FREQUENCY AND TIME TRANSMISSION

new LF and VLF antennas and transmitters under construction

THE BUREAU is in the process of raising 400-foot antennas and building 50-kw transmitters to substantially increase the coverage of the standard frequency and time transmissions of NBS stations WWVB (60 kc/s) and WWVL (20 kc/s). The new facilities will be located at a carefully-chosen site near Fort Collins, Colo., and are expected to be in operation by early 1963.

The wide-scale distribution of the U.S. Frequency Standard and of time signals is needed to coordinate the operations of the global network of missile and satellite stations, to improve the uniformity of frequency measurement on a national and international basis, and to provide a more accurate "yardstick" of frequency—easily available to many users—for electronic research and development.

The importance of higher accuracy and wider distribution in the transmission of the U.S. Standard of Frequency is indicated by the strong support which this program has received from the National Aeronautics and Space Administration. This agency provided financial assistance for construction of both the initial 20-kc/s station (WWVL) and the transmitters and large antenna for the new 20-kc/s station.

Both WWVB and WWVL have been transmitting for several years from sites near the Boulder (Colo.) Laboratories of the Bureau. The existing stations are quite small and electrically inefficient but they have served to substantiate the basic concepts of using the lower frequencies to obtain more stable signals and wider coverage for standard frequency and time-signal broadcasts. Although WWVL, located in the mountains near Boulder,[1] radiates less power than a 15-watt light bulb, its signal has been received in New Zealand. Even under present conditions the reliability and accuracy of signals from the two stations has enabled some organizations to cancel plans for installing expensive atomic frequency standards within their own laboratories.

With the new antennas and transmitters the radiated power of WWVL will be increased to 1 kilowatt: for WWVB the radiated power will be increased from 2 watts to 7 kilowatts. Signals from both stations will be compared continuously with the U.S. Frequency Standard, which is provided by two cesium beam atomic clocks maintained by the NBS Radio Standards Laboratory.

The 60-kc/s transmission of WWVB is particularly designed to serve users in the continental United States, since signals at this frequency propagate with more stability than those at 20 kc/s for distances up to about 2,000 miles. Time signals (to be given for the first time at 60 kc/s) will offer a precision ranging from a hundred-thousandth to a millionth of a second, depending upon the distance from the transmitter. This is 100 to 1,000 times more stable than the short-wave signals from NBS station WWV, Beltsville, Md. The WWVB time signal will be emitted once per second and will consist of modulation by five cycles of a 1,000-c/s sine wave.

The WWVL 20-kc/s transmission is designed to extend the experimental studies required to provide accurate time signals, clock synchronization, and frequency transmission over most of the world with very narrow band signals.

NBS considered using very-low frequencies (VLF) for their standard frequency transmission as early as 1930. The principal reason for adopting a high-frequency (HF) system, at station WWV and NBS station WWVH, Maui, Hawaii, however, was that few users at that time had low-frequency receivers. Two other reasons for not using low frequencies were the high cost of the antenna and the possibility of interference from natural noise.

Since 1930 the problem of natural noise has been overcome by reducing the bandwidth and by using integration-type measuring techniques. Also, VLF and HF receivers are now approximately equal in cost. The high stability and long-range coverage of the lower frequencies have been thoroughly established by both theory and by experiment—much of which was contributed by the Central Radio Propagation Laboratory at NBS.

The basic reason for the different characteristics of the higher and lower frequency ranges is the difference in the way these signals travel around the globe. The high-frequency transmissions of WWV and WWVH bounce between the earth and the ionosphere and depend upon the mirrorlike qualities of the ionosphere to be reflected to distant points. However, the reflective quality of the ionosphere varies because of changes in the atmosphere and in radiation from the sun. (During a large solar storm the ionosphere can become so disrupted that it does not reflect the high-frequency signals at all.) These variations cause the time for a high-frequency signal to travel between two points to change continuously and sometimes cause the signal to be entirely lost in outer space.

LF and VLF transmissions follow the curvature of the earth since the ionosphere and the ground act as upper and lower limits of a gigantic duct to guide the signals over the globe. In such cases the ionosphere serves only as a boundary, not a direct reflector, and thus has little effect upon the speed of the waves. The lower frequencies travel a more direct route between points on the surface of the earth.

