STANDARD TEMPERATURE

FOR

INTERCOMPARISON

OF

INDUSTRIAL STANDARDS OF LENGTH

This is 1st translation

Mr George K Burgess Director
Bureau of Standards
Washington D C

Dear Sir:

Your interesting letters of April 13 and June 25th regarding "the question of international agreement on the standard temperature for intercomparison of industrial standards of length", have been duly received and I herewith have the pleasure to send you my opinion in the question, explaining my experience in using different "normal temperatures" for standards of length, in my pioneer work in Eskilstuna, Sweden, making gage-blocks and accessories thereto, which at the present time, excluding those made in Dearborn, Michigan, (Ford-Johanson Blocks) amount to about one million gage-blocks in metric and inch systems.

After having designed and made my first set of block gages in the year 1896 I commenced to investigate different makes of gages as micrometers and end standards of American and European make: for instance, from Brown & Sharp Mfg. Co., U.S.A.; Ludwig Lowe, Berlin, and Reinecker, Chemnitz; and also from the State Industrial Works in France, for the purpose of obtaining the right measuring values for millimeters and inches. From this investigation I found that nearly all of these concerns used different adjusting temperatures (standard-temperature) for their gages; that is Brown & Sharp Company, U.S.A. used $\pm 62^{\circ}$ F.; Ludwig Lowe, Berlin $\pm 25^{\circ}$ C; Reinecker, Chemnitz, Germany, $\pm 14^{\circ}$ C; and in the State Works of France 0° C or its equivalent $\pm 32^{\circ}$ F. were used.

In my experimental work and during the time I made up the first thousand sets of my combination block gages for the market from 1899 to 1914, I found that the average and middle temperature in laboratories and shops in which end gages were used, was about 20° C or 68° F and I therefore always tried to keep the temperature in my laboratory constant at that temperature (± 20° C) and only when the customers expressed their wishes to have the block-gages adjusted to hold the measuring value at another certain temperature did I do so, for instance: for France (in mm) at 0° C. = 32° F., and for England (in inches) at ± 62° F., and in some cases, although only a few sets, at ± 66° F.

Nevertheless and although my customers in France requested to have the block-gages hold their measuring value at 0°C, I made the adjusting and checking at 20° C. (68° F.)(at which temperature the block-gages would be used) thereby using a "standard block" 100 mm calibrated at nearly 20° C. at the Bureau International des Poids et Mesures, Paris, and by them calculated to its measuring value at 0° Centigrade.

An exception from the adjusting and measuring of the block-gages at the temperature of definition (Standard Temperature) of 20° C (68° F) has been the Master Standard Combination Blocks made for England, which blocks I adjusted and measured at 62° F. For Japan I also made the combination block sets at 62° F. until that country in 1926 adopted the metric system. The block sets in metric for Japan are now adjusted at 20° C (68° F) as standard temperature.

Adjusting block gages at 62° F. however, I found it more difficult to make the adjusting and calibrating at that lower temperature than at 20° C (68° F).

The radiation of the warmth from the body of the operator had a quicker influence on the block gages at 62° F. than at 68° F. Consequently the gage blocks during the adjusting and measuring operations at 62° F. were increasing quicker and more in length, due to the expansion of the steel, than they were when the adjusting and measuring operations were made at 20° C.

Another advantageous circumstance in using 20° C. (68° F.) as standard temperature is that in reductions from Centigrade to Fahrenheit the figures 20 and 68 go evenly up and the calculations are more simple and easy to handle.

The Johansson gage blocks have been delivered during the years 1899 to 1928 inclusive to all industrial countries of the world, about 1,000,000 gage blocks having been produced and sold at Eskilstuna, Sweden, and approximately 100,000 by the Ford Motor Company at Dearborn, Michigan. Most of these gage blocks (which are used as standard blocks) are adjusted and calibrated at 20°C. (68° F.) and the industries of all countries except England and the State Works in France have found this temperature practical and good from every standpoint. Even in England some manufacturers have expressed their desire to adopt 68° F. (20° C.) as standard temperature.

