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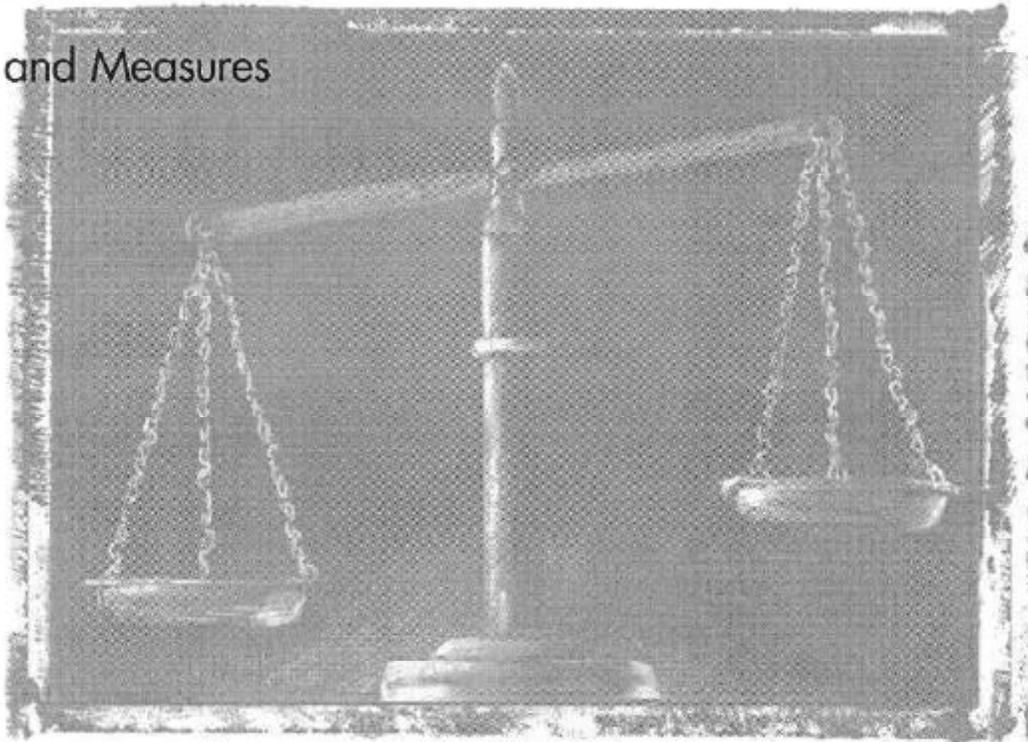
Technology  
Administration

National Institute  
of Standards and  
Technology

# SPECIFICATIONS AND TOLERANCES

for Reference Standards  
and Field Standard

Weights and Measures



## 5. Specifications and Tolerances for Field Standard Stopwatches

NIST  
Handbook

**105-5**  
1997

**Specifications and**

**Tolerances**

**for Reference Standards**

**and Field Standard**

**Weights and Measures**

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## **Preface**

The effort to develop a 105-series handbook for field standard timing devices was undertaken by Ross Andersen (NY) in 1991 to respond to the need for specifications, tolerances, and procedures for timing devices used in weights and measures enforcement activities. This publication is the result of the draft prepared by Ross Andersen.

Special thanks regarding this handbook are given to Karl Herken, metrologist with the State of Kansas, for his assistance with review of reference materials, evaluation of comments submitted during peer review, and for typing and editing the document in WordPerfect format. Thanks are also given to numerous metrologists (of both State and industry laboratories) for their technical review of several drafts.

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**SPECIFICATIONS AND TOLERANCES  
FOR REFERENCE STANDARDS AND FIELD STANDARD  
WEIGHTS AND MEASURES**

5. Specifications and Tolerances for  
Field Standard Stopwatches

These specifications and tolerances are recommended as minimum requirements for standards used in the field by State and local weights and measures officials and others involved in the quantity determinations of time intervals.

