Tech Brief: Axial Fan Research for Automotive and Building Ventilation Applications

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INTRODUCTION

Axial fans provide airflows over an extremely large range of flow rates and pressure rise values. Their distinguishing feature is that the pressure rise will be relatively small and the flow rate relatively large in comparison with prime movers of other designs, e.g., cent-axial and centrifugal. Numerous general discussions of axial fans exist; the following are among those that can be recommended: Wallis (1961), Osborne (1966), and Bleier (1998).

The present communication is to provide a focus on two classes of fans that have been investigated in the writers' laboratory. These two classes can be described in terms of the application areas served: automotive engine thermal management and agricultural building ventilation. The importance of the former is apparent when one realizes that nominally one-third of the released energy in the combustion process must be transferred to the ambient air through the cooling water jacket and the radiator. (Air conditioning and auxiliary heat exchangers add to this thermal "load".)

Numerous factors make prediction of the underhood cooling flows a most challenging task. Among these are the influence of the upstream restrictions on the fan performance and the blockage elements that exist downstream of the fan. Lifting the hood on a modern passenger car will immediately clarify this issue. These complexities and the importance of properly addressing them has provided the motivation for auto manufacturers to invest in detailed investigations of these flows. As specific examples, the writers' efforts have been supported by the Ford Motor Co. (now including Visteon, Inc.) and Daimler-Chrysler; some of the results from these investigations are presented below.

Axial fans found in agricultural applications include those used in greenhouse and livestock building ventilation. Heat and moisture removal, along with the discharging of contaminated air are the primary issues for these ventilation systems. Two specific applications, poultry and swine production are described below.

Poultry buildings are typically 18 m (60 ft) wide × 122 m (400 ft) long and house 100,000 birds. In these buildings, air is exhausted via an array of axial fans located along the width of one end. Clean air is then drawn in through the opposite end, where it is either cooled via evaporative heat exchangers or conditioned through a series of filters. This system is termed "tunnel ventilation". During the summer months, heat removal is critical; it can be readily appreciated that a failure of the airflow system would cause catastrophic losses as the temperature in the building would dramatically increase with 100,000 birds serving as localized heat sources, producing 7.2 watts/bird (or 12 BTU/hour/bird). During the winter months, heat removal is less of a concern, but moisture removal and oxygen replacement become increasingly important. Egg production and weight gain (meat) are adversely affected by increased temperature and decreased amounts of fresh air. For the farmer/producer, enhanced air-moving efficiency will translate directly into increased profits given that the fans account for nominally 50-60 percent of the operation's total costs.

The size of a swine building varies depending on the stage of the animals' development (the swine are moved into different buildings as they grow). For the "finishing" stage, which is the final stage and thus houses the swine at their largest size, the building is typically 12 m (40 ft) wide × 60 m (200 ft) long and houses 1000 animals. In these facilities, heat and moisture removal are the most critical issues in the summer; in the winter, moisture and ammonia removal (a potentially suffocating by-product from the animal's waste), along with oxygen replacement are the most important considerations. It is noted that "cleansing the discharge air" is both environmentally friendly as well as costly in terms of the additional pressure rise across (or power input to) the induction fans.

The limited profit margins in these facilities places a premium on the cost effective provision of the needed airflows. This motivation led to Phase I and Phase II USDA/SBIR contracts to Digital Flow Technologies, Inc. (DFTI) with subcontracts made available to the writers' laboratory. A leading manufacturer of such fans: Aerotech, Inc. of Mason, MI, has partnered with DFTI to commercialize these developments. The USDA and the Aerotech, Inc. support has also led to the results summarized below.

GENERAL CONSIDERATIONS REGARDING AXIAL FANS

The essential character of an axial fan is revealed by a lifting surface (an airfoil) that is translating in a quiescent medium. Following the passage of the surface, the drag experienced by the surrounding fluid will lead to an in-line component of velocity and the lift on the surface will produce a corresponding momentum flux in the direction opposite to the lift.

If the lifting surface were a fan blade, these motions could be resolved into the azimuthal and axial velocity components downstream of the fan. Since the airfoil sections experience a translation velocity of magnitude ($\Omega \times R$), and since the blade will not have a uniform shape for all (R), the induced velocities may be a complicated function of R. Concomitant effects, developed by the centrifugal ($-\Omega \times \Omega \times R$) and the Coriollis ($-2\Omega \times V$) "force" effects and augmented by a pressure rise across the fan plane, will lead to a radial velocity component in the induced motion. It is useful to note that the technological motivation for an axial fan: "to move fluid from the upstream to the downstream domains" is primarily achieved by the axial component. A positive radial component, depending upon the fan/shroud geometry, may also contribute to the mass flux. The azimuthal component simply represents an "energy sink".

