Thomas William Fraser RUSSELL

Date of Birth: August 5, 1934
Place of Birth: Moose Jaw, Saskatchewan, CANADA
Citizenship: Dual-United States and Canada

PRESENT POSITION

Allan P. Colburn Professor Emeritus
Chemical Engineering, University of Delaware

EDUCATION

PhD (Chemical Engineering), University of Delaware, 1964
MSc (Chemical Engineering), University of Alberta, 1958
BSc (Chemical Engineering), University of Alberta, 1956

ACADEMIC EXPERIENCE

University of Delaware - Newark, Delaware
Allan P. Colburn Professor, 1981-2009
Vice Provost for Research, 2000-2005
Chief Engineer, Institute of Energy Conversion, 1996-2009
Director, Institute of Energy Conversion, 1979-1995
Chairman, Department of Chemical Engineering, 1986-1991
Acting Dean, College of Engineering, 1978-1979
Associate Dean, College of Engineering, 1974-1977
Professor of Chemical Engineering, 1970-1981
Associate Professor of Chemical Engineering, 1967-1970
Assistant Professor of Chemical Engineering, 1964-1967

HONORS AND AWARDS

AIChE Warren K Lewis Award 2010
Honorary Doctor of Science University of Delaware 2010
ASEE Chemical Engineering Division Lifetime Achievement Award in Chemical Engineering Pedagogical Scholarship 2009
Alumni Wall of Fame, University of Delaware, 2006
Engineering Excellence Award (Du/Pont), 2005
Fellow, American Institute of Chemical Engineers (AIChE), 1995
Member, National Academy of Engineering, 1990
Francis Alison Award (University of Delaware), 1990
AIChE Wilmington Section Thomas H. Chilton Award, 1988
AIChE Award in Chemical Engineering Practice, 1987
ASEE Chemical Engineering Division 3M Lectureship Award, 1984
ACS Leo Friend Award (CHEMTECH), 1982
Allan P. Colburn Professor of Chemical Engineering, 1981
Excellence in Teaching Award (University of Delaware), 1968

PROFESSIONAL ASSOCIATIONS

Registered Professional Engineer, Delaware (4946)
Member, American Chemical Society (ACS)
Fellow, American Institute of Chemical Engineers (AIChE)
Member, American Society for Engineering Education (ASEE)

ADMINISTRATIVE EXPERIENCE

Board of Directors, Ascent Solar Technologies Inc.
Denver Colorado
2005-2010

Vice Provost for Research Office
University of Delaware
2000-2005

The Office of the Vice Provost for Research serves as an advocate for persons in the University Community who are interested in identifying, applying for, receiving, and conducting research with support from government and non-government sponsors, and in assisting administrators with the stewardship of research funds and equipment.

This office is also concerned with intellectual property issues and the transfer of technology from university laboratories into the commercial sector. This is accomplished with 19 professional staff and 5 salaried staff.

Chairman
Department of Chemical Engineering
University of Delaware
1986-1991

The Department of Chemical Engineering is ranked in the top five departments in the United States. It has 20 faculty, some 120 graduate students and some 270 undergraduates.

The Chairman is responsible to the Faculty and the University for the Department's educational programs of teaching and research and fiscal management of the Department.

Director
Institute of Energy Conversion (IEC)
University of Delaware
1979 - 1995

The Institute of Energy Conversion is a laboratory devoted to thin-film photovoltaic cell research. It has a staff of some 30 persons and a yearly budget raised from sources outside the University between 1.5 and 2.0 million dollars. It is the largest academic laboratory in the U.S. doing solar cell research. In the past decade it has published over 300 papers, has had 19 patents issued, and has provided extensive experience for some 50 professionals who are now working in the evolving photovoltaic industry. IEC researchers produced the first thin-film solar cell to exceed 10% efficiency, and they have now achieved between 10% and 15% efficiency with four different cell materials. They were first to show that the semiconductor layers of a polycrystalline solar cell could be deposited continuously on a moving substrate.

IEC was designated as a University Center of Excellence for Photovoltaic Research and Education by the Department of Energy and the National Renewable Energy Laboratory in August 1992. There are only two such centers in the United States.

Associate Dean, Acting Dean
College of Engineering
University of Delaware
1974-1977, 1978-1979

The College of Engineering has four departments: Chemical, Civil, Mechanical, and Electrical with fifty-seven faculty and eighty-one professional and other staff. The Dean and the Associate Dean are responsible to the Faculty and the Provost for the educational programs of teaching and research and the fiscal management of the college.

Design and Project Engineer
Union Carbide Canada
Montreal, Quebec, Canada
1958-1961

Completion of the process design, design drafting and construction for the processing units described in Section VI required supervision of four professional engineers for a period of eight months; the supervision of a design drafting office with sixty personnel for a period of eight months; and supervision of various construction groups for a period of one year.

INDUSTRIAL EXPERIENCE

FULL-TIME EMPLOYMENT

UNION CARBIDE CANADA
Montreal, Quebec, Canada
June 1958-September 1961

A design engineer during a period of extensive expansion of Union Carbide's Montreal East facilities, with complete responsibility for economic evaluation, process design, drafting, field construction, and start-up for the following units:

Ethylene Glycol Unit
Multi-Purpose Glycol Ethers and Ethanolamines Unit

The above work resulted in some $2,800,000 worth of capital expenditure (1960 dollars) and was the first multi-purpose continuous processing unit in Canada. (Publications 3, 4, 5)

RESEARCH COUNCIL OF ALBERTA
Edmonton, Alberta, Canada
May 1956-June 1958

A research engineer studying liquid-liquid flow as part of the development work on the Athabasca tar sands. (Publications 1, 2)

BRITISH AMERICAN OIL COMPANY
Edmonton, Alberta, Canada
May - September 1953 - Shift Chemist
May - September 1954 - Refinery Operator
May - September 1955 - Design Engineer

CONSULTING

E. I. DU PONT DE NEMOURS
Wilmington, Delaware
1968-1998

This consulting contract was with the Engineering Service Division, the internal consulting group for the DuPont Company. Contact averages one day per week. Consultation is provided for multi-phase processing problems in both a research and engineering context. A number of two-phase reactor design and two-phase piping design problems have been successfully solved and appropriate changes in the equipment and systems made.

PFIZER (Minerals, Pigments, and Metals Division)
Easton, Pennsylvania
1975-1984

Under this contract a complete analysis of the design and operation of Pfizer's multi-phase precipitated calcium carbonate process was completed.

ETHYL CORPORATION
Baton Rouge, Louisiana
1973-1975

This contract required five two-day visits per year to consult on a variety of chemical engineering research and design problems.

UNION CARBIDE CANADA
Montreal, Quebec
1962-1969

Under this contract all process design work for the ethylene oxide derived chemical units in Union Carbide's Montreal East Plant was completed. In addition extensive consultation was provided on reactor design and analysis for a low pressure polyethylene process and a phenol formaldehyde process. Contact averaged one day per week for seven years.

OTHER:

Consultation with the following firms was done for specific projects. Contact ranged from a few days to a few months.

American Cyanamid - Stamford, Connecticut
Avco-Everett - Boston, Massachusetts
Chevron Research Company - Richmond, California
Cadwalader, Wickersham & Taft (Attorneys) - New York, New York
Ciba-Geigy - Basel, Switzerland
CRDEC Aberdeen Proving Ground - Aberdeen, Maryland
Hoffman-LaRoche - Basel, Switzerland
Institute of Waste Water Treatment - Stuttgart, Germany
JRB Associates - Richmond, Virginia
McCarter & English (Attorneys)– Newark, NJ
Miles Laboratory - Elkhart, Indiana
Omega Chemical - Wilmington, Delaware
Smith Kline Chemical - Conshohocken, Pennsylvania
Sun Oil Company - Marcus Hook, Pennsylvania
Research Corp. of the University of Hawaii - Honolulu, HI
Research Triangle Institute, Research Triangle Park, NC
Roy F. Weston, West Chester, Pennsylvania

RESEARCH ACTIVITY

SEMICONDUCTOR CHEMICAL REACTOR ENGINEERING AND PHOTOVOLTAIC UNIT OPERATIONS

This is a cooperative research effort between the Institute of Energy Conversion and the Department of Chemical Engineering at the University of Delaware. Chemical reactor and reaction engineering procedures are applied to electronic material processing problems with particular emphasis on the analysis of semiconductor deposition reactors. Amorphous silicon and three polycrystalline semiconductor materials are currently being studied. Theoretical and experimental research is being carried out at the laboratory and unit operations scale. This latter effort is directed toward photovoltaic cell manufacture and develops the information needed for commercial-scale design.

MULTI-PHASE FLUID MECHANICS AND GAS-LIQUID SYSTEM DESIGN

This research program under initial sponsorship by the National Science Foundation and the Design Institute for Multiphase Processing, (DIMP) has three parts:

1. Studies of Fundamental Fluid Mechanics

   Theoretical and experimental work is carried out to increase understanding of basic fluid motions. To date, studies have been completed on droplet formation, movement and deposition, on bubble formation, bubble size and movement, and on liquid circulation patterns in both tank-type and tubular devices.

2. Application

   Procedures for the design of commercial-scale gas-liquid tank-type and tubular reactors are under development and a number have been tested and proven on commercial-scale equipment. A tubular gas-liquid fermenter has been designed, built and tested and procedures have been developed for large-scale fermenter design.

   A complete process design for the treatment of domestic sewage in two-phase pipelines has been completed and two large-scale field tests have been completed by others.

PhD THESES SUPERVISED

Eighteen students have completed a PhD thesis under my direction. The titles, dates, and students involved are listed in Appendix A.

MChE THESES SUPERVISED

Thirty-six MChE theses have been completed. The details are given in Appendix B.

PUBLICATIONS

BOOKS

1. "Introduction to Chemical Engineering Analysis," T. W. F. Russell and M. M. Denn, J. Wiley (1972).

2. "Structure of the Chemical Processing Industries: Function and Economics," J. Wei, T. W. F. Russell, and M. W. Swartzlander, McGraw-Hill (1978).

3. " Mass and Heat Transfer Analysis of Mass Contactors and Heat Exchangers," T W Fraser Russell, Anne Skaja Robinson, Norman J Wagner, Cambridge Press (2008)

BOOK CHAPTERS

1. "Heat Transfer in Tubular Fluid-Fluid Systems," G. E. O'Connor and T. W. F. Russell, Advances in Chemical Engineering, Academic Press (1978).

2. "Two Phase Gas Liquid Flow," T. W. F. Russell and M. M. Denn in Process Fluid Mechanics, M. M. Denn, Prentice-Hall, Inc. (1980).

3. "Chapter 12, Chemical Engineering in Electronic Material Processing Design and Development," Frank Vilbrandt Memorial Volume on Recent Developments in Chemical Process and Plant Design, T. W. F. Russell, Wiley, (1987).

4. "Physical Vapor Deposition Reactors," T. W. F. Russell, Bill N. Baron, Scott C. Jackson and Richard E. Rocheleau, in Advances in Chemistry Series No. 221, Microelectronics Processing: Chemical Engineering Aspects, Chapter 4 (1989).

5. "Energy and Environmental Concerns," T.W.F. Russell in Advances in Chemical Engineering Volume 16, Perspectives in Chemical Engineering, Research and Education, Chapter 14 (1991).

TECHNICAL PAPERS

1. "Horizontal Pipeline Flow of Mixtures of Oil and Water," T. W. F. Russell, G. W. Hodgson, and G. W. Govier, Canadian Journal of Chemical Engineering, Vol. 37, p. 9 (February 1959).

2. "The Effect of the Less Viscous Liquid in the Laminar Flow of Two Immiscible Liquids," T. W. F. Russell and M. E. Charles, Canadian Journal of Chemical Engineering, Vol. 37, p. 18 (February 1959).

3. "Plant Design for Multi-Purpose Use," T. W. F. Russell, Canadian Chemical Processing, Vol. 45, No. 12, p. 70 (December 1961).

4. "How to Design a Multi-Purpose Plant," T. W. F. Russell, Petro Process Engineering, p. 40 (March-April 1962).

5. "Flexible Design - Many Products from Union Carbide's Montreal Plant," T. W. F. Russell, Canadian Oil and Gas Industries (January 1963).

6. "Flow Mechanism of Two-Phase Annual Flow," T. W. F. Russell and D. E. Lamb, Canadian Journal of Chemical Engineering, Vol. 43, p. 327 (October 1965).

7. "Designing for Two-Phase Flow - Part I," R. J. Anderson and T. W. F. Russell, Chemical Engineering, p. 75 (December 6, 1965).

8. "Designing for Two-Phase Flow - Part II," R. J. Anderson and T. W. F. Russell, Chemical Engineering, p. 99 (December 20, 1965).

9. "Designing for Two-Phase Flow - Part III," R. J. Anderson and T. W. F. Russell, Chemical Engineering, p. 87 (January 3, 1966).

10. "Two-Phase Reactor Design, Tank-Type Reactors, R. W. Schaftlein and T. W. F. Russell, I&EC. Vol. 60, p. 12 (May 1968).

11. "Reactor Analysis and Process Synthesis for a Class of Complex Reactions," T. W. F. Russell and D. T. Buzzelli, I&EC Process Design & Development, Vol. 8, p. 2 (January 1969).

12. "Two-Phase Reactor Design Tubular Reactors - Reactor Model Development," P. T. Cichy, J. S. Ultman, and T. W. F. Russell, I&EC, Vol. 61, No. 8, p. 6 (August 1969).

13. "Two-Phase Reactor Design Tubular Reactors - Reactor Model Parameters," P. T. Cichy and T. W. F. Russell, I&EC, Vol. 61, No. 8, p. 15 (August 1969).

14. "Fluid Flow," T. W. F. Russell, McGraw-Hill Yearbook of Science and Technology (1969).

15. "Flow Configuration Transitions and Holdup in Gas-Liquid Horizontal Flow," T. W. F. Russell and A. W. Etchells, 19th Canadian Chemical Engineering Conference and Third Symposium on Catalysts Symposium Series (October 1969).

16. "Film Formation in Two-Phase Annular Flow," R. J. Anderson and T. W. F. Russell, AIChE Journal, Vol. 16, No. 4, p. 626 (July 1970).

17. "Circumferential Variation of Interchange in Horizontal Annular Two-Phase Flow," R. J. Anderson and T. W. F. Russell, I&EC Fundamentals, Vol. 9, p. 340 (August 1970).

18. "Product Distribution Problems in Gas-Liquid Reactors," T. W. F. Russell and R. Rothenberger, Chemical Reaction Engineering, Advances in Chemistry Series 109 (1972).

19. "Secondary Sewage Treatment in Pipeline Contractors," T. W. F. Russell, Canadian Journal of Chemical Engineering, Vol. 50, p. 179 (April 1972).

20. "Droplet Behavior in Horizontal Gas-Liquid Reactors," T. W. F. Russell and R. W. Rogers, AIChE Symposium Series No. 127, Vol. 69 (1973).

21. "Mass Transfer to Naturally Flowing Streams," V. M. Nadkarni and T. W. F. Russell, I&EC Process Design & Development, Vol. 12, p. 414 (October 1973).

22. "Pressure Drop and Holdup in Stratified Gas-Liquid Flow," T. W. F. Russell, A. W. Etchells, R. H. Jensen, and P. J. Arruda, AIChE Journal, Vol. 20, No. 4, p. 664 (July 1974).

23. "Feedback on Reaction Engineering Techniques," J. M. Douglas, T. R. Keane, R. M. Koros, W. H. Manogue, V. W. Weekman, and T. W. F. Russell, Chemical Engineering Progress, Vol. 70, no. 7, p. 31 (July 1974).

24. "The Tubular Loop Batch Fermenter: Basic Concepts," T. W. F. Russell, I. J. Dunn and H. W. Blanch, Biotechnology and Bioengineering, Vol. XVVI, p. 1261 (1974).

25. "Horizontal Bubble Flow," T. L. Holmes and T. W. F. Russell, International Journal of Multiphase Flow, Vol. 2, p. 51 (1975).

26. "The Recycling Index," T. W. F. Russell and M. W. Swartzlander, Chemical Technology, Vol. 6, p. 32 (January 1976).

27. "The Tubular Loop Fermenter: Oxygen Transfer, Growth Kinetics and Design," H. Ziegler, D. Meister, I. J. Dunn, H. W. Blanch, and T. W. F. Russell, Biotechnology and Bioengineering, Vol. XIX, p. 507 (1977).

28. "The Design of Gas-Sparged Devices for Viscous Liquid Systems," S. M. Bhavaraju, T. W. F. Russell, and H. W. Blanch, AIChE Journal, Vol. 24, No. 3, p. 454 (May 1978).

29. "Chemical Recycle Can Save Energy," P. K. Mathur and T. W. F. Russell, Hydrocarbon Processing, p. 89 (July 1978).

30. "Two-Phase Process Design," T. W. F. Russell and R. N. Pratt, Computers & Chemical Engineering, Vol. 3, p. 437 (1979).

31. "Testing Process Designs by Their Simulated Performance in the Market Place," T. W. F. Russell, Computers & Chemical Engineering, Vol. 3, p. 455 (1979).

32. "A Low-Cost Manufacturing Process for Thin-Film Solar Cells," T. W. F. Russell, A. M. Barnett, B. N. Baron, J. V. Masi, and R. E. Rocheleau, Proc. of the 14th Photovoltaic Specialists Conference, San Diego, p. 354 (January 1980).

33. "Applying Microeconomics to Process Design," T. W. F. Russell and Ricardo J. Bogaert, I&EC Process Design & Development, Vol. 19, p. 282 (April 1980).

34. "Technology Considerations for Thin-Film Solar Cells," V. L. Dalal, B. N. Baron, and T.W. F. Russell, Proc. of the 1980 Annual Meeting of the American Section of the International Solar Energy Society, Phoenix, Vol. 3.2, p. 981 (June 1980).

35. "Bubble Coalescence and Break-Up in Fermentations," Christopher McBride, James Walter, Harvey W. Blanch, and T. W. F. Russell, Advances in Biotechnology, Proc. of the 6th International Fermentation Symposium, London, Canada, Vol. 1, p. 489 (July 1980).

36. "The Need for Photovoltaic Unit Operations Experimentation," T. W. F. Russell, B. N. Baron, and R. E. Rocheleau, Proc. of the Third European Communities Photovoltaic Solar Energy Conference, Cannes, France, p. 348 (October 1980).

37. "The Potential for Thin-Film Photovoltaic Cells," T. W. F. Russell and V. L. Dalal, IEEE Transactions on Education, Vol. E-24, No. 3, p. 239 (August 1981).

38. "Commercial-Scale Process Design for Thin-Film Solar Cells," T. W. F. Russell, B. N. Baron, and R. E. Rocheleau, AIChE Symposium Series: Fundamentals and Applications of Solar Energy Part II, p. 70 (1981).

39. "Continuous Deposition of Photovoltaic-Grade CdS Sheet at the Unit Operations Scale," R. E. Rocheleau, P. J. Lutz, D. F. Brestovansky, B. N. Baron, and T. W. F. Russell, Proc. of the Fourth European Communities Photovoltaic Solar Energy Conference, Stresa, Italy, p. 798 (May 10-14, 1982).

40. "Analysis of Evaporation of Cadmium Sulfide for Manufacture of Solar Cells," R. E. Rocheleau, B. N. Baron and T. W. F. Russell, AIChE Journal, Vol. 24, No. 4, p. 656 (July 1982).

41. "Photovoltaic Unit Operations," T. W. F. Russell, CHEMTECH, Vol. 12, p. 540 (September 1982).

42. "Properties of Continuously-Deposited Photovoltaic-Grade CdS," T. W. F. Russell, R. E. Rocheleau, P. J. Lutz, D. F. Brestovansky, and B. N. Baron, Proc. of the 16th IEEE Photovoltaic Specialists Conference, San Diego, p. 743 (September 1982).

43. "Designing Gas-Sparged Vessels for Mass Transfer," J. N. Tilton and T. W. F. Russell, Chemical Engineering (November 29, 1982).

44. "Analysis of the Rate of Vaporization of CuCl for Solar Cell Fabrication," D. F. Brestovansky, B. N. Baron, R. E. Rocheleau, and T. W. F. Russell, J. Vac. Sci. Technol. A., p. 28 (January-March 1983).

45. "Thin-Film Photovoltaic Systems," T. W. F. Russell, Proc. of the DOE Annual Photovoltaic Program Review, Arlington, p. 73 (February 1983).

46. "Large-Scale Production Process," T. W. F. Russell, Proc. of the DOE Photovoltaic Advanced Research & Development 5th Annual Review Meeting, Denver, p. 107 (May 1983).

47. "Commercial-Scale Processing Potential for Thin-Film Photovoltaic Systems," T. W. F. Russell, B. N. Baron, and R. E. Rocheleau, Proc. of the Fifth European Communities Photovoltaic Solar Energy Conference, Athens, Greece, p. 835 (October 1983).

48. "Polycrystalline Thin-Film Solar Cells," T. W. F. Russell and J. E. Phillips, Solar Cells, 12, p. 185 (1984).

49. "Chemical Reaction Engineering in Photovoltaic Cell Processing," T. W. F. Russell, 1. Chem. E. Symposium Series, No. 87, p. 271 (1984).

50. "Economics of Processing Thin-Film Solar Cells," T. W. F. Russell, B. N. Baron, and R. E. Rocheleau, J. Vac. Sci. Technol. B 2, 4, Oct-Dec 1984, p. 840.

51. "Some Observations on Flow Patterns in Tank-Type Systems," Z. Otero, J. N. Tilton, and T. W. F. Russell, in J. Multiphase Flow Vol. 11, No. 4, pp. 583-589 (1985).

52. "Semiconductor Chemical Reactor Engineering and Photovoltaic Unit Operations," T. W. F. Russell, in Chemical Engineering Education, ASEE, Spring p. 72-108 (1985).

53. "Molecular Beam Distributions From High Rate Sources," S. C. Jackson, B. N. Baron, R. E. Rocheleau, and T. W. F. Russell, in J. Vac. Sci. Technol. A3(5), p. 1916-1920 (1985).

54. "Flow Patterns in Gas-Sparged Vessels," T. W. F. Russell, Z. Otero, J. N. Tilton, U. Y. Choi, and R. P. Hesketh, AIChE Design Institute for Multiphase Processing Design Manual TFP-1, AIChE, New York, NY.

55. "Liquid Circulation in Gas-Sparged Vessels," T. W. Russell, Z. Otero, J. N. Tilton, U. Y. Choi, and R. P. Hesketh, AIChE Design Institute for Multiphase Processing Design Manual LC-1, AIChE, New York, NY.

56. "Design of Commercial Scale Gas-Liquid Contactors," Z. Otero Keil and T. W. F. Russell, in AIChE Journal, 33 (3), p. 488-496 (March 1987).

57. "Bubble Size in Horizontal Pipelines," R. P. Hesketh, A. W. Etchells, and T. W. F. Russell, in AIChE Journal, 33 (4), p. 663-667 (April 1987).

58. "A Chemical Reaction Model for Physical Vapor Deposition of Compound Semiconductor Films," S. C. Jackson, B. N. Baron, R. E. Rocheleau, and T. W. F. Russell, in AIChE Journal, 33(5), p. 711-721 (May 1987).

59. "Chemical Vapor Deposition of Zinc Phosphide Thin Films," E. Papazoglou and T. W. F. Russell, in Journal of Vacuum Science and Technology, A5(6), p. 3378-3382 (Nov/Dec 1987).

60. "Microeconomic Predictions for Design Strategy Compared with Case Histories," D. F. Brestovansky, D. W. T. Rippin, and T. W. F. Russell, I&EC Research 25, p. 2509-2515 (1987).

61. "Effects of Hydrogen Radicals on the Composition and Hydrogen Bonding of Amorphous Silicon-Germanium Thin Films," T. W. F. Russell, C. M. Fortmann, D. E. Albright, Proc. of the 1989 Materials Research Society Symposium on Amorphous Silicon Technology, April 24-29, San Diego.

62. "Microcrystallinity in a-Si and a-SiC Films Made by Hg-Sensitized Photo-CVD," C. M. Fortmann, N. Saxena, T. W. F. Russell, Proc. of the 1989 Materials Research Society Symposium on Amorphous Silicon Technology, April 24-29, San Diego.

63. "Temperature Dependence of H Radical Etching in the Deposition of Microcrystalline Silicon Alloy Thin Films by Hg-Sensitized Photo-CVD," N. Saxena, C. M. Fortmann, T. W. F. Russell, and D. E. Albright, Journal of Non-Crystalline Solids, 114, p. 801-803, North Holland Publishing Co. (1989).

64. "Stable High Efficiency Amorphous Silicon Based Solar Cells," B. N. Baron, C. M. Fortmann, S. S. Hegedus, W. A. Buchanan, D. E. Albright, N. Saxena, T. X. Zhou, and T.W. F. Russell, Proc. of the 9th European Photovoltaic Solar Energy Conference, Freiburg, Germany, p. 56, September 25-29, 1989.

65. "Reactor Analysis of Copper Indium Selenization," R. D. Varrin, Jr., S. Verma, R. W. Birkmire, B. E. McCandless, and T. W. F. Russell, Proc. of the 21st IEEE PV Specialists Conference, Kissimmee, Florida, p. 529, May 21-25, 1990.

66. "Auger Line Shape and Electron Energy Loss Spectroscopy Analysis of Amorphous, Microcrystalline, and b-SiC," A. J. Nelson, A. R. Mason, A. B. Swartzlander, L. L. Kazmerski, N.

Saxena, C. M. Fortmann, and T. W. F. Russell, J. Vac. Sci. Technol. A, Vol. 8, No. 3, p. 1538-1543, May/June 1990.

67. "Mercury-Sensitized Photochemical Vapor Deposition of Amorphous Silicon," D. E. Albright, N. Saxena, C. M. Fortmann, R. E. Rocheleau, and T. W. F. Russell, AIChE Journal, Vol. 36, No. 10, p. 1555-1561, October 1990.

68. "Bubble Breakage in Pipeline Flow," R. P. Hesketh, A. W. Etchells, and T. W. F. Russell, Chemical Engineering Science, Vol. 46, No. 1, p. 1-9 (1991).

69. "Chemical Vapor Deposition of Hydrogenated Amorphous Silicon from Disilane," R. J. Bogaert, T. W. F. Russell, and M. T. Klein, J. Electrochem. Soc., Vol. 136, No. 10, p. 2960-2968, October 1989.

70. "CuInSe2 and CdTe Solar Cells--Inexpensive Electric Power Generation," T. W. F. Russell, Proc. of the Fourth International Symposium on Uses of Selenium and Tellurium, May 8-10, 1989, Banff, Alberta, Canada.

71. "Experimental Observations of Bubble Breakage in Turbulent Flow," R. P. Hesketh, A. W. Etchells, and T. W. F. Russell, I&EC Research, Vol. 30, No. 5, p. 835-841, 1991.

72. "Critical Process Issues in Selenization," S. Verma, R. D. Varrin, Jr., R. W. Birkmire and T. W. F. Russell, Proc. 22nd IEEE Photovoltaic Specialists Conf., Las Vegas, NV, October 7-11, 1991.

73. "Polycrystalline Heterojunction Solar Cells: Processing Perspective," R. W. Birkmire, S. S. Hegedus, B. E. McCandless, J. E. Phillips, T. W. F. Russell, W. N. Shafarman, S. Verma, S. Yamanaka, Proc. PV Advanced Research and Development Project 11th Review Mtg., Denver, CO, May 13-15, 1992, AIP Conf. Proc. 268, ed. Rommel Noufi, p. 212.

74. "Reaction Pathways to CuInSe2 Formation by Selenization," S. Verma, S. Yamanaka, R. W. Birkmire, B. E. McCandless, T. W. F. Russell, Proc. 11th European PV Solar Energy Conf., Montreaux, Switzerland, p. 807, October 12-17, 1992.

75. "The Effect of O2 on H2Se Selenization in a Continuous Flow Reactor," S. Verma, T.W.F. Russell, and R. W. Birkmire, Proc. 23rd IEEE Photovoltaic Specialists Conf., Louisville, KY, May 10-14, 1993.

76. "Chemical Process and Device Analysis of CuInSe2-Based Solar Cell Materials," TWF Russell, R.W. Birkmire, J.E. Phillips, S. Verma and W.N. Shafarman, AIP Conf. Proc. 306, 390 (1993).

77. "Structure and Chemistry of CuInSe2 for Solar Cell Technology: Current Understanding and Recommendations," A. Rockett, T. W. F. Russell et al., Thin Solid Films, 237 (1994) 1-11.

78. "Chemical Kinetic Studies of Copper Indium Selenization," T. W. F. Russell, S. Verma, R. W. Birkmire, Proc. 12th European PV Solar Energy Conf. 1, 633 (1994).

79. "A Chemical Kinetic Analysis of the Formation of CuInSe2 at Different Temperatures," T. W. F. Russell, N. Orbey, R. W. Birkmire, Proc. 1st World Conf. on Photovoltaic Energy Conversion, Waikoloa, Hawaii, December 5-9, 1994, p. 238 (1995).

80. "Chemical Reaction Analysis of Copper Indium Selenization," S. Verma, N. Orbey, R. W. Birkmire and T. W. F. Russell, Progress in Photovoltaics, 4, 341-353 (1996).

81. "Reaction Analysis of the Formation of CIS at Temperatures from 250 to 400˚C," N. Orbey, H. Hichri, R.W. Birkmire, & TWF Russell, Proc. 25th IEEE Photovoltaic Specialists Conf., 981 (1996).

82. "Technology Development Versus New Ideas Development by Universities," Russell, T.W.F., First Generation Photovoltaic Technologies: First NREL Conference, AIP Conf. Proc., 1997, pp. 93-99.

83. "Effect of Temperature on Copper Indium Selenization," N. Orbey, H. Hichri, R.W. Birkmire, and T.W.F. Russell, Progress in Photovoltaics 5, 237-247 (1997).

84. "Reaction Analysis of the Formation of CuInSe2 Films in a Physical Vapor Deposition Reactor," N. Orbey, G. Norsworthy, R.W. Birkmire, and T.W.F. Russell, Prog. Photovolt. Res. Appl. 6, 79-86 (1998). August 1997.

85. "Effect of Reduced Deposition Temperature, Time and Thickness on Cu(InGa)Se2 Films and Devices", W.N. Shafarman, R.W. Birkmire, S. Marsillac, M. Marudachalam, N. Orbey, and T.W.F. Russell, Proc. 26th IEEE PVSC, 331 (1997).

86. "Design of Critical Experiments for Scale-up," T.W.F. Russell, V. Dalal, R. Gay and S. Guha, Progress in Photovoltaics 5, 353-357 (1997).

87. "Copper Indium Alloy Transformations," N. Orbey, G.A. Jones, R.W. Birkmire, and T.W.F. Russell, Journal of Phase Equilibria, Vol. 21, No. 6, 509-513 (2000).

88. "Process Analysis and Modeling of Thin Silicon Film Deposition by Hot-Wire Chemical Vapor Deposition," R. Aparicio, R. Birkmire, A. Pant, M. Huff, TWF Russell and M. Mauk, 16th European Photovoltaic Solar Energy Conference and Exhibition, Glasgow, UK (May 1-5, 2000).

89. "Hot-Wire Chemical Vapor Deposition of Silicon from Silane: Effect of Process Conditions," A. Pant, T.W.F. Russell, M. Huff, R. Aparicio, and R. Birkmire, Industrial & Engineering Chemistry Research, Vol. 40, No. 5, 1377-1385 (2001).

90. "Reactor and Reaction Model for the Hot-Wire Chemical Vapor Deposition of Silicon from Silane," A. Pant, M. Huff, T.W.F. Russell, Industrial & Engineering Chemistry Research, Vol. 40, No. 5, 1386-1396 (2001).

ENGINEERING EDUCATIONAL RESEARCH PAPERS

1. "Introduction to ChE Analysis," T. W. F. Russell and M. M. Denn, Chemical Engineering Education, p. 117 (Summer 1973).

2. "Learning About Engineering Through Design - Booklet I," T. W. F. Russell (January 1976).

3. "Internship in Chemical Engineering Design," T. W. F. Russell and H. E. Turner, Chemical Engineering Education, p. 74 (Spring 1977).

4. "Biochemical Engineering," H. W. Blanch and T. W. F. Russell, Chemical Engineering Education, p. 170 (Fall 1977).

5. "Can We Limit Enrollment by Professional Society Action?" T. W. F. Russell and R. L. Daugherty, Chemical Engineering Education, p. 41 (Winter 1977).

6. "Teaching the Basic Element of Process Design with a Business Game," T. W. F. Russell and D. S. Frankel, Chemical Engineering Education, p. 18 (Winter 1978).

7. "The Structure of the Chemical Processing Industries," T. W. F. Russell, Chemical Engineering Education, p. 194 (Fall 1979).

8. "Estimating Undergraduate Student Capacity for an Engineering Department," T. W. F. Russell, R. L. Daugherty, and A. F. Graziano, Insights into Engineering Education Administration, a monograph by ASEE Publications Committee (1980).

9. "Simulation of the Manufacture of a Chemical Product in a Competitive Environment," T. W. F. Russell, D. F. Brestovansky, and R. L. McCullough, Chemical Engineering Education, p. 76 (Spring 1982).

10. "Technically Feasible Design," T. W. F. Russell and N. Orbey, Chemical Engineering Education, (1992).

11. "DuPont Teaching Fellow Program," T. W. F. Russell, Chemical Engineering Education, (1993).

PATENTS

A. U.S. Patent No. 4,318,938 - "Method for the Continuous Manufacture of Thin-Film Solar Cells" - Allen M. Barnett, Bill N. Baron, James V. Masi, and T. W.F. Russell (issued March 9, 1982).

B. U.S. Patent No. 4,325,986 - "Method for the Continuous Deposition of Vacuum Evaporation" - Bill N. Baron, Richard E. Rocheleau, and T. W. F. Russell (issued April 20, 1982).

C. U.S. Patent No. 4,401,052 - "Apparatus for Continuous Deposition by Vacuum Evaporation" - Bill N. Baron, Richard E. Rocheleau, and T. W. F. Russell (issued August 30, 1983).

D. U.S. Patent No. 6,310,281 – "Thin-Film, Flexible Photovoltais Module" – R.G. Wendt; G.M. Hanket, R.W. Birkmire, T.W.F. Russell (issued October 30, 2001).

E. "Thin-Film, Flexible Photovoltaic Module" – R.G. Wendt, G.M. Hanket, R.W. Birkmire, T.W.R. Russell (filed by Tucson Electric – S.N. 09/527,316; filing date – 3/16/00).

F. "Vapor-Phase, Plural-Constituent, Co-Deposition Environment for Production of Thin-Film Device Layer" – R.Wendt, G.M. Hanket, R.W. Birkmire, T.W.F. Russell (filed by Tucson Electric – S.M. 09/613,950; filing date – 7/11/00).

G. "System for Creating Vapor-Phase, Plural Constituent, Co_Deposition Environment for Production of Thin-Film Device Layer" – R. Wendt, G. M. Hanket, R. W. Birkmire, T.W. F. Russell (filed by Tucson Electric – S.M. 09/614,532, filing date – 7/11/00).

EDUCATIONAL DEVELOPMENT ACTIVITY

PROGRAMS DEVELOPED

The following programs were personally initiated, developed, and made an integral part of the graduate and undergraduate programs in the College of Engineering. (Publications, Section C)

1. Intern Program (1974 to 1983)

   A graduate level program designed to provide an alternative to the usual master's level research. Students in the program learn about the art as well as the science of engineering by combining graduate level course work with an internship served under an experienced engineer in local industrial organizations. Contracts were signed with E. I. duPont de Nemours and Company, Mobil Research and Development Corporation, Union Carbide Corporation, Sun Company, Inc. and Smith Kline.

2. Master's Degree Program for Chemists

   A special set of self-study techniques and regularly scheduled classes are used in this program so that persons with a bachelor's degree in chemistry can obtain a master's degree in chemical engineering in two years.

3. Partnership Program for Chemical Process Design (1968-present)

   In this continuing arrangement an experienced design engineer is appointed for a two-year term as an adjunct professor to enable him to teach half of the senior level course in process design. The technique has been highly successful educationally and is an effective way to utilize talents and skills of persons outside the University. It is now in its twenty-fifth year of a most successful operation.

4. Bachelor's-Master's Program

   A program designed so that exceptional undergraduate students can obtain a combined graduate and undergraduate degree in a four-year period.

COURSES DEVELOPED

1. Introduction to Chemical Engineering Analysis

   A complete revision of the undergraduate curriculum in chemical engineering was undertaken and a totally new sophomore year course designed. This work resulted in the publication of a new text: "Introduction to Chemical Engineering Analysis," T. W. F. Russell and M. M. Denn, John Wiley, 1972.

2. Engineering Analysis for Non-Engineers

   This course was designed to show students whose major is outside engineering how engineers solve problems. The course has been successful in attracting students from chemistry, biological sciences, mathematics, computer science, and economics.

3. Engineering Analysis for Chemists and Other Professionals

   This course was developed both in the university and as a continuing education course for practicing chemists in both the United States and Switzerland.

4. The Structure of the Chemical Processing Industries

   A course developed to broaden the scope of chemical engineering students and practitioners by examining the organization and use of resources in chemical manufacturing, the economic and social-political forces that affect the chemical process industry and the need of industry to adapt to these influences to survive. A text, "The Structure of the Chemical Process Industries-Function and Economics" by J. Wei, T. W. F. Russell, and M. W. Swartzlander, McGraw-Hill, 1978 was developed to meet the needs of this course.

5. Fluid-Fluid System Design

   An upper level graduate course developed to show how both tank-type and tubular gas-liquid and liquid-liquid systems are designed.

6. Biochemical Engineering

   An upper level graduate course in which the fundamentals of gas-liquid fluid mechanics are applied to the design of biochemical reactors.

TEACHING ACTIVITY

TEACHING EVALUATION AND AWARDS

1. Consistently rated as one of the most effective teachers in the department.

2. Excellence in Teaching Award - May 2, 1968
   This $1,000 award was presented to seven faculty members with five years' or less of full-time college teaching experience on the basis of (1) outstanding classroom performance; (2) contribution to circular development; and (3) effective advisement of students.

COURSES TAUGHT

1. Undergraduate (University of Delaware)

   EG 125 Introduction to Engineering
   ChE 009 Freshman Seminar
   ChE 112 Introduction to Chemical Engineering
   ChE 230 Industrial Stoichiometry
   ChE 231 Introduction to Chemical Engineering Analysis
   ChE 342 Heat and Mass Transfer
   ChE 431 Kinetics and Reactor Design
   ChE 432 Chemical Process Analysis
   ChE 433 Transfer Operations
   ChE 530 Introduction to Engineering Analysis

2. Graduate (University of Delaware)

ChE 620 Biochemical Engineering
ChE 677 Biological Waste Water Treatment
ChE 690 Structure of the Chemical Processing Industries
ChE 831 Advanced Topics in Fluid Mechanics
ChE 835 Chemical Engineering Kinetics
ChE 836 Advanced Topics in Kinetics and Reactor Design
ChE 867 Special Topics in Two-Phase Flow
ChE 881 Optimal Process Design
ChE 882 Design of Gas-Liquid Systems
ChE 667 Chemical Engineering for Advanced Electronics

3. Industrial "In-House" Courses

The following courses were taught by invitation of the companies listed.

a. Union Carbide Canada
Chemical Engineering Kinetics, 1964
Chemical Equilibrium Thermodynamics, 1965

b. Houdry Chemical and Processing
Chemical Engineering Kinetics, 1965

c. Sun Oil Company
Chemical Engineering Kinetics, 1965

d. Scott Paper
Introduction to Chemical Engineering Analysis, 1968

e. E. I. duPont de Nemours & Company
Design and Analysis of Fluid-Fluid Systems, 1969
Process Chemistry, 1971, 1973
Chemical Engineering Analysis for Chemists and Other Professionals, 1974, 1978

f. Group of Swiss Chemical Companies
Chemical Engineering Analysis for the Chemical Industry, 1973, 1974

g. IMP-Pemex (Mexico)
Structure of the Chemical Processing Industries, 1980

4. Professional Society Courses

   a. American Institute of Chemical Engineers (AIChE)
      Introduction to Chemical Engineering, 1968, 1969
      Structure of the Chemical Processing Industries, 1972, 1977

   b. Delaware Valley Section, AIChE
      Introduction to Chemical Engineering Analysis, 1969
      Structure of the Chemical Processing Industries, 1977

   c. South Jersey Chapter, AIChE
      Introduction to Chemical Engineering Analysis, 1966
      Optimal Process Design, 1968
      Kinetics and Reactor Design, 1969

   d. American Chemical Society (ACS)
      Chemical Engineering Analysis for Chemists, 1974

ACADEMIC SERVICE

UNIVERSITY COMMITTEES

1. Member, Student Activities Committee (1965-1967)
2. Chairman, Student Activities Committee (1968)
3. Member, Committee on Judicial Reform (1967-1969)
4. Member, Special Advisory Committee to Vice-President for Student Affairs (1968-1970)
5. Member, Committee on Undergraduate Education (1970-1972)
6. Member, President's Advisory Council (1970-1972)
7. Member, Committee on Promotion and Tenure (1971)
8. Member, Committee on Innovation and Planning (1973-1974)
9. Chairman, Committee on Innovation and Planning (1974-1978)
10. Member, Coordinating Committee on Education (1974-1978)
11. Member, Committee to Evaluate the Office of Alumni Relations (1980-1981)
12. Deans Advisory Council (1986 - present)
13. President's Task Force on Centers and Institutes (1988)
14. Electric Power Partners Program Advisory Board (1988)
15. Presidential Search Committee, Chairman, Faculty Advisory Committee (1990 - 1991)
16. Rise Director Search Committee (1992)
17. Provost's Advisory Committee on Promoting Excellence in Teaching (1992)

PROFESSIONAL SERVICE

1. Member, AIChE Education and Accreditation Committee Accreditation Board for Engineering and Technology, 1987 - Present.
   This committee is responsible for visiting Chemical Engineering departments and evaluating their programs for accreditation purposes.

2. Co-chairman, ASEE Summer School for Chemical Engineering Faculty, 1982
   This summer school has been held every five years since 1939 and is designed to acquaint faculty with new developments in chemical engineering education. It requires a budget of some $120,000 which was raised by an appeal to industrial firms.

3. Solar Electric Research Division Science and Technology Review Committee, National Renewable Energy Laboratory (NREL) (formerly Solar Energy Research Institute, (SERI)), 1983 - 1996
   This committee reviews photovoltaic research programs on a regular basis and makes recommendation to NREL management.

4. Member, National Research Council Committee to Survey Chemical Engineering, 1985 -1987

5. Member, AIChE Awards Committee, 1989 - 1993
   Chairman, Professional Progress Award Committee, 1992

6. Director, Council for Photovoltaic Research (CPR), 1988 - 1995
   The Council provides a voice for the photovoltaic research community in establishing federal energy policy.

Revised 04/24/2012

APPENDIX A - PhD THESES SUPERVISED

1. "Characteristics of the Gas Liquid Interface in Two-Phase Annular Flow," R. W. Swanson, June 1966.

2. "Interchange in Horizontal Annular Two-Phase Flow," R. J. Anderson, June 1968.

3. "Stratified Horizontal Two-Phase Flow in Pipe," A.W. Etchells, June 1970.

4. "Basic Heat Transfer Mechanisms in Gas-Liquid and Liquid-Liquid Contractors," G. W. O'Conner, May 1971.

5. "Formation and Movement of Gas Cavities in Stationary and Moving Liquids," P. T. Cichy, May 1971.

6. "Fluid Mechanics of Horizontal Bubble Flow," T. L. Holmes, May 1973.

7. "The Generation, Movement and Deposition of Droplets in Annular Two-Phase Flow," D.R.C. Chang, May 1973.

8. "Mass Transfer in Simple and Viscous Gas-Liquid Contactors for Fermentation Process," S. M. Bhavaraju, May 1978.

9. "Design Procedures for a Commercial-Scale Thermal Evaporation System to Deposit Cadmium Sulfide for Solar Cell Manufacture," R. E. Rocheleau, May 1980.

10. "Liquid Circulation and Mass Transfer in Gas-Liquid Contactors," Z. Otero, August 1983.

11. "Engineering Analysis of the Deposition of Cadmium-Zinc Sulfide Semiconductor Film," S. C. Jackson, June 1984.

12. "Chemical Vapor Deposition of Amorphous Silicon Films From Disilane," R. J. Bogaert, June 1986.

13. "Bubble Breakage in Turbulent Liquid Flow," R. P. Hesketh, May 1987.

14. "Mercury Sensitized Photochemical Vapor Deposition of Amorphous Silicon Germanium Thin Films," D. E. Albright, December 1990.

15. "Selenization: Formation of CuInSe2 Polycrystalline Thin Films for Photovoltaic Devices," R. D. Varrin, Jr., May 1991.

16. "Mercury Sensitized Photochemical Vapor Deposition of Amorphous and Microcrystalline Silicon Carbide Thin Films," N. Saxena, June 1991.
17. "A Chemical Reactor and Reaction Engineering Analysis of the Formation of CuInSe2 by Selenization," Sandeep Verma, April 1993.

18. “Analysis and Modeling of Hot Wire Chemical Vapor Deposition of Silicon Films,” Atul Pant, May 2000.

APPENDIX B

MChE THESES SUPERVISED

1. "Reactor Design Aspects of Complex Reactions," D. T. Buzzelli, June 1966.

2. "Mass Transfer and Chemical Reaction in a Bubble Reactor," R. W. Schaftlein, June 1967.

3. "Mass Transfer and Reaction in Two-Phase Flow," J. W. Ultman, June 1967.

4. "Droplet Formation and Movement in Annular Two-Phase Flow," D. L. Kerr, June 1968.

5. "Oscillatory Motion on Sieve Trays," D. C. Sundberg, June 1968.

6. "Droplet Behavior in Horizontal Annual Two-Phase Flow," R. W. Rodgers, June 1969.

7. "Sewage Treatment in Transfer Lines," T. L. Holmes, June 1969.

8. "Stratified Wavy Transition in Horizontal Two-Phase Flow," P. J. Arruda, June 1970.

9. "Product Distribution in Two-Phase Reactors," R. Rothenberger, May 1971.

10. "Mass Transfer in Horizontal Two-Phase Flow," J. Ostermaier, May 1971.

11. "Mass Transfer During Bubble Formation," M. S. Galuskin, May 1971.

12. "Pressure Drop and Hold-up in Stratified Flows," R. H. Jensen, May 1972.

13. "Horizontal Bubble Flow," P. C. Steacy, May 1975.

14. "A Computer Program for the Calculation of Two-Phase Flow Design Parameters," F. M. Morris, May 1975.

15. "Recycling our Chemical Resources - Method of Assessment," M. W. Swartzlander, June 1976.

16. Evaluation of Process Designs by Economic Performance in a Simulated Market," P. C. Bediako, June 1976.

17. "Manufacturing Trends and Production Functions in the Chemical Processing Industry," J. J. Lazzeri, June 1977.

18. "Applications of Microeconomics to Process Design," R. J. Bogaert, June 1979.

19. "Reduced Resource Consumption via Chemical Recycle - An Analysis," P. K. Mathur, June 1979.

20. "A Design Analysis of the Copper Sulfide Formation Process for Solar Cell Manufacturing," D. F. Brestovansky, May 1980.

21. "Modeling and Computer-Aided Design of Gas-Sparged Devices for Mass Transfer," J. N. Tilton, December 1981.

22. "Modeling and Control of a Unit Operations Scale System to Deposit Cadmium Sulfide for Solar Cell Manufacture," A. W. Griffin, June 1982.

23. "Deposition of the Copper Sulfide Layer by the Ion Exchange Process," G. S. Shealey, June 1983.

24. "Chemical Vapor Deposition of Zinc Phosphide," E. Papazoglou, May 1984.

25. "Plasma-Enhanced Deposition of Amorphous Silicon," J.S.B. Filho, June 1986.

26. "The Effect of Deposition Conditions on the Grain Structure of Cadmium Telluride Thin Films," Ui Young Choi, June 1986.

27. Ten jointly supervised theses as part of the Industrial Intern Program.

28. "Plasma Enhanced Chemical Vapor Deposition of Low Hydrogen Amorphous and Microcrystalline Silicon," Richard Zielinski, December 1992.