Key words: Stopwatches; specifications; standards; time intervals; timing tolerances; tolerances

**Introduction**

A field standard stopwatch is an interval timer where its' primary use is in testing commercial weighing and measuring devices for compliance with the requirements of NIST Handbook 44.<sup>1</sup> The general requirements described in this handbook apply to "field-standard" stop watches and interval timers that are used to determine whether devices meet commercial weights and measures regulations. The listed specifications are intended to permit the use of the equipment in normal field testing operations as field standards for interval timing. The commercial devices subject to testing include taximeters and other timing devices for determining charges for services based on time intervals ranging from less than one minute to several hours.

**1 Scope**

The listed specifications and tolerances apply to stopwatches and interval timing devices. The field standards covered in this publication are intended to be used by weights and measures officials. Industrial, manufacturing and test laboratories may also find this publication useful in tracing timed industrial activities back to national standards. Use of these standards at all levels of concern will help promote accuracy and uniformity in commerce and quality control. The tolerances apply to all stopwatches in service. The specifications are general to allow the use of a wide variety of suitable timepieces. For example, many over-the-counter digital wristwatches with stopwatch functions would easily meet the specifications and tolerances prescribed (with the exception of a unique serial number, which may be added).

**1.1 Transfer standard types**

The term stopwatch used in this publication refers to timing devices used for time interval determination. These devices are generally hand held. This standard does not address the primary or secondary time standards that are used to calibrate the above mentioned stopwatches. Since most calibration methods involve human reaction time, the measurement resolution is often limited to 0.1 s.

**1.2 Classification**

This standard covers two types of stopwatches reflecting two different technologies. The specifications for each type differ, but tolerances are applied equally.

**1.2.1 Type I**

These stopwatches employ digital, electronic circuitry to measure time intervals. They use the mechanical vibrations of an electrically stimulated oscillator (usually quartz) to provide a stable time base frequency (usually over 1 MHz). This time base frequency is then divided electronically and counted.

**1.2.2 Type II**

These stopwatches employ analog, mechanical mechanisms to measure time intervals. The most common form is a watch movement powered by a mainspring that drives a series of hands to record seconds and minutes. The watch movement has a characteristic beat frequency that regulates the speed of the moving hands. A less common form is a timer driven by a synchronous motor that drives either hands or numbered wheels. The synchronous motor is regulated by the precise 60 Hz frequency of AC electric power (house current) supplied by utilities. Please note that house power

and communication disturbances from telephone lines or computer systems may have to be evaluated for precision measurements.

### **1.3 Retroactivity**

These specifications are not intended to make obsolete those field standards presently in service, provided they continue to meet these tolerances. All new stopwatches must meet these requirements prior to certification for legal use. For stopwatches placed in service before the publication of this standard that do not meet these specifications, they must be tested with the procedures of this standard and meet the prescribed tolerances, or be removed from service.

### **1.4 Safety**

*The use of this standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Some industrial measurements may expose testing personnel to hazardous materials for which a material safety data sheet (MSDS) will need to be consulted.*

## **2 Reference Documents**

### **2.1 NIST**

- 2.1.1 Handbook 44, Specifications, Tolerances and Other Technical Requirements for Weighing and Measuring Devices, see current edition, published annually.
- 2.1.2 Special Publication 432, Time and Frequency Dissemination Services, 1990.
- 2.1.3 Special Publication 559, Time and Frequency Users' Manual, 1990.
- 2.1.4 Handbook 145, Handbook for the Quality Assurance of Metrological Measurements, 1986 or later edition.

## **3 Terminology**

**CHU.** The shortwave broadcast station operated by the National Research Council of Canada to disseminate time and frequency information. CHU is located in Ottawa, Canada and broadcasts a range of frequencies. See NIST Special Publication 559 for details on program content.

**Coordinated Universal Time (UTC).** An internationally coordinated time scale maintained by the Bureau International des Poids et Mesures (BIPM), which forms the basis of a coordinated dissemination of standard frequencies and time signals. UTC is defined by averaging data from over 40 laboratories. Nearly all of these laboratories maintain time within 1  $\mu$ s of the average.

