

Progress in Inertial Fusion Energy Technology: June - September 2001

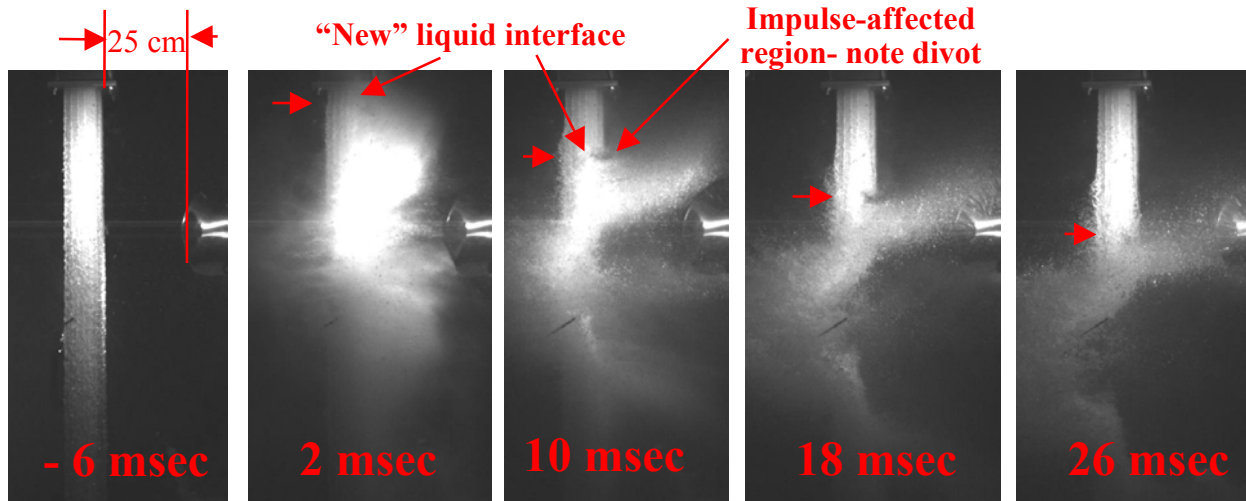
Compiled by J. F. Latkowski
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Progress in IFE Technology: June - September 2001 (Cont'd.)

Thick-Liquid Protection — University of California, Berkeley

P. F. Peterson, S. Pemberton (student), C. Debonnel (student), G. Fukuda (student), D. Olander

- UCB has successfully created and disrupted jet arrays composed of 95 separate jets, recording the results using high-speed video for a stationary nozzle. Observed shock propagation into the jet array is consistent with theoretical predictions. Current efforts are working with the jets array in oscillating mode. Here the major issue is flow conditioning to achieve equal velocity to each jet to permit synchronous oscillation.



**95-jet nozzle
assembly in operation**



**Vortex injection
nozzle**

- UCB completed design, fabrication, and initial testing of a vortex-injection nozzle (pictured at left) that allows the generation of smooth vortices by the tangential injection of liquid through large numbers of small holes in the pipe wall. Initial tests show the formation of the required vortex geometry.
- A new ternary salt mixture was identified, which adds NaF to the LiF and BeF₂ that have been studied previously. The new salt, called “flinabe,” has a substantially lower melting temperature (~320°C) compared to flibe (460°C). Used at lower temperatures, flinabe has an extremely low vapor pressure that can enhance performance in HIF beam lines and in MFE liquid-protection.

Publications and Presentations:

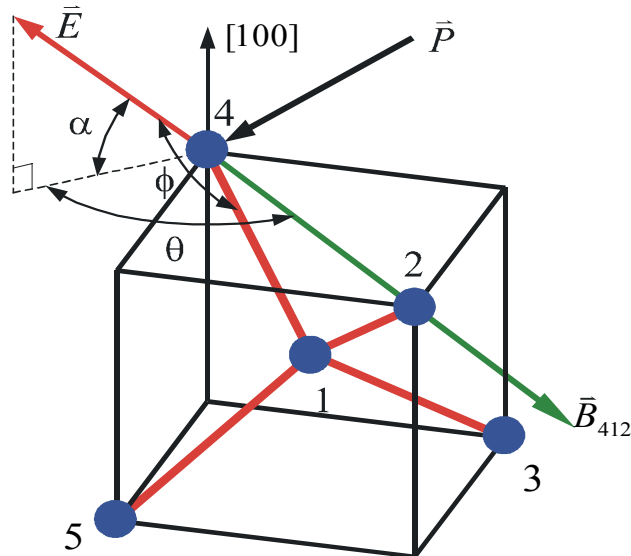
P. Peterson, “Liquid Jet Work at UCB,” Presented at the Heavy Ion IFE Meeting, Livermore, CA (July 2001).

