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Scope

This Technical Reference covers the use, design and specifications of the Sartorius-Scale-450 kg scale used in the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) Fire Research Laboratory (FRL).

Instrument Description

GENERAL

The Sartorius-Scale-450 kg weighing device is used primarily for mass measurements up to a capacity of 1000 lb_m. This scale offers a modular design incorporating the use of four load cells, a weighing platform, and an indicator unit. The components of Sartorius-Scale-450 kg weighing device are calibrated as one unit in accordance with manufacturer and ATF specifications.

Load Cell

The Sartorius-Scale-450 kg uses four model GWT-011462 500 lb_m capacity load cells, two load cells each loaded in compression and tension, allowing for a maximum measurement capacity of 1000 lb_m. The load cells respond to an applied load positioned on a weighing platform and relays an electrical response to a Sartorius model PR6130 Cable Junction Box. The four responses are then combined into a single analog electrical signal and transmitted to the indicator unit.

Weighing Platform

The Sartorius-Scale-450 kg uses a Sartorius model CAPPU-1000KK-LU weighing platform with a 0.91 m x 0.91 m (36” x 36”) steel load plate. The platform must be leveled manually by the user prior to testing to reduce measurement errors caused by the angular orientation of the scale. Adjusting the supports on each of the corners of the weighing platform raises or lowers each corner if the scale is used on an unlevel surface.

Indicator

The Sartorius-Scale-450 kg uses a Sartorius Combics 3 model CIS3-U indicator unit to provide a digital display of the analog electrical output signal from the load cells. The indicator offers 22000 scale divisions allowing for a maximum readability of 0.05 lb_m (0.02 kg) at a 1000 lb_m (453 kg) capacity. The indicator also contains functions that zero, tare, and offset mass measurements to the full capacity defined by the indicator.

CONNECTING TO THE DATA ACQUISITION

The Sartorius Combics 3 indicator allows for transmitting data to the data acquisition (DAQ) system by means of a network cable connected to a FireTOSS jack.

Uncertainty

The measurement uncertainty was determined using guidelines in the National Institute of Standards and Technology (NIST) Technical Note 1297[i], Special Publication 1007[ii], and the NIST Uncertainty Workshop[iii]. The uncertainty of mass measurements includes the allowable uncertainty, random uncertainty, and combined uncertainty.

ALLOWABLE UNCERTAINTY

The allowable uncertainty is determined from allowable tolerances provided in the manufacturer's specifications[iv] and NIST Handbook 44[v]. The allowable tolerances defined by the manufacturer are:

- the linearity as ±0.1 lb_m,
- the repeatability as ±0.15 lb_m,

Additional allowable tolerances mandated by NIST Handbook 44 are:

- the tolerance as ±0.5 lb_m,
- the zero balance as ±0.5 lb_m,
- the sensitivity as ±0.1 lb_m,
- the temperature effect on the minimum dead load output as ±0.05 lb_m over a temperature change of 5°C [4].

The error associated with each tolerance, T, assumes a rectangular probably distribution and can be calculated by dividing the tolerance by $\sqrt{3}$. The allowable uncertainty, U_A, can be calculated by combining the error components in quadrature using Equation 1.1.

$$U_A = \sqrt{\sum \left(\frac{T}{\sqrt{3}}\right)^2} \qquad \textbf{(1.1)}$$

The allowable uncertainty for the weighing device is ±0.1933 kg (±0.4261 lb_m) or ±4.26 x 10^{-2} % of a 450 kg (1000 lb_m) capacity.

RANDOM UNCERTAINTY

The random uncertainty, U_R, is determined from random errors that occur naturally during operation. The errors are determined using sample measurements taken during typical test conditions. The random uncertainty is calculated by applying the standard deviation, *S*, and the number of measurements, *n*, in a sample to Equation 1.2.

$$UU_{RR} = \frac{S}{\sqrt{n}} \tag{1.2}$$

The random uncertainty is based on a sample containing 600 measurements. The random uncertainty for the weighing device is ± 0.00 kg (0.00 lb_m) or 0 % of a 450 kg (1000 lb_m) capacity.

COMBINED UNCERTAINTY

The combined uncertainty, U_C, is determined from the combining the allowable uncertainty and random uncertainty in quadrature. The combined uncertainty is calculated using Equation 1.3.

$$UU_{CC} = \sqrt{UU_{AA}^2 + UU_{RR}^2} \tag{1.3}$$

The combined uncertainty for the weighing device is ±0.1933 kg (±0.4261 lb_m) or ±4.26 x 10^{-2} % of a 450 kg (1000 lb_m) capacity.

References

1. Taylor, B. N., & Kuyatt, C. E., "NIST Technical Note 1297: Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results," National Institute of Standards and Technology, Gaithersburg, MD, 1993.
2. Bryant, A.R., Ohlemiller, T.J., Johnsson, E.L, Hamins, A., Grove, B.S., Guthrie, W.F., Maranghides, A., Mulholland, G.W., "Special Publication 1007," National Institute of Standards and Technology, Gaithersburg, MD, 2003.
3. Guthrie, W. & Liu, H., "Hands-on Workshop on Estimating and Reporting Measurement Uncertainty," National Institute of Standards and Technology, Presentation given to CPSC, 2007.
4. "Instruction Manual: Adventurer Balances," Ohaus Corporation, Pine Brook, NJ 07058.
5. "Handbook 44: Specifications, Tolerances, and Other Technical Requirements for Weighing Devices," National Institute of Standards and Technology, Gaithersburg, MD, 2010.