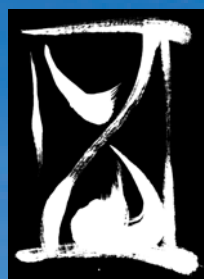A *Two-fer* for Durham University UK:
Bingham Medalist Tom McLeish
Metzner Awardee Suzanne Fielding

Rheology Bulletin

Inside:

On the Cover:

Photo of the Durham University World Heritage Site of Durham Castle (University College) and Durham Cathedral. Former built by William the Conqueror, latter completed in 1130.

Table of Contents

Standing Committees

Membership Committee (2009-2011)
Shelley L. Anna, chair
Saad Khan
Jason Maxey
Lisa Mondy
Chris White

Education Committee (2009-2011)
Michael J. Solomon, chair
Anne M. Grillet
Marie-Claude Heuzey
Maryam Sepehr
Patrick Spicer

Bingham Award Committee
Timothy Lodge (2007-2010), chair
Jae Chun Hyun (2009-2012)
Christopher Macosko (2008-2011)
Kalman Migler (2008-2011)
Jeffrey Morris (2009-2012)
Susan J. Muller (2007-2010)
Michael Rubinstein (2008-2011)

Metzner Award Committee
Lynn Walker (2008-2010), chair
Peter Fischer (2009-2012)
Charles P. Lusignan (2008-2010)
Gareth McKinley (2009-2012)
Michael J. Solomon (2008-2010)

Meetings Policy Committee
Jeffrey Giacomin, Chair (Vice President)
Victor Breedveld (2011 Program)
Albert Co (Webmaster)
Saad Khan (2010 Program)
Andrew Kraynik (2010 Local)
Gregory McKenna (2010 Program)
Jonathan Rothstein (2011 Program)

Bingham Medalist 2010:

Tom McLeish

Profile by Ron Larson
University of Michigan USA

I am delighted to profile the achievements of Tom McLeish that merit his selection as Bingham Medalist for 2010. I first met Tom when he was a graduate student at Cambridge in the mid -1980's, and have immensely enjoyed Tom's friendship and collaborations over the years, as have so many others. Tom is a delightfully gifted individual, possessing great scientific talent, and an ever-youthful enthusiasm for science in general and rheology in particular. His research in polymers relevant to rheology has encompassed the gamut of topics, ranging from synthesis, molecular dynamics and polymer physics, fluid mechanics, processing, flow instabilities, neutron scattering, phase separation, gelation, and crystallization. In addition, he has contributed profoundly important work on the rheology of surfactant solutions, colloids, electrorheological fluids, and other materials, encompassing both theoretical and experimental methods. He is a Renaissance man: gifted in science and engineering, languages, music, the humanities and theology, and possessing wonderful organizational and interpersonal skills as well.

Tom received a B.S. degree from Emmanuel College, University of Cambridge in 1984, and an M.A. and Ph.D. also from Cambridge, in 1987. He was an ICI Research Fellow, Theory of Condensed Matter Group, at the Cavendish Laboratory, Cambridge, from 1987 to 1989. He then became

Lecturer in the Department of Physics, University of Sheffield from 1989 to 1993. He moved to the University of Leeds in 1993 where he was appointed Professor of Polymer Physics, and director of the UK Polymer IRC (involving also the Universities of Durham, Sheffield, and Bradford). He moved to Durham University as Pro-Vice-Chancellor of Research in 2008, his current position. He has held numerous administrative positions, including Directorship of the Microscale Polymer Processing Consortium. Tom has twice been a recipient of the *Journal of Rheology* Publication Award and was awarded the Weissenberg Medal of the European Society of Rheology in 2007.

Not as punctual as they might be, here is the McLeish family, Julie and Tom, with children Katie, Nicholas, Max and Rosie, at the Coliseum but just 1900 years too late for the big game.

Tom's ability to pursue science at the highest level was demonstrated very early, when during or shortly after his Ph.D. thesis, he and Robin Ball applied the idea of "dynamic dilution" to the relaxation of star polymers. Tom thereafter applied this concept to branched polymers in general, with great success. Tom added to "dynamic dilution" the idea of "hierarchical relaxation," whereby branched polymers of arbitrary architecture, including hyperbranched polymers, relax sequentially, starting from the tips of the arms. As they relax, they release constraints on other molecules, progressively "diluting" the density of constraints in the melt, as longer time scales are accessed. He also created a theoretical scheme that allows the effects of relaxation at each stage on subsequent stages to be accounted for through the dynamic dilution ansatz. These ideas have become the basis of modern theories for relaxation and rheology of long-chain-branched polymers, a very important topic both intellectually and commercially. Not satisfied with superficial understanding, Tom has critiqued the dynamic dilution ansatz and has shown how it can be rationalized as approximation to a much deeper theoretical picture.

Using dynamic dilution and other creative ideas, including the most rigorous version of Marrucci's "convective constraint release" idea, Tom and his coworkers published a series of papers predicting the linear and non-linear dynamics and rheology of linear, star-branched, "H", and other polymers, all of which have become the "standard" models for relaxation and rheology of these polymers. Moreover, Tom and his collaborators have extended these ideas to the prediction of polymer processing flows, such as the contraction flows imaged by both neutron scattering and birefringence, published in *Science*. In this tour de force, Tom and his collaborators subjected specially synthesized monodisperse polymers to flow through a contraction, and measured polymer orientation through both birefringence and neutron scattering. The results of these measurements were successfully compared with the predictions of advanced rheological models for polymers, also developed by Tom and his many collaborators. This work combined anionic polymer synthesis, rheological measurements and theory, scattering methods, polymer processing, and computational fluid dynamics, to build and test a practical constitutive model. The work consummated a long-sought goal of rheological studies: the encoding of experimental and theoretical rheological knowledge into a constitutive equation useful for predicting the results of polymer processing flows. Few, if any, rheologists in the world possess the broad and deep scientific and en-

gineering knowledge, as well as the collaborative skills, needed to bring such a project to fruition. All who work in the field of polymer rheology are well aware of Tom's seminal contributions, and often turn first to his papers when seeking to understand the latest developments in this area. Besides de Gennes, Doi, Edwards, and Marrucci, there is no one who has contributed as much to our understanding of polymer rheology as has Tom McLeish. This body of work alone qualifies Tom for the Bingham Medal.

But Tom's accomplishments go well beyond this. He worked out a theory of polymer "spurt." He has made important contributions to measurements and theory of surfactant liquid crystal rheology. His recent work with Tim Lodge on the structure and properties of polymer blends is gaining a large following in polymer blend structure and dynamics, with clear implications for rheology. He has recently developed an understanding of protein dynamics under strong stretching flows. His C.V. shows his contributions to numerous other areas of importance to rheology.

These accomplishments reflect not only on Tom's scientific genius, but also his skill at collaborations. The European research programs that Tom has organized in the area of polymer dynamics and rheology are the best funded and most comprehensive in the world on this topic. Tom regularly unites people of widely varying backgrounds from both industry and academia, worldwide, into productive enterprises. Tom delights in

Diving off Monterey harbour during recreational time in the International Congress on Rheology in 2008. Going with the flow in a new light.

Dr. Suzanne Fielding has been chosen to receive the 2010 Arthur B. Metzner Early Career Award, which is given to a member of the Society who is younger than 35 who has distinguished him/herself in rheological research, rheological practice, or service to rheology.

2010
Metzner Early Career Award: Suzanne Fielding

In choosing Fielding for this distinction, the Committee cited the breadth of her research, the impact of her work, and the level of independence that she has achieved at this early stage of her career. These accomplishments indicate that Fielding will have an important and positive impact on the field of rheology on an ongoing basis.

Suzanne Fielding is a Senior Lecturer in the Department of Physics at Durham University UK and a recipient of an Advanced Research Fellowship from the Engineering and Physical Sciences Research Council (UK). She received her first degree in physics from Oxford University in 1997 and her Ph.D. in Physics from Edinburgh University in 2000. In her work Fielding combines careful numerics with analytical theory that maintains close connections with experimentalists in the field. She is regularly invited to visit experimental laboratories, and these visits allow her to ensure that her work is always relevant, novel, and grounded. Fielding's publication record is impressive, and the impact of the work considerable. She is the lead author on most of her publications, and her papers attract high numbers of citations (more than 500 so far).

Fielding's seminal paper, which was published in the *Journal of Rheology*, is on glassy rheology and glassy dynamics and has received an impressive 116 citations to date. In this work Fielding studied the role of aging on the mechanical properties of disordered soft glassy materials. By exploiting analogies with theories of other disordered systems, Fielding established the first rigorous framework for analyzing rheological data in aging materials in which the translational invariance is lost. She also provided the first concrete calculation of aging rheological
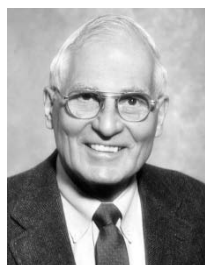
The *SOR Early Career Award*, established in 2009, was named for Art Metzner, distinguished rheologist, university professor, editor of the *Journal of Rheology*, and Bingham medalist.

response functions. This work explained a large body of existing data and stimulated a series of subsequent experiments.

