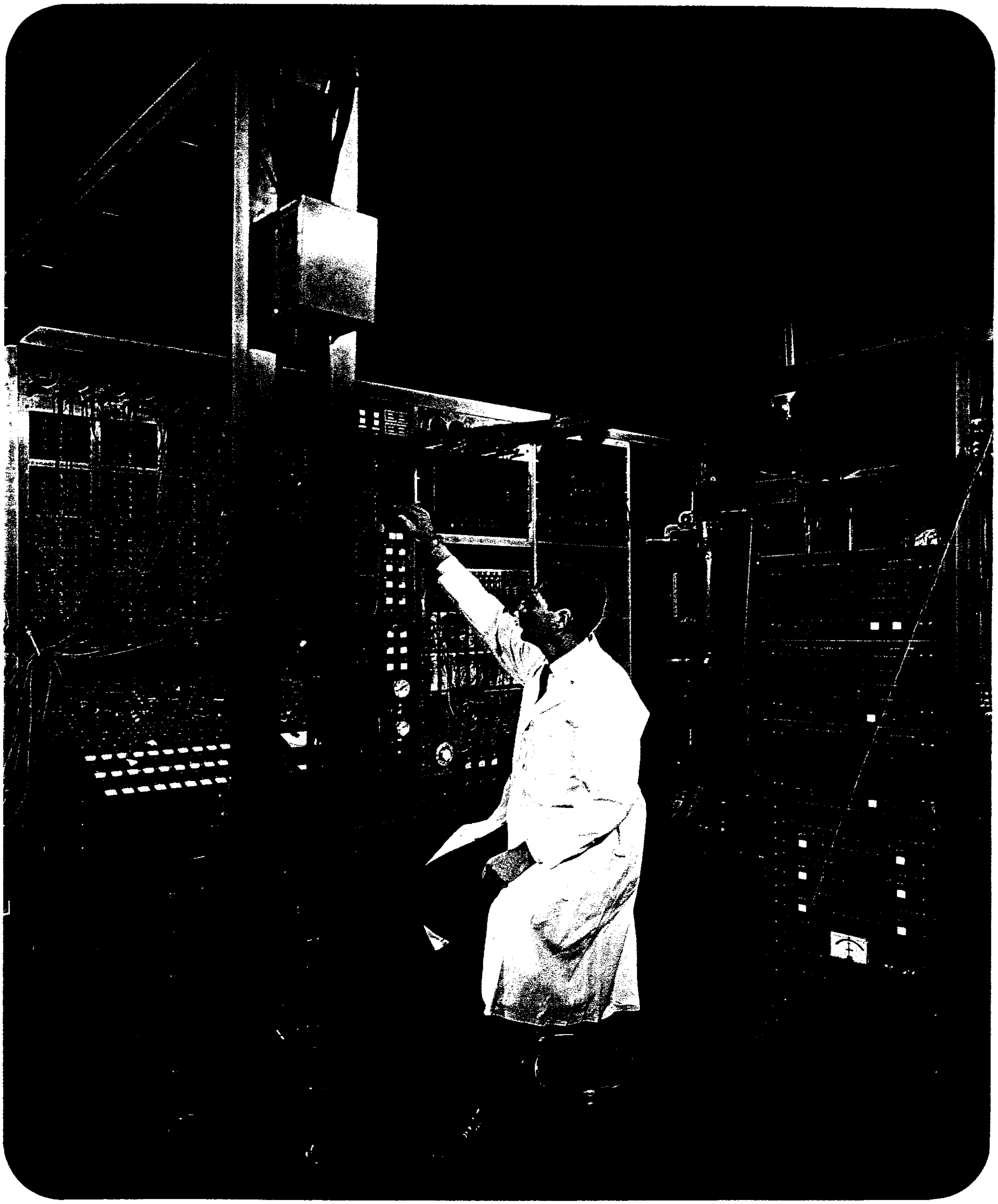
MAY 1968

R/D Research/Development ®



Graduate Education in Instrumental Sciences – see page 24

To be a specialist in instrumentation, you have to be a generalist. That's the basis of a unique program that uses research on a broad range of instrumental technique as a teaching tool for

Graduate Education in Instrumental Sciences

by M. K. Testerman

In January of this year the PhD degree with a major in Instrumental Sciences was awarded to two men at the University of Arkansas. Although there have been a number of MS graduates, these were the first PhD students to come out of a unique program at the Graduate Institute of Technology in Little Rock. The Graduate Institute was born some 10 years ago when a handful of men and their research in instrumentation moved from the Fayetteville campus to form the nucleus of a Graduate Institute that now also offers other more traditional programs in chemistry, physics, engineering, and mathematics along with instrumental sciences. The MS program in Instrumental Sciences was initiated in 1960, the PhD program was approved for the latter third of 1964.

The Department of Electronics and Instrumentation has conceived an unusual program of course work and compatible research that produces graduates with the hybrid training so necessary to function creatively in the modern technology of measuring chemical, physical, electrical and mechanical properties in our environment with instruments. Modern research in universities and industry could scarcely function without the wealth of powerful instruments available to them. Modern technology requires more and more instruments that not only measure and control but are capable of augmenting the human intellect in all of its technical pursuits.

THE PHILOSOPHY OF THE PROGRAM

Perhaps the main departure of this graduate program from those more conventionally designed involves the concept that the science of R and D in the field of instrumentation is a respected field in itself. In the past, R and D in instrumentation has been tolerated only to the extent that the person or group can use it as a tool in a project aimed only at making a series of measurements to deduce some parameter or property of the system of interest. Our academic and research program is interested in making the measurements only to the extent that we can prove accuracy and reliability of the technique. The data gathering and the deductions about a system under study is a problem that the classical scientist or engineer can perform.

