Divertor Design Status

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Outline

- **PSI Conference Summary**
- **FIRE Physics Workshop Output**
- **Baffle Calculations**
- **Plans**

PSI Conference Summary

- **Flux dependence of carbon chemical erosion has been shown to be false**
  - **Increase chemical erosion of carbon**
  - **Increased hydrogen trapping**
- **Some species of chemically eroded carbon have low sticking probability and are transported long distances**
  - **Deep inaccessible burial sites for codeposited layers**
  - **Explains TFTR data**
- **Some machines see control of carbon erosion in divertor but no change in core content**
  - **CX erosion of the first wall is important**

PSI Conference Summary

- **New carbon data have pushed ITER to propose removal of carbon from the baseline divertor concept (not final yet)**
- **ASDEX-U has covered a significant portion of the inner wall with W**
  - **No W contamination of the plasma was observed**
- **TEXTOR has run with W limiters**
  - **Until the coating failed due to high heat flux there was no significant W contamination of the plasma**
- **New High Z data has caused ITER to consider the backup to an all W/Be design to be an ALL W design**

PSI Conference Summary

- **Modeling and experiments have confirmed the usefulness of a “closed” divertor geometry**
- **The “vertical” target design has been implemented on several machines with good results**
- **Divertor pumping has proven useful on two machines**
- **There is a general shortage of double null results**

PSI Conference Summary

- **ASDEX-U has put together a neural network for predicting disruptions**
  - **Trained on known disruptions**
  - **Compared to a subset of known disruptions not used for training and predicted 90% with a 5% false positive rate**
  - **Predicts the time until a disruption (50 ms is trigger point)**
  - **Has been used on actual shots with the same accuracy**
  - **Has been used to trigger “killer pellets” with the results being a reduction in halo currents**

