LNG Safety Research: FEM3A Model Development

Quarterly Report
07-01-05 to 09-30-05

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ABSTRACT

This quarterly report for DE-FG26-04NT42030 covers a period from July 1, 2005 to September 31, 2005. GTI's activities during the report quarter were limited to administrative work. The work at the University of Arkansas continued in line with the initial scope of work and identified the questions regarding surface to cloud heat transfer as being largely responsible for the instability problems previously encountered. A brief summary of results is included in this section and the complete report from University of Arkansas is attached as Appendix A.

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EXECUTIVE SUMMARY

Work has continued to address numerical problems experienced with simulation of low-wind-speed, stable, atmospheric conditions with FEM3A. Steps 1 through 8 in the plan outlined in the first Quarterly report have been satisfied. Researchers at the University of Arkansas have all indications that the important problems related to stability of the simulations at regulatory conditions of low wind speed and stable atmospheric conditions have been resolved.

EXPERIMENTAL

Primary effort has continued and substantial progress has been made. Equipment has been readied for measurement of wind tunnel turbulence spectra requested by NETL, as well as initiation of near-field measurements of gas concentration (within the dike/tank assembly), as agreed upon at a meeting at the University of Arkansas with NETL representatives.

The primary purpose of this task was to repeat and extend former experiments using uniform roughness elements covering the wind tunnel floor to create turbulence properties similar to field scale wind conditions. The roughness used had already been characterized in a related research program; consequently, only the gas concentration measurements will have to be repeated. The resulting data set(s) will be a valuable addition to the data archives demonstrating the FEM3A model for application to LNG vapor dispersion prediction.

There are strong indications that the experimental data from the wind tunnel would be more applicable to field conditions, and therefore more useful for model validation, when the floor is artificially roughened.

RESULTS AND DISCUSSION

Data from experimental work will be used to verify the FEM3A model for application involving dispersion over rough surfaces (for example, suburban housing) with and without the presence of obstacles such as tank and/or dike structures and industrial buildings. The end product will be an advanced turbulence closure model (for describing the turbulent mixing involved in the dispersion process) that will allow for more realistic description of dispersion problems with obstacles and terrain features of greater complexity (the real world).

CONCLUSION

Researchers at the University of Arkansas have commenced work to determine the spectral analysis of the turbulence in the wind tunnel but work was delayed because of equipment problems with the hot wire anemometry system. Aside from some cleanup work on the stability issue, they are ready to commence further experimental investigations.

APPENDIX A

Report by Dr. Jerry Havens and Dr. Tom Spicer
University of Arkansas

October 31, 2005

Vapor Dispersion and Thermal Hazard Modeling

Sixth Quarterly Report
(July – September, 2005)

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For
GAS TECHNOLOGY INSTITUTE
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GTI Project Manager
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October 31, 2005

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1.0 RESEARCH SUMMARY

Title	Vapor Dispersion and Thermal Hazard Modeling
Contractor	University of Arkansas GTI Contract Number: K100029184
Principal Investigators	Jerry Havens Tom Spicer
Contract Period	April 2004 – March 2006
Objective	To develop the FEMA3A model for application to general scenarios involving dispersion problems with obstacles and terrain features of realistic complexity, and for very low wind speed, stable weather conditions as required for LNG vapor dispersion application specified in 49 CFR 193.
Technical Perspective	The dispersion model DEGADIS specified in 49 CFR 193 is limited to application for dispersion over smooth, level terrain free of obstacles (such as buildings, tanks, or dikes). There is a need for a dispersion model that allows consideration of the effects of terrain features and obstacles on the dispersion of LNG vapor clouds.
Project Milestones	A. Simulation of Low-Wind-Speed Stable Atmospheric Conditions. B. Verification for Dispersion over Rough Surfaces, With and Without Obstacles. C. Adapting the FEM3A Model for General Application.
Results In Quarter 6	Work has continued to address numerical problems experienced with simulation of low-wind-speed, stable, atmospheric conditions with FEM3A. Steps 1 through 8 in the plan outlined in the first Quarterly report have been satisfied, and we believe we have solved the important problems related to stability of the simulations at regulatory conditions

of low wind speed and stable atmospheric conditions.

We have commenced work to determine the spectral analysis of the turbulence in the wind tunnel as requested by representatives from DOE–NETL during their visit last quarter. Aside from some minor cleanup work on the stability issue, we are ready to commence further experimental investigation. We will be in touch with DOE/NETL in order to plan that phase of the work. Finally, we plan to address during that experimental program the need for changes in the turbulence closure methods in use in FEM3A required to bring the model predictions into closer alignment with the overall wind tunnel results. We are on track to finish these latter phases of the project, which will fulfill the contract requirements, on schedule.