The writer will herewith present the fundamental rules and principles regarding temperature, which have been used since 1903, when determining the measuring values of Master Standards used in adjusting and calibrating block gages made in Eskilstuna, Sweden, and in Dearborn, Michigan.

1. <u>For the Metric System:</u>

In 1903 I made one 100 mm end-rod marked "B", at 20° C. with flat and parallel measuring surfaces and sent it to the International Bureau

at Paris for calibration, with the request that they would measure it and give me the temperature at which it held its length, 100 mm, exactly. On April 29th, 1903, the International Bureau issued a certificate, with a description of its work, when determining the length in comparison with the Prototype Meter, and the temperature given in said certificate was $20^{o}.63$ Centigrade at which temperature the 100 mm (B) held its right measure-value of 100 mm.

I therefore had to increase the length of the 100 mm (B) about .0007 mm to give me the "absolute" measuring-value of 100 mm at 20^{o}C.

I proceeded with the work of the block gages and I sent in new Blocks to the International Bureau for calibration and in a certificate dated April 22, 1912, I received the following figures:

	'a 0^{o}	'a 20^{o}
100	100 mm $-23.^{u}5$	100 mm $+0.^{u}1$
50	50 mm $-11.^{u}8$	50 mm 0.o
25.	25 mm $-6.^{u}o$	25 mm $-0.^{u}1$
25..	25 mm $-5.^{u}9$	25 mm 0.o

These same measuring values have been the Master-Standard measuring values for all metric Johansson block gages made and distributed during the period 1912-1928, and are also equivalent to the measuring values during the years 1903-1911.

2. <u>For the Inch System</u>:

<u>A. English Inch</u>

In the year 1904, I received from Monsieur Rene Benoit, Director of the International Bureau, Paris, the equivalent between the English Inch and the millimeter as being: 1 inch = 25.3999772 mm and these figures

were confirmed in 1908 by Dr R J Glazebrook, then Director of the National Physical Laboratory, London.

Using this equivalent 25.3999772 and the measuring value of the "100 mm B" calibrated at the International Bureau in 1903 (Certificate of April 29, 1903) I made the first set of combination block-gages in inches for the National Physical Laboratory in accordance with their standards for 62° F.

In the year 1908 I made a set of block gages, containing 81 end gages for the English Admiralty at 62° F. and sent this set to the National Physical Laboratory for calibration. On September 23, 1908, I received a certificate of examination, which shows that the National Physical Laboratory found th size and parallelism of all block-gages in the set to be within .000,01 part of one inch.

For investigating the measuring-values from time to time, block gages were sent to the National Physical Laboratory and Bureau International for calibration. The Certificate of October 23, 1922, shows two 4" block gages to correspond with the National Physical Laboratory's Standards at 62° F. within respectively .000001" and .000,002".

B. American Inch

The Legal Equivalent adopted by Act of Congress, July 28, 1866, viz: 1 Meter = 39.37 inches gives us the value of the American inch as 25.400,050,8(00,1) mm.

In the year 1905 one 3-inch block gage (Marked "F") of my make was inspected by the Bureau of Standards, Washington, and a certificate was

issued which gives the following values:

Gage F = 3.00030 inches at 27°5 C.

= 2.99994 inches at 62° Fahr.

based upon the use of the temperature coefficient 0.000,011 per degree Centigrade, and using the same temperature coefficient I got the measuring value of 3.000,052" at 20° C (468° F.).

Based upon the temperature coefficient .000,011" per inch, per degree Centigrade, I found the measuring-value of "Gage F" at 66° F. = 18.9° C. to be: 3.000016 inches.

Therefore, according to the Bureau of Standards measuring result, Test No. 1604 and Certificate of August 19, 1905, I considered said "Gage F" to be nearly correct, to give the measuring-value of the American inch within the limit at that time.

Consequently around the year 1908 I marked some sets of the block gages thus: "at 66° F" and made other blocks in the block-gage set subdivisions of said "Gage F", the measuring-value of which I, for some years, used for comparison of the measuring-value for the American inch.