The standard description of a fan's performance is given in terms of the pressure rise (ΔP) as a function of the flow rate (Q). These variables are best considered in dimensionless form. The length and velocity scales most commonly used are the fan diameter (D) and tip speed (U_{tip}), respectively. The pressure coefficient:

$$\psi = \Delta P / \rho U_{tip}^2 \qquad (1)$$

and the flow coefficient

$$\phi = Q / (\pi D^2/4) U_{tip} \qquad (2)$$

are defined to provide a new functional dependence: $\psi = \psi(\phi)$. For a given blade shape, this relationship will be valid for a wide range of fan sizes and speeds. This reflects the insensitivity of the flow field to the Reynolds number. That is, the non-dimensional velocity and pressure fields are dominantly controlled by inertial effects and the imposed boundary conditions; they are insensitive to viscous effects. The above dimensional reasoning leads to what is conventionally referred to as "fan laws". Specifically, the scaling of dependent variables which are independent of Reynolds number provides a set of standard relationships commonly found in the literature and texts.

Figure 1 shows a typical automotive cooling fan installed in a test configuration. The geometrical configuration for this test is referred to as a 'free inlet-free outlet' or FIFO condition. This configuration is used to benchmark fan performance without the effects of blockage elements. The latter, which are in close proximity to the installed fan, significantly affect its performance.

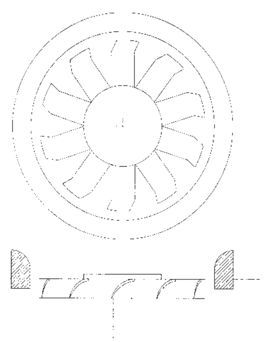


Figure 1. A typical underhood cooling fan in a shroud that permits the free inflow/free outflow (FIFO) condition to be examined.

Figure 2 shows a typical building ventilation fan. This 0.67m (26.5-inch) diameter fan is typical of the fans that would be found in hog buildings. The performance is also typical in that a relatively low pressure rise and high volume flow rate are provided. Several aerodynamic differences exist between the automotive and ventilation fans which lead to these different performance characteristics. Specifically, the number of blades, hub-to-tip ratio, and solidity are design parameters which play an important role in a fan's performance and all of these are larger for the automotive fan.

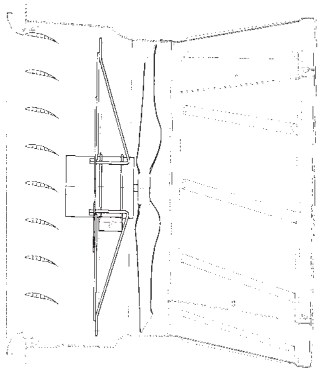


Figure 2. Aerotech 26 inch axial fan with inlet shutter and diffuser cone.

A variable which is also of considerable interest is the fan efficiency. Unlike performance, the definition of efficiency depends on the specific application of the fan. For automotive cooling fans, the chosen velocity and length scales are used to normalize the input power. The definition of efficiency follows (where ρ_{shaft} is the power delivered to the fan's drive shaft):

$$\eta = \frac{\Delta PQ}{P_{shaft}} \qquad (3)$$

The ventilation industry typically defines efficiency as a dimensional number: flow rate/input power. This is usually expressed in CFM/Watt.

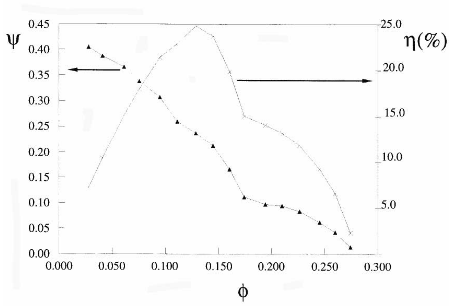
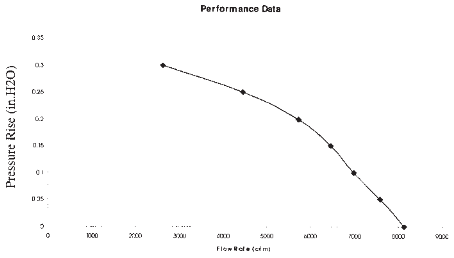
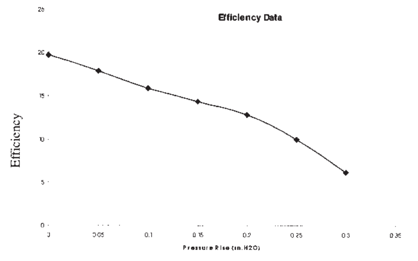


Figure 3. The nondimensional pressure rise (ψ) and efficiency (η) as a function of the nondimensional flow rate. Note, see equations 1, 2 and 3 for ψ , ϕ and η.



a) pressure rise as a function of the flow rate



b) fan efficiency (cfm/watt)

Figure 4. Performance data: the aerotech fan assembly of Figure 2.