Toward this end, the department tries to create graduates with the attitude that they will stoop to any technique that best suits the seduction of information from the system under attack. To augment this spirit, the department seeks to acquire faculty that are not irrevocably married to a narrow range of interest. For example, any person being considered for the faculty or staff that might say, "If it can't be done with infrared, it isn't worth doing," would be avoided.

A summary of our approach to the type of graduates we are trying to turn out is that we do not wish to produce a "honcho" in a narrow field of specialization, but rather a student who is able to look at the "big picture" with a minimum of personal emotional bias as to evaluating the best approach to the problem. The broadness of the academic program, as well as the exposure of the student to a diversity of areas of research projects, is further complemented by the fact that we accept into the program for graduate work persons with a BS in the physical sciences, mathematics or engineering who are experimentally inclined. (This is further spelled out later in this presentation.) We find the "rubbing of shoulders" of graduate students from different backgrounds beneficial.

I have been approached about the possibility of establishing an undergraduate program in this area of instrumental sciences, and I have stated that this would be unwise because such a development would defeat some of the purposes of the over-all graduate program. Although many persons in the classical disciplines consider us specialists, this is not so, and an undergraduate program might succeed in moving the program in such a direction.

THE COURSES

Since students enter the department with undergraduate degrees in various fields, the courses they take at the Institute are designed to fill in their backgrounds in the other areas and to develop a breadth of scientific competence in the many disciplines required to do effective work in instrumentation. In addition to the 15 specially constructed courses taught by the E & I department, there are approximately 80 courses also offered on demand by the chemistry, physics, engineering, and mathematics faculty of the Institute. A student spends about two-thirds of his course work in E & I taking such courses as Measurement Techniques, Principles of Physical Phenomena, Solid State Electronics, Computer Theory and Process Control. The remainder of his time is devoted to broadening his background by taking courses in the other disciplines and performing research on actual instrumental projects. The PhD candidate will take the following general types of courses following his BS degree:

- 24 semester hours of E & I core curriculum (some of which are not E & I departmental courses)
- 24 semester hours of E & I electives
- 24 semester hours of other department courses (at least 12 hours of which must be advanced mathematical courses)
- PhD dissertation research.

Graduate assistantships provide the financial basis for the education of most of the students. These assistantships are for research work rather than teaching. They provide an important part of the student's education—actual training and experience in real-life research projects. They do not replace the doctoral thesis research, which is carried out in addition.

In general, the department tries to dissuade the graduate assistant from choosing a dissertation problem that is in the same area as that of the assigned project research he is doing for his graduate assistantship. This approach further exposes him to two, rather than one, set of research techniques employed in the study or studies involved. In seeking research projects for the staff and students, an effort is made to look for a wide spectrum of research areas—particularly those in the new, frontier fields. The departmental research grants and contracts range from purely exploratory research to developmental types aimed at a specific goal. These projects acquaint the students with research as they will find it later in their careers, and the nature of the projects encourages original thought. The department operates on a 12-month basis with a current group of 25 graduate students.

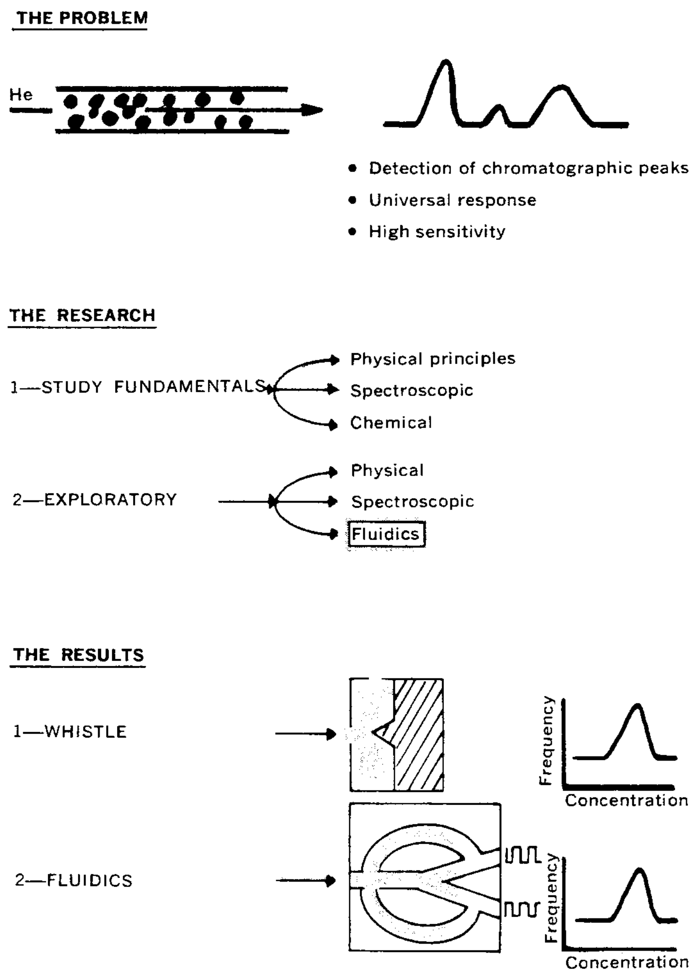


Fig. 1. Development of new chromatographic detectors.