Progress in IFE Technology: June - September 2001 (Cont'd.)

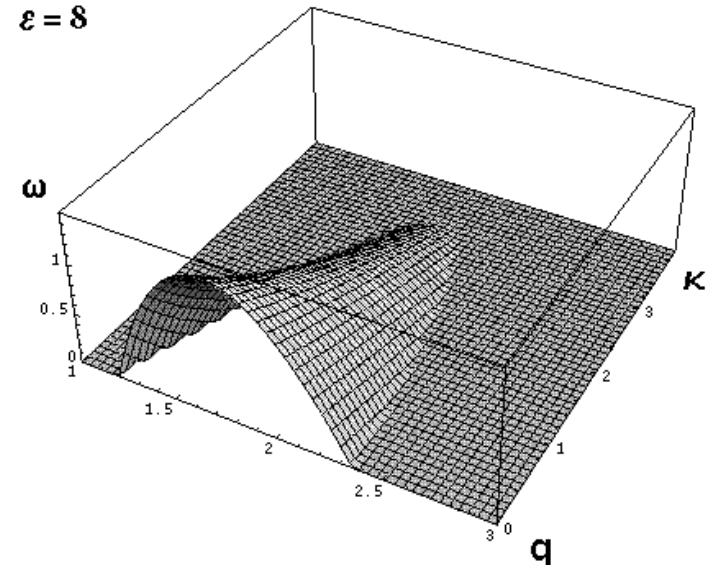
Laser Damage to Optics — University of California, Los Angeles

N.M. Ghoniem, Z. Wang and Q. Hu (see: http://puma.seas.ucla.edu/web_pages/)

- National plan for development of laser IFE materials has been nearly completed.
- Laser-Induced Damage Threshold (LIDT):
 - Re-worked some aspects of the manuscript on laser-induced damage to covalently bonded materials, submitted to Phys Rev: D. Walgraef and N.M. Ghoniem, "The Effects of Crystal Anisotropy and Adherence Forces on Laser Induced Deformation Patterns in Thin Films," submitted to *Phys. Rev.*
 - Completed a report that contains all experimental data and proposed theories for Laser-induced damage threshold.
 - Participated with Tillack and Payne in a paper that was presented at the IFSA conference in Japan, September 2001.



Interaction forces between the laser electric field and covalent bonds in SiC



Growth rate of unstable surface deformation modes of thin films as a function of the wavelength, q, and the adhesion force constant K.

Publications and Presentations:

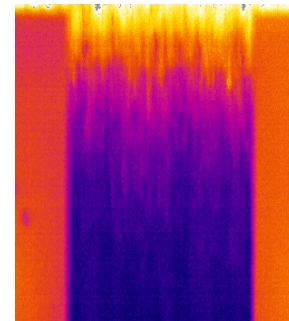
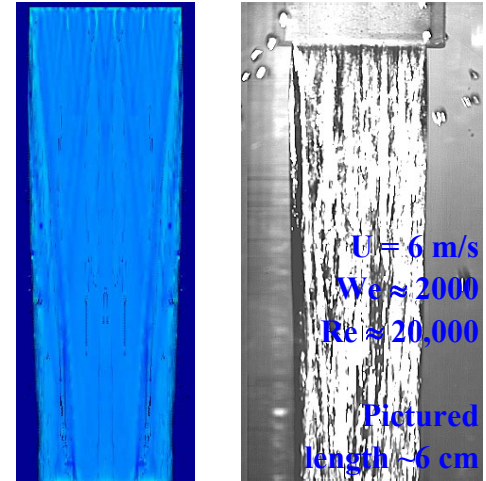
- (1) Q. Hu and N.M. Ghoniem, "Laser-Induced Damage to Reflective Mirrors: A Critical Review of Experimental Data and Theoretical Models," UCLA Report, September 2001.
- (2) M. S. Tillack, S. A. Payne and N. M. Ghoniem, "Damage threats and response of final optics for laser-fusion power plants," Proceedings of Second International Conference on Inertial Fusion Sciences and Applications, IFSA 2001, Kyoto, Japan, September 9-14, 2001.