THE AXIAL FAN RESEARCH AND DEVELOPMENT FACILITY

Figure 3 presents the performance (Δp~Q) and the efficiency data for the fan/shroud combination of Fig. 1. These data are presented in non-dimensional form which would permit their extension for other rpm values (1000 rpm was used for the plot) and for other geometrically similar configurations. The experimental data for Figure 3 were acquired in a unique facility: the Axial Fan Research and Development (AFRD) facility located in the Turbulent Shear Flows Laboratory at Michigan State University. Similarly, the performance and efficiency data (Figure 2) are presented in Figure 4. This flow system is shown in Figure 5.

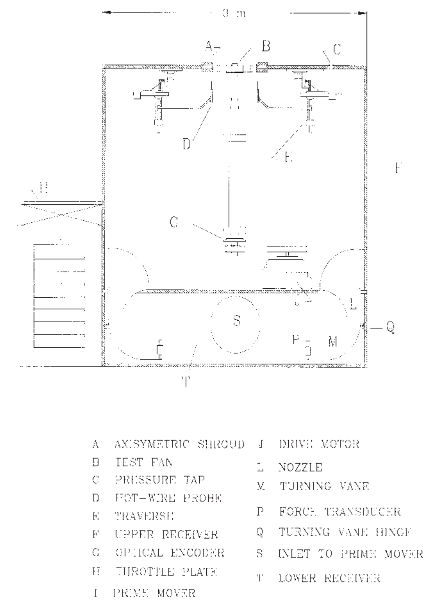


Figure 5. A schematic representation of the aeroshroud. Note, a typical engine mounted fan is shown in this figure. (Drawing is to scale).

Laboratory air is delivered through the test-fan-plane into the upper receiver of the AFRD. The corresponding Δp is easily measured via the indicated pressure tap. A novel moment-of-momentum flux device (see Fig. 6 and Morris, et al. (2000)) is used to determine the volume flow rate delivered by the test fan against the back pressure of the upper receiver. This pressure is controlled by the throttled condition of the large centrifugal fan which exhausts the lower receiver of the AFRD. This complete system has been fully described in the MS thesis by Morris (1997).

The favorable attribute of the moment-of-momentum flux flow meter is its insensitivity to the approach flow condition. This is important given the large variations that are experienced in the AFRD. Specifically, the unobstructed flow from the fan will be downward to the floor of the upper receiver and it will horizontally enter the nozzle contraction. Conversely, an obstructed fan flow (e.g., a simulated engine which blocks the fan flow) will enter the nozzle from the outer walls of the upper receiver.

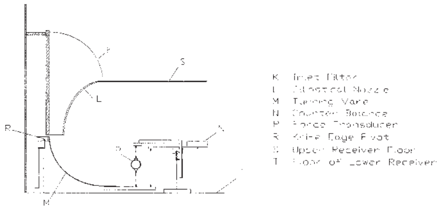


Figure 6. The moment-of-momentum flux device that is used as the flow rate metering technique in the AFRD.

A 15 HP, ±1% speed controlled drive system is used to power the automotive cooling fans. This drive train includes a torque meter that permits an accurate ±0.15% of full scale) measure, when combined with the fan's rotational speed of the delivered power. Independent electrical measurements allow the drive train losses to be assessed and they provide a consistency check on the direct power measurement.

Detailed hot-wire surveys can be executed in the outflow from the fan. For these, a calibrated x-array of hot-wire sensors is aligned with the time mean flow direction that has been independently determined using the technique described by Morris (1997). A three-dimensional probe alignment device (see Fig. 7) is used to support the probe shaft with the correct spherical angles of the time mean velocity. The time series data (E_1, E_2) then allow $u(t)$ - plus - $v(t)$ and, with a 90-degree rotation about the probe axis, $u(t)$ - plus - $w(t)$ to be acquired. These Cartesian components: u,v,w are referenced to the "probe coordinates" for each measurement. The time resolved velocity data can be used to recover the time mean, the fluctuation intensities, and the kinematic Reynolds shear stress quantities in the axial, tangential directions if the probe is in this plane for the u,v measurements. (This is the condition for the data presented below). The time mean and fluctuating intensity data for the radial velocity component follow from the u,w data given the same constraint.

Figures 8 and 9, which were obtained using the configuration of the next section, are included here as demonstrations of the level of detail that can be obtained from the measurements described above. These data have been abstracted from Morris (1997) and the manuscript that has been submitted to *JFE*: Morris and Foss (2000). One quadrant of the full data set is shown. These phase sampled data are referenced to the fan's angular position (θ) by an optical encoder which is reset (n=0,1,2...N) for each revolution. The ensemble averaged data represent 900 independent samples, i.e., N=899.

