SUMMARY AND COLLECTED COMMENTS ON THE FOURTH INTERNATIONAL WORKSHOP ON MEASUREMENT AND COMPUTATION OF TURBULENT NONPREMIXED FLAMES

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INTRODUCTION:

The Fourth International Workshop on Measurement and Computation of Turbulent Nonpremixed Flames (TNF4) was hosted by the Darmstadt University of Technology and was attended by 87 researchers from 10 countries. The main topics of discussion included:

- results for the piloted CH_4/air jet flames D, E, and F
- progress on calculations of bluff-body stabilized flames
- progress on LES for combustion
- experimental progress on flames of interest to the workshop
- priorities for TNF-related research
- organization of TNF5

This summary provides comments on the main discussion topics as reflected by the notes of some of the organizers and participants. These comments do not necessarily represent a consensus of opinion, and they are not intended to be a complete record of TNF4 discussions. This summary and the complete TNF4 Proceedings are available on the Web at http://www.ca.sandia.gov/tdf/Workshop.html. The Proceedings include the agenda, list of attendees, plotted comparisons of measured and modeled results for the target flames (piloted CH_4/air jet flames), poster abstracts, and materials (vugraph copies) on some of the discussion topics.

Background, Scope, and Objectives

The TNF Workshop series is intended to facilitate collaboration and information exchange among experimental and computational researchers in the field of turbulent nonpremixed combustion, with an emphasis on fundamental issues of turbulence-chemistry interactions. Our overall objectives are: i) to provide an effective framework for comparison of different combustion modeling approaches, ii) to identify and correct inconsistencies or gaps in the experimental data sets, and iii) to establish a series of benchmark experiments and calculations that cover a progression in geometric and chemical kinetic complexity. We emphasize that this is not a competition among models, but rather a means of identifying areas for potential improvements in a variety of modeling approaches. This collaborative process benefits from contributions by participants having different areas of expertise, including velocity measurements, scalar measurements, turbulence modeling, chemical kinetics, reduced mechanisms, mixing models, radiation, and combustion theory. The process also benefits from the rapid time scale of communication that is afforded by the internet.

Recommended Restrictions on Use of TNF Proceedings

Results in this and other TNF Workshop proceedings are contributed in the spirit of open collaboration to facilitate information exchange among active research projects. Some results represent completed work, while others are from work in progress. Readers should keep this in mind when reviewing these materials. It would be inappropriate to quote or reference specific results from these proceedings without first checking with the individual authors for permission and for their latest information on results and references.

PILOTED FLAMES D, E, AND F:

The piloted CH_4/air flames were the only target flames for which multiple simulation results were submitted for comparison with experiments. Comparisons were plotted and presented by Rob Barlow (update on flame D) and Alex Hinz (E and F results and D, E, F progression). Major points from the presenters' observations and from the discussion sessions are listed below.

Flame D:

1. **Velocity Field** – Ten new calculations of Flame D were submitted in addition to the seven from TNF3. These new calculations showed a wider spread in the results for the overall flow field as represented by the axial and radial profiles of mean velocity and velocity fluctuations. The reasons for this are not clear, but it is generally true that models were not tuned to match the flow field. Some participants expressed the opinion that more complete guidelines or requirements for calculations of target flames be used in the future in order to minimize ambiguity in the comparison of turbulence/chemistry submodels. Part of this job would be to provide updated and more complete velocity boundary conditions for the piloted flames, including recent LDV measurements from Darmstadt and perhaps a recommended exit profile of the turbulent energy dissipation. It may also be useful to provide a reference calculation for flame D. However, the main focus of the TNF workshop remains on fundamental issues of turbulence/chemistry interactions, rather than refinement of RANS models. The approach adopted in Naples that allows for tuning (and reporting) of model constants to match the overall flow/mixing field is still considered to be appropriate for the TNF Workshop purposes.

