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Rheology Bulletin

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2005 Bingham Medalist Jan Mewis was feted at a symposium that was held in his honor on 22 Sept 2004 in Leuven. Pictured are W. Russel, H. Masuhara, H.M. Laun, M.M. Denn, J. Mewis, K. Walters, G. Marrucci, and R. Keunings.

The *Rheology Bulletin* is the news and information publication of The Society of Rheology (SOR), and is published twice a year in January and July. Subscription is free on membership in The Society of Rheology

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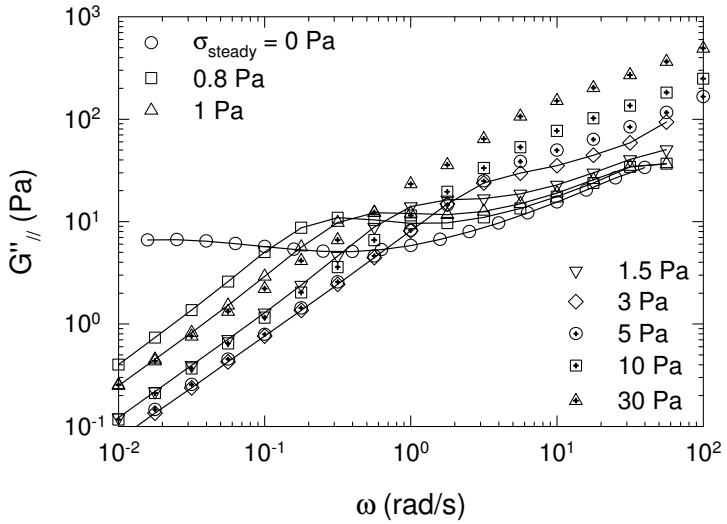
Mewis Recognized for Suspension Work

On 27 March 2005 SOR President Susan Muller announced that the Bingham Committee had selected Professor Jan Mewis of the Katholieke Universiteit Leuven as the 2005 recipient of the Bingham Medal. The Bingham Medal, the Society of Rheology's highest honor, is given to a resident of the North American Continent or a member of The Society who has made an outstanding contribution to the science of rheology or who has performed particularly meritorious service to The Society.

Mewis will receive his medal at the 77th meeting of The Society of Rheology in Vancouver in October 2005. Attendees of the Vancouver meeting will benefit from an address by Mewis, and in return Mewis will be honored and perhaps roasted a bit at the Bingham Banquet on Monday 17 October 2005. A detailed profile of the 2005 Bingham Medalist appears below.



Suspension dynamics and structure can be probed with small-amplitude oscillatory shear superposed on steady shearing. The resulting moduli indicate the profound effect of flow, even at steady shear stresses well below the stress at which shear thickening occurs (10Pa). From Mewis and Biebauld J. Rheol. 45, 799 (2001).

Profile by Paula Moldenaers

Jan Mewis studied Chemical Engineering at the Katholieke Universiteit Leuven in Belgium, where he received his master degree in 1961. While working at the IVP Laboratory, the research institute of the Belgian paint and printing ink industry, he obtained his Ph.D. with a thesis on "Tack of Printing Inks." This was the start of a lifelong interest in complex fluids and in relating their industrial behavior to their fundamental properties. In 1969

Jan Mewis returned to K.U. Leuven as a fulltime faculty member, where over the years he taught a wide range of courses, including the unavoidable "Theoretical Theology." He was chairman of the Chemical Engineering Department from 1989 to 1995 and again from 1999 until 2002. In 1971-72 he spent a year at the University at Delaware with a NATO fellowship, working with A.B. Metzner. He was twice a visiting professor at the same university (1981 and 2004) and also at Princeton University in 1982. He spent shorter periods at various universities in the U.S. and Australia. For a number of years he was a regular winter visitor at U.C. Berkeley, where he collaborated with Morton M. Denn.

The research activities of Jan Mewis can be situated in the general area of rheology and processing of complex fluids. He has authored or co-authored about 200 publications and has given hundreds of lectures and seminars all over the world on this topic. He is best known for his often cited work in three specific areas. In the area of suspension rheology he published with A.B Metzner the now classical paper on extensional flow of fiber suspensions, as well as a series of papers establishing the rheology of sterically stabilized suspensions. Later, he contributed substantially to the present understanding of the rheology of liquid crystalline polymers and that of immiscible polymer blends. In all these cases his approach was to link the rheology to the underlying flow-induced changes in microstructure. He successfully applied a wide range of rheological procedures for probing the microstructure during flow. This was supplemented very early by adding other techniques for in-situ, time-resolved structural analysis during flow. These included various scattering techniques, especially rheo-optics, as well as dielectric techniques. For his various contributions to the field of rheology he received the Gold Medal of the British Society of Rheology in March 2005.

It is perhaps less known to the rheological community that Jan Mewis led for many years a second life, i.e. as an expert in the safety of chemical plants. He was one of the very first to teach a systematic course on this subject to chemical engineering students and also authored a book on hazardous materials. As an official safety expert, he could decide whether a design was safe enough, or not, to be executed. This is a kind of power that is totally out of reach of us, regular rheologists.

Throughout his career Jan Mewis maintained a link with the industrial applications of rheology. He served on various industrial committees, he was active as a consultant both in Europe and in the U.S., and is member of the Innovation Board of Elementis-Specialties, a company that manufactures, among other things, rheological agents.

Jan Mewis has been quite active in the rheological community. He is a co-founder and former president of the Belgian Group of Rheology, and he was chairman of the International Committee on Rheology (1992-96) after he co-chaired with Marcel Crochet the 11th International Congress on Rheology in Brussels in 1992. Until April 2005 he was also a member of the Executive Committee of the European Society of Rheology. Since October 2003 Jan Mewis has been professor-emeritus at Katholieke Universiteit Leuven, where he is still active in research and consulting. Together with Norm Wagner, he is, among other things, working on a book on suspension rheology.