Progress in IFE Technology: June - September 2001 (Cont'd.)

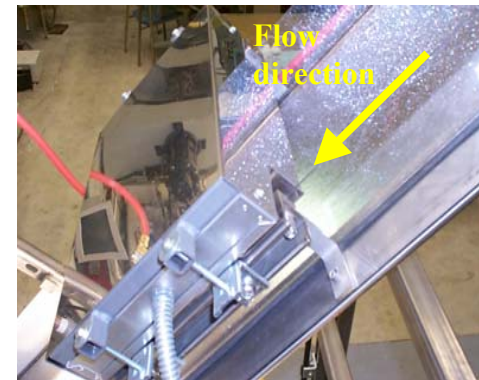
Thick-Liquid Protection — University of California, Los Angeles

P. Calderoni (student), B. Freeze (student), A. Konkachabaev (student), M. Abdou, N.B. Morley, T. Sketchley, S. Smolentsev, A.Y. Ying

- Worked with GA to improve safety and functionality of the vapor condensation facility:
 - Crowbar diode is now being connected in parallel with the capacitor bank to prevent voltage reversal, and a tri-plate transmission line is currently being constructed and installed to give minimum inductance to the circuit.
 - GA has agreed to loan UCLA a spectrometer (SPEX 1702 0.75m), a sans detector head, and sans electronics, which will be instrumented with CCD line scan sensors (to be purchased by UCLA) for evaluation of the initial ionized gas pressure conditions.
- Work is continuing in Large Eddy Simulation type modeling for predicting and correlating ripple measurements on turbulent liquid jets:
 - By controlling inlet boundary conditions in space and time, we are attempting to model the effects of initial turbulence distributions, nozzle velocity profiles and surface roughness to help better understand the mechanisms leading to downstream jet rippling in center regions of the jet.
 - The picture to the right shows the combined effect of surface tension distorting the near-corner regions and leading to large corner waves, and a 5% RMS turbulence seed in the bulk flow leading to small streak-like surface waves in the central region of the jet. Calculations closely match experimental data (shown far right)
 - Better turbulence seeds and numerical procedures are being developed in order to increase the accuracy of these calculations and their usefulness for IFE chamber development.
- New work studying heat transfer at the free surface of a fast turbulent film flow has begun:
 - This problem is relevant to both MFE and IFE and is being carried out with assistance from Sandia National Laboratory.
 - Data on surface cooling, flow height and waviness as a function of velocity and inclination is currently being acquired and correlated with numerical predictions using k-ε turbulence model.



IR image of water surface emerging from IR heater section showing "streaky" temperature structures.



Water film flowing under IR heater in UCLA FLIHY Experiment.

Publications and Presentations:

N. Morley, "Liquid Jet and Vortex Modeling and Experiments," and P. Calderoni, "Vapor Dynamics and Condensation Study for IFE Liquid Chambers," Presented at the Heavy Ion IFE Meeting, Livermore, CA (July 2001).

