THE CHRONICLE OF THE AMERICAN ASSOCIATION FOR WIND ENGINEERING

The Wind Engineer

December 1995

GOOD BYE WERC! HELLO AAWE!

President Kareem recently took steps to change our organization's name from the Wind Engineering Research Council (WERC) to the American Association for Wind Engineering (AAWE). The name change was proposed in the last issue of The Wind Engineer. "Hearing no objections, and receiving one letter in support of the name change, I proceeded with the legalities to make the change," President Ahsan said. There were several reasons for the change. The mission of the organization has changed from one of wind engineering research, to being a proactive voice of the wind engineering community. The new name is more reflective of these activities. People from a variety of disciplines, including meteorologists, sociologists and economists, in addition to wind engineers make up today's membership.

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The term "American" is appropriate, because it distinguishes the organization from a number of international wind engineering associations.

WERC was organized in 1976 as a nonprofit corporation in Colorado. The first president of the organization was Jack Cermak, who held the office for ten years. Kishor Mehta served four years from 1986 to 1989. Dale Perry followed Kishor with a four year term. Ahsan Kareem took office in 1994 and will complete his term in 1997.

SBCCI REJECTS MISSILE IMPACT REQUIREMENTS

At their recent mid-year code hearing, the SBCCI membership narrowly rejected a code change proposal that would require window protection from flying debris in hurricane zones where the fifty-year mean recurrence wind speed was greater than 90 mph (fastest-mile wind). The issue was also defeated two years ago. Proponents of the code change argued that broken windows were a major cause of damage in Hurricane Andrew. A breach of the building envelope allows wind and water inside a building, causing additional damage to finishes and contents. Increase in internal pressure contributes to additional structural damage as well. The need for additional study to clearly define the missile impact criteria was cited by opponents of the measure.

SBCCI adopted Missile Impact Standard 12-93, which establishes the protocol for testing window glass and window coverings for missile impact. Two impact tests are defined: a large missile and small missile test. The large missile test calls for two impacts of a 9-lb 2x4 timber plank traveling at 50 ft per second. The small missile impact criteria requires 30 hits of a 2-gram steel ball traveling at 130 ft per second to impact the glass. In addition to the missile impact, the window is subjected to 9000 cycles of uniform pressure loading following a prescribed pattern of pressure and suction. If, after impact, the glass remains in the opening for the duration of the cyclic loading, the window or window covering is judged to be in compliance with the missile impact standard. To date only Dade and Broward Counties in Florida have adopted missile impact criteria. Their standard is similar to the one proposed for SBCCI. The Texas Department of Insurance proposed the SCBBI missile impact standard in their new windstorm code for the fourteen Texas counties along the Gulf coast. Adoption of the windstorm code is pending completion of an ongoing public review.

SBCCI adopted Missile Impact Standard 12-93, which establishes the protocol for testing window glass and window coverings for missile impact.

A number of laboratories in Florida are testing windows and shutters for compliance with the Dade, Broward, or SBCCI impact standards. Dave Hattis, who is Chairman of an ASTM Subcommittee attempting to write an ASTM impact standard, stated that more than 200 windows and window coverings have passed the tests so far.

TEXAS TECH UNIVERSITY COMMEMORATES THE 25TH ANNIVERSARY OF THE LUBBOCK TORNADO

The Tornado of May 11, 1970, changed the course of history in the City of Lubbock, Texas. At the time, the $135 million loss was the largest on record. Twenty-six persons died; more than 300 were injured. The destruction covered one eighth of the city, including a large section of the downtown area, a depressed minority neighborhood, an industrial area and the municipal airport. The city's well-conceived emergency response plan had been practiced just prior to the storm. Reaction and recovery were swift and efficient. A major redevelopment in the downtown area was initiated. Urban renal relocated citizens to other areas of the city. The City then redeveloped the land by constructing a new civic center and library. Significant other commercial development followed, including a new Department of Transportation office, hotels, restaurants and other commercial establishments. The twenty-story Great Plains Life building, which bore the brunt of the tornado winds, was reconstructed and placed back in service. The twelve inches of permanent deformation in the steel frame is still visible today if one looks up the southwest corner of the building. Other major city improvements included construction of the Canyon Lakes and expansion of the Lubbock air terminal.

The tornado also marked the beginning of the wind engineering research program at Texas Tech University (TTU). Faculty members in Civil and Industrial Engineering, Atmospheric Science and Sociology conducted studies of the tornado damage and its impact on the population. Thanks to a grant from the the National Science Foundation, TTU engineers studied 98 buildings and structures affected by the storm in minute detail. This marked the first time engineers looked at tornado damage in a systematic and scientific manner. These early studies put to rest many of the myths and misunderstandings about tornadoes. Major discoveries included the fact that aerodynamic wind effects, not atmospheric pressure change, is the major damaging mechanism in tornadoes. In addition, it was determined that maximum tornado winds are not 600 to 800 mph, but more likely in the 250 to 300 mph range.

> To Commemorate the 25th Anniversary of the Lubbock tornado, an exhibit was developed for the Museum of Texas Tech.

The wind engineering program, through the Institute for Disaster Research and the Wind Engineering Research Center, has continued to be active in wind research. Interests expanded from tornado damage investigations to many other fields of wind engineering. Under the leadership of Kishor Mehta, Joe Minor and Jim McDonald, fields of study expanded to building codes and standards, window glass research, occupant protection, and tornado resistant structures.

Today, the program includes automobile aerodynamics, wind erosion, non-boundary layer winds, computational fluid dynamics and full-scale measurements of wind effects on low-rise buildings. The wind research program actively involves more than 25 graduate students and 20 undergraduates. External funding exceeds $1 million per year.

To commemorate the 25th anniversary of the Lubbock Tornado, an exhibit was developed for the Museum of Texas Tech. The exhibit features memorabilia from the Lubbock tornado, TTU Wind Engineering accomplishments and educational activities on wind and weather. The exhibit opened the week of May 11, 1995, and will run through December 31, 1995. An exhibit catalog is available from the Texas Tech University Museum for $3.00 plus shipping and handling. Write to: Texas Tech Museum, Box 43191, Lubbock, Texas 79409-3191.