Numerous processing operations of complex fluids involve free surface deformations; examples include spraying and atomization of fertilizers and pesticides, fiber-spinning operations, paint application, roll-coating of adhesives and food processing operations such as container- and bottle-filling. Systematically understanding such flows can be extremely difficult

Dimensionless Groups For Understanding Free Surface Flows of Complex Fluids

Gareth H. McKinley
Director, Hatsopoulos Microfluids Laboratory
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Cambridge MA 02139

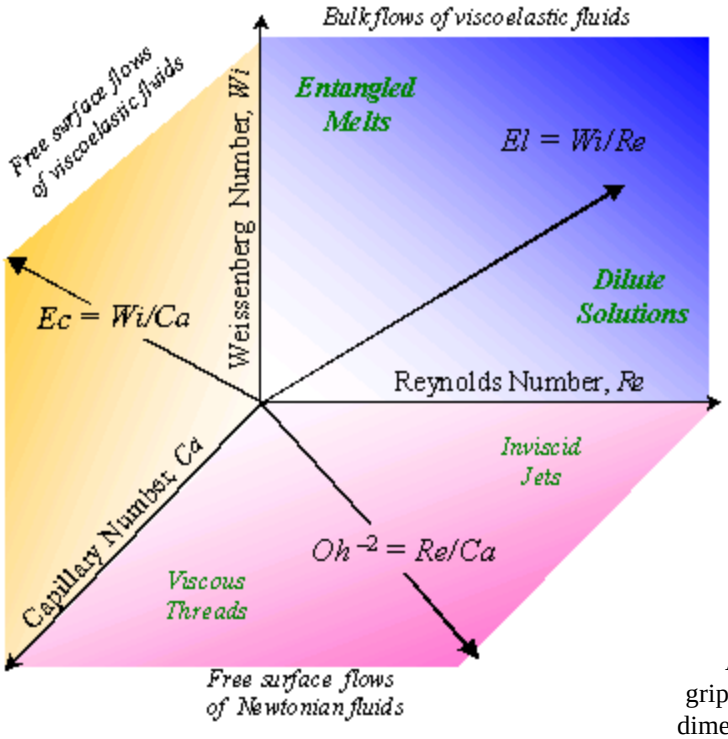

Figure 1: 'Operating diagram' showing the key dimensionless parameters characterizing free surface flows of complex fluids.

because of the large number of different forces that may be involved; including capillarity, viscosity, inertia, gravity as well as the additional stresses resulting from the extensional deformation of the microstructure within the fluid. Consequently many free-surface phenomena are described by heuristic and poorly-quantified words such as 'spinnability,' 'tackiness' and 'stringiness.' Additional specialized terms used in other industries include 'pituity' in lubricious aqueous coatings, 'body' and 'length' in the printing ink business, 'ropiness' in yogurts and 'long/short textures' in starch processing.

A good approach to systematically getting to grips with such problems is through the tools of dimensional analysis (Bridgman, 1963), and this short note is intended to review the physics behind some of the plethora of specialized dimensionless groups one encounters when reading the scientific literature. The dominant balance of forces

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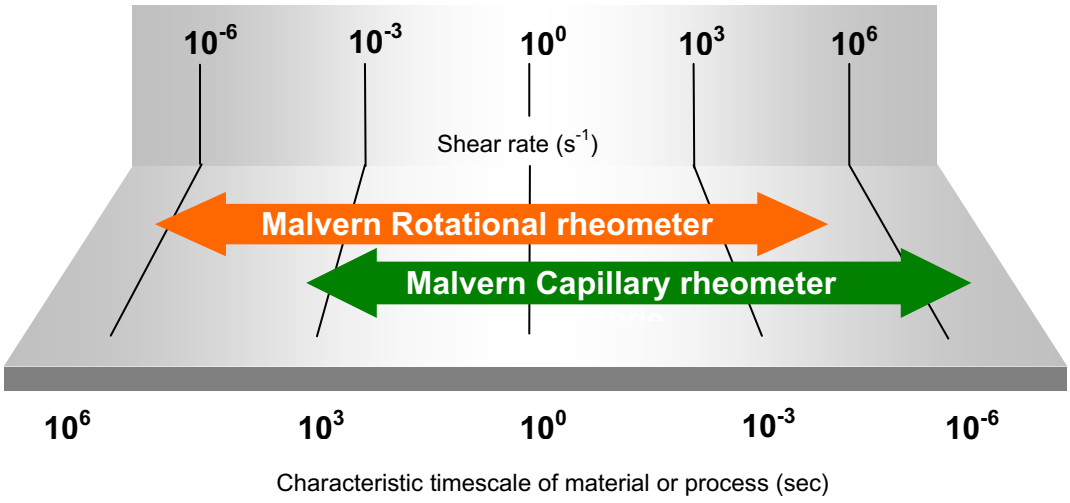

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controlling the dynamics of any process depends on the relative magnitudes of each underlying physical effect entering the set of governing equations. In many (but certainly not all) problems, the dynamics are controlled by no more than two or three different contributions; and results from disparate experimental observations or numerical studies which describe different processing regimes or domains of stable/unstable operation can often be conveniently assembled in terms of processing diagrams such as those sketched in Figures 1 & 2.

For bulk flows of non-Newtonian fluids the relative importance of inertial effects and elastic stresses with respect to viscous stresses are characterized by the *Reynolds number*, $Re=\rho V \ell/\eta$ and the *Weissenberg number* $Wi=\lambda V/\ell$ respectively. Here V and ℓ are characteristic velocity and length scales for the flow of interest and ρ, η, λ are the density, viscosity and longest – or characteristic – relaxation time of the test fluid. I have chosen the notation *Wi* here to avoid confusion with the *Weber number* which is commonly used in free surface flows (see further discussion below); however, much of the older literature will use *We* or *Ws* for this dimensionless ratio of elastic to viscous stresses in a deforming viscoelastic fluid.

The product $\lambda V/\ell$ may also be interpreted as a Deborah number (Reiner, 1964) as it is a ratio of the polymeric time scale to a convective timescale $t_{conv}=\ell/V$. Indeed, in a steady channel flow the Deborah number and the Weissenberg number are interchangeable. However, as first noted by Metzner et al. (1966), there are important differences in more complex flows that are associated with the unsteadiness (in either the Eulerian or Lagrangian sense) of the process, and these two dimensionless measures of viscoelastic effects are typically interconnected by a dimensionless geometric parameter characterizing the process of interest. The debate around the most appropriate terminology is endless and not terribly helpful (see Metzner et al. (1966) and Bird et al. (1987) Chp. 2 for further discussion); here we shall retain the notation *Wi* because we use the Deborah number below to describe a true ratio of timescales that are of importance in free surface flows.

