

How long is a “foot”?

A. D. Russell

The fundamental units of measure are generally taken to be those of the metric (SI) system [2]. U.S. Customary Units are legally defined in terms of SI units. Unfortunately, the definitions of the Customary Units often differ slightly from the internationally accepted equivalent units.

Consider the lowly foot. The accepted definition of the (International) foot is 1 foot = 0.3048 meter or, equivalently, 1 inch = 0.0254 meter and these equalities are *exact*. And then there is the U.S. Customary Foot, on which the U.S. land survey is based. The U.S. Customary Foot is defined (under an 1893 Act of Congress) by the relation 12 meters = 39.37 feet or, equivalently, 1 meter = 39.37 inches. Then 1 U.S. Customary Foot is $12/39.37 = 0.30480061\dots$ meter.

This small difference is insignificant for many applications. If the design dimension is, say, 10 m, the designer converts using the International definition, and the builder/surveyor uses the US Customary definition the difference is $\approx 0.000065' \approx 0.000787''$. However, for a structure the size of the Main Injector the difference can be significant. The design orbit length is 3319.4187 m. Converted to International feet, this is 10889.48130'. If the machine is then installed using U.S. Customary Foot, the actual installed orbit length will be 3319.42534 m: 6.64 mm $\approx 0.261''$ too long.

For the Tevatron and Main Ring the design orbit length is 2π km. If the designer calculates installation coordinates using the International Foot and the surveyor/installer uses the instruments calibrated to the U.S. Customary Foot, the orbit will be too long by 12.57 mm. For comparison, consider the report of Kerns et al.,[1] that the Tevatron orbit length is 39.0 mm too long.

The Fermilab Alignment Section uses instruments calibrated to the U.S. Customary Foot. To eliminate needless confusion and possible systematic errors all metric/Customary conversions should use 12 meters = 39.37 feet. The importance of consistency at this level is further emphasized when one considers the use of standard DUSAF coordinates with A0 at (100000,100000) feet: 100000 Int. ft = 30480.0 m; 100000 USC ft = 30480.06096 m. This implies a potential placement error of 6 cm or more.

References

- [1] Kerns, C., Q. Kerns, H. Miller, IEEE NS-32, 1930, 1985
- [2] International and metric units of measurement, Marvin H. Green, Chemical Publishing Co., Inc., New York, N.Y., 1973 International Bureau of Weights and Measures. Systeme international d'units. English: The international system of units (SI), edited by David T. Goldman, R. J. Bell, 1986 ed. Gaithersburg, MD: U.S. Dept. of Commerce, National Bureau of Standards; Washington, DC