Fielding has also investigated the complex dynamics of shear-banded flows. This is an exciting area in rheology, as many complex fluids undergo shear-induced transitions to coexisting shear bands of differing viscosities and internal structures. To address disparities seen be-

tween experimental observations and existing theories, Fielding constructed the first model of spatio-temporal oscillations and rheological chaos in shear-banding systems. She has made further contributions to this field by considering the nature of the interface in shear-banded flows. Fielding is one of the key figures in centralizing understanding in the exciting area of complex dynamics of shear-banded flows.

Fielding has won several prestigious research fellowships allowing her to concentrate on independent research in theoretical rheology. She has used this opportunity to broaden the scope of her work. Fielding has

82ⁿᵈ SOR Meeting 24-28 October

Santa Fe, NM USA

October in the Southwest USA is a beautiful time of year. Plan to join us in Santa Fe for the 82nd Annual Meeting of The Society of Rheology, 24-28 October 2010. The meeting will be held in the Santa Fe Convention Center, located two blocks from the historic plaza, which is surrounded by numerous restaurants, art galleries and shops. Santa Fe is located in northern New Mexico, an hour's drive north of Albuquerque, the state's largest city and major air gateway. More information on Santa Fe and on getting to and from the meeting is available at *santafe.org* and on the Society's meeting web pages (*www.rheology.org/sor/annual_meeting/2010Oct/info.htm*).

As is customary at SOR meetings, there will be many opportunities to meet and socialize with fellow rheologists in Santa Fe. The Welcoming Reception will be held on Sunday 24 October from 7 pm to 9 pm at the Hilton of Santa Fe, the meeting headquarters hotel. The Society Reception will be held at the New Mexico History Museum on Monday 25 October from 6:30 pm to 9 pm, and there will be time to visit the collections during the reception. All attendees are encouraged to attend the annual business meeting of The Society of Rheology on Tuesday 26 October; the meeting starts at 5:30 pm, immediately following the technical sessions in the Convention Center.

The Bingham Award Reception and Banquet will be held in the historic La Fonda on the Plaza on Tuesday 26 October, and Tom McLeish of Durham University UK will receive the 2010 Bingham medal at the banquet. The Award Reception begins at 7 pm in the New Mexico and Santa Fe rooms, and is immediately followed by the Bingham Award Banquet at 8 pm in the ballroom. Various Society prizes and recognitions will be awarded at the banquet.

On the weekend preceding the technical meeting two rheological short courses will be offered. A two-day course in Colloidal Dispersion Rheology will be presented by Jan Mewis, (Katholieke Universiteit Leuven) and Norman Wagner, (University of Delaware) on 23-24 October 2010 (Saturday and Sunday). A one day course on Microrheology: Theory, Practice and Applications will take place on 24 October 2010 (Sunday). The instructors for the Microrheology course are Eric Furst, (University of Delaware), Patrick Doyle, (Massachusetts Institute of Technology), and Patrick Spicer (Procter and Gamble Company). Details of the short course offerings are in a separate article in this *Bulletin* and on the web at *www.rheology.org/sor/short_course/2010Oct/default.htm*.

Local Arrangements

Andy Kraynik
Department 1514 MS 0836
Sandia National Laboratories
Albuquerque, NM 87185-0836
(505) 844-9696
amkrayn@sandia.gov

TA INSTRUMENTS

IT'S NOT A RHEOMETER... IT'S THE NEW ARES-G2.

NEW ARES-G2

• Unique separate motor and transducer technology

• New FRT with 5,000,000:1 dynamic range

• New high torque, friction free brushless DC motor with high resolution optical encoder

• Inertia free dynamic measurements to 100 Hz

• New advanced strain and stress control

• New touch screen with intuitive graphical interface

• New Force Convection Oven with Camera Viewer

• New Smart Swap™ Peltier Plate with Solvent Trap

• New TRIOS Software

WWW.TAINSTRUMENTS.COM

*The previous issue of the Bulletin carried a brief obitu-
ary of Joseph M. Starita who died November 2009 after
a long battle with brain cancer. Here we recognize the
significant contributions that Joe Starita made to the
field of rheology.*

Joe Starita
Father of Modern Rheometry

Joe Starita demonstrating the Rheometrics
Mechanical Spectometer 605 to a customer.

*Chris Macosko
University of Minnesota, USA*

What was the state of rheology in 1966 as Joe Starita
began is Ph.D. in Princeton's Department of Chemical
Engineering? Actually, many of the important phenom-
ena had been discovered. In 1948 Karl Weissenberg had
reported that polymeric liquids could generate remark-
able shear normal stresses.[1] Linear viscoelasticity was
well known, particularly through John Ferry's popular
text.[2] However, measuring these properties was difficult
and primarily confined to academic laboratories. Most
instruments were home-built, driven through gear boxes,
measuring torque via mechanical-stress transducers.
In this era before personal computers, G' and G" were
determined by resonance devices or by tracing Lisajous
figures. Instruments capable of the high temperatures
needed for polymer melts were generally unavailable.
Most industrial rheology was limited to shear-rate de-
pendent viscosity, measured using capillary viscometers
or simple rotational rheometers with soft spring trans-
ducers that introduced compliance errors. The Weissen-
berg Rheogoniometer was the only commercial instru-
ment capable of shear normal-stress measurements.

In their 1963 book, van Wazer and his colleagues at
Monsanto summarized the state of instruments for visco-
elastic measurements, concluding with "Unfortunately,
except for the Rheogoniometer, such equipment is not
yet commercially available, although it is expected that
some enterprising company will manufacture this kind
of apparatus shortly."[3] It was not long before Joe Starita
answered that challenge.

In 1965, Joe's thesis advisor at Princeton,
Bryce Maxwell, invented the orthogonal
(eccentric rotating disks) rheometer which
generated G' and G" values directly.[4] Joe
soon began working with another Maxwell
advisee, myself, to redesign Maxwell's ap-
paratus. We recognized the opportunity to
measure all the shear material functions of
polymer melts in one apparatus. We invented
a transducer to measure torque and normal
forces as well as the x and y forces needed for
the orthogonal mode.[5] We incorporated a fast
convection oven and demonstrated the ability
of the new rheometer to make rapid, reliable
measurements on a wide range of materials[6]
and in 1970, while completing our theses, we
founded Rheometrics Inc.

Joe Starita and Ron Garritano discussing
a new rheometer design.

SOR 2010: Short Courses Santa Fe

23-24 October 2010 (Saturday-Sunday)

24 October 2010 (Sunday)

Colloidal Dispersion Rheology

Jan Mewis
Department of Chemical Engineering
Katholieke Universiteit Leuven, Belgium

Norman Wagner
Department of Chemical Engineering
University of Delaware, USA

The course is designed to be an introduction to the rheology of colloidal dispersions with emphasis on practical measurement and interpretation of rheological measurements on colloidal dispersions. The object is to provide the participants with:

- a qualitative understanding of the various phenomena that contribute to the rheology of suspensions;
- scaling relations and quantitative laws to predict the basic rheology of such systems;
- strategies to measure, characterize and design suspensions with well defined processing or application properties.

This course is appropriate for students and practitioners of colloid rheology in industry as well as academia. A basic understanding of physical chemistry is necessary with some familiarity with colloidal science and basic rheology helpful but not required.

The suspension course is structured so as to build upon the fundamental understanding of how various properties of colloids and their interactions lead to the observed rheological behavior in a systematic treatment. This starts with systems where only purely hydrodynamic effects are present (i.e., suspensions with non-colloidal particles). Next, colloidal particles are introduced; with Brownian motion but without any particle interaction force. After that, systems with additionally repulsive interparticle forces are dealt with: i.e., colloidally stable systems. Finally attractive forces are added which can lead to flocculated suspensions and colloidal gels. The methods of rheological measurement design and execution are discussed, treating the special difficulties that arise in the case of suspensions. Case studies will be analyzed to illustrate the basic concepts of the course. Finally, special advanced topics are to be included depending on the interest of the students. Time will be available for a question and answer session based on problems and issued submitted by students prior to the course.

Microrheology: Theory, Practice and Applications

Eric Furst
Department of Chemical Engineering
University of Delaware USA

Patrick Doyle
Department of Chemical Engineering
Massachusetts Institute of Technology USA

Patrick Spicer
Complex Fluids Group
Procter and Gamble Company

For decades, conventional (macroscopic) rheology has been employed as a powerful method to characterize and understand complex biological, technological and industrial soft materials. The past decade, in turn, has seen the development of microrheology, in which the motion of colloidal tracer particles is related to the viscoelastic properties of the surrounding material. Significantly, microrheological measurements require mere microliters of sample, provide an extended range of frequencies, enable spatially resolved rheological measurements and other benefits. For these reasons, microrheology has emerged as a powerful complement to traditional bulk rheological characterization.

