embark upon a new phase of development, seeking both to amplify the vocabulary and to increase the ability of the machine to handle a wider range of operational syntax. The six rules will have to be vastly increased in number. Dostert estimates that about 100 rules would be needed to govern a vocabulary of 20,000 words. All this will require a great deal of additional linguistic research, as well as a special study, from the mechanical-translation point of view, of the source language vis-à-vis the target language. From the technical standpoint, this will involve increasing the machine storage and possibly the devising of special circuits. It will be necessary to analyze translation samples of increasing length and complexity and to adjust the results progressively after each analysis. The validity of the programming must continually be tested against machine equipment.

Looking realistically at the electronic translator, its developers recognize that the I.B.M. 701, which costs about $500,000, is "overdesigned" for language translation; it has many functions not essential to this task that were built in to solve problems in astronomy and physics. The bulkiness of the 11 units, which occupy roughly the same area as a tennis court, is another drawback. According to Hurd, I.B.M. is considering the development of a machine exclusively intended for translation. However, this cannot be accomplished until the Georgetown language specialists have elaborated additional instructions and specifications based on the experience that has been gained in the first phase of the joint project.

The time is still distant when it will be possible to insert a Russian scientific book into a translating machine and to receive from it an acceptable translation. It is highly doubtful that any machine could ever be devised that is capable of performing satisfactory translations of works of fiction or writings in which fine shades of meaning and subjective interpretations are involved. The translation of such a work as Milton's *Paradise Lost* or Tolstoy's *War and Peace* is in itself a creative act. Nor would mechanical devices ever eliminate the need for professional human translators. On the contrary, the latter would be freed from dull, routine hackwork and could devote themselves to the translation of works of literary and artistic merit that are more challenging in nature.

Neil MacDonald, describing the Georgetown-I.B.M. project in his article "Language translation by machine," which was published in the February 1954 issue of *Computers and Automation,* pointed out that the search for the solution of the translation problem brought to light many new facts that will tend to bridge the gap between the humanities and science. For example, it was found that the formulation of the logic required to convert word meanings properly, even in a small segment of two languages, necessitated as many instructions to the computer as are required to simulate the flight of a guided missile. He predicted that in the future

"Linguists will be able to study a language in the way that a physicist studies material in physics, with very few human prejudices and preconceptions, because the language has to be reduced to its operational characteristics in order to be handled electronically." All this suggests that a new discipline may emerge in which science and linguistics combine to solve international problems of human communication.

It may not be too visionary to suggest that with the perfecting of mechanical translation, significant writings of one land will be made available to interested readers in other countries shortly after they emerge from the presses. Thus, underdeveloped areas of the globe could receive the benefits of advanced science, technology, and knowledge at a rate impossible today. The general problem of the lag in the translation of key works from one language to another will certainly be remedied proportionally as machine translation becomes better developed.

Oceanographic Instrumentation

Allyn C. Vine

Oceanography as a science is still small enough so that physicists, biologists, chemists, geologists, and others who concentrate on the marine aspects of the profession are usually called oceanographers, particularly if they go to sea. Because it is a borderline field, the instrument requirements are as diverse as the problems; and because work on a ship is so different from work in a conventional laboratory, the instruments often develop along unconventional lines. In a short paper it is impractical to go into detail, or even to give fair coverage to all oceanographic instruments. Instead, I shall emphasize oceanographic problems, techniques, and instrument development, of which I have reasonable knowledge.

Sverdrup, Fleming, and Johnson have covered instruments in use up to 1940 in considerable detail (*1*). In 1952, the National Research Council and the Office of Naval Research sponsored a 3-day symposium on oceanographic instrumentation (*2*) that covered the present field of oceanographic instrumentation. Since each of the 12 papers had several discussants, the instrument problems were considered from different points of view, and much of the prevalent philosophy behind instrument development emerged in printed form. From the numerous references in these two sources, one can get fairly complete and up-to-date information.

