IFPRI

**International Fine Particle Research Institute, Inc.**

October, 2018

Dear Colleague,

Professors James N. Michaels and R. Bertrum Diemer created a unique Master of Engineering program in Particle Technology (MEPT) at the University of Delaware. They asked us, Karl Jacob (Dow Chemical Company), Michel Louge (Cornell University), and Willie Hendrickson (AVEKA, Inc. and the International Fine Particle Research Institute), to evaluate it for content, scope and objectives. We have all been active in teaching and promoting Particle Technology (PT) and we represent both large and small manufacturing companies, academia, and non-profit NGOs all with the understanding of the criticality of PT to American Industry (Please see attached Biographies for more information on each of the signatories). This letter summarizes our findings and outlines recommendations.

PT is central to many industries, such as consumer products, pharmaceuticals, oil and gas, fine chemicals, mining, glass, concrete, food, etc. Yet because this subject is seldom taught at institutions of higher education, students rarely grasp its significance, and companies struggle to recruit new graduates who appreciate it.

To raise awareness of the importance of PT, industry and academia have formed a consortium, the International Fine Particle Research Institute https://ifpri.net/ , that brings together leading companies (Merck, DowDupont, Corning, Nestlé, Unilever, P&G, etc) with like-minded academics to carry out fundamental research on PT challenges of interest to industrial members. The signatories of the present letter, both Professors Michaels and Diemer, and the current and past Chairmen of the Chemical Engineering Department at University of Delaware have all been or are still involved in IFPRI, as company representatives, academic grantees, consultants to IFPRI, or as Officers of IFPRI. All parties are keenly aware of the considerable gaps in PT understanding and application in American Industry and the potential that better education and understanding of PT can have to advance growth and profitability.

PT depends on a remarkably wide range of physical and chemical phenomena. As such, it resides at the intersection of traditional disciplines, including chemical engineering, applied physics, mechanical engineering, materials science, chemistry, biology, food science, and agriculture.

In this context, Profs Michaels and Diemer have sensibly avoided to anchor their courses in a single discipline, thereby preserving generality. As Professors of Practice with impressive industrial experience, they have lent considerable legitimacy to their teaching, and they have leveraged their contacts to provide meaningful internships to their students. A success story, for example, is their training of Mr. Matt Maille, a distinguished PT engineer employed by Keurig Doctor Pepper, and a rising star in IFPRI.

The President's Office: 2045 Wooddale Drive; Woodbury, MN 55125; Tel: 651-730-1729; Cell: 651-295-3716; Fax: 651-730-1826; Email: whendrickson@aveka.com

We have found the curriculum developed by Profs Michaels and Diemer to be well-balanced and thorough. While conveniently anchored in Chemical Engineering, their instructions expands to topics that industrial practitioners of PT should know. For example: simple models based on spherical particle approximations; grade efficiency, particle size distributions and population balances; particle packings and jamming; grinding and size reduction; force balances involving particle friction; sampling and characterization techniques; segregation and mixing; particle drag, two-phase flow, and transport; principles of fluidization, slurries, hoppers, cyclones and conveyors; drying; surface forces; crystallization; flow through porous media; and unit operations.

Profs Michaels and Diemer bolster these topics with mathematics and physics that is seldom taught elsewhere, for example an introduction to capillary forces; particle morphology; contact mechanics; colloidal interactions and suspension rheology.

It is rare for an institution of higher education to muster experts in all relevant PT topics. The program that Profs Michaels and Diemer have designed constitutes a unique niche that no other school, to our knowledge, has yet been able to fill.

Our recommendation is to expand its enrollment by all means possible. To that end, we suggest that the program be made more visible by tying it up more closely with a consortium like IFPRI, or with like-minded institutions, perhaps through student exchanges or distance learning.
Given industry demand for employee PT training, one may also consider attaching a continuing education component or summer courses to the existing program. At home, MEPT could reinforce its experiential learning from successful design exercises like 'CHEG 675 – Particle-Based Product Design & Economics' to other courses in its curriculum.

In short, MEPT is a robust program that deserves to be continued and expanded. Its principal challenge is one of publicity. We hope that the University of Delaware can help these two talented PT educators turn it into a flagship program.

