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Annual Literature Survey 1995: Multiphase Flow

Keeping abreast of the ever increasing literature on multiphase flow presents the active researcher with a challenge. To assist in the sifting and sorting process the *International Journal of Multiphase Flow* is pleased to include a new section which provides an overview of the international literature related to multiphase flow that was published during 1995.

The data presented here was selected from the full coverage of FLUIDEX - the fluid engineering database - using a profile of keywords. Some 500 items have been included in this review and are presented in alphabetical order by source title - usually journal or periodical title - to enable rapid scanning of sources that you may not be familiar with.

It is planned that a similar review of the 1996 literature will be published in a future issue of *International Journal of Multiphase Flow* and so any comments that readers may have on format or content will be welcomed.

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ANNUAL LITERATURE SURVEY 1995: MULTIPHASE FLOW
Generated from the FLUIDEX database

Fluid vortices
Green S.I., (Kluwer Academic Publishers; Fluid Mechanics and its Applications 30), ISBN (HARDBACK) 0 7923 33, 1995.
This book is an up-to-date overview covering all salient flows in which fluid vortices play a significant role. Topics addressed include: fundamental vortex flows (mixing layer vortices, vortex rings, wake vortices and vortex stability); industrial and environmental vortex flows (aero-propulsion system vortices, vortex-structure interaction, atmospheric vortices and computational methods); and multiphase vortex flows (free-surface effects, vortex cavitation and bubble and particle interactions with vortices). (S.E.Brown)

Proceedings of the 2nd International Conference on multiphase flow, '95 Kyoto, April 1995. Volume 1
Serizawa A., Fukano T. & Bataille J., (The Japan Society of Multiphase Flow), 1995.
There are fifty-two papers included in this first volume of the proceedings of the International Conference on Multiphase Flow. They are divided into ten sections. These sections cover subject areas as follows: particle, bubble and droplet dynamics; instrumentation; spray; combustion; pressure wave and high speed flow; interfacial, liquid film and separated flow phenomena. (A.Slowey)

Proceedings of the 2nd International Conference on multiphase flow, '95 Kyoto, April 1995. Volume 2
Serizawa A., Fukano T. & Bataille J., (The Japan Society of Multiphase Flow), 1995.
There are ninety-eight papers included in this second volume of the International Conference on Multiphase Flow. They are divided into fifteen sections. These sections cover the following subject areas: particle, bubble & droplet dynamics; particle and bubble turbulence interaction; internal flow; interfacial, liquid film and separated flow phenomena; phase change; biofluids; numerics; instrumentation and visualization; large code; bubble particle problems. (A.Slowey)

Proceedings of the 2nd International Conference on multiphase flow, '95 Kyoto, April 1995. Volume 3
Serizawa A., Fukano T. & Bataille J., (The Japan Society of Multiphase Flow), 1995.
There are 108 papers included in this third volume of the International Conference on Multiphase Flow. They are divided into nineteen sections. These sections cover the following subject areas: international cooperation in critical technologies; particle/bubble turbulence interaction; enivironment; fluidized beds; vapour explosion; CHF and flooding; industrial applications and problems; flow patterns and three phase flows; modelling; flow characteristics; phase change; microgravity. (A.Slowey)

Proceedings of the 2nd International Conference on multiphase flow, '95 Kyoto, April 1995. Volume 4
Serizawa A., Fukano T. & Bataille J., (The Japan Society of Multiphase Flow), 1995.
There are sixty-seven papers included in this fourth volume of the International Conference on Multiphase Flow. They are divided into eight sections. These sections cover the following subject areas: particle/wall interaction: two-phase flow in tube bundles; two-phase flow in porous media; flow control; analysis and visualization; fluidized beds; industrial applications; environment and flow patterns. (A.Slowey)

Numerical methods in laminar and turbulent flow. Proceedings of the Ninth International Conference, Atlanta, July 1995. Volume 9. Part 2
Taylor C. & Durbetaki P., (Pineridge Press, UK), ISBN (HARDBACK) 0 906674, 1995.
A significant number of the papers of this book concentrate on new areas of research and application as well as acting as indicators to areas of further research. The papers presented in this second volume are divided into five subject areas. These are: free surface flow and wave propagation; grid generation: multigrid and adaptive techniques; flow in ducts; two and multiphase flow; solid/fluid interaction. (A.Slowey)

Topographic effects in stratified flows
Baines P.G., (Cambridge University Press; Cambridge Monographs on Mechanics), ISBN (HARDBACK) 0 521 435, 1995.
With an emphasis on both theory and experiment, this test describes the behaviour of homogeneous and density-stratified fluids over and around topography. In examining the similarities between the flow of a river over a barrier or weir and the flow of the atmosphere over a mountain range, this book presents a comprehensive synthesis of this topic in terms suitable for scientists, engineers, teachers and students of fluid dynamics. The book concludes with a discussion of how applications of the properties and principles of these diverse phenomena may be modelled in practical terms. (from Publishers)

Proceedings - ASME heat transfer and fluids engineering divisions, San Francisco, November 1995
Hoyt J.W., 18 others et al., (American Society of Mechanical Engineers, New York), ISBN (PAPERBACK) 0 7918 1, 1995.
This book includes the proceedings from four symposiums which took place at the ASME International Mechanical Engineering Congress and Exposition. The symposiums were entitled: fluid mechanics and heat transfer in sprays; heat, mass and momentum transfer in environmental flows; measurement techniques in multiphase flows; and multiphase transport in porous media. Ninety papers are included. (A.Slowey)

Two-phase flows with phase transition
ANON, (Von Karman Institute for Fluid Dynamics, Rhode Saint Genese; Lecture Series 1995 - 06), 1995.
This volume treats problems in relations with steam turbines, heat exchangers and sprays. There are contributions on topics such as: nucleation and droplet growth; droplet processes; gas dynamics of steam and water vapour/carrier gas mixtures; condensation conditioned instabilities; boiling and condensation heat transfer; and evaporation. Emphasis is put on: numerical modelling of condensing flows in steam turbine bladings; heat exchangers; and steady and unsteady sprays. (after Editor)

Computer methods and water resources III. Proceedings of an international conference, Beirut, September 1995
Abousleiman Y., Breddia C.A., Cheng A.H.D. & Ouazar D., (Computational Mechanics Publications, Southampton), ISBN 1853124249, 1995.
It is reflected in this book that issues of water quality, quantity, management planning, as well as other related scientific and

engineering topics are crucial to the international community and have a pressing urgency at the regional level of the Mediterranean and the Middle East. The contents includes: groundwater flow models; shallow water models; contaminant transport and dispersion; contaminant containment; water quality and pollution control; groundwater remediation; risk analysis; flow in rivers and channels; wave propagation; coastal engineering models; estuarine problems; reservor modelling; reservoir simulation; sedimentation; multiphase flow; hydrological studies; flow in fractured porous media; porosity modelling. (from Publisher)

Recent progress in the studies of two-phase flow at microgravity conditions
Rezkallah K.S., *Advances in Space Research*, 1995, 16/7 (123-132).
Methods of transporting heat along the structure of a spacecraft are pursued. Two-phase flow is an excellent alternative to the conventional single-phase system in transporting large amount of thermal energy at a uniform temperature regardless of variations in the heat loads. Systems include material processing and ceramics at ultra high temperatures, bioreactors and life-support systems, storage and transport of cryogenics, tank filling and fluid management, and in the design of many cold plate assemblies where heating (or cooling) takes place at the instrument/utility interface. Reliable design of such systems and many others require a thorough understanding of the mechanics of the two-phase flow under microgravity conditions. Of most interest are the phase distribution in a conduit (the flow patterns/regimes), the pressure drop, and the heat-transfer rates at different liquid and gas flow rates. Recent progress in the study of gas-liquid flows at microgravity conditions will be reviewed and discussed in this paper. (from Author)

A flow pattern map for two-phase liquid-gas flows under reduced gravity conditions
Rezkallah K.S. & Zhao L., *Advances in Space Research*, 1995, 16/7 (133-136).
Two-phase gas-liquid flows have a wide range of applications in space including the flow of cryogenics in transport lines and heat-transfer fluids in a thermal control system. Experimental studies on two-phase flow patterns and their transitions were conducted aboard the NASA KC-135 aircraft. A large set of flow pattern data for water-air and glycerin/water-air of different viscosities was reported. It was shown that two-phase flow under reduced gravity can be classified into four flow patterns: bubbly, slug, frothy slug-annular, and annular flows. Transitions between slug and frothy slug-annular, and frothy slug-annular and annular flows were predicted using the liquid and gas Weber numbers as the mapping coordinates. (from Authors)

Gas-liquid pipe flow under microgravity conditions: influence of tube diameter on flow patterns and pressure drops
Colin C. & Fabre J., *Advances in Space Research*, 1995, 16/7 (137-142).
Gas-liquid flow experiments have been performed in small tubes of 19 mm, 10 mm and 6 mm diameter, during parabolic flights, for a range of superficial liquid velocities from 0.1 to 2 m/s and superficial gas velocities from 0.05 m/s to 10 m/s. Results are compared to those previously obtained by Colin et al., in a 40 mm i.d. tube. The flow patterns identified are: bubbly flow, slug flow and a pattern halfway between slug and annular flows. The main difference between the experiments in small tubes and the previous ones, concerns the transition between bubbly flow and slug flow, the role of coalescence and the wall fraction factor. Coalescence is shown to play a major role in the transition from bubbly to slug flow. (from Authors)

Multi-droplet Marangoni motion in immiscible Al-Si-Bi alloys - results of a D-2 experiment
Ratke L., 6 others et al., *Advances in Space Research*, 1995, 16/7 (185-190).
In the Isothermal Heating Facility (IHF) of the Werkstofflabor on board the D2-mission we performed directional melting and solidification experiments with liquid immiscible Al-Si-Bi alloys. Their main objective was to investigate the Marangoni motion of a large number of Bi droplets within a well defined temperature field ahead of the solid-liquid interface, their hydrodynamic interaction and thus the collision and coagulation processes between them. Two samples with a Bi-content of 7 wt.% and two different melting velocities were melted and solidified. Their microstructures clearly show that the Bi droplets moved by Marangoni motion as anticipated. The results are analysed with a new kind of numerical simulation, the Discrete Multi-Particle Approach (DMPA), developed especially for the decomposition and microstructure evolution in liquid immiscible systems. (from Authors)

The remelting and solidification of turbine blade samples within the scope of the D2 mission
Amende W. & Holl S., *Advances in Space Research*, 1995, 16/7 (191-194).
In the scope of the German D 2 mission, samples of a nickel super alloy CMSX6 were remelted and solidified. The sintered sample material contained a strengthening dispersion of Al_2O_3 particles with a grain size of approximately 50 nm. Reference samples consisted of the cast material without particles. The samples shape was similar to small turbine blades. In order to preserve their geometry the samples were provided with a thin ceramic mold skin. The main objectives of the experiments were the shape preservation by means of the skin and informations of the particles behaviour. The local and the chronological temperature profile was evaluated by computer simulation additionally to the ground lab runs. Both results showed a good consistency. (from Authors)

A semianalytic approach to tracer flow modeling in heterogeneous permeable media
Datta-Gupta A. & King M.J., *Advances in Water Resources*, 1995, 18/1 (9-24).
A semianalytic approach for modeling tracer motion in heterogeneous permeable media is presented. The method is analytic along streamlines; the streamlines are derived from an underlying velocity field which is obtained numerically from a conventional fluid flow simulator. This generalizes the approach to any arbitrary configuration of wells and also to areally heterogeneous permeability fields. The semianalytic scheme is based on the observation that in a velocity field derived by finite difference, streamlines can be approximated by piecewise hyperbolic intervals. Along each of these intervals the evolution equation can be solved exactly. (from Authors)

Robust numerical methods for saturated-unsaturated flow with dry initial conditions in heterogeneous media
Forsyth P.A., Wu Y.S. & Pruess K., *Advances in Water Resources*, 1995, 18/1 (25-38).
A robust numerical method for saturated-unsaturated flow is developed which uses a monotone discretization and variable substitution. This method is compared to a conventional formulation and to a two phase (active air phase) model. On some published test examples of infiltration into dry media, the variable substitution method shows an order of magnitude improvement (in terms of nonlinear iterations) compared to the conventional pressure based method. One, two and three dimensional computations using both finite element and finite volume discretizations are presented. (Authors)

Multi-phase flow modeling of air sparging
Van Dijke M.I.J., Van der Zee S.E.A.T.M. & Van Duijn C.J., *Advances in Water Resources*, 1995, 18/6 (319-333).
Air injection into groundwater (air sparging) in a homogeneous axially symmetric porous medium is modeled using a two-phase flow approach. A numerical method based on the mixed form of the Richards equation for both phases is presented. Furthermore

two analytical approximations are discussed to explain the numerical results. One is a one-dimensional description explaining the occurrence of small air saturations. The other is a closed form approximation for the distribution of the air saturation in the resulting steady state. The analytical approximation at steady state and the numerical results are in good agreement. (from Authors)

Migration of aerosol spheres under the combined action of thermophoretic and gravitational effects
Huan Keh J. & Jiunn Yu L., *Aerosol Science & Technology*, 1995, 22/3 (250-260).
The migration of an aerosol spherical particle subject to the combined action of gravity and a vertical temperature gradient is considered. In the limit of small Reynolds and Peclet numbers, the solution for the stream function of the fluid flow and the migration velocity of particle is obtained by superposition of the individual solutions for sedimentation and thermophoresis. The flow structures for the fluid phase, being illustrated via streamlines in meridian section, reveal complex topology whether in the laboratory frame of reference or a reference frame traveling with the particle. The results demonstrate that fresh intuition must be developed regarding this class of problems. (Authors)

Movement and deposition of fibers in an airway with steady viscous flow
Asgharian B. & Anijilvel S., *Aerosol Science & Technology*, 1995, 22/3 (261-270).
Deposition of fibrous particles in lung airways is drastically different from deposition of spherical particles because of aerodynamic differences. In the past, assessment of fibrous particle deposition in airways used appropriate modifications of the analytical expressions for deposition efficiency for spherical particles. In this study, inertial effects on both rotation and translation of the fiber are neglected. Equations for fiber orientation are derived in terms of Euler angles phi and theta, and flow variables. The behavior of fiber orientation is found to be a function of the aspect ratio and initial orientation of the fiber, as well as the fluid strain and vorticity. A set of equations is obtained that describes translation of fibers in the flow field. The differential equations of translation and rotation, which are coupled through the dependence of fiber drag on its orientation in the flow field, are simultaneously solved numerically using a predictor-corrector method. (from Authors)

Generating particle beams of controlled dimensions and divergence: I. Theory of particle motion in aerodynamic lenses and nozzle expansions
Peng Liu, Ziemann P.J., Kittelson D.B. & McMurry P.H., *Aerosol Science & Technology*, 1995, 22/3 (293-313).
A particle beam is produced when a particle-laden gas expands through a nozzle into a vacuum. This work discusses the theoretical basis of a novel method for producing highly collimated and tightly focused particle beams. The approach is to pass the particle-laden gas through a series of axisymmetric contractions and enlargements (so-called aerodynamic lenses) before the nozzle expansion. Particles are moved closer to the axis by a lens if the particle sizes are less than a critical value and particles can be confined very closely to the axis by using multiple lenses in series. Since particles close to the axis experience small radial drag forces, they stay close to the axis during nozzle expansion and therefore form a narrow particle beam downstream. The major effects that limit the minimum beam width are Brownian motion and lift forces on particles during the nozzle expansion. Simple theoretical models are developed in this work to estimate the minimum particle beam width set by these effects. (from Authors)

Generating particle beams of controlled dimensions and divergence: II. Experimental evaluation of particle motion in aerodynamic lenses and nozzle expansions
Peng Liu, Ziemann P.J., Kittelson D.B. & McMurry P.H., *Aerosol Science & Technology*, 1995, 22/3 (314-324).
A particle-beam-forming apparatus for producing narrow particle beams was developed based on the theory discussed in paper I of this series. It consists of a variable number of aerodynamic lenses (short capillaries and/or thin-plate orifices with diameters ranging from 3.5 to 7.0 mm) followed by an accelerating nozzle (3 mm). It was evaluated using monodisperse DOS and NaCl particles (0.02-0.24 mum) at upstream pressures on the order of 1 torr. The particle beams produced by the lens-nozzle system were focused through a skimmer (1 mm) into a high vacuum chamber (10^{-4}-10^{-5} torr) where the beam widths, velocities and transport efficiencies were measured. The experiments showed that as more lenses were added the particle beam widths were reduced asymptotically to the minimum values. For spherical particles (DOS) these minimum values are in good agreement with the Brownian limit derived previously. (from Authors)

A turbulent flow without particle mixing
Crowe C.T., Troutt T.R., Chung J.N., Davis R.W. & Moore E.F., *Aerosol Science & Technology*, 1995, 22/1 (135-138).
We report on an investigation which indicates that the conventional wisdom that turbulence is always an effective agent for gas-particle mixing is not universally valid. Studies of particles injected into the wake of a bluff body show that, under certain conditions, particles will tend to concentrate near the edges of the vortex structures shed by this body. A photograph of the concentration patterns of glass beads injected into the wake of a bluff body is shown in Figure 1. One notes that the large turbulent structures tend to 'demix' the particles rather than produce a homogeneous mixture. This phenomenon has been referred to as a 'focusing' effect (Tang et al, [1992]). That this effect is occurring in the presence of small-scale turbulence is clear from smoke wire visualizations of this flow, which appear very similar to that presented in Tang et al (1992) for a higher Reynolds number. (from Authors)

Particle-surface interactions: charge transfer, energy loss, resuspension, and deagglomeration
John W., *Aerosol Science & Technology*, 1995, 23/1 (2-24).
As an introduction to the 1993 symposium on particle-surface interactions, the nearly 20 years of research on that topic at Berkeley is reviewed. Four main processes are covered - electrical charge transfer between particles and surfaces during impaction, particle energy loss and adhesion to surfaces in impaction, particle resuspension induced by particle impaction, and deagglomeration of particles by impaction. All of these processes are strongly dependent on the physical and chemical condition of the surfaces. (from Author)

Nucleation and growth in microcellar materials: supercritical CO_2 as foaming agent
Goel S.K. & Beckman E.J., *AIChE Journal*, 1995, 41/2 (357-367).
Bubble growth is a phenomenon encountered in several commercially important processes. A mathematical model presented here describes the growth of bubbles during phase separation of an initially homogeneous polymer-supercritical fluid mixture, triggered by a sudden pressure drop at constant temperature. It is a modification of the viscoelastic model of Arefmanesh and Advani (1991) in which the polymer is treated as a single relaxation-time Maxwell fluid. The viscosity of polymer/fluid mixture, density of the mixture, diffusivity of CO_2 in the mixture, and relaxation time for poly(methyl methacrylate) swollen by supercritical carbon dioxide are, therefore, predicted as functions of CO_2 pressure and temperature using appropriate model equations at each step of the bubble growth simulation. (from Authors)

Monolith froth reactor: development of a novel three-phase catalytic system
Crynes L.L., Cerro R.L. & Abraham M.A., *AIChE Journal*, 1995, 41/2 (337-345).
The monolith froth reactor, involving two-phase flow and a monolith catalyst, is developed. The flow within monolith channels, consisting of trains of gas bubbles and liquid slugs, is produced by forming a two-phase froth in a chamber immediately below the bottom of the monolith. The froth then flows upward into the monolith channels through pressure forces, which differs from previous methods since it may be carried out for a commercial-scale reactor. Catalytic oxidation of aqueous phenol over copper oxide supported on gamma-Al_2O_3 is used as a model reaction for investigating reactor performance. Generation of a froth is confirmed by visual inspection; the average bubble size is approximately that predicted by a force balance. The effect of externally controllable process variables (liquid and gas flow rates, temperature, and pressure) on the rate of phenol oxidation was investigated. (from Authors)

3-D mapping of solids flow fields in multiphase reactors with RPT
Larachi F., Chaouki J. & Kennedy G., *AIChE Journal*, 1995, 41/2 (439-443).
This article describes a new radioactive particle tracking system (RPT) developed for mapping solids velocity fields in multiphase reactors by tracking a gamma-emitting particle that follows the solid phase. In principle, the method is similar to CARPT, but it should yield improved spatial resolution because of the use of a model which accurately describes the interactions of the gamma rays with the reactor and the detectors and a least-squares 3-D (three-dimensional) inverse reconstruction algorithm. The new technique is currently being used to map the mean Eulerian solids velocity fields in three-phase fluidized beds, in gas-solid spouted beds and soon will be operational on circulating and turbulent gas-solid fluidized beds. (from Authors)

Phenomenological model for dispersed bubbly flow in pipes
Nikitopoulos D.E. & Michaelides E.E., *AIChE Journal*, 1995, 41/1 (12-22).
An analytical approach to the problem of steady-state, axisymmetrically dispersed, bubbly flow in pipes based on a zero equation turbulence model is discussed. The two-phase mixture is modeled as a variable-density single fluid assuming an empirical void distribution family. The turbulent shear stress is formed from the contributions of both the velocity and density variation, and the solution of the resulting Reynolds-type equation yields the velocity profile of the flow. The velocity profiles of this model agree reasonably well with experiments. Predictions for the friction multiplier are compared to six widely used correlations, as well as to experimental data. All the correlations severely underpredict the friction multiplier in the dispersed bubbly flow regime, while the results of the proposed model agree well with the measurements, within the range of its validity. (from Authors)

The effect of gravity degradation on low-speed centrifuge capillary pressure data
Zhigang Chen A. & Ruth D.W., *AIChE Journal*, 1995, 41/3 (469-480).
The gravity degradation effect has been identified as a significant physical problem in using centrifuge techniques for determining capillary pressure curves. In 1992, the authors characterized the effect by an angle; however, such an evaluation is simplistic. Here, a new model is constructed to characterize the effect quantitatively. The results with simulated data sets show that there exists a pronounced effect of gravitation on the horizontal centrifugal field in low-speed experiments (= or 500 rpm on a standard Beckman centrifuge). Gravity affects the production history for some samples, which leads to inaccurate interpretations of capillary pressure information near the threshold pressure. (Authors)

Diffusion in heterogeneous media: application to immobilized cell systems
Riley M.R., Muzzio F.J., Buettner H.M. & Reyes S.C., *AIChE Journal*, 1995, 41/3 (691-700).
Transport of small molecules in heterogeneous materials can be an important factor in many engineering and biological applications. This study focuses on the diffusion of cellular nutrients in an immobilized cell system. A Monte Carlo simulation technique is used to describe the diffusion of small molecules in a variety of simulated cellular structures. Diffusivity predictions are in close agreement with experimental values as well as with theoretical bounds reported in the literature. It is revealed that effective diffusivities are highly dependent on the diffusivities of the species in the various phases and on the volume fraction of cells. (from Authors)

Turbulence structure in bubble disengagement zone: role of polymer addition
Desai R.B., Kolhatkar R.V., Joshi J.B., Ranade V.V. & Mashelkar R.A., *AIChE Journal*, 1995, 41/5 (1329-1332).
Experimental studies of turbulent stresses have been reported near the gas-liquid interface of a two-dimensional bubble column using a laser doppler anemometer. The breakage of bubble in this region results in extra turbulence and energy dissipation causing damage to the cells. The thickness of the region of high turbulence has been measured. The level of turbulence was reduced by the addition of drag reducing polyacrylamide polymer. A simple model has been proposed for the prediction of extra turbulence in the bubble breakage layer. (from Authors)

Dilute turbulent gas-solid flow in risers with particle-particle interactions
Bolio E.J., Yasuna J.A. & Sinclair J.L., *AIChE Journal*, 1995, 41/6 (1375-1388).
Earlier work of Sinclair and Jackson that treats the laminar flow of gas-solid suspensions is extended to model dilute turbulent flow. The random particle motion, often exceeding the turbulent fluctuations in the gas, is obtained using a model based on the kinetic theory of granular materials. A two-equation low Reynolds number turbulence model is modified to account for the presence of the dilute particle phase. Comparisons of the model predictions with available experimental data for the mean and fluctuating velocity profiles for both phases indicate that the resulting theory captures many of the flow features observed in the pneumatic transport of large particles. The model predictions did not manifest an extreme sensitivity to the degree of inelasticity in the particle-particle collisions for the range of solid loading ratios investigated. (Authors)

Tortuosity of bubble rise path in a liquid-solid fluidized bed: effect of particle shape
Tsuchiya K. & Furumoto A., *AIChE Journal*, 1995, 41/6 (1368-1374).
Effects of particle properties on the rise of single bubbles in a liquid-solid fluidized bed are studied by focusing on the particle-shape effect at various bed voidages near incipient fluidization of glass beads and sand particles. The shape effect, being significant when the close-range (surface-to-surface) interactions between the particles are predominant, is appreciable for the relative solids holdups exceeding 0.9. Marked reduction in the bubble rise velocity is observed as the bubble size is decreased below 8 and 12 mm for the spherical glass and irregular sand particles, respectively. This anomalous reduction stems partly from the tortuousness in the rise path and partly from the 'hesitation' in the net vertical movement. The former is quantified in terms of the tortuosity of the 2-D rise path. (from Authors)

Two-phase flow in the vicinity of an elongated bubble in a fluidized bed
Levy Y. & Dorfman Y., *AIChE Journal*, 1995, 41/5 (1113-1121).

Fluid and solid dynamics inside and outside a stable elongated gas bubble in operating conditions corresponding to those of the channeling regime in a fluidized bed are described. The results of the analytical model show a significant increase of the fluid velocity inside the bubble with the growth of its relative height. The maximum values of the fluid velocities exist along the vertical axis of the bubble. For the limiting case of a spherical bubble, the fluid and gas performance, such as the existence of a surface of penetration outside the bubble boundaries and circulation zone inside the bubble, are in good agreement with the existing theory. (from Authors)

Origin of disturbances in cocurrent gas-liquid packed bed flows
Krieg D.A., Helwick J.A., Dillon P.O. & McCready M.J., *AIChE Journal*, 1995, 41/7 (1653-1666).
Visual, video, pressure, and conductance techniques were used to study time-varying disturbances in cocurrent flow in packed beds with vertical and horizontal columns. It is found that the trickle-pulse transition, as defined in previous studies, corresponds to conditions where traveling disturbances finally become measurable, not the conditions at which infinitesimal disturbances begin to grow. Horizontal packed bed experiments, designed to study how regions of differing liquid holdup interact, indicate that the first type of disturbance is infiltration of gas into the liquid region. A simple model suggests that infiltration occurs if the pressure drop exceeds a value necessary to push gas through liquid-filled pores. A three-layer Kelvin-Helmholtz stability model is used to interpret the growth of disturbances in horizontal flows. It should be possible to describe flow behavior in these systems with volume-averaged equations, as long as the presence of segregated regions is considered. Column diameter or thickness significantly affects the frequency of disturbances. (from Authors)

Droplet deposition and momentum transfer in annular flow
Fore L.B. & Dukler A.E., *AIChE Journal*, 1995, 41/9 (2040-2046).
Entrainment and deposition in gas-liquid annular upflow are known to account for as much as 20% of the pressure gradient, through droplet accelerations in the core region. Momentum is transferred from the core when droplets decelerate upon impact with the liquid film. It is usually assumed that all of this momentum is transferred to the film, essentially driving the film upward in conjunction with interfacial friction. New data, obtained for annular gas-liquid upflow in a 5.08-cm-ID tube, are used in a momentum balance analysis to determine the mechanism of momentum transfer from depositing droplets. Measurements include the liquid film thickness, wall shear stress, pressure gradient, entrained liquid fraction, droplet deposition rate, droplet centerline axial velocity, and mass-average drop size for two gas-liquid systems. This analysis supports the idea that large droplets displace the film locally and decelerate primarily at the wall, effectively transferring negligible momentum to the liquid film. (Authors)

Surface interactions in a shear field
Dietsche L.J., Denn M.M. & Bell A.T., *AIChE Journal*, 1995, 41/5 (1266-1272).
The dynamics of chain exchange between flowing bulk melt and the channel wall were studied for oligomeric polyolefins using attenuated total reflectance Fourier transform infrared spectroscopy (ATR/FTIR). The dynamics are dominated by a surprisingly slow first-order process which depends on flow rate and materials of construction of the channel wall. The picture which seems to emerge is an entropically-driven flow-rate-(or stress-) dependent adsorption equilibrium which retards the exchange between the surface and bulk. (Authors)

Ternary microemulsions as model disordered media
Knackstedt M.A. & Ninham B.W., *AIChE Journal*, 1995, 41/5 (1295-1305).
The ternary microemulsion systems alkane/water/DDAB (didodecyldimethylammonium bromide) form ideal model-disordered media. The static microstructure is described by a simple parameter-free model that can be predetermined and agrees with SAXS and SANS scattering experiments. Structural transitions are analyzed in the context of theories of percolative phenomena. Experimental transport properties agree well with model predictions based on an effective medium approximation. Critical exponents that describe the scaling of the transport properties near percolation are consistent with theoretical expectations near a static percolation transition. (from Authors)

Numerical computation of turbulent gas-solid particle flow in a 90 degrees bend
Tu J.Y. & Fletcher C.A.J., *AIChE Journal*, 1995, 41/10 (2187-2197).
A numerical computation of the LDV results of Kliafas and Holt is reported for a turbulent gas-solid particle flow in a square-sectioned 90 degrees bend. A Eulerian model with generalized Eulerian solid surface boundary conditions for the particle-phase momentum exchanges with solid walls are included. The turbulent closure is affected by using the gas-phase RNG-based k-epsilon turbulence model, and the particulate turbulence diffusivity is related to the turbulent viscosity of the gas phase. Comparisons are made with experimental data for the mean streamwise velocities of both phases, the streamwise turbulence intensity of the gas phase, and the particulate concentration distribution in the bend. The localized high particulate concentration near the outer curve of the bend that occurs at large Stokes number is accurately predicted. (from Authors)

Colloidal crystals
Murray C.A. & Grier D.G., *American Scientist*, 1995, 83/3 (238-245).
Colloids differ from solutions in that the particles are large and dispersed throughout the fluid. Colloidal particles in ordered arrays exhibit optical properties different from those of the bulk solution. The properties of colloids are outlined: Brownian motion; particle repulsion and attraction; particle density. Melting and freezing of colloidal crystals is discussed. The relations between particles during these processes and the structures formed are considered. (A.Peters)

Flow and heat transfer in a lid-driven cavity filled with a stably stratified fluid
Mohamad A.A. & Viskanta R., *Applied Mathematical Modelling*, 1995, 19/8 (465-472).
Three-dimensional numerical simulations of fluid flow and heat transfer in a lid-driven cavity filled with a stably stratified fluid have been performed to study the effect of a sliding lid on the flow and thermal structures in a shallow cavity. The cavity is heated from above and cooled from below. The Richardson numbers investigated are 0.1, 1, and 10 for two values of Rayleigh numbers 1×10^4 and 1×10^5. The Prandtl number is fixed at 6.0 (water). The flow is found to be three-dimensional in nature. Interesting flow features are predicted and include longitudinal circulations for certain flow conditions. (Authors)

Particle simulation of large carbon dioxide bubbles in water
Greenspan D., *Applied Mathematical Modelling*, 1995, 19/12 (738-745).
A method that can be applied to simulate the motion of fluid drops within fluids is described through a detailed study of a prototype problem, the motion of carbon dioxide bubbles in water. The mathematical formulation uses classical molecular dynamics type formulas and results in an n-body problem that is solved numerically. The rise of the bubbles is described, as is the motion of the

water near the bubbles. For variety, both H_2O water and D_2O heavy water are considered. Only workstation computer capabilities are required. (Author)

Mie scattering from a sonoluminescing air bubble in water
Lentz W.J., Atchley A.A. & Gaitan D.F., *Applied Optics*, 1995, 34/15 (2648-2654).
A single bubble air in water can emit pulses of blue-white light that have durations of less than 50 ps while it is oscillating in an acoustic standing wave. The emission is called sonoluminescence. A knowledge of the bubble diameter throughout the cycle, and in particular near the time of sonoluminescence emission, can provide important information about the phenomenon. A new Mie scattering technique is developed to determine the size of the bubble through its expansion and collapse during the acoustic cycle. The technique does not rely on an independent means of calibration or on accurate measurements of the scattered intensity. (Authors)

Waste biogas residual slurry as an adsorbent for the removal of Pb(II) from aqueous solution and radiator manufacturing industry wastewater
Namasivayam C. & Yamuna R.T., *Bioresource Technology*, 1995, 52/2 (125-131).
Waste biogas residual slurry (BRS) was used for the adsorption of Pb(II) from aqueous solution, over a range of initial metal ion concentrations (20-100 mg litre^{-1}), agitation times (5-70 min), adsorbent doses (0.4-5.0 g litre^{-1}) and initial pH values (1.5-6.0). The applicability of the Lagergren rate equation was also investigated. The process of uptake of Pb(II) by BRS followed the Langmuir isotherm model and the adsorption capacity was 28 mg g^{-1}. Application of BRS for the effective removal of Pb(II) from radiator manufacturing industry wastewater has been demonstrated. (from Authors)

Conversion of waste biomass (pea-shells) into hydrogen and methane through anaerobic digestion
Kalia V.C. & Joshi A.P., *Bioresource Technology*, 1995, 53/2 (165-168).
Waste pea-shells were digested under batch anaerobic conditions. Digestion of pea-shell slurries (PSS) at 1-5% total solids (TS) concentration, with H_2-producing organisms yielded 99-362 l biogass-H/kg organic solids reduced (biogas-H: mixture of H_2, CO_2 and H_2S). Hydrogen constituted 33-46% of the total biogas-H. Methanogenesis of PSS (1-5% TS) was most effective at 1% TS level. During 25 days of incubation, 507 l biogas/kg was generated (biogas: mixture of CH_4, CO_2 and H_2S). Methane accounted for 43% of the total biogas yield. Biogas yield of 1% TS PSS without the fibrous sheath was only 16.5% of that of 1% TS PSS with the fibrous sheath. However, 3% TS PSS without the fibrous sheath showed improved results, which could be employed for continuous-culture digestions. (Authors)

Stably stratified flow in a marine atmospheric surface layer
Bergstrom H. & Smedman A.-S., *Boundary-Layer Meteorology*, 1995, 72/3 (239-265).
Data from the marine atmospheric surface layer have been analysed. The data set consists of about two weeks with tower measurements up to 31 m of mean profiles of wind, temperature, and humidity, together with 20 Hz turbulence data. Mean wind, temperature, and humidity profiles up to 2000 m are also available from pibal trackings and radio soundings. Wave height was measured at 2 Hz, using an inverted echo-sounder. It was found from pibal wind profiles that low level jets were present during 2/3 of the measurements, having their maxima in the height interval 40 to 300 m. Here only data from the remaining 1/3 of the measurements, without low level jets, have been analysed. (from Authors)

Determination of the non-saturated permeability of clay materials of low porosity (Determination de la permeabilite non saturee des materiaux argileux a faible porosite)
Robinet J.C. & Rhattas M., *Canadian Geotechnical Journal*, 1995, 32/6 (1035-1043). In French.
The presence of impermeable natural or artificial clayey layers plays a fundamental role in protecting ground water from pollution. In the case of low porosity and partially saturated clays, the experimental determination of transfer coefficient is particularly difficult because of a considerable reduction in hydraulic head and of water-particle interactions that reduce the interstitial water mobility. Experimental work was carried out to obtain, in a simple way, the hydrodynamic characteristics of two clayey formations: Boom and Bassin Parisien. The hydraulic profiles were determined by soaking tests and the sorption-desorption isotherms were evaluated. The spatio-temporal analysis of the hydraulic profiles reveals the variations in isothermal diffusion coefficient according to the water content. The total diffusivity combined with retention curves allows calculation of the permeability as a function of the saturation. (from English summary)

Effects of different parameters on the speed of transition of the turbulent regime in fluidization (Effets de differents parametres sur les vitesses de transition de la fluidisation en regime turbulent)
Chehbouni A., Chaouki J., Guy C. & Klvana D., *Canadian Journal of Chemical Engineering*, 1995, 73/1 (41-50). In French.
Much controversy exists in the literature about the effects of different variables on the onset of the turbulent regime in gas-solid fluidization, U_c, and on the transport velocity, U_{tr}. In order to study the effect of four hydrodynamic factors upon these transition velocities, a basic 8-run Plackett-Burman design was used. The factors and their level were: (a) diameter of column (82 vs 200 mm), (b) particles (FCC vs sand), (d) static bed height (300 vs 450 mm), and (g) size distribution of particles (narrow vs wide). In each run, U_c and U_{tr} were determined experimentally by means of differential pressure transducer and also with a capacitance probe. The experimental results and statistical analysis show that bed diameter has the most important impact (61% variability upon U_c and 51% upon U_{tr}). The product of particle size and density ($rho_p d_p$) seems to have a significant effect (35% variability upon U_c and 47% upon U_{tr}). Static bed height has a slight impact. There is essentially no effect of the particle size distribution. Results show that interactions effects are negligible between these factors. Finally, two correlations for U_c and U_{tr}, which are in agreement with literature data are proposed. (English summary)

Experimental studies on flow boiling in inclined tubes: in the regions encountered in solar collectors
Maddi M.K. & Rao D.P., *Canadian Journal of Chemical Engineering*, 1995, 73/1 (73-84).
Flow boiling in inclined tubes is encountered in solar collectors, but there is no literature on inclined flow boiling on which to base their design. Experimental studies have been carried out on heat transfer, pressure drop and flow maps for flow boiling of water in a circular tube. The angle of inclination was varied from 0 degrees to 90 degrees. The inclination was found to influence the transport processes in the bubbly and the intermittent flow regimes. The correlation of Chen (1966) has been extended to correlate the heat-transfer data to account for the angle of inclination. The Baroczy (1965) and the Lockhart-Martinelli (1949) correlations were adapted to correlate the frictional pressure gradient in the inclined flow boiling. The observed flow patterns were presented as flow maps. (Authors)

Fluidized bed gasification of coal
Chatterjee P.K., Datta A.B. & Kundu K.M., *Canadian Journal of Chemical Engineering*, 1995, 73/2 (204-210).

Gasification of high ash India coal has been studied in a laboratory-scale, atmospheric fluidized bed gasifier using steam and air as fluidizing media. A one-dimensional analysis of the gasification process has been presented incorporating a two-phase theory of fluidization, char gasification, volatile release and an overall system energy balance. Results are presented on the variation of product gas composition, bed temperature, calorific value and carbon conversion with oxygen and steam feed. Comparison between predicted and experimental data has been presented, and the predictions show similar trends as in the experiments. (Authors)

Visual study of an airlift pump operating at low submergence ratios
Tramba A., Topalidou A., Kastrinakis E.G., Nychas S.G., Francois P. & Scrivener O., *Canadian Journal of Chemical Engineering*, 1995, 73/5 (755-764).

The operation of an airlift pump, working under low submergence ratios (between 0.17 and 0.31), has been visually studied. The two-phase flow structures occurring in the riser channel and around the injection sector were recorded by a high speed video system. A quasi-periodic burst-like behaviour characterised the flow pattern in the riser tube, which appeared to dominate the operation of the airlift pump under the conditions of low submergence ratios. An interesting aspect of the airlift pump operation, under these conditions, is that the two phases show a large interface area; this is due to the high dispersion degree of the two-phase mixture in the riser duct. Data and pictures from video recordings regarding the sequence, time and length scales of the occurring flow patterns are reported. (Authors)

Theoretical analysis of absorption of chlorine in aqueous slurries of calcium hydroxide: desorption of hypochlorous acid gas
Mogal M.M.B. & Yadav G.D., *Canadian Journal of Chemical Engineering*, 1995, 73/5 (693-716).

A theory has been developed for the absorption of chlorine in aqueous slurries of calcium hydroxide accompanied by a two-step instantaneous reaction and desorption and simulation is carried out to study the effect of various parameters. The rates of absorption of chlorine and desorption of HOCl from the aqueous slurry are enhanced when fine particles are present in two diffusion film regions on the liquid side. It is concluded that intensification in the rates of absorption of chlorine and rates of desorption can be realized by using high loading of smaller particle size. An optimum k_L must be used to enhance rates of Cl_2 absorption and HOCl desorption in order to permit the formation of two reaction planes in the diffusion film. Rates can be identified by an order of magnitude by the proper selection of operating conditions. (Authors)

Hydrodynamics of a gas-liquid-solid three phase circulating fluidized bed
Liang W., Wu Q., Yu Z., Jin Y. & Wang Z., *Canadian Journal of Chemical Engineering*, 1995, 73/5 (656-661).

The hydrodyanmics of a gas-liquid-solid circulating fluidized bed was investigated. A new regime, the three phase circulating fluidization regime, was discovered for the first time. The characteristics of this regime were compared with that of the conventional fluidization regime and the transport regime. The particle circulation rate and the gas and solids holdups in circulating fluidization regime were studied. (Authors)

A model for two-phase turbulent mixing at a jet bubble column
Mitra-Majumdar D., Farouk B., Shah Y.T. & Wisecarver K., *Canadian Journal of Chemical Engineering*, 1995, 73/5 (772-778).

Mixing behavior of the two phase air-water turbulent flow in a jet bubble column is examined. The time evolution of the mixing behavior of a liquid tracer in a turbulent air-water flow within a jet bubble column is predicted using a model based on the fundamental governing equations of fluid motion. The predictions of the model are compared with experimental measurements. Measured residence time distributions of the liquid tracer within the cone agree well with the predicted values given by the model. For the range of parameters considered in the study, lack of radial mixing and large axial mixing are evident within the cone of the jet bubble column. Fundamental mathematical models for the study of hydrodynamics in a two-phase conventional bubble column were extended to predict the mixing characteristics in a jet bubble column. (from Authors)

Determination of minimum fluidization velocity by pressure fluctuation measurement
Wilkinson D., *Canadian Journal of Chemical Engineering*, 1995, 73/4 (562-565).

Using the standard deviation of pressure fluctuations to find the minimum fluidization velocity, U_{mf}, avoids the need to de-fluidize the bed so U_{mf} can be found for operational bubbling fluidized beds without disrupting the process provided only that the superficial velocity may be altered and that the bed remains in the bubbling fluidized state. This investigation has concentrated on two distinct aspects of the pressure fluctuation method for U_{mf} determination: (1) the minimum number of pressure measurements required to obtain reliable estimates of standard deviation has been identified as about 10 000 and (2) pressure fluctuation measurements in the plenum below the gas distributor are suitable for U_{mf} determination so the problems of pressure probe clogging and erosion by bed particles may be avoided. (Author)

Structure formation in cavitation bubble fields
Parlitz U., Scheffczyk C., Akhatov I. & Lauterborn W., *Chaos, Solitons & Fractals*, 1995, 5/10 (1881-1891).

Two approaches for modelling the formation of filamentary structures in cavitation bubble fields are presented. The first one describes the interaction of the sound field and the distribution of microbubbles in terms of a set of two coupled partial differential equations that determine the evolution of the sound-field amplitude and the bubble density. The second approach consists of a quasideterministic aggregation model, where the bubbles are treated as pulsating particles which experience radiation forces due to the sound-fields radiated from the other pulsating bubbles. Results of numerical simulations are presented for both models. The validity and the limitations of both approaches are discussed. (Authors)

Analyzing the effectiveness of an intake compensator for a piston mud pump
Itkis Ya. M. & Sotnikov O.A., *Chemical & Petroleum Engineering*, 1995/96, 31/5-6 (243-247; translated from: Khimicheskoe i Neftyanoe Mashinostroenie, 5, 1995).

A mathematical procedure is given for calculating the effectiveness of an intake compensator for a piston mud pump. The intake compensator of a piston pump increases the suction head and decreases the possibility of cavitation caused by decreased inertial losses in the inlet pipe. The procedure can be applied to both cylindrical and conical compensators. (P.M.Taylor)

Prediction of the range of operation of centrifugal pumps according to the cavitation criterion
Yalovoi N.S. & Kats A.M., *Chemical & Petroleum Engineering*, 1995, 31/9-10 (477-480; translated from: Khimicheskoe i Neftyanoe Mashinostroenie, 9, 1995).

Cavitation tests of a centrifugal pump are used to estimate the suction capacity at the theoretical point and at the limits of the operating range of feeds. Cavitation tests of a low-speed centrifugal pump were conducted with a wide range of feeds and different experimental impellers. Cavitation margins corresponding to a 3% drop of head were determined for each impeller. The limits of

operation of the pump were determined by correlating the cavitation margin of the pump with the geometric and kinematic parameters of impellers in dimensionless form. (A.Peters)

Hermetically sealed valves eliminate leakage
Paul B.O., *Chemical Engineer*, 1995, 58/2 (47-48).
Chevron Pipe Line Co.'s pipeline delivering fuel products to terminals in Northern California experienced problems with destructive cavitation and stem packing in control valves, causing leakage. The problems were eliminated by replacing four control valves with hermetically sealed, magnetically actuated control valves requiring no air or hydraulic fluid for operation. The new valves have reduced unscheduled valve downtime and have required little maintenance during operation for 5 years. (A.Peters)

Pneumatic conveying
Dixon G., *Chemical Engineer*, 1995, 600/- (26-29).
The link between solids characterization and pneumatic conveying is examined. Two types of systems can be identified (i) systems in which the movement of air is ignored (continuum approach); (2) systems in which it is necessary to consider the movement of solids and air (two-phase flow approach). The flow of solids in hoppers at feed and discharges is considered. The flow function and two-phase are discussed. Bubble, minimum fluidization and terminal velocities are described for fine, coarse and large particles. (A.Peters)

Taking a powder
Hayati I., *Chemical Engineer*, 1995, 588/- (12, 14-15).
The main test equipment needed to set up a powders characterization laboratory to generate information for process control and quality control. Powder measurements should be conducted in a controlled environment. Methods for measuring particle size distribution, bulk density, flowability, dust generated by tumbling, degree of attrition by fluidization, tendency for caking, dust content, and colour are described. (A. Peters)

Mixing in the food industry
Niranjan K., *Chemical Engineer*, 1995, 591/- (20-22).
Mixing occurs in several processes practiced by the food industry. Food systems cover a wide spectrum of materials: from dry, free-flowing materials to slurries, pastes and doughs. Flow properties of the components and mixtures are complex and time-dependent. Mixers can be classified into three categories: dissolving and dispersing liquids; blending particulate material; mixing solids and liquids. The characteristics of these types of mixers are outlined. (A. Peters)

Theoretical and experimental analysis of venting-induced processes in reacting and non-reacting two-phase systems
Friedel L., Kranz N.-J., Wehmeier G. & Westphal F., *Chemical Engineering & Processing*, 1995, 34/2 (71-78).
Top venting of initially saturated methanol and water and of a reacting methanol/acetic anhydride mixture has been carried out in a semi-technical scale test facility. Measured variables were the pressure in the reactor and the catchtank and mass flow rate and quality in the vent line. The experimental results compare satisfactorily with predictions obtained by using an in-house modified version of the SAFIRE code. (Authors)

Internally circulating fluidized bed for continuous adsorption and desorption
Reichhold A. & Hofbauer H., *Chemical Engineering & Processing*, 1995, 34/6 (521-527).
An internally circulating fluidized bed has been developed for continuous adsorption and desorption. It helps to separate and to recover gaseous pollutants and reusable compounds (eg. CO_2, SO_2, organic solvent vapors, along with other gases). Two fluidized beds are arranged next to each other. The partition wall in the upper and lower part of the fluidized beds has horizontal openings to let solid matter pass through. As the two beds are fluidized at different rates, the bed material starts to circulate between the two beds. The bed material doubles as an adsorbent. In the asorption zone, polluted gas is used for fluidization; in the desorption zone, heated air or steam is used. (from Authors)

The effect of gas injection on the flow of immiscible liquids in horizontal pipes
Nadler M. & Mewes D., *Chemical Engineering & Technology*, 1995, 18/3 (156-165).
The flow of two immiscible liquids and the influence of an additional inserted gas phase in horizontal pipes is investigated. Experimental results are presented for the flow regimes of the two phase and three phase flow of oil, water and gas mixtures. The effect of phase inversion on the pressure drop is measured. The experimental results obtained for the three phase flow of oil, water and air indicate that drag reduction is possible by injecting gas in laminar flowing mixtures of oil and water. In the aerated slug flow regime of oil, water and air a water dominated and an oil dominated flow system can be distinguished. The pressure drop of the three phase flow system is of the magnitude as the pressure drop of the two phase flow of gas and the dominating liquid phase. (from Authors)

Modeling of sulphur retention in atmospheric fluidized bed combustors. Sensitivity analysis and simulation
Adanez J. & Garcia-Labiano F., *Chemical Engineering & Technology*, 1995, 18/4 (229-242).
For the design, simulation and optimization of sulphur retention in atmospheric fluidized bed coal combustors, a mathematical model is needed that would be able to predict the behaviour of the combustor in a wide range of operating conditions. In this work, a sensitivity analysis of the sulphur retention predictions of the different hypotheses, equations and parameters, which define the different submodels and phenomena occurring in the combustor, has been carried out. The greatest effect on sulphur retention predictions is exercised by the parameters defining the fines elutriation and sorbent sulphation capacity. However, those corresponding to the bed hydrodynamics (minimum fluidization velocity and bed expansion) do not have a significant effect on the sulphur retention predictions. The sulphur retentions obtained in the combustion of high sulphur lignites with eight different limestones were used for model validation. (from Authors)

Vertical motion of spherical particles
Michalski J.A., *Chemical Engineering & Technology*, 1995, 18/6 (434-439).
A theoretical analysis is presented for the time-dependent vertical motion of spherical particles in a gas stream. Laminar, transitional and turbulent flows are considered, and equations are developed to predict particle velocity and distance travelled as functions of time in both stagnant and slowly-moving gases. In both cases the equations are shown not to be universally applicable, and algorithms for estimating the limits within which they remain valid are briefly presented. (Author)

Pressure losses in two-phase gas-non-Newtonian liquid flow in a vertical tube
Das S.K. & Biswas M.N., *Chemical Engineering Communications*, 1995, 135/- (229-237).

