areas. Most came from generally accessible equipment areas with low tritium-in-air levels, where once-through ventilation is used. In these stations, there is no strong incentive to reduce component water leakage in dried areas—or to put additional contaminated rooms on dryers—if the station emission targets are being met. For normal operation, dryer sizing is determined by the rate of air leakage into the dried area, the tritiated coolant leakage rate, and the acceptable tritium-in-air levels. The room size is important for emergency cleanup. For the ITER/NET systems handling tritiated coolant, it was suggested that one air change per day would be a practical leaktightness.

The total water loss from leakage and spills was estimated to be 0.2 to 2 kg/h. Better documentation of the CANDU water leakage experience was noted as an area that would allow better predictions, although it would not include any effects due to high salt concentrations. Assuming 0.2 kg/h total water leakage at up to 30 Ci/kg into dried rooms, six 1.9 m^3/s (4000 ft^3/min) CANDU-type driers were suggested as adequate.

Scoping analyses were presented for accident involving internal blanket breeder tube failure, failure of breeder tube leading to first-wall rupture, and loss of coolant. Preliminary results indicate that breeder tube break accidents, with loss of building confinement, may have acceptable off-site doses. It was reported that off-site doses from a loss-of-coolant accident may approach the 10-rem ITER target for passive safety, with the assumed high release fractions of corrosion products dominating the dose. In all cases, loss of the tokamak boundary integrity would considerably worsen the accident consequences because of the possible release of tokamak dust, first-wall tritium, volatilized first-wall steel, and hydrogen from steam/graphite reactions. The important factors in determining accident consequences are the tritium concentrations, water evaporation rates, and the release of circulating and deposited activation products. The modeling of the accident scenarios, release fractions, and accident frequency is not well characterized at this time.

Hydrogen safety was also discussed with respect to Ontario Hydro's experience in the design of the Tritium Removal Facility. The desire to release and disperse hydrogen before it can accumulate and detonate works against the desire to contain tritium releases. Industrial experience is that 30 to 40% of all hydrogen leaks result in fires (mostly) or explosions. Fusion facilities handling hydrogen must be designed for hydrogen safety: physical separation of systems with large hydrogen inventory from systems with large radioactivity inventory and safety design features to minimize the likelihood of a hydrogen release leading to a detonation (e.g., adequate room volume to prevent flammable mixtures forming).

CONCLUSIONS

This workshop was the first occasion in which all the major active participants in this area—in all technical disciplines—were brought together to review both their own technical areas, as well as its relation to the other tasks in supporting the ALSB concept. Several new experimental and analytic results were presented. Based on the workshop presentations and discussion, it appears that the ITER reference design (4 *M* LiOH operating at <100°C) is feasible. At the same time, several areas were identified where future work is required. On the experimental side, the key area is system chemistry. On the analytic side, the key area is safety. Some of the issues will be addressed within the context of current plans, but additional effort will be required.

P. J. Gierszewski

Canadian Fusion Fuels Technology Project
2700 Lakeshore Road West
Mississauga, Ontario, Canada L5J 1K3

D. K. Sze

Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

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SUMMARY OF THE U.S.-JAPAN WORKSHOP ON EVALUATION OF IMPURITY PELLET INJECTION FOR ALPHA DIAGNOSTICS, SAN DIEGO, CALIFORNIA, JANUARY 16-17, 1989

INTRODUCTION

The U.S.-Japan Workshop on Evaluation of Impurity Pellet Injection for Alpha Diagnostics was held on January 16-17, 1989, at General Atomics (GA) in San Diego, California. The first day was devoted to presentations from the participants describing their relevant work. The second day was a roundtable discussion of the important issues and future plans. The meeting agenda is given in Table I, and a list of attendees is given in Table II.

