

Gallery of fluids

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INTRODUCTION

During the I Annual Meeting of the Division of Fluid Dynamics, held in October 1995 at the Universidad de Zacatecas, and in parallel to the XXXIX National Physics Meeting, a Gallery of Fluids exhibition was organized with the purpose of introducing a new way to communicate scientific results in Mexico. To show fluid phenomena in highly attractive photographs, as part of the standard activities to exchange research results, is a novel idea in our country. Abroad, similar exhibits have been very successful in promoting research in fluid mechanics, besides being a way for the viewers to learn about some techniques of flow visualization and display.

In this first gallery, nine entries were considered by an international panel of experts, whom were asked to judge the beauty, original content, and interest of each contribution. I'm grateful to Professors Robert Behringer (Duke University, USA), Fernando Lund (Universidad de Chile, Chile), Roddam Narasimha (Indian Institute of Science, India), and Pedro Ripa (CICESE, Mexico) for their interest in judging the entries.

I would like to thank all of the participants for their enthusiasm and interest, which indicates that such activities will become a successful part of future scientific meetings in fluid dynamics. Also, I must thank the editors of *Revista Mexicana de Física* for their interest in publishing the outstanding contributions in this first Gallery of Fluids.

Collision of dipolar vortices

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Large scale atmospheric and oceanic motions (that is to say, winds or currents which extend horizontally for hundreds or thousands of kilometers and evolve slowly over periods of days or weeks) are fundamentally affected by the Earth's rotation and sphericity. The fluid motion takes place in planes perpendicular to the (local) vertical component of the

Earth's rotation, but due to the sphericity the magnitude of this component increases with the geographical latitude. Consequently, the effective rotation experienced by the fluid is an increasing function of the latitude (β effect).

The quasi-two-dimensional fluid motion is characterized by the spontaneous emergence of coherent vortices. One of such vortices is the dipolar vortex or dipole, which can be defined as an approximately circular structure where the fluid contained in each half rotates in opposite directions. The dipole moves in the direction defined by its symmetry axis and carries with it a finite amount of mass. In the presence of the β -effect the dipole is stationary—or moves with a uniform velocity—only if its axis of symmetry coincides with a geographical parallel.

Two equal dipoles which propagate in opposite directions along a parallel of latitude exchange partners after they collide [1]. In this way, the two newly formed dipoles move—in opposite directions—along a line perpendicular to the motion of the original dipoles. Because of the β -effect the trajectories become curved: in clockwise sense for the northern dipole and in anticlockwise sense for southern one. Therefore another collision with partner exchange takes place when the dipoles return to their original latitude. The original dipoles are thus reestablished.

In the laboratory the Earth's rotation is easily reproduced with a turntable in fast rotation. The effect of the Earth's curvature is simulated with a uniform gradient in the fluid's depth—making use of the principle of conservation of potential vorticity. A dipolar vortex is generated by slowly moving a small bottomless cylinder in some direction through the tank while lifting it out of the water.

In particular, the vortices shown here move in tap water contained in a 100 cm \times 150 cm tank. The tank rotates uniformly with a period 11.1 seconds and has a flat inclined bottom. The water depth is 14 cm in the top side of the pictures and 18 cm in the bottom side.

Figure 1 (p. 902) shows the original vortices just before the first collision: it may be seen that the vortices are neither perfectly aligned nor are they completely symmetrical. The partner exchange is observed in Fig. 2 (p. 902), whereas the curved trajectories of the newly formed dipoles are clearly displayed in Figs. 3 and 4 (p. 903). A second partner exchange (which would reestablish the original dipoles) has not yet been observed in the laboratory [2]. It seems that such an event requires a degree of symmetry that can only be achieved theoretically.

ACKNOWLEDGMENTS

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REFERENCES

1. M. Makino, T. Kamimura and T. Taniuti, *J. Phys. Soc. Japan*, **50** (1981) 980.
2. O.V. Velasco Fuentes and G.J.F. van Heijst, *Phys. of Fluids* **7** (1995) 2735.