The Wind Engineer

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Published periodically by the
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Ask the Wind Engineer

How do you convert fastest-mile wind speed to 3-second gust, or any other averaging time?

If one records a time history of wind speed at a certain location over a period of time, the magnitude of a reported wind speed depends on the averaging time. A typical 3-cup anemometer has a response time of 2-3 seconds. Hence, the peak gust, the largest wind in the record, is a 2-3 second gust. The largest one-minute average wind speed in the record will be smaller than the peak gust. Likewise, the largest 10-minute (average) wind speed will be less than the largest one-minute wind speed. The mean hourly wind speed will be smaller than the 10-minute wind speed, etc.

A relationship between mean hourly wind speed and any other averaging times can be found using wind data obtained by Durst (1960) in flat open terrain (Exposure C). Simiu and Scanlan (1986) present an equation based on the Durst relationship. The wind speed for any averaging time t (in seconds) at a height z is expressed in terms of a mean hourly wind speed at height z:$(t = 3600\ sec)$.

$$U_t(z) = U_{3600}(z)\left[1 + \frac{\beta^{\frac{1}{2}} c(t)}{2.5 Ln(z / z_o)}\right] \quad (1)$$

At a height of 10 m in open terrain; $z = 10$, $z_0 = 0.05$, and $\beta = 6.5$. Equation (1) becomes

$$U_t = U_{3600}\,[1 + 0.1925\ c(t)] \quad (2)$$

Values of $c\ (t)$ are listed in Table 1. Linear interpolation is permissible for other averaging times.

Fastest mile wind speed has a variable averaging time. The averaging time in seconds is given by

$$t = \frac{3600}{U_{fm}}. \quad (3)$$

Suppose U_{fm} is 90 mph, what is the equivalent 3-second gust speed? The averaging time for 90 mph is 40 sec. From Equation (2),

$$U_{3600} = \frac{U_{40}}{[1 + 0.1925c(40)]}$$

$$= \frac{90}{[1 + 0.1925(1.54)]}$$

$$= 69.4 \text{ mph}$$

Table 1:

Values of c(t)

t(sec)	1	2	3	5	10	20	30	40	50	60
c(t)	3.00	2.96	2.92	2.75	2.32	2.00	1.73	1.54	1.35	1.28
t(sec)	100	200	300	500	600	900	1000	1200	1800	3600
c(t)	1.02	0.70	0.54	0.42	0.36	0.21	0.16	0.15	0.11	0.00

$$U_3 = U_{3600}\ [1 + 0.1925\ c\ (3)]$$
$$= 69.4\ [1 + 0.1925\ (2.92)]$$
$$= 69.4\ (1.56)$$
$$= 108 \text{ mph}$$

An alternative approach is available. For $60 < U_{fm} < 300$, a 3-second peak gust wind speed U_{pg} is obtained from the following equation:

$$U_{pg} = 1.0546\ [U_{fm} + 11.94] \qquad (4)$$

If U_{fm} is 90 mph,

$$U_{pg} = 1.0546\ [90 + 11.94]$$
$$= 108 \text{ mph.}$$

For $U_{pg} \leq 60$ mph, a 3-second peak gust wind speed is approximated by

$$U_{pg} = 1.2645\ U_{fm} \qquad (5)$$

Kryer and Marshall (1992) showed that the Durst relationship does not hold true for hurricane winds.

References

Durst, C.S., (1960): "Wind Speeds Over Short Periods Of Time," Meteorological Magazine, Vol. 89, London, England.

Simiu, E., and Scanlan, R.H, (1986): Wind Effects on Structures, 2nd Ed., John Wily and Sons, New York, New York.

Kryer, W.R. and Marshall, R.D., (1992): "Gust Factors Applied to Hurricane Winds," *Bulletin of the American Meteorological South*, Vol. 73, Boston, Massachusetts.

A group of officers, directors, past presidents, and interested parties met on November 6, 1995, in Arlington, VA at the offices of the NSF to make plans and set priorities for the future of AAWE. Frank and open discussions were held throughout the all-day meeting. A synopsis of some of the main points that came out of the brainstorming session are presented below.

There is a bill in congress to amend the National Earthquake Hazards Reduction Program to make it multi-disciplinary, including wind engineering. The group felt that AAWE should have a strong voice in setting priorities relating to wind engineering research in NEHRP. The following strategy was developed for promoting wind in NEHRP:

(1) Publicize the need for wind research
(2) Assess and prioritize wind research needs
(3) Establish a framework for research
(4) Promote a broad spectrum of research

The group agreed that AAWE must show support for those persons taking the lead in promoting bills in Congress. We need to visit members of Congress and provide them with input. AAWE needs a long range definitive plan for wind damage mitigation. We cannot simply ask for more money to do research. We must make Congress aware that wind-related destruction is a long-range problem that cannot be solved quickly, due to all of the existing construction that is at risk.

Dr. Nora Sabadell (NSF) also stressed that the wind engineering community must provide more guidance for wind engineering research. The concept of sustainable growth is fashionable and should be kept in mind when proposing solutions to the wind damage problem. Wind engineers must also consider several other concepts as they attempt solutions to the wind problem. Engineers should take reliability into account and treat it as a new direction. Wind engineers must also interact more with other disciplines. Economic aspects need to be taken into account. Cost versus the benefits of stricter code provisions and retrofit recommendations should also be evaluated. We need to look at human factors in addition to the technical aspects of the wind problem.

Dr. Sabadell continued by discussing the attempts being made to put in place a national mitigation program. The task is a difficult one as a result of low funding. She also emphasized that engineers must take into account other disciplines that recognize societal problems. A link with FEMA is very important. Mitigation is a better word than research when approaching FEMA. Linking with emergency management personnel is also necessary. AAWE should assemble a plan, take it to FEMA, and show how the plan can assist them.