The purpose of this workshop was to evaluate progress and discuss future plans for work on developing a diagnostic of fast confined alpha particles in a fusion plasma using impurity pellet injection. Methods based on charge-exchange (CX), nuclear, and X-ray excitation interactions of the alphas with the pellet cloud were discussed.

Pellet Penetration

All the proposed methods share the problem of getting a suitable pellet far enough into a hot, dense, burning plasma. For example, a carbon pellet, sized to cause only a 5% volume-averaged electron density perturbation, must be injected at ~10 km/s to penetrate near the center of the Compact Ignition Tokamak (CIT) at $n_{e_0} = 7 \times 10^{14}\ cm^{-3}$, $T_{e_0} = 25$ keV. This result is based on a pellet ablation model developed by Parks et al.[1] Presentations were made on two possible pellet injection methods. K. Sato described the Nagoya University Institute of Plasma Physics (IPP) work on accelerating pellets using laser ablation. This approach may lead to high velocities; J. Osher mentioned that Lawrence Livermore National Laboratory (LLNL) had accidently accelerated an ammonia pellet to 8 km/s in a 1-kJ laser heating experiment. Unfortunately, the work in Japan was part of the Reacting Plasma Project (R-Project) and has stopped due to lack of funding. Osher described the work on electric guns at LLNL where kapton ($C_{22}H_{11}N_2O_5$) projectiles have been accelerated to >20 to 25 km/s. Adapting this technology into a tokamak impurity pellet injector requires testing the gun's

TABLE I

Workshop Agenda

Monday, January 16, 1989
Welcome/Introduction, R. Fisher (GA) and J. Fujita (Nagoya University IPP)
Impurity Pellet Injection into JIPP T-IIU, S. Morita (Nagoya University IPP)
Results on Alcator-C/Future Plans for Impurity Pellet Injection on TFTR, J. Terry (MIT)
TEXT Impurity Pellet Experiment Status and Plans, S. McCool (University of Texas)
GA Program on Fast-Alpha Diagnostics Using Pellet Injection, R. Fisher (GA)
Experimental Results of Fueling Pellet Injection and Plans for Lithium Pellet Injection for q-Profile Measurements on JT-60, T. Nishitani [Japan Atomic Energy Research Institute (JAERI)]
Impurity Pellet Acceleration by Laser Irradiation for Alpha-Particle Diagnostics, K. Sato (Nagoya University IPP)
LLNL Electric Guns, J. Osher (LLNL)
Low-Z Ablation Cloud Profile Simulation for Alpha Diagnostics, G. Gerdin (Old Dominion University)
Striations in Pellet Ablation Cloud, P. Parks (GA)
Tuesday, January 17, 1989
Roundtable discussion of pellet ablation modeling—status and needs
Roundtable discussion on present status and future prospects for alpha diagnostics using pellet injection, including discussion of double CX, single CX, and nuclear interaction techniques

TABLE II

Workshop Attendees

United States
D. Priester (U.S. Department of Energy) J. Terry (MIT) S. McCool (University of Texas) J. Osher (LLNL) G. Gerdin (Old Dominion University) R. Fisher (GA) P. Parks (GA) A. Howald (GA) D. Thomas (GA) P. West (GA) M. Thomas (GA) T. Leonard (GA)
Japan
J. Fujita (Nagoya University IPP) S. Morita (Nagoya University IPP) K. Sato (Nagoya University IPP) T. Mizuuchi (Kyoto University) S. Takamura (Nagoya University) T. Watari (Nagoya University IPP) A. Tsushima (Tokohu University) T. Nishitani (JAERI)

directional accuracy, the ability of impurity pellets to survive the rapid acceleration, and whether any unwanted debris accompanies the pellet. Other technologies that may result in a sufficiently high velocity injector include two-stage gas guns and electron-beam ablation of pellets.

In parallel, we need to improve our capability to predict the pellet velocity needed. Impurity pellet injection experiments on existing tokamaks can be used to determine how much a given size pellet perturbs the plasma. This will allow us to better estimate how large a pellet we can inject for alpha diagnostics.