Experimental data on pressure drop for two-phase gas-non-Newtonian pseudoplastic liquid vertical slug flow have been analysed. Correlation have been proposed for predicting the two-phase friction factor as a function of the physical and dynamic variables of the system. (Authors)

Non-equilibrium two-phase flow in a horizontal T-junction
El-Dessouky H., *Chemical Engineering Communications*, 1995, 134/- (211-230).
The paper discusses the flow of saturated or nearly saturated water in a horizontal sharp edged T-junction. Equations were developed to predict the vapour mass fraction and the splitting ratio in both the run and branch lines. Experimental measurements obtained showed that the mass of vapour formed in the branch line was much higher than that formed in the run line. The calculated vapour mass fractions in both the run and branch lines were higher than, but close to, the measured data. The measured branch line splitting ratio was higher than that calculated from the developed model. A good agreement was obtained between the experimental results and the model predictions. (Author)

Prediction of a gas-particle turbulent jet with the fluctuation-spectrum-random-trajectory model
Jianren Fan, Jun Jin & Kefa Cen, *Chemical Engineering Communications*, 1995, 135/- (101-112).
A numerical treatment for determining the particle velocity and the trajectories in a two-phase flow is described herein and this new fluctuation-spectrum-random-trajectory (FSRT) model is proposed to account for the turbulent diffusion of particles. It is predicted for the flow of a turbulent axisymmetric gaseous jet laden with spherical solid particles of nonuniform size. The particle velocity and the concentration field are obtained by the revised volume average method. The predictions are compared with experiment. (Authors)

Power consumption and gas holdup in a gas-liquid reciprocating plate column
Bankovic-Ilic I.B., Veljkovic V.B., Lazic M.L. & Skala D.U., *Chemical Engineering Communications*, 1995, 134/- (17-32).
The pressure fluctuation at the column base is confirmed to be proportional to the vibration intensity on a power of 2 in non-gassed conditions and up to a critical vibration intensity, corresponding to the dispersion resonance frequency, in gassed conditions. The power consumption is successfully correlated with the vibration intensity and the liquid holdup. The gas holdup in both mixer-settler and emulsion regime is well correlated with the power consumption and the superficial gas velocity. The effect of the superficial gas velocity is more important than that of the power consumption. The effects of the liquid phase properties, the wetting tendency of the plate material and the fraction free area above 41% were not observed. (Authors)

Mass transfer and gas-liquid circulation in an airlift bioreactor with viscous non-Newtonian fluids
Guo-Qing Li, Shou-Zhi Yang, Zhao-Ling Cai & Jia-Yong Chen, *Chemical Engineering Journal*, 1995, 56/2 (B101-B107).
In an internal loop airlift reactor of 55 l working volume, gas-liquid volumetric oxygen mass transfer coefficient $k_L a$, gas holdup epsilon$_G$ and liquid circulation time t_c were measured with the solution of carboxymethyl cellulose to simulate the performance of a reactor with highly viscous broth. Electric conductivity and oxygen probes were used to measure the local gas holdup, liquid circulation time and oxygen mass transfer coefficient in the individual sections of the reactor (riser, downcomer and separator) and the total reactor respectively. The values of $k_L a$ in the riser, downcomer and separator sections of the reactor total reactor estimated and compared with that in the total reactor. (from Authors)

The development of a dual mode tomograph for three-component flow imaging
Johansen G.A., 8 others et al., *Chemical Engineering Journal*, 1995, 56/3 (175-182).
A dual mode tomograph for three-component flow imaging has been designed and is being built in a cooperative project between the University of Bergen, Christian Michelsen Research AS and Norsk Hydro AS. It is based on an eight-electrode capacitance tomograph and a gamma-ray tomograph with five radiation sources and 85 compact detectors. Embedded Transputers using memory-mapping ensure high speed data acquisition into the transputer-based reconstruction unit. The quality of the reconstructed images from the capacitance system is improved by the use of new reconstruction algorithms. New efficient gamma-ray detectors enable real-time flow imaging. (from Authors)

Industrial applications of nuclear magnetic resonance
Gladden L.F., *Chemical Engineering Journal*, 1995, 56/3 (149-158).
During the past decade, the potential application of nuclear magnetic resonance (NMR) imaging techniques to industrial processing problems has been recognized. The particular strength of NMR is its ability to distinguish between chemical species and to yield information simultaneously on the structure, concentration distribution and flow processes occurring within a given process unit. In this paper, examples of specific applications are discussed including the study of ceramics processing, the structure of polymeric materials and the application of polymers in controlled release technology, transport in porous media, transport in reactors, food processing, and two-phase flow. (Author)

Modelling velocity profiles in inclined multiphase flow to provide a priori information for flow imaging
Lucas G.P., *Chemical Engineering Journal*, 1995, 56/3 (167-173).
Velocity profile measurements obtained by cross correlating between two axially separated image planes are becoming increasingly important in multiphase flow measurement systems. At present, considerable computing power is required to implement this technique because no use is made of the constraints imposed by the physics of the flow. This paper describes a mathematical model which, when combined with a simple auxiliary measurement, provides an accurate initial estimate of the velocity profile of an inclined multiphase flow. The paper describes how this a priori information can be used to reduce significantly the amount of data processing required to obtain velocity profile measurements by cross correlating between image planes. (from Author)

Development of solid-liquid mixing models using tomographic techniques
McKee S.L., Williams R.A. & Boxman A., *Chemical Engineering Journal*, 1995, 56/3 (101-107).
The need for tomographic technology to assist in the development of reliable correlations for scale-up of slurry mixing processes is described. In situ measurements of the axial and radial solid concentration profiles and vector velocities of particulates are required which indicate the effect of mixing impeller geometry, mixing speed, solid concentration and size distribution of solids on mixing performance. The current status of tomographic techniques that could be suited for these applications is assessed. Recent results obtained using the two methods of electrical resistance tomography (ERT) and positron emission tomography (PET) are described together with complementary measurements performed using an invasive single point conductivity probe. (from Authors)

Mass transfer-reaction coupling in two-phase multicomponent fluid systems
Kenig Ya. E., *Chemical Engineering Journal*, 1995, 57/2 (189-204).

The paper considers two-phase multicomponent mass transfer complicated by chemical reactions. The basis of theoretical description is partial differential equations of convective mass transport which are coupled by diffusional interactions in gas (vapor) phase and by both diffusional and chemical interactions in liquid phase. In addition, the boundary conditions of conjugation are taken into account at the interfaces which are of matrix coupled form as well. A calculation method combining analytical and numerical techniques is proposed for solving the problem under consideration. The method makes it possible to determine local concentration distributions of the components and, on this basis, to obtain all the relevant information about the process. Calculated examples demonstrating the regularities and peculiarities of the two-phase mass transfer-reaction process are given for different flow conditions. (Author)

The phase holdups in a gas-liquid-solid circulating fluidized bed
Wugeng Liang, Zhiqing Yu, Yong Jin, Zhangwen Wang & Qunwei Wu, *Chemical Engineering Journal*, 1995, 58/3 (259-264).
A special operation of gas-liquid-solid fluidization (the three-phase circulating fluidization) was investigated. The particle circulation flow rate in the circulating regime was measured. The gas holdup in this regime was obtained with a conductive probe. The relative solids holdup in the bubble wake and the ratio of wake volume to bubble volume were measured using a solids holdup probe. The predicted phase holdups with the generalized wake model in the circulating regime were consistent with the experimental results. (Authors)

Effect of measurement method on the velocities used to demarcate the onset of turbulent fluidization
Bi H.T. & Grace J.R., *Chemical Engineering Journal*, 1995, 57/3 (261-271).
The transition velocity U_c corresponding to the maximum rms amplitude of pressure fluctuations in a 102 mm diameter fluidized bed was found to be a strong function of measurement method, while the other commonly used transition velocity U_k depends on the solids return system and is not a well defined parameter. Different results and trends are obtained for U_c depending on whether one uses absolute or differential pressure fluctuations and whether or not one normalizes by the time-mean local or differential pressure. For differential pressure fluctuation measurements, a higher U_c was obtained from the dimensionless standard deviation normalized by the local pressure drop, and the value decreased with height. For local voidage fluctuation measurements using an optical fibre probe, a maximum point also appeared in the standard deviation curve. (from Authors)

Determination of effective diffusivities and convective coefficients of pure gases in single pellets
Weiruo Sun, Costa C.A.V. & Rodrigues A.E., *Chemical Engineering Journal*, 1995, 57/3 (285-294).
The determination of the effective diffusivities and convective coefficients of pure component gases in single porous pellets can be done separately using the diffusion-convection cell experimental technique; this simplifies the experimental procedure and the theoretical exploitation of the experimental results and improves the precision of parameter estimation. The validity of the assumption of perfect mixing inside the chambers and negligible film diffusion resistance was confirmed by a blank chamber test and by comparison of the responses obtained using the possible maximum and minimum film diffusion resistances respectively. The effective intrapellet diffusivities are determined by fitting the theoretical response of both chambers to the experimental values for a tracer gas stream. The dead-end pore volume can be evaluated from the results obtained using the steady and the transient responses. The effective convective coefficients were obtained from the top and bottom chamber inlet and outlet flow rates for a pure component stream keeping a given pressure difference across the pellet. (from Authors)

High-pressure segregation of solids with a wide particle size distributon when fluidized with a gas
Sciazko M. & Bandrowksi J., *Chemical Engineering Journal*, 1995, 60/1-3 (89-95).
The segregation of polydisperse mixtures of solid particles was investigated at pressures of 0.1-6.3 MPa in a bed of diameter 10 cm. It was found that fluidization at higher pressures is smoother and results in less segregation. The final effect depends on the properties of the solid mixtures, classified according to Geldart's groups A and B. Solids typical of group B segregate more strongly, as a result of the promoting effect of rising bubbles. (Authors)

The variation of crossflow filtration rate with wall shear stress and the effect of deposit thickness
Holdich R.G., Cumming I.W. & Ismail B., *Chemical Engineering Research & Design*, 1995, 73/A1 (20-26).
The crossflow filtration of magnesium hydroxide slurries is described. The pseudo steady state flux is shown to correlate with the wall shear stress. A deposit of appreciable thickness builds up on the filter tube, and the correlation improves when the deposit thickness is included in the calculation of wall shear stress. A technique to deduce the deposit thickness from pressure measurement in a single filtering tube is described. The model has been tested using filter tubes with an uncoated diameter of 4 mm and 14 mm filtering non-Newtonian slurries with solids concentrations ranging from 13% to 24% by volume. For particles which can substantially penetrate a filter the wall shear stress model is shown not to apply, as the filter membrane is subject to internal blocking, which severely reduces the filtration rate. (Authors)

Modelling the effect of dissolved gases on the viscosity of heavy oils
Miadonye A., Singh B., Huang S.S., Srivastava R. & Puttagunta V.R., *Chemical Engineering Research & Design*, 1995, 73/A2 (208-213).
The effect of dissolved gases on the viscosity of heavy oils has been modelled using a generalized correlation. The viscosity data for three heavy crude oils and crude oil-gas mixtures were obtained using a PVT-cell equipped with an on-line capillary tube viscometer. The measurements were conducted at various temperatures and pressures; and the viscosities calculated from the data using the Hagen-Poisseuille pipe flow equation. In this paper it is shown that the complex effect of three parameters, (temperature, pressure and dissolved gas concentration) on heavy oil viscosities can be accurately predicted by the correlation which requires only one viscosity measurement at a reference condition of 30 degrees C and one atmosphere. (Authors)

Regime transitions affecting gas-solids suspensions and fluidized beds
Bi H.T., Grace J.R. & Zhu J., *Chemical Engineering Research & Design*, 1995, 73/A2 (154-161).
Type A choking velocities, which set the boundary between fast fluidization and co-current upward transport, have been determined experimentally in a 152 X 152 mm riser based on differential pressure fluctuation and local voidage fluctuation measurements. The overall volumetric solids concentration at Type A choking velocities, ie the saturation concentration, rarely exceeds 0.01 for large Group B and Group D particles, but can be as high as 0.03 for fine Group A particles. A critical velocity U_{se}, which marks the onset of significant particle entrainment from the riser, delineates the boundary between turbulent fluidization and high velocity fast fluidization. The critical velocity is much higher than the particle terminal settling velocity for Group A particles, while the two velocities are almost equal for Group D particles. Recent information is incorporated on an extended flow regime map. (Authors)

Hydrodynamics and expansion of fluidized beds of coarse particles
San Jose M.J., Olazar M., Benito P.L. & Bilbao J., *Chemical Engineering Research & Design*, 1995, 73/A4 (473-479).
The limitations of correlations used in the literature for calculation of the minimum fluidization velocity of coarse particles (of group D of the Geldert classification) have been proven and original correlations for calculation of the minimum fluidization velocity have been proposed. The Ergun type correlation proposed suitably fits the experimental results up to a value of the Archimedes modulus of 5.8×10^7. An original correlation for calculation of the expansion of fluidized beds formed by group D particles has been proposed as a function of the ratio of drag and gravitational forces. (Authors)

A general correlation for two-phase pressure drop in intermittent flow of gas and non-Newtonian liquid mixtures in a pipe
Dziubinski M., *Chemical Engineering Research & Design*, 1995, 73/A5 (528-534).
A two-phase flow of a gas and a non-Newtonian liquid in a pipe enables a significant reduction in the average pressure gradient to be reached, which is of great practical importance in transporting non-Newtonian liquids. In the literature, a limited amount of information is available concerning the determining of pressure drop in two-phase flow of non-Newtonian liquids. Proposed equations describing two-phase pressure drop are valid in a very narrow range of gas and liquid superficial velocities. In this paper a semi-theoretical general method of correlation of experimental data concerning single and two-phase flow of gas and non-Newtonian liquid in a pipe is presented. (Author)

Studies of an independently-driven, dual impeller protofermenter with and without a draft tube: power and hold-up
John A.H., Bujalski W., Nienow A.W., Sanchez A., Torres L. & Galindo E., *Chemical Engineering Research & Design*, 1995, 73/A5 (535-541).
An independently-driven, dual impeller system in a transparent vessel of diameter 0.75 m and a liquid height with an aspect ratio of 2 has been studied, with and without a draft tube installed. A Rushton turbine and a Scaba 3SHP1 axial flow impeller were employed with water as the fluid. The power drawn by each impeller was measured independently, both under unaerated and aerated conditions. The hold-up was also measured and both parameters are related to the observed hydrodynamics of the two-phase flow associated with each combination of impellers. Overall, the dual impeller combination with the two being driven at different speeds in the presence of the draft tube, gave the most stable operating conditions and the highest hold-up when compared at equivalent aeration and energy dissipation rates. (Authors)

Gas-liquid-solid systems: an industrial perspective
Katti S.S., *Chemical Engineering Research & Design*, 1995, 73/A6 (595-607).
Multi-phase reactions and reactors occupy a crucial position in the chemical process industry. This lecture addresses some of the multi-phase (primarily gas-liquid) process fundamentals used to optimize performance in industrial practice. Traditionally, a theoretical equilibrium stage approach has been used in the engineering of mass transfer processes. The use of a rate approach in the engineering of mass transfer processes represents a paradigm shift in industrial practice. A comparison is made between the two approaches. The rate approach is able to predict several observed phenomena which cannot be explained on the basis of the traditional approach. (from Author)

Local particle-liquid heat transfer and hydrodynamics in three-phase fluidized beds with light particles
Galy-Jammou P., Briens C., Bergougnou M. & Large J.F., *Chemical Engineering Research & Design*, 1995, 73/A6 (661-668).
The conductivity technique used provided a good degree of accuracy in ascertaining local variations of phase holdups. Results successfully determined the transition zone in heavy particle fluidized beds and showed a gradual variation of phase holdups in light particle systems. With light particle systems, the local particle-liquid heat transfer coefficient measurements revealed a gradual variation with axial distance at low liquid and gas velocities. Measurements at higher flowrates presented a flat constant profile. Results were correlated with the variations of local phase holdups. (from Authors)

Bubble-particle interactions in three-phase fluidised beds: effect of bed voidage
Lee J.C., Alkaisi A.-H. & Al-Saigh A.M.J., *Chemical Engineering Research & Design*, 1995, 73/A6 (739-744).
The sizes of bubbles produced in a bed of 2.3 mm diameter glass particles fluidised by a hydrocarbon oil have been measured photographically. The gas was introduced in two ways, either as a continuous stream or injected as a pulse to form a large bubble. As the voidage of the bed was increased from 0.42 to 0.85, the character of the gas flow changed from the coalesced bubble regime to the dispersed bubble regime, which was the purpose in selecting the particular hydrocarbon liquid chosen. It is suggested that the transition between the two gas flow regimes might be characterised by a Weber number based on this impact velocity. (from Authors)

Hydrodynamics of a plunging liquid jet bubble column
Evans G.M. & Jameson G.J., *Chemical Engineering Research & Design*, 1995, 73/A6 (679-684).
In this study the flow characteristics in the pipe-flow zone of a plunging liquid jet bubble column are investigated. The effect of column diameter, and gas and liquid flow rates on the bubble size and gas void fraction for the bubbly and churn-turbulent flow regimes are determined experimentally for an air-water system. Applying drift-flux analysis to the flow, it was found that in the bubbly flow regime the distribution coefficient was approximately unity for a liquid Reynolds number above 10 000. A similar trend was observed for the churn-turbulent flow regime. It was also found that the bubble size remained constant in the bubbly flow regime. In the churn-turbulent flow regime, however, an increase in bubble size was observed due to coalescence. (from Authors)

Mass transfer in multistage slurry bubble column: analysis by back flow model
Tsuge H., Yamada T., Terasaka K. & Miyakawa S., *Chemical Engineering Research & Design*, 1995, 73/A6 (669-675).
Longitudinal concentration distributions were measured under various conditions in the case of oxygen absorption in standard and multistage slurry bubble columns. By measuring the time at the maximum of residence time distribution in the multistage slurry bubble column and by using the relationships between gas holdup, volumetric mass transfer coefficient, and the mean superficial gas velocity in a standard slurry bubble column, the concentration distributions of dissolved oxygen in the multistage slurry bubble column could be estimated by the back flow model, in which perfect mixing in each stage and back flow between stages were assumed. The concentration distributions were expressed adequately by the back flow model. (from Authors)

Gas hold-up, liquid circulation and gas-liquid mass transfer in slurry bubble columns
Gavroy D., Joly-Vuillemin C., Cordier G. & Delmas H., *Chemical Engineering Research & Design*, 1995, 73/A6 (637-642).
Hydrodynamic experiments have been performed with a small transparent piece of equipment, with and without an internal draft tube, operated at atmospheric pressure and room temperature. The effects of many parameters have been analysed separately; the role of the draft tube with various liquid phases at various catalyst loadings. (from Authors)

X-ray imaging of slurry bubble column reactors: the effects of system pressure and scale
Smith G.B., Gamblin B.R. & Newton D., *Chemical Engineering Research & Design*, 1995, 73/A6 (632-636).
This paper reports results from an experimental investigation into the hydrodynamic properties of slurry bubble columns or three-phase fluidized beds. A non-intrusive X-ray technique was used to measure bubble sizes, velocities and hold-up for different solid particles and loadings with nitrogen gas and water/glycerol mitures. A comparison between a sinter plate distributor and a holed grid plate are also reported. (from Authors)

Modelling of mass transfer coefficient K_L in bubble columns
Cockx A., Roustan M., Line A. & Hebrard G., *Chemical Engineering Research & Design*, 1995, 73/A6 (627-631).
The study of mass transfer (oxygen or ozone) from gas bubbles to a liquid phase is based on experiments and modelling. Two pilot plants have been used: a deep U-tube (DUT) and a classical bubble column. The experiments were carried out in the bubbly flow pattern. The void fraction, the pressure gradient, the bubble diameter and the volumetric mass transfer coefficient were measured. A two-fluid model was developed and validated in comparison to the experimental data. (from Authors)

Physical and chemical mass transfer enhancement at a gas-liquid interface due to fine catalyst particles
Py X., Roizard C., Bergault I. & Midoux N., *Chemical Engineering Research & Design*, 1995, 73/A3 (253-257).
Sulphur dioxide absorption rate in sulphuric acid solutions and activated carbon slurries was studied in a flat interface stirred cell. Experiments were performed in which the stirrer speed, the weight fraction of catalyst, the particle size and the partial pressures of both SO_2 and O_2 were varied. The gas-liquid mass transfer rate was found to be enhanced by the presence of powder activated carbon in the liquid film close to the interface. As the heterogeneous oxidation rate of sulphur dioxide was slow compared to the adsorption rate, and the activated carbon used had a very high adsorption capacity, the enhancement was probably due to both the shuttle effect and the adhesion of the powdered catalyst to the gas-liquid interface. (Authors)

Inhibition of gas hydrate formation by means of chemical additives - I. Development of an experimental set-up for characterization of gas hydrate inhibitor efficiency with respect to flow properties and deposition
Urdahl O., Lund A., Mork P. & Nilsen T.-N., *Chemical Engineering Science*, 1995, 50/5 (863-870).
A high-pressure test wheel for flow simulation has been used to study gas hydrate formation and inhibition in hydrocarbon gas-water-oil systems. The stainless steel wheel, which could be rotated in a temperature controlled chamber at a constant angular velocity, was equipped with pressure (0-150bar), temperature (-10-150 degrees C) and torque sensors. The sensor signals were transfered to a real time PC-based data acquisition system. A video camera mounted on a perspex window on the wheel allowed recorded data to be correlated with the visual information obtained. Viscosity changes, hydrate initiation and agglomeration changes in hydrate macrostructure and deposits on the pipe wall were easily detected. The gas hydrate inhibiting properties of several chemical additives have been examined. The discouraging results obtained with some previously patented additives indicate that the rotating wheel represents a more conservative and realistic test method than those hitherto applied. (from Authors)

Modelling of two-phase blowdown from pipelines - I. A hyperbolic model based on variational principles
Chen J.R., Richardson S.M. & Saville G., *Chemical Engineering Science*, 1995, 50/4 (695-713).
Geurst's variational principle for bubbly flow is extended to generalised multicomponent two-phase dispersions. The present variational principle allows both phases to be compressible in deriving the momentum equations. A mixture energy equation is obtained using Noether's invariant theorem and is shown to be comparable with the averaging formulation. Under the marginally stable conditions, all the information related to the structure of the flow is found to be embedded in an inertial coupling constant and an expression for this constant is obtained based on critical flow data. The marginally stability model gives correct sonic characteristics up to void fractions of 0.8. The clearly defined sonic characteristics make possible the rigorous determination of the critical flow condition for rapid depressurisation of pipelines. (from Authors)

Discrete element simulation of granular flow in 2D and 3D hoppers: dependence of discharge rate and wall stress on particle interactions
Langston P.A., Tuzun U. & Heyes D.M., *Chemical Engineering Science*, 1995, 50/6 (967-987).
Discrete element Newtonian dynamics simulations have been carried out of filling and discharge under gravity of non-cohesive discs (in two dimensions) and spheres (in three dimensions) from model hoppers. The current model improves that developed previously in several respects. We introduce a continuous and gradual hopper filling method, a more realistic normal-tangential interaction between the particles, particle size polydispersity, and the model is extended from two to three dimensions (3D). The hopper discharge rate has been computed as a function of material head height, outlet size and the hopper half-angle. The model results are, in general, in very good agreement with established literature empirical predictions. (Authors)

Gas bubble volume at a narrow slot nozzle in a liquid
Wraith A.E., Rui-Qing Li & Harris R., *Chemical Engineering Science*, 1995, 50/6 (1057-1058).
Recent work has shown that a gas injected through a narrow, upward-acting slot nozzle in a liquid forms bubbles spontaneously at nodes on the gas-liquid interface along the slot. The nodes are attributed to the Rayleigh-Taylor instability. There is a distiction between interface behaviour at high and low gas flow rates. Larger gas flow rates produce an uneven linear blanket of gas which overlies the slot and bubbles develop at active instability nodes on its upper surface. At much lower flow rates, the interface withdraws into the slot. The instabilities then appear as an array of peaks and troughs of relatively regular wavelength which extend the length of the slot below the opening. Peaks which emerge at the slot mouth act as dicrete separate bubble sources. As a step towards quantifying more clearly the dispersion characteristics of slot nozzles, this note presents a predictive equation for bubble size and formation frequency based upon the superficial gas velocity in a slot. (Authors)

Impeller-agitated aerobic reactor: the influence of tiny bubbles on gas hold-up and mass transfer in highly viscous liquids
Khare A.S. & Niranjan K., *Chemical Engineering Science*, 1995, 50/7 (1091-1105).
Gas hold-up structure in aerated viscous media (mu > 0.1 Pa s), which is distinctively characterised by a nearly bimodal bubble size distribution, has been investigated in an impeller agitated reactor having a standard geometric configuration. Experiments were performed with aqueous solutions of CMC, castor oil and rapeseed oil in a glass vessel of 0.3 m internal diameter agitated by a standard six-bladed disc turbine. Large bubbles, some as large as the impeller, were formed, while tiny bubbles (d_t = 0.1-3 mm) were found to accumulate for a while during aeration. As a result, the gas hold-up was found to vary with time. The effect of the formation of tiny bubbles on mass transfer rates, in particular oxygen transfer rates in an aerobic bioreactor, has been discussed. A theoretical framework to establish when the contribution of tiny bubbles to oxygen transfer can be significant is presented. (from Authors)

Interphase interaction in fine suspension flow
Buyevich Yu. A., *Chemical Engineering Science*, 1995, 50/4 (641-650).
A self-consistent model of moderately concentrated fine suspensions of identical spherical particles is developed. The model allows also to obtain all constitutive rheological relations which determine terms of those equations as functions of unknown variables and physical parameters. The rheological relations are found to an explicit form for effective stresses and different constituents of the interphase interaction force in weakly unsteady flow of a moderately concentrated suspension. The stresses are shown to take shape as a result of a certain relaxation process. The force constituents are of the same origin and have basically the same meaning as those for a single particle in an unbounded fluid. It is demonstrated that it is the density of the fluidized bed as a whole that must be used while expressing the buoyancy force, but not that of the fluidizing fluid alone. (from Author)

The enhancement of the physical absorption of gases in aqueous activated carbon slurries
Tinge J.T. & Drinkenburg A.A.H., *Chemical Engineering Science*, 1995, 50/6 (937-942).
The enhancement of the gas-liquid mass transfer rates in aqueous slurries containing small activated carbon particles was studied in a semi-batchwise operated stirred cell absorber with a plane interface. The maximum observed enhancement factors for absorption of propane, ethene and hydrogen in the aqueous slurries were 3.6, 3.3 and 2.0, respectively. It was shown that for our results and those reported in the literature the maximum enhancement factor decreases with increasing liquid side gas-liquid mass transfer coefficient. To describe these results a simple theory is presented. (Authors)

Hydrodynamics of a pressurized fluidized bed with horizontal tubes: influence of pressure, fluidization velocity and tube-bank geometry
Olsson S.E., Wiman J. & Almstedt A.E., *Chemical Engineering Science*, 1995, 50/4 (581-592).
Measurements of the bubble hydrodynamics were carried out in a cold pressurized bed with horizontal tubes. The mean bubble rise velocity, the bubble frequency, the mean pierced length, the bubble volume fraction, and the visible bubble flow rate were measured using capacitance probes. The absolute gas velocity through the bubbles was measured using Pitot-static pressure probes. The bed expansion ratio was determined by measuring the pressure difference between the freeboard and the bed at different heights and extrapolating the pressure difference down to zero. The fluctuations in the pressure drop over the entire bed height were also measured, and the power spectral density distribution of these fluctuations was calculated. The influence of pressure, fluidization velocity, and tube-bank geometry on the bubble behaviour and gas-flow distribution were studied. (from Authors)

The effect of particle slip on the sterilisation of solid-liquid food mixtures
Mankad S., Branch C.A. & Fryer P.J., *Chemical Engineering Science*, 1995, 50/8 (1323-1336).
Experiments have demonstrated that particles and liquids can move at different velocities in real food systems. A one-dimensional computational model, which explicitly takes account of the variation in velocities, has been developed. The model has been used to study the variation in design length which results from solid-liquid slip. Steriliser sizes have been calculated for varying solid-liquid slip velocities and delivered solids concentration for a fixed flow rate. Plots of the variation of heat tube length as a function of slip variation and solids concentration are presented as a function of particle Biot number, and the possible effects on the design of real systems suggested. (from Authors)

Analysis of drag and particulate stress in porous media flows
Tosun I., Willis M.S., Desai F. & Chase G.G., *Chemical Engineering Science*, 1995, 50/12 (1961-1969).
The momentum transfer mechanism between the fluid and solid phases and the practical implications of such a mechanism are investigated for flow through porous media. The continuum-mechanical approach based on the volume averaged equations for multiphase systems is used for the analysis. The results show that the drag between the two phases is equal to the local pressure gradient and that this drag force causes particle movement and not the particulate stress. The pressure gradient identifies regions within the porous media with high drag. Alterations of these regions can change global flow rates in porous media. (from Authors)

Hysteresis in liquid-solid tapered fluidized beds
Yimin Peng & Fan L.T., *Chemical Engineering Science*, 1995, 50/16 (2669-2671).
This note is to report the occurrence of the remarkable or profound pressure drop-flow rate hysteresis in the liquid-solid fluidized bed in a tapered column around the condition of incipient fluidization, even when the bed is operated under the conditions that do not induce hysteresis in a straight column. The fact that this phenomenon has apparently not been reported hitherto is indeed surprising since tapered fluidized beds have increasingly been adopted for a wide variety of applications because of their well-publicized stability and ease of operation under broad ranges of operating conditions. (from Authors)

Modelling of two-phase blowdown from pipelines - II. A simplified numerical method for multi-component mixtures
Chen J.R., Richardson S.M. & Saville G., *Chemical Engineering Science*, 1995, 50/13 (2173-2187).
A simplified numerical method is proposed to solve general two-phase flow equations for multi-component mixtures. The method is applied to solve the marginal stability model proposed in the first part of this paper. Case studies are performed and validated against experimental data for the blowdown of pipelines containing one-or two-component mixtures. The results show that the marginal stability model performs better than the simple homogeneous model for blowdown from short pipes. For blowdown from long pipes, the results of both models are quite similar. Concentration stratification is found to be insignificant in the overall blowdown predictions. (Authors)

Dynamic ultrafiltration model for charged colloidal dispersions: a Wigner-Seitz cell approach
Bowen W.R. & Jenner F., *Chemical Engineering Science*, 1995, 50/11 (1707-1736).
A rigorous, dynamic mathematical model for predicting the rate of ultrafiltration of charged colloidal dispersions is developed. The model is based on sophisticated descriptions of the particle-particle interactions within filter cakes which are responsible for controlling permeation rates. Electrostatic (double layer) interactions are accounted for by means of a Wigner-Seitz cell approach, including a numerical solution of the non-linear Poisson-Boltzmann equation, which is known to give an excellent description of the configurational electrostatic interaction energy of particle assemblages. London-van der Waals forces are calculated using a computationally efficient means of approximating screened, retarded Lifshitz-Hamaker constants. Hydration forces are included by utilising mathematical expressions derived from the latest results obtained with surface-forces apparatus. Configurational entropy effects are calculated using an equation of state giving excellent agreement with molecular dynamic data. Electroviscous effects are also accounted for. (from Authors)

Heat transfer in circulating fluidized beds
Wirth K.-E., *Chemical Engineering Science*, 1995, 50/13 (2137-2151).

The wall-to-suspension heat transfer in circulating fluidized beds depends on the fluid mechanics immediately near the wall and on the thermal properties of the gas used. Experimental investigations of circulating fluidized beds of low dimensionless pressure gradients with different solid particles like bronze, glass and polystyrene at ambient temperatures show no influence of the conductivity and the heat capacity of the solids on the heat transfer coefficient. Consequently the heat transfer coefficient in form of the dimensionless Nusselt number can be described in dependence of dimensionless numbers which characterize the gas-solid flow near the wall. These numbers are the Archimedes number and the pressure-drop number. The last number relates the cross-sectional average solids concentration to the solids concentration at minimum fluidization condition. With the aid of the model of the segregated vertical gas-solid flow the flow pattern in the wall region can be calculated and consequently the wall heat transfer. (from Author)

Calculation of circulating flows in bubble columns
Millies M. & Mewes D., *Chemical Engineering Science*, 1995, 50/13 (2093-2106).
The liquid circulation in bubble columns is a flow instability caused by a disturbance of gas distribution. The onset of the liquid circulation is investigated in the present paper by applying an analytical method. The flow field of several consecutive circulation cells is obtained applying a numerical method, which is specially adapted for this kind of flow instability. Our focus is on understanding the mechanism of the circulation cells. Thus, all terms of smaller orders of magnitudes are neglected in the mass and momentum balances for both phases. The main terms, which cause the flow instability, are extensively discussed. We assumed a small but stationary disturbance of gas distribution in order to simplify the calculations. (from Authors)

Correlation for calculation of the gas dispersion coefficient in conical spouted beds
San Jose M.J., Olazar M., Penas F.J., Arandes J.M. & Bilbao J., *Chemical Engineering Science*, 1995, 50/13 (2161-2172).
On the basis of the experimental study of air velocity profiles in a pilot plant scale unit, the validity of the hypotheses of the gas flow model proposed for conical spouted beds, that is to say, flow rate conservation along each streamtube and plug flow in the spout zone, has been proven. A correlation has been obtained for calculation of the local velocity as a function of the contactor geometric factors (angle, inlet diameter) and of the operating conditions (solid density, particle size, relative air velocity). The validity of the gas flow model has been proven in a wide range of operating conditions and a correlation has been obtained for calculation of the dispersion coefficient as a function of the following moduli: bed upper diameter/contactor base diameter, Archimedes number, tangent of the angle, relative air velocity. (Authors)

Gas-solids flow in the riser of a circulating fluidized bed
Yinghe He & Rudolph V., *Chemical Engineering Science*, 1995, 50/21 (3443-3453).
A new approach to the modelling of gross gas-solids flow through the riser in a circulating fluidized-bed system is proposed in this paper. This approach differs from the previous ones, which are found to be theoretically incorrect based on a fundamental analysis of the riser process hydrodynamics. Starting from the basic principles, the new approach tackles the modelling problem from both energy and momentum balance perspectives. It also identifies that a riser may be operating in two different flow regimes: the entrainment regime and the dragging regime. Experimental results from a compartmented dense-phase circulating fluidized bed, developed for a continuous coal combustion-gasification process, verified the existence of the two flow regimes. (Authors)

Erosion of horizontal tubes in a pressurized fluidized bed - influence of pressure, fluidization velocity and tube-bank geometry
Wiman J., Mahpour B. & Almstedt A.E., *Chemical Engineering Science*, 1995, 50/21 (3345-3356).
Measurements of local tube erosion were carried out in a cold pressurized bed with horizontal tubes. The influence of fluidization velocity, pressure and circumferential position was studied at different locations within tube banks for three different tube-bank geometries. The erosion results were correlated with the hydrodynamic properties of the bed obtained in a previous investigation under the same operating conditions. At high pressures, the erosion decreases with increasing pressure. Preliminary results from heat transfer measurements in the bed show a significant increase of the bed-to-tube heat transfer coefficient with increasing pressure. (from Authors)

Settling and slumping in a Newtonian slurry, and implications for proppant placement during hydraulic fracturing of gas wells
Hammond P.S., *Chemical Engineering Science*, 1995, 50/20 (3247-3260).
Analytical estimates of the amount of gravity-driven vertical motion of proppant which can occur within a hydraulic facture during placement are derived, and used to investigate the conditions under which large gravity driven flows can occur. Two major types of gravity-driven rearrangement are considered; settling and slumping. The flow of slurry within the fracture is described using a set of equations formulated in terms of cross-fracture averaged fluxes. Constitutive functions are calculated for homogeneous flow, and for flow in which some process has caused all the proppant to migrate into a close packed sheet at the fracture centre. (from Author)

Local instantaneous and time-averaged heat transfer in a pressurized fluidized bed with horizontal tubes: influence of pressure fluidization velocity and tube-bank geometry
Olsson S.E. & Almstedt A.E., *Chemical Engineering Science*, 1995, 50/20 (3231-3245).
Measurements of local instantaneous bed-to-tube heat transfer were carried out in a cold pressurized bed with horizontal tubes. The influence of fluidization velocity and pressure was studied at different circumferential positions around a horizontal tube within a tube bank for three different tube-bank geometries. The signal from a heat transfer sensor was compared with capacitance probe signals sampled simultaneously in an adjacent position. The local time-averaged heat transfer coefficients at the different circumferential positions were determined from the instantaneous heat transfer signals, for the different operating conditions, as were the spatial-averaged heat transfer coefficient for the tube. The time-averaged heat transfer results were correlated with the hydrodynamic properties of the bed obtained in a previous investigation under the same operating conditions, and a strong coupling between the local mean bubble frequency and the local time-averaged heat transfer was obtained. (from Authors)

Flooding phenomena in vertical counter-current annular two-phase (gas-liquid) flow
Shah M., *Chemical Engineering World*, 1995, 30/3 (135-138).
Flooding phenomena have been investigated extensively throughout the power, chemical and other industries for the past sixty years. Sherwood et al (1930) were the first investigators of this phenomena in packed columns. This phenomena is a subject of engineering interest, particularly in conjunction with the design of packed columns, heat pipes, heat exchangers, reflux condensers and nuclear reactors. Flooding places an upper limit on equipment capacity, because in most cases flooding is unacceptable for proper operation. It is therefore essential to have a clear understanding of flooding phenomena to have a better performance and design basis for the above mentioned equipments under flooding condition. (Author)

Equations for a one-particle distribution function
Lebed I.V., *Chemical Physics Reports*, 1995, 13/6 (1132-1140).
It is shown that in the initial stage of rarefied gas modeling, the equation for a one-particle distribution function takes the closed form, is the solution of the BBGKY chain are stable in the Lyapunov sense. However, in t* kinetic stage, this equation does not transform into the Boltzmann equation of molecular chaos, even though the states of pairs of particles at the boundary of the interaction region are statistically independent. (Journal summary)

Ignition of forest crowns from a ground-fire source
Grishin A.M. & Perminov V.A., *Chemical Physics Reports*, 1995, 13/8-9 (1551-1559).
The laws of mechanics of multiphase reacting media are used to construct a mathematical model of transition from ground forest fire to crown fire. The igniting hot spot was simulated by a surface muss source of hot combustion products emitting light as a black body with an effective blackness factor. Forest crowns are simulated by a two-temperature multiphase porous reactive mixture. The fields of the basic parameters of the process are calculated using numerical solution of the governing equations. The critical distances from the ground fuel layer to the lower crown boundary at which no ignition occurs are assessed. (from Journal summary)

Adsorption of chromium (VI) by a low-cost adsorbent: biogas residual slurry
Namasivayam C. & Yamuna R.T., *Chemosphere*, 1995, 30/3 (561-578).
The ability of waste biogas residual slurry (BRS) to remove Cr (VI) from aqueous solutions was investigated. The influence of various parameters such as metal ion concentration, contact time, adsorbent dosage, adsorbent particle size, temperature and pH on the removal of Cr (VI) has been studied. The adsorption followed first-order rate expression. The equilibrium data fit well into Langmuir and Freundlich isotherms. Adsorption was maximum at an initial pH of 1.51. Temperature studies showed that the adsorption process was endothermic in nature. (Authors)

Flow boiling heat transfer with fluidized solid particles
Li XiuLun, Wen Jianping & Gu Junjie, *Chinese Journal of Chemical Engineering*, 1995, 3/3 (163-170).
In order to solve the fouling problems in boiling processes, a boiling system was designed by adding solid particles to the boiling liquid. In this paper, both theoretical analyses and experimental studies on the boiling heat transfer in such a three-phase flow boiling were carried out. Based on the analysis of heat transfer characters of this three-phase flow boiling, a mathematical model for the heat transfer coefficient of flow boiling was developed. The fluidized particles rub the heat transfer wall to prevent and to clean the fouling. (from Authors)

On the oscillation of combustion of a laminar spray
Levy Y. & Bulzan D.L., *Combustion & Flame*, 1995, 100/4 (543-549).
A spray combustor, with flow velocities in the laminar range, exhibits a unique operating mode where large amplitude, self-induced oscillations of the flame shape occur. The phenomenon, not previously encountered, only occurs when fuel is supplied in the form of fine liquid droplets and does not occur when fuel is supplied in gaseous form. Several flow mechanisms are coupled in such a fashion as to trigger and maintain the oscillatory motion of the flame. These mechanisms include heat transfer and evaporation processes, dynamics of two-phase flows, and effects of gravity (buoyancy forces). An interface volume, lying between the fuel nozzle and the flame was found to be the most susceptible to gravity effects, and postulated to be responsible for inducing the oscillatory motion. Heptane fuel was used in the majority of the tests. (Authors)

Electrodiffusion study of a liquid-liquid interface (Etude d'une interface liquide-liquide par la methode electrodiffusionnelle)
Cognet G., Martemianov S., Pascal G. & Sobolik V., *Comptes Rendus - Academie des Science, Serie II: Mecanique, Physique, Chimie, Astronomie*, 1995, 320/10 (505-508). In French.
A comparative study of solid/liquid and liquid/liquid interface has been performed using electrodiffusion measurements with a gallium drop as a working electrode. The gallium transforms from solid to liquid state at 29.8 degrees C, that is why one can ascertain the difference between mass transfer coefficient for solid and liquid interfaces in the same hydrodynamical conditions. The experiments were performed in a cylindrical vessel which was subjected to heating and agitation. The gallium electrode was placed at the bottom of the vessel. The transformation of the gallium electrode from the solid to the liquid state manifests itself in the decrease of the global mass transfer rate. (English summary)

(Enhancement of a particle take-off criterion in a turbulent boundary-layer) (Amelioration d'un critere d'envol de particules dans une couche limite turbulente)
Foucaut J.-M. & Stanislas M., *Comptes Rendus - Academie des Sciences, Serie II: Mecanique, Physique, Chimie, Astronomie*, 1995, 320/8 (387-390). In French.
A new representation of the criterion for particles take-off proposed by Bagnold is presented which shows that, generally, particles in a range of diameter take-off. A semi-empirical formula, based on the results of B. R. White is proposed and validated by numerous experimental results from the literature. (English summary)

(Experimental characterization of backlayering occurrence) (Caracterisation experimentale de l'apparition d'une nappe de retour)
Vauquelin O., *Comptes Rendus - Academie des Sciences, Serie II: Mecanique, Physique, Chimie, Astronomie*, 1995, 321/1 (15-18). In French.
This note reports on the experimental and dimensional study of a buoyant jet emitted in a ventilated rectangular channel. In some cases, there can occur a stratified layer flowing against the ventilation. We focus on the critical condition corresponding to the occurrence of this layer. (English Summary)

(Drainage in a capillary: a complete approximated description of the interface) (Drainage dans un capillaire: une description complete approchee de l'interface)
Lasseux D., *Comptes Rendus - Academie des Sciences, Serie II: Mecanique, Physique, Chimie, Astronomie*, 1995, 321/4 (125-131). In French.
A semi-analytical and approximated solution to the gas-liquid drainage problem in vertical capillaries is presented. It provides a precise description of the entire free-boundary and improves Landau's classical solution in terms of film thickness on cylindrical capillary tubes of circular cross-section and Hele-Shaw cells. For this last configuration, the present results are successfully compared with experimental results and data obtained from a direct numerical computation of the two-phase free-surface flow problem. There is an abridged English version. (English summary)

A new finite element formulation of shock-induced hull cavitation
Sandberg G., *Computer Methods in Applied Mechanics & Engineering*, 1995, 120/1-2 (33-44).
A new formulation for non-linear, elastic wave propagation, based on the pressure and density, is introduced. The formulation accounts for a non-linear relation between speed of sound and density. The pressure and density are interpolated by identical shape functions between the nodes. The equation of state is introduced in the discretized system, hence the non-linearity is enforced point-wise. This procedure concentrates on proper interpolation of the balance equations by relaxing the non-linear constitutive relation between the nodes. A standard finite element procedure focuses on the constitutive equation and thereby produces a less consistent representation of the balance equation. In addition, the formulation accounts for fluid-structure interaction. (Author)

Numerical analysis of two operator splitting methods for an hyperbolic system of conservation laws with stiff relaxation
Burman E. & Sainsaulieu L., *Computer Methods in Applied Mechanics & Engineering*, 1995, 128/3-4 (291-314).
This paper is concerned with the discretization of an hyperbolic system of conservation laws with stiff relaxation source terms that model a two-phase fluid flow. It is shown both theoretically and numerically that the usual operator splitting method poorly computes the propagation of sound waves in a two-phase medium. We propose a new operator splitting, based on physical considerations. This numerical method gives very good results regarding both the propagation velocity and the attenuation coefficient of sound waves in a two-phase medium. (Authors)

A dynamic two-phase flow model for a purification plant
Prager W. & Propst G., *Computers & Chemical Engineering*, 1995, 19/3 (309-320).
A mathematical model for the flow through the siphon of a sewage purification machine is presented. The model is based on the average unifirectional flow velocities of the two plases (water and bubbles of air), the evaluation of hydrodynamic forces corresponding to the plant's geometry, and on estimates of the mechanical interaction of the two phases. Data from experiments with an industrial machine are used to identify the model parameters and a comparison of the model's trajectories with the experimental records is given. (Authors)

Lattice methods and their applications to reacting systems
Chen S., Dawson S.P., Doolen G.D., Janecky D.R. & Lawniczak A., *Computers & Chemical Engineering*, 1995, 19/6-7 (617-646).
We introduce the basic principles of the lattice gas method and the lattice Boltzmann method, their numerical implementations and applications to chemically reacting systems. Comparisons of the lattice Boltzman method with the lattice gas technique and other traditional numerical schemes, including the finite difference scheme and the pseudo-spectral method, for solving the Navier-Stokes hydrodynamic fluid flows will be discussed. Recent developments of the lattice gas and the lattice Boltzmann method and their implications to pattern formation in chemical reaction-diffusion systems, multiphase fluid flows and polymeric dynamics will be presented. (from Authors)

An accurate numerical method for systems of differentio-integral equations associated with multiphase flow
Jian-Jun Shu & Wilks G., *Computers & Fluids*, 1995, 24/6 (625-652).
An accurate numerical method which is applicable to systems of differentio-integral equations with quite general boundary conditions has been developed. The method is a useful extension of the Keller box scheme designed to facilitate the solution of differential systems involving integral operators which naturally arise in multiphase flows. A combination of merging and reduction procedures is introduced to handle the multilayer and integral operator features of such problems. The development of the method is demonstrated in the context of laminar film condensation in the presence of both external forcing and body forces. (Authors)

