tion is not so available at this time with respect to generators 3, 4, 5, 20, and 21, partly for reasons of national security.

We also take this opportunity to point out that this survey may be made more complete and brought up to date through submitted discussions.

Acknowledgments

We wish to acknowledge the assistance of the following individuals and their organizations for furnishing information and data which have been directly usable in this survey. The numbers correspond to those in Table 1 and in the text:

1 Case Institute of Technology, Cleveland, Ohio, D. P. Eckman.
2 Carbide and Carbon Chemicals Company, South Charleston, W. Va., F. A. Woods.
3 E. I. du Pont de Nemours & Company, Charleston, W. Va., R. S. Lovett.
4 E. I. du Pont de Nemours & Company, Orange, Texas, P. S. Buckley.
5 E. I. du Pont de Nemours & Company, Wilmington, Del., J. T. Thomas.
6 Eastman Kodak Company, Rochester, N. Y., D. W. St. Clair.
7 The Foxboro Company, Foxboro, Mass., A. R. Catheron.
8 Hartmann and Braun, Frankfurt on Main, West Germany, W. Oppelt.
9 Imperial Chemical Industries Ltd., the Frythe, Welwyn, Herts, England, A. R. Aikman.
10, 11, 12 George Kent Ltd., Luton, Bedfordshire, England, R. S. Medock.
13 Minneapolis-Honeywell Regulator Company, Brown Instruments Division, Philadelphia, Pa., E. F. Hochschild.
14 Shell Development Company, Emeryville, Calif., B. D. Stanton. (Unit built by Librascope, Inc., Glendale, Calif. Direct inquiries here.)
15, 16 Shell Laboratorium, Delft, Holland, A. J. Johnson (At Emeryville, Calif.).
17 Taylor Instrument Companies, Rochester, N. Y., E. M. Barr.
18 Taylor Instrument Companies, Rochester, N. Y., L. M. Zoss.
19 Taylor Instrument Companies, Rochester, N. Y., F. B. Newell.
20 United States Naval Air Missile Test Center, Point Mugu, Calif., W. F. Abbott.
21 United States Naval Air Missile Test Center, Point Mugu, Calif., T. E. Hanes.
22 The Ahrendt Instrument Company, College Park, Md., W. R. Ahrendt.
23 Shell Development Company, Emeryville, Calif. (Unit built by Librascope, Inc., Glendale, Calif. Direct inquiries to E. W. Silvertooth here.)
24 Woodward Governor Company, Rockford, Ill., H. B. Capwell.
25 Plessey International Ltd., Ilford, Essex, England, R. W. Hardisty.
26 Massachusetts Institute of Technology, Cambridge, Mass., Emery St. George, Jr.

The following organizations are actively applying frequency-response techniques to evaluations or are in the process of developing wave generators:

Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill., G. A. Nothmann.

Battelle Memorial Institute, Columbus, Ohio, F. C. Todd.

British Iron and Steel Research Association, London, England, S. S. Carlisle.

Elliott Bros. Ltd., Borehamwood, Herts, England, A. E. DeBarr.

We also here express our appreciation to the many individuals who have provided references and given leads in connection with this survey.

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3 "An Automatic Transfer Function Measuring and Recording System," by R. J. Ehret, J. M. Embree, E. F. Hochschild, and E. C. Grogan, Proceedings of the AIEE Conference on Recording and Controlling Instruments, Philadelphia, Pa., November, 1952. (Also to be published in AIEE Transactions, *Electrical Engineering*, in digest form.)

4 "Dynamic Pressure Transmitter Calibrator," by R. D. Meyer, *Review of Scientific Instruments*, vol. 17, May, 1946, p. 199.

5 "Signal Generators for Servo System Measurements," by C. F. White, Naval Research Laboratory.

6 "A Frequency Spectrum Analyzer for the Study of Servo Mechanisms," by F. H. Ferguson, Naval Ordnance Laboratory, Memorandum 9317.

7 "Harmonic Response Test Gear," Vickers Armstrong Ltd., Newcastle, England.

8 "A Technique for Rapid Determination of the Harmonic Response Characteristics of a Position Control Servo Mechanism," by E. B. Pearson and G. F. Lingwood, *Instrument Practice*, March, 1953, p. 340.

Discussion

F. A. Woods.[5] The authors are to be congratulated for bringing together so much information on this diversified subject and presenting it in such an interesting manner.

