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Lawrence Berkeley Laboratory

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I. INTRODUCTION[1]

During the past three decades tremendous strides have been made in the industrial progress of our country. However, during this same period we have witnessed an increasing degradation to the quality of our environment. The question has been raised, can we continue to enjoy the benefits of labor-saving devices, improved communications and better transportation without at the same time rendering our planet uninhabitable. The answer is that of course we can if we apply the same diligence that gave us our present high standard of living. With each decision we must conscientiously analyze the effects of the environmental impact along with such other factors as return on investment, efficiency and marketability. An engineering executive speaking of power plant design said recently that our main concern today is to reduce the environmental unbalance. A word of caution must be injected at this point, namely, it is of great importance that while investigating every facet of the ecological balance, we do not completely impede progress and enter a period of industrial dark ages. For example, it is within our present technological capabilities to meet our new power requirements without sacrificing the quality of the air we breathe and the water we drink. Also new chemical complexes can be constructed without blighting the surrounding neighborhoods. Petroleum can be refined and transported without our rivers and coastline suffering from oily residue. These are all engineering problems. Once a problem of this type has been formulated it can be solved using sound scientific principles.

Let us look at the tools available to us: The great national resource of technical expertise resulting from the R and D that has taken place at universities, National laboratories, research institutes and corporations since World War II. However, the technology which has become commonplace in physics, chemistry and nuclear research and development has not yet been fully applied to problems of environmental protection. This is a problem of education and communication. We must be certain that good and rapid, two-way communication channels exist between R and D groups in university and industrial laboratories and those responsible for improving our environment.

In technology we find physical measurement to be fundamental to the whole concept of carrying out the task before us. As Lord Kelvin so aptly stated almost one hundred years ago, "I often say that when you can measure what you are speaking about and express it in numbers you know something about it, but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind." In our broad definition of measurement we mean the ability to determine the numerical value of some quality or parameter in terms of a known standard. Having made a series of measurements we are then in a position to make a value judgement as to the consequences of a change in that parameter. We may realize that the air around us is contaminated simply by the smell; however, we must make measurements to determine the sources of the contamination. One of the weaknesses of the environmental problem is the scarcity of fundamentally new concepts. It is particularly important that each new idea, each novel technique wherever it is developed be exploited to the fullest to improve the quality of our surroundings.

Consider the presently known principles that may be employed in the measurement of the physical world about us. The electromagnetic spectrum (including both electrical and magnetic effects) extending from the shortest to longest wavelengths includes x-radiation, ultraviolet, visible, infrared, microwave, radio frequency to audio frequencies. See Fig. 1 . To this may be added mechanical effects (such as acoustic waves), chemical effects, and high-energy elementary particles. Measurement in general is limited to some observation of these phenomena.

A whole class of measurement is to expose a specimen under investigation to some part of the spectrum and to observe properties such as the resultant transmission, absorption, reflection or perhaps reradiation at another wavelength. The generic term for such a measuring instrument is a spectrometer; thus a device measuring the absorption of a portion of the ultraviolet spectrum may be called a UV spectrometer. This type of measurement is particularly valuable in the context of our studies. Many highly specialized subsets have arisen which explore one or more qualities of only a part of the whole electromagnetic spectrum, e.g., lasers and holography.

In our present discussion we cannot possibly cover all detection methods. Three methods employing recently developed technology that we expect to be valuable in environmental measurement will be explored in more detail: X-ray fluorescence, microwave spectroscopy and nuclear magnetic resonance.

The bibliography lists several sources in the literature describing current air and water monitoring methods.

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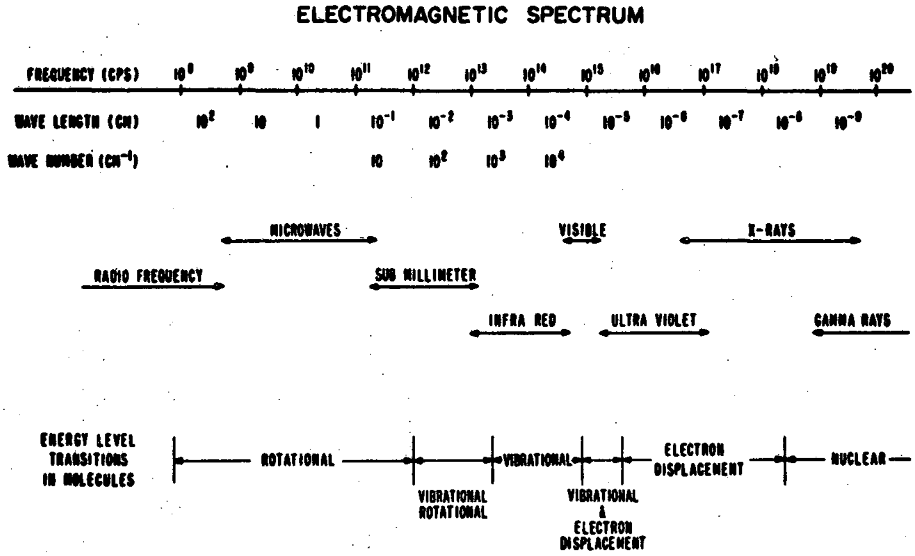

Figure 1. The electromagnetic spectrum

(From Hearn, Ref. 5)

II. APPLICATIONS OF NEW TECHNOLOGIES

A. X-Ray Fluorescence Spectroscopy

X-Ray emission spectroscopy has been a well-known technique for many years.[1] An x-ray tube usually provided the primary excitation. The target material in the tube was selected to give x-rays (or photons) in the energy range of interest. Photons striking the surface of the specimen under examination caused x-rays to be emitted which were characteristic of the elements present in the specimen. The process required that the sample be analyzed by x-rays (or particles) of enough energy to kick out inner-shell electrons in the atom. When higher energy electrons replaced these, x-rays were emitted. These secondary x-rays were then analyzed by scattering from the surface of a crystal. A radiation counter mounted at a precise angle was the detector. The advent of the semiconductor detector, perfected by Goulding and others in the field during the 1960's significantly changed the whole technique.[2,3,4]

Now the efficiency of the process (and thus the time to make the measurement) has improved by orders of magnitude. The mechanical construction has been significantly simplified. It is no longer necessary to construct an elaborate goniometer to measure the scattering angle from the crystal. The high-intensity x-ray tube can be replaced by either a low-intensity tube or a radioisotope source. Thus an expensive, cumbersome apparatus has now become a convenient instrument.

Fig. 2 illustrates the presently employed method for exciting a specimen under examination. The excitation may take several forms depending on the application. Radioactive sources such as Americium 241 may be used; in this case it is often convenient to make the source in the shape of a ring. Another method of excitation has been the development of low-power, monochromatic x-ray tubes. If a scanning electron microscope is employed for excitation, regions as small as 1 μ can be explored.[4] The use of ion beams allows one to detect quantities of less than a nanogram for a number of elements.

Of the various methods employed, however, x-ray excitation appears to be the most sensitive and versatile.[2] To compare this method with competing technologies let me quote from Landis et al., (Ref. 3):

"Semiconductor X-ray spectrometers are distinguished by their ability to simultaneously survey a whole spectrum of trace elements present in samples at levels substantially lower than 1 ppm. More sensitive methods can be devised for particular elements: for example, atomic absorption can be used for such elements as mercury. Neutron activation can exhibit greater sensitivity than X-ray fluorescence for some elements; but its sensitivity is poor for many elements, and the activation process is slow and costly. The activation of sodium in biological samples necessitates a long "cooling off" period (often a month) before a sample can be analyzed. Other methods

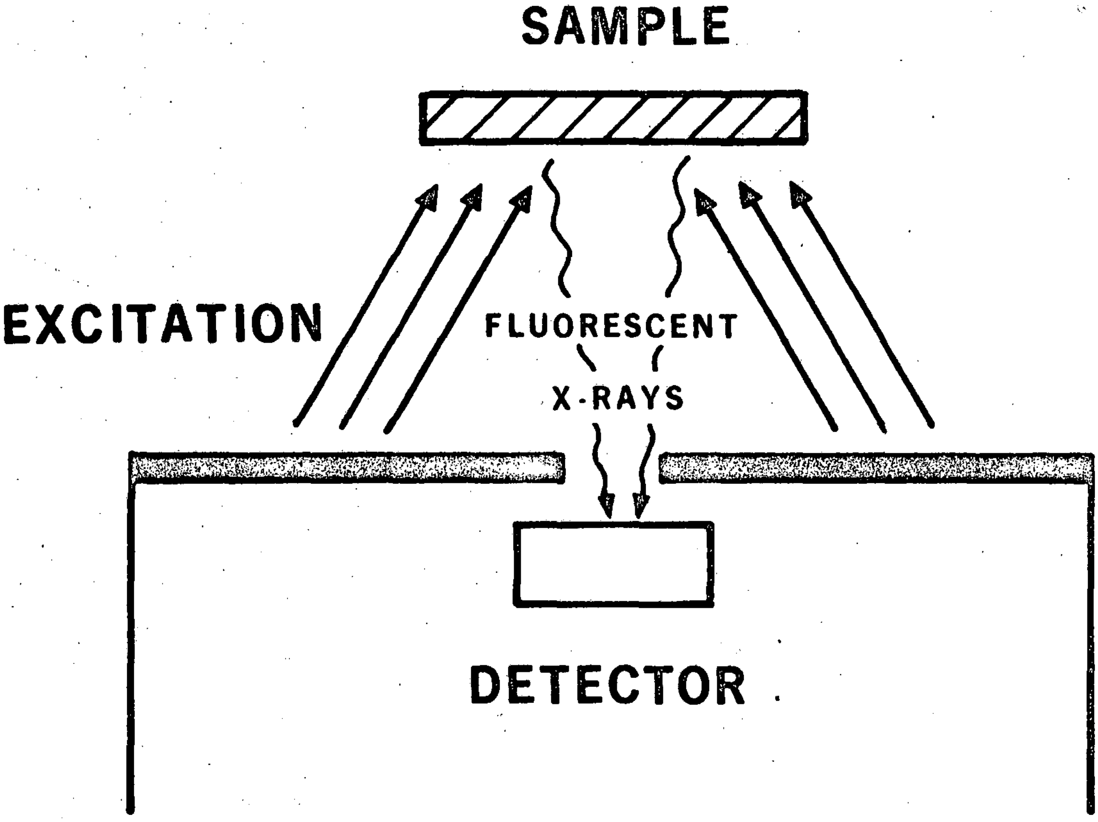

Fig. 2 Schematic of X-ray fluorescence method. (From Jaklevic and Goulding, Ref. 2)

including atomic absorption, require extensive sample preparation, while X-ray fluorescence requires very little, though removal of water by freeze-drying is useful in many cases. For these reasons, it seems that X-ray fluorescence analysis may find a wide range of applications."

The application of this new technology to environmental problems is obvious. Fig. 3 is an analysis by x-ray fluorescence spectroscopy of an air-filter which had been exposed to atmospheric particulates for four hours.[2] The figures above each element refer to the concentrations on the filter in micrograms per cm^2. The power of this method is illustrated by the large number of elements that can be detected simultaneously.

Medical applications of this technology may turn out to be the most important. Fig. 4 is the analysis of a sample of freeze-dried whole blood.[2] The data-taking interval was only ten minutes. The total blood sample required was less than 2 cc. The concentration of lead is several times normal which corroborates with the fact that the child from whom the sample was taken suffered from lead poisoning.

Limitations of this technique are that it can only detect elemental rather than molecular concentrations. Because of signal-to-noise problems it is presently impossible to detect elements lighter than carbon.

These are only two of many examples in air, water and biomedical monitoring wherein x-ray fluorescence is a most promising method of analysis.

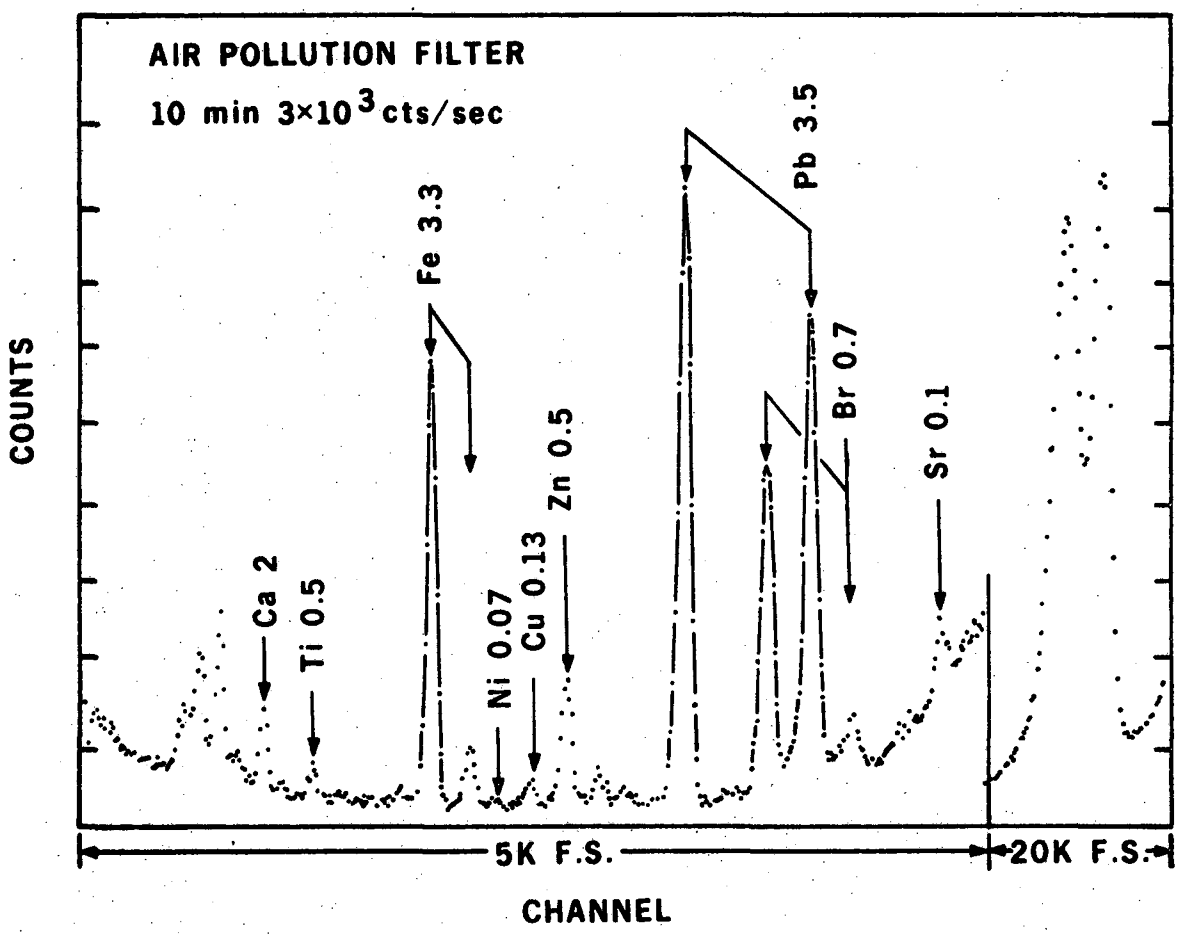

Fig. 3 Fluorescence spectrum of air pollution filter. Numbers are concentrations on the filter in μgm/cm^2. (From Jaklevic and Goulding, Ref. 2)