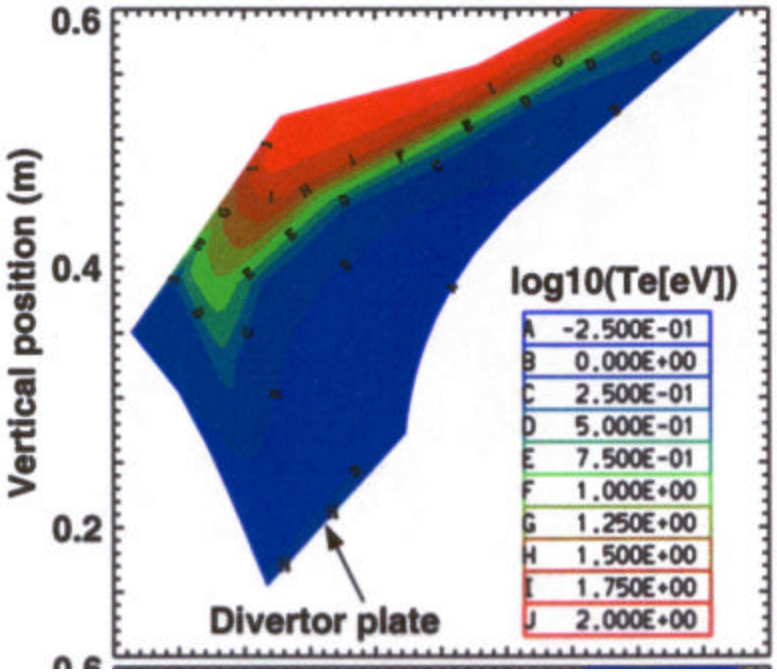
PSI Conference Summary

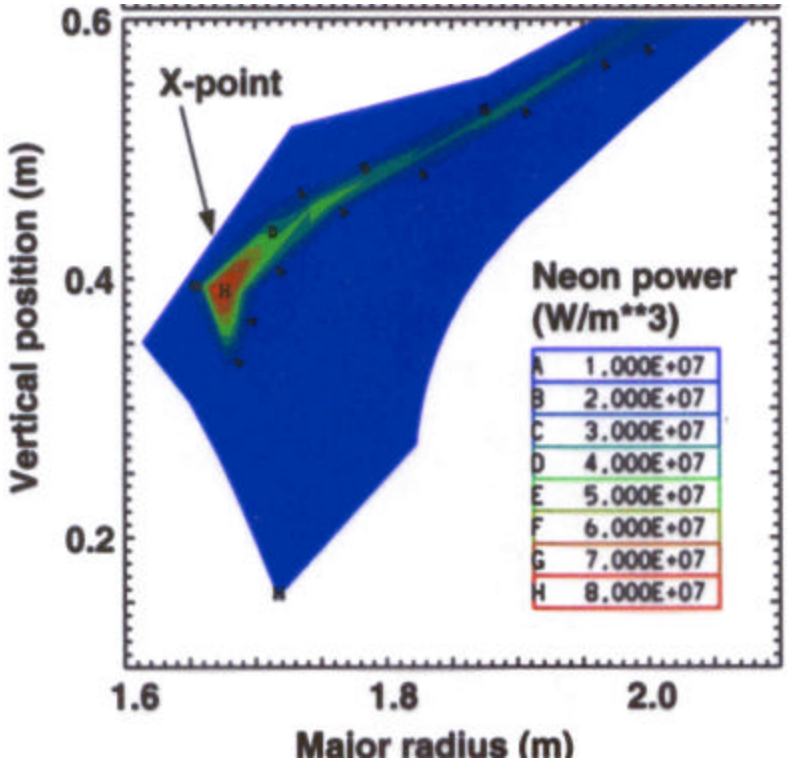
- Many studies have been conducted on the effect of ELMs on the divertor
- Higher ELM frequency reduces the energy content of an ELM but also decreases plasma energy confinement
- ELMs can dump 10% of the plasma stored energy onto the divertor in < 1ms (mini-disruption)
- ELMs can cause reattachment
- ELMs could be life limiting for divertor plates if the energy content is too high

FIRE Physics Workshop Output