UTC time-of-day announcements (like those broadcast by WWV, WWVH, and CHU) are referenced to the time zone centered around Greenwich, England(UK). Local time generally differs from UTC by a integral number of hours. See NIST Special Publications 432 or 559 or the NIST Time and Frequency Division home page on the World Wide Web for details: (<http://www.bldrdoc.gov/timefreq>).

**Clock.** A device for maintaining and displaying time.

**Dual Action Stopwatches.** A dual action stopwatch performs the same operations as a single action stopwatch but with an additional control to indicate "split" or "lap" times. This feature allows the operator to stop one function temporarily to obtain intermediate times without interfering with the overall timing process. Activating the main start control also activates the split control. Subsequently, activating the split control stops the display until the split control re-started, at which time the indicator displays the current total elapsed time.

**LED.** Light emitting diode. Refers to the display type on electronic stopwatches, Type I time interval stopwatches. Emits red, yellow or green light that is used to form numbers.

**LCD.** Liquid crystal display. Refers to the display type on electronic stopwatches, Type I time interval stopwatches. Does not emit light, but uses contrast against a background to form numbers.

*Rollover.* The point where the elapsed time exceeds the maximum indication of time provided by the stopwatch. At the rollover point, the stopwatch automatically starts again at zero or shuts itself off. The user of the stopwatch must account for each rollover to correctly measure long elapsed times.

*Second.* The basic unit of time or time interval in the International System of Units (SI) which is equal, to 9 192 631 770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of cesium-133 as defined at the 1967 Conference Generale des Poids et Mesures.

*Single Action Stopwatch.* A single action stopwatch is controlled by activating the start, stop, and reset controls. Some single action stopwatch mechanisms control all three actions. A separate reset control allows the start control to restart timing from a current reading without resetting to zero.

*Time standard.* Device used for the realization of the time unit. A continuously operating device used for the realization of a time scale in accordance with the definition of the second and with an appropriately chosen origin.

*WWV and WWVH.* The shortwave broadcast radio stations operated by National Institute of Standards and Technology to disseminate time and frequency information. WWV is located in Fort Collins, Colorado and WWVH is located in Kauai, Hawaii. Each broadcasts a range of shortwave frequencies and provides phone access for the audio portion of the programming. (See NIST Special Publication 432 for details on program content.)

## **4 Specifications**

### **4.1 Materials**

#### **4.1.1 Case**

The case of a stopwatch shall be made of corrosion-resistant metal or impact resistant plastic. The case shall be constructed so that it may be disassembled periodically for maintenance, repair, or battery replacement.

#### **4.1.2 Crystal**

The indications, dials, or hands of a stopwatch shall be protected by a crystal. The crystal shall be maintained to ensure that indications are easily read under normal operating conditions and that foreign material is kept out of the operating mechanism.

##### **4.1.2.1 Crystal, Type I**

A type I stopwatch crystal may be tinted and also employ magnification to enhance the readability of the digital indications.

##### **4.1.2.2 Crystal, Type II**

All type II stopwatches crystal shall be clear and untinted.

### **4.2 Physical and Mechanical Properties**

#### **4.2.1 Minimum Time Interval Type I**

Stopwatches powered by a battery shall provide a minimum of 48 hours of operation without replacing or recharging a battery.

#### **4.2.2 Minimum Time Interval Type II**

Stopwatches driven by a mainspring shall provide a minimum of 3 hours of operation on a fully wound spring.

#### **4.2.3 Start and Stop**

A stopwatch shall have single control to start and stop timing. The stopwatch shall provide a signal in the form of a tactile click or an audible tone at the activation of the start and stop control.

#### **4.2.4 Reset**

A stopwatch shall have a control to reset the indications to a definite zero indication. This control may also be used as the start and stop control.

#### **4.2.5 Split Time**

A dual action stopwatch shall have controls to temporarily halt and restart the indications to obtain an intermediate time interval (split or lap time). The mode must be indicated in the display when used.

#### **4.2.6 Operating Force**

The force required to activate the start, stop, split time, or reset controls shall not exceed 1.8 N (0.4046 lbf).