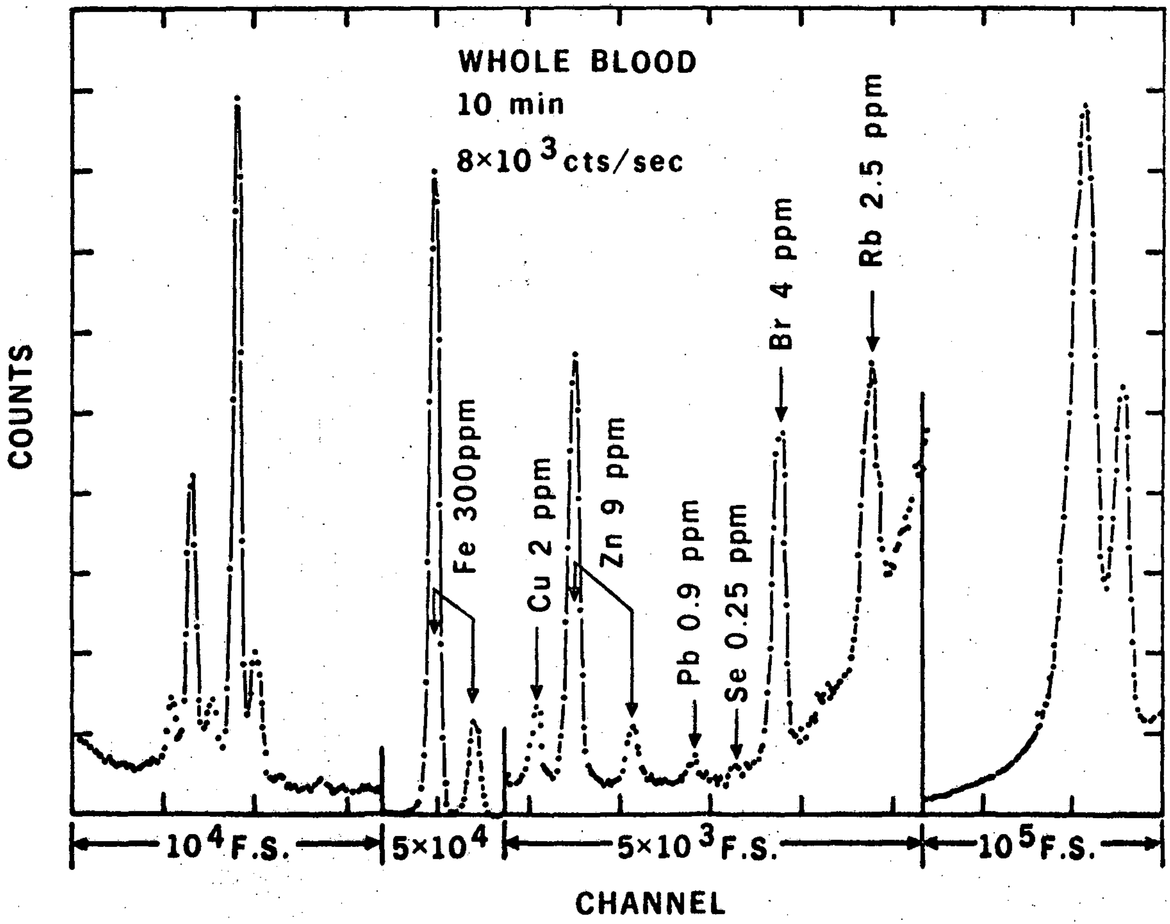

Fig. 4 X-ray fluorescence spectrum of whole blood. The measured concentration of lead is several times normal indicating lead poisoning.

(From Jaklevic and Goulding, Ref. 2)

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B. Microwave Spectroscopy

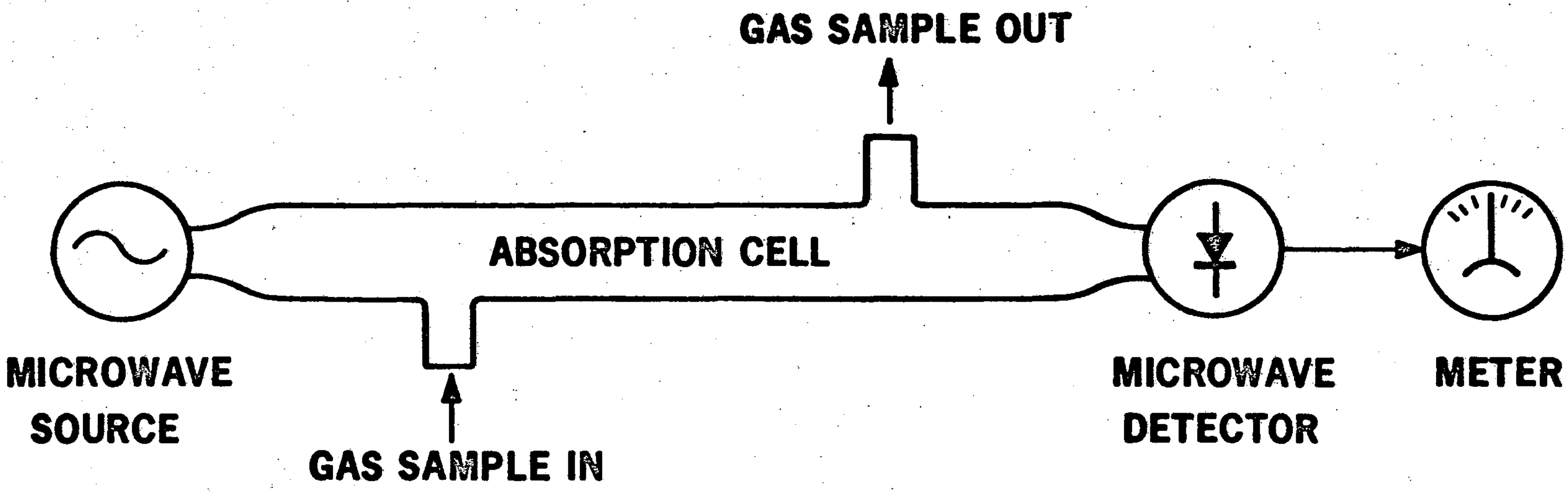
Another technology which has only begun to be employed in Environmental Monitoring is Microwave Spectroscopy[1]. This phenomenon depends upon the selective absorption of microwave energy by some gases at low pressure. To make the measurement, the microwave radiation is swept over a given frequency range, and the power transmitted through the sample is observed. Transmission (or absorption) is plotted as a function of frequency. While microwave spectroscopy was suited only to laboratory analysis in its early development, with the advent of solid-state microwave radio-frequency sources, it is expected to become practical for both laboratory and field monitoring. A simplified block diagram of a spectrometer is shown in Fig. 5 .

In microwave spectroscopy one is interested in the changes in molecular rotational energy states of gases. Or, in simpler terms, a molecule with a built-in electric dipole moment may be thought of as a spinning top. At certain microwave frequencies there is a change in the speed of rotation. Since each chemically different molecule has a significantly different structural configuration, its rotational spectra offer a distinct fingerprint in any mixture. Microwave spectroscopy helps us to identify these fingerprints.

Most molecules have permanent dipole moments, but a few like CO_2 and benzene do not. Only molecules with permanent dipole moments lend themselves to measurement by this method. The sensitivity to microwave absorption depends upon the value of the absorption coefficient. Some gases, such as ammonia with intense absorption coefficients, can be detected to nearly 5 ppb while for other pollutants, spectrometers may be sensitive to only 100 ppb. For ultimate resolution this method presently cannot compete with a gas chromatograph-mass spectrometer.

Sensitivity may be increased by preconcentrating the gas sample. Leskovar[2] has pointed out that the sensitivity of this method will also be improved as microwave generators and detectors with improved noise spectral characteristics become available. On the other hand, the length of the absorption cell (presently not less than 1 meter) could be proportionally shortened for the same sensitivity making a more compact unit.

At the present time 100 GHz is about the upper limit of frequency generation at the power levels required. As the frequency of microwave sources increases, other spectra may be expected to be present and aid in the identification.



SIMPLIFIED MICROWAVE SPECTROMETER

Fig. 5

This technology also has the advantage of requiring small samples; for gases with strong absorption, as little as 10^{-12} mole is sufficient sample.

Whereas X-Ray Fluorescence is suitable for identifying several elements which may be simultaneously present in a sample, microwave spectroscopy is applicable for measuring several gaseous compounds which may be present at the same time. Simple spectra such as formaldehyde (HCOH) may be identified by sight. See Fig. 6. More complex spectra can often be identified by comparison with known constituents. See, for example, Fig. 7, again taken from Hearn, Ref. 3. (ETSH refers to Ethyl Mercaptan and MESH to Methyl Mercaptan.) Complex spectra require a computer to sort out the various compounds. This is accomplished by having the computer compare each spectrum with a library of known spectra stored in its memory. Molecules with greater than twenty atoms[4] have such complicated spectra that they have not yet been cataloged. Jones[5] has prepared a bibliography of studies of a number of organic and inorganic molecules. Ten thousand lines have been identified in the frequency range of 25 - 40 GHz . Over 23,000 lines of isotopic species have been listed according to frequency.[6,7]

Another important property of this technique is the ability to measure both the quantity as well as constituency of the gases. The absorption is directly proportional to the gas concentration. Thus with appropriate computer circuitry one might develop an instrument that would identify each of one hundred different compounds and then provide the precise concentration of each. The limitations of this method are that the sample must be in gaseous form and for good resolution, the measurement must be made at low pressure. Also, some gases are not detectable.

Hewlett-Packard has recently introduced a commercial microwave spectrometer designed for air monitoring. It is the Model 8460A Molecular Rotational-Resonance Spectrometer.

In summary this technique appears to have a promising future. It is expected to complement GC - MS and NMR in the identification of organic and inorganic compounds. Where one is doing tracer studies by tagging with radioactive isotopes, microwave spectroscopy offers a real potential. Chemically identical molecules composed of different isotopes can be separately identified!

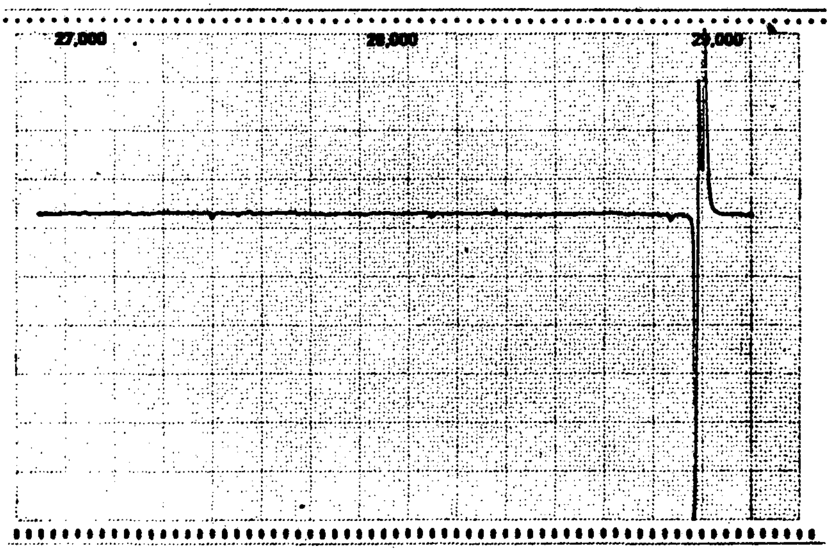
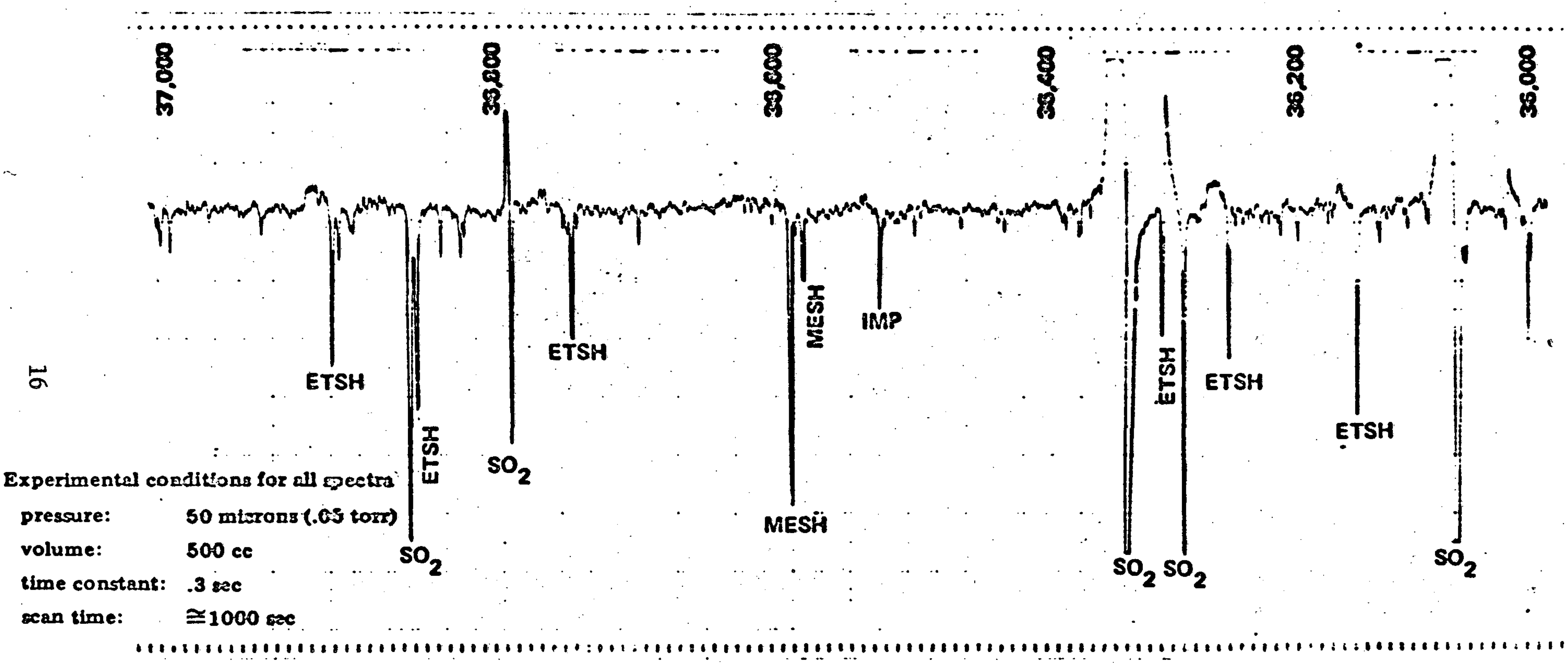


Figure 6 Formaldehyde (HCOH)

(From Hearn, Ref. 3)



Experimental conditions for all spectra

pressure: 50 microns (.05 torr)

volume: 500 cc

time constant: .3 sec

scan time: ≅1000 sec

Figure 7 Mixture of Sulfur Compounds

(From Hearn, Ref. 3)

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C. Nuclear Magnetic Resonance

A third technology that has enjoyed widespread use in research laboratories is Nuclear Magnetic Resonance.[1,2,3] The original discovery of NMR was made independently by physicists working at Stanford and Harvard in 1946. This resulted in Professors Block and Purcell jointly sharing the Nobel Prize in Physics in 1952. The fundamental equation of NMR relates frequency and magnetic field strength. This constant, called the gyromagnetic ratio, is the relation of the magnetic moment of an atom to its nuclear spin.

A spectrometer consists essentially of a sample probe, a magnet, a radio-frequency source, a detector and the associated identification and recording circuits. A block diagram of a simple spectrometer is shown in Fig. 8. The interaction between the radio frequency and the magnetic field is observed as an absorption in the energy coupled to the sample probe. Usually the magnetic field is slowly varied about the absorption point; however, some units sweep the frequency instead. Most sample probes have the provision of rotating the sample in a capsule with an air-bearing turbine to reduce the inhomogeneity of the magnet field. Also the sample is often cooled to improve the signal-to-noise ratio. Further improvement in signal-to-noise ratio may be made by signal averaging techniques or computer processing of the output signal.

