Force and Torque Standards Group
Research Institute for Engineering Measurement
NMIJ/AIST

Force and Torque Standards in Japan

Force Standard

1) National standard of the unit of force is realized by force standard machines (FSMs) of deadweight type, of lever amplification type and of hydraulic amplification type. Gravity acting on deadweights is directly utilized in the deadweight type FSMs, while gravity is amplified by lever mechanism or hydraulic cylinders in the FSMs of lever amplification type and hydraulic amplification type. Mass of the deadweights is adjusted within a relative deviation of approx. 1×10^{-6}, and is calibrated with being traceable to the national standard of mass. Acceleration due to gravity is measured using a gravimeter which keeps traceability to the national standards of time and length.

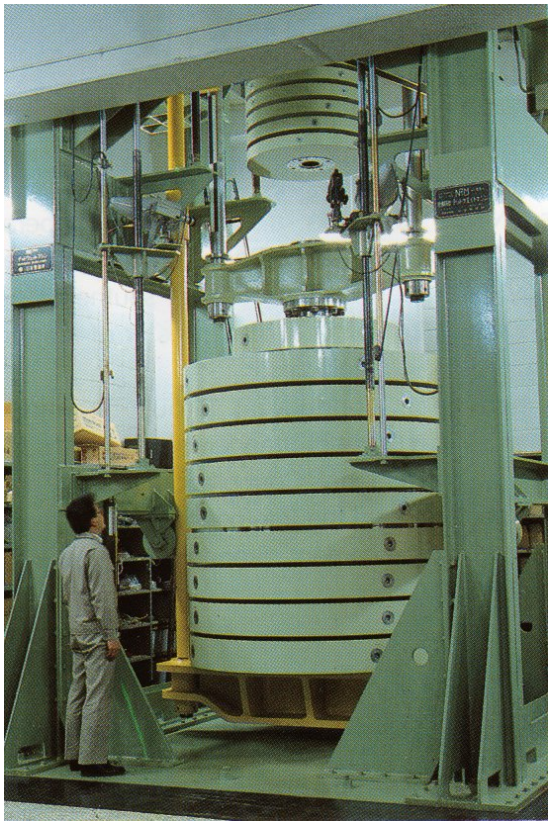
2) The FSMs are used in ordinary calibrations as well.

Range and uncertainty of calibration

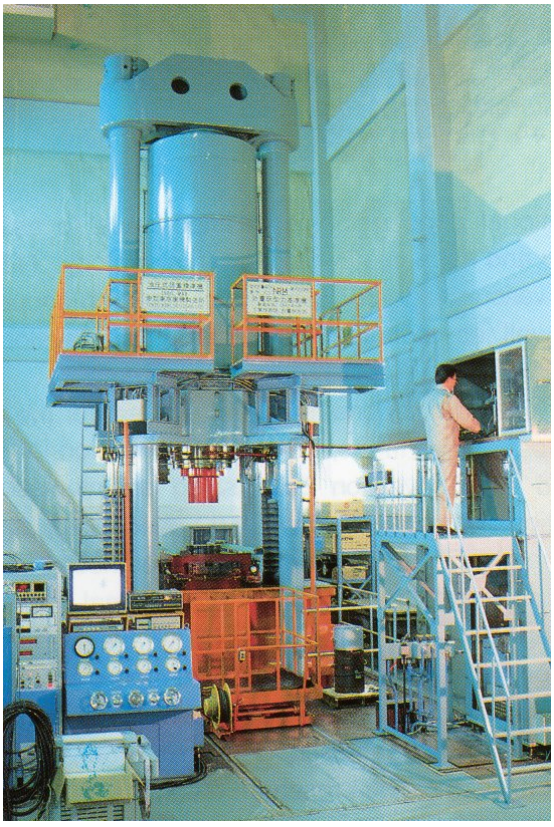
10 N - 540 kN: 2.0×10^{-5} (k=2) by the deadweight type FSMs