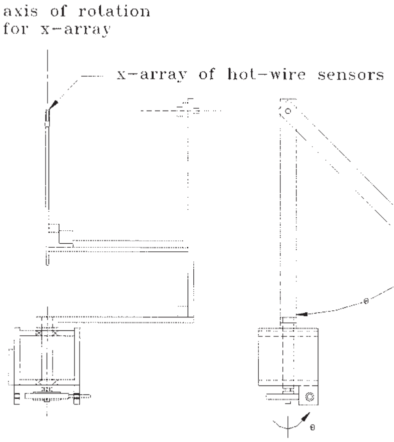


Figure 7. The spherical angle position device which allows x-array hot-wire measurements to be aligned with the time mean wake flow at a given r/R position.

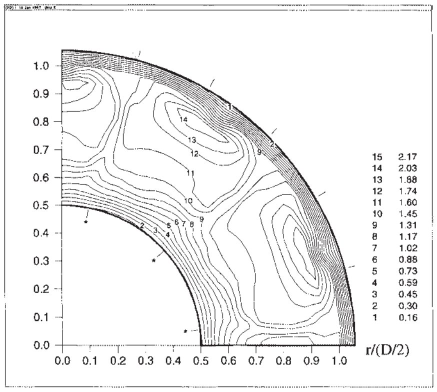


Figure 8. Contours of phase averaged axial velocity: U_x/U_{tip}. Note: Blade rotation is clockwise.

Note that the signatures of the blades are well resolved in these data. The spatially differentiated $v_r(r,\theta)$ and $v_\theta(r,\theta)$ data permit the axial vorticity

$$\omega_x = \frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r} - \frac{1}{r}\frac{\partial v_r}{\partial \theta} \qquad (4)$$

to be determined. The wingtip vortex motions are clearly evident in Fig. 9.

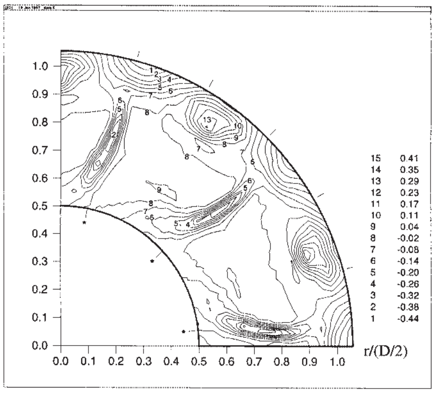


Figure 9. Contours of phase averaged axial vorticity: ω_x/DU_{tip}. Note: Blade rotation is clockwise.

THE AERODYNAMIC SHROUD (AN MSU INVENTION)

The aerodynamic shroud, shown schematically in Fig. 10 and described by Foss (1998) and Foss and Morris (1999), provides two distinct benefits for the axial fans considered in this communication. An engine driven fan must be configured with a large tip clearance given the relatively large (≈25mm) motion between the chassis mounted shroud and the engine mounted fan. A concomitant result of this condition is the presence of large "tip region losses" or flows from the pressure to the suction side of the blade in the tip region. A ventilation fan will typically operate with a small tip clearance, but the downstream diffuser cone is vulnerable to flow separation effects given the limited energy that can be supplied to the boundary layer fluid by the fan. In both of these conditions, the enhanced axial momentum at the fan plane, as provided by the Coanda jet of the aeroshroud, leads to improved system performance. A recent study by Neuendorf and Wyganski (1999) has identified the benefits of using a properly shaped inlet shroud contraction. Their identification of an enhanced entrainment for a curved surface wall jet will be investigated in our search for an improved aeroshroud design.

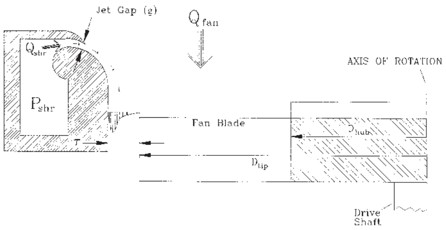


Figure 10. A schematic representation of the aeroshroud. Note, a typical engine mounted fan is shown in this figure.

The beneficial influence of the aeroshroud on the automotive fan's performance is clearly shown by the $\Delta p \sim q$ curves of Fig. 11. Morris (1997) showed that the product of the aeroshroud's flow rate and pressure rise - i.e., its power - correlated the performance data. This product, suitably non-dimensionalized, is shown as the parameter X in Fig. 11. Its definition is:

$$X = \Delta PQ / \rho A_{flow} U_{tip}^3 \qquad (5)$$

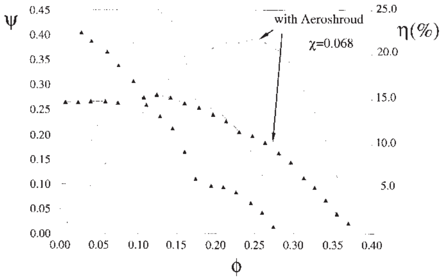


Figure 11. Enhanced cooling fan performance with the aeroshroud of Figure 10. Note, χ is defined in equation 5.