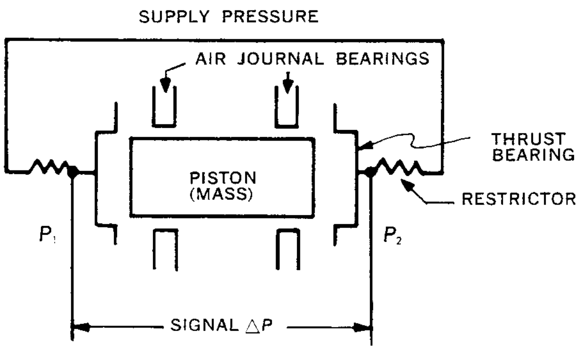
THE RESEARCH

Described below in varying degrees of detail are some examples of the various types of research programs we have performed or are performing in the department as a complementary activity to our graduate course work. We chose these to illustrate our diversity of research activities, not to give an all-inclusive description of our activities. Our research projects are supported by both government and industry as well as internally. To reiterate, this work is a complement to our academic program and is not meant to infer that we are a research institute.

Fluidics

Several years ago, a particular research contract called for the evaluation of any physical principles not currently in use that might provide the basis for a chromatographic detector of high sensitivity and universal response. This study led the staff into the field now referred to as Fluidics through the process shown in Fig. 1.

After the initial exploratory study and work, the principle of using a whistle to detect the chromatographic effluent was demonstrated to be sound. The



$(P_1 - P_2)\ A = ma$

A = effective area of piston faces

P_1 and P_2 = thrust pad pressures

m = piston mass

a = acceleration

If A and m are constant

$a = k \triangle P$

Fig. 2. Principle of the fluidic accelerometer.

first detectors of this type studied were of the jet-edge, resonator cavity design that operated in the ultrasonic range. Subsequent study more strongly indicates these detectors possess a relaxation oscillator mode of operation.

These small ultrasonic whistles had cavity volumes on the order of 1½ microliters. The carrier gas flowing through the chromatographs provided the energy necessary for the generation of a constant frequency or tone from the ultrasonic whistle. This frequency was monitored with the aid of a high frequency capacitance microphone. When a chromatographic sample elutes from a chromatographic column and enters the detector, the frequency emitted by the whistle changes depending upon the amount of gaseous sample present and its molecular weight. Using hydrogen carrier gas, the frequency of the whistle was found to decrease when any sample passed through. The basic operating frequency of the whistles could be varied between 50 and 100 kHz. If digital output is desired (that is, where the number of cycles of frequency change from the baseline frequency that occurred during the passing of the sample is counted), two whistles can be employed at the same frequency so that their outputs are beat together, resulting in a zero frequency output. When the sample passes through the sample whistle its frequency changes, thus giving the output from the system only while the sample is present. The difference between the frequency of the whistles is then counted by standard digital techniques, resulting in a digital measurement of the area under the chromatogram peak. To provide an analog presentation, one whistle can be employed and the frequency (the baseline frequency of the whistle) can be converted by normal D/A techniques with zero suppression applied to position the baseline at any desirable point. A sample passing through the whistle changes the frequency, giving a change in the dc output from the D/A converter and resulting in a normal appearing chromatogram.

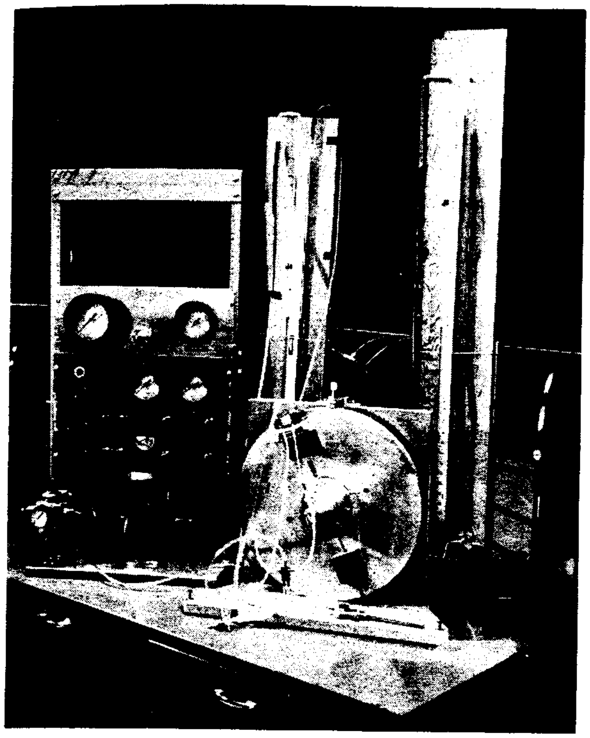
As a chromatographic detector, the whistle responds linearly to both a variation in sample size and molecular weight within its dynamic range. The maximum digital sensitivity recorded for the whistles is a 2500 to 1 signal-to-noise ratio, per per cent methane instantaneous concentration in hydrogen carrier. Since one is confined to assume one bit as the minimum detectable noise level in a digital system, the analog sensitivity is usually to be found from 2 to 4 times greater in terms of signal-to-noise than the digital sensitivity since the actual noise level is considerably less than one cycle. The whistle is a rugged device with a universal response to eluted components, and is fast—it has a time constant of approximately 12 milliseconds.

A separate study was made of the ability of the whistle to perform as a chromatograph detector at high temperatures. The whistle was found to operate satisfactorily and repeatably at temperatures as high as 800 C. Single runs were made as high as 1000 C, but oxidation problems prevented either repeatable or multiple runs at this temperature. In the process of using a whistle at high temperatures, a microphone had to be constructed which could be operated in the same environment and temperature as the whistle. This proved to be a difficult but not an insurmountable problem. During the course of the investigation, frequencies as high as 450 kHz were recorded.

