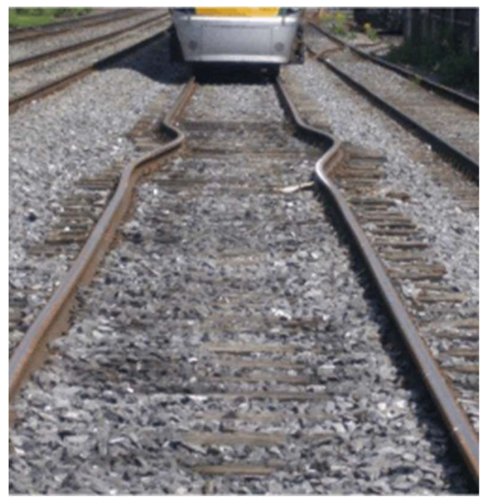
Sunshine on the Railways

2018 has been a great summer in Ireland (depending on your perspective). For most people, it has been a chance to “catch some rays” and enjoy lots of outdoor activities. But the warm weather is not good news for everyone. In particular, farmers are struggling with high temperatures and extremely low levels of rainfall and their plight has been well covered in the media. The highest temperature recorded so far this year (time of writing: Aug 7th) was 32.0°C recorded at Shannon Airport, Co Clare (13.7°C above its LTA) on the 28th June[i].

The unusual warm weather also affects things that are not so obvious and one of those is rail travel. Rail tracks expand and contract due to changes in environmental conditions, the most influential being ambient temperature and the exposure to direct sunlight. The expansion and contraction of the steel rails leads to stresses, compression in the case of high temperatures and tension in the case of low temperatures. When the rail is subject to high temperatures, it will expand and will be subject to compressive stresses: should these stresses become too large, the rail will buckle. When the rail is subject to low temperatures, it will contract and be subject to tensile stresses: should these stresses become too large, the rail will break.



Each time a train travels along a section of track, the train exerts forces on the rail/ sleeper/ ballast structure: the faster a train is travelling, the more force is exerted on that section of track. These kinetic forces result in wear on the rail head, damage to the sleepers and ties, displacement and crushing of the ballast, all of which eventually lead to a weaker rail/ sleeper/ ballast structure. Sometimes in very warm weather, this extra force is enough to trigger a track buckle and the almost inevitable consequence is a derailment. Speed restrictions may have to be imposed where the network operator believes there is a risk of buckling. This has a knock-on effect on the timetable and will result in loss of revenue and inconvenience to the rail customers.

There are various measures that can be taken to ensure that the risk of buckling is minimised, the most important being:

- Ensuring that the rail/ sleeper/ rock ballast structure is as “stiff” as possible
- Ensuring that the rail is laid and stressed to the Rail Neutral Temperature (closely related to the Median Temperature experienced by the rail over the course of the year)
- Know what the current rail temperature is

Ensuring the rail/ sleeper/ rock ballast matrix is as stiff as possible is a combination of good design and regular inspection and maintenance. In the ideal world, this matrix would provide infinite resistance to rail movement but of course this is not possible. Compromises need to be made in the size of the rail: standard profiles are between 50 – 60kg/m. Rail sleepers are usually made from reinforced concrete and are connected to the rail to allow longitudinal movement (to allow for expansion/ contraction) but no lateral movement (buckling). Specifications for ballast list minimum required values for rock size/ resistance to movement (coarseness).

Maintenance programmes ensure the rail network is inspected regularly to check for any damage or wear that may have occurred. Tamping operations are carried out on a scheduled basis to ensure that the ballast is well packed around the sleepers. Ballast is also replaced when the rock sizes fall below the minimum required standards.

The Rail Neutral Temperature is the temperature at which the rail has no longitudinal stress: if the temperature of the rail rises above this temperature, it will be in compression; if the temperature of the rail falls below this temperature, it will be in tension. The Rail Neutral Temperature is closely aligned to the Median Temperature experienced by the Rail Network through the course of a year. As a result, warmer countries use higher Rail Neutral Temperatures, and vice versa for colder countries.