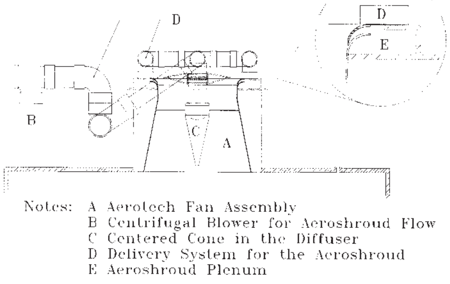


Figure 12. Aeroshroud configuration for the 26 inch fan of Figure 2.

Table 1: Performance improvements for the ventilation fan that has been fitted with an aeroshroud

	Without Aeroshroud	With Aeroshroud	%Difference
Q	61.5	79.5	29.2
Efficiency	15.9	16.8	6.11

Significant performance improvements were also experienced in the ventilation fan studies. The configuration, shown in Fig. 12, when fitted with an active aeroshroud, achieved the performance improvements shown in Table 1. These numerical values represent a pressure rise condition of 0.1 inches of water; however, similar gains were observed for all pressure rise conditions.

Note, the efficiency improvement was assessed using an estimated 70% efficient centrifugal fan to pressurize the aeroshroud. Also, since the inflow to the aeroshroud can be taken from the building to be ventilated, the figures in Table 1 include the shroud flow rate in the enhanced Q value.

SUMMARY

Axial fans are utilized in a wide range of applications. Two of these: underhood cooling fans and building ventilation fans have been considered in this communication. The writers' capability to execute detailed velocity measurements, as well as performance measurements, has been demonstrated. An MSU invention: the aerodynamic shroud, has been shown to enhance the performance of both styles of fans.

REFERENCES

Bleier, F.P., *Fan Handbook: selection, application, and design*, New York: McGraw-Hill, 1998.

Foss, J.F., "Improved Cooling Fan Shroud," U.S. Patent No. 5,762,034, 1998.

Foss, J.F. and Morris, S.C., "Fan Shroud with Integral Air Supply," U.S. Patent No. 5,991.685, 1999.

Morris, S.C., "Experimental Investigation of an Aerodynamic Shroud for Cooling Fan Applications," Masters Thesis, Michigan State University, Dept. of Mechanical Engineering, 1997.

Morris, S.C., Foss, J.F., "Performance Measurements of an Aerodynamic Fan Shroud," submitted to *J. Fluids Engineering*, 2000.

Nuendorf, R. and Wyganski, I., "On a turbulent wall jet flowing over a circular cylinder", *Journal of Fluid Mechanics*, vol. 38, 1999, pp. 1-25.

Osborne, W.C., *Fans*, New York: Pergamon Press 1996.

Wallis, A.R., *Axial Flow Fans: design and practice*, New York: Academic Press 1961.

Fluids Engineering Division Committees & Coordinating Groups

The Fluids Engineering Division has three coordinating groups and three technical committees. The functions of the coordinating groups and committees are related to the areas of fluids engineering reflected by their names.

Participation in the committees and coordinating groups is on a voluntary basis. Each committee and group meets twice each year-once at the FED Summer Meeting and once at the International Mechanical Engineers Congress & Exposition. Schedules for these meetings can be found on the web site just prior to each meeting-or at the registration desk at the site hotel. If ASME members wish to participate in a committee or coordinating group proceedings-they are free to do so; this is one of the many benefits of ASME membership in the Fluids Engineering Division.

Specific activities and functions of each of the committees and coordinating group activities are described in the following paragraphs. Usually the contact point is the Chair-however if difficulty in contacting the Chair arises, please contact Richard R. Schultz (208 526-9508; FAX: 208 528-0628; srr@inel.gov).

Coordinating Group on Fluid Measurements

The Coordinating Group on Fluid Measurements (CGFM) is the center for experimental measurements within the FED. The CGFM membership includes specialists in instrumentation, experimental techniques, design of experiments, measurement accuracy and uncertainty, and data acquisition and analysis. The group membership is composed of individuals from each of the Technical Committees as the topic of fluid measurements permeates all of the FED. As a Coordinating Group, the group charter is to work closely with the technical committees and to provide updates on the latest developments in fluid measurements through programs at technical meetings and other technology transfer activities.

During recent FED meetings the CGFM has cooperated on such recurring symposia and forums as Laser Anemometry, Experimental and Numerical Flow Visualization, Measuring and Metering Unsteady Flows, and Measurement Techniques in Multiphase Flows. In addition, the group hosts technical sessions including recurring programs in Fluid Measurements and Instrumentation and Fluid Measurement Uncertainty Applications. Along with these recurring themes, the group organizes or participates in upcoming topical sessions on Cryogenic Fluid Flows, Liquid Crystal Thermometry, Flow Measurements in Opaque Multiphase Fluids, and Experimental Needs for CFD Development and Verification.