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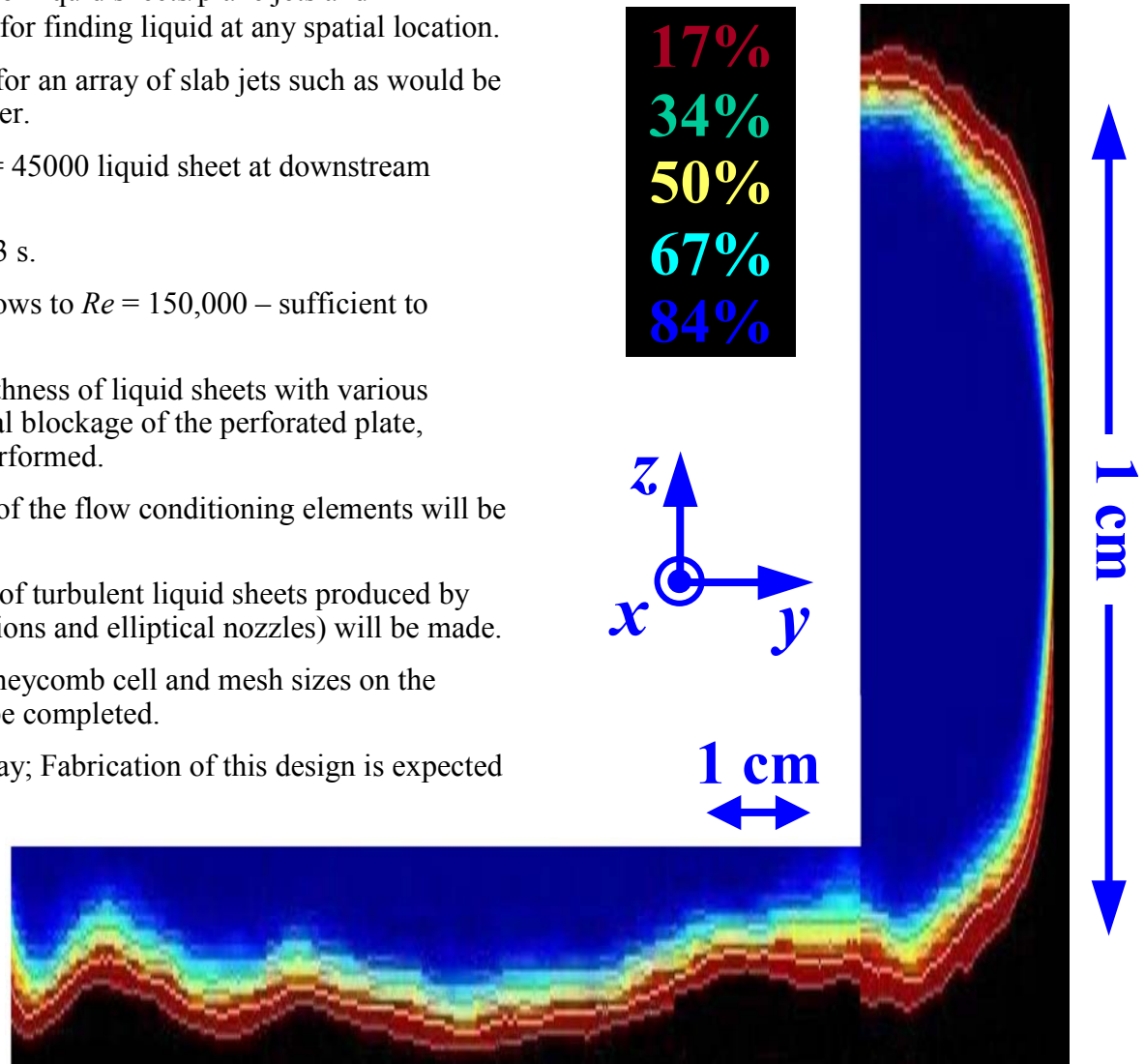
Thick-Liquid Protection — Georgia Institute of Technology

S.G. Durbin (student), J.R. Reperant (student), M. Yoda, S.I. Abdel-Khalik

- Experimentally measured surface roughness of liquid sheets/plane jets and determined the probability distribution (PD) for finding liquid at any spatial location.
- The PD will be used to optimize jet spacing for an array of slab jets such as would be used in a thick-liquid protected target chamber.
- Plot shows probability distribution for a $Re = 45000$ liquid sheet at downstream distance of $x/\delta = 25$.
- Data span 4 sets of 100 images, each over 3.3 s.
- Work is underway to increase liquid sheet flows to $Re = 150,000$ – sufficient to simulate HYLIFE-II flows:
 - Direct comparisons of the surface smoothness of liquid sheets with various blockages of the settling chamber (partial blockage of the perforated plate, honeycomb and mesh screen) will be performed.
 - Robustness and long-term performance of the flow conditioning elements will be investigated.
 - Comparisons of the surface smoothness of turbulent liquid sheets produced by different nozzles (including 3D contractions and elliptical nozzles) will be made.
 - Evaluation of the impact of different honeycomb cell and mesh sizes on the surface smoothness of these flows will be completed.
- Design of a 3D contraction nozzle is underway; Fabrication of this design is expected to begin by the end of October.