Corrosion control in cooling systems of heavy-duty diesel engines
Valdez Salas B. & Hernandez-Duque Delgadillo G., *Corrosion Reviews*, 1995, 13/2-4 (245-259).
Pitting and cavitation corrosion in ferrous components of heavy-duty diesel engine cooling systems are a serious problem in the Mexican transportation industry. An appropriate corrosion inhibitor formulation for an antifreeze-coolant was developed to avoid the occurrence of corrosion. Chemical analysis, metallographic assays, gravimetric and electrochemical polorization studies, were carried out for the evaluation of corrosion inhibition. The causes of the problem were found and a new formulation was developed. Solutions for corrosion problems and recommendations for longer operational life of diesel engines are presented. (from Authors)

Hydraulic control and maximal flow in rotating stratified hydraulics
Killworth P.D., *Deep-Sea Research, Part I*, 1995, 42/6 (859-871).
A general condition for the hydraulic control of rotating stratified fluid passing through a sill of arbitrary bottom topography is given, first for a one-layer reduced gravity model, and then extended to a continuously stratified fluid. As with non-rotating channel flow, control involves a pair of conditions. The first relates to the flow itself (and plays the equivalent role to unit Froude number in non-rotating hydraulics). The second relates to the local geometry of the sill (and is equivalent to the requirement of maximal constriction or topography in non-rotating hydraulics). Virtual controls are possible, and there may be an infinite number of these. These results are linked to conditions for maximal flow, and it is shown that this occurs if and only if the flow is controlled (again just as in the non-rotating case). (Author)

An analytical model of the balanced flow created by localized convective mass transfer in a rotating fluid
Shutts G., *Dynamics of Atmospheres & Oceans*, 1995, 22/1-2 (1-17).
A class of exact analytic solutions is presented which represent the steady flow which persists after a finite region of stratified fluid is displaced vertically under the action of non-entraining, moist convection. In this process, the absolute momentum and equivalent potential temperature are imagined to mix within the convecting fluid so that the end state has constant absolute momentum and (dry) static stability. The balanced flow that remains consists of a vertical shear-line front in the region from which the fluid was withdrawn and a lenticular region characterized by zero absolute vorticity with adiabatic warming below and cooling above. A contour integration technique for evaluating the total energy of this class of solution is presented. (from Author)

The interaction of a pair of point potential vortices in uniform shear
Walsh D. & Pratt L.J., *Dynamics of Atmospheres & Oceans*, 1995, 22/3 (135-160).
A simple point vortex model is formulated to investigate the deformation and translation of lens-like oceanic eddies, such as Mediterranean salt lenses, in large-scale shear. The idealized eddy is represented by a pair of quasigeostrophic 'point potential vortices' at different depths in a uniformly stratified fluid. The point vortices are assumed to be embedded in a flow with uniform vertical and horizontal shear, and they are advected by the background flow as they interact with one another. The model successfully reproduces many aspects of the behaviour of low-mode disturbances found in models with continuous (non-singular)

representations. Depending upon the strengths of the vortices, their initial separation, and the intensity of the background shear, the vortex pair is either torn apart by the shear, or else remains coupled for all time, in which case the vortices execute a periodic motion wile propagating with respect to the ambient fluid. Solutions representing steadily translating point vortex configurations are obtained for certain values of the model parameters. (from Authors)

Combustion and co-combustion of auto fluff
Saxena S.C., Rao N.S., Rehmat A. & Mensinger M.C., *Energy (Oxford)*, 1995, 20/9 (877-887).
Fluidization experiments at ambient conditions and combustion experiments with auto fluff have been conducted as a preamble to development of a two-stage combustion process by IGT. Fluidized-bed combustion has revealed unique properties of auto fluff. The CO concentration in the flue gas fluctuates widely with non-steady feeding of fluff. The effects of fractional excess air, fluidizing air velocity, bed temperature, and auto-fluff feed rate have been examined to establish optimium combustion conditions. Carbon analyses in the different streams and an overall carbon balance suggest that use of a second-stage cyclonic combustor is advisable both for energy recovery and compliance with EPA emission requirements. (Authors)

Longitudinal solute transport in the upper Clyde Estuary, Scotland
Wallis S.G., Crowther J.M. & Curran J.C., *Environment International*, 1995, 21/6 (765-778).
The paper discusses vertical profiles of salinity and longitudinal velocity observed in an 11-km study reach of the Upper Clyde Estuary in Scotland. Corresponding tide level measurements and calculated area mean velocities are also presented. The data indicate that the upper estuary was highly stratified during two survey periods and was almost well mixed during a third. When the upper estuary is stratified, the salinity data demonstrate the existence of a classical multi-layer flow structure consisting of an approximately well-mixed upper layer, an approximately well-mixed lower layer, and an interfacial layer containing a large vertical density gradient. The velocity data, obtained from one of the stratified flow periods, reveal a commensurate velocity field with water moving seawards in the upper layer and landwards in the lower layer. As a consequence of strong vertical shear, longitudinal dispersion coefficients of the order of 1000 m^2/s are estimated. The data clearly indicate that water quality models of the upper estuary need to be capable of resolving the depth variation of environmental parameters. (Authors)

Bubble column apparatus for gas-liquid heterogeneous chemistry studies
Shorter J.A., 7 others et al., *Environmental Science & Technology*, 1995, 29/5 (1171-1178).
A bubble column apparatus has been designed to conduct time-resolved gas-liquid interaction studies of interest in atmospheric chemistry. In the apparatus, a low pressure gas flow, carrying trace gas diluted in helium carrier gas, is 'bubbled' through a flask containing 3.5 L of temperature-controlled liquid. The outlet gas flow is then sampled by a differentially pumped mass spectrometer. The position of the bubble injector, which determines the gas-liquid contact time, is computer controlled by means of a stepping motor. Modeling of the gas uptake and the validation of the apparatus performance are described. (from Authors)

Wettability effects on scaling two-and three-fluid capillary pressure-saturation relations
Bradford S.A. & Leij F.J., *Environmental Science & Technology*, 1995, 29/6 (1446-1455).
Capillary pressure (P_c) - saturation (S) relationships for porous media containing three fluids, often predicted from two-fluid P_c-S curves, were investigated for porous media with different wettabilities. Two-and three-fluid P_c-S curves were measured for sands containing air and water; air and oil, oil and water, and air, oil, and water. Similar P_c-S curves were found for air-oil systems while differences occurred for air-water or oil-water due to differences in hydrophobicity and contact angle hysteresis. Three-fluid P_c-S curves could be accurately predicted for hydrophilic media from two-fluid P_c-S data with scaling, using fitted contact angles and measured interfacial tensions, and Leverett's assumption. Such predictions were found to be inadequate for hydrophobic media because the intermediate fluid is presumably discontinuous. (from Authors)

Boiling heat transfer on finned tube bundle with lower tubes heated with constant heat flux
Zhi-Xin Li & Hahne E., *Experimental Thermal & Fluid Science*, 1995, 11/2 (174-180).
The boiling heat transfer on a finned tube bundle was experimentally studied. The heat transfer coefficient of the bundle and the time-averaged liquid velocity under the bundle were measured when the tubes of the lower rows were heated with high constant heat flux. The results indicate that the boiling heat transfer is strongly enhanced by the strong two-phase flow induced by the tubes of the lower rows. The results show us a way to enhance the boiling heat transfer in the intermediate region between natural convection and fully developed boiling and suggest that the bundle heat exchanger should be designed to work in the intermediate region. (from Authors)

Dynamic instabilities of boiling two-phase flow in a single horizontal channel
Ding Y., Kakac S. & Chen X.J., *Experimental Thermal & Fluid Science*, 1995, 11/4 (327-342).
Dynamic instabilities of two-phase flow associated with refrigerant R-11 in a uniformly heated horizontal in-tube boiling system were experimentally investigated. An experimental setup was designed and built to work in a wide range of mass fluxes G[75-1050 $kg/(m^2s)$], heat fluxes q(0-100 kW/m^2), and fluid inlet temperatures T_{inlet} (2-24 degrees C). Dynamic instability data were obtained under various working conditions. The dependence of oscillation amplitude and period on system parameters is discussed, and the boundaries of various oscillations are located on the steady-state characteristic curves. (Authors)

Void fraction profile measurements in two-phase mercury - Nitrogen flows using gamma-ray attenuation method
Thiyagarajan T.K., Satyamurthy P., Dixit N.S., Venkatramani N., Garg A. & Kanvinde N.R., *Experimental Thermal & Fluid Science*, 1995, 10/3 (347-354).
A nonintrusive measurement system using gamma rays from a ^{60}Co source is developed to measure the void fraction profile in a two-phase flow of a high-density liquid metal and nitrogen. The method is based on the attenuation of gamma rays along various chord lengths in the cross section of a pipe line. Both the chord segment inversion (CSI) method and the least squares solution (LSS) method were applied to obtain void fraction profiles from the data. The CSI method gave spurious oscillations in the void fraction profiles, which could be attributed to the Poisson corruption due to low count rate. On the other hand, the LSS method did not contain any oscillations. Experiments were performed in the vertical riser pipe of a gravitational-type liquid metal magnetohydrodynamic loop with mercury-nitrogen two-phase flow. (from Authors)

Monitoring particles in liquids
Hunt T., *Filtration & Separation*, 1995, 32/3 (205-211).
This article reviews here the large variety of techniques which is available for the monitoring of particles in liquids, in the context of the particle/liquid relationship. (Author)

The use of polypropylene fibre needlefelt in the filtration of mineral slurries
Hu Xiaomin, Li Chunbo, Duan Qifu & Diao Jinlun, *Filtration & Separation*, 1995, 32/4 (307-311).
The development of and trials with a new kind of filter medium, polypropylene fibre needlefelt, on the filtration of mineral processing products is described. The new needlefelt filter medium has been successfully applied in the filtration of iron oxide concentrate slurry. The results show that the polypropylene fibre needlefelt has longer service life, higher filtration efficiency, greater cake yield, lower cake moisture content and less metal loss when compared with the conventional woven filter cloth often used in mineral processing industry. The filter medium is a very important part in a filtration system, and is usually considered as the 'heart' of the filter. The efficiency of solid/liquid separation and the production capacity of a filtration system are directly affected by the filter medium's properties and the choice of the medium. However, the development and study of filter media are not matched with its important role in the filtration process. For example, the filter cloth used in vacuum filters for the filtration of mineral processing products is rather monotonous. The conventional woven filter cloth has been used for a long time in mineral processing. This type of filter cloth has higher resistance to filtrate, but does not have greater retention of particulates, which may bring some problems such as lower production capacity, higher cake moisture content and greater metal loss. Taking the characteristics of mineral processing products into account, we have developed a new kind of filter medium - polypropylene fibre needlefelt - which is more suitable for the filtration of mineral slurries. The new material has been successfully applied in many iron concentrators. This article is intended to provide some information on the new type of filter medium and on its application in the minerals industry. (from Authors)

Annular two-phase flow measurements using phase Doppler anemometry with scattering angles of 30 degrees and 70 degrees
Bates C.J. & Ayob R., *Flow Measurement & Instrumentation*, 1995, 6/1 (21-28).
Phase Doppler aneomometry measurements are reported on the centreline of an upward annular gas-liquid two-phase flow in a 32 mm diameter pipe with a 7.3 m development length. Two scattering angles (30 degrees and 70 degrees) have been considered, together with optical geometries which provide probe volume lengths/diameters of 4.90 mm/155 mum and 9.56 mm/302 mum respectively. The sizing ranges cover spherical droplets up to a maximum of 843 mum. The measurements clearly show that, whereas the number mean diameter (d_{10}) shows little variation with either scattering angle or optical geometry, significant differences are evident with the Sauter mean diameter (d_{32}) due to the influence of a relatively small number of large droplets (400 mum) observed with the 30 degrees scattering angle. (Authors)

A gamma-ray tomographic scanner for imaging voidage distribution in two-phase flow systems
Kumar S.B., Moslemian D. & Dudukovic M.P., *Flow Measurement & Instrumentation*, 1995, 6/1 (61-73).
A computed tomographic scanner using gamma-rays has been implemented for the measurement of void fraction and its distribution in two-phase flow systems such as fluidized beds and bubble columns. The automated scanner is capable of imaging flows in test sections between 2.5 cm and 45.0 cm in diameter. The developed system hardware, the adopted algorithm for image reconstruction and possible sources of error in measurement are discussed. Typical results for void fraction distribution in bubble columns are presented. (Authors)

A new method of two-phase flow measurement by orifice plate differential pressure noise
Wang Wenran & Tong Yunxian, *Flow Measurement & Instrumentation*, 1995, 6/4 (265-270).
The mechanism of differential pressure noise of orifices in two-phase flow has been investigated and a theoretical model has been developed for measurement of the double parameters, i.e. mass flow rate and phase fraction (steam quality). The model has been proved in a set of orifice experiments in a two-phase flow system at a pressure range of 5.8-12.1 MPa and steam quality of 0.05-0.95, and a practical model has been fitted. The results of the studies create a method to measure double parameters of two-phase flow at once using only a single orifice. (from Authors)

Development of a turbine meter for two-phase measurement in vertical pipes
Johnson M.W. & Farroll S., *Flow Measurement & Instrumentation*, 1995, 6/4 (279-282).
The performance of a turbine meter in two-phase (water/air) flow in a vertical pipe is assessed. If the single phase (water) meter factor is used in two-phase flow, the total (water and air) flowrate is found to be underpredicted. The error can be as much as 12.5% at a void fraction of 25%. A technique for using measurements of the fluctuations in the turbine meter rotor velocity to determine void fraction (= air flowrate/total flowrate) is described. A single meter is then used to measure, using this technique, both the water flowrate to an accuracy of +/-2% and void fraction to an accuracy of +/-0.02. (Authors)

Flow and temperature measurement of two immiscible liquid layers
Himmel A., Bozian U., Wozniak K. & Siekmann J., *Flow Measurement & Instrumentation*, 1995, 6/4 (295-299).
Surface tension driven flow of two immiscible liquid layers subjected to a horizontal temperature gradient has been observed. The objective of this study is the visualization of the thermoconvective flow of a double layer fluid system and the implementation of the liquid crystal tracer technqiue. This flow configuration simulates the encapsulation of electronic melts, where the lower liquid layer represents the melt and the upper layer represents the confining liquid having the task to stop the fluid motion of the melt component. The influence of different encapsulation conditions on the resultant flow pattern of the melt layer has been observed using liquid crystal tracers. (from Authors)

Initiation of cavitation by injection of hot steam into a cold liquid jet
Ocheretyanyi S.A. & Prokof'ev V.V., *Fluid Dynamics*, 1995, 30/5 (717-724; translated from: Izvestiya Rossiiskoi Akademii Nauk, Mekhanika Zhidkosti i Gaza, 5, 1995).
The problem of the dynamics of a hot steam bubble in the nonuniform flowfield of a plane cold liquid jet is considered. The motion of the bubble along the symmetry axis is analyzed with allowance for nonequilibrium and heat conduction by the steam and the liquid. The domain of jet and steam parameters corresponding to the dynamic cavitation bubble initiation mode, is evaluated. The dynamics of a collapsing steam bubble in the nonuniform flowfield of a jet is analyzed numerically. The thermal problem is solved for bubbles within the framework of the homobaric model in the spherical symmetry approximation with allowance for nonequilibrium condensation. (from Journal translation)

Cavitation flow past an arbitrarily-shaped airfoil
Maklakov D.V. & Naborova M.V., *Fluid Dynamics*, 1995, 30/5 (713-716; translated from: Izvestiya Rossiiskoi Akademii Nauk, Mekhanika Zhidkosti i Gaza, 5, 1995).
The problem of two-dimensional inviscid incompressible flow past an arbitrarily-shaped airfoil in the presence of developed cavitation is studied in an accurate nonlinear formulation. (from Journal summary)

Combination of the homogenization and effective medium methods for flow through porous media in a nonperiodic external perturbation field
Panfilov M.B., *Fluid Dynamics*, 1995, 30/4 (578-585; translated from: Izvestiya Rossiiskoi Akademii Nauk, Mekhanika Zhidkosti i Gaza, 4, 1995).
Models described by parabolic equations with a rapidly oscillating nonperiodic right side are investigated by means of averaging theory methods. For a nonperiodic perturbation field a combined homogenization and effective medium method is developed. This method makes it possible to obtain the solution of the cell problems in a finite form correct to the second order in the inhomogeneity parameter. The method is applied to problems of single-phase and two-phase flow through porous media. The technique of the method is outlined and explicit solutions of cell problems are constructed. (Journal summary)

Hydrodynamical modeling of the development of non-homogeneous oil reservoirs
Entov V.M. & Turetskaya F.D., *Fluid Dynamics*, 1995, 30/6 (877-882; translated from: Izvestiya Rossiiskoi Akademii Nauk, Mekhanika Zhidkosti i Gaza, 6, 1995).
Results of mathematical modeling of two-phase flow in non-homogeneous (layered) reservoirs are reported. Characteristic patterns of flow in reservoirs with high layer permeability contrast are investigated. It is shown that in such reservoirs crossflow between layers must be taken into account. Specific features of the use of hydrodynamic methods of improving oil recovery in such reservoirs based upon flow pattern control are studied. The possibility of using rational flow management to improve oil recovery partially blocking the reservoir in the neighborhood of the wells is demonstrated. (Journal summary)

Structure of the wake behind a cylinder in a fluid with a variable buoyancy frequency, studied with the help of echo sounding and optical observation
Prokhorov V.E. & Chashechkin Yu. D., *Fluid Dynamics*, 1995, 30/6 (803-809; translated from: Izvestiya Rossiiskoi Akademii Nauk, Mekhanika Zhidkosti i Gaza, 6, 1995).
Acoustic sounding of the wake behind a circular cylinder and observation of the shadow pattern indicate that for a density gradient varying on distances of the order of the cylinder's vertical dimension two parametrically different vortex systems may coexist in the wake. If the Froude number $Fr = u/NR$ is based on the flow velocity u, the radius of the cylinder R, and the current value of the buoyancy frequency N, then the observed flow pattern corresponds to known regime diagrams presented by several authors. In the present experiments N was found using the characteristic periods of oscillation of the intensity of volume ultrasonic scattering. The vertical profiles of the coefficient of backscattering of ultrasound and the synchronous shadow flow patterns in the wake behind the body are subjected to simultaneous analysis. (from Journal summary)

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Motion of two viscous fluids in a precessing vessel
Kazmerchuk I.M. & Samsonov V.A., *Fluid Dynamics*, 1995, 30/5 (666-672; translated from: Izvestiya Rossiiskoi Akademii Nauk, Mekhanika Zhidkosti i Gaza, 5, 1995).
An approximate solution of the problem of the motion of two viscous fluids in a cylindrical vessel executing slow regular precession with an arbitrary angle of nutation is constructed. The axial component of the moment of the forces exerted by the fluid on the lateral surface of the vessel is determined. (Journal summary)

Gasdynamics of the scattering of the detonation products of a cylindrical explosive charge with inert metal particles
Gonor A.L. & Teverovskii M.A., *Fluid Dynamics*, 1995, 30/5 (725-733; translated from: Izvestiya Rossiiskoi Akademii Nauk, Mekhanika Zhidkosti i Gaza, 5, 1995).
A mathematical model of the scattering of the detonation products of a condensed explosive with inert metal particles when the wave travels along the axis of a cylindrical charge is proposed and numerical calculations are carried out. Detonation product scattering is simulated by a two-phase nonequilibrium axisymmetric jet flow in a supersonic external airstream. A technique for calculating the product gas-suspension behind the detonation wave is developed. The optimal values of the difference scheme parameters ensuring the required calculation accuracy are found. The gasdynamic properties of the process associated with the particles and the lateral speed are investigated. (Journal summary)

Two-phase multicomponent turbulent jet with phase transitions
Zuev Yu. V. & Lepeshinskii I.A., *Fluid Dynamics*, 1995, 30/5 (750-757; translated from: Izvestiya Rossiiskoi Akademii Nauk, Mekhanika Zhidkosti i Gaza, 5, 1995).
A mathematical model of a gas-droplet nonisothermal multicomponent polydisperse turbulent jet is proposed. This model takes

into account phase velocity and temperature nonequilibrium, gas and liquid phase inhomogeneity, the droplet coagulation and disintegration, and the possibility of the presence of vapor condensation or fluid evaporation, depending on the specific conditions in the jet. Certain results of calculating the parameters of both a nonisothermal two-component polydisperse gas-disperse jet with phase transitions and droplet coagulation and a three-component polydisperse gas-disperse jet without allowance for phase transitions are presented. The results obtained are analyzed. (Journal summary)

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On the law of turbulent entrainment across a density interface
Tanny J., Chai A. & Kit E., *Fluid Dynamics Research*, 1995, 15/1 (69-74).

Turbulent entrainment laws obtained experimentally for an annular two-layer stratified flow are predicted theoretically using the mixing model recently developed by Mory (1991). This paper shows how the salinity spectra measured by Chai and Kit (1991) can be utilized by the model equations to predict the power of the entrainment law for a flow in an annulus with or without a velocity shear across the density interface. The predicted values are found to be very close to the measured ones. (Author)

Analytical and experimental study of the oblique passing of a solitary wave over a shelf in a two-layer fluid
Pinettes M.-J., Renouard D. & Germain J.-P., *Fluid Dynamics Research*, 1995, 16/4 (217-235).

A surface or internal solitary wave passing over a shelf is partially reflected and there are at least two transmitted waves. When the incident wave is oblique relative to the shelf, there is a refraction phenomenon as for optical waves. The refraction angle of the transmitted wave is a function of the incident angle as well as of the relative height of the shelf. Within the framework of the slowly time-varying long waves in shallow water, we compute both the refraction angle of the transmitted waves, and the amplitudes of the reflected and transmitted waves far from the shelf, in non-rotating fluid. The method also allows for the computations of the local perturbations in the shelf-slope region thus providing a complete description of the phenomena at the first order approximation. (from Authors)

The random sweeping decorrelation hypothesis in stratified turbulent flows
Katul G., Parlange M., Albertson J. & Chia-Ren Chu, *Fluid Dynamics Research*, 1995, 16/5 (275-295).

Longitudinal velocity measurements above a uniform dry lakebed were carried out to investigate the applicability of the random sweeping decorrelation hypothesis to thermally stratified turbulent flow. The higher order velocity structure functions of order m were measured and modeled using sweeping decorrelation hypothesis. In order to reduce the influence of Taylor's frozen hypothesis on the assessment of the sweeping decorrelation hypothesis, two dimensionless quantities, developed by Praskovsky et al. (1993), were used. It was found that strong interaction existed between the energy containing scales and the inertial subrange

scales, indicating that the sweeping action alone does not fully describe the higher order structure function. Also, local temperature-velocity interactions were measured and found to be significant thus weakening the validity of the sweeping decorrelation hypothesis. However, these two interaction mechanisms appeared to be opposite in sign and counteracted each other. (from Authors)

The relative dispersion of particles in isotropic homogeneous turbulence
Reynolds A.M., *Fluid Dynamics Research*, 1995, 16/1 (1-10).
The effects of particle inertia and drift velocity on the relative dispersion of particles in turbulent flows have been investigated using numerical simulations of isotropic homogeneous turbulence. Isotropic homogeneous turbulence was simulated kinematically using random Fourier modes. Particle drift velocity was found to reduce relative dispersion, unequally in directions parallel and normal to the drift direction. Increasing particle inertia was found to enhance 'long time' relative diffusivity. The implications of these results for the turbulent mixing of particles, concentration fluctuations and the evolution of particle clouds dispersing in turbulent flows is discussed. (from Author)

The flow generated by the rotation of a horizontal disk in a stratified fluid
Davies P.A., Yakun Guo, Boyer D.L. & Folkard A.M., *Fluid Dynamics Research*, 1995, 17/1 (27-47).
Results are presented from a series of laboratory experiments in which a flow has been generated in a linearly-stratified fluid (initially at rest in a cylindrical container of radius R_T) by the impulsive steady azimuthal rotation of a flat, smooth, horizontal circular disk of radius R_d. Experiments have been conducted for a range of disk sizes R_d, disk rotation rates omega and buoyancy frequencies N_0 and the spatial and temporal development of the motion and density fields (and mixing associated therewith) have beenshown to be critically dependent on the ratio R_d/R_T. A scaling analysis is advanced to predict the growth rate of the primary interface and the experimental data are shown to be in good agreement with the analysis. (from Authors)

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High pressure-high temperature reservoir fluids: investigation of synthetic condensate gases containing a solid hydrocarbon
Ungerer P., 6 others et al., *Fluid Phase Equilibria*, 1995, 111/2 (287-311).
Four synthetic gas condensates containing 6 or 7 components have been investigated in a visual cell to show the sensitivity of phase equilibria with respect to small quantities of heavy alkanes (nC_{36}) and aromatics (phenanthrene). A very large sensitivity has been found, since addition of about 1% mol. of a heavy hydrocarbon may increase dew pressures by 200 bar in some cases. Crystallization of heavy hydrocarbons has been observed for temperatures 10-30 degrees C lower than pure component melting temperatures. These features have been modelled, using the Peng-Robinson equation of state for fluid phases. As a general feature, the Peng-Robinson EOS reproduces adequately the phase envelope of these fluids with regressed interaction parameters between methane and the heaviest hydrocarbon. However, prediction of liquid dropout is unsatisfactory. A simple model of crystallization has been used to predict appearance of solid from gas, which accounts for solid state transitions. (from Authors)

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Photoluminescent volumetric imaging: a technique for the exploration of multiphase flow and transport in porous media
Montemagno C.D. & Gray W.G., *Geophysical Research Letters*, 1995, 22/4 (425-428).
A new measurement technique, photoluminescent volumetric imaging (PVI), has been developed for the visualization and quantification of multiphase flows and interface behavior in porous media. The planar digital images produced are processes to generate a true three-dimensional data set that allows for quantitative study of the distribution of phases and interfaces within the porous medium. Sample volumes up to 125 mm^3 in size with a resolution of better than 1 mum have been measured. Because of the large sample size and the high resolution of the measured data, geometric, flow, and phase interface information can be visualized and extracted at both subpore and system scales. (from Authors)

Quantitative visualization of entrapped phase dissolution within a horizontal flowing fracture
Glass R.J. & Nicholl M.J., *Geophysical Research Letters*, 1995, 22/11 (1413-1416).
An experiment was conducted to demonstrate the utility of quantitative fracture flow visualization techniques in the study of entrapped fluid phase (air) dissolution into a flowing phase (water) within a horizontal, transparent, analog rough-walled fracture. The fracture aperture field and phase occupancy were measured using light transmission techniques and then combined to calculate bulk water-phase saturation within the fracture as a function of time. Fracture relative permeability as a function of water-phase saturation showed a smooth power law behavior during dissolution. Results demonstrate channeling induced by the entrapped air phase. Clusters of the entrapped air-phase exhibited three types of dissolution behavior: general shrinkage, interfacial recession along cluster appendages, and cluster splitting. Results suggest that within an individual cluster of the entrapped phase, fluid pressure is at equilibrium and that the path of cluster shrinkage may be controlled primarily by capillary forces. (from Authors)

Unique tidal flume available for European research institutes
ANON, *Hydro Delft*, 1995, 83/- (11-12).
For the validation and improvement of numerical hydrodynamic models there is a great need for measurements in facilities that

enable the control of flow conditions and for the accurate measurements of water motion and concentration distribution. Delft Hydraulics' Tidal Flume is a unique facility for execution of such validation experiments in stratified (tidal) flow conditions which also may contain silt transports, if required. This article discusses the tidal flume. (Author)

Winter methane dynamics beneath ice and in snow in a temperate poor fen
Melloh R.A. & Crill P.M., *Hydrological Processes*, 1995, 9/8 (947-956).
The influence of winter on methane (CH_4) stored in pore water and emitted through snow was investigated in a temperate poor fen in New Hampshire over two winters. Methane accumulated beneath ice layers (1 cm) deposited by freezing rain, resulting in snow-pore air mixing ratios as high as 140 ppmv during the first winter and 600 ppmv during the second. An early winter snow crust of 300 kg m^{-3} caused no discontinuity in a linear mixing ratio profile and therefore was not observed to retard snowpack emissions. Methane concentration-depth profiles in pore water steepened and concentrations increased by as much as 400 muM at the 10 and 20 cm depths as the ice cover formed. This suggests that the peat-ice cover plays an important part in CH_4 build-up in pore water by limiting the transport of gases between the peat and the atmosphere. Pore water concentrations gradually declined through late winter. (from Authors)

Measures to improve the hydraulic operating conditions of the eddy shaft spillway at the Tel'mam hydro development
Rozanov N.P., Khanov N.V. & Fedorkov A.M., *Hydrotechnical Construction*, 1995, 29/4 (237-241; translated from: Gidrotekhnicheskoe Stroitel'stvo, 4, 1995).
Hydraulic studies have been carried out on a model of a high-head eddy shaft spillway designed for the Tel'mam hydro development on the Mamakan River. The spillway was designed with two lines with two discharge channels emptying into the stilling basin symmetrically relative to is longitudinal axis. The effectiveness of swirled flow in dissipating energy of the flow inside the structure and reducing the occurrence of cavitation erosion of spillyway elements was evaluated. (P.M.Taylor)

Improvement of turbine blade systems to reduce cavitation erosion
Sotnikov A.A., Stepanov V.N., Livshits A.M. & Bukchin S.M., *Hydrotechnical Construction*, 1995, 28/12 (746-750; translated from: Gidrotekhnicheskoe Stroitel'stvo, 12, 1994).
The problems of cavitation erosion in turbine blade systems are examined. Findings from operating experience and model erosion tests carried out on mixed-flow turbines and on adjustable-blade turbines are discussed. Ways of reducing or eliminating cavitation erosion are described including blade modification. (P.M.Taylor)

Effect of the content of free air on cavitation erosion
Sotnikov A.A. & Livshits A.M., *Hydrotechnical Construction*, 1995, 28/12 (755-757; translated from: Gidrotekhnicheskoe Stroitel'stvo, 12, 1994).
The influence of free air in the circulating liquid on the cavitation and cavitation erosion in turbine runners was investigated. An air delivery system was designed and evaluated for reducing cavitation erosion. The system reduced the rate of cavitation erosion ten-fold while improving operating efficiency of the turbine. (P.M.Taylor)

Ways to increase the reliability and operating life of hydraulic turbine equipment when reconstructing hydroelectric stations
Grigor'ev V.I., *Hydrotechnical Construction*, 1995, 28/12 (700-703; translated from: Gidrotekhnicheskoe Stroitel'stvo, 12, 1994).
Approaches are discussed for improving the reliability and operating life of hydraulic turbine equipment during the reconstruction of hydroelectric power stations. Ways of increasing the power and cavitation characteristics of the turbines are described. Factors influencing the operating reliability of turbine equipment and the efficiency of hydrostations are examined. (P.M.Taylor)

Use and improvement of dredge ejectors
Kozhevnikov N.N., *Hydrotechnical Construction*, 1995, 29/1 (35-41; translated from: Gidrotekhnicheskoe Stroilel'stvo, 1, 1995).
It is known that the presence of a vacuum in the suction pipe of a dredge pump above 5-6 m H_2O column has as extremely unfavorable effect on its operation, since the development of cavitation begins. The parameters of the pressure, delivery, and efficiency of the pump here decrease substantially, which in turn limits the productivity of the dredgers with respect to material and depth of excavating the face. A radical and most economical method of increasing the vacuum-gauge suction height of a dredge pump is its submergence under water, but the realization of this method on dredges produced earlier was associated with considerable design changes, and in the case of keeping the cutter modernization is virtually impossible. The use of ejection on the suction pipeline of the dredge is much simpler, though less economical with respect to energy consumption. When developing ejecting device, it is necessary to take into account the experience of their wide use on dredges at the Energogidromekhanizatsiya trust and the recommendations of the present article. The use of ejecting devices makes it possible to substantially increase the productivity of dredges and depth of excavation with a decrease of energy expenditures per cubic meter of material. The simplicity of manufacture and high efficiency of the devices enable recommending them on all dredges where it is impossible to installed a submersible pump. (from Journal translation)

Boundary layer solution for a bubble rising through a liquid containing surface-active contaminants
Andrews G.F. & Shu-Lun Wong S., *Industrial & Engineering Chemistry Research*, 1995, 34/4 (1371-1382).
Millimeter-sized bubbles rise through most liquids with Reynolds numbers of several hundred. A boundary layer solution is given for flow over the upper surface of spherical or spherical-cap bubbles when surface-active solutes adsorb on the bubble interface and inhibit its motion. Diffusion of adsorbed surfactant along the interface is shown to be negligible. The surfactant accumulates not as a cap around the bottom of the bubble, as in the creeping-flow case, but in a band around a flow separation point from where it desorbs back into solution. The bubble interface is stationary at, or slightly abve (if diffusion along the interface is considered), the flow separation point. (from Authors)

Oxidative coupling of methane in a vibrofluidized bed at low fluidizing velocities
Santos A., Santamaria J. & Menendez M., *Industrial & Engineering Chemistry Research*, 1995, 34/5 (1581-1587).
A fluidized bed reactor has been used to study the influence of the operation parameters on the reactor behavior during oxidative coupling of methane. A vibration device was employed to avoid the agglomeration of the catalyst particles, thus allowing operation at low gas velocities, near the minimum fluidization velocity. An improved selectivity for hydrocarbons was obtained in this way, compared to the results at high gas velocities. (Authors)

Bulk-density distributions of solids in the freeboard of a gas-solid fluizied bed
Bao-Chun Shen, Fan L.T. & Walawender W.P., *Industrial & Engineering Chemistry Research*, 1995, 34/5 (1919-1925).
The freeboard region above the bubbling zone of a gas-solid fluidized bed provides the space not only for the disengagement of particles but also for additional contact and reaction between the particles and gas. The flow pattern and behavior of particles as

well as their bulk-density distribution in the freeboard have a significant impact on the efficiency of fluidization. The results of numerous previous experimental studies indicate that the bulk density of solids essentially decreases exponentially as a function of the height of the freeboard. In the present work, this distribution has been obtained by first deriving the Fokker-Planck equation from the linearized equation of motion of a single particle and then transforming this Fokker-Planck equation into that for the bulk-density distribution of solids. (from Authors)

Theory of multicomponent gas/oil displacements
Orr Jr F.M., Dindoruk B. & Johns R.T., *Industrial & Engineering Chemistry Research*, 1995, 34/8 (2661-2669).
Chromatographic separations that occur during two-phase flow in a porous medium are analyzed for one-dimensional, dispersion-free displacement of a liquid hydrocarbon mixture (oil) by a vapor phase mixture (gas). We show that displacement behavior is controlled by a set of key equilibrium tie lines, all of which are determined by geometric constructions in composition space. Very efficient displacement of oil by gas results if any of the key tie lines is a critical tie line. That high displacement efficiency is the basis of so-called miscible gas injection processes for enhanced oil recovery. (from Authors)

Characterization of heavy oils. 3. Prediction of gas injection behavior: swelling test, multicontact test, multiple-contact minimum miscibility pressure, and multiple-contact minimum miscibility enrichment
Jaubert J.-N., Neau E., Avaullee L. & Zaborowski G., *Industrial & Engineering Chemistry Research*, 1995, 34/11 (4016-4032).
The modeling of miscible gas injection into reservoir crude oils was performed using a cubic equation of state coupled with a predictive procedure for characterizing the heavy fractions. It is shown that experimental data on the swelling test, multicontact test, slim tube minimum miscibility pressure (MMP), and minimum miscibility enrichment (MME) for 10 different crude oils from different fields are satisfactorily calculated using the predictive characterization. However, in the case of MMP and MME calculations, a significant deviation may appear between predicted and experimental values. Reasons for this discrepancy are discussed. The influence of tuning the equation of state parameters in the estimation of results for the swelling test is also discussed. (Authors)

Transition from bubbling to turbulent fluidization
Bi H.T., Grace J.R. & Lim K.S., *Industrial & Engineering Chemistry Research*, 1995, 34/11 (4003-4008).
Two types of transition to turbulent fluidization are proposed on the basis of bubble-bubble interaction. A relatively sharp transition (type I) is triggered when bubbles grow to such a size that following wakes become open and turbulent. The type II gradual transition occurs when the wake is closed at the transition point. A mechanistic model is developed to predict the type I transition and is found to be consistent with experimental results obtained in a column of 102-mm diameter and with extensive data from the literature. The model also successfully predicts the variation of U_c with particle properties, measurement location, and system pressure. (Authors)

Experimental characterization of the solid phase chaotic dynamics in three-phase fluidization
Cassanello M., Larachi F., Marie M.-N., Guy C. & Chaouki J., *Industrial & Engineering Chemistry Research*, 1995, 34/9 (2971-2980).
An experimental study of the solid phase dynamics in a three-phase fluidized bed reactor using heavy and light particles is carried out. A radioactive particle tracking technique is employed to obtain extended time series of the tracer path. A rescaled range analysis is applied to time series of the fluctuating velocities to investigate the features of solid phase turbulence. It is found that turbulence is anisotropic. In the axial direction, the correlations between the fluctuating velocities are persistent in time, indicating a superdispersive axial dispersion of the solids. Hence a constant axial dispersion coefficient, which is traditionally used in these reactors to represent the solid phase turbulence, only constitutes a lumped parameter hardly extrapolable to different operating conditions, different systems, and different geometries. The tracer path is also analyzed according to the theory of deterministic chaos. It is found that the solids motion is chaotic. (from Authors)

Macroscopic flow structures in a bubbling paper pulp-water slurry
Lindsay J.D., Mostafa Ghiaasiaan S. & Abdel-Khalik S.I., *Industrial & Engineering Chemistry Research*, 1995, 34/10 (3342-3354).
The hydrodynamic characteristisc of three-phase slurry columns containing water, paper fibers, and air have been experimentally investigated. Such systems are relevant to flotation deinking, a critical but poorly understood separation process in the production of recycled paper. Two transparent bubble columns were used, one for quiescent liquid and one for cocurrent air and liquid flow. Water and dilute aqueous pulp slurries were studied using gamma-densitometry to obtain local gas holdup (void fraction). Results in pulp slurries were significantly different than in pure water. In the quiescent flow system, network formation alters bubble size distributions and promotes transition to regimes with lower interfacial area. In contrast, with cocurrent flow, gas holdup and interfacial area can be greater in pulp slurries than in pure water. (from Authors)

On the prediction of frozen skin ratio in injection molding process by using boundary-tracking FDM
Liao M.K. & Li C.S., *International Communications in Heat & Mass Transfer*, 1995, 22/1 (133-143).
This research was aimed to realize the growth of frozen skin ratio in the multi-gapsize flow field during injection molding. By theoretical and physical approach, the relationship between the gapwise thickness of products and the rate of solidification had been investigated. Through the usage of the boundary-tracking skill based on the finite difference method (FDM), the location of solidified layer in injection molding process described by the compressible Hele-Shaw model for generalized Newtonian fluid was predicted precisely. (from Authors)

Forced convection solid-liquid mass transfer at a fixed bed of Raschig rings
Noseir S.A., El-Kayar A., Farag H.A. & Sedahmed G.H., *International Communications in Heat & Mass Transfer*, 1995, 22/1 (111-122).
Solid-liquid mass transfer characteristics of fixed beds of Raschig rings were studied by measuring the rate of diffusion-controlled dissolution of copper rings in acidified chromate solution. Variables studied were ring diameter, physical properties of the solution and flow rate of the solution. A comparison was made between the mass transfer behavior of beds packed with Raschig rings and beds packed with other packing geometries. (from Authors)

Thermal dispersion in vertical gas-liquid flows with foaming and non-foaming liquids
Pino L.R.Z. & Saez A.E., *International Communications in Heat & Mass Transfer*, 1995, 22/3 (391-400).
Heat transfer experiments have been performed in gas-liquids upwards flow in a vertical column with non-foaming (water) and foaming (kerosene) liquids. The main purpose of the experiments has been to characterize the degree of thermal mixing in the system. For the range of conditions employed, the non-foaming liquid exhibits complete mixing at low liquid superficial velocities. An increase in liquid velocity leads to incomplete mixing. In the latter case, the thermal dispersion coefficient at low gas superficial

velocities is larger than what correlations in the literature predict. For the foaming liquid, when foaming and bubbling regions coexist in the bubble column, each region behaves as a completely-mixed subsystem. (Authors)

Refrigerant flow in capillary tube: an assessment of the two-phase viscosity correlations on model prediction
Wong T.N. & Ooi K.T., *International Communications in Heat & Mass Transfer*, 1995, 22/4 (595-604).
The homogeneous flow model has been widely used to analyze the two-phase flow of refrigerant in a capillary tube of a vapour compression refrigeration system. However, to effectively apply the model, it is necessary to use an appropriate two-phase friction factor with a suitable two-phase viscosity correlation. In this paper, the effects of the various two-phase viscosity correlations on the homogeneous flow model prediction are assessed by comparing with the predicted pressure drops along the capillary tube with measured data. (Authors)

Analog of the Kutateladze crisis and uplifting water formation in drum boiler
Shreiber I., *International Communications in Heat & Mass Transfer*, 1995, 22/4 (493-497).
The paper deals with a model for the formation of a vapor bubble cavitation zone within a water layer due to a rarefied wave propagating in a drum boiler circulation circuit. The water in the layer is close to the saturation line (subheated). Models are presented for vapor cavitation zone development, pressure field formation and the phenomenon of swelling. The specific feature of the cavitation problem is the multiply reflected rarefied wave at the bottom and the formation of the most intensive cavitation zone near the bottom. The coalescing and floating bubbles can uplift the water layer and create an emergency situation in the control of the drum. The phenomenon is similar to the Kutateladze crisis for boiling liquid near a wall. The control system of the power station must take into account the danger of such uplifting. (Author)

Determination of the critical speed of a particle interacting with a freezing front (Determination de la vitesse critique d'une particule en interaction avec un front de solidification)
Casses P. & Azouni M.A., *International Communications in Heat & Mass Transfer*, 1995, 22/4 (605-615). In French.
Critical velocities of a freezing front interacting with spherical particles are determined by a new theoretical approach. Analytical and numerical results are then compared to recent experimental observations. (Authors)

Experimental direct contact heat transfer in upward air-water developing annular flow
Fossa M., Pisoni C. & Tagliafico L., *International Communications in Heat & Mass Transfer*, 1995, 22/6 (825-835).
Some experimental results are presented in order to quantify the impact of several operating parameters on the direct contact heat and mass transfer processes between hot water and cooling air, flowing upward inside a vertical, adiabatic, circular tube (12 mm i.d.), in the developing co-current annular flow regime. The proposed temperature measurement technique for the gas phase is based on the energy and mass balance equations applied to proper control volumes. The data processing method seems to be particularly suitable for the performance evaluation of the direct contact heat transfer occurring between the phases during the flow. Further developments are expected in the characterisation of different injection systems used for the mixing of two fluids in thermodynamic non-equilibrium conditions. (Authors)

Liquid phase controlled mass transfer in gas-liquid slug flow at low Reynolds numbers
Elperin T. & Fominykh A., *International Communications in Heat & Mass Transfer*, 1995, 22/5 (741-750).
A model of mass transfer during isothermal gas absorption from slugs rising in a channel filled with liquid at small Reynolds numbers is suggested. Fluid flow in the region below the bottom of gas slugs is assumed laminar and therefore vortex rings are not formed at the trailing edge of a gas slug. It is assumed also that a flow of dissolved gas can be described by a point source of mass which is located at the bottom of a gas slug. Using this model a recurrent relation for mass flux from the n-th gas slug is derived and the total mass flux from n gas slugs in a gas-liquid slug flow is determined. (from Authors)

A semi-empirical correlation for adiabatic interfacial friction factor in horizontal air-water countercurrent stratified flow
Moon-Hyun Chun & Yang-Seok Kim, *International Communications in Heat & Mass Transfer*, 1995, 22/5 (617-628).
A semi-empirical correlation for an adiabatic interfacial friction factor (f_{ia}) in a stratified wavy flow, based on the simultaneous measurements of the main flow parameters in air-water countercurrent stratified flows and the concept of surface roughness in a wavy flow, has been developed. The functional form for f_{ia}, in particular, has been obtained by making an analogy between the effect of surface roughness on the gas-to-wall friction factor (F_g) in a pipe flow and the effect of gas-water interface roughness on the air-water interface friction factor (f_{ia}) in a wavy flow. (from Authors)

A parallelized Lattice-Gas Solver for transient Navier-Stokes flow: implementation and simulation results
Krafczyk M. & Rank E., *International Journal for Numerical Methods in Engineering*, 1995, 38/8 (1243-1258).
The last decade has seen the development of Lattice-Gas (LG) schemes as a complementary if not alternative method for the simulation of moderate Reynolds-Number Navier-Stokes flow. After a short theoretical introduction we present a detailed discussion of implementation features for a specific 2D-LG algorithm, which runs in parallel on a workstation-cluster, discuss simulation results and compare one of them to experimental studies. Finally, we attempt to point out present problems and perspectives of these methods. (Authors)

Accurate computation of convective transport in transient two-phase flow
Andrews M.J., *International Journal for Numerical Methods in Fluids*, 1995, 21/3 (205-222).
The Van Leer method for the computation of convective fluxes is extended to two-phase flow. By preventing spurious undershoots and overshoots, the scheme preserves physical realism while maintaining high-order accuracy. The scheme described here is constructed to guarantee that the sum of the volume fractions is always unity and that the volume fractions are always greater than or equal to zero. In addition to multiphase flow applications, setting equal phase velocities results in a volume marker scheme that is well suited to single-phase interface tracking problems. (from Author)

One-dimensional, time-dependent, homogenous, two-phase flow in volcanic conduits
Ramos J.I., *International Journal for Numerical Methods in Fluids*, 1995, 21/3 (253-278).
A one-dimensional, time-dependent, isothermal, homogenous, two-phase flow model was developed to study magma ascent in volcanic conduits. The physical modeling equations were numerically solved by means of a TVD (total variation diminishing) predictor-corrector procedure and by means of a predictor-corrector technique based on the method of characteristics. The results from the transient model were verified with an analytical solution for wave propagation in conduits without frictions and gravitational effects. The numerical solutions were also compared with those of a safety-state, homogenous, two-phase model for basaltic and rhyolitic magma ascents in the fissures and circular conduits of Vesuvius and Mt St. Helens. An application of the model to magma decompression in conduits indicates very short times for gas exsolution, fragmentation, and shock wave pro-

pagation, implying that the modelling of gas exsolution should involve non-equilibrium kinetics effects. Future coupling of the transient magma ascent model with magma chamber and pyroclastic dispersion models should allow for more realistic simulations of the time-dependent behavior of real volcanic eruptions. (Author)

A note on unsteady flow of an electrically conducting dusty viscous liquid through a channel
Ram P.C. & Takhar H.S., *International Journal of Energy Research*, 1995, 19/2 (181-183).
The study of two-phase flows has gained considerable importance in recent years with the most important work being done in aircraft propulsion, missile cooling and nuclear reactor design. Such flows play an important role in the process industry of distillation, diffusion, absorption and extraction. Dube and Sharma (1975) have considered unsteady flow of a dusty viscous liquid in a channel bounded by two parallel flat plates. Singh and Ram (1977) have extended the same problem in the presence of a transverse magnetic field. In the present note we have reconsidered the said problem for the sake of generality by using another set of nondimensional quantities. The solution of more general equations has been discussed physically with respect to the influence of Strouhal and Reynolds numbers. (Authors)

Experimental investigation of the two-phase theory in a fluidized-bed combustor
Stubington J.F. & Yongbin Cui, *International Journal of Energy Research*, 1995, 19/8 (699-719).
Though the two-phase theory of fluidization is well-accepted, no direct experimental measurements of the different gas concentrations predicted to occur in bubble and particulate phases could be found in the literature. For the first time, theoretical predictions of these different gas concentrations have been validated experimentally, using a combined oxygen/bubble probe. Based on the two-phase theory, a mathematical model was developed for the combustion of a batch of char particles in a fluidized-bed combustor. The temperature difference between the char and bed particles (DELTAT) was the only adjustable parameter in the model. The DELTAT value of 20 degrees C was significantly lower than experimental measurements of maximum burning char particle temperatures, reported to be 70 degrees C for the small-diameter bed particles used in this work. (from Authors)

A simple model to evaluate direct contact heat transfer and flow characteristics in annular two-phase flow
Fossa M., *International Journal of Heat & Fluid Flow*, 1995, 16/4 (272-279).
Calculations are performed to study the behavior of air-water mixtures in vertical flows employing a simple model for the description of mass, momentum, and energy transfer in annular gas-liquid flows. The model is applied to various flow conditions including thermal nonequilibrium and variable cross section ducts. Theoretical results agree reasonably well with experimental data regarding well-known isothermal flows. A contribution is provided to the understanding of the two-phase mixtures interactions for gas-liquid heat transfer in two-phase, annular, nonisothermal flows. (Author)

Experimental investigation of geyser boiling in an annular two-phase closed thermosyphon
Lin T.F., Lin W.T., Tsay Y.L., Wu J.C. & Shyu R.J., *International Journal of Heat & Mass Transfer*, 1995, 38/2 (295-307).
Geyser boiling in a vertical annular two-phase closed thermosyphon was experimentally studied. The effects of the heat load, condenser temperature, degree of liquid fill and length of the evaporator on the characteristics of the geyser boiling were investigated in detail for both water and ethanol as working fluids. Flow visualization at light heat load clearly illustrates the process of geyser boiling. It also indicates that it occurs more frequently and irregularly at high heat load. The wall temperature measurement dictates that the period of geyser boiling is shorter at a higher heat load, a shorter evaporator length and a smaller liquid fill. Additionally, the heat transfer coefficient is found to increase approximately linearly with the heat load on a logarithmic scale. An empirical equation was proposed to correlate the data for the heat transfer coefficient. A criterion was suggested for the occurrence of geyser boiling based on the present data. (Authors)

Axial development of interfacial area and void concentration profiles measured by double-sensor probe method
Leung W.H., Revankar S.T., Ishii Y. & Ishii M., *International Journal of Heat & Mass Transfer*, 1995, 38/3 (445-453).
The local geometric and statistical characteristics of upward cocurrent dispersed bubbly flow in a pipe have been studied both at the entrance and at a region far away from the entrance. A double-sensor probe was employed to measure the radial profiles of void fraction, interfacial area concentration, Sauter mean diameter, bubble velocity and bubble frequency. The wall peak of the void fraction profile was established within a short distance from the entrance. The flow characteristics changed very little from the entrance regiion to the fully developed region except for the flow case of $j_l = 0.1\ m\ s^{-1}$. The area averaged flow quantities were also presented. (from Authors)

Spectrum of temperature fluctuations in high-temperature turbulent gas-particle flow
Lisin F.N. & Hetsroni G., *International Journal of Heat & Mass Transfer*, 1995, 38/4 (723-730).
The effects of both the interphase convective interaction and radiative energy transfer on the spectra of temperature fluctuations are considered for homogeneous and isotropic turbulence in high-temperature, two-phase flow. The analysis is carried out for two kinds of small particles (with low Reynolds number), mainly scattering sapphire particles (Al_2O_3), and strongly absorbing coal particles. The radiative properties of the particles was calculated using Mie theory. Radiation modifies the spectrum of temperature fluctuations significantly, and increases the suppression of temperature fluctuations by the particles. Effects of radiation are different in various regions of wave space and depends on the radiative properties of particles and their concentration. (from Authors)

Numerical modeling of multiphase plasma/soil flow and heat transfer in an electric arc furnace
Seungho Paik & Hoa Nguyen D., *International Journal of Heat & Mass Transfer*, 1995, 38/7 (1161-1171).
A study on an arc melter used for waste minimization process is presented. The plasma phase of the arc and the liquid-solid phases of the molten soil are simulated simultaneously. Newtonian fluid model is used for both the plasma and the molten phases. Parametric study is made on different arc lengths and arc currents with varying input powers. Calculations show that both convective heat transfer and Joule heating mechanism yield high heat dissipation in the melt pool. It is found that the buoyancy and the surface shear driven convection established in the melt pool are the major contribution to the more uniform mixing of the molten soil. (from Authors)

Effects of heater length and orientation on the trigger mechanism for near-saturated flow boiling critical heat flux - II. Critical heat flux model
Gersey C.O. & Mudawar I., *International Journal of Heat & Mass Transfer*, 1995, 38/4 (643-654).
A critical heat flux (CHF) model is presented that accounts for both heater length and orientation effects. The model is verified with FC-72 data obtained for 10-, 30-and 110-mm long heaters that were flush-mounted in a 10-mm X 5-mm channel and orientations including vertical upflow, 45-degree inclined flow, and horizontal flow, with liquid flowing above the heaters. Formulation of the model was based on flow visualization and photomicrography of the vapor-liquid interface along the heaters.

