ernment program, Phillips now has a pilot plant operating in North Carolina that was developed in this way.

Numerous other examples of the range of sample types analyzable by ICP exist. The materials include metals and alloys, minerals and refractory oxides, whole blood and serum, oils and organic compounds, soils, effluents, mineral acids, and rare earths. Observers say that monitoring environmental pollutants, determining contamination during food processing, and clinical analysis could all become major applications of ICP in the near future. A potential large industrial use is in wear metal analysis, a procedure in which wearing of metal parts in machinery is detected from the concentration of metal in lubricating oil.

As an atomic emission technique, ICP

Instrument Highlights

A New Meaning for the Term "Service Call"

One overlooked aspect of the microprocessor/minicomputer revolution in analytical instruments is that these components can facilitate servicing of the instruments. When all aspects of instrument operation are controlled by the electronic brain, then remote operation of the instrument—and remote servicing—by factory technicians becomes possible. This development can bring a new meaning to the term "service call."

One example of this approach is provided by the DuPont Company's DP-1, a gas chromatograph–mass spectrometer-data system with an integrated minicomputer that controls data collection and instrument operation. Through the use of a relatively inexpensive (about $1000) device known as a Modem, the DP-1 can be linked to any telephone receiver and operated from a remote location. If the instrument is not operating correctly, the owner or user can call a toll-free number at DuPont and place the telephone handset in the Modem; a technician at the factory can then operate the instrument and diagnose the problem in much the same manner as if he were physically present at the instrument site. Dan Carroll of DuPont estimates that as many as 90 percent of all electronic malfunctions can be diagnosed in this manner. Mechanical malfunctions, however, can be diagnosed only if they affect the electronics in some specific manner. In many cases, the malfunction can be repaired by the owner without further involvement of the technician. If a service call is required, the technician will know what the problem is and what parts may be required. The Finnigan Company has offered a similar service for about 3 years but, like DuPont, has only begun to publicize it this year.

The advantages to the instrument user are obvious: The amount of time the instrument is out of service can be reduced dramatically (particularly if the instrument is located at a site distant from a service center) and the cost of service is reduced. There are advantages for the manufacturer also. The cost of operating a service organization is astronomical, Carroll says, and anything that reduces that cost is beneficial to the company. The service also increases customer confidence in the equipment and the company, he adds.

Carroll thinks that most companies will be providing this type of service for large-ticket items within 5 to 10 years, both to reduce costs and to meet competition. It is not yet clear, however, whether it will be feasible to extend the service to lower-cost instruments. For many of these, the cost of the Modem would represent a substantial fraction of the initial purchase price—although the cost of Modems may decline as more are produced. Even for the less expensive instruments, though, microprocessors can reduce service requirements. Many microprocessor-equipped instruments manufactured, for example, by Perkin-Elmer Corporation incorporate programming that leads the user through a series of diagnostic steps to determine which part of the instrument is malfunctioning. Many types of problems can then be repaired without the delay and expense associated with a conventional service call.

—T.H.M.

A New, Rapid Method for Fourier Transforms

The Fast Fourier Transform (FFT) is a strong contender for the mathematical technique most commonly implemented on computers. Developed in 1965 by James Cooley of IBM and John Tukey of Princeton University, the FFT provides a way to calculate discrete Fourier transforms rapidly. It has thereby revolutionized the analysis of data in a number of fields, such as molecular spectroscopy, seismology, and signal processing for speech analysis, radar, and sonar.

Now, however, Shmuel Winograd of IBM has found a new way to compute discrete Fourier transforms rapidly. Although Winograd's method seems unlikely to knock the FFT from its perch as one of the mathematical techniques most often used, it may replace the FFT on certain special-purpose computers, such as those built around microprocessors.

The discrete Fourier transform is a mathematical technique that separates a complex signal into the frequencies that make it up. For example, a spoken word is recorded as a combination of sound frequencies. When these frequencies are separated, "voice prints" of individuals can be identified. Similarly, specific molecules are characterized by the energies of their electrons and the vibrations and rotations of their component atoms. These energies may give rise to spectral lines with very closely spaced or even overlapping frequencies, which may then be separated by the discrete Fourier transform.

The idea of analyzing spectral data with discrete Fourier transforms is an old one, but such analyses were computationally impractical before the FFT was developed. The problem is that the obvious way to compute a discrete Fourier transform of n data points requires n^2 additions and n^2 multiplications. In practice, n is often about 1000. Thus about 1 million multiplications and 1 million additions are required.

The FFT is based on theoretical developments leading to special tricks that allow investigators to combine some of the operations necessary to compute discrete Fourier transforms. Cooley and Tukey showed that, if n is a power of 2, the number of necessary additions and multiplications is only $\log_2 n$. Thus, if n is about 1000, the number of additions and multiplications can be reduced 100-fold. This meant that discrete Fourier transforms could be implemented on computers without being prohibitively expensive.