2. **Mixture Fraction Field** – Most of the calculations of flame D are in reasonable agreement with the axial profiles of the Favre means and rms fluctuations of mixture fraction and temperature. This is not to say that the calculations fall mainly within the experimental error bars. However, the level of agreement for most of the calculations is believed to be close enough to allow meaningful comparison of turbulence/chemistry results in mixture fraction coordinates.

3. **Some Anomalies** – Conditional means reveal problems with a few of the calculations. First, the ILDM results for CO and H_2 are unrealistic outside the near-stoichiometric region. As discussed by Maas in Boulder, this implementation of ILDM uses two progress variables (CO_2 and H_2O), and the manifold is only defined for a limited interval in mixture fraction. The unrealistic results for CO and H_2 are due to unrealistic assumptions that are applied outside this interval. ILDM is, however, able to predict localized extinction. Second, the two calculations based on 4-step reduced chemistry yield unrealistic values for H_2. This may result from the implementation of the 4-step mechanism rather than a fundamental problem with the 4-step representation of the chemistry. Third, the conditional means from the LES calculation are inconsistent with other measured and computed results. However, it was made clear that these LES calculations should be viewed only as works in progress.

4. **Rich-Side Problems** – The majority of calculations of flame D yield good agreement with measured conditional means of all scalars for fuel-lean conditions and for mixture fractions up to about f=0.4. In fuel-rich samples the calculated results tend to diverge, with ODT, CMC, and steady flamelet methods predicting higher mass fractions of CO and H_2 and lower mass fractions of CH_4 than are measured. The two steady flamelet (Le=1) calculations by Chen and Coelho give very similar results, even though different chemical mechanisms were used.

5. **Unresolved Question** – Related to the above, an important question from TNF3 has yet to be resolved. Why do the different methods (flamelet, CMC, PDF) predict significantly different results for fuel-rich mixtures when the calculations are run using the same mechanism. J-Y Chen presented results of a parametric set of PDF calculations that showed

a dependence of the CO mass fraction on the localness (in mixture fraction space) of the mixing model. Plots are included in the section on Additional Contributions in the TNF4 Proceedings. Bob Bilger expressed the opinion that the chemical mechanism may be a primary issue, and that GRI Mech may be predicting too rapid a rate of methane consumption at fuel-rich conditions in these partially premixed flames. Resolution of these issues is one of the highest priorities for the TNF Workshop.

6. **Pdf Results** – With the exception of problems noted in 3, the various pdf calculations gave similar results for conditional means. The Lindstedt calculation yields somewhat higher peak values for CO and H_2. A comparison presented at TNF3 by J-Y Chen of pdf calculations of flame D using several different mechanisms showed relatively small differences between CO and H_2 predictions using the GRI 1.2 and Warnatz (1998) mechanisms. This comparison is also included under the Additional Contributions in the TNF4 Proceedings. Expanding this comparison to include the mechanisms from Lindstedt, Williams, and Peters would be interesting. Flame D results suggest there are not great differences between the Chen 12-step, Lindstedt 16-step, and Peters mechanisms, as far as major species and CO are concerned. PDF/EMST/ISAT calculations of flames D and F by Xu & Pope were not available in time for inclusion in the overall comparison plots. However, vugraphs on these rather impressive results were presented separately and are included in the TNF4 Proceedings under Additional Contributions.

7. **Validation of Chemical Mechanisms** – The need for validation of chemical mechanisms against detailed measurements of laminar, opposed-flow, partially-premixed flames was discussed at some length. Experimental data on such flames is limited. Li and Williams (C&F 118:399-414) report measurements in flames with equivalence ratios of 1.5 and 2.5 on the fuel side. Peter Lindstedt and J-Y Chen plan to run laminar flame calculations to compare with these measurements. Laser measurements in laminar opposed-flow flames with the same fuel composition (equivalence ratio 3.17) as the piloted flames are planned by the Darmstadt group and later at Sandia. Some results may be available before TNF5.