Prototypical steady polymer processing operations can be compared by their relative location in the back-plane of Figure 1. If we consider a particular process operation as a set of coordinates in this operating space we thus move outwards, away from

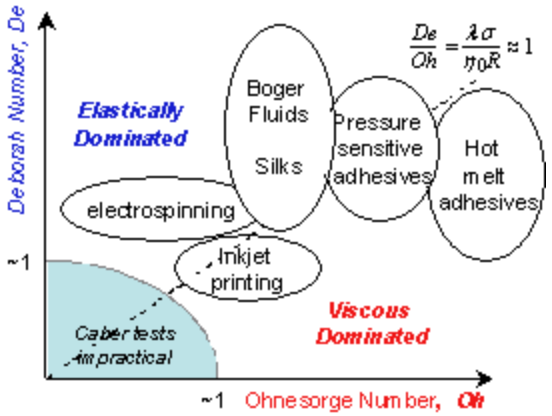

Figure 2 An 'operating diagram' for capillary self-thinning and break-up of complex fluids; organized in terms of the natural time scales for capillary, viscous, and elastic phenomena. Sketched are the loci for some common representative free surface flows of complex fluids.

the origin as the process throughput (i.e. the characteristic velocity V) is incremented and both the Reynolds number and the Weissenberg increase. The relative magnitudes of inertial stresses and elastic stresses can also be compared by taking the ratio of the two groups represented on the two axes. This parameter is not associated with any particular famous fluid mechanician or rheologist but is now commonly referred to as the *elasticity number* (Denn and Porteous, 1971) or sometimes the first elasticity number (Astarita and Marrucci, 1974). From the definitions of *Re* and *Wi* we obtain

Elasticity number:

$$El = Wi/Re = \eta\lambda/\rho\ell^2 \qquad (1)$$

where the viscosity (and also the relaxation time) should be evaluated at a deformation rate appropriate to the flow of interest. It can be seen that this group is independent of the process kinematics (i.e. V) and only depends on the rheological properties of the fluid and the geometry of interest. It thus sets the slope of the trajectory followed through the processing diagram and corresponds to the ratio of the time scale for stress evolution (λ) to the time scale for diffusion of momentum (ℓ^2/ν, where $\nu=\eta/\rho$ is the kinematic viscosity of the fluid). For example, extrusion of polymer melts corresponds to $El >> 1$, whereas processing flows for dilute polymer solutions (such as spin-casting) typically correspond to $El << 1$.

In analogous fashion, free surface flows of Newtonian fluids can be characterized by the magnitude of the Reynolds number and the capillary number $Ca = \eta V/\sigma$ (where σ is the surface tension of the fluid), and can be represented on the horizontal plane of Figure 1. The slope of trajectories in this plane is again independent of the imposed velocity and corresponds to differing values of a parameter now referred to as the *Ohnesorge number* (Ohnesorge, 1936). There is much inconsistency in the use of this group; in his original work on jet breakup, von Ohnesorge defined this dimensionless parameter by the term $Z=\eta/\mathrm{sqrt}(\rho\sigma\ell)$. However, it is more common nowadays to use the notation *Oh*, and the trajectory of interest is given by the inverse square of the Ohnesorge number, $Oh^{-2} = Re/Ca=(\rho\sigma\ell/\eta^2)$. This group may also be usefully viewed as a Reynolds number based on a characteristic 'capillary velocity' $V_{cap}=\sigma/\eta$ (i.e. the velocity at which a viscous thread of fluid such as glycerol or pancake syrup would thin down and break; see for example Eggers (1997)). Coating operations and jetting/spraying operations with Newtonian fluids are fully parameterized by the values of *Ca* and *Oh* for the process of interest (for specific results see Quéré (1999) and Basaran (2002) respectively). However other combinations of these dimensionless parameters may also be used; for example, studies of high-speed jet breakup are commonly reported in terms of the *Weber number* $We=ReCa=\rho V^2\ell/\sigma$ and the Ohnesorge number (Becher, 1990).

Inertialess flows of elastic fluids with a free surface are represented by the left-hand vertical plane. Taking the ratio of the abscissa and ordinate axes gives another dimensionless parameter measuring the combined importance of elastic and capillary effects as compared to viscous stresses. This parameter can thus be thought of as an *elasto-capillary number* $Ec = Wi/Ca=\lambda\sigma/(\eta\ell)$. and it is again a function only of the fluid rheology and the geometry. Much less is known about flows in this plane. Bousfield et al. (1986) were the first to study the nonlinear evolution of viscoelastic fluid jets and showed that increasing the elastocapillary number (denoted ϕ therein) resulted in strong stabilization of the jet. More recently, Spiegelberg and McKinley (1996) and Rasmussen and Hassager (2001) have investigated the effects of changes in *Ec* on adhesive fingering instabilities.

The three-dimensional interior of the parameter space shown in Figure 1 corresponds to general visco-elasto-capillary flows. The relative co-ordinates of a particular process or geometry can then be specified by values of {*Re*, *Ca*, *Wi*}. Since all three of these parameters vary with the characteristic process speed *V*, it is preferable to pick a single dynamical variable (say *Re*) that scales with *V* and then specify the other two coordinates using the material/geometric parameters, *Oh* and *El*. The literature in this area is much less well-developed and a fertile area for future research.

One particularly important subclass of free-surface flows are 'self-thinning' processes in which no external driving force is imposed (or in which the internal dynamics that develop spontaneously in the fluid are much faster than any external forcing). In such flows the fluid jet, thread, film or sheet thins down and breaks up naturally under the action of capillary forces. To characterize this breakup process it is then necessary to seek a different set of dimensionless parameters that do not depend on the velocity scale *V*. Such capillary-thinning and break-up processes are governed by (at least) three characteristic time scales; a viscous time scale $t_{visc}\sim\eta\ell/\sigma$, the polymeric timescale $t_{polym}\sim\lambda$ and an inertial or Rayleigh time-scale $t_R\sim\mathrm{sqrt}(\rho\ell^3/\sigma)$ (Rayleigh, 1879). The relative balances of these time-scales (and the associated contributions to the total force in the fluid thread) can thus be represented in terms of two dimensionless parameters; one of these is the Ohnesorge Number we have seen before; $Oh = t_{visc}/t_R\sim\eta/\mathrm{sqrt}(\rho\sigma\ell)$. The other parameter is the ratio of the polymeric relaxation time to the Rayleigh time-scale for capillary breakup. This parameter corresponds to an 'intrinsic' or 'natural' Deborah number for free surface viscoelastic flows and represents the ratio of the time scale for elastic stress relaxation, to the 'Rayleigh time scale' for inertio-capillary break-up of an inviscid jet:

Intrinsic Deborah Number:

$$De = t_{polym}/t_R = \lambda/\mathrm{sqrt}(\rho\ell^3/\sigma) \qquad (2)$$

Note that in contrast to the Weissenberg number defined above, this viscoelastic parameter does not depend on the imposed kinematics (*V*). These two dimensionless parameters can be used to define a two-dimensional 'operating space' for instruments such as capillary-thinning/break-up extensional rheometers and other self-thinning free surface processes involving non-Newtonian fluids. Such a diagram is sketched in Figure 2.

