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Submitted to Air Infiltration Review

AIR INFILTRATION RESEARCH AT THE LAWRENCE BERKELEY LABORATORY

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May 1983

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DISCLAIMER

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Because air infiltration can account for one-third to one-half of annual space-heating and space-cooling energy use, it has been the focus of the largest ongoing project in the Energy Performance of Buildings Group, which is a part of the Energy Efficient Buildings project at the Lawrence Berkeley Laboratory. Our work in this area concerns measuring, modeling, and reducing air infiltration in buildings; objectives are to develop the theoretical and experimental expertise needed by researchers, architects, and engineers, to provide design guidelines, and to develop construction quality standards for optimal air leakage and infiltration. A major achievement of this program has been the development of a model that predicts infiltration from weather data and a single leakage parameter--the effective leakage area. The magnitude of leakage area can serve as an important criterion for designers and builders and is a useful diagnostic aid for auditors or house doctors.

AC PRESSURIZATION

One of the most interesting experimental techniques we have developed is called AC pressurization. This is a method for determining the leakage of the envelope of a building at low pressures. It has several advantages over conventional (DC) fan pressurization, which uses a blower door. AC pressurization has a much higher signal-to-noise ratio (i.e., it is more precise), is capable of working in the low pressures typical of natural infiltration (i.e., 1 to 10 pascal), and combines both pressurization and depressurization results simultaneously. The physical process of AC pressurization changes the effective volume of the test space periodically and monitors the resultant internal pressure change; knowing the size of the volume change and the pressure response as a function of time allows the direct (on-line) calculation of leakage.

The first version of AC pressurization was built to investigate the low-pressure leakage behavior of a structure and to validate the technique. It was successful and led to the concept of effective leakage area. The second version was a stand-alone system that did not pierce the building envelope; it was designed to calculate the leakage area in real time. Measurements taken in 1982 included a study on a single structure at frequencies in the (sub-audible) range of 0.1-3.0 Hz; they showed that the apparatus could respond in real time to changes in the leakage area of the envelope at driving pressures on the order of 1 pascal. A sample output is shown in Figure 1. The traces show, from bottom to top: the absolute pressure in the sealed back volume behind the piston; the changes in pressure in the test space caused by the changes in volume; the changes in volume in the test space (called the volume drive, calculated in real time from the absolute pressure); and finally the leakage area, which is calculated in real time from the volume drive and the test-space pressure. The second version has laid the groundwork for a useful field instrument that could replace conventional fan pressurization; the final instrument may operate with acoustic techniques in the 10-Hz range.

MODELING

The concept of effective leakage area combined with that of weather-induced pressures led to the development of the LBL infiltration model. It expresses natural ventilation as a function of total leakage area, wind speed, temperature, and building configuration and can be used to predict infiltration from weather and blower-door measurements for both short-term and long-term purposes. For short-term measurements, the model has an accuracy of approximately 20%; for longer-term averages, the accuracy is as good as 5%. The model is used in the computer programs Computerized Instrumented Residential Audit (CIRA), DOE-2.1, and BLAST and is included in the 1981 ASHRAE Handbook of

Fundamentals. Other institutions that have used the model include the Naval Civil Engineering Laboratory, Retrospectors, and the Bonneville Power Administration.

FIELD MEASUREMENTS

We have made several sets of field measurements of infiltration and leakage. Our Mobile Infiltration Test Unit (MITU), a portable, full-size structure, makes simultaneous measurements of infiltration, pressure, wind, and temperature and records them for future analysis. Air infiltration is measured by the Continuous Infiltration Monitoring System (CIMS), which continuously injects a tracer gas. The mobile unit is shown in Figure 2. Because of the value of MITU for understanding and verifying infiltration models, we have continued to make field measurements with it on the grounds of the Reno, Nevada, airport. Most of our work using MITU has been concentrated on the relationship between measured and predicted infiltration, but we have also used it to monitor independently the interior and exterior pressures on MITU. Figure 3 shows the dependence of the exterior pressure coefficient on angle for one of the faces of MITU. A pressure coefficient is a dimensionless factor giving the increase in pressure caused by the wind. It should be positive for windward orientations and negative for leeward ones.

