

The sound of weights and measures

In first-century China, emperor Wang Mang standardized weights and measures in his newly established dynasty. Noa Hegesh tells the story of sound as the basis for this standardization.

We consider the standardization of weights and measures a rather modern feat, but achieving metrological unity had already preoccupied the minds of early societies, such as that of elite society in first-century China. Placed at the nexus between heaven and earth, the emperor was responsible for the synchronization between natural and social patterns. Together with sundial shadow measures, pitch calculations helped assess seasonal changes and regulate the timing of astronomical events, which in turn, affected decision making in the court. Inaccuracy in the timing and prediction of natural processes could result in uprisings, famine, floods, wars or even the fall of the empire.

When Wang Mang (王莽) usurped the imperial throne and established the short-lived Xin dynasty (新; 9–23 CE), he used sound as the foundation for imperial metrological standardization as part of his declaration of power. The ability to control sound was considered to reflect his ability to synchronize heaven and earth, the cosmic and the human. The image of his authority and ruling legitimacy rested in the physical dimensions of a single pitch pipe that produced the cardinal tone in the traditional musical system, Yellow Bell (*Huangzhong* 黃鍾).

This imperial conceptualization of sound is particularly visible in treatises dedicated to tuning and mathematical astronomy (*Lüli zhi* 律歷志). The literatus official, Liu Xin (劉歆; 46 BCE–23 CE), gathered a large group of experts on musical temperament and compiled a treatise on the subject with a focus on the standardization of weights and measures of the Xin dynasty¹. The text subordinated the discussion about metrology to a larger conversation about the mathematical calculation of sound and its place in Xin cosmology. The standardization of weights and measures linked length and volume to the length and the volume of the Yellow Bell, and weights and balances to its weight.

In order to measure the dimensions of the pipe, the treatise prescribes millet



Credit: National Palace Museum

grains of equal size: 90 grains measured the length of the pipe and 1200 grains its volume, called *yue* (龠 or 籥), which was equal to a weight of 12 *zhu* (銖), which when doubled was a larger unit of weight called a *liang* (兩).

Liu's treatise describes a large bronze vessel (similar to that pictured) with two ears containing five compartments of different sizes — each embodies a standard for volume, while the two central compartments also embody the standard for length (depth).

The vessel's main inscription at its centre dates it to the first year of the Xin dynasty and describes the cosmological conditions heralding the ascent to power of the new emperor. It also exalts his first actions: the recalibration of the calendar, and correspondence between the standards of tuning (*lü* 律), length, volume and weight.

Five additional inscriptions for each of the compartments provide the formula for deriving the diameter of a circle from a circumscribed square in order to calculate the volume of the specific chamber. However, these may have been added at a later date².

The lower-left compartment corresponds to the smallest measure, identified with an inscription as a *yue*, with the additional text: “like the volume of the Yellow Bell [pipe.]” According to studies published in 2011, the *yue* inner diameter is 3.3 cm, its height is

1.2 cm, it weighs 7.7295 g and it has a volume of 10.65 ml (ref. ³). The features of the vessel and its inscriptions indicate that this was a standardized measuring tool, which matches Liu's description.

From the mid-third century BCE, calculating interval ratios and measuring sound on pitch pipes and string tuners became crucial elements to determine the state of the cosmos throughout the year: observers in the office of astronomy together with learned officials in charge of setting solstice rituals and court literati designed sound distribution models that depicted its transition from one winter solstice to the next. Some marked the pitch and scale for each of the twelve solar months, while others marked smaller divisions, in which each pitch corresponded to several days.

The pictured vessel was likely an exemplary model, aimed to convey an imperial image of such cosmological order and its extension to the social one. The vessel may have been used for copying and disseminating the new standards across the territory. Anchoring metrological standards in the dimensions of the fundamental pitch of the music system announced the legitimacy of the usurper. Although the pitch pipe no longer exists, the essence of the Yellow Bell survives in the smallest compartment of this object as an embodiment of standardized measurement, an echo of the sound of the Xin dynasty. □

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