0.1 MN - 1 MN: 1.0×10^{-4} (k=2) by the lever amplification type FSM

0.2 MN - 20 MN: 1.0×10^{-4} (k=2) by the hydraulic amplification type FSM

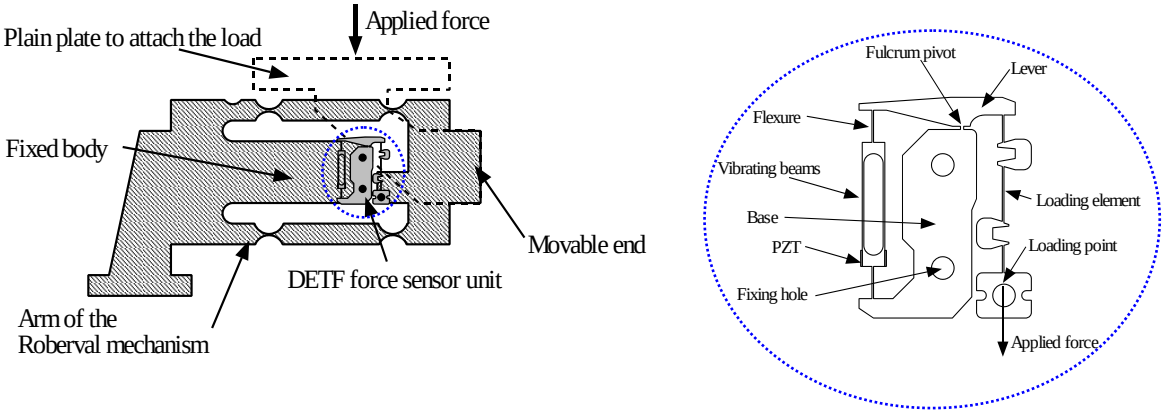


540-kN deadweight type force standard machine



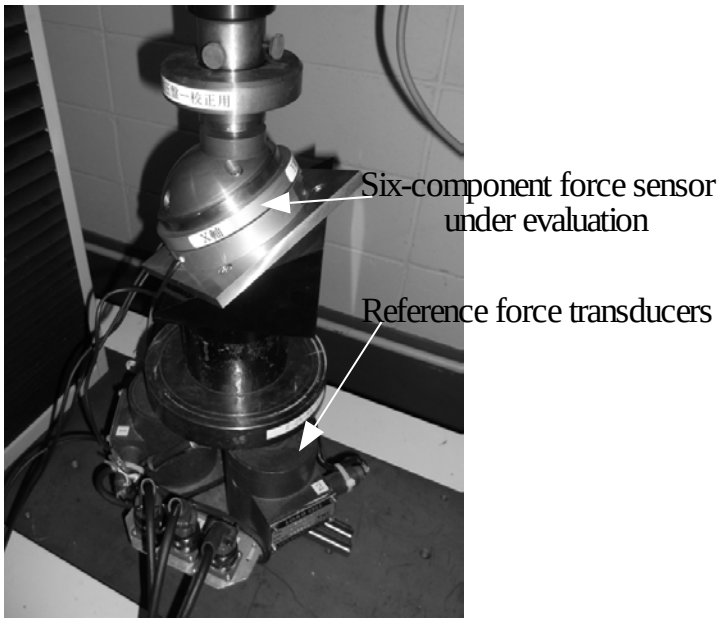
20-MN hydraulic amplification type force standard machine

3) In order to disseminate the force standard to the industry with maintaining its high precision, it is indispensable to utilize force measuring instruments having long term stabilities of sensitivities for transfer standards. The Force and Torque Standards Group is developing a force measuring instrument with high stability and high precision in which tuning fork is adopted as force sensing unit.