At about this point in time the invention of fluid amplifiers was announced by Harry Diamond Laboratories. It was immediately obvious that these devices could be made into fluidic oscillators, and it was felt that they should respond much the same as whistles. A group of these devices was designed and submitted to the Corning Glass Works (at that time in Bradford, Pennsylvania) for construction. The devices were etched in photosensitive glass and sealed with glass lids. In about 1962 these were considered to be extremely small fluidic devices in that the power nozzle was only 6 mil wide by 24 mil deep. These devices were found to perform very satisfactorily as chromatographic detectors, and in general the data obtained from fluid oscillators were practically identical to that of the ultrasonic whistles. The over-all properties were approximately the same, but the fluidic devices had no moving parts and could be produced at considerably less cost than the ultrasonic whistles.

It was felt that the use of the fluid oscillators as chromatographic detectors would be especially important in those areas where the detector for a chromatograph could be easily clogged or otherwise harmed by reaction with the environment, sample or carrier gas. In such an application, if the fluid oscillators became inoperable for other reasons they could be replaced immediately. No attempt would be made to repair them as would normally be the case with the more expensive and more complicated detectors. Neither the fluid oscillator nor the ultrasonic whistle requires complicated electronics. There are no dc amplifiers or electrometers required, which minimizes drift problems. The signal from the whistle is monitored by the use of the small high frequency microphone and then amplified with standard ac amplifiers.

Next, work was initiated on studying the properties of larger whistles so that some of the typical properties of whistles might be better understood. The study of the small ultrasonic whistles produced some data in disagreement with the more widely accepted ideas of whistles, and it was felt that further work should be done starting with larger models. This work, which was supported by Corning Glass Works, did not an-



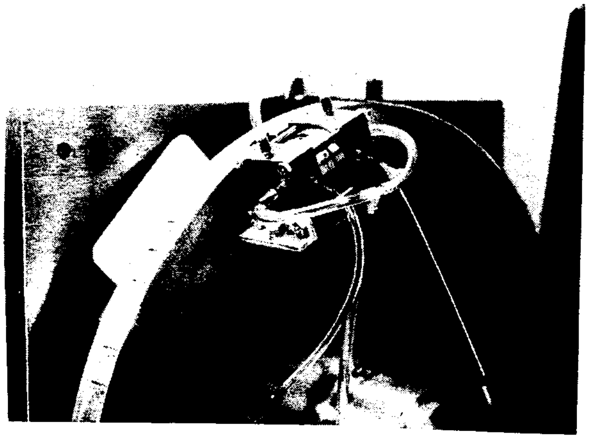


Fig. 3. Experimental apparatus for fluidic accelerometer studies.

swer all the initial questions concerning the whistles but did prove that whistles could be scaled over a size range of 8 to 10 without losing knowledge of the operating characteristics. The most significant result of the investigation was that many new questions and many new peculiarities of whistles were found. A great deal of information was catalogued that might aid one in attempting to design a whistle for a specific purpose, to operate in a specific atmosphere and at a given frequency.

Fluidic Accelerometer. Prof. Paul C. McLeod, a faculty member until recently, who is now directing product research at Corning Glass supervised the studies and initiated a study of a fluid accelerometer. Dr. J. P. Prideaux will assume the direction of our work in fluidics. Its objective: to develop an accelerometer based on fluidic principles that can be coupled directly to fluidic amplifiers and measure acceleration along one axis. Such a device was designed and proved to be very satisfactory. The experimental apparatus is shown in Fig. 2, and its principle is illustrated in Fig. 3. The device consisted of a mass supported by two air journal bearings so that it could move freely through a close-fitting cylinder. Thrust bearings were positioned at the ends of the free piston to restrict the piston movement. The thrust bearing consisted of restricted air thrust pads. The pressure within these two pads was monitored to provide the indication of acceleration.

When the acceleration was applied along the axis of the piston, the piston was found to move to a position where the difference in pressure across the piston exactly equalled the acceleration force. The response within the dynamic range of the accelerometer remained linear until saturation, or when the piston rested against one pad. It was found to be insensitive to most problems normally associated with sensors and was especially insensitive to changes in the supply pressure. The only result of changing the supply pressure was that it changed the dynamic range or the point at which the device saturated. By changing the mass-to-area ratio (that is the mass of the piston versus the active area of the two thrusts at the ends of the piston) one can alter the slope of the ΔP versus acceleration curve to fit the situation. This device was especially versatile since the piston was supported independently from the acceleration measuring air pads and changes could be made without interaction between the two types of air bearing system. With a design such as previously described, the mass-to-area ratio can be changed such that the device can be made extremely sensitive or can produce large signals for as little as 0.1 g acceleration.

