# A New verification system of mobile scales

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**Abstract：** The paper describes a new method to verify the fixed electronic scales or called mobile scales being weighing range of 50-150t. It consists of 4 parts: standard weights of class $M_1$, a 150 t mass comparator (MC), a set of moveable build-up force standard machines( MBM) and mobile scale (MS) to be verified, which is called 4M verification system(4MS). The paper describes principle, construction and specifications of MBM. It has been done to make comparison of the two verification methods by $M_1$ weights and MBM, of which the verification results are quite agreeable.

**Key words:** standard weight, mass comparator, moveable build-up force standard machine, mobile scale.

## 1. Introduction

There are three methods used to verify the fixed electronic scales or called mobile scales being weighing range of 50-150t, which are standard weights, additional verifying apparatus, and standard weights with its substitutes [1]. It is known there are some difficulties for the methods 1 and 3 in practice, which includes work hard, quite more masses to transfer, time consuming, etc. In order to avoid the problems mentioned, a new method has been studied in China. The new method covers 4 parts: masses of class $M_1$[2], a 150 t mass comparator (MC), a set of moveable build-up force standard machines( MBM) and mobile scale (MS) to be verified, which is called 4M verification system(4MS).

## 2. The new verification system

Fig. 0 shows the 4MS verification system.

- The first part consists of 150 pieces of 1t $M_1$ mass being MPE of $\pm 5 \times 10^{-5}$.

- The second part is a mass comparator being capacity 150t, the minimum reading 0.1kg, the division d=1kg, the division numbers of the full scale n=150000, which is used as a reference scale (RS) usually.

- The third part consists of 8 pieces of moveable force build-up machines (MBM) which could be operated individually or parallel. Each MBM has capacity of 25t, the minimum reading 0.1kg, the division d=1kg and the division numbers of the full scale n=25000. In order to character MBM, each one is placed on the centre of the MC platform, and calibrated up to 22 t. At the same time, a force calibration machine is used to

calibrate load cells of the MBM, and calculate its technical specifications. The MC is used to verify/calibrate a system paralleled by 8 pieces of MBM which is called MBMs, and to obtain its repeatability, calibration data, etc.
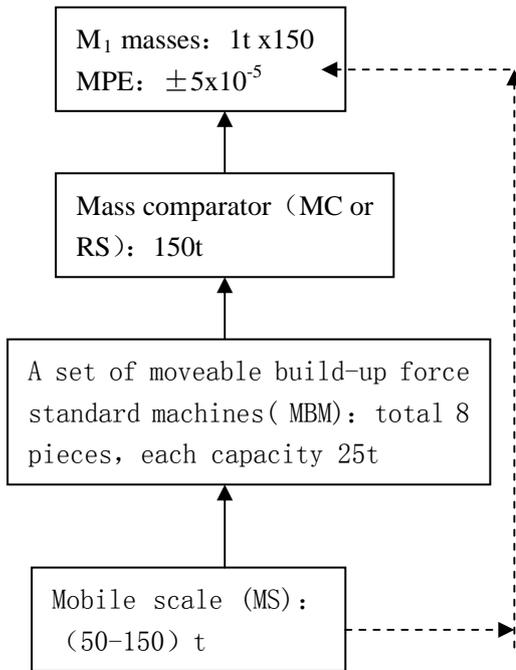
M₁ masses: 1t x150
MPE: ±5x10⁻⁵

$M_1$ masses: 1t x150
MPE: $\pm 5 \times 10^{-5}$

Mass comparator（MC or RS）: 150t

A set of moveable build-up force standard machines（MBM）: total 8 pieces，each capacity 25t

Mobile scale (MS):
（50-150）t

Fig.0 4MS Traceability system

## 3. Test results

There are complete tests carried out until the end of 2011,which covers 1) verification of 150 pieces of $M_1$ 1t weights by KD500 comparator made by METTLER TOLEDO; 2) verification of the mass comparator 150t; 3）testing 10 pieces of the moveable force build-up machines(MBM);4)verifying a 150t mobile scale(MS) with the both methods of the $M_1$ weights and MBMs. Before that, a 100t MS had been verified by two methods as well as a 6t scale.

## 3.1 Verification of the MC

Photo 1 shows profile of the 150 MC. Characteristics of load cells used in the MC are listed in table 1.