This short course will present a broad overview of microrheology, emphasizing the underlying theory, practical aspects of its implementation and current applications in academic and industrial laboratories. The microrheology literature continues to rapidly evolve, and applications are expanding at an accelerating pace. Participants of this course will learn the key methods and techniques. For instance, microrheological measurements can be as simple as recording video microscopy data. As long as the analysis and sources of experimental error are accounted for appropriately, these simple experiments can yield rich rheological information. The course will cover topics ranging from active microrheology using laser or magnetic tweezers to passive microrheology, such as multiple particle tracking and diffusing wave spectroscopy. Overall, this course will provide a comprehensive introduction to microrheology for industrial and academic researchers who either wish to become informed in this relatively new field of rheology, or seek to incorporate these methods in their own research.

www.rheology.org/SoR/short_course/2010Oct/

Weissenberg and Deborah Numbers – Their Definition and Use

John M. Dealy
McGill University Canada

Introduction

Dimensionless (NOT "non-dimensional") groups have proven extremely useful to scientists and engineers in the presentation of experimental data in such a way that a single plot in terms of such groups brings together data for a range of materials and flow conditions. Inspired by this success, there has been considerable interest in making use of this approach to represent data on non-Newtonian fluids. A group used with great success to correlate flow data for Newtonian fluids is the Reynolds number. For such fluids, only a single parameter, the viscosity, is required to describe rheological behavior. Inspired by this success, there has been considerable interest in using this approach to represent data for non-Newtonian fluids. For viscoelastic fluids, rheological behavior cannot be described by a single number, and two dimensionless groups are currently in use to correlate data for such materials. The Deborah number (De) governs the degree to which elasticity manifests itself in response to a transient deformation. It is the ratio of a characteristic time of the fluid to the duration of observation. Unless a deformation is very small or very slow, the behavior of a viscoelastic fluid is strongly nonlinear, and the group intended to describe the degree to which nonlinearity is exhibited is the Weissenberg number (Wi). It is the product of a characteristic time of the fluid and a characteristic rate of deformation. In polymeric fluids and suspensions of anisotropic particles, the Weissenberg number also governs the onset of stress anisotropy. In this article, we discuss the challenges involved in defining dimensionless groups for non-Newtonian fluids and establishing values for the parameters appearing in them. There is currently widespread misapplication of these groups that arises from misunderstanding of these issues. When these have been cleared away, we will find that except in a few special situations, it has not been possible to achieve the desired generalization of data.

Besides elasticity there is another type of time-dependency that is not related to elasticity and thus not governed by a Deborah number, and that is a structural time-dependency caused by changes in the structure of suspended particles as the result of deformation. Such materials are time-dependent and nonlinear but not elastic, unless the suspending medium is elastic. The present discussion is limited to single-phase, polymeric liquids in which structural time-dependency does not occur.

Characteristic Time of a Fluid

A major challenge in the use of the Weissenberg and Deborah numbers is the identification of a single, appropriate characteristic time of the fluid. A single-element Maxwell element has one relaxation time, but a polymeric liquid generally has a spectrum of relaxation times, and it is not obvious which, if any, particular time governs a fluid's nonlinearity and elasticity. There are two approaches to this issue. One is to define a characteristic time empirically based on a measurable quantity, for example a moment of the relaxation spectrum. The other approach is to use a time from a molecular theory, and possible choices include the longest Rouse time, the equilibration time, and the reptation time, the latter two of which arise in the Doi-Edwards model for entangled polymers. The fact that a distribution of relaxation times rather than a single characteristic time governs nonlinearity and viscoelasticity in polymeric liquids restricts the usefulness of De and Wi to plotting either model predictions or to correlating data for polymers that are monodisperse in terms of both molecular weight and structure. Slattery [1] examined this issue and concluded that to scale-up the flow behavior of multimodal viscoelastic fluids for engineering applications "...it is necessary to use the same fluid in the model experiments as that which one hopes to use in the full-scale process."

Deborah Number

In his after-dinner talk presented at the Fourth International Congress of Rheology [2] Marcus Reiner told the story of the origin of the Deborah number. In 1928, he was working with Eugene Bingham to create the science of rheology, and they realized that there is a very broad range of ways in which materials respond to forces or deformations. In order to classify these, Reiner took inspiration from an early English translation of the Bible. Quoting Reiner, "In her famous song after the victory over the Philistines, [the prophetess Deborah] sang 'The mountains flowed before the lord.'" He proposed that the Deborah number therefore be defined as: De = time of relaxation/time of observation. Thus, it is a ratio of a property of the material to a time related to the duration of the observation. The definition currently given by Wikipedia is drawn from the Reiner source and is for the most part as given above, as is the one in the NIST Guide to Rheological Nomenclature [3]. Marrucci and Astarita [4] have suggested a more rigorous definition of

the Deborah number.

Metzner et al. [5] point out that in homogeneous deformations, the "time of observation" i.e, the duration of observation, is not the reciprocal of the rate of deformation, although this error continues to be made all too often in presentations and publications. This point is emphasized by Marruccci and Astarita [4], who note that in any flow with constant stretch history the Deborah number is identically zero. Examples of homogeneous deformations are steady simple shear and steady simple extension. In these flows, we see no change in behavior no matter how long we observe, and the reciprocal of the strain rate is not the duration of observation in the Deborah number. The rate of deformation does enter into the Weissenberg number in homogeneous flow, and there are non-homogeneous flows, e.g., flow at a contraction, in which a characteristic strain rate and a characteristic duration of the deformation are related. This issue is examined below.

Weissenberg Number

The Weissenberg number is commonly written as either We or Wi, but to avoid confusion with the Weber number [6] we will use Wi. The Weissenberg number was introduced by White [7] who wrote Cauchy's momentum equation for the case of a "second order fluid" and identified the governing dimensionless groups. His analysis yielded two groups involving the rheological behavior of the fluid, the Weissenberg number and the "Viscoelastic ratio number." He defined the Weissenberg number as $\lambda U/L$, where U is a velocity, L a length, and λ a characteristic time of the material, which in his analysis was the ratio of zero-shear limiting values of two viscometric functions $\Psi_{1,0}/\eta_0$. The viscoelastic ratio number was defined by White as $\Psi_{2,0}/\Psi_{1,0}$, the ratio of the limiting zero-shear rate values of the second and first normal stress differences. White named the first new group in honor of Karl Weissenberg [8] who was the first to recognize the significance of normal stress differences in the behavior of non-Newtonian fluids and was the inventor of the first instrument for their measurement, the Weissenberg Rheogoniometer.*

We note that the Deborah number does not arise in White's analysis, and this is because the rheological behavior exhibited by a "second order fluid" is actually that given by the first two terms of an infinite series about the rest state of a "simple fluid." It is valid not for a class of materials but for a very slow motion that varies very slowly and continuously with time. As a result of

this choice, the only deviation from Newtonian behavior that emerges from this analysis is the presence of non-zero first and second normal stress differences. In other words, we have a second-order, slow-flow approximation, not a model for a general class of materials, and viscoelasticity as a time-dependent phenomenon is not described. Since the second-order analysis is not able to describe elastic behavior, White's way of defining the characteristic time of the material is not generally applicable.

In White's definition of Wi the characteristic time of the material is multiplied by U/L, which is a strain rate. In flows with constant stretch history, in particular, steady simple shear and steady simple extension, the Weissenberg numbers are clearly $\dot{\gamma}\lambda$ and $\dot{\varepsilon}\lambda$ respectively. In inhomogeneous and time-unsteady flows, the situation is less clear, and Wi in three such flows is described below. The definition of Wi currently given in Wikipedia is remarkably good, although no sources are cited. The concise definition in the NIST Guidelines [3] is "…the degree of nonlinearity or the degree to which normal stress differences are exhibited…" In any case, the key point is that Wi involves a characteristic rate of deformation, not the duration of observation.
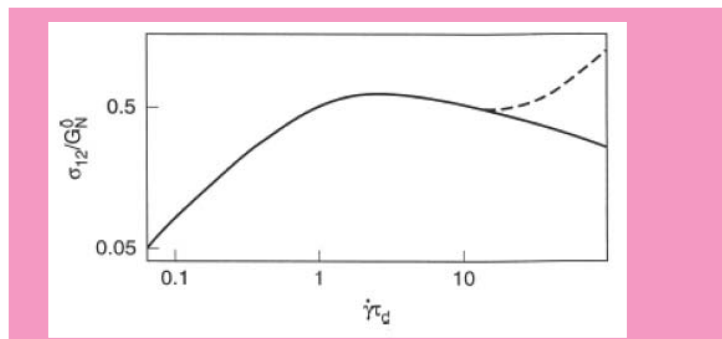
Figure 1: Dimensionless shear stress versus Wi based on the disengagement time as predicted by the Doi-Edwards theory (solid line). Dashed line adds a speculated contribution from Rouse modes. (Doi and Edwards [10]).