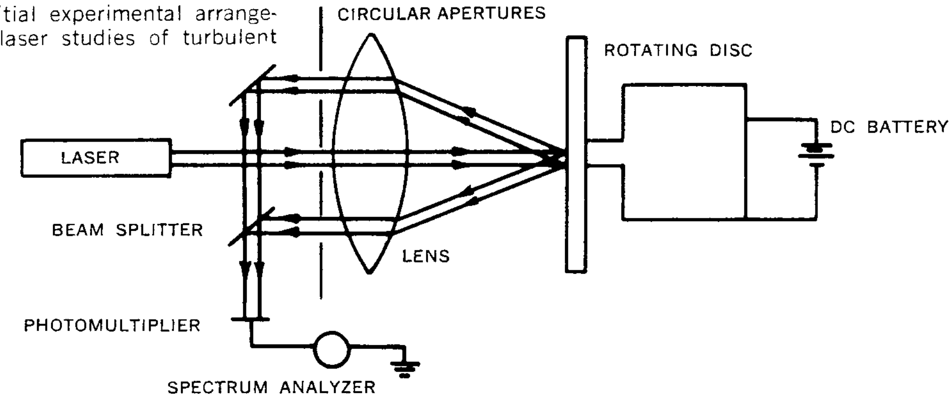
These studies led to the realization that this device and principle could be used to measure level to an accuracy in the milliradian range. The device shown in Fig. 2 can do this by measuring the acceleration of gravity.

Instrumental Applications of Lasers

The investigation of the applications of lasers, under the direction of Dr. Joseph Story and Mr. George Ballard, is one of the areas in which both research by faculty, staff and students and thesis work is done. One of the two major areas is holography. In this area, work has been performed on making holograms with a pulsed ruby laser, on the application of holography to schlieren systems to render flow patterns visible, and on the use of a holographically reconstructed grating against a real grating (moire effect) to make a pseudo-interferometer. Work is continuing in several more theoretical aspects of holography with emphasis toward instrumental applications.

Another area of laser research is directed toward utilizing the laser in a device to study the turbulent

Fig. 4. Initial experimental arrangement for laser studies of turbulent flow.



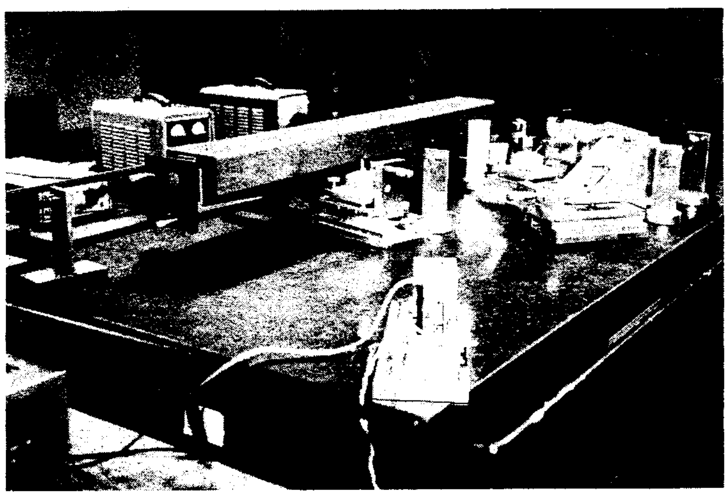


Fig. 5. Experimental apparatus to study calibration techniques with laser-beam interferometer for micro-miniature accelerometers. It operates in the 1 to 10 Angstrom region at frequencies up to 100 kHz.

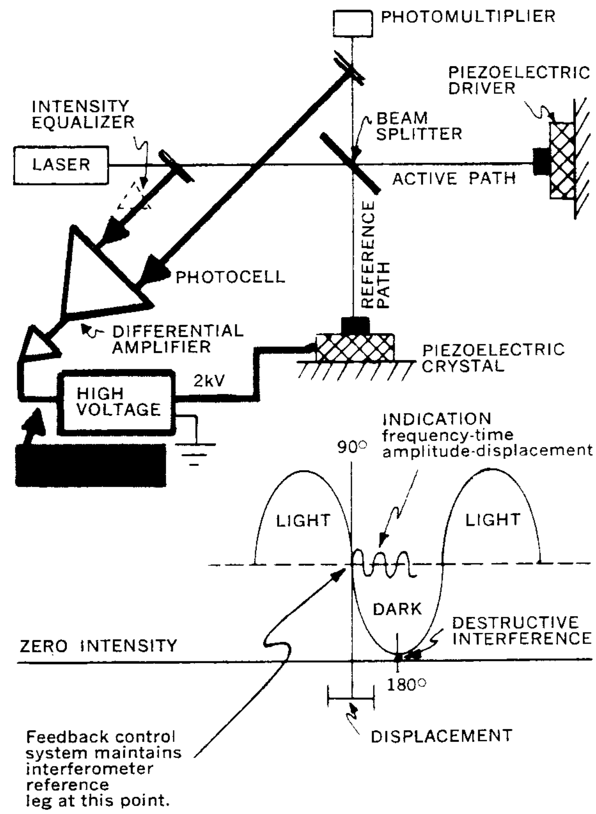


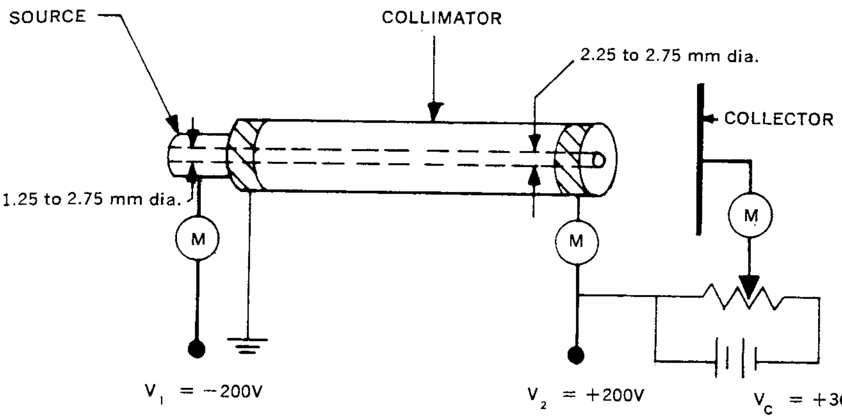
Fig. 6. Principle of the laser-beam interferometer used for accelerometer measurements.

