Idaho National Engineering and Environmental Laboratory

CFC-Air Chemical Reactivity for IFE Safety Analysis

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Fusion Safety Program
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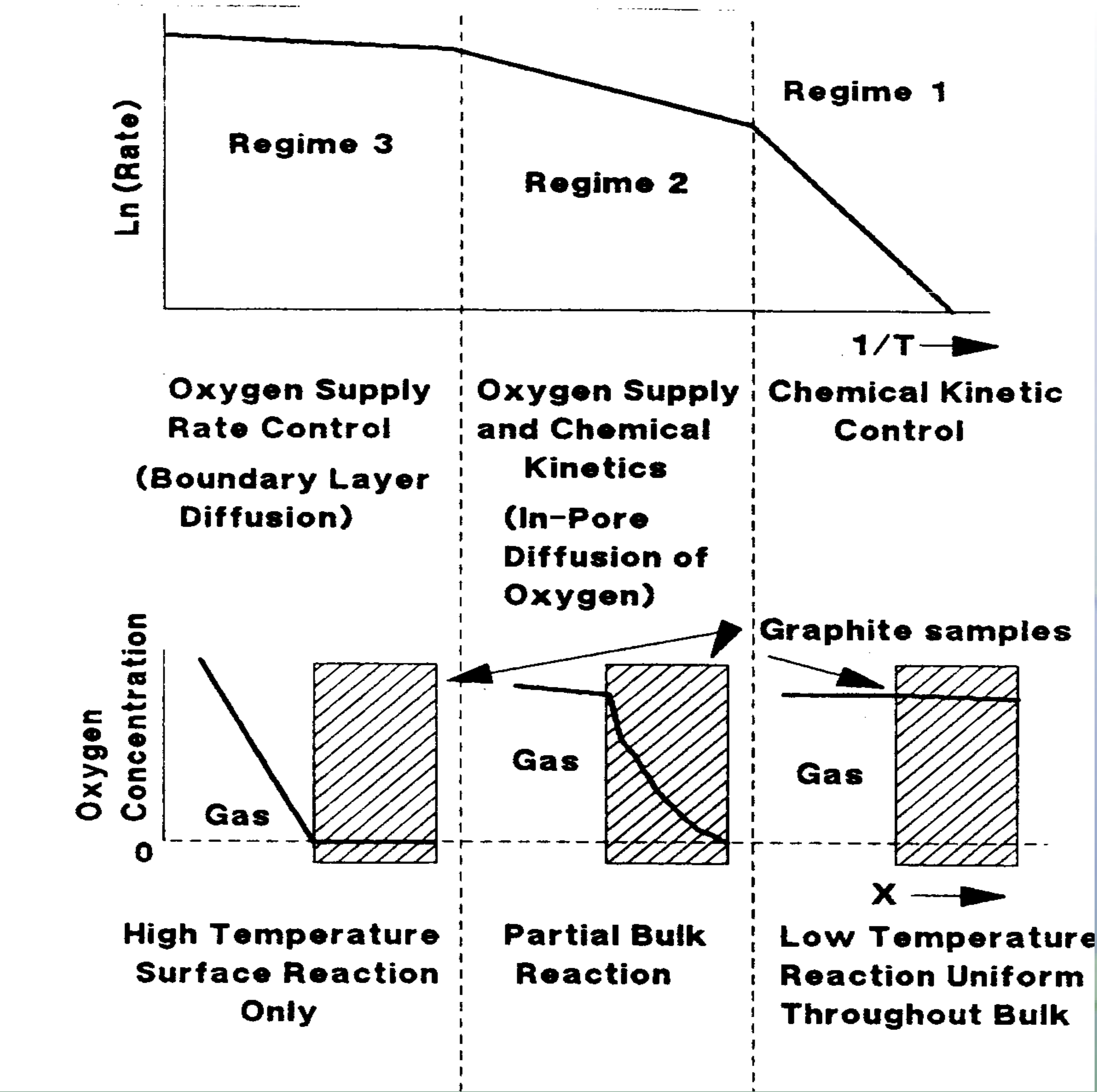
Graphite oxidation is temperature-dependent