The CHF model incorporates the observed stream-wise reduction in wetting fronts with a criterion for lift-off heat flux to obtain a simplifed set of equations for CHF. Local information such as pressure, phase velocities, and average vapor layer thickness along the heater were also incorporated in the CHF model using the assumption of separated two-phase flow. (from Authors)

Confined single-and multiple-jet impingement heat transfer - I. Turbulent submerged liquid jets
Chang C.T., Kojasoy G., Landis F. & Downing S., *International Journal of Heat & Mass Transfer*, 1995, 38/5 (833-842).
An experimental study was conducted to determine the heat transfer for single and multiple confined and submerged impingement jets in single-and multi-phase flows. This type of heat transfer is of commercial interest in high performance finned coolers used in avionic equipment. Part I deals with single-phase liquid flows of Freon R-113 with Part II covering two-phase flows. Stagnation point and local average Nusselt numbers, suitable for design purposes, were determined as functions of the Reynolds number, the dimensionless spacing between the confining plates, and, for multiple jets, as a function of pitch spacing. The resulting correlation equations match the experimental data from +/-10% to +/-25%. (Authors)

Confined single-and multiple-jet impingement heat transfer - II. Turbulent two-phase flow
Chang C.T., Kojasoy G., Landis F. & Downing S., *International Journal of Heat & Mass Transfer*, 1995, 38/5 (843-851).
The single-phase confined and submerged jet impingement heat transfer studies presented in Part I are here extended to two-phase flows with Freon R-113. Correlations are developed showing the influence on heat transfer of jet Reynolds number, flow quality, plate spacings and, for multiple jets, pitch-to-jet diameter ratio. In all cases the Nusselt numbers obtained are referenced back to single-jet, single-phase conditions. It is shown that the heat transfer rate can be improved significantly over that possible with a single-phase liquid operating with the same geometry although, depending on the configuration, the pressure drop encountered with two-phase cooling may not be acceptable. (Authors)

The interaction of an isolated sprinkler spray and a two-layer compartment fire environment
Cooper L.Y., *International Journal of Heat & Mass Transfer*, 1995, 38/4 (679-690).
A model is developed to simulate the interaction of a sprinkler and a two-layer environment under arbitrary conditions of sprinkler elevation, upper-and lower-layer thickness, and temperature. The sprinkler is characterized by a water flow rate and four measurable device parameters. The model simulates the effects of the sprinkler spray as it entrains, drives downwards, humidifies, and cools gases in the upper and lower layers. It predicts the flow rates of mass, enthalpy, products of combustion and evaporated water to each of the two layers as a result of sprinkler operation. Results of example calculations are presented. (Author)

Direct contact evaporation of nearly saturated R 114 in water
Celata G.P., Cumo M., D'Annibale D., Gugliermetti F. & Ingui G., *International Journal of Heat & Mass Transfer*, 1995, 38/8 (1495-1504).
This paper reports the results of an experimental investigation on direct contact boiling of immiscible liquids. The continuous phase, water, is under stagnant conditions, while the dispersed one, Freon 114, is injected in the test section with different velocity and thermodynamic conditions through a nozzle. Experimental data are obtained from high-speed movies of the continuous phase level during and after the Freon 114 injection, as well as from the movies of the rising boiling dispersed phase (injected under nearly saturation conditions). Vaporization rate has been characterized as a function of thermal hydraulic conditions (ie water temperature, system pressure and Freon mass flow rate). Direct contact boiling efficiency was derived by the evaluation of the fraction of Freon that did not undergo the boiling process during the transit in the test section. (from Authors)

Convective heat transfer in a vertical anisotropic porous layer
Degan G., Vasseur P. & Bilgen E., *International Journal of Heat & Mass Transfer*, 1995, 38/11 (1975-1987).
This paper summarizes an analytical and numerical study of natural convection in a fluid-saturated porous medium filled in a rectangular cavity. The porous medium is assumed to be both hydrodynamically and thermally anisotropic. The principal directions of the permeability are oriented in a direction that is oblique to the gravity vector, while those of thermal conductivity coincide with the horizontal and vertical coordinate axes. The side walls of the cavity are, respectively, heated and cooled by a constant heat flux while the horizontal walls are adiabatic. An analytical solution, valid for stratified flow in slender enclosures, is presented. Scale analysis is applied to predict the order of magnitudes involved in the boundary layer regime. Comparisons between the fully numerical and analytical solutions are presented. (Authors)

Forces on bubbles growing and detaching in flow along a vertical wall
Van Helden W.G.J., Van der Geld C.W.M. & Boot P.G.M., *International Journal of Heat & Mass Transfer*, 1995, 38/11 (2075-2088).
Experiments are performed on bubble detachment from an artificial cavity in a plane wall of a vertical rectangular channel. Mean upward velocity is varied. Steam bubbles are generated by local heating of the cavity, nitrogen bubbles of about the same size by injection. The experiments show a difference in take off direction between vapor and nitrogen bubbles. Steam bubbles take off into the liquid, while nitrogen bubbles more or less slide parallel to the wall. The bubble detachment radius decreases for increasing bulk liquid velocity, in a way that merely depends on the detachment radius without convection. Nitrogen bubbles, coming from a capillary with approximately the same radius are larger than water vapor bubbles. A force coefficient fit is performed on force components perpendicular to the wall. By analysing flow-and non-flow experiments separately, some of the forces are quantified. By combining the results of nitrogen bubble and steam bubble experiments, a force due to the temperature difference at the bubble foot is studied. (Authors)

Instability of a liquid film moving under the effect of gravity and gas flow
Alekseenko S.V. & Nakoryakov V.E., *International Journal of Heat & Mass Transfer*, 1995, 38/11 (2127-2134).
The model two-wave equation for weakly nonlinear long waves on a liquid film moving along an inclined plane under the effect of gravity and gas flow is derived on the basis of an integral approach. The linear stability of a liquid film flowing concurrently or countercurrently with a gas stream is studied over a wide range of regime parameters. It is found that the dispersive curve has two branches which interact with one another under certain conditions. (Authors)

The penetration rate of solid-liquid phase-change heat transfer interface with different kinds of boundary conditions
Ji Ma & Bu-Xuan Wang, *International Journal of Heat & Mass Transfer*, 1995, 38/11 (2135-2138).
Investigations of one-dimensional moving boundary problems associated with freezing and thawing have been of great practical use and theoretical significance, as in freezing and melting of lake ice, cooling of large masses of igneous rock, materials processing and purification, metal casting and growth of pure crystals from melts and solutions. Many analytical solutions have been reported with a few special classes of boundary and initial conditions, and different approximate solutions have been obtained to predict the temperature distribution and interface movement in the phase change heat transfer process for complicated

boundary conditions. We present a comparison of penetration rate characteristics of conduction-dominated freezing phase change interface for the case of a semi-infinite body with different boundary conditions. The emphasis focuses on the two-phase problems with convective cooling boundary conditions. (Authors)

Isokinetic sampling probe and image processing system for droplet size measurement in two-phase flow
Zhang G.J. & Ishii M., *International Journal of Heat & Mass Transfer*, 1995, 38/11 (2019-2027).
The present system consists of an isokinetic sampling probe, droplet collection mechanism and an image processing package. A droplet sample was extracted from flow field by the sampling probe and collected by an immiscible liquid. Droplet images were grabbed and digitized by an image processing system. Image processing software was developed for droplet counting and sizing, with the capability of distinguishing overlapping droplets. Possible measurement distortion factors such as droplet deposition in the probe, droplet breakup and coalescence were studied. A simple criterion for minimizing measurement distortion was obtained. The system can be used for both water and liquid-metal droplets. (Authors)

Condensation in a gas-loaded thermosyphon
Zhou X. & Collins R.E., *International Journal of Heat & Mass Transfer*, 1995, 38/9 (1605-1617).
An experimental and modelling study is presented of condensation in a cylindrical, two-phase reflux thermosyphon containing non-condensable gas. The diffusion equations in the interface region are solved numerically. The spatial distribution of condensing heat flux is determined from accurate measurements of the thickness of the condensed liquid film. At high power levels, fluctuations can occur in the interface region indicating that, under such conditions, the vapour-gas interface is intrinsically unstable. At lower power levels, stable operation is observed and the width of the interface region is measured as significantly greater than that predicted by the diffusion model. The mass transfer in the interface region is strongly influenced by convection in this domain. At very low power levels, the experimental measurements of spatial distribution of heat flux in the interface region are in excellent agreement with the predictions of the diffusion model, indicating that diffusion is the dominant process which influences condensation in the interface region under these conditions. (Authors)

Bubble dynamics on the evolving bubble formed from the droplet at the superheat limit
Ho-Young Kwak, Si-Doek Oh & Cheon-Ho Park, *International Journal of Heat & Mass Transfer*, 1995, 38/9 (1709-1718).
The violent oscillation of the bubble formed from the evaporated droplet at the superheat limit has been investigated analytically and numerically. In this study, we have formulated a general bubble dynamics model, which is suitable for the oscillating bubble in an incompressible liquid medium. One of distinct features of this model is that the velocity and temperature distribution of the gas inside the bubble are obtained by solving continuity and energy equations for the gas analytically. With uniform density and temperature distribution approximation, the calculated values of the far field pressure signal from the evolving bubble formed from the fully evaporated droplet are in good agreement with experimental results. (Authors)

Macrosegregation near a cast surface caused by exudation and solidification shrinkage
Haug E., Mo A. & Thevik H.J., *International Journal of Heat & Mass Transfer*, 1995, 38/9 (1553-1563).
A one-dimensional mathematical model for the development of an exudated layer and macro-segregation near a cast surface is established. While forced convection leads to a highly segregated layer at the surface of the casting and a solute depleted zone near the surface, solidification shrinkage induced flow makes the negative segregation within the casting less pronounced. Parameter studies reveal that the heat transfer coefficient for chill contact, the metallostatic head, and the criterion for onset of exudation, all have a major influence on the resulting macrosegregation. The mathematical model is used to estimate macrosegregation development in the direct chill casting of an Al-4.5% Cu rolling slab. (from Authors)

Melting and solidification of thin wires: a class of phase-change problems with a mobile interface - I. Analysis
Huang L.J., Ayyaswamy P.S. & Cohen I.M., *International Journal of Heat & Mass Transfer*, 1995, 38/9 (1637-1645).
In this paper, a model that describes the transient heating of a thin wire causing the tip to melt, roll-up of the molten mass into a ball due to surface tension forces, and the subsequent solidification of the molten material due to conduction up the wire and convection and radiation from the surface, has been provided. The wire is assumed to be heated at its lower tip to a temperature beyond the melting temperature of the wire material by heat flux from an electrical discharge. The shape of the melt is analytically/numerically determined by solving equations based on minimum energy principles. The departure from sphericity of the melt that is formed is examined by perturbation schemes. Temperature fields in the melt have been obtained by solving the energy equation using a body-fitted coordinate system. Temperature fields in the wire above the melt were calculated as well. (from Authors)

Melting and solidification of thin wires: a class of phase-change problems with a mobile interface - II. Experimental confirmation
Cohen I.M., Huang L.J. & Ayyaswamy P.S., *International Journal of Heat & Mass Transfer*, 1995, 38/9 (1647-1659).
In Part I, we formulated the problem of wire heating, melting, roll-up into a ball, cooling and solidification. In this part, we describe experimental observations of the melting and solidification processes using high speed photography in an arc chamber. These observations provide results for comparison with the theoretical model. In the numerical computations for the theoretical model, the heat flux from the arc plasma to the wire is an input parameter. The value of this heat flux is obtained from temperature measurements made by thermocouples embedded in the unmelted wire above the ball, thus enabling comparisons between the predictions of the theoretical model and experimental observations. The heat transfer results indicate that conduction up the wire, for thin wires, is the dominant mechanism; the solidification front in the melt progresses from top downwards. (from Authors)

Inertial effects on thermophoretic transport of small particles to walls with streamwise curvature - I. Theory
Konstandopoulos A.G. & Rosner D.E., *International Journal of Heat & Mass Transfer*, 1995, 38/12 (2305-2315).
The combined action of particle inertia and thermophoresis in boundary aerosol flows over surfaces with streamwise curvature were studied, in the limit of small particle Stokes number, Stk, when the interaction between these two transport mechanisms is expected to be most significant. The governing dimensionless parameter controlling inertial effects is found to be $Stk.Re_x^{1/2}$, which can be large enough to cause dramatic changes in deposition rates even when Stk = or 1, due to the largeness of the streamwise Reynolds number, Re_x in boundary layer flows. Predictions are presented for concave/convex surfaces either 'colder' or 'hotter' than the mainstream. (from Authors)

Inertial effects on thermophoretic transport of small particles to walls with streamwise curvature - II. Experiment
Konstandopoulos A.G. & Rosner D.E., *International Journal of Heat & Mass Transfer*, 1995, 38/12 (2317-2327).
Directing a high-speed, high-temperature, seeded jet generated by a micro-combustor past the concave side of a 'cold', platinum circular foil whose temperature is actively controlled, we investigate the simultaneous action of inertial and thermophoretic effects on particle deposition from curved, laminar boundary layer flows. Although particle Stokes numbers in these experiments are of $O(10^{-2})$, much smaller than the values customarily thought to signal the onset of inertial effects, we observe a significant increase of

particle deposition rates over those expected based on 'pure thermophoresis' theory, in agreement with a recently developed theory of inertially modified thermophoresis in such flows. (Authors)

A micro/macro model for fluid flow evolution and microstructure formation in solidification processes
Li B.Q. & Anyalebechi P.N., *International Journal of Heat & Mass Transfer*, 1995, 38/13 (2367-2381).
A micro/macro model is developed to represent the evolution of fluid flow, temperature field and microstructure formation in solidification processes. The macro model for fluid flow and heat transfer is established using the finite element method coupled with an Eulerian-Lagrangian formulation, while the micro model for nucleation and grain growth is derived based on the principle of statistical physics. The macro and micro models are coupled through an iterative micro/macro time step scheme. The numerical treatment is given. As an example, the integrated micro/macro model is applied to describe the evolution of fluid flow, temperature and the formation of solidification microstructure during the start-up phase in continuous casting of aluminum alloy. (from Authors)

Heat and mass transfer coupling between vaporizing droplets and turbulence using a Lagrangian approach
Berlemont A., Grancher M.S. & Gouesbet G., *International Journal of Heat & Mass Transfer*, 1995, 38/16 (3023-3034).
A Lagrangian approach is developed for droplet vaporization in turbulent fields, with two-way coupling between phases. Specific source terms induced by phase changes are described and results are presented for methyl alcohol droplet vaporization in a heated turbulent round jet. A high coupling is observed between production and diffusion processes for the vapour mass fraction and fluid temperatures. Droplet diameter distributions are strongly dependent on the turbulent dispersion and droplet history. (Authors)

An experimental investigation of the solidification process in a V-shaped sump
Burton R., Yang G., Dong Z.F. & Ebadian M.A., *International Journal of Heat & Mass Transfer*, 1995, 38/13 (2383-2393).
An experimental study of binary mixture solidification in a V-shaped sump is conducted. NH_4Cl-H_2O is used as the phase change material. The variations of temperature, concentration, as well as the location of the interface front, are measured and reported in this investigation. The results indicate that the solidification process exhibits totally different behavior when the initial component of the solution is varied. For a hypoeutectic solution, the columnar solidification in the dendritic interface is the dominant mechanism. For the hypereutectic solution, both columnar and equiaxed solidification are important. The solidification starts as the equiaxed dendrites grow and coalesce in the entire solution. They then descend and settle at the bottom of the sump to form a loose, mushy zone. The solid region grows underneath the mushy zone. (Authors)

Drag on non-spherical particles in viscous fluids
Venu Madhav G. & Chhabra R.P., *International Journal of Mineral Processing*, 1995, 43/1-2 (15-29).
The terminal settling velocity of several cylinders (of stainless steel, perspex and glass), needles (of steel) and rectangular prisms (of perspex) falling with their major axis parallel to the direction of motion has been measured in three Newtonian liquids. The measurements have been carried out in three to four fall tubes of different diameters to correct the measured terminal velocity for wall effects. Terminal velocity data (corrected for wall effects) have been correlated using two approaches, namely, the usual drag coefficient-Reynolds number relationship, and in terms of a dimensionless velocity factor denoting the departure from the behaviour of an equivalent sphere. Predictive expressions have been developed using both schemes. Detailed comparisons between the present results and the prior investigations available in the literature are given. (from Authors)

Influence of unsteady forces acting on a particle in a suspension: application to the sound propagation
Dodemand E., Prud'homme R. & Kuentzmann P., *International Journal of Multiphase Flow*, 1995, 21/1 (27-51).
First, the influence of the unsteady forces (the pressure gradient, the virtual mass effect and the Basset history term) on the complex velocities ratio of the fluid and of the dispersed phases has been studied. It is shown that the unsteady terms are of great importance when the coefficient chi, mass density of the particle divided by the mass density of the fluid, becomes small. A particular study of the Basset history term is also investigated. Then, a two fluids theory, including viscous and thermal losses effects, is developed for calculating the velocity and the damping of the sound propagating in a two-phase flow. (from Authors)

Dynamics of fluidized suspensions of spheres of finite size
Singh P. & Joseph D.D., *International Journal of Multiphase Flow*, 1995, 21/1 (1-26).
We propose a one-dimensional theory of fluidized suspensions in which the fluids and solids momentum equations are decoupled by using a new mean drag law for the particles. Our mean drag law differs from the standard drag laws frequently used in that the drag is assumed to depend on the area fraction rather than the number density. The nonlinear theory contains bounded solutions when a certain dimensionless 'growth rate' parameter is below a critical value. The power spectrum of these bounded solutions is broad banded in both space and time, and is very low for the wave numbers that are marginally stable in the linear theory. These results agree with our experiments, as well as with the previous experimental results from diffraction studies. (from Authors)

Stratified three phase flow in pipes
Taitel Y., Barnea D. & Brill J.P., *International Journal of Multiphase Flow*, 1995, 21/1 (53-60).
The gas/oil/water holdups for stratified three phase flow are calculated. This information is usually the first step for analyzing the stability of stratified flow, but only the configuration with the thinnest total liquid layer is stable and can actually occur. Taitel & Dukler (AIChE Jl 22, 47-55, 1976) criterion for transition from stratified flow was applied to the three phase flow case and was found to yield good agreement for low gas flow rates. (from Authors)

Experimental investigation of flow regimes and oscillatory phenomena of condensing steam in a single vertical annular passage
Boyer B.D., Robinson G.E. & Hughes T.G., *International Journal of Multiphase Flow*, 1995, 21/1 (61-74).
Steam condensing in vertical annular passages experiences regular flow and pressure oscillations. An experimental program with a counterflow condensing heat exchanger with flow visualization was designed to obtain the flow and pressure data along with photographic and video records of condensing steam in vertical upflow in annular passages. The experimental results were compared to the literature on condensation oscillations. From the observations and data collected in the experiment, a 3-region physical model of the condensing process was developed. The observed flow and pressure oscillations were indicative of oscillations unique to condensing passages previously observed in condensation experiments that used a refrigerant as the working fluid. (from Authors)

Linear, nonlinear small-amplitude, steady and shock waves in magnetically stabilized liquid-solid and gas-solid fluidized beds
Sergeev Yu. A. & Dobritsyn D.A., *International Journal of Multiphase Flow*, 1995, 21/1 (75-94).
The propagation of solid concentration disturbances in fluidized beds in an external magnetic field is considered. The effect of simultaneous magnetization of particles and fluid as well as the influence of the inertial component of interphase interaction force

on the resulting criterion of stability of the uniform fluidization are analysed. The model of propagation of nonlinear waves is developed in approximation of small finite-amplitude waves. Possible configurations of the concentration wavefront are studied, including the oscillating wavefronts and small-amplitude shocks. (from Authors)

Gravity-driven two-layer flow down a slightly wavy periodic incline at low Reynolds numbers
Feng Kang & Kangping Chen, *International Journal of Multiphase Flow*, 1995, 21/3 (501-513).
Gravity-driven two-layer flow down a slightly wavy periodic incline at low Reynolds numbers is studied by a perturbation approach. Amplitude ratios and phase shifts of the fluid-fluid interface and the fluid-air free surface relative to the wavy wall are obtained as functions of the incline angle, wavelength of the roughness, and the ratios of film mean thickness, density and viscosity. Effects of surface tension and interface are included, and wall-shear-stress distributions are also discussed. (Authors)

Investigation of bubble flow developments and its transition based on the instability of void fraction waves
Chul Hwa Song, Hee Cheon No & Moon Ki Chung, *International Journal of Multiphase Flow*, 1995, 21/3 (381-404).
The developments of bubble flow structures and their effect on the propagation properties of void fraction waves are experimentally investigated in vertical upwards, air-water flow. The bubble-to-slug flow regime transition (BSFRT) is investigated based on the instability of the void fraction waves. Several statistical parameters are evaluated from the void fraction signals to objectively characterize the developing flow structures and to investigate the wave propagation properties. Two distinct modes of flow structural developments in bubbly flow are observed which are dependent on the bubble size. It is also shown that the different features of wave propagation properties are mainly due to the differences in the developing mode of the flow structures. (from Authors)

A cascade model for neutrally buoyant dispersed two-phase homogeneous tubulence - I. Model formulation
Jairazbhoy V., Tavlarides L.L. & Lewalle J., *International Journal of Multiphase Flow*, 1995, 21/3 (467-483).
This work proposes a cascade model approach to describe two-phase turbulent flows of neutrally buoyant liquid dispersions for high dispersed phase fractions. The cascade model of Desnyansky & Novikov is extended to describe the energy spectrum and eddy intermittency in the presence of a dispersed phase. Specific drop-eddy events such as grazing collisions, drop entrapment and eddy shattering are suggested and their effects on the turbulent energy spectrum, eddy intermittencies and drop size distributions are examined. The energy, intermittency and population balance equations modified to include the effects of drop-eddy interactions form the proposed two-phase cascade model for homogeneous, neutrally buoyant, turbulent dispersions. (from Authors)

A cascade model for neutrally buoyant dispersed two-phase homogeneous turbulence - II. Numerical solution and results
Jairazbhoy V. & Tavlarides L.L., *International Journal of Multiphase Flow*, 1995, 21/3 (485-500).
The two-phase cascade model for homogeneous, neutrally buoyant turbulent dispersions proposed earlier results in a system of partial integrodifferential equations. These are the energy, intermittency and population balance equations, and they account for the effects of drop-eddy interactions. A semi-discretization technique is developed for the solution. The drop number densities are discretized non-uniformly, the integrals approximated by Gaussian quadrature, and the remaining transient ODEs solved numerically to steady state using an integrator package. The results represent steady, isotropic turbulence with constant power input in the large eddies. The effects of phase fraction, drop size, Reynolds number and the model parameter on the turbulent spectrum and drop populations are examined. Computation results comparing the energy spectra are in agreement with the model of Al Taweel & Landau at smaller and intermediate wave numbers, over which range comparisons are valid. (from Authors)

A numerical study of three-dimensional combined buoyancy and thermocapillary convection
Behnia M., Stella F. & Guj G., *International Journal of Multiphase Flow*, 1995, 21/3 (529-542).
In the present study we consider the problem of combined buoyancy and thermocapillary convection in an upright cube with a top free surface. The Navier-Stokes, continuity and energy equations are cast in the velocity-vorticity formulation. The governing equations are discretized by using finite difference approximations. The solution procedure consists of a three level Alternating Direction Implicit (ADI) scheme. In order to save on computational cost, the equations were marched in time using the false transient technique. Results are presented for a typical fluid with a moderate Prandtl number (ie Pr = 7). The effects of positive and negative Marangoni number on the three-dimensional convection at different Rayleigh numbers will be considered and discussed. (from Authors)

A transient two-fluid model for the simulation of slug flow in pipelines - I. Theory
De Henau V. & Raithby G.D., *International Journal of Multiphase Flow*, 1995, 21/3 (335-349).
A one-dimensional transient two-fluid model is developed to predict transient slug flow in pipelines. To account for the interphase interactions, new constitutive relations for the drag coefficient and the virtual mass force for the slug flow regime are derived by applying the conservation equations to a geometrically simplified slug unit. New coefficients in the pressure gradient term in the two-fluid momentum conservation equations are also obtained to account for the non-uniform distribution of the phases and of the pressure drop along a slug unit. The new relations yield a more accurate treatment of the hydrodynamics of slug flow than traditional two-fluid models. (from Authors)

A transient two-fluid model for the simulation of slug flow in pipelines - II. Validation
De Henau V. & Raithby G.D., *International Journal of Multiphase Flow*, 1995, 21/3 (351-363).
This is the second of two papers which discuss a transient two-fluid model for the simulation of slug flow in pipelines. In the first paper, new constitutive relations for the drag coefficient and the virtual mass force for the slug flow regime were derived. In this paper, the new components of the transient two-fluid model are validated by comparing the model predictions for gas (or liquid) fractions and pressure drops for steady-state and transient slug flow in pipes to available numerical and experimental data. These comparisons show the potential of the present approach to predict general transient slug flow problems in pipelines. (from Authors)

A study of terrain-induced slugging in two-phase flow pipelines
De Henau V. & Raithby G.D., *International Journal of Multiphase Flow*, 1995, 21/3 (365-379).
In this paper, a transient two-fluid model is validated for conditions of terrain-induced slugging. This model contains new correlations, for the drag coefficient and the virtual mass force for the slug flow regime, that were presented in previous papers. An experimental study of terrain-induced slugging in a laboratory scale pipeline, made of two uphill and two downhill sections, is also reported. This provides data for the model validation. The model predicts all the major features of the data, and is in good quantitative agreement. (from Authors)

Experimental studies of flooding in nearly horizontal pipes
Ki Yong Choi & Hee Cheon No, *International Journal of Multiphase Flow*, 1995, 21/3 (419-436).
To investigate the flooding phenomenon in nearly horizontal pipes, experimental studies are performed for air and water counter-current flow in a test section with a length of 2160 mm, with three different inner diameters of 40, 60, and 70 mm, with different types of end geometry, and with various inclination angles. The effects of the pipe diameter, end geometry and inclination angle on flooding are examined. Two mechanisms governing the transition to flooding are proposed: inner flooding and entrance flooding. Two local void fractions are measured by parallel wire probes and a scale marked rule in two regions (sub-and super-critical regions). The local effects of the void fraction on slug formation models are investigated. (from Authors)

The split of horizontal semi-annular flow at a large diameter T-junction
Roberts P.A., Azzopardi B.J. & Hibberd S., *International Journal of Multiphase Flow*, 1995, 21/3 (455-466).
Experimental results are presented for the phase split which occurs at a T-junction made up of 0.125 m diameter pipes all on the same horizontal plane. Measurements were performed in the stratified and annular flow regimes and near the boundary of stratified-annular flow. A new phenomenological model is presented to determine the phase split of low liquid hold-up (0.04) semi-annular flow and predictions compared with measurements from this present study, other sources of data and published phase separation models. Excellent agreement is found dependent on the various correlations implemented in the model. (Authors)

Experimental study of the two-phase flow dynamics in nucleate and film pool boiling
Carrica P.M., Leonardi S.A. & Clausse A., *International Journal of Multiphase Flow*, 1995, 21/3 (405-418).
An experimental study is conducted to measure the transient characteristics of the local boiling process close to the heated wall. Nucleate and film boiling two-phase parameters were measured for power oscillations in a small horizontal heater immersed in stagnant liquid. A method for measuring fast temporal variations of void fraction and the interfacial impact rate is presented. The critical heat flux in freons is associated with a sudden transition in the impact rate and the void fraction, which supports the theory of hydrodynamic instability. On the other hand, the experiments in water suggest the existence of two transitions: a hydrodynamic transition from bubbling regime to 'mushroom' regime followed by a liquid film dryout type of CHF, in agreement with the theory of Haramura & Katto. (from Authors)

Gas-liquid annular flow at a vertical tee junction - part I. Flow separation
Charron Y. & Whalley P.B., *International Journal of Multiphase Flow*, 1995, 21/4 (569-589).
Some mechanisms of flow separation at a vertical tee junction with a horizontal outlet are examined in single-phase and two-phase annular flows. In single-phase flow, some characteristics of the vena contracta at the vertical exit and the shape of the dividing streamline boundaries at the tee entrance are measured. In two-phase flow, experiments carried out with cotton threads indicate, that at low branch take-off a large fraction of the liquid film flow entering the branch is rejected to the tree then entrained to the vertical exit. At high branch take-off, some of the liquid in the vertical exit falls back into the tee junction. This phenomenon is examined with a liquid dye and a high speed video camera, indicating two causes for the liquid to fall along this tube and providing some information on the subsequent division of the falling flow. Finally, the predictions of several flow separation models are compared with the present data and the validity of some assumptions made in mechanistic models is reviewed in relation with the observations provided by the present experiments. (Authors)

The distribution of drop size and velocity in gas-liquid annular flow
Fore L.B. & Dukler A.E., *International Journal of Multiphase Flow*, 1995, 21/2 (137-149).
An experimental study of the droplet size and velocity distributions in gas-liquid annular upflow is reported for a 50.8 mm i.d. vertical tube. Included are the effects of liquid viscosity and the radial variation of drop size and velocity. Additional measurements of the centerline gas velocity are used to estimate the gas-droplet slip ratio. The drop size distributions exhibit a bimodal nature, discounting the use of previously suggested functions for their description. Mean drop sizes are observed to increase with liquid flow rate and viscosity. On average, droplets at the tube centerline are observed to travel at 80% of the local gas velocity. (Authors)

An experimental study of viscous resuspension in a pressure-driven plane channel flow
Schaflinger U., Acrivos A. & Stibi H., *International Journal of Multiphase Flow*, 1995, 21/4 (693-704).
Resuspension is a process by which an initially settled layer of heavy particles in contact with a clear fluid above it is set into motion by a laminar shear flow. Experiments were performed in a fully-developed Hagen-Poiseuille stratified channel flow with a clear fluid overlying a suspension, in order to measure the pressure drop and the particle velocity at the suspension-clear fluid interface as functions of the well-mixed particle volume fraction ϕ_i and a Shields number kappa which is a measure of the relative importance of viscous forces to those of gravity. The measured particle velocity at the interface showed good agreement with the theory for small values of kappa. At larger values, however, the observed particle velocity at the interface was up to several times larger than that predicted due to the existence of a detached particle layer that moved very rapidly. Finally, an additional flow instability was observed, a ripple type of instability, when the bottom of the channel was covered by a monolayer of particles. (from Authors)

On the modeling and investigation of polydispersed rotating suspensions
Ungarish M., *International Journal of Multiphase Flow*, 1995, 21/2 (267-284).
The flow field associated with the centrifugal separation of non-colloidal polydispersed (in particular, bidispersed) suspensions is considered. The 'mixture' model framework is developed, and some indicative solutions are obtained and discussed. It is shown that the treatment of rotating polydispersions, in particular for non-small values of particle Taylor number, encounters idiosyncratic physical and mathematical complications. Therefore, the state of knowledge in the centrifugal case lags much behind the gravity analog. (Author)

The fundamental equations of gas-droplet multiphase flow
Young J.B., *International Journal of Multiphase Flow*, 1995, 21/2 (175-191).
This paper describes the derivation of an equation set for the multiphase flow of small polydispersed liquid droplets in a continuous gas-phase consisting of either a pure vapour (of the same chemical species as the liquid droplets) or a mixture of pure vapour and an inert gas. The analysis includes a consistent model to represent the surface energy and entropy of the liquid droplets. Surface effects are normally neglected but must be included if consistency is to be maintained with droplet growth models in which the droplet temperature depends on its radius due to the effects of capillarity. A derivation of the equation for the rate of entropy creation due to departures from equilibrium is also presented. The form of the entropy creation equation allows an interpretation using the

methods of linear irreversible thermodynamics and indicates that some mathematical models of droplet growth in common use, derived on an informal basis, may not be physically realistic in certain circumstances. (from Author)

Studies on the relationship between the statistics of void fraction fluctuations and the parameters of two-phase flows
Kozma R., *International Journal of Multiphase Flow*, 1995, 21/2 (241-251).
Based on Bernoulli statistics of bubble dynamics, a model of void fraction fluctuations in two-phase flows is introduced. The model is used to characterize changes of the intensity of void fraction fluctuations at various two-phase flow regimes, i.e. bubbly, slug and annular flows. Depending on the applied frequency band, the behavior of the band-passed variance of void fraction fluctuations changes significantly. At high frequencies, the band-passed variance increases monotonously with increasing void fractions, while the variance over the whole frequency range has a prominent maximum. By performing model calculations, the relationship between microscopic two-phase flow parameters and macroscopic flow quantities has been analyzed. (Author)

Measurement and correlation of the pressure drop in air-water two-phase flow in horizontal helicoidal pipes
Awwad A., Xin R.C., Dong Z.F., Ebadian M.A. & Soliman H.M., *International Journal of Multiphase Flow*, 1995, 21/4 (607-619).
Experimental investigations are conducted for air-water two-phase flow in horizontal helicoidal pipes of varying configurations. The helicoidal pipes are constructed by wrapping Tygon tubing around cylindrical concrete forms. Four different inside diameters of tubing and two different outside diameters of the cylindrical concrete forms are used to make the helicoidal pipe with different configurations. Also, the helix angle of helicoidal pipes varies up to 20 degrees. The pressure drop of the air-water two-phase flow is measured and the data are well correlated. It was found that the pressure drop multiplier relates strongly to the superficial velocities of air or water, and that the helix angle has almost no effect on the pressure drop, although the pipe and coil diameters have certain effects in low rates of flow. Correlation for two-phase flow in the horizontal helicoidal pipes has been established based on the present experimental data. (from Authors)

Analysis of high density gas-solids stratified pipe flow
Hong J. & Tomita Y., *International Journal of Multiphase Flow*, 1995, 21/4 (649-665).
This paper presents an improved model for high density gas-solids stratified pipe flow, in which the particle-particle interactions between the suspension and the sliding bed are taken into account by introducing suspended particle distribution coefficients, and examines the transition of stable stratified flow. Furthermore, phase diagram, distribution of suspended particles, solids concentration and velocity are predicted by the present model. It is found that particles begin to drop out of the gas phase at the theoretial saltation point at which the velocity is higher than that at the Rizk saltation point. The turning point in a diagram of dimensionless sliding bed height versus Froude number is close to the Rizk saltation point, while the Muschelknautz & Wojahn critical point is reasonable as the lower limit of the stable stratified flow of fine particles. In the phase diagram, the minimum pressure-drop point is to the left of the Rizk saltation point. (from Authors)

Measurement of circumferential and axial liquid film velocities in horizontal annular flow
Sutharshan B., Kawaji M. & Ousaka A., *International Journal of Multiphase Flow*, 1995, 21/2 (193-206).
The mechanism of liquid transport around the inner perimeter of a tube in horizontal annular flow has been experimentally investigated by using a photochromic dye activation technique. The experiments were conducted in a 5.28 m long horizontal tube with 25.4 mm i.d. at near atmospheric pressure conditions using air and kerosene. Over the ranges of gas and liquid flow rates tested, the base film was always seen to drain down the tube wall. During the periodic passage of disturbance waves, however, the spot dye trace moved upward indicating the transport of liquid in an upward direction against the force of gravity. The ripples propagating upward over the base film were also observed to transport the liquid upward, however, their contributions were less significant compared to those of the disturbance waves. These results indicate that the liquid is transported to the upper part of the tube by the disturbance waves and not by the secondary gas flow or other mechanisms as previously hypothesized. (from Authors)

Gas-phase secondary flow in horizontal, stratified and annular two-phase flow
Flores A.G., Crowe K.E. & Griffith P., *International Journal of Multiphase Flow*, 1995, 21/2 (207-221).
Experiments were performed and semi-empirical correlations were developed to both prove the existence of gas-phase secondary flow and to predict annular to stratified transition limits for isothermal and heated horizontal annular two-phase flows in pipes. At the low vapor velocities, where this transition from stratified flow occurs and the entrainment/deposition mechanism is insignificant, secondary flow in the vapor core plays the principal role in the full development of the liquid annulus. Direct measurements of secondary flow are presented along with a simple model to correlate its behavior. The secondary flow model is used in conjunction with the fluid mechanics of the film to derive a boundary model for the onset of annular flow in this transition region. The resulting boundary agrees well with both the thermal and isothermal transition data. (Authors)

Pressure drop in a long radius 90 degrees horizontal bend for the flow of multisized heterogeneous slurries
Mukhtar A., Singh S.N. & Seshadri V., *International Journal of Multiphase Flow*, 1995, 21/2 (329-334).
The pressure loss in a bend is a strong function of the concentration of solid particles, the pipe diameter, the mean flow velocity, radius of curvature of bend, bend angle, specific gravity and PSD of the solid as well as the geometrical configuration of the bend. The data on the pressure drop in bends for a two-phase flow, particularly for multisized particulate slurries, is very limited. Hence in the present work, data has been generated on bend pressure drop on two materials, namely slurries of iron ore and zinc tailings. These two materials have been chosen because they differed widely in specific gravity as well as particle size distribution. (from Authors)

Propagation of voidage waves in a two-dimensional liquid-fluidized bed
Poletto M., Bai R. & Joseph D.D., *International Journal of Multiphase Flow*, 1995, 21/2 (223-239).
Digital video recordings were used to obtain voidage distribution in a narrow fluidized bed with a small gap slightly larger than three particle diameters. From these recordings we determined auto-correlations and power spectra in spatial and temporal and joint spatial-temporal power spectra. Increases in the fluidization velocity lead to increasing disorganized non-periodic flows. Our experimental results are discussed in the light of experimental results and theories found in literature. (Authors)

Large bubbles attached to spargers in downwards two-phase flow
Bacon R.P., Scott D.M. & Thorpe R.B., *International Journal of Multiphase Flow*, 1995, 21/5 (949-959).
It has been demonstrated that a large bubble forms under spargers in downward vertical two-phase flow. The presence of this bubble will have undesirable effects in many situations. A maximum gas entrainment rate for a given liquid flow rate has been identified. This represents an upper limit to the air flow rate which can be used in any such system. It is also a flow rate which must cause a circulating bubble column to stall. This maximum entrainment rate can be increased by the design of the sparger. (from Authors)

Experimental studies on a co-current gas-liquid downflow bubble column
Kundu G., Mukherjee D. & Mitra A.K., *International Journal of Multiphase Flow*, 1995, 21/5 (893-906).
Two-phase co-current vertical downflow systems offer some distinct advantages. In the present work the hydrodynamics of a vertical downflow bubble column fitted with an ejector have been evaluated. Experimental studies have been carried out to evaluate the total pressure gradient and gas holdup. Similarity analysis was used for analysing the data in order to overcome the complex flow behaviour in the system. Correlations have been developed to predict pressure drop and holdup of gas as a function of different physical and dynamic variables. (from Authors)

Pressure drop in gas-liquid flow at microgravity conditions
Zhao L. & Rezkallah K.S., *International Journal of Multiphase Flow*, 1995, 21/5 (837-849).
A new set of experimental pressure drop air-water flow data at microgravity conditions obtained aboard the NASA KC-135 aircraft is reported. Comparisons between pressure drop values at mu - g and 1 - g vertical upward flow suggest that the forced convection two-phase flow frictional pressure drop at microgravity is of the same order of magnitude as that at normal gravity for otherwise the same tube geometry and flow conditions. The main reason seems to be that the flow is mainly inertia dominated over the range of liquid and gas flow rates tested. All models gave reasonable predictions. (from Authors)

Modulation of shear layer thickness due to large bubbles
Loth E. & Cebrzynski M.S., *International Journal of Multiphase Flow*, 1995, 21/5 (919-927).
This study employed a closed-circuit vertical water tunnel modified to create a mixing layer with approximately uniform concentrations of ellipsoidal bubbles. Laser induced fluorescence and digital image analysis was used to determine the shear layer thickness for both single-phase and bubbly flow conditions. In general, it was found that decreases in the passive scalar shear layer thickness were qualitatively associated with increased eddy and braid coherency and higher drag loadings, whereas increases in thickness were observed for Stokes numbers of order unity and supercritical dispersion length scale ratios, perhaps due to bubble wake excitation of the flow. (from Authors)

The inertial coupling force
Verloop W.C., *International Journal of Multiphase Flow*, 1995, 21/5 (929-933).
Mainly two approaches of modelling two-phase flows can be distinguished. One approach, the two-fluid model, considers two-phase flow as a flow of two mutually interacting continua. The other approach treats two-phase flow from a suspension point of view. Herein the flow is regarded as one continuum. An equation for the mixture momentum can be derived which is essentially the same as the well-known Navier-Stokes equation for single-phase flow. When the mixture velocity in the suspension equation is separated into the individual velocities of the two phases, the so-called inertial coupling force arises. In this paper the inertial coupling forces to be applied in the momentum equations of the individual phases are derived. (from Author)

Linear stability of stratified channel flow
Kuru W.C., Sangalli M., Uphold D.D. & McCready M.J., *International Journal of Multiphase Flow*, 1995, 21/5 (733-753).
Linear stability of horizontal gas-liquid stratified flow was solved using a tau spectral method this is valid for all wavenumbers. Pressures of 0.1-10 atm and liquid viscosities of 1-600 cP were examined. Comparison of these results with Kelvin-Helmholtz, integral momentum and rigorous long wave expansion approaches indicates that the approximate models do not correctly predict the point of neutral stability. The discrepancies in the models are due to more than differences in the calculation of interfacial perturbation stress components and differences in the base states. Stability predictions that include gas phase turbulence, as modeled with either a polynomial velocity profile or with imposed boundary conditions obtained from measured pressure and shear stress variations, are similar to laminar results if the interfacial stress and liquid depth are the same. The long wave stability boundary is found to correlate well for different channel height, density ratio and viscosity ratio, using a gas superficial Froude number corrected with a square root of density ratio and a liquid superficial Froude number. For gas-liquid channel flow waves that grow fastest typically have dimensionless wavenumbers of order unity. (from Authors)

Experimental study of air-water two-phase flow through a fracture (narrow channel)
Fourar M. & Bories S., *International Journal of Multiphase Flow*, 1995, 21/4 (621-637).
Two-phase (air-water) flow experiments were conducted in artificial horizontal fractures (narrow channels). Two experimental set-ups were utilized. One set of experiments was performed by using two glass plates. The second set of experiments was performed using two bricks made of baked clay. Air and water were injected separately, through alternating capillary tubes for the first set-up and through a porous medium for the second. These flow structures show more similarity to those observed in pipes than to those expected in porous media. Using the formalism developed for two-phase flow in pipes, and by taking experimental observations into account, a theoretical relationship for the two-phase pressure gradient is proposed. This relationship is evaluated with experimental data. (from Authors)

Formation of waves on a horizontal erodible bed of particles
Kuru W.C., Leighton D.T. & McCready M.J., *International Journal of Multiphase Flow*, 1995, 21/6 (1123-1140).
The mechanisms responsible for the initial growth of sand waves on the surface of a settled layer of particles are studied experimentally and theoretically. Experimentally obtained regime maps of sand wave behavior and data on the wavelengths of the sand waves that first appear on the surface of the settled bed are presented. Turbulence in the clear liquid is not necessary for formation of waves and there is no dramatic change in behavior as the flowrate is increased across the turbulent transition. The initial wavelength varies as the Froude number to the first power. Because a flowing suspension phase is observed before waves form, linear stability analysis of the clear-layer-suspension-layer cocurrent two-phase flow is presented. (from Authors)

Bubble interaction in low-viscosity liquids
Stewart C.W., *International Journal of Multiphase Flow*, 1995, 21/6 (1037-1046).
An experimental study investigated how freely rising ellipsoidal bubbles approach each other, make contact and coalesce or breakup. Pulsed planar swarms of 10-20 bubbles with Eotvos numbers from 6.0 to 27.5 were released simultaneously in aqueous solutions of 0-48 wt% sugar with Morton numbers from 3.2×10^{-11} to 3.7×10^{-6}. Bubble interaction was recorded by a video camera following the rising bubbles. Essentially, all coalescence and breakup events occurred after, not during, wake-induced collisions by a complex process related to the bubble vortex shedding cycle. This same process was also found in multi-bubble clusters and may account for excess turbulent kinetic energy generation in bubbly flow. (Author)