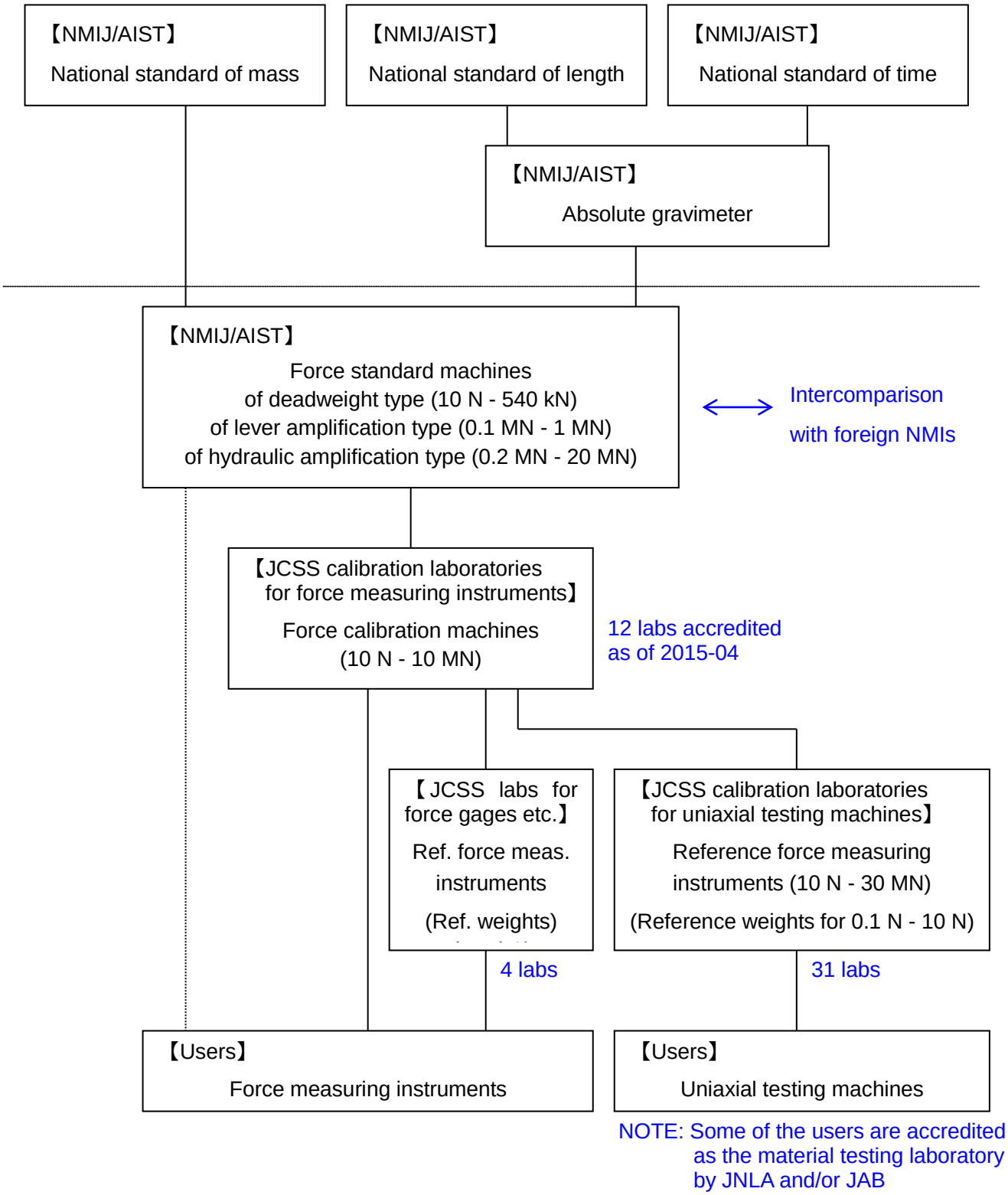


An illustration of inner structure of the force measuring instrument of the tuning fork type

3) In the practical situations of force measurements in industry, it is often required to simultaneously measure forces (and torques) acting not only in one direction but in many directions as well. A study is under way to develop evaluation methods for multi-component force transducers' characteristics.