Determining how far such a pellet will penetrate into a burning plasma requires modeling of the pellet ablation processes. Experiments in existing tokamaks can be used to compare experimentally observed pellet penetration with predictions of these models. This will increase our confidence in our projections as to what velocity injectors will eventually be needed for a deuterium-tritium (D-T) alpha experiment. Preliminary results on the Texas Experimental Tokamak (TEXT) show carbon pellets do not penetrate as far as Park's code model predicts. Good agreement is obtained when comparing Park's model to carbon experiments in T-10 and lithium pellets on Alcator-C. A possible explanation for the discrepancy between the model and the TEXT results is enhanced ablation by a population of nonthermal "slideaway" electrons. Most of the TEXT data could be explained by a factor of ~2 increase in line integral heat loading. This would require only a 0.1% fraction of electrons with energies of the order of 100 keV. It is thought these slideaway electrons may be the cause of the toroidal pellet deflection seen on TEXT.

A second effect complicating our ability to model the pellet penetration is the presence of a "cold wave" that precedes the pellet.

This cold wave effect was observed on Alcator-C, TEXT, and JIPP T-IIU. The TEXT experiments will be repeated using Thomson scattering to make sure the effect is not due to refraction or cutoff effects on the electron cyclotron emission (ECE) diagnostic. A cold wave requires that we correct for a generally lower heat flux than that for prepellet plasma conditions. We hope data soon to be collected on lithium and carbon pellets injected into Tokamak Fusion Test Reactor (TFTR) will yield further information on pellet penetration.

Pellet Deflection

Alcator-C experiments showed a few-degree upward deflection. No explanation has been found. TEXT pellets show a significant toroidal deflection in the direction of the electron drift. One possible explanation is a nonthermal slideaway (~10- to 100-keV) electron distribution that provides a toroidally asymmetric ablation. Runaway (mega-electron-volt) electrons have a range in carbon too large to produce asymmetric (surface) heating of the pellet. No correlation between large deflection and high runaway content (large hard X-ray flux) was observed on TEXT. Experiments are planned with a reversed plasma current and also monitoring the slideaway electron population via lower energy X-ray detectors.

Other issues are specific to the interaction mechanism of interest.

Double CX Issues

GA feels that double CX is the most promising approach to alpha diagnostics:

$$\mathrm{He}^{++} + \mathrm{C}^{N+} \rightarrow \mathrm{He}^{0} + \mathrm{C}^{(N+2)+} \ .$$

GA's work shows that the charge state distribution in the ablation cloud trailing the pellet will contain a large region (a few centimetres parallel to B by a few centimetres along the pellet path in CIT) where the C^{4+} ionization state will predominate. By viewing the pellet path with a collimated neutral detector and analyzing only helium neutrals created during the time the C^{4+} region of the cloud passes through the collimator, the incident alpha energy distribution is given by

$$\frac{dN_{\mathrm{He}^{++}}}{dE} = \frac{dN_{\mathrm{He}^{0}}}{dE}(\text{measured})\frac{\sigma_{01}(E,Z=4)}{\sigma_{20}(E,Z=4)} \ .$$

Hence, the absolute value of the alpha-particle energy distribution can be determined.

G. Gerdin is developing a code model for the charge state distribution. His model includes non-local thermodynamic equilibrium (LTE) effects. At present, it assumes spherical expansion but will be upgraded to require expansion only along the magnetic field lines.

Single CX Issues

Line radiation from excited singly ionized helium produced via single CX interactions in the cloud will be Doppler shifted by the energy of the incident alpha. The principal issue is whether this line radiation is observable above the bright continuum radiation produced in the pellet ablation cloud. Measurements of the background radiation near 304, 1604, and 4688 Å need to be made for pellet injection experiments on existing tokamaks.