The Weissenberg and Deborah numbers are most useful in dealing with viscoelastic materials when plotting either predictions of a theory or when correlating data for polymers that are monodisperse in both molecular weight and structure. Uses of Wi for these two purposes are illustrated in Figs. 1 and 2. Figure 1 shows the prediction of the Doi-Edwards model for steady simple shear, while Fig. 2 is a plot of steady-state extensional stress data for model polystyrenes.

There are fluids that do not exhibit elasticity or normal stress differences but that still have shear-rate-dependent

---

*White interpreted his Weissenberg number as a measure of "the amount of recoverable strain in the fluid," citing a proposal made earlier by Weissenberg [8] that "the recoverable strain …coordinates the rheological states with respect to similitude in anisotropy in the sheared states…" And Philippoff and Gaskins [9] later proposed that the recoverable strain s in simple shear was given by the ratio of the first normal stress difference to the shear stress and used this concept to interpret their data on the flow of a polymer solution in a capillary. However, these interpretations are not useful as definitions of Wi for use as a correlating parameter, because they involve dependent variables.

Figure 2 Steady-state extensional stress versus Wi based on the Rouse time for solutions of linear (open symbols) and star polystyrene entangled solutions Bhattacharjee et al. [11].
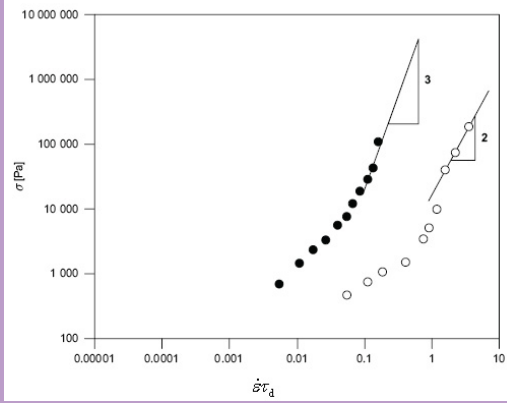
viscosities, and Wi may be useful in dealing with such materials. Whether or not elasticity plays a role, any dimensionally consistent equation describing the dependency of viscosity on shear rate must have a parameter with units of time that may be identified with a characteristic rate of deformation and thus used in Wi. The common power-law model (Eq. 1) does not include such a parameter, but it does contain a parameter whose units are not physically meaningful and, worse, these units depend on the value of another parameter.

$$\eta = k \left(\dot{\gamma}\right)^{n-1} \tag{1}$$

where k is the power-law consistency with SI units of Pa s^n. This deficiency can be easily dealt with by introducing parameters with units of viscosity and time as shown by Eq. 2.

$$\eta = \eta_0 \left(\lambda \dot{\gamma}\right)^{n-1} \tag{2}$$

In this form the power-law model now contains a characteristic time with physical significance: the reciprocal of the shear rate at which the extrapolation of the power-law line reaches the value of η_0 is equal to λ.

Start-up flows

A start-up flow is one in which a steady rate of deformation is suddenly imposed at time $t = 0$, and the time of observation is simply t, so the Deborah number depends on time and is given by Eq. 3.

$$\text{De} = \lambda/t \tag{3}$$

At long times the flow approaches steady state, and De approaches zero, but at early times, the response depends strongly on the relaxation spectrum of the material.

At $t = 0$, De is infinite, and one wonders how this should be interpreted. Of course it is practically impossible to accelerate the moving surface of a rheometer along with the fluid to a non-zero velocity instantaneously, and one should use the true start-up ramp time as the initial value of t in De. But what if one could accelerate the moving rheometer surface to a constant velocity instantaneously?

There would be no time for Brownian motion to accommodate the deformation, so the response would be that of a solid, and deformation could only occur as the result of the bending of chemical bonds. This would involve an extremely high stress, which would almost certainly result in slip or rupture of the material rather than homogeneous deformation. In fact, rupture (catastrophic disentanglement) is often observed in start-up experiments on highly-entangled polymeric liquids. In addition, for a truly instantaneous motion of the surface, a shear wave would have to penetrate through the sample before homogeneous deformation could be established.

Large-amplitude oscillatory flow

Large amplitude oscillatory shear has been used to characterize the nonlinear behavior of polymers during a shearing deformation. The shear strain is sinusoidal, as in the measurement of the storage and loss moduli, but the strain amplitude is sufficiently large that the response is not governed by the Boltzmann superposition principle. As a result, the stress is not sinusoidal and cannot be interpreted in terms of in-phase and out-of-phase components. For an isotropic material, the stress should have certain symmetry properties such that it can be represented as a Fourier series:

$$\tag{4}$$
$$\sigma(t; \omega, \gamma_0) = \gamma_0 \sum_{n=1(odd)}^{\infty} \left[G'_n(\omega, \gamma_0) \sin(n\omega t) + G''_n(\omega, \gamma_0) \cos(n\omega t) \right]$$

where γ_0 is the strain amplitude, and ω is the frequency. Giacomin and Dealy [12] have described the use of this technique, and Wilhelm et al. [13] have proposed a method for inferring the higher harmonics of the response by high-sensitivity Fourier transform.

Unfortunately, there is no way to interpret specific harmonics in terms of particular features of molecular structure or specific features of a constitutive equation. In addition, this representation has the undesirable feature that the coefficients in a truncation depend on the number of terms included. Ewoldt et al. [14] have shown that the use of a Chebyshev polynomial rather than a Fourier series avoids this problem.

Large-amplitude oscillatory shear has the interesting feature that the Weissenberg and Deborah numbers can be varied independently. The Weissenberg number is $\dot{\gamma}_0 \tau$, where, $\dot{\gamma}_0 \equiv \gamma_0 \omega$ and τ is a time describing the first onset of nonlinearity as the frequency increases from zero, which is τ_d according to the tube model. This low-frequency nonlinearity is related to orientation, while nonlinearity due to chain stretch will appear at $\text{Wi} \approx \gamma_0 \omega \tau_R$. The Deborah number is $\omega\tau$, where τ is

16

the longest relaxation time, which is τ_d in tube models.

Channel entry flow - Wi related to De

Converging flow involves simultaneous extensional and shear deformations, and this complicates the use of De and Wi, particularly with regard to the identification of a characteristic duration of the deformation and a characteristic rate of deformation. For a characteristic shear rate, the obvious basis is fully-developed flow in the channel. We will consider here the case of axially symmetric entrance flow from a reservoir of radius R_0 into a smaller tube (capillary) of radius R_C. In addition to the geometric parameters there is one kinematic one, the volumetric flow rate, Q. The only characteristic shear rate that we can calculate directly from these parameters is the apparent wall shear rate in the smaller tube, that is, that for a Newtonian fluid:

$$\dot{\gamma}_A = \frac{4Q}{\pi R_C^3} \tag{5}$$

Then the Weissenberg for the shear flow is:

$$\text{Wi} = \lambda \dot{\gamma}_A = \frac{\lambda 4Q}{\pi R_C^3} \tag{6}$$

It is also possible to estimate a Weissenberg number for the extensional flow that occurs due to the converging streamlines. The total Hencky strain ε can be estimated from the change in length of a fluid element, from L_0 to L_C as it moves from the reservoir, in which the average axial velocity is U_0, into the capillary, where the average velocity is U_C.

$$\varepsilon = \ln\left(\frac{L_C}{L_0}\right) = \ln\left(\frac{U_C}{U_0}\right) = \ln\left(\frac{R_0}{R_C}\right)^2 \tag{7}$$

The identification of a characteristic extensional strain rate is not straightforward. Based on many observations, we will assume that the extensional deformation takes place over an axial distance that is a multiple N of the capillary diameter, where N is in the range of 4 to 8. The time required for flow through this length of channel is:

$$t_{flow} = \frac{NR_C}{2U_C} = \frac{\pi N R_C^3}{32Q} \tag{8}$$

A characteristic extensional strain rate is then:

$$\dot{\varepsilon} \approx \ln\left[\left(\frac{R_0}{R_C}\right)^2\right]\left(\frac{32Q}{\pi N R_C^3}\right) \tag{9}$$

and a Weissenberg number for the extensional flow is:

$$\text{Wi} = \lambda \ln\left[\left(\frac{R_0}{R_C}\right)^2\right]\left(\frac{32Q}{\pi N R_C^3}\right) \tag{10}$$

For a Deborah number, we divide a characteristic relaxation time by the duration of the time-unsteady flow.

$$\text{De} = \frac{32\lambda Q}{\pi N R_C^3} \tag{11}$$

For a given geometry, we see that Wi and De are proportional to each other. However, Wi and De are poorly defined, and, in general, we conclude that for inhomogeneous flows De and Wi are unlikely to be useful.