Usefulness of NMR arises from its ability to interpret reactions within and between molecules. About one hundred and fifty different isotopes have permanent nuclear magnetic moments; a number of these have been employed in chemical identification by NMR. However, about 90% of all NMR studies have centered upon the protons (the nucleus of hydrogen) in molecules.[1]

Chemical shift is a term that describes the characteristics of the internal structure of molecules. Chemical shifts, resolution and sensitivity all increase with increasing magnetic field. Thus it is important that the field strength be as high as possible (usually 25 - 70 kilogauss). Early spectrometers employed electromagnets or permanent magnets; recently higher-resolution instruments have used superconducting magnets.

NMR is a powerful technique that allows not only the identification of the atoms making up the molecules but also the bonds linking the various rings of organic molecules. The technique has been useful in studying synthetic polymers, proteins and nucleic acids. It is also expected to be useful in identifying the many constituents involved in air and water pollution.

A shortcoming of NMR is that some abundant isotopes, such as ^{12}C and ^{16}O, do not possess magnetic moments and are thus not detectable.

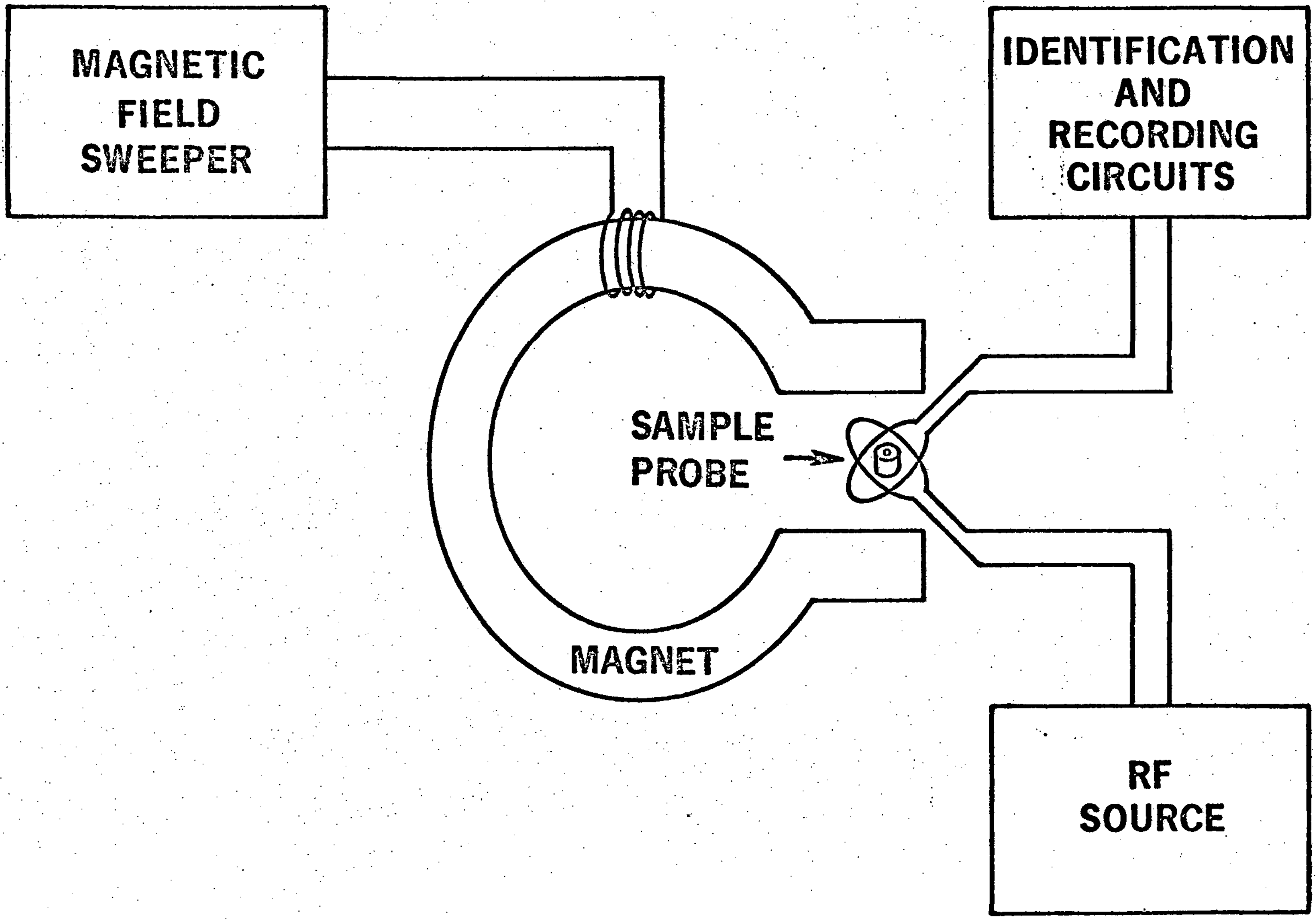

Fig. 8 Simplified NMR Spectrometer

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III. GENERAL INSTRUMENTATION CONSIDERATIONS

A. The Ideal Instrument

After reviewing several technologies in some detail, it is appropriate to consider the overall class of environmental instrumentation in general.

Present-day instruments although adequate in many respects still have a number of shortcomings. Let us list what would be the "ideal" instrument for the next generation of environmental monitoring:

1. The detector or transducer should respond to various elements, compounds or parameters and allow one to distinguish clearly among each constituent. That is, the detector should be specific and not subject to interferences. Conversely, instruments that can identify a number of parameters, e.g., Technicon Air Monitor IV, are meeting with more and more popularity.

2. The transducer should indicate the material present quantitatively as well as qualitatively.

3. Transducers operating on physical principles are preferred to those requiring the use of wet-chemical methods.

4. The instrument should have a fast response so that one can immediately take advantage of the information gained. A number of reactions are time dependent; for example, the conversion of nitrogen dioxide to nitric oxide and atomic oxygen in the presence of sunlight must be measured rapidly. The reaction $NO_2 + h\nu \longrightarrow NO + O$ stops within 10 seconds after the sunlight disappears.

5. Greater sensitivity is of particular importance. As the ambient levels of contamination decrease, it is desirable that the instrumentation be able to cope with these lower levels.

6. Instruments should be capable of being read out both directly, e.g., for field use, and into remote data-handling facilities (for stationary or laboratory use).

7. The instruments should be capable of accurate calibration either in the laboratory or the field. Erroneous data are worse than no data at all.

8. Instruments should be rugged and thoroughly reliable.

9. An finally, the price must be right.

B. State-of-the-Art Electronics

At this point it would be appropriate to make a quick review of the state-of-the-art in electronics instrumentation and readout. Electronic readout devices designed prior to the early 1950's employed electron tubes almost exclusively; however, during the 1950's transistors supplanted tubes. Likewise electromechanical display devices were replaced by gaseous and solid-state displays. Weight, volume and power requirements shrunk by factors of 10 to 100. A small module would now accomplish the same mission where a whole chassis was needed previously.

The reliability on well-designed electron-tube equipment experienced catastrophic failure rates ranging between 1 and 0.1% per 1,000 hours of operation (1 per 10^5 to 1 per 10^6) for each tube in the circuit. Likewise, transistors in well-designed equipment can be expected to have failure rates that are ten times better, i.e., 0.01% per 1,000 hours of operation of each transistor. The technology of integrated circuits is now advanced such that nearly all of the components are contained in packages typically 0.3 inches wide X 0.8 inches long X 0.2 inches high.

Each integrated circuit (I.C.) such as an operational amplifier or a storage register will usually contain ten to one-hundred or more active devices (transistors). The reliability of this entire unit will be approximately the same as a single transistor mentioned above - 0.01% per 1,000 hours of operation. It may take some reflection to compare maintenance to replacement cost ratios, but the exercise should be done.

Speaking of costs, the reduction in price of electronics equipment to industrial users is no less dramatic. Electron tube amplifiers costing $50 could be replaced by discrete-component semiconductor amplifiers for $10. Nowadays the price of a Texas Instruments, high-performance Op-Amp, SN 72709P is $0.97 in lots of 10 to 99. Why then is the cost of modern equipment so much higher? The increased price of present-day equipment is due in large part to the greatly increased sophistication of the tasks it is capable of performing.

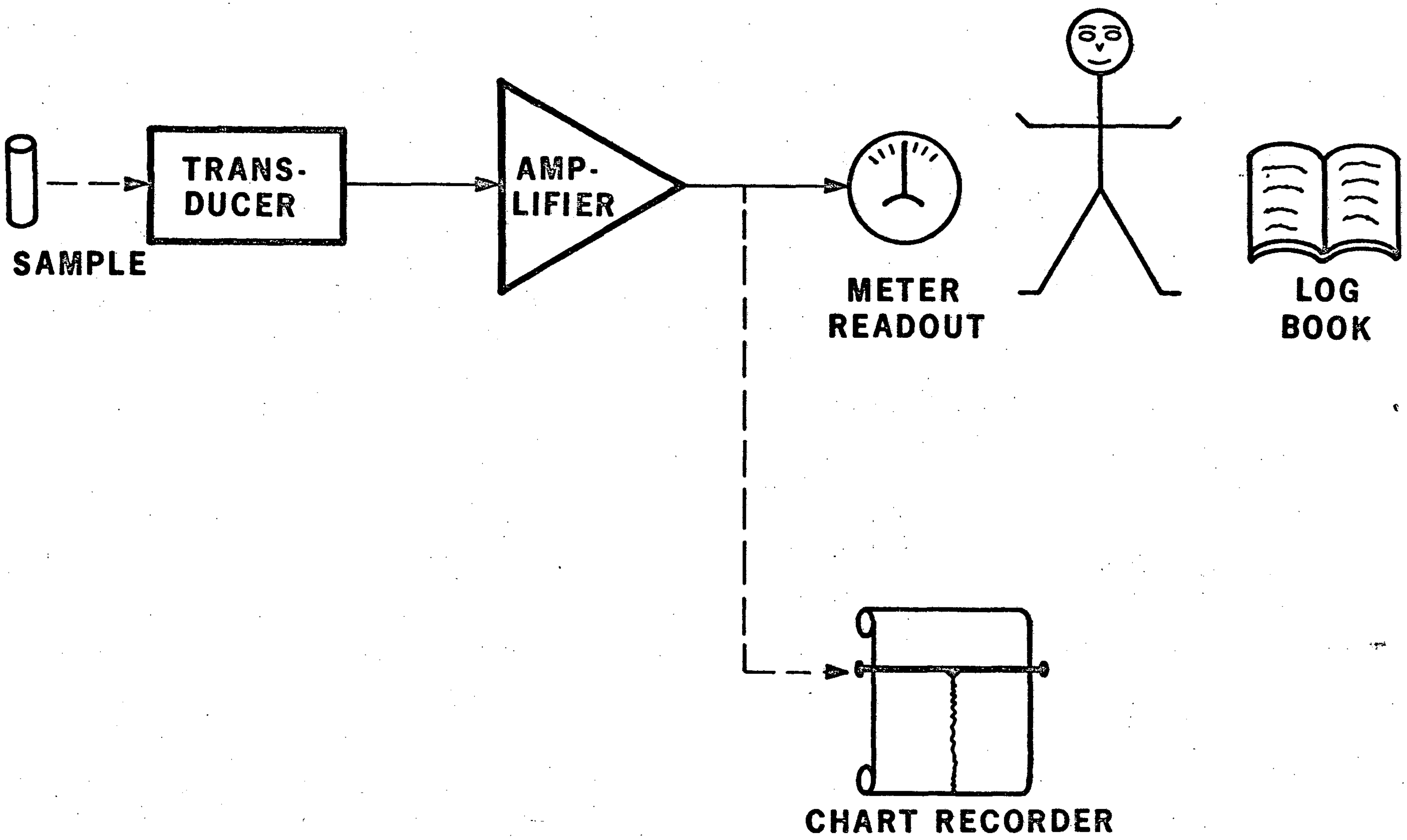
If your corporation is manufacturing environmental monitoring or control equipment, you should review your equipment design at the earliest opportunity. All presently manufactured equipment employing thermionic electron tubes (except for high power) should be redesigned at the earliest possible moment. Apparatus employing discrete, semiconductor components should likewise be examined in view of converting a great deal of the design to integrated circuits. Companies using monitoring or control instrumentation for plant processing should likewise review the long-term maintenance/replacement cost ratio on existing equipment.

C. Data Recording Principles

Let us examine the various ways in which information may be recorded. Data consists fundamentally of two kinds of information. First is the numerical value of a particular parameter which may have one value out of many possible values. For example, the carbon-monoxide concentration in the ambient atmosphere or the concentration of DDT in ppm of stream water. The second property of data is the time at which the record was made. In some observations only the numerical value of the parameter is important. In many other observations both the time as well as the numerical value of the observation are significant. For example, in a study of the concentration of oxides of nitrogen over the Santa Ana Freeway in Los Angeles, one needs to know both the concentrations in micrograms per cubic meter as well as the hour, day and year of the occurrence.

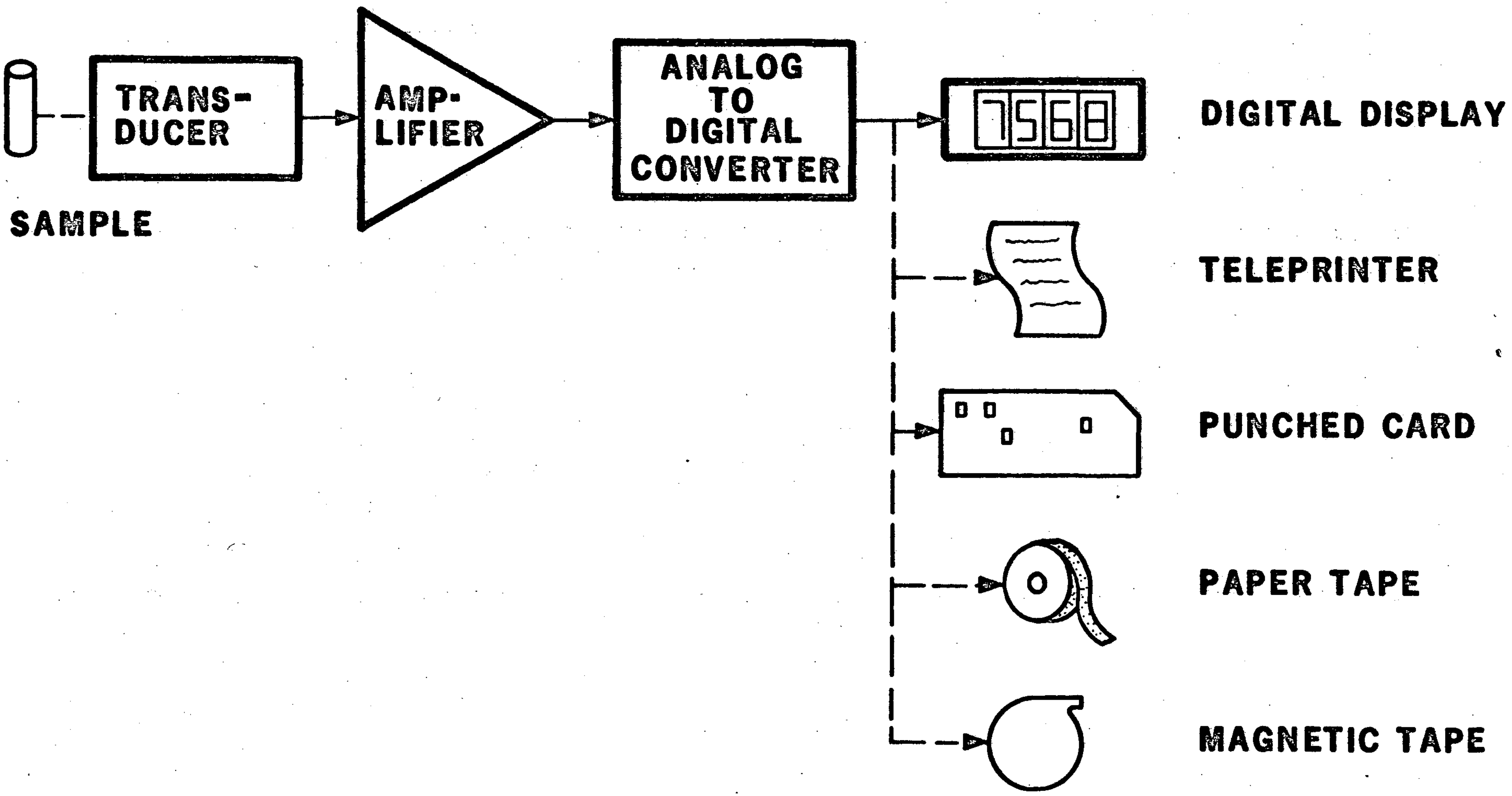
At this point we should discuss the different kinds of time data that can be observed. Real time data I would describe as those being observed, processed and fed to the decision making point while the experiment or test is still in progress. Thus, if the results of the tests indicate that there should be a modification to the test, it can be made while the experiment is still in progress. In contrast, delayed-time data are not generally available for decision making while the test is still in progress. In a simple analogy "live" TV may be considered to be a real-time observation; while last year's re-run is observed in delayed time. When data taking is not interrupted it is defined as being continuous. If data are recorded only periodically, a sampling process takes place, and the information is called sampled data. For example, an uninterrupted chart record of temperature is continuous; a reading made every hour is sampled.