A SUSTAINABLE WIND ENGINEERING PROGRAM

After much discussion, the group committed to the following actions, with the hope of establishing a sustainable wind engineering program.

(1) Produce a white paper that clearly delineates a plan for wind engineering in the future.
(2) Compile a list of alliances that should be established between AAWE and other organizations or agencies.
(3) Produce a slick brochure that concisely defines the needs and develops a plan for wind damage mitigation in the United States.
(4) Compile a brief history and background of WERC/AAWE.

Upon completion of this plan of action, the group made task assignments and established a strict time table for accomplishing them.

UPCOMING CONFERENCES AND SHORT COURSES

BBAA III

The Third International Colloquium on Bluff Body and Aerodynamics & Applications, **BBAA III**, will be held at the Donaldson Brown Hotel and Conference Center in Blacksburg, Virginia, USA, from July 28-August 1, 1996. The scope of the Colloquium will include fundamental studies, such as vortex dynamics, near wake flows, aeroelasticity, and dynamic responses, etc. Building, bridge, and vehicle aerodynamics, bluff-body aeroacoustics, wind tunnel measurement techniques and computational studies related to bluff-body aerodynamics will be among some of the topics focused upon. For more information, contact Dr. M.R. Hajj, Organizing Secretary, BBAA III, ESM Department, Virginia Tech, Mail Code 0219, Blacksburg, VA 24061, USA Telephone: (703) 231-4190, FAX: (703) 231-4574 e-mail: hajj@vtml.cc.vt.edu

IAWE

Professor Giovanni Solari announced that the **Second European and African Regional Conference on Wind Engineering** will take place in Genova, Italy on June 22-26, 1997. The Call for Papers will be circulated in early 1996. Further inquiries should be directed to: Professor Giovanni Solari, Conference Chairman, IAWE European and African Coordinator, Istituto di Scienza delle Costruzioni, University of Genova, Via Montallegro, 1, 16145 Genova, ITALY.

CWE 96

The Fluid Mechanics and Wind Engineering Program at Colorado State University has organized the Second International Symposium On Computational Wind Engineering, **CWE96**, for August 4-8, 1996. The theme of the Symposium is computational methods as applied to wind engineering. Among the various topics discussed will be numerical methods for steady and unsteady atmospheric surface-layer flows, as well as the effects of turbulent flows on bluff body shears layers, separation and vortices. The effects of turbulence modeling, Reynolds averaging, higher order models, large-eddy simulation, parallel processing and computer speed and memory problems, along with other concerns, will all be considered. Invited lecturers will provide reviews of key subjects such as numerical algorithms, finite difference, control volume, finite element and boundary element methods, in addition to other selected topics of interest. The Symposium will be held at Colorado State University in Fort Collins, Colorado. For more information, contact Ms. Janet L. Montera, CWE96, Symposium. Telephone: (970) 491-7425.

Announcement of a Short Course

Engineering For Extreme Winds: 1996

A two and one-half day short course entitled *Engineering for Extreme Winds: 1996* will be presented at Texas Tech University, Lubbock, Texas, on February 7-9, 1996, by the Wind Engineering Research Center and the Institute for Disaster Research. Course instructors include Drs. Kishor Mehta, James R. McDonald, Joseph E. Minor, and Douglas A. Smith. This course, offered annually, is intended for architects, engineers, building officials, and members of other fields that are involved with the design and construction of buildings to resist extreme winds, as well as individuals who interpret standards and codes. The wind load provisions of ASCE 7-95 will be presented and discussed. Additional topics will include wind effects on structures, codes and standards, design for hurricane winds, and design for tornadoes. For additional information contact: Division of Continuing Education, Texas Tech University, Box 42191, Lubbock, TX 79409-2191, Attn: P & PO. (806) 742 - 2352 ext. 272, Fax (806) 742-2318.

BOB BURPEE NAMED NEW DIRECTOR OF NATIONAL HURRICANE CENTER

During opening ceremonies for the new National Hurricane Center (NHC) building at Florida International University in Miami, Ron Brown, Secretary of the Department of Commerce, announced that Dr. Robert W. Burpee had been selected as the new director of NHC.

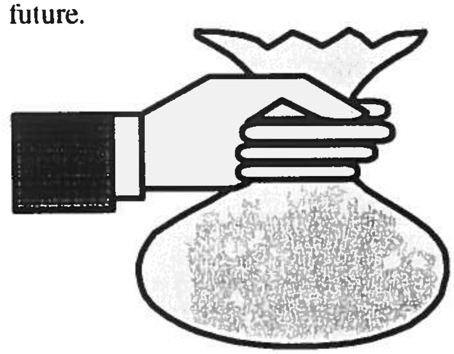
Dr. Burpee replaces Dr. Robert Sheets who retired after leading NHC since 1987. Bob Burpee holds a Ph.D. from MIT, where he did pioneering research on the origin and dynamics of tropical easterly waves (wave disturbances are usually associated with the development of hurricanes). Burpee is a fellow of the American Meteorological Society and has been a research scientist at NOAA's Hurricane Research Division (HRD) since 1971, running HRD's aircraft field program and becoming director of HRD in 1993. While at HRD, Burpee developed the concept of monitoring the environmental flow that "steers" hurricanes by launching expendable measurement devices called "Omega Dropwindsondes" from the NOAA P3 research aircraft. These instruments measure vertical profiles of wind, temperature, and humidity between flight level and the sea surface. Research has demonstrated that the accuracy of hurricane track forecast models improves significantly when provided with input data on environmental flow. This work has demonstrated that hurricane track forecast model accuracy's increase dramatically when provided with input data on environmental flow. Dr. Burpee ranks 11th on the list of current NOAA employees with aircraft flight passes through hurricane eyewalls or "penetrations" with 264.

