The Consortium for Risk Evaluation with Stakeholder Participation III

*Consortium Universities: **Vanderbilt University**, Howard University, Oregon State University, Robert Wood Johnson Medical School, Rutgers University, University of Arizona, University of Pittsburgh*

January 10, 2007

Mr. Roy Schepens, Manager
U.S. Department of Energy
Office of River Protection
P.O. Box 450 MSIN: H6-60
2440 Stevens Center Place
Richland, WA 99354

RE: CRESP Review Team Letter Report 1

Dear Mr. Schepens:

The Consortium for Risk Evaluation with Stakeholder Participation (CRESP) was requested by you, the Manager of the Office of River Protection Project, with the concurrence of the Deputy Assistant Secretary for Engineering and Technology (EM-20, Mark Gilbertson), to form a independent expert review team in support of treatment of high level waste currently stored in tanks at the Office of River Protection (ORP). The CRESP Review Team, in an on-going manner, is to provide input to the Manager of the Office of River Protection Project on the adequacy of available data, test plans and testing results to support design, integration and operation of specific component processes, and issue resolution for the Waste Treatment Plant (WTP) and alternate Low Activity Waste (LAW) treatment technologies. These reviews are in follow up to prior reviews by others that identified specific process issues that require additional testing and evaluation.

The specific component processes and issues associated with WTP currently identified for review by CRESP are the following items identified in the report "Comprehensive Review of the Hanford Waste Treatment Plant Flowsheet and Throughput" prepared by the external flowsheet review team (EFRT) comprised of technical experts with experience from industry, academia, and scientific laboratories: (i) Plugging in Process Piping (M1), (ii) Inadequate Design of Mixing Systems (M3), (iii) Undemonstrated Leaching Process (M12) for waste pretreatment, (iv) Inadequate Ultrafilter Area and Flux (M13), and (v) Task Technical and Quality Assurance Plan for Evaluation of Degradation Products and Rates of Anti-Foaming Agent in WTP Tanks Equipped with Pulse Jet Mixers and Air Spargers. In addition, review has been requested of the test plans and

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results for the bulk mixer/dryer process component of the Demonstration Bulk Vitrification System Project.

The CRESP Review Team has been formed in response to the identified review needs to include expertise in (i) chemical engineering process design and scale-up, (ii) rheology, (iii) mixing processes, (iv) filtration, (v) process operations, and (vi) nuclear engineering (including safety). The CRESP Review Team currently consists of David Kosson (chairman), Richard Calabrese, Willard Gekler, Robert Powell and Stanley Sandler. Brief vita for each of the team members is provided as Attachment A.

The first request for the CRESP Review Team was to review (i) the basis for scale of the engineering-scale test platform (pilot plant) for development and demonstration of the WTP pretreatment (leaching and ultrafiltration) process in response to External Flowsheet Review Team (EFRT) issue M-12 Undemonstrated Leaching Process, and (ii) the engineering study of improvement of ultrafiltration surface area and flux in response to EFRT M-13 Inadequate Ultrafilter Area and Flux. The CRESP review team received supporting materials specific to these issues for review approximately one week prior to a two-day review meeting on November 27-28, 2006 that included presentations by the ORP WTP contractors and follow up discussion. Attachment B provides a list of materials and presentations provided to the CRESP Review Team as part of this review.

This letter report provides the observations and comments of the CRESP Review Team in response to the review meeting held on November 27-28, 2006.

General Comments

1. Presentation materials and documentation given to this committee should reflect most current configuration to the extent practical.

2. All design and decision documentation should include clear citation to prior documents that are the sources of specific supporting information (e.g., correlations for engineering design, prior testing results, test plans) and a summary of the underlying assumptions and uncertainties associated with the supporting information.

3. Information for review was provided just prior to the Thanksgiving holiday with the review meeting carried out the following Monday. More detailed comments will be provided as the information received is reviewed in more depth and as additional information is provided.

M-12 Undemonstrated Leaching Process – Evaluation of Scaling Analysis for Pilot-Scale Simulant Testing

1. An overview of the engineering-scale objectives, rationale for the scaling used and proposed engineering scale design for an integrated system was provided. Insufficient documentation and detail were provided for an in-depth review at this

time. A schedule for completion of scaling and design documentation has not been developed. The Committee believes that review of a scaling and design documentation report (at least in draft form) is important prior to finalizing system configuration and procurement of critical items. The information received did not provide sufficient clarity on the validity of the scaling basis and on the justification for a single scale factor for all components in the engineering scale integrated test platform.

2. The currently stated objective is to provide a scaled testing approach *for the integrated*[1] *system*. This approach results in compromises in order to balance competing scaling issues (e.g., scaling with respect to time vs. geometry). The Committee recommends that consideration also be given to the possibility of engineering scale testing of individual key process systems and processing steps separately using the engineering-scale test platform, allowing for more realistic scaling and operation times of individual process steps (e.g., carry out leaching steps at planned full-scale timing)[2]. The key process systems are (i) UF Feed Preparation Vessel (for mixing and Al leaching), (ii) UF Feed Vessel (i.e., for mixing and Cr oxidative leaching and potentially Al leaching), and (iii) Ultrafilters. In addition, although not included as part of the information provided as part of this review, the potential for plugging in the heat exchanger also should be evaluated. Key process steps are (i) caustic leaching for Al separation, (ii) oxidative leaching for Cr separation, (iii) rinsing after the leaching steps, and (iv) filtration steps to concentrate solids and recover permeate. In this way, unit processes can be evaluated separately in appropriate sequence, although the time lines are not scaled. Appropriate integration of time sequencing process steps can then be evaluated using flow sheet modeling.

3. There was some concern raised by the EFRT consultants about the scaling analysis and testing approach, particularly with respect to the unusual practice of coupling the mixing with process objectives. Given our concerns, it is important

[1] There was considerable discussion about the usage of the term "integrated" with respect to the engineering scale testing. The committee endorses the concept of a consistently designed and appropriately inter-connected test platform, but raises concerns about using the term "integrated" to infer constant scaling of all spatial and temporal relationships, because of the inherent conflicts that would arise from this approach. Furthermore, testing and evaluation of individual unit processes using the engineering scale test platform, as well as sequences of process steps would be appropriate. Subsequently, a clearer definition of "integrated" was provided: "We do not mean 'integrated' to imply consistent scaling. 'Integrated' to us means building a system where there is continuous, consistent product delivery (vs. manual delivery) from one unit operation to the next." Clear definition and consistent understanding and usage of terminology across the project team are important.

[2] This approach is embodied in the Issue Response Plan, 24590-WTP-PL-ENG-06-0024, Section 3.5.2 but was not clear during the review presentation and discussion. This section states "Engineering evaluation of the UFP system, to establish the requirements for the engineering scale testing system, may identify the requirements to test single components at a larger scale, such as mixing vessels and filter element flow characteristics. If identified, the basis for the additional testing will be provided to WTP Engineering for review and comment. A budget allowance is provided in the planning basis for this potential testing. The requirements for this testing will be evaluated against this planning basis and appropriate approval obtained."

that members of our team be given the time and support to thoroughly digest the basis for the scaling criteria, and subsequently provide more informed comments as appropriate.

4. In general, a scaling factor of approximately 4 to 10 (i.e., the engineering scale testing is nominally at 10-25% of the full-scale system on a geometric basis) is appropriate. However, more important than the geometric scaling factor itself, is that the appropriate basis is used to scale with respect to the specific processes being evaluated. Insufficient information was provided to evaluate the specific scaling factor selected. Also, insufficient information was available to evaluate the scaling basis for the UF Feed Preparation Vessel and the UF Feed Vessel.