8. **NO Prediction** – There are now several calculations of NO mass fractions in flame D. Some of these are in good agreement with the measurements. It is not clear, however, that this agreement is achieved for the right reasons. Accurate prediction of NO in these flames (right answer for the right reasons) requires accurate prediction of the overall flow/mixing field and radiation losses, as well as the various chemical pathways for NO formation and destruction. Questions were raised at TNF3 regarding the accuracy of the measured radiant fraction and the appropriateness of the optically-thin assumption for the piloted flames. Checks on these have yet to be done. It was suggested that future calculations report the total radiant fraction. Regarding chemistry, the comment was made that the rate of prompt NO formation from GRI Mech may be off by a factor of two due to problems with CH. Comparison of NO results based on different chemical mechanisms used within the same turbulent flame code would be interesting. Comparisons of the relative importance of prompt, thermal, and reburn chemistry in these calculations would also be interesting.

Flames E and F:

9. **Overview** – Five calculations were submitted for flame E (including PDF, CMC, and ODT methods), and seven calculations were submitted for flame F (including PDF, ODT, and LES methods). Again, the LES calculations of flames D and F are considered works in progress, and they are not included in the following comments.

10. **Favre Averages** – While each of the models shows good agreement with some aspects of the measured Favre average velocity and mixture fraction profiles, none of the models gives good overall agreement with the experiment. For example, the Hinz PDF-ILDM calculation gives relatively good agreement with the measured radial profiles of mean and rms velocity, but does less well on mixture fraction. The reverse can be said of the Chen calculations. The more rapid decay of the axial profile of mixture fraction in the extinction region of flame F as compared to flame D is not reproduced by the calculations.

This may be due to the under prediction of extinction by the models. Generally, the Favre average profiles of mixture fraction and temperature are most useful in comparing different models. Results on species are best compared in mixture fraction coordinates.

11. **Conditional Means** – Conditional means show differences among rich-side predictions that are similar to those noted for flame D. Flame E has a slightly longer stoichiometric length than D, so that measured conditional means at x/d=45 extend to higher mixture fraction values. This reveals relatively good agreement between the experiment and some of the models for most scalars up to f=0.5 (or higher) at this streamwise location where the flame is fully re-ignited.

12. **Degree of Extinction** – The scatter plots for measured temperature at x/d=15 and 30 in flame F show greater effects of local extinction than most of the predictions, especially for fuel-rich conditions. The Xu & Pope comparisons do not include scatter plots, but their conditional pdf's for flame F indicate that extinction and reignition are captured relatively well. ODT does not predict any extinction in these flames. CMC would need a higher order closure to capture local extinction. Scatter plots show that the IEM mixing model generates deterministic patterns of highly-strained or extinguished samples.

13. **Extinction as Target Problem** – Predicting the probability of localized extinction in these piloted flames is expected to be a difficult problem. It is observed experimentally that flames with significant local extinction are extremely sensitive to small changes in boundary conditions. Furthermore, small asymmetries in the burner or inlet flows can cause large asymmetries in the flame. Therefore, it seems unreasonable to expect close agreement between measured and modeled results for any one such flame. The prediction of trends observed in the series of piloted flames may be more reasonable near-term goal. Comparison of scatter plots, conditional means, and conditional pdf's can be useful in this regard. However, the limited number of samples in most of the PDF calculations limits the usefulness of the cpdf comparison plots. Definition of convenient measure of reactedness or convenient criteria for local extinction would be useful for quantitative comparisons of trends in extinction and re-ignition.