There is little that can be added to the information which has been given on our sine-wave generator itself (generator No. 2 as listed in the paper). However, the methods used by various people in recording and extracting the pertinent data once the sine-wave generator is running on a given test are also of considerable interest.

The measurement of the input and output sine waves produced with the use of this generator is accomplished by means of a two-pen pneumatic strip chart recorder. Two chart speeds are available, 1 iph and 1 ipm, which essentially cover the range of frequencies available. From the chart records obtained the magnitude ratio and phase angle for each frequency tested are extracted and then plotted in the normal manner. This task represents the greatest single drawback to our system since it is quite tedious, and the measurement of phase angle is inclined to be inaccurate for certain frequencies. However, taking all these things into consideration, the system described is simple to operate and relatively inexpensive. It has been found to be quite adequate for laboratory and demonstration purposes.

The writer would be interested in hearing how others have approached and solved these same problems.

E. L. Coulter.[6] Although this paper probably has a good deal of general-interest value, it is especially interesting to those associated with the fields employing frequency-response techniques. To one who is engaged in the use of such equipment in measurements, it offers an unusual opportunity to compare with others who have been faced with the same problems.

[5] Instrument Engineer, Carbide & Carbon Chemicals Company, S. Charleston, W. Va.

[6] Engineer, Air Arm, Westinghouse Electric Corp., Baltimore, Md.

The author is certainly correct when he says that companies wishing to use pneumatic wave generators must develop their own. It is felt that this statement can be extended for mechanical and electrical sine-wave generators also to a large degree. Of course the commercially available equipment does cover the more common electrical and mechanical applications.

Table 1 of the paper is a useful reference both for determining what is being done elsewhere and for comparison.

The two devices which S. L. Gillespie discusses under "mechanical" are novel. They merit general publicity.

L. W. Erath demonstrates a novel application of electrolytics.

A paper of this type is necessarily limited because of the wide usage of the equipment discussed. A broad field of activity is to be found in the aircraft industry. The authors seem generally to have confined themselves to the industrial-control field which also is a very interesting field.

This paper should serve to illustrate the value of papers devoted to surveys. It is felt that other survey papers on other phases of measurement in the frequency-response field could be written.

One method of generating sine waves which was not covered in the paper, and which is believed to be of enough general interest to merit mention, is the so-called underexcited synchro method. This method is treated in the literature[7] but it is felt to be of general enough use to be mentioned in conjunction with such a paper. Briefly, it consists of a continuously rotating underexcited synchro being compared with a normally excited synchro. The resultant signal is a suppressed carrier sine wave modulated at a frequency equal to the speed of rotation of the underexcited synchro. A method of obtaining accurate phase information at high servo frequencies is available by using a third synchro and a mechanical differential.

[7] "Principles of Servomechanisms," by G. S. Brown and D. P. Campbell, John Wiley and Sons, Inc., New York, N. Y., 1948.

It is easily understandable that with three experts such as the authors, the paper would naturally divide into three subdivisions, one for the specialty of each. It is hoped, however, that the large amount of overlap between the three fields is not obscured by this division. In fact, attempts at building universal sine-wave generators have been made and a fair degree of success has been achieved in some cases. One particular model of this type was developed by the writer's company.

In order to demonstrate the degree of overlap of the three divisions a brief description of this generator will be given. The speed range is from 0.005 to 54 cps. This range is obtained with a closed-loop magnetic-amplifier speed control on a servomotor and four gear ratios.

The output of the speed control is a continuously rotating shaft. Driven by this shaft are a Scotch yoke and two continuously rotating synchros which may be adjusted differentially. The Scotch yoke drives a rack and pinion which in turn oscillates a shaft on which potentiometers and synchros are mounted. This shaft is also available for rotational harmonic motion and the rack is available for rectilinear harmonic motion. If the electrical output is used to drive a transfer valve which actuates a bellows the device can become pneumatic also.

It is hoped that this discussion demonstrates that one good set of measuring apparatus may be adapted for use in most applications. The amount of specialization should depend on the amount of variation of jobs handled by the equipment user. Rarely would one user require three different sets of equipment.

Authors' Closure

The authors thank each of the discussers for his interest in the survey. Mr. Coulter is quite correct when he points out the great amount of overlap between the fields. While we have no specific figures it appears that the wave generators being used the greatest number of hours per day on industrial applications are those combining two and three fields of operation.