DUES ARE NOW DUE

Did you notice some extra change in your pocket in 1995? It may be because you were not billed for WERC (AAWE) dues. President Kareem explained that because the dues increase from $25 to $40 was on such short notice last year, a moratorium was declared (with Board approval) on dues. Expect to receive an invoice for 1996 dues in the mail soon. The rates will remain

MEMBER	**$ 40.00**
STUDENT	**$10.00**
CORPORATE	**$ 500.00**

Everyone is urged to continue their support of AAWE by paying their 1996 dues. Based on the excitement and enthusiasm displayed at the recent Brainstorming meeting in Arlington, VA, you can expect a lot more activity from AAWE in 1996. AAWE is working on a plan (see p.) and will be a voice for the wind engineering community in the future.



WHY CORPORATE SPONSORS?

Corporate sponsors are companies or organizations that have a keen interest in wind engineering research. Corporate sponsors receive many advantages from their membership in AAWE, some of which include:

- **direct communication with the wind engineering community**
- **copies of all AAWE publications, including The Wind Engineer**
- **A voice in identifying wind engineering research needs and the setting of research priorities**
- **recognition as an active supporter of the wind engineering community**
- **designation of five colleagues or employees as individual AAWE corporate members with all the rights and privileges of regular membership**

Current corporate members (1994 & 1995):

Factory Mutual Engineering & Research Corp.	Cermak, Peterha & Peterson (CPP)
IIPLR	ESSCO
Colorado State University	ICBO
Rowan, Williams, Davis & Irwin	University of Western Ontario
Chubb & Sons Inc.	Texas Tech University

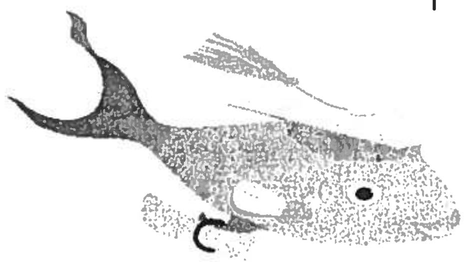
THE PRESIDENT'S MESSAGE

Greetings from Notre Dame: In my last message I told you about the plans to change the name of the Wind Engineering Research Council. We discussed this issue with several legal experts. Among the options available to us, the most attractive and the least expensive choice was to add a new name for the existing corporation, Then, we have the choice to conduct business under any one of the names. I proceeded with the name change and presently we are registered under the old name as well as AAWE Inc., and American Association for Wind Engineering Inc. We will be operating under the new name or its acronym. I believe that the new name better reflects our mission, our present activities and future plans.

As all of you have witnessed a very busy hurricane season, AAWE has been active in learning from the aftermath of these storms. We sent teams or members to join other teams to visit areas affected by Hurricanes Marilyn, Erin and Opal. Th travel related funds for those who participated

Continued on page 11

UNIVERSITY REPORTS



TEXAS TECH AND COLORADO STATE

Following a very successful and productive Cooperative Program in Wind Engineering between Colorado State and Texas Tech, a new five-year program is now in place. The program, funded by NSF, focuses on wind effects on low-rise buildings. The three areas of emphasis are wind loads, wind engineering meteorology and wind flow around buildings.
The program has a strong emphasis on economics and technology transfer. Seven faculty members and approximately twelve graduate students from the two institutes are participating in the project. A technical advisory council reviews progress and provides guidance in establishing priorities and direction of the project.

CLEMSON UNIVERSITY

The BRERWULF stays busy at Clemson, along with the wind tunnel and other research facilities. The BRERWULF is a mechanical device for applying dynamic wind loads on various roofing systems, such as standing seam roofs and mechanically attached membranes. Work continues on the pilot project to develop a "Wall of Wind" for testing full-size structures at winds in excess of 100 mph. The Idaho National Engineering Laboratory is working with the Clemson group on the feasibility of locating the facility at the INEL site.

TEXAS A&M UNIVERSITY

Drs. Dale Perry and Norris Stubbs have been busy this hurricane season documenting wind damage for the purpose of developing maximum probable loss modules. The data obtained will be used to refine the existing MPL modules and develop more sophisticated ones.

JOHNS HOPKINS UNIVERSITY

Dr. Nick Jones recently took wind vibration measurements on a cable-stayed bridge under construction in Houston, Texas.

VIRGINIA TECH

Henry Tielman is busy organizing the BBAAII boundary Layer Wind Conference to be held at Virginia Tech in 1996.

NOTRE DAME

Ahsan Kareem has made several trips to China and Japan recently, participating in cooperative studies in Wind Engineering.

Some Personal Notes

Joseph E. Minor recently retired from the University of Missouri at Rolla and now lives in Rockport, Texas. Between fishing trips, Joe continues to do consulting for the glass industry.

Dr. Ted Fujita, of the University of Chicago, was invited to participate in the activities commemorating the 25th anniversary of the Lubbock tornado. To every one's surprise, Ted said, "I don't do tornadoes anymore." He is now professor emeritus, but continues to perform research on over-the-ocean storms for the Office of Naval Research.

Allan Pearson, who for many years was director of the National Severe Storms Research Center in Kansas City, Missouri, is now retired. He still lives in Kansas City.

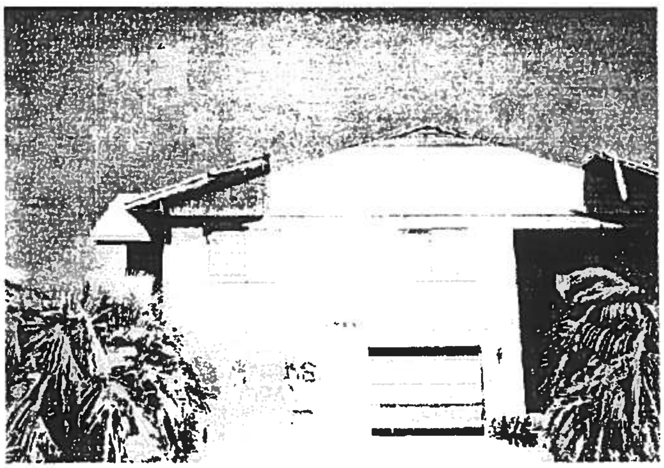
Bob Sheets retired from his position as Director of the National Hurricane Center in July 1995, after leading the NHC since 1987. He is replaced by Dr. Robert W. Burpee.