(continues page 19)

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77th Annual SOR Meeting to be held October 16-20, 2005 Vancouver, B.C. Canada

The 77th Annual Meeting of The Society of Rheology will be held in Vancouver, BC, Canada from 16-20 October 2005; the associated short course on new microscopy techniques for rheology will be offered on 15 and 16 October (see article page 15). All sessions will be held at the Westin Bayshore Hotel in downtown Vancouver, located beside the famous Stanley Park, the largest city park in Canada.

As usual, the meeting will begin with a Welcome Reception in the hotel on Sunday evening. A Society luncheon will be held on Monday 17 October, and the Bingham Award will be presented at a dinner on Monday evening; the poster session will take place on Wednesday evening. Plenary speakers will be Bingham Medalist Jan Mewis of Katholieke Universiteit Leuven Belgium, Bamin Khomami of Washington University St. Louis USA, and Stephen Quake from California Institute of Technology USA.

Vancouver is a beautiful city on the Pacific Ocean with spectacular natural attractions, including harbor, mountains, and beaches. The city is cosmopolitan with a mixture of eastern and western influences and world class cuisine. Downtown Vancouver includes the Gastown area, which is a restored historic area, the second largest Chinatown in North America, and a wide variety of shopping districts. Other sites to visit are the Vancouver Museum, the Vancouver Art Gallery, the Queen Elizabeth Theatre, the Aquarium, and the new city library. Day trips may be made to enjoy nearby forests and mountain peaks.

The Westin Bayshore is approximately 25 minutes (16km/11mi) from the Vancouver International airport. Taxis and an Airporter shuttle can be picked up at the front of the airport. Please visit www.yvrairporter.com for more information on the Airporter shuttle.

Hotel reservations can be made directly with the Westin Bayshore Resort and Marina by calling 604-682-3377 or 1-800-WESTIN-1. Please reserve by September 15, 2005, and please indicate that you are an attendee of the 77th Annual Meeting of the Society of Rheology to receive the group rate.

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For more information please visit www.rheology.org/sor/annual_meeting/2005Oct/info.htm

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Report from

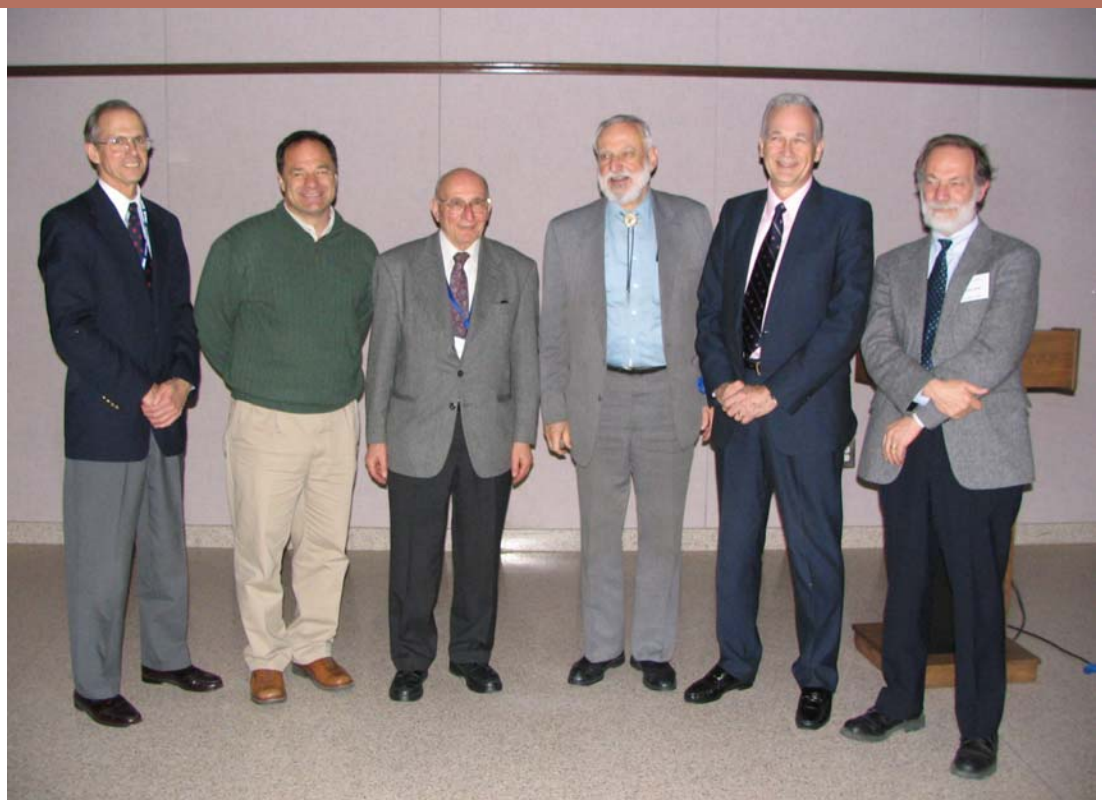
Over 250 rheologists gathered 13-17 February 2005 at the Lubbock Memorial Civic Center in Lubbock, Texas USA (home of Texas Tech University) for the 76th Annual Meeting of the Society of Rheology. Hosted by Local Arrangements Chair Greg McKenna (pictured at right), the meeting saw 213 papers and 30 posters presented. A local arrangements committee of Professors McKenna, Sindee Simon, Jeremy Leggoe and Lenore Dai from the Texas Tech Department of Chemical Engineering handled the logistics for the meeting.