14. **Conditional Pdf's** – Only the ODT calculation and the PDF calculations by Lindstedt and Xu & Pope include a large enough sample size to allow clear interpretation of the conditional pdfs. The complete set of cpdf's from the Lindstedt calculations was not available for inclusion in the notebook. Comparisons of the Xu & Pope results with measured cpdf's for flames D and F are included in the TNF4 Proceedings under Additional Contributions. This calculation yields more extinction than the other PDF calculations, and the resulting cpdf's are in relatively good agreement with measurements, given the limitations mentioned above. Other PDF calculations show a trend of increasing extinction with increasing jet velocity. However, the cpdf's are generally too noisy for detailed comparisons. Inclusion of more particles per cell in future PDF calculations would be useful, though cost is an issue. One of the places where a measured trend is clearly seen in a calculation is in the burning part of the cpdf's of OH at x/d=15 from the ODT calculation. There is a shift to higher OH mass fractions as the jet velocity increases.

15. **Proper Normalization of Conditional Pdf's** – Conditional pdf's in the TNF4 Proceedings are not properly normalized (divided by bin width) to yield unity area under the pdf. This follows an error in presenting the measured cpdf's (Barlow and Frank, 27th Combustion Symposium). Any future TNF Workshop comparisons of pdf's should use proper normalization.

16. **Flame Stabilization** – Some calculations required special treatment of the near field in order to obtain a stable burning solution (e.g., Chen PDF-MC) while others did not. (e.g., Lindstedt and Xu & Pope). The reasons for this are not clear and may involve several aspects of the calculations. One particular question to resolve is whether the number of particles per cell affects the stability of a PDF calculation. There may also be effects of turbulence model, mixing model, boundary conditions, chemical mechanism, grid

resolution, numerics, and the interactions of these. Some further investigations on what parts of the calculations influence flame stability would be useful, particularly in the context of the E and F flames, where significant local extinction is measured at 15 diameters from the nozzle.

PROBLEMS AND NUMERICAL ISSUES IN COMPUTING THE BLUFF-BODY FLOWS:

One of the original objectives for TNF4 was to encourage modelers to apply "advanced" methods to the bluff body problem. Only one new calculation of the Sydney CH_4/H_2 bluff-body flame was submitted for comparison with measurements, and it became clear that one year was not sufficient time for major progress in this area. Consequently, Assaad Masri organized the session as a discussion opportunity with contributions from four groups that have been working on these flows (Imperial College, Fluent, TU Delft, and Cornell). The first two groups are using LES, while the latter two are using PDF methods. The objectives of the session were to exchange ideas and to promote collaboration on this difficult problem. Some of the information presented is in the poster abstracts. A few points from the discussions are: i) 3D is essential for LES of the bluff-body geometry, ii) grid-independent solutions are difficult to achieve but may be easier to achieve in combination with more refined (low Re) treatment of the near-wall region, iii) both LES and PDF calculations are sensitive to boundary conditions and need to be started upstream of the bluff-body surface.

Obtaining good predictions for the flow and mixing fields is essential before attempting any serious calculations of the composition field. In the previous workshop (TNF3), calculations using standard turbulence modeling approaches such as k-e and RS were attempted and compared with experimental data. In order to get the correct flow and mixing fields some adjustment of the model constants was done. This, if necessary, seems to be an acceptable strategy. At the conclusion of TNF4, it was seen as useful to use the standard modeling approaches (as well as advanced ones) with detailed chemistry to compute the compositional structure in these flames and especially in the reaction zone with a special focus on NO. Four or five research groups have expressed interest in attempting such computations for TNF5.

PROSPECTIVE TARGET FLAMES AND OTHER EXPERIMENTAL PROGRESS:

A stated objective of the TNF Workshop series is to develop a library of a few well-documented flames that are appropriate for investigations of fundamental issues in turbulent combustion and for collaborative testing of various models. The data library includes flames with increasing complexity in terms of flow geometry and chemical complexity. As a practical matter, the workshop has selected target flames based on the level of interest among the modelers, and not all flames in the library are expected to be used as formal targets. Participants in the TNF Workshops have interests that range from fundamental to applied. Therefore, as progress is made on the "simpler" flames, we can expect the TNF to look toward more complicated flames.