5. The planned use of full-size UF filter tubes with a reduced number of tubes within a bundle appears appropriate. In this case testing at planned design conditions (particularly flow velocity and differential pressure) would be appropriate

6. With regard to all of the testing it would be good to tabulate what process measurements are possible? desirable? and planned? How will the full-scale process schedule and operating conditions be adjusted in response to system performance at the engineering scale? How will engineering-scale measurements be used to establish the measurement basis for full-scale operations?

7. The engineering-scale test system design should be reviewed by other issue response teams to identify if the system should be and can be readily configured to address additional priority issues identified by the EFRT.

M-13 Engineering Study of Improvement of Ultrafiltration Surface Area and Flux

1. The objective of seeking improvements in Ultrafiltration surface area and flux, within design constraints was achieved. The impact on other processing pinch points was not discussed[3].

2. Documentation in the Engineering Study should be improved to include appropriate citations, discussion of bases/assumptions and magnitude of uncertainty associated with correlations and data used in support of the study and the overall conclusions.

[3] This scope is required as part of Issue Response Plan 12, Task 1. Section 3.1 of the Issue Response Plan states that design studies and follow-on modeling will "Assess the capacity of the cesium ion exchange, cesium nitric acid recovery, treated low-activity waste evaporation, and other affected PT systems after accounting for the process flowsheet changes to ensure effective caustic leaching and appropriate UFP system sizing. Changes to the ultrafilter system or leaching flowsheets can impact other system performance requirements. Process modeling to demonstrate that facility performance meets facility specifications must be performed to support potential changes to the ultrafiltration and leaching processes."

3. The upper limits of filtration temperature should be evaluated. This evaluation should include the potential to further increase filter flux, but also system corrosion, particle settling and other design considerations[4].

4. The ability to transfer materials between UF Feed Vessel A and UF Feed Vessel B or between the two UF Filter systems should evaluated. This capability would facilitate use of both vessels and process trains in the event of failure of one of the UF Filter systems or during periods when only one UF Filter system would be operational. For example, this modification would allow continued, though reduced, operation if part of system A fails and a different part of system B fails. In this way the operational flexibility and reliability of the total system would be improved.

5. The potential to improve filtration rate by first settling solids in the UF Feed Vessels prior to ultrafiltration should be evaluated. This would require a second withdrawal location (other than at the bottom) for these tanks.

6. The oxidation demand associated with other slurry components (e.g., organic constituents, Fe-cyanides, other reduced species) should be considered when determining the amount of permanganate required and the process kinetics[5].

7. Criteria for removal of Cr and Al, and associated residual concentrations in solids, should be clarified[6].

8. The nomenclature for "parallel" vs. "simultaneous" operation of both process trains should be clarified. The need has not been established to operate both process trains in lockstep coordination as described in the review since it does not appear that alternatives have been thoroughly explored. It appears that this dichotomy results from an assumption that waste will be treated based on recipes rather than achieving specific measurable process endpoints, which is the more desirable way to manage treatment.

9. A clear relationship should be documented between the blended, archived tank waste samples to be characterized and the full-scale process batches anticipated.

10. What is the relationship between particle size distribution, solids content and ultrafiltration flux? Can an explanation of prior test conditions and phenomena that resulted in reduced flux in one experiment be provided? What is the minimum particle detection limit for the instrumentation being used to evaluate

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[4] Assessment of filtration up to 45C will be addressed in Issue Response Plan M12 and M6, *Process Operating Limits not Completely Defined*, will determine operation limits.

[5] Research and Development activities separate from IRP M12 and 13 are underway to further define the oxidative leaching process. Additionally, IRP M6, *Process Operating Limits not Completely Defined*, and M5, *Must have Feed Prequalification Capability*, will address permanganate addition requirements.

[6] The M12 testing program will be used to establish appropriate Cr and Al removal criteria.

particle size distributions? Would particles below the detection limit have an adverse effect on membrane plugging and flux?[7]

11. Assuming that some membrane plugging will occur, is it possible to predict the reduction in filtering performance with continued plant operation, and its impact on processing time?

12. An approach needs to be developed for evaluating tradeoffs between processing rates for HLW and LAW in process design and operation decisions, reflecting overall site priorities.

13. A preliminary concept evaluation of Spintech and other alternative filter systems should be considered.

The CRESP Review Team looks forward to further discussion regarding these topics and future review meetings.

Sincerely,

David S. Kosson, Ph. D.
CRESP Review Team Chairman
Professor and Chair of the Department of Civil and Environmental Engineering
Vanderbilt University

Richard V. Calabrese, Ph.D.
Professor, Department of Chemical Engineering
University of Maryland

Willard C. Gekler
Chemical and Nuclear Engineer

Robert L. Powell, Ph.D.
Professor & Chair
Department of Chemical Engineering & Materials Science
University of California

Stanley I. Sandler, Ph.D.
Henry Belin du Pont Chair
Department of Chemical Engineering
University of Delaware

Cc: S. Olinger, ORP
M. Gilbertson (EM-20)

[7] This question will be addressed as part of the M12 bench scale and simulant development tasks.

Attachment A
CRESP Review Team

- David S. Kosson
- Richard V. Calabrese
- Willard C. Gekler
- Robert L. Powell
- Stanley I. Sandler

DAVID S. KOSSON

PROFESSIONAL PREPARATION

Rutgers, The State University of New Jersey, B.S. high honors, Chem. & Biochem. Eng., 1983
Rutgers, The State University of New Jersey, M.S., Chemical & Biochemical Eng., 1984
Rutgers, The State University of New Jersey, Ph.D., Chemical & Biochemical Eng., 1986

APPOINTMENTS

2000 - Present	Professor and Chairman, Vanderbilt University, Department of Civil and Environmental Engineering; also Professor of Chemical Engineering (2000-), Professor of Earth and Environmental Sciences (2005-)
1996 - 1999	Professor I**,** Rutgers, The State University of New Jersey, Department of Chemical and Biochemical Engineering
1990 - 1996	Associate Professor with Tenure, Rutgers, The State University of New Jersey, Department of Chemical and Biochemical Engineering
1986 - 1990	Assistant Professor, Rutgers, The State University of New Jersey, Department of Chemical and Biochemical Engineering

JOURNAL PUBLICATIONS (REPRESENTATIVE, >80 IN-PRINT OR IN-PRESS TO-DATE)

Van Gerven, T., Cornelis, G., Vandoren, E., Vandecasteele, C., Garrabrants, A.C., Sanchez, F. and Kosson, D.S. (2006) Effects of progressive carbonation on heavy metal leaching from cement-bound waste. AIChE J. 52(2):826-837.

Greenberg, M., Burger, J., Gochfeld, M., Kosson, D.S., Lowrie, K., Mayer, H., Powers, C., Volz, C. and Vyas, V. (2006) "End State Land Uses, Sustainable Protective Systems, and Risk Management: A Chalenge for Multi-Generational Stewards." *Remediation Journal* 16(1): 91-105.

Mayer, H., Greenberg, M., Burger, J., Gochfeld, M., Powers, C., Kosson, D.S., Keren, R., Danis, C. and Vyas, V. (2006) "Using Integrated Geospatial Mapping and Conceptual Site Models to Guide Risk-Based Environmental Clean-Up Decisions." *Risk Analysis*, 25(2):429-446.

Sanchez, F. and Kosson, D. S. (2006) "Probabilistic approach for estimating the release of contaminants under field management scenarios," *Waste Management*, 25, 463-472.

Burger, J., M. Gochfeld, D. S. Kosson, C. W. Powers, B. Friedlander, J. Eichelberger, D. Barnes, L. K. Duffy, S. C. Jewett, and C. D. Volz. (2005) Science, policy, and stakeholders: developing a consensus science plan for Amchitka Island, Laeutians, Alaska. *Environmental Management*, 35:557-568.