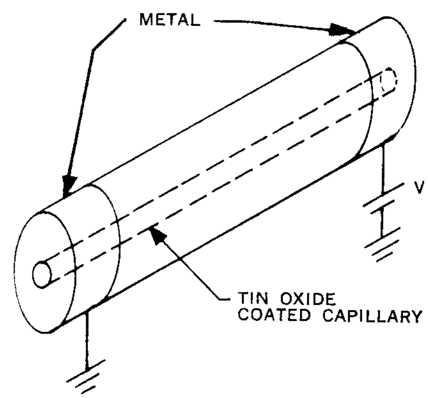
flow of fluids. If one uses a conventional sensing device (such as a hot-wire anemometer) the flow is disturbed by the sensing device itself, and one is no longer looking at what he wants to see. The approach used is to bring the laser to a focus at the point in the fluid at which the observation is to be made. If suitably sized particles are injected into the flow, they will follow the flow and those passing through the point focus will be intensely illuminated. Suitably sized particles will scatter the light in all directions. The light scattered in the various directions will have its wavelength (or its frequency) changed by the Doppler effect of the moving particle. Thus, light scattered in two different directions will have two different wavelengths. If the waves are added together one will get a "beat frequency" (optical heterodyning) that is low enough in frequency to fall within the range of commercially available electronic apparati. One can now "do things" (to be described later) with this electronic signal to determine the velocity of the particle causing the Doppler shift. If one simultaneously looks at the velocity from three different angles, he has enough information to describe the direction of the motion of the particle as well as its velocity.

The observation of this Doppler frequency shift by a moving particle has been done by earlier investigators. One distinctive feature of the study at GIT is a detailed investigation of the ways in which the instrumentation itself (optical and electronic) contributes to the observed result.

A schematic diagram of the optical system is shown in Fig. 4. In this device, the system being observed is at the extreme right. (This offers the advantage that the system being studied does not have to be encompassed by a measuring system. Thus the device can be used as a probe.) The laser beam passes through a 4-inch lens and is focused on the surface of the rotating disc that is used to provide the constant and well-known velocity needed for "pinning down" instrument variables. (Note that the point being observed is actually near the edge of the disc—the axis of the disc lies out of the plane of the paper.) This disc was planar in the early studies, but is a three-dimensional suspension of particles in a clear polymer for later studies involving three-dimensional effects.

The light scattered from a point on the disc then passes backwards through the lens and is again made parallel. Two circular apertures in a plate then block





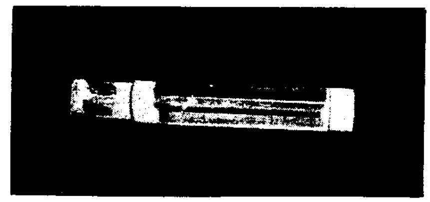


Fig. 7. Cold electron source.

off all of these light rays except two circular beams. These beams are then merged into a single beam by reflection from a mirror (top beam) and a beam splitter (bottom beam). The merged beam then falls on a photomultiplier, where the "beat frequency" is produced and transmitted to a spectrum analyzer.

The display on the cathode ray tube of the spectrum analyzer can be interpreted as a plot of frequency (horizontal axis) versus intensity (vertical axis). If one had an ideal system he would see only a single vertical line at the frequency corresponding to the velocity he was observing. But this does not happen. In practice, one sees the line spread into a curve that peaks at the frequency of interest. If one intended to use the device to measure only constant velocities, he would simply read this peak and ignore the rest of the curve. But if one wants to study turbulent flow (and use the curve in detail) this spread constitutes a serious problem. The spread should be minimized and its nature understood.

Here we can do little more than list the various contributing factors that have been recognized and quantitatively described. The causes of frequency spread in a symmetrical system (such as that shown) are:

1. The spectrum analyzer itself. This is related to the problem of obtaining a satisfactory signal-to-noise ratio.

2. The dimensions of the scattering volume. The two volume dimensions corresponding to the plane of the paper in Fig. 4 enter into frequency spread because of the uncertainty in observation angle. The volume dimensions perpendicular to the plane of the paper enter into the consideration only through the actual differences in velocity across the volume.

If one uses an unsymmetrical system (such as other investigators have used) additional factors cause frequency spread. These are:

1. The angle of convergence of the incident beam. This introduces an uncertainty in determination of the angle of observation.

2. The dimensions of the circular aperture. In the case of the symmetrical arrangement this was shown to cancel out.

Another important consideration is the signal-to-noise ratio previously mentioned. The various causes of signal loss and noise were investigated. Besides the obvious losses in the optical components themselves, it was found that the longitudinal laser modes and the beam divergence caused losses when the path lengths were not equal. Also, the scattered light is elliptically polarized, and the noncoincidence of the major axes of the ellipses causes a loss in optical heterodyne efficiency. The noise arising within the electronic apparatus was minimal. The major source of noise was optical and came from the laser. There also were other less serious sources of optical noise.

As a part of the three-dimensional studies, it was found that the observed volume was controllable and could be made very small. Study was extended to an actual flowing system (laminar), and the same results were obtained.

Another laser application being studied is use of a laser-beam interferometer for accelerometer measurements. Experimental apparatus is shown in Fig. 5, and Fig. 6 illustrates the principles used in this application.