- The reproducibility has been tested

- The fourth part is a mobile scale to be verified being classes III or IIII, which has capacities of 150t，120t，100t，80t，60t，50t,the division numbers of the full scale n=3000, the divisions being 50kg (for 150t，120t，100t，80t)，20kg (for 60t,50t) separately.

with loading and unloading for two times at the range of （0.5—30）t. The results are shown in Fig.1, of which the reproducibility is calculated with the difference between two weighting results on the same point tested. It could be seen that the reproducibility is less than or equal to 5 kg.

- Indication error has been tested with loading and unloading at the range of （0.5—150）t, of which results are showed in Fig.2. The indication error including loading and unloading is less than or equal to 30 kg, and the indication error on loading is less than that on unloading.
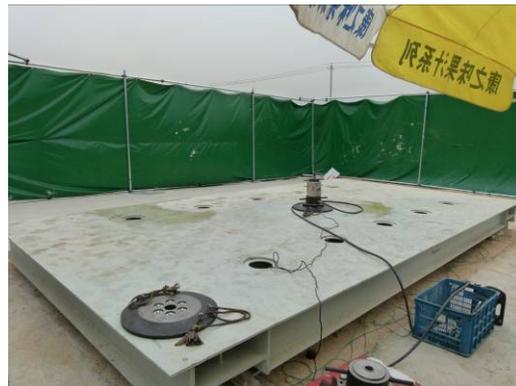


Photo1 150t mass comparator

Table 1  Characteristics of load cells used in the 150t MC and the 150t MS verified

| No. | Describe | MC 150t | MS 150t |
|---|---|---|---|
| 1 | Type of cells | Sartorius PR6221/50t C5,total 4 pieces | Sartorius HM14C-C3-50t-13B6 total 8 pieces |
| 2 | Rated output mv/v | 1.49978-1.50016 | 1.4985—1.5013 |
| 3 | Repeatability /R.O. | <0.005% | ±0.01% |
| 4 | Creep /30min/R.O. | <0.01% | ----- |
| 5 | Liniarity /R.O. | <0.01% | 0.02% |
| 6 | Hysteresis /R.O. | <0.01% | 0.02% |
| 7 | Temperature effect on zero output /R.O./10K | -0.002% | 0.02% |
| 8 | Temperature effect on rated output /R.O./10K | 0.004% | 0.02% |
| 9 | Combined error | ----- | 0.02% |
| 10 | Size of platform, length x width x height m | 6.0x4.3x0.57 | 18x3x0.57 |



Fig.1 Reproducibility of MC tested



Fig.2 Indication error of MC
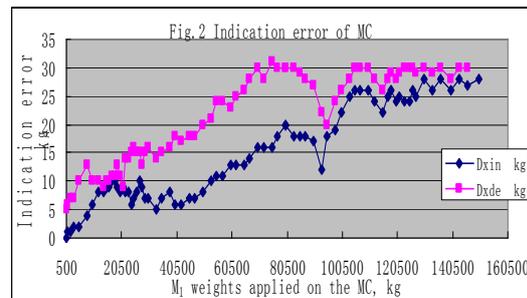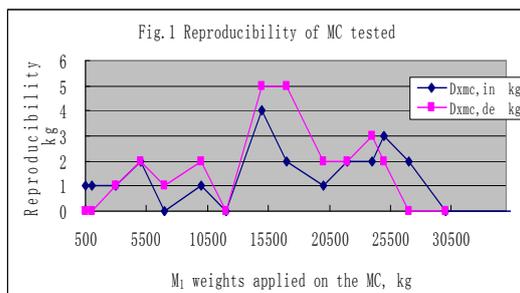
It is shown that the MC could be used to verify the MBM with the traditional method "A-B-A" or "A-B-B-A", which is more accuracy, but time-consuming and work-consuming. After considering the MC being quite good reproducibility, the MC could be used as a reference scale while the MBM is calibrated by it.