Winograd's new method of computing discrete Fourier transforms also relies on special tricks, but the method is totally different from the FFT. For example, rather than requiring n (the number of bears many resemblances to conventional arc, spark, or flame atomic emission. The elements to be analyzed are excited to numerous high-energy quantum states by an excitation source. The intensity of the light given off as these atoms decay to lower-energy states is then proportional to the concentration of the elements in the sample. One difference between ICP and other emission techniques comes in the selection of the emission lines to be monitored. A particular species will generally emit light at several wavelengths. The chosen wavelength depends on which spectral line has the strongest emission relative to the underlying background and noise. Since the excitation conditions in the plasma are different from those in arcs, sparks, and flames, the optimum spectral line can be different as well.

data points) to be a power of 2, Winograd requires it to be a product of relatively prime numbers—that is, numbers such as 7, 8, and 9 that have no common factors. He finds that he can perform discrete Fourier transforms with only about 1/5 of the multiplications required by the FFT. Moreover, he has shown that, at least when n is a prime, the number of required multiplications cannot be further reduced. Winograd reports that his method and the FFT require about the same number of additions.

With such a drastic reduction in the number of multiplications, it seems logical that Winograd's method should replace the FFT. The problem is that the time required for multiplication and addition is only part of the picture. Time is also required for what computer scientists call "overhead"—loading data into the computer, storing it, and moving it around. James McClellan of the Massachusetts Institute of Technology (MIT) is among those who have found that Winograd's method requires more overhead than the FFT—and this increased overhead affects the feasibility of the method.

McClellan points out that multiplication is very rapid on today's general-purpose computers, such as the IBM 360 or the PDP 11. On these computers, the FFT is still faster than Winograd's method. On the other hand, McClellan and his student Hamid Nawab, find that Winograd's method is faster than the FFT on special-purpose computers, such as microprocessors, on which multiplication is very slow.

Since Winograd's method may be a viable alternative to the FFT for some users, Charles Rader of MIT's Lincoln Laboratories is beginning to work on computer hardware to implement it. Thomas Parks of Rice University developed a slightly different way of implementing Winograd's method that further improves its performances on special-purpose, but not on general-purpose, computers. Parks says he has received a number of inquiries about his work from such instrument companies as Tektronix. Representatives of these companies, however, say they are still in the preliminary stages of investigating Winograd's method.

It is Rader's opinion that it will take another year or two for the relative merits of the methods to be sorted out. Even if Winograd's method does not replace the FFT, it is based on what Rader calls "a bag of tricks" that should prove useful to those investigating signal processing.

—G.B.K.

NSF to Fund Regional Instrumentation Facilities

The rapid increase in instrument capabilities demonstrated at the Pittsburgh Conference in recent years is a blessing to scientists because it extends the range of experiments that can be performed and the speed with which they can be carried out. It is, however, a mixed blessing. Increases in sophistication lead to a rapid obsolescence of existing equipment. They generally also lead to increases in cost, and many types of instruments, including nuclear magnetic resonance (NMR) spectrometers, mass spectrometers, and x-ray diffractometers, are being priced out of the reach of individual investigators. More and more, it is becoming apparent that these large ticket items must be shared among a number of investigators.

One step in this direction, now being initiated by the National Science Foundation (NSF), is the establishment of regional instrumentation facilities. NSF has allocated about $3 million during fiscal 1978 for the establishment of five or six such centers. The new laboratories will be designed to ensure that state of the art instruments are available to those who need them and that highly qualified personnel will be on hand to operate and maintain the instruments and, if necessary, to help in the interpretation of data. Ideally, says the program's director, Tom Farrar, the funds will be used to augment existing centers where expertise already exists.

A unique feature of the NSF program is that industrial scientists, particularly those from small companies, will be encouraged to use the facilities. In this manner, NSF hopes to achieve the twin goals of promoting basic research in industry and fostering more cooperation between university and industrial scientists. Preference will thus be given to applications that demonstrate industrial interest.

The idea of sharing instruments is, of course, not new. The Department of Energy (DOE and its predecessor agencies), for example, has for many years provided academic scientists with access to instruments and opportunities for research collaboration. DOE will, in effect, extend this program by making a financial contribution to the NSF project for at least the first year and by participating in proposal selection. The National Institutes of Health (NIH) has an ongoing program, similar to that proposed by NSF, to support facilities for scientists engaged in biomedical research; at these facilities, however, priority for use of the instruments is given to NIH-supported scientists. NIH will join the NSF program in an advisory role and will also assist in proposal selection.

One example of what such a facility might be like is the 360-megahertz NMR spectrometer facility opened at the University of Pennsylvania at the end of January. This NIH-supported regional facility is meant to extend high-resolution NMR techniques to biological specimens. The $440,000 spectrometer is particularly useful for studying nuclei, such as phosphorous-31, carbon-13, and fluorine-19, that can be incorporated into living systems. Use of the instrument is available to anyone whose research is publicly funded; the cost is $10 per hour, in line with the policies of both NIH and NSF to keep user costs low. A similar NMR facility has been in operation at Stanford University for 3 years.

The first grants under the new NSF system are expected to be awarded in September.—T.H.M.