But as I had since the year 1903 made all metric block gage sets (except a few for the French State Works) for a standard temperature, temperature of definition, of 20° C. and as I had in 1912 received the Inter-

national Bureau's Certificate dated April 22, 1912, which testified to the high accuracy in my block gages in mm at that temperature, my next step was now to make up a block gage set in inches, which would correspond with the metric measuring value at 20° C. (+ 68° F) and since that time (1912) I adjusted all for the American industry ordered block-gages at and for the temperature 20° C. (68° F.) to correspond with the equivalent: 1 inch = 25.40000 mm increased by a positive, progressive tolerance of + 0.000051 mm (+.000,002") per inch, and in that way making efforts to keep the legal measuring-value of the American inch = 25.400,050,8 mm with following result:

October 1, 1928, The Bureau of Standards, Washington, gave the absolute measuring-values at + 20° C. = + 68° F. of 7 block-gages (5 only one inch blocks and 2 only four inch blocks). All were well within the given tolerance of accuracy of .000,002" per inch. These blocks were all adjusted in the Johansson Gage Department of Ford Motor Company, Dearborn, Michigan, and out of them 4 only one inch blocks handed to Bureau of Standards 1926, where they were calibrated, were sent further to all of the following authorities for comparison with their standards and for obtaining their result of calibrations for absolute measuring-values:

National Physical Laboratory, England,

Physicalisch-Technishe Reichanstalt, Germany,

Bureau International des Poids et Mesures, France,

and these Institutes in addition to

The Bureau of Standards, Washington, D.C., U.S.A.

have found said 4 only one inch block-gages at + 20° C. = + 68° F. to be as follows:

1 inch Gage Block, marked B1. = 1.000,001,7 inch.

1 inch Gage Block, marked B1: = 1.000,000,1 inch.

1 inch Gage Block, marked B.". = 1.000,001,4 inch.

1 inch Gage Block, marked B1:: = 1.000,001,5 inch.

The measuring-values I used adjusting these Gage blocks were the same as given in above mentioned Certificate of April 22, 1912, from Bureau International des Poids et Mesures France, and the equivalent:

1 inch = 25.400,050,8 mm, corresponding with the legal equivalent for the American inch.

Having thus during my experimenting and manufacturing of more than 1,000,000 Block-gages distributed in all industrial countries, covering a period of over 30 years, investigated and worked out rules and principles for temperatures and measuring-values of End standards for lengths, I have found it important to watch the following temperatures:

I Foundation Temperature 0°C. = + 32° F.

Corresponding with the temperature of the Prototype meter (Meter des Archives). This temperature to be used as a basis from which the other temperatures are calculated.

II Standard Temperature + 20°C. = + 68°F.

At which temperature the gage blocks and end standards, etc., are chosen to hold their nominal (absolute) measuring-value.

III Adjusting Temperature + 20°C. = + 68° F.

I.E. the temperature at which gage blocks and end standards, etc., are to be adjusted to their size must correspond with the standard temperature + 20°C. = + 68° F.

IV Inspecting Temperature + 20° C = + 68°F.

I.E. the temperature at which gage blocks and end standards, etc.. are to be calibrated must correspond with the standard and adjusting temperature + 20° C. = + 68° F.

V Working Temperature

a. Gage Work The temperature in the working-room, the work pieces and the gages should correspond with each other, and in accurate work, i.e. manufacturing, adjusting and calibrating of high precision gages and the like, the standard temperature + 20° C. = + 68° F. must be held.

b. Production Work, the ideal condition for producing and measuring of interchangeable machine parts and the like would be to do all work and inspection at + 20°C = + 68°F., then all severe trouble would be eliminated what measuring-values are concerned.

But when this can not be done, the next best and more possible way is to use cooling plates or other means for bringing the work and the gages to the same temperature. In this case the difference in coefficient of expansion only would change the measuring-value, and in most cases it would be found to be well within the given tolerance and thus a cheap and good interchangeable product can be obtained.

Trusting that above description of my work and experience will help to enlighten the subject and serve to make the question clear when choosing the international Standard Temperature, I beg to remain

Yours very truly

C. E. Johansson

Detroit, Mich.
5440 Cass Ave.,
October 25th 1928.