Perhaps a brief description of some of the more significant characteristics of the ocean from the standpoint of a research worker or designer of instruments would be helpful. The fact that the ocean covers 70 percent of the earth is well known, but its division into surprisingly well-defined areas of continental shelves, oceanic basins, and deep trenches, somewhat comparable to the plains, plateaus, and mountain ranges on land, is less well known. In actual practice, this means that oceanographic instruments that are sensitive to, or dependent on, pressure are usually built and used for one of the following maximum depths: (i) 10 meters for har-

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bors and coastlines and for wave measurements, (ii) 200 meters for the continental shelf and the wind-stirred layer, (iii) 6000 meters for most of the open ocean, and (iv) 10,000 meters for the deep trenches.

Thus, oceanographic ships carry 5 to 6 miles of steel cable on their winches, and most deep-sea instrumentation must operate at water pressures of 600 kilograms per square centimeter (8500 pounds per square inch). In deep water the weight of the wire comes so close to the strength of the cable that tapered cables are often required for the great depths. Studying the depths or the bottom of the ocean can, with some justification, be compared to studying the continents from a balloon or aircraft at night at a height of 2 miles.

Water temperatures in the ocean vary from about $-1°C$ to about $30°C$. The salinity can vary from nearly 40 parts per 1000 in the Red Sea to nearly fresh off the mouth of the Amazon. However, in the open sea the salinity seldom varies more than 2 parts from 35 parts per 1000.

Physically, the ocean seems homogeneous only to those who do not investigate it closely. Patches, streaks, and transients keep appearing as detailed observations are made. Biologically, many fish are in schools, and plankton concentration varies with depth and location. Observations made within a given similar area or time often must be made very precisely. Investigations aimed at studying the transition zones must be more numerous and emphasize qualitative features.

Research Vessel

Perhaps the most important instrument of all is the research vessel itself. Away from the dock it becomes not only a laboratory but a home and a way of life. The type of problem tackled and the quantity and precision of data obtained are determined to a large extent by the ability of the ship to go somewhere and get a job done, particularly in adverse weather. Shipboard research quickly convinces one of the importance of teamwork, and being considered a good shipmate is high praise. Equipment breakdowns at sea without adequate repair facilities bring out or show the lack of resourcefulness. Laboratory space is often cramped and inefficient. Yet a good research vessel has an undeniable laboratory atmosphere about it, because it represents our most effective large-scale contact with the ocean. Although both research ships and land-based laboratories are required in oceanography, the question of which should be regarded as the service facility for the other is debatable.

An efficient vessel is so important in oceanography that much consideration has been given recently to the design of a truly modern research vessel with increased maneuverability, larger and more convenient laboratory space, relative freedom from roll, and greater versatility. There has been a steady output of new laboratories, accelerating machines, and so forth, for research on land, but there has been no equivalent, sustained emphasis or building program to develop more versatile and capable research vessels for the study of the ocean. A research vessel is as specialized as a yacht, merchantman, or a warship, and converting one to the other can give only a partially adequate vessel.

Aircraft are being used more and more in oceanography and offer great possibilities for observation and the collection of data. It seems almost certain that the airplane will be used in direct proportion to the number of good oceanographic instruments designed for aircraft use.

The wider thinking and use of buoys to supplement ship or aircraft in the collection of data are also broadening the field of techniques and desirable instrumentation. A ship can plant or herd quite a number of buoys and thus increase its area of coverage. Buoys that float even at the bottom of the ocean have also been used to replace wires or cables and can carry instruments down to and back from the deepest parts of the ocean. This technique permits deep-water research to be done from a ship without a winch and also permits the equipment to stay on the bottom for a considerable length of time.

Temperature and Salinity Measurements

Because of the relative ease in measuring temperature in comparison with measuring salinity, density, or current, temperature has remained important, not only as an end in itself, but also as an indicator of other changes. It is presumed that temperature measurements will continue to be one of the most powerful and versatile ways to figure out our oceanographic puzzle.

During the years, we have gradually accumulated enough temperature measurements to obtain a rough over-all picture of the northern Atlantic and Pacific that is reasonably descriptive for large-scale phenomena. We are unable, however, to describe in a detailed way how thermal exchanges take place or accurately to predict small-scale oceanographic features.