The Lubbock meeting was the 2004 meeting of the SOR, offset from the usual October meeting time frame by the 2004 International Congress, which took place in Seoul, South Korea in August 2004.

In addition to the technical sessions and plenaries, the Lubbock meeting featured a lively social program. The opening reception was held at the Holiday Inn and Towers, and a wine reception and buffet took place on Monday at the Caprock Winery just outside of Lubbock. The wine reception featured a flowing chocolate fountain, which allowed for some tasty rheological experiments. The Bingham Banquet took place on Tuesday evening at the Museum of Texas Tech and featured a lively roast of the 2004 Bingham medalist, Chris Macosko from the University of Minnesota USA. Macosko and his wife Kathleen sat patiently through some good-natured ribbing at the hands of Minnesota colleague Tim Lodge, who traced in detail the trail of sabbatical leaves that Macosko has enjoyed throughout his career. Macosko's serious contributions to the advancement of rheometry since the beginning of commercial instrumentation in the 1970s was made apparent during his Bingham lecture earlier in the day.

The Lubbock gathering also included the official business meeting of The Society; the minutes of the Executive Committee meeting and the Business Meeting are printed in this *Bulletin* beginning on page 20.

Lubbock



Bingham medalists present in Lubbock included Bill Russel, Gerry Fuller, Kurt Wissbrun, Don Placzek, 2004 Medalist Chris Macosko, and Mort Denn.

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Microscopy Techniques Short Course 15-16 October 2005 in Vancouver

Three top researchers investigating single-particle dynamics will present a two-day short course in Vancouver in conjunction with the 77th Annual Meeting of the SOR in October 2005. The short course, "*Resolving Single Particles and Molecules: New Microscopy Techniques for Rheology*," will take place Saturday and Sunday 15-16 October 2005 at the Westin Bayshore Resort and Marina in Vancouver, British Columbia, Canada.

The instructors for the course are Michael J. Solomon, University of Michigan, Patrick S. Doyle, Massachusetts Institute of Technology, and Eric M. Furst, University of Delaware.

Direct visualization methods such as optical microscopy are today increasingly applied to study complex fluid structure, dynamics and rheology. Materials for which direct visualization methods are key characterization tools include particulate suspensions, emulsions and DNA. Microscopy in particular is applied across a broad spectrum of problems of current interest to rheologists. Optical tweezers and microrheology are also widely applied. This short course will focus on introducing participants to the state-of-the-art in instrumentation, flow cell design, materials for visualization, image processing, and data analysis for direct visualization studies.

The aim of this short course will be to introduce a broad audience to the methods outlined above so that they can be applied to an even greater degree in rheology. A particular emphasis will be to compare best practices prevalent in different areas of rheology. For example, quite different experimental and image processing methods are used in studying colloidal suspension structure, DNA dynamics, and emulsion relaxation. Many of the methods used have very different origins: some come from condensed matter physics, others from mechanical engineering, and still others from the life sciences. By introducing these various methods in a single course, participants will efficiently learn about techniques that have been successful in other areas and potentially apply them to their own problems of interest. The course will offer a comprehensive introduction to those industrial researchers, graduate students and faculty that seek to incorporate direct visualization methods into their research.

Short course registration is $450 for SOR members ($250 for student members), and $505 for nonmembers ($275 for student nonmembers). All amounts are in US dollars and fees increase after 2 September 2005. Details may be found on the web at www.rheology.org/sor/short_course/2005Oct/.

Microscopy Course Outline

I. Instrumentation
- A. General principles of microscopy
- B. Epifluorescence microscopy
- C. Confocal micrscopy
- D. Optical tweezers

II. Materials Synthesis and Preparation
- A. Fluorescent dye selection
- B. Fluorescent colloidal particles synthesis
- C. DNA preparation
- D. Actin preparation

III. Image Processing
- A. General identification methods
- B. Software availability and selection
- C. Particle tracking
- D. Error analysis

IV. Flow Cell Design
- A. Viscometric flows for microscopy
- B. Microscopy and microfluidics

V. Data Processing and Analysis
- A. Characterization of structure
- B. Characterization of dynamics and micro-rheology
- C. Connection to other methods such as scattering

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Rheology News

Soft Matter Launches

The Royal Society of Chemistry, Cambridge U.K. announces a new journal focusing on soft matter. The scope of the subject matter in the journal *Soft Matter* is outlined in the first issue by Nobel Prize winner and founding father of soft matter research, Pierre-Gilles de Gennes. Launching in July 2005, *Soft Matter* aims to provide an interdisciplinary platform for the exchange of information and discussion between researchers working at the fringes of traditional disciplines (such as physics, materials science, chemistry, and biology), who have a particular interest in soft materials.

Papers in the first issue demonstrate the diversity of research already underway at these interfaces - ranging from the switching of polymer brushes from soft to hard matter, modeling of the flow of complex fluids in channels, the use of gels in art conservation, and the use of microfluidic devices to formulate double emulsions. 'By bringing together scientists from different disciplines, we hope not only to promote communication … but to see further growth of the area as a whole,' state Ullrich Steiner and Carol Stanier (*Soft Matter* editorial board chair and editor, respectively) in the first issue editorial. The entire first issue is available for trial at www.softmatter.org.

Applied Rheology at KU in Seoul

On 19 May 2005 the Applied Rheology Center at Korea University held its *6th International Symposium on Applied Rheology*. Speakers included Pino Marrucci (Naples, Italy), Malcolm Mackley (Cambridge, UK), Kiyohito Koyama (Yamagata, Japan), Yoshiaki Takahashi (Kyushu, Japan), Antony Beris (Delaware, USA), Jae Chun Hyun (Korea University), Sehyun Shin (Kyungpook, Korea), and Kyung Hyun Ahn (Seoul, Korea). These symposia are held annually and focus on areas of applied rheology.

Student Poster Competition Vancouver

In conjunction with the poster session, the SOR is sponsoring a student poster competition to encourage student presentations and participation in the meeting and to recognize excellence. To participate in the competition, in addition to normal abstract submission for the poster session, students must also submit a PowerPoint-type poster in PDF format by midnight (EST) 16 September 2005.

A panel of judges will select up to 8 finalists based on the entries, with the final selection of the winner to be made by the judges at the poster session. An award of $200 US will be made to the winner at the conclusion of the poster session. Details may be found on the web at http://www.rheology.org/sor/annual_meeting/2005Oct/poster_competition.htm.