The planning of experiments must normally be done at least a year ahead of the time when the TNF Workshop might take up a flame as a target for calculations. Discussions between experimentalists and modelers during the planning stages are extremely valuable, and this is considered to be a major function of the workshop. New experiments on flames that have already been targets can also be valuable, particularly in the context of LES model validation. We can expect that the addition of new flames and the improvement of data sets already in the library will proceed in parallel.

Several prospective target flames were discussed at TNF4:

17. **Sydney Swirl Flame** – Assaad Masri presented information on a swirl burner under investigation at U Sydney. The geometry is similar to that of the Sydney bluff-body flame,

but with the addition of an annular flow of swirling air. This flame is intended as a simpler alternative to the Tecflam swirl flame. One point of discussion involved the possibility of obtaining velocity measurements inside the air annulus.

18. **Tecflam Swirl Flame** – Several groups in Germany have been working on this flame for a number of years. Wolfgang Leuckel presented an overview of experimental work. This is a relatively complicated burner to operate and to calculate. However, the fact that it is closer to practical applications is a significant motivating factor for several participants. Before this flame can serve as a TNF target, it will be necessary for the data to be consolidated, checked for consistency, documented, and made available on the internet.

19. **Berkeley Jet in Products** – As presented by Bob Dibble, this is essentially a jet flame burning in a coflow of lean products of combustion. The intent is to investigate the same chemistry as in a recirculation zone, while avoiding the fluid-dynamic complications of a recirculating flow with wall interactions.

20. **Turbulent Opposed Jet Flows and Flames** – Several TNF participants plan to investigate the opposed jet geometry as a test case for fundamental research on turbulence models (including LES) and mixing models. Nondas Mastorakos presented an overview of past work on opposed jet flames. His annotated bibliography on this topic is under Additional Contributions in the TNF4 Proceedings. Dirk Geyer introduced the burner design that has been developed at Darmstadt. This burner was also demonstrated during the laboratory tour.

21. **O_2 Coflow Jet Flame** – Jim Driscoll presented imaging results on a CH_4/N_2 jet burning in a coflow of pure O_2. In the context of the TNF data library the interesting features of this flame are: simple jet flame geometry, no partial premixing with air, minimal differential diffusion of fuel components, low levels of soot precursors that interfere with laser diagnostics. The diagnostic technique identifies the stoichiometric surface in 2D, and results may be useful for comparison with LES.

In addition, results were outlined from some recent experiments on flames that are already in the TNF library.

22. **DLR $CH_4/H_2/N_2$ Flames** – Wolfgang Meier presented results of scalar measurements in the two jet flames (Re=15,200 and Re=22,800) that were measured using the Raman/Rayleigh/LIF system in the TDF Lab at Sandia. These new measurements add OH and NO to the data set, as well as improved measurements of CO.

23. **Delft Piloted Flames** – Theo Van der Meer presented favorable comparisons of CARS temperature measurements in the Delft III flame with previous Rayleigh/Raman measurements. Multi-shot OH PLIF images have been obtained recently in these flames through a collaboration with the Alden group at Lund University.

PROGRESS ON LES FOR COMBUSTION:

This session included brief work-in-progress presentations from several groups. Poster abstracts include additional information on these contributions. The increasing level of LES activity among active workshop participants makes it clear that LES for combustion will be an important topic of future TNF Workshops. This will include greater attention to experiments that are relevant to LES.

Contributions regarding LES during TNF4

24. **ODT of Jet Flames** – Tarek Echekki and John Hewson presented an overview of recent work on the one-dimensional turbulence (ODT) model. The model resolves the full range of scalars in a single dimension, providing exact treatment of chemical reaction and

molecular mixing at Reynolds and Damkohler numbers not accessible to DNS. ODT results for flames D, E, and F (Echekki) are included in the comparisons outlined above. The calculation was carried out on a 1D-domain transverse to the mean flow by evolving the time series of 1D Lagrangian fields and ensemble averaging the results. A 12-step chemistry model and mixture-averaged transport using the CHEMKIN library were implemented. ODT results for $CO/H_2/N_2$ flames were presented by John Hewson. Both ODT calculations cast the problem as a planar jet, which means that spatial profiles cannot be compared directly.