Wang, W., Shor, L., LeBoeuf, E., Wikswo, J. and Kosson, D.S. (2005) "Mobility of Protozoa Through Narrow Channels." *Applied and Environmental Microbiology*, 71(8)4628-4637.

Garrabrants, A.C., Sanchez, F., and Kosson, D.S. (2004) Changes in constituent equilibrium leaching and pore water characteristics of a Portland cement mortar as a result of carbonation. *Waste Management*, 24(1):19-36.

Gervais, C., Garrabrants, A.C., Sanchez, F., Barna, R., Moszkowicz, P., and Kosson, D.S. (2004) The effects of carbonation and drying during intermittent leaching on the release of inorganic constituents from a cement-based matrix. *Cement and Concrete Research*, 34(1):119-131.

Shor, L., Kosson, D.S., Rockne, K.J., Young, L.Y., Taghon, G.L (2004) Combined effects of contaminant desorption and toxicity on risk from PAH contaminated sediments. *Risk Analysis*, 24(5):1109-20.

Switzer, C., Slagle, T., Hunter, D., and Kosson, D.S. (2004) Use of rebound testing for evaluation of soil vapor extraction performance at the Savannah river site, *Ground Water Monitoring and Remediation*, 24(4):106-118.

Shor, L.M., Rockne, K.J., Young, L.Y., Taghon, G.L., and Kosson, D.S. (2004) Synergistic effects of contaminant desorption and toxicity: Implications for environmental risk assessment. *Risk Analysis*, 24(5):1109-1120.

Garrabrants, A.C., and Kosson, D.S. (2003) Modeling moisture transport from a Portland cement-based material during storage in reactive and inert atmospheres. *Drying Technology*, 21(5):775-805.

Sanchez, F., Garrabrants, A.C., and Kosson, D.S. (2003) Effects of intermittent wetting on concentration profiles and release from a cement-based waste matrix. *Environmental Engineering Science*, 20(2):135-153.

Shor, L.M., Lian, W., Rockne, K.J., Young, L.Y., Taghon, Gary L., and Kosson D.S. (2003) Intra-aggregate mass transport-limited bioavaibility of polycyclic aromatic hydrocarbons to mycobacterium strain PC01. *Environmental Science & Technology*, 37(8):1545-1552.

Shor, L.M, Rockne, K.J., Taghon, G.L., Young, L.Y., and Kosson, D.S. (2003) Desorption kinetics for field-aged polycyclic aromatic hydrocarbons from sediments. *Environmental Science and Technology*, 37(8):1535-1544.

Garrabrants, A.C., Sanchez, F., and Kosson, D.S. (2003) Leaching model for a cement mortar exposed to intermittent wetting and drying. *AIChe Journal*, 49(5):1317-1333.

Sanchez, F., Garrabrants, A.C., Vandecastelle, C., Moszkowicz, P., and Kosson, D.S. (2003) Environmental assessment of waste matrices contaminated with arsenic. *Journal of Hazardous Materials*, 96(2-3):229-257.

Sanchez, F., Massry, I.W., Eighmy, T., and Kosson, D.S. (2003) Multi-regime transport model for leaching behavior of heterogeneous porous materials. *Waste Management*, 23(3):219-224.

Hacherl, E.L., Kosson, D.S., and Cowan, R.M. (2003) A kinetic model for bacterial Fe(III) oxide reduction in batch cultures. *Water Resources Research*, 39(4):1-18.

Sanchez, F., Gervais, C., Garrabrants, A. C., Barna, R. and Kosson, D. S. (2002). Leaching of inorganic contaminants from cement-based waste materials as a result of carbonation during intermittent wetting. *Waste Management*, 22(2):249-260.

Garrabrants, A.C., Sanchez, F., Gervais, C., Moszkowicz, P. and Kosson, D. (2002) The effect of storage in an inert atmosphere on the release of inorganic constituents during intermittent wetting of a cement-based material. *Journal of Hazardous Materials* B91(1-3):159-185.

Kosson, D.S., van der Sloot, H.A., Sanchez, F. and Garrabrants, A.C. (2002) An integrated framework for evaluating leaching in waste management and utilization of secondary materials. *Environmental Engineering Science* 19(3):159-204.

Sanchez, F., Mattus, C., Morris, M. and Kosson, D.S. (2002) Use of a new leaching test framework for evaluating alternative treatment processes for mercury contaminated soils. *Environmental Engineering Science* 19(4):251-269.

Rockne, K.J., Shor, L.M., Young, L.Y., Taghon, G.L., and Kosson, D.K. (2002) Distributed sequestration and release of PAHs in weathered sediment: The role of sediment structure and organic carbon properties. *Environmental Science and Technology*. 36(12):2636-2644.

Hacherl, E.L., Kosson, D.S., Young, L.Y., and Cowan, R.M. (2001) Measurement of iron(III) bioavailability in pure iron oxide minerals and soils using anthraquinone-2,6-disulfonate oxidation. *Environmental Science and Technology*, 35(24):4886-4893.

Hacherl, E.L., Kosson, D.S., Young, L.Y., and Cowan, R.M. (2001). Measurement of iron(III) bioavailabilty in pure iron oxide minerals and soils using anthraquinone-2,6-disulfonate oxidation. *Environmental Science and Technology*, 35:4886-4893.

Schaefer, C.E., Arands, R.R., and Kosson, D.S. (1999) Measurement of pore connectivity to describe diffusion through a trapped non-aqueous phase in unsaturated soils. *Journal of Contaminant Hydrology*, 40(3):221-238.

Schaefer, C.E., Arands, R.R., van der Sloot, H.A., and Kosson, D.S. (1995) Prediction and experimental verification of liquid phase diffusion resistance in unsaturated soils. *Journal of Contaminant Hydrology*, 20(1-2):145-166.

DOE Related Reports

Switzer, C., Brown, K., Kosson, D.S., Clarke, J. and Parker, F. Preliminary Risk Evaluation of Calcined High-Level Waste Disposition at the Idaho Site. Consortium for Risk Evaluation with Stakeholder Participation, Institute for Responsible Management, Piscataway, NJ, 2005.

Brown, K., Switzer, C., Kosson, D.S., Clarke, J. and Parker, F. Preliminary Risk Evaluation of Options for Buried Waste Disposition at the Idaho Site. Consortium for Risk Evaluation with Stakeholder Participation, Institute for Responsible Management, Piscataway, NJ, 2005.

Powers, C.W., Burger, J., Kosson, D.S., Gochfeld, M. and Barnes, D., et al. Biological and Geophysical Aspects of Potential Radionuclide Exposure in the Amchitka Marine Environment. Consortium for Risk Evaluation with Stakeholder Participation, Institute for Responsible Management, Piscataway, NJ, 2005.

Kosson, D.S., Grogan, H., Higley, K., Maddalena, R., Whipple, C. Merit Panel Review of the C-Tank Farm Closure Performance Assessment. Consortium for Risk Evaluation with Stakeholder Participation, Institute for Responsible Management, Piscataway, NJ, 2004.

SYNERGISTIC ACTIVITIES

Chairman, Department of Civil and Environmental Engineering.
Co-PI on NSF IGERT Interdisciplinary Reliability and Risk Engineering and Management Doctoral Prog.
National Research Council Committees (Board on Army Science and Technology):

- Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons: Phase 2 (ACW II), Member 2000 to 2002.
- Chair, Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program (Standing Committee), July 1998-July 2000; Member, 1993-2000.
- Panel on Review and Evaluation of Alternative Chemical Disposal Technologies, Member,1995-1996.