Rheologist Joins *JFM* Editorial Team

Mike Graham has joined the editorial board of the *Journal of Fluid Mechanics* as an associate editor. The Editors of JFM are Steve Davis and Tim Pedley, who head a team of associate editors. The *Journal of Fluid Mechanics* publishes theoretical, computational, and experimental investigations of all aspects of the mechanics of fluids. It is published by Cambridge University Press and was founded in 1956 by George Batchelor.

Smart Coatings 2006: Call for Papers

The Coatings Research Institute of Eastern Michigan University is seeking technical papers to be considered for presentation at the *2nd Annual Smart Coatings Symposium* to be held 15-17 February 2006 in Orlando, Florida USA. Topics include bioactive coatings, stimulus and response, nanotechnology-based coatings, and self-assembled intelligent layers; the intended audience for the meeting is researchers in academia, government, industry, formulators and engineers involved in polymers and coating development, and users and raw materials suppliers. Abstracts (100-200 words) may be submitted until 15 August 2005 to Sandra Tanner (stanner@emich.edu). For more information see www.emich.edu/public/coatings_research/smartcoatings.

(continued from page 9)

Successful operation of a capillary thinning instrument or other non-Newtonian free surface flow typically requires that the fluid is 'sufficiently viscous' or has enough 'spinnability'. Diagrams such as Figure 2 allow us to express such verbal statements in terms of dimensionless parameters. For example in a capillary thinning test we require surface tension to drive the thinning and either viscosity or elasticity to resist the necking process; therefore we need either *Oh* or *De* to be approximately equal to or greater than one (Rodd et al., 2005). A 'low viscosity elastic' fluid (Harrison and Boger, 2000) corresponds (at least in a free surface flow) to $t_{polym} > t_R > t_{visc}$ or equivalently $De > 1 > Oh$. In such flows, viscous effects are never important (see, for example, Amarouchene *et al.* (2001)), and one is interested in the limit of 'inviscid elastic fluids' or more accurately irrotational flows of elastic liquids (Wang et al., 2005). Similarly, in operations such as electrospinning it is essential to be able to form a uniform filament in the absence of beads-on-a-string morphology (Fong et al., 1999); hence one needs to design the fluid rheology and geometry to ensure $De \geq Oh > 1$. Conversely in inkjet printing neither long elastic tails nor inertially-induced satellite drops are desirable; consequently one may seek both *De* and *Oh* approximately equal to 1.

For very viscous fluids, the inertial time-scale t_R of course becomes irrelevant, and the dynamics of the thinning process depends solely on the relative magnitude of the viscous and elastic time scales. This leads us again to the elasto-capillary number.

Elastocapillary Number:

$$Ec = De/Oh = t_{polym}/t_v = \lambda\sigma/(\eta \ell) \qquad (3)$$

Elastically-dominated and viscously-dominated self-thinning and necking processes (for example the fibrils that form during decohesion of tacky polymer melts and solutions (Rasmussen and Hassager, 2001) are thus demarcated by the line *Ec* approximagely equal to 1 sketched in Figure 2.

In this short note I have attempted to provide an overview of some of the spectrum of dimensionless groups used in describing free surface flows of elastic fluids. I have not discussed the perturbative effects of gravity explicitly. Consideration of the gravitational body force leads to a characteristic length scale referred to as the *capillary length*, $\ell_{cap} \sim \mathrm{sqrt}(\sigma/\rho g)$. For most fluids ℓ_{cap} is about 1-2mm, and on length scales smaller than this gravity becomes increasingly unimportant. This length

scale can also be substituted into any of the dimensionless groups defined above to lead to yet another set of dimensionless groups! It is worth noting that as interest in microscale and nanoscale manufacturing intensifies, and the characteristic length-scale ℓ of a particular process decreases, the elasticity number, elastocapillary number and intrinsic Deborah number will all increase. Non-Newtonian effects in the processing of complex fluids will thus become increasingly prevalent on the microscale. For example, in 'low viscosity' and 'weakly elastic' fluids, inertial effects often overwhelm the non-Newtonian stresses in the fluid making both the shear and extensional rheology difficult to measure (see e.g. Linder *et al.* (2003)). A consideration of the dimensionless parameters defined above shows that as the length scale decreases into the micrometer range, inertial forces in a fluid thread become progressively less important and viscoelastic forces once again dominate. Microscale measurements using instruments such as capillary-thinning devices may thus make excellent micro-rheometers for 'low viscosity non-Newtonian fluids' such as agricultural fertilizers, and inks or paints used in jetting and spraying operations.

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Society Business

NEWS

SOR Officer Elections

In accordance with Article V of the Rules of The Society of Rheology, members of The Society were informed in April 2005 of the list of nominees for the 2005 Election, as reported by the Nominating Committee of David James (chair), Lisa Mondy, and Pat Mather:

President:
Andy Kraynik, Sandia National Laboratories
Vice President:
Bob Powell, University of California, Davis
Bob Prud'homme, Princeton University
Secretary:
A. Jeffrey Giacomin, University of Wisconsin
Treasurer:
Monty Shaw, University of Connecticut
Editor:
John Brady, California Institute of Technology
Members at Large
Dan Klingenberg, University of Wisconsin
Tim Lodge, University of Minnesota
Charles Lusignan, Eastman Kodak Company
Eric Shaqfeh, Stanford University
Lynn Walker, Carnegie Mellon University

For a period of forty-five (45) days following the date of notification, which occurred by email on 26 April 2005, additional nominees were accepted by petition forwarded to the Secretary and signed by at least fifteen (15) members in good standing of The Society (nomination period closed 10 June 05).

Members will cast their votes electronically at https://www.rheology.org/sorvote/. This web site will be available on approximantely 30 July 2005. SOR members will be notified by e-mail when the web site is on line. All officers serve 2-year terms. The Constitution and Rules of The Society may be accessed at www.rheology.org/sor/info/Constitution.htm.

Minutes of the Executive Committee Meeting

Sunday, February 13, 2005

Susan Muller called the meeting to order at 8:25 a.m. in the Petroleum Room of the Holiday Inn Hotel and Towers in Lubbock. Committee members in attendance were Susan Muller, Andy Kraynik, Bill Russel, Monty Shaw, Tim Lodge, Lynn Walker, Wes Burghardt, Jeff Giacomin, and Mort Denn. Invited guests were John Brady, Janis Bennett, Albert Co, Kalman Migler, Savvas Hatzikiriakos, Greg McKenna, and Faith Morrison. The minutes of the previous meeting were read and approved.