Data may be recorded in either analog or digital form. A simple example may clarify the difference: The speedometer on an automobile indicates speed in analog form while the odometer records the distance travelled in digital form. When data are recorded as a continuous function of the variable being observed, they are known as analog data. See Fig. 9. When data are recorded as a series of discrete values, for example in Arabic numbers, the recording is termed digital. See Fig. 10. In the example above the distance which an automobile has travelled is displayed numerically to the nearest tenth of a mile. Most of us have grown up using the decimal numbering system where ten different symbols represent the numbers between zero and nine. Electronic circuits, on the other hand, are more easily constructed and more accurate if they respond to only two numerical values, on and off or zero and one. This simplest of all counting methods is called the binary number system. A whole technology in the last 30 years has grown up wherein we may represent any value of a variable by an appropriate series of binary digits. The number "1" is the same



AIR- OR WATER- QUALITY MONITOR WITH ANALOG READOUT

Fig. 9



AIR- OR WATER- QUALITY MONITOR
WITH DIGITAL READOUT

Fig. 10

in both binary or decimal representation; however, the number 47 in decimal form becomes 101111 in binary form.

It is appropriate at this point to ask when analog and when digital recording are more appropriate. To answer this one must consider the precision or accuracy of the reading that is required. If one is only concerned, for example, that the temperature of a solution is normal or abnormally high, a binary indicator is sufficient, for example, the indication of a warning light or bell. If it is necessary, however, to read the temperature within one part in a hundred (1%), an analog meter reading is often used. When accuracies of greater than 1% are desired, digital recording again becomes desirable for two reasons, 1) it is often more practical to transmit, store and record digital information than analog information, and 2) it is generally difficult to display information in analog form with better than 1% resolution. For example, a paper chart ten inches wide can easily be read to within one-tenth of an inch but may only be read to within a hundreth of an inch with difficulty. It might also be pointed out that digital data lends itself to coding and error checking more readily than analog; where data are to be transmitted over noisy lines a "Grey code" is employed: - only one digit at a time is changed between consecutive numbers to reduce error.

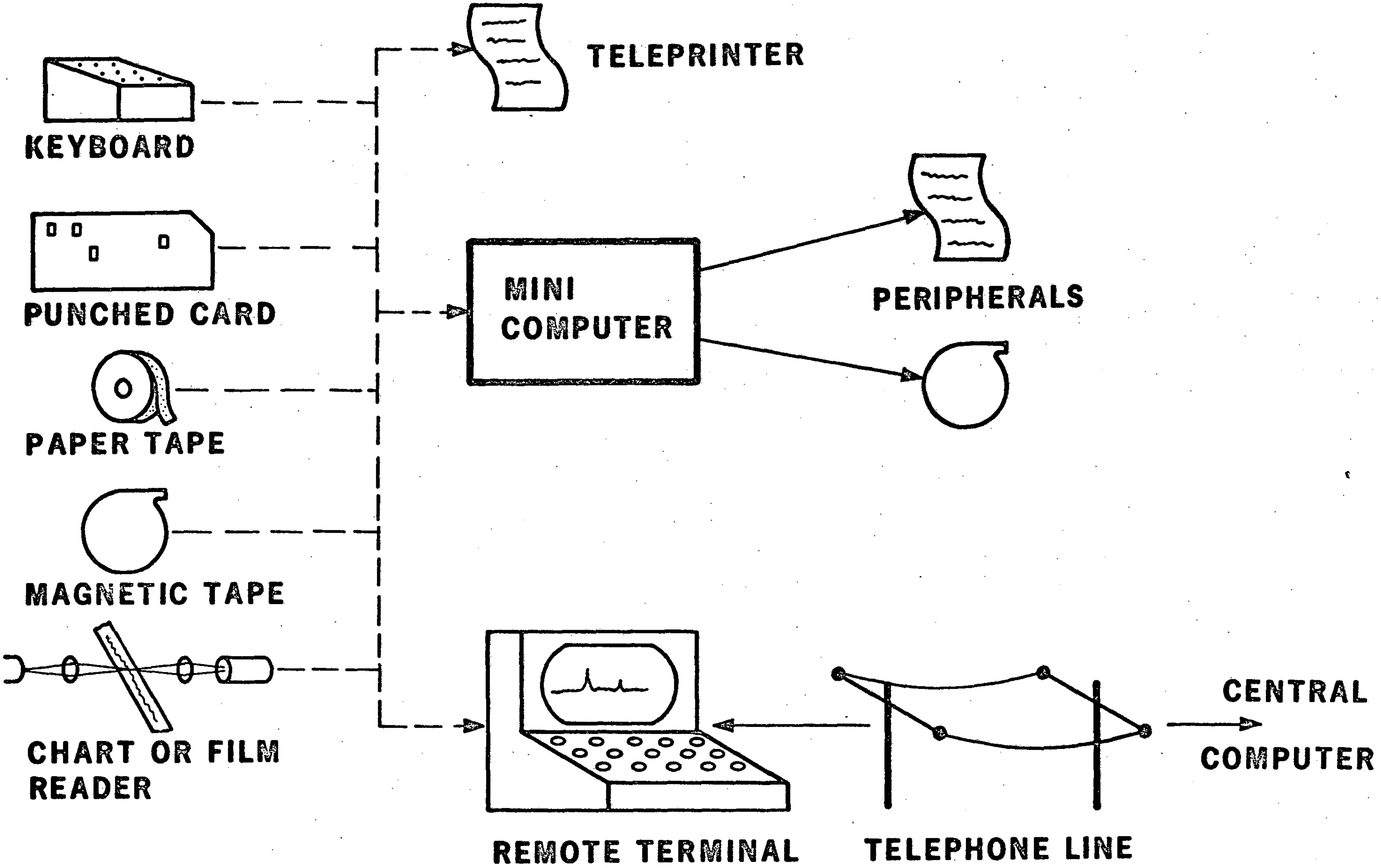
In tracing the history of environmental instrumentation one becomes aware of the fact that we have not taken full advantage of the advances in science and technology; consequently we have not come as far as we should. The great majority of instruments which were first employed used wet-chemical processes. In colorimetric determinations, for example, the color of a solution at the end-point of the process was compared with a reference chart or to the color of a standard solution; in a process where the evaporated residue of a water sample was weighed, the results were logged in a notebook. As transducers responding to chemical or physical parameters were developed readout became possible by means of electrical meters, see Fig. 9. Of course, most meters were incapable of storage and so an operator was required to make a record whenever a reading was desired. Further refinement came when a recording pen was affixed to the meter needle and the chart recorder was born. Less than 10% of the presently used monitoring instruments have advanced beyond the most sophisticated recorder mentioned above. The majority have not gone this far; thus all should be considered primitive in terms of what can be done today. When a comparison of the color of solutions is made or a strip-chart recording is read manually, the process is subject to human interpretation and error. Interpretation is a matter of degree: - Is the solution blue-green or green-blue? Error is simply a human mistake, such as the transposition of the order of numbers in the transmission of information. Human beings although very versatile and capable of making observations under difficult conditions still are prone to judge their observations by how they feel. Electronic comparison circuits, on the other hand, if properly calibrated and checked, are much less prone to error. Recording methods which have been employed in nuclear research or the computer industry for many years should certainly be considered in the design, use and maintenance of environmental instrumentation. Although some operating personnel may say that you cannot afford to automate the read-out functions; in many instances due to the increased cost of labor, automated readout is imperative. An example will illustrate the case. At an oil refinery visited last August, one skilled technician spent full time reading and interpreting strip-chart recordings from gas chromatographs. Let's explore the equipment and manpower costs to bring the identification and quantitation of these GC records under computer control. Assume that the operator presently spends 10% of his time preparing samples and injecting them into the GC. The remainder of his time is spent in identifying each peak by retention time and finding the concentrations of each. The utilization of a small on-line computer could reduce the time required by the operator by 70 to 80%. If the manpower cost is presently $20K per annum, the net annual manpower savings could be as much as $16K. The equipment costs for a small computer and the necessary interface to the existing chromatograph could run between $25K and $40K. The price would depend on the peripherals attached to the computer. An example in this price range is the Hewlett-Packard 2100 computer with 8K of memory. It could store up to 15 different methods of analysis (8 methods would be available simultaneously in foreground and 7 methods in background). The program could also operate with 8 different channels simultaneously. Each method would correspond to a simple, unique spectra to which the unknown spectra would be compared. Each channel would correspond to a different chromatogram to be analyzed. For the lower price figure one would expect only a few computer peripherals; the $40K figure would include the ability to read and write punched paper tape thus allowing the computer to be used for additional calculation.

To make a practical comparison between the two methods described above, one must consider what additional tasks the former operator can now undertake to make effective use of his time.

Let us return to the situation of data recorded in delayed time. Fig. 11 illustrates how information recorded in several modes may be entered into either a small computer or remote-entry station:

1. Logbook data may be entered via a keyboard,

2. Punched cards, paper tape or magnetic tape may likewise be employed for semiautomated reading in of information.



DELAYED-TIME PRINTING AND COMPUTING FACILITIES

Fig. 11

3. Data on strip-charts or film may also be digitized and sent to a computer.

When real-time data processing is undertaken due either to the urgency of fast turn-around time or the volume of data is such that no advantage is gained by delaying the analysis, a system shown in Fig. 12 is appropriate. A number of air or water samples may be simultaneously analyzed and the resulting analog information fed to a multiplexer. (A multiplexer is a device which permits several input transducers to be read by the same digitizer.) The digitized signals are then available for immediate entry into a computer.

Two examples where pressure, temperature and liquid fuel flow were monitored by an on-line computer are discussed in References 1 and 2.

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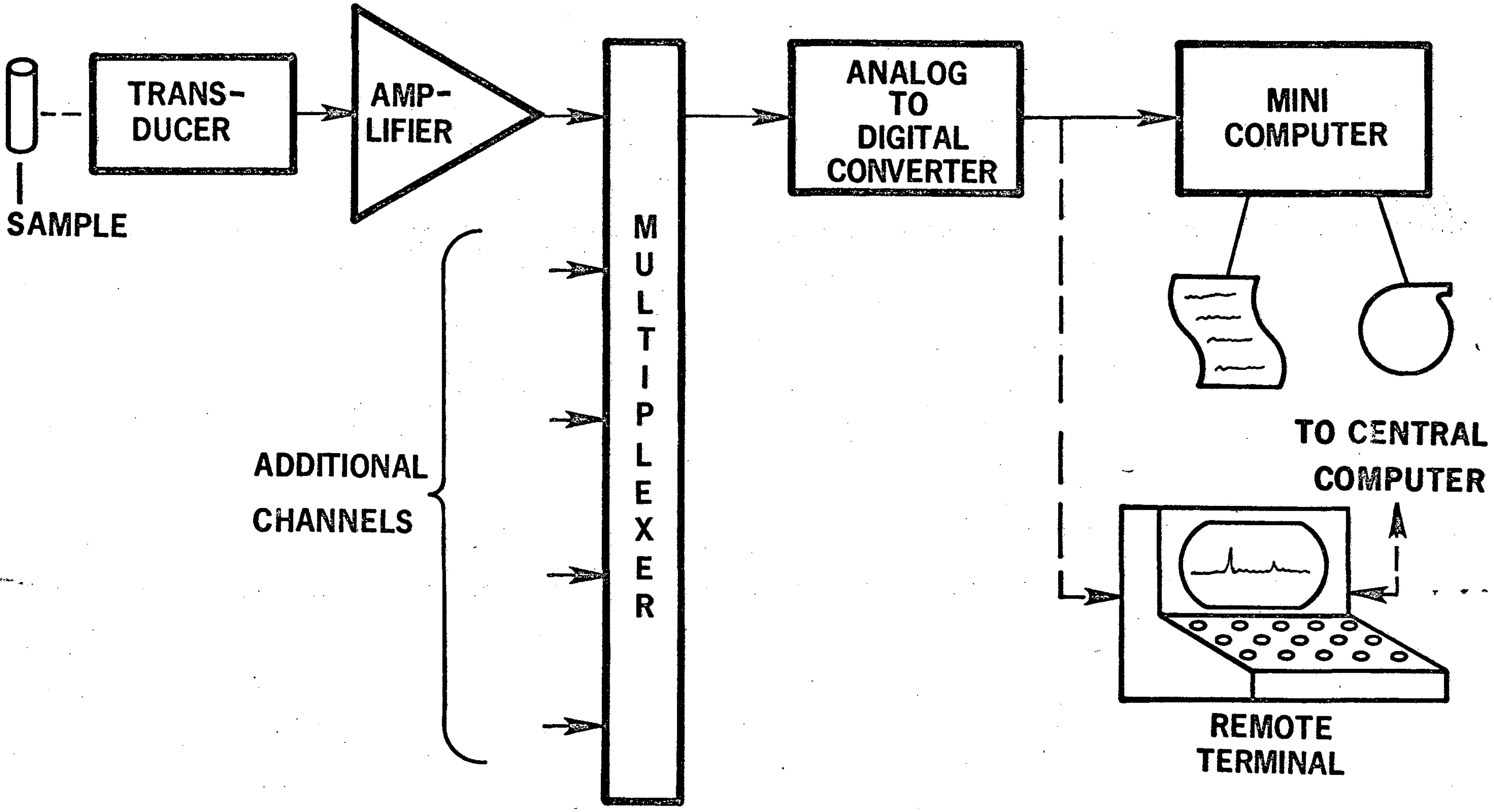

AIR- OR WATER- QUALITY MONITORS
INTERFACED TO ON-LINE COMPUTER OR REMOTE TERMINAL

Fig. 12

IV. SYSTEMS APPROACH TO DATA HANDLING

A. Nuclear Instrument Modules (NIM)

In 1964 representatives from a number of national laboratories met in Washington, D. C., and formed a committee on Nuclear Instrumentation Modules (NIM). This NIM Committee[1] drew up specifications insuring the mechanical and electrical interchangeability of instrument modules. The first commercial components were displayed at the American Physical Society Meeting in New York in 1965. Since that time the NIM System has become accepted as the laboratory standard for nuclear instrumentation throughout the world. Mr. Louis Costrell, Chairman of the U.S. NIM Committee, estimates that there are well over 50,000 NIM bins in operation throughout the world. Approximately 30% of the bins are used overseas. Now that the adolescence of the NIM System has passed, the important application to industrial monitoring and process control lies ahead. The growing pains typical to any new system have to a very large degree been recognized and corrected. The development and design have already been done. The system is available with very little investment required on the part of business and industry.