Chairman of Leadership Committee - Vanderbilt Institute for Environmental Risk and Resources Management.
The Consortium for Risk Evaluation with Stakeholder Participant (CRESP) – Chairman of Remediation and Risk Mitigation Technology Center of Expertise

COLLABORATORS AND CO-EDITORS

David Stensel, University of Washington; Joel Massman, University of Washington, Mark Benjamin, University of Washington, David Stahl, University of Washington, Joanna Burger, Rutgers University, Micheal Greenberg, Rutgers University, Panos Georgopolous,Rutgers University, Lily Young, Rutgers University, Gary Taghon, Rutgers University, Taylor Eighmy, University of New Hampshire, William Rixey, University of Houston, Paul Lioy, University of Medicine and Dentistry of New Jersey. Institutional Conflict: Rutgers University

Thesis Advisor: Dr. Robert C. Ahlert (currently emeritus)

Total number of graduate students as primary advisor: 33 completed, 4 current
Total number of post-docs supervised: 10 completed, 2 current

Richard V. Calabrese

Professor, Department of Chemical Engineering
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PERSONAL: Born: July 2, 1946, Male, Married, 2 children
Residence: 8252 Sandy Stream Road, Laurel, MD 20723; Phone: (301) 317-6820

EDUCATION: Ph.D., Chemical Engineering, University of Massachusetts, February 1976
M.S., Chemical Engineering, University of Massachusetts, June 1971
B.S., Chemical Engineering, University of Rochester, June 1969

POSITIONS HELD:

1975 – 1978: Stevens Institute of Technology, Assistant Professor of Chemical Engineering
1979 – 1981: Pickard, Lowe and Garrick, Inc., Washington, DC, Engineering Consultant: Electric Power
1981 – Present: Department of Chemical Engineering, University of Maryland, College Park, MD

1981 – 1986:	Assistant Professor	1987 – 1995:	Associate Professor
1992 – 1994:	Acting Chair	1996 – Present:	Professor

EXPERIENCE: Expertise is in the areas of turbulent mixing & multiphase flow phenomena, with emphasis on droplet dispersion & coalescence processes, prediction & measurement of particle size distribution, and prediction & measurement of velocity fields in stirred vessels & other processing equipment.

PROFESSIONAL SOCIETIES: American Institute of Chemical Engineers
Fulbright Association

PROFESSIONAL SERVICE:

Consultant to Altus Pharmaceuticals, Avecia, Ltd., Bechtel National, Becton Dickinson, BHR Group, Bristol-Myers Squibb, Charles Ross & Son., Chemineer, ChevronTexaco, Colorcon, Dow Chemical Co., Dow Corning Corp., DuPont, Exxon, W.R. Grace, ICI Ltd., IGENE Biotechnology, Koch Materials Co., Life Technologies, Lightnin, Merck., Procter & Gamble, Searle/Pharmacia, S. C. Jonhson's & Son, Sonus Pharmaceuticals , WSRC, & Zeneca/Syngenta

Chair (1990-1995), Group 6-Mixing, AIChE National Program Committee

Emiritus Member of Executive Council (2003 - present), Past President, President (1999 - 2001), Vice President (1997 - 1999), Treasurer (1989-1995) and Founding Member, North American Mixing Forum of the AIChE

Chair, MIXING XV - 15th Biennial North American Mixing Conference, Banff, Alberta, Canada, June 1995

Subject Editor for Fluid Flow, Chemical Engineering Research and Design - Transactions of the Institution of Chemical Engineers (UK), Part A

HONORS, AWARDS and APPOINTMENTS:

Outstanding Teaching Award for Junior Faculty, College of Engineering, Univ. of Maryland, Dec. 1986

Fulbright Senior Scholar Award, United Kingdom, Sept. 1991 to June 1992

Visiting Fellow, Univ. of Birmingham, United Kingdom Science & Engineering Council, Sept. 1991 to Aug. 1992

Merck Distinguished Lecturer - Collaboratus V, Rutgers University, February 9, 1995

Outstanding Teacher Award, AIChE Student Chapter, Univ. of Maryland, May 1995

Celebrating Teachers Award, Office of Multi-Ethnic Student Education, Univ. of Maryland, May 1995

Poole & Kent Teaching Award for Senior Faculty, College of Engineering, Univ. of Maryland, May 1997

North American Mixing Forum of the AIChE, 1997 Annual Award for Sustained Contributions to Mixing Research and Practice, AIChE Annual Meeting, Los Angeles, CA, Nov. 1997

Tau Beta Pi, National Engineering Honor Society, elected for significant lifetime achievement, Dec. 1999

Fellow of the American Institute of Chemical Engineers, elected Oct. 2000

Visiting Scientist, PARSAT Group, DuPont Central Research and Development, Experimental Station, Wilmington, DE, July 1, 2000 to December 31, 2001

BOOKS CHAPTERS:

1. Atiemo-Obeng, V. A. and R. V. Calabrese, "Rotor-Stator Mixing Devices", Chapter 8 in **Handbook of Industrial Mixing Science and Practice**, E. L. Paul, V. A. Atiemo-Obeng and S. M. Kresta, Editors, John Wiley & Sons, New York, 2004 (pp. 479 to 505).
2. Leng, D. E, and R. V. Calabrese, "Immiscible Liquid-Liquid Systems", Chapter 12 in **Handbook of Industrial Mixing Science and Practice**, E. L. Paul, V. A. Atiemo-Obeng and S. M. Kresta, Editors, John Wiley & Sons, New York, 2004, (pp. 639 to 753).
3. Calabrese, "R. V., D. E. Leng and P. M. Armenante, "Liquid-Liquid Mixing in Agitated Reactors", **Encyclopedia of Chemical Processing**, S. Lee, Editor, Marcel Dekker, New York, 2006.
4. Tatterson, G. B., R. V. Calabrese and W. R. Penny, **Editors**, "Process Mixing: Chemical and Biochemical Applications", AIChE Symposium Series, Vol. **88**, 1992; Vol. **89**, 1993; Vol. **90**, 1994; Vol. **91**, 1995.

PUBLICATION DESCRIPTION:

Over 60 publications and reports, and more than 240 presentations in the areas of experience described above.

SELECTED PUBLICATIONS:

1. Calabrese, R. V. and S. Middleman, "The Dispersion of Discrete Particles in a Turbulent Fluid Field", AIChE J, **25**, 1025-1035, 1979.
2. Calabrese, R. V., et. al, "Drop Breakup in Turbulent Stirred Tank Contactors", Part I: "Effect of Dispersed Phase Viscosity", AIChE J, **32**, 657-666, 1986.; Part II: "Relative Influence of Viscosity & Interfacial Tension", AIChE J, **32**, 667-676,1986.; Part III: "Correlations for Mean Size and Drop Size Distribution", AIChE J, **32**, 677-681, 1986.
3. Berkman, P. D. and R. V. Calabrese, "The Dispersion of Viscous Liquids by Turbulent Flow in a Static Mixer", AIChE J., **34**, 602-609, 1988.
4. Calabrese, R.V. and C. M. Stoots, "Flow in the Impeller Region of a Stirred Tank", Chem. Eng. Prog., **85**, 43-50, May 1989.
5. Chang, Y. C., R. V. Calabrese and J. W. Gentry, "An Algorithm for Determination of the Size-Dependent Breakage Frequency of Droplets, Flocs and Aggregates", Part. Part. Syst. Charact., **8**, 315-322, 1991.
6. Zhang, N., Y. C. Chang, R. V. Calabrese and J. W. Gentry, "The Potential Use of Sequences of Fibonacci Series to Simulate Breakage and Agglomeration", Atm. Env., **28**,1073-1080, 1994.
7. Pacek, A. W., I. P. T. Moore, A. W. Nienow and R. V. Calabrese, "A Video Technique for the Measurement of the Dynamics of Liquid-Liquid Dispersions During Phase Inversion", AIChE J., **40**, 1940-1949, 1994.
8. Stoots, C. M. and R. V. Calabrese, "The Mean Velocity Field Relative to a Rushton Turbine Blade", AIChEJ, **41**, 1-11, 1995.
9. Calabrese, R. V., S. H. Cheng, J. C. Lin and J. W. Gentry, "Effect of Kernel on Aggregation or Coalescence of Large Clusters", Part. Sci. & Tech., **13**, 37-53, 1995.
10. Bakker, A., R. D. LaRoche, M. H. Wang and R. V. Calabrese, "Sliding Mesh Simulation of Laminar Flow in Stirred Reactors" Trans. I. Chem. E. **75:A**, 42-44, 1997.
11. Bigio, D. I., C. R. Marks and R. V. Calabrese, "Predicting Drop Breakup in Complex Flows from Model Flow Experiments", Intern. Polymer Processing, **XIII**, 192-198, 1998.
12. Gaspard, P., M. E. Briggs, M. K. Francis, J. V. Sengers, R. W. Gammon, J. R. Dorfman and R. V. Calabrese, "Experimental Evidence for Microscopic Chaos", Nature, **394**, 865-868, 1998.
13. Calabrese, R. V., M. K. Francis, V. P. Mishra and S. Phongikaroon, **"**Measurement and Analysis of Drop Size in a Batch Rotor-Stator Mixer", Proceedings: 10th European Conference on Mixing, H. E. A. van den Akker and J. J. Derksen, Editors, pp. 149-156, Elsevier Science B. V, 2000.
14. Briggs, M. E., J. V. Sengers, M. K. Francis, P. Gaspard, R. W. Gammon, J. R. Dorfman and R. V. Calabrese, "Tracking a Colloidal Particle for the Measurement of Dynamic Entropies", Physica **A**, **296**, 42-59, 2001.
15. Calabrese, R.V., M. K. Francis, K. R. Kevala, V. P. Mishra, G. A. Padron and S. Phongikaroon, "Fluid Dynamics and Emulsification in High Shear Mixers", Proc: 3rd World Congress on Emulsions, Lyon, France, 2002.
16. Phongikaroon, S., R. V. Calabrese and K. J. Carpenter, "Elucidation of Polyurethane Dispersions in a Batch Rotor-Stator Mixer", JCT Research, **1**, 329-335, 2004.
17. Phongikaroon, S. and R. V. Calabrese, "Effect of Internal and External Resistances on the Swelling of Droplets", AIChE J., **51**, 379-391, 2005.

SELECTED PRESENTATIONS (2002 to 2005):

1. Calabrese, R. V., "Dry and Liquid Dispersion for Powder Processing", ECBC Next Generation Materials for US Army Obscurants Workshop, Baltimore, MD, March 2002.

2. Calabrese, R. V., K. R. Kevala and V. P. Mishra, "The Turbulent Velocity Field in a High Speed, In-Line Rotor-Stator Mixer", Robert S. Brodkey Symposium on Turbulence in Chemical Processing, USNCTAM 14, Blacksburg, VA, June 2002.

3. Green, J., G. Sunshine, G. A. Padron, S. Phongikaroon and R. V. Calabrese, "Adsorption Kinetics at Liquid-Liquid Interfaces for Application to Emulsification Processes", 3rd World Congress on Emulsions, Lyon, France, September 2002.

4. Calabrese, R. V., M. K. Francis, K. R. Kevala, V. P. Mishra, G. A. Padron and S. Phongikaroon, "Fluid Dynamics and Emulsification in High Shear Mixers", Plenary Lecture, 3rd World Congress on Emulsions, Lyon, France, September 2002.

5. Zhang, H-J, R. V. Calabrese and J. W. Gentry, "Asymmetrical Particle Size Distributions Arising from Ternary and Pantamerous Breakage and Coagulation", Paper No. PD1-02, AAAR Annual Conference, Charlotte, NC, October 2002.

6. Phongikaroon, S., G. A. Padron, R. V. Calabrese, J. Green and G. Sunshine, "Adsorption Kinetics at Liquid-liquid Interfaces for Application to Emulsification Processes" Paper No. 178b, AIChE Annual Meeting, Indianapolis, IN, November 2002.

7. Dhanasekharan, K. M., A. H. Haidari and R. V. Calabrese, "Simulation of Liquid-Liquid Dispersion in Turbine Stirred Vessels", MIXING XIX, 19th Biennial North American Mixing Conference, Lake Placid, NY, June 2003.

8. Plenary Lecture: Calabrese, R. V., K. R. Kevala, V. P. Mishra, and K. T. Kiger, "Measurement and Simulation of Turbulent Flow in an In-line Rotor-Stator Mixer", ISMIP-5, Int. Sym. Mix. Ind. Process, Seville, Spain, June 2004.

9. Calabrese, R. V. and G. A. Padron, "Effect of Surfactant Concentration on Drop Size Distribution for Dilute Liquid-Liquid Dispersions", Paper No. 189a, AIChE Annual Meeting, Austin, TX, November 2004.

10. Calabrese, R. V., M. L. Charrouf and M. B. Ranade, "CFD Simulation of a Virtual Impactor for Sub-micron Aerosols", Paper No. 289f, AIChE Annual Meeting, Austin, TX, November 2004.

11. Calabrese, R. V., K. R. Kevala and K. T. Kiger, "Single Pass Drop Size Distributions Produced in a In-Line Rotor-Stator Mixer" Paper No. 323e, AIChE Annual Meeting, Austin, TX, November 2004.

12. Calabrese, R. V., K. R. Kevala and K. T. Kiger, "Measurement and Simulation of Turbulent Flow in an In-line Rotor-Stator Mixer" Paper No. 328e, AIChE Annual Meeting, Austin, TX, November 2004.

13. Calabrese, R. V. and G. A. Padron, "Effect of Surfactant Concentration on Drop Size Distribution for Dilute Liquid-Liquid Dispersions", MIXING XX, 20th Biennial North American Mixing Conference, Parksville, BC, Canada, June 2005.

14. Calabrese, R. V., K. R. Kevala and K. T. Kiger, "Measurement and Simulation of Turbulent Flow in an In-line Rotor-Stator Mixer", MIXING XX, 20th Biennial North American Mixing Conference, Parksville, BC, Canada, June 2005.

15. Calabrese, R. V., K. R. Kevala and K. T. Kiger, "Single Pass Drop Size Distributions: Equilibrium Lost", MIXING XX, 20th Biennial North American Mixing Conference, Parksville, BC, Canada, June 2005.

16. Calabrese, R. V., K. R. Kevala and K. T. Kiger, "Using a Dispersed Phase Model to Track Particle Paths and Deformation Rates in Complex Mixing Geometries", Paper No. 131b, AIChE Annual Meeting, Cincinnati, OH, October 2005.

17. Kevala, K. R., K. T. Kiger and R. V. Calabrese, "Single Pass Drop Size Distributions in an Inline Rotor-Stator Mixer", Paper No. GB.00004, APS Division of Fluid Dynamics 58th Annual Meeting (DFD05), Chicago, IL, November 2005.