Most of the water in the ocean is nearly isothermal and, at most, only a few degrees above freezing. However, except for the polar regions, in the winter the upper few hundred meters of the water column is warmed, and the result is a thermocline with a consequent density gradient that tends to isolate surface water from deep water. The high degree of vertical stability in the ocean is of great importance and is intimately tied up with the circulation of the ocean. The temperature gradients of the upper 100 or 200 meters of water may change with the seasons. If gradients are present at greater depths, they are referred to as the permanent thermocline.

Near the surface, large temperature changes can occur in a small depth difference, for example, as much as 10°C in 10 meters. At depth, the situation is reversed, and the temperature change may be as little as 0.1°C in 1000 meters. These important facts must be considered before one starts to build an all-purpose thermometer.

The Richter reversing thermometer is a mercury thermometer, which was developed in the 19th century, that, when upended, preserves the temperature reading at the moment of reversal to within about 0.01°C. This thermometer is mounted on a Nansen sampling bottle of about 1-liter capacity that closes off a sample of water when it is upended. From the sample the oxygen or salinity content of the water can be determined. A suitably spaced series of bottles and thermometers are placed on the wire and are tripped by an ingenious series of messengers that slide down the wire. The thermometers are usually used in pairs. The protected types are inside a pressure-proof glass case and read the true temperature of the water. The unprotected ones have the slightly compressible glass mercury bulb exposed to sea pressure; they read high by about 1°C per 100 meters of depth. This pressure coefficient of temperature thus furnishes a precise depth gage. The Nansen bottle-reversing thermometer combination has many limitations, but it is such a trouble-free and accurate device that it will surely be in use for a long time.

The bathythermograph, designed and improved just before World War II, was a significant step in making observations from a ship underway, and as a result there are several hundred thousand continuous temperature-depth traces for the top 50 to 250 meters over much of the ocean. The bathythermograph (BT) is a small, commercially available, torpedo-shaped instrument, with its mechanism exposed to sea water, that records on a smoked microscope slide. The speed of thermal response is only 0.8 seconds for a 90-percent response, and the precision is good to about 2 percent in depth and 0.1°C in temperature, depending somewhat on the instrument, the operator, and the usage. In operation, it is dropped overboard and the 3/32-inch steel cable is paid out faster than the ship is moving. When depth is reached, the operator stops the winch, the BT rises nearly to the surface, and the operator then hoists the BT back to the ship and aboard.

A more recent instrument, the STD, continuously measures the temperature, electric conductivity, and depth and automatically computes the salinity of the water from the temperature-conductivity-salinity relationships and records temperature, salinity, and depth. This instrument has been of value in studying inshore and estuarine waters, but it needs another order of precision to be used on most offshore problems where changes tend to be smaller. The fact that the STD continuously computes and records a desired variable makes it a prototype instrument of unusual interest.

The study of thermal microstructure and the vertical distribution of temperature in the sediments under the bottom are new and interesting fields that are beginning to receive attention. Infrared measurements of surface temperatures from aircraft show great promise of delineating gross features, such as the edge of the Gulf Stream, with a detail and speed that was not possible before.

Current Measurements

The circulation of the ocean is sufficiently complex and interesting to bring out a full array of ideas and instruments. Many current measurements are made as they were hundreds of years ago (and as the jet stream was recently discovered in the upper atmosphere) by recording errors in dead reckoning. This amounts to the navigator noting that his ship did not go where he thought it was going. If good navigation or loran is available, this ship-set method is not as crude as one might suppose.

The drift method has been elaborated by setting out and following drifting buoys that transmit radio signals that can be homed on from the land or a ship. The motion of water far below the surface has been observed by following surface buoys that are secured by thin piano wire to deep-sea anchors made of aviator's parachutes and located at the depths of interest. Where offshore navigation is inadequate, buoys have been anchored to the bottom by piano wire even in several miles of water and have served as fixed references for making local current measurements or local bathymetric surveys.