- **Plasma Edge Modeling (Rognlein)**
  - **More realistic geometries have been used**
  - **Detached solutions for the outer divertor have been found**
  - **Be alone is not sufficient for detachment**
  - **Ne addition is sufficient to cause detachment**
  - **There is a fairly narrow range for Ne injection (feedback control is needed)**
  - **Heat loads on the sidewalls are available**

FIRE Physics Workshop Output





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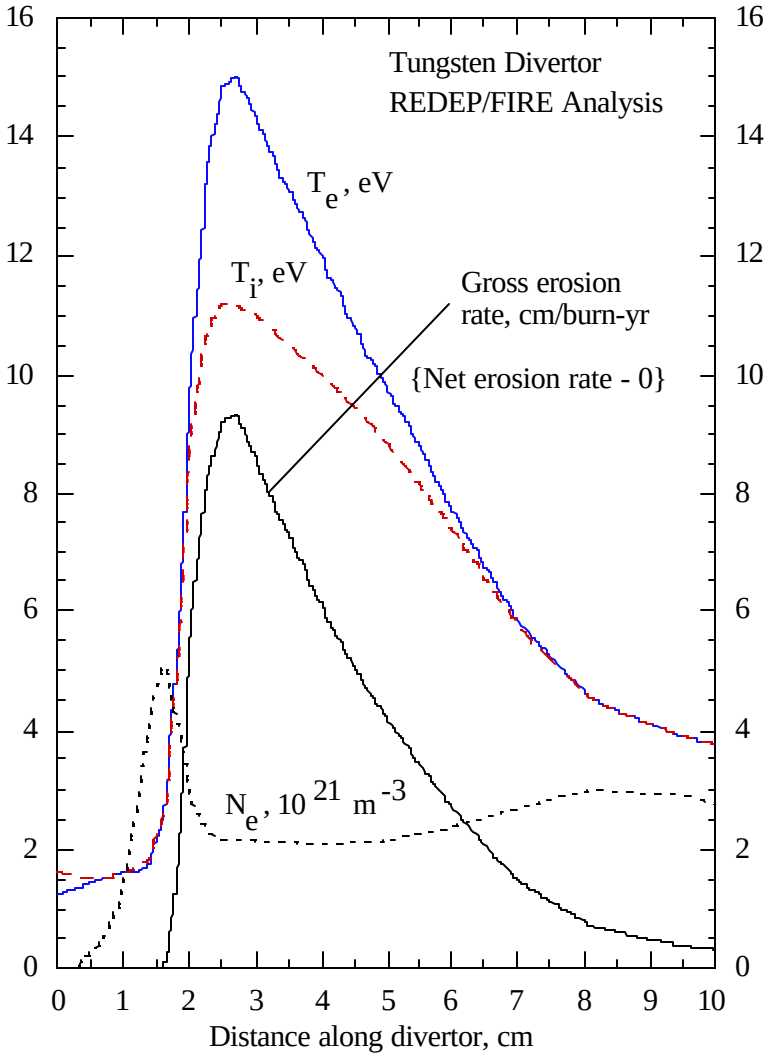
FIRE Physics Workshop Output