Publications and Presentations:

M. Yoda, “Surface Ripple in Turbulent Liquid Sheets,” Presented at the Heavy Ion IFE Meeting, Livermore, CA (July 2001).

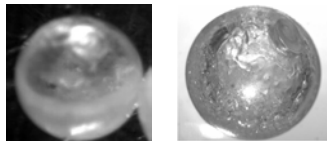


Progress in IFE Technology: June - September 2001 (Cont'd.)

Target Fabrication, Injection, and Tracking — GA, LANL, UCSD

D. Goodin, A. Nobile, R. Petzoldt, N. Alexander, A. Nikroo, L. Brown, G. Besenbruch, S. Willms, A. Schwendt, M. Tillack, J. Pulsifer

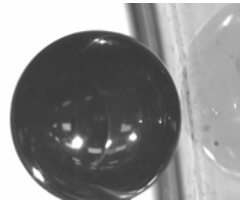
- Completed preliminary design review for the Target Injection and Tracking Experimental System.
- Verified gold coatings on shells have ~10% non-uniformity and with 300 Å layer increases fill time by ~10X.
- Coated flat surfaces and shells with 300-1200 Å of palladium. Measured optical properties of Pd and related them to reactor conditions (normal incidence integrated reflectivity of a 300 Å layer on GDP was 76% for a chamber wall temperature of 1480 C, 79% at 1000 C, and 82% at 627 C).
- Measured hydrogen permeability through Pd coated shell (unchanged from uncoated shell).
- Performed H₂ exposure experiments - palladium on flat silicon degraded substantially, but was unaffected on PAMS shell.
- Prepared molds and demonstrated initial injection molding of foam hemi-shells.
- Demonstrated target layering in a fluidized bed with a room temperature surrogate in place of hydrogen.
- Developed a multistage model to predict the performance of an electromagnetic injector (backup to the gas gun).
- Developed a “scalloped insulator” method to passively control temperatures for in-hohlraum tube layering.



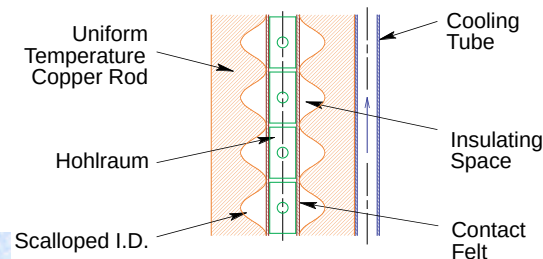
Before

After

**Proof of principle
demonstrated for fluidized
bed layering with surrogate**



**600 Å Pd coated shells
fabricated & evaluated**



In-hohlraum layering



Injection molding

Publications and Presentations:

D.T. Goodin, C.R. Gibson, R.W. Petzoldt, N.P. Siegel, L. Thompson, A. Nobile, G.E. Besenbruch, and K.R. Schultz: “Developing the Basis for Target Injection and Tracking in Inertial Fusion Energy Power Plants”, Accepted for publication in Fusion Engineering and Design

Target presentations at 2nd International Conference on Inertial Fusion Sciences and Applications, Kyoto, Japan, Sep. 9-14, 2001.

(1) D. T. Goodin, et al., "Progress Towards Demonstrating IFE Target Fabrication and Injection", (2) R. Stephens, et al., "Target Fabrication and Injection Possibilities for Fast Ignitor IFE", (3) D. T. Goodin, et al., "Reducing the Costs of Targets for Inertial Fusion Energy", (4) J. Pulsifer, et al., "Thermal Control Techniques for Improved DT Layering of Indirect Drive IFE Targets"

Presentations at the Heavy Ion VNL meeting, Livermore, CA, July 23-24, 2001.