An experiment to characterize a six-component force transducer
using an uniaxial testing machine and a inclined loding plate



Traceability system of force measurements

Torque Standard

1) National standard of the unit of torque (moment of force) is realized by torque standard machines(TSMs) of deadweight type. Gravity acting on deadweights is applied to a tip of a moment arm, and generates well-defined torque. Mass of the deadweights is adjusted within a relative deviation of approx. $1x10^{-6}$, and is calibrated with being traceable to the national standard of mass. Acceleration due to gravity is measured using a gravimeter which keeps traceability to the national standards of time and length. Length of the moment arm is measured by a coordinate measuring machine which keeps traceablility to the national standard of length, and thermal expansion of the moment arm is monitored during a calibration and compensated for.

NOTE: The compensation is not applied to the 10 N·m deadweight type TSM, as its moment arm is made of a kind of low thermal expansion material.

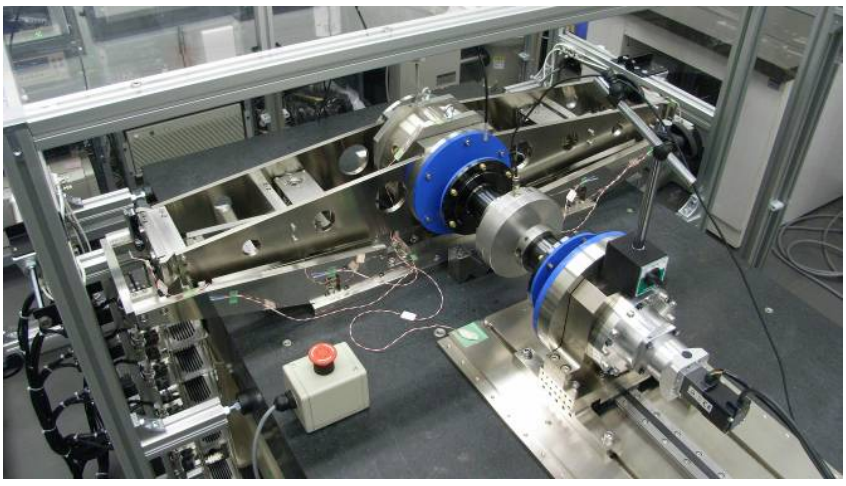
2) The TSMs are used in ordinary calibrations as well.

Range and uncertainty of calibration

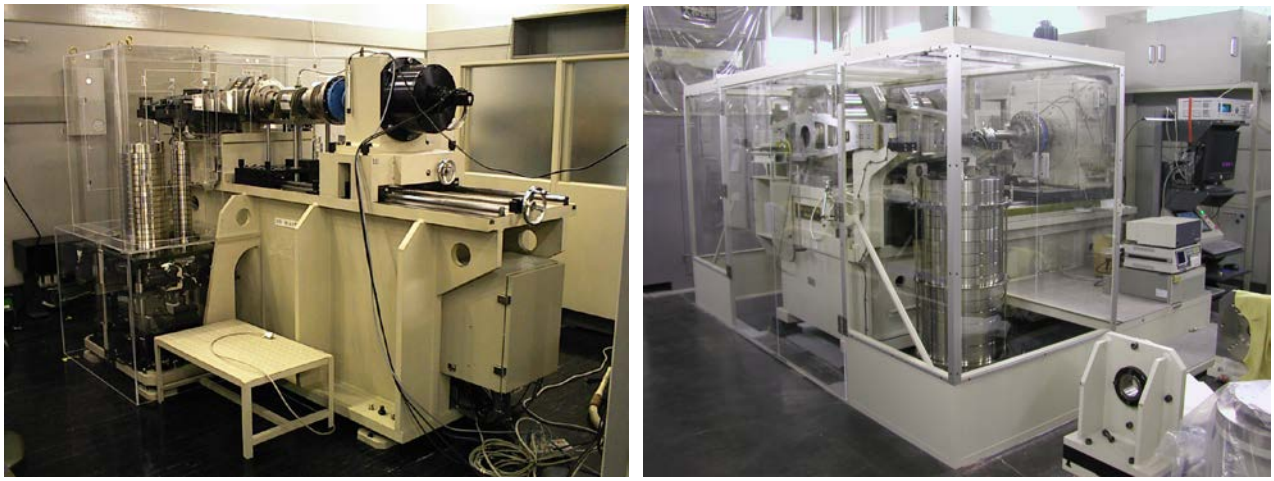
* Torque measuring instruments (for pure torque)
  - 0.1 N·m - 10 N·m: $1.0x10^{-4}$ (k=2) by the 10 N·m deadweight type TSM
  - 2 N·m - 1 kN·m: $5.0x10^{-5}$ (k=2) by the 1 kN·m deadweight type TSM