- **Erosion and redeposition have been studied for the UEDGE cases (Brooks)**
  - **There is no net erosion of W even for the attached divertor cases because of the short mean free path for ionization of W**
  - **Incorporation of impurities (e.g., Be) in the top surface layer should be investigated**

FIRE Physics Workshop Output



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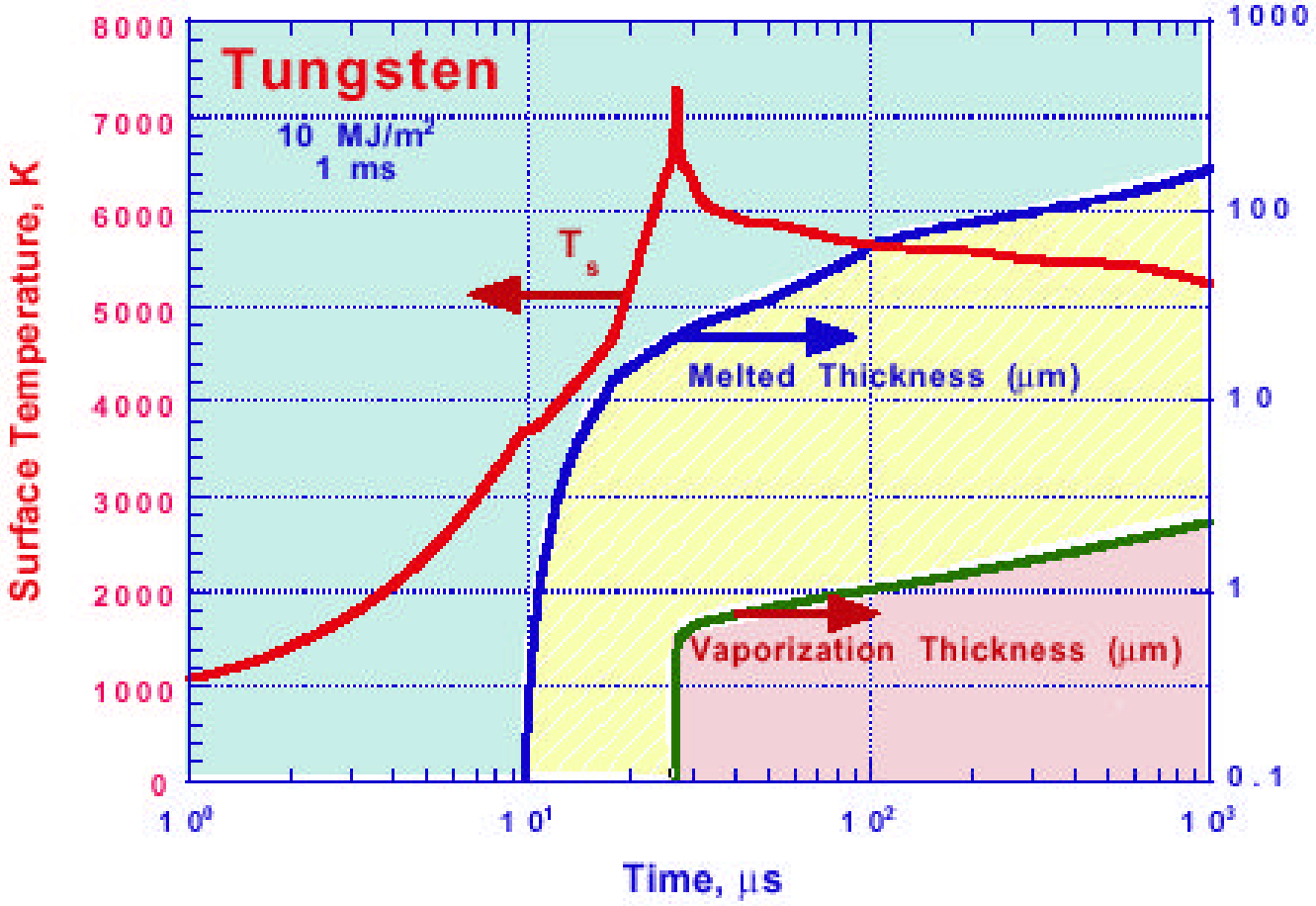
FIRE Physics Workshop Output