The "High Weissenberg Number Problem" in Numerical Simulation

Those wishing to do numerical modeling of flows of viscoelastic fluids have long faced a major problem in dealing with flows involving high local stress concentrations, and this difficulty is called the "high Weissenberg number problem" [15,16,17]. The problem was first confronted when using continuum mechanics models such as the upper-convected Maxwell or Oldroyd-B models, and obtaining numerically accurate and mesh-convergent solutions using such models in flows in which there are corner singularities is still not possible [18].

However, success has been achieved using sophisticated numerical techniques for simulations based on molecular models or for micro-macro simulations based on "realistic" coarse-grain models, although these models have much less "elasticity" than the older and simpler continuum models. Also, the value of Wi is usually based on a zero-shear (effective) relaxation time and can thus reach high values while the effective stress ratio is still moderate or even low [19].

Flows of polymeric fluids that require numerical models involve nonuniform deformations in which there are both extensional and shear components, and the flow is time-unsteady from the point of view of a fluid element, i.e., in a Lagrangian frame. Thus, both nonlinearity (Wi) and viscoelasticity (De) are important. Calling the difficulty that arise at high velocities the "high Weissenberg problem" assumes that it arises from nonlinearity, but it is equally or even more likely that the problem arises because of the time-dependency (viscoelasticity) of the fluid. It may thus be more appropriate to refer to it as the "high Deborah number problem." But Roland Keuning comments that "changing from HWNP to HDNP won't make the problem any simpler."

Summary and Conclusion

The Deborah number is intended to describe the extent to which the response of a material to a deformation is

viscoelastic rather than purely viscous. It is the ratio of a characteristic time of the fluid to a time reflecting the duration of observation. The Weissenberg number, on the other hand, is a dimensionless group intended to describe the nonlinearity of the rheological response. It is the product of a characteristic time of the fluid and a characteristic rate of deformation. The problem that arises in the use of these groups is the identification of a characteristic time of the fluid and a characteristic duration of observation and/or a characteristic rate of deformation. Failure to deal with these issues correctly has led to incorrect statements in many papers and books. But even when Wi and De are used correctly, it has not been possible, except under certain conditions, to achieve the desired generalization of data. The conditions under which generalization has been possible are as follows:

1. The flow must be homogeneous;
2. If a transient deformation, its time-dependency must be describable in terms of a single variable, for example the frequency in large-amplitude oscillatory flow;
3. It must be possible to describe the rate of deformation by a single parameter;
4. The fluid must have a well-defined characteristic time that can be measured or predicted, and this time must correlate with the duration of the observation and the phenomena of interest.

These requirements are fully met for viscoelastic materials only when plotting either predictions of a theory or when correlating data for polymers that are monodisperse in terms of both molecular weight and structure.

Acknowledgements

References

1. J. C. Slattery, "Dimensional considerations in viscoelastic flows," *A.I.Ch.E.J.*, 14, 516-518 (1968).
2. M. Reiner, "The Deborah number," *Physics Today*, 17 (1), p. 62 (1964).
3. V. A. Hackley and C. F. Ferraris, "The use of nomenclature in dispersion science and technology." NIST Special Publication 960-3, National Institute of Standards and Tecnnology, Gaithersburg, MD (2001).
4. G. Marrucci and G. Astarita, "Significance of the Deborah number in steady flows," *Meccanica*, Sept. 1967, 141-143.
5. A. B. Metzner, J. L. White and M. M. Denn, "Constitutive eqations for viscoelastic fluids for short deformation periods and for rapidly changing flows: Significance of the Deborah number," *A.I.Ch.E.J.*, 12, 863-866 (1966).
6. G. H. McKinley, "Dimensionless groups for understanding free surface flows of complex fluids," *Rheol Bulletin (Soc. of Rheol.)*. 72 (2) 6-9,18-19 (2005).
7. J. L. White, "Dynamics of viscoelastic fluids, melt fracture, and the rheology of fiber spinning," *J. Appl. Polym. Sci.*, 8, 2339-2357 (1964).
8. K. Weissenberg, "A continuum theory of rheological phenomena," *Nature*, 159, 310-311 (1947).
9. W. Philippoff and F. H. Gaskins, "The capillary experiment in rheology," *Trans. Soc. Rheol.*, 2, 263-284 (1958).
10. M. Doi, M. And S.F. Edwards "Dynamics of concentrated polymer systems. Part 4 – Rheological properties." *J. Chem. Soc. Faraday Trans. II*, 75, 38-54 (1979).
11. Bhattacharjee, P.K., Ye, X., Sridhar, T. "Effect of molecular architecture on extensional flow of polymeric fluids." *Proc. 2nd Inter. Symp. Appl. Rheology* (2003) Seoul, Korea.
12. A. J. Giacomin, J. M. Dealy, "Using large amplitude oscillatory shear," in: AA Collyer and DW Clegg, eds. *Rheological Measurement*, 2nd Edit. London: Chapman & Hall, Chap 11. (1998).
13. M. Wilhelm, P. Reinheimer and ,M. Ortseifer, "High sensitivity Fourier-transform rheology," *Rheol. Acta* (1999) 38, pp. 349-356 (1999).
14. R. H. Ewoldt, G. H. McKinley and A. E. Hosoi, "Fingerprinting soft materials: A framework for characterizing nonlinear viscoelasticity," *J. Rheol.,* 52, pp. 1427-1458 (2008).
15. R. I. Tanner, "The stability of some numerical schemes for model viscoelastic fluids," *J. Non-Newt. Fl. Mech.*, 10, pp. 169-174 (1982).
16. R. Keunings, "On the high Weissenberg number problem," *J. Non-Newt. Fl. Mech.*, 20, 209-226 (1986).
17. F. P. T. Baaijens, "Mixed finite element methods for viscoelastic flow analysis: a review," *J. Non-Newt. Fl. Mech.*, 79, pp. 361-385 (1998).
18. M. Bajaj, M. Pasquali, and J. R. Prakash, "Coil-stretch transition and the breakdown of computations for viscoelastic fluid flow around a confined cylinder," *J. Rheol*, 52, pp. 197-223 (2008).
19. P. Wapperom and R. Keunings, "Impact of decoupling approximation between stretch and orientation in rheometrical and complex flow of entangled polymers," *J. Non-Newt. Fl. Mech.*, 122, pp. 33-43 (2004).

Edward B. Bagley (1927-2009)

by Kurt Wissbrun

It is with great regret that we announce the death of Edward B. Bagley as a result of a heart attack. He is survived by his wife Jennifer, their three children, ten grandchildren and two great-grand-children.

Ed attended the University of Western Ontario and received his Ph.D. in physical chemistry from Cornell University. He joined Canadian Industries Limited (CIL), one of the early manufacturers of high-density polyethylene and began studies of its melt rheology. He is perhaps best-known to the rheological community for the "Bagley correction" to measure the viscosity of polymer melts from capillary flow measurements. However, in addition, he and his colleagues at CIL did many of the pioneering experiments to characterize the rheology of polymer melts and to control their processing behavior, on phenomena such as extrudate swelling, distortion, and fracture, on die entry flow patterns, on flow curve discontinuities, and on effects of molecular weight distribution and long-chain branching. For this body of work Ed was awarded the Bingham Medal of The Society of Rheology in 1982. His collegiality and outgoing personality and broad interest in the progress of rheology were instrumental in his election to the Presidency of The Society for 1980-81.

Ed left CIL and joined Washington University of St. Louis in 1964 as Professor of Chemical Engineering. There he began research on polymer solution thermodynamics and on processing of intractable polymers. Subsequently, in 1971 he joined the Northern Regional Research Center of the U.S. Department of Agriculture, where he had an astoundingly productive career, culminating in being chosen as one of only five scientists to be honored as a member of the Agricultural Research Service Hall of Fame. Much of his research there was of course on agricultural and food materials, and included the invention of superabsorbent graft polymerized starch derivatives, and a process for the decontamination of aflatoxin in corn. However, he also did considerable research on the rheology of food materials and of concentrated suspensions. Overall he authored over 200 publications, including research papers, patents, and book chapters, and received numerous honors other than those cited. Ed retired in 1995, but continued to serve as a consultant and journal reviewer.

The diverse nature of the technical fields to which Ed contributed is one illustration of his wide range of interests in all aspects of life experiences.

Tai-Hun Kwon (2010)

Professor Tai-Hun Kwon from Pohang University of Science and Technology, Pohang, Korea suddenly passed away last month. Professor Kwon was a member of the Editorial Board of the *Journal of Polymer Engineering* and highly respected in the polymer community. An obituary is planed for the *Journal of Polymer Engineering*.

Society Business

NEWS

5th Australian-Korean Rheology Conference

by Howard See, Roger Tanner, and Ahmad Jabbrazadeh

The 5th Australian-Korean Rheology Conference was held at the University of Sydney Australia, 1-4 Nov 2009. There were over 100 delegates and accompanying persons.