Bubbles in search for pressure minima

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In this paper we report the behavior of bubbles in a rotating flow as a fluid undergoes various transitions when the external forcing is varied.

The experiment consists of a horizontal cylinder of constant circular cross section in which a mixture of glycerine and water fills half of the cylinder; air fills the remaining half. The cylinder is forced to rotate uniformly about its symmetry axis and in the process, air is trapped by the dense fluid mixture.

The first authors to consider this system were Karweit and Corrsin [1] and it is still a subject of interest [2,3]; extensive work has been done on the closely related problem in which the fluid is on the outside of the cylinder [4,5]. This paper is based on some recent results [6,7].

As the angular velocity of the cylinder (Ω) is slowly increased, a sequence of flow patterns is observed; the latter depend on the dominating forces. For low rotation rates, gravity (g) keeps the denser fluid on the lower half, with a free surface that is essentially flat, except for a thin layer near the surface of the cylinder, where it deforms as a result of the stick boundary condition; the symmetry of this *basic* flow is due to translational invariance along the cylinder axis. After this regime loses its stability, a periodic structure becomes apparent, reflecting the competing effects of gravity and the centrifugal force; in this state, *cell* flow, the global symmetry along the axis of the cylinder is broken. The last transition, for high angular velocity ($\Omega^2 \gg g/a$ where a is the radius of the cylinder), leads to a flow dominated by the centrifugal force, in which the dense fluid rotates with the cylinder and the air forms a *tube* around the axis of the cylinder; in this *annular* flow, the system has the highest symmetry, being invariant with respect to translations along the axis and rotations around it. The flow remains laminar at all values of the forcing, in spite of the fact that the topology undergoes some drastic changes along the way.

Due to a partial entrainment of the air, very small bubbles begin to form as the system starts to rotate. The bubbles form continuously during the first two flow regimes; the presence of the bubbles has the advantage that they play the role of tracers, revealing the structure of the streamlines. Their complicated motion is the result of two effects that act at different time scales. In one, they follow the motion of the dense fluid. On a longer time scale, they slowly diffuse towards regions where the pressure is low, due to local buoyancy.

For cell flow, the air is either trapped in small bubbles or filling the upper part of each cell in a periodic structure along the axis of the cylinder. When the volume fraction of air to glycerine-water mixture is 0.75, the cells appear as large bubbles that are located at the axis of rotation, as in Fig. 5 (p. 904). The small bubbles are organized in tori around the walls of the cells, migrating slowly towards the free surface.

In the annular flow, the two fluids form concentric cylinders, with the air in the innermost region and the dense mixture in contact with the rotating cylinder. The bubbles form bands within the fluid that rotates with the cylinder. In Fig. 6 (p. 904), the dark regions are void of bubbles illustrating that what seems to be a simple solid body rotation flow has a periodic pressure distribution that decays on time. At larger times, the bubbles migrate to the free surface and the whole system recovers its translucent quality.

Figure 7 (p. 905) corresponds to the case in which the annular flow has lost its stability, by lowering Ω , and the collapse has led to several irregular long cells (large bubbles). Most of the small bubbles are concentrated on the free surface (whitest region), while others are trapped in areas in which the pressure reaches local minima.

ACKNOWLEDGMENT

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REFERENCES

1. M.J. Karweit, and J. Corrsin, *Phys. Fluids* **18** 1 (1975) 111.
2. L. Preziosi and D.D. Joseph, *J. Fluid Mech.* **187** (1988) 99.
3. D.P. Vallette, W.S. Edwards and J.P. Gollub, *Phys. Rev. E* **49** (1994) R4783.
4. C.S. Yih, *Proc. Roy. Soc. A* **258** (1960) 63.
5. D.D. Joseph and Y.Y. Renardy, *Fundamentals of two-fluid dynamics. Part I: Mathematical theory and applications*, Springer-Verlag (1993).
6. R. Chicharro, R. Peralta-Fabi, R.M. Velasco, *Proceedings of the 3rd Caribbean Congress on Fluid Dynamics & 3rd Latin-American Symposium on Fluid Mechanics*, Vol. II, pp C1-C4, Universidad Simón Bolívar, Febrero, Caracas, Ven. (1995).
7. R. Chicharro Serra, M. Sc. Thesis, Patrones generados en flujos con superficie libre, en rotación, Facultad de Ciencias, UNAM, Mexico (1995).

