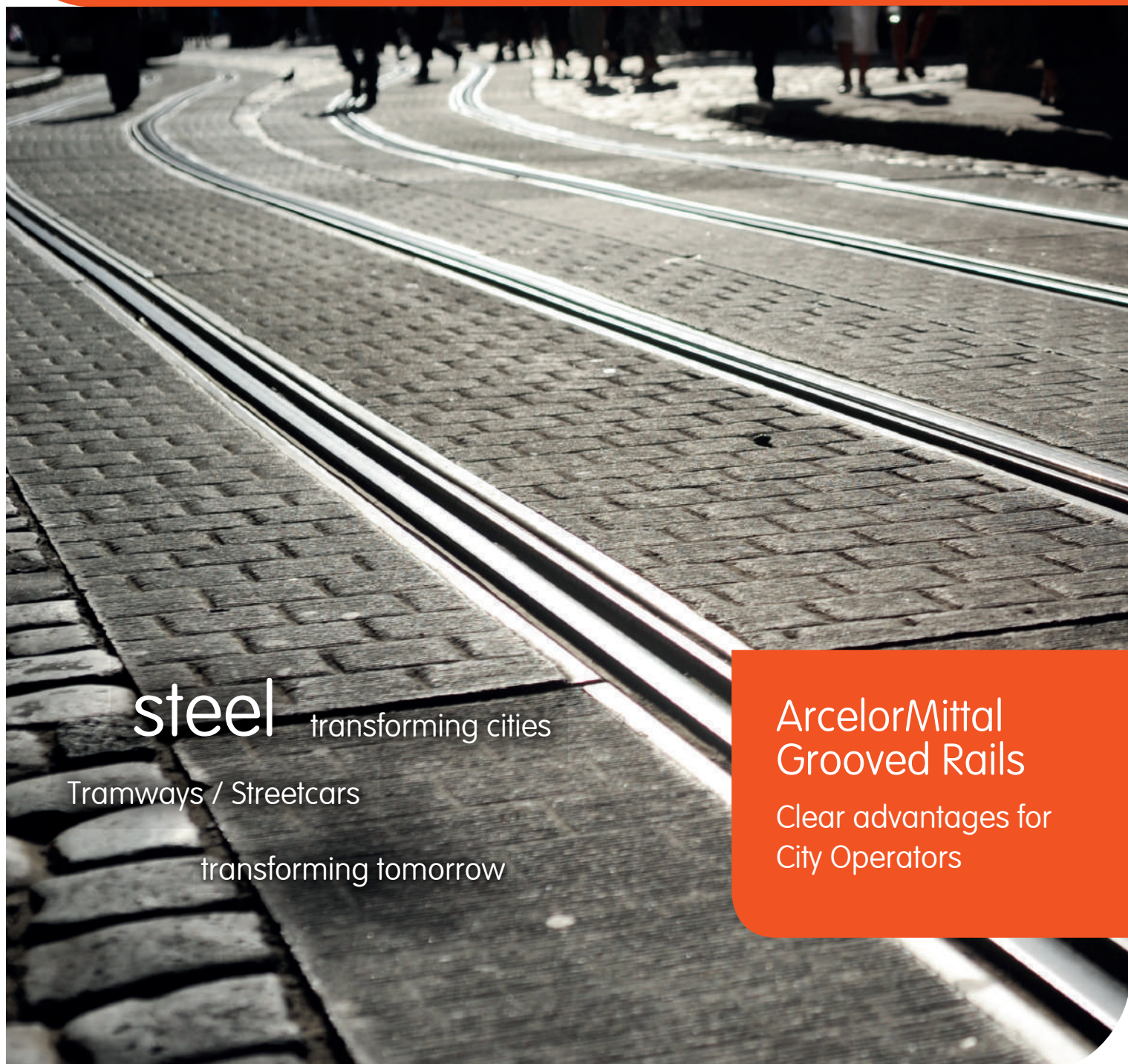


ArcelorMittal Europe Long Products  
Rails & Special Sections



ArcelorMittal

# Grooved Rails for Tramways Technical Manual



steel transforming cities

Tramways / Streetcars

transforming tomorrow

ArcelorMittal  
Grooved Rails

Clear advantages for  
City Operators



## Background

Traditionally, Head Hardened as-rolled vignole rails have been extensively used for heavy axle weight applications linked with freight or mining operations and even in some metro systems.

**This “Head Hardened” approach has ended up also being used in embedded grooved rail with the common belief that Hardened as-rolled rails will last longer. In fact, experience has shown the opposite. Low Carbon (softer steel) rails are most suitable for City Transit embedded tracks due to their Low Carbon content allowing for best welding and deposit welding techniques.** Thus, extending the life of the rail, and avoiding the high cost of replacing embedded grooved rail and street disruption.

The use of Low Carbon Vanadium (LCV) rails with the addition of very small amounts (less than 0.20%) of Vanadium, **provides an increased grain