For more information, visit the CGFM web site at http:/www.asme.org/divisions/fed/cgfm.html. The CGFM encourages all who are interested in planning, organizing, or participating in technical sessions in the general area of fluid measurements to become involved. For more information on the CGFM, or to receive future meeting notifications and minutes, feel free to contact the Chair: Dr. Joel T. Park of the U.S. Navy Large Cavitation Channel (901) 947-3117 or the Vice-Chair: Professor Jim Liburdy of Oregon State University (541) 737-7017.

Coordinating Group on Computational Fluid Dynamics

The Coordinating Group on Computational Fluid Dynamics (CGCFD) is a body dedicated to providing a means for researchers and applications scientists and engineers to disseminate CFD related information through symposia and forums at ASME meetings. In addition, CGCFD encourages acceptance of CFD by industry and provides for networking of CFD professionals worldwide. At the FED summer meetings the CGCFD organizes symposia and forums centered on topics such as finite element applications in fluid mechanics, high speed jet flows, flows in manufacturing processes, numerical developments in CFD, advances in free surface and interface flows, and bifurcation, instability, and hysteresis in fluid flow. The Group is also frequently sponsors tutorials on CFD-specific topics and panel sessions.

The Chair of the Group is Prof. Urmila Ghia, Department Head of Mechanical, Industrial and Nuclear Engineering at the University of Cincinnati. The Vice-Chair of the Group is Prof. Peter Raad, Professor of Mechanical Engineering at the Southern Methodist University in Dallas, Texas, and Associate Dean of the School of Engineering and Applied Science. If questions arise, please contact Prof. Urmila Ghia at 513-556-4612, urmila.ghia@uc.edu; or Prof. Peter Raad at (214) 768-3043; peter@seas.smu.edu.

Coordinating Group on Industrial Technology

The Coordinating Group on Industrial Technology (CGIT) was formed in 1999. The primary function of CGIT is to develop symposia, forums, and panels that specifically address technology issues important to industry and to work with the other technical committees and coordinating groups of FED. Although the CGIT does not have a long tradition in the FED it is responsible for one of the most interesting ares in fluids engineering: the application of fundamental principles to solve industrial problems.

If questions arise, please contact the Chair: Dr. Mano Dhaubhadel of the Case Co. (630-887-2009) or the Vice Chair: John Navickas of the Boeing Co. (714-372-1432).

Fluid Applications and Systems Technical Committee

The Fluid Applications & Systems Technical Committee (FASTC) programs focus on providing state-of-the-art knowledge to support mature, developing, and emerging applications in the general field of fluid mechanics. FASTC does this by providing an interface between designers, developers, and researchers. FASTC activities also include programs designed to enhance learning and discussion. Examples include panel discussions, tutorials, and clinics earmarked for promoting participation from industry. FASTC is organized into three subcommittees: Fluid Transients, Fluid Machinery, and Emerging and Developing Applications.

In the past FASTC has sponsored symposia and forums (sometimes in conjunction with other committees or coordinating groups) such as Fluid Measurements and Instrumentation, Industrial and Environmental Applications of Fluid Mechanics, Fluid Machinery Forum, Industrial Applications of Swirling Flow, and Computational Methods for Analysis of Fluid Machinery. FASTC also offers a Pumping Machinery Symposium on a regular basis.

If you would like to participate in FASTC activities, or if you have any questions or suggestions, please contact the Chair: Dr. Adiel Guinzburg of Boeing (818-586-7622) or the Vice Chair: Dr. Awatef Hamed of the University of Cincinnati (513) 556-3553.. You can also obtain additional information by visiting the FASTC Web Site: http://www.asme.org/divisions/def/fastc

Fluid Mechanics Technical Committee (FMTC)

The Fluid Mechanics Technical Committee (FMTC) serves as the focal point within ASME for technical activities in fundamental fluid mechanics. The main activity of FMTC is to organize symposia and forums related to all aspects of basic fluid mechanics. The committee strives to provide timely technical information to the ASME membership through well-organized technical sessions and to foster dialog among the membership. Currently, there is a major emphasis on the development of rolling three-year plans for symposia and forum development. Typically, the symposia and forms are planned and organized through one of our four sub-committees. The FMTC sub-committees are External Flows; Internal Flows; Unconventional/ Emerging Topics; and Unsteady Flows. Members are welcome to participate and to help organize the technical sessions and other activities of the FMTC.