Nuclear Reaction Issues

By choosing an appropriate pellet material, it should be possible to observe the products of nuclear reactions between incident alphas and pellet ablation cloud targets as proposed by Sato and Sasao.[2] For example, the reaction

$$\mathrm{He}^{4} + \mathrm{Be}^{9} \rightarrow \mathrm{C}^{12} + n$$

will result in a burst of neutrons as the pellet cloud passes through a collimated neutron detector, yielding information

TABLE III

Summary of Impurity Pellet Injection on JIPP TII-U, Alcator-C, TEXT, and TFTR

Parameter	JIPP TII-U	Alcator-C	TEXT	TFTR
Machine				
R (cm)	91	64	100	245
a (cm)	23	16.5	26	85
B_z (T)	≤ 3	5 to 10	1.0 to 2.8	≤ 4.5
I_p (kA)	≤ 300	300 to 500	150 to 400	≤ 2000
Heating	Ohmic heating (OH), lower hybrid current drive (LHCD) with pellets [ICRF and neutral beam (NB) also available]	OH for lithium; OH, LHCD for H_2	OH, ECRH; diagnostic NB	OH, NB; ICRF
Pellet				
Materials	Aluminum, stainless steel, plastic (H_2/D_2)	H_2, lithium	H_2, lithium, carbon, boron, iron, titanium	Lithium, carbon
Size	0.2- to 0.5-mm-diam spheres (1.0- to 1.4-mm-diam cylinders)	0.7-mm cubes	0.25- to 0.5-mm-diam cylinders	
Velocity (m/s)	300 to 400 (300 to 950)	550 to 800	200 to 700	300 to 850
Pellets/shot	1 to 3/shot	1/shot	1/shot	Multiple
Observations	CI, CIV, Hα; FeI, AII, bremsstrahlung; $\Delta n_e n_e < 1$; $n_{e_c} \sim 10^{17}\ \mathrm{cm}^{-3}$ (CII); cloud size ~ 1 cm	LiI, LiII; $\Delta n/n \sim 0.5$ to 3; $n_{e_c} \sim 10^{18}$ to $10^{19}\ \mathrm{cm}^{-3}$ (Li^0); $n_{e_c} \leq 10^{17}\ \mathrm{cm}^{-3}$ (Li^+); pellet deflects up and toroidally; cold fronts seen for H_2 pellet	Carbon lines, $\Delta n/n \sim 0.2$ to 3.5, impurity charge states, toroidal deflection, ECE cold wave, striations	

on the local alpha-particle density. Unfortunately, the nuclear cross sections are much smaller than the atomic cross section, and hence it is unlikely sufficient signal will be available to use (α,n) or (α,γ) reactions and neutron or gamma-ray spectroscopy to determine the incident alpha energy distribution. This would also require a very fast neutron or gamma-ray spectrometer due to the short (~100-μs) lifetime of the high-density pellet cloud. E. Cecil at Colorado School of Mines is developing a fast gamma spectrometer.

Future Plans

Additional pellet injection experiments on JIPP TII-U, JT-60, TFTR, and TEXT will address the issues of pellet penetration and perturbation of the plasma. The TEXT experiments will also address the carbon charge state distribution behind the cloud. Table III summarizes the pellet injection work on each of the tokamaks.

Development of a suitable high-velocity pellet injector is an important issue requiring more support. LLNL will perform preliminary tests relevant to adapting the electric gun technology to the needs of an alpha diagnostic. An electric gun that operates at a few kilometres per second will be tested on TEXT. Work at Nagoya University on the laser ablation technique is no longer funded.

The need for a high-velocity deuterium pellet injector for plasma fueling will help since a deuterium injector should always be adaptable into an impurity pellet injector.

The Japanese invited U.S. collaboration on pellet injection experiments on JIPP T-IIU. J. Fujita reported plans for a second U.S.-Japan workshop on this topic planned in conjunction with International Atomic Energy Agency meetings in Washington, D.C. in 1990.