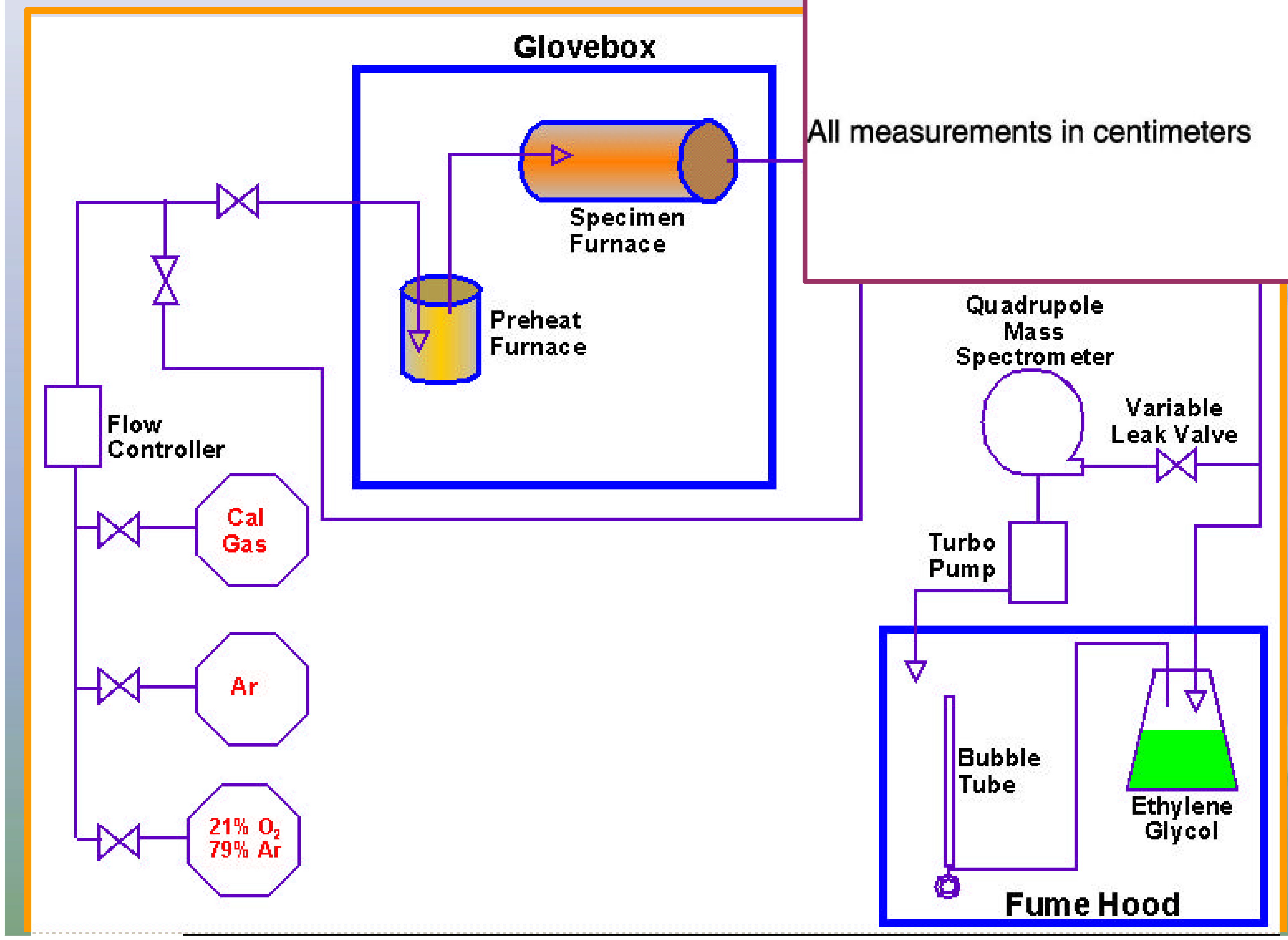


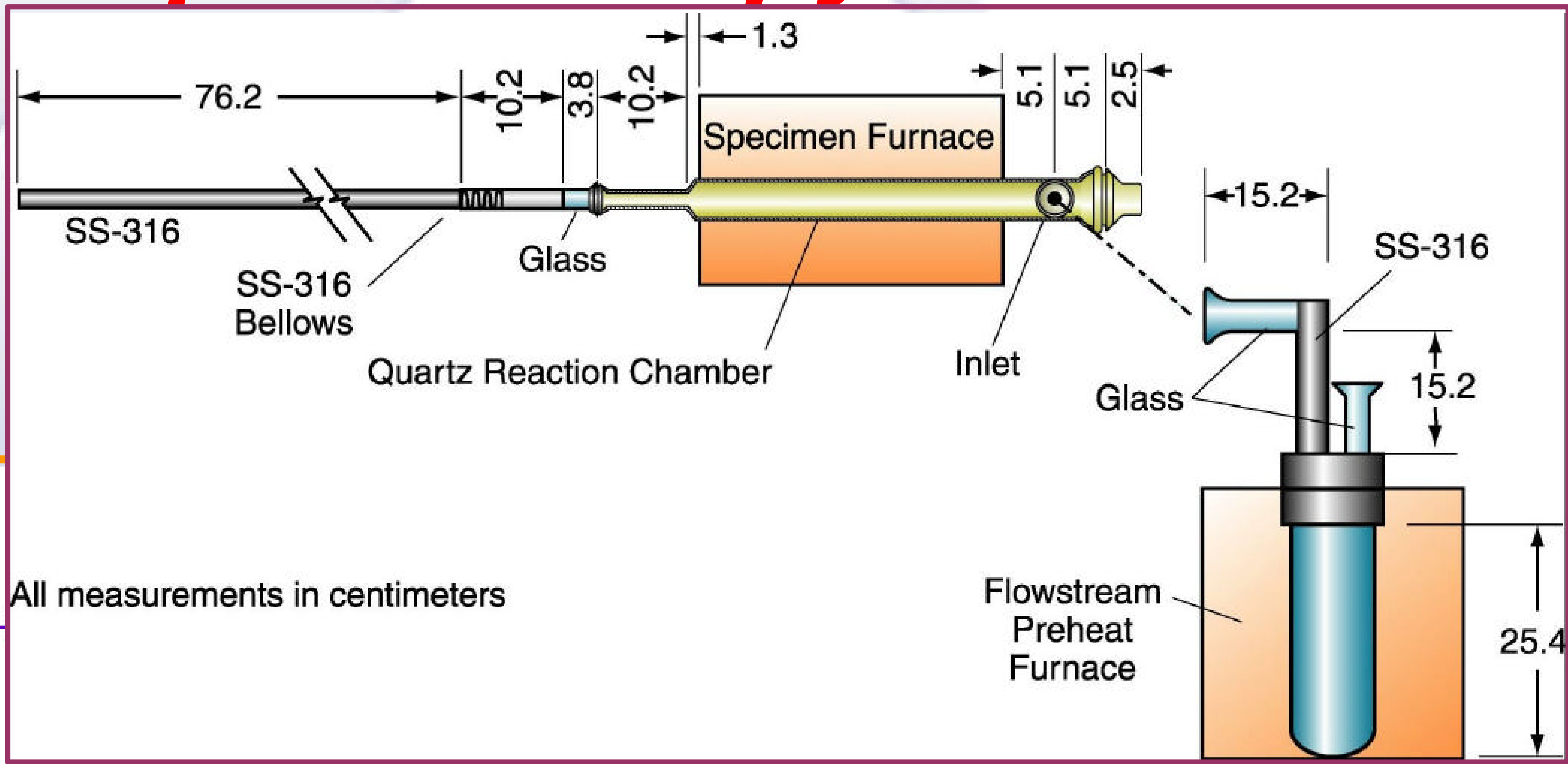
- *Low T ==> chemical kinetic control (flow rate independent)*
- *Moderate T ==> in-pore diffusion of oxygen (flow rate independent)*
- *High T ==> boundary layer diffusion and potential oxygen starvation (flow rate dependent)*

CFC-air reactivity tests were performed to improve fusion safety models

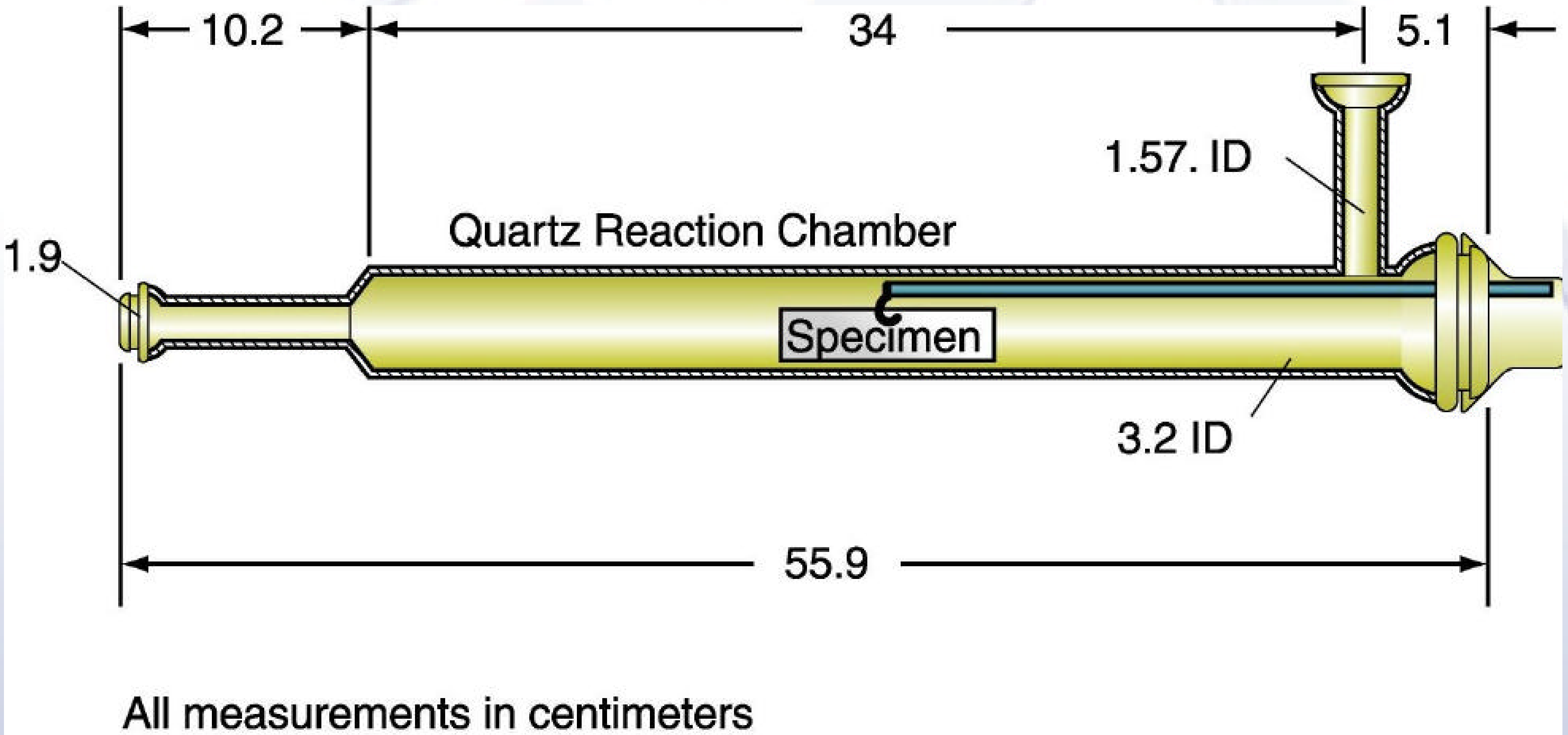
- *Safety model used for SOMBERO analysis includes reactivity data from 1988 INEEL experiments:*
  - *reactivity data primarily in boundary layer diffusion regime*
  - *15,000 sccm flow rate with older bulk graphite (Poco)*
  - *800 - 1800 ºC temperature range*
- *2002 CFC-air reactivity experiment was designed to:*
  - *generate data in Regimes I and II of kinetic transport*
  - *utilize a modern 3D CFC (NB31)*
  - *utilize a state-of-the art experiment (QMS, BET, Dm_C)*
  - *525 - 1000 ºC temperature range*