Fountain effect in a centrifugal pump

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A solid object (a cylinder, a sphere or a cone) rotates uniformly about its symmetry axis, with its lower end in contact with a water surface. At the contact area, due to the sticking boundary condition, the water is forced to rotate and, depending on the angular velocity (Ω), various flow regimes become apparent.

The first observations were reported by a group in Israel [1,2], noting the first three flow regimes; the last stage, the *fountain effect*, was apparently discovered by two colleagues at the CINVESTAV, in Mexico City [3]. The experiment and its quantitative analysis was further extended by one of the authors [4].

The velocity gradient that results from the rotation of the axi-symmetric body, gives rise to a pressure gradient within the fluid, leading to a net flow towards the contact region; the latter is the mechanism responsible for the various flow patterns apparent at the surface, near the rotating solid. When Ω exceeds a critical value, and the last flow regime is established, the water arriving at the body creeps up in a thin laminar layer. At some particular height, which depends on the geometry of the body, the fluid is ejected in a jet that breaks into drops that fly out tangentially from the surface of the body. All flow regimes are present at their corresponding values of Ω regardless of the way the surface is prepared (rough or smooth, wetting or not, etc.).

Figures 8–10 (pp. 905, 906, 906) show the jet leaving the rotating body for the case of a cylinder, a sphere and a slender cone. The heights at which the jets are ejected vary between 2 and 3 mm for cylinders, the equator of the sphere, regardless of its radius, and ~ 3 cm for a 15° cone; for wider cones the fluid creeps up all the way to their base.

Figure 11 (p. 907) illustrates the fountain effect for a 9.9 cm diameter sphere. Hair shampoo has been added to the water to visualize the raising layer on the sphere, as well as a way to distinguish the circle traced by the falling drops; the latter grows with Ω .

A qualitative explanation is that the fluid moves towards regions of lower pressure, the surface of the body. If the surface of the body is such that the tangential velocity increases with height, as it is the case of spheres and cones, the pressure diminishes accordingly, and the fluid keeps moving up due to inertia. For spheres, the largest tangential velocity is at the equator, hence the layer never goes up any further. For cones with angles exceeding 15° , the fluid moves up until it reaches the end, the base of the cone. In the case of cylinders, with a constant cross section, the height of the jet varies very little as the diameter is changed.

ACKNOWLEDGMENT

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REFERENCES

1. B.Z. Bobrovsky, D.J. Shlien, A. Brosh and G. Kleinstein, *Phys. Fluids* **22** (1979) 781.
2. D.J. Shlien, B.Z. Bobrovsky, A. Brosh, *Phys. Fluids* **23** (1980) 1075.
3. J. Méndez and A. Enciso, (1987) (unpublished).
4. J.R. Sánchez-Jácome, B. Sc. Thesis, Facultad de Ciencias, UNAM, Mexico (submitted).