## 3.2 Verification and calibration of the moveable force build-up machines (MBM)

Construction of a single MBM is shown in the Fig. 3a, which is connected with platform of the MC or MS as well as Fig. 3b. Fig.4 shows block-schedule of the control system for the MBM[3].
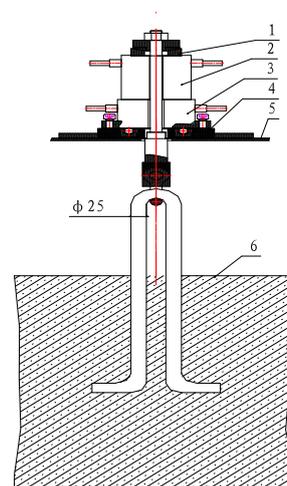


Fig.3a  Construction of MBM connected with a platform of MC or MS 1-self-centering block, 2- reference load cell, 3-ram-cylinder system, 4-self-fixing plate, 5-platform of MC or MS, 6-base
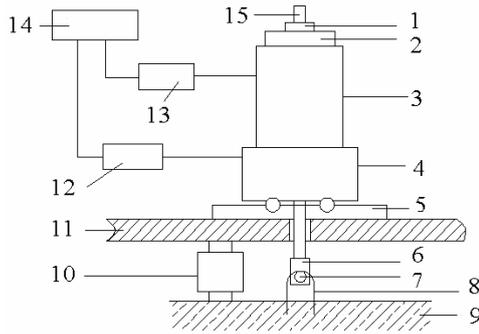
Fig.3b Construction of MBM connected with the platform of MC or MS (detailed)
1-nut, 2-plate, 3-reference load cell, 4-ram-cylinder system, 5-self-fixing plate,6-U-pull block, 7-pin, 8-pull-ring,9-base , 10-load cell of MC/MS,11- platform of MC/MS,12-loading-controller,13-precise instrument,14-computer, 15-pull-rod,



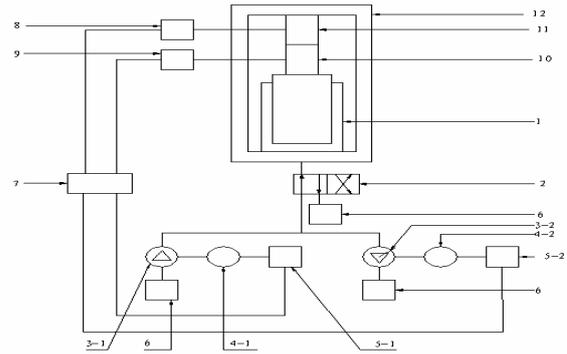Fig.4 Block-schedule of control system for the BM
(1) cylinder; (2) valve to alternative direction; (3-1, 3-2) two pumps; (4-1,4-2) two servo-motors; (5-1, 5-2) two servo-controllers; (6) a tank; (7) acquire-control system; (8) indicator for a transducer (11) under calibration; (9) indicator for the reference transducers(10); (12) main framework or loading system, etc.

The MBM consists of 5 units, which are 1) a special strain gage load cell with middle hole along its vertical axial; 2)a self-alignment part;3) a piston-cylinder loading system; 4) force measuring system; 5) others associated. Table 2 gives specifications of the load cells used in the MBM.

Table 2 Specifications of the load cells used

| No. | Describe | Specifications |
|---|---|---|
| 1 | Load cell | LC-3/250kN |
| 2 | Rated output mv/v | 1.52—1.54 |
| 3 | Repeatability/R.O. | 0.01% |

| 4 | Creep/30min/R.O. | ----- |
|---|---|---|
| 5 | Liniarity/R.O. | ±0.02% |
| 6 | Hysteresis/R.O. | ±0.02% |
| 7 | Temperature effect on zero output/R.O. /10K | ±0.005% |
| 8 | Temperature effect on rated output /R.O./10K | ±0.005% |
| 9 | Long-term stability/5 months | ±0.015% |

Fig.4a shows the indication error within ±0.03% at range of 20kN—220kN, and Fig.4b shows the long-term stability of the 9 cells, which is within ±0.015%