The basic concept of NIM is to help provide a systems approach to instrumentation. By systems approach we mean a plan whereby the signal sampling procedure, the initial transducer, the data-acquisition facilities, the data processor on through to the readout display is considered as a single total problem. Too many data monitoring facilities have grown like topsy. They are simply an agglomeration of interconnected chasses.

An instrumentation standard such as NIM can bring real order out of chaos. Let us consider the advantages of instrumentation standards. One is the availability and economy that can result from mass production of hardware of known capability. Most industrialists would be embarrassed to admit to the amount of time their technicians have spent haywiring together one-of-a-kind breadboards. The NIM concept largely eliminated the necessity and desire for each engineer to come up with his own methods of construction.

A second advantage is the uniformity of specification of electrical signal levels, signal impedances, and supply voltages; for NIM components these have become accepted throughout the world.

A third advantage is that individual units for a NIM System such as analog-to-digital converters or coincidence circuits can be completely designed, constructed, and tested before the construction of the remainder of the particular operating system is even begun.

Fig. 13 shows a NIM Bin and several typical modules. The bin can accept up to 12 single-width modules; modules may be any width from 1 to 12 units wide. Interconnections may be made from either the front or rear panels. If a system is comprised of more than 12 modules, it may be extended to additional bins. Power for each bin is usually furnished by a supply affixed to the rear of the bin.

A manufacturer employing the NIM System in his plant may purchase modules that best meet his needs from a number of sources. NIM components are manufactured by at least 100 companies. A standard NIM bin with power supply costs between $400 and $800. Blank, single-width modules cost $8 to $30 and fully instrumented modules run from $50 up to $2,000. For example, an ORTEC Model 410 Linear Amplifier costs $690.

Where only one or two special systems functions are required, in-house engineers can readily design and construct these circuits in blank modules.

System maintenance is greatly facilitated by the modular approach. Routine calibration and checkout of individual modules may be easily performed either in the bin in which it is normally located or in a test bin at a calibration facility.

In the same fashion a failure in a module may readily be corrected by simply interchanging the offending module with a spare unit. Repair may then be undertaken at a center outfitted with appropriate test equipment and away from the pressure of returning the production line to normal operation in a split second.

During the past 8 years the NIM System has caught on. NIM modules now provide an extremely viable means for packaging and interconnecting scientific instrumentation radiating from the U.S. across Europe to Israel. It is my belief that the same advantages will accrue to manufacturers employing NIM concepts for industrial monitoring and control.

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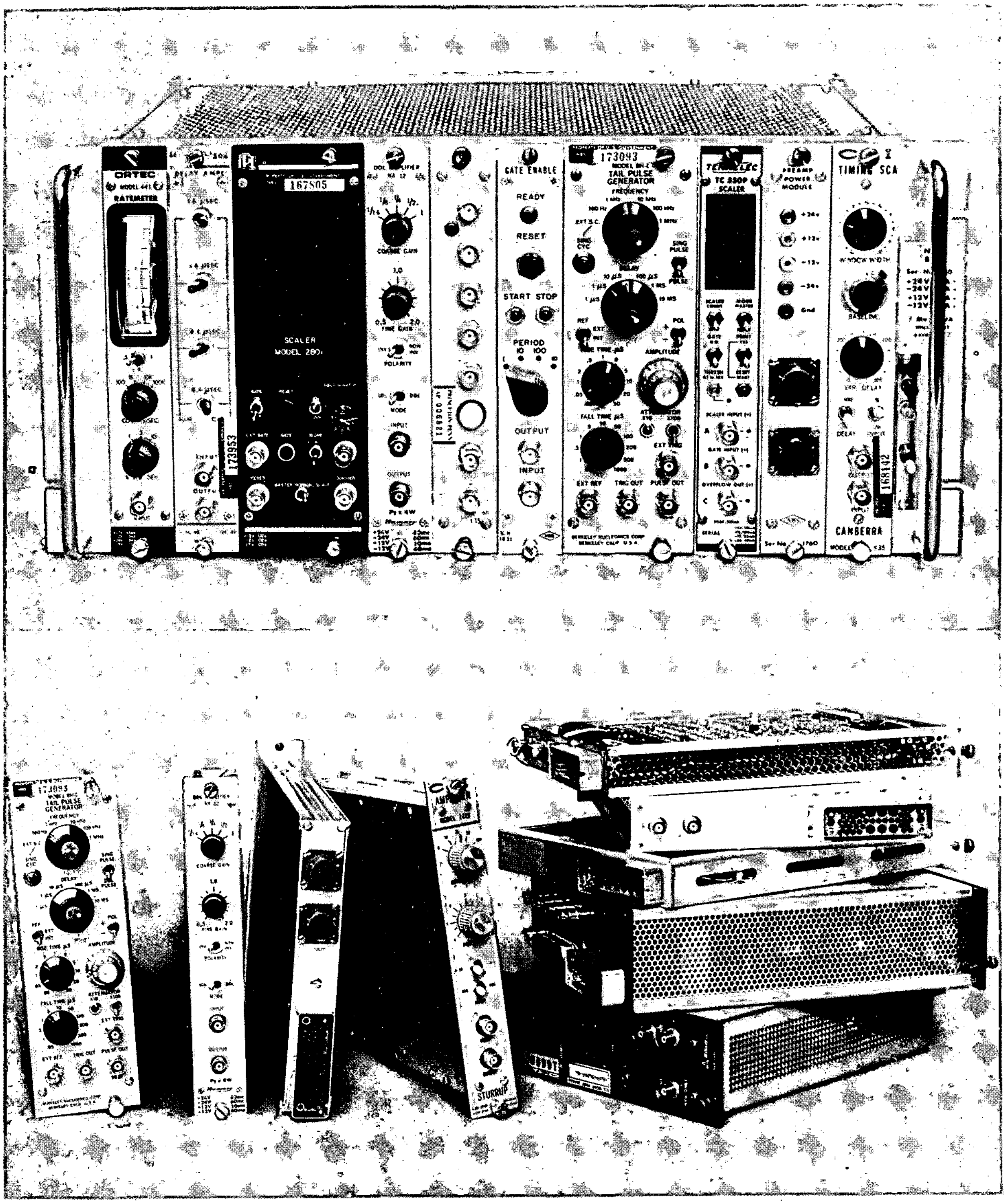


Fig. 13 NIM System Modules from a Number of Laboratories and Manufacturers

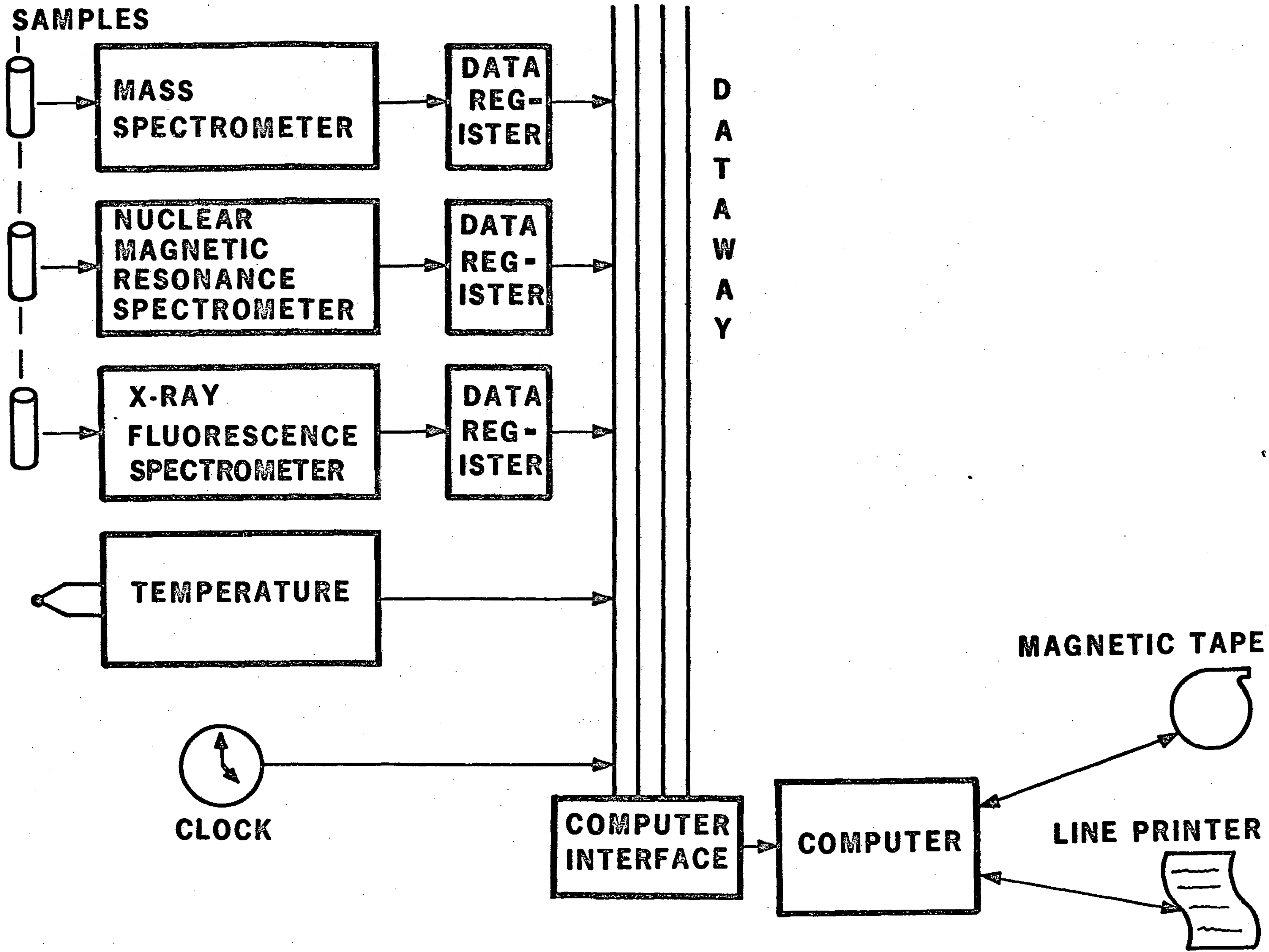
Modules of any standard width can be inserted into the bin without any changes in the bin. (From Costrell, Ref. 1)

B. CAMAC Digital Data Handling System

Coincident with the interest in constructing complex analog instrumentation systems, scientists and engineers were confronted with the problem of gathering many millions of bits of data and placing them in a format compatible for entry into a computer. The data came from many sources; voltage and current measurements, radiation detectors, temperature and pressure readings, elapsed time figures, switch closures and similar transducers. How could all of these data from hundreds of different devices be handled in an orderly manner for entry into any of a dozen different computers. The answer is to employ some form of data highway. Digital devices of differing function could each take their turn to feedinformation onto the highway. As long as only one device at a time is allowed access and each device is identified, orderly entry can readily be maintained. However, a study into the commercial data-handling field showed a great lack of uniformity. A recent Electronics Engineers' Master Catalog listed 68 companies manufacturing integrated-circuit logic cards; no doubt this list is far from complete. In general, each manufacturer supplies proprietary logic cards for designers wishing to augment the input-output (I/O) channel on its particular computer. As Fred Kirsten of our Laboratory has pointed out, "The data-bussing systems used by various laboratories and commercial firms in the United States share the common feature of being mutually incompatible ....no one of the existing systems except CAMAC has had the necessary widespread acceptance and momentum to make it a practical candidate for alleviating the compatibility problem".[1] Granted, you may make specifications, how do you establish interface standards so that they do not reduce performance to the lowest common denominator of your computer selection? This is our dilemma!

The very significant progress that accrued from the use of Nuclear Instrument Modules when applied largely to analog systems showed some very real shortcomings when used in large digital systems. In analog systems signals are usually amplified, shaped or processed and then converted into digital form. The individual modules are usually connected in tandem - one following the other. Digital systems, as mentioned above, quite often require that the modules be connected one at a time to a common data highway accessing the computer. See Fig. 14 .

Any standard is admittedly arbitrary; however, if one begins with initial principles, there are several fundamental requirements for a digital data-handling system: A



DATA ACQUISITION SYSTEM

Fig. 14

dataway with at least 16 lines (to match modern mini-computers) capable of reading data from modules to a data processor. The same 16 or additional lines are needed to read data into modules from the processor. A command structure with the functions of read, write, interrupt, address and test are basic. Also necessary are the utilitarian responses of initialize, clear, busy and some form of "hand shaking" to indicate that the information that has been transmitted is accepted.

Late in 1964 some of our European colleagues took advantage of the impact of circuit integration and the small digital computer on the world of measurement and control. Elimination of manual controls in favor of program control, shrinking volume requirements as integrated circuits replaced discrete components, and flexibility afforded by digital processors all pointed toward a specification for digital data handling. The European Standards for Nuclear Electronics (ESONE Committee) representing 34 European laboratories, fostered just such a scheme. Working with their North American NIM counterparts, represented by 21 laboratories, the CAMAC system, a modular instrumentation system for data handling, was announced in September 1968. Specifications were first published in January 1969. Soon afterwards the NIM Committee endorsed the CAMAC system and recommended its implementation in North America.

Incidentally, the word CAMAC is not an acronym, but a palindrome: it reads the same backwards as forwards, signifying that a computer interface must look in the direction of both the experiment and the computer.

From the viewpoint of a business man we ask, 'What will CAMAC do for me?

A typical data-gathering monitor may consist of a number of data sources which are at various times connected to a number of data processors and recorders; in like fashion data processors and recorders are fed to a number of readout devices such as cathode-ray tube displays and XY plotters. For each input-output device connected to a processor, a separate interface unit is usually required. These are indicated by "X" in the matrix of Fig. 15. Thus, the total number of interface units required is, in general, the product of the number of input-output devices and processors. On the other hand, if a dataway is employed that is compatible with all devices, the number of interfaces required is only the sum of the number of input-output devices and processors; these are indicated by "O" in the matrix of Fig. 15. It is obvious that the resultant savings can be significant.

	COMPUTER A	COMPUTER B	COMPUTER C	MAG. TAPE TRANSPORT A	MAG. TAPE TRANSPORT B	INCREMENTAL TAPE TRANSPORT	TELETYPE
INPUT DEVICES							
ANALOG-TO-DIGITAL CONVERTER A	⊗	X	X	X	X	X	X
ANALOG-TO-DIGITAL CONVERTER B	⊗	X	X	X	X	X	X
SCALER	⊗	X	X	X	X	X	X
SHAFT ENCODER REGISTER	⊗	X	X	X	X	X	X
X-Y POSITION REGISTER	⊗	X	X	X	X	X	X
FIXED DATA ENTRY	⊗	X	X	X	X	X	X
CLOCK	⊗	X	X	X	X	X	X
OUTPUT DEVICES							
DIGITAL-TO-ANALOG CONVERTER	⊗	X	X				
CRT DISPLAY	⊗	X	X				
LIGHT DISPLAY	⊗	X	X				
STEPPING MOTOR CONTROL	⊗	X	X				
RELAY CONTROL	⊗	⊗	⊗	○	○	○	○

NUMBER OF INTERFACE UNITS REQUIRED BETWEEN I/O DEVICES AND COMPUTER/RECORDERS

Fig. 15

Monitoring setups may change with the changing environment; if reconfiguration can be accomplished rapidly, very real advantages result. There is no such panacea as an instant monitoring facility; however, as soon as a module is plugged into a crate, it is instantly available to respond to software commands. For example, programs can be written to address one location after another in a crate. If a module responds, it is read out; if it does not respond, the program skips to the next addressed module. Thus software may be written with system expansion in mind.

