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REALISATION OF THE UNIT OF FORCE AND DISSEMINATION IN KENYA.

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ABSTRACT: This paper highlights how the S.I unit of force (newton) is realized in the Kenya Bureau of Standards Force Laboratory. The use of the 1MN Multi-Lever Force Standard Machine. The dissemination of the Unit (N) in the organization (KEBS) and in the Kenyan industry. Calculation of uncertainty of measurement.

Keywords: Calibration, Uncertainty of Measurement, Dissemination, Terminology.

1.0. INTRODUCTION

The calibration of material testing machines (Tensile/Compression/Universal) using calibrated force-proving instruments (Load cells, proving Rings and Digital compensators (Read outs)). It applies for the Kenya Bureau of Standards owned testing machines and those for external clients from the Kenyan's Industries.

The Load cells and proving Rings are calibrated in the Laboratory using the 1 MN Multi-Lever Force Standards Machine.

1.1 The Force Standard Machine At Kenya Bureau Of Standards

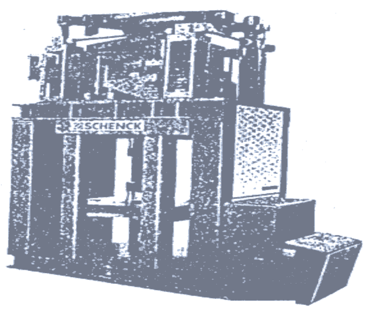

Fig. 1: General view of the
1 MN Multi-Lever Force Machine

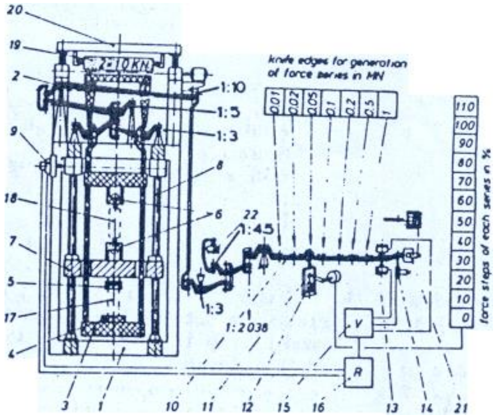

Fig. 2: Schematic Diagram of the 1MN Multi-Lever Force Machine at KEBS

The force standard machine at Kenya Bureau of Standards was installed in 1981. These is one the Force standard machine at the KEBS Force laboratory, carrying out the verification in the range from secondary standards to ordinary force measuring devices. The machine is a compound lever system, Fig. 1, /3/, with a maximum capacity of 1000kN (1MN). It is a prototype machine, where the dead weight part of the machine is replaced by a modified weighing machine which incorporated weights. In order to take care of the disadvantages of the lever deflection, the lever length is reduced by dividing the total multiplication ratios as shown in fig. 2, /3/. The nominal capacity of the machine is divided into seven ranges with a nominal capacity of 10 kN, 20 kN, 50 kN, 100 kN, 200 kN, 500 kN and 1 MN, each having a different multiplication ratio. On the average, the multiplication ratio varies from 1:2 000 at the lower ranges to 1:15 000 in the 1 MN range.

For the generation of force steps at 10% intervals, in each of the seven ranges, the weighing machine is equipped with 70 weights. This type of design has helped in achieving a compact and very stable machine.

2.0 TERMINOLOGY

2.1 For the purposes of this publication the following terms apply:

2.2 Calibration: Specific types of measurement performed on measurement standards, material measures and measuring instruments to establish the relationship between the indicated values and known values of a measured quantity. The term covers calibrations carried out using appropriate reference equipment at any location.

2.3 Check: Specific types of inspection and/or measurement performed on materials and equipment to indicate compliance or otherwise with stated criteria. The term covers checks carried out at any location.

2.4 Repeatability: ***r*** Is the value below which the absolute difference between two or more single test results obtained with the same method on replicate test samples, under the same conditions, (same operator, same apparatus, same laboratory and a short interval of time), may be expected to lie with a specified probability; which, in the absence of other indicators, is 95%.

2.5 Reproducibility: ***R*** Is the value below which the absolute difference between two or more single test results obtained with the same method on replicate test samples, under different conditions (different operators and/or different apparatus and/or different laboratories and/or different time), may be expected to lie with a specified probability; which, in the absence of other indications, is 95%.

2.6 Uncertainty Of Measurement: A statement of the limits of the range within which the true value of a measurement is expected to lie at a given level of confidence (*The Expression of Uncertainty and Confidence in Measurement*).The definitions of *r* and *R* are consistent with those given in BSI PD 6461 : Part 1 :1995 : Vocabulary of Metrology.

3.0. CALIBRATION OF MATERIAL TESTING MACHINE

3.1. Preliminary Preparation

3.1.1 Check the testing machine by visual inspection/observation, functional and operational tests to determine if the machine is in good working order.

3.1.2 Clean the machine thoroughly until the loading platens and/or tensile jaws are free of grease, oil and dirt.

3.1.3 Mount the load cell centrally between the loading platens of machine and connect the digital compensator (DMP 40 Readout) .

3.1.4 Connect DMP 40 Readout to an AC power source 240 V/50 Hz out, switch on and leave it for 30 minutes to attain equilibrium (warm-up).

3.1.5 For a machine with many ranges, set the range under calibration starting with the range Containing the of the machine.

3.1.6 For compression move the loading platen to within an air gap off (1 mm) the load cell and set the machine gauge and digital readout to zero.

