US Department
of Transportation

**Federal Railroad
Administration**

Research Results

RR 08-31
December 2008

Development Of Rail Neutral Temperature Monitoring Device

SUMMARY

With the increased use of continuously welded rail (CWR), interest in accurately, reliably, and cost-effectively monitoring rail neutral temperature (the temperature at which the rail has no longitudinal stress) has continually grown. One cannot safely assume that the rail neutral temperature remains fixed at the installation temperature, as experience has shown that it, in fact, varies with time because of the dynamic loads that the track structure experiences. As a result, the Federal Railroad Administration (FRA) Office of Research and Development has initiated a research project to develop a cost-effective rail neutral temperature monitoring device.

The rail neutral temperature monitoring device consists of a sensor unit and a readout unit (Figure 1). The former is attached magnetically to the rail web at the location where the neutral temperature is to be monitored. The sensor unit collects the rail strain and temperature data at fixed intervals throughout the day and stores them in its nonvolatile memory. The readout unit, which consists of a small proprietary receiver/global positioning system (GPS) sensor attached to an ultra-compact computer or typical laptop, can be held at a maximum distance of 200 ft from the sensor unit to collect the sensor data (Figure 2). The readout unit can be used while moving in a wayside road vehicle, or a hi-railer, or from a moving train. The readout unit performs calculations to determine the rail force, the neutral temperature, and the change in the neutral temperature from the original installation value. The device has been rigorously tested in the laboratory for accuracy under different load and temperature levels. The accuracy was found to be very good (± 0.1% error). The device was tested in the field under extreme weather conditions. The device was evaluated over several months to monitor the rail force and the neutral temperature successfully.

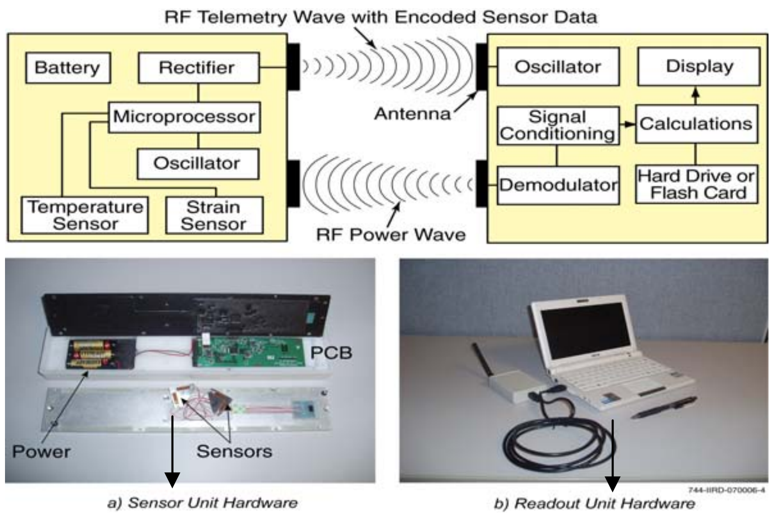

Figure 1. Sensor and readout units

BACKGROUND

Track buckling-related derailments are very costly to the railroad industry. In 2006, there were 50 track buckling-related derailments with \$13 million reportable damages, and in 2007, the reportable damages rose to \$14 million with 34 track-buckling-related derailments occurring that year.

The safety of CWR against buckling can be evaluated using the criterion [1]:

$$(T_M - T_N) \leq T_{all} \quad (1)$$

where T_N = Rail neutral (force free) temperature

T_M = Maximum rail temperature

T_{all} = Allowable rail temperature

The allowable temperature can be evaluated using CWR-Safe [2] (or equivalent computer program). The buckling strength depends on the track parameters such as the tie lateral and longitudinal resistance, rail sectional properties, and lateral geometric irregularities.

From the tests carried out by British Rail Research in the late 1970s, findings show the neutral temperature of CWR can change from its initial installation value because of rail movement through fasteners, caused by train action, diurnal heating and cooling, ground subsidence, and so on. Monitoring the neutral temperature is important and ensuring that Equation 1 is satisfied throughout the CWR operations for assurance of safety of CWR against buckling.

OBJECTIVES

The project objectives were:

- To fabricate a prototype of the rail neutral temperature monitoring device. The device should be low cost, robust, able to withstand rail vibrations, durable, and operable under low power. It should be operable by track personnel with minimal training. The device can be handheld or vehicle mounted and capable of automatic data collection.
- To validate the accuracy of the device by testing in the laboratory
- To demonstrate the use of the device in setting up the desired neutral temperature during tensor restressing and to monitor the change in neutral temperature due to traffic and diurnal cycles.