(1) M. S. Tillack, et al., "In-hohlraum Layering of Indirect Drive Targets", (2) R. W. Petzoldt, "Indirect Drive Target Injection", (3) D. T. Goodin, "Summary of Target Design, Target Fabrication, and Chamber Workshop", (4) E. M. Campbell, "Heavy Ion Fusion and General Atomics"

Presentations at the ARIES meeting, San Diego, CA, June 7-8, 2001.

(1) D. T. Goodin, "Progress in IFE Target Fabrication", (2) R. W. Petzoldt, "Indirect Drive Target Injection"

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Laser Interactions and Final Optics Studies — University of California, San Diego

M. S. Tillack, M. Zaghloul, T. K. Mau, F. Najmabadi, J. Pulsifer, A. Gaeris, S. S. Harilal, B. Harilal, L. Chousal

(see: <http://joy.ucsd.edu/RESEARCH/ife.shtml>)

- Damage curves (fluence vs. shot count) have been obtained for Al-1100 and pure Al. As shown in Fig. 1, pure Al shows very high damage threshold as compared with impure alloys: 160 J/cm² for a single shot and 60 J/cm² for up to 10⁴ shots.
- An SBS cell for beam smoothing has been built and initial studies are underway.
- Focal spot imaging is being performed as a complement to the Shack Hartmann measurements.
- Pb samples have been fabricated in order to obtain optical data needed to assess the effect of Pb contamination on optics for wetted wall chambers.
- The vacuum system and test chamber have been fabricated, leak-tested and installed in the lab (see Fig. 2).
- All optics & diagnostics have been assembled for laser propagation studies and initial testing has begun in air.

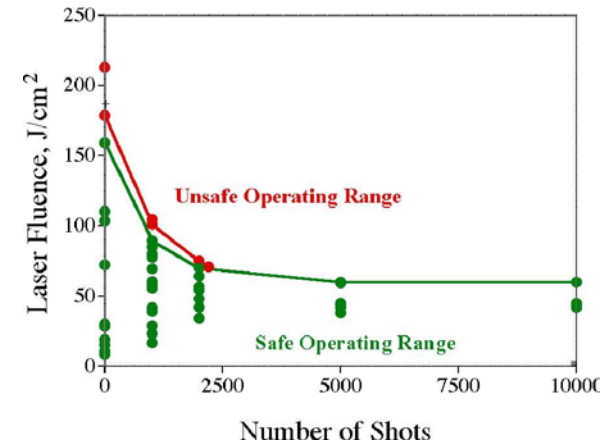


Fig. 1 Damage curve for 99.999% pure Al

Publications and Presentations:

M. S. Tillack et al. "Damage Threats and Response of Final Optics for Laser-Fusion Power Plants," Presented at the 2nd International Symposium of Inertial Fusion Sciences and Applications, Kyoto, Japan (Sep. 2001). <http://aries.ucsd.edu/LOCAL/PEOPLE/tillack-pubs.shtml>

M. S. Tillack, "Overview of Inertial Fusion Energy Technology Research at UC San Diego," Presented at General Atomics (Aug. 2001). <http://aries.ucsd.edu/LIB/TALK/MST/>

M. S. Tillack, "Overview of Inertial Fusion Energy Technology Activities," Presented at CIEMAT, Madrid, Spain (Jul. 2001). <http://aries.ucsd.edu/LIB/TALK/MST/>

M. S. Tillack et al., "Thermal Modeling of Indirect Drive Targets," Presented at the Heavy Ion IFE Meeting, Livermore, CA (Jul. 2001).

F. Najmabadi et al., "ARIES Work on Chambers for Indirect Drive Targets," Presented at the Heavy Ion IFE Meeting, Livermore, CA (Jul. 2001).



Fig. 2 Chamber physics vacuum system

Progress in IFE Technology: June - September 2001 (Cont'd.)