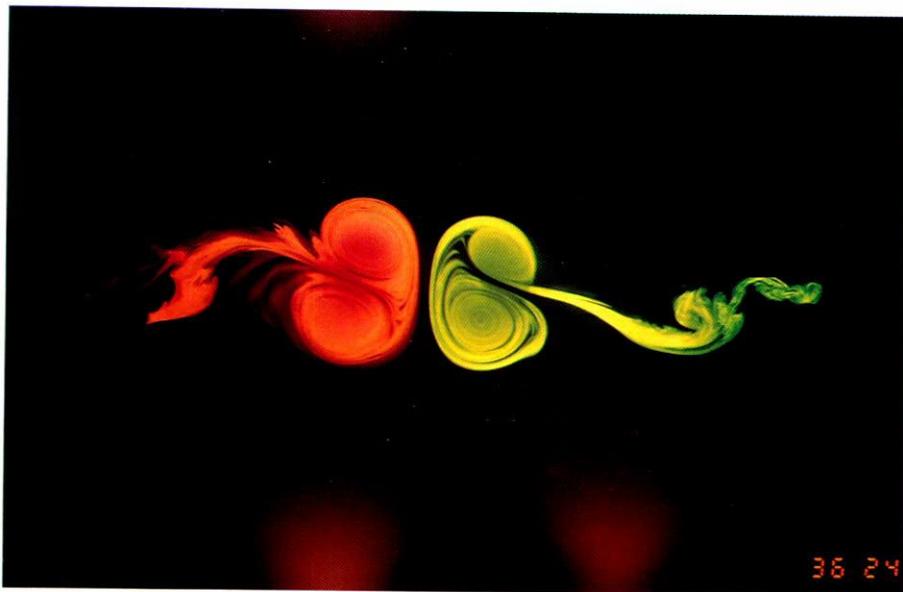


FIGURE 1.

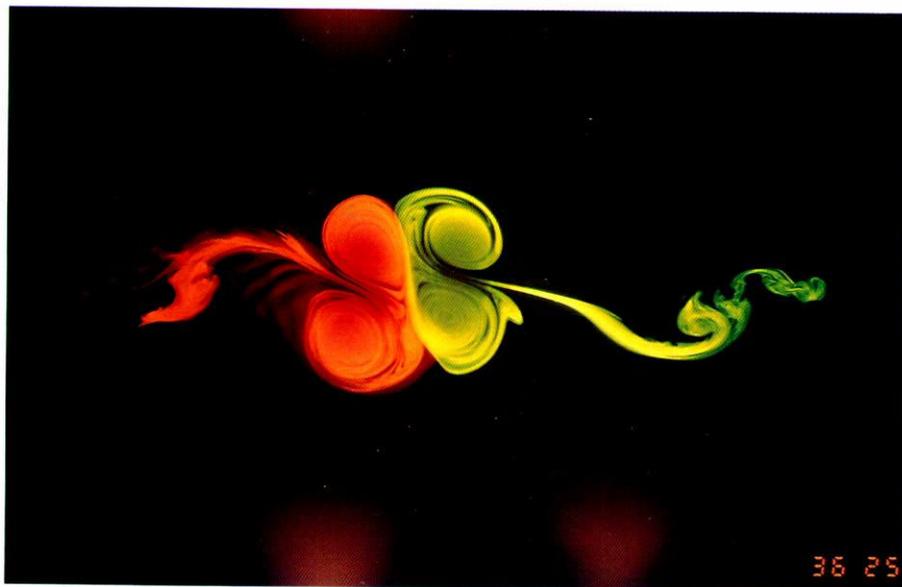


FIGURE 2.