2.0 PROGRAM OBJECTIVE

The primary objective of this research is to develop the FEM3A dispersion model for application to general scenarios involving dispersion problems with obstacle and terrain features of realistic complexity, and for very low wind speed, stable weather conditions as required for LNG vapor dispersion application specifies in 49 CFR 193. The program involves three principal tasks:

Task A – Simulation of Low-Wind-Speed Stable Atmospheric Conditions

It has been necessary to validate the FEM3A model from neutral (stability) wind tunnel boundary layer experiments, since suitable experimental facilities for simulating a stable boundary layer (at the required scale) in a wind tunnel do not exist. However, the regulatory code (49 CFR 193) requires the model prediction to be made for very low wind speed, stable weather conditions. The FEM3A code has not been applied previously for such conditions, and calculations at the University of Arkansas had shown that FEM3A simulations of stably stratified conditions were subject to numerical stability problems. We were confident that such problems could be eliminated, and research has been underway to modify the turbulence closure model along with certain boundary condition problems that had been identified and to verify the model changes by conducting experiments in the University of Arkansas Ultra-Low-Speed wind tunnel. This is a high priority requirement since the normal application of the code for compliance with the regulation, as well as for application to counter-terrorism issues, frequently requires the simulation to be made for such conditions, which often are worst-case.

Task B – Verification for Dispersion over Rough Surfaces, With and Without Obstacles

Previous experiments in the CHRC wind tunnel to validate the FEM3A model prediction of the effect of the presence of tank and dike structures utilized a smooth wind tunnel floor. Past research work in the CHRC wind tunnel indicated that the presence of the smooth floor combined with the low wind speeds required to simulate the dense gas effects involved in LNG vapor dispersion can result in the tendency for the boundary layer near the floor to laminarize. Under such conditions the wind tunnel flow is not similar to the atmospheric wind flow because field conditions are normally fully turbulent (laminarization does not normally occur at field scale). There are strong indications that the experimental data from the wind tunnel would be more applicable to field conditions, and therefore more useful for model validation, when the floor is artificially roughened.

The primary purpose of this task was to repeat and extend former experiments using uniform roughness elements covering the wind tunnel floor to create turbulence properties similar to field scale wind conditions. The roughness used had already been characterized in a related research program; consequently, only the gas concentration measurements will have to be repeated. The resulting data set(s) will be a valuable addition to the data archives demonstrating the FEM3A model for application to LNG vapor dispersion prediction.

Data from this Task will be used to verify the FEM3A model for application involving dispersion over rough surfaces (for example, suburban housing) with and without the presence of obstacles such as tank and/or dike structures and industrial buildings. The product of this task will be an advanced turbulence closure model (for describing the turbulent mixing involved in the dispersion process) that will allow for more realistic description of dispersion problems with obstacles and terrain features of greater complexity (the real world).

Task C – Adapting the FEM3A Model for More General Application

As more complex applications of the FEM3A model are proposed, it is anticipated that there will be additional questions that can best be addressed by experimentation in the CHRC wind tunnel. The major advantage of this approach is that the specific questions regarding the application of the model to different scenarios can be addressed experimentally without having to recreate all of the experimental conditions in the real scenario, and without the high cost and insufficient controllability that is inherent in larger scale field tests. FEM3A simulations of more complex scenarios will inevitably require experimental verification efforts, and the continued availability of the CHRC wind tunnel for such verification is a necessary adjunct for the successful standardization of the FEM3A model for general application. Examples of complex scenarios that will be considered are evaluations of vapor fences for containment of flammable gases and aerosols, scenarios containing multiple obstacles, and major terrain features.

3.0 PROGRAM TIME SCHEDULE

Tasks A and B were pursued concurrently because they are coupled. However preparations for Task A, which are computational in nature, were initiated first, with concurrent experimental validation efforts immediately following. Task A was completed this quarter (Q6). Tasks B and C will be the primary effort during the last two Quarters, as both will require continuing experimental verification work.

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Task A								
Numerical Stability	X	X	X	X	X	**X**		
Task B								
Model Verification		X	X	X	X	**X**	X	X
Task C								
General Application							X	X

4.0 WORK PERFORMED DURING JULY-SEPTEMBER (QUARTER 6)

Work has continued to address numerical problems experienced with simulation of low-wind-speed, stable, atmospheric conditions with FEM3A. Steps 1 through 8 in the plan outlined in the first Quarterly report have now been satisfied, and we believe we have solved the important problems related to stability of the simulations at regulatory conditions of low wind speed and stable atmospheric conditions.

We have commenced work to determine the spectral analysis of the turbulence in the wind tunnel as requested by representatives from DOE–NETL during their visit last quarter, but that work was delayed because of equipment problems with our hot wire anemometry system. Aside from some cleanup work on the stability issue, we are ready to commence further experimental investigation. We will be in touch with DOE/NETL in order to plan that phase of the work. Finally, we plan to address during that experimental program the need for changes in the turbulence closure methods in use in FEM3A required to bring the model predictions into closer alignment with the overall wind tunnel results.

5.0 PLANS FOR FUTURE WORK

Contract tasks are expected to be completed on schedule as shown in Section 3.0.