A note on the axisymmetric interaction of pairs of rising, deforming gas bubbles
Boulton-Stone J.M., Robinson P.B. & Blake J.R., *International Journal of Multiphase Flow*, 1995, 21/6 (1237-1241).
Many studies of the motion of gas bubbles are reported in the literature. Due to the complexity of the problem, much of the theory is

confined to the steady motion of bubbles assumed to be spherical or oblate ellipsodial. Nevertheless, the unsteady initial rise and deformation of bubbles has also received some attention. Most physically realistic models of gas bubble formation deal with a bubble emerging from some form of orifice. The rise from rest of an initially spherical gas bubble is a more fundamental problem. Calculations of the unsteady rise of single deforming bubbles have been made with the aim of examining vortex ring bubbles. We examine some of the effects on the motion and deformation due to the interaction of a pair of bubbles rising in an axisymmetric geometry. (from Authors)

Gas turbulence modulation in the pneumatic conveying of massive particles in vertical tubes
Bolio E.J. & Sinclair J.L., *International Journal of Multiphase Flow*, 1995, 21/6 (985-1001).
The present work is concerned with the interaction between large particles and gas phase turbulence. Gas turbulence modulation in these systems is considered to be dominated by a generation mechanism which arises due to the presence of wakes behind particles. Following a recent proposal, a closure for gas turbulence modulation accounting for the effect of wakes is employed within the context of a mathematical model for particle-laden, turbulent flows. The model accounts for particle-particle and particle-wall interactions associated with larger particles based on concepts from gas kinetic theory. It is shown that due to the significant flattening of the mean gas velocity profile with the addition of particles, and the corresponding decrease in turbulent energy production, a generation mechanism must be present in order to produce gas velocity fluctuation predictions which are consistent with the experimental measurements, even in the case where the experimental results indicate a net suppression of gas phase turbulence in the presence of particles. (Authors)

Relationships between distributions of chord lengths and distributions of bubble sizes including their statistical parameters
Liu W. & Clark N.N., *International Journal of Multiphase Flow*, 1995, 21/6 (1073-1089).
The performance of fluidized beds is strongly influenced by bubble behavior. Among various hydrodynamic properties, bubble size distributions are of prime concern, but in practice, bubble size is not readily measured. When a probe is used to determine bubble size, it intersects a bubble with a chord length other than the largest vertical dimension. The relationships between the size distribution of bubbles in the bed, the size distribution of bubbles touching the probe and the distribution of chord lengths must be resolved for correct interpretation of probe signals. A method for translating statistical parameters, namely mean and standard deviation of chord lengths to mean and standard deviation of bubble sizes, and an approach to infer the size distribution of bubbles touching the probe and the size distribution of bubbles in the bed system by using the distribution of chord lengths measured by a probe in closed form are proposed for the first time. (Authors)

Gas-particle two-phase turbulent flow in a vertical duct
Cao J. & Ahmadi G., *International Journal of Multiphase Flow*, 1995, 21/6 (1203-1228).
Two-phase gas-phase turbulent flows at various loadings between the two vertical parallel plates are analyzed. A thermodynamically consistent turbulent two-phase flow model that accounts for the phase fluctuation energy transport and interaction is used. The computational model is first applied to dilute gas-particle turbulent flow between two parallel vertical walls. The predicted mean velocity and turbulence intensity profiles are compared with the experimental data of Tsuji et al. (1984) for vertical flows, and good agreement is observed. Examples of additional flow properties such as the phasic fluctuation energy, phasic fluctuation energy production and dissipation, as well as interaction momentum and energy supply terms are also presented and discussed. (from Authors)

An experimental investigation of outflow of liquids from single-outlet vessels
Schmidt O. & Kubie J., *International Journal of Multiphase Flow*, 1995, 21/6 (1163-1168).
This paper considers the outflow of liquid from a single outlet vessel, ie a vessel in which the outflowing liquid is displaced by another fluid which enters the vessel through the same opening. The simplest possible arrangement is investigated: a sealed axisymmetric cylindrical vessel with an outlet in its base, in which water is displaced by air. It is shown experimentally that the average liquid discharge velocity is independent of the liquid level in the vessel and the shape of the outlet for the range of outpets employed; it increases weakly with both the diameter of the vessel and the diameter of the outlet. (Authors)

Experimental and theoretical study of the distribution of mass concentration of solid particles in the two-phase laminar boundary layer on a flat plate
Hussainov M., Kartushinsky A., Mulgi A., Rudi U. & Tisler S., *International Journal of Multiphase Flow*, 1995, 21/6 (1141-1161).
The essential non-uniform distribution of particle mass concentration, with vivid maximum value inside the two-phase laminar boundary layer developed in the flow past a flat plate, has been found by experimental investigation. The mathematical model based on the approximation of the dispersed phase within the viscous fluid, taking into consideration pseudoviscosity coefficients, has been elaborated for description of the motion and distribution of solid admixture. The dispersed phase is considered as a polydispersed phase, which consists of a finite number of particle fractions. The numerical results from the simplest version of the model are in good agreement with the experimental results. (from Authors)

Numerical simulation of the ticking hourglass
Manger E., Solberg T., Hjertager B.H. & Vareide D., *International Journal of Multiphase Flow*, 1995, 21/4 (561-567).
Using a two-phase fluid flow model based on kinetic theory for granular flow the oscillatory flow of sand in an hourglass first observed experimentally by Wu et al. has been simulated. The oscillations appear to be caused by the interaction between the gas pressure and the flow of sand through the orifice of the hourglass. The simulations confirm the ticking of the hourglass and the suggested mechanisms for this behaviour found experimentally by Wu et al. The simulations also show bubbles of air rising through the powder as observed experimentally. (Authors)

Electrophoresis of two arbitrary axisymmetric prolate particles
Ke-Li Sun & Wang-Yi Wu, *International Journal of Multiphase Flow*, 1995, 21/4 (705-714).
The electrophoretic motion of two freely-suspended, non-conducting arbitrary coaxial prolate particles of revolution with thin electrical double layers is investigated using the method of internal distribution of singularities. Corrections to the Smoluchowski equation due to particle interactions are determined. The electrophoretic mobilities of two prolate spheroid particles are calculated for different distances of two particles, various ratios of zeta potentials and a variety of parameters of particle shape. It is also found that the electrophoretic particles in our problem do not interact with one another when they have equal surface zeta potentials. (Authors)

Hydrodynamics of gas-solid fluidization
Kim K.S., Zhu J.X. & Grace J.R., *International Journal of Multiphase Flow*, 1995, 21/Suppl. (141-193).
Work published on gas-solid fluidization since 1986 is reviewed, with emphasis on findings that appear to be new or to represent

significant steps forward in advancing the understanding of fluidization phenomena, or which have potential practical implications. Hydrodynamic regimes ranging from bubbling to fast fluidization are addressed. Mixing phenomena and circulating fluidized beds are given special attention. (Authors)

Numerical study of enhanced oil recovery using surfactants
Chatterjee A. & Muralidhar K., *International Journal of Numerical Methods for Heat & Fluid Flow*, 1995, 5/4 (301-311).
The analysis of enhanced oil recovery using surfactants is presented here. Surfactants lower the surface tension between oil and water and hence the capillary resistance to flow. The mathematical description of this problem requires modelling of multi-phase flow in a porous medium. A pressure-based formulation has been used in the present study. The governing partial differential equations have been solved by a finite difference method. Both Newtonian and non-Newtonian (shear thinning) behaviour of oil are considered. Results clearly show an improvement in oil recovery in the presence of surfactants. (from Authors)

Agriculture and water quality: a regional study
Foy R.H. & Kirk M., *Journal - Chartered Institution of Water & Environmental Management*, 1995, 9/3 (247-256).
Water quality, measured on a fisheries ecosystem scale of 1 (good/salmonid) to 6 (bad/fish absent), of forty-two lowland streams in two Northern Ireland river catchments was inversely correlated with the stocking rate of grazing animals. A decrease in water quality of one class was associated with an increase in the combined grazing/stocking rate of cattle and sheep of 0.6 dairy cow equivalents/ha. This dairy cow equivalent stocking rate was significantly correlated with maximum BOD and total amm.N concentrations and minimum dissolved-oxygen levels. The worst pollution events, with BOD concentrations in excess of 100 mg/l, occurred at the end of May and were caused by discharges of silage effluent. Smaller BOD peaks, which occurred in late winter and early spring, were related to the land spreading of animal slurries. It was concluded that poultry and pig farms were not having a major impact of water quality. (Authors)

Effects of hoop stress, initial shear stress, and shear viscosity ratio on the steady two-phase fiber spinning
Woei-Shyong Lee, *Journal - Chinese Institute of Chemical Engineers*, 1995, 26/3 (174-181).
The steady analysis of a two-phase fiber spinning was further investigated in this study. A simple model was selected to examine a two-phase flow in which the two fluids are a Newtonian fluid as the core layer and an upper-conventional Maxwell fluid as the skin layer, respectively. Additionally, the hoop stress was considered to investigate the effect on the flow behavior of the two-phase fiber spinning. Steady analysis results indicated that the hoop stress can affect the flow only at the region near the die exit. Those results revealed that the flow system is insensitive to the selection of the initial shear stress unless the initial shear stress is extremely large. Furthermore, the ratio of shear viscosities of two different materials was varied to make a comparison of the flow behaviors, revealing that the material with a high shear viscosity dominates the flow. (Author)

The chemical buffer system in raw and digested animal slurry
Sommer S.G. & Husted S., *Journal of Agricultural Science (Cambridge)*, 1995, 124/1 (45-53).
Slurry pH is of great importance for the regulation of ammonia volatilization from livestock slurry, and therefore more knowledge of the buffer system controlling pH is urgently needed for modelling ammonia losses from stored and surface-applied slurry. The composition of 17 different Danish cattle, pig and biogas plant-digested slurries was studied. The results were used to describe the main buffer components in the slurries, and to discover the most important chemical components necessary for modelling slurry pH. The results showed that the pH of slurry was mainly controlled by the species NH_4^+/NH_3, $CO_2/HCO_3^-/CO^{2-}{}_3$ and CH_3COOH/CH_3COO^-, and that ion pair formation did not change the ionic balance significantly. There were only trace amounts of Ca^{2+}, Mg^{2+} and inorganic phosphates in solution due to precipitation of $CaCO_3$ (calcite) and $MgNH_4PO_4.6H_2O$ (struvite). Measured electrical conductivities were found to be strongly correlated with the calculated ionic strength. (Authors)

The Eulerian-Lagrangian transformation in two-dimensional random flows
Hesthaven J.S., Nielsen A.H., Pecseli H.L. & Rasmussen J.J., *Journal of Atmospheric & Terrestrial Physics*, 1995, 57/3 (215-223).
The relation between the Eulerian and the Lagrangian correlation functions is studied in two spatial dimensions. Simple analytical expressions for the full space-time varying Eulerian correlation are derived solely on the basis of the one-dimensional wavenumber power spectrum of the velocity fluctuations. It is demonstrated that an extension of the arguments giving the foregoing results allows also for derivation of analytical expressions for the Lagrangian autocorrelation function. The results are supported by direct numerical solutions of the non-dissipative Euler equations for the fluctuating velocity. (from Authors)

Correlation of solubilities for CO_2 and NH_3 in H_2O using Soave-Redlich-Kwong equation of state with MHV2 mixing rule
Mishima K., Sugino J., Ueno M., Matsuyama K. & Nagatani M., *Journal of Chemical Engineering of Japan*, 1995, 28/2 (144-147).
The flexibility and applicability of the modified Huron-Vidal second order (MHV2) mixing rule have been examined for the correlation of solubilities for CO_2 and NH_3 in H_2O as an example of a system containing volatile weak electrolytes. The MHV2 mixing rule is one of the excess Gibbs energy (g^E) mixing rules. The g^E mixing rules are well known to be able to predict vapor-liquid equilibria (VLE) of polar or non-polar mixture systems under high pressure. We have used the Soave-Redlich-Kwong equation of state (SRK-EOS) with the MHV2 mixing rule. Assuming a series reaction between CO_2 and NH_3 in the aqueous phase and the temperature dependence of the equilibrium constant, the solubility behavior of the CO_2-NH_3-H_2O system can be correlated with reasonable accuracy. (Authors)

Electrostatic phenomena in gas fluidized beds and influence of non-geometrical variables
Guardiola J., Rojo V. & Ramos G., *Journal of Chemical Engineering of Japan*, 1995, 28/2 (231-234).
Static charge generation on the surface of insulating materials is well known in technological processes where if frequency gives rise to trouble or danger. The phenomenon is usually referred to as contact or friction electrification (triboelectrification). Solid-gas fluidization coincides with the phenomena, specifically when there is no escape path for the generated electric charge. Understanding of electric charge production in fluidized beds is important to avoid bad performance and it can be applied to processes of mixture separation (solid-solid binary mixtures, or for isolating polluting or valuable particles that are found in industrial flows). This paper studies the influence of non-geometric variables - the fluidization rate, particle size and relative humidity - on the appearance of electric charge in the fluidized bed. Non-geometric is taken as equivalent to dynamic variables because it allows relative humidity to be included. (Authors)

Gas-liquid turbulent two phase flow along vertical flat plate with gas evolution
Matsuura A., Nakamura H., Hiraoka S., Tada Y., Kato Y. & Koh Seung-Tae, *Journal of Chemical Engineering of Japan*, 1995, 28/3 (250-256).
Gas-liquid turbulent two phase flow along a vertical flat plate with gas evolution was numerically simulated with a two-fluid model and Plandtl's mixing length theory using the SIMPLER method. The calculation domain was assumed to be two-dimensional and

gas bubbles to be evolved uniformly from the plate surface. The computed velocity profiles were affected by void fraction on the wall and the bubble diameters, but not by the bubble departure velocity from the plate surface. Both the gas and liquid velocity profiles and the computed wall shear stress with the present model were qualitatively and quantitatively coincident with those measured using LDV for the vertical flat plate electrode with H_2 or O_2 gas evolution. (Authors)

Application of fuzzy logic to moisture control in fluidized bed granulation
Watano S., Sato Y. & Miyanami K., *Journal of Chemical Engineering of Japan*, 1995, 28/3 (282-287).
Application of fuzzy logic to control of moisture content during fluidized bed granulation is described. To avoid overshoot and to maintain control stability, a linguistic algorithm employing IF-THEN rules, with process lag element taken into consideration, was constructed using moisture content and its changing rate as input variables. Good response and stability without overshoot, which had been impossible to attain with conventional techniques, were achieved by adopting the developed systems. This system also maintained stability by favorable response to rapid increase in fluidization air velocity during operation. (from Authors)

A correlation for bed voidage in three-phase fluidized bed
Hirata A., Bulos F.B. & Noguchi M., *Journal of Chemical Engineering of Japan*, 1995, 28/4 (400-404).
Previously published data of three-phase fluidization were correlated to develop a new empirical correlation for predicting bed voidage in gas-liquid-solid fluidized beds. The proposed correlation model, when used in conjunction with any suitable two-phase model for bed voidage, can serve as a correlation for bed voidage in both two-and three-phase fluidized beds. It describes the bed expansion and contraction phenomena observed during fluidization and is valid even as the superficial gas velocity approaches zero. A new criterion for quantitifying the bed expansion and contraction phenomena based on this empirical model is derived and is also discussed in this paper. (Authors)

Friction on a solid sphere exposed to gas-liquid and gas-liquid-solid flow in bubble column and fluidized bed reactors
Essadki H., Delmas H. & Svendsen H.F., *Journal of Chemical Technology & Biotechnology*, 1995, 62/3 (301-309).
Local velocity gradients on a solid spherical surface have been studied in a bubble column and in two-and three-phase fluidized beds, in order to clarify the influence of gas flow. The electrochemical method, measuring apparent local mass transfer coefficients, was verified and used to obtain the local velocity gradients, shear stresses and total frictional forces. The observed mass transfer rate was independent of liquid velocity, owing to a non-changing flow structure around the particles and not to averaging opposing effects. Use of velocity gradient measurements, including span of fluctuations and exposure time, to predict biomass growth and mechanical degradation in a reactor is also discussed. (from Authors)

Measurement and prediction of pressure drop in two-phase flow
Ferguson M.E.G. & Spedding P.L., *Journal of Chemical Technology & Biotechnology*, 1995, 63/3 (262-278).
Experimental data for air-water two-phase co-current flow in two different pipe diameters were used to test the prediction of pressure drop by a number of existing theories and correlations. Several models are shown to be useful for prediction, particularly with the stratified regimes which have proved difficult to handle in the past. The model suggested by Olujic proved to be of particular value. (Authors)

Biological and integrated chemical-biological treatment of PCB congeners in soil/sediment-containing systems
Aronstein B.N. & Rice L.E., *Journal of Chemical Technology & Biotechnology*, 1995, 63/4 (321-328).
A series of experiments was conducted on the integrated chemical-biological treatment of ^{14}C-labelled polychlorinated biphenyl congeners in soil/sediment-containing systems. The hydroxyl radicals, generated by Fenton's reagent (1% (v/v) H_2O_2, 1 mmol dm^{-3} $FeSO_4$), followed by inoculation with Pseudomonas sp., strain LB400, and Alcaligenes eutrophus, strain H850, increased the overall extent of 2-chlorobiphenyl mineralisation in slurries of contaminated manufactured gas plant soil and sediment by 2.9 and 7.4 times, respectively, compared with biodegradation alone. In uncontaminated topsoil slurries the effect of chemical pretreatment was not observed. In the systems amended with 2,2 minutes ,4,4 minutes -tetrachlorobiphenyl, the application of Fenton's reagent increased the overall extent of mineralisation by 2.4 times, compared with the biological treatment alone, but had no effect in the slurries of contaminated soil and sediment. (from Authors)

Stepwise pumping approach to improve free phase light hydrocarbon recovery from unconfined aquifers
Cooper Jr G.S., Peralta R.C. & Kaluarachchi J.J., *Journal of Contaminant Hydrology*, 1995, 18/2 (141-159).
A stepwise, time-varying pumping approach is developed to improve free phase oil recovery of light non-aqueous phase liquids (LNAPL) from a homogeneous, unconfined aquifer. Stepwise pumping is used to contain the floating oil plume and obtain efficient free oil recovery. The pumping approach is developed using detailed simulations, multiple linear regression and graphical plots. The approach uses ARMOS, an areal two-dimensional multiphase flow, finite-element simulation model. The best stepwise pumping strategy recovers more free oil by reducing the amount of residual oil left in the system due to pumping drawdown. This stepwise pumping approach can be used to enhance free oil recovery and provide for cost-effective design and management of LNAPL cleanup. (from Authors)

Electrokinetic transport of colloidal particles with heterogeneous surfaces
Anderson J.L., *Journal of Electrostatics*, 1995, 34/2-3 (189-203).
In the past few years mathematical techniques for solving Stokes-flow problems have been applied to particles with nonuniformly distributed charges on their surfaces to model the motion of colloids of various shapes. With these advances it is possible to determine the translational and rotational velocities of spheroidal and chain-like particles given some information about the charge distribution, for example, the first few moments. These models make it possible to use electrokinetic measurements to deduce properties of the charge distribution on colloids. The theory can also be applied to predict the rotational velocity of a slender particle of uniform charge in a nonuniform electric field. (from Author)

Process concepts using field-stabilized two-phase fluidized flow
Rosensweig R.E., *Journal of Electrostatics*, 1995, 34/2-3 (163-187).
Studies over the past two to three decades concerning the influence of electromagnetic fields on the stability of two-fluid systems have defined a remarkable diversity of phenomena and related application concepts. This report examines stationary and moving bed applications of field-stabilized gas-solids and liquid-solids fluidized systems. The application concepts range over processes for the control of chemical reactions, the separation of molecular species, and the transfer of heat, mass, and momentum in areas of petrochemical processing, pollution control, power generation, and biotechnology. (Author)

Effect of ambient stratification on buoyant jets in cross-flow
Hwang R.R., Yang W.C. & Chiang T.P., *Journal of Engineering Mechanics*, 1995, 121/8 (865-872).

A numerical technique for integrating the fully elliptic Reynolds-averaged Navier-Stokes and diffusion equations has been used to investigate the effect of ambient density stratification on the flow characteristics of a vertical force plume in a cross-flow of a stably linear stratified environment. Some basic, flow features and a structure for the interaction of the buoyant jets with a density-stratified cross-flow are obtained. The results show that the ambient stratification tends to inhibit the flow development of the buoyant source and to encourage the formation of secondary and third pairs in the jet cross section as a plume flowing downstream. It then results in causing the jet-flow oscillation from its maximum height-of-rise. (from Authors)

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Phenanthrene removal from soil slurries with surfactant-treated oxides
Jae-Woo Park & Jaffe P.R., *Journal of Environmental Engineering - ASCE*, 1995, 121/6 (430-437).
A soil-slurry washing technique to decontaminate soils containing low-solubility nonionic organic pollutants was investigated, using phenanthrene as a model pollutant. The technique is based on first transferring the sorbed phenanthrene from the soil to anionic surfactant-coated oxide particles, and then separating these anionic surfactant-coated oxide particles with the sorbed phenanthrene from the soil slurry via a magnetic separation technique. The decontamination of two soils with different particle sizes and soil organic matter content was investigated. The proposed soil-slurry washing technique was effective in removing a strongly sorbing nonionic organic contaminant from soil slurries. Various operational scenarios of multistage soil-slurry reactors were evaluated with a mathematical model. (Authors)

Modeling of CSO-induced pollutant transport in Mt. Hope Bay
Wenrui Huang & Spaulding M., *Journal of Environmental Engineering - ASCE*, 1995, 121/7 (492-498).
Combined sewage overflow (CSO) discharges due to a storm event create strongly stratified pollutant plumes on the surface of Mt. Hope Bay, of Rhode Island and Massachusetts. To examine the CSO-induced pollutant impact, a three-dimensional numerical model was used to simulate the transport processes in the bay resulting from a dye release at CSO discharges during a storm event on September 22, 1990. Model predictions reasonably showed that the CSO plume remained concentrated near the surface and was transported down bay along the eastern shore. (from Authors)

Three-dimensional calculations of the simple shear flow around a single particle between two moving walls
Nirschl H., Dwyer H.A. & Denk V., *Journal of Fluid Mechanics*, 1995, 283/- (273-285).
Three-dimensional solutions have been obtained for the steady simple shear flow over a spherical particle in the intermediate Reynolds number range 0.1 = or Re = or 100. The shear flow was generated by two walls which move at the same speed but in opposite directions, and the particle was located in the middle of the gap between the walls. The particle-wall interaction is treated by introducing a fully three-dimensional Chimera or overset grid scheme. The Chimera grid scheme allows each component of a flow to be accurately and efficiently treated. For low Reynolds numbers and without any wall influence we have verified the solution of Taylor (1932) for the shear around a rigid sphere. A detailed analysis of the influence of the wall distance and Reynolds number on the surface distributions of pressure, shear stress and heat transfer has also been carried out. (from Authors)

Stability of eccentric core-annular flow
Huang A. & Joseph D.D., *Journal of Fluid Mechanics*, 1995, 282/- (233-245).
Perfect core-annular flows are two-phase flows, for example of oil and water, with the oil in a perfectly round core of constant radius and the water outside. Eccentric core flows can be perfect, but the centre of the core is displaced off the centre of the pipe. The flow is driven by a constant pressure gradient, and is unidirectional. This kind of flow configuration is a steady solution of the governing fluid dynamics equations in the cases when gravity is absent or the densities of the two fluids are matched. The position of the core is indeterminate so that there is a family of these eccentric core flow steady solutions. We study the linear stability of this family of flows using the finite element method to solve a group of PDEs. The large asymmetric eigenvalue problem generated by the finite element method is solved by an iterative Arnoldi's method. (from Authors)

Mixing induced by oscillatory stratified flow past a right-circular cylinder
Perera M.J.A.M., Fernando H.J.S. & Boyer D.L., *Journal of Fluid Mechanics*, 1995, 284/- (1-21).
A series of laboratory experiments was performed to investigate the overall mixing characteristics of oscillatory stratified flow past an insolated topography. An expression is derived to relate the rate of change of potential energy of the system to the basin-averaged buoyancy flux. This formula was then used to calculate the mean buoyancy flux from measurements of the rate of change of potential energy of the fluid system. Basin-averaged diapycnal eddy diffusivities for the experiments were evaluated and the results were found to be in good agreement with the predictions of a heuristic model based on the energetics of the mixing. Observations on the spreading of intrusions and the evolution of the density field are also presented. (from Authors)

The effects of a vertical contraction on turbulence dynamics in a stably stratified fluid
Thoroddsen S.T. & Van Atta C.W., *Journal of Fluid Mechanics*, 1995, 285/- (371-406).
We have experimentally studied the effects of mean strain on the evolution of stably stratified turbulence. Grid-generated turbulence (Re_{lambda} = or 25) in a stable linear mean background density gradient was passed through a two-dimensional contraction, contracting the stream only in the vertical direction. Comparison between non-stratified and stratified experiments shows that the stratification significantly reduces the vertical velocity fluctuations. Velocity spectra show that the revival of vertical velocity fluctuations, due to the strong restratification, starts at the very largest scales but is then subsequently transferred to smaller scales. The distance from the turbulence-generating grid to the entrance of the contraction is an important parameter which was varied in the experiments. The evolution of the various turbulence length scales is described. Two-point measurements of velocity and temperature transverse intergral scales were also performed inside the contraction. (from Authors)

Cavitation in the rotational structures of a turbulent wake
Belahadji B., Franc J.P. & Michel J.M., *Journal of Fluid Mechanics*, 1995, 287/- (383-403).
Experiments show that cavitation, if moderately developed, makes three kinds of vortical coherent structures visible inside the turbulent wake of a two-dimensional obstacle: Benard-Karman vortices, streamwise three-dimensional vortices and finally the

vortices which appear on the borders of the very near wake. The latter, which are called here near-wake vortices, result by successive pairing in the first ones and there is some indication that they are also the origin of streamwise vortices. Cavitation is not a passive agent of visualization, as can be established on the basis of fundamental arguments, and it reacts with the flow as soon as it appears; when it is developed, it breaks the connection between the elongation rate and the vorticity rate of the vortex filaments. By adapting a simple model due to Kermeen & Parkin (1957) and Arndt (1976), and counting near-wake vortices, it is possible to accurately predict the conditions of cavitation inception. (from Authors)

Low Reynolds number motion of bubbles, drops and rigid spheres through fluid-fluid interfaces
Manga M. & Stone H.A., *Journal of Fluid Mechanics*, 1995, 287/- (279-298).
The low Reynolds number buoyancy-driven translation of a deformable drop towards and through a fluid-fluid interface is studied using boundary integral calculations and laboratory experiments. The Bond numbers characteristic of both the drop and the initially flat fluid-fluid interface are sufficiently large that the drop and interface become highly deformed, substantial volumes of fluid may be entrained across the interface, and breakup of both interfaces may occur. For sufficiently large drop Bond numbers, the drop may deform continuously, developing either an elongating tail or enlarging cavity at the back of the drop, analogous to the deformation characteristic of a single deformable drop in an unbounded fluid. The film of fluid between the drop and interface thins most rapidly for those cases that the drop enters a more viscous fluid or has a viscosity lower than the surrounding fluids. (from Authors)

The occurrence of moist 'anticonvection' in a water-air system
Perestenko O.V. & Ingel Kh. L., *Journal of Fluid Mechanics*, 1995, 287/- (1-20).
This paper discusses the possibility of 'anticonvection' occurring in a water-air system, taking into account evaporation, stratification with respect to moisture, thermocapillary effects and the presence of a surface heat source at the water-air interface. A linear problem of stability is solved, in which the Rayleigh number analogues in each of the fluids are its eigenvalues in one case and the increments of disturbances in the other. The mechanism of the oscillatory regime of the loss of stability in the system under study was found and considered in detail. Increments and wavelengths of the growing modes are calculated, and the possibility of experimental investigation of moist anticonvection in laboratory and field conditions is discussed. (from Authors)

Flow regimes and relative permeabilities during steady-state two-phase flow in porous media
Avraam D.G. & Payatakes A.C., *Journal of Fluid Mechanics*, 1995, 293/- (207-236).
Steady-state two-phase flow in porous media was studied experimentally, using a model pore network of the chamber-and-throat type, etched in glass. Optical observations and macroscopic measurements were used to determine the flow regimes, and to calculate the corresponding relative permeabilities and fractional flow values. Four main flow regimes were observed and videorecorded, namely large-ganglion dynamics (LGD), small-ganglion dynamics (SGD) , drop-traffic flow (DTF) and connected pathway flow (CPF). A map of the flow regimes is given. The relative permeabilities are shown to correlate strongly with the flow regimes. (from Authors)

Observations and scaling of travelling bubble cavitation
De Chizelle Y.K., Ceccio S.L. & Brennen C.E., *Journal of Fluid Mechanics*, 1995, 293/- (99-126).
Recent observations of growing and collapsing bubbles in flows over axisymmetric headforms have revealed the complexity of the 'micro-fluid-mechanics' associated with these bubbles. Among the complex features observed were the bubble-to-bubble and bubble-to-boundary-layer interactions which leads to the shearing of the underside of the bubble and alters the collapsing process. All of these previous tests, though, were performed on small headform sizes. The focus of this research is to analyse the scaling effects of these phenomena due to variations in model size, Reynolds number and cavitation number. An unsteady numerical code was developed which uses travelling sources to model the interactions between the bubble (or bubbles) and the pressure gradients in the irrotational flow outside the boundary layer on the headform. (from Authors)

On penetrative convection at low Peclet number
Lister J.R., *Journal of Fluid Mechanics*, 1995, 292/- (229-248).
A new theoretical model is developed for the growth of a convecting fluid layer at the base of a stable, thermally stratified layer when heated from below. A similarity solution is derived for the case of an initially linear temperature gradient and uniform heating. Solutions are also given for a heat flux that undergoes a step change and for a heat flux determined from a four-thirds power law with a fixed base temperature. Numerical calculations show that the predictions of the model are in good agreement with previously reported experimental measurements. Similar calculations are applicable to a wide range of geophysical problems in which the tendency for diffusive restratification is comparable to that for mixed-layer deepening by entrainment. (from Author)

The rise velocity and shape of bubbles in pure water at high Reynolds number
Duineveld P.C., *Journal of Fluid Mechanics*, 1995, 292/- (325-332).
The velocity and shape of rising bubbles, with an equivalent radius of 0.33-1.00 mm, in 'hyper clean' water, have been experimentally determined. For the small bubbles there is perfect agreement with theory, proving that this water can be considered as pure (no surfactants). For the larger bubbles there is a small discrepancy due to an overestimation in the theory. (Author)

Stratified circular Couette flow: instability and flow regimes
Boubnov B.M., Gledzer E.B. & Hopfinger E.J., *Journal of Fluid Mechanics*, 1995, 292/- (333-358).
The stability conditions of the flow between two concentric cylinders with the inner one rotating (circular Couette flow) have been investigated experimentally and theoretically for a fluid with axial, stable linear density stratification. Experiments show that stratification has a stabilizing effect on the flow with the critical Reynolds number depending on N, in agreement with linear stability theory. The theoretical analysis is based on a linear stability consideration of the axisymmetric problem. This gives bounds of instability in the parameter space (OMEGA,N) for given vertical and radial wavenumbers. These bounds are in qualitative agreement with experiments. The possibility of oscillatory-type instability (overstability) observed experimentally is also discussed. (from Authors)

On convection and mixing driven by sedimentation
Cardoso S.S.S. & Woods A.W., *Journal of Fluid Mechanics*, 1995, 285/- (165-180).
Novel laboratory experiments involving sedimentation below a two-layer stratified region show that turbulent mixing and entrainment across the top density interface is significant for a broad range of the Richardson number. A simple theoretical model predicting the rate of erosion of the stratification above the convecting layer agrees well with these experiments. The model is then extended to include the case of an overlying continuous density gradient and compared successfully with both new experimental data and the original data of Kerr (1991). Our model calculations suggest that turbulent mixing an entrainment

driven by sedimentation may be significant in the atmospheric and oceanic contexts, in both of which stratification is weak. (from Authors)

Self-diffusion of bimodal suspensions of hydrodynamically interacting spherical particles in shearing flow
Chingyi Chang & Powell R.L., *Journal of Fluid Mechanics*, 1995, 281/- (51-80).
We study the average mobilities and long-time self-diffusion coefficients of a suspension of bimodally distributed spherical particles. Stokesian dynamics is used to calculate the particle trajectories for a monolayer of bimodal-sized spheres. Hydrodynamic forces only are considered and they are calculated using the inverse of the grand mobility matrix for far-field many-body interactions and lubrication formulae for near-field effects. We determine both the detailed microstructure (eg the pair-connectedness function and cluster formation) and the macroscopic properties (eg viscosity and self-diffusion coefficients). Effects of both the size ratio and the relative fractions of the different-sized particles are examined. We also consider the effect of the initial configuration by letting the spheres be both organized (size segregated) and randomly placed. We find that it takes a longer time for a suspension with an initially organized structure to achieve steady state than one with a random structure. (from Authors)

Baroclinic instability of quasi-geostrophic flows localized in a thin layer
Benilov E.S., *Journal of Fluid Mechanics*, 1995, 288/- (175-199).
This paper examines the baroclinic instability of a quasi-geostrophic flow with vertical shear in a continuously stratified fluid. The flow and density stratification are both localized in a thin upper layer. Disturbances whose wavelength is much smaller than the deformation radius (based on the depth of the upper layer) are demonstrated to satisfy an 'equivalent two-layer model' with properly chosen parameters. For disturbances whose wavelength is of the order of, or greater than, the deformation radius, a sufficient stability criterion is derived. The above analysis is applied to the subtropical and subarctic frontal currents in the Northern Pacific. The effective time of growth of disturbances (i) is found to be 16-22 days, the characteristic spatial scale is 130-150 km. (Author)

Stability of large-amplitude geostrophic flows localized in a thin layer
Benilov E.S., *Journal of Fluid Mechanics*, 1995, 288/- (157-174).
In this paper the dynamics of geostrophic flows localized in a thin layer of continuously stratified fluid, which overrides a thick homogeneous layer are studied. The displacement of isopycnal surfaces is assumed large; the beta-effect is strong, i.e. (R_0/R_e) cot theta = or epsilon, where epsilon is the Rossby number, theta is the latitude; R_e is the Earth's radius, and R_0 is the deformation radius based on the total depth of the ocean. An asymptotic system of equations is derived and used to study the stability of zonal currents. Three sufficient conditions of stability are obtained, which restrict the slope of the interface between the stratified and non-stratified layers. The results obtained are applied to the subtropical and subarctic frontal currents in the Northern Pacific: the former was found to be stable, the latter was found to be unstable. However, the growth rate of the instability is very small (the effective time of growth is about 2 years). (Author)

Three-dimensional calculations of the simple shear flow around a single particle between two moving walls
Nirschl H., Dwyer H.A. & Denk V., *Journal of Fluid Mechanics*, 1995, 283/- (273-285).
Three-dimensional solutions have been obtained for the steady simple shear flow over a spherical particle in the intermediate Reynolds number range 0.1 = or Re = or 100. The shear flow was generated by two walls which move at the same speed but in opposite directions, and the particle was located in the middle of the gap between the walls. The particle-wall interaction is treated by introducing a fully three-dimensional Chimera or overset grid scheme. For low Reynolds numbers and without any wall influence the solution of Taylor (1932) has been verified for the shear around a rigid sphere. With increasing Reynolds numbers the angular velocity for zero moment for the sphere decreases with increasing Reynolds number. The influence of the wall has been quantified with the global particle surface characteristics such as net torque and Nusselt number. A detailed analysis of the influence of the wall distance and Reynolds number on the surface distributions of pressure, shear stress and heat transfer has also been carried out. (from Authors)

Energetics of grid turbulence in a stably stratified fluid
Hsien-Ta Liu, *Journal of Fluid Mechanics*, 1995, 296/- (127-157).
A biplane grid with a mesh spacing of 10.8 cm was towed horizontally in a towing tank to generate turbulence in a non-stratified fluid and in stratified fluids with different constant density gradients. Turbulence velocity components and density fluctuations were measured using an array of cross-film and conductivity probes. The decay rates of the (turbulence) kinetic, potential and total energies and the dissipation rates of the kinetic and potential energies were calculated from the experimental data. Our results are consistent with those of direct numerical simulations and agree reasonably well with those obtained in stratified wind and water tunnels. However, the results differ from laboratory results obtained using an optical method to measure the turbulent motion of tracer particles in the wake of a vertically towed grid. A similar trend is also observed in results obtained in facilities with fairly high background turbulence or internal waves. This discrepancy is discussed and an explanation is presented. (from Author)

The interaction of a moving fluid/fluid interface with a flat plate
Billingham J. & King A.C., *Journal of Fluid Mechanics*, 1995, 296/- (325-351).
A well-known technique for metering a multiphase flow is to use small probes that utilize some measurement principle to detect the presence of different phases surrounding their tips. In almost all cases of relevance to the oil industry, the flow around such local probes is inviscid and driven by surface tension, with negligible gravitational effects. In order to study the features of the flow around a local probe when it meets a droplet, we analyse a model problem: the interaction of an infinite, initially straight, interface between two inviscid fluids, advected in an initially uniform flow towards a semi-infinite thin flat plate oriented at 90 degrees to the interface. The small-time and linearized large-time problems are solved analyticaly, using Mellin transforms, whilst the general large-time problem is solved numerically, using a boundary integral method. The form of the dynamic contact angle as a function of contact line velocity is the most important factor in determining how an interface domain as it meets and moves over the plate. (from Authors)

Stability of eccentric core-annualar flow
Huang A. & Joseph D.D., *Journal of Fluid Mechanics*, 1995, 282/- (233-245).
Perfect-core annular flows are two-phase flows, for example of oil and water, with the oil in a perfectly round core of constant radius and the water outside. Eccentric core flows can be perfect, but the centre of the core is displaced off the centre of the pipe. The flow is driven by a constant pressure gradient, and is unidirectional. The position of the core is indeterminate so that there is a family of these eccentric core flow steady solutions. The linear stability of this family of flows is studied using the finite element method to solve a group of PDEs. The large asymmetric eigenvalue problem generated by the finite element method is solved by an iterative Arnoldi's method. It was found there is no linear selection mechanism, eccentric flow is stable when concentric flow is

stable. The interface shape of the most unstable mode changes from varicose to sinuous as the eccentricity increases from zero. (Authors)

Air entrapment by a falling water mass
Oguz H.N., Prosperetti A. & Kolaini A.R., *Journal of Fluid Mechanics*, 1995, 294/- (181-207).
The impact of a nearly cylindrical water mass on a water surface is studied both experimentally and theoretically. The experiments consist of the rapid release of water from the bottom of a cylindrical container suspended above a large water tank and of the recording of the free-surface shape of the resulting crater with a high-speed camera. A bubble with a diameter of about twice that of the initial cylinder remains entrapped at the bottom of the crater when the aspect ratio and the energy of the falling water mass are sufficiently large. Many of the salient features of the phenomenon are explained on the basis of simple physical arguments. Boundary-integral potential-flow simulations of the process are also described. (from Authors)

Forced convection and sedimentation past a flat plate
Pelekasis N.A. & Acrivos A., *Journal of Fluid Mechanics*, 1995, 294/- (301-321).
The steady laminar flow of a well-mixed suspension of monodisperse solid spheres, convected steadily past a horizontal flat plate and sedimenting under the action of gravity, is examined. The particle concentration remains uniform throughout the $O(Re^{-1/2})$ thick Blasius boundary layer except for two O(epsilon$^{2/3}$) thin regions on either side of the plate, where the concentration profile becomes nonuniform owing to the presence of shear-induced particle diffusion which balances the particle flux due to convection and sedimentation. The system of equations within this concentration boundary layer admits a similarity solution near the leading edge of the plate, according to which the particle concentration along the top surface of the plate increases from its value in the free stream by an amount proportional to $X^{5/6}$, with X measuring the distance along the plate, and decreases in a similar fashion along the underside. But, unlike the case of gravity settling on an inclined plate in the absence of a bulk flow at infinity considered earlier (Nir & Acrivos 1990), here the concentration profile remains continuous everywhere. This model, with minor modifications, can be used to describe particle migration in other shear flows, as, for example, in the case of crossflow microfiltration. (from Authors)

Axisymmetric particle-driven gravity currents
Bonnecaze R.T., Hallworth M.A., Huppert H.E. & Lister J.R., *Journal of Fluid Mechanics*, 1995, 294/- (93-121).
Axisymmetric gravity currents that result when a dense suspension intrudes under a lighter ambient fluid are studied theoretically and experimentally. An advective transport equation models the distribution of particles in the current, and this distribution determines the local buoyancy force in the shallow-water equations. The coupled equations of the model are solved numerically. To test the model several laboratory experiments were performed to determine both the radius of an axisymmetric particle-driven gravity current as a function of time and its deposition pattern for a variety of initial particle concentrations, particle sizes, volumes and flow rates. (from Authors)

On the two-way interaction in two-dimensional particle-laden flows: the accumulation of particles and flow modification
Druzhinin O.A., *Journal of Fluid Mechanics*, 1995, 297/- (49-76).
The evolution of two-dimensional regular flows laden with solid heavy particles is studied analytically and numerically. The particulate phase is assumed to be dilute enough to neglect the effects of particle-particle interactions. Flows with large Reynolds and Froude numbers are considered, when effects related to viscous dissipation and gravity are negligible. A Cauchy problem is solved for an initially uniform distribution of particles with Stokes (St) and Reynolds (Re_p) numbers of order unity in several types of flows representing steady solutions of the two-dimensional Euler equations. Flows in the vicinity of the hyperbolic stagnation point (with a uniform strain and zero vorticity) and the elliptic stagnation point (where vorticity is uniform), a circular vortex (with vorticity depending on the radius) and Stuart vortex flow are considered. (from Author)

Available potential energy and mixing in density-stratified fluids
Winters K.B., Lombard P.N., Riley J.J. & D'Asaro E.A., *Journal of Fluid Mechanics*, 1995, 289/- (115-128).
A conceptual framework for analysing the energetics of density-stratified Boussinesq fluid flows is discussed. The concept of gravitational available potential energy is used to formulate an energy budget in which the evolution of the background potential energy can be explicitly examined. For closed systems, the background potential energy can change only due to diabatic processes. The rate of change of background potential energy is proportional to the molecular diffusivity. Changes in the background potential energy provide a direct measure of the potential energy changes due to irreversible diapycnal mixing. For open systems, background potential energy can also change due to boundary fluxes, which can be explicitly measured. (from Authors)

Free decay of shape oscillations of bubbles acoustically trapped in water and sea water
Asaki T.J. & Marston P.L., *Journal of Fluid Mechanics*, 1995, 300/- (149-167).
Asymptotic results for the free decay of shape oscillations of viscous liquid spheres have been extended to include higher-order terms in the ratios of the inner and outer viscous penetration lengths to the radius. The new expressions are shown to be important for studies in which the two fluids have dissimilar densities and viscosities such as air/liquid systems. The analysis also includes an expansion for the frequency of maximum response of driven oscillations. The results are interpreted in terms of the initial-value problem. Measurements were also carried out on bubbles in 0.5 m NaCl solution and in sea water. The transition from this anomalous damping to theoretical damping is a very abrupt function of radius. All observations were carried out with similar acoustic fields for counteracting buoyancy. The excess damping appears to be associated with some nonlinear response of the bubble. (from Authors)

The effect of rotation on double-diffusive convection in a laterally heated vertical slot
Kerr O.S., *Journal of Fluid Mechanics*, 1995, 301/- (345-370).
The effect of rotation about a vertical axis on the linear stability of a salt-stratified fluid enclosed in a vertical slot when subjected to a temperature difference between the walls is investigated. It is found that for large salinity stratifications there are three distinct regimes of instability for different values of the rotation rate. The effect of rotation on double-diffusive instabilities caused by more general horizontal temperature and salinity gradients in a salt-stratified fluid is also investigated, with particular reference to the case of heating the salinity gradient from a single sidewall. This analysis is restricted to the case where the rotation rate is low. (from Author)

The effect of vortex pairing on particle dispersion and kinetic energy transfer in a two-phase turbulent shear layer
Kiger K.T. & Lasheras J.C., *Journal of Fluid Mechanics*, 1995, 302/- (149-178).
The transport of heavy, polydispersed particles and the inter-phase transfer of kinetic energy due to the viscous drag forces is measured experimentally in a turbulent shear layer. To study the effect of the large-scale vortex event, the shear layer is forced simultaneously with a fundamental and subharmonic perturbation. The kinetic energy transfer is shown to exhibit notable

positive and negative peaks located beneath the cores and the stagnation points of the large-scale eddy field, and these peaks are shown to result from the irrotational velocity perturbations created by the vortices. This energy exchange mechanism remains a prominent process as long as the Stokes number of the particles relative to the vortices is of order unity. (from Authors)

Sedimentation and entrainment in dense layers of suspended particles stirred by an oscillating grid
Huppert H.E., Turner J.S. & Hallworth M.A., *Journal of Fluid Mechanics*, 1995, 289/- (263-293).
Many flows, including those containing suspended particles, are kept turbulent by the action of the bottom stress, and this turbulence is also responsible for maintaining sedimenting particles in suspension and in some cases entraining more particles from the bed. We report the results of a series of experiments with a grid located close to the bottom boundary to simulate the action of stresses acting at a rough boundary, and compare the results with those obtained using the more extensively studied geometry in which a similar grid is located in the interior of a stirred fluid layer. Experiments have been conducted both with dense, particle-free fluid layers and with layers containing sufficiently high concentrations of dense particles to have a significant effect on the bulk density. Theoretical arguments are presented which provide a satisfactory scaling of the experimental data. These are compared with previous theories and numerical experiments aimed at modelling both the one-dimensional problem and the corresponding processes in turbulent gravity currents. Comparisons are also made with sediment-laden channel flows and convecting layers containing sedimenting particles. (from Authors)

The effect of vortex pairing on particle dispersion and kinetic energy transfer in a two-phase turbulent shear layer
Kiger K.T. & Lasheras J.C., *Journal of Fluid Mechanics*, 1995, 302/- (149-178).
The transport of heavy, polydispersed particles and the inter-phase transfer of kinetic energy due to the viscous drag forces is measured experimentally in a turbulent shear layer. To study the effect of the large-scale vortex event, the shear layer is forced simultaneously with a fundamental and subharmonic perturbation. The kinetic energy transfer is shown to exhibit notable positive and negative peaks located beneath the cores and the stagnation points of the large-scale eddy field, and these peaks are shown to result from the irrotational velocity perturbations created by the vortices. This energy exchange mechanism remains a prominent process as long as the Stokes number of the particles relative to the vortices is of order unity. (from Authors)

The effect of rotation on double-diffusive convection in a laterally heated vertical slot
Kerr O.S., *Journal of Fluid Mechanics*, 1995, 301/- (345-370).
The effect of rotation about a vertical axis on the linear stability of a salt-stratified fluid enclosed in a vertical slot when subjected to a temperature difference between the walls is investigated. It is found that for large salinity stratifications there are three distinct regimes of instability for different values of the rotation rate. The effect of rotation on double-diffusive instabilities caused by more general horizontal temperature and salinity gradients in a salt-stratified fluid is also investigated, with particular reference to the case of heating the salinity gradient from a single sidewall. This analysis is restricted to the case where the rotation rate is low. (from Author)

Free decay of shape oscillations of bubbles acoustically trapped in water and sea water
Asaki T.J. & Marston P.L., *Journal of Fluid Mechanics*, 1995, 300/- (149-167).
Asymptotic results for the free decay of shape oscillations of viscous liquid spheres have been extended to include higher-order terms in the ratios of the inner and outer viscous penetration lengths to the radius. The new expressions are shown to be important for studies in which the two fluids have dissimilar densities and viscosities such as air/liquid systems. The analysis also includes an expansion for the frequency of maximum response of driven oscillations. The results are interpreted in terms of the initial-value problem. Measurements were also carried out on bubbles in 0.5 m NaCl solution and in sea water. The transition from this anomalous damping to theoretical damping is a very abrupt function of radius. All observations were carried out with similar acoustic fields for counteracting buoyancy. The excess damping appears to be associated with some nonlinear response of the bubble. (from Authors)