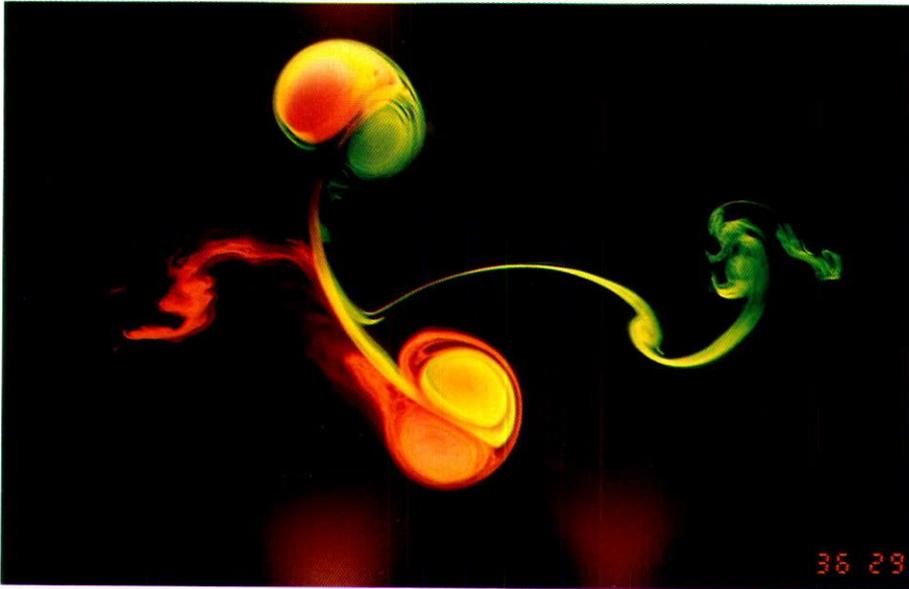


FIGURE 3.

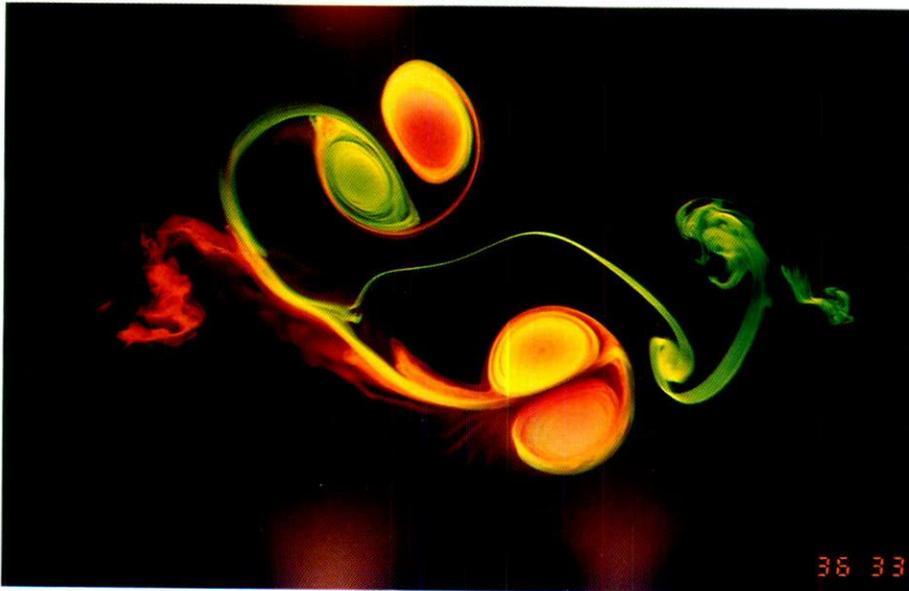


FIGURE 4.

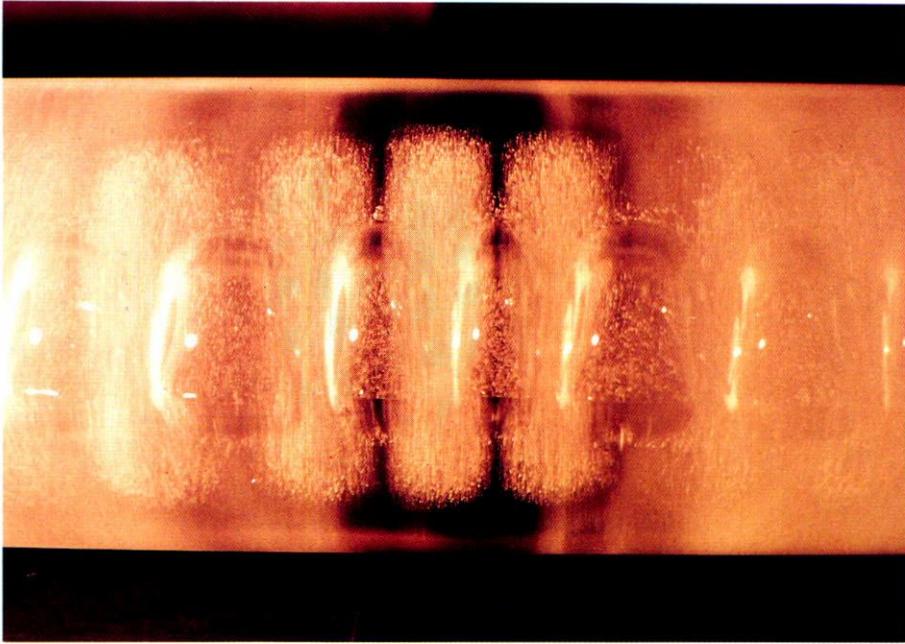


FIGURE 5. Tori made up of small bubbles that surround the areas where the cells are separated by thin walls.