THE WIND ENGINEER

SPECIAL HURRICANE SUPPLEMENT DECEMBER 1995

1995: A NEAR RECORD SEASON FOR HURRICANE ACTIVITY

Nineteen tropical cyclones formed in the Atlantic-Caribbean basin this season, eleven of which were hurricanes. The only year with more hurricanes was 1969 (12) and the only year with more tropical cyclones was 1933 with twenty-one, eleven of which were hurricanes. The death toll from this year's activity reached 137 (according to news reports) with 58 in the U.S., Puerto Rico, and the Virgin Islands. According to the Miami Herald (Nov. 30, 1995), Hurricane Erin took eleven lives with estimated insured losses of $360 million and federal costs of $56 million. Hurricanes Iris, Marilyn, and Luis combined to strike many of the northeast Caribbean islands. Luis was a category 4 storm on the Saffir-Simpson scale and caused extensive damage and fourteen deaths in St. Martin/St. Maarten and Antigua. Hurricane Felix threatened the eastern seaboard of the U.S. as it stalled about 150 miles offshore for two days. Waves from Felix caused considerable beach erosion from North Carolina to New Jersey, and were responsible for nine deaths from drowning. Marilyn killed eight and contributed to insured losses estimated at $875 million with an estimated economic loss of $3 billion according to the U.S. Virgin Islands Bureau of Economic Research. Hurricane Opal claimed sixty-three lives; 50 from flooding in Guatemala and Mexico, and thirteen in the U.S. It is remarkable that none of the U.S. fatalities in Opal were due to storm surge; the one death in Florida was due to a tornado, and the other deaths in Georgia, Alabama and North Carolina were due to falling trees. Insured losses in Opal are estimated at near $1 billion; flood and recovery costs should add substantially to this figure. Hurricane Roxanne roamed the southern half of the Gulf of Mexico for over a week in October; claiming fourteen lives and centering most of her damage on the Mexican coastal states.



AAWE PARTICIPATION

This special supplement to the Wind Engineer includes an analysis of the wind speeds as Hurricane Opal came ashore along the Florida Panhandle by Mark Powell of the NOAA Hurricane Research Division (HRD). Dr. Tim Reinhold describes the AAWE damage documentation and presents some preliminary observations on the extent of damage and wind speeds in Hurricane Opal.

REAL-TIME ANALYSIS OF HURRICANE WINDS IN OPAL

by Mark D. Powell and Samuel H. Houston
NOAA-Hurricane Research Division

Hurricane Opal struck the northwest Florida Gulf of Mexico coast on October 4, 1995. According to the National Hurricane Center (NHC) Preliminary Report (Mayfield, 1995), Opal was a marginal Category 3 hurricane on the Saffir-Simpson Scale. A combination of low central sea-level pressure (slp) at landfall of 942 mb, storm surge estimated as high as 4.5 m, and waves (on top of the surge) as high as 3 m, contributed to Opal's categorization as a "3". According to NHC, most of the affected area received winds of a Category 1 or 2 hurricane, except for a small area from the extreme east end of Chochtawatchee Bay to about midway between Destin and Panama City Beach. Based on Air Force reconnaissance aircraft measurements at 3 km and Doppler radar measurements from Eglin Air Force Base, NHC estimates that this area may have received sustained surface winds as high as 100 kts (115 mph).

The NOAA Hurricane Research Division (HRD) conducted wind analyses of Opal in real time as part of an experimental program. Real-time analyses indicated winds as high as 100 kts (115 mph) in the area as indicated in the NHC report. After the landfall, several additional data sources were collected from sites in the vicinity of Baldwin County, Alabama, Pensacola, Eglin Air Force Base, Panama City Beach, and Apalachicola, Florida. In addition, preliminary analyses were conducted on NOAA research aircraft Doppler radar data. Examination of these new data indicates that Opal was a hurricane with a complicated wind structure.

As described by Mayfield (1995), early on the day of landfall, Opal had attained Category 4 status with a central slp of 916 mb and maximum sustained surface winds estimated at 130 kts (115 mph). Opal intensified at the end of an eyewall contraction cycle (Willoughby, 1982) and then proceeded to weaken as the inner eyewall diminished and an outer, larger diameter eyewall became dominant. At the same time, Opal began to interact with an approaching cold front while entering a region of lower sea surface temperatures in the northern Gulf of Mexico. Preliminary analyses of NOAA Airborne Doppler measurements (Fig. 1) indicate that the affect of the cold front was to cause Opal to become imbedded in a background flow from the SW to NE. This flow increased with height such that it was strongest at the 3 km level. The affect of the flow would be to reinforce hurricane winds on the (when looking in the direction the storm is going) right side and diminish winds on the left side. Hence maximum winds on the right (or east) side would be at 3 km, and on the left (west)