Another advantage is the ability to build large data-gathering systems without the user's needing to know the internal details of the individual modules; he needs to know only function codes and program routines.

In addition, if a system breaks down, it is easier to restore performance by exchanging modular blocks than to discover the integrated circuit that is at fault.

Basic specifications are listed in "CAMAC, A Modular Instrumentation System for Data Handling"[2], a companion document dealing with means for interconnecting several crates to a data processor or computer is also available. The report, "Organization of Multi-Crate Systems"[3] has just been published. A supplement describing implementations of the CAMAC system should be available soon[4]. A recent journal presented 12 papers dealing with the utilization of CAMAC systems[5].

It is fundamental to note that CAMAC is not restricted to scientific instrumentation, but is applicable to all forms of data processing and control. The CAMAC specifications may be used without license or charge by any organization or manufacturer!

The basic building block in the CAMAC system is the plug-in module: see Fig. 16 . Modules communicate to a controller connected to a dataway via an 86-pin printed-circuit connector. One of the attractive features of the module is its economy. Hardware for a basic module, less the printed circuit board, costs approximately three dollars. A crate capable of mounting in a 19-inch relay rack may contain up to 25 stations or module locations; see Fig. 17. In practice, the two right-hand positions are reserved for a crate controller. The minimum time of a dataway operations is one microsecond; this allows operations as fast as 10^6 per second. Logic levels have been selected to correspond to those currently used by Transistor-Transistor Logic (TTL) integrated circuits now generally employed internationally. Bus voltages of ±6 and

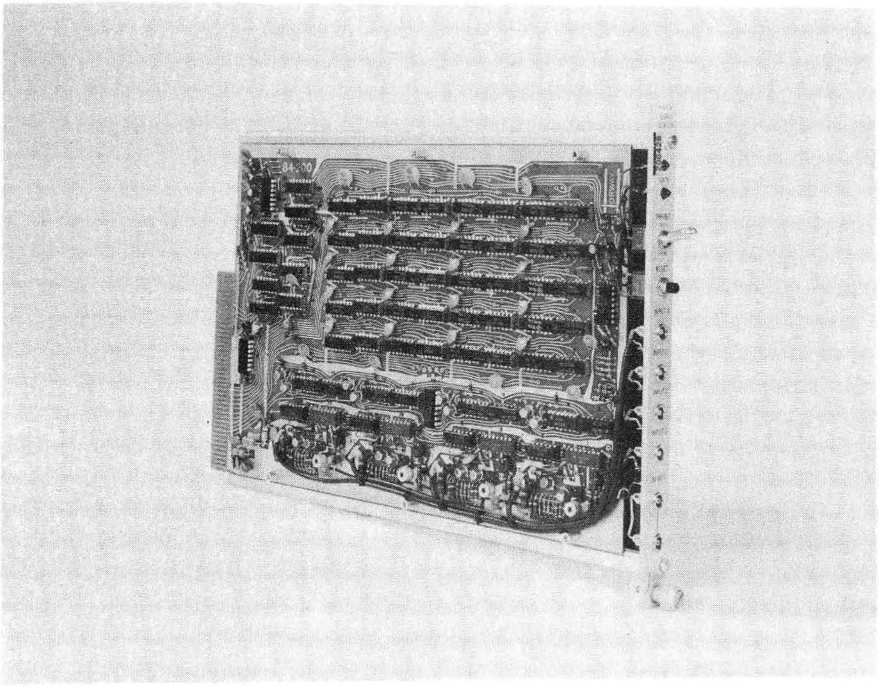


Fig. 16 Typical CAMAC Plug-In Module

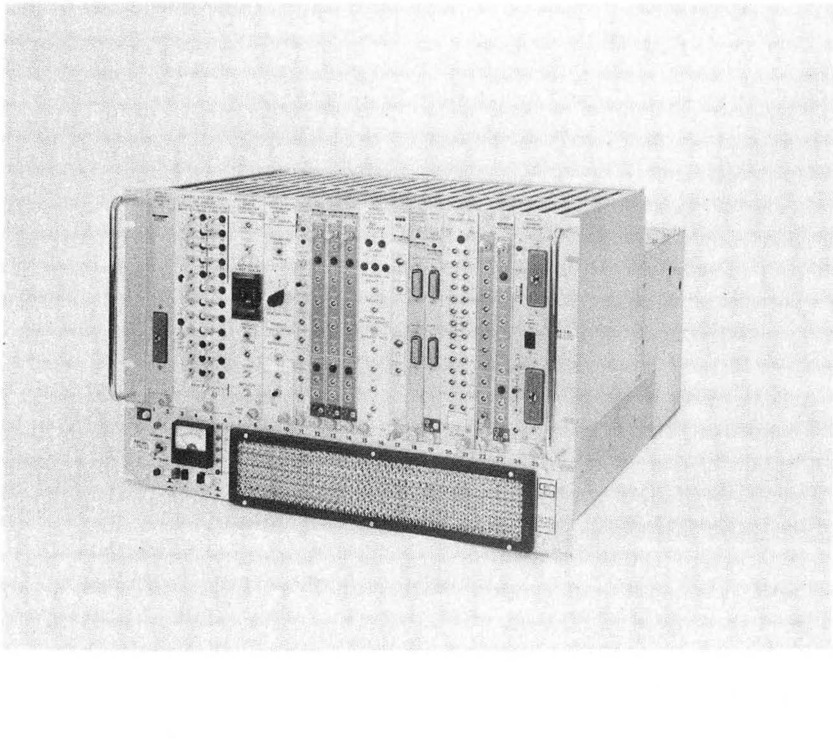


Fig. 17 Typical CAMAC Crate and Power Supply

±24V will accommodate in addition the use of emitter-coupled logic and discrete-component circuits where higher speeds or higher signal swings may be required.

Small data-acquisition systems often lend themselves to off-line data recording. When the turn-around time between the information acquisition and the interpretation of results will permit, one may record data directly on magnetic tape or perhaps even on a teletypewriter. Analysis of the data in delayed time may then be made at another appropriate location and time.

Where higher data rates are encountered or the urgency of at least preliminary data sorting or selection is required, computations can be made in real time with the aid of an on-line computer. While most CAMAC systems are designed to operate under program control, the concept does not depend upon a computer being present; off-line operation is entirely feasible.

Originally it was envisioned that single-crate systems would interface to small computers via a computer controller. Thus it would be necessary to have a controller available for each crate as well as each type of computer. Along these lines Strauss, et al.[6], at the Argonne National Laboratory are developing systems whereby the controller in each crate serves as an interface between the computer I/O bus and the CAMAC dataway; up to 14 individual crates can be addressed by a single computer.

As the CAMAC concept has evolved, less interest has been evidenced in computer controllers dedicated to interfacing a single crate to a specific computer. Instead a "branch highway" has been developed to link one or more crates (and their controllers) to a computer. Fig. 18 shows a block diagram of a CAMAC branch highway. In this manner a system exceeding the capacity of a single crate can easily be expanded into additional crates. The branch highway can extend operation up to a maximum of seven crates. In actual practice the branch highway is a 66-pair cable containing all the necessary timing, control, and data lines for branch operation.

The crate controller is now a universal device dedicated to servicing the requests of modules, passing these requests on the branch highway to the computer as well as relaying computer instructions back to the modules.

The branch highway interfaces a computer via a device termed a branch driver; it is specifically designed to relate branch

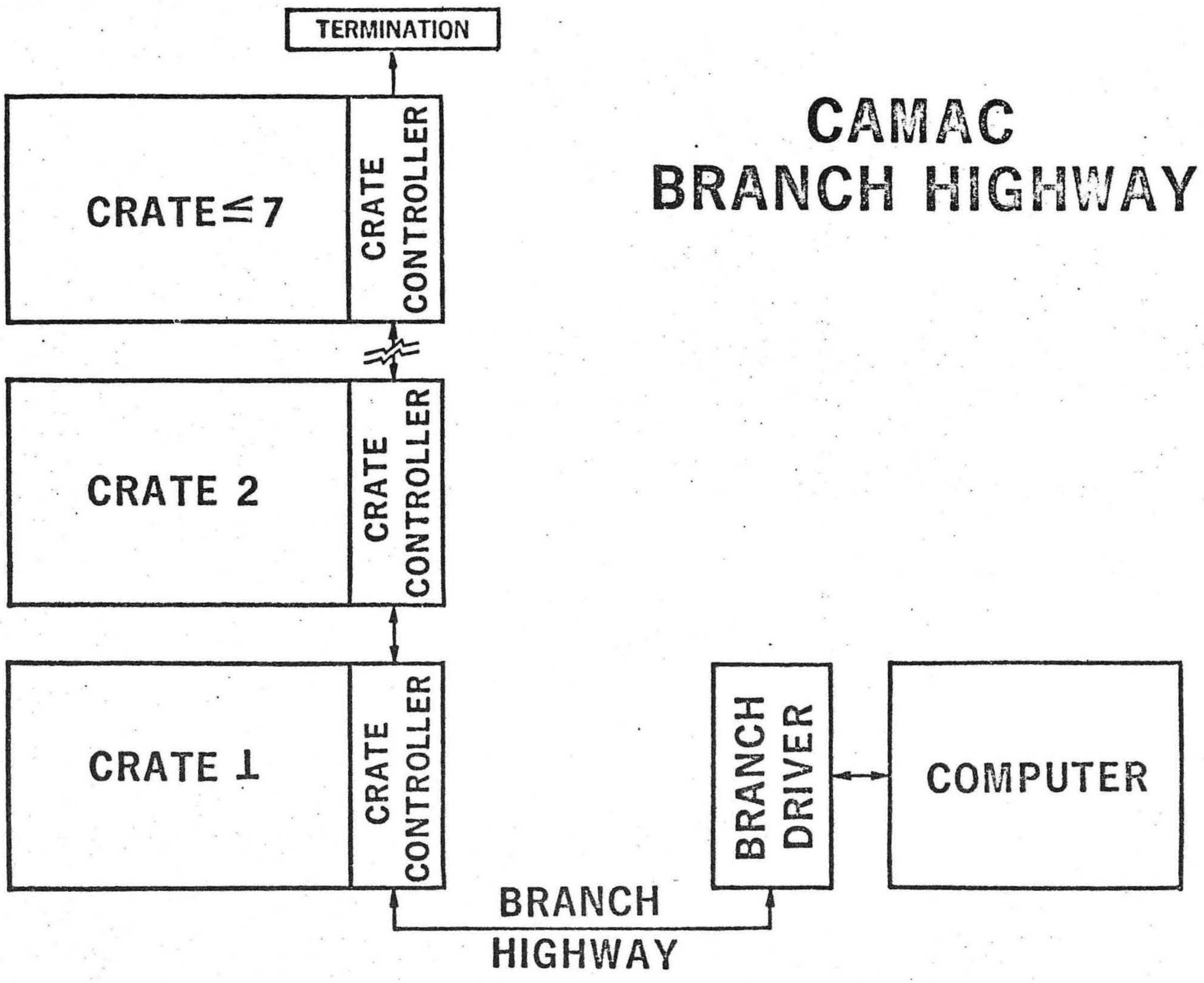

CAMAC
BRANCH HIGHWAY
TERMINATION
CRATE≦7
CRATE CONTROLLER
CRATE 2
CRATE CONTROLLER
CRATE ⊥
CRATE CONTROLLER
BRANCH HIGHWAY
BRANCH DRIVER
COMPUTER

Fig. 18

operation to the I/O structure of a given computer. Simple branch drivers operate only on the programmed I/O computer input, more advanced units operate on either the programmed I/O or direct memory access inputs, and other branch drivers operate on both modes. The physical length of the branch highway is limited to approximately 200 feet, the upper limit being primarily dependent upon noise pickup and line drops. However, these factors can be alleviated by the use of balanced lines or cables of sufficiently low voltage drop. Specifications for branch highways are outlined in Ref. 3.

While most engineers use programs that are either their own or provided by a commercial computer organization, CAMAC committees in both North America and Europe are meeting to consider the feasibility of CAMAC software that would be suitable for a number of small computers.

It is appropriate to give a progress report of the acceptance and availability of CAMAC components at this time. At present at least two companies in the United States are fabricating crates and module hardware; at least three other companies are exporting these items from Europe. To date more than 1,000 CAMAC crates and hardware for approximately 20,000 modules have been delivered in the United States. At least four companies are offering CAMAC power supplies. Three manufacturers are constructing A-to-D and D-to-A converters, scalers, and related data-handling modules. At least thirty-one other companies are manufacturing CAMAC instrumentation or components in Europe. Three manufacturers in the United States and five in Europe are offering the Crate Controller, Type A, used in conjunction with the branch highway. Among United States and European laboratories and manufacturers, engineers have designed and are manufacturing branch drivers for the HP 2114, HP 2115, and HP 2116, PDP-8, PDP-9, PDP-11, PDP-15 and the Nova and Super Nova and Sigma 3 computers. CAMAC systems are now operating in eight of the National Laboratories in the United States. Extensive use is being made at the TRIUMF accelerator in Vancouver, Canada. Four astronomical observatories are now employing CAMAC for their data-acquisition systems.

In summary digital data-handling systems are finding wide application in a number of areas of research. A great deal of study and planning on both sides of the Atlantic has gone into CAMAC. Those business men who take advantage of this program by sharing in the development and implementation of systems can expect substantial savings in return[7].

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5. CAMAC Tutorial Issue, IEEE Trans. Nucl. Sci., NS-18 (April 1971) lists 12 descriptive papers on application of the CAMAC System.

6. M. Strauss, et al., "Computer Controlled CAMAC Systems at Argonne", IEEE Trans. Nucl. Sci. NS-18(2) 46 (1971).

7. CAMAC Fundamentals, Specifications, Status, A Panel Discussion, will be held at the 1972 Nuclear Science Symposium, December 6-8, 1972, Deauville Hotel, Miami Beach, Fla. Also a number of papers related to the application of CAMAC will be presented.

C. Remote Data Handling Facilities

The cost of remote terminals depends, of course, upon the sophistication of the equipment. The least expensive terminal may run less than $1,000; there is little upper limit on the price of the largest terminals. As one considers more powerful remote-entry stations, one finds that more and more initial sorting and calculation may be done at the terminal. Often the terminal is itself a small computer. If even more computing power is added at the terminal, indeed, the bulk of the processing may be accomplished at the remote site. The central computer may then be employed only to access its large memory or take advantage of its higher speed computing processor. A typical unit is the Tektronix Model 4010 Computer Display Terminal ($3,950 to $4,550) and Model 4610 Hardcopy Unit ($3,550 to $3,950) as shown in Fig.19.

Remote terminals and satellite computers may communicate with the central computer either by direct lines (privately installed or leased) or telephone company equipment. In the first method a direct line is connected between the terminal and the computer. This method is usually only practical where the distances are a few hundred feet. For increased distances the binary pulses are converted into modulated signals through a device called a Modem (Modulator-demodulator) mounted at each end of the line. For the second method the telephone company offers a variety of services. The simplest remote terminal is a teleprinter. Most popular examples are the ASR-33 Teletypewriter or electric trypewriters. They may access a remote computer by either direct lines or via a telephone. An acoustic coupler is a popular telephone coupling device; the handset of the telephone is simply placed on the coupler, and the teleprinter then "talks" to the computer by means of appropriately transmitted audio tones. The advantage of the acoustic coupler is that it may be attached to any conventional telephone anywhere in the country. You may even take it home with you. Remember computer access time is usually much shorter in the evening and is almost instantaneous after midnight. In more permanent systems the remote terminal Modem may be connected directly to the telephone lines through a Data-Access Arrangement (monthly service charge about $2) or through a Dataphone dataset (monthly fees $12 to $125, depending upon the maximum data transmission rate).