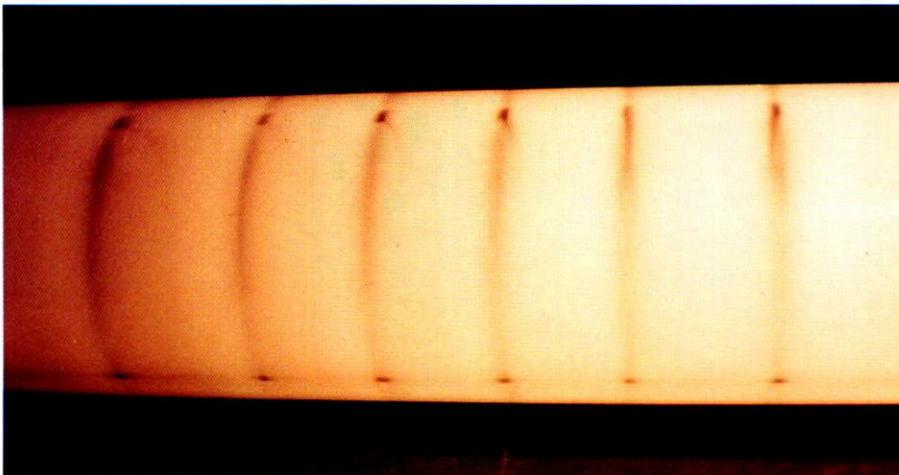


FIGURE 6. The dense fluid mixture rotates with the cylinder, while an air tube encloses the axis of rotation. The small bubbles organize in bands with lower pressure, illustrating the periodic structure of an otherwise uniform flow. Dark bands are void of bubbles.



FIGURE 7. Lowering the rotation rate after annular flow has stabilized, leads to pinching of the inner air tube. The small bubbles are trapped in areas with local pressure minima.