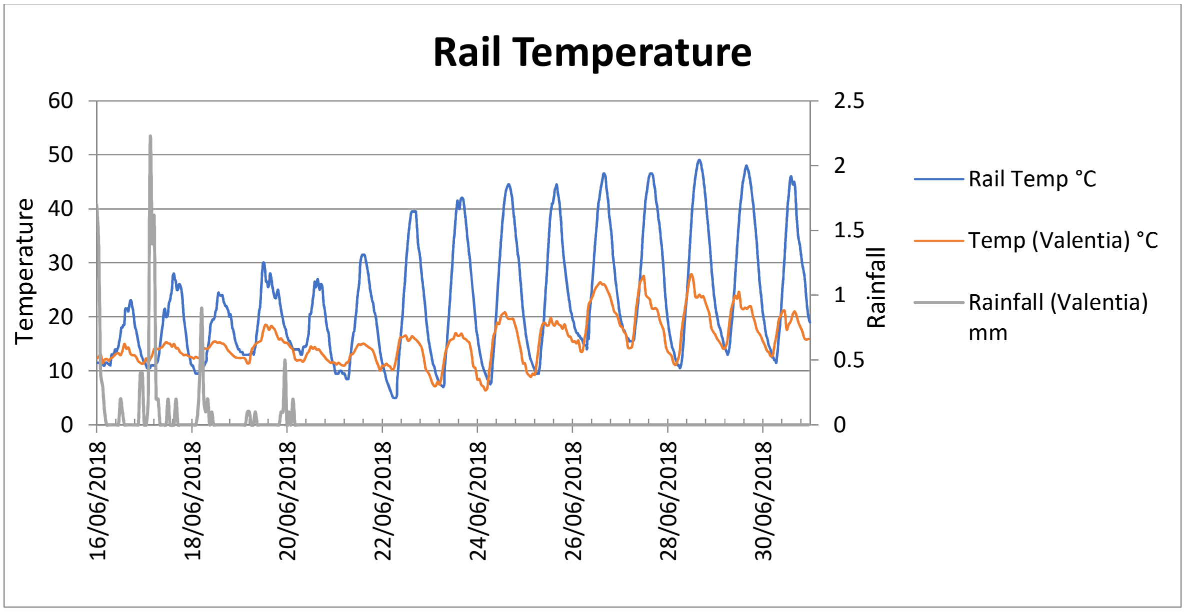
Practicality once again comes to the fore when laying rail as it would be a long, pain-staking process to replace rails if the work could only be done when the ambient temperature is at the Rail Neutral Temperature. Rail-laying machinery allows the rail to be stressed (either in tension or compression) to adjust for the ambient temperature when the rail is being laid. So, the trick when laying rails is to know the Rail Neutral Temperature and calculate from there. This begs the question "How is the median temperature known so that the Rail Neutral Temperature is specified"?

Traditionally, the temperature of the rail was measured using a temperature gauge fixed magnetically to the rail web (on the shaded side) and monitored manually. While this is a simple method of measuring the rail temperature, it doesn't really allow continuous monitoring which makes it difficult to detect the maximum and minimum temperatures for a region. It also relies on the data being collected and manually recorded, collated and stored. Each of these steps gives opportunities for errors/ data loss and a difficulty in sharing the data accurately and reliably. Because of these difficulties, personnel often resort to their past experience to estimate the minimum and maximum temperatures. This is a very difficult task given the variables at play.

