resistor Design Assumptions

- Must dissipate 1.4 GJ
- Solenoid current = 14.5 kA
- Peak Discharge Voltage < ± 300 V
- CMS (@ 2.7 GJ, 20 kA and ± 300 V) is the model
- Both solenoids have similar inductance of 13.4 H. It will be reasonable to assume that both should have similar discharge times.
- Assume the same CMS discharge resistance of 30 mΩ.

Water Cooled Design Choices

- Option 1: Boil the water and vent to atmosphere.

  30 C to boiling h_v = 2.55 MJ/liter >> 550 liter x 2 = 1100 liter

  Problem: Either vent this in the hall with condensation, heat and noise problems or run a long pipe outside. The required volume must be doubled to ensure the resistor is always cooled.

- Option 2: Heat the water just to the boiling point.

  30 C to 100 C C_p = 0.29 MJ/liter >> 4830 liter

- **Option 3**: Heat water to 150 C & 4.8 bar (54 psig) in an ASME vessel without venting.

  30 C to 150 C C_p = 0.50 MJ/liter >> 2800 liter

Resistor Thermal Design

- The resistor boils water on its surface even though there is no bulk boiling.
- Max Power Generated = Max Power Dissipated

Stay below the peak nucleate boil flux = 125 W/cm^2

Use 100 W/cm^2

~ 20 C difference between conductor and water

$I^2R = 14500^2 \times 0.030 = 6.3$ MW

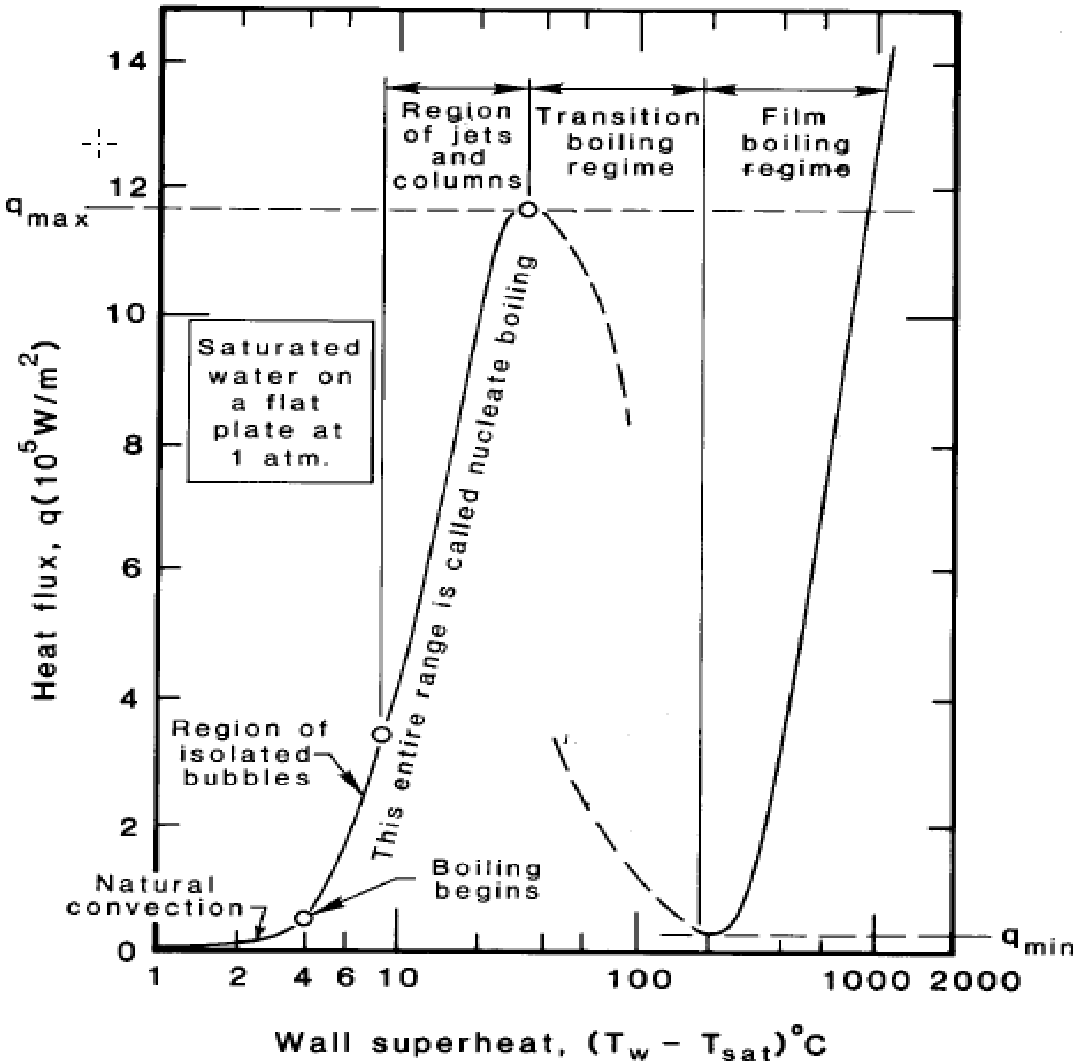
Pick a 1.27 cm X 10.16 cm (.5" X 4") conductor size

This then requires 53 meter to get 0.030 ohm

Heat dissipated = 100 W/cm^2 X 22.9 cm2/cm X 5300 cm = 12.2 MW

Safety Factor = 12.2/6.3 X 125/100 = 2.4

Boiling Curve for Water



Resistor Mechanical Design

- The 304 SS steel bars are bent in a serpentine fashion:
  - Overall length 70 cm
  - Gap between turns = 8 cm
  - 6 bends per layer with 12 layers
  - 4 cm spacing between layers
  - Resistor size 70 cm X 56 cm X 170 cm tall
- The resistor is hung from the top head
- Furnace brazed connections between layers
- Magnetic forces less than 1000 N/turn

Water Containing Vessel

- ASME coded with hemispherical ends
- 1.25 m diameter X 3.5 m tall
- Top head is flanged.
- Cylindrical section 2.25 m; fill to 2.0 meter
- Total water volume = 2960 liter = 780 gal
- Total air volume = 820 liter
- Penetrations:

  2 copper 15 kA bus bars

  1 copper 500 A bus bar for center tap ground on resistor

  Instrumentation feed through

  View ports

  1 Pressure relief valve

  Water drain and fill valves

  Water inlet/outlet for internal cool down plumbing lines

Conclusion

- No known dump resistor of this type
- Small compact design
- Volume is set by stored energy not quench protection details
- Engineering straight forward. Lots of data.
- Still should try a test with only a few turns using the solenoids power supply.
- Conductor feed throughs require some thought, but are not a big problem because

  V < 300 volt to shell (ground)