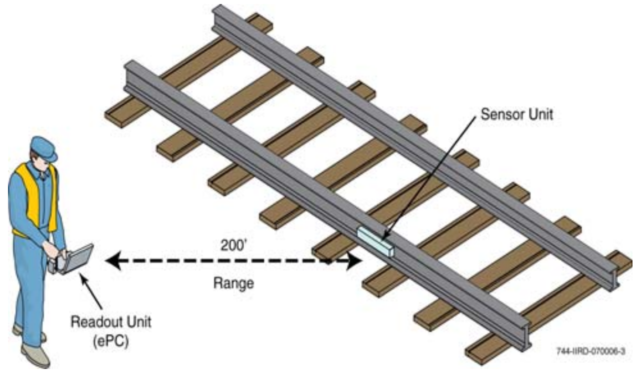

Figure 2. Readout unit capturing sensor unit data

METHODS

Sensor Unit

The sensor unit electrical elements are schematically shown in Figure 1a. The sensor unit hardware was designed to be attached to the rail web. The electric components performing signal conditioning, the analog to digital conversion of sensor signals, the microprocessor, and the software are all designed in a proprietary printed circuit board (PCB), which is packaged in the sensor unit and protected from rail vibration and the environment. The sensor unit is programmed to wake up from battery power saving mode in the unit to collect the rail strain and temperature readings at desired intervals (usually 1 hr), and store the data in a nonvolatile memory chip. This and other power management methods will ensure the battery lasts for more than a year. Replacing the batteries is an easy process and will not require recalibrating or resetting the reference neutral temperature after the battery is replaced.

The sensor unit uses strain gages for determining longitudinal strain in the rails and a thermocouple for the rail temperature. The sensor system has an onboard clock and the strain gages and wiring are integrally attached to the unit. After welding the strain gages to the rail web, the sensor package is attached to the rail in less than one minute using built-in powerful magnets. No drilling or bonding to the rail web is required.

Readout Unit

The readout unit electrical components are schematically shown in Figure 1b. This unit can interrogate the sensor unit to obtain strain and temperature data recorded as well as instantaneous readings. It contains an industrial, scientific, and medical (known as ISM) band transceiver as well as a GPS receiver for accurate location and time determination. The user interface can be an ultra-compact computer (such as an Eee PC by ASUS) or a typical laptop operating the Windows XP platform.

A transponder with USB port is also provided with the readout unit to communicate with the sensor system. The sensor system uses a custom designed communication technology, similar to that of Bluetooth wireless technology. Frequency hopping is used by the sensor unit to communicate with the readout unit, which satisfies the Federal Communications Comission requirement (47 Code of Federal Regulations Part 15.247). It is designed to be operated by track crew with minimal training (when they are performing track inspections and heat patrols). The readout unit can generally take the sensor data up to a maximum range of 200 ft. The readout unit can be mounted on a wayside road vehicle, or it can be used from a hi-railer, or mounted on a moving train to read the data from the sensor unit. The advantage of the handheld readout unit being operated by track personnel is that the track inspector can make decisions on the spot to introduce slow orders until the rail is destressed to avoid immediate buckling risk. The data collected can also be sent to a central office by the track crew, or a cellular modem can be added to the sensor unit for this purpose. Once the sensor unit is installed on the rail, the only operation it requires is a change of batteries once per year. The data collection frequency by the sensor unit and all other operations can be performed using the readout unit by personnel with minimal training.

RESULTS

Field Testing

The rail neutral temperature monitoring device has been undergoing rigorous testing in the field in winter, spring, and summer conditions. On Massachusetts Bay Transportation Authority (MBTA) tracks at two locations (in Belmont and Weston), the device has been deployed to monitor the rail temperature and strain data. Basically, the device has been used to monitor the neutral temperature and rail restressing operations.

Figure 3 shows the test data for a site with wood tie track in Belmont at which the neutral temperature monitoring device was installed to conform to the known neutral temperature value at the time of installation (~ 95°F). From this installation, the rail has been monitored for a period of more than 3 months. The figure shows data for rail and neutral temperature, rail force and change in neutral temperature. Data for 600 hr are shown for detail and simplicity. The change in neutral temperature is found to be very small for this specific section of track.