#### **4.2.7 Winding Control, Type II**

A spring driven stopwatch shall have a crown piece to facilitate winding the mainspring.

#### **4.2.8 Electronic Display Types**

Type I stopwatches are presently made with two types of displays:

**4.2.8.1 LED - Light emitting diode.** This type of display is best used in low light conditions. Generally LED displays are lit on demand to reduce battery drainage. A display that is continuously lit is not practical for long-term, portable use.

**4.2.8.2 LCD - Liquid crystal display.** This type of display has very low power consumption and is ideal for long-term portable use. A back-lit display is helpful for use in poor lighting conditions.

### **4.3 Workmanship, Finish, Appearance**

#### **4.3.1 General**

A stopwatch shall provide an indication of elapsed time starting from zero. Graduations, indicators, and displays used to indicate time shall be clear, definite, and easily read.

#### **4.3.2 Dial and Hands, Type II**

For watches with indicating hands, the dial face of a Type II stopwatch shall be white with graduations in black or red. The hands shall be black or red and shall reach to the smallest graduations. Each graduation representing a full second shall be emphasized, and no graduation shall be omitted. A third hand may be used to indicate fractions of a second.

#### **4.3.3 Units**

A stopwatch shall indicate elapsed time in units of seconds, minutes and seconds, or hours, minutes, and seconds.

### **4.4 Markings**

#### **4.4.1 Identification**

A stopwatch must have a unique serial number. A nondetachable serial number, such as an engraving or a melted imprint in plastic cases, is preferred since standards are hand-held and used in a variety of environments.

#### **4.4.2 Manufacturer's Name**

A stopwatch shall be marked with the manufacturer's name or trademark.

#### **4.4.3 Model Markings**

A Type I stopwatch shall be marked with a model designation.

#### 4.4.4 Digital Displays, Type I

Stopwatches shall provide a delimiting character to separate the hours, minutes, and seconds. The colon ":" is the preferred character. A decimal point "." is acceptable if the units of the display are clearly identified using words or symbols.

#### 4.5 Other requirements

##### 4.5.1 Display Formats

Digital displays on Type I stopwatches conforming to the following formats need not have identifying words or symbols to identify units.

Units	Acceptable Display Formats
min, s	MM:SS.S or MM:SS.SS
h, min, s	HH:MM:SS.S or HH:MM:SS.SS

Note: h = hour, min = minute, and s = second.

##### 4.5.2 Minimum Displayed Increment

The smallest displayed increment of time shall be less than or equal to 0.2 s.

##### 4.5.3 Minimum Elapsed Time at Rollover, Type I

The elapsed time at rollover on a Type I stopwatch shall be 1 hour or greater.

##### 4.5.4 Minimum Elapsed Time at Rollover, Type II

The elapsed time at rollover on a Type II stopwatch shall be 30 minutes or greater.

##### 4.5.5 Lanyard

A hand-held stopwatch shall have provisions for attachment of a lanyard to help prevent damage from dropping.

### 5 Tolerances

#### 5.1 Limiting Tolerance

The tolerances are set such that the error in the stopwatch is one-third or less of the smallest tolerance applied to the commercial device being tested. (See NIST Handbook 44 Fundamental Considerations.) The user of the field standard stopwatch must employ test methods for the commercial device that do not add significantly to this error. A stopwatch shall be maintained accurate to 0.02 percent of the time interval under test (approximately 2 seconds in 3 hours) with values truncated to the nearest 0.1 s.

#### 5.2 Physical Orientation

A stopwatch shall meet the tolerances specified regardless of physical orientation.

### 6 Verification Requirements

#### 6.1 Legal Requirements

The listed specifications and tolerances are intended to permit the use of the equipment in normal field testing operations as standards having nominal values. Weights and measures requirements, including but not limited to, inspection, testing, and sealing, by a NIST recognized laboratory shall be followed.

NOTE: Some States have requirements not documented here. Check with the local jurisdiction for specific requirements.

## **6.2 Traceability**

Field standards used for legal metrology shall be traceable to national standards by calibration in a laboratory recognized by NIST in that parameter, range, and scope and evidence shall be documented and provided.

