which are in many ways analogous to the glass electrode for hydrogen ion activity. The Fisher carbon induction furnace is useful for rapid carbon analysis of soils, giving a determination in three minutes. The mass spectrometer has added further to soil biochemical analysis of nitrogen fixation processes, through the analysis of nitrogen-15.

A Look Forward in Development

The newest addition to the family of instruments used in routine is the flame emission spectrophotometer. It, therefore, is probably the subject at this time for the most significant improvements for soil and water analysis. A recently developed circuit increases the sensitivity range for magnesium, manganese, and other elements which are excited only weakly or barely strongly enough for determination with present amplifying equipment of the low concentrations in soil extracts and waters. Better flame stability is needed. Multichannel recording and automatic recording are important new possibilities.

The rotating disk type of electrode, made of carbon or silver, gives the arc or spark emission spectrophotometer the advantage of a continuous source characteristic of the flame type of emission instrument. A newly increased sensitivity is being provided by electrode design of the polarograph, and this will make the determination of copper in soil and water much more accurate and easy. Improved stability of electron tubes and possible use of transistors in various electronic instruments from pH meters on up would cut down on off-duty time for repairs, and in portable instruments extend battery life. Neutron scatter instruments are being developed for the determination of soil water content. Glass electrodes for pH measurement are being made increasingly more sturdy.

Soller slits in x-ray diffractometers have reduced background and improved the diffraction pattern. Mounting of layer silicate clays on flat suction plates has improved the diffractometer results for some samples. Mounting clay particles by freeze-drying and fog techniques has improved the electron microscope pictures of some soil colloids. Commercial X *vs.* Y recorders have improved the ease of construction of differential thermal apparatus, which is highly useful in research in soil chemistry.

Summing up, the soil chemist has an increasingly wide array of commercial precision instruments for soil and water analysis, and these instruments are constantly being improved. He will make more rapid strides in research and public service in measure that effective use is made of these instruments.

Instruments in

FERTILIZER RESEARCH AND PRODUCTION

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MOST FERTILIZERS and fertilizer materials are solids, a fact that precludes use of the many modern precision instruments based on the properties of gases and liquids. Nevertheless, there are a number of important applications of instruments in fertilizer work.

In the early years of the fertilizer industry, the number of raw materials was small and the processing of these materials into finished products was simple. The principal raw materials were ammonium sulfate and sodium nitrate as nitrogen sources, normal superphosphate as the phosphorus source, and potassium chloride as the potassium source. These materials were used for direct application or dry mixed in various proportions to form low analysis mixed fertilizers. Sometimes considerable amounts of inert fillers such as sand were used, which further contributed to low analysis. The application of instruments in these operations and related research work was very limited.

In more recent years many changes have taken place in the industry, which have resulted in more complex products and processes. Some of these changes are as follows:

- Use of nitrogen solutions composed of various proportions and combinations of ammonia, ammonium nitrate, urea, and water. The introduction of the liquid phase in fertilizer mixing increased the possibility of chemical reactions occurring and increased the complexity of the mixing process.
- Use of many new phosphate materials such as triple superphosphate, ammonium phosphates, and nitric phosphates.
- Use of continuous rather than batch operation for many of the newer mixing processes.

The Coleman Junior spectrophotometer and the Model 21 flame photometer. The latter is widely used to determine sodium, potassium, and calcium in fertilizers

• A growing demand for granulated instead of pulverized fertilizers, which further increased the complexity of the mixing process.

• A growing demand for high analysis fertilizers which, with the residual demand for low analysis materials by older farmers, has increased the number of grades that a mixing plant must produce.

All of these factors have resulted in more opportunity and necessity for various instruments, both in production and research.