Jeff Giacomin spoke on AIP author-optional open access whereby some journals make their articles freely available to everyone when the author opts to pay a fee. A motion was passed for the *Journal of Rheology* to provide authors with this option too, at the earliest opportunity, with a fee of $2,500. Giacomin led a discussion on bringing Volumes 1-6 of the *Journal of Rheology* (1929-1935) on-line to complete the on-line archive. Edited by Eugene Bingham, these preceded the *Transactions of the Society of Rheology* which began in 1957 with Volume I. This project is called *Jurassic JOR*; a motion was passed to proceed post-haste with this project.

Pat Mather, Chair of the Membership Committee, reported on activities of the Membership Committee.

Susan Muller read a report on behalf of Norman Wagner, Chair of the Education Committee. A short course titled “Resolving Single Particles and Molecules: New Microscopy Techniques for

Rheology" will be given in Vancouver by Mike Solomon, Patrick Doyle and Eric Furst.

Susan Muller announced that the new Nominating Committee for the upcoming election will be David James (Chair), Lisa Mondy, and Pat Mather. (The Nominating Committee slate must be announced to the membership by 26 May 2005.)

Monty Shaw presented the Treasurer's report. The Society is financially healthy. The committee voted to mail the *Rheology Bulletin* to US members by First Class Mail.

Albert Co provided his report as Webmaster.

Faith Morrison reported on her activities as Editor of the *Rheology Bulletin*.

Janis Bennett discussed her support of Society issues at AIP.

Andy Kraynik led a discussion on future meetings of The Society. Savvas Hatzikiriakos reported on local arrangements for the Vancouver Meeting in October 2005. Albert Co reported on local arrangements for the Portland Meeting (2006). Jay Magda reported on local arrangements for the Salt Lake City Meeting (2007).

Susan Muller discussed AIP Executive Committee matters. The Executive session was held.

The committee voted to establish a $3000 discretionary fund for the Webmaster. Morton Denn reported on JOR editorial matters. John Brady, as nominee for Editor, discussed future plans for the *Journal of Rheology*.

The meeting was adjourned at 5:33 PM.

Minutes of the Business Meeting

Tuesday, February 15, 2005

Susan Muller called the meeting to order at 5:40 p.m. in Room 107 of the Civic Center in Lubbock. Read by the Secretary, a motion was passed to accept the minutes of the previous business meeting in Pittsburgh.

President Muller reported on the results of the Editor search for Mort Denn's successor at the *Journal of Rheology*. With enthusiasm, Muller announced that Professor John Brady will succeed Mort Denn as Editor.

Presdident Muller announced that Albert Co has continued to improve our Society website which now allows non-members to join The Society on-line. The site also now allows password access to all manner of meeting details. This new meeting archive will greatly facilitate meeting planning and operation.

Susan Muller announced that, as of the start of this business meeting, there were 255 registrants to the Lubbock meeting.

Each officer report and each committee report presented at the Executive Committee meeting (see above) was presented and accepted at the business meeting.

The meeting was adjourned at 6:32 p.m.

Treasurer's Report

To the Membership,

Appended are the standard Treasurer's reports to the Membership: receipts and disbursements sheets for the Journal of Rheology, our largest operation, and The Society as a whole, and the 2004 year-end balance sheet.

Examination of these reveals that the financial position of The Society is reasonably sound, and no dues increment will be needed for another year. This contrasts sharply with other societies that impose annual dues increases on their members. However, look for additional discussion of a two-tier dues system comprising a modest decrease for members who do not need a hardcopy of the journal and an even more modest increase for all other members to take up the slack.

A proposed budget for 2006 has been included in this report. Please examine it carefully, as approval by the membership will be sought at the Vancouver meeting.

Not apparent from the financial reports are several of my miscellaneous activities. These include the seemingly endless transfer of accounting activities from paper to electronic. While our web-based merchant account has taken flight thanks to an intense effort by Webmaster Albert Co, the account-

Treasurer's Report

ing remains a challenge due to the cryptic reports provided by our bank, the card companies, and our gateway service. (A gateway processes the web transactions and distributes them to the correct card companies.) Another long-term project is to organize The Society's archives of financial records. These records fill almost a dozen file boxes. Important documents such as contracts and tax records are being scanned and stored electronically to facilitate retrieval. Finally, I participate actively in the Society Treasurers' Committee of the AIP. This committee meets annually to discuss a range of financial issues such as tax laws, dues structure, meeting contracts, insurance, etc. This meeting also provides a forum for the societies to address financial changes proposed by AIP. Some of these changes can have a large impact on our finances, and it is important to make sure we are treated fairly.

Respectfully submitted,
Montgomery Shaw, Treasurer

The Society of Rheology
Receipts and Disbursements

	2006 Budget	2005 Budget	2004 Actual	2004 Budget	2003 Actual
RECEIPTS					
Dues	55,000	55,000	54,885	55,000	58,271
Interest	12,000	10,000	10,958	9,000	8,266
Journal of Rheology	229,000	256,000	253,126	238,500	261,770
Mailing List Sales	1,000	1,000	0	1,000	697
Donations	0	0	0	0	0
Bulletin Advertising	4,000	3,000	3,504	2,000	1,488
Annual Meeting (net)	0	0	36,586	0	11,099
Short Course (net)	0	0	8,915	0	15,061
TOTAL RECEIPTS	301,000	325,000	367,974	305,500	356,651
DISBURSEMENTS					
AIP Dues Bill & Collect.	12,000	12,000	12,715	7,000	10,106
AIP Adm. Services	9,500	9,500	9,553	9,500	9,549
AIP Mem. Soc. Dues	7,600	7,600	8,343	7,600	7,585
Contributions and Prizes	1,900	1,900	1,700	3,000	1,994
Journal of Rheology	212,294	234,349	232,262	256,197	247,382
Bulletin	7,000	7,000	6,930	4,000	3,302
Bingham Award	7,000	14,000	0	7,500	5,015
Executive Cmt. Meetings	13,000	13,000	7,486	9,000	12,464
Pres. Discretionary Fund	1,500	1,500	0	1,500	0
Treas. Discr. Fund	1,500	1,500	286	1,500	0
Progr. Chm. Discr. Fund	2,000	4,000	0	2,000	1,895
Webmaster Discr. Fund	3,000	3,000	0	0	0
Office Expenses	4,000	3,000	3,755	6,000	5,270
Banking Services	300	100	333	100	78
Liability Insurance	7,500	7,500	3,330	6,000	4,330
Membership Broch. & Appl.	500	1,500	422	200	0
Accountant	2,200	2,200	1,910	2,200	1,920
Student member travel	12,000	24,000	13,100	600	0
Annual meetings, future	7,000	7,000	7,532	3,000	1,000
Website	1,000	1,000	3,936	1,000	0
Miscellaneous	1,000	1,000	0	1,500	425
TOTAL DISBURSEMENTS	313,794	356,649	313,594	329,397	312,315
Net	**-12,794**	**-31,649**	**54,380**	**-23,897**	**44,337**