The following are short summaries of their work written by the speakers. There will be no other publications of the conference proceedings. Copies of the viewgraphs were distributed to all of the conference participants.

REFERENCES

1. P. B. PARKS, J. S. LEFFLER, and R. K. FISHER, "Analysis of Low-Z_a Impurity Pellet Ablation for Fusion Diagnostic Studies," *Nucl. Fusion*, **28**, 477 (1988).

2. K. SATO and M. SASAO, *Annu. Rev. IPP Nagoya*, p. 51 (1981-1982).

WORKSHOP SUMMARIES

Future Plans for Impurity Pellet Injection on TFTR, *J. Terry (Massachusetts Institute of Technology (MIT))*

A two-shot impurity (lithium and carbon) pellet injector was installed on TFTR and will be operated during the next run period (starting March 1989). The injector is a single-stage pneumatic gun producing pellet speeds from 300 to 850 m/s (helium propellant). The following pellet sizes are available (the shape is cylindrical with a length variable from 0.5 to ~1 times the diameter): lithium 0.045-, 0.061-, and 0.081-in. diam, and carbon 0.032-in. diam.

These pellets will be injected into plasma with the following plasma parameters:

1. $n_{e_0} \sim 1 \times 10^{13}$ cm^{-3}, $T_{e_0} \sim 4$ to 5 keV (supershot target plasmas)
2. $n_{e_0} \sim 6 \times 10^{13}$ cm^{-3}, $T_{e_0} \sim 8$ to 9 keV (supershots)
3. $n_{e_0} \sim 3 \times 10^{13}$ cm^{-3}, $T_{e_0} \sim 5$ keV (ohmic plasmas).

We plan to investigate the following phenomena: pellet penetration, broadening of $\text{Li}^+ - 5485$-Å line, broadening of $\text{Li}^0 - 6708$-Å line, up-down motion of the ablation pellets, toroidal curvature of the ablating pellets, the fueling effects (profile modification) from pellets, and "pumpout" of injected nuclei.

Impurity Pellet Injection into JIPP T-IIU, *S. Morita (Nagoya University IPP)*

Spherical carbon (plastic), aluminum, and iron (stainless steel) impurity pellets were injected into ohmic and radio-frequency (rf) current-driven plasmas in the JIPP T-IIU tokamak ($R = 91$ cm, $a = 23$ cm, $B_T = 3$ T). The injector is a pneumatic gun using helium propellant gas. Pellet velocities range from 300 to 500 m/s, depending on the pellet size, which varies from 0.1- to 0.5-mm diam.

For ohmic plasmas, pellet penetration and plasma density rise, and impurity transport were studied. Injection of stainless steel or aluminum pellets led to plasma disruption. A simple calculation of pellet ablation, using a model in which the sublimation energy of the material is an adjustable variable, was compared with the experimental results.

For rf current-driven plasmas, the interaction of the current-carrying (i.e., nonthermal) electrons with the pellet was studied. The plasma showed no disruptions or current terminations for any of the injected pellet materials.

In the future, we plan to inject carbon pellets into ion cyclotron resonance frequency (ICRF)-heated plasma, in which there are many nonthermal ions. This will enable us to study the enhancement of the ablation rate due to nonthermal ions.

Impurity Pellet Acceleration by Laser Irradiation for Alpha-Particle Diagnostics, *K. N. Sato (Nagoya University IPP)*

A feasibility study of alpha-particle diagnostics was carried out at Nagoya University IPP as part of the R-Project.[1] It was proposed to use injected impurity pellets as a target for CX (Ref. 2) and nuclear reaction processes.[3]

Laser irradiation as a means of accelerating pellets has several desirable features. Limiting velocities are high, and the method is suitable for the acceleration of small pellets.

