STANDARD MUSICAL PITCH

ONE of the lesser known services of the National Bureau of Standards is the broadcasting of a musical tone of standard pitch—middle "A" at 440 cycles per second—over its shortwave stations WWV (Beltsville, Md.) and WWVH (Maui, Hawaii). These broadcasts make standard pitch available day and night throughout the United States and over much of the world. Because a shortwave receiver is all that is needed, easy access to standard pitch is thus provided for piano tuners and amateur and professional musicians, as well as for makers of musical instruments.

A 600-c/s tone is also broadcast. This, together with the 440-c/s tone, is used by scientists, electronics engineers, and manufacturers in the measurement of short intervals of time and for calibrating instruments and devices that operate in the audio and ultrasonic frequency ranges. Both the 440- and the 600-c/s tones are obtained from an electronic, crystal-controlled oscillator and are accurate, as transmitted, to better than 1 part in 100,000,000.

The two frequencies are broadcast alternatively, starting with 600 c/s on the hour for 3 min, interrupted 2 min, followed by 440 c/s for 3 min and interrupted 2 min. Each 10-min period is the same except that WWV is off the air for 4 min beginning at 45 min after each hour; and WWVH is silent for a 34-min period each day beginning at 1900 Universal Time (9 A. M. in Hawaii or 2 P. M. EST).

To provide greater assurance of reliable reception, transmissions from the NBS stations are made simultaneously on several standard broadcast frequencies. WWV broadcasts on 2.5, 5, 10, 15, 20, and 25 Mc (megacycles per second) and WWVH broadcasts on 5, 10, and 15 Mc.

In this country, A=440 c/s has been accepted as standard pitch since 1925. Initially, this value was agreed upon by the Music Industries Chamber of Commerce as a useful compromise among the various pitches chosen arbitrarily by different musical groups. In 1936 the same pitch standard was adopted by the American Standards Association, giving it the status of an industrial standard. Three years later the International Federation of National Standards Associations (ISA)[1] sponsored a conference in London. France, Germany, Great Britain, Holland, and Italy sent delegates, and the United States and Switzerland sent official messages. Six of the seven countries independently proposed A=440 as the standard and the conference adopted it unanimously. The same standard was again endorsed by the International Organization for Standardization (ISO) in 1953; and was accepted as an ISO Recommendation at Stockholm in 1955.

The National Bureau of Standards maintains the A=440 standard as the one on which general agreement has been reached. The musical merits of any particular standard are, of course, outside its province.

Earlier Pitch Standards

Previous standards of pitch[2] were defined in terms of the frequency of a particular tuning fork or bar, or the length of a specified vibrating air column (organ pipe). Because the sound frequencies generated by these devices vary with the surrounding temperature, it is necessary to specify the temperature at which comparisons with these standards should be made.

In 1859 the "Diapason Normal" was defined in terms of a standard tuning fork deposited by the French Government at the Paris Conservatory of Music. The vibration frequency of this fork was stated to be 435 c/s when measured at the then standard laboratory temperature of 15° C. When R. Koenig (1880) made a careful determination of the frequency, it proved to be 435.45 c/s at 15° C and to have a thermal coefficient of −0.0486 c/s per degree centigrade. Thus the fork would really have the defined standard frequency at slightly over 24° C.

An international congress in Vienna in 1891 adopted the French definition of the Diapason Normal, and it acquired the name of "International Pitch." Great Britain and the United States apparently did not attend this meeting, though A = 435 was used as a standard by a number of musical groups and instrument makers in this country after its adoption by the Vienna congress.

In many places the pitch standards in actual use were strongly influenced by the way large, permanently installed pipe organs were tuned. Yet, of all the mechanical devices used to generate musical frequencies, the vibrating air column of the pipe organ is the most sensitive to changes in temperature. Their frequency would therefore depend on what the temperature happened to be when they were adjusted to conform to the standard fork in the Conservatory at Paris. Since the advent of better heating systems and air conditioning, the temperature at which most musical instruments are used today—in the United States, at least—is better represented by 20° C (68° F) than by the temperature of 15° C (59° F) associated with the Diapason Normal. Luckily, an organ pipe tuned to A = 435 at 15° C will actually be tuned almost exactly to A = 440 at 20° C.

Advantages of Present Standard

From a technical point of view, the present standard of musical pitch, as maintained by the Bureau, has the advantage that it is free from the vagaries of the material objects (tuning forks, organ pipes) that embodied past standards. Thanks to modern electronic techniques for generating and stabilizing oscillations, a tone is produced that for all practical purposes is independent of the temperature of the surroundings.

This would apply, of course, to any musical frequency that might be chosen. It happens, however, that the 440-c/s frequency stands in a very simple relation to other frequency standards maintained by the Bureau and can therefore be produced with a minimum of additional equipment. A tone of 435-c/s, for example, would require a somewhat more complicated technical arrangement.

In changing over to Standard Pitch, little or no alteration is necessary in adjusting instruments tuned to the older standard. Instruments tuned by string tension and the open vibrating air columns of pipe organs present no problems at all. Woodwinds can be corrected partly by the tuning adjustment of the instrument and partly by the breath control of the player; and changes required in the reed stops of the organ are within the range of the instrument's tuning adjustments.

[1] *This has now been superseded by the International Organization for Standardization (ISO).*

[2] *A history of earlier standards of pitch is appended to the English translation of* Sensations of Tone, *by Helmholtz, translated by A. Ellis, published by Longmans, Green & Co., New York, 1895 (reprinted by Dover, New York, 1954). A history of British standards of pitch is given in the folder,* British Concert Pitch, *published by British Standards Institution, 28 Victoria St., London, SW1.*

Below, left: Seconds-pulse generator and time-interval selector at station WWV. This serves as the motivating unit to remove (and then return) the audiofrequency tones—standard musical pitch at 440 c/s and a 600-c/s tone—from the broadcast signal for periods of 1/25 sec once each second. During the 1/25-sec interval a short train of 1000-c/s oscillations is used to provide a seconds "tick." The mechanical gears shown (below) serve only a gating purpose and do not determine the precision of the timing operations. The precision is electronically controlled. _Right:_ Audiofrequency racks used for generating standard musical pitch, 440 c/s (A above middle C), at station WWV. The day and night broadcasts from WWV and from the Bureau's other station, WWVH in Hawaii, make the standard tone available to shortwave sets throughout the United States and a large part of the world. The racks shown also generate a 600-c/s tone, and each of the two tones is broadcast for 3 min in alternate 5-min intervals. Three audioracks are maintained, two of them for standby purposes in case of failure of the one in use. The engineer is here adjusting the phase relationships of the audio oscillations generated by the different racks to keep them in accurate synchronism.