for 5 months at the range of 15kN—220kN.
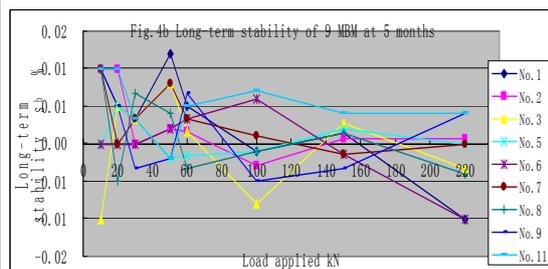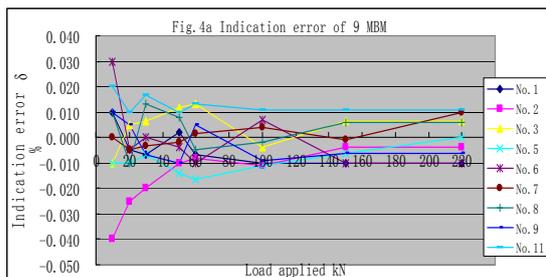
A MBM is fixed on the centre of MC, and calibrated by the MC. Since the MBM can generate force as need, it would be done to test characteristics of the MBM with comparison of mass values indicated by MBM and MC. The characteristics cover repeatability $R_a$ in absolute value which is calculated with maximum deviation of three measurements tested; rotation effect $R_{ota}$ which is calculated with maximum deviation of three measurements tested at positions of $0^o$(taking first cycle value), $120^0$and $240^0$ [4]; reproducibility $R_{pa}$ which is calculated with maximum deviation of three measurements tested while the MBM are re-fixed for three times. The results obtained on $R_a$, $R_{ota}$ and $R_{pa}$ are less than or equal to 1kg.

As an example, Fig.5a shows $R_a$, $R_{ota}$ of $NO_1$.MBM and Fig.5b for its $R_{pa}$.
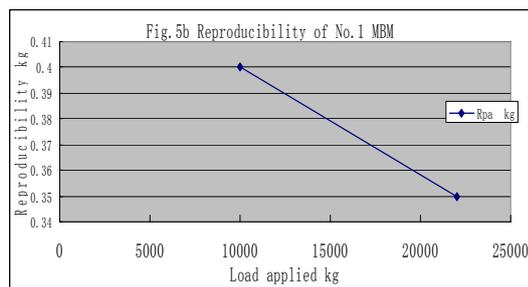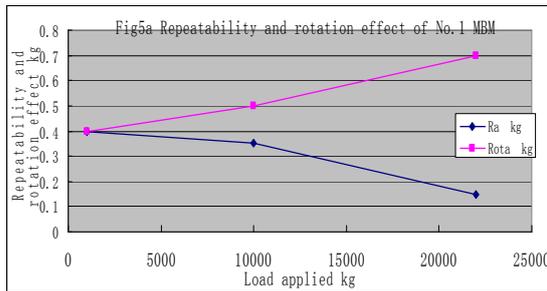




At the same time, the 8 pieces of MBM are fixed on the MC( see photo 2), and MC is loaded by MBMs uniformly and simultaneity. It is done to preload the MBMs up to 150t for three times, and to verify the MBMs by MC step by step including 8 mass points of 1t, 8t, 20t, 25t, 50t, 75t, 100t and 150t. Fig.6 shows its verification results including repeatability on increasing and decreasing as well as indication error, which are within range from -1kg to +7kg.
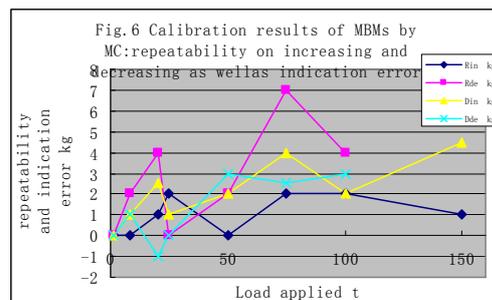


Photo 2 MBMs of 8 MBM calibrated by MC



Fig.6 Calibration results of MBMs by MC:repeatability on increasing and decreasing as wellas indication error



Photo3 150t MS verified by $M_1$ weights



Photo4 150t MS verified by MBMs

## 3.3 Verification of the 150 t mobile scale (150t MS)

First the 150t MS was verified by 150t $M_1$ standard weights, and verified by MBMs. It has been done to compare the both results obtained, and to investigate its agreement of verification results.Photo3 and photo4 show the two verifications. The verification covered "Zero set", "Eccentricity weight", "Weighing", "Repeating", "Set tare" and "Discriminate". Table 3 shows the two verification results obtained. The both results show that the 150t MS meets the requirement of class III scale. It took about 4 days to verify the scale by weights (exception of 2 days for transferring the 150t weights).It took 1 days to verify the scale by MBMs which cavers 0.5 day for preparing, and 0.5 day for verifying.