- **Disruption erosion cases have been studied using the HEIGHTS code (Hassanein)**
  - **W melt layer is 150 to 200 μm thick**
  - **W evaporation is 2 to 4 μm**
  - **Vapor shielding is very effective (X10 increase in heat deposition causes almost no change in melt layer or evaporation)**
  - **Splashing of the molten W will be the life limiting factor for disruptions**
  - **Predicted lifetimes are a few hundred disruptions if the melt layer is lost**

FIRE Physics Workshop Output



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Baffle Calculations

- **Temperature profiles in the baffle have been calculated (Baxi, GA)**
  - Heat Sink Cu-Cr-Zr
  - PFC: Tungsten Rods .125” Dia at .128” pitch (86.5 % volume fraction)
  - Height = 5 mm
  - Water Inlet temperature 30 C
    - » **Pressure 1.5 MPa**
  - Number of Modules=32

Input Conditions

	Outer Divertor	Baffle
Total Power (MW)	34.3	10.7
Peak Power/module (MW)	2.32	0.58
Peak Heat Flux (MW/m^2)	20.0	6.00
Nuclear heating in W (W/cm^3)	42	34
Nuclear heating in Cu (W/cm^3)	16	13

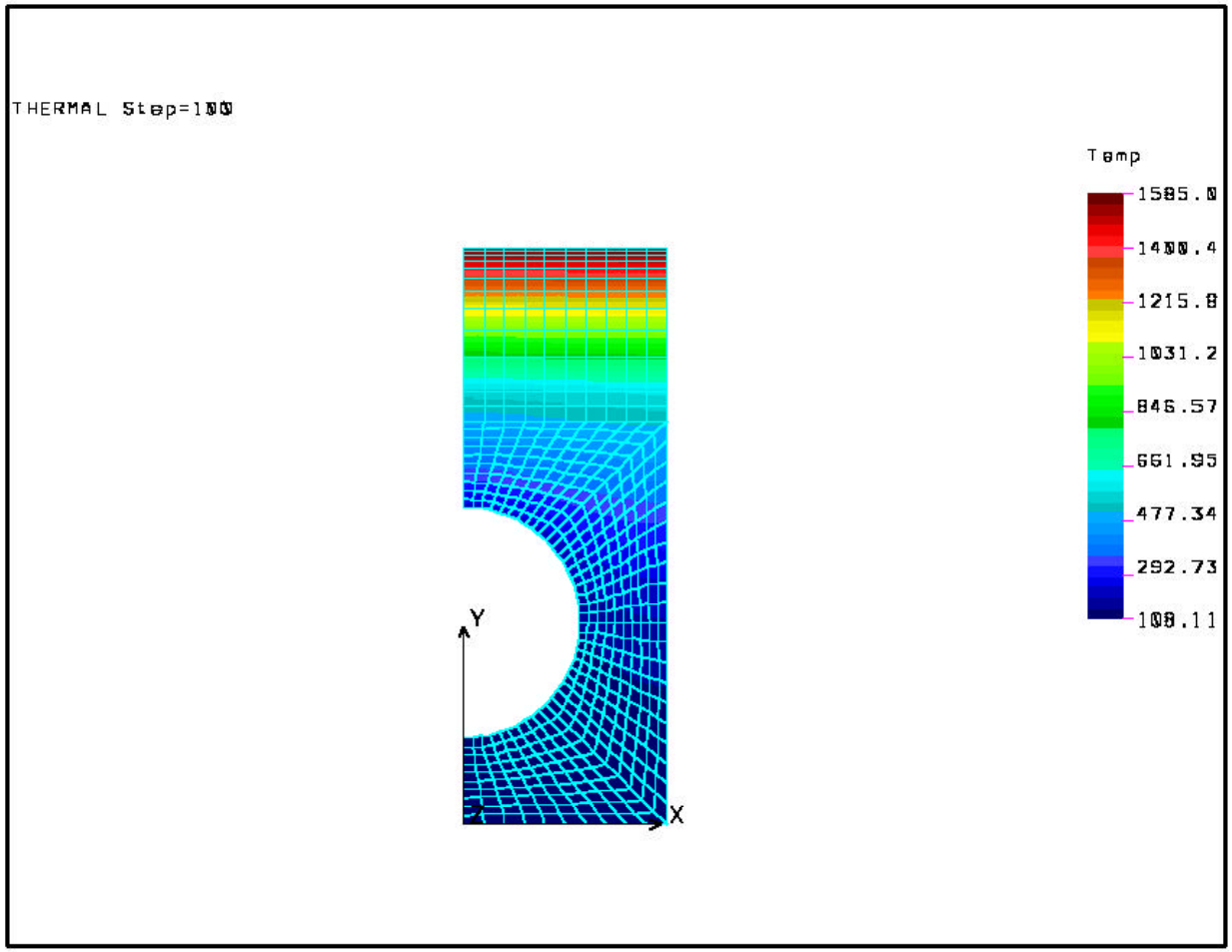
Input Conditions

	Outer Divertor	Baffle
Peak Heat Flux(MW/m^2)	20	6
Channel Diameter (mm)	8	10
Pitch (mm)	14	21
Number per module	48	30
Number in series	2	2
Enhancement	ST, t=1.5 mm Y= 2	no

Results of Analysis

	Outer Divertor	Baffle
Maximum PFC temperature (C)	1585	738
Maximum copper Temperature (C)	488	404
Flow velocity (m/s)	10	3
Flow/module (l/s)	9	3.5
Exit coolant Temperature(C)	95	73.3
Exit Pressure(MPa)	1.06	1.48