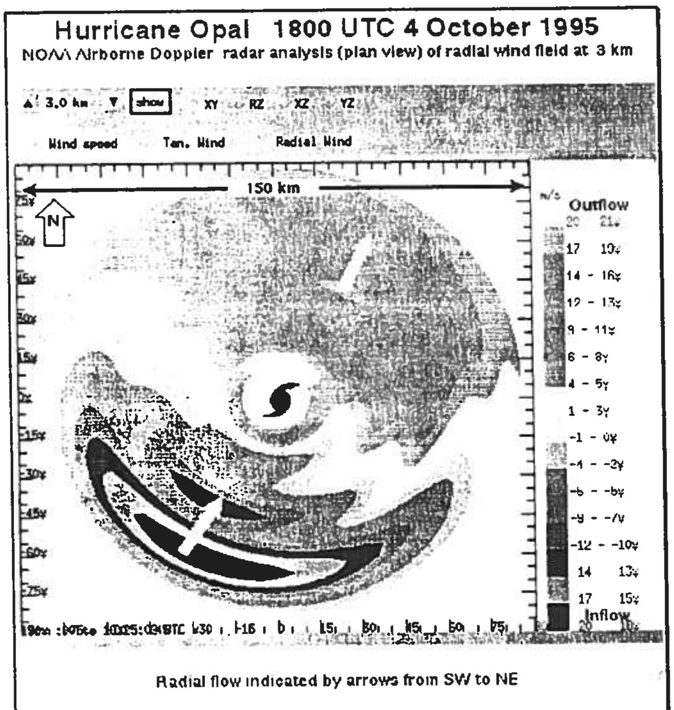


Figure 1

side they would be near 1 km (where the background flow would be weakest). Because of this effect, flight-level winds on the west side of the storm were actually weaker than winds measured by NOAA Coastal Marine Automated (C-MAN) platforms at Dauphin Island, Alabama and Southwest Pass, Louisiana. Another factor affecting winds on the west side was the acceleration of the wind when passing from land to water. Offshore flow on the west side was relatively cool with air temperatures of 22-24°C. When this air passed over the 27-28°C water of the Gulf of Mexico, unstable conditions were created, allowing vigorous mixing of higher momentum air from near 1 km. On the east side of the storm, the flow was relatively warm; water temperatures were near or slightly cooler than the air, causing slightly stable or neutral conditions to occur with less mixing. Another complication in the wind field may be related to the convective activity (degree of intensity of the rainfall) of the storm. At landfall, most of the active convection was associated with the remnants of the northern eyewall; no strong convection was visible to outline the southern half of the eye. Typically, higher gusts are expected where convection is present and the isolated peak gust of 125 kts (144 mph) at Hurlburt Field appears to have been associated with active convection. An outer rainband was located farther to the east, where the flight-level winds measured by the reconnaissance aircraft were highest. According to NOAA aircraft observations from 5 km altitude, this band was not as convectively active as the eyewall. The Eglin Doppler radar data (when available) may shed more light on the nature of this outer rainband. The weaker convective activity of the outer rainband, together with the weaker, turbulent mixing on the east side of the storm, may have inhibited mixing of strong winds from the 3 km level to the surface.

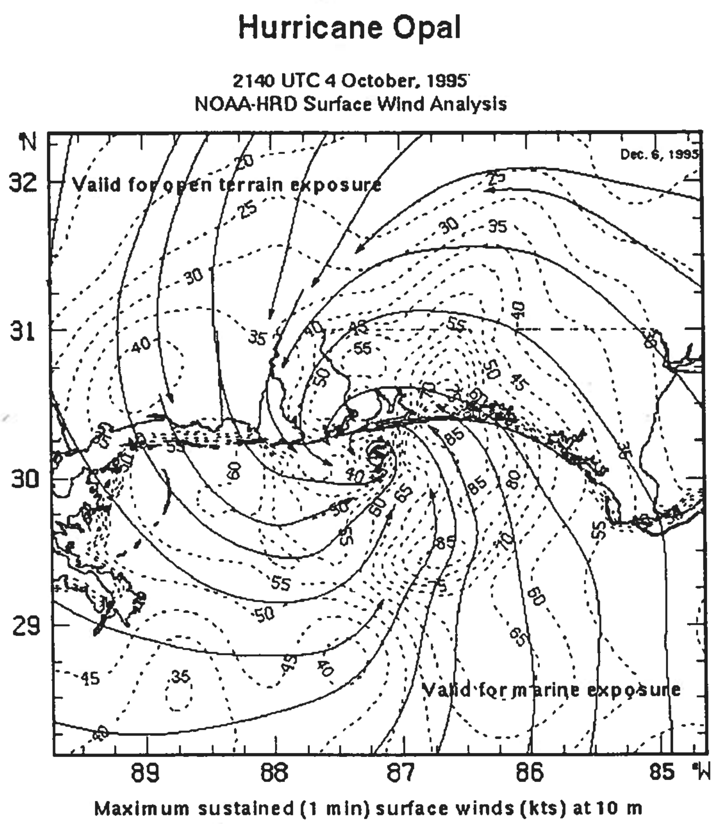


Figure 2

HRD is in the process of revising analyses of Opal's surface wind field. We have conducted a new analysis that uses only surface observations on the west side of the storm where the flight level observations are relatively weak. On the east side of the storm, we use surface observations together with a limited amount of flight level data where no surface information was available. Flight level measurements were assumed to be equivalent in magnitude to mean boundary layer winds and adjusted to the surface with a boundary layer model assuming neutral stability for oceanic exposure and using stable conditions for open terrain roughness over land. Separate analyses are conducted in a storm-relative coordinate system for marine and land (open terrain) exposures. The storm-relative coordinate system allows data to be included for a time period of several hours. This has the advantage of increasing data coverage around the storm; analyses are considered to be the mean representation of the storm over the time period. Details on the analysis method can be found in Powell et al., (1995), which has recently been accepted by the journal "Weather and Forecasting". To help fill in data gaps and provide time continuity, a background field was created from an earlier analysis for 2115 UTC, 4 October, which used data collected from 1616-2115 UTC. Background field grid points, ships, and adjusted aircraft data are weighted at 1%, 40%, and 70%, respectively, relative to the conventional surface observations (e.g., buoys, coastal platforms, airport anemometers). Both analyses used observations from 2115 UTC 4 October to 0000 UTC 5 October. The analyses were then merged at the coastline, resulting in Figure 2. Merging the analyses creates a discontinuity at the coastline that represents a transition zone where the flow is adapting to a new underlying surface. Maximum sustained winds in the remnant eyewall to the northeast of the center affected the area from Navarre Beach to Fort Walton Beach with winds of 85-89 kts (98-102 mph) on the coast, decreasing to 75-80 kts (86-92 mph) just inland. This maximum is based on a combination of observations from Hurlburt Field, the Eglin Air Force Base mesonet, and adjusted flight level observations. These high winds extend farther east to the vicinity of Destin and are based on adjusted flight-level measurements. This maximum is less prominent and located farther west than the real-time analyses conducted during the storm because of the addition of NOAA National Ocean Service observations from Panama City Beach Pier. Also noted in the analysis is the aforementioned increase of wind speeds on the west side of the storm where the flow accelerates over the water due to enhanced turbulent mixing.

