INTER-COMPARISONON TEMPERATURE MEASUREMENT USING FLUKE THERMOMETER MODEL 1502A

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ABSTRACT

Since 2010, BMKG has been carrying out Inter-comparison on temperature measurement using Fluke Thermometer type 1502A. The events are held every year with Calibration Laboratory of Meteorology Climatology and Geophysic Agency (BMKG) in five region as the participants. In addition to domestic inter-comparison, since 2006, Calibration Laboratory BMKG-Jakarta has also conducted inter-comparison with other Laboratory like Australia (BoM), Korea (KMA), China (CMA), Philippines (PAGASA), and Japan (JMA). The inter-comparison was carried out in order to assess the competence of participants and to maintain traceability and consistency of measurement results generated by the observation instruments. Moreover, is to assure that the instruments are working properly and the results of the evaluation meet the requirements applicable as well in order to fulfill one of the clause contained in ISO 17025-2005. Beneficially, the inter-comparison facilitate the link between the members and the national measurement system, as well as for the exchange of experience in measurement techniques.

This paper presents the results of inter-comparison on thermometer fluke model 1502A in 2013 which were followed by 6 participants: Calibration Laboratory BMKG-Jakarta, Calibration Laboratory BBMG Region I Medan, Calibration Laboratory BBMG Region II Ciputat, Calibration Laboratory BBMG Region III Denpasar, Calibration Laboratory BBMG Region IV Makassar and Calibration Laboratory BBMG Region V Jayapura.

In this inter-comparison, temperature sensors of the participants are inserted into the temperature chamber, where the temperature is set from 0°C to 40°C with graduation intervals of 10°C.The results of inter-comparison on temperature measuring devices were evaluated and analyzed based on the ISO / IEC Guide 43-1, 1997, which expressed as En. When the value of $En_{(Lab)} \leq 1$, then it is considered as satisfactory. Otherwise, when the value of $En_{(Lab)} > 1$, then it is considered as unsatisfactory.

I. INTRODUCTION

One of the mission of Meteorological Climatological and Geophysical Agency of Indonesia (BMKG) is to provide data and information services in the fields of meteorology, climatology, and geophysics to the public. In that regard, there is an obligation that the observation equipments have to be traceable to the national and international standards.

Toward to ensure traceability of the observation equipments, they should be calibrated by using standard equipment that has been traceable to the national and international standards.

Observations of meteorological elements which include observations of air temperature, sea temperature, and soil temperature. In Indonesia temperature observations commonly use glass thermometer or digital thermometer. To maintain traceability and accuracy of the measurement, every new thermometer have to be calibrated n the laboratory and routine field calibration will be done after they have mounted. On the other hand the standard thermometer must be calibrated against national or international standards. The calibration activities of the standard equipments are called inter-comparison on laboratories equipments.

In addition to compare standard instuments, this inter-comparison is one of the activities of the auditing standard equipments, eventhough the emphasizing is more on the spirit of collaboration and support rather then the spirit of the inspection. And the purpose of the inter-comparison is to get the correction and *En* values of standard equipments.

Inter-comparison can also maintain traceability and guarantee the accuracy of standard equipment using in laboratories, so that the laboratories that follow the inter-comparison can meet one of the requirements in ISO/IEC-17025-2005, and it will guarantee the traceability and accuracy of measurement of equipments used at the observation.

This inter-comparison activity also facilitates link between the members and as a medium for exchange of technical experience in measurement and calibration.

The International Vocabulary of Basic and General Terms in Metrology (VIM) defines traceability as "the nature of the measurement results or values of reference standards that can be connected to an appropriate standard, usually national or international standards through an unbroken chain of comparisons, which each chain has an uncertainty value".

Based on the above definition, characteristics of traceability can be decomposed into three elements :

1. Linkage to appropriate standards. Appropriate standard here could include:
   - SI (International System Of Units)
   - CRM (Certified Reference Materials)
   - Reference method
2. Unbroken chain of comparisons. Traceability begins with an unbroken chain of comparisons originated from national measurement standards, International standards or intrinsic measurement standards.
3. Uncertainty of measurement. The measurement uncertainty of every step in the traceability chain must be calculated using the appropriate methods and must be declared at every step so that the total uncertainty of the whole chain can be taken into account.

Calibration laboratory is an important subject in order to ensure the quality of the periodic calibration of observation equipment. Each calibration laboratory must establish and maintain traceability to national or international level. Recognition and analysis of the source of uncertainty is the most important subject toward to develop and evaluate the calibration procedure.