Minimum temperatures typically follow the air temperature in a given area and occur at night so there is no interference from direct sunlight etc and so, are not too difficult to predict although they are affected by precipitation. Maximum temperatures are a different story. The maximum temperature will always occur during daylight hours and can be affected by:

- The direction of the rail (north-south/ east-west etc.)
- The landscape in the particular area (sheltered from wind &/or direct sunlight)
- Precipitation
- Ballast colour/ sleeper construction material/ rail colour
- Duration of weather event (e.g. how long a hot spell has lasted)

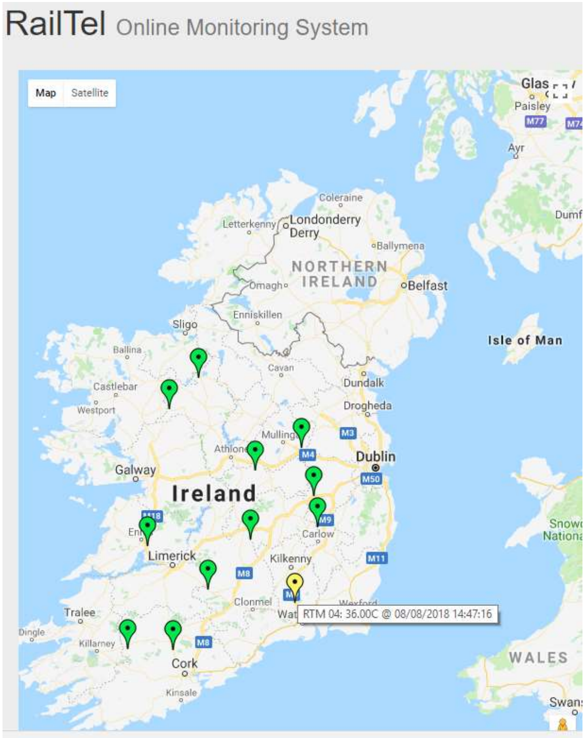
Given the number of variables, it becomes very challenging to predict when and where a maximum temperature may occur from a weather forecast.



The Rail Temperature chart is compiled from Rail Temperature data collected via RailTel from an Irish Rail installation 75km to Met Eireann Valentia Observatory[ii]. There are a number of trends that can be seen from the chart:

- The minimum air and rail temperatures correlate pretty well during darkness hours when it is dry
- The correlation between air and rail temperatures varies during periods of precipitation (it can be inferred that there are clouds present when precipitation occurs, thus affecting direct sunlight on the rail)
- During periods of sunshine, there is a divergence between air and rail temperatures
- There is a small lag in ramp up and ramp down rail temperatures compared with air temperatures (probably due to thermal mass of the ballast/ rail etc)

The above shows that it is quite an undertaking to accurately predict maximum and minimum rail temperatures, so it then becomes a task for continuous monitoring. The Internet of Things once again comes to the rescue in the shape of the RailTel unit developed by Aldolex. The product has been in use in Ireland for the last number of years and has become an important data gathering instrument. The unit continuously measures the rail temperature and sends the data to a central database. The temperature sensor connects to the bottom of the rail and communicates wirelessly with a base station mounted a safe distance from the track. The unit requires no external power or data connection and uses IoT technology to save the data centrally and provide secure web access to authorised personnel. The system notifies relevant personnel when temperatures reach programmable thresholds, allowing targetted personnel deployment for local inspections.



The data gathered over the last number of years has allowed Irish Rail to accurately measure the temperature of its network. A Rail Neutral Temperature is then chosen from accurate data rather than guesswork and this figure is used by the track laying machinery to stress the rail being laid to the correct load. The result has been that this summer, one of the hottest in living memory, has resulted in no temperature-related speed restrictions on the Irish Rail network, a win for both Irish Rail and the rail commuter.

The Maximum rail temperature recorded in 2018 was 49.0°C on 28-Jun; minimum rail temperature recorded in 2018 was -7.5°C on 08-Jan

The RailTel product is currently under development and will be launched with new capabilities by the end of 2019. New capabilities will allow for:

- Rail temperature monitoring
- Groundwater level monitoring
- Embankment/ Cut-Away slip monitoring
- Weather monitoring
- Enhanced charging offering modular solar/ wind/ solar & wind charging capabilities

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[i] Met Eireann Weather data https://www.met.ie/warm-and-dry-weather-of-june-and-july
[ii] Met Eireann Weather data https://www.met.ie/climate/available-data/historical-data