EXPERIMENTAL METHODS, INSTRUMENTATION, AND LABORATORY PRACTICE

The purpose of this introduction is to briefly review various aspects of the experimental methods, instrumentation, and laboratory practice that must be considered by a student first attending a fluid laboratory. It is important to state immediately that experiments, and their degree of complexity, vary widely depending on their purpose.

Experiments may be classified as follows:

(a) fundamental experiments - to answer clearly defined and specific questions. For example, does the momentum equation provide an adequate theoretical basis for analyzing the performance of a free jet of air? In general these experiments lead to an extensive program of research;

(b) experiments less “open-ended” than (a) - where still there is need to consider a number of other questions before one can start work in the laboratory;

(c) Testing - Laboratory investigations for industrial calibration and instructional purposes for which there are no questions requiring deep study of the underlying theory, which is already well established, but questions of accuracy are of prime importance.

The last category of experiments is of interest herein. In planning them, careful consideration must be given to the test conditions and to the accuracy of the instrumentation. The design of experiments in general is a difficult art, best learned by carrying out, with a critical mind, experiments designed by others.

Experimental methods

Experiments should be designed to consider several approaches to obtain the final result. The experiments in this course are closely related to the instrumentation available. Thus, the following factors usually are considered when selecting an experimental method:

- experience in the use of instruments;
- knowledge of calibration methods and awareness of the different errors to which instruments are subject;
- understanding of the relative merits and limitations of alternate instrumentation and their applicability to different experimental situations.

Instrumentation

There is a strong tendency for the inexperienced laboratory student to believe the readings of his instruments. However, the experienced experimenter knows that every reading is suspect, that he/she must calibrate the instruments, and that he/she must continuously be on the alert to notice faults in the installation or performance of the instruments. The relative merits of different types of instrumentation for measuring the same quantity is a vast subject. A few key principles in selecting the instrumentation are as follows:

- cumulative measurements are generally preferable to rate measurements (measurement of the rate of flow of a liquid by collecting it for a period of time, rather than by using a previously calibrated rate meter);
- "absolute" methods are preferred to "relative" methods. Pressure measurement by a column of mercury is preferable to a measurement by a Bourdon gage which gives a relative pressure;
- in selecting instrumentation simplicity is a virtue. Each increment of sophistication adds a potential source of error. This concern applies particularly to electronic apparatus.

The sensitivity of an instrument may be defined as the smallest change in applied signal that may be detected (in the case of a pressure gauge it is affected particularly by friction and backlash in the mechanism). The precision of an instrument is defined in terms of the smallest difference in reading that may be observed. Typically, it is possible to estimate readings to within 1/10 of the space between graduations, if the reading is steady.

Laboratory practice

Laboratory work is largely concerned with the taking of measurements, and a major purpose of any laboratory course is the inculcation of skill in the use of measuring instruments. For an introductory course in Fluid Mechanics the best way to capture the interest is to acquire this knowledge in the course of general work not through a preliminary course in instrumentation.

Laboratory work, at any rate in the engineering field, is usually a group activity. Most experiments require a group of four students to work together. For example, one student should direct the test and record the results, while the reminder of the group should each be responsible for taking certain of the necessary readings. The group should be rotated so that each member gains experience in each task. It is desirable that a preliminary plot of the results be made during the laboratory period, so that faulty readings may be rejected and any unduly large gaps between successive test points filled in.

Some important skills necessary for performing fluid-mechanics experiments are listed below:

- accurate checking of zero values;

- correct interpolation of the readings of the instrumentation pointers;
- reading of manometers (a straightedge should be used to read the value indicated by a meniscus);
- averaging of readings in experiments involving fluids in motion (roughly half a minute it is frequently necessary to establish a true mean value of such a reading);
- recordings of readings to the correct number of significant figures (e.g., if a manometer level is oscillating with an amplitude ± 5 mm, it is meaningless to quote the average level to an accuracy greater than 1 mm);
- allowance of sufficient time for readings to stabilize, particularly when temperature is concerned;
- accurate use of stop-watches (it is recommended that students make successive timings of a regularly repeated process, e.g., to time a period of ten seconds on a continuously running stop-watch, using a second watch for the purpose);
- correct use of such standard laboratory apparatus as balances;
- acquisition of a general skill in the handling of instruments and controls, (e.g., a calibration knob on an electrical instrument must be handled differently from the handwheel of a 10 cm hydraulic valve).