A calibration certificate does not guarantee satisfactory performance under actual operating conditions, but it is an important starting point, and it is expressed about the quality of the sensor. Calibration certificate shall include at least the full operating range of the instrument. Field measurements required as input for modeling of numerical weather prediction, agriculture, hydrology or climatology. This measurement requirements described in the WMO Guide to Meteorological Instruments and Methods of Observation (WMO No. 8, Cimo Guide).

II. THEORY

Implementation activities of inter-comparison on temperature measuring devices (thermometers) performed at the Laboratory calibration BMKG and followed by Laboratory Calibration BBMG Region I Medan, Laboratory Calibration BBMG Region II Ciputat, Laboratory Calibration BBMG Region III Denpasar, Laboratory Calibration BBMG Region IV Makassar and Laboratory Calibration BBMG Region V Jayapura.

In the implementation of the inter-comparison, which is done is capture the data generated in the laboratory BMKG monitor (primary) and standard laboratory (BBMG region I through V) and Laboratory Calibration BMKG. Once the data is obtained, the data were compared by using the following formula :

Corrected standard readings :

$$t_{(std,corrected)} = t_{(std,reading)} + correction_{Cert}$$

correction value of the sensor or unit under test (uut)

$$t_{i(correction)} = t_{i_{(std,corrected)}} - t_{i(uut)}$$

$$t_{i(correction)} = \left(\left(t_{i(std,reading)} + correction_{Cert}\right) - t_{i(uut)}\right)$$

Annotation :
$t_{std, corrected}$ = value of corrected standard reading
$t_{i, correction}$ = value of correction of standard
$t_{std, reading}$ = value of standard reading

After the correction value is known, it is necessary to calculate the uncertainty of laboratory equipment inter-comparison participants by entering uncertainty budgets, so as to obtain the value of the instrument uncertainty (U_{95Lab}), uncertainty budgets affecting the measurement uncertainty value as follows :

1. Certificate Standard
   Measurement uncertainty values derived from standard certificate obtained from the standard calibration certificate traceable to national and international standards.

2. Drift
   This uncertainty value is derived from the standard deviation of the equipment that calibrated annually. This value can be obtained by the following equation :

$$u_{drift} = \frac{(\text{biggest correction on year} - x) - (\text{biggest correction on year} - (x-1)}{2}$$

3. Standard resolution
   Nilai ketidakpastian resolusi standar diperoleh dengan persamaan sebagai berikut :

   Standard resolution
   Standard uncertainty value standard on resolution is obtained by the following equation :

$$u_{resolution} = \frac{\text{smallest resolution value}}{2}$$

4. Media Inhomogenity
   Media measurement uncertainty value is derived from the uniformity of media used on inter-comparison. Uncertainty value can be obtained by using the equation as follows :

$$H^2 = \left(\frac{S_{\min} - S_{maks}}{2}\right)^2 + U_R{}^2 + U_A{}^2$$

   Annotation :
   H = Media Inhomogenity
   S_{min} = The smallest value of correction value of data retrieval
   S_{maks} = The biggest value of correction value of data retrieval
   U_R = Standard instrument uncertainty
   U_A = Reference instrument uncertainty

To determine the value derived from this inter-comparison can be determined using the following equation:

$$En = \left|\frac{LAB - REF}{\sqrt{u_{95\,Lab}{}^2 - u_{95\,Ref}{}^2}}\right|$$

Annotation :
En = Value of the inter-comparison results

LAB = Certificate correction value of Standard Equipment
REF = Certificate correction value of Reference
$U_{95\ Lab}$ = Uncertainty value of Standard Equipment
$U_{95\ Ref}$ = Uncertainty value of Standard Reference

Results inter-comparison value is considered good or satisfactory if the value of En ≤ 1.

III. WORK PROCEDURES

Thermometer which is used as a standard equipment in Laboratory Calibration BMKG Jakarta as well as Region is sensor Fluke type 5627A with Fluke type 1502A Fluke as display. This sensor must be calibrated annually with the Water triple point and use bath media as the temperature conditioner.

In this inter-comparison implementation, the steps are as follows :

1. Preparation
   Before the process of data collection, it is necessary to prepare the equipment to be used including :
   a. Triple Water Bath
      This bath, that consists of a cell as scene for the sensor, is used to check the triple point of water. Besides, Bath is also used as a conditioner for temperature remains stable in the cell.
   b. Primary and standard equipments to be used
      Primary equipment is equipment that has been calibrated or compared with international standards, such as: Korean Meteorological Administration (KMA), Berau of Meteorology (BoM) and the China Meteorological Administration (CMA). While the standard equipment are the equipment that will be operate in Calibration Laboratory Calibration BMKG Jakarta and Laboratory BBMKG Region I through V.