Experiments were done on the acceleration of aluminum, beryllium, and iron pellets by a 20-J, 25-ns Nd-glass laser. Cubic pellets of approximately millimetre size were suspended by two silk fibers and irradiated from one side. A two-dimensional shadowgraph system and several ion collectors were used to obtain information on the expansion of the resulting plasma. The pellet momentum measured by the shadowgraph agrees well with that calculated from the parameters of the expanding plasma, as measured by the ion collectors. The pellet momentum p increases with increasing laser energy E_l as

$$p \propto E_l^{0.70-0.78}$$

for various pellet materials. This is in good agreement with the theoretical prediction of Burgess et al.[4]

In addition, an analytical study was done for comparison with the above-mentioned experimental results. From this study, it appears that useful pellet velocities may be obtained by this method, but more research is needed, especially in the regime of small pellet size.

REFERENCES

1. K. N. SATO, *Nucl. Eng. Design/Fusion*, **4**, 399 (1987).
2. M. SASAO et al., "Active Diagnostics of Magnetically Confined Alpha Particles by Pellet Injection," *Nucl. Fusion*, **27**, 335 (1987).
3. K. N. SATO and M. SASAO, *Ann. Rev. IPP Nagoya*, p. 51 (1981-1982).
4. M. BURGESS et al., *Nucl. Fusion*, Suppl. 3, 421 (1979).

TEXT Impurity Pellet Experiment Status and Plans, *S. McCool (University of Texas)*

The TEXT impurity pellet experiment began operating in September 1988. To date, we have injected ~300 pellets of carbon, lithium, boron, and titanium. Cylindrical pellets ranging in size from $D = 290$ μm and $L = 180$ μm to $D = L = 510$ μm have been reliably injected at velocities ranging from 40 to 700 m/s. The chord average density increase ranged from 0.7 to 5.4×10^{13} cm^{-3}. So far, we have characterized the plasma response, including profile changes. The density and radiated power profiles peak significantly, while the T_e profiles broaden only transiently. Both long and short confinement regimes have been observed.

We have begun various experiments using impurity pellets as both a perturbation and a diagnostic tool. The study of pellet ablation dynamics is well under way. We are studying pellet penetration depth as well as striations and curvature. Impurity and thermal transport studies have just begun. In the future, we will attempt to measure the current density profile during electron cyclotron resonance heating (ECRH) using both the striation angle technique and the Zeeman polarimetry method.

The following are our hardware and program objectives for the next year: (a) install a velocity timer on the TEXT injector; (b) implement an automatic loader and multiple pellet size system; (c) perfect pellet manufacturing techniques for boron, silicon dioxide, ice, etc.; (d) install a two-stage injector for high-velocity injection of very small pellets; and (e) continue our pellet ablation studies comparing experimental data with existing models and attempt both current density measurement techniques.

GA Program on Fast-Alpha Diagnostics, *R. K. Fisher (GA)*

GA's efforts concentrate on the double CX approach. A small fraction of the incident alphas passing through the pellet ablation cloud will pick up two electrons via

$$\mathrm{He}^{++} + \mathrm{C}^{N+} \rightarrow \mathrm{He}^0 + \mathrm{C}^{(N+2)+}$$

interactions. By measuring the energy distribution of the resultant helium neutrals $d_{n_{\mathrm{He}}0}/d_E$, it should be possible to determine the energy distribution of the incident fast confined alphas:

$$\frac{dN_{\mathrm{He}^{++}}}{dE} = \frac{1}{F_0^\infty(E)} \times \frac{dN_{\mathrm{He}^0}}{dE} ,$$

