Johnson Noise Thermometry (JNT)

The International Temperature Scale of 1990 (ITS-90) is an artifact-based temperature scale. Temperatures on the ITS-90, T_{90}, are designed to approximate thermodynamic temperature T, with a thermodynamic error characterized by the value of $\tilde{T}T_{90}$. Johnson Noise Thermometry (JNT) is a primary method currently in use at NIST to determine $\tilde{T}T_{90}$ in the range 500 K to 950 K, overlapping both acoustic-based (in CSTL) and radiation-based thermometry (in the Physics Laboratory).

W.L. Tew and J.R. Labenski (Div. 836)

The JNT system designed at NIST, will provide critical data linking together the highly accurate acoustic-based data at lower temperatures with the higher-temperature radiation-based data. Recent advances in digital electronics have made the computationally intensive processing required for JNT economically viable. In turn, this has enabled the development of other JNT systems in use in power generation, hydrogen co-generation, in-situ artifact probe calibration, and nano-scale temperature calibration. The NIST JNT effort complements those efforts with our focus on the core measurement science of JNT. Much of the technical solution for noise-power-comparisons employed by NIST was developed in collaboration with the Electronics and Electrical Engineering Laboratory. In the past year, we integrated our vacuum furnace comparator and standard platinum thermometer systems with the noise thermometry systems. This has enabled direct comparison of noise temperatures T_{noise} with those defined under the ITS-90 up to 660 °C. In the course of this work we have addressed a number of electromagnetic interference (EMI) and compatibility issues leading to significant improvements in the experimental systems, and we have optimized our probe designs for JNT measurements. This collaboration has also yielded better understanding and modeling of transmission line effects. We have confirmed our ability to make accurate JNT measurements by performing JNT measurements in the range 273 K to 303 K where the thermodynamic temperature is already well known.

The technical solutions developed for the NIST JNT system have value for future applications of JNT. For example, all JNT systems face technical challenges related to EMI, and optimizing the noise-temperature probe design is a key consideration in solving those challenges for both metrology and industrial applications. Transmission line effects are even more critical for practical installations of future JNT systems in industrial application environments. Technical progress in these areas is therefore important for all practitioners of JNT.

JNT, as a thermodynamic method, has significant advantages over artifact-based thermometry in application environments where thermometric stability is critical and thermometer serviceability is limited.

A highly uniform and stable vacuum furnace is used to make direct comparisons of Standard Platinum Resistance Thermometers (SPRTs) and JNT thermometers.

Traditional artifact thermometers, such as thermocouples, are inexpensive and interchangeable, but they are subject to drift and require periodic replacement or recalibration, leading to high usage cost. In contrast, a JNT system is immune to the effects of drift, chemical contamination, and radiation damage. Successful application of the NIST JNT system in the laboratory will promote development of practical systems for nuclear and fossil-fuel power generation, accelerated product testing, defense missions, and other long-term missions with remote or harsh environments.

Future Plans: In 2006, we will perform measurements near 300 °C to assess overall system performance. These measurements will pave the way for a complete series of comparisons of T_{noise} and T_{90} between the Sn freezing point (232 °C) and the Al freezing point (933 °C).

References:

Tew, W. L., Nam, S. W., Benz, S. P., Dresselhaus, Martinis, J. M., and Hashemian, H. M., ***"New Technologies for Noise Thermometry with Applications in Harsh and/or Remote Operating Environments,"*** Proc. 51st International Instrumentation Symposium, ISA Volume 457 (2005).

Nam, S. W., Benz, S. P., Dresselhaus, P. , Burroughs, C., Tew, W. L., White, D. R. and Martinis, J. M, ***"Progress on Johnson Noise Thermometry Using a Quantized Voltage Noise Source for Calibration,"*** IEEE Trans. Instrum. Meas. **54**, 653-657 (2005).