The Reception was held in the Main Quadrangle of the University of Sydney, with the delegates enjoying the historic sandstone buildings and courtyard. The conference sessions were held at the University's Veterinary Science Conference Centre. There were two parallel sessions of oral presentations, as well as a poster session on the afternoon of 2 Nov. The Conference Banquet was held in the magnificent Refectory at the University of Sydney. The delegates ended their conference on 4 Nov by enjoying Sydney Harbour on board a luncheon cruise ship.

The Plenary Speakers were Prof Martin Kröger of ETH Zurich who spoke on "Rheology & structure of simple complex matter," and Prof O Ok Park of KAIST Korea who spoke on "Polymer Nanocomposites and Some Rheological Aspects."

The meeting was organized by the Australian Society of Rheology, in consultation with the Korean Society of Rheology. Its success served to emphasize yet again the strong link between the Korean and Australian rheological communities. It is hoped that this relationship continues to grow and deepen, to serve not just rheologists from those two countries, but rheologists across the entire Pacific region and indeed the world.

Rheologist Baird Named Giacco Professor at Virginia Tech

BLACKSBURG, Va., November 10, 2009 -- Donald G. Baird, professor of chemical engineering at Virginia Tech has been named the Alexander F. Giacco Professor of Chemical Engineering by the Virginia Tech Board of Visitors.

The Alexander F. Giacco professorship is funded through the Alexander F. Giacco Endowed Presidential Chair Fund, which was initiated by a donation from Hercules Inc. to honor the many contributions to business and education by Alexander F. Giacco, former president of Hercules and a 1942 alumnus of the Virginia Tech Department of Chemical Engineering.

Baird is internationally known for his expertise, research, and teaching in the field of polymer rheology and its application to polymer, biopolymer, and polymer composite processing. His research utilizes both theoretical and experimental tools, and he continues to

Don Baird with his polymers and rheology research group at Virginia Tech. First row, left to right: M. Lee, C. Chen, G. Velez, D. Baird, S. Mazahir, J. Huang. Second row: K. Ortman N. Agarwahl, C. McGrady, M. Heinzer. Not shown K. Meyer and J. Hoffman.

find ways to apply these tools to new areas of research, including fuel cells and bio-materials.

During the past 31 years, he has been the principal or co-principal investigator on research funding totaling more than $33 million. Baird has authored more than 153 peer-reviewed publications, including four major review articles, 107 refereed preprints, 43 other publications, 10 book chapters, and a major textbook.

He is active in many major technical societies and has served on the executive committees of several professional organizations, including The Society of Rheology. He has received numerous awards for both his research and teaching, including the International Award from the Society of Plastics Engineering (the highest sward presented by the society), the Jack Breslin Award from Michigan State University, the Alumni Research Award from Virginia Tech, the Dean's Award for Excellence in Research, the Dean's Award for Excellence in Teaching, and the DuPont Young Faculty Award.

Baird received his bachelor's degree and master's degree from Michigan State University and a Ph.D. from the University of Wisconsin at Madison. While at Michigan State he earned All Big Ten, Academic All Big Ten, and Academic All American Honors in football.

Travel Grants Available for Santa Fe 2010

The Society of Rheology is again offering grants to partially support the cost of attending the Annual Meeting of the Society in Santa Fe, New Mexico USA. These grants are available to any graduate student who is a member of the Society as of 24 July 2010 and whose faculty advisor is also a member as of that date. We anticipate that each grant will cover up to a maximum of four days of lodging at the conference hotel. Only students who have never before received an SOR travel grant are eligible.

To apply, the student must write a letter requesting the grant. The student's faculty advisor should add a letter of support, certifying that both the advisor and the student

are members of The Society of Rheology. Only one application per faculty advisor will be accepted for each meeting. Letters from the student and advisor should be submitted to Norman Wagner by 24 July 2010 using the web process per the instructions at *www.rheology.org/ sor/annual_meeting/2010Oct/student.htm*.

2011 SOR Nominating Committee to be Formed

Elections for officers of The Society of Rheology will take place in 2011. The Nominating Committee will be formed in October 2010. Members interested in serving on the Nominating Committee or in any other capacity in The Society of Rheology are encouraged to contact Faith Morrison (fmorriso@mtu.edu) or other members of the Executive Committee (see page 2).

UniPHY Acquired by Elsevier

UniPHY, the world's first literature-based profes-

Rheology and The Society of Rheology were well represented at the 5-day workshop on "Small scale hydrodynamics: microfluidics and thin films" at the Banff International Research Station, held February 2010. The workshop was organized by Richard Craster (University of Alberta), G. M. Homsy (University of British Columbia), and Demetrios Papageorgiou (Imperial College London).

sional social networking site for physical scientists, was acquired by Elsevier in May 2010. UniPHY (*www. aipuniphy.org/Portal/Portal.aspx*) is a service developed for the American Institute of Physics (AIP) by Collexis Holdings, Inc beginning in July 2009. The Society of Rheology is a founding member of AIP.

The purpose of UniPHY is to enable physicists, engineers, and other scientists to connect with colleagues through a professional social networking internet site. The goal of UniPHY is to promote future collaborations as well as to deepen existing relationships among physical scientists.

Rheometer Donation Received by ZDS

Central College of the German Confectionery Industry (ZDS) in Solingen recently enhanced its rheological capability through its receipt of a donation of a Thermo Scientific HAAKE Viscotester 550 rotational viscometer. The instrument, used to determine the flow behavior and yield point of chocolate melts, was donated by the manufacturer, Thermo Fisher Scientific. The new instrument will be used by students to evaluate the quality of the chocolate they make.

"The donation of the rotational viscosimeter enables the ZDS to present the important topic of rheology in a modern and professional setting for training and career development," said Andreas Bertram, managing director of the ZDS. Founded in 1951, the ZDS in Sollingen, Germany is a center for training and professional development for all sectors of the confectionery industry.

Bulletin Photos Sought

SOR members are invited to submit photographs for consideration for publication in the *Rheology Bulletin*. Photographs of rheological phenomena are particularly welcome for use on the cover. The Bulletin also publishes photographs covering rheological meetings and events. Please send any submissions to the editor at fmorriso@mtu.edu. Please include any photo-credits that should accompany the photo when published.

Minutes of the ExCom Meeting

Sunday, May 9, 2010
St. Paul, Minnesota

Attending: Faith Morrison, Jeffrey Giacomin, Albert Co, Monty Shaw, John Brady, Bob Prud'homme, Hiroshi Watanabe, Norm Wagner, Ole Hassager, Andy Kraynik, Tim Lodge, Lynn Walker, Shelley Anna, Pat Mather, Jai Pathak, Robert Harington (AIP).

President Faith Morrison called the meeting to order at 8:45 a.m. in the Metropolitan Room at the Minneapolis-St. Paul International Airport Conference Center, Lindbergh Terminal, 4300 Glumack Drive, St. Paul, Minnesota.

The minutes were read by Secretary Albert Co. A motion to approve the minutes was passed.

John Brady, *JOR* Editor, reported on the status of *JOR*. There were around 130 submissions in 2009, with and average of 130 days from receipt to final decision. The 2009 issues of *JOR* have 1463 pages, with around 250 pages per issue. The current impact factor of *JOR* is 2.69 and its 5-year impact factor is 3.01. It was suggested that members of the editorial board be brought in for consultation and support when contentious issues arise in the editorial process.

Monty Shaw reported on the financial status of the Society and of *JOR*. Jeffrey Giacomin brought up the issue of paper costs for *JOR*, which are rising. Jeffrey Giacomin and Robert Harington of AIP will look further into the source and justification for these increases. The net receipts of the Madison meeting are $4,599 (not including the cost of the Student Member Travel Grants); the net receipts for the short course in Madison are $5,578. The cost of the Student Member Travel Grants was $21,542. The library subscription rate of JOR is $550/year and has not risen in many years.

Albert Co, Secretary and Webmaster, reported on web activities. Co presented lists of available PDF archives for the *Rheology Bulletin* and available databases of annual meeting abstracts. Harrington was asked to request a quote from AIP Publishing Services for producing electronic records of meeting abstracts for those years not currently covered by the web archive. The member-only side of the website is scheduled for an update in the

summer of 2010. The *Rheology Bulletin* archive and ExCom minutes archive are planned to be added to the member-only side of the website at that time.

Faith Morrison brought up the AIP request for support on a letter regarding Federal Research Public Access Act. The letter was discussed, but no action was taken.

Tim Lodge, Chair of the Bingham Committee, reported on the selection procedure of the Bingham Award. A motion to include in the Bingham medal guidelines stating unsuccessful nominations will be reconsidered in a subsequent year, after which nomination packages need to be resubmitted, was passed. A motion to remove from the guidelines the requirement that "the contributions for which the award is granted shall have been made during the ten years preceding the award" was passed.