Recently, we began a project to study the effect of wind on natural ventilation for its usefulness in mitigating cooling loads in hot, humid climates. Three dissimilar buildings at the Kaneohe Marine Corps Air Station (KMACS), Hawaii, were instrumented with surface-pressure, temperature, humidity, and air-velocity probes; on-site weather parameters (air temperature, humidity, wind speed, and wind direction) were also monitored. Other field work has included an investigation into component leakage in a small sample of houses and several sets of long-term average infiltration measurements using our low-cost Average Infiltration Monitor (AIM).

INTERNATIONAL RESEARCH EXCHANGE

Much important work has been contributed by international researchers visiting our group; many governmental and academic institutions have sent scientists to work with us in the pursuit of our research goals. In the past we have had visits of up to one year from distinguished researchers from throughout the world: Ake Blomsterberg from the Royal Institute of Technology, Stockholm, Sweden; Prof. Masaya Narasaki from the University of Osaka, Japan; Dr. Jean-Yves Garnier from the Paul Sabatier University, Toulouse, France; Prof. David Wilson from the University of Alberta, Edmonton, Canada; Pierre Ninane and Paul Blaude from the University of Liege, Belgium; Dr. Chistoph Zuercher from the Federal Institute of Technology, Zurich, Switzerland; Helmut Feustel from the Hermann Rietschel Institute, Berlin, Federal Republic of Germany; and Pierfrancesco Brunello from the University of Padua, Italy. We currently have three distinguished scientists visiting our program, all of whom are from Scandinavian countries: Per Levin, Claus Reinhold, and Eimund Skaaret.

Per Levin graduated from the Royal Institute of Technology, Stockholm, Sweden, in Civil Engineering 1978 and since then has been involved in research regarding airtightness and the consequences thereof for energy-efficient houses at the RIT, Division of Building Technology. Together with Arne Elmroth, he has produced "Air Infiltration Control in Housing: A Guide to International Practice" for the Air Infiltration Center. At LBL, his work is concerned with infiltration modeling and with developing air tightness standards and building technology for new housing in the U.S.

Claus Reinhold works at the Danish Building Research Institute with the Indoor Climate and Energy Division. This division runs two mobile laboratories: Indoor Climate Measurements; and Energy Measurements; these mobile laboratories use tracer gas measurements in the investigation of infiltration and ventilation efficiency. The mobile Energy Measurement Laboratory, of which Claus is the the project leader, analyzes the effect of infiltration on energy consumption by analyzing weather data and records of the energy consumption. While at the

Lawrence Berkeley Laboratory Claus is participating in several ongoing projects: developing instrumentation for measuring the low pressure function of a building (AC pressurization); developing mobile Air Infiltration Monitors (AIM); and describing a method to calculate building leakage areas based on component information.

Eimund Skaaret is an associate professor in the fields of heating and ventilating at the Norwegian Institute of Technology, Division of Heating and Ventilating. He received his Ph.D. in Heating and Ventilating in 1975: Modeling of Indoor Environment—Physical Small-Scale Flow Models of Ventilated Rooms. Since 1970 he has worked on engineering calculations of air flow in ventilated rooms, which led in 1979 to the study of the efficiency of ventilation. The basis for this work was formed working with industrial ventilation, where it became obvious that ventilation systems aiming at complete mixing were not the best ones. In addition to the definition of various concepts of ventilation efficiency, which have led to new methods for studying air infiltration, guidelines for efficient ventilation are being developed. In short, ventilation systems should be designed to create displacement flow pattern (preferably with air supply direct to the zone of occupation) and not to create complete mixing. The scope of his work at LBL is to study in more detail the local ventilation efficiency specifically related to pollutant transport, which is highly influenced by the characteristics of the contaminant sources and thermal conditions of the rooms and the ventilating system. To study this effect, a project, entitled single-room infiltration and ventilation efficiency, will be carried out in a 27-m^3 test chamber, using tracer gas to simulate the sources for contamination. Tracer-gas concentrations will be monitored at 33 points in the room. Various types of ventilation arrangements will be used ranging from infiltration to balanced mechanical ventilation.