    NOTE: The uncertainty is $1.0x10^{-4}$ (k=2) when calibrations are made in the range of 2 N·m - 20 N·m.
  - 0.2 kN·m - 20 kN·m: $7.0x10^{-5}$ (k=2) by the 20 kN·m deadweight type TSM
* Reference torque wrenches
  - 5 N·m - 1 kN·m: $7.0x10^{-5}$ (k=2) by the 1 kN·m deadweight type TSM
  - 0.2 kN·m - 5 kN·m: $1.0x10^{-4}$ (k=2) by the 20 kN·m deadweight type TSM

3) Aiming at the establishment of traceability system of torque measurements, documentation work is going on, in collaboration with relevant industry, to settle and to revise technical regulations and guidelines needed for calibration labs of torque measuring instruments.

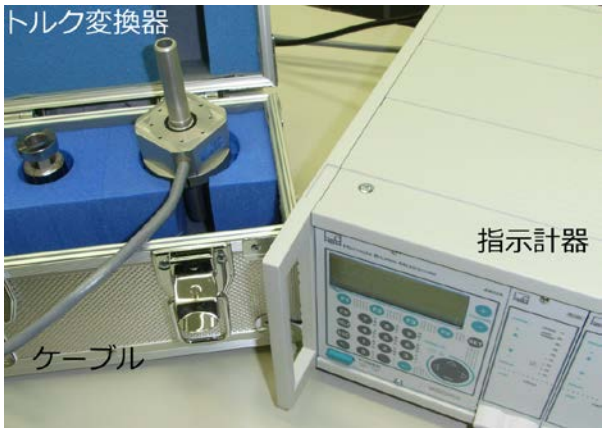


10 N·m deadweight type torque standard machine

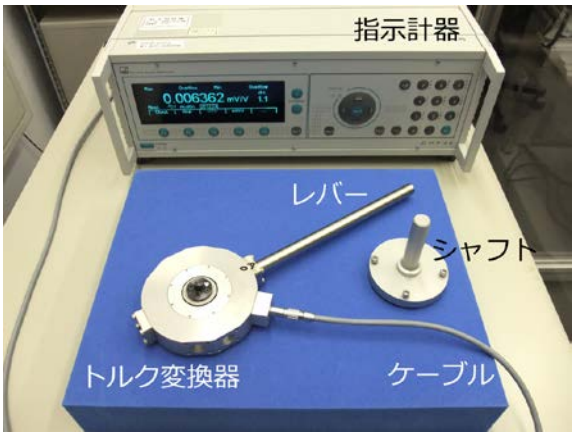


Deadweight type torque standard machines of 1 kN･m (left) and of 20 kN･m (right)

4) Measurements of small torques with high precision and reliability are required in performance evaluations of small capacity motors used for medical instruments and office automation equipment and in verifications of hand torque tools such as hand torque screwdrivers. The Force and Torque Standards Group is making research for expanding the lower limit of the torque standards from current limit of 0.1 N･m down to 0.01 N･m. The group is also developing small rated-capacity torque measuring instruments to be used as transfer standards, in cooperation with manufacturers of torque transducers.