where $F_0^\infty(E)$ is the fraction of the incident alphas that is neutralized on passing through the cloud. The cloud densities will be high enough to produce an equilibrium fraction $F_0^\infty(E)$ of neutrals. To determine $F_0^\infty(E)$, the appropriate charge transfer and ionization processes must be included. We have shown that a large spatial region of the ablation cloud trailing a high-velocity carbon pellet injected into CIT will be predominantly in the C^{4+} ionization state. For neutrals created in this region of the cloud, one can show that $F_0^\infty(E) = \sigma_{20}(E)/\sigma_{01}(E)$, where $\sigma_{20}(E)$ is the cross section for $\mathrm{He}^{++} + \mathrm{C}^{4+} \rightarrow \mathrm{He}^0 + \mathrm{C}^{6+}$ and $\sigma_{01}(E)$ is the cross section for reionization of the resultant neutral $\mathrm{He}^0 + \mathrm{C}^{4+} \rightarrow \mathrm{He}^+ + e^- + \mathrm{C}^{4+}$ before it escapes the cloud.

Experiments in collaboration with the University of Texas are under way at TEXT to measure the spatial distribution of the ionization states of carbon in the pellet cloud. Preliminary results are in agreement with our calculations of the carbon ionization time scales. Other goals of the TEXT pellet injection experiments are to study pellet penetration and pellet perturbation of the plasma to determine the size and velocity of pellets needed to penetrate a CIT-sized tokamak.

We are working with LLNL to explore the possibility of using the LLNL electric gun as a high-velocity pellet injector. After tests of pellet directionality, the ability of carbon pellets to survive the acceleration, etc., we plan to test a 5 km/s electric gun pellet launcher on TEXT to demonstrate its compatibility with a tokamak experiment.

We are also studying possible alpha "simulation" experiments on TEXT involving either thermal or injected helium ions. A longer term goal is to perform a diagnostic measurement of the alpha-energy distribution during D-T operation of TFTR.

Low-*Z* Ablation Cloud Profile Simulation for Alpha Diagnostics, *G. Gerdin (Old Dominion University)*

The goal of this project is to devise a reliable computer model to simulate the impurity pellet/plasma interaction for plasmas of temperature and density relevant to those of CIT. The computer model was developed in collaboration with GA personnel and is to be used to predict the temperature and density profiles of the various charge states in the ablation cloud of carbon pellets in CIT. The resulting profiles will then be analyzed to determine the feasibility of unfolding the alpha energy distributions through interactions of the alphas with these cloud profiles. To test the reliability of the computer model, its predictions will be checked against the results of impurity pellet injection experiments performed on Alcator-C, TEXT (lithium, carbon), TFTR (lithium), and in Japan.

This work started in September 1988, and considerable progress has been made in two areas: (a) determination of the effects when the assumption of LTE breaks down for hydrogen pellets and (b) extension of the non-LTE model to lithium pellets. The first study was necessary because, for the higher charge states of the low-*Z* pellets, the assumption of LTE breaks down at considerably higher electron densities than for hydrogen ($n_e > 10^{17}$/cm^3 for LTE in hydrogen at $T = 1$ eV versus $n_e > 5 \times 10^{21}$/cm^3 for LTE in C^{+4} at $T = 1$ eV). Thus, large regions of the flow will not satisfy LTE for the low-Z ablatants, whereas this occurs in hydrogen only when the background electron temperature is <2 keV. Extending the model to lithium pellets is an important step in testing our methodology since considerable experimental data are available from Alcator-C and more will soon be available from lithium pellet experiments to be conducted on TEXT and TFTR.

The addition of non-LTE effects in hydrogen removed discontinuities in the flow outside the sonic surface in the non-LTE region. If extrapolated to the low-Z case, this would greatly affect the predictions for the charge state distributions. The computer model for lithium pellets has just begun operation with some preliminary results presented at this workshop.

The immediate plans are to test the present lithium program, remove the present assumption of spherical symmetry (in collaboration with P. Parks of GA), and compare the results with experiments. A similar program will be developed for carbon during the summer, and predictions of the radiation background from the cloud at 304 and 1640 Å should be available by September 1989.

R. K. Fisher

General Atomics
P.O. Box 85608
San Diego, California 92138-5608

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