   In addition to using tiple water bath, it was also use triple cell water, wherein the temperature of the triple point of water is 0.0010 C. The following preparations were made:
   a. It takes the temperature of dry ice to reach 0.0010 C.
   b. Crush the dry ice until granulated.
   c. Then the grain dry ice was added to the water triple cell.
   d. In putting the dry ice, Caution is required and must be maintained so the decreasing of the temperature in the environment will not go down quickly, it has to do so that the triple point of water is not going to be broken.
   e. Once the triple point cell has been formed, put it into the water triple bath water to keep the temperature stable.

2. Data Collection Process

   After the preparation, data collection process was then performed . This process was done by reading the data directly . The readings was recorded in the temporary work result sheet. This was done after the display of standard and reference equipment unchanged exceeds ± 0.006 ^{0}C and the process is repeated as many as possible , but at least 4 data that is considered stable to be used. Whenever the triple point of water data collection was completed, both sensor was then inserted into the Temperature Bath media where both the sensors were close together but not touching one another. The display of bath temperature was set to 0.00 ^{0}C , this display was set to stabilize the media in accordance with the display. Wait until the Bath media get stable (display indicator on both sensor did not change in the period of 2-3 minutes , or unchanged exceeds ± 0.010 0C . Then read display of standard and reference in the following order : standard - reference - reference - standard . This reading order was taken for 5 times . The readings were recorded in the Temporary Calibration Results sheet . Afterwards repeat the reading process for set point of temperature on display Bath at 20 ^{0}C , 30 ^{0}C , and 40 ^{0}C .

IV. RESULTS

By the implementation of this inter-comparison, correction values and standard instrument uncertainty (U_{95Lab}) were obtained for every instrument of each inter-comparison participants. Inter-comparison outcome data for each Calibration Laboratoriies BBMG region I to V are presented in the table below.

Point of Reference	Lab. BMKG (Standard)		Lab. BBMG Region I Medan		**En**
	Correction	U_{95}	Correction	U_{95}	
(^{0}C)	(^{0}C)	(^{0}C)	(^{0}C)	(^{0}C)	
0	0	0,000	-0,004	0,006	0,669
10	0,003	0,020	-0,012	0,025	0,451
20	0,003	0,020	-0,023	0,025	0,803
30	0,002	0,020	-0,026	0,025	0,857
40	0,004	0,020	-0,027	0,025	0,965
50	0,002	0,020	-0,024	0,025	0,802

Table-1. Inter-comparison value results of Calibration Laboratory BBMG Region I Medan

Point of Reference	Lab. BMKG (Standard)		LAB. BBMG Region II Ciputat		**En**
	Correction	U_{95}	Correction	U_{95}	
(^{0}C)	(^{0}C)	(^{0}C)	(^{0}C)	(^{0}C)	
0	0	0,000	-0,006	0,006	0,925
10	0,003	0,020	-0,010	0,025	0,413
20	0,003	0,020	-0,019	0,025	0,678
30	0,002	0,020	-0,025	0,025	0,849
40	0,004	0,020	-0,021	0,025	0,779
50	0,002	0,020	-0,029	0,025	0,974

Table-2. Inter-comparison value results of Calibration Laboratory BBMG Region II Ciputat

Point of Reference	Lab. BMKG (Standard)		Lab. BBMG Region III Denpasar		**En**
	Correction	U_{95}	Correction	U_{95}	
(^{0}C)	(^{0}C)	(^{0}C)	(^{0}C)	(^{0}C)	
0	0	0,000	-0,004	0,006	0,669
10	0,003	0,020	0,019	0,025	0,498
20	0,003	0,020	0,016	0,025	0,397
30	0,002	0,020	0,032	0,025	0,950
40	0,004	0,020	0,032	0,025	0,880
50	0,002	0,020	0,028	0,025	0,818

Table-3. Inter-comparison value results of Calibration Laboratory BBMG Region III Denpasar

Point of Reference	Lab. BMKG (Standard)		Lab. BBMG Region IV Makassar		**En**
	Correction	U_{95}	Correction	U_{95}	
(^{0}C)	(^{0}C)	(^{0}C)	(^{0}C)	(^{0}C)	
0	0,000	0,000	-0,006	0,006	0,925
10	0,003	0,020	-0,012	0,025	0,475
20	0,003	0,020	-0,023	0,025	0,810
30	0,002	0,020	-0,023	0,025	0,763
40	0,004	0,020	-0,020	0,025	0,756
50	0,002	0,020	-0,012	0,025	0,429