25. **LES of H_2 Flame** – In the contribution of Forkel and Janicka a time integration procedure for LES of incompressible, reacting flows was presented. The method was applied to the simulation of a turbulent hydrogen diffusion flame and good agreement with measurements was achieved. The numerical procedure is based on the pressure correction scheme that is well known for LES of constant density flows. The local chemical composition of the fluid is described by solving a transport equation for the Favre-filtered mixture fraction. Density, temperature and species mass fractions are evaluated applying a laminar flamelet model with zero scalar-dissipation-rate. A β-function is assumed for the sub-grid PDF, the variance of the mixture fraction is calculated from the resolved fluctuations.

26. **LES of Flame D** – DiMare and Jones carried out a LES calculation of the piloted methane diffusion flames (Sandia Flame D). They applied the Smagorinsky SGS model and a steady flamelet with zero scalar dissipation. Comparisons between predictions and measurements are shown up to x/D=10. Pitsch and Steiner also presented a LES of the flame D. The species mass fractions as functions of mixture fraction are obtained using the unsteady flamelet model. The pdf is presumed to follow a β-function, whose shape is determined by the mean and the subgrid-scale variance of the mixture fraction. The mixture fraction variance and the Smagorinsky constant are determined by a dynamic procedure. The spatial filtered scalar dissipation rate is expressed in terms of the eddy diffusivity and the gradient of the resolved mixture fraction.

Conclusions and Future Work on LES

The discussion can be summarized as follows:

27. **Future of Combustion LES** – LES appears to be a promising tool for the prediction of turbulent combustion processes. The principle weakness of this method with respect to the simulation of near-wall behavior is less critical for combustion processes compared to, e.g., aerodynamic applications because the combustion takes place mainly in the large-scale dominated region far away from walls inside a combustor.

28. **Combustion Submodels** – Up to now only state of the art RANS-combustion models have been employed for LES combustion simulation. Application range, advantages, and disadvantages of these models are not known for the time being and will be subjects of future research.

29. **Sensitivity to BC's** – The precise description of flow- and scalar fields via LES requires the precise knowledge of boundary conditions. LES models are more sensitive to boundary conditions than RANS models. Obviously, physically correct conditions in a LES environment are more difficult to generate.

30. **Scalar Transport** – First LES calculation of the bluff-body flames yield a reasonable prediction of the flow field combined with unsatisfactory results for the scalar field. Scalar-transport models based on an eddy-viscosity approach with constant Schmidt-number may account for this observation. More sophisticated scalar transport models are needed for the future.

31. **Experimental Needs** – Additional experimental information are required for the validation of LES. Because LES reveals detailed spatial structures, suitable experiments like line-Raman are needed to meet this requirement. The sensitivity of LES to boundary conditions places additional demands on experiments. These considerations accentuate the need for collaboration among modelers and experimentalists in the design of experiments that will support LES model validation.

PRIORITIES FOR TNF-RELATED RESEARCH:

The final session included discussion of the priorities for research related to the TNF workshop. Listed below are some specific items that were identified as important for further progress on the piloted and bluff-body flames. Work was initiated on some topics in the weeks after TNF4, and it is hoped that results can be reported for some items well before TNF5.

32. **Compare and Validate Methane Mechanisms** – Comparisons of chemical mechanisms should be expanded to include all the major methane mechanisms used by various groups involved in the TNF Workshop. It would be useful to have comparisons for turbulent flames and for laminar flames over a range of strain rates. Methane mechanisms also need to be validated for laminar partially premixed flames. Experimental data on such flames are limited, and there is a clear need for detailed measurements of laminar opposed-jet flames with partial premixing. If possible, comparisons and data should include NO.