Lynn Walker, Chair of the Metzner Committee, reported on the selection procedure of the Metzner Award. A motion to include in the guidelines stating "unsuccessful nominations may be reconsidered in a subsequent year if the nominee is still qualified and the nominator sends a letter requesting reconsideration to the chair of the Metzner Award committee" was passed. The ExCom directed Webmaster Co to work with Morrison to clarify the Metzner requirements on the web, including both the fact that the award need not be given annually and the new provision passed above.

Shelley Anna, Chair of the Membership Committee, reported on several membership statistics. There are 1405 members as of April 2010, including 179 student members. Proposals for conducting an exit survey, conducting a survey of current members, and providing gifts for graduating Ph.D. students were presented. A motion to fund gifts for graduating Ph.D. students who are student members for more than a year was passed. Tim Lodge suggested the SOR may wish to recognize 10-year or other members in some way.

Andy Kraynik reported on the status of the upcoming Santa Fe meeting; planning is proceeding well. Kraynik also presented the layout of the meeting rooms and locations of the social events. The possibility of a lecture to be given by the Metzner awardee was discussed; this was not adopted out of concern for the possible disruption caused by the scheduling of this talk. Pat Mather reported on updates of the Cleveland meeting in 2011. Layout of the meeting rooms and options of the locations of the social events were discussed. Norm Wagner reported that the contract for the Philadelphia meeting in 2014 has been signed. John Brady reported on the status of Pasadena meeting in February 2013 and described various social event options. Jai Pathak presented

a proposal to hold the annual meeting in Baltimore during 10-15 October 2015. Meeting room layout and social program options were described. The Committee expressed some concern with room-rate costs. Hiroshi Watanabe reported that negotiation is still ongoing for ICR 2016 in Asia.

Robert Harington discussed possibilities of publishing partnerships with AIP.

Faith Morrison reported for Michael Solomon that the Education Committee is considering short course proposals for the Cleveland meeting; the committee will report its recommendations for Cleveland at the ExCom meeting in October.

The meeting entered into Executive Session at 3:05 p.m.

The meeting was adjourned at 3:25 p.m.

Submitted by Albert Co, Secretary

Treasurer's Report

To the membership:

The tables below summarize the financial position and activities of The Society of Rheology for 2009. Included is the approved 2010 budget, along with a proposed budget for 2011; the latter will be presented to the Membership for approval at the 2010 business meeting in Santa Fe. While the Society weathered the recession successfully, we suffered from the low interest rates associated with the recovery. Also, we need to be aware of ominous trends in publishing, particularly legislation forcing publishers to provide open access for papers based on U.S. federally supported research. Such legislation, could threaten our major source of income—the *Journal of Rheology*. For the time being, however, the Society is in a stable financial position: the annual meetings and short courses continue to fair well, the membership has declined only slightly, and licensing of subscription consortia has buoyed *JOR* institutional subscription numbers.

Respectfully submitted,

Montgomery T. Shaw
Treasurer

The Society of Rheology, Inc.
Balance Sheet

(all amounts, USD)	2009 Year End	2008 Year End	2007 Year End	2006 Year End	2005 Year End
Assets					
Cash in checking account(s)	18,330	10,859	24,466	9,777	12,721
Securities	0	0	0	0	0
Balance in AIP account	1,425,005	1,342,819	1,292,672	1,185,978	1,056,188
Total Assets	1,443,335	1,353,678	1,317,138	1,195,755	1,068,909
Liabilities and Net Assets					
Liabilities					
Deferred revenue	125,501	87,675	111,995	129,339	132,396
Total Liabilities	125,501	87,675	111,995	129,339	132,396
Net Assets					
Publication reserve	450,000	450,000	450,000	450,000	450,000
Student travel grant reserve	30,000	10,000	10,000	10,000	10,000
Annual Meeting reserve	300,000	300,000	300,000	200,000	200,000
Operating reserve	150,000	100,000	100,000	100,000	100,000
Unrestricted	387,834	406,003	345,143	306,416	176,513
Total Net Assets	1,317,834	1,266,003	1,205,143	1,066,416	936,513
Total liabilities and net assets	1,443,335	1,353,678	1,317,138	1,195,755	1,068,909

Journal of Rheology
Receipts and Disbursements

(all amounts, USD)	2011 Budget	2010 Budget	2009 Year End	2009 Budget	2008 Year End
RECEIPTS					
Subscriptions	175,000	172,000	174,199	171,000	172,338
Royalties & Reprint Sales	4,000	11,000	4,951	23,200	12,736
Ad Sales	41,000	39,000	39,198	34,000	43,582
JORO revenue	61,000	54,000	59,588	54,000	54,612
Miscellaneous	2,000	2,500	2,000	1,000	525
TOTAL RECEIPTS	283,000	278,500	279,936	283,200	283,793
DISBURSEMENTS					
Ads	10,000	11,000	9,990	10,000	10,671
Reprints, Single Copy	2,200	1,300	1,999	1,800	1,255
Paper, Printing	36,000	40,000	31,189	24,000	21,811
SOR Editorial	36,000	39,000	35,769	39,000	37,298
Production	39,000	41,000	39,208	42,000	39,055
Fulfillment	5,725	5,825	5,538	6,425	5,934
Distribution	26,700	28,800	24,899	25,100	20,290
Electronic publishing	39,000	38,000	35,595	34,000	32,570
Miscellaneous	7,500	7,600	6,863	7,300	5,583
TOTAL DISBURSEMENTS	202,125	212,525	191,048	189,625	174,468
Net	**80,875**	**65,975**	**88,888**	**93,575**	**109,325**

rer's Report

The Society of Rheology
Receipts and
Disbursements
(all amounts, USD)

	2011 Budget	2010 Budget	2009 Year End	2009 Budget	2008 Year End
RECEIPTS					
Dues	49,000	48,000	51,355	52,000	49,955
Interest	8,000	6,000	5,716	52,000	35,734
Journal of Rheology	283,000	278,500	279,936	283,200	283,793
Mailing List Sales	300	100	465	0	80
Donations		0	0	0	0
Bulletin Advertising	10,000	9,000	10,400	5,000	11,150
Annual Meeting (net)	0	0	4,599	0	-54,096
Short Course (net)	0	0	5,578	0	-8,347
TOTAL RECEIPTS	350,300	341,600	358,049	392,200	318,269
DISBURSEMENTS					
AIP Dues Bill & Collect.	11,000	11,000	11,076	11,000	10,834
AIP Adm. Services	8,000	9,000	6,912	9,000	9,187
AIP Mem. Soc. Dues	7,500	8,000	7,879	7,600	8,119
Contributions and Prizes	10,000	22,000	9,690	12,000	1,699
Journal of Rheology	202,125	175,000	191,048	189,625	174,468
Bulletin	19,000	19,000	18,735	16,000	18,557
Bingham Award	12,000	12,000	10,000	12,000	5,000
Executive Cmt. Meetings	11,000	8,500	11,583	11,000	8,751
Pres. Discretionary Fund	1,500	1,500	0	1,500	750
Treas. Discr. Fund	1,500	1,500	0	1,500	0
Bulletin Editor Discr. Fund	1,500	1,500	0	1,500	1,366
Progr. Chm. Discr. Fund	3,000	2,000	3,176	2,000	0
Webmaster Discr. Fund	3,000	3,000	1,202	3,000	0
International Activities Fund	5,000	5,000	886		
Office Expenses	4,000	3,000	4,288	3,000	2,196
Banking Services	100	100	90	66	65
Liability Insurance	3,900	3,900	3,830	4,500	3,830
Membership Broch. & Appl.	500	500	0	500	0
Accountant	2,000	2,000	1,920	2,100	1,940
Student member travel	26,000	26,000	21,542	24,000	0
Annual meetings, future	8,000	9,000	5,926	8,000	6,533
Website	1,500	500	2,846	500	420
Miscellaneous	500	500	19	500	0
TOTAL DISBURSEMENTS	342,625	324,500	312,649	320,891	253,714
Net	**7,675**	**17,100**	**45,400**	**71,309**	**64,555**

the end

By 1975 Rheometrics had grown significantly. Joe left his position at General Electric Research to run the company full time. He recruited and led a team of engineers who converted the gears on the instrument to an electronic drive and implemented sinusoidal oscillations with phase-angle measurement.[7] The team jumped on the digital revolution, and soon they converted all instruments from analog to digital control and data analysis. The low compliance force-rebalance transducer was patented[8] and is still the heart of the TA ARES rheometers. Joe enlisted leading rheologists like Joachim Meissner and Gerry Fuller to help develop new instruments, including several extensional rheometers. Rheometrics grew rapidly through the 1980's to become the world leader in rheometry. The expanding plastics, thermoset, and rubber industries all began to use rheology to develop nearly all their new materials, to solve processing problems, and even to control the quality of their products.

