A FORCED CONVECTION DEMONSTRATION USING SOLID CO_2 SUBLIMATION

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One of the features of the transport processes sequence presently taught to chemical engineering undergraduate students at UCSB is the weekly laboratory which is used to illustrate selected principles from the lectures. Experiments performed during the laboratory period usually take the form of a demonstration where data are taken to be analyzed by the students in an assigned home problem. In this way many of the home problems cover a practical transport problem involving the analysis of real data.

The department sub-sonic wind tunnel is used for the majority of these demonstrations. Hence, in the fluid dynamics course the demonstrations start with simple air stream velocity measurements, cover the standard demonstrations of drag on a bluff object, boundary layers, etc. In the course on heat transport, demonstrations cover such topics as heat transfer from a cylinder in transverse air flow.

In the concluding course dealing with analogous mass transport phenomena, the difficulties encountered in designing appropriate demonstrations are significantly greater. The authors, in a recent paper[1], described an experiment developed by students as a term project which covers mass transfer from a cylinder in transverse air flow. In this experiment the cylinder is cast from naphthalene with a liquid nitrogen quench to obtain a very fine grain structure at the surface of the cylinder. The low sublimation rate of naphthalene, even under conditions of forced convection, requires running times in the wind tunnel on the order of a full day to achieve measurable material loss from the cylinder. The advantage of the naphthalene cylinder experiment, however, is that simple mechanical methods can be used to measure accurately the rates of mass transfer. These data can then be compared to analogous data from heat transfer experiments.

Obviously this experiment requires too much time to serve as an effective demonstration. Consequently, we have developed a complementary experiment, utilizing a dry ice cylinder, to furnish a rapid visual demonstration of mass transfer in transverse air flow. Solidified carbon dioxide has a much higher vapor pressure than most common solids; hence, with a vastly increased driving force for mass transfer, wind tunnel demonstrations can be run in several minutes. A further advantage of the use of a dry ice cylinder is that normally there is enough moisture in the ambient air which condenses in the vicinity of the cylinder to provide effective visual evidence of boundary layer formation and separation, vortexing in the cylinder wake, and the flow patterns in the vicinity of the rear stagnation point.

The experiment is quite simple to carry out. A mount (shown in the accompanying figure) supports the cylinder in the wind tunnel test section. The mount is adjusted to hold the cylinder

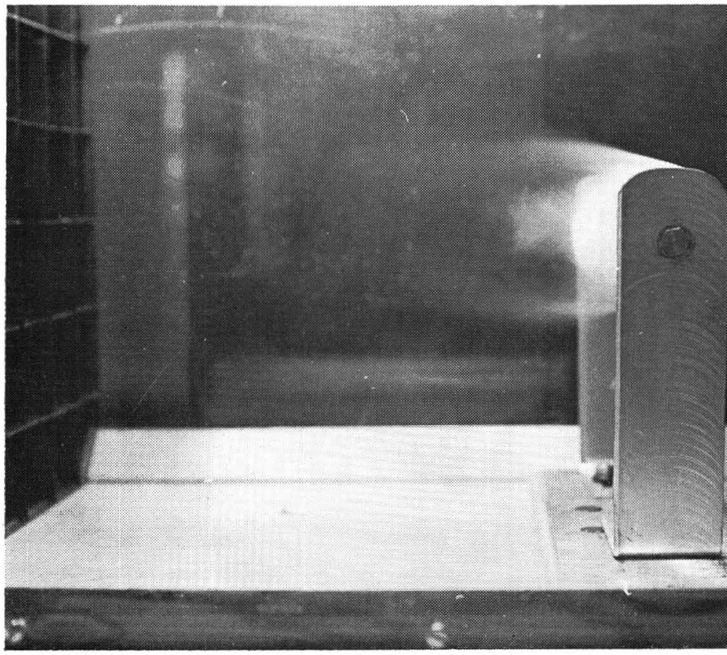
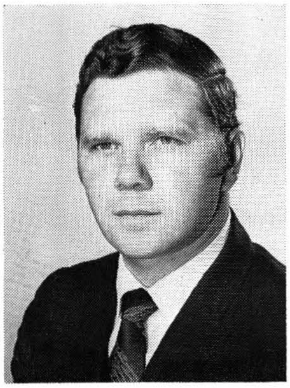
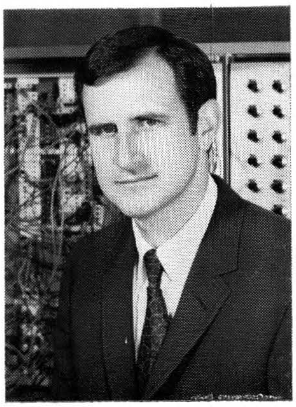


Figure 1
Dry Ice Cylinder Mounted in Wind Tunnel.





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The department sub-sonic wind tunnel is used for demonstrations in fluid mechanics and heat and mass transport phenomena.

in compression with dense foam rubber (in our case, rubber backed carpeting) gaskets used to insulate the cylinder from the mount and to maintain the compressive force as the ends of the cylinder sublime. Preparation of the cylinder is very simple, if somewhat novel. An ordinary three pound block of dry ice is set-up in our machine shop metal lathe. It is quickly turned to the required diameter by standard machining techniques and immediately brought to the wind tunnel for the demonstration.

After mounting the dry ice cylinder in the wind tunnel the air flow is turned on and is quickly adjusted to correspond to the desired Reynolds number. It was found that at prevailing air relative humidities of approximately 50%, the streamline patterns of condensed moisture were clearly visible at air velocities of approximately 50 ft./sec. For the 2-inch diameter cylinders used in the demonstration, this corresponds to a Reynolds number of about 50,000. At this Reynolds number the laminar boundary layer separates before it becomes turbulent, the point of separation occurring at an angle of about 80 degrees from the forward stagnation point. The streamline patterns clearly show the separation point and the angle of separation is easily estimated by the students to be at approximately 80 degrees fro mthe forward stagnation point. The streamlines in the downstream turbulent wake are also clearly visible particularly near the rear stagnation point.

After running the demonstration for about five minutes the wind tunnel is turned off and the dry ice cylinder may be inspected. This length of time is sufficient for a protruding ridge to appear at the separation point. This ridge indicates the sharp minimum in the local mass transfer coefficient that occurs at the point of boundary layer separation.

REFERENCE

1. Sandall, O. C., and Mellichamp, D. A., "A Simple Forced Convection Experiment", **Chemi. Engi. Edu.** Vol. 5, 134-136 (1971).

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Report writing was further simplified by the fact that students did not primarily write for the instructor but rather for their class-mates whose technical competence they knew.

CONCLUDING REMARKS

Although it is clear that not all undergraduate experiments should be replaced by Evolutionary Experiments, the addition of one or two can considerably enliven a laboratory course. In order to maintain student interest, the topics should be frequently changed. The following projects, which have either been conducted or are planned at U.B.C., may serve as further examples of Evolutionary Experiments: production of crystalline copper sulphate from an Arizona ore, extraction of protein from fish meal, manufacture of furfuraldehyde from sawdust and recovery of metals from scrap tin cans. The latter two projects were initiated by Dr. K. B. Mathur and Dr. A. P. Watkinson, respectively.

REFERENCE

1. O. Levenspiel, Chemical Reaction Engineering, p. 338, John Wiley and Sons, New York, 1962.