Cold Electron Source

An electron source not associated with thermionic emission would have many advantages for use in research studies. The development of a "cold" electron source, one with an operating temperature of 300 K or less, is the objective of this research, directed by Dr. T. A. Raju. It has progressed to the study of a solid state device that promises to achieve the objective. The device is illustrated in Fig. 7.

The device is constructed in two sections: a source and a collimator, which are connected by use of a conductive epoxy. To prepare the source, a thin tin-oxide film along with metal films are deposited on a Vycor glass substrate. The substrate is a 3 cm section of capillary tubing approximately 1.5 mm inner diameter and 7 mm outer diameter. The tin oxide is deposited along the inner diameter of the capillary by a vapor deposition technique. After the inner diameter of the capillary is deposited, metal thin films of gold, aluminum or silver are vacuum evaporated into each end of the tubing to provide electrical contact with the tin-oxide film.

After the films are deposited, an activation procedure is carried out. Voltage is applied across the capillary by making electrical contact with the metal films. The voltage is slowly increased until the voltage-current relationship becomes nonlinear, at which time the current increases with constant voltage. A maximum current is reached and a transition occurs, thus causing the current to decrease to below 1 ma. When the current decreases to this value, free electrons are emitted from the metal-metal oxide junction in this device.

Since the electrons emitted from the source are dispersed, a collimator must be attached to yield a collimated beam. The collimator is fabricated identically to the source except that no activating process is followed and its resistance is approximately a factor of 10^{-5} larger. The higher resistance is obtained by doping the tin-oxide film, *n*-type semiconductor, with indium, *p*-type semiconductor. After the source is activated the collimator is attached to the source by means of a conductive epoxy. The diameter of the beam of electrons obtained is approximately the same as the inside diameter of the collimator; the beam size can be changed by using different inside diameters for the bore in the collimator.

After fabrication, the device is operated and tested at pressures below 10^{-5} torr. A diagram of the device with the complete electrical circuit is shown in Fig. 7. Typical operating conditions would be 200 volts dc (V_1) applied across the source and 200 volts dc (V_2) applied across the collimator. A collector is placed in front of the collimator and approximately 300 volts dc (V_3) applied to it with respect to ground. Electrons emitted into the vacuum will be collected at the collector, and the electron current will be indicated by meter (I_3).

Collector currents as high as 0.5 ma have been obtained from the cold electron devices with efficiencies as high as 50 per cent. This is a considerable improvement over heated filament devices, which usually possess efficiencies of less than 1 per cent. The energy distribution of the emitted electrons has been determined to be approximately 100 volts. An effort is being made to operate the collimator in saturation, therefore giving a smaller energy distribution as well as a self-contained electron emission regulator.

Water Quality Monitor

Another program, supervised by Prof. Raymond W. Raible and sponsored by the Department of the Interior Federal Water Pollution Control Administration, concerns the development of a portable water quality control monitor that does not require permanent installation of utility lines or buildings for housing. Because the unit is intended for use in temporary situations, provisions for changing the parameters to be measured are also desirable. To limit the scope of the program and reduce costs, commercial transducers are being used wherever possible.

At present, the system under study is capable of measuring pH, conductivity, water temperature, dissolved oxygen, redox, chlorides and sunlight. Work is proceeding on the measurement of turbidity and of other specific ions.

Considerable effort has been spent in testing commercial electrodes and in construction and testing of newer modified type electrodes for the measurement of oxygen. Up to the present time no dissolved-oxygen electrode has been found that meets all of the criteria desired for use in the situations intended. The two most serious problems at present are: limited unattended lifetime for valid measurement, and the necessity for providing flow rate for the transducers in use. Efforts are under way to eliminate the flow requirements of the presently available electrodes.

Transducers to measure the various parameters undergo the following tests: Flow and temperature response are measured in a clean system (that is, no biological life is present). If the electrodes or transducers pass the test for unattended lifetime, reproducibility, and ability to measure the parameter of interest, they are transferred to a flowing system containing bacteria, algae and fish. This system simulates a stream or lake with a high probability of producing degradation of transducer response because of fouling by growth of films on electrode surfaces. If the transducer passes this test it is considered usable for field applications.

Consideration and tests of various power sources for this system were made in the earlier stages of development. Thermoelectric generators, fuel cells, solar cells with nickel-cadmium batteries, lead-acid storage batteries and Snap-type generators were all considered. Because of the power consumed by the flow requirements for the dissolved oxygen electrode, solar cells and storage batteries were discarded. Either of these systems becomes a distinct possibility if the flow requirement can be eliminated. Snap generators were considered to be expensive for the application intended. Fuel cells available were too large for the application intended and presented a cost problem.

Butane-operated thermoelectric generators were purchased and tested. Degradation with life was considered to be too serious to offer an economical solution to the problem.

The presently used power source consists of a gasoline motor-generator set with automatic starting facilities similar to the type used by telephone companies in their unattended stations. This generator is used to charge a pair of automotive type lead-acid storage batteries. One of these batteries operates the water quality system, and the other is reserved only for starting the motor-generator set when the first battery has reached a low state of charge. This solution, while not elegant, does appear to be practical and allows use of proven components. The gasoline engine cycles at 12 to 36 hour intervals depending upon the load and the ambient temperature. The running time of the engine generator combination varies from ½ hour to 1½ hours per cycle. If line power is available, the motor-generator battery system may be disconnected and a conventional line-operated 12 volt power supply substituted in its place.