Safety and Environment — Idaho National Engineering and Environmental Laboratory

L. C. Cadwallader, D. A. Petti, B. J. Merrill and R. L. Moore

- Work on identification of accident initiating events for inertial fusion energy conceptual designs is progressing:
 - SOMBRERO design was examined as it is representative of laser-driven, dry wall designs—see Fig. 1.
 - HYLIFE-II design will be examined as it is representative of thick-liquid, ion-driven designs.
- Dave Petti and Lee Cadwallader of INEEL and Gottfried Besenbruch and Dan Goodin of GA visited the headquarters and manufacturing complex of Micron Technology, a computer chip manufacturer in Boise, Idaho:
 - As Micron Technology produces large numbers of small components as extremely high levels of quality control, a tour of their facilities was deemed to be relevant to the production of IFE targets, which must be produced at ~5 Hz with high levels of precision and reliability.
 - The group viewed the various stages of chip production, and they talked to the staff about some of the issues involved with making large numbers of products.
 - Issues included costs, future planning, quality and reliability, and some technical issues such as control of electrostatic buildup and methods to examine the parts during manufacture.
 - A trip report was written, approved by Micron Technology, and distributed to the ARIES Team.

Publications and Presentations:

L. C. Cadwallader and J. F. Latkowski, "Preliminary Identification of Accident Initiating Events for IFE Power Plants," to be presented at the 19th Symposium on Fusion Engineering, Atlantic City, NJ.