What of the future? During the next 5 years a greater number of scientists, engineers and administrators will install remote terminals in their offices. This terminal can replace a slide rule, a desk calculator and to some extent a reference library. Simple calculations will be made locally; more complex processing will be done at the corporate computing facilities. Data searches will be conducted by any of a

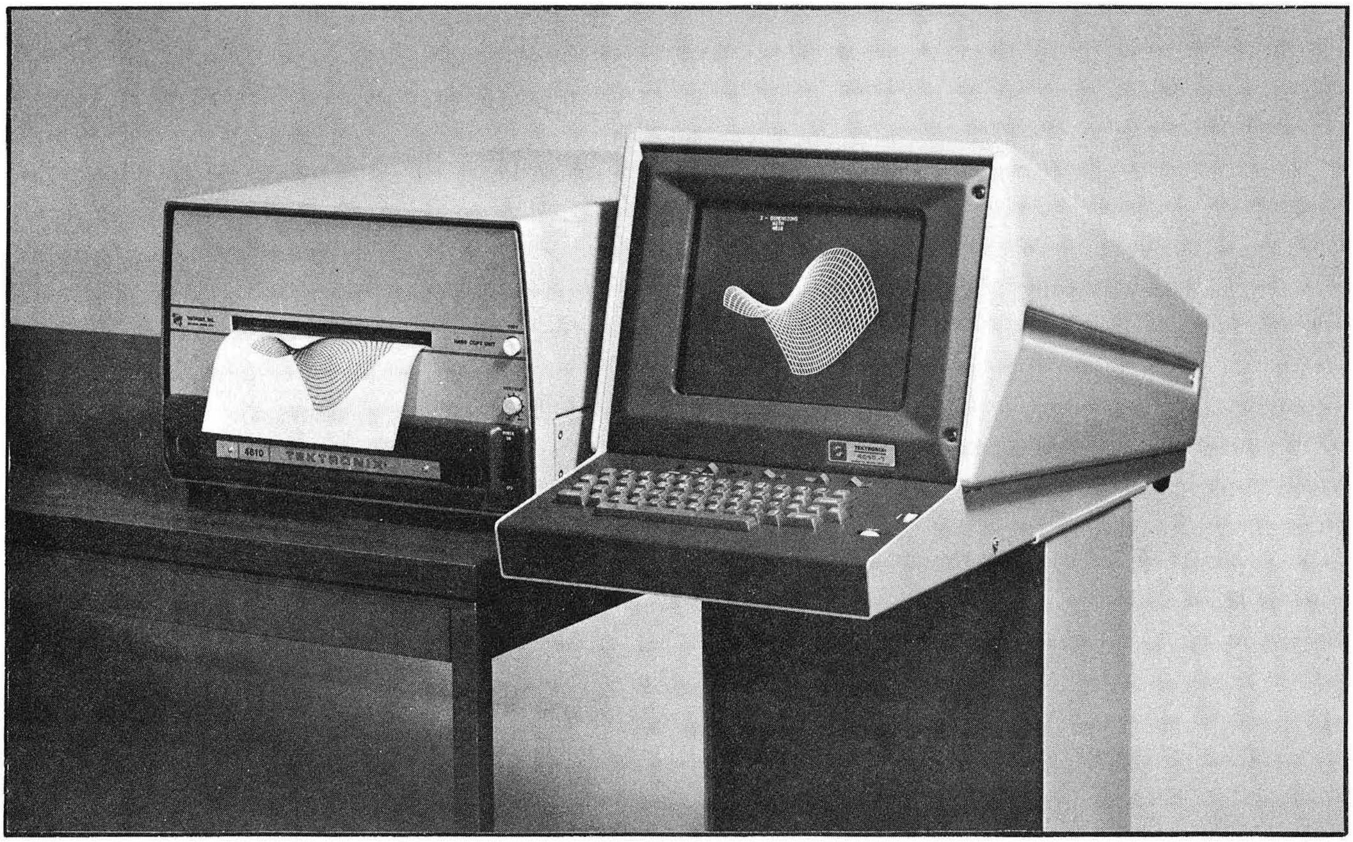

Fig. 19 Computer Display Terminal and Hardcopy Unit

number of data banks located throughout the country. In fact the EPA Analytical Quality Control Laboratory in Cincinnati recently relayed water-quality data via the Nimbus Satellite.

In the more distant future there will be little need for an engineer or company executive to leave his own working area except for daily exercise. The information necessary for decision making will all be available at his personal information center. Requests for information will be entered either by spoken request, keyboard entry, an electronic sketch pad or a TV camera.

The center may be used for a number of services:

1. Looking up mathematical tables, dictionary definitions, or atlas information.

2. Performing mathematical calculations using either previously or presently stored equations.

3. Making statistical computations from data entered from remote field stations.

4. Making document searches from specialized information centers.

5. Assisting the user in decision-making roles by providing him with background information from a number of sources.

Answers will be in the form of either a spoken message, TV-like display, printed copy or line drawings. The same information center may also be used for conducting conferences, linking each participant by TV from a different part of the country or eventually the world.

In summary, it must be remembered that the information center should only be a tool in the hands of the user. It's computed or analyzed output is only as reliable as its information and program inputs. As L. Frank Baum said in 1907 in Ozma of Oz, "I am on-ly a ma-chine", said Tiktok. "I can-not be kind an-y more than I can be sor-ry or glad. I can on-ly do what I am wound up to do." Decisions should always involve the human element of conscience, fair play and empathy.

D. Displays

Long ago a Chinese philosopher said that one picture was worth more than ten-thousand words. Engineers many years later, confronted with displaying thousands of information points, came to the same conclusion: a graphic display allows the human mind to relate a number of different pieces of data much more rapidly than can be accomplished by scanning a column of figures. The most obvious manifestation of this is that graphs have supplanted tables in many scientific research papers. This graphical technique has now become common during data-taking phases of experimental work as well as during data-analysis. Recent improvements in the storage capability of cathode-ray oscilloscopes allow an almost flicker-free display of pieces of data. In nuclear research the multichannel analyzer has become an exceedingly useful instrument for displaying the energy spectrum of the decay products of a radioisotope. In the most elementary display the abundance of the radiation (number of impulses from decay products) is displayed on the vertical axis, and the energy of the radiation is displayed on the horizontal axis. This horizontal axis has traditionally been divided into a number of intervals called channels. Data gathering usually takes place over an interval of several minutes to several hours. Display can be as long as is desired. Early analyzers were constructed with only a few channels; now the number of channels may extend to 8000 or more. To examine some portion of the display spectrum in more detail, a certain fraction of the horizontal axis is often expanded. See upper and lower displays of Fig. 20. This and all of the following figures have been taken from Ref. 1. The lower display shows the entire output of the analyzer (channels 0 to 1023). The upper display has expanded the horizontal axis and presents only the information in channels 256 to 384.

An additional sophisitication in display techniques is the correlation of information from two different data sources, for example, the signals from two radiation counters which detect different decay products of the same nuclear event. Here the the two horizontal axes represent the energies of each of two simultaneously emitted particles. The vertical axis represents the abundance or number of times particles with energies X and Y have occurred. Figures 21 and 22 indicate graphically the power of such a display to portray relations that could never be perceived by a two-axis presentation. In Figures 21 and 22 the data have been integrated or smoothed to present a continuous line diagram. In Fig. 23 the digital characteristic has been retained, allowing the user to ascertain the number of individual impulses for each of the possible events.

Other modes of display are indicated in Figures 24 and 25, where contour displays allow quite precise determinations of the energy relations of an event. Of course for precise calculations one must always turn to the actual numerical values.

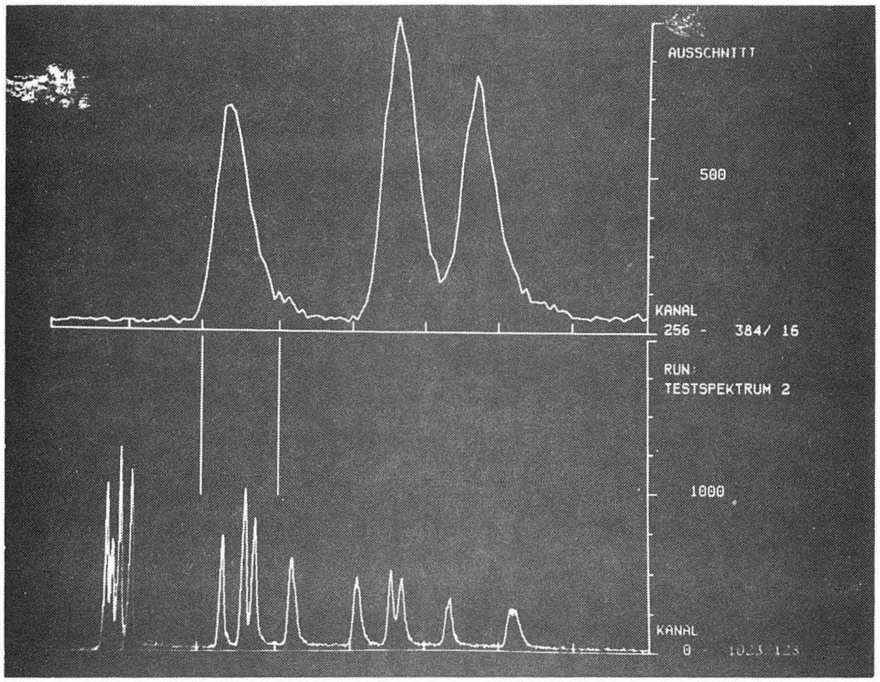

Fig. 20. Upper: Expanded Display Channels 256 to 384
Lower: Display of Number of Counts vs 1024 Channels
(From Abend, Ref. 1)