General information about FMTC including planned symposia / forums as well as the past minutes of business meetings can be found on our web page (http://www.asme.org/divisions/fed/FMTC). For further information you may contact either the FMTC Chair: Professor Ganesh Raman of the Illinois Institute of Technology (312) 567-3554 or the Vice-Chair: Dr. George Papadopoulos of Dantec Measurement Technology (201) 512-0037, x 121.

Multiphase Flow Technical Committee

The Multiphase Flow Technical Committee (MPFTC) organizes symposia and forums related to gas-liquid and fluid-solid flows in odd years and computational and experimental methods in even years at the FED Summer Meetings. Generally, multiphase flow is a huge technological activity that transcends what has been the traditional scope of past meetings. Serving our membership therefore calls for new initiatives that go beyond these traditional boundaries. The ICMECE offers a great opportunity for the organization of joint activities with other divisions which also have a strong multiphase flow component such as Heat Transfer, Manufacturing, Acoustics, and others. The planning of joint symposia with these divisions is well under way.

If you have questions or suggestions please contact the Chair: Dr. Steven L. Ceccio of the University of Michigan (313) 936-0433 or the Vice Chair: Professor Gretar Trygvasson of the Worcester Polytechnic Institute (508) 831-5759.

2001 Fluids Engineering Division
Summer Meeting
May 29–June 1, 2001
New Orleans, Louisiana
Sheraton New Orleans Hotel
www.asme.org/conf/fed01

The Fluids Engineering Division Summer Meeting will take place at the Sheraton New Orleans, May 29 through June 1, 2001. Full conference information is available on the conference web site at **http://www.asme.org/conf/fed01**. There will be approximately 80 technical sessions and all of the FED committees will hold their meetings there. There will also be a number of special events, including Fluids Engineering Clinics, in which conference attendees are invited to meet with technical experts and get their advice (see article by Demetri Telionis), tutorials, and plenary lectures. There will be three tutorials, on 1) "Pumping Machinery" by Adiel Guinzburg, The Boeing Company, 2) "Modern Applications of Experimental Uncertainty Analysis" by Hugh W. Coleman, University of Alabama in Huntsville and W. Glenn Steele, Mississippi State University, and 3) "Code Verification and Validation" by Frederick Stern, University of Iowa. The plenary lectures will be held each morning, and will be on 1) "The U. S. R&D Enterprise - Status and Future Trends" by Norm Abramson, Southwest Research Institute (retired), 2) "Improving the Acceptability of Flow Measurements" by George Mattingly, NIST, 3) "Pump Technology - Are We Making Progress?" by S. Ghopalakrishnan, Flowserve Corporation, and 4) "Agile Engineering for Advanced Turbomachinery Products" David Japikse, Concepts NREC, The FED awards luncheon will be held Wednesday, May 30. Our luncheon speaker is Marvin Perrett of the National D-Day Museum in New Orleans, who will give a talk entitled "Return to Normandy."

This will be an exciting time for fluid dynamics in New Orleans. The International Conference on Multiphase Flows (ICMF-2001) will also take place in New Orleans, LA from May 27 through June 1 at the Marriott Hotel, directly across the street from the ASME Fluids Engineering Division Meeting. All full-paid registrants of the ASME-FED Meeting will be entitled to attend all technical events of the ICMF-2001. They will also receive, at no extra cost, a program and the CD-ROM proceedings of the ICMF-2001. The following week the ASME Turbo Expo and International Joint Power Generation Conference and Exposition will be held at the Ernest Morial Convention Center. There are also several fluids-related ASME Continuing Education courses that will be held in New Orleans around the FED conference, including Waterhammer and Fluid Structure Interaction in Piping Systems, May 31-June 1, and The Gas Turbine: Principles and Applications, June 4-5. For more information on these courses, visit www.asme.org/pro_dev.

Clinics at the FED Summer Meeting

We are organizing again a clinic session at our summer meeting. This activity provides the opportunity for practicing engineers to interact directly with experts in specific fields.The clinics will be again part of the broader program "Industry Exchange Program". Here is how this activity will be structured:

On an afternoon during the meeting, a large room will be set aside for the clinics. Each clinic is given a table and is identified with a sign. Each clinic is concerned with a specific topic of importance to industry. At each table sit the "clinicians". These are experts on the topic, from government, academia or industry, willing to offer their advice and short consulting during the clinic, free of charge. Participants of the meeting are welcome to visit a clinic and present their problem. This leads either to discussions among "clinicians" and visitors or specific working sessions on a one-to-one basis. These discussions can be carried on during the clinic, but partnerships thus established can lead to formal consulting work or other agreements that can be negotiated later.