Journal of Rheology

Report

(All amounts: USD)	2006 Budget	2005 Budget	2004 Actual	2004 Budget	2003 Actual
RECEIPTS					
Subscriptions	176,000	187,000	184,797	187,000	204,598
Reprint Sales	7,000	7,000	9,606	5,500	5,876
Ad Sales	33,000	33,000	32,177	32,000	33,052
JORO revenue	12,000	27,000	25,447	13,000	17,034
Miscellaneous	1,000	2,000	1,100	1,000	1,210
TOTAL RECEIPTS	229,000	256,000	253,126	238,500	261,770
DISBURSEMENTS					
Ads	9,000	9,000	7,991	9,000	7,360
Reprints, Single Copy	5,400	5,400	5,025	5,400	5,445
Paper, Printing	32,374	30,529	31,547	38,000	34,853
SOR Editorial	42,000	49,000	49,217	49,897	52,388
Production	43,500	52,500	63,552	73,500	73,179
Fulfillment	7,600	7,600	6,676	6,300	6,924
Distribution	17,020	16,920	17,123	20,500	19,226
Electronic publishing	48,000	48,000	42,489	48,000	42,332
Miscellaneous	7,400	15,400	8,642	5,600	5,675
TOTAL DISBURSEMENTS	212,294	234,349	232,262	256,197	247,382
Net	16,706	21,651	20,864	-17,697	14,388

The Society of Rheology, Inc.
Balance Sheet

(all amounts, USD)

	2004 Year End	2003 Year End	2002 Year End	2001 Year End	2000 Year End
Assets					
Cash in checking account	29,012	2,047	466	9,374	9,400
Securities	0	0	0	0	15,000
Balance in AIP account	976,655	938,047	915,334	843,151	827,040
Total Assets	1,005,667	940,094	915,800	852,525	851,440
Liabilities and Net Assets					
Liabilities					
Deferred revenue	155,969	143,603	162,363	137,468	181,800
Total Liabilities	155,969	143,603	162,363	137,468	181,800
Net Assets					
Publication reserve	450,000	450,000	450,000	450,000	450,000
Student travel grant reserve	10,000	10,000	10,000	10,000	10,000
Annual Meeting reserve	100,000	100,000	70,000	70,000	35,000
Operating reserve	100,000	70,000	70,000	70,000	70,000
Unrestricted	189,698	166,491	153,437	115,057	104,640
Total Net Assets	849,698	796,491	753,437	715,057	669,640
Total liabilities and net assets	1,005,667	940,094	915,800	852,525	851,440

the end

CALENDAR OF RHEOLOGY CONFERENCES AND COURSES

2005

7-11 August 2005
4th Pacific Rim Conference on Rheology (PRCR4), Purple Mountain Hotel, Shanghai,China (www.prcr4.org.cn/)

23-26 August 2005
Third International Conference on Engineering Rheology ICER 2005, Zielona Góra, Poland, Anna Walicka, www.ijame.uz.zgora.pl/ijame_files/icer05/

15-16 October 2005
SOR Short Course on *Resolving Single Particles and Molecules: New Microscopy Techniques for Rheology*, by Michael Solomon, Patrick Doyle, and Eric Furst, Vancouver Canada

16-20 October 2005
77th Annual Meeting of The Society of Rheology, Vancouver Canada, Saavas Hatzikiriakos

16-18 November 2005
International Workshop on Complex Systems, Sendai, Japan, www.ifs.tohoku.ac.jp/tokuyama-lab/IWCS2005/

2006

2006 TBA
IUTAM Symposium on Flow Control with MEMS, London, UK, J.F. (Jonathan) Morrison

19-23 February 2006
4th International Symposium on Food Rheology and Structure - ISFRS 2006, Zurich Switzerland (www.isfrs.ethz.ch/)

26-31 March 2006
IUTAM Symposium on Interactions for Dispersed Systems in Newtonian and Viscoeleastic Fluids,Mexico, George Homsy, Roberto Zenit

27-29 April 2006
3rd Annual European Rheology Conference AERC 2006, Hersonissos Crete

7-8 October 2006
SOR Short Course on Rheology (topic TBA), Portland, Maine USA

8-12 October 2006
78th Annual Meeting of The Society of Rheology, Portland, Maine USA, Albert Co

2006 TBA
IUTAM Symposium on Interactions for Dispersed Systems in Newtonian and Viscoeleastic Fluids, Santa Barbara, CA, USA, G.M. (George) Homsy

2007

2007 TBA
IUTAM Symposium on Recent Advances in Multiphase Flows: Numerical and Experimental, Istanbul, Turkey, Andreas Acrivos and Can Delale

Spring 2007
4th Annual European Rheology Conference AERC 2007, location TBA

6-8 September 2007
IUTAM Symposium on Advances in Micro- and Nanofluidics, Dresden, Germany, N.A. (Nikolaus) Adams

6-7 October 2007
SOR Short Course on Rheology (topic TBA), Salt Lake City, Utah USA

7-11 October 2007
79th Annual Meeting of The Society of Rheology, Salt Lake City, Utah USA, Jay Magda

2008

3-8 August 2008
XVth International Congress on Rheology and 80th Annual Meeting of The Society of Rheology, Monterey, California USA, Gerry Fuller

2009

18-22 October 2009
81st Annual Meeting of The Society of Rheology, Madison, Wisconsin USA, Jeff Giacomin