## **6.3 Calibration Report**

The report shall identify the stopwatch referenced, calibration error and uncertainty, time interval of test, and any other necessary information.

## **6.4 Initial and Periodic Verification**

Field standards must be verified prior to use and rechecked as often as regulations or circumstances require, especially when damage is known or suspected. Consideration must be given to any State or local weights and measures regulations.

## **7 Test Methods**

### **7.1 Documented Testing Procedures**

Testing methods shall comply with those documented in NIST (NBS) Handbook 145 or a nationally recognized test method.

#### **7.1.1 Minimum Test Interval**

The tolerance testing of a stopwatch shall consist of at least two tests of approximately 3 hours duration each, except as noted below. Two tests are used to obtain an estimate of process repeatability.

#### **7.1.2 Observed Error**

Each test shall consist of operating the stopwatch over a standard time interval. The observed error is defined as the difference between the elapsed time indicated on the stopwatch and the standard time interval.

#### **7.1.3 Orientation Testing**

On a spring driven Type II stopwatch the two required tests shall be performed in two different orientations: horizontal (with dial fac of stopwatch up), and vertical (with crown of stopwatch up.) The mainspring shall be fully wound before beginning each test.

#### **7.1.4 Test Information**

The data sheet for the test(s) shall record the date, the standard time intervals, and the observed errors in the stopwatch for each test performed. This data shall be maintained on file for the interval specified in the laboratory's quality control documentation or its local jurisdiction's policies.

#### **7.1.5 Test Time Intervals**

Time intervals shorter than three hours may be used for Type II stopwatches placed in service before the publication of this standard. This is permitted only if the stopwatch will not operate for 3 hours on a single winding of the mainspring. In no case shall the standard time interval be less than 1 hour.

## **8 Uncertainties**

### **8.1 Legal Applications**

Uncertainties of the calibration must be evaluated according to the ISO Guide to the Expression of Uncertainty in Measurement,<sup>2</sup>

1993 to ensure that the three-to-one uncertainty to tolerance ratio contained in NIST Handbook 44 is maintained.

### **8.2 Sources of Variation**

#### **8.2.1 Accuracy/Bias**

“By mutual agreement, the United States and Canada have recognized each other's time scales as being equivalent at a level of 10  $\mu$ s. This means that North American users of precise time information may get their time ‘hacks’ from shortwave radio stations at either NIST or the National Research Council of Canada with equal certainty. Depending

on the level of accuracy desired, users still will have to compensate for propagation delays in broadcast time signals. For very low accuracy requirements (e.g., 0.1 s to 1 s) there is little or no need for propagation correction.<sup>3</sup> Time may be obtained through the radio system as described in this handbook or from the NIST Automated Computer Time Service (ACTS.) The ACTS requires a computer, modem, telephone line, and software. It provides NIST time with an uncertainty of less than 5 ms. The overall uncertainty estimates are well within the approximate 2 s per 3 hr tolerances described in this handbook.

### **8.2.2 Repeatability**

Radio and telephone connections have shown repeatability of  $\pm 1$  ms. Human reaction time is estimated at 0.1 s, which is significantly higher than other technical factors involved in the measurement and which vary from one person to another. Laboratory data collected during the development of this handbook<sup>4</sup> indicated a standard deviation of 0.071 s with three operators under controlled conditions when compared to a standard. (Field reaction times may be much less repeatable.) This uncertainty factor may be minimized by extending the time interval over which the device is tested.

## Notes

1. NIST Handbook 44, Specifications, Tolerances, and Other Technical Requirements for weighing and Measuring Devices. (See current edition.) NIST, Gaithersburg, MD, 20899.
2. ISO, International Organization for Standardization, Geneva, Switzerland.
3. News Briefs, Jrnl of Res of the Natl Inst of Stds and Techn, Vol. 97, No. 6, Nov-Dec 1992.
4. Ross Andersen, New York Weights and Measures Laboratory, July 8, 1991.