Forced convection and sedimentation past a flat plate
Pelekasis N.A. & Acrivos A., *Journal of Fluid Mechanics*, 1995, 294/- (301-321).
The steady laminar flow of a well-mixed suspension of monodisperse solid spheres, convected steadily past a horizontal flat plate and sedimenting under the action of gravity, is examined. The particle concentration remains uniform throughout the $O(Re^{-1/2})$ thick Blasius boundary layer except for two O(epsilon$^{2/3}$) thin regions on either side of the plate, where the concentration profile becomes nonuniform owing to the presence of shear-induced particle diffusion which balances the particle flux due to convection and sedimentation. The system of equations within this concentration boundary layer admits a similarity solution near the leading edge of the plate, according to which the particle concentration along the top surface of the plate increases from its value in the free stream by an amount proportional to $X^{5/6}$, with X measuring the distance along the plate, and decreases in a similar fashion along the underside. But, unlike the case of gravity settling on an inclined plate in the absence of a bulk flow at infinity considered earlier (Nir & Acrivos 1990), here the concentration profile remains continuous everywhere. This model, with minor modifications, can be used to describe particle migration in other shear flows, as, for example, in the case of crossflow microfiltration. (from Authors)

Air entrapment by a falling water mass
Oguz H.N., Prosperetti A. & Kolaini A.R., *Journal of Fluid Mechanics*, 1995, 294/- (181-207).
The impact of a nearly cylindrical water mass on a water surface is studied both experimentally and theoretically. The experiments consist of the rapid release of water from the bottom of a cylindrical container suspended above a large water tank and of the recording of the free-surface shape of the resulting crater with a high-speed camera. A bubble with a diameter of about twice that of the initial cylinder remains entrapped at the bottom of the crater when the aspect ratio and the energy of the falling water mass are sufficiently large. Many of the salient features of the phenomenon are explained on the basis of simple physical arguments. Boundary-integral potential-flow simulations of the process are also described. (from Authors)

Axisymmetric particle-driven gravity currents
Bonnecaze R.T., Hallworth M.A., Huppert H.E. & Lister J.R., *Journal of Fluid Mechanics*, 1995, 294/- (93-121).
Axisymmetric gravity currents that result when a dense suspension intrudes under a lighter ambient fluid are studied theoretically and experimentally. An advective transport equation models the distribution of particles in the current, and this distribution determines the local buoyancy force in the shallow-water equations. The coupled equations of the model are solved numerically. To test the model several laboratory experiments were performed to determine both the radius of an axisymmetric particle-driven gravity current as a function of time and its deposition pattern for a variety of initial particle concentrations, particle sizes, volumes and flow rates. (from Authors)

'Particle stress' in disperse two-phase potential flow
Bulthuis H.F., Prosperetti A. & Sangani A.S., *Journal of Fluid Mechanics,* 1995, 294/- (1-16).
The problem of determining the particle-phase stress in potential flow has been examined recently using two different procedures by Sangani & Didwania (1993 a) and by Bulthuis (Appendix C of Zhang & Prosperetti 1994). The present study corrects errors in the expression given by Sangani & Didwania, recasts the expression given by Bulthuis in a form suitable for computation, and shows the equivalence of the results obtained by the two methods. (Authors)

Study on the vibrational characteristics of a tube array caused by two-phase flow. Part II: fluidelastic vibration
Nakamura T., Fujita K., Kawanishi K., Yamaguchi N. & Tsuge A., *Journal of Fluids & Structures,* 1995, 9/5 (539-562).
This paper presents experimental results on the fluidelastic vibration caused by air-water flow and by steam-water two-phase flow in conditions of up to 7.0 MPa pressure and temperatures reaching 284 degrees C. A new criterion, based on an assumption of energy balance per cycle of oscillation, is introduced using the 'true' flow velocity. However, comparison with the experimental data indicates that, in the slug or froth flow regimes, the speed of the intermittently rising slugs, introduced in Part I of this study, should be used; hence, a new modified criterion for the slug and froth flow regimes is derived. In addition, the new criterion is compared with the usual Connors-type criterion which greatly depends on the estimation of the damping in two-phase flow. (from Authors)

Study on the vibrational characteristics of a tube array caused by two-phase flow. Part I: random vibration
Nakamura T., Fujita K., Kawanishi K., Yamaguchi N. & Tsuge A., *Journal of Fluids & Structures,* 1995, 9/5 (519-538).
This paper presents the experimental results on turbulent buffeting forces generated both by air-water flow and by stream-water two-phase flow for the extreme pressure conditions up to 5.8 MPa and temperatures reaching 272 degrees C, the explanation of the mechanism producing these forces, and a method for evaluating the tube response caused by two-phase flow. Here, the main source of the buffeting forces in slug or froth two-phase flow is recognized to be the impact forces caused by the intermittently rising water slugs. The slug speed and the fluid forces acting on a tube are estimated, together with an estimation of the period of the occurrence of the rising water slug. The accuracy of this estimation method is proved by comparing the theoretical response with the measured one. (from Authors)

Bubble dynamics fluid-structure interaction simulation by coupling fluid BEM and structural FEM codes
Kalumuck K.M., Duraiswami R. & Chahine G.L., *Journal of Fluids & Structures,* 1995, 9/8 (861-883).
In this paper we report on fully coupled fluid-structure modeling using our boundary element fluid codes (2DYNAFS, 3DYNAFS) and existing finite element structural codes (NIKE2D, NIKE3D) and present some example results. Significant effects due to the structural response on the bubble dynamics are observed including modification of the bubble period, re-entrant jet formation, and pressure generated on the solid body. The growth and collapse of micron-sized bubbles near boundaries such as propeller blades holds the key to understanding the deleterious effects of cavitation on such structures. The interaction of much larger bubbles with underwater and offshore structures has important naval and marine applications. In this study we present results from our efforts to create an integrated bubble-structure simulation program. The structural portion of the program has been developed from the NIKE suite of finite element programs developed by Lawrence Livermore National Laboratories. The results presented here concentrate on model problems of the interaction of a relatively large bubble at a distance from a spherical shell in an infinite medium of liquid. (from Authors)

Fluidelastic instability in a tube array subjected to two-phase R-11 cross-flow
Feenstra P.A., Judd R.L. & Weaver D.S., *Journal of Fluids & Structures,* 1995, 9/7 (747-771).
The purpose of the research reported in this paper was to investigate the effects of liquid and two-phase R-11 cross-flow on the fluidelastic instability of a tube array. The experimental facility is described, and the procedure used for void fraction determination. The stability behaviour and flow regime characteristics are presented for a range of void fraction and compared with comparable air-water and steam-water results from the literature. (from Authors)

Electrokinetic remediation: basics and technology status
Acar Y.B., 6 others et al., *Journal of Hazardous Materials,* 1995, 40/2 (117-137).
Electrokinetic remediation, variably named as electrochemical soil processing, electromigration, electrokinetic decontamination or electroreclamation uses electric currents to extract radionuclides, heavy metals, certain organic compounds, or mixed inorganic species and some organic wastes from soils and slurries. An overview of the principals of the electrokinetic remediation technique in soils is presented. The types of waste and media in which the technology could potentially be applicable are outlined and some envisioned environmental uses of conduction phenomena in soils under electric fields are presented. (from Authors)

A two-phase release model for quantifying risk reduction for modified HF alkylation catalysts
Muralidhar R., Jersey G.R., Krambeck F.J. & Sundaresan S., *Journal of Hazardous Materials,* 1995, 44/2-3 (141-183).
This paper describes a two-phase jet model for predicting the HF rainout (capture) in HF/additive releases. The parent droplets of the release mixture constitute the first phase. The second phase is a vapor-liquid fog. The drops are not in equilibrium with the fog phase with which they exchange mass and energy. The fog at any location is assumed to be in local equilibrium. The fog-phase calculations account for HF oligomerization and HF-water complex equilibria in the vapor phase and vapor-liquid equilibrium in the fog. The model incorporates jet trajectory calculations and hence can predict liquid 'rainout' and the capture distance. The model HF capture predictions are in agreement with small and large scale HF/additive release experiments. The fog properties and flow rate may be used to initialize atmospheric fog dispersion models for use in risk assessment calculations. (Authors)

Effects of two-dimensional on pipe transients modeling
Brunone B., Golia U.M. & Greco M., *Journal of Hydraulic Engineering - ASCE,* 1995, 121/12 (906-912).
The paper discusses the rapid damping of pressure peaks in a water-hammer phenomenon after the end of a complete valve-closure maneuver. Applying a 2-D model, recently proposed in the literature, to expand the limited experimental data available with numerical results, useful information on the evolution of the velocity profiles during a transient has been obtained. Starting from an in-depth inspection of the terms in the momentum equation, an additional term is introduced to model the effects of the flow-field two-dimensionally in a 1-D formulation. Finally, the adequacy of a relationship previously proposed by the writers to evaluate the additional term is specifically showed for fast transients in the field of low-Reynolds-number flows when no cavitation occurs, even if its validity has been proven elsewhere for rather different conditions. (from Authors)

Modeling of mixing by turbulent jet in stably stratified fluid
Larson M. & Jonsson L., *Journal of Hydraulic Engineering - ASCE,* 1995, 121/12 (853-862).
A model that describes the density-profile evolution in a confined region with a stably stratified fluid, where mixing is induced by a

circular, nonswirling turbulent jet discharged vertically down into the fluid is presented here. The interaction between the downward-moving jet and a resulting rise plume is modeled. A schematized flow pattern in the ambient fluid is employed to determine the effect of the jet/plume mixing on the density-profile evolution, and a diffusion equation is used to describe additional mixing processes in the ambient fluid outside the jet/plume region. The model is validated with experimental data on the density-profile evolution in a rectangular container produced by a mixing jet. (from Authors)

Sediment-laden flow in open channels from two-phase flow viewpoint
Zhixian Cao, Liangyan Wei & Jianheng Xie, *Journal of Hydraulic Engineering - ASCE,* 1995, 121/10 (725-735).
This paper presents an analysis, on the basis of the fundamental equations for fluid-solid two-phase flows, of the velocity and sediment concentration profiles in open-channel flows. A new diffusion equation is established for suspended sediment concentration from a rigorous derivation of the water-sediment mixture's normal velocity in the sense of mass flux conservation. The differences between this new equation and Schmidt's as well as Hunt's are shown to be attributable to the different approximations of sediment velocity. The developed model is extensively tested against available measurements, and satisfactory of fairly good agreement is obtained. (from Authors)

Application of neural networks in stratified flow stability analysis
Grubert J.P., *Journal of Hydraulic Engineering - ASCE,* 1995, 121/7 (523-532).
A feed-forward back-propagation-type neural network was used to predict the flow conditions when interfacial mixing in stratified estuaries commences. This was achieved by training the network to extrapolate data from laboratory experiments performed over many years by several researchers. Results were compared with an approximate stability equation utilizing results from inviscid flow theory, rough turbulent flow theory, and laboratory experiments on interfacial friction. Although the agreement was not exact, it was close enough to predict what the stability conditions in real estuaries should be. (from Author)

Incipient fluidization of fine sands in deep seabed
Law A.W.K., *Journal of Hydraulic Engineering - ASCE,* 1995, 121/9 (653-656).
The pore pressure increase in a deep sandy seabed due to the discharges from a buried source pipe was studied analytically. Darcy's law was assumed. The injection flow from the discharge ports of the source pipe was simulated as line discharges. An analytical solution of the pore-pressure increase was obtained using the technique of conformal mappings and the method of images. The pore-pressure distribution was analyzed for a burial depth 5-20 times the pipe diameter. The results indicated that the effect of the pipe size was confined to a distance from the center of the pipe of approximately half of the burial depth. Based on the analytical solution, the flow rate for the incipient fluidization of the cover sands was determined using the fluidization criterion adopted in 1990 by Lennon, Chang, and Weisman. (Author)

Head requirement for incipient fluidization of fine sands in unbounded domains
Lennon G.P. & Weisman R.N., *Journal of Hydraulic Engineering - ASCE,* 1995, 121/11 (838-841).
Fluidization systems in the coastal environment can be used to maintain channels and aid in sand bypassing. Induced flow from small holes in a buried source pipe will fluidize the overlying sand for a sufficiently high flow rate. One important design parameter is the required hydraulic head at the incipient fluidization condition to overcome the porous media head loss. The three-dimensional governing equation for head was solved with the finite-difference method using the theoretical critical hydraulic gradient at the incipient fluidization condition. After comparison to two-dimensional solutions and experimental results, the incipient-condition head-loss requirement was simulated for field geometries. (from Authors)

A review of the slip (wall depletion) of polymer solutions, emulsions and particle suspensions in viscometers: its cause, character, and cure
Barnes H.A., *Journal of Non-Newtonian Fluid Mechanics,* 1995, 56/3 (221-251).
Slip occurs in the flow of two-phase systems because of the displacement of the disperse phase away from solid boundaries. This arises from steric, hydrodynamic, viscoelastic and chemical forces and constraints acting on the disperse phase immediately adjacent to the walls. The enrichment of the boundary near the wall with the continuous (and usually low-viscosity) phase means that any flow of the fluid over the boundary is easier because of the lubrication effect. Because this effect is usually confined to a very narrow layer - with typical thickness of 0.1-10 mum - it so resembles the slip of solids over surfaces that it has historically been given the same terminology. The restoring force for all the forces that cause an increase in concentration is usually osmotic, and this will always limit the effective slip. In dilute systems, concentration gradients can be present over relatively large distances out from walls, giving what might be interpreted on an overall basis as a thick solvent-only layer. However, as the concentration of the system increases, the layer gets thinner and thinner because it is more difficult to create with the large reverse osmotic force present. However, the enormous increase in the bulk viscosity with increase in concentration means that although thinner, the layer becomes, paradoxically, even more important. (from Author)

Numerical simulation of particle migration in concentrated suspensions by a finite volume method
Zhiwu Fang & Nhan Phan-Thien, *Journal of Non-Newtonian Fluid Mechanics,* 1995, 58/1 (67-81).
This paper is concerned with the numerical modelling of particle migration in concentrated suspensions by the finite volume method. The constitutive equation for the particle flux, originally proposed by Phillips (1992), in one dimension, is implemented in general two-dimensional flows with arbitrary geometry and boundary conditions. The numerical implementation is benchmarked against the exact solution in circular Couette flow, including the transient case where a closed-form solution is not available. The numerical predictions in an eccentric circular geometry, where the inner cylinder is placed off the axis of the outer cylinder, are given, showing that particles migrate towards the outer cylinder, but at different rates depending on their azimuthal positions. (Authors)

Non-Newtonian cavitation analysis in journal bearings
Lemaitre F. & Berker A., *Journal of Non-Newtonian Fluid Mechanics,* 1995, 59/1 (31-48).
Cavitation can occur in both static and dynamically loaded journal bearings. For Newtonian fluids an effluent numerical algorithm which addresses these problems has been proposed by Elrod. We have extended the Elrod algorithm to also cover non-Newtonian fluids and implemented it in an axially symmetric finite journal bearing. For a Newtonian lubricant, under isothermal conditions, both static and dynamic loading cases have been solved. For the non-Newtonian case, a generalized Reynolds equation has been derived. This equation has been solved (under static loading) for a particular shear thinning Generalized Newtonian Fluid. Predictions compare favorably with existing literature. (from Authors)

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Use of in situ saturation data in estimation of two-phase flow functions in porous media
Mejia G.M., Mohanty K.K. & Watson A.T., *Journal of Petroleum Science & Engineering*, 1995, 12/3 (233-245).
Accurate estimates of multiphase flow functions (relative permeability and capillary pressure) are necessary for reliable prediction of oil recovery from a reservoir and nonaqueous phase (NAPL) contaminants from aquifers. Current methods of estimating two-phase relative permeabilities from unsteady state displacement experiments are based on Buckley-Leverett model. This model assumes that the medium is homogeneous, flow is one-dimensional and capillary effects are negligible. These assumptions are not valid for many reservoir rock samples. In this work, a parameter estimation procedure has been used to predict simultaneously relative permeabilities and capillary pressure functions from production, pressure drops as well as in situ saturation data of unsteady state displacements. Heterogeneities in porosity, permeability, residual oil saturation and initial saturation are accounted for in the model. Experimental data, estimated flow functions, and associated uncertainties are presented for two reservoir rock samples. (from Authors)

Two-phase calculations and comparative flow experiments through heterogeneous orthogonal stratified systems
Laribi S., Bertin H. & Quintard M., *Journal of Petroleum Science & Engineering*, 1995, 12/3 (183-199).
Experimental and theoretical results for two-phase flow in vertically stratifed systems, the flow being normal to the strata, are presented. The experimental study is focused on the following points: a) the initial oil-drainage process and the evolution of the water distribution during the capillary equilibrium process, and b) the time evolution of the saturation fields during water-flooding experiments. Saturation fields were measured using a gamma-rays attenuation system. The physics of two-phase flow through vertically stratified porous media can be analysed by a large-scale averaging method. This methodology is described briefly. The water-flooding experiments were interpreted using the large-scale averaging method, first in the quasi-static case, second using a simplied closure problem taking into account dynamic effects. (from Authors)

Determination of porosity types from NMR data and their relationship to porosity types derived from thin section
Bowers M.C., Ehrlich R., Howard J.J. & Kenyon W.E., *Journal of Petroleum Science & Engineering*, 1995, 13/1 (1-14).
This paper discusses the cross validation of NMR T_1 relaxation distributions of porosity and how they are related to distributions obtained from image analysis of porosity in thin section. Both sets of distributions are polymodal and decomposition of each yields porosity types. Each pore type represents a subdistribution of pores with a characteristic size and shape. The mean T_1 values associated with the NMR pore types are linearly related to the mean size of pore types determined from image analysis. The constant of proportionality of this relationship represents the surface relaxivity (rho), a parameter that represents the enhancement of relaxation caused by nuclei interacting with the pore wall. The major difference between image analysis and NMR methods is that NMR can resolve much smaller pores. The relationships between pore types and throat sizes using NMR generated pore types are the same as that using image analysis generated pore types. (from Authors)

Application of the dynamic Wilhelmy plate to identification of slippage at a liquid-liquid-solid three-phase line of contact
Mennella A., Morrow N.R. & Xie X., *Journal of Petroleum Science & Engineering*, 1995, 13/3-4 (179-192).
In the present work, wetting behavior of liquid-liquid-solid systems is investigated with changes in wetting properties of silica or glass substrates induced by crude oil. Two initial plate positions are analyzed. Idealized force-distance records have been calculated for which receding and advancing contact angles are constant and the three-phase line of contact remains pinned during contact angle transitions that result from reversing the direction of motion of the plate. Comparison of experimental results with the idealized behavior shows that stabilized wetting conditions are not always achieved. It was often observed that slippage of the three-phase line of contact caused the distance of plate motion over which contact angle transitions occur to be much longer than that predicted by theory. (from Authors)

Laboratory measurements of the drag force on a family of two-dimensional ice keel models in a two-layer flow
Pite H.D., Topham D.R. & Van Hardenberg B.J., *Journal of Physical Oceanography*, 1995, 25/12 (3008-3031).
A review of the upper structure of the Arctic Ocean and its overlying ice cover suggests that significant potential exists for the generation of internal wave fields by the deeper drafts of the pressure ridge keels. Laboratory measurements are presented of the drag force on two-dimensional ice keel models of varying degrees of slenderness in both homogeneous and two-layer fluid systems. The results shown that the two-layer stratification increases the drag dramatically over that in a corresponding homogeneous flow, reaching a maximum in the transcritical flow regime as a result of the establishment of a system of internal waves. The increase in drag was greatest for the most slender obstacle, For the more steeply sloped obstacles, the wave growth is limited by dispersion, with a corresponding reduction in the peak drag force. Scaling the laboratory measurements to the Arctic Ocean suggests that the deeper ice keels may exert a considerable influence on the ice-ocean drag forces. (from Authors)

Numerical simulation for abrupt contraction flow of fiber suspensions in polymeric fluid
Yasuda K., Nishimura T. & Nakamura K., *Journal of Textile Machinery Society of Japan*, 1995, 48/1 (47-54).
Flow pattern and fiber orientation of fiber suspensions in polymeric fluid through a two-dimensional abrupt contraction are calculated using the Giesekus model and the Dinh-Armstrong model. The flow pattern of fiber suspensions in polymeric fluid is different from that of polymeric fluid; a vortex near the salient corner in the suspension flow becomes larger than that in the polymeric fluid flow. The dependence of the vortex length on a mobility parameter alpha in the Giesekus model and a characteristic parameter of fiber suspensions in the Dinh-Armstrong model are discussed. (Authors)

Permanent and transient upstream effects in nonlinear stratified flow over a ridge
Garner S.T., *Journal of the Atmospheric Sciences*, 1995, 52/2 (227-246).
The 'high drag' state of stratified flow over isolated terrain is still an impediment to theoretical and experimental estimation of topographic wave drag and mean-flow modification. A time-dependent numerical model with open boundaries is used in an effort to distinguish between permanent and transient upstream flow changes and to relate these to developments near the mountain. A nonrotating atmosphere with initially uniform wind and static stability is assumed. It is found that permanent alterations are primarily due to an initial surge not directly related to wave breaking. Indeed, there are no obvious parameter thresholds in the time-mean upstream state until 'orographic adjustment' (deep blocking) commences. Wave breaking, in addition to establishing the downstream shooting flow, generates a persistent, quasi-periodic, upstream transience, which apparently involves the ducting

properties of the downslope mixed region. To understand the inflow alteration and transience, the energy and momentum budgets are examined in regions near the mountain. (from Author)

The mixing of mass and momentum by Kelvin-Helmholtz billows
Scinocca J.F., *Journal of the Atmospheric Sciences*, 1995, 52/14 (2509-2530).
The mixing of mass and momentum induced by the full life-cycle of stratified shear instability is considered. In particular, the nonlinear numerical simulation of a stratified shear layer that is unstable to Kelvin-Helmholtz (K-H) waves is undertaken in three spatial dimensions. For weakly unstable stratified shear layers good agreement is found between the numerical simulations and similar physical (tilted tank) experiments. For strongly unstable stratified shear layers there is less agreement since the final state of the numerical simulations is a long-lived, two-dimensional vortex associated with the primary K-H instability. Quantitative estimates of the efficiency of mixing are made by calculating the flux Richardson number of the modeled mixing events. (from Author)

Structural stability of the coalescence/breakup equation
Brown Jr P.S., *Journal of the Atmospheric Sciences*, 1995, 52/22 (3857-3865).
An analysis of the structural stability of the coalescence/breakup equation is performed to determine the degree to which changes in the equation's formulation can affect the solution. Both analytical procedures and numerical experiments, in which hypothetical changes in the rate coefficients are assumed, show the coalescence/breakup equation in its current formulation to be structurally stable. Not only do small changes in the rate coefficients produce negligible change in the solutions, but even large changes in the rate coefficients fail to destroy the fundamental behavior of the system in that all solutions continue to approach a unique equilibrium. Moderate-sized perturbations of the coefficients are found to have only minor influence on the solutions unless the coalescence and breakup efficiencies, constituents of the rate coefficients, are perturbed in an opposite sense to reinforce the individual effects. (from Author)

Effects of relative humidity on the coalescence of small precipitation drops in free fall
Ochs III H.T., Beard K.V., Laird N.F., Holdridge D.J. & Schaufelberger D.E., *Journal of the Atmospheric Sciences*, 1995, 52/21 (3673-3680).
Findings are presented on the effect of high and low relative humidity on collisions between freely falling drops. Comparisons between the collision outcomes (coalescence, bounce, and temporary coalescence with and without satellite drops) for high-humidity (RH95%) and low-humidity (RH approx 30%) experiments were made for small precipitation drops at terminal velocity and with minimal electric charge. Experiments with higher drop charge were used to examine further the influence of humidity on coalescence. Our results show that relative humidity does not affect the coalescence efficiency for small precipitation drops. The effect of humidity is limited to collisions where permanent coalescence does not occur, and the collision outcome can be temporary coalescence. Other experiments showed that the increase in satellite drops at higher relative humidities also occurs for cases where collision outcomes are limited to coalescence or temporary coalescence. Since there are more temporary coalescence outcomes at the higher relative humidities in clouds, there are also more satellite drops that can act as embryos for new raindrops. These results apply to rain shafts within and below clouds. (from Authors)

Pseudomomentum diagnostics for two-dimensional stratified compressible flow
Durran D.R., *Journal of the Atmospheric Sciences*, 1995, 52/22 (3997-4009).
Expressions are derived for the local pseudomomentum density in two-dimensional compressible stratified flow and are compared with the expressions for pseudomomentum in two-dimensional Boussinesq and anelastic flow derived by Shepherd and by Scinocca and Shepherd. To facilitate this comparison, algebraically simpler expressions for the anelastic and Boussinesq pseudomomentum are also obtained. The extension of these compressible pseudomomentum diagnostics to viscous flow and to three-dimensional flows with zero potential vorticity is also discussed. An expression is derived for the pseudomomentum flux in stratified compressible flow. This flux is shown to simultaneously satisfy the group-velocity condition for both sound waves and gravity waves in an isothermal atmosphere with a constant basic-state wind speed. Consistent with the earlier results of Andrews and McIntrye, it is shown that for inviscid flow over a topographic barrier, the pseudomomentum flux through the lower boundary is identical to those to the cross-mountain pressure drag - provided that the flow is steady and that the elevation of the topography returns to its upstream value on the downstream side of the mountain. (from Author)

Influence of two-phase thermocapillary flow on liquid retention in microscopic pores
Schmidt G.R., Nadarajah A., Chung T.J. & Karr G.R., *Journal of Thermophysics & Heat Transfer*, 1995, 9/1 (151-158).
An important feature of screened propellant acquisition devices is the retention capability or maximum maintainable pressure difference across the porous barrier separating the liquid and gas. The objective of this article is to determine if the thermocapillary convection arising from phase change in the microscopic pores of such screens could cause these disparities in performance. A numerical model of flow in a single pore suggests that the thermocapillary-induced gradient in liquid pressure along the surface can strongly affect surface morphology. In an evaporative environment, this gradient exerts a stabilizing influence on surface curvature, and preserves the momentum balance between the liquid and gas. With condensation, it causes a force imbalance and a destabilizing suction in the middle of the pore that reduced retention. Results also indicate that introducing an inert gas, such as helium, suppresses this retention loss mechanism by lowering thermocapillary circulation and its associated interfacial pressure gradient. (from Authors)

Visualization of solidification process in kinetics control system with interferometry
Iwasaki A., 6 others et al., *Journal of Thermophysics & Heat Transfer*, 1995, 9/3 (537-542).
The behavior of a solid-liquid interface and temperature distribution in the supercooled melt during solidification were observed. Salol, an organic material, was solidified in a temperature gradient environment, where the process was controlled by both kinetics and diffusion. The thickness of the temperature-reversed layer in front of the interface was measured by interferometry with the moire technique. It was found that as the interface advanced, the macroscopic roughness of the interface increased markedly in the flight experiment on a sounding rocket. Heat transfer during solidification was numerically calculated and was compared with experimental data. (Authors)

High-speed stereo-observations of violent vibrations associated with three types of cavitation
Naka H., Soyama H., Sakagami K., Oba R. & Yamabe M., *JSME International Journal, Series B: Fluids & Thermal Engineering*, 1995, 38/1 (66-72).
In order to improve the reliability of high-speed hydraulic machinery, detailed behavior of the violent vibrations appearing on a typically low-drag Eppler foil is systematically observed by means of high-speed stereophotography. We can clearly observe the following three types of violent vibrations: the vibrations resulting from a singly-attached cavity, usually arising at a higher

incidence alphai; ones resulting from large travelling bubbles arising at a lower incidence, and a mixture of these two types. (Authors)

Measurement apparatus for magnetic susceptibility of magnetic fluid
Matsuno Y. & Ohshima K., *JSME International Journal, Series B: Fluids & Thermal Engineering*, 1995, 38/1 (73-78).
A magnetic fluid is a kind of multiphase fluid which consists of a stable colloidal dispersion of magnetic particles in a liquid carrier. The most basic factor governing its behavior is magnetic susceptibility. This paper describes the research on a measurement apparatus for magnetic susceptibility of a magnetic fluid by means of electromagnetic measurement. The apparatus is equipped with an electromagnet having a very low residual magnetization and magnetic field gradient adequate to secure a measurement of high accuracy. The measurement results of magnetic susceptibility with this apparatus are also reported for several kinds of magnetic fluids in various magnetic fields, temperatures and concentrations. (Authors)

Suitable region of high-speed submerged water jets for cutting and peening
Yamauchi Y., 7 others et al., *JSME International Journal, Series B: Fluids & Thermal Engineering*, 1995, 38/1 (31-38).
In order to establish useful techniques of cutting, drilling, peening and flushing by high-speed submerged water jets, we systematically observe the eroded surface on aluminum-alloy specimens in relation to the characteristics of cavitating jets, especially for the impinging jet through lucite specimens, for several types of nozzles. The impulsive pressures induced by the cavitating jets are also measured by means of pressure-sensitive film. It is concluded that the erosion characteristics are quite different in two typical standoff distances, ie, the 1st and 2nd peak. (from Authors)

High-speed observations of the cavitation cloud around a high-speed submerged water jet
Soyama H., Yamauchi Y., Adachi Y., Sato K., Shindo T. & Oba R., *JSME International Journal, Series B: Fluids & Thermal Engineering*, 1995, 38/2 (245-251).
We attempt to clarify the jet structure and the behavior of severely erosive cavitation clouds around a high-speed submerged water jet, using a high-speed movie camera with a framing rate of ten thousand frames. The effects of the injection pressure and the nozzle geometry on cavitation are also investigated. The experiments are performed with both a free jet and an impinging jet. It is clearly found that the cavitation clouds are periodically discharged. The cavitation clouds are also closely related to downstream instability and to the impinging erosion. (from Authors)

Peculiar behavior of disc drag during force measurements for supercavitating hydrofoils
Naka H., Kuwako H., Ito Y., Ogata H. & Oba R., *JSME International Journal, Series B: Fluids & Thermal Engineering*, 1995, 38/2 (252-257).
The behavior of the disc drag and the effects of the gap between the test foil and the facing side-wall are carefully investigated for three typical supercavitating hydrofoils whose nose shapes are slightly modified, in a wider range of cavitation number sigma, for various incidences $alpha_i$ and gap distances h. Unexpectedly from Numachi's disc-drag experiments, the disc drag significantly decreases within the transient region from the subcavitating region to the supercavitating region. It is also very sensitive to foil shapes and incidences. (from Authors)

Characteristics of vertical annular two-phase flow with local liquid fall-back
Adachi H., Abe Y. & Tsukakoshi M., *JSME International Journal, Series B: Fluids & Thermal Engineering*, 1995, 38/2 (280-287).
A new analysis method for two-phase flow is proposed, in which the most easily occurring and, thus, most stable two-phase flow situation is assumed to be realized. The flow situation with smaller pressure energy consumption rate for unit mass of penetrating two-phase fluid through each channel cross section is assumed to be more stable. In addition, two-dimensional turbulent flow analysis is applied to the annular flow regime in which partical or total downflow of the liquid film is allowed. Experimental analysis based on the data from an air-water two-phase flow experiment, which was performed at atmospheric pressure and room temperature, indicated the applicability of the proposed analytical method. (from Authors)

Fundamental nonlinear theory for micropolar electrically conducting fluids (conservation law, nonequilibrium thermodynamics, Peltier effect)
Tanahashi T. & Nakai T., *JSME International Journal, Series B: Fluids & Thermal Engineering*, 1995, 38/2 (273-279).
The conservation laws for micropolar electrically conducting fluids with many small fine particles are discussed on the basis of a nonequilibrium thermodynamics relation. This gives precise expressions of the energy flux vector and the dissipation function of micropolar fluids. The thermodynamic pressure defined here is based on the local conservation laws of mass, momentum and entropy, which satisfies the mutually complementary relationship with the sum of kinetic energy and internal energy. Euler's thermodynamic relation is obtained as a homogeneous function in the first order of entropy, density and pressure. (Authors)

Bubble behavior in magnetic fluid under a nonuniform magnetic field
Ishimoto J., Okubo M., Kamiyama S. & Higashitani M., *JSME International Journal, Series B: Fluids & Thermal Engineering*, 1995, 38/3 (382-387).
Experimental study is made to clarify the effects of nonuniform magnetic field on bubble behavior in a magnetic fluid. The behavior of vapor bubbles is visualized with ultrasonic wave echo under the nonuniform magnetic field. It is found that the void fraction in two-phase flow decreases with increase in the magnetic field due to the effect of magnetic body force. Furthermore, the effects of nonuniform magnetic field on translational motion and deformation of a single gas bubble in a magnetic fluid are experimentally examined using a transparent thin duct, called a Hele-Shaw cell. (from Authors)

Simultaneous measurements of flow rates and particle concentrations in heterogeneous solid-water two-phase flows by means of one venturi
Hirata Y., Takano M. & Narasaka T., *JSME International Journal, Series B: Fluids & Thermal Engineering*, 1995, 38/3 (440-447).
In order to establish an accurate measurement method for simultaneous measurements of flow rates Q and particle concentrations C_v in heterogeneous solid-water two-phase flows, the pressure-drop ratios were investigated in detail at the exit of a typical Hershel-type venturi in both horizontal and vertical pipe arrangements for six different kinds of solid-water flows with various Q and C_v. The results were represented by a simple formula similarly to that in our previous report on throat measurements. (from Authors)

Application of a two phase flow model based on local relative velocity to gas-liquid-solid three-phase flows
Tomiyama A., Minagawa H., Furutani N. & Sakaguchi T., *JSME International Journal, Series B: Fluids & Thermal Engineering*, 1995, 38/4 (555-562).
A two-phase flow model based on local relative velocity, which was previously proposed by the authors, was extended to a model

for gas-liquid-solid three-phase flows. The extension was carried out utilizing a hypothetical two-phase flow, which was conceived by removing one of the three phases. In order to examine the usefulness of the extended model, the measured area-averaged volumetric fractions of gas-liquid-solid three-phase bubbly or slug flow in vertical pipes were correlated based on the basic equations of the extended model. The accuracy of the obtained correlation was compared with those of the drift-flux correlation, the correlation based on a multiplier method and the correlation based on a gas-liquid three-phase slug flow model. It was confirmed that the extended model gives simpler and more accurate correlations for the area-averaged volumetric fractions of the gas-liquid-solid three-phase flows. (Authors)

Droplet deposition and heat transfer simulations of turbulent air-water dispersed flow in a vertical tube
Matida E.A. & Torii K., *JSME International Journal, Series B: Fluids & Thermal Engineering*, 1995, 38/4 (628-636).
A theoretical study of the droplet deposition and heat transfer of a vertically heated tube cooled internally by a turbulent air-water dispersed flow has been performed. In the analysis of the droplet deposition on the wall, an equation for the dimensionless droplet deposition velocity k_d/u^* is proposed, and the calculated results show good agreement with experimental data. In the heat transfer analysis, a model is proposed taking into account the presence of an initial liquid film on the wall that flows uniformly until the dryout point. Calculations of wall temperature distribution and heat transfer enhancement are performed and compared with experimental values. The heat transfer enhancement is found to be caused mainly by the evaporation of the liquid film on the wall. It is assumed that the liquid film on the wall breaks down nonuniformly before the dryout point, depending on the wall heat flux and the liquid film flow rate. (from Authors)

Effect of hood on selective withdrawal in cross-flow
Islam A.K.M.S., *JSME International Journal, Series B: Fluids & Thermal Engineering*, 1995, 38/4 (600-605).
Selective withdrawal from a two-layered thermally stratified cross-flow through a single round hole with and without a hood (cap) is considered. Experimental measurements of drawdown, the critical withdrawal rate and the mean temperature profile in the vicinity of the hole are provided for both cases. Flow visualization is reported, which provides detailed information on the structure and dynamics of mixing of warm and cold water. Flow visualization studies show the formation and shedding of a horseshoe vortex at moderate withdrawal rates for a hooded case, which is independent of stratification. The presence of a hood inhibits drawdown of the interface over the hole and thus reduces the amount of drawdown at any withdrawal rate. (Author)

Finite element simulations of ductile rupture in a constrained metal foil
Chowdhury S.R. & Narasimhan R., *Materials Science & Engineering A*, 1995, (27-37).
A numerical study of the ductile rupture in a metal oil constrained between two stiff ceramic blocks is performed using finite element analysis. The rate-independent version of the Gurson model that accounts for the ductile failure mechanisms of microvoid nucleation, growth and coalescence is employed to represent the behavior of the metal foil. Different distributions of void nucleating sites in the metal foil are considered for triggering the initiation of discrete voids. Far-field triaxiality-induced cavitation is the dominant failure mode when the spacing of the void nucleating sites is large. Void coalescence near the notch tip is found to be the operative failure mechanism when closely spaced void nucleating sites are considered. (from Authors)

A computer-based hot-film technique for two-phase flow measurements
Farrar B., Samways A.L., Ali J. & Bruun H.H., *Measurement Science & Technology*, 1995, 6/10 (1528-1537).
This paper describes the development of a novel computer-based hot-film anemometer measurement technique for the investigation of the local structure of two-phase flows. The technique enables the total signal to be separated into the parts corresponding to bubbles and continuous phase, from which the local volume fraction can be evaluated. Methods are described and discussed for the evaluation of the longitudinal mean velocity, normal stress, autocorrelation and energy spectrum. Finally typical results for a vertical up-flow of a bubbly kerosene/water mixture are presented. (from Authors)

Optical fibre sensors for process tomography
Green R.G., Horbury N.M., Rahim R.A., Dickin F.J., Naylor B.D. & Pridmore T.P., *Measurement Science & Technology*, 1995, 6/12 (1699-1704).
This paper describes an investigation into the use of an optical fibre sensor to measure the flow of pneumatically conveyed solid particles. Typical results for the mass flow rate of dry sand versus transducer output voltage are presented for a 1 mm diameter sensor fibre. The frequency bandwidth of the sensor is determined for a range of fibre diameters and compared with the calculated response obtained using spatial filtering considerations. (Authors)

A two-dimensional numerical analysis of two-phase flows under natural circulation conditions using drift-flux model
Xu Zhang, Yan Fei Rao & Fukuda K., *Memoirs - Kyushu University, Faculty of Engineering*, 1995, 55/1 (65-78).
Advanced nuclear reactor safety analyses require more detailed and reliable multi-dimensional simulation of gas-liquid two-phase flow. In the present study, a two-dimensional numerical analysis code based on the drift-flux model is developed for the study of transient, two-dimensional circulating two-phase flows. The difference equations are obtained by the control-volume method and solved numerically with the SIMPLE scheme. Two-phase flow structures under natural circulation conditions in a tank with a plate heat source are simulated with the developed code. Flow structures and coolabilities of the circulating flows are discussed. Comparisons of the present simulation results with those by other studies are also described. (Authors)

Experimental study on the geysering mechanism in a closed two-phase thermosyphon
Kuncoro H., Rao Y.F. & Fukuda K., *Memoirs - Kyushu University, Faculty of Engineering*, 1995, 55/3 (333-348).
An experimental study is carried out to investigate the mechanism of periodical boiling or geysering in a single-tube, closed two-phase thermosyphon made of glass to make visual observation possible. The filling percentage is 100% of the evaporator volume, and the working fluids are R113 and water. The system pressure fluctuation and the transient temperature profile along the thermosyphon are measured. It is found from the water experiment that besides the physical properties of the working fluids and wall surface conditions, the temperature distribution or the internal-energy storage pattern may initiate a geyser, as long as the temperature distribution supports simultaneous boiling. In the case of R113 experiment, on the other hand, superheat is the driving force of a geyser. (from Authors)

Experimental simulation of cavitation erosion in journal bearings (Die experimentelle Simulation von Kavitationsschaden im Gleitlager)
Haller R., Wollfarth M. & Heumer H., *MTZ (Motortechnische Zeitschrift)*, 1995, 56/1 (45-47). In German.
A test rig for journal bearing cavitation erosion simulation at the Karlsruhe University Department of Mechanical Engineering and Motor Vehicle Design gives good agreement with practical cavitation damage. Parameter studies have begun as a contribution

to further study of the cavitation causes and effects. The realistic modelling data are presented for flow cavitation and other types of damage. (R.H.)

Phase volume-fraction measurement in oil-water-gas flow using fast neutrons
Hussein E.M.A. & Han P., *Nuclear Geophysics*, 1995, 9/3 (229-234).
A fast-neutron transmission/scattering method is presented for measuring the volume fraction of each of the three-phases of an oil-water-gas flow in a pipe. The gas fraction is determined by a transmission measurement. The relative oil-to-water content is obtained from the scattering count rate by taking advantage of the salinity of water. Monte Carlo simulations and experiments are presented to demonstrate the feasibility of the technique. (Authors)

Photon energy selection for dual energy gamma-and/or X-ray absorption composition measurements in oil-water-gas mixtures
Van Santen H., Kolar Z.I. & Scheers A.M., *Nuclear Geophysics*, 1995, 9/3 (193-202).
Dual energy gamma-and/or X-ray absorption techniques can be used to monitor the composition of oil-water-gas mixtures in pipes. Criteria for the selection of the two photon energies and their relative intensities are developed, that maximise the precision of the mixture composition determination. A correction for the effects of pressure and temperature changes is presented. Changes of the salinity of the water and variations of the mixture composition in time and in space, even in the case of bubble flow, are shown to deteriorate the results. (Authors)

Trial of a gamma-ray multiphase flow meter on the West Kingfish oil platform
Hartley P.E., Roach G.J., Stewart D., Watt J.S., Zastawany H.W. & Ellis W.K., *Nuclear Geophysics*, 1995, 9/6 (533-552).
The gamma-ray multiphase flow meter determines the flow rates of oil, water and gas in pipelines from oil wells. It is based on two specialized gamma-ray transmission gauges mounted on a pipe carrying the full flow of oil, water and gas. One gauge uses gamma-ray transmission and the other dual energy gamma-ray transmission (DUET). This paper describes a trial of the MFM, undertaken by CSIRO and Esso Australia Ltd, on the West Kingfish offshore oil platform, Bass Strait, Australia. The West Kingfish trial and two earlier field trials, demonstrate that, after calibration, the MFM measures flow rates and water cut accurately and performs reliably. CSIRO now expect to appoint a commercial licensee to further industrialize the equipment, manufacture and market the MFM. (from Authors)

Guidelines for cementing deepwater conductor strings
Griffith J., *Offshore*, 1995, 55/1 (46,48).
Presents guidelines for successful deepwater conductor cementing operations. Three key techniques have been identified: proper drilling fluids and application, foamed cement with accelerators, and ultrafine/hollow ceramic bed slurries. Recommended mud system properties and placement techniques are summarised. Recommendations to help prevent fluid migration, and for dealing with problem formations, are given. (J.M.McLaughlin)

Multiphase pumping - where to now?
ANON, *Offshore*, 1995, 55/5 (105-110,150).
Based on a series of viewpoints from industry specialists, this article details technical and commercial aspects, and industry attitudes to multiphase pumping. Current systems lack long term operating experience, particularly subsea, and operators are reluctant to use them. Despite this, progress is being made. Commercial, cost-effective systems capable of many applications are available. (J.M.McLaughlin)

Versatile heat inductor eases control of wax and hydrates
ANON, *Offshore*, 1995, 55/8 (147).
Describes the Combipipe heat induction system for controlling hydrate and wax formation in subsea pipeline multiphase flows. The system integrates electrical cables within the pipeline coating. It also allows electricity to be delivered to remote subsea facilities. A fibre optic cable can also be incorporated for subsea equipment control and pipeline temperature monitoring. The system was jointly developed by Aker Engineering and Alcatel Contracting Norway. Statoil is to install a Combipipe system on its gas and condensate pipeline between The Sleipner West wellhead and processing platforms. Operational benefits and costs are outlined. (J.M.McLaughlin)

Agip using live wells for deepwater production, subsea equipment tests
ANON, *Offshore*, 1995, 55/8 (105-106).
Reviews Agips's experience and research and development activities in advanced offshore technologies. Multiphase technology, the subsea boosting system (SBS) for installation in water depths to 1000 m, multiphase flow meters and multiphase simulation tools, floating production systems, tension leg platforms (TLP) and TLP tendons, the turret floating production system (TFPS) concept, subsea systems, the SAF project for developing new generation subsea systems for deepwater marginal fields, and subsea control systems which eliminate the need for umbilicals are described. (J.M.McLaughlin)

British Gas rationalises research, but test outstations set to stay
ANON, *Offshore*, 1995, 55/8 (162,164).
This article looks at British Gas' rationalisation of its research and development activities. The research budget has been cut and the Engineering Research Station at Killingworth is to close. However, the four outstations which were supervised from Killingworth are to remain. Facilities and activities at these outstations are described. Two provide pipeline flow test facilities. Work carried out has included calibration of turbine meters and tests on ultrasonic flowmeters. Current projects include the development of an autonomous subsea tree system which can generate power from gas flow. A third facility can simulate multiphase flows. The fourth is used for hazardous oil and gas and petrochemical tests. British Gas has created Pipeline Integrity International to market its pipeline technology (including inspection pigs) world-wide. (J.M.McLaughlin)

Norwegian oil trio puts multiphase meters through simultaneous tests
Terde N., *Offshore*, 1995, 55/9 (78,80).
Norway has made a significant contribution to the development of multiphase meters for subsea oil and gas applications. Norsk Hydro, Statoil and Saga have sponsored a test programme to evaluate four meters simultaneously. The meters under test are from Fluenta, Framo Engineering, Kongsberg Offshore, and Multi-Fluid International (MFI). This article describes the features of each of these meters, the test programme, and results achieved to date. So far, it appears that pressure is a more important determinant of flow conditions than temperature. (J.M.McLaughlin)

Long plagued by HT-HP and economics, Erskine development plan moves ahead
ANON, *Offshore*, 1995, 55/5 (118,122).
Development of the high temperature, high pressure gas/gas condensate Erskine Field in the UK North Sea is described. A not-normally manned platform controlled from the Lomond Platform 30 km distant is intended. Unprocessed gas and liquids will be transported by multiphase pipeline to Lomond for separation and export. Pipeline design considerations are outlined. A dedicated process/compression module has to be retrofitted on the Lomond Platform. (J.M. McLaughlin)

Draugen's multiphase booster up and running
ANON, *Offshore Engineer*, 1995, (65, 67-68).
The Shell multiphase underwater booster station (Smubs) is the worlds first commercial subsea multiphase boosting system. Developed by Norske Shell, Shell Internationale Petroleum Maatschappij (SIPM) and Framo Engineering the system has successfully increased production on Norske Shell's Draugen field. The article discusses the design, installation, operation and performance of the system. (C.Paice)

Flowmeter set for S Scott debut
ANON, *Offshore Engineer*, 1995, (11).
Describes the worlds first subsea multiphase flowmeter. The meter will be installed on Amerada Hess' South Scott field and will monitor well performance in real time so making it easier to identify changing production trends and allow rapid remedial action to be taken. (C. Paice)

Software toolkit for pipeline engineers
ANON, *Offshore Research Focus*, 1995, 106/- (3).
Building on the success of PLAC, their transient multi-phase flowline simulator, AEA Technology is now embarked on the development of an associated modular software toolkit. It addresses a broad range of issues associated with produced fluids. The first phase of the development was completed in 1994. It has prepared much of the groundwork of integrating separate specialist software tools into the toolkit. Significant results include: provision of a steady-state preprocessor for PLAC; implementation of steady-state three-phase flow simulation; and capability to model heat transfer within flowline bundles. The Oil and Gas Projects and Supplies Office (OSO) supported this first phase development. (Author)

Multiphase meter to undergo North Sea tests
ANON, *Oil & Gas Journal*, 1995, 93/16 (69-71).
The different approaches to multiphase metering and the principles of multicomponent flow (MCF) meters are detailed. Kongsberg Offshore's KOS MCF 351 multiphase meter and forthcoming field tests in the North Sea are described. The meter can handle both gas and oil-external emulsion as well and gas and water-external emulsion up to 100% water cut. It includes a control system which calculates data for the flow rates. Kongsberg have established an advanced multiphase flow laboratory in Norway to support development of the MCF series of multiphase flow meters. (J.M.McLaughlin)