Reactivity experiment provides weight loss and mass spectroscopy data



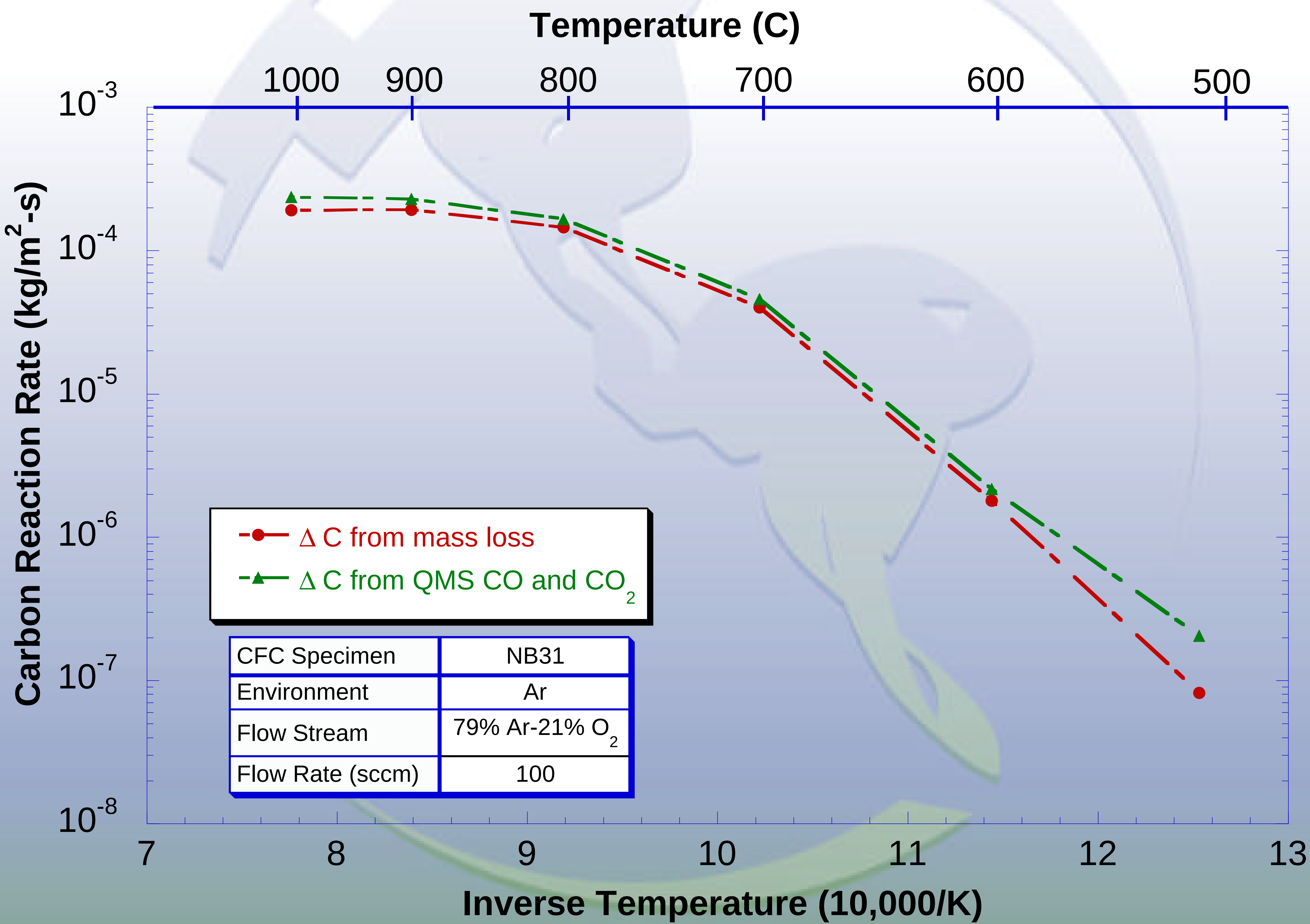


Test Parameters for 3D CFC NB31



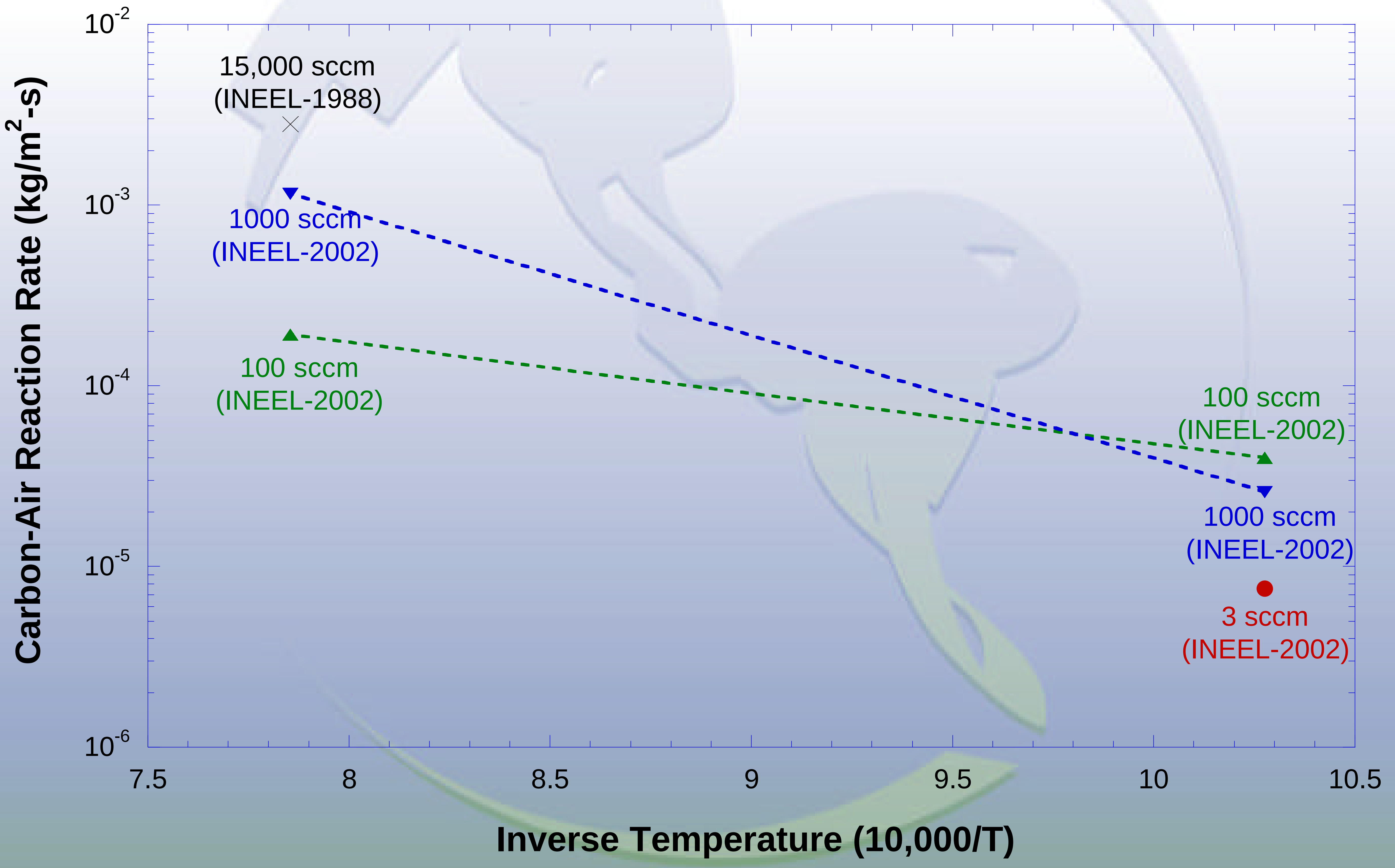
Test Specimen	CRC Type	NB-31
	Specimens	10
	Weight (avg)	1.6114 g
	Geometric Surface Area (avg)	6.78 cm^2
Experiment	Temperature	525 - 1000 °C
	Flow Rate	3, 100, 1000 sccm
	Flow Mixture	79%Ar-21%O_2