This year we organized the following clinics at the FED Summer Meeting in New Orleans:

- "Consultation on the Application of CFD Codes - Application of CFD to Real-World Problems" Chris Freitas and Mano Dhaubhadel
- "Surface Pressure and Temperature Methods, Five- and Seven-hole probes. Pressure Transducers, Scanners,etc."Timothy Wei and Demetri Telionis
- "Internal Flow Velocity and Turbulence Measurements - Laser-Doppler Velocimetry (LDV),Volkan Otungen
- "Particle-Image Velocimetry (PIV)" Pavlos Vlachos
- "Multi-Phase Flow - Cavitation, Particulate Flow, Modeling" Upendra Rohatgi and Joe Katz

Honors & Awards

2000 Fluids Engineering Award

The winner of the 2000 Fluids Engineering Award is Dr. Fazle Hussain of University of Houston. Dr. Hussain was selected for this award for his outstanding contributions to fluid mechanics research and teaching. Dr. Hussain has served on several editorial boards for such leading journals as *The Physics of Fluids*, *Journal of Fluids Engineering*, *Turbulence in Liquids and Experimental Thermal and Fluid Science*. He has also served on numerous national and international review panels and scientific committees and organized a number of workshops and conferences. He is a Fellow of APS and ASME and an Associate Fellow of AIAA. Currently, he is Distinguished Professor at University of Houston and the Director of the Institute of Fluid Dynamics and Turbulence, which comprises of the Aerodynamics and Turbulence Laboratory and the Vortex Technology Center.

Dr. Hussain obtained his BSME from Bangladesh University in 1963 and became a lecturer the same year. In 1965, he received the highly competitive Fulbright Scholarship to pursue graduate studies in mechanical engineering at Stanford University. His Ph.D. thesis won him the Stanford's Eckhart Prize for excellence in 1969. After serving for 18 moths as Assistant Professor at Johns Hopkins University, he joined University of Houston as an Assistant Professor in Mechanical Engineering. He became a Professor in 1976. Dr. Hussain has supervised numerous graduate and undergraduate research projects and dissertations. He has received continuing support for his research through grants from federal agencies and has published extensively in fluids engineering journals and presented numerous seminars and invited and keynote lectures at major national and international conferences. In 1985, the University of Houston recognized his outstanding achievements by awarding him the first Research Excellence Award and promoting him to Distinguished University Professor. In 1989, he became the Cullen Distinguished Professor. During his career, he has received numerous other awards and recognitions including the ASME Freeman Scholar award in 1984. He was also awarded the 1998 Fluid Dynamics Prize by the American Physical Society.

Robert T. Knapp Award

This award is given to the authors of the best paper presented to the Fluids Engineering Division dealing with analytical, numerical and laboratory research. The year 2000 award is received by Mr. Scott Coppen and Dr. Chris Rogers for the paper "Correlating Particle Dynamics with Local Fluid Structures in Turbulent Flows". The paper was presented at the 3rd ASME/JSME Joint Fluids Engineering Conference in San Francisco, CA, in July 1999. The paper presented advances to the understanding of particle-laden turbulent flows and the effects of large mass loading on diffusivity.

Scott Coppen received his BSME degree from University of Massachusetts at Dartmouth. He received his MSME degree from Tufts University in 1998 and is currently working toward the Ph.D. degree. Dr. Rogers received all his degrees at Stanford University. He is currently at Tufts University.

Lewis F. Moody Award

The Lewis F. Moody Award is given to the authors of the best paper presented to the Fluids Engineering Division dealing with a topic useful to mechanical engineering practice. The year 2000 award is received by Dr. Michael Amitay and Dr. Ari Glezer for their paper "Aerodynamic Flow Control of a Thick Airfoil Using Synthetic Jet Actuators". The paper was presented at the 3rd ASME/JSME Joint Fluids Engineering Conference in San Francisco, CA, in July 1999. The paper presents the development and practical application of a MEMs-based synthetic actuator for flow control.

Dr. Michael Amitay has been a Research Engineer at Georgia Tech Research Institute since 1996. Dr. Amitay received his BSc., MSc. and D.Sc. in Aerospace Engineering from the Technion, Israel Institute of Technology in 1987, 1990 and 1994, respectively. Dr. Ari Gleser is Professor of Fluid Mechanics in the George W. Woodruff School of Mechanical Engineering at Georgia Institute of Technology. He received his MS. And Ph.D. degrees from California Institute of Technology in 1975 and 1981, respectively.

Fluids Engineering Division 2001

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International Mechanical Engineering Congress and Exposition

November 11-16 2001
New York Hilton Hotel & Towers and
Sheraton New York Hotel & Towers
New York, New York

The forums presented at the upcoming meeting will be:

Fluid Transients

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Global Measurements: Techniques and Industrial Applications

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Forum on Bifurcation, Instability and Hysteresis in Fluid Flow

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Multiphase Flows in Biomedical Applications and Processes

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Open Forum on Computational Techniques in Micro and Nano Scale Flow and Heat Transfer

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University-Industry Collaborative Research in Multiphase Flow

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