These analyses highlight the complexity of the hurricane wind field when encountering rapidly changing synoptic conditions that often occur with hurricanes making landfall in the continental U.S. Such conditions can make it difficult to interpret flight-level observations; simple models based on pressure-wind relationships or rotation-plus-translation cannot hope to capture the complexity. The best solution is to actually measure the quantity we are trying to predict. For hurricanes over water this means hastening the transfer of remote surface wind sensing capabilities from research to operations. Over land, this means enhancing the survivability and accessibility of high quality surface wind observations. Final analyses of Opal's wind field at landfall will await the synthesis of the NOAA aircraft and Eglin Doppler radar data. If the geometry is adequate, these data can be used together to provide a better estimate of the two-dimensional wind at the lowest level possible (about 1 km due to ground clutter and beam geometry limitations). The winds can then be adjusted to the 10 m level with a boundary layer model and combined with the remainder of the observations for analysis.

Acknowledgments. The authors appreciate the assistance of members of AAWE, including Drs. Tim Reinhold and Peter Vickery, and other disaster survey teams in obtaining data and site exposure descriptions. Additional data were supplied by Steve Gill of NOAA NOS, Dick Stearns of FAA Pensacola, James Dugan of NWS Pensacola, Gary Beeler of NWS Mobile, Rocco Calaci of Eglin Air Force Base, Karl Harker for data recorded by the Southeast Agricultural Weather Service center (SEAWSC) and the Alabama Cooperative Extension Service (ACES). Also, the NOAA National Data Buoy Center for buoy and C-MAN data retrieved from the Seaboard Bulletin Board. Steven Fox of Coral Gables Senior High School digitized and quality-controlled much of the data.

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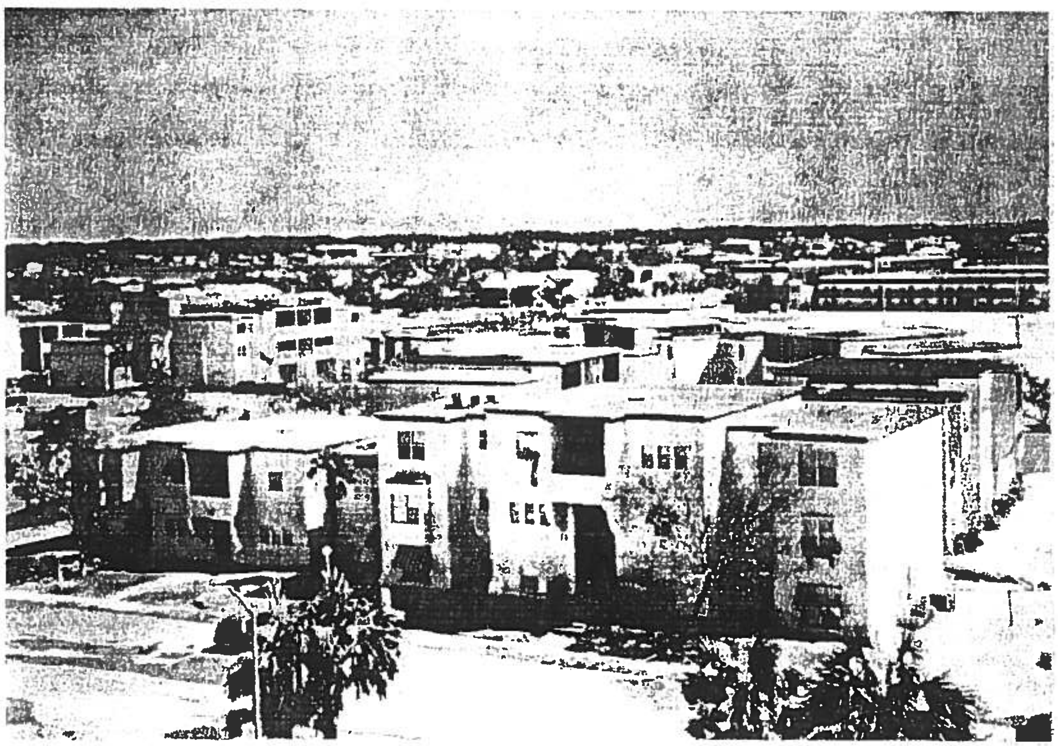
AAWE MEMBERS PERFORM WIND DAMAGE SURVEYS FOR HURRICANE OPAL

Hurricane Opal made landfall on the Florida Panhandle during the night of Wednesday, October 4, 1995. Following the event, a number of post-disaster survey teams were dispatched to the affected area. Dr. Tim Reinhold, who is Chairman of the AAWE Post-Disaster Survey Committee, coordinated the survey activities in cooperation with the Insurance Institute for Property Loss Reduction (IIPLR), Clemson University and Texas Tech University. In addition to the Clemson and TTU survey teams, participants arrived from the University of Hawaii, North Carolina Sea Grant and Louisiana State University. These efforts were funded in part by NSF and



IIPLR. Insurance companies supported at least two other teams with specific objectives. Chubb & Sons, Inc. sponsored a team involving Texas A&M University and other industry representatives to gather data for developing damage functions. State Farm Fire and Casualty Company dispatched a team to collect information on windborne debris. Attempts were made by AAWE to coordinate the efforts of the various teams in order to minimize duplication during the investigations.

Specific objectives of the post-disaster investigation were to:

- Document damage to different types of structures;
- Document windborne debris and transport distances;
- Collect information on site-specific wind speeds;
- Observe construction practices that appeared to resist the hurricane;
- Observe construction practices that did not appear to resist the hurricane;
- Collect data in a systematic fashion on building performance which would provide insight into damage modes that can be correlated with loss data when it becomes available;
- Prepare a final report documenting the team's observations that could be used to develop strategies to manage the losses that will occur due to future wind storms.