SELECTED INVITED SEMINARS (2002 to Present):

1. Dow Corning Corp., Midland, MI, "Fluid Dynamics 7 Emulsification in High Shear Mixers", January 10, 2002.
2. Case Western Reserve University, Cleveland, OH, IFPRI Fine Particle Processing & Technology Research Symposium, "High Magnification Video Probe for In-Situ Measurement of Particle Size Distribution", April 8, 2002.
3. IKA Werke GmbH & Co. KG, Staufen, Germany, "Fluid Dynamics and Emulsification in High Shear Mixers", September 23, 2002.
4. Rohm and Haas Co., Spring House, PA, "Assessment of Rotor-Stator Mixing Devices", December 9, 2002.
5. AEA Technology - Engineering Software Inc., Pittsburg, PA, "CFD Prediction and Experimental Validation of the Turbulent Velocity Field in Stirred Vessels and Rotor-Stator Mixers", January 14, 2003.
6. Lightnin, Rochester, NY, "Assessment of Rotor-Stator Mixing Devices", August 26, 2003.
7. Sonus Pharmaceuticals, Bothell, WA, "Assessment of High Shear Devices for Emulsification Processes, September 26, 2003.
8. Ecole Polytechnique de Montreal, Canada, Department of Chemical Engineering, "Measurement and Analysis of Drop Size Distribution in Batch Rotor-Stator Mixers", April 29, 2004.
9. Silverson Machines, Ltd., Chesham, Bucks, UK, "Measurements and Simulation of Turbulent Flow in an In-Line Rotor-Stator Mixer", May 27, 2004.
10. Silverson Machines, Ltd., Chesham, Bucks, UK, "Measurement and Analysis of Drop Size Distribution in Rotor-Stator Mixers", May 27, 2004.
11. Merck & Co., Inc., West Point, PA, "Measurements and Simulation of Turbulent Flow in an In-Line Rotor-Stator Mixer", June 29, 2004.
12. Merck & Co., Inc., West Point, PA, "Measurement and Analysis of Drop Size Distribution in Batch Rotor-Stator Mixers", June 29, 2004.
13. ChevronTexaco ETC, Houston, TX, "Assessment of Rotor-Stator Mixing Devices", October 18, 2004.
14. Bristol-Myers Squibb Co., New Brunswick, NJ, "Assessment of Rotor-Stator Mixing Devices", April 8, 2005.
15. The Procter & Gamble, Co., Corporate Engineering Technologies laboratory, West Chester, OH, "Assessment of Rotor-Stator Mixing Devices", August 18, 2005.
16. Mettler Toledo Workshop on Particles in Process Engineering, Hilton Woodbridge Hotel, Iselin, NJ, "Assessment of Rotor-Stator Mixers for Dispersion Processes", August 24, 2005.
17. Altus Pharmaceuticals, Inc., Cambridge, MA, "Assessment of Rotor-Stator Mixers for Dispersion Processes", September 19, 2005.
18. Silverson Machines, Inc., East Longmeadow, MA, "Prediction and Measurement of Velocity Fields in Rotor-Stator Mixers", January 5, 2006.
19. Silverson Machines, Inc., East Longmeadow, MA, "Measurement and Analysis of Drop Size Distribution in Rotor-Stator Mixers", January 5, 2006.
20. Colorcon, West Point, PA, "Practical Turbulent Flows: Modelling and Experimental Validation", January 11, 2006.
21. Colorcon, West Point, PA, "Effect of Surfactant Concentration on Drop Size Distribution in a Batch Rotor-Stator Mixer", January 11, 2006.
22. Syngenta Crop Protection, Greensboro, NC, "Assessment of Rotor-Stator Mixers for Dispersion Processes", February 22, 2006.
23. Syngenta Crop Protection, Greensboro, NC, "Effect of Surfactant Concentration on Drop Size Distribution in a Batch Rotor-Stator Mixer", February 22, 2006.
24. BRH Group, Inc., Fluid Mixing Processes Steering Committee Meeting, Philadelphia, PA, "Effect of Surfactant Concentration on Drop Size Distribution for Dilute Liquid-Liquid Dispersions", March 23, 2006.
25. The Dow Chemical Company, Midland, MI, "Agitated, non-Coalescing Liquid-Liquid Dispersions: Drop Size Correlations and the Effect of Surfactant Concentration", April 24, 2006.
26. Akzo Nobel Symposium on Emulsification Technology, Stenungsund, Sweden, "Measurement and Simulation of Turbulent Flow in an In-line Rotor-Stator Mixer", May 17, 2006.
27. Akzo Nobel Symposium on Emulsification Technology, Stenungsund, Sweden, "Agitated, non-Coalescing Liquid-Liquid Dispersions: Drop Size Correlations and the Effect of Surfactant Concentration" May 17, 2006.
28. Fluent, Inc., Lebanon, NH, "Assessment of Rotor-Stator Mixing Devices", August 9, 2006.

Curriculum Vitae

WILLARD C. GEKLER

Summary

A chemical and nuclear engineer with over 45 years experience in design and analysis of chemical process plants and nuclear facilities. Has specialized in hazard evaluation, quantitative risk assessment, reliability assessment, and database development for risk and reliability assessments. Has managed numerous projects in quantitative risk and reliability assessment for complex engineered systems and in the design of facilities for new technology applications.

Experience

Currently serving on the Committee On Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons. The committee is part of the National Research Council (NRC) of the National Academy of Science. Has served as member of other chemical weapons destruction alternative technology review committees of the NRC since 1998.

Retired from PLG, Inc. in 1998 after serving as Vice President and Chief Engineer where he was responsible for management and technical direction of safety and risk analysis work for the chemical and petroleum industries. Project manager and key technical contributor to over 30 Risk Management and Prevention Programs (RMPP) prepared by PLG. RMPPs include refineries, chemical and petrochemical facilities, and other facilities handling and using hazardous materials. Served as leader of hazard and operability (HAZOP) studies for many RMPPs and Process Safety Management (PSM) program applications. Developed and presented training seminars on various elements of PSM programs and RMPPs. Project manager of screening risk assessment characterizing potential releases of toxic chemicals and flammable materials at 28 refining and chemical facilities operated by a major petroleum company. Project manager and technical contributor to systems safety analyses and preliminary hazard analyses for DOE facilities processing tritium and transuranic elements. Project manager of pilot quantitative risk assessment for major petrochemical facility and for a semiconductor manufacturing research facility.

Project manager for the PLG Independent Oversight Team providing continuous surveillance of a major uranium fuel facility converting yellowcake to uranium hexafluoride. Directed and participated in surveillance of all plant operations for over two years. Performed evaluation and safety analyses of material handling activities and safety protection systems.

Project manager and lead investigator for reliability/availability assessments of waste-fueled cogeneration systems. Led development of availability management programs for nuclear generating stations. Lead investigator in study of safety criteria for spent fuel transport cask risk. Project manager and key contributor in development of an integrated model for concurrent evaluation of availability, health risk, and utility investment risk at the Sequoyah Nuclear Power Plant. Project manager for preparation of probabilistic risk assessment of the Nine Mile Point 1 nuclear power plant. Participated in development of reliability-based preventive maintenance planning methodology and workshops for methodology implementation. Principal investigator in development of availability data management system for geothermal power plants.

Previously served as technical director of consulting services for a major engineering-construction firm. Responsible for engineering design and analyses for nuclear and chemical facilities including nuclear reactors, waste transport and storage systems, and power plant component test facilities for the Liquid Metal Fast Breeder Reactor Program. Directed performance of facility design study for monitored retrievable storage system for spent nuclear fuel.

Project manager for design criteria studies development of concept design for all systems and activities at the Johnston Atoll Chemical Agent Disposal System (JACADS), the first production-rated chemical agent demilitarization facility. Investigated various processes for removal and destruction of chemical agents, prepared facility layout and safety studies, assessed available sites and facilities, and prepared complete facility design criteria package. Under separate contract with U.S. Army Chemical Corps developed quantitative risk assessment methodology for risk evaluation of various transport modes, routes, and packages for agent stockpile-to-target sequences. Co-contributor to development and marketing of new cogeneration concepts. Also served as process engineer providing research, development, and field-test direction for new products and product quality improvement at a major petroleum refinery.