Laboratory Instruments

To meet regulations of state and federal agencies, the guaranteed analysis of fertilizers must be based on the procedures of the Association of Official Agricultural Chemists. These procedures are mostly based on classical volumetric and gravimetric principles and do not permit extensive use of instruments. Nevertheless many instrumental analytical methods for fertilizers have been developed and may be profitably used for control and research purposes if they are periodically checked against official methods. Most of the elements occurring in fertilizers may be determined colorimetrically. The flame photometer is widely used with good precision for determination of potassium. Polarographic methods have been developed for many fertilizer elements. Other methods occasionally used are based on turbidimetry, high frequency titration, and potentiometric titration.

Determination of moisture by means of a direct reading infrared moisture balance is very useful for rapid control work, although it is not sufficiently precise for final analysis.

Installation of x-ray diffractometer and x-ray spectrograph. X-ray diffraction is useful in fertilizer process research

In addition to complete chemical analysis of fertilizers, other chemical and physical properties are important and can sometimes be determined with instruments. Some of these properties are chemical constitution, crystal structure, particle size, degree of crystallinity, and porosity.

For example, one of the most important characteristics of fertilizer is its ability to be stored for long periods without caking. This ability depends on many properties of the product which in turn depend on conditions of manufacture and storage. Determination of these properties leads to a better understanding of the factors influencing caking and helps to prevent it. Some of these properties may be determined by instruments as described below:

X-Ray Diffraction. One of the most useful tools in fertilizer research is the x-ray diffraction technique. With this technique it is possible to determine the crystalline lattice structure of the principal components of the materials, thereby determining the chemical compounds present. An example of its use is the determination of the extent to which the base exchange reaction between ammonium nitrate and potassium chloride has taken place in a mixed fertilizer. Another example is determination of whether superphosphates of different physical properties are also different in chemical constitution. It is very useful in determining the extent of hydration of various components.

Unfortunately x-ray diffraction techniques are limited to crystalline materials and are of no use with amorphous materials.

Microscopes. Microscopic examination of fertilizer materials can yield a surprising amount of information. Techniques used by the Tennessee Valley Authority result in a semiquantitative determination of the principal crystalline constituents of fertilizer mixtures. These techniques are based on examination and separation of the materials under a stereoscopic microscope. This is followed by identification of the individual crystals under a polarizing microscope, which is based largely on determination of their refractive index by use of calibrated oils.

Polarizing microscopes have also been used to determine the degree of crystallinity of fused phosphate fertilizers.

Electron micrography is occasionally useful in determining the size and shape of particles in the sub-micron range.

G. L. BRIDGER, head of fertilizer research for Davison Chemical, has made many contributions to fertilizer production. Now chairman of the ACS Division of Fertilizer and Soil Chemistry, Dr. Bridger joined Davison last year after eight years as head of the department of chemical and mining engineering at Iowa State College. Previous to that, he was chief of process development for TVA.

Isotopic Methods. The use of radioactive isotopes of some of the fertilizer elements permits determination of the distribution of a material throughout a given process. This technique has been used with outstanding success in plant growth studies with phosphorus-32, which has a convenient half life. It has also been used occasionally in fertilizer research, as for example in distinguishing between the phosphorus derived from phosphoric acid and that derived from phosphate rock in the manufacture of triple superphosphate. These methods of course require use of precise radiation counters.

For estimation of elements present in extremely small quantities and preliminary screening of unknown materials, emission spectrography is very useful.

Some of the more common other instruments used in fertilizer research are pH meters, indicating and recording potentiometers for temperature measurement, colorimeters, and flame photometers.

Fertilizer Plants

A modern fertilizer mixing plant consists of units for proportioning, mixing, drying, cooling, and classification, all carried out on a continuous basis. Many instruments are used including recording potentiometers, flow controllers and recorders for both solids and liquids, level indicators, and various electrical instruments. The control room in a modern fertilizer mixing plant is not unlike that in many other chemical plants and the tendency is more and more toward so-called push button type of operation. Plants for manufacture of fertilizer raw materials and intermediates such as ammonia, ammonium nitrate, urea, sulfuric acid, and phosphoric acid require instrumentation even more complete than in fertilizer mixing plants.