Table-4. Inter-comparison value results of Calibration Laboratory BBMG Region IV Makassar

Point of Reference	Lab. BMKG (Standard)		Lab. BBMG Region V Jayapura		**En**
	Correction	U_{95}	Correction	U_{95}	
(^{0}C)	(^{0}C)	(^{0}C)	(^{0}C)	(^{0}C)	
0	0,000	0,000	-0,003	0,006	0,502
10	0,003	0,020	0,018	0,025	0,467
20	0,003	0,020	0,008	0,025	0,140
30	0,002	0,020	0,023	0,025	0,662
40	0,004	0,020	0,028	0,025	0,763
50	0,002	0,020	0,000	0,025	0,055

Table-5. Inter-comparison value results of Calibration Laboratory BBMG Region V Jayapura

Inter-comparison BBMG Region I to V has obtained correction value of standard instrument as shown in Table-1 untill Table-5 and can be illustrated graphically as in chart 1

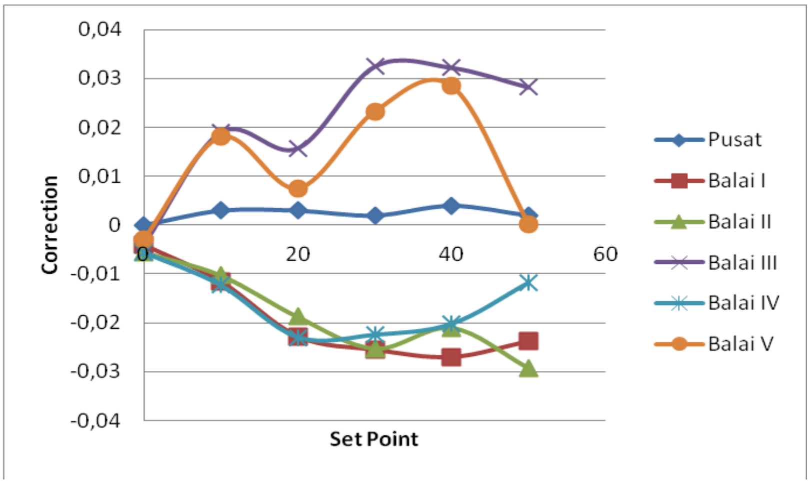

Chart-1. Combined of Correction Value of BMKG Jakarta with the 5 Regional Center

Data corrected value of the results inter-comparison on temperature measuring equipment between Calibration Laboratory BMKG Jakarta and Calibration Laboratory BBMG Region I to V can be analyzed as follows:

1. For BBMG Region I Medan, BBMG Region II Ciputat, and BBMG Region IV Makassar, the deviation on temperature measurement is below the standard value where the temperature deviation is below the standard deviation range -0.003 ^{o}C to -0.03 ^{o}C.

2. For BBMG Region III Denpasar Medan and BBMG Region V Jayapura, the deviation on temperature measurement is above the standard value where the temperature deviation is below the standard deviation range -0.003 ^{o}C to +0.032 ^{o}C.

The calculation of the uncertainty in the implementation of inter-comparison can be seen in Table-1 through Table-5 as illustrated in Chart-2.

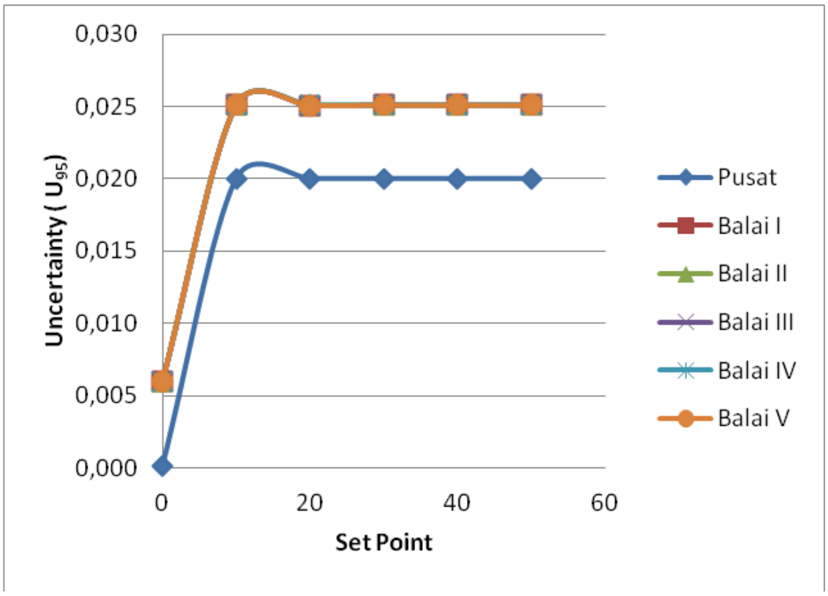

Chart-2. Combined of Measurement Uncertainty value as the result of BMKG Jakarta with the 5 Regional Center