Education

Graduate Work, Nuclear Engineering, University of California, Los Angeles, 1960-1963
P.R.E. (Petroleum Refining Engineer), Colorado School of Mines, 1954
Reactor Safety Course, United Kingdom Atomic Energy Authority, 1967
Systems Safety Analysis Course, University of Washington, 1965

Membership, Licenses, and Honors

American Nuclear Society
American Institute of Chemical Engineers
Co-Editor of "The Analysis, Communication, and Perception of Risk", The Society for Risk Analysis, Plenum Press, New York, 1991

CURRICULUM VITA

ROBERT LOUIS POWELL
Professor & Chair
Department of Chemical Engineering & Materials Science
University of California
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EDUCATION

Bachelor of Engineering Science - 1972
Master of Science in Engineering - 1973
Doctor of Philosophy - 1978
Department of Mechanics and Materials Science
The Johns Hopkins University, Baltimore, Maryland

POSITIONS

University of California, Davis, California

Chair, Department of Chemical Engineering & Materials Science – July 2002 to Present
Professor of Food Science & Technology – July 2000 to Present
Professor of Chemical Engineering & Materials Science - July 1990 to Present
Associate Professor of Chemical Engineering - July 1984 to June 1990

Washington University, St. Louis, Missouri

Associate Professor of Chemical Engineering - July 1983 to June 1984
Assistant Professor of Chemical Engineering - August 1979 to June 1983

McGill University, Montreal, Quebec

Post-Doctoral Fellow, Department of Chemistry - March 1978 to June 1979

PROFESSIONAL AND HONORARY SOCIETIES

American Association for the Advancement of Science
American Chemical Society
American Institute of Chemical Engineers
American Physical Society (Fellow)
Society of Rheology
Society of Sigma Xi
Tau Beta Pi
Technical Association of the Pulp and Paper Industry (TAPPI)

VISITING & TEMPORARY APPOINTMENTS

University of California, Davis Campus

Interim Director, UC Davis Washington DC Center – September, 1999 to December, 1999
Special Assistant to the Provost – Univ. Outreach & International Programs - July 1998 to August 1999
Faculty Assistant to the Provost - July 1996 to June 1998
Acting Chair, Department of Chemical Engineering - January 1993 to March 1993

National Science Foundation
Program Director, Fluid Dynamics and Hydraulics Program, Division of Chemical and Transport Systems - March 1994 to September 1995

Sandia National Laboratories
Summer University Faculty Employee, Albuquerque, NM - June 1987 to September 1987

Swedish Forest Products Research Laboratory, Stockholm, Sweden
Research Scientist - June 1981

KEY CONSULTANTSHIPS AND REVIEW PANELS (2000-PRESENT)

1998 – Present	Consultant – Mars Corporation
1998 – Present	Executive Committee – UC Davis/Mars Corp. Multidisciplinary Research Unit
2001 & 2002	NSF Career Panel
2003	Visiting Committee – American University of Sharjah
2004	Member NASA Flight Review Panel
2004 & 2005	Member, USDA NRI Panel
2005	Graduate Program Review Committee – Chem. Engr., Oregon State Univ.
2005-08	Panel Manager, USDA NRI Panel
2006-	CRESP / DOE Panel – Hanford: Office of River Protection

KEY ACADEMIC COMMITTEES AND DUTIES (SINCE 2000)

University of California, Davis Campus

1992 - Present	Member, NMR Center Advisory Committee
2000 – 02, 2004,2006 -	Member, Committee on Planning and Budget
2003 -	Member, Committee on Committees (elected)
2004-05	Vice Chair, Committee on Committees (elected)
2005-06	Chair, Committee on Committees (elected)
2003 - 2004	Chair, Administrative Review Committee for the Davis Honors Challenge
2005-07	Member, Executive Council
2005-07	Member, Provost/Academic Senate Chairs Advisory Group
2006-07	Vice Chair, Academic Senate

College of Engineering

2002 -	Dean's Advisory Committee

College of Agricultural and Environmental Sciences

2001 – 2002	Chair, Planning Committee for the Robert Mondavi Institute for Wine and Food Science
2002 – 2004	Chair, Robert Mondavi Institute Implementation Committee
2004 – present	Chair, Executive Committee, Robert Mondavi Institute

Support

Department of Energy
Noninvasive Techniques for Process Monitoring - $700,000 – 9/00-9/04

NASA
Studies of Emulsion Dynamics Using Magnetic Resonance Imaging - $400,000 – 9/03-12/06

Dept. of Education
Graduate Student Fellowships - $650,000 – 7/04 – 7/08.

Mars Corp.
Nanotechnology Applications - $150,000 – 7/4 – 12/5

Relevant and Recent Publications

1993 J. D. Seymour, J. E. Maneval, **R.L. Powell**, K. L. McCarthy and M. J. McCarthy. NMRI Phase Encoded Velocity Measurements of Fibrous Suspensions. Physics of Fluids A 5: 3010-3012.

1994 W. J. Milliken and **R. L. Powell.** "Short Fiber Suspensions," in *Flow Phenomena in Polymeric Composites,* S. Advani, ed., Elsevier (invited) pp. 53 - 85.

1994 T.-Q. Li, **R.L. Powell**, M. J. McCarthy and K. McCarthy. Velocity Measurements of Fiber Suspensions in Pipe Flow by Nuclear Magnetic Resonance Imaging. TAPPI Journal 77(3): 145-149.

1994 T.-Q. Li, M. J. McCarthy, K. L. McCarthy, J. D. Seymour, L. Ödberg and **R. L. Powell**. Visualization of the Flow Patterns of Cellulose Fiber Suspensions by Nuclear Magnetic Resonance Imaging. American Institute of Chemical Engineers Journal 40:1408-1411.

1994 T. Q. Li, J. D. Seymour, M. J. McCarthy, K. L. McCarthy, L. Ödberg and **R. L. Powell**. Turbulent Pipe Flow at High Reynolds Number Studied by Time-Averaged NMR Imaging: Measurement of Velocity and Turbulent Intensity Profiles. Magnetic Resonance Imaging 12:923-934.

1995 M. A. Turney, M. K. Cheung, M. J. McCarthy and **R. L. Powell**. Hindered Settling of Rod-Like Particles Measured with Magnetic Resonance Imaging. American Institute of Chemical Engineers Journal. 41: 251-257.

1995 M. A. Turney, M. K. Cheung, M. J. McCarthy and **R. L. Powell**. Magnetic Resonance Imaging Study of Sedimenting Suspensions of Non-Colloidal Spheres. Physics of Fluids. 7: 904-911.

1995. T. - Q. Li, M. J. McCarthy, M. Weldon, L. Ödberg and **R. L. Powell**. Flow of Pulp Suspensions through an Abrupt Contraction Studied by Flow Encoded Nuclear Magnetic Resonance Imaging. Nordic Pulp and Paper Research Journal 10:133-138, cont. p 151.

1995 T.-Q. Li, L. Ödberg, **R. L. Powell** and M. J. McCarthy. Quantitative Measurements of Flow Acceleration by Means of Nuclear Magnetic Resonance Imaging. J. Magnetic Resonance. Series B 109: 213-217

1995 T. Q. Li, M. Weldon, L. Ödberg, M. J. McCarthy and R. L. Powell. Pipe Flow Behavior of Hardwood Pulp Suspensions Studied by NMRI. J. Pulp and Paper Science 21: J408-J414.

1997 S. Ramaswamy, M. J. McCarthy and R. L. Powell, Pulp Flow Visualization Usig NMR Imaging. in *Tomographic Techniques for Process Monitoring* , J. Chaouki, F. Larachi and M. P. Dudukovic, eds., Elsevier (INVITED) pp. 247-261.

1998 D. F. Arola, **R. L. Powell,** G. A. Barrall and M. J. McCarthy. A Simplified Method for Accuracy Estimation of Nuclear Magnetic Resonant Imaging. Rev. Scientific Instruments 69: 3300-3307.

1998 D. F. Arola, T.-Q. Li, L. Ödberg, **R. L. Powell**, and M. J. McCarthy. Flow of Pulp Suspensions through a Sudden Expansion. AIChE Journal 44, 2597-2606.

1999 D. F. Arola, G. A. Barrall **R. L. Powell**, and M. J. McCarthy. Pointwise Observations for Rheological Characterization. Journal of Rheology 43: 9-30.

2001 Y. Uludag, G. A. Barrall, D. F. Arola, M. J. McCarthy and **R. L. Powell**. Polymer Melt Rheology by Magnetic Resonance Imaging. Macromolecules 34: 5520-5524.

2001 **R. L. Powell**, T. Morrison and W. J. Milliken. Rheology of Suspensions of Randomly Oriented Rods by Falling Ball Rheometry. Physics of Fluids 13: 588-593.

2002 N. Dogan, M. J. McCarthy and **R. L. Powell**. In-line measurement of yield stress and shear viscosity and modeling of apparent wall slip in diced tomato products. Journal of Food Science 67:2235-2240.

2002 C. Chang and **R.L. Powell**. Prediction of the Hydrodynamic Transport Properties of Concentrated Suspensions of Non-Spherical from their Shape and Packing Behavior. American Institute of Chemical Engineers Journal 48: 2475-2480.

2003 N. Shapley, M. D'Avila, J. Walton, **R. L. Powell** , S. R. Dungan and R. J. Phillips. Complex Flow Transitions in a Homogeneous, Concentrated Emulsion. Physics of Fluids. Physics of Fluids 15: 881-891.

2003 N. Dogan, M. J. McCarthy and **R. L. Powell**. Comparison of in-line consistency measurements of tomato concentrates using ultrasonics and capillary methods. Journal of Food Process Engineering 25:571-587.

2003 M. D'Avila, N. Shapley, J. Walton, R. J. Phillips, S. R. Dungan and **R. L. Powell**. Mixing of Concentrated Oil-in-Water Emulsions Measured by Nuclear Magnetic Resonance Imaging. Physics of Fluids **15**: 2499-2511.

2004 Y. Uludag, M.J. McCarthy and **R. L. Powell**. Effects of Flow Fluctuations on Magnetic Resonance Flow Images. American Institute of Chemical Engineers Journal 50: 1662-1671.

2005 J. J. Stickel and **R. L. Powell**. Fluid Mechanics and Rheology of Concentrated Suspensions. Annual Reviews of Fluid Mechanics, **37**, 129-149.

2005 N. Dogan, M. J. McCarthy and **R. L. Powell.** Application of an In-Line Rheological Characterization Method to Chemically Modified and Native Corn Starch. Journal of Texture Studies. **36**, 237–254.

2005 N. Dogan, M. J. McCarthy and **R. L. Powell**. Polymer Melt Rheology using Ultrasonics. Measurement Science and Technology, **16** 1684-1690.

2005 N. Dogan, M. J. McCarthy and **R. L. Powell**. A Method for Accuracy Estimation of Ultrasonics-Based Rheological Measurements. Ultrasonics

2006 M. D'Avila, N. Shapley, J. Walton, R. J. Phillips, **R. L. Powell** and S. R. Dungan. A Novel Gravity-Induced Flow Transition in Two-Phase Fluids," accepted for publication in Physics of Fluids, Oct. 2006.

2006 J. J. Stickel, R. J. Phillips and **R. L. Powell**. Constitutive Modeling of Microstructure and Total Stress for Fluid Suspensions. Journal of Rheology, **50**, 379-414.

2007 E. Talu, **R.L.Powel**l and M.L. Longo. Long-term Stability by Lipid Coating Monodisperse Microbubbles Formed by a Flow Focusing Device. Macromolecules to appear

STANLEY I. SANDLER

Present Employment: Department of Chemical Engineering, University of Delaware
Henry Belin du Pont Chair (since 2000)
Henry Belin du Pont Professor (since 1982-2000)
Director, Center for Molecular and Engineering Thermodynamics (since 1992)
Professor of Chemistry and Biochemistry (since 1993)
Editor, AIChE Journal (since September 2000)

Education: B.Ch.E. City College of New York 1962
Ph.D. , Chemical Engineering, University of Minnesota, 1966
Postdoctoral NSF Fellow, Institute for Molecular Physics, University of Maryland, 1966-1967

Awards and Honors:
National Academy of Engineering, 1996;
E. V. Murphree Award, ACS, 1998;
Rossini Award, Thermodynamics Commission, I.U.P.A.C. 1998;
Warren K. Lewis Award, AIChE, 1996;
Fellow, AIChE, 1993;
Fellow, IChemE (Britian), 2003;
Chartered Engineer, (Britian), 2003;
Alexander von Humboldt Foundation Distinguished U.S. Senior Scientist Award, 1988;
3M Chemical Engineering Lectureship Award, ASEE, 1988;
Professional Progress Award, AIChE, 1984;
Camille and Henry Dreyfus Foundation Faculty - Scholar, 1971-1976.

Visiting and Honorary Professorships
Honorary Professorial Fellow, University of Melbourne (Australia), 2004-2009.
ExxonMobil Professor, National University of Singapore, 2006-2009.
University of California, Berkeley
Visiting Professor, Department of Chemical Engineering, 1995
Technische Universitat Berlin (West)
Visiting Professor at the Institut fur Thermodynamik und Anlagentechnik, 1981, 1988, 1989
University of Queensland (Brisbane, Australia)
Visiting Professor, Department of Chemical Engineering, 1989, 1996
Universidad Nacional Del Sur (Bahia Blanca, Argentina)
Visiting Professor in Departmento Ingenieria Quimica and Planta Piloto de Ingenieria Quimica 1985
Imperial College (London)
Visiting Professor in the Department of Chemical Engineering and Chemical Technology 1973 -1974

Current Editorial Boards:
Fluid Phase Equilibria;
Journal of Supercritical Fluids;
Chemical Engineering Education;
Cambridge University Press Series in Chemical Engineering,

Current Advisory Boards:
Chemical Engineering Department at Carnegie-Mellon University.
Chemical Engineering Department at Princeton University.
Chemical Engineering Department at the City College of New York.

Books

"Chemical, Biochemical and Engineering Thermodynamics" by S. I. Sandler. Published by J. Wiley and Sons, NY, 2006 (4^{th} edition of following item).

"Chemical and Engineering Thermodynamics" by S. I. Sandler. Published by J. Wiley and Sons, NY, (1st ed. 1977; 2ed 1989, 3^{rd} ed. 1999) and solutions manuals (translated in Spanish, Korean and Chinese; also reprinted in various paperback versions.)

"Proceedings of the Engineering Foundation Conference on the Estimation and Correlation of Phase Equilibria and Fluid Properties in the Chemical Industry," edited by T. S. Storvick and S. I. Sandler. Published as American Chemical Society Symposium Series No. 60 in 1977.

"Chemical Engineering Education in a Changing Environment" edited by S. I. Sandler and B. A. Finlayson. Published by the Engineering Foundation and distributed by the American Institute of Chemical Engineers, 1989.

"The Kinetic and Thermodynamic Lumping in Multicomponent Mixtures" edited by G. Astarita and S. I. Sandler. Published by Elsevier, Amsterdam, 1991.

"Models for Thermodynamic and Phase Equilibria Calculations" edited by S. I. Sandler. Published by Marcel-Dekker, New York, 1993.

"Cubic Equations of State for Modelling the Vapor-Liquid Equilibrium of Nonideal Mixtures: Role of the Mixing Rules" by H. Orbey and S. I. Sandler, Published by Cambridge University Press, 1998.

Papers: Approximately 350 papers in refereed journals.

National Reports: Co-author of 5 National Research Council reports of technologies for the disposal of armed weapons containing chemical and nerve agents.