Joe Starita and Rheometrics built the first commercial rheometers that were able to measure all the important material functions over a wide range of rates and temperatures. Using his rheometers, a lab technician could obtain precise data rapidly and reproducibly and apply that data to practical situations. Joe traveled all over the world teaching hundreds of industrial chemists and engineers how to apply rheology to their processing and materials-characterization problems. Starita showed that rheological instruments could become a significant business. His example encouraged other companies to enter the field (many benefiting from the expertise of former Rheometrics employees), creating the sophisticated, robust and economical instruments that we as rheologists have to choose from today. He is the single person today to whom we should credit this revolution. Rheometrics was acquired by TA Instruments in 2003.

Joe left Rheometrics in 1993 and began a polymer consulting firm. He married Renee Kelly and with her developed a love for animals which continues today in Noah's Ark Veterinary Hospital in Dublin Ohio. Joe is also survived by two brothers, his first wife Mary Diehl and their daughters, Carol (David) Zydiak, Karen (James) Troiano and Mary Jo (Tristan) Muller and five grandchildren.

Ron Garritano, a close collaborator and colleague of Joe's from Rheometrics shared these memories of Joe. "*The early years at Rheometrics were the most productive in its history. Looking back, it's hard to fathom how we developed so many instruments in such a short time period. Joe was the catalyst. He loved the science, assembled a very competent team, and treated us all as partners. He always listened to the customer and was a consummate teacher.*

Joe discussing dinner with Countess on his farm in Marysville, Ohio.

From the very moment he started the business, Joe visited and brought in customers from all over the world... Europe, Australia, Japan, China, India, and Korea. University professors, corporate leaders, scientists and lab technicians were proudly introduced to most of our team. He had a vision of where the world was headed and wanted all to be part of it.

Through it all, Joe always had a great sense of humor. He hid the business pressures of the times from most of the employees, especially engineering. He was our #1 practical jokester, and I could always tell by that grin and glint in his eye that he was up to no good."

References
1. S.D. Freeman and K. Weissenberg, Some new rheological phenomena, *Nature* 162 pp. 320 ff. 1948.
2. J.D. Ferry, *Viscoelastic Properties of Polymers*, Wiley, New York, 1961.
3. J.R. Van Wazer, J.W. Lyons, K.I. Kim and R.E. Colwell, *Viscosity and Flow Measurement: A Laboratory Handbook of Rheology*, Interscience, New York, 1963. p 329.
4. B. Maxwell, R.P. Chartoff, "Studies of a polymer melt in an orthogonal rheometer," *Trans. Soc. Rheol.* 9, 41–52, 1965.
5. J.M. Starita and C.W. Macosko, "A Force Measuring Apparatus," US 3,363,425, 1972.
6. C.W. Macosko and J.M. Starita, "A new rheometer is put to the test," *SPE Journ.* 27(11), p38, 1971.
7. C.W. Macosko and J.M. Starita and R. Garritano, "Automated dynamic mechanical spectra," *SPE Annual Technical Conference (ANTEC)*, 24, p2, 1978.
8. R.F. Garritano, "Apparatus and for Measurement of Viscoelastic Properties of Materials," US 4,601,495, 1986.

all aspects of the scientific endeavor, carrying out his work in a highly social setting, with plenty of stimulating discussion and interaction. He knows how to spot, attract, and cultivate, talent, as evidenced by those he has drawn into his groups at various times, including Sasha Semenov, Peter Olmsted, and Alexei Likhtman, all brilliant theorists. Tom is also a prolific organizer. His interests outside of science add zest to his personality; meetings with Tom at the helm or as co-organizer are always memorable, successful, and fun. I was one of many to experience the "McLeish effect" at the Isaac Newton Program on Complex Fluids in 1996, and the more recent Institute for Theoretical Physics (ITP) program at Santa Barbara on complex fluids, as well as at other venues. Indeed, Tom has a unique ability to draw out the best from everyone in the scientific arena. Anyone who has collaborated with Tom is eager to repeat the experience.

Tom retains a youthful enthusiasm for research ideas. He has an insatiable curiosity and is constantly looking for connections with his own work. At the UCSB ITP on complex fluids, Tom spotted a poster on solar dynamics, and drew the author into a discussion on the relationship between solar magnetic flux tubes and polymers! (This discussion resulted in a publication in *Astrophysical Journal*.) In a lunch talk at the ITP, Tom explained Rouse modes to solar physicists by using a rope, held at one end by an audience member and jostled by Tom at the other, to produce "Brownian motion." Tom's breadth, clarity, humor, and enthusiasm make him a delightful lecturer and a wonderful teacher. Tom also is a frequent publisher in popular journals, giving him a very broad exposure to the scientific community and into the wider non-scientific community. Tom has frequently been interviewed by news, radio, and T.V. journalists, such as BBC, Netherlands, ABC, and others. He somehow also finds time to play French horn, to sing in ensembles, to compose music with Leeds composer Richard Kenwood-Herriot, to scuba dive, sail, and hike and camp with his wife and four children.

I am pleased to be one of many to count Tom as a dear friend and to congratulate him on his well-deserved selection as Bingham Medalist. Good show, Tom!

5-9 October 2014
86th Annual Meeting of The Society of Rheology, Philadelphia, PA USA, Michael Mackey and Norm Wagner

2015

October 2015
SOR Short Course on Rheology (topic and location TBA)

October 2015
87th Annual Meeting of The Society of Rheology, (location TBA)

2016

August 2016
XVIIth International Congress on Rheology (every four years; in 2016 in Asia)

See also:
www.rheology.org/sor/info/Other_Mettings.htm
www.rheology-esr.org/Meetings.php
www.appliedrheology.org/ (click on conferences)

been considering the coupling of shear-induced demixing and the mechanical shear-banding problem and has provided a unified framework within which both types of transitions can be studied. Most recently, Fielding has turned her attention to the areas of shear banding in yielding and glassy fluids and instabilities in active fluids (for example, bacteria, swarming fish, and birds). She has made significant contributions in both areas already. Fielding's ability to choose important areas of study, and to have an impact quickly, are two of the many qualities cited by the committee as reasons for her selection for the Metzner Award.

CALENDAR OF RHEOLOGY CONFERENCES AND COURSES

2010

4-7 July 2010
26th Annual Meeting of the Polymer Processing Society, Banff, Canada, U. Sundararaj

19-21 July 2010
Short Course on *Coatings for People in General Industry, Sales and Marketing*, Missouri University of Science and Technology, St. Louis, MO. (coatings.mst.edu)

1-6 August 2010
5th Pacific Rim Conference on Rheology, Hokkaido University, Sapporo, Hokkaido, Japan, Hiroshi Watanabe (*prcr2010.com*)
(approximately every 4 years)

20-24 September 2010
Short Course on *Basic Composition of Coatings*, Missouri University of Science and Technology, St. Louis, MO. (coatings.mst.edu)

23-24 October 2010
SOR Short Course on *Suspension Rheology*, a two day course by Jan Mewis and Norman Wagner, Santa Fe, NM USA

24 October 2010
SOR Short Course on *Microrheology: Theory, Practice and Applications*, by Eric Furst, Patrick Doyle and Patrick Spicer, Santa Fe, NM USA

24-28 October 2010
82nd Annual Meeting of The Society of Rheology, Santa Fe, New Mexico USA, Andy Kraynik

2011

Spring 2011
7th Annual European Rheology Conference AERC 2011, Suzdal, Russia, Valery Kulichikhin (*www.rheology-esr.org/AERC/2011/*)

Summer 2011
14th International Congress of Biorheology and the 7th International Conference on Clinical Hemorheology (held every three years), location TBA (last conference: *www.outreach.psu.edu/programs/isbisch/*)

June 2011
27th Annual Meeting of the Polymer Processing Society, Marrakesh, Morocco, M. Bousmina

8-9 October 2011
SOR Short Course on Rheology (topic TBA), Cleveland, Ohio USA

9-13 October 2011
83rd Annual Meeting of The Society of Rheology, Cleveland, Ohio USA, Pat Mather

2012

5-10 August 2012
XVIth International Congress on Rheology, Lisbon, Portugal, João M. Lopes Maia (every four years; in 2016 in Asia)

19-24 August 2012
XXIIIrd International Congress of Theoretical and Applied Mechanics ICTAM 2012; Beijing, China (every four years)

2013

9-10 February 2013
SOR Short Course on Rheology (topic TBA), Pasadena, CA USA

10-14 February 2013
84th Annual Meeting of The Society of Rheology, Pasadena, California, USA, John Brady

12-13 October 2013
SOR Short Course on Rheology (topic TBA), Montreal, Quebec, Canada.

13-17 October 2013
85th Annual Meeting of The Society of Rheology, Montreal Quebec Canada, Marie-Claude Heuzey, Paula Wood-Adams.

2014

4-5 October 2014
SOR Short Course on Rheology (topic TBA), Philadelphia, Pennsylvania USA