| Table3 two verification results obtained | | | | | |
|---|---|---|---|---|---|
| Describe | By $M_1$ weights | | By MBMs | | mpe |
| Zero set, kg | −5 | | −5 | | ±10 |
| Eccentricity weight (20t load),kg | Within ±15 | | Within ±10 | | ±25 |
| Weighing | load t | Increasing kg | Decreasing kg | Increasing kg | Decreasing kg | |
| | 0 | −5 | −20 | 0 | 0 | ±25kg |
| | 1 | −5 | −20 | −5 | +5 | |
| | 2.5 | | | −15 | 0 | |
| | 50 | 0 | +10 | −35 | −20 | ±50kg |
| | 75 | −10 | 0 | −30 | −40 | |
| | 100 | −25 | −15 | −30 | −35 | |
| | 150 | +40 | ---- | +35 | ---- | ±75kg |
| Repeating, maximum deviation between 2 tests | load t | Increasing kg | Decreasing kg | Increasing kg | Decreasing kg | |
| | 0 | 10 | 10 | 0 | 0 | ±25kg |
| | 75 | 25 | 10 | 0 | 5 | ±50kg |
| | 100 | --- | --- | 10 | 5 | |
| | 150 | --- | --- | 15 | ---- | ±75kg |
| Set tare | load t | Increasing kg | Decreasing kg | Increasing kg | Decreasing kg | |
| Tare =10t | 0 | 0 | 0 | 0 | 0 | ±25kg |
| | 1 | −5 | 0 | +5 | 0 | |
| | 25 | 5 | 5 | +20 | −5 | |
| | 50 | −10 | −10 | −10 | −10 | ±50kg |
| | 75 | −10 | −20 | −20 | −35 | |
| | 100 | −20 | −5 | −20 | −15 | ±75kg |
| | 140 | 20 | --- | +30 | --- | |
| tare=20t | load t | Increasing kg | Decreasing kg | Increasing kg | Decreasing kg | |
| | 0 | 0 | −5 | 0 | +5 | ±25kg |
| | 1 | 5 | −10 | +5 | +10 | |
| | 25 | 10 | −15 | +15 | −5 | |
| | 50 | −5 | 15 | 0 | −15 | ±50kg |
| | 75 | −25 | −15 | −25 | −30 | |

| | 100 | −30 | 25 | | −30 | −35 | ±75kg |
|---|---|---|---|---|---|---|---|
| | 130 | 25 | --- | | +15 | --- | |
| Discriminate kg | Load* | 50 | | 50 | | | |
| | * (1—150) t ; It is carried out together with weighing test. | | | | | | |

## 4 Conclusion

- The new system(4MS) for verification of the mobile scales with capacity 150t has been established, which consists of $M_1$ standard weights, the mass comparator(MC), the moveable build-up force standard machines(MBM) and mobile scales to be verified (MS).

- The MC is verified by $M_1$ weights, of which indication error for both loads of increasing and decreasing is not bigger than 30kg with range of 150t.

- The MC could be used as a normal comparator verifying the MBM with methods of "A-B-A" or "A-B-B-A", which would be of higher accuracy, but time-consuming, work-consuming. It is more often to use the MC as a reference scale, which would be time-saving and work-saving.

- The MBMs covers 8 moveable force build-up machines, of which each consists of the special strain gage load cell. The long-term stability in five months is within ±0.015%.

- The MBM can generate force and measure it. The repeatability, rotation effect and reproducibility for each one is not bigger than 1 kg at the range of 1t,10t and 22t. The 8 pieces of the MBMs were verified by the MC, and its repeatability for both loads of increasing and decreasing is within (−1kg—+7kg) at the range of 1t-150t as well as indication error.

- The 150t MS were verified by $M_1$ weights and the MBMs, of which both results are agreeable meeting the requirement of class III scale.

- Comparing the $M_1$ method, the MBMs method is saving time at two thirds, saving work at 95%, saving cost at four fifth. The MBMs can verify a mobile scale following [1].

Reference

[1] OIML R76E 《Non-automatic scales》

[2] OIML，Draft Revision R111 《Weights of class $E_1, E_2, F_1, F_2, M_1, M_{1-2}, M_2, M_{2-3}, M_3$ Part 1 Metrological and technical requirements, 2004.01.29.

[3] Li Qingzhong, Yao Jinhui, Xu Hang, Li Haigen, 《10 MN Build-up force standard machine developed in China 》 , Imeko, 11/2010, TC3, TC5, TC22 Conferences Proceedings, pp37-40, Pattaya, Thailand.

[4] ISO 376:1998 《 Metallic materials-Calibration of force-proving instruments used for the verification of uniaxial testing machines》 .