**Table 1. Tolerance for determined intervals**

Tolerance Test Interval	Calculated Tolerance (s)	Applied Tolerance (s)
3 h 0 min	2.160	2.1
3 h 8 min	2.256	2.2
3 h 9 min	2.268	2.2

**Table 2. U.S. and N.A broadcast time standards**

Station	Frequencies (MHz)	Location
WWV	2.5 5 10 15 20	Fort Collins, CO (NIST)
WWVH	2.5 5 10 15	Kauai, HI (NIST)
CHU	3.33 7.335 14.67	Ottawa, Ontario (Canada, NRCC)

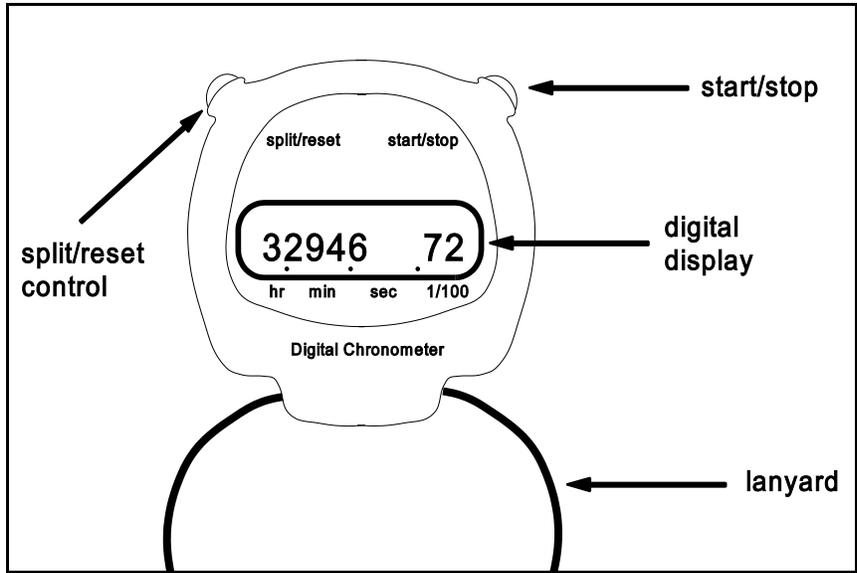


Figure 1. Type I stopwatch.

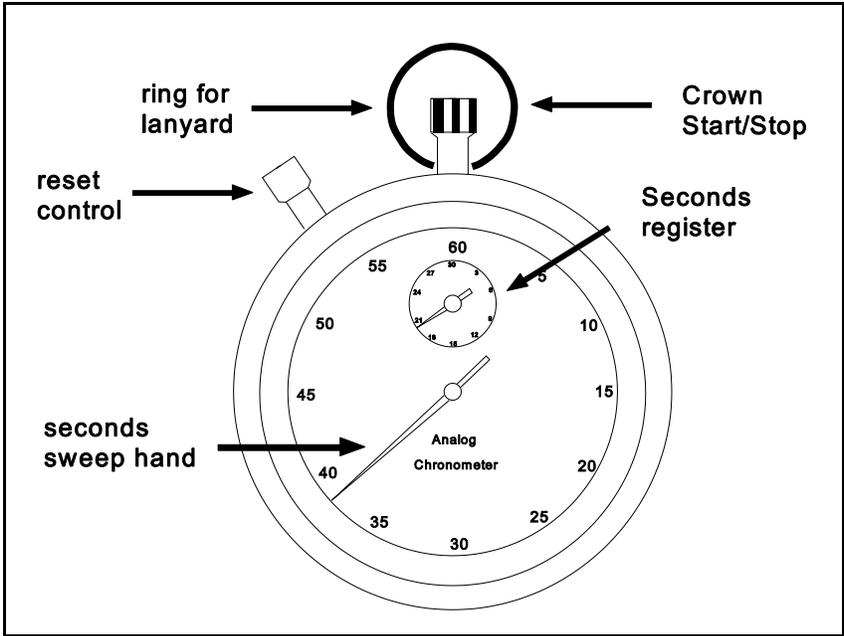


Figure 2. Type II stopwatch.