3.1.7 Pre-load the load cell three times to machine capacity to remove any inherent stresses in the load cell and record the values. During pre-load, the load is left to act approximately one and half of a minute each time.

3.2 . Calibration:

3.2.1 Six sets of increasing load readings are taken at 10 % intervals of the machine capacity.

3.2.2 The load cell is rotated through 0°, 120° and 240° and at each position, two sets of readings at 10 % interval taken in order to reduce the error that may occur due to eccentric loading.

3.2.3 The average of the six sets of readings are then worked out at every load step.

3.2.4 Repeat the above for each range of the machine

3.3. Analysis of Results

3.3.1 This is done in order to classify the load cell:-

i) Error = Applied force – Indicated force

ii) $\%Error = \frac{\text{(Applied force – Indicated force)}}{\text{Applied force}} \times 100\ \%$

ii) $Play\ (Repeatability) = \frac{Highest\ deviation\ in\ loadcell}{\text{Mean}} \times 100\ \%$

iv) $Variation\ coefficient = \frac{Standard\ deviation\ in\ reverse\ loading}{\text{Mean}} \times 100\ \%$

4.0. CACULTATION OF UNCERTAINTY OF MEASUREMENT

4.1 The uncertainty of measurement is an estimate of that part of the expression of the result characterizing type range of values within which the true value of the quality to be measured lies.

4.1.2 Random Uncertainty U_r

4.1.2.1 If observations are repeated a number of times in precision measurements under the same conditions, the results will not be identical. This is due to the presence of small independent random variables.

4.1.2.2 Determination of Random Uncertainty

i) Arithmetic sample mean of the individual measured values is given by.

$$x_i = \overline{v}_i = \frac{1}{n}\sum_{j=1}^{n} v_{ij} \qquad (1)$$

Where n is the number of results taken $\overline{v_{ij}}(j = 1, n)$. The limiting values of the sample mean when n tends to infinity becomes the population mean μ where

$$u_i = \frac{lim}{n \Rightarrow \alpha} \left(\frac{1}{n} \sum_{j=1}^{n} x_i \right) \quad (2)$$

ii) An estimate of the standard deviation of the distribution of values S_{vi}

$$S_{vi} = \sqrt{\frac{1}{n-1} \sum_{j=1}^{n} (v_{ij} - v_i)^2} \quad (3)$$

ii) Population standard deviation is the limiting values of the sample standard deviation when n tends to infinity is given by

$$S_v = \frac{lim}{n \Rightarrow \alpha} \sqrt{\frac{1}{n} \sum_{j=1}^{n} (v_{ij} - v_i)^2} \quad (4)$$

4.1.3 Systematic Uncertainty U_s

4.1.3.1 Systematic uncertainty normally follows rectangular probability, so the true values lies between $(\bar{x} - a)$ and $(\bar{x} + a)$, a being the semi-range in the distribution. If only upper and lower limits a_{ui} and a_{li} can be estimated for the value of influence quantity e.g limit of error of a measuring instrument, etc.

$$x_i = \frac{1}{2}(a_{ui} + a_{li}) \quad (5)$$

For the expected values, and for estimated variance

$$S_{xi}^2 = \frac{1}{12}(a_{ui} + a_{li})^2 \quad (6)$$

If the difference between the limiting values is denoted by $2a_i$ then equation (6) becomes then equation (6) becomes

$$S_{xi}^2 = \frac{1}{3} {a_i}^2$$

4.1.3.2 Uncertainty that follow rectangular probability are due to the following Contributions

a) Zero error. Estimated relative variance

$$u_{zer}{}^2 = \frac{1}{3} a^2 \quad (7)$$

b) Reproducibility without rotation.

$$u_{rep}{}^2 = \frac{1}{3} a^2 \quad (8)$$

c) Resolution. Estimated relative variance

$$u_{res}{}^2 = \frac{1}{3} a^2 \quad (9)$$

d) Reversibility (hysteresis).

$$u_{rev}{}^2 = \frac{1}{3} a^2 \quad (10)$$

4.1.3.3 Contributions to systematic uncertainty that do not follow rectangular probability distribution are also given below.

e) Reproducibility with rotation. This follows U-shaped distribution as is given by estimated relative variance Estimated elative variance

$$u_{rot}{}^2 = \frac{1}{2} a^2 \quad (11)$$

f) Interpolation error. This follows triangular distribution as is given by estimated relative variance.

$$u_{int}{}^2 = \frac{1}{6} a^2 \quad (12)$$

In all cases, a = half width of the input quality

4.1.3.4 After the relative variance for each force step has been determined, the relative combined uncertainty μ_{tra} for k=2 will be calculated from equation 13 and 14 for any force step.

$$u_{c(tra)} = \sqrt{u_{zer}{}^2 + u_{rep}{}^2 + u_{rot}{}^2 + u_{int}{}^2 + u_{res}{}^2 + u_{rev}{}^2} \quad (13)$$

$$u_{c(tra)} = k.U_{c(tra)} \quad (14)$$

4.1.3.5 The relative uncertainty U_s is determined by considering the best measurement capability of force calibration (standard) machine as follows.

$$u_s = \sqrt{(u_{tra})^2 + (u_{bmc})^2} \quad (15)$$

4.1.3.6 Overall uncertainty

$$\therefore \pm U = k\sqrt{(U_r)^2 + (U_s)^2} \quad (16)$$

5.0 CONCLUSION

The calibration of material testing machines (Tensile/Compression/Universal) using calibrated force-proving instruments (Load cells, proving Rings and Digital compensators (Read outs)) is very important for Industry and Research Institutions in
any country in the world.

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