Teams began arriving on Thursday, October 5th, mustering in Gulfport, Mississippi, Mobile, Alabama and Panama City Beach, Florida, depending on individual housing arrangements.

Access to the area was obtained for some teams from the Governor of Florida, through the State of Florida's Department of Emergency Response. Other teams obtained access through FEMA contacts and local Emergency Management Officers. Most of the surveys were completed by Tuesday, October 10.

In total, teams investigated damage from Pensacola Beach, South of Pensacola, Florida through Mexico Beach which is Southeast of Panama City, Florida. Field data and site conditions obtained from a number of anemometer sites were forwarded to the NOAA Atlantic Oceanographic and Meteorological Laboratory's Hurricane Research Division, and have been used in the accompanying wind field analysis report.

The large damage investigation response resulted from preliminary estimates of 125 miles per hour wind speeds, along the coast. However, as noted in the accompanying article by Mark Powell and Sam Houston, complex mechanisms contributed to a significant reduction in actual wind speeds along the coast. As a result, there was limited direct wind damage in most areas surveyed.

The most common damage was to roof coverings. In nearly all of the areas surveyed, residential construction suffered less that 10% roof covering damage. There were extremely few instances of roof sheathing damage. Commercial properties suffered roof damage, but the extent of damage was generally small. Very few windows were broken on either the barrier islands or in residential areas on the mainland. Storefront glass was virtually untouched unless damaged by the surge. Manufactured homes performed well at the level of winds encountered. Many were located in amongst trees and were reasonably well sheltered. Transmission poles remained standing and most still had their conductors in place along the major highways. In residential areas and along waterfront highways in inland areas, falling trees were responsible for many broken conductors.

Opal was a minimal hurricane in terms of direct wind damage. Storm surge caused the bulk of the damage. Because Hurricane Erin passed through the area two months before, much of the observed wind damage was produced by Erin rather than by Opal. Discussions with residents were needed to sort out which storm caused the damage to a particular structure. In a number of instances, repairs to damage from Erin were underway when Opal hit.

Despite the relatively light direct wind damage observed, useful information was gained. First, losses associated with properties north of the coastal highway will provide a good estimate of water penetration losses associated with relatively minor damage to the building envelope. There were several instances where water blown through gable end vents caused ceilings to collapse. A number of instances of re-roofing over existing shingles were observed where damage to the new roof was much greater than damage to surrounding roof coverings. This leads to a recommendation that new roof coverings should not be installed over old roof coverings in high wind areas. Re-roofing should require removal of the old roofing material.

Unfortunately, Hurricane Opal is viewed by many residents as a 140+ mph event due to media reports and a peak velocity recorded at Hurlburt Field. Consequently, AAWE has been working with NOAA'a AOML Hurricane Research Division and the National Hurricane Center to provide data and observations for use in their post event analysis. The accompanying article by Mark Powell and Sam Houston provides wind speed estimates that are in much better agreement with the field observations than initial wind speed estimates. However, it is imperative that surface data sites be improved to provide backup power and high fidelity data in the event of a major storm. Once again, the collection of surface wind data was plagued by loss of power and instruments being shut down and abandoned prior to the storm. The particularly high peak wind speed measurement at Hurlburt Field may well be a result of water on the thermal anemometer. The sustained wind speed was significantly lower and in line with data from another instrument at the other end of the field.

A final report that details results of the damage surveys and wind field estimates is planned for an early 1996 release.

A WORD FROM YOUR EDITOR

There are many things happening in the wind engineering community. Even with this, the largest issue ever of The Wind Engineer, many stories were left out. I hope you enjoyed the news. Your comments and suggestions are always welcome. I can always use news and information for inclusion in future issues.

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THE PRESIDENT'S MESSAGE (continued from page 9)

on behalf of AAWE were covered by grants from the National Science Foundation (NSF) and the insurance Institute for Property loss Reduction (IIPRL). On behalf of AAWE, I would like to thank Dr. J. E. Sabadell and Mr. E. L. Lecomte for their support of this activity. You will find an insert in this issue of The Wind Engineer detailing a summary of the observations made by these teams.

I am very pleased to announce that Dr. Greg Chiu, staff engineer from IIPLR, has agreed to serve as the Secretary/Treasurer for the remainder of my term. Dr. Chiu is a recent graduate from Stanford University, he specializes in risk assessment.

I would like to bring you up to date on our other activities of interest to you. First, we have written letters to several congressmen and senators concerning a possible amendment to Bill S.1043. This amendment would provide more focus on wind related hazards to ensure that we do not repeat our past mistakes, rather that we invest in reducing not only colossal property damage but also human suffering and disruption of life for thousands. We will keep you informed of our progress. We also held a workshop entitled *Wind Engineering: Planning for the Future* on Nov. 6 in Arlington, Virginia. The main purposes of the meeting were to brainstorm, to set up priorities in wind engineering research and to layout a plan of action for establishing a national wind risk mitigation program. This November, Lockheed Martin's Idaho National Engineering Laboratory (INEL) held a Severe Windstorm

(Continued on next page)

President's Message Cont.

Testing Workshop in Idaho Falls to address issues concerning a large/full-scale test facility for extreme natural and man-made loadings, e.g., earthquakes, severe wind, aging, and terrorist acts. The focus of this workshop was on defining the requirements for a severer windstorm test facility. We will provide details of this workshop in our next issue. The International Wind Engineering Forum (IWEF) held two meetings of interest to wind engineers this fall in the Tokyo area. The focus of these meetings was on structural damping and computational wind engineering. Both meetings had a good attendance rate and the proceedings are available through the IWEF.

In closing, I seek again you help through your input, comments, advice and willingness to volunteer time to AAWE. I wish you a very happy holiday season and a prosperous new year.

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