Weight Loss and QMS Yield Similar R_{ox}



CFC Specimen	NB31
Environment	Ar
Flow Stream	79% Ar-21% O_2
Flow Rate (sccm)	100

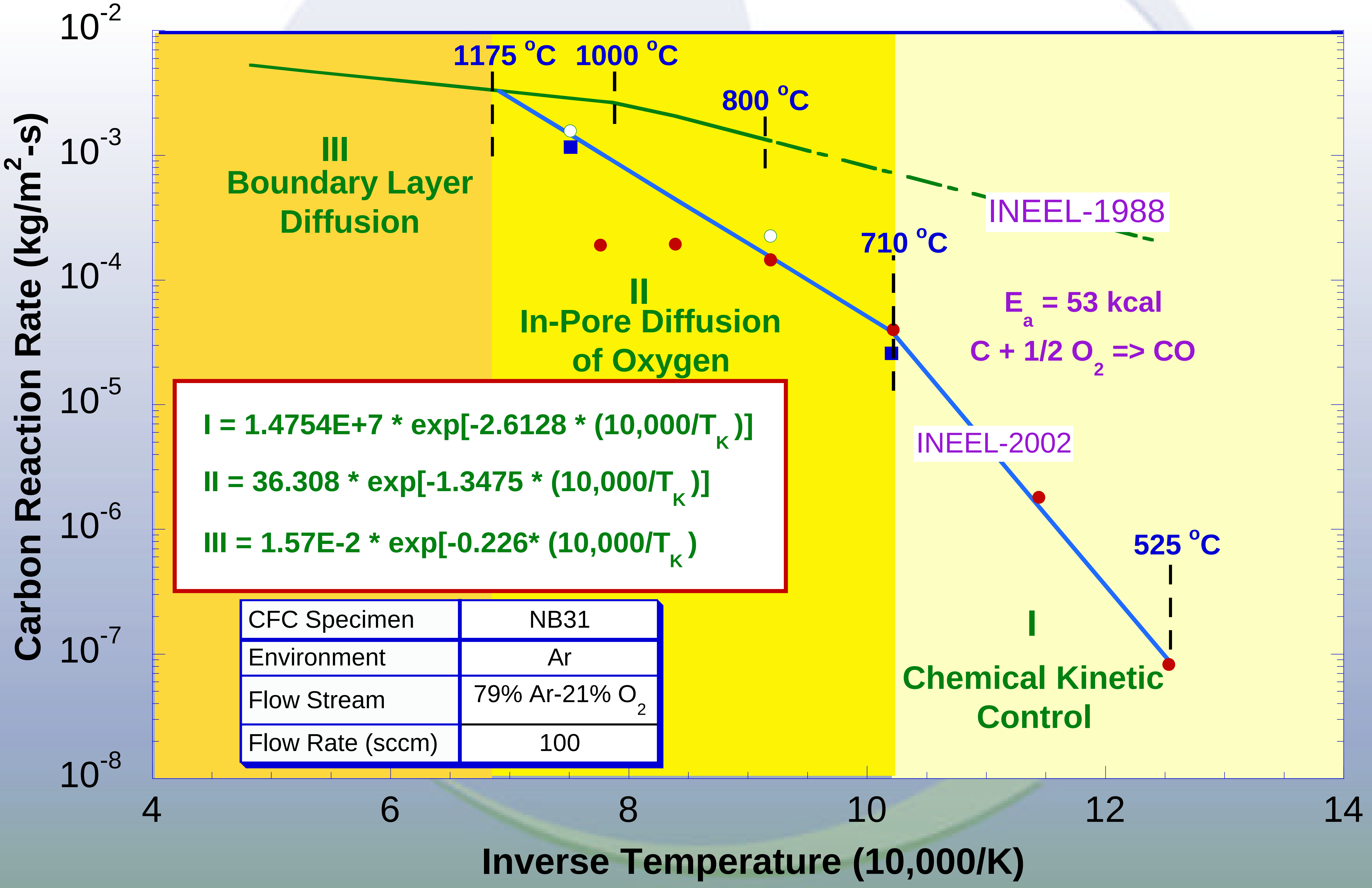
O_2 Flow Rate Influences R_{ox} in Regime III