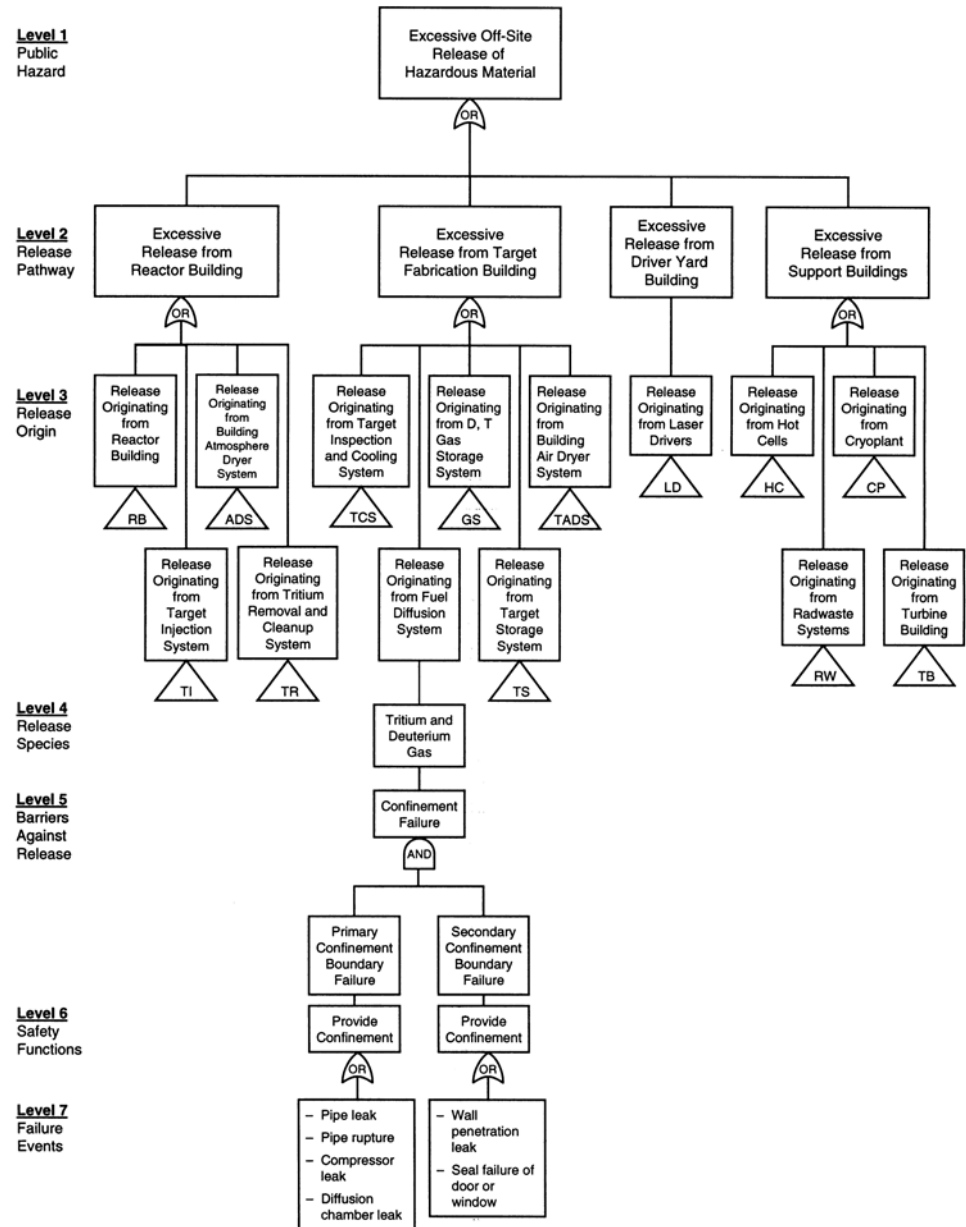


Fig. 1. The preliminary Master Logic Diagram for the SOMBRERO design, showing one branch expanded to level 7.

Progress in IFE Technology: June - September 2001 (Cont'd.)

Integration, Systems Studies, Safety & Environment and Driver-Chamber Interface — Lawrence Livermore National Laboratory *W. R. Meier, J. F. Latkowski, R. W. Moir, and S. Reyes*

- LLNL organized and hosted a meeting on Heavy Ion IFE in July with over 40 people representing all areas of HIF attending (HI drivers, target physics, target fabrication and injection, chamber design, safety and environment):
 - The purpose was to allow the different groups to provide updates on current activities and to discuss interface issues and design integration for HI power plants.
 - In the near term, the community will work together on updating the design parameters for a HI power plant based on the thick liquid wall design.
 - Based on feedback from participants, we plan to hold this type of community-wide meeting annually.
- Completed a study comparing the chemical and radiological hazards posed by mercury and lead as high-Z target materials (report in press). Results show that, for both materials, chemical hazards dominate over radiological hazards.
- Completed an experimental plan/proposal for a rep-rated, x-ray ablation experiment:
 - Facility would be capable of delivering 0.3-18 J/cm² of 100-500 eV x-rays at 10 Hz to a 1.4-3.0 mm spot-size.
 - Work would be funded by High-Average Power Laser IFE Program, but also would have application to HIF designs.
 - With OFES funding, facility could be modified to enable study of liquid response to x-rays at fluences that might be experienced at the vortices of a thick-liquid protected design or at the first wall of a wetted-wall design.
- Hosted Summer Student Samuel Durbin from the Georgia Institute of Technology; Completed study of x-ray energy deposition in optical materials from direct- and indirect-drive targets.
 - Results used in time- & spatially-dependent heat transfer analysis to determine temperature distribution on/near surface.
 - Analysis will be useful in determination of damage limits for typical optics such as silica or grazing incidence mirrors made of aluminum or liquid sodium.
- Grazing incidence liquid metal mirrors with a flowing film of sodium must have small temperature variations otherwise ripple is caused by convection currents driven by differences in temperature dependent surface tension. Calculations show that with care the cooling design can keep the temperature variations small enough to focus to a spot size of 1/4 μm at 30 m distance or smaller.

Publications and Presentations:

Talks presented at the Heavy Ion IFE Meeting, Livermore, CA (Jul. 2001):
(1) W. R. Meier, "Introduction to HI Chamber Activities," (2) D. A. Petti & S. Reyes, "IFE Safety and Environmental Work," (3) W. R. Meier, "Strawman Design Point Based on Hybrid Target," and (4) J. F. Latkowski, "Nuclear Aspects of the Driver-Chamber Interface."

S. Reyes, "Safety Assessment for Inertial Confinements Fusion Energy Power Plants: Methodology and Application to the Analysis of the HYLIFE-II and SOMBRERO Conceptual Designs," Lawrence Livermore National Laboratory, UCRL-LR-142678, Ph.D. Thesis (May 2001).

R. W. Moir, "Marangoni Convection Induced Ripple on Grazing Incidence Liquid Metal Mirror (GILMM) Used for Laser Inertial Fusion Energy," Lawrence Livermore National Laboratory, UCRL-ID-145529 (Aug. 2001).

S. G. Durbin and R. W. Moir, "One-Dimensional Heat Transfer Analysis for Thin Films with Applications in Inertial Fusion Energy," Lawrence Livermore National Laboratory, UCRL-ID-145435 (Sep. 2001).