FUTURE WORK

We will continue our research efforts into natural ventilation by analyzing full-scale measurements of wind-induced infiltration, and we will continue to analyze the data from KMACS. If the information is to be useful in hot, humid climates, it will be important to consider comfort levels, as opposed to just air temperature, in the analysis of the data. As the full-scale work progresses, we will begin to make scaled measurements in a wind tunnel. We plan to develop the AC pressurization equipment into a device that can easily be used to measure leakage area and that would replace the current fan-pressurization apparatus.

We will extend our investigations into new areas: multichamber infiltration, HVAC interactions with infiltration, and occupancy effects. We plan to use MITU to make full-scale measurements on the interaction between HVAC systems and total ventilation, including flues and chimneys for combustion appliances and vents and stacks (powered or unpowered) for ventilation; we will also consider the effect of duct leakage and total ventilation. We also intend to survey a large number of occupied dwellings to extract the occupant contribution to infiltration.

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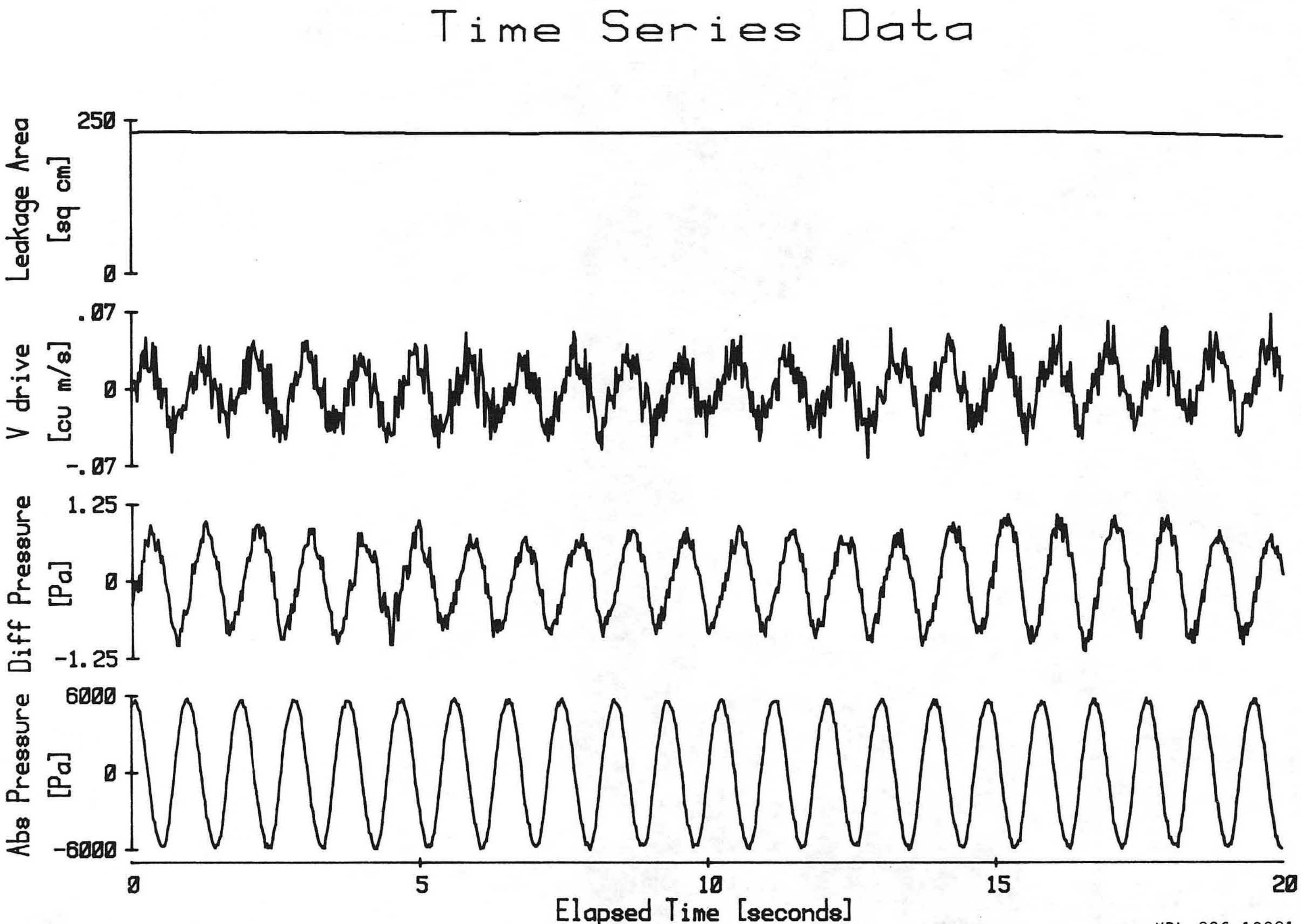

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Figure 1. Output from the AC-pressurization equipment, which measures effective leakage area in real time without penetrating the envelope of the building. For an explanation of the traces, see the text.