Two-phase modeling improves diverter design for shallow gas hazards
Bourgoyne Jr A.T. & Abel L.W., *Oil & Gas Journal*, 1995, 93/30 (29-35).
Conclusion in a series of articles on well control. The analysis of two-phase, high velocity flow in the design of diverters and in planning dynamic kill operations for shallow gas blowouts is discussed. A computer spreadsheet approach is recommended for systems of equations describing sonic exit pressure, flowing pressure gradients, formation productivity, formation fracture gradient and erosion. A case history involving a Far East onshore well is described in detail. (J.M.McLaughlin)

Entrainment method enhanced to account for oil's water content
Yiing-Mei Wu, *Oil & Gas Journal*, 1995, 93/35 (83-84,86).
This article presents a method for estimating minimum oil-flow velocity in an oil-water multiphase stream sufficient to entrain all free water. Removing all free water eliminates a separated settled-water phase which could cause corrosion in pipelines. The method improves on an earlier method developed by M. Wicks and J.P. Fraser. It accounts for water content already in the oil. This new approach uses characteristic flow patterns and relevant physical properties to determine transition criteria. Maximum drop size, stratified flow, and mist flow are described. Calculated examples are presented. Effects of water and wetting of the pipe wall by entrained water droplets are discussed. (J.M.McLaughlin)

Multiphase booster ups production from subsea well
ANON, *Oil & Gas Journal*, 1995, 93/18 (84, 87).
This article describes the Shell multiphase underwater booster station (Smubs) which produces to A/S Norske Shell's Draugen field. Smubs provides additional energy to transport a mixture of gas and liquids over long distances. This reduces the back pressure on the reservoir and potentially enhances both production and recovery. The concept features, project description, design basis, implementation, start-up and ongoing development are discussed. (C. Paice)

Flow rate calculation taking into account the influence of cavitation (Berechnung des Volumenstromes unter Berucksichtigung des Kavitationseinflusses)
Gratz U., *Olhydraulik & Pneumatik*, 1995, 4/- (355-359). In German.
Cavitation in hydraulic transmissions and controls is an undesirable phenomenon. It cannot however always be avoided. Cavitation causes increased wear in hydraulic components and is also responsible for higher noise emission levels and changes in the flow impedance characteristics. This results in higher energy losses. A cavitation criterion together with a model description for hydraulic restrictions enables the flow rate through a hydraulic resistance to be calculated with and without cavitation influence. (English summary)

Propagation and interaction of non-linear surface and internal waves in a two-layer fluid
Korsunsky S.V., *Physical Oceanography*, 1995, 6/5 (331-341).
This paper focuses on the study of linear and non-linear surface and internal waves, in a complete setting, using a two-layer model of a stratified fluid. The respective Korteweg-de Vries evolutionary equations have been obtained, analysed, and compared with the 'rigid lid' model data. Boussinesq-type equations have been derived for the interacting modes pertaining to one type and to different types. It is shown that in addition to the known mechanisms of interaction between internal and surface waves, interaction between long non-linear baroclinic modes and barotropic modes, propagating in the same direction, is likely in such a system. (Journal summary)

Decay of dipolar vortex structures in a stratified fluid
Flor J.B., Van Heijst G.J.F. & Delfos R., *Physics of Fluids*, 1995, 7/2 (374-383).
In this paper the viscous decay of dipolar vortex structures in a linearly stratified fluid is investigated experimentally, and a comparison of the experimental results with simple theoretical models is made. The dipoles are generated by a pulsed horizontal injection of fluid. In a related experimental study by Flor and van Heijst, it was shown that, after the emergence of the pancake-shaped vortex structure, the flow is quasi-two-dimensional and decays due to the vertical diffusion of vorticity and entrainment of ambient irrotational fluid. This results in an expansion of the vortex structure. Two decay models with the horizontal flow based on the viscously decaying Lamb-Chaplygin dipole, are presented. In a first model, the thickness and radius of the dipole are assumed constant, and in a second model also the increasing thickness of the vortex structure is taken into account. The models are compared with experimental data. (from Authors)

Steadily translating vortices in a stratified fluid
Arendt S., *Physics of Fluids*, 1995, 7/2 (384-388).
The existence of steadily translating vortices in a semi-infinite barotropic fluid stratified by a constant gravitational field is considered. Assuming that the flow field of the vortex is subsonic and contains finite total kinetic energy, it is found that steadily translating vortices do not exist in three dimensions, but do exist in two dimensions. An analogy between a subsonic, barotropic, stratified fluid, and a uniform fluid with a free-slip planar boundary is exploited to show that the same result applies in a semi-infinite uniform fluid. (Author)

The role of dynamic surface tension in air assist atomization
Shavit U. & Chigier N., *Physics of Fluids*, 1995, 7/1 (24-33).
Aqueous surfactant solutions were atomized using an air assist atomizer, and the effects of dynamic surface tension on atomization were studied. The solutions differ from one another in their dynamic behavior, but all have the same equilibrium surface tension. The constant equilibrium surface tension was achieved by choosing surfactant concentrations above the critical micelle concentration (CMC). The dynamic change of surface tension in aqueous Tergitol NP-10 solutions of 1.5, 3, 6, 12, and 60 mM was measured using the oscillating jet technique. While atomizing the liquid jet, it was found that frequencies and amplitudes of the flapping motion of the liquid jet increased with surfactant concentration showing that surface tension decreases in the region between th nozzle exit and breakup. The length of the intact liquid jet was found to be insensitive to surfactant concentration. (from Authors)

Lagrangian self-diffusion of Brownian particles in periodic flow fields
Mauri R., *Physics of Fluids*, 1995, 7/2 (275-284).
The steady transport of Brownian particles convected by a periodic flow field is studied by following the motion of a randomly chosen tagged particle in an otherwise uniform solute concentration field. A nonlocal, Fickian constitutive relation is derived, in which the steady mass flux of Brownian particles equals a convolution integral of the concentration gradient times a (tensorial) diffusion function. In turn, the diffusion function is uniquely determined via the nth diffusivities, which are determined analytically in terms of the nth cumulants of the probability distribution by exploiting the translational symmetry of the velocity field. The Lagrangian, long-time self-diffusion function is shown to be equal to the symmetric part of the Eulerian, gradient diffusion function. The present results are applied to study the transport of solute particles immersed in a fluid flowing in rectilinear pipes and through periodic fixed beds of spheres at low Peclet number. In the first case, the first six nth diffusivities are determined; in the second, the first two diffusivities are calculated. (from Author)

Dynamics of heavy particles in a Burgers vortex
Marcu B., Meiburg E. & Newton P.K., *Physics of Fluids*, 1995, 7/2 (400-410).
This paper presents a linear stability analysis as well as some numerical results for the motion of heavy particles in the flow field of a Burgers vortex, under the combined effects of particle inertia, Stokes drag, and gravity. By rendering the particle motion equations dimensionless, the particle Stokes number, a Froude number, and a vortex Reynolds number are obtained as the governing three parameters. In the absence of gravity, the vortex center represents a stable equilibrium point for particles up to a critical value of the Stokes number, as the inward drag overcomes the destabilizing centrifugal force on the particle. Particles exceeding the critical Stokes number value asymptotically approach closed circular orbits. Under the influence of gravity, one or three equilibrium points appear away from the vortex center. Both their locations and their stability characteristics are derived analytically. (from Authors)

The structure of (linearly) stable double diffusive flow patterns in a laterally heated stratified liquid
Kranenborg E.J. & Dijkstra H.A., *Physics of Fluids*, 1995, 7/3 (680-682).
Layered double diffusive flow patterns in a laterally heated stably stratified liquid are considered in a configuration which allows for steady states to exist. For the heat/salt system, these flows are characterized by the thermal and solutal Rayleigh numbers Ra_T and Ra_S, or equivalently by Ra_T and the buoyancy ratio R_{rho}. The bifurcation structure of steady patterns with respect to Ra_T is computed for two cases: fixed Ra_S and fixed R_{rho}. (from Authors)

Nonlinear modeling of jet atomization in the wind-induced regime
Spangler C.A., Hilbing J.H. & Heister S.D., *Physics of Fluids*, 1995, 7/5 (964-971).
The atomization of a liquid jet in a gaseous environment is a fundamental problem in two-phase flows. The numerous applications of this flow include devices used for liquid fuel injection systems, spray painting, and ink jet printing. This work presents an extension of the model due to Mansour and Lundgren for the case where gas-phase pressure variations are not negligible. The model, based on a BEM approach, is discussed. Comparisons are made for both linear theory and measured drop sizes, and detailed surface evolutions are presented as well. (from Authors)

Stably stratified turbulence subjected to a constant area vertical expansion
Thoroddsen S.T. & Van Atta C.W., *Physics of Fluids*, 1995, 7/5 (1165-1167).
In a recent experiment we have passed stably stratified turbulence through a localized two-dimensional contraction, where the flow is contracted in the vertical direction only, while having a constant width. Downstream of the contraction the increased strength of stratification was found to lead to a rapid fossilization and subsequent turbulence revival through zombie-like restratification. To study the inverse effect we have passed a stably stratified turbulent field through an expansion in the vertical direction. We have chosen a linear expansion, while keeping the cross-sectional area of the test-section constant, by contracting the side-walls. This configuration avoided separation of the flow from the expanding floor and ceiling. The resulting reduction in stratification strength interacts with the vortex stretching due to the induced cross-strain, an effect first studied by Townsend in a

homogeneous fluid. The expansion is applied to the turbulence at two different states of evolution, by using two different stratification strengths. (after Authors)

Magnetic resonance imaging study of sedimenting suspensions of noncolloidal spheres
Turney M.A., Man Ken Cheung, McCarthy M.J. & Powell R.L., *Physics of Fluids*, 1995, 7/5 (904-911).
Sedimentation is an important means of concentrating suspensions of particles. The design of equipment and processes involving sedimentation of particles requires accurate knowlege of sedimentation rates and concentration profiles. Batch sedimentation experiments were conducted with suspensions of noncolloidal spherical particles. Using nuclear magnetic resonance imaging (NMRI), the time evolution of the volume fraction versus height profile was measured for initial suspension volume fractions, phi$_i$, ranging from 0.08 to 0.44. NMRI clearly delineates the clear fluid layer at the top of the suspension, below which there is a transition to a region having the initial mean particle concentration. The hindered settling function determined from these data corresponds well with previous results. (after Authors)

Particle behavior in the turbulent boundary layer. I. Motion, deposition, and entrainment
Kaftori D., Hetsroni G. & Banerjee S., *Physics of Fluids*, 1995, 7/5 (1095-1106).
The behavior of solid particles in the wall region of a turbulent boundary layer is of importance for the understanding of deposition, fouling, entrainment, and resuspension in industrial and environmental processes. Though the mechanisms governing such phenomena have been extensively studied in the past they are not completely understood. The motion of solid particles near the wall in a turbulent boundary layer was investigated experimentally in a water flume by flow visualization techniques and by LDA. The particles were of polystyrene with diameters ranging from 100 to 900 mum. Results show that particle motion, as well as entrainment and deposition processes, are controlled by the action of coherent wall structures, which appear to be funnel vortices. (after Authors)

Particle behavior i· the turbulent boundary layer. II. Velocity and distribution profiles
Kaftori D., Hetsroni G. & Banerjee S., *Physics of Fluids*, 1995, 7/5 (1107-1121).
This paper is the second part of a series regarding the behavior of solid particles in a turbulent boundary layer. In Part I, the motion of heavier-than-fluid particles near the wall of a horizontal water flume was studied, as well as the mechanisms of particle entrainment and deposition. It was found that these processes are directly related to the effects of turbulence wall structures. The work of Part I is now expanded to include the effects of funnel vortices on the behavior of particles away from the wall. The velocity, distribution, and concentration profiles throughout the boundary layer were measured and photographed. It is found that the vortices may be the reason for the average velocity difference between particles and fluid, and that they may have a significant effect on the shape of the particle distribution and concentration profiles. (from Authors)

The linear instability of an oscillatory two-phase channel flow in the limit of small Stokes numbers
Yen-Cho Chen & Chung J.N., *Physics of Fluids*, 1995, 7/6 (1510-1512).
The instability of a two-phase flow is important to many industrial and energy related processes. The qualitative behavior of linear stability characteristics of the steady gas-particle channel flow has been investigated by Saffman. He found that if the Stokes number is smaller than unity, the addition of particles destabilizes a gas flow; whereas if the Stokes number is greater than unity, the particles have a stabilizing action. Flow oscillation has been shown to have many applications in multiphase flow and the instability characteristics of the gas-particle flow are essential to the understanding of turbulent flow. This note, concentrates on the case of small Stokes numbers. Some new findings are provided for the particle effects on the linear instability characteristics of an oscillatory gas-particle channel flow. (from Authors)

Equilibrium salt-fingering convection
Shen C.Y., *Physics of Fluids*, 1995, 7/4 (706-717).
A numerical model of a continuously heat and salt stratified fluid system was used to investigate the possible existence of salt fingering in a deep fingering domain, equivalent to large Rayleigh number fingering convection. Growth of fingering heat and salt fluxes is shown to be limited by the instability of fingering cells, and an equilibrium state is reached when the instability has increased the energy dissipation sufficiently to balance buoyancy forcing generated by double diffusion. Equilibrium fluxes are shown to be proportional to mean vertical T and S gradients. The equilibrium convection structure is shown to be disorganised and turbulent, characterised by incoherently rising and sinking blobs of anomalous density. A model of equilibrium fingering based on the blob structure is presented. A critical Rayleigh number for delineating equilibrium fingering from low Rayleigh number fingering is suggested. (from Author)

The effect of shear in selective withdrawal
Clarke S.R. & Imberger J., *Physics of Fluids*, 1995, 7/7 (1523-1528).
When fluid is withdrawn from a vertically stratified water body it is found that at sufficiently low Froude numbers the withdrawn fluid comes from a narrow layer adjacent to the level of the sink. This process, known as selective withdrawal, has widespread application in the management of reservoirs. The evolution of the withdrawal through a line sink of an initially quiescent, linearly stratified fluid in a semi-infinite, horizontal duct is investigated. An alternative mechanism for the control of this flow is proposed based on solutions for the vertical structure of linear, long, internal waves in horizontal shear. This results in a model for unsteady selective withdrawal in agreement with steady-state solutions. (after Authors)

Macroscopic behavior of vibrating beds of smooth inelastic spheres
Lan Y. & Rosato A.D., *Physics of Fluids*, 1995, 7/8 (1818-1831).
Despite the tremendous use of bulk solids in a wide variety of industrial settings there is no general understanding or model of even the most seemingly simple flows capable of describing behavior over the entire spectrum of possible flow regimes. Bulk solids are usually subjected to handling processes, including the use of vibrations to facilitate their transport. A variety of interesting effects can occur depending on vibratory parameters, particle size, density and shape distributions, material properties, and geometry. These include convection, fluidization, heaping segregation, and the development of surface waves and arching, within the bed. Three-dimensional granular dynamics simulation are carried out to investigate macroscopic behavior of granular materials subjected to vibrations. Computed granular temperature and solids fraction depth profiles are in good agreement with recent kinetic theory predictions when the acceleration is large enough, while bed expansion at lower accelerations is quantitatively consistent with existing experimental data. (from Authors)

Particle interactions in diffusiophoresis in nonelectroylte gradients
Keh H.J. & Luo S.C., *Physics of Fluids*, 1995, 7/9 (2122-2131).
An analytical study is presented for the diffusiophoretic motion of two colloidal spheres in a constant gradient of a nonionic solute

using a method of reflections. The particles are oriented arbitrarily relative to the gradient, and they are allowed to differ in radius and in surface properties. A normal flux of the solute and a slip velocity of the fluid at the outer edge of the thin diffuse layer are used at the boundary conditions for the fluid domain outside the diffuse layers. The method of reflections is based on an analysis of the solute concentration and fluid velocity distribances generated by a single sphere placed in an arbitrarily varying concentration field. Based on a microscopic model, the results for two-sphere interactions are used to find the effect of the volume fraction of particles of each type on the average diffusiophoretic velocity in a bounded suspension. For a suspension of identical spheres, this average velocity is decreased as the particle volume fraction is much weaker than that on sedimentation. (after Authors)

Photographic study of the shock-induced dispersion of microscopic gas bubbles
Szumowski A.P. & Falkowski K., *Physics of Fluids*, 1995, 7/11 (2529-2531).
The dynamics of cavitation bubble collapse has been a subject of interest for many years (Rayleigh). Diverse practical problems, eg the erosion of surfaces, and other effects of cavitation motivated numerous investigators to study this phenomenon. Separated and attached microscopic air bubbles excited by a sequence of expansion and compression (shock) waves are considered. (after Authors)

The collapse of a cavitation bubble in shear flows-a numerical study
Po-Wen Yu, Ceccio S.L. & Tryggvason G., *Physics of Fluids*, 1995, 7/11 (2608-2616).
Three dimensional, direct numerical simulation of the dynamics of cavitation bubbles can reveal new insight into more complex cavitating flows such as flow with non-spherical, non-axisymmetric bubbles, and bubble clouds in vortical flows. In this work, the dynamics of cavitation bubbles is estimated directly, and the effects of fluid viscosity and surface tension are considered. Although our technique allows us to simulate the interaction of several bubbles with the flow field and nearby solid boundaries, we only report results from simulations of single cavitating bubbles here. (after Authors)

Effect of flow geometry on the rheology of dispersed two-phase blends of polystyrene and poly(methyl methacrylate)
Han J.H., Chin Choi-Feng, De-Jie Li & Chang Dae Han, *Polymer*, 1995, 36/12 (2451-2462).
Thr rheological properties of blends of poly(methyl methacrylate) (PMMA) and polystyrene (PS), forming two phases in the molten state, were measured using cone-and-plate and capillary rheometers. For the PS/PMMA blends, we have found that logarithmic plots of steady shear viscosity versus shear rate obtained by a cone-and-plate rheometer do not overlap those obtained by a capillary rheometer, whereas for the homopolymers PS and PMMA there is a good agreement between the two. This observation is explained in terms of the differences in the morphological states of the blends between the uniform shear flow in a cone-and-plate rheometer and the non-uniform shear flow in a capillary rheometer, which involves the entrance and exit effects. (from Authors)

A novel thermotropic polyester with a flexible side group: synthesis and characterization, as well as rheology of its poly(theylene terephthalate) blends
Narayan-Sarathy S., Wedler W., Lenz R.W. & Kantor S.W., *Polymer*, 1995, 36/12 (2467-2471).
A thermotropic liquid crystalline (LC) polyester containing the 2-butoxyethyleneoxy-1,4-phenylene terephthalate unit (PBEPT) was synthesized and characterized by viscosity measurements, thermogravimetry (tga), dsc and polarizing microscopy. The polymer exhibited liquid crystallinity in the processing temperature range of poly(ethylene terephthalate) (PET). Blends of PBEPT and PET were prepared. Rheological measurements of the blends were conducted, and compared with data for pure PET, in order to evaluate the effect of the LC polyester on the viscoelasticity of the matrix polymer. (from Authors)

Use of acidobasic indicators to detect interfacial reactivity during alkaline flooding
Hornof V., Neale G.H. & Gholam-Hosseini M., *Powder Technology*, 1995, 82/2 (205-208).
A novel technique has been developed to detect the depletion of the alkaline reagent that occurs during the displacement of an acidified oil by an aqueous alkaline solution in a consolidated model porous medium. An acidobasic indicator (thymolphthalein) was added to the displacing aqueous solution in order to monitor the progress of the chemical reaction. The initially blue alkaline solution turned colorless after prolonged contact with the acidified oil, indicating that the alkali in the vicinity of the interface became depleted as a direct result of interfacial chemical reaction. The disappearance of color was particularly pronounced at low alkali concentrations and low flowrates. (from Authors)

Theory of sound propagation in suspensions: a guide to particle size and concentration characterization
Kytomaa H.K., *Powder Technology*, 1995, 82/1 (115-121).
There has been recent increasing interest in the acoustic properties of suspensions for applications such as ultrasonic particle size and concentration instrumentation. This paper aims to summarize what it known about the acoustic properties of suspensions of solids in a liquid and aims to identify the methods that enable useful information to be extracted from sound speed and attenuation information such as particle size, concentration, and the mechanical properties of the constituents. The paper identifies regime of sound propagation and present models for these that can be used for size characterization of slurries. (Author)

Fluidization of FCC powders in the bubble-free regime: effect of types of gases and temperature
Xie H.-Y. & Geldart D., *Powder Technology*, 1995, 82/3 (269-277).
A 0.152 m diameter stainless steel fluidization column was constructed which can operate at closely regulated temperatures up to 500 degrees C. A wide range of experiments was performed at different temperatures using specially-prepared size fractions of FCC powders in various gases: air, argon, neon, carbon dioxide and Freon-12. Measurements of the incipient fluidization and bubbling velocities, and the voidage at the bubbling point, are compared with existing correlations and new improved correlations have been developed. Published theoretical equations, which are based entirely on hydrodynamic considerations, predict that the voidage at minimum bubbling should increase as temperature increases, but our experimental results show virtually no change. Although these equations predict the voidage well for the coarser fractions at room temperature, they become increasingly inaccurate as particle size is decreased, and this is believed to be the result of ignoring the interparticle forces. (Authors)

Propagation of pressure waves and forced oscillations in gas-solid fluidized beds and their influence on diagnostics of local hydrodynamics
Bi H.T., Grace J.R. & Zhu J., *Powder Technology*, 1995, 82/3 (239-253).
Experiments were conducted in a 50 mm diameter gas-fluidized bed to investigate the origin and propagation behaviour of pressure waves. The attenuation and amplification of pressure waves during propagation away from their sources are explained by the interaction between particles and the fact that forced oscillations of fluidized beds are coupled with propagating pressure waves. Both the pseudo-homogeneous compressible wave theory and the separated flow compressible wave theory are shown to give good predictions of the propagation velocity of pressure waves in gas-fluidized beds. The dramatic increase in wave velocity

when the superficial gas velocity is decreased below the minimum fluidization velocity is attributed to a change in the forms of waves. (from Authors)

Compression and rarefaction waves in granular flow
Ocone R. & Astarita G., *Powder Technology*, 1995, 82/3 (231-237).
The propagation of finite one-dimensional discontinuities of particulate-phase pressure in dry granular flow is examined. These discontinuities are classified depending on whether the granular pressure behind the discontinuity is larger or smaller than that in front of it. If the speed of propagation of infinitesimal discontinuities is regarded as 'sonic', the former propagate 'supersonically', while the latter propagate 'subsonically'. Rarefaction and compression waves are also analyzed, and we show that, based on realistic constitutive assumptions on the density dependence of particulate-phase pressure, rarefaction waves smooth out as they propagate, while compression waves reinforce each other to become shocks. (Authors)

The influence of the frequency of acoustic waves on sound-assisted fluidization of beds of fine particles
Russo P., Chirone R., Massimilla L. & Russo S., *Powder Technology*, 1995, 82/3 (219-230).
Sound-assisted fluidization of nonfluent 0.5-45 mum catalyst particles has been studied with a 145 mm i.d. column. For given weight W and sound pressure level SPL, the ranges of frequency within which channel-free homogeneous fluidization could be obtained have been determined, and within these ranges of kinds of curves for sizes of subclusters d_s as a function of the frequency have been outlined. The nonmonotonic form of these curves could not be explained by means of the original sound-assisted fluidization model, which assumes a rigid cluster-subcluster structure. The existence of elastic forces between clusters and subclusters, assumed by the cluster/subcluster oscillators model, yields theoretical d_s versus f curves with the same trend as those from experiments. (from Authors)

Heat transfer coefficients between gas fluidized beds and immersed spheres: dependence on the sphere size
Donsi G. & Ferrari G., *Powder Technology*, 1995, 82/3 (293-299).
Heat transfer coefficients between gas-fluidized beds and immersed spheres of different sizes have been experimentally determined for different fluidization velocities, bed particle properties and temperatures, in the lower range of the bubbling bed regime. Results elucidate the pattern of the dependence of heat transfer coefficients on the different variables and demonstrate that the size of the immersed sphere and the fluidization excess velocity are the main factors influencing the heat transport process, together with the bed particle size. Discussion of the results suggests a possible physical interpretation, consistent with the regular flow of bed solids past the immersed object so that the particle residence time can be correlated in terms of the excess gas velocity. (from Authors)

Modelling of the trajectories of particles conveyed by a gaseous jet onto a plane surface. Comparison with experience (Modelisation des trajectoires de particules projetees par un jet gazeux sur une surface plane. Comparaison avec l'experience)
Lede J., Barillon B., Villermaux J. & Marcant S., *Powder Technology*, 1995, 83/2 (173-186). In French.
The purpose of the present paper is the theoretical study of the behaviour of particles conveyed by a gaseous jet onto a flat surface. The calculations of the trajectories of the particle are made by a Lagrangian approach by means of a simplified hypothesis on the velocity field of the gas. The model shows that the particles undergo a first collision on the surface followed by successive rebounds before final settling. The trajectories are studied as a function of operating conditions. The values of the settling locations of the particles are compared finally with results derived from two different experimental approaches. (English summary)

Quantitative predictions of gas-particle flow in a vertical pipe with particle-particle interactions
Yasuna J.A., Moyer H.R., Elliott S. & Sinclair J.L., *Powder Technology*, 1995, 84/1 (23-34).
A computational study of fully-developed gas-particle flow in vertical risers is carried out, using the model of Sinclair and Jackson, in order to assess quantitatively the predictive capabilities of the model. Results from comparisons between model predictions and a large body of available experimental data are summarized. In addition, the growing body of data on gas-solid flows is analyzed in a self-consistent manner. Pita and Sundaresan have recently shown that the model was able to reproduce one set of experimental data surprisingly well although the model neglects some important physics relevant to the problem; for example, only elastic particle-particle oscillations were considered. In this study, attention is restricted to the same case, and it is found that, in general, the model predictions compare favorably with the experimental data. Predictions from a model which neglects particle-particle interactions are shown, as well as the effect of these interactions on the complex relationship between the operating variables. (Authors)

Gas-solids circulating fluidization in a packed bed
Xuqi Song, Zhanwen Wang, Yong Jin & Tanaka Z., *Powder Technology*, 1995, 83/2 (127-131).
Gas-solid-solid circulating fluidized bed is a novel gas-solid contactor which offers interesting heat and mass transfer properties. The pressure gradient and powder hold-up in the packing have been measured in a rectangular fluidized bed. A theoretical analysis for the prediction of pressure drop, which is caused by the powder hold-up and the friction between gas and packing and between powders and packing, has been proposed. The predicted results agree well with the experimental results. (from Authors)

Relationship between rheological properties of slurries and pore size distribution of cast and compressed compacts of mullite
Hashi Y. & Senna M., *Powder Technology*, 1995, 83/3 (187-191).
Mullite slurries with varying particle size, solid fraction and dispersant content were cast, dried and subsequently compressed to obtain a series of green compacts. The relationship between the rheological properties of slurries and pore size distribution of the green compacts was examined. Slip cast bodies obtained from shear thinning slurries have larger total pore volume, which decreases considerably with increasing pressure during post-compression. The ratio of the median pore diameter of the compact to the median particle size is higher on the as-cast bodies obtained from shear thinning slurries than on those from Newtonian ones. The difference of the ratio becomes smaller with increasing post-compressive pressure. (from Authors)

Entrainment and elutriation modelling in bubbling fluidized beds
Milioli F.E. & Foster P.J., *Powder Technology*, 1995, 83/3 (233-243).
In bubbling fluidized bed combustion and catalytic cracking, elutriation is a major cause of inefficiency, while it is highly desirable, for instance, in sludge incineration. Whether the intention is to quench or promote elutriation, the involved phenomena must be properly known if the process is to be efficiently controlled. In this work, entrainment and elutriation are reviewed and a modelling proposal is developed. The main concern relates to bubbling beds of wide spread particle size distributions under vigorous fluidization. The particles are subdivided into three classes: critical fines, smalls and larges. The bed surface entrainment model presents parameters which must be evaluated from empirical data. Comparison to experiment shows that, for U/U_{mf} = or 10, f_w xi_k should increase with U/U_{mf}, and a correlation is proposed to account for this variation. (from Authors)

Rheology of a gas-fluidized bed
Anjaneyulu P. & Khakhar D.V., *Powder Technology*, 1995, 83/1 (29-34).
Apparent shear viscosities of gas-fluidized beds result from microscopic forces due to collisions between particles as well as interparticle friction. Estimation of such rheological properties is important for the modelling of the hydrodynamics of fluidized beds. In this work, rheological measurements for a gas-fluidized bed of glass beads are carried out using an annular geometry. The parameters varied in the study are the gas flowrate in a small range close to the minimum fluidization value, and the particle size. The experiments show that the fluidized bed behaves like a Bingham plastic. The values of the viscosity obtained are in agreement with previously reported values (0.1-2.5 Pa s), and the yield stress is in the range 1-5 Pa. Further confirmation of the Bingham model is obtained from flow visualization experiments, which show the existence of a finite sheared layer with a thickness that is in reasonable agreement with the theoretically predicted value. (Authors)

Characterization of dilute gas-solids flows using the rescaled range analysis
Cabrejos F.J. & Klinzing G.E., *Powder Technology*, 1995, 84/2 (139-156).
A diagnostic technique to predict the flow patterns of fully developed flows of dilute gas-solids suspensions inside horizontal straight pipes has been developed. This technique is based on the rescaled range analysis of absolute and differential wall pressure fluctuating signals. Experiments have been carried out in a 2 in pipeline with 3 mm poly(ester) polymers, 450 mum glass beads, and 450 mum alumina at different loading conditions so that different flow regimes could be achieved. The study includes the generation of general state diagrams and flow-pattern maps to fully understand the complex behavior of particles conveyed pneumatically through pipelines. (from Authors)

Effect of surfactant treatment on the formation of bound polymer on titanium dioxide powders
Arellano M., Manas-Zloczower I. & Feke D.L., *Powder Technology*, 1995, 84/2 (117-126).
The dispersibility of agglomerates into polymeric media is affected by the interactions between the medium and the particles and between the particles themselves. The amount of bound polymer was used as a measure of interfacial interactions between the particles and the medium. Titanium dioxide powders with surfaces modified with silica and/or alumina were analyzed for their interactions with various liquid media by suspending them in different solvents and monitoring dispersion stability for given periods of time. Determination of the bound polymer in dispersions of different coated titania particles in linear low density poly(ethylene) showed better interactions between the polymer and the filter particles for surfactant treated powders. (from Authors)

The cluster size distribution and motion behavior in a fast fluidized bed
Hongzhong Li, Qingshan Zhu, Hua Liu & Yufeng Zhou, *Powder Technology*, 1995, 84/3 (241-246).
The cluster size distribution and motion behavior in a fast fluidized bed have been measured systematically by using two optical fiber probes and a computer data acquisition system. There are two phases in fast fluidized bed: a dispersed phase and a cluster phase. In the dispersed phase the particles present essentially as individuals, while in the cluster phase the particles agglomerate with one another and are enmeshed in the dispersed phase. The motion behavior of clusters in the lower dense section and the upper dilute section are similar to the motion behavior of particles in the lower dense region and the upper freeboard region of a bubbling fluidized bed, respectively. (from Authors)

A new criterion for prejudging the fluidization behavior of powders
Zhaolin Wang & Hongzhong Li, *Powder Technology*, 1995, 84/2 (191-195).
A new intrinsic criterion, equivalent specific surface area A_e, is proposed, by which different fluidized behaviors of particles can be classified. In addition, this criterion has been introduced to prejudge fluidization behaviors of mono-component particles which have wide size distributions and multi-component mixtures of Geldart's type A, B or D powders. (Authors)

Pneumatic conveying of ice particles through mine-shaft pipelines
Sheer T.J., *Powder Technology*, 1995, 85/3 (203-219).
A pilot-plant experimental investigation is described into the pneumatic conveying of large ice particles through long pipelines extending down deep mine shafts. Using low-pressure plastic piping with an inner diameter of 136 mm and cylindrical ice particles with initial dimensions of up to 34 mm, the main testing programme encompassed ice flow rates of up to 7.4 kg/s through a pipeline 2968 m long and extending to a depth of 1770 m below the surface. Ice was also delivered to a depth of 2407 m below the surface through a pipeline 3905 m long. Various regimes of two-phase flow were observed in the various and horizontal sections of the pipeline, including dilute-phase flow and cohesive plug flow. Equations are presented for the prediction of pressure gradients along the respective sections, with empirical correlations for solids friction factors. (from Author)

Measurement of particle flow properties in a suspension by a laser system
Bao J. & Soo S.L., *Powder Technology*, 1995, 85/3 (261-268).
Particle cloud density and velocity in a gaseous suspension with a particle-size distribution were determined by a two-dimensional system. Measurements were made possible by the combined use of a two-dimensional laser Doppler velocimeter and a phase Doppler particle analyzer. The results and data system show the feasibility of determining average and fluctuating properties and Reynolds stresses. (Authors)

Measurement of distribution of solids concentration on high density gas-solids flow using an optical-fiber probe system
Hong J. & Tomita Y., *Powder Technology*, 1995, 83/1 (85-91).
A method for calibrating the optical-fiber probe has been developed with adequate confidence. The distribution of solids volume concentration was then measured in a gas-solids flow at high solids loading ratio (i.e. solids/gas mass flowrate ratio) up to 70 in a pneumatic horizontal system with 18 mm and 30 mm i.d. pipelines. The local volume concentration of solids near the pipe bottom is well known to be smaller than its concentration in the loosely packed bed and to increase slowly with increasing solids loading ratio and decreasing pipe size, whereas the solids in the upper part of the pipe tend to concentrate to form a higher local concentration, probably because of electrostatic effects. However, the validity of the model Hong et. al., is reasonably well supported by the experimental average volume concentration of solids. (Authors)

Internal recirculation flow structure in vertical upflow gas-solid suspensions part II. Flow structure predictions
Bai D., Zhu J.-X., Jin Y. & Yu Z., *Powder Technology*, 1995, 85/2 (179-188).
A predictive two-region model previously developed by D.-R. Bai, J.-X. Zhu, Y. Jin and Z.-Q. *Yu, Powder Technol., 85 (1995) 171, is used to illustrate the characteristics of the core-annulus internal recirculation flow structure in circulating fluidized beds. The variations of the flow parameters with operating conditions are examined using the simulation results. While most predictions

agree well with the available experimental data, other simulation results are yet to be confirmed when more relevant experimental results become available. (Authors)

Internal recirculation flow structure in vertical upflow gas-solids suspensions part I. A core-annulus model
Bai D., Zhu J.-X., Jin Y. & Yu Z., *Powder Technology*, 1995, 85/2 (171-177).
A comprehensive, predictive two-region model has been developed to describe the core-annular internal recirculation flow structure in vertical gas-solids upward flowing suspensions. This new model is more flexible by allowing axial variations of the core radius and the gas and particle velocities in both the core and the annular regions. The validity of the model has been confirmed by good agreement between the predicted values and the various experimental measurements reported in the literature, including the radius of core region, voidage in the core region, solids recirculation ratio and deposition coefficient. (Authors)

The use of a circulating fluidized bed absorber for the control of sulfur dioxide emissions by calcium oxide sorbent via in situ hydration
Jiang M.X., Keener T.C. & Khang S.J., *Powder Technology*, 1995, 85/2 (115-126).
A circulating fluidized bed absorber (CFBA) was developed and evaluated for sulfur dioxide removal from flue gas by use of a CaO sorbent at humid conditions. SO_2 removal in this process strongly depends on the system approach to saturation temperature, which increases with an increase of the approach to saturation temperature (smaller DELTAT). The operability of the CFBA by use of very large CaO particles (initial size 1800 mum) indicates substantial cost savings for application to full scale systems. A CFBA reactor model based on the assumption of a turbulent fluidization region, was developed for system analysis and SO_2 removal data analysis. The reaction rate constant, k_s, was found to be a function of the system approach to saturation temperature; the value of k_s increases exponentially with an increase of the approach to saturation temperature. This model, with some modifications could be successfully used in the prediction of SO_2 removal efficiency. (from Authors)

Theoretical evaluation of the effects of the impeller entrance geometry and of the incident angle on cavitation inception in centrifugal pumps
Ardizzon G. & Pavesi G., *Proceedings - IMechE: C, Journal of Mechanical Engineering Science*, 1995, 209/C1 (29-38).
A method, based on quasi three-dimensional analysis, of describing pump cavitation behaviour is proposed. Cavitation performance is related to impeller entrance design and the influence of the angle of attack of the leading edges on the flow is studied. Coefficients are derived from the pressure drop due separately to the vanes and shroud. The influence of incident angle on cavitation is shown as a function of the blade geometry and discussed. By comparison with experimental data on centrifugal pumps, it is shown that the present model can simulate the characteristics of inception cavitation at design and off-design conditions. (Authors)

On the performance of a cascade of turbine rotor tip section blading in nucleating steam. Part 1: surface pressure distributions
Bakhtar F., Ebrahimi M. & Webb R.A., *Proceedings - IMechE: C, Journal of Mechanical Engineering Science*, 1995, 209/C2 (115-124).
During the course of expansion in turbines, steam first supercools and then nucleates to become a two-phase mixture. Formation and subsequent behaviour of the liquid lower the performance of turbine wet stages. To reproduce turbine nucleating and wet flow conditions requires a supply of supercooled steam which can be achieved under blow-down conditions by the equipment employed. The performance of a cascade of rotor tip section blading in nucleating steam has been studied. The results of the surface pressure measurements are described in the paper. (Authors)

On the performance of a cascade of turbine rotor tip section blading in nucleating steam. Part 2: wake traverses
Bakhtar F., Ebrahimi M. & Bamkole B.O., *Proceedings - IMechE: C, Journal of Mechanical Engineering Science*, 1995, 209/C3 (169-177).
During the course of expansion of steam in turbines the fluid first supercools and then nucleates to become a two-phase mixture. To reproduce turbine two-phase flow conditions requires a supply of supercooled vapour which can be achieved under blow-down conditions by the equipment employed. This paper is the second of a set describing an investigation into the performance of a cascade of rotor tip section profiles in nucleating steam and presents the results of the wake traverses and droplet measurements. (Authors)

A generalized computational fluid dynamics approach for journal bearing performance prediction
Tucker P.G. & Keogh P.S., *Proceedings - IMechE: J, Journal of Engineering Tribology*, 1995, 209/J2 (99-108).
This paper addresses the application of a full three-dimensional thermohydrodynamic CFD approach to journal bearings. The journal/shaft may extend beyond the bearing length and the rotation effect is accounted for in the thermal transport process. A circumferentially uniform shaft surface temperature is not assumed. Cavitation modelling is based on averaged lubricant/vapour properties and does not set pressures directly, allowing sub-ambient pressures to be predicted. Lubricant inlet grooves are incorporated with conservation of mass and the possibility of backflow. The modelling is validated against published experimental work on fully circumferential, single inlet and two-inlet circular bore bearings. The predicted and experimental results are in general agreement. (Authors)

Flow over mountains: Coriolis force, transient troughs and three dimensionality
Peng M.S., Shang-Wu Li, Chang S.W. & Williams R.T., *Quarterly Journal - Royal Meteorological Society*, 1995, 121/523 (593-613).
Some issues, concerning uniform, stratified flow over a three-dimensional mountain, that have not been fully explored are studied using primitive-equation models. When the Froude number (Fr) is small (e.g. Fr 0.5), we find that the Coriolis force cannot be neglected for flow over small-scale mountains (characteristic length L 50 km) even though the Rossby number (Ro) is large. Therefore, the importance of the Coriolis effect is determined by both Ro and Fr. Simulations of flows over mountains in two-dimensional and three-dimensional models with the same cross-sectional profile are compared. For small-scale mountains (L 100 km), the two-dimensional model overestimates the amount of airflow over the mountain and also the lee-side downslope wind. (from Authors)

Development of capacitance tomographic imaging systems for oil pipeline measurements
Yang W.Q., Stott A.L., Beck M.S. & Xie C.G., *Review of Scientific Instruments*, 1995, 66/8 (4326-4332).
Oil pipelines contain mixtures of oil, gas and water. To measure such multicomponent flows, various electrical instruments utilising the electrical properties of the flowing materials (conductance, capacitance or inductance) have been investigated. In the 1980s a new technique - process tomography (PT) emerged. In recent years, PT systems using a variety of transducers have been developed, especially electrical impedance tomography (EIT) systems including electrical resistance tomography (ERT), elec-

trical capacitance tomography (ECT) and electro-magnetic tomography (EMT) systems. This paper describes the ECT systems developed at UMIST to measure flows having components with distinct permittivities, particularly the gas/oil and oil/water mixtures found in the oil industry. (after Authors)

Computational fluid dynamics for reactor engineering
Ranade V.V., *Reviews in Chemical Engineering*, 1995, 11/3 (229-289).
Computational fluid dynamics (CFD) offers the possibility of predicting the detailed flow and turbulence characteristics of the reactor under different geometrical and operating conditions. This review focuses on CFD methods for simulating recirculating, turbulent single and two phase flows in reactors. An attempt has been made to convey and clarify the potential of CFD for reactor engineering research. The emphasis is on informing the reader about different aspects of constructing CFD simulation models of reactors rather than an exhaustive literature review. Formulation of transport equations for flow modelling is discussed for single and dispersed two phase flows. Flow simulations of the two most commonly used reactors, namely the stirred tank reactor and the bubble column reactor, are discussed in detail. The limitations of the present state of knowledge with respect to possible applications in reactor engineering are discussed. Some suggestions for further research are offered. (from Author)

A unified model for slug flow generation
Bernicot M. & Deheuvels P., *Revue - Institut Francais du Petrole*, 1995, 50/2 (219-236).
In order to improve the global safety and reliability level of multi-phase production systems and to guarantee their economical efficiency, a better understanding and control of hydraulic instabilities observed at the outlet of multi-phase sea-lines is needed. This may be obtained through the development of slug flow stochastic models, which must be able to explain: the generation of the various types of slug length distributions which are observed on experimental data sets; and the evolution of these distributions along the sea-lines up to their outlets, where large hydraulic fluctuations may be dangerous for the treatment installations. Based on experimental as well as theoretical arguments, such a model is presented with emphasis on slug generation. A detailed theoretical analysis is given, together with a discussion of the underlying assumptions which justify the introduction of this model. (Authors)

Behavior of surface layers of material in cavitational wear
Tsvetkov Yu. N. & Pogodaev L.I., *Russian Engineering Research*, 1995, 15/3 (7-11; translated from: Vestnik Mashinostroeniya, 75(3), 1995).
The most objective characteristic allowing materials to be grouped in terms of the parameters of the wear-time curve is the accumulation (incubation) period of cavitational wear. The changes undergone by the surface layers of the material in the initial period, under repeated microimpact loading, determine the development of wear in subsequent stages, in which the erosion rate increases to the maximum value. In developing methods to predict the life of components, it is expedient to investigate the behavior of the surface layers of materials in microimpact loading and the ability of microvolumes to absorb the energy of plastic deformation in the period preceding the onset of catastrophic wear with the formation of developed surface relief. In the present work, as a first step, the goal is to obtain such a dependence on the basis of the analysis of experimental data. (from Journal translation)

Calculation of settling velocity of small solid particles in stratified suspension flows
Pyrkin Y.G. & Silaev M.A., *Russian Meteorology & Hydrology*, 1994/95, 7/- (51-55).
Formulas for calculating settling velocities of small particles are derived from the equation of continuity extended to the dynamics of variable-density flows. The formulas have been tested successfully on results of a laboratory experiment specially performed at the Chair of Sea and Land Water Physics of the Physical Department of Moscow State University. (Authors)

Wear testing in water slurries
Backmark U., *Scientific Impeller*, 1995, 3/- (37-39).
A test apparatus developed at ITT Flygt makes it possible to evaluate the wear resistance of materials used in pumps that handle slurries. Different polymeric and metallic materials were tested under various conditions. Tests with slurries of aluminium oxide and crushed rock show that a knowledge of the effects of sharpness and hardness of the particles is essential if one is to make useful comparisons between different materials. (Author)

Study on the guide impeller of large axial flow pump
Chen Jian, Zheng Yuchun & Qiu Chuanxin, *Shuili Xuebao/Journal of Hydraulic Engineering*, 1995, 10/- (8-14). In Chinese.
Combining the technical innovation of the 28CJ56 large pump in Hubei Nantaogou Pumping Station, problems such as serious cavitation, noise and shaking, arising from insufficiency of the submerged depth or other reasons, are solved by building a front guide impeller in front of the large vertical axial-flow pump. The principle operation of the guide impeller, characteristics of the cavitation and energy and the structure of the guide impeller and its influence upon the structure and function of the unit are also discussed. Theoretical analysis suggests that this method can be applied to the technical innovation of the pumping station and the enhancement of the sucking action of the pump. (Di Wu)

Improved computational procedure for retention relations of immiscible fluids using pressure cells
Liu H.H. & Dane J.H., *Soil Science Society of America Journal*, 1995, 59/6 (1520-1524).
The capillary pressure-saturation relation, or the capillary pressure head-volumetric fluid content relation, is of widespread interest in modeling and predicting multiphase fluid flow. The sensitivity analysis in this study shows that the pressure cell height, the positions of the pressure measuring devices, which can coincide with the in-and outflow ports, and the relative density difference of the fluids, can give rise to considerable errors in the determination of capillary pressure head-volumetric fluid content relations by the standard procedure using pressure cells. We, therefore, propose a curve-fitting method that considers nonuniform distributions of capillary pressure and volumetric fluid content of multiphase fluids. (from Authors)

A new technique for evaluating field cement mixing
Benge G., *SPE Drilling & Completion*, 1995, 10/2 (122-126).
This study investigates the ability of existing mixing equipment to deliver a cement slurry at a specified density and rate. This paper takes data recorded on location and graphically presents it in a three dimension graph of rate, density and volume percentage. This paper presents three dimension histograms from several cement jobs, attempts to evaluate the mixing errors on those jobs, and outlines the efforts taken to correct the problems. From the data evaluated, this analysis method allows for better evaluation of cement mixing, and the quantification of mixing characteristics of various pieces of cement equipment. (Author)

Pigging dynamics in two-phase flow pipelines: experiment and modeling
Minami K. & Shoham O., *SPE Production & Facilities*, 1995, 10/4 (225-231).