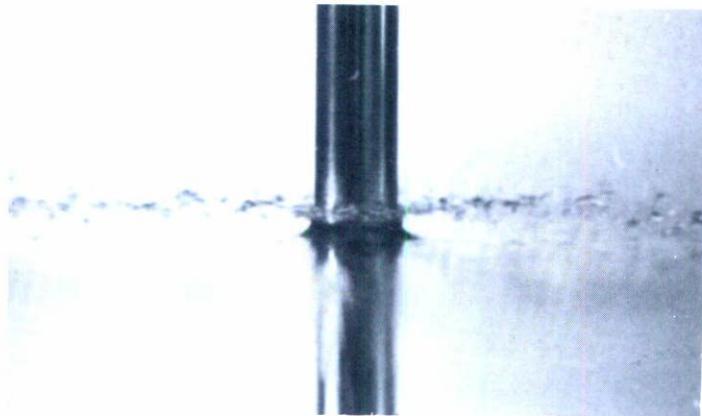


FIGURE 8. A 2.48 cm diameter cylinder spinning at a rate of 190 Hz

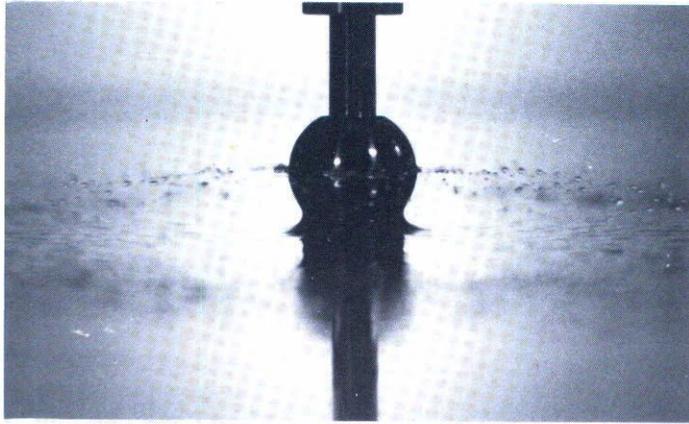


FIGURE 9. A 4.76 cm diameter sphere rotating at 49 Hz.

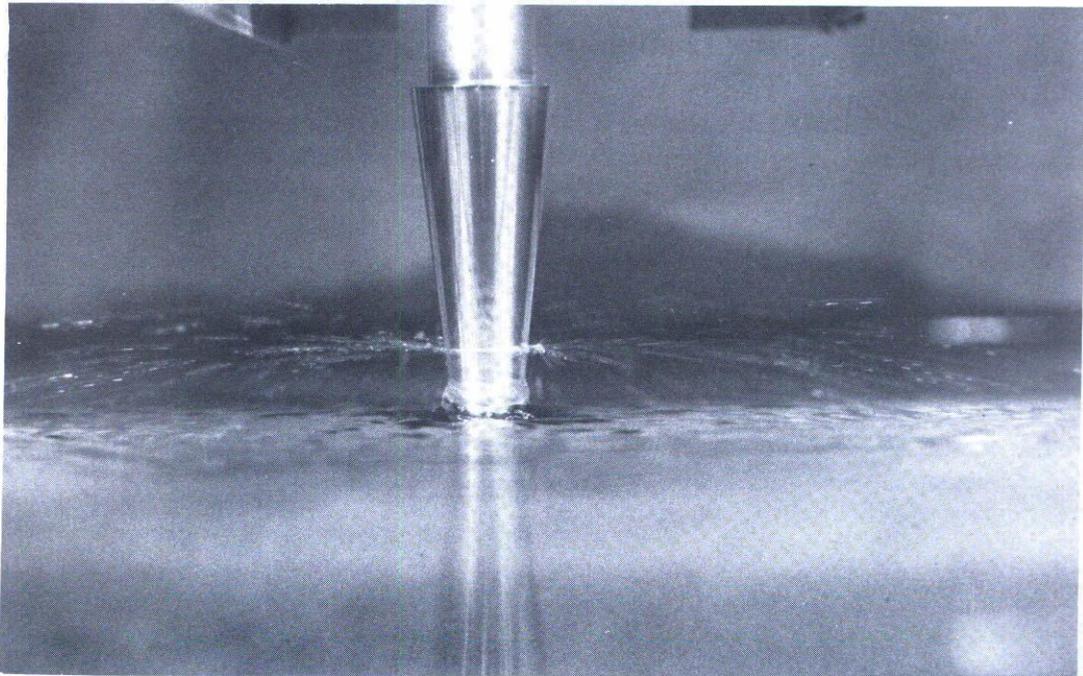


FIGURE 10. A 15° cone rotating at 88 Hz; 5 cm of the tip are immersed.