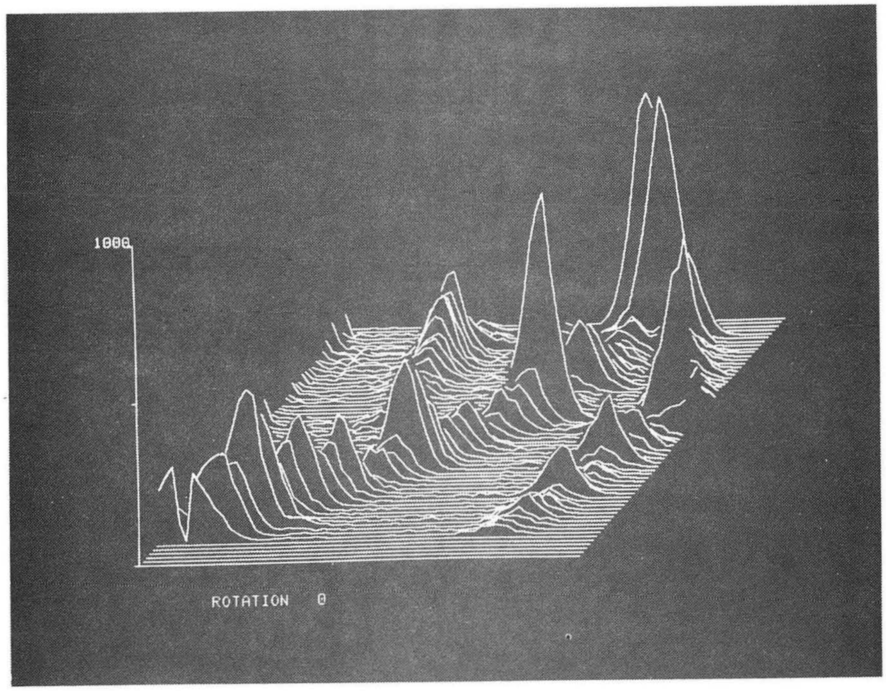

Fig. 21. Isometric Display, Integrated Response

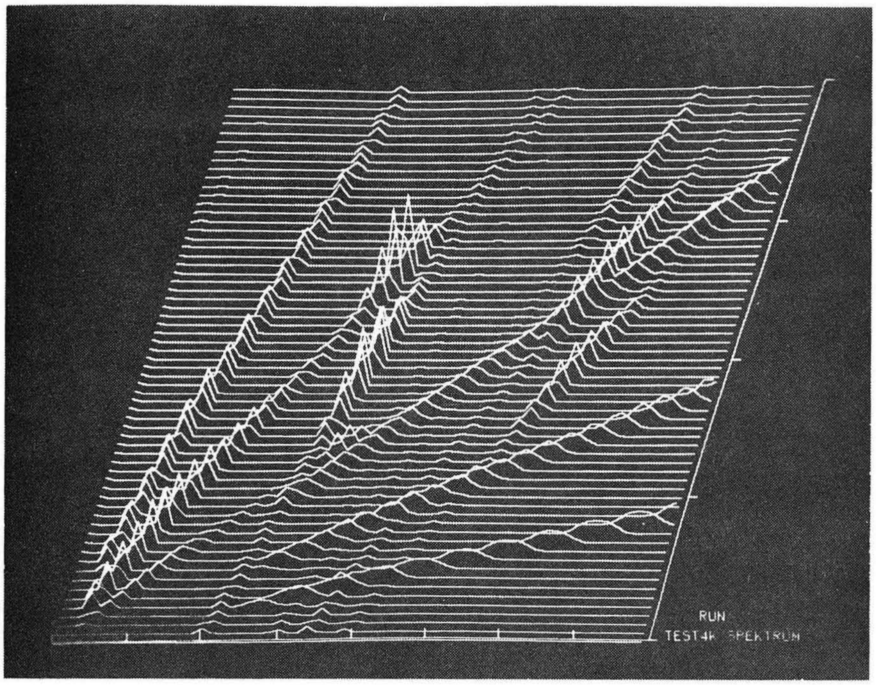

Fig. 22. Isometric Display, Integrated Response

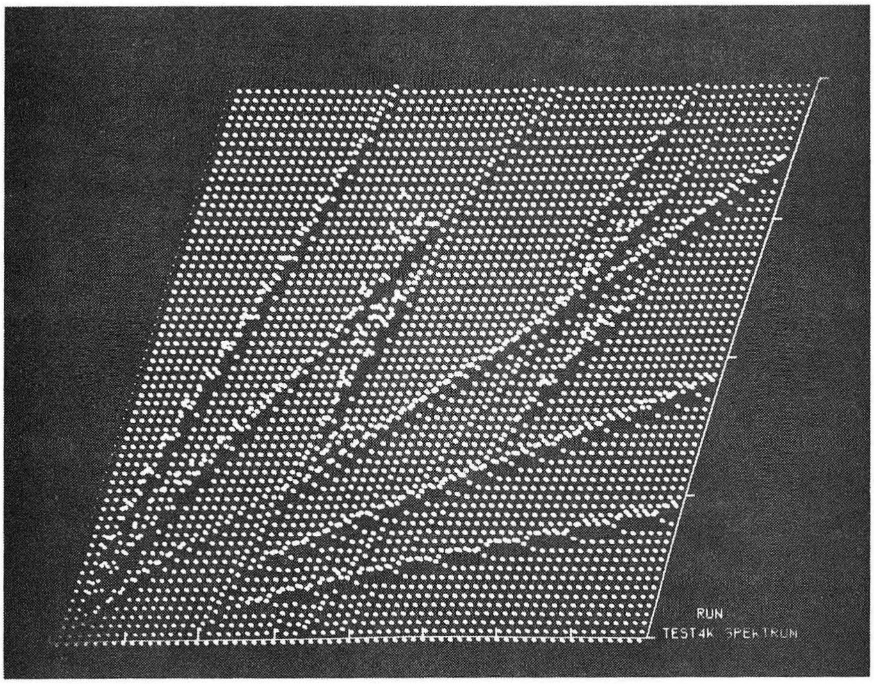

Fig. 23. Isometric Display, Digital Response

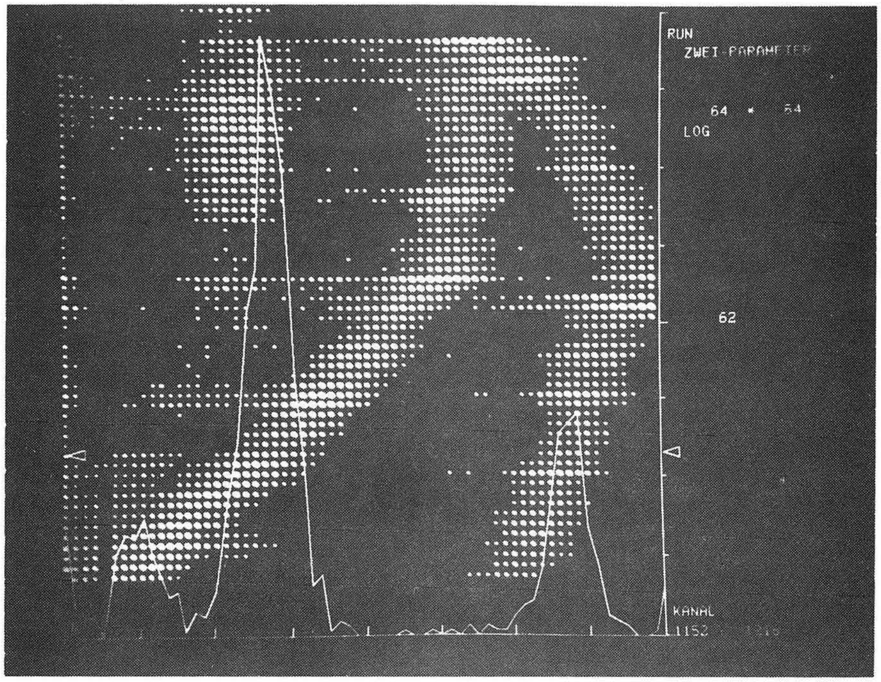

Fig. 24. Map Display

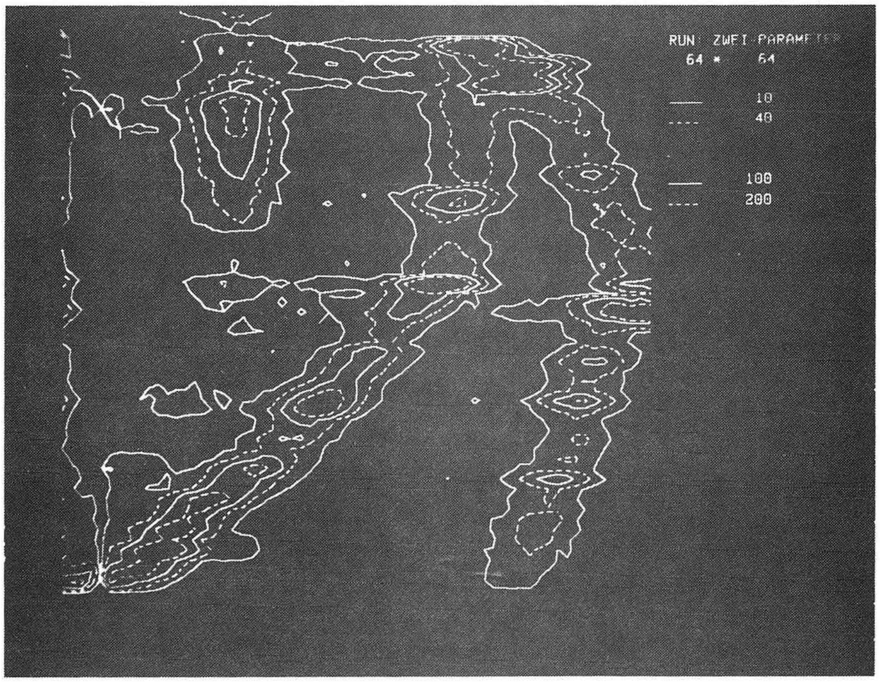

Fig. 25. Intensity Contour Display

As the sophistication of the displays has progressed, so has the equipment that generates the display. Elementary displays may be produced by analyzers capable of performing only one or two functions; multiparameter displays are usually generated with the use of a small computer.

Another widespread use of multichannel analysis is the assignment of the horizontal axis to represent time (rather than energy). The display then has several advantages over a strip-chart recorder: (1) the results of one or the composite results of many measurements may be seen, (2) it is possible to view many such displays (recorded in the memory of the analyzer or computer) in rapid sequence, (3) several displays may be overlaid to provide differential comparisons, (4) the display can in many cases retain its digital nature, and (5) the display is visual.

Only a little imagination is required to see how effectively isometric and contour displays lend themselves to presenting environmental information. For instance, it portrays the relation between the concentration, time of occurance and distance of various pollutants using laser-long path techniques. When color storage oscilloscopes are available, different contaminents could be displayed in different colors.

It would also be possible to display the concentration levels of air or water pollutants with a map overlayed on the face of an oscilloscope.

Bibliography:

P. Abend, R. Bublitz, D. Jackel, H. Klessmann, A. Kollbach, J. Zahn, "A Graphic Display Terminal for Nuclear Experiments with On-Line Computer, Part 1: Function, Characteristics, Description", Report No. HMI-B100 (NDV4) (July 1970) (In German) Hahn-Meitner Institut für Kernforschung, 1 Berlin 39, Glienicker str 100 West Germany.

E. Data Information Centers

Of great interest to those in any organization who are charged with the responsibility of protecting and improving the environment is the program that is underway to provide access to the vast store of environmental information. This information is being gathered and stored in a number of Data Bases. A Data Base may be defined as a collection of information in machine-readable form. It is essentially a library in which the documents are in a form that can be read by a computer and the resulting computer output is delivered to the reader at some remote point. Data-Base information may be in the form of document-type or data-type. In document-type the entire document or at least an abstract of it is available for recall. In data-type the original data with perhaps some consolidation is available for readout. Obviously, most business and environment readers will be primarily interested in document-type readout.

Information centers may be interrogated in several ways:
1) A request may be made by an individual via his own teleprinter or remote terminal using a Dataphone or a conventional telephone.
2) A request may be made to a regional office which has a remote computer-access terminal. Information residing in the central computer file of the Data Base may be interrogated and read out via this remote terminal.
3) Of course a request for a particular document or information in a particular area of interest may be mailed to the Data Base as can be done in the case of a more conventional information center.

Table I lists some Data Bases, a person to contact for more information on it, and the method of interrogation.

The Association of Scientific Information Dissemination Centers (ASIDIC) has published an informative report entitled "ASIDIC Survey of Information Center Services". It lists some forty-eight Data Bases, gives contact personnel and states user service charges. Copies of the Survey are available for $7.50 from Mr. R. Bruce Briggs, ASIDIC Secretary, Campus Computing Network, University of California, Los Angeles, Calif. (90024)

A well-ordered data base can be very useful beyond the field of environmental control and serve as an adjunct to a company's technical library. All of the new data in a base may be screened periodically against a carefully prepared "profile" listing of a user's area of interest. The Data Base concept is relatively new but is already proving enormously valuable, though like all new things has certain (temporary) shortcomings. For example a number of presently available Data Bases are (1) lacking in adequate descriptors (descriptors are the key terms by which documents are recalled), (2) the time lag between the original date of issue of a report and its availability in the Data Base is too great, and (3) the access time to the central-memory facilities by the remote terminal is too great.

Table I

Environmental Data Bases

NAME	CONTRACT	METHOD OF ACCESS
Air Pollution Abstracts	John Knight Air Pollution Technical Information Center (APTIC) Research Triangle Park, N.C. 27711 phone (919) 549-8411 ext. 2141	Written
Environmental Information System	Dr. G. U. Ulrikson Oak Ridge National Laboratory, Oak Ridge, Tenn. 37830 phone (615) 483-8611 ext. 6560	Written
Water Resources Abstracts	George W. Reid or L.E. Streebin, Water Resources Information Center, Univ. of Oklahoma, Norman, Okla.	Written

V. PROCESS COMPUTER CONTROL FOR ENVIRONMENTAL PROBLEMS

A. Instrumentation and Control Devices

The discussion thus far has been limited to data gathering and analysis. Equally relevant is the question of how to apply the analyzed information to minimize the environmental impact. When an increase in the effluent from an industrial process has been observed and the conditions under which deleterious discharges are known, it then becomes imperative to close the loop and apply corrective measures as soon as possible.

Process Computer Control as described here refers to the use of a computer (under adequate supervision) to control a manufacturing or industrial process.

A hierarchy of adequate controls provides data inputs from each step involved in the process along with decision-making inputs from each management level within the organization.

The environmental gains to be achieved are several: Good programmed control can provide closer regulation to processing than is possible under manual control. Thus excursions from normal operation with their attendant effluent can be minimized.

Programmed control is most useful for bringing a large plant up from a cold start to full operation. Under emergency conditions computer control can be expected to take remedial action before an operator has diagnosed the system failure. The Purdue Laboratory for Applied Industrial Control has for several years studied the problem in view of reaching standardization of industrial processing.[1] Fig. 26 illustrates a number of analog and digital devices that typically lend themselves to programmed control. References 2 and 3 respectively discuss computer control of a very large and a very small system process.

Bibliography:

1. "ISA Computer Control Workshop, Minutes" May 22-24, 1972, Purdue University, Contact Prof. T. J. Williams, Purdue Laboratory for Applied Industrial Control, Purdue Univ., Lafayette, Ind. 47907.

2. J. A. Murphy, "Computer Control of An Aluminum Reduction Plant", Instrumentation Technology, P. 25, (April 1972).

3. "Closed Loop Production Testing", Hewlett-Packard Application Note 135-4 (1971) Palo Alto, CA.

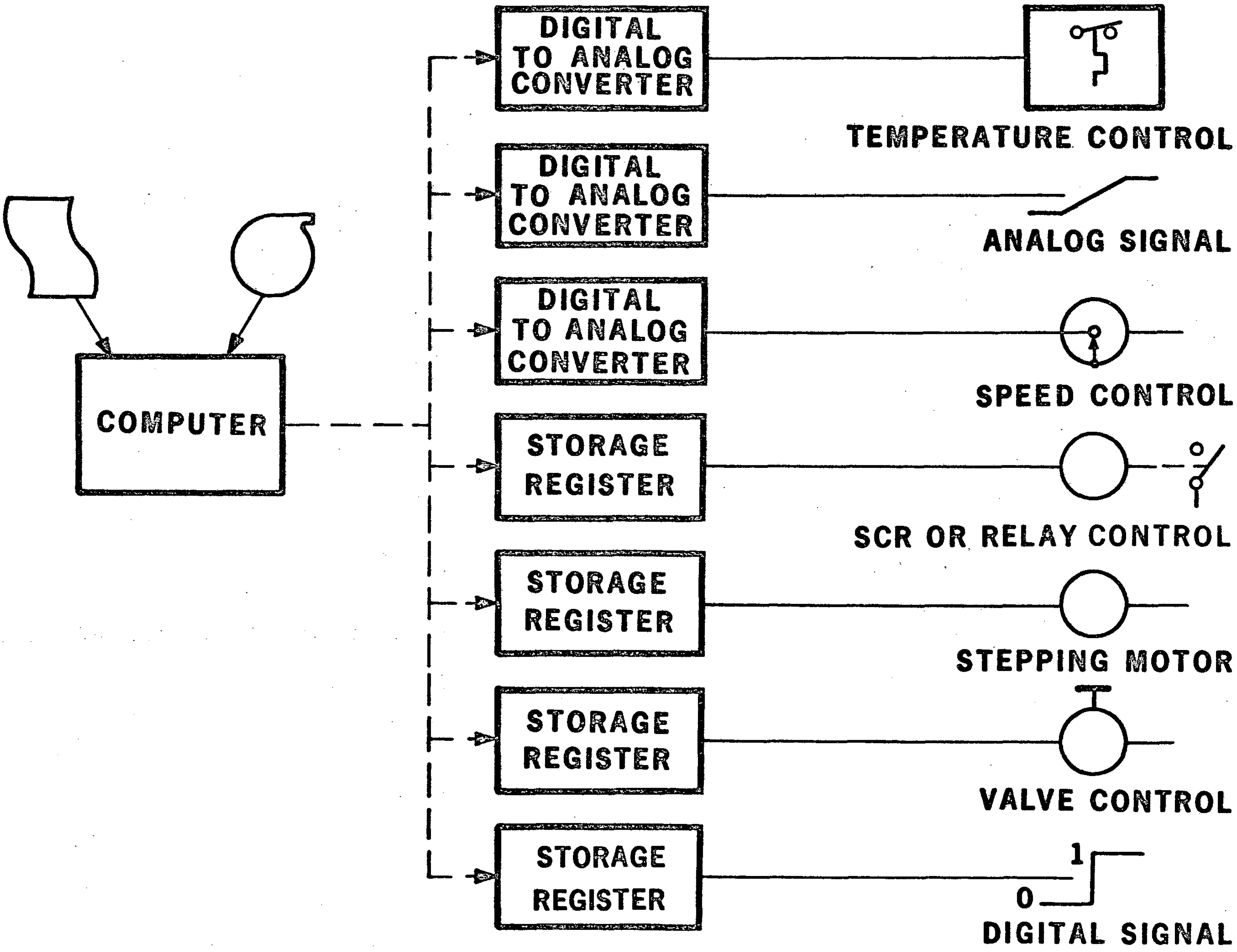

Fig. 26 PROGRAMMED PROCESS CONTROL

CONCLUSION

A quotation comes to mind from the Psalms, "The heavens are telling the glory of God; and the firmament proclaims his handiwork." Only with conscious effort can we pass on to our children the rich heritage of creation as we received it. Let's pass it on a little cleaner than the way we found it.

ACKNOWLEDGEMENT

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APPENDIX

INSTRUMENTATION FOR ENVIRONMENTAL MONITORING

The National Science Foundation has engaged the Environmental Instrumentation Group of the Lawrence Berkeley Laboratory (formerly Lawrence Radiation Laboratory) to conduct a survey of instrumentation for environmental monitoring. Instruments being investigated are those useful for measurements of Air, Water, Radiation, and Biomedicine related to environmental research and monitoring. Consideration is given to instruments and techniques presently in use and to those developed for other purposes but having possible applications to this work. The results of the survey include descriptions of the physical and operating characteristics of available instruments, critical comparisons among instrumentation methods and recommendations for the development of new instruments, and of promising methodology. The survey material is compiled in four loose-leaf volumes which will be periodically updated.

Instrumentation for Environmental Monitoring AIR, Lawrence Berkeley Laboratory report LBL-1, Volume 1, will be available April 1972 from the Technical Information Division, Lawrence Berkeley Laboratory, University of California, Berkeley, CA., 94720, at a cost of $7.00 per volume, postage paid. Volume 1 as initially issued covers Sulfur Dioxide monitoring; additional sections on Oxides of Nitrogen, Photochemical Oxidants, Mercury, Lead, Beryllium and Asbestos will be issued during the year. The price includes the cost of additional sections that will be issued through June 30, 1973.

Instrumentation for Environmental Monitoring WATER, Lawrence Berkeley Laboratory report LBL-1, Volume 2, is expected to be available in late 1972.

Instrumentation for Environmental Monitoring RADIATION, Lawrence Berkeley Laboratory report LBL-1, Volume 3, will be available April 1972 from the Technical Information Division, Lawrence Berkeley Laboratory, University of California, Berkeley, CA., 94720, at a cost of $7.00 per volume, postage paid. Volume 3 as initially issued covers Ionizing Radiation: Accelerators, Calibration Methods, Gamma, X Radiation, Neutrons; Nonionizing Radiation: Microwaves, Lasers and Ultraviolet. Additional sections on Reactors, Dosimeters, Radionuclides and Infrared will be issued during the year. The price includes the cost of additional sections that will be issued through June 30, 1973.

Instrumentation for Environmental Monitoring BIOMEDICINE, Lawrence Berkeley Laboratory report LBL-1, Volume 4, is expected to be available in late 1972.

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