1. Purpose of Experiments

1. Test parametric dependence of density limit [1]
2. Look for changes in transport and turbulence as limit is approached.
2a. Investigate connection to observation of the dependence of edge particle transport on collisionality (LaBombard [2])
3. Compare with computational work on density limit by Rogers and Drake [3]
4. Look for a change in high density confinement degradation for $P > P_{\text{THRESHOLD}}$.

2. Background

Earlier work[1] has suggested that the tokamak density limit can be explained fully only by consideration of transport effects. While there is little dispute about the final stages of a density limit collapse - edge cooling via radiation then shrinkage of the current channel leading to MHD instability and disruption - theories based on edge power balance physics alone can not explain important aspects of density limit phenomenology. In particular, the power balance theories predict a density limit with strong dependence on input power and on impurity content. Neither of these dependences are generally observed. These classes of theories also have difficulty explaining the robustness of the density limit with respect to plasma configuration, divertor topology, or operational regime. Finally there is data from Alcator C, TEXT, and MTX (nee Alcator C) which show degradation of particle confinement or enhanced fluctuations in the vicinity of the limit.

The work by Drake and Rogers suggest a specific turbulence mechanism for this phenomenon. The simulations show a boundary, above which fluctuations increase dramatically from nominal “L” mode levels. This boundary has somewhat complex parametric
dependence but has much in common with the empirical limit derived in reference [1]. The edge pressure gradient is an important parameterization for the computationally derived boundary - thus we propose a power scan as part of this mp. We note in passing, the rough agreement with the L/H threshold of simulations carried out with the same code [4].

Recent studies by LaBombard [2] have suggested that the edge diffusivity increases strongly with local collisionality. Since the edge temperature is roughly fixed by parallel transport, this correlation is consistent with an increase in transport as the density is increased.

A number of machines have reported a degradation in H-mode confinement as the density limit is approached. This effect apparently sets in at lower densities for \( P \sim P_{\text{THRESHOLD}} \). So far, C-Mod H-modes have been in this regime. With additional RF power we should be able to access the regime with \( P >> P_{\text{THRESHOLD}} \).

3. Approach
Describe the methodology to be employed; explain the rationale for the choice of parameters, etc. Describe the analysis techniques to be employed in interpreting the data, if applicable. If the approach is standard or otherwise self-evident, this section may be absorbed into the Experimental Plan.

The measurements required to test the Rogers and Drake theory are edge parameters; temperature and density gradients, taken just before a density limit disruption. Dedicated time is required since we reach the density limit in flattop plasmas only rarely, usually during poloidal detachment events (shark-fins). On the other hand, density limit disruptions are not uncommon during current ramp-down.

Pedestal and fluctuation diagnostics, particularly those viewing the edge should be operated to look for changes as the limit is approached. Operation of the scanning probe would allow corresponding measurements in the SOL and far edge. In combination with the Ly\(_\alpha\) array, local diffusion coefficients can be computed.

The proposal follows the approach of 980115 where density limit disruptions were studied at high \( n_e/I_P \) during current rampdown. The B\(_T\) flattop should be extended through the current rampdown phase, which will keep the ECE channels viewing the edge. The edge Thomson system and other pedestal diagnostics are essential for this run since the edge pressure gradient is thought to be an important parameter.

4. Resources

4.1 Machine and Plasma Parameters
Give values or range for:

**Toroidal Field:** 4.5 - 6.2 T
**Plasma Current:** 0.85 - 1.2 MA
**Working gas species:** D\(_2\)**
Density:

Equilibrium configuration (if possible, refer to database equilibria): SNB

Pulse length, typical current & density waveforms, etc. Refer to database or sketch desired waveforms.

4.2 Auxiliary Systems

RF Power, pulse length, phasing: 0 - Maximum (>5 MW)

Pellet Injection (species):

Impurity blow-off injection: yes, why not?

Special gas puffing:

Other:

4.3 Diagnostics

List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

All standard core diagnostics.

All pedestal and edge fluctuation diagnostics.

Fluctuation diagnostics should be set up with window during H/L transition and near L-mode disruption if possible.

4.4 Neutron Budget

Estimate the neutron dose rate at the site boundary. Give basis for estimate. (Once some experience has been gained a standard formula will be provided for estimating dose rates.)

nominal

5. Experimental Plan

5.1 Run sequence plan

Specify total number of runs required, and any special requirements, such as consecutive days, no Monday runs, extended run period (10 hours maximum), etc.

1 run, relatively high power RF should be available.

5.2 Shot sequence plan

For each run day, give detailed specification for proposed shot sequence: number of shots at each condition, specific parameters and auxiliary systems requirements, etc. Include contingency plans, if appropriate.

As before, the approach will be to produce high density H-modes then to ramp down the plasma current to approach the density limit. The $B_T$ programming should be altered to allow edge profile measurements until the time of the disruptions. 980115021 would be a good starting point. Setting up this scenario for the standard conditions might take about 5 shots.
Two basic scans are proposed.

1. B\textsubscript{T} scan to get the maximum $\beta$ variation consistent with good heating. The target should be $B_T = 4.5$, 5.3, and 6.2 T. If this fails to show good heating, the field should be adjusted to move the ICRF resonance closer to the magnetic axis. The starting $I_P$ should be adjusted to give constant $q_{95}$, that is $\sim 0.85$, 1.0, 1.2 MA. Power would be minimal at the higher field (consistent with operation in H-mode) and maximum at the lower field. The scanning probe will be operated on at least one shot per condition. 8-10 shots.

2. A power scan to examine regime where $P >> P_{\text{THRESHOLD}}$. To get the lowest threshold power (and to provide additional high $\beta$ information) this should be performed at reduced $B_T$. Perhaps $B_T \sim 4.8$ or lower. 8-10 shots.

6. Anticipated Results

Discuss possible experimental outcomes and implications. Indicate if the program may be expected to lead to publications, milestone completions, improved operating techniques, etc. Indicate if the experiments are intended to contribute to a joint research effort, or an external database.

This work should provide data to test theories for the density limit, in particular those of Rogers and Drake. We will also be looking for the degradation of H-mode confinement at high density and it’s dependence on $P_{\text{THRESHOLD}}$.

7. References

Include references both to external and internal literature or communications which bear on this proposal. See Section 2.


[2] LaBombard, 1999 APS