20 s pulse with 20 MW/m^2



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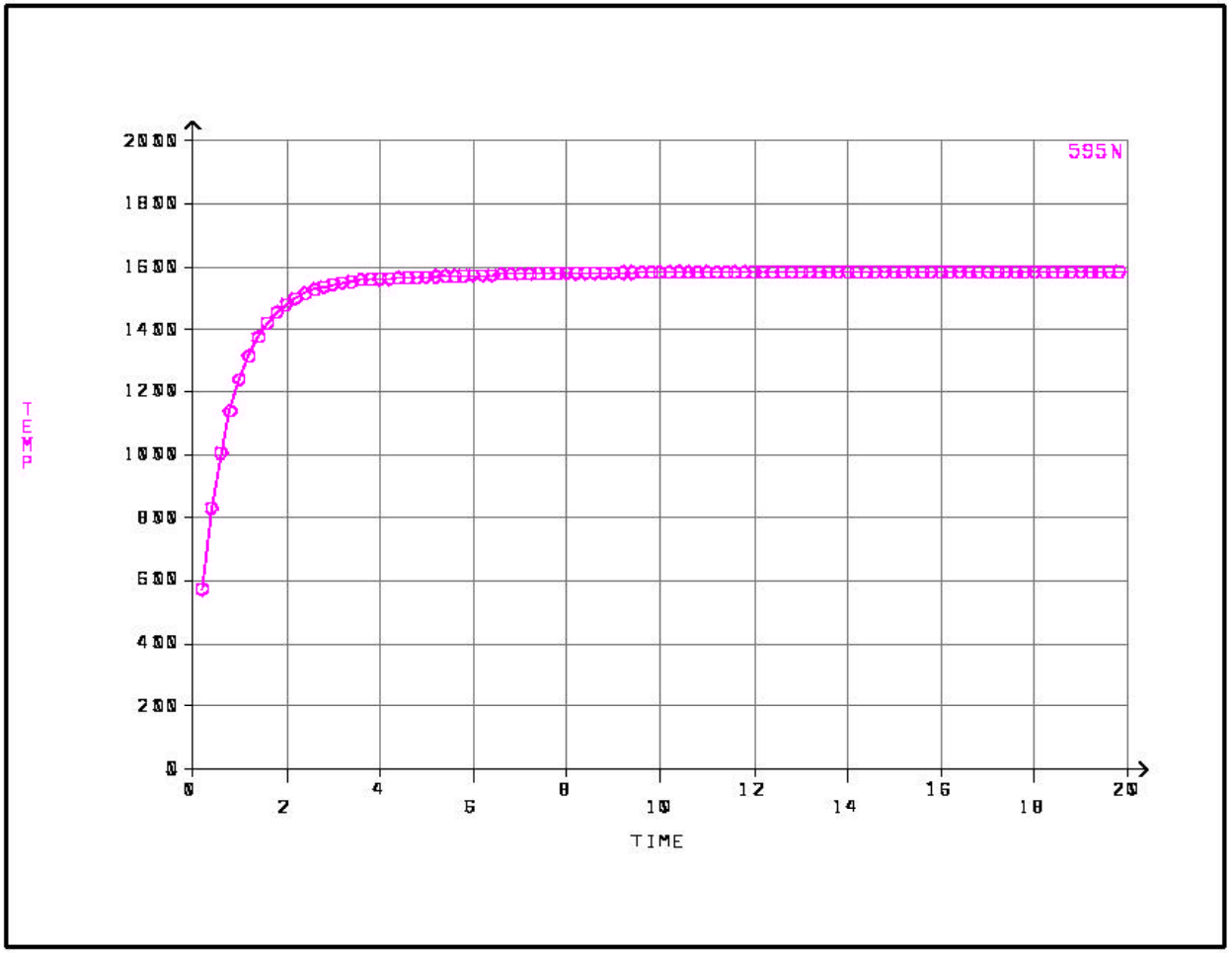
Time Variation of the Temperature