Observations from INEEL data

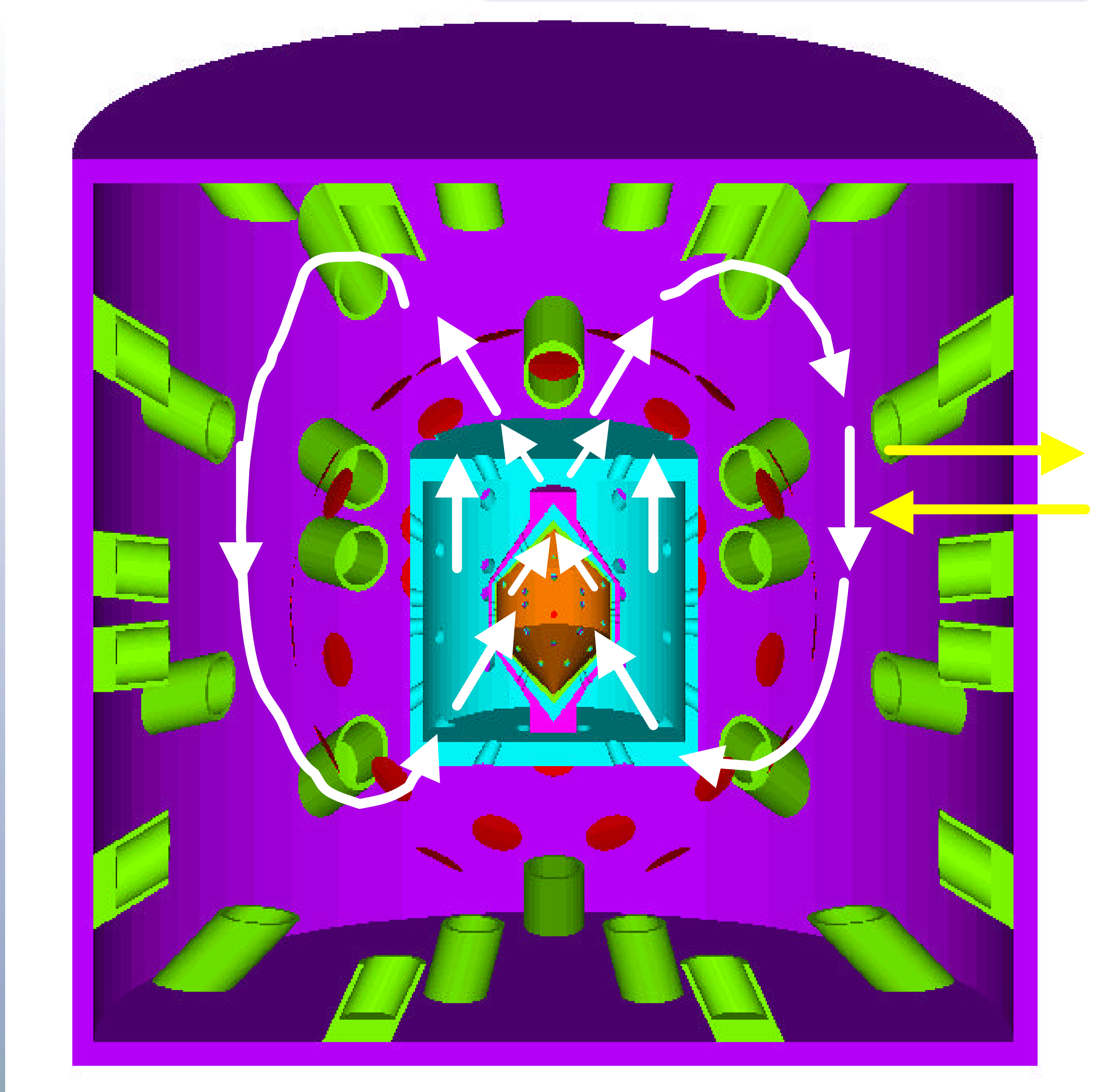
- *INEEL-1988 data are for dry air and bulk graphite, INEEL-2002 are for 79% Ar- 21% O_2 mixture and 3D NB31 CFC.*
- *The INEEL-1988 data fit:*
  - *predicts a different transition temperature for the different types of graphite. between Regimes II and III (1000 ^oC bulk graphite vs 1175 ^oC CFC),*
  - *extrapolation over-predicts R_{ox} in Regime I ($T < 700$ ^oC)*
- *INEEL-2002 reactivity tests revealed:*
  - *oxygen starvation at 1000 ^oC observed due to the low flow rate,*
  - *significant CO_2 production at both low and high specimen temperatures,*
  - *activation energy of 53 kcal in the chemical kinetic control regime implies that $C + 1/2\ O_2 = CO$ (50 - 58 kcal) is the primary reaction at the specimen surface and agrees with the literature,*
  - *hypothesis that CO_2 is produced in the Ar-O_2 mixture downstream of the specimen.*
- *Updated correlation used in MELCOR uses new data in Regimes I and II and older data in Regime III for accurate safety analysis.*

Fit of INEEL-2002 CFC-Air R_{ox} data and comparison with INEEL-1988 R_{ox} data.