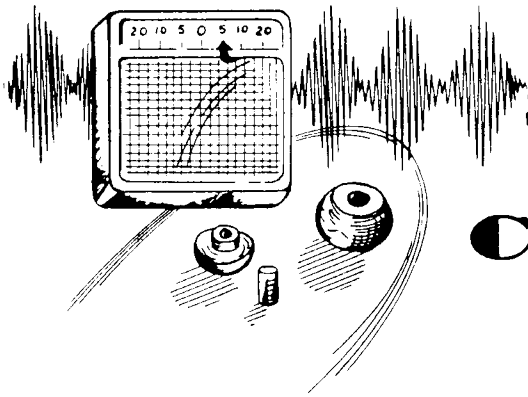
The instabilities of high-frequency propagation necessitate the averaging of signals from WWV for a period of up to 30 days to achieve a precision of 1 part in 10 billion; the usual attainable precision is only about 1 part in 10 million. Reliable reception is limited to a distance of a few thousand miles. The 20-kc/s transmission will offer a precision of 1 part in 10 billion or better, on a global basis, within an observing period of about 1 day. Within the same 1-day observing period the 60-kc/s transmission will offer a precision of 5 parts in 100 billion within the continental United States.

In addition to having more powerful transmitters and more efficient antennas, the new stations will be more effective because of the characteristics of the new 380-acre site. Its primary assets are high soil conductivity, the availability of electric power, relative freedom from violent weather extremes and manmade noise, and ease of access.

The diamond-shaped antenna for each station will be about 1,900 ft long and 750 ft wide. Each antenna will be supported by four 400-ft guyed steel masts.

WWVB and WWVL will not replace the shortwave transmissions of WWV or WWVH. The high-frequency signals require only simple receivers and their accuracy is sufficient to meet the current needs of television and radio stations, electric power companies, amateurs, smaller businesses, and the general public.

[1] New Standard Frequency Broadcasts, *NBS Tech. News Bull.* **44,** *120 (July 1960).*



STANDARDS AND CALIBRATION

NBS Temperature Calibrations

TODAY'S expanding technology has created a demand for temperature measurements of greater accuracy—and over a greater range—than ever before. To meet these needs, the Bureau conducts research on a wide variety of temperature measurement problems. It also calibrates temperature measuring devices to promote accuracy and uniformity of temperature measurement in this country.

Inquiries are often made as to how accurately the Bureau can calibrate an instrument. The following discussion, with the accompanying chart, is presented in clarification of these questions.

Calibrations and Accuracies

The Bureau undertakes the calibration [1] of certain types of precise temperature measuring instruments both for Government agencies and for private organizations or individuals. In general, only instruments suitable for use as laboratory standards are accepted for calibration. The calibrations are made in terms of the International Practical Temperature Scale (IPTS), which is accurately reproduced at the Bureau to serve as the Nation's standard for temperature measurements.

The accuracies ultimately realized in use with such calibrated instruments depend upon several factors: (1) The accuracy with which the IPTS is realized in the NBS laboratories; (2) the accuracy with which the instrument can be compared with the temperature scale; and (3) several use factors which involve the inherent limitations of the particular instrument and the soundness of the techniques which are employed in its use. In the following description of NBS calibration services estimated limits are assigned to accuracies associated with the first two factors outlined above, but a consideration of use factors is not included.

Temperature Scales Maintained at NBS

The International Practical Temperature Scale [2] serves to define temperatures from −182.97 °C upwards. This scale, which has been agreed upon by the 37 nations which subscribe to the actions of the General Conference on Weights and Measures, is defined by six reproducible temperatures to which values have been assigned. These "defining points" are the normal boiling points of oxygen at −182.97° Celsius (centigrade), water at 100 °C, and sulfur at 444.6 °C; the freezing points of silver at 960.8 °C, and gold at 1063 °C; and the triple point of water at 0.01 °C. The IPTS is further defined by specified instruments for interpolation between the fixed points, together with recommendations relating to their calibration at the appropriate fixed points. Thus the accuracy with which the scale may be reproduced varies in different temperature ranges throughout the scale, and in some cases depends more upon the precision of the specified instrument of interpolation than the accuracy with which the defining points may be reproduced. The standard platinum resistance thermometer is the specified instrument between −182.97 and +630.5 °C, and the platinum versus platinum-10 percent rhodium thermocouple from 630.5 to 1063 °C. Above 1063 °C, a temperature *t* on the scale is defined as a function