Sincerely,

Karl Jacob
Dow Fellow (retired)

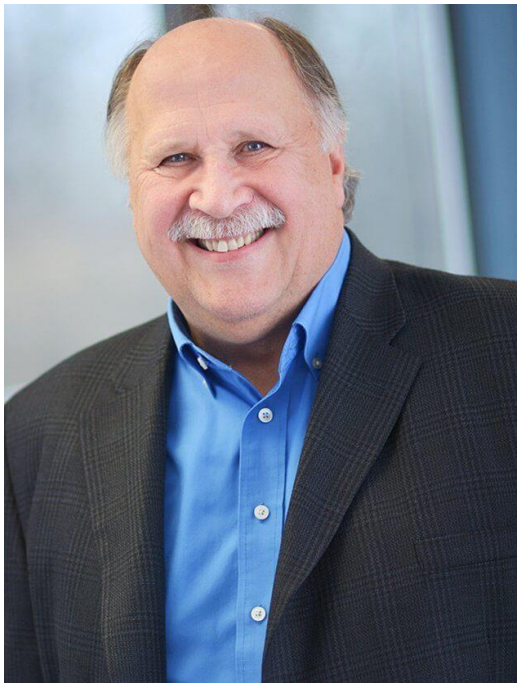
Michel Louge
Professor Cornell University

Willie Hendrickson
President IFPRI
CEO AVEKA, Inc.

The President's Office: 2045 Wooddale Drive; Woodbury, MN 55125; Tel: 651-730-1729; Cell: 651-295-3716; Fax: 651-730-1826; Email: whendrickson@aveka.com

**Biography – Willie Hendrickson**

Willie is the founder and CEO of the AVEKA Group. AVEKA was founded in 1994 as a spin off from 3M with 3 people and one site. Currently, the AVEKA Group comprises 5 manufacturing sites and 250 people for industrial, chemical, food and pharmaceutical contract manufacturing and process development of particulate materials. Prior to starting AVEKA, Willie worked at 3M as the Technical Manager for Particle Processing in 3M's Corporate Research Facility. Willie received his Ph.D. from the University of Florida in organometallic synthesis. He is currently the President of the International Fine Particle Research Institute and is an Adjunct Professor at the University of Minnesota's Department of Food Science. He has authored or coauthored over 20 technical papers or book chapters and is the current holder of 50 issued or applied for US patents.



**Karl Jacob**

Karl Jacob has recently retired as Fellow in Engineering & Process Sciences at The Dow Chemical Company. He is founder of the Solids Processing Lab at Dow and for the last 36 years has worked on a vast array of particle technology problems, with particular expertise in silo/hopper design, powder mechanics, pneumatic conveying, particle engineering and drying. He is past chair of the Particle Technology Forum and was on the Board of Directors for AIChE. He is the senior editor for the Solids Processing and Particle Technology chapter for the ninth edition of Perry's Chemical Engineers' Handbook. In addition to his industrial work, he enjoys teaching solids processing and process design at the University of Michigan. In recognition of his efforts in chemical engineering, he has been awarded the Particle Technology Forum Award for lifetime achievement in particle technology and the Lawrence Evans Award from the AIChE for chemical engineering practice.

# RÉSUMÉ

MICHEL LOUGE

## Contents



This is a abbreviated CV. A more exhaustive version is available by clicking on this link. Research interests and results are found at this site. Publications and citation metrics are linked to my ORCID number 0000-0002-1155-9163, Google Scholar profile, or ResearcherID A-4380-2018.
Blue-colored text indicates a hyperlink to a relevant web page, article, or document.

## 1. Education

- Diplôme d'Ingénieur, École Centrale des Arts et Manufactures, Paris, France (1978).
- M.S., Mechanical Engineering, Stanford University, Stanford, CA (1979).
- Ph.D., Mechanical Engineering, Stanford University, Stanford, CA (1985).
  Thesis 'Shock-tube study of cyanide species kinetics and spectroscopy'.
  Advisor: Ronald K. Hanson.

## 2. Appointments

- Professor, Mechanical and Aerospace Engineering (M&AE), Cornell University, 1998-present. Members of the fields of Mechanical Engineering, Aerospace Engineering, and Electrical Engineering.
- Assistant Professor, M&AE, 1985-1991. Associate Professor, M&AE, 1991-1998.
- Visiting Scientist, Merck, Sharpe & Dohme, West Point, PA, Process Analytical Technologies, May-August, 2018. Technology transfer.
- Visiting Professor, Tsinghua University, Center for Combustion Energy, Beijing, China, Fall 2017. Teaching and research.