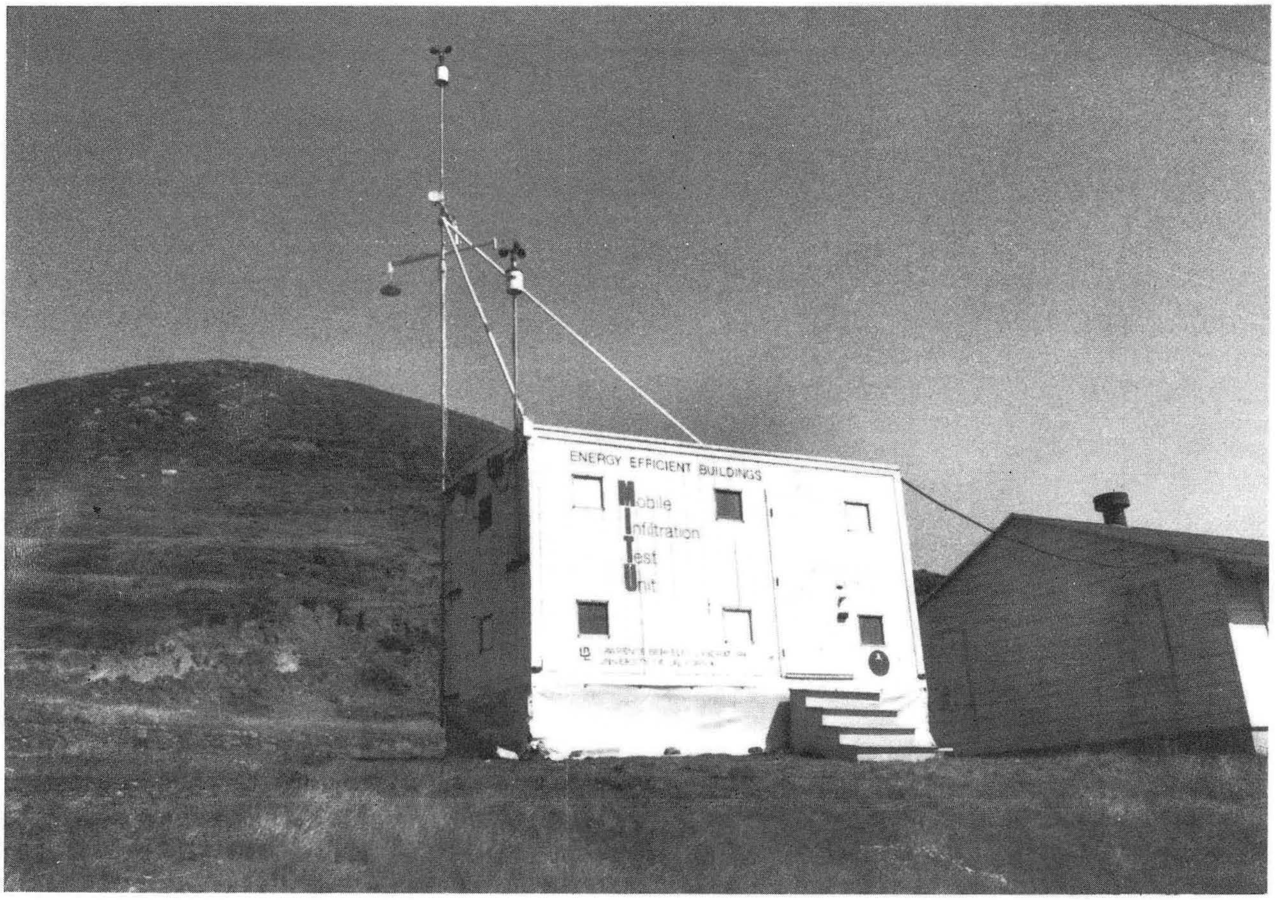

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Figure 2. The Mobile Infiltration Test Unit at a site near Fort Cronkhite, CA.