This paper presents an experimental and theoretical study on transient pigging operation. An extensive experimental program was carried out to acquire two-phase transient flow and pigging data on a 420 m [1378 ft] long, 77.9 mm [3.068 in] diameter horizontal pipeline. A computer-based data-acquisition system was used to obtain detailed information of the flow behavior during the experimental runs. The data include measurements of the time variation of the liquids slug size ahead of the pig, flow rates during the slug delivery, pig velocity, and pressure and liquid holdup distributions. A pigging model was developed for predicting the dymamics of a pigging operation. The model incorporates an improved simplified transient model that has been validated with the experimental data. A mixed Eulerean-Lagrangean approach was used to couple the transient model and the pigging model. The resulting computer simulator can predict the transient two-phase flow in a pipeline with or without pigging. (from Authors)

An experimental study of two-phase slug flow in hilly terrain pipelines
Zheng G.H., Brill J.P. & Shoham O., *SPE Production & Facilities*, 1995, 10/4 (233-239).
Experiments were conducted in a 76.2 mm diameter, 420 m long two-phase flow loop to study slug flow behavior in hilly terrain pipelines. Complex physical phenomena were observed, including generation of pseudoslugs at the horizontal/uphill elbow, variation of slug length along the pipeline, and persistent existence of slug flow in the downhill section. (Authors)

Two-phase flow in horizontal wells
Ihara M., Yanai K. & Takao S., *SPE Production & Facilities*, 1995, 10/4 (249-255).
Flow in horizontal wells and two-phase flow interaction with the reservoir were investigated experimentally and theoretically. Two-phase flow behavior has been recognized as one of the most important problems in production engineering. The authors designed and constructed a new test facility suitable for acquiring data on the relationship between pressure drop and liquid holdup along the well and fluid influx from the reservoir. For the theoretical work, an initial model was proposed to describe the flow behavior in a horizontal well configuration. The model uses the inflow-performance-relationship (IPR) approach and empirical correlations or mechanistic models for wellbore hydraulics. Although good agreement was found between the model and experimental data, a new IPR apart from the extension of Darcy's law must be investigated extensively to aid in the proper design of horizontal wells. (Authors)

Cavitation protection by low temperature TiCN coatings
Munsterer S. & Kohlhof K., *Surface & Coatings Technology*, 1995, 74-75/1-3 (642-647).
Cavitation erosion occurring at components exposed to fluids under high pressure is a fatigue wear-out process. As protective layers titanium-based coatings deposited on ball-bearing steel at a substrate temperature of 200 degrees C by unbalanced magnetron sputtering were investigated. The fatigue wear produced in an ultrasonic erosion test was evaluated by optical examination and digital image processing techniques. A droplet-free sputter deposition process was used. Cavitation wear behaviour could be correlated with physical properties of the coatings such as stoichiometry, microhardness, stress and structure. The cavitation resistance of state-of-the-art TiN films could be improved by incorporating carbon in the TiN lattice. Compared with TiN films the TiCN films exhibit a very prolonged incubation time for the onset of cavitation erosion. (from Authors)

Particle behavior in a two-fluid turbulent plasma jet
Huang P.C., Heberlein J. & Pfender E., *Surface & Coatings Technology*, 1995, 73/3 (142-151).
This paper is concerned with the application of a two-fluid turbulence model for plasma spray processes at atmospheric pressure, for improving our physical insight into the plasma/particle interactions. The turbulent stream is treated as a two-phase mixture. A stochastic approach is then used to study particle behavior under the influence of the two-fluid parcels. The Stokes number is introduced as an indicator of particle dispersion behavior. A series of simulations is performed to include the influence of different injection locations, particle sizes, and injection velocities. The results indicate the importance of the existence of large-scale eddies and variable property, Knudsen, and mass-transfer cooling effects on the particle motion and heating history. (from Authors)

Hydrodynamics of the forming section: the origin of nonuniform fiber orientation
Aidun C.K. & Kovacs A.E., *Tappi Journal*, 1995, 78/11 (97-106).
There are two kinds of secondary flow in a headbox. One comes from the geometric effects and the kinematics, and the turbulent motion of the field generates the other. In headbox hydrodynamic analysis, the anisotropy of normal Reynolds stresses is important in the analysis. Enhancement of the present computational method provides the mean Reynolds stresses through direct numerical simulation of the evolution of the instantaneous velocity field. The authors propose calibration of parameters using such data with comparison to previous experimental results. (Authors)

EHD analysis, including structural inertia effects and a mass-conservating cavitation model
Bonneau D., GuinesFrene D.J. & Toplosky J., *Transaction - ASME: Journal of Tribology*, 1995, 117/3 (540-547).
The dynamic behavior of two elastic connecting-rod bearings is studied. The Newton-Raphson method and 8-node isoparametric elements for the lubrication analysis are used. For the structural analysis, 3-D elasticity assumptions are made and 20 nodes isoparametric elements are used. Inertia forces due to the kinematics of the structure are incorporated with the effects of the hydrodynamic pressures in the elastic deformations of the bearing. Comparisons with Goenka's results are presented for the General Motors connecting-rod bearing. A mass-conserving model used in conjunction with Murty's algorithm is presented for the transient evolution of the cavitation area. This model is applied for the EHD study of a Renault connecting-rod bearing. (Authors)

Eccentric operation and blade-loss simulation of a rigid rotor supported by an improved squeeze film damper
Zhao J.Y. & Hahn E.J., *Transaction - ASME: Journal of Tribology*, 1995, 117/3 (490-497).
This paper outlines an improved squeeze film damper which reduces significantly the dependence of the stiffness of conventional squeeze film dampers on the vibration amplitudes. This improved damper consists of a conventional squeeze film damper with a flexibility supported outer ring. This secondary flexible support is considered to be massless, and to have a constant stiffness and damping. Assuming the short bearing approximation and the 'pi' film cavitation model, the performances of this damper in preventing bistable operation and sub-synchronous and nonsynchronous motions are theoretically demonstrated for a rigid rotor supported on a squeeze film damper. Blade-loss simulations are carried out numerically. (Authors)

Determination of fluid-particle convective heat transfer coefficient
Bhamidipati S. & Singh R.K., *Transactions - American Society of Agricultural Engineers*, 1995, 38/3 (857-862).
Fluid-to-particle convective heat transfer coefficient (h_{fp}) was determined by continuous particle center temperature measurements in a hold tube by a temperature sensor system using the transmitter particle technique. The fluid used was carboxy methyl cellulose (CMC) at concentrations of 0.5, 1.0, and 1.2% (w/w) and temperatures of 22.22 degrees, 65.56 degrees, 76.67 degrees, and 82.22 degrees C. Temperature dependent viscosity parameters of CMC were determined and used in calculating h_{fp}. Specific

heat and thermal resistance of the sensor were experimentally determined and used in solving the energy balance equation to obtain $h_{f\,p}$ values. The results are expected as a correlation of dimensionless numbers. (from Authors)

A theoretical investigation of the effect of structural stiffness in underwater shock wave loading using the plane wave approximation
Dawson R.L. & Sullivan G.M., *Transactions - ASME: Journal of Applied Mechanics*, 1995, 62/1 (260-262).
The equations of motion for an explosively loaded infinite plate with stiffness are derived. The structural response of this plate is compared to that of an explosively loaded infinite plate without stiffness. The effect of stiffness on water cavitation and plate displacement is determined. (Authors)

Calculation of two-phase flow in gas turbine combustors
Tolpadi A.K., *Transactions - ASME: Journal of Engineering for Gas Turbines & Power*, 1995, 117/4 (695-703).
A method is presented for computing steady two-phase turbulent combusting flow in a gas turbine combustor. The gas phase equations are solved in an Eulerian frame of reference. The two-phase calculations are performed by using a liquid droplet spray combustion model and treating the motion of the evaporating fuel droplets in a Lagrangian reference. This two-phase model was applied to a real piece of combustion hardware in the form of a modern GE/SNECMA single annular CFM56 turbofan engine combustor. The effect on the solution of two extreme situations of the fuel as a gas and initially as a liquid was examined. The calculated exit gas temperature was compared with test rig measurements. Under both low and high-power conditions, the temperature appeared to show an improved agreement with the measured data when the calculations were performed with the spray model as compared to a single-phase calculation. (from Author)

Investigation of centrifugal pump performance under two-phase flow conditions
Noghrehkar G.R., Kawaji M., Chan A.M.C., Nakamura H. & Kukita Y., *Transactions - ASME: Journal of Fluids Engineering*, 1995, 117/1 (129-137).
A one-dimensional two-fluid model has been used to study the centrifugal pump head degradation phenomena and to analyze the gas-liquid interaction within the pump impeller under high pressure, steam-water two-phase flow conditions. The analytical model was used to predict the two-phase pump head data for the small-scale and full-scale nuclear reactor pumps and the predictions of the head degradation compared favorably with the test data for different suction void fractions. The physical mechanisms responsible for head degradation were also investigated. (Authors)

Effect of hydrofoil planform on tip vortex roll-up and cavitation
Fruman D.H., Cerrutti P., Pichon T. & Dupont P., *Transactions - ASME: Journal of Fluids Engineering*, 1995, 117/1 (162-169).
The effect of the planform of hydrofoils on tip vortex roll-up and cavitation has been investigated by testing three foils having the same NACA 16020 cross section but different shapes. One foil has an elliptical shape while the other two are shaped like quarters of ellipses; one with a straight leading edge and the other with a straight trailing edge. Hydrodynamic forces as well as cavitation inception and desinence performance were measured as a function of Reynolds number and foil incidence angle. Laser Doppler measurements of the tangential and axial velocity profiles in the region immediately downstream of the tip were also performed. (from Authors)

Liquid jet pumps for two-phase flows
Cunningham R.G., *Transactions - ASME: Journal of Fluids Engineering*, 1995, 117/2 (309-316).
Isothermal compression of a bubbly secondary fluid in a mixing-throat and diffuser is described by a one-dimensional flow model of a liquid-jet pump. Friction-loss coefficients used in the four equations may be determined experimentally, or taken from the literature. The model reduces to the liquid-jet gas compressor case if the secondary liquid is zero. Conversely, a zero secondary-gas flow reduces the liquid-jet gas and liquid (LJGL) model to that of the familiar liquid-jet pump. A 'jet loss' occurs in liquid-jet pumps is the nozzle tip is withdrawn from the entrance plane of the throat, and jet loss is included in the efficiency equations. Comparisons are made with published test data for liquid-jet liquid pumps and for liquid-jet gas compressors. The LJGL model is used to explore jet pump responses to two-phase secondary flows, nozzle-to-throat are ratio, and primary-jet velocity. (from Author)

Planar ultrasonic imaging of a two-phase mixture
Shekarriz A. & Brenden B.B., *Transactions - ASME: Journal of Fluids Engineering*, 1995, 117/2 (317-319).
Flows of solid-liquid mixture, fiber suspensions, polymer melts, and colloidal dispersions are commonly encountered in chemical, petroleum, pulp and paper, and food industries. In most cases, the dynamics of the flow field can impact the rheology of the mixture and the morphology of the final products. The system used in this study is a real-time ultrasonic imaging system (RTUIS). It has unique characteristics with a usable degree of spatial resolution and with a temporal resolution much higher than other (non-optical) planar tehcniques. The objectives of this study are to demonstrate the feasibility of using RTUIS for non-instusive planar velocity measurement on the basis of the motion of visible texture caused by the scattering particles. A simple two-phase channel flow is utilized for demonstration of the current technique. (from Authors)

Mechanisms of heat transfer enhancement of gas-solid fluidized bed: estimation of direct contact heat exchange from heat transfer surface to fluidized particles using an optical visualization technique
Kurosaki Y., Satoh I. & Ishize T., *Transactions - ASME: Journal of Heat Transfer*, 1995, 117/1 (104-112).
This paper deals with mechanisms of heat transfer in a gas-solid fluidized bed. Heat transfer due to heat exchange by direct contact from a heat transfer tube immersed in the bed to fluidized particles was studied by means of visualization of contact of the fluidized particles to the heat transfer surface. The results show that the duration of contact of fluidized particles was almost uniform over the tube circumference and was hardly affected by the flow rate of fluidizing gas. On the other hand, the contact frequency between the particles and heat transfer tube was evidently influenced by the gas flow rate and particle diameter, as well as the location on the tube circumference. Using the visualized results, the amount of heat conducted to fluidized particles during the contact was estimated. This result showed that unsteady heat conduction to the fluidized particles plays an important role in the heat transfer, especially at the condition of incipient fluidization. (Authors)

Stratified flow film boiling inside horizontal tubes
Chan A.M.C., *Transactions - ASME: Journal of Heat Transfer*, 1995, 117/1 (179-184).
Stratified flow film boiling inside a horizontal tube was investigated. A one-dimensional flow model was used to solve for the local vapor film thickness and vapor velocity in the vapor channel in the circumferential direction. Analytical solutions for the local vapor film thickness and heat transfer coefficient at the bottom of the tube were derived. The solutions were compared with expressions obtained for other external geometries. A simple experiment was also performed to provide local heat transfer data for direct comparison. It was found that the local heat transfer coefficient normalized with respect to h_0 can be represented by a single

curve for different liquid inventory and initial wall temperatures. The curve was expressed in the form of a polynomial and it provides a simple way of calculating the local heat transfer coefficient in stratified flow film boiling in horizontal tubes. (Author)

The effect of inlet subcooling on the critical heat flux for downward flow with upstream compressiblity
Huang X.C., Ruan S.W. & Bartsch G., *Transactions - ASME: Journal of Heat Transfer*, 1995, 117/2 (536-538).
Various systems involving two-phase flow and heat transfer, such as nuclear reactors, boilers, refineries, and refrigeration units are subject to thermohydraulic instability. A consequence is that the critical heat flux (CHF) may be much lower than under stable flow conditions. Two kinds of CHF conditions: a stable CHF and a pulsating CHF, have been observed. These two CHF conditions were called CHF 1 and CHF 2. CHF 1 corresponds to transition from bubbly flow to slug flow. Annular flow prevails to the occurrence of CHF 2. The flow patterns at different heat flux levels are considered. It immediately suggests that the first boiling crisis CHF 1 represents an unoverridable barrier for transition from bubbly flow through slug/churn flow to the annular flow when the experiments are carried out in the conventional way, ie, increasing the heating power with all inlet conditions being held constant. However, it does not exclude the possibility that annular flow exists behind the barrier, and can be reached in a special way. In this paper, experimental verification of this idea will be described. (from Authors)

Interfacial heat transfer between steam bubbles and subcooled water in vertical upward flow
Zeitoun O., Shoukri M. & Chatoorgoon V., *Transactions - ASME: Journal of Heat Transfer*, 1995, 117/2 (402-407).
Experiments were carried out to obtain a data base for the development of interfacial transport models, or correlations, for subcooled water-steam bubbly flow in vertical conduits. In the present investigation, bubble condensation in subcooled water-steam flow in a vertical annulus at low flow rate and low pressure is investigated experimentally. A high-speed video system was used to visualize two orthogonal views of the flow simultaneously. A digital image processing technique was used to track and measure the velocity and size of the collapsing bubbles. The axial void fraction distribution was also measured by a single beam gamma densitometer. The results were compared with existing correlations and a new correlation for bubble condensation Nusselt number was obtained based on the present data. (from Authors)

Influence of direction of heat flow on Nusselt numbers for a gas-particle crossflow
Scholten J.W. & Murray D.B., *Transactions - ASME: Journal of Heat Transfer*, 1995, 117/4 (1088-1090).
The effect of solid particles in suspension on the heat transfer characteristics of tube arrays in crossflow is of interest for the design of heat exchangers to be located in the freeboard regions of fluidized bed combustors. For very fine particle suspensions, direct particle-wall conduction and the higher effective density of the suspension will also contribute to the enhancement of heat transfer. In addition, it is possible that the heat transfer will be influenced by turbulence modification resulting from eddy-particle interactions (Owen, 1969; Hetsroni, 1989). In the wake region, lower turbulence levels resulting from delayed boundary layer separation may also contribute to a reduction in heat transfer. The objective of the present study is to investigate the effect of the direction of heat flow on the convective heat transfer characteristics of a tube array in a particulate crossflow. Experimental results from an electrically heated tube and a water-cooled tube are examined in the light of the dominant heat transfer mechanisms for suspension flows and the likely significance of the thermophoretic effect is assessed. (from Authors)

Boundary layer analysis of buoyancy-driven two-phase flow in capillary porous media
Wang C.Y. & Beckermann C., *Transactions - ASME: Journal of Heat Transfer*, 1995, 117/4 (1082-1087).
Buoyancy-driven two-phase flow in a porous medium is encountered in numerous important technological applications. Examples include boiling flow along an intrusion in geothermal reservoirs and condensing flow adjacent to a cold surface heat pipes and porous insulation materials. Recently, condensing flow has received particular attention, because the flow in the two-phase region, which results from the capillary force, is believed to exert a significant effect on film condensation heat transfer. Based on a newly developed two-phase mixture model (Wang and Beckermann, 1993a), we perform a two-phase boundary layer analysis for buoyancy-driven two-phase (both condensing and boiling) flow in porous media, wherein only classical boundary layer approximations (Schlichting, 1968) are employed. A parallel theory for pressure-driven boiling flow has been presented by Wang and Beckermann (1993b). Second, using the present full two-phase solution, we quantitatively examine the validity of the unsaturated flow theory for buoyancy-driven condensing flow, so as to reveal the capillary effect on film condensation (or boiling) heat transfer in porous media more accurately. (from Authors)

Heat transfer analysis of an inclined two-phase closed thermosyphon
Zuo Z.J. & Gunnerson F.S., *Transactions - ASME: Journal of Heat Transfer*, 1995, 117/4 (1073-1075).
Many experimental studies have been conducted on film condensation heat transfer in inclined thermosyphons (Gross, 1992). According to these studies, as the thermosyphon is tilted from the vertical position, liquid film thickness becomes nonaxisymmetric and mean heat transfer coefficient increases. There is no limiting mechanism on the inclination angle in these empiricial correlations. This note presents a numerical model of inclined thermosyphon performance. Liquid-vapor interfacial shear stress and effects of working fluid inventory at various inclination angles, not addressed in previous studies, are included within. Two important limiting mechanisms, dry-out and flooding, are related to the behavior of performance parameters. Comparisons with experiments and previous studies indicate that the model is capable of predicting the performance of an inclined thermosyphon. (from Authors)

On heat transfer augmentation using dilute gas-solid suspensions
Bhaskarwar A.N. & Phanikumar M.S., *Transactions - ASME: Journal of Heat Transfer*, 1995, 117/4 (1091-1094).
The problem of heat transfer in particulate flows is of interest in a wide variety of applications and in environmental processes. We present detailed comparisons with experimental data for the case of turbulent flow of a gas-solid suspension flowing in vertical pipes. In a dilute suspension, the particle-fluid interaction is predominant when compared to the particle-particle interaction. Pfeffer et al. (1966) identified the particle loading range 0 = or M = or 10 for a dilute suspension while Nosov and Syromyatnikov (1965) indicate that, for their experimental conditions, the region of low concentrations corresponds to 0 = or M = or 25. A more rigorous criterion for diluteness is provided by Soo (1990) in the form of an upper limit for the volume fraction of solids in the suspension as a function of the density ratio (rho_s lrho_g) and a particle-fluid interaction parameter. When translated to an upper limit for the loading ratio on a weight basis (M), this criterion essentially gives the conclusion shown above. (from Authors)

Numerical simulation of a ball impacting and rebounding a lubricated surface
Larsson R. & Hoglund E., *Transactions - ASME: Journal of Tribology*, 1995, 117/1 (94-102).
The case of a ball bouncing on a flat surface covered by a thin lubricant layer is analyzed theoretically. Both impact and rebound are studied. A Newtonian lubricant and perfect elastic solids are assumed. As long as the ball approaches the flat surface the pressure in the contact increases and a lubricant entrapment is formed at the center of the contact. When the ball begins to leave the surface, cavitation occurs. At the periphery of the contact a pressure spike is formed. Just before the ball leaves the lubricated surface, very

high pressure values arise at and near the contact center. These results are compared with the case of nonlubricated impact. It is found that the pressure in the contact at lubricated impact is higher than in the case of dry impact. (from Authors)

Sizing of an aircraft fuel pump
Rohatgi U.S., *Transactions - ASME: Journal of Tribology*, 1995, 117/2 (298-302).
A need to pump a mixture of two-phase fluid appears naturally in many situations. One example of this situation is aircraft fuel systems, where the pump inlet may have two-phase mixture due to the desorption of the dissolved gases at low pressures at higher altitudes. A simple procedure of selecting proper design conditions for the inlet inducer and a method of sizing the inducer, impeller and volute to meet all the design requirements has been described. This procedure has also been applied to a typical fighter plane boost pump design. (Author)

Cavitation in normal separation of square and circular plates
Boedo S. & Booker J.F., *Transactions - ASME: Journal of Tribology*, 1995, 117/3 (403-410).
The 'negative squeeze' lubrication problem is investigated by means of mass-conservating finite element cavitation algorithm within the context of a dimensionless study of lubricant film behavior between rigid, parallel separating surfaces. Appropriate mesh geometrics which capture spatial and temporal mixture density history and satisfy JFO conditions on the cavitation interface are determined. Present simulation results agree qualitatively with previous experiments, supporting the validity of the algorithm and its utility in the bearing design process. (Authors)

Axial oil film rupture in high speed bearings due to the effect of the centrifugal force
Koeneke C.E., Tanaka M. & Motoi H., *Transactions - ASME: Journal of Tribology*, 1995, 117/3 (394-398).
The two-dimensional steady-state Navier-Stokes equation and the continuity equation are applied to the lubricating film assumed to be concentric in journal bearings operating at very high speeds. The equations are numerically solved for the pressure variation in the axial direction and also across the film thickness with the centrifugal force being considered to act on the lubricant film due to high rotational speed of the journal. Linked with a new cavitation model proposed, the lubricant film is theoretically found to rupture near the journal surface toward the bearing end. This axial film rupture is shown to reduce the driving torque of the inner film of floating bush bearings at very high shaft speeds, and some phenomena observed in the operation of floating bush bearings can be explained with this model. (Authors)

A transient thermohydrodynamic analysis including mass conserving cavitation for dynamically loaded journal bearings
Paranjpe R.S. & Han T., *Transactions - ASME: Journal of Tribology*, 1995, 117/3 (369-378).
A comprehensive transient thermohydrodynamic analysis for dynamically loaded journal bearings such as engine crankshaft bearings had been developed. A key element in this analysis is consideration of different time scales for the oil film, journal and bushing. Mass conserving cavitation is included via the Elrod cavitation algorithm. The 3-D energy equation is solved without any simplification in the oil film or the bushing. The journal is treated as a lumped thermal element. It was found that the time scales for thermal transients in the oil film are of the same order as the period of the dynamic loading; consequently, thermal transients in the oil film were considered. However, the time scales for thermal transients in the journal and bushing are several orders of magnitude greater that those for the oil film. These elements were treated as if they were in quadi-steady state over one loading cycle. Results from this analysis are presented for an engine crankshaft main bearing under sinusoidal loading. (from Authors)

Prediction of cavitation in journal bearings using a boundary element method
Qiulin Yu & Theo Jr K.G., *Transactions - ASME: Journal of Tribology*, 1995, 117/3 (411-421).
A boundary element cavitation algorithm is utilized to predict cavitation in journal bearings with axially variable clearance. Film rupture and reformation boundary conditions, obtained from the JFO theory, are directly combined with the generalized boundary integral equation which is derived from Elrod's universal differential equation. The governing equation is transformed into an undetermined boundary problem. The results for aligned and misaligned journal bearings are compared with those obtained using the finite difference method. Tapered, barrel, and hourglass journal bearings are also analyzed. The computational results demonstrate the effects of the journal geometric parameters on journal bearing performance. (from Authors)

Ideas about viscous coupling in anisotropic media
Rose W., *Transport in Porous Media*, 1995, 18/1 (87-93).
Laboratory techniques for measuring simple transport coefficients such as specific permeability in flow through anisotropic porous media are fraught with many measurement difficulties. When multiphase flow cases of immiscible fluids are considered however, and especially when these are perturbed by difficult-to-measure viscous coupling effects, it is to be expected that many measurement problems - including those that heretofore have remained unspecified - will become all the more bothersome. That is why it is believed to be timely now to call attention to the matter even if the statements to be given here fall short of settling all of the outstanding issues. The analysis that follows is based on a familiar supposition, namely that the general theory of viscous coupling that is being espoused in many current papers can be accepted at face value as a fruitful starting point for the development of the transport equations that will be descriptive of multiphase flow in anisotropic media. (from Author)

Stochastic analysis of two-phase flow in porous media: I. Spectral/perturbation approach
Ching-Min Chang, Kemblowski M.W., Kaluarachchi J.J. & Abdin A., *Transport in Porous Media*, 1995, 19/3 (233-259).
Stochastic analysis of steady-state two-phase (water and oil) flow in heterogeneous porous media is performed using the perturbation theory and spectral representation techniques. The governing equations describing the flow are coupled and nonlinear. The key stochastic input variables are intrinsic permeability, k, and the soil and fluid dependent retention parameter, GAMMA. Three different stochastic combinations of these two input parameters were considered. The perturbation/spectral analysis were used to develop closed-form expressions that describe stochastic variability of key output processes, such as capillary and individual phase pressures and specific discharges. The analysis also included the estimation of the effective flow properties. The impact of the spatial variability of k and GAMMA on the variances of pressures, effective conductivities, and specific discharges was examined. (Authors)

Stochastic analysis of two-phase flow in porous media: II. Comparison between perturbation and Monte-Carlo results
Abdin A., Kaluarachchi J.J., Ching-Min Chang & Kemblowski M.W., *Transport in Porous Media*, 1995, 19/3 (261-280).
The first paper (Chang et al, 1995) described stochastic analysis of two-phase flow in a fully liquid-saturated system. In this paper, the results of Monte-Carlo simulations are compared with the closed-form expressions obtained using the perturbation approach. Analytical solutions to the one-dimensional, steady-state-oil-and-water flow equations are presented. These solutions are subsequently used in the Monte-Carlo analysis to estimate the statistical properties of the key output processes. The comparison between the results of perturbation and Monte-Carlo approaches shows a good agreement between the two methods over a wide

range ln k (k is the intrinsic permeability) variability with three different combinations of input stochastic processes of ln k and soil parameter GAMMA. In particular, a good agreement was obtained for capillary and individual pressure variances and effective phase conductivities. The first-order perturbation theory can be successfully used to describe the effective behavior of large-scale, two-phase systems. (from Authors)

Fluid distribution and pore-scale displacement mechanisms in drainage dominated three-phase flow
Oren P.E. & Pinczewski W.V., *Transport in Porous Media*, 1995, 20/1-2 (105-133).
Presents a precise description of the fluid distribution and pore-scale displacement mechanisms for three-phase flow under strongly wetting conditions when the displacing fluid is a nonwetting phase. It is shown that on the pore-scale the fluids may adopt one of three basic configurations depending on the values of the three interfacial tensions and the wetting preference of the solid. The nature of the three-phase displacement mechanisms is determined by the pore-scale fluid distribution. The displacing phase may advance by two basic mechanisms: a double drainage mechanism involving all three phases - a three-phase displacement - or, a direct drainage mechanism - a two-phase displacement. The three-phase displacement mechanism is described by a simple generalisation of two-phase flow mechanisms. The basic displacement mechanisms are incorporated into a numerical percolation-type network model which is used to compute phase recoveries for three-phase displacements. (from Authors)

Lattice-Boltzmann simulations of flow through Fontainebleau sandstone
Ferreol B. & Rothman D.H., *Transport in Porous Media*, 1995, 20/1-2 (3-20).
Reports preliminary results from simulations of single-phase and two-phase flow through three-dimensional tomographic reconstructions of Fontainebleau sandstone. The simulations are performed with the lattice-Boltzmann method, a variant of lattice-gas cellular-automation models of fluid mechanics. Simulations of single-phase flow on a sample of linear size 0.2 cm yield a calculated permeability in the range 1.0-1.5 darcys, depending on direction, which compares qualitatively well with a laboratory measurement of 1.3 darcys on a sample approximately an order of magnitude larger. The sensitivity of permeability calculations to sample size, grid resolution, and choice of model parameters is quantified empirically. The authors also present a qualitative study of immiscible two-phase flow in a sample of linear size 0.05 cm; simulations of both drainage and imbibition are presented. (Authors)

The effect of capillary forces on immiscible two-phase flow in heterogeneous porous media
Van Duijn C.J., Molenaar J. & De Neef M.J., *Transport in Porous Media*, 1995, 21/1 (71-93).
Considers the one-dimensional two-phase flow including capillary effects through a heterogeneous porous medium. The heterogeneity is due to the spatial variation of the absolute permeability and the porosity. Both these quantities are assumed to be piecewise constant. At interfaces where the rock properties are discontinuous, the authors derive, by a regularisation technique, conditions to match the values of the saturation on both sides. There are two conditions: a flux condition and an extended pressure condition. Applying these conditions it is shown that trapping of the wetting phase may occur near heterogeneities. To illustrate the behaviour of the saturation a time-dependent diffusion problem without convection, a stationary convection-diffusion problem, and the full time-dependent convection-diffusion problem (numerically) are considered. In particular the last two problems explicitly show the trapping behaviour. (Authors)

Generalized relative permeability coefficients during steady-state two-phase flow in porous media, and correlation with the flow mechanisms
Avraam D.G. & Payatakes A.C., *Transport in Porous Media*, 1995, 20/1-2 (135-168).
A parametric experimental investigation of the coupling effects during steady-state two-phase flow in porous media was carried out using a large model pore network of the chamber-and-throat type, etched in glass. The wetting phase saturation, S_1, the capillary number, Ca, and the viscosity ratio, kappa, were changed systematically. The fluid flow rate and the pressure drop were measured independently for each fluid. During each experiment, the pore-scale flow mechanisms were observed and videorecorded, and the mean water saturation was determined with image analysis. Conventional relative permeability, as well as generalized relative permeability coefficients (with the viscous coupling terms taken explicitly into account) were determined. A simple relationship between the conventional relative permeabilities and the generalized relative permeability coefficients is established. The coupling indices are introduced here. A correlation of the coupling indices with the underlying flow mechanisms and the pertinent flow parameters is established. (from Authors)

An elastohydrodynamic cavitation algorithm for piston ring lubrication
Qingmin Yang & Keith Jr T.G., *Tribology Transactions*, 1995, 38/1 (97-107).
An elastohydrodynamic cavitation algorithm is developed for piston ring lubrication. This algorithm combines a compresible fluid model, a pressure-viscosity relation and elastic surface deformation with cavitation. Also, it conserves mass flow and automatically determines full film, cavitation and pressure reformation regions. Results for a typical automotive engine reveal that the pressure calculated by using the Reynolds boundary condition leads to a large error in pressure in the full-film region and, in turn, affects the film thickness prediction. Piston ring lubrication using the Reynolds boundary condition is considered to be valid only when the pressure acting on the trailing edge of a piston ring is negligible. (Authors)

Hydrodynamic behavior of graphite powder slurries in journal bearings
Batra A. & Dareing D.W., *Tribology Transactions*, 1995, 38/1 (161-167).
In this study, the behavior of graphite-ethylene glycol slurry is evaluated in a hydrodynamic journal bearing operating at ambient temperatures. The evaluation is based on laboratory testing and provides some insight on the lubrication capabilities of the non-Newtonian slurry. A laboratory test rig was designed and fabricated and the effect evaluated in terms of the difference in fluid film pressure between the pure carrier fluid and the powder slurry. It is observed that the addition of graphite increases the effective viscosity of the carrier fluid, causing not only an increase in pressure, but also an increase in fluid temperature. (from Authors)

Hydrodynamics of a transient slug motion in an empty pipe system (Bos bir boru sisteminde degisken akimli bir su kutlesinin (paketinin) hidrodinamigi)
Bozkus Z., *Turkish Journal of Engineering & Environmental Sciences*, 1995, 19/4 (269-277). In Turkish.
Liquid slugs (water pockets) are propelled into an empty pipe under various driving pressures; the pipe's extension ends at an elbow whereon the slugs impact and disintegrate. Dynamic pressures recorded at various locations along the system indicate the complex and somewhat random structure of the transient. High-speed movies of the evolving slug just prior to impact show that significant air entrainment and breakup of the slug occurs. A simplified analytical model is developed to predict the slug dynamics; in spite of the complexity of the flow, reasonable comparisons of peak pressures and impulse loads at the elbow are obtained and are in parallel with results reported in an earlier study. (English summary)

Wet oxidation of refractory organic compounds in industrial aqueous wastes via the OXYJET technology
Gasso S., Gonzalez M., Baldasano J.M., Lemonnier J.P., Abatzoglou N. & Chornet E., *Waste Management & Research*, 1995, 13/1 (37-46).

The work presented in this paper is concerned with the application of a jet-mixer device to the wet oxidation process. This device allows the formation of a mist two-phase flow that leads to oxidation of the organic matter in a kinetically controlled regime. Thus a compact technology, denoted as OXYJET, based on jet-mixers and tubular reactors has been developed. The oxidation of standard solutions used as prototype of toxic effluents and organic industrial aqueous wastes is considered. In the experimental work, total organic carbon (TOC) feed concentration ranged between 3400 to 80 000 mgl^{-1}. (Authors)

Photocatalytic degradation of methyl-tert-butyl ether in TiO_2 slurries: a proposed reaction scheme
Barreto R.D., Gray K.A. & Anders K., *Water Research*, 1995, 29/5 (1243-1248).

Among the various alternatives to enhance the octane rating of gasoline, methyl-tert-butyl ether (MTBE) has become increasingly the compound of choice. Due to its high solubility in water there are some environmental concerns related to the remediation of waters contaminated with gasoline containing MTBE. Although MTBE is difficult to treat economically with conventional techniques, it has been found to be readily degraded photocatalytically. In batch TiO_2 slurries and under the experimental conditions used in these experiments MTBE degradation proceeded with an initial pseudo first-order rate constant of $1.2 \times 10^{-3} s^{-1}$. The primary by-products of this reaction have been identified as t-butyl formate and t-butyl alcohol, both of which are also readily degraded photocatalytically, albeit at slightly slower rates than MTBE. Mass balance calculations have shown that MTBE is virtually completely mineralized and a reaction scheme is proposed. (Authors)

Photocatalytic transformation and mineralization of 2,4,6-trinitrotoluene (TNT) in TiO_2 slurries
Schmelling D.C. & Gray K.A., *Water Research*, 1995, 29/12 (2651-2662).

An analysis of the photodegradation of TNT in a TiO_2 slurry reactor is presented. The rates and extent of TNT transformation and mineralization are compared for photocatalytic and direct photolytic reactions under conditions of varying light energies and in the presence and absence of oxygen. Certain initial organic transformation products are identified for both photocatalytic and photolytic reactions. Nitrate, nitrite, and ammonium ions are analyzed and the possibility of semiconductor sensitization by colored compounds is considered. The photocatalytic transformation of TNT appears to involve both oxidative and reductive steps and sensitization by colored compounds plays no detectable role in degradation. (from Authors)

The phase distribution of polychlorobiphenyl congeners in surfactant-amended sediment slurries
Jafvert C.T., Van Hoof P.L. & Wei Chu, *Water Research*, 1995, 29/10 (2387-2397).

The surfactant-aided recoveries of polychlorobiphenyls (PCBs) from a sample of Ashtabula River (Ohio) sediment were compared to calculated recoveries based on an equilibrium phase distribution model. The equilibrium model contains as parameters: (i) the surfactant concentration in the micelles, (ii) the mass of organic carbon in the sediment (or soil) per aqueous volume, (iii) a constant characterizing solute affinity for the micelle, and (iv) a constant characterizing solute affinity for the sediment carbon. The recovery of specific PCB congeners from the sediment by surfactant micelles at equilibrium were invariant with congener number as predicted by the model. This invariant behavior results from the fact that the PCBs are partitioned between two lipophilic phases (soil organic carbon and micelles) through hydrophobic interactions. (from Authors)

Two-phase flow visualization and relative permeability measurement in natural rough-walled rock fractures
Persoff P. & Pruess K., *Water Resources Research*, 1995, 31/5 (1175-1186).

A laboratory flow apparatus was used to visualize and measure two-phase gas-liquid flows in natural rough-walled rock fractures. Experiments at carefully controlled flow rate and pressure conditions have been performed using a natural fracture and three transparent fracture replicas. Two-phase flow exhibited persistent instabilities with cyclic pressure and flow rate variations even under conditions of constant applied boundary conditions. Visual observations of changes in pore occupancy showed that the instabilities could be explained as resulting from an interplay between capillary effects and pressure drop due to viscous flow. Measurements of relative permeabilities indicated strong phase interference. (from Authors)

Solving the estimation-identification problem in two-phase flow modeling
Finsterle S. & Pruess K., *Water Resources Research*, 1995, 31/4 (913-924).

In this paper a procedure is presented to solve the estimation-identification problem in two-phase flow modeling. Given discrete observations made on the system response, an optimum parameter set is derived for an appropriate conceptual model by solving the inverse problem using standard optimization techniques. Subsequently, a detailed error analysis is performed, and nonlinearity effects are considered. We discuss the iterative process of model identification and parameter estimation for a ventilation test performed at the Grimsel Rock Laboratory, Switzerland. A numerical model of the ventilation drift and the surrounding crystalline rock matrix is developed. Evaporation of moisture at the drift surface and the propagation of the unsaturated zone into the formation are simulated. (from Authors)

Considerations for robust compositional simulations of subsurface nonaqueous phase liquid contamination and remediation
Panday S., Forsyth P.A., Falta R.W., Yu-Shu Wu & Huyakorn P.S., *Water Resources Research*, 1995, 31/5 (1273-1289).

A nonisothermal compositional model has been developed for examining nonaqueous phase liquid contamination and remediation scenarios. The governing mass balance equations and constraints have been presented, and various types of compositional formulations available have been examined. An efficient and robust formulation has been developed that addressed certain issues related to groundwater situations and overcomes numerical difficulties encountered with previous formulations. The proposed formulation collapses to that corresponding to the multiphase flow equation set when interface mass transfer is neglected. Numerical implementation of the formulation has been discussed, and example problems have been presented for benchmark and verification. (from Authors)

Variability of point source infiltration rates for two-phase flow in heterogeneous porous media
Kueper B.H. & Gerhard J.I., *Water Resources Research*, 1995, 31/12 (2971-2980).

This study examines the influence of source release location, size, and strength on the infiltration rate and degree of lateral spreading of a dense nonwetting liquid infiltrating into an initially wetting liquid saturated, heterogeneous porous medium. It is demonstrated through numerical simulation in 25 realizations of a spatially correlated random hydraulic conductivity field that infiltration rates for point source releases are lognormally distributed with a variance equal to that of the underlying hydraulic conductivity distribution. Numerical simulations carried out in an equivalent homogeneous porous medium incorporating large-scale anisotropy of intrinsic permeability provided infiltration rates below the ensemble average. A series of 10 simulations conducted in a single realization demonstrates that the degree of lateral spreading (second moment) along main drainage is a

function of the average nonwetting phase saturation with greater degrees of lateral spreading at low capillary pressures. (from Authors)

Multiphase nonisothermal transport of systems of reacting chemicals
White S.P., *Water Resources Research*, 1995, 31/7 (1761-1772).
A mathematical model of multiphase transport of heat, mass, and reacting chemical species in a porous media is developed. The model is appropriate for describing many of the reactions that take place in a geothermal reservoir. This model leads to the separation of transport terms from reaction terms in the equations for chemical species concentration. A numerical method for the solution of the transport equations is developed based on the integrated finite difference method. Four example problems representative of those of interest in geothermal reservoirs are solved. These examples consider up to 14 chemical species and nine chemical reactions among these species. (Author)

Bacterial sedimentation through a porous medium
Jiamin Wan, Tokunaga T.K. & Chin-Fu Tsang, *Water Resources Research*, 1995, 31/7 (1627-1636).
This study examines the potential significance of sedimentation as a mechanism for bacterial transport. A simple model is developed to predict the behavior of particles (bacterial or inorganic colloids) sedimenting through granular porous media under hydrostatic conditions. The model indicates that tortuosity-limited sedimentation velocities through porous media consisting of large, well-rounded grains can proceed at velocities close to (approx = 90% that of) free sedimentation in water columns when particle-grain interactions involve only tortuosity. The two nonmotile bacterial strains selected for sedimentation experiments were Arthrobacter globiformis B672 (isolated from the Middendorf aquifer, 259-m depth), and OYS3, a streptomycin-resistant strain isolated from shallow groundwaters at Oyster, Virginia. Surface physical-chemical interactions, grain and pore size distributions, and grain surface microtopography can be very important in controlling the effectiveness of bacterial sedimentation as a transport mechanism. (from Authors)

The cavitation erosion of Fe-Mn-Al alloys
Chang S.C., Weng W.H., Chen H.C., Lin S.J. & Chung P.C.K., *Wear*, 1995, 181-183 part ii/- (511-515).
The cavitation erosion of Fe-Mn-Al alloys and 304 stainless steel in both distilled water and 3.5% NaCl solution was studied by an ultrasonic vibration system. In distilled water, the cavitation erosion resistance of solution heat treated Fe-Mn-Al alloys are superior to that of 304 stainless steel. The solution heat treated alloys with higher hardness shows better cavitation resistance. But, cavitation resistance could not be improved by age hardening. In 3.5% NaCl solution, the cavitation erosion resistance of Fe-Mn-Al alloys was degraded by corrosion. But, little change of the Fe-Mn-Al alloy that contains 2.6% Cr was observed and it was more cavitation resistant than 304 stainless steel, In the dual phase Fe-Mn-Al alloy (Alloy A), the ferrite phase was harder and more cavitation resistant than the austenite phase in distilled water. The addition of 0.3M $NaNO_2$ that could inhibit the corrosion was found to reduce the cavitation damage of dual phase Fe-Mn-Al alloy in 3.5% NaCl solution to the level obtained in distilled water. (from Authors)

Comparison of tunnel and jet methods for cavitation erosion testing
Coleman S.L., Scott V.D., McEnaney B., Angell B. & Stokes K.R., *Wear*, 1995, 184/1 (73-81).
The cavitation erosion behaviour of a number of metals has been studied using a sea water cavitation tunnel test and a fresh water jet cavitation method. Erosion parameters, including erosion rate and depth of damage, have been obtained for both systems and the data shown to correlate with mechanical properties of the metal, such as plasticity and hardness. Analysis of eroded specimens subjected to interrupted jet cavitation tests, combined with parallel microstructural studies on all eroded specimens, have shown that the erosion damage produced by the two test methods, whilst differing in degree, is generally similar in character. Hence it may be concluded that the jet cavitation test provides, with qualification, a satisfactory alternative for the more traditional cavitation tunnel technique. (Authors)

Prediction of uneven wear in a slurry pipeline on the basis of measurements in a pot tester
Gupta R., Singh S.N. & Sehadri V., *Wear*, 1995, 184/2 (169-178).
This paper reports a systematic study conducted on a pot tester to establish the effect of velocity, concentration and particle size on erosion wear. Two correlations have been proposed, based on the data generated for equisized particulate slurries in the pot tester, to predict the expected erosion wear for two pipe materials, namely brass and mild steel. The proposed correlations have been used to predict the extent of uneven erosion wear in a slurry pipeline using local concentration, local effective particle size and average velocity. The comparison between predicted and experimental results shows agreement within +/-13.5% for brass and +/-14% for mild steel. (from Authors)

Relation between impact load and the damage produced by cavitation bubble collapse
Okada T., Iwai Y., Hattori S. & Tanimura N., *Wear*, 1995, 184/2 (231-239).
In order to study the relation between impact load by collapsing cavitation bubbles and erosion damage, a new pressure detector which can measure impact loads and erosion damage (size of indents or pits and volume loss) simultaneously was developed. The detector consisting of a test specimen with a diameter of 3 mm and a piezoelectric ceramic disk was used for venturi tests and vibratory tests. Impact loads by collapsing bubbles were observed directly in a venturi tunnel and as piled-up pulses on an alternative wave of hydrodynamic pressure produced by a vibrating disk in a vibratory device. Impact load occurring in an early stage in the venturi facility and vibratory device were compared with indent size which were observed with a microscope on the surfaces of pure aluminum, pure copper and austenitic stainless steel (SUS304). A linear relation was obtained between impact load and the area of indents in both the venturi and vibratory tests. (from Authors)

Cavitation erosion of laser surface alloyed coatings on Al-12%Si
Tomlinson W.J. & Bransden A.S., *Wear*, 1995, 185/1-2 (59-65).
Laser surface alloyed coatings on Al-12%Si have been eroded in distilled water at 20 degrees C using a 20 kHz ultrasonic facility operating with a 50 mum peak-to-peak amplitude. Erosion was measured by weight loss and the damage examined using microscopical techniques. Eight coatings were selected for examination on the basis of high hardness and structural integrity. These consisted of a series of Fe and Ni alloys each with additions of either Mn, Cu or Cr. The linear erosion rate of Al-12%Si was 27.6 mg h^{-1}. This was decreased in the iron alloy coatings to 7.2-3.8 mg h^{-1} and in the nickel coatings to 2.47-0.71 mg h^{-1}. These rates show the erosion resistance of the coatings are better than some structural ceramics. Improvements in the incubation period were generally less substantial and the results varied greatly from alloy to alloy. (from Authors)

The solid particle and cavitation erosion of titanium aluminide intermetallic alloys
Howard R.L. & Ball A., *Wear*, 1995, 186-187/1 (123-128).

The mode of material removal during solid particle erosion and cavitation erosion of rolled super alpha$_2$ and plasma arc-melted gamma titanium aluminide alloys have been investigated. Particle erosion tests were performed using an air blast rig, and vibratory equipment with a stationary specimen were used to investigate the cavitation erosion performance. Erosion rates were measured and characteristic damage features were identified on the surface of eroded specimens. (from Authors)

Cavitation erosion of flame spray weld coating of nickel-base alloy powder
Kezheng Sang & Yugang Li, *Wear*, 1995, 189/1-2 (20-24).
The cavitation erosion of flame spray weld coating of five kinds of commercial nickel alloy powder was investigated by using a vibratory cavitation apparatus. For comparison a plain carbon steel and a stainless steel were also studied. The result showed that the cavitation erosion resistance of the flame spray weld coating of the nickel alloys was strongly related to the degree of solution hardening of the matrix and the quantity, fineness and dispersivity of the second (compound). (Authors)

Influence of environmental variables on erosion-corrosion of carbon steel in spent liquor reheaters in Bayer plant
Meyer U. & Atrens A., *Wear*, 1995, 189/1-2 (107-116).
The present work studied the factors involved in service erosion-corrosion of mild steel in spent liquor reheaters in Bayer plant. The impinging jet test rig was used to study the influence of 1) Bayer liquor composition, 2) nature of local flow, particularly recirculating flow, 3) nature and concentration of atmospheric gases (such as oxygen) in the liquor, and 4) quantity and nature of two phase flow, (including liquid + vapour and liquid + particulates). Low damage rates were associated with all conditions of single phase liquid flow. There was damage for experiments in which atmospheric gases (O_2 and N_2) were present. There was no significant damage for particles loading typical of service. High damage rates can be associated with two-phase liquid-vapour flow. (from Authors)

Acoustic emission in monitoring sliding contact behaviour
Miettinen J. & Siekkinen V., *Wear*, 1995, 181-183 part ii/- (897-900).
This paper describes the usage of acoustic emission (AE) measurement in monitoring sliding contact behaviour in mechanical face seals. The mechanical face seal works normally in boundary lubrication region. If the leakage rate of the seal rises, hydrodynamic lubrication takes a part in the sliding contact. Correspondingly if the cooling water disappears it can lead to a dry contact situation. Cavitation is a result of boiling of the lubricant in the contact can effect severe wear in the sliding materials. A measuring gauge was situated quite near the sliding contact because high frequency AE signals attenuate very quickly in boundary surfaces. The seal was tested when the sliding contact was normal and dry and also when the leakage was high. Also tests at high temperatures were made and the temperature region where sliding contact becomes unstable was determined using temperature and AE measurement. (from Authors)

An energy absorbing viscous upper layer for limited domain stratified flows over an obstacle
Holmes D.J., *Wind Engineering*, 1995, 19/4 (173-182).
For many years, researchers have attempted to understand the motion of a fluid passing over an obstacle. This report briefly focuses upon one aspect of the numerical modelling of such situations. In attempting to simulate wind flow, a major difficulty arises in the treatment of the 'far-field' behaviour of the fluid. The problem consists of constructing appropriate boundary conditions. In this report, attention will be focused upon the upper boundary. A rigid boundary is not, however, amenable at the upper boundary. A number of attempts have been made to construct a boundary condition allowing energy to pass through the boundary and out of the domain. One particular example uses the so-called Sommerfeld condition. Others have used rather complex Fourier methods. This report will deal with a computationally more straightforward method, which involves inserting a viscous layer above the domain of interest in an attempt to absorb vertically propagating wave energy. (from Author)

Product focus: peristaltic pumps
ANON, *World Pumps*, 1995, 343/- (24-29).
Over the past twenty years, the peristaltic pump has moved from laboratory and medical applications to meet a growing number of niche duties in industry. Nowadays, hose pumps can be found in varied applications ranging from sewage sludge to industrial slurries and food products. As a consequence of the growing success of the peristaltic pump at solving difficult pumping problems, an increasing number of manufacturers are marketing industrial pumps in this design. (Author)

Avoiding cavitation in the suction stage of high-energy pumps
Sloteman D.P., *World Pumps*, 1995, 348/- (40-48).
Cavitation in suction stages of high energy pumps can lead to damage and instability of the piping system. Manufacturers have made efforts to understand and characterise the elements of pump design which contribute to this problem. This article discusses the causes of cavitation and cavitation induced instability in such pumps. The high energy pumps considered here are multi-stage pumps operating at low NSPH, at high speeds and over a wide range of flows. They are common in boiler feed, oilfield injection and oil pipelines services. The article considers suction instabilities, changes in fluid characteristics, piping influences, and the effects of impeller geometry. Estimation of impeller cavitation life and impeller blade design are also considered. A new 'biased-wedge' impeller blade design has been found to provide cavitation bubble free operation over a wide range of flows. (J.M.McLaughlin)