Many propeller-type current meters have been built and several types are in frequent use. Perhaps the most novel current meter has been the GEK (Geomagnetic Electro Kinetograph), which, in effect, measures with a potentiometer the difference in voltage induced in a wire towed behind a ship and the voltage induced in the ocean as it flows through the earth's vertical magnetic field. The voltage difference is of the order of 1 millivolt per knot of current for spacing of 100 meters between the silver-silver chloride electrodes and is independent of the ship's velocity. The instrument is also known as the Jog Log, because the navigator is asked to make frequent three-sided rectangular jogs from the ship's base course in order to obtain two components of the current and to redetermine the electric zero of the instrument. In spite of certain theoretical and practical limitations, particularly in shoal water, the GEK has quickly become a basic and widely used oceanographic instrument.

Acoustic Measurements

Because the ocean is so much more transparent to acoustic waves than to electromagnetic waves, sound is a principal means of studying the ocean with both active and passive sonar gear. The echo sounder is the most widely used acoustic instrument. At sea it has been used successfully in studying the daily vertical migration of organisms as well as the depth of the water, and in shallow water it sometimes shows the depths of thin sediments. Geophysical seismic exploration techniques have been used at sea for nearly two decades and have produced quantitative and exciting data about geologic structures under the ocean. Explosives are a favorite sound source for acoustics work, because they are such convenient high-energy, broad-band sources. The use of broad-band sources and frequency analysis on the signal often gives clues regarding the creature or geologic layer being studied.

One of the most exciting new uses for sound is in telemetering scientific data to the surface as it is being taken. Not only does this permit more data to be taken, but it also permits the scientists to study changes and transients in a less haphazard and survey manner. Acoustic beacons also provide a way of locating or following surface or subsurface buoys or of using a bottomed beacon as a local fixed point for a bathymetric survey.

Underwater Photography

In harbors the visibility may drop to a fraction of a meter. The visibility in the open sea is comparable to a thick fog and may range between 10 and 80 meters. Good pictures can be taken at about one-third to one-half of this distance. Although this limits photography or vision, it permits clear underwater pictures to be taken over a larger area than can usually be illuminated with artificial light. Numerous bottom photographs have been taken at depths up to several thousand meters. The problems of underwater photography are not primarily optical ones; rather, they are the mechanics and techniques required to handle the gear and to keep the camera at the right range from and pointed toward the target. The lens focus is set at three-fourths of the distance that it would be in air, and the amount of illumination is increased. Flashbulbs and electronic light sources have both been used with success. The easiest photographic subject to get is the bottom, because the picture can be taken in a downward direction, with the distance established when a weight on a known length of string touches bottom.

Underwater television is in its infancy, but it should do much to increase our knowledge of the ocean bottom and marine life at shallow depths.

Bathymetry

The development of piano wire in the 19th century permitted, for the first time, the making of a reasonable number of soundings in the open ocean. The invention in this century of the echo sounder, which electrically times and records a sound wave going to the bottom and back, has permitted continuous depth profiles to be made from ships underway. The great submerged ranges and deep trenches showed up very quickly, but only in the last few years have echo sounders been developed to give depths to, say, 1 meter out of 5000. This type of precision has been obtained by making the timing circuit and recorder precise to better than 1 millisecond, as in facsimile recorders that are used for transmitting weather maps. As usual in science, newer and more accurate data continue to open up new problems. The added precision is never a hindrance, and often it is essential in order to tell whether the ocean bottom is really flat, like parts of Kansas, or rolling, like parts of new England. In addition, it has shown that little ridges or valleys exist in broad plain areas, which might otherwise have been thought to be instrumental error. The finite width of the acoustic beam below the ship has some advantages and some disadvantages. The recording shows the closest bottom, whether it is exactly under the ship or not. Because of this, the records sometimes need greater interpretation, but also there is more there to interpret. The full potentialities of the echo sounder and its many variations have not yet been fully recognized or widely exploited.

Pressure Vessels and Materials

It is often possible to make instruments that do not need pressure-proof cases. A surprising number of commercial items, such as small photoflashbulbs, work well under pressure. Some subminiature vacuum tubes and electronic parts will stand depths of thousands of meters when they are housed in an oil-filled flexible container. Automobile and flashlight batteries operate satisfactorily at the bottom of the ocean if external insulation is provided. Smoked glass, waxed paper, or soft metal plates are water resistant and can be scribed with very light pressures.