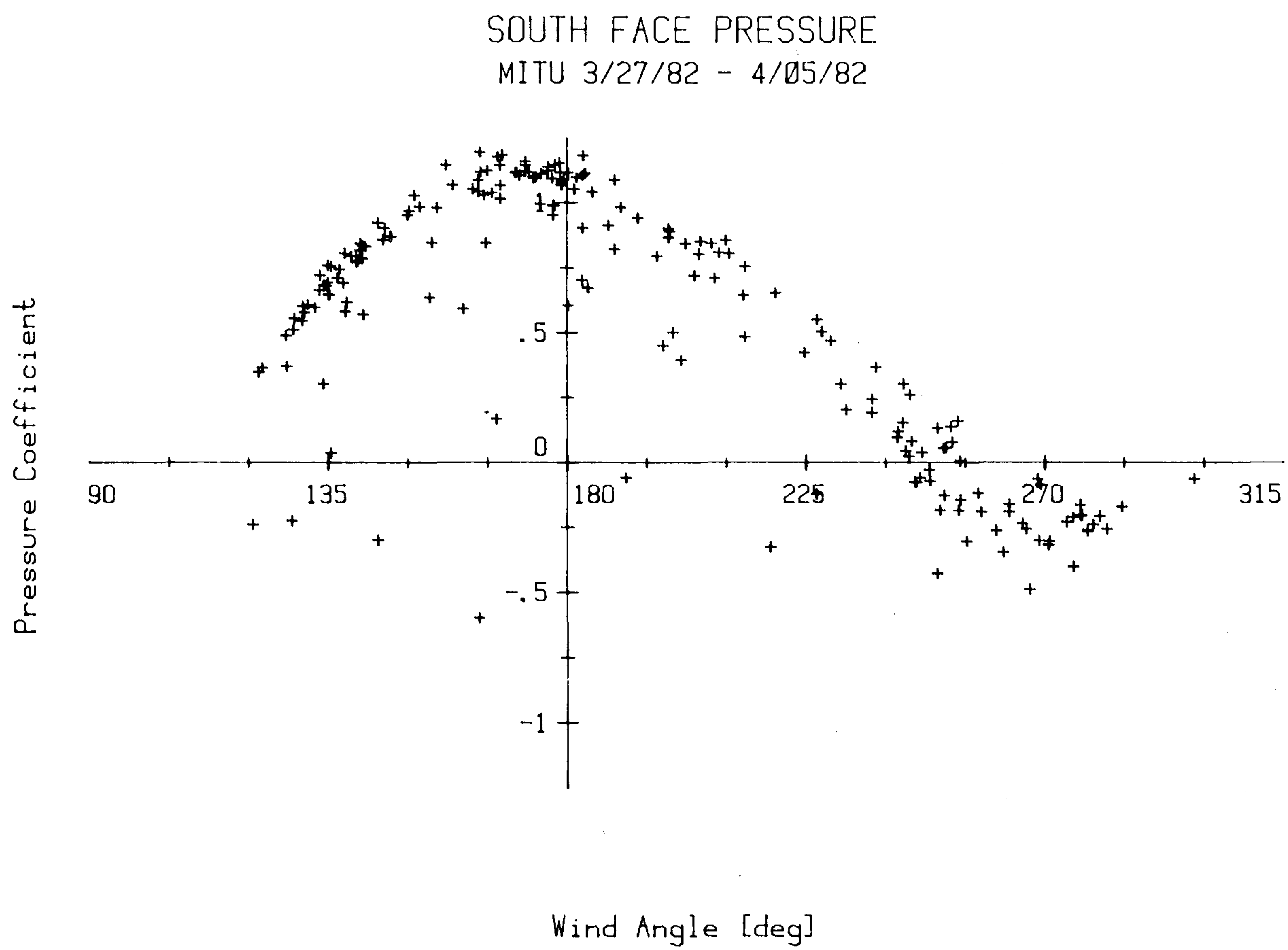

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Figure 3. Instantaneous pressure coefficients measured by the Mobile Infiltration Test Unit (MITU) at Reno, NV.

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