1. Purpose of Experiments

Include immediate goal of the experiments, scientific importance and/or programatic relevance. Refer to any relevant program milestones or ITER/TPX R&D commitments.

Inject metallic pellets into a VDE to terminate the plasma much more quickly than normal.

2. Background

Discuss Physics basis of the proposed research, Prior results at Alcator or elsewhere, and any related work being carried out separately.

At a recent ITER workshop on disruptions, the problem of damage to the divertor and first wall was discussed. ITER has proposed that one possible way to make the engineering issues tractable might be to ‘kill’ an unrecoverable VDE so quickly that it doesn’t have time to drift far off the midplane. There are several possible beneficial effects: (1) the plasma thermal energy would be dissipated by radiation, which is distributed uniformly over the entire first wall, (2) halo currents in the divertor would be eliminated (at the expense of the inboard midplane, where the forces can be more easily handled), and (3) the generation of post-thermal-quench runaways, which is another thing that ITER is very concerned about, would be greatly reduced, since the period in which the runaway population builds up would be much shorter. The weapon of choice would be frozen krypton pellets, but it is not known whether this killer pellet idea would actually work. ITER would like to see experimental results of this from current machines.

JET has run a series of ‘pellet shutdown’ experiments using large polyethylene pellets ($\Delta n_e/n_e = 20$) which cool the plasma from 3.5 keV to 300 eV, initiating a disruption within 2 ms. They find that the current quenches faster than normal, so that the current is gone by the time the plasma is only 50 cm down, rather than 100 cm. They report that this reduces forces on both the divertor and vessel considerably. They have no halo current data on these shots.

JT-60U already has the capability to inject frozen neon pellets, although they did not mention any attempts to kill disruptions with them yet. They are also thinking about making frozen krypton pellets, for just such a purpose.
Alcator C-Mod is unique in that we have good halo current diagnostics, including a measurement of poloidal current on the inboard midplane, and we have the capability of injecting lithium pellets doped with high Z metals such as copper, molybdenum, tungsten, gold, etc. After looking through our disruption database, I have found at least one example where we *may* have inadvertently caused a very fast quench, possibly with a piece of a molybdenum tile. Figures 1 and 2 show a typical thermal quench disruption, illustrating the 5 ms timescale of the current quench, during which time the plasma moves all the way down to the divertor plates. Figures 3 and 4 show that shot 941123012 had an extremely fast current quench in comparison, and in fact, the plasma did not have time to move far off the midplane. The evidence for this being due to a molybdenum injection is rather scant, and is from the large increase in soft x-ray emission about a millisecond before the disruption (figure 5).

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.

Start with a typical diverted 0.8 MA plasma. VDE’s can be initiated at a fixed, repeatable time by turning off the ZCUR PID gains at some point during the flattop. After a few shots, it will be possible to determine the vertical motion of the plasma as a function of time and measure quench times, halo currents, etc, and to see how repeatable these are. Then enable the LPI, and set its trigger so that the pellet will hit the plasma after it has moved a given distance down ... 5 cm seems reasonable. The pellets can be easily doped with small chips of metal. For this run, we will use 50-100 µg of gold, which should give about 50 MW of radiation, effectively getting rid of all the thermal energy in ≤ 1 ms. (For spectroscopic diagnostic purposes, it would be desirable to use something that doesn’t occur naturally in the plasma). Two different lithium pellet sizes should be available. Measurements to be made include pellet speed, penetration distance, Δn_e/n_e, T_e, P_rad, as well as the disruption characteristics already mentioned. Filament reconstructions will show how far the plasma moves, and particular attention should be paid to the vertical array of Rogowski segments on the inboard wall.

As always, monitor total halo currents to ensure that we stay within the administrative limits, and have a backup MP planned in case we strike out.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

Toroidal Field: 5.3 T
Plasma Current: 0.8 MA
Working gas species: D₂
Density: \( n_l^0 4 = 1.0 \times 10^{20} \text{ m}^{-2} \)

Equilibrium configuration (if possible, refer to database equilibria): a recent non-disruptive 0.8 MA diverted plasma. The plasma should be positioned 2 cm below the midplane, in order by ensure that most disruptions go downward.

Pulse length, typical current & density waveforms, etc. pulse length\( \geq 1.5 \text{ s} \), flattop\( \geq 0.5 \text{ s} \).

4.2 Auxiliary Systems

RF Power, pulse length, phasing: None

Pellet Injection (species): Lithium, doped with Au

Impurity blow-off injection: None

Special gas puffing: None

Other:

4.3 Diagnostics

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

magnetics, halo diagnostics, spectroscopic diagnostics for looking at the injected impurity, pellet tracking diagnostics, ECE, interferometer. If possible, set up for fast digitisation at the disruption time.

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.)

NA

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.

About 15 plasma shots

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.

Establish the baseline shot, a non-disrupting 0.8 MA diverted plasma (3 shots)

Turn off ZCUR PID gains at 0.8 s (3 downward-going shots, 3 fizzes)

This will probably take a while, since fizzes are likely, and
perhaps one of the disruptions will go upward.
Repeat, with the LPI firing the smaller doped pellets.
(3 downward-going shots, 3 fizzes, and
perhaps additional shots to account for LPI failures, upward-going
VDE’s, etc.)
Repeat with the LPI firing the larger doped pellets.
Repair machine as necessary.

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.

   We will have contributed uniquely to one of the ITER EDA’s most difficult issues.

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