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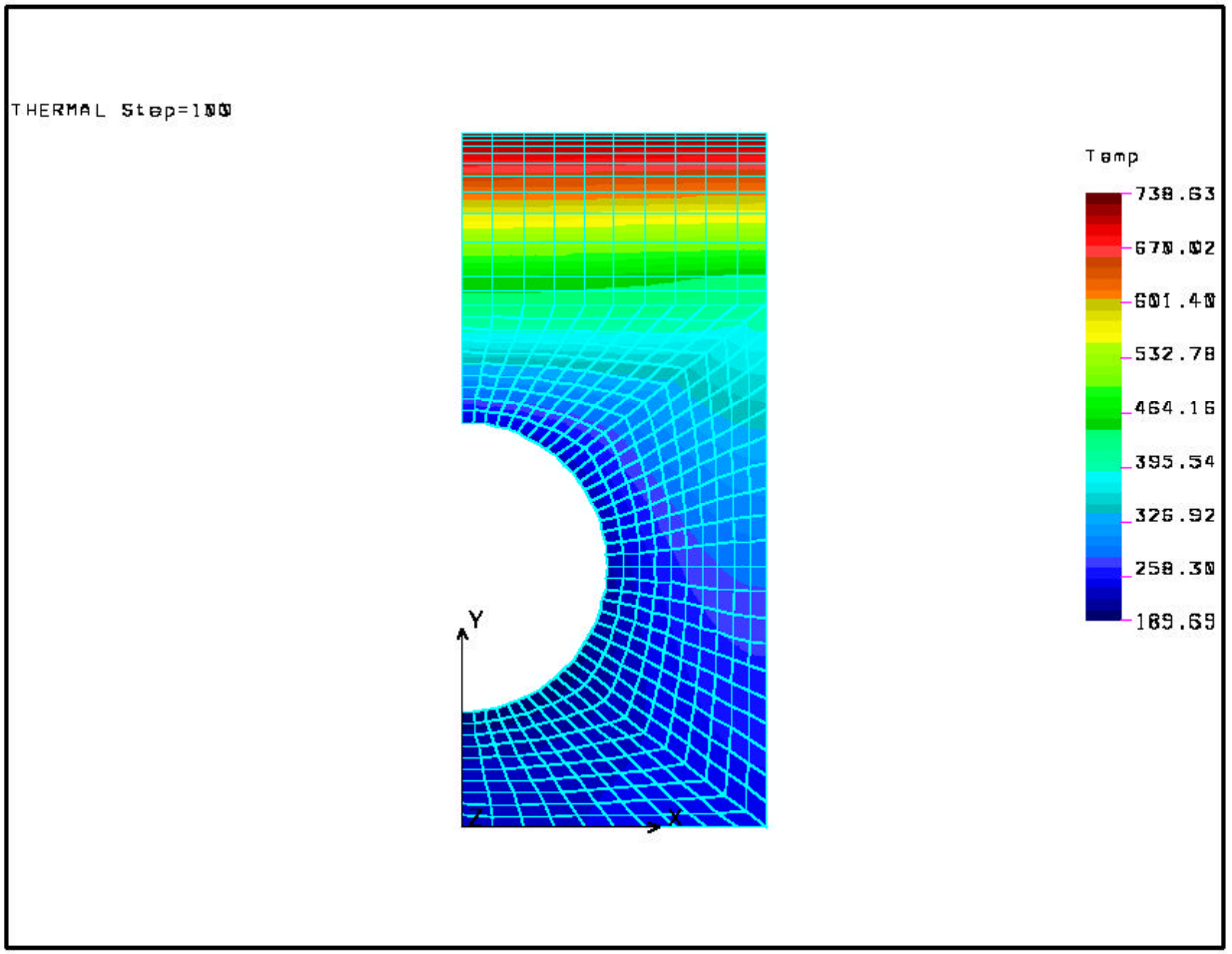
20 s pulse with 6 MW/m^2