Temperature measurement uncertainty calculations owned by Calibration Laboratory BBMG Region I through V are similar, this is caused by their uncertainty budgets are also the same as those equipments are derived from standard equipment of Laboratory Calibratioan Jakarta, then their uncertainty value will be bigger than the reference.
Inter-comparison values expressed in En. An inter-comparison value will be considered as good or satisfactory if the value of En ≤ 1 . Otherwise, it will be considered as unsatisfactory if the value of En>1. The value of inter-comparison results illustrated in Chart-3.
The combined value of En through the Calibration Laboratory BBMG Regions I to V wasobtained in a range of 0.055 to 0.974.

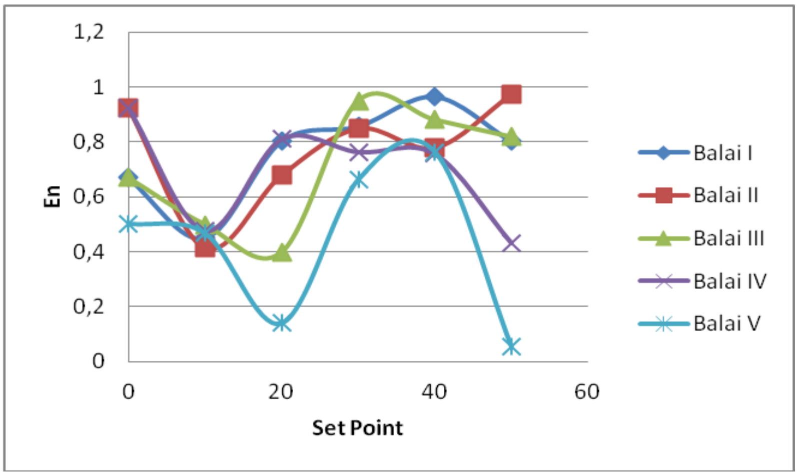

Chart-3. Combined of inter-comparison value of 5 Regional Center

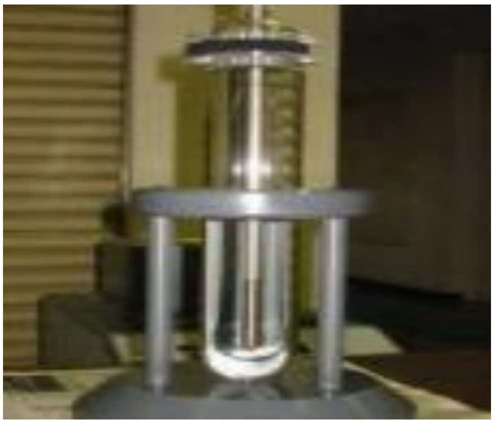

Figure-1. Water Triple Point

Figure-2. Sensor 5627A dan Display 1502A

V. CONCLUSIONS

The results of inter-comparison on temperature measuring instruments owned by Laboratory Calibration BBMG Regions I through V and Laboratory Calibration BMKG Jakarta can be summarized as follows :

1. Correction value for temperature measuring instruments owned by Laboratory Calibration BBMG Region I through V are relatively small and can be considered to be fit.
2. Uncertainty value of temperature measuring instruments owned by Laboratory Calibration BBMG Region I through V are similar.
3. Intercomparison value of temperature measuring instruments owned by Laboratory Calibration BBMG Region I through V that is obtained is En<1, then the calibration process that was carried out in the laboratory calibration BMKG are in accordance with ISO IEC 17025:2005 Reference Manual.
4. Inter-comparison recommended that the implementation can be done annually.

BIBLIOGRAPHY

1. The Law of the Republic of Indonesia No. 31 Year 2009 on the Meteorology, Climatology, and Geophysics.
2. Regulation of the Head of the Meteorology and Geophysics No. Kep.002 in 2007, on the Fixed Procedure for Implementing Meteorology, Climatology, Air Quality, and Geophysics Instruments Calibration.
3. WMO No. 8, Guide to Meteorological Instruments and Methods of Observation.
4. The ISO / IEC 17025: 2005, General Requirements for the Competence of Testing and Calibration Labortories.
5. Manual book of PRT sensor Fluke type of 5627A with Fluke display type of 1502A.