Parameter interchangeability is accomplished by making each parameter-measuring circuit a separate printed circuit card that plugs into a main frame. This card contains signal treatment components and logic selection components which determine whether the system considers the measurement to be an ac bridge type measurement, a potentiometric dc measurement, or several other possibilities. Each parameter card is selected in turn by a timing programmer. The servosystem reads the output of the transducer at the end of

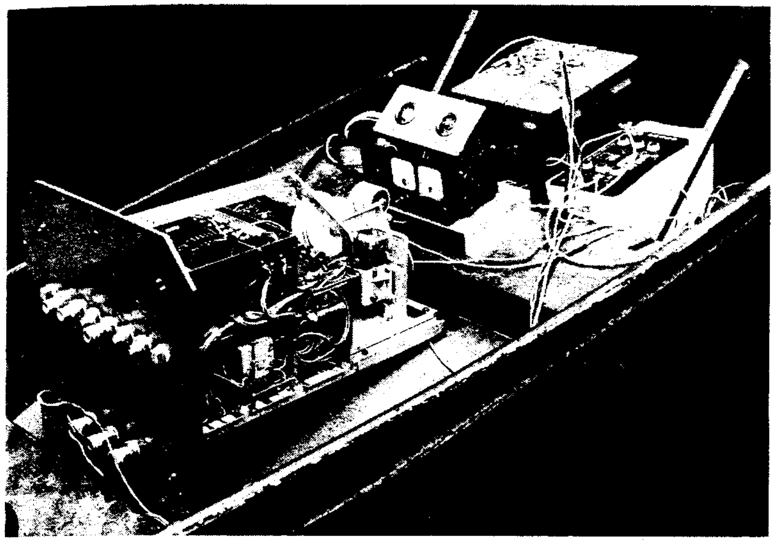


Fig. 8. Completed instrumentation for monitoring the quality of water streams in remote locations.

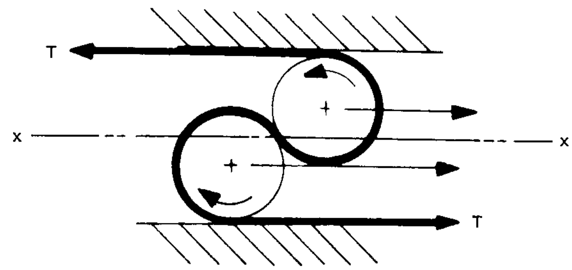


Fig. 9. Basic Rolamite configuration. To determine if slippage is present, a Michelson interferometer will be used to monitor linear motion for incremental values of shaft rotation.

the measurement period. The punched paper tape recorder records the measurement. The system at the present time has the capability of measuring six parameters in three minutes. The programmer itself is controlled by a temperature compensated electrical clock, which determines the measurement intervals. The data are recorded on punched paper tape in binary coded decimal form. The recording system has the capability of recording from zero to 9,999. Accuracy of the system is limited by the system noise and by transducer characteristics, not by the recorder.

Field calibration consists of making electrical adjustments using voltage sources and resistors as standards. The transducers are characterized in the laboratory. A computer is used to translate the recorded reading, the water temperature and the transducer characteristics into the parameter reading.

Provision is made for selection of normal ranges of parameters, providing output of daily maximum, minimum, and average values within these ranges, and additional provisions are made for output of all data during periods when parameter values go outside of these previously selected limits.

The field-tested unit is shown in Fig. 8.

Rolamite Bearing Study

The Sandia Laboratory has developed a new bearing called a Rolamite, which exhibits from 1 to 10 per cent of the friction found in ball or roller bearings. The principle of operation is illustrated in Fig. 9, which shows two rollers locked between guide surfaces by a flexible band under tension. In the configuration shown, the rollers are free to move in either direction with pure rolling motion.

Results from an Instron tensile testing machine indicate there should be no slip between the roller and the band. The study at GIT is aimed at determining this property of the Rolamite by using a Michelson interferometer to monitor the linear motion for incremental values of the shaft rotation. The experimental task is to determine if slippage is present and the relationship of the observed slippage to band tensions and roller contact angle. Dr. J. P. Prideaux is assuming direction of this newly initiated study.

THE FUTURE

It seems rather paradoxical that in order to create a so-called specialist in instrumental sciences it is necessary to provide the student with a very broad, general background. But this appears to be very necessary, because such a base is needed to function creatively in a field that touches all segments of scientific and engineering activities and is based on any known physical and chemical principle. The GIT graduates are moving into many diverse areas of industrial and academic activities.

The change in university research alone typifies the need for such people. Not too many years ago respectable research could be carried out with some rather simple bits of apparatus—test tubes, pH meters, thermometers. Now it is hardly possible to function without such instruments as NMR, mass and infrared spectrometers, chromatography, nuclear and solid state instrumentation. These instruments provide a knowledge base that permits rapid progress in all the research activities. When one begins to plan his research, the special instrumentation apparatus is an early consideration. Research establishments that have staff members specifically trained and working in these areas have a very decided advantage in the way they are able to function and produce research results.

The progress in digital computer design and use has invaded almost every segment of our life today. This is no less true in instrumentation. More and more one sees small or baby computers becoming part of the instrument as a whole. Such combinations have a synergistic effect—the whole being far more powerful than the sum of its parts. The view of the teaching lab shown on the front cover illustrates some of the efforts being made to create this awareness in the students.

Instrumentation and control is a discipline that may be said to be polygamous by nature in that of necessity it must be married to all the classical technical disciplines as well as the new hybrid fields coming into existence as each new day dawns.

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