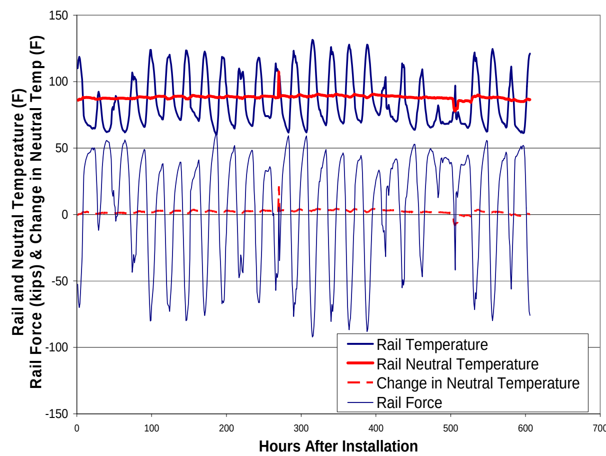

Figure 3. Monitoring change in Rail Neutral Temperature at the Belmont site location

The second objective referred to earlier is to set the correct neutral temperature when the rail is destressed and restressed using hydraulic tensors. Two important parameters are the gap size prior to tensor application and welding, and the unfastened rail length on each side. The device has built in software to direct track crew to select the required gap and unfastened section lengths to obtain the desired neutral temperature. The device monitors tensor force before welding, as well as the rail force and neutral temperature after welding and tensor removal.

Figures 4 and 5 show an example of restressing with hydraulic tensors. Figure 4 shows the tensor force and longitudinal rail force. Figure 5 shows the rail temperature and rail neutral temperature. The rail neutral temperature increased to 115°F as soon as the tensor force reached 100 kips. When the tensors were removed after an hour, the neutral temperature dropped to 102°F. After 20 hr of restressing, the neutral temperature reached 95°F. Inadequate initial gap length and inadequate length of unfastened rail section during destressing were considered to be contributing factors to the initial loss of neutral temperature. However, this practice followed by MBTA conforms to the standard practice followed by all the rail industries and per existing manuals.

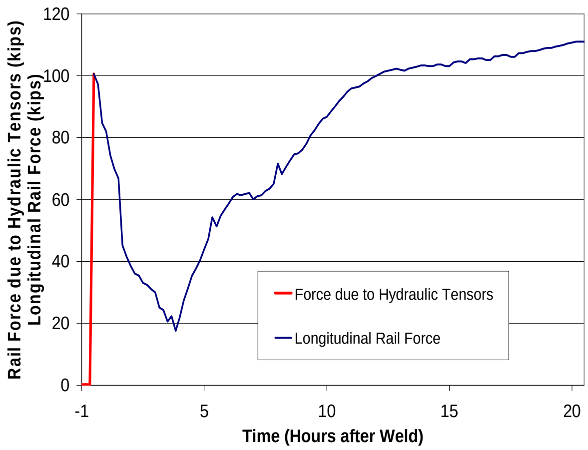

Figure 4. Tensor and Rail Force during Restressing

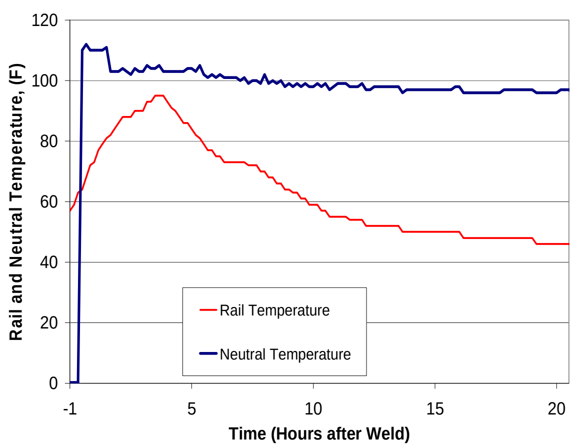

Figure 5. Rail and Neutral Temperature Data During Restressing

REFERENCES

[1] Samavedam G., and Kish A., “Continuous Welded Rail Track Buckling Safety Assurance Through Field Measurments of Track Resistance and Rail Force” Transportation Research Record No. 1289, Lateral Track Stability, 1991.
[2] Kasturi K. “CWR Safe, Program and User’s Guide”, Foster-Miller Report prepared for U.S. Department of Transportation, February 2001.

ACKNOWLEDGEMENTS

Dr. Gopal Samavedam and Mr. John Kidd of Foster-Miller performed this work under contract with FRA.

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