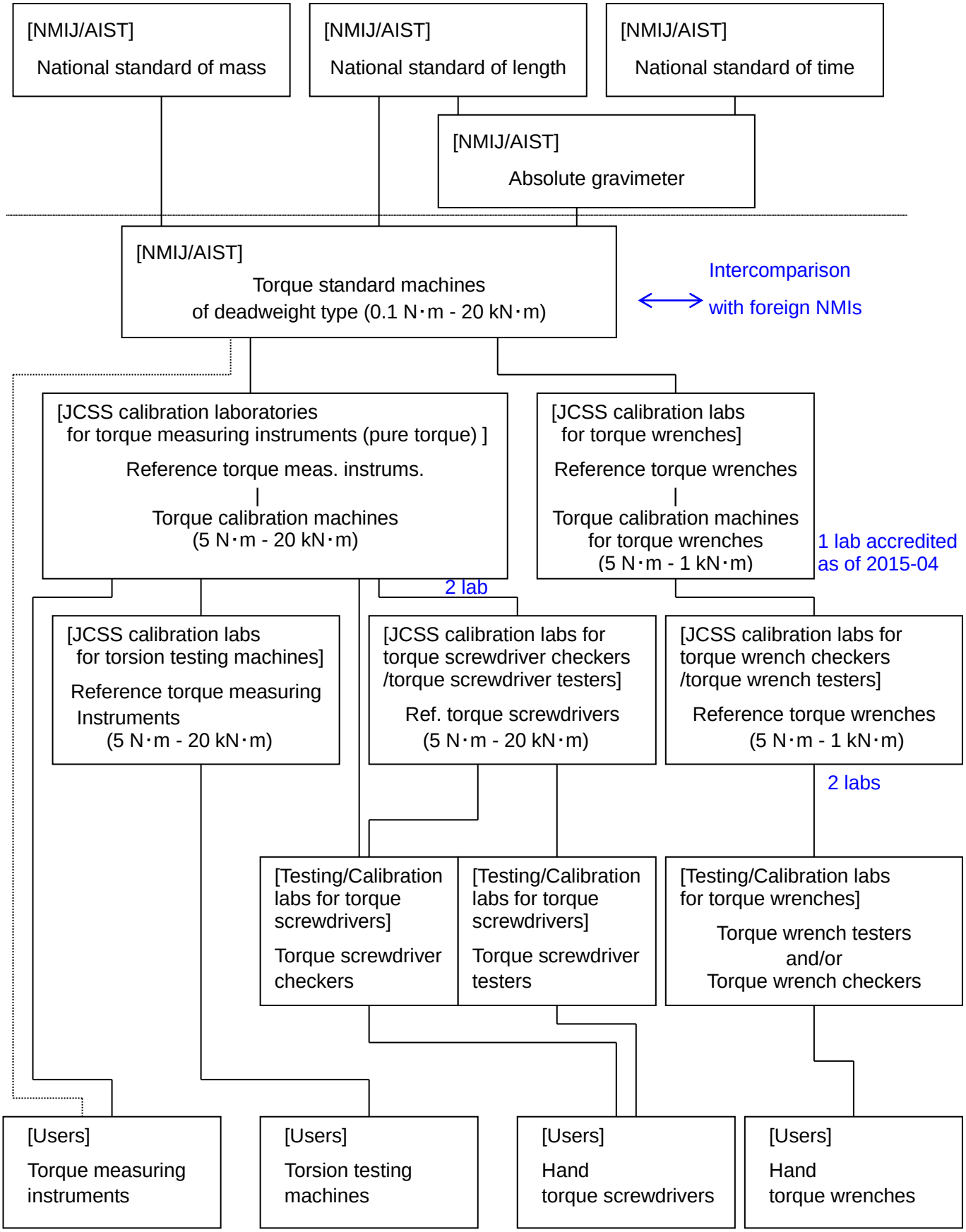


1 N･m reference torque measuring instrument



5 N･m reference torque wrench

5) In the practical situations of torque measurements, such as automobile engine (power train) test systems, motor torque testers and torsional fatigue testing machines, it is necessary to measure torques that vary with time, *i.e*., dynamic torques. We are developing methods for evaluating dynamic characteristics of torque testing machines.



Traceability system of torque measurements