33. **Compare Mixing Models** – Further work is needed to understand the influence of mixing models on the rich-side predictions for the piloted flames. Can chemical mechanism and mixing model be considered as independent submodels?

34. **Update Boundary Conditions for Piloted and BB Flames** – Updated and more complete velocity boundary conditions for the piloted flames should be assembled and made available as soon as possible. Tests of the sensitivity of calculations to details of the boundary conditions would be useful in this context. Data on the bluff-body surface temperature for the CH_4/H_2 cases are needed.

35. **Resolve Radiation Questions** – Accuracy of the measurements of radiant fraction needs to be evaluated. The validity of the optically thin radiation model for the various target flames should be assessed. These are both important for any comparison of measured and predicted NO levels. Modelers should plan to calculate and report radiant fraction for all calculations that include NO.

36. **Particles per Cell** – The influence (if any) of the number of particles per cell on the stable burner of the piloted flames should be resolved.

37. **Tecflam Consolidation** – Four groups expressed interest in calculating the Tecflam swirl burner. Data from the various sources should be consolidated, evaluated for consistency and completeness, and made available on the internet.

ORGANIZATION OF TNF5:

38. **Location and Dates** – The Fifth TNF Workshop will be hosted by Dirk Roekaerts at the Delft University of Technology. Tentative dates are 26-28 July 2000, just before the 28th Combustion Symposium.

39. **Target Problems –** Several groups expressed interest in pursuing work on the following three tentative target problems. Primary contacts for each flame are listed:

(a) Piloted CH_4/air flames with emphasis on resolution of issues outlined above and on detailed consideration of NO. Additional measurements and guidance on the radiation problem will be needed. (Rob Barlow)

(b) Bluff-body CH_4/H_2 flame with emphasis on prediction of NO in the recirculation zone. Guidance on boundary conditions and grid resolution maybe useful. Additional information on bluff-body surface temperature is needed. (Assaad Masri)

(c) Tecflam burner. Four groups intend to calculate it. Data and boundary conditions need to be consolidated and documented. (Egon Hassel)

In addition, there is ongoing experimental work on several prospective target flames, ongoing work on submodel development, and ongoing modeling work by individuals on the DLR $CH_4/H_2/N_2$ flames and the Sandia $CO/H_2/N_2$. We can expect to hear about progress in some of these areas. Parametric studies that isolate the sensitivity of results to changes in a single submodel or parameter are encouraged.

40. **Avoiding Conflicts** – The TNF organizers are in agreement that the workshop activities should complement the Combustion Symposium, rather than conflict with it. As a general guideline, TNF participants will be asked to avoid presenting results at the workshop that are included in a Symposium paper.

41. **Initial Poster Session –** It is likely that we will begin TNF5 with an afternoon/evening poster session and reception on Wednesday July 26th. This will allow more time for participants to view and discuss posters without cutting into the main discussion sessions. An effort will be made to have target-flame comparison presented on posters, so participants can review results before the regular sessions. This arrangement is preferred over a proposed alternative of scheduling 3-minute presentations on each poster. We will try to schedule more time for informal discussions in the poster room.

42. **Limited Attendance** – Attendance will be limited at TNF5. This is considered by the organizers as a necessary step to maintain the productive atmosphere of a small workshop. Based on past experience, attendance between 60 and 75 is sensible. Final numbers will depend on the level of interest and the available facilities. Preference will be given to those groups most directly involved in research related to the TNF Workshop topics.

43. **TNF Emphasis** – The Workshop organizers will continue to promote an emphasis on open discussion rather than formal presentation, cooperation rather than competition in addressing research problems, and exchange of information on what does not work as well as what does work. A primary objective of the TNF Workshop series is to promote collaboration among experimental and computational researchers. Several groups have active and continuous collaborations, and all TNF participants are encouraged to maintain a steady exchange of questions, results, and ideas throughout the year.