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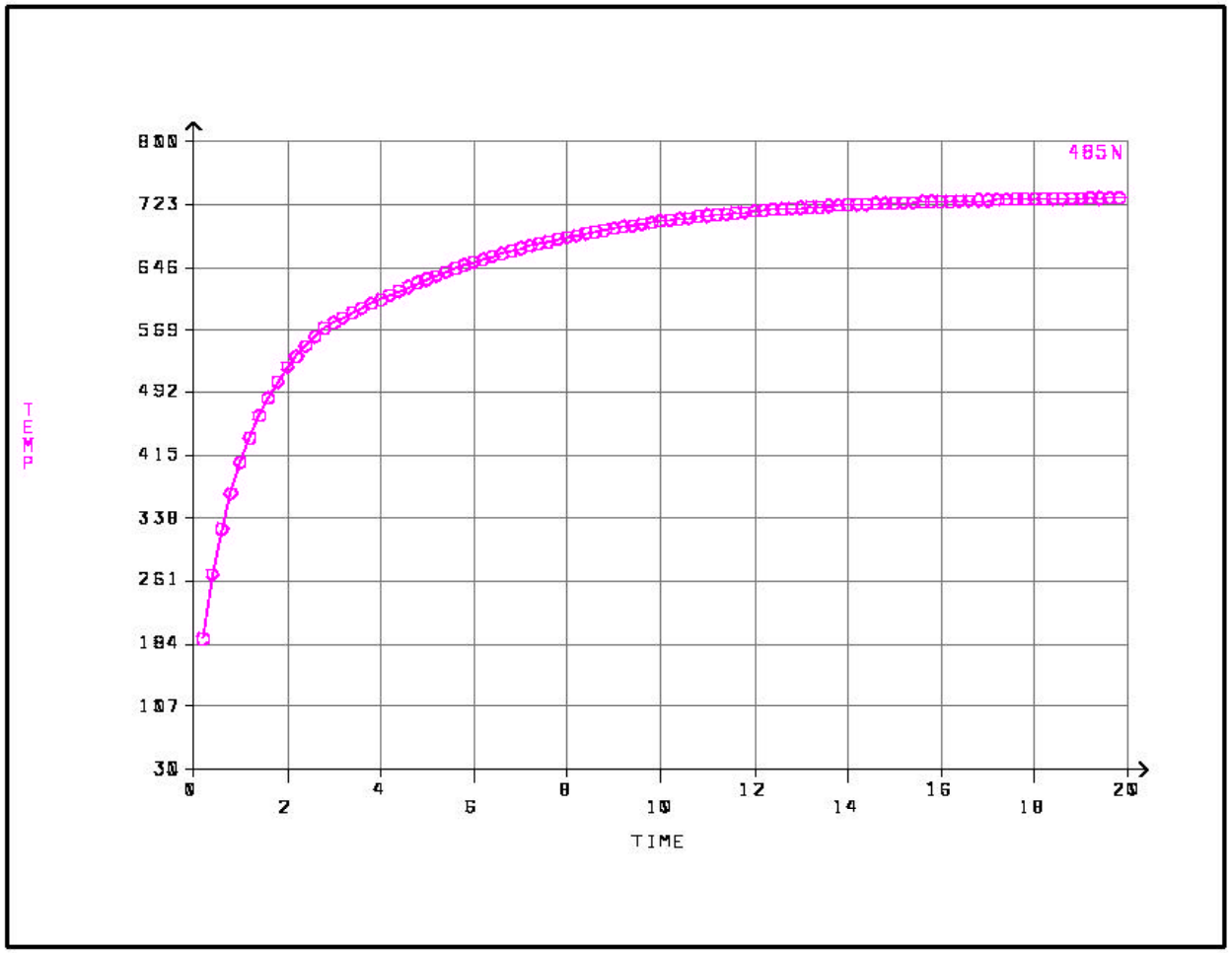
Time Variation of the Baffle Temperature



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Summary

- **The PSI Conference has provided additional support for the choices made in the FIRE divertor design**
- **Significant progress has been made on the modeling of FIRE edge plasma conditions, erosion, and disruption effects**
- **Thermal analysis of the baffle is nearly complete**
- **Disruption force analysis is in progress**