Glass, bronze, stainless steel, aluminum, plastics, and ordinary steel have all been used successfully as pressure vessels, with the choice being dependent on weight, handling problems, availability, and cost. For the thicker instrument cases of cylindrical form, one can consider the ratio of the wall thickness to the radius of the tube to be the same as the ratio of the external pressure to the desired maximum working stress of the material. It is also possible to make pressure vessels of glass or aluminum that can go to a depth of several miles and still be light enough to be buoyant. Corrosion problems can be minimized by proper choice of materials, design clearances, and "elbow grease."

Oddly enough, oceanographers are seldom bothered more by leaks at great depth than they are at shallow depths. This is because, when designing for great depths, they usually take pains to design seals properly. Modern electronic equipment is amazingly trouble free if given reasonable care.

Conclusion

Many instrument problems, such as navigation, the collection of bottom samples, the measurement of gravity at sea, the design of unattended instruments, towed electric cables, marine meteorology, marine biology, and the study of radioactive waste disposal, are just as interesting and essential as those to which space has been devoted. Also, it has not been possible to discuss here the many oceanographic instruments in the shore laboratory that are needed to supplement seagoing work. This omission is only partly excusable on the grounds that they tend to be more like conventional instruments.

I hope that this article (*3*) gives some idea of the scope of oceanographic instruments. It should be apparent that most instrumentation should be simple, rugged, and reliable. However, for exploratory work, serious scientists use the best instruments available. In most cases, the designer has to be shipmates with his creation before it can be called an instrument. The designer and user must work as a team, because simple measurements and precise thinking usually result in a greater scientific product than precise measurements and simple thinking. Rather than dwell on the relative merits of theory versus measurement, I hope that instrument designers, experimentalists, and theoreticians will each do their work aggressively and well.

References and Notes

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Determination of Sources of Particulate Atmospheric Carbon

George D. Clayton, James R. Arnold, Frank A. Patty

The Los Angeles smog is probably the most publicized of any air pollution problem. Millions of dollars have been spent, and additional millions are presently being expended in an effort to determine the causative agent or agents that produce eye irritation, reduced visibility, rubber cracking, and plant damage. The attack on the problem by the multitude of agencies and organizations may be classified into two broad categories: (i) determination of the contaminant or contaminants causing the smog; and (ii) determination of the sources of pollution.

There is substantial evidence that an irradiated gaseous mixture of hydrocarbons and oxides of nitrogen produce the strong oxidizing property found in the Los Angeles basin air. It has been proved in experiments that a laboratory mixture having similar oxidizing properties to that found in the Los Angeles air (reported as ozone, with concentrations reported as high as 1.0 part per million) can cause rubber cracking, eye irritation, and plant damage.

The sources of contaminants have been extensively studied, and it is reported that the largest quantity of air contaminants in Los Angeles originate from combustion processes. It is estimated that approximately half of the pollution is created by auto exhausts and backyard incineration. According to calculations based on the consumption of gasoline, approximately 1000 tons of hydrocarbons, 300 tons of organic acids and aldehydes, and oxides of nitrogen and sulfur are emitted from exhaust pipes daily.

Larson (*1*) states that, on the basis of 3 pounds of rubbish per person per day, commercial and household rubbish amounts to about 6000 tons each day, with most of this material being disposed of by backyard incineration. Industrial rubbish, amounting to 3000 tons per day, is handled either by industrial incineration or by "cut and fill" operation.

Although extensive work has been done in studying the effluent of single sources of pollution, it has been understandably difficult to relate these findings to what is found in the general atmosphere.

It is well known that particulate matter in the atmosphere influences visibility. Photographs taken while backyard incineration was in progress show the effect this source has on reduced visibility in Los Angeles. The purpose of our investigation was to study the origin of the carbon constituent of atmospheric particulate matter.

There exists an unequivocal method for distinguishing between carbonaceous

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