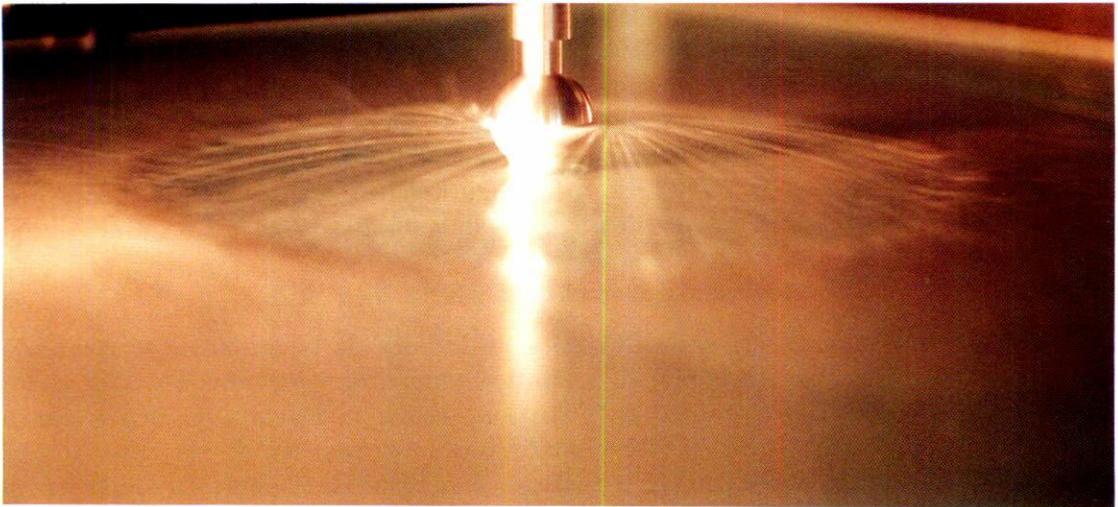


FIGURE 11. A 9.9 cm diameter sphere rotating at 27 Hz; hair shampoo has been added to the water for visualization purposes.

Gallery of Fluids: Presentation

During the I Congreso de la División de Dinámica de Fluidos of the Sociedad Mexicana de Física, a novel way to report research results, which are particularly suitable for graphic display, was introduced in a special section: Gallery of Fluids. In this section, similar to poster sessions in most meetings, contributions are mainly photographs illustrating new features on fluid flow or graphical exhibits on numerical results, with a bare minimum of text to make the presentation self explanatory. By petition of the Organizing Committee of the Meeting, the Editorial Board of the *Revista Mexicana de Física* has accepted to publish a number of selected contributions in a section with the same name. In order to maintain the same high standards that are required for all published papers, based on originality, clarity and quality, the peer review procedure will be done as follows. A panel of at least four distinguished members of the fluid dynamics community, two of whom should be well known foreign experts, will select the contributions to be published, based on their original content, and both their scientific and aesthetic qualities. A similar and very successful action was taken by the American Institute of Physics, through the *Physics of Fluids* journal, with the entries in the corresponding meeting of the American Physical Society.

This new section will appear on a yearly basis, after the annual meeting with two main goals. One is to promote an active field of research that in Mexico is at its very early stage, in such a way that the results are accessible to all our readers. The second, of course, is to publish original research that complies with the quality standards set forth by our journal.

Presentación de sección: Galería de Fluidos

En el I Congreso de la División de Dinámica de Fluidos de la Sociedad Mexicana de Física, se introdujo una novedosa modalidad para el reporte de resultados de investigación de contenido principalmente gráfico: la "Galería de Fluidos". En ésta, los participantes exhiben aquellos resultados de su investigación que se prestan en forma especial a su presentación en mural y con un mínimo de texto. A petición del Comité Organizador del evento, el Consejo Editorial de la *Revista Mexicana de Física* aceptó abrir una sección, con el mismo nombre, para la publicación de algunos de los trabajos inscritos y presentados. Con el propósito de mantener el estándar de originalidad y calidad de los trabajos que se publican, el procedimiento de arbitraje subsiste en la siguiente forma. Un jurado formado por al menos cuatro investigadores destacados, donde dos son extranjeros de reconocido prestigio, selecciona los trabajos que por su originalidad, calidad y contenido estético merecen ser publicados. El antecedente de esta iniciativa es la revista *Physics of Fluids*, en la que se publican los trabajos seleccionados en un evento semejante de la American Physical Society.

Esta sección, que aparecerá una vez al año después del congreso correspondiente, tiene dos propósitos principales. El primero es la difusión del trabajo en un activo campo de investigación; la forma de presentación y la extensión limitada de los trabajos permitirá que el contenido sea accesible a todos los lectores. El segundo es, desde luego, la publicación de trabajos originales que cumplan con todos los requisitos de nuestra revista.