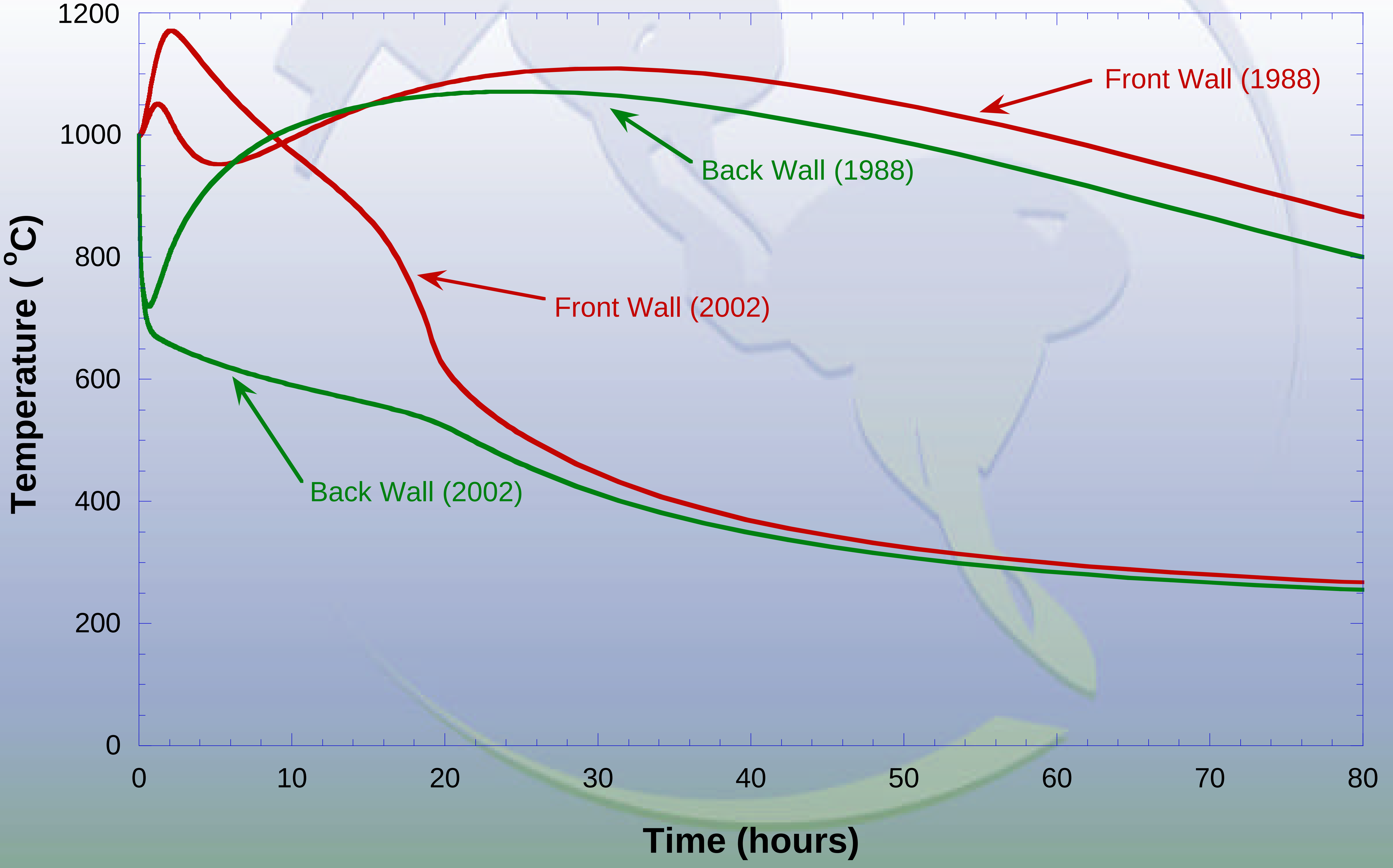
CFC Specimen	NB31
Environment	Ar
Flow Stream	79% Ar-21% O_2
Flow Rate (sccm)	100

Important phenomena in loss of vacuum/air ingress with loss of heat sink



- Air enters vacuum chamber through break (~ 3 hrs to reach 1 atm)
- With only one boundary to breach, the accident begins
- Blanket starts to cool down
- Graphite oxidation begins to produce CO/CO_2. Blanket heats up
- Vessel breathes (based on Japanese LOVA experiments) --> natural convection flow pattern is established --> CO/CO_2 flows out and more air flows in

Sombrero LOVA analysis using INEEL-2002 and INEEL-1988 CFC-Air R_{ox} data.



Observations from analysis using updated correlation

- *Sombrero LOVA analysis revealed:*
  - *lower R_{ox} on the "back wall" allows more oxygen to be transported to the front wall, which increases the partial pressure of O_2 in the target chamber and hence the oxidation at the "front wall",*
  - *higher peak temperature using INEEL-2002 R_{ox},*
  - *R_{ox} from INEEL-1988 and INEEL-2002 produce a peak temperature above 800 ^oC, thus tritium retention is still a concern, most of the graphite oxidation occurs in Regime II - in-pore diffusion, which is strongly dependent upon the type of graphite used in the blanket.*
  - *final decision on the impact of these differences depends on tritium inventory, its mobilization as a function of temperature and the LOVA probability.*

Summary

- *Performed CFC-air reactivity experiments for flow rates of 100 and 1000 sccm and temperatures between 525 - 1000 ^{o}C, significantly augmenting the database.*
- *High confidence in the generated CFC-O_2 reaction rates:*
  - *equivalent R_{ox} calculated using two different methods.*
  - *E_a of 53 kcal in the chemical kinetic control regime for the 100 sccm experiment agrees very well with literature by Walker[1].*
- *New MELCOR calculations show different blanket response during a LOVA and strongly depend on the type of graphite expected in SOMBRERO.*
- *INEEL report expected in April 2002.*

[1]P.L. Walker et al., Advances in Catalysis, Academic Press Inc., 1959, pg 157.