- Distinguished Visiting Fellow of the Royal Academy of Engineering, Department of Civil Engineering, University of Nottingham, UK, 2014. Research.
- Professor, 'Classe Exceptionnelle', CentraleSupélec, Paris, France, 2012-2013. Academic consulting, teaching and research.
- Professor, 'Première Classe', Université de Rennes 1, Rennes, France, 2005-2006. Research and teaching.
- Visiting Professor, Institut de Physique de Rennes, Rennes, France, 1998-2011. Research.
- Visiting Professor, Université de Provence, Marseilles, France, 1991-1992. Industrial R&D.

## 3. Administrative, editorial and outreach activities

- Academic consultant to the Executive Committee of the École Centrale des Arts et Manufactures, Paris, 2012-2013. Advised the Director on university governance upon relocation to its new Saclay campus and its merger with the École Supérieure d'Électricité to create the new institution CentraleSupélec.
- Advisory panel chair for its 'Laboratoire de Génie des Procédés et Matériaux', 2008. Convener of a focus group for stakeholders. Recommendation on laboratory restructuration and hiring.
- Faculty in Residence, Cornell University, 2007-2011. Residential programs and advising.
- Associate Director for Undergraduate Affairs, Mechanical Engineering, Cornell University, 2003-2005 and 2009. Curricular deployment of M&AE faculty. Orchestrated the first ABET 2000 accreditation of M&AE at Cornell.
- Director, Master of Engineering Program, Mechanical Engineering, Cornell, 1999-2003. Established sustainable department funding from this program.
- Associate Director for Graduate Affairs, Mechanical Engineering, Cornell, 1993-1996. Computerized student records, modernized recruitment, and established the first group visit to streamline admissions.
- Cornell committees: Presidential Commission on Undergraduate Education (1987–1989); Chair, Reserve Officer Training Corps Relations Committee (1988–1991); Library Board (1989–1993); Traffic Advisory Board (1995–1997); Rugby Club advisor (1988–1991); Engineering Committee on International Relations (2003–2005; 2006–2008); International Studies Advisory Council (2003–2004); Chair, College Master of Engineering Committee (2006–2008); Faculty Senator (2006–2009 and 2015–2018); University Appeals Panel (2008–2013); Residential Program Houses Committee (2008–2010); Council on Mental Health (2009–2015).

- Associate Editor, J. Geophysical Research - Earth Surface, 2014-present.
- Associate Editor, Mechanics Research Communications, 2007-present.

- Guest Editor (with Alexandre Valance, Institut de Physique de Rennes), Special Issue of Compte-Rendus Physique (journal of the French Academy of Sciences) on Granular Materials (2014).
- Chair of the second Gordon Conference on Granular and Granular-Fluid Flow in Colby College, Maine, June 27 to July 2, 2004, sponsored by NSF funding.
- Leader of the US delegation to the NASA-sponsored 2nd International Conference on the Formation and Migration of Dunes, Nouakchott, Mauritania, Feb 2001.
- Outreach to DeWitt Middle School, Ithaca, NY (2000-2012).

- Frequent reviewer for journals in multiphase physics. NSF review panels since 1990.

## 4. Industrial experience

- Powder Flow consultant, International Fine Particle Research Institute, a global network of companies and academics with active research programs in particle science and technology, 2003-2009 and 2015-present. Advisor on IFPRI grant funding priorities. Chair of two IFPRI workshops on Powder Flow (Bremen, 2003; Amsterdam, 2017).
- Consultant, Merck, Sharp and Dohme, pharmaceutical powder instrumentation, 2001, 2016-present.
- Consultant, Capacitec, Inc., development of capacitance instruments to record the stratigraphy of snow packs under an SBIR Phase I and II from the US Army Research Office, 1997-2001.
- Other clients in powder technology: Maersk Oil in Qatar (2013–2017) Pall Corporation (2012), Procter & Gamble (2001), Inhale Pharmaceuticals (2001), Huntsman Tioxide (2000), UOP (1999), Praxair (1997), Swiss Institute for Snow and Avalanche Research (1996), 3M (1995), Exxon (1995-1997), Norton (1996), CANMET (1994), Dow Corning (1994-1999), ABB Combustion Engineering (1988-1990), Shell Oil (1991), Shell Laboratorium Amsterdam (1992), Électricité de France (1992), Amoco (1990), Cabot (1987).
- Visiting Scientist, CNIM group, circulating fluidized bed combustion, La-Seyne-sur-Mer, France.
- Process Development Engineer, Shell, The Hague, the Netherlands, 1984-1985.
- Officer, French Naval Reserve, 1979-1999. Last rank: LCdr. Officer of the watch. Deep underwater operations.

## 5. Teaching and mentoring

- Cornell M&AE 5430 Combustion Processes (1985–present).
- Cornell M&AE 4272 Fluids/Heat Transfer Laboratory (1985–present).
- Université de Rennes 1, France, Fluid Mechanics (2006).
- Tsinghua University, Thermodynamics (2017).

- CentraleSupélec, Paris, France, Transferts Thermiques (2012).
- Cornell M&AE 3240 Heat Transfer (2008-2018).
- M&AE 6020: Foundations of Fluid Mechanics II (2011, 2012, 2015, with S. Pope).
- Université de Rennes 1, Methods of Modern Research, (summer 2007–2008).
- Cornell M&AE 449 Combustion Engines and Fuel Cells (2007).
- Cornell M&AE 6510 Advanced Heat & Mass Transfer (1988-1997).
- Cornell M&AE 101 Naval Ship Systems (1988–2010, with Cornell NROTC).
- Cornell M&AE 2250 Mechanical Synthesis (1998–2016).

- Graduate students: Epaminondas Mastorakos (1989), Catherine Acree-Riley (1989), Michael Opie (1990), Hongder Chang (1991), Subramanyam Iyer (1991), Jamaludin Mohd. Yusof (1992), D. Jeffrey Lischer (1993), Samuel Foerster (1993), Stéphane Martin-Letellier, Mark Tuccio, Vincent Bricout (2000), Elizabeth Griffith (2000), Haitao Xu (2003), Xinglong Chen (2005), Cian Carroll (2011), Jin Xu (2015), Shilpa Sahoo.
- Visitors and post-docs: Lili Gu (Tsinghua, 2015), Barbara Turnbull (2007–2008), Frédéric Beaud (Électricité de France, 1992), Khédidja Allia (Université dAlger, 1991), Hongder Chang (1991–1992).

- Project team advisor: Odysseus Space (1999–2005); Baja SAE (2009–2012); Hyperloop (2015–2016).

- Recipient of Cornell's Kendall S. Carpenter Memorial Advising Award, 2011.

## 6. Research

Archival articles below illustrate my contributions to subjects in gas-solid fluidization, granular flows, particle impact, heat transfer, nanoparticles, instrumentation, desert microbiology, sand dunes, snow science, chemical kinetics, spectroscopy, and capillary phenomena. This research involved laboratory experiments, field expeditions, microgravity platforms, numerical simulations, models, and the development of theory. I involved many undergraduates, included 19 as co-authors, and advised 17 graduate students.

(1) Circulating gas-solid fluidization in a facility recycling $CO_2$, He and $SF_6$ to study scale-up and pressurized operations. Sponsors: NSF, US DoE, Électricité de France.

- V. Bricout and M. Louge (2004). Measurements of cyclone performance under conditions analogous to pressurized circulating fluidization, *Chem. Eng. Sci.*, **59**, 3059–3070, doi:10.1016/j.ces.2004.03.034.
- V. Bricout and M. Louge (2004). A verification of Glicksman's reduced scaling under conditions analogous to pressurized circulating fluidization, *Chem. Eng. Sci.*, **59**, 2633–2638, doi:10.1016/j.ces.2004.03.017.
- Louge M.Y., Bricout V. and Martin-Letellier S. (1999). On the dynamics of pressurized and atmospheric circulating fluidized bed risers, *Chem. Eng. Sci.*, **54**, 1811–1824, doi:10.1016/S0009-2509(98)00310-8.
- E. Griffith and M. Louge (1998). The scaling of cluster velocity at the wall of circulating fluidized bed risers, *Chem. Eng. Sci.*, **53**, 3059–3070, doi:10.1016/S0009-2509(98)00038-4.
- Chang H. and Louge M. (1992). Fluid dynamic similarity of circulating fluidized beds, *Powder Tech.*, **70**, 259–270, doi:10.1016/0032-5910(92)80061-Z.
- Louge M. and Chang H. (1990). Pressure and voidage gradients in vertical gas-solid risers, *Powder Tech.*, **60**, 197, doi:10.1016/0032-5910(90)80144-N.
- Louge M., Lischer D.J. and Chang H. (1990). Measurements of voidage near the wall of a circulating fluidized bed riser, *Powder Tech.*, **62**, 269–276, doi:10.1016/0032-5910(90)80114-E.

(2) Impact of small spheres: measurement of restitution and friction coefficients. Sponsors: US DoE, NASA.

- C.M. Sorace, M.Y. Louge, M.D. Crozier, and V.H.C. Law (2009). High apparent adhesion energy in the breakdown of normal restitution for binary impacts of small spheres at low speed, *Mechanics Res. Comm.*, **36**, 364–368, doi:10.1016/j.mechrescom.2008.10.009.
- M.Y. Louge and M.E. Adams (2002). Anomalous behavior of normal kinematic restitution in the oblique impacts of a hard sphere on an elasto-plastic plate, *Phys. Rev. E*, **65**, 021303, doi:10.1103/PhysRevE.65.021303.
- M. Y. Louge, C. Tuozzolo and A. Lorenz (1997). On binary impacts of small liquid-filled shells, *Phys. Fluids*, **9**, 3670–3677, doi:10.1063/1.869504.
- A. Lorenz, C. Tuozzolo and M.Y. Louge (1997). Measurements of impact properties of small, nearly spherical particles, *Experimental Mechanics*, **37**, 292–298, doi:10.1007/BF02317421.
- S.F. Foerster, M.Y. Louge, H. Chang, and K. Allia (1994). Measurements of the collision properties of small spheres, *Phys. Fluids*, **6**, 1108–1115, doi:10.1063/1.868282.

(3) Numerical simulations of granular flows. Sponsors: US DoE, NASA.

- Louge, M.Y. (1994). Computer simulations of rapid granular flows of Spheres interacting with a flat, frictional boundary, *Phys. Fluids*, **6**, 2253–2269, doi:10.1063/1.868178.
- Hopkins M., Jenkins J. and Louge M. (1993). On the structure of three-dimensional shear flows, *Mechanics of Materials*, **16**, 179–187, doi:10.1016/0167-6636(93)90041-O.
- M. Louge, J. Jenkins and M.A. Hopkins (1993). The relaxation of the second moments in rapid shear flows of smooth disks, *Mechanics of Materials*, **16**, 199–203, doi:10.1016/0167-6636(93)90043-Q.
- Hopkins, M.A. and Louge M. (1991). Inelastic microstructure in rapid granular flows of smooth disks, *Phys. Fluids A*, **3**, 47–57, doi:10.1063/1.857863.
- Louge M., Jenkins J.T. and Hopkins M. (1990). Computer simulations of rapid granular shear flows between parallel bumpy boundaries, *Phys. Fluids A*, **2**, 1042–1044, doi:10.1063/1.857642.

(4) Granular and gas-solid flow theory. Sponsors: US DoE, NASA, International Fine Particle Research Institute.

- Louge, M.Y. (2012). Phonon conductivity along a column of spheres in contact – Relation to volume fraction invariance in the core of granular flows down inclines, *Granular Matter*, **14**, 203–208, doi:10.1007/s10035-011-0296-x.
- H. Xu, R. Verberg, D. Koch and M. Louge (2009). Dense, bounded shear flows of agitated solid spheres in a gas at intermediate Stokes and finite Reynolds numbers, *J. Fluid Mech.*, **618**, 181–208, doi:10.1017/S0022112008004333.
- R. Delannay, M. Louge, P. Richard, N. Taberlet, and A. Valance (2007). Towards a theoretical picture of dense granular flows down inclines, *Nature Materials*, **6**, 99–108, doi:10.1038/nmat1813.
- Louge, M.Y. (2003). Model for dense granular flows down bumpy inclines, *Phys. Rev. E*, **67**, 061303, doi:10.1103/PhysRevE.67.061303.
- J. T. Jenkins and M. Louge (1997). On the flux of fluctuation energy in a collisional grain flow at a flat, frictional wall, *Phys. Fluids*, **9**, 2835–2840, doi:10.1063/1.869396.
- Louge, M.Y., Mastorakos, E. and Jenkins, J.T. (1991). The role of particle collisions in pneumatic transport, *J. Fluid Mech.*, **231**, 345–359, doi:10.1017/S0022112091003427.

(5) Granular flow experiments: inclined flows and microgravity. Sponsors: US DoE, NASA.

- Louge, M. Y., A. Valance, P. Lancelot, R. Delannay, and O. Artieres (2015). Granular flows on a dissipative base, *Phys Rev. E*, **92**, 022204, doi:10.1103/PhysRevE.92.022204.
- P. Richard, A. Valance, J-F. Métayer, P. Sanchez, J. Crassous, M. Louge, and R. Delannay (2008). Rheology of confined granular flows: Scale invariance, glass transition and friction weakening, *Phys. Rev. Lett.*, **101**, 248002, doi:10.1103/PhysRevLett.101.248002.
- H. Xu, A. P. Reeves and M. Y. Louge (2004). Measurement errors in the mean and fluctuation velocities of spherical grains from a computer analysis of digital images, *Rev. Sci. Instrum.*, **75**, 811–819, doi:10.1063/1.1666989.
- H. Xu, M. Louge and A. Reeves (2003). Solutions of the kinetic theory for bounded collisional granular flows, *Continuum Mechanics and Thermodynamics*, **15**, 321–349, doi:10.1007/s00161-003-0116-6.
- M. Louge and S. Keast (2001). On dense granular flows down flat frictional inclines, *Phys. Fluids*, **13**, 1213–1233, doi:10.1063/1.1358870.

(6) Granular heat transfer: experiments, simulations and theory. Sponsor: NASA.

- X. Chen and M.Y. Louge (2008). Heat transfer enhancement in dense suspensions of agitated solids. Part I: Theory, *Int. J. Heat Mass Transfer*, **51**, 5108–5118, doi:10.1016/j.ijheatmasstransfer.2008.04.059.
- X. Chen and M.Y. Louge (2008). Heat transfer enhancement in dense suspensions of agitated solids. Part II: Experiments in the exchange limit, *Int. J. Heat Mass Transfer*, **51**, 5119–5129, doi:10.1016/j.ijheatmasstransfer.2008.04.064.
- Louge, M., Mohd. Yusof J. and Jenkins J.T. (1993). Heat transfer in the pneumatic transport of massive particles, *Int. J. Heat Mass Transfer*, **36**, 265–275, doi:10.1016/0017-9310(93)80002-C.

(7) Nanoparticle heat transfer. Sponsor: NASA.

- M.Y. Louge and X. Chen (2008). Heat transfer enhancement in dense suspensions of agitated solids. Part III: Thermophoretic transport of nanoparticles in the diffusion limit, *Int. J. Heat Mass Transfer*, **51**, 5130–5143, doi:10.1016/j.ijheatmasstransfer.2008.04.058.

(8) Instruments for geophysical and industrial applications. Sponsors: US DoE, Qatar National Research Foundation, US Army Research Office.

- A. E. Griffith, M.Y. Louge and J Mohd. Yusof (2000). Simultaneous, non-invasive measurements of convective heat transfer and solid volume fraction at the wall of an entrained gas-solid suspension, *Rev. Sci. Instrum.*, **71**, 2922–2927, doi:10.1063/1.1150711.
- Louge M.Y., Foster R.L., Jensen N. and Patterson R. (1998). A portable capacitance snow sounding instrument, *Cold Regions Science and Technology*, **28**, 73–81, doi:10.1016/S0165-232X(98)00015-9.
- Dent, J. D., Burrell, K. J., Schmidt, D. S., Louge, M. Y., Adams, E. E., and Jazbutis, T. G. (1998). Density, velocity and friction measurements in a dry-snow avalanche, *Annals of Glaciology*, **26**, 247–252, doi:10.3189/1998AoG26-1-247-252.
- Louge M.Y., Steiner R., Keast S.C., Decker R., Dent J. and Schneebeli M. (1997). Application of capacitance instrumentation to the measurement of density and velocity of flowing snow, *Cold Regions Science and Technology*, **25**, 47–63, doi:10.1016/S0165-232X(96)00016-X.
- M. Louge (1997). Experimental Techniques, chapter 9 in *Circulating Fluidized Beds*, J. Grace, T. Knowlton and A. Avidan, eds, Blackie Academic & Professional, pp. 312–368, ISBN:0751402710.
- M. Louge, M. Tuccio, E. Lander, and P. Connors (1996). Capacitance measurements of the volume fraction and velocity of dielectric solids near a grounded wall, *Rev. Sci. Instrum.*, **67**, 1899–1877, doi:10.1063/1.1146991.
- Lischer, D.J. and Louge, M. (1992). Optical fiber measurements of particle concentration in dense suspensions: calibration and simulation, *Applied Optics*, **31**, 5106–5113, doi:10.1364/AO.31.005106.
- Louge, M.Y., Iyer, S.A., Giannelis, E.P., Lischer, D.J. and Chang, H. (1991). Optical fiber measurements of particle velocity using Laser-Induced Phosphorescence, *Applied Optics*, **30**, 1976–1981, doi:10.1364/AO.30.001976.
- Louge M. and Opie M. (1990). Measurements of the effective dielectric permittivity of suspensions, *Powder Tech.*, **62**, 85–94, doi:10.1016/0032-5910(90)80026-U.
- Acree Riley, C. and Louge, M.Y. (1989). Quantitative capacitive measurements of voidage in dense gas-solid flows, *Particulate Science & Tech.*, **7**, 51–59, doi:10.1080/02726358908906523.

- M.Y. Louge (August 13, 1996). Guarded capacitance probes for measuring particle concentration and flow, **US Patent 5546006**, licensed to Capacitec for industrial solid concentration and moisture measurements.
- M.Y. Louge (October 17, 1995). Guarded capacitance probes for measuring particle concentration and flow, **US Patent 5459406**.

(9) Snow avalanches: field experiments and modeling. Sponsors: Petroleum Research Fund.

- B. Sovilla, J. N. McElwaine, and M. Y. Louge (2015). The structure of powder snow avalanches (Structure des avalanches en aérosol), *Compte-Rendus de Physique*, **16**, 97–104, doi:10.1016/j.crhy.2014.11.005.
- C.S. Carroll, M.Y. Louge, and B. Turnbull (2013). Frontal dynamics of powder snow avalanches, *J. Geophys. Res.*, **118**, 1–12, doi:10.1002/jgrf.20068.
- C.S. Carroll, B. Turnbull, and Louge, M. Y. (2012). Role of fluid density in shaping suspension currents driven by frontal particle blow-out, *Phys. Fluids*, **24**, 066603, doi:10.1063/1.4725538.
- M.Y. Louge, B. Turnbull and C.S. Carroll (2012). Volume growth of a powder snow avalanche, *Annals of Glaciology*, **53**, 57–60, doi:10.3189/2012AoG61A030.
- Louge, M. Y., C.S. Carroll, and B. Turnbull (2011). Role of pore pressure gradients in sustaining frontal particle entrainment in eruption currents – the case of powder snow avalanches, *J. Geophys. Res.*, **116**, F04030, doi:10.1029/2011JF002065.

(10) Desert microbiology. Sponsor: Qatar National Research Foundation.

- S. Abdul Majid, M. F. Graw, A. Chatziefthymiou, H. Nguyen, R. Richer, M. Louge, A. A. Sultan, P. Schloss, A. G. Hay (2016). Microbial Characterization of Qatari Barchan Sand Dunes, *PLoS ONE*, **11**, e0161836, doi:10.1371/journal.pone.0161836.
- Louge, M. Y., A. Valance, A. Ould el-Moctar, J. Xu, A. G. Hay, and R. Richer (2013). Temperature and humidity within a mobile barchan sand dune, implications for microbial survival, *J. Geophys. Res.*, **118**, doi:10.1002/2013JF0028396.

(11) Hyper-arid, dusty regions and desertification research. Sponsor: Qatar National Research Foundation.

- Musa, R. A., S. Takarrouht, M. Y. Louge, J. Xu, and M. E. Berberich (2014). Pore pressure in a wind-swept rippled bed below the suspension threshold, *J. Geophys. Res. Earth Surf.*, **119**, doi:10.1002/2014JF003293.
- Louge, M. Y., A. Valance, A. Ould el-Moctar, and P. Dupont (2010). Packing variations on a ripple of nearly monodisperse dry sand, *J. Geophys. Res.*, **115**, F02001, doi:10.1029/2009JF001384.
- Louge, M. Y., A. Valance, H. Mint Babah, J.-C. Moreau-Trouvé, A. Ould el-Moctar, P. Dupont, and D. Ould Ahmedou (2010). Seepage-induced penetration of water vapor and dust beneath ripples and dunes, *J. Geophys. Res.*, **115**, F02002, doi:10.1029/2009JF001385.

(12) Capillarity and unsaturated porous media. Sponsor: NASA.

- M. Y. Louge (2017). Statistical mechanics of the triple contact line, *Phys. Rev E*, **95**, 032804, doi:10.1103/PhysRevE.95.032804.
- M. Y. Louge and S. Sahoo (2017). Model of inertial spreading and imbibition of a liquid drop on a capillary plate, *AIChE J.*, **63**, 5474–5481, doi:10.1002/aic.15953.
- L. Steub, J. Kollmer, D. Paxson, A. Sack, T. Pöschel, J. Bartlett, D. Berman, Y. Richardson, and M. Y. Louge (2017). Microgravity spreading of water spheres on hydrophobic capillary plates, *EPJ Web of Conferences*, **140**, 16001, doi:10.1051/epjconf/201714016001.
- J. Xu and M. Y. Louge (2015). Statistical mechanics of unsaturated porous media, *Phys. Rev E*, **92**, 062405, doi:10.1103/PhysRevE.92.062405.

(13) Combustion, chemical kinetics and spectroscopy

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## 7. Major funding and awards

- NSF-CASIS (2016-present, with Olivier Desjardins). Inertial spreading and imbibition of a liquid drop through a porous surface, $300k.
- Qatar National Research Foundation (2013–2017), Microbial stabilization of mobile dunes for infrastructure protection and environmental preservation, NPRP 6-059-2-023, $1m.

- Qatar National Research Foundation (2010–2014), Understanding the link between moisture dynamics and microbial activity in mobile dunes, NPRP 09-546-2-206, $1m
- Best Environment Research Program of the Year, Qatar Foundation, 2011, $100k.
- ACS Petroleum Research Fund 47782-AC8 (2008-2012), The role of erosion at the head of turbidity currents – experiments and theory, $100k.
- NSF 0233212 (2003), U.S.-France Cooperative Research: Flows of Grains Down Inclined Channels, $21k.
- Recipient of a Pentagon Quality Award for SBIR contract DAAD19-00-C-0010 with Capacitec, Inc., 'A Multi-Parameter Snow Sounding probe', 2002.
- NASA NCC3-797 and NCC3-468, Studies of gas-particle interactions in a microgravity flow cell (1998–2005), $686k (with J.T. Jenkins).
- NASA NAG3-2705, Microgravity segregation in binary mixtures of inelastic spheres driven by velocity fluctuation gradients (1996–2000), $780k (with J.T. Jenkins).
- NASA NAG3-2112, Microgravity segregation in binary mixtures of inelastic spheres driven by velocity fluctuation gradients (2000–2005), $800k (with J.T. Jenkins).
- International Fine Particle Research Institute (IFPRI) Experimental rapid shear (1995, $100k); Collaboration grant with Sankaran Sundaresan (Princeton) (1998, $5k); Studies of gas-particle interactions in a microgravity flow cell (1999, $100k).
- US Department of Energy DE-FG22-95PC95228, University Coal Research Prgm, Pittsburgh Energy Technology Ctr (1995–1998, $400k, with L. Glicksman, MIT).
- US Department of Energy DE-FG22-93PC93216, University Coal Research Program, Pittsburgh Energy Technology Center (1993–1997, $200k).
- NSF 9512931 (1996), U.S.-France Cooperative Research: The mechanics and statistical physics of particle motion on an inclined, bumpy surface, $21k.
- US Department of Energy DE-AC22-91PC90183, Granular Flow Advanced Research Objective (1991–1995, $700k, with J. Jenkins).
- Électricité de France, Circulating fluidized bed combustion (1993, $68k).
- US Department of Energy DE-FG22-88PC88929, University Coal Research Program (1988, $390k).
- NSF 8809347 (1988), Research Initiation: A Systematic Investigation of Circulation Fluidized Bed Scale-Up, $69k.
- NSF 8704993 (1987), Engineering Research Equipment Grant: Pulsed Dye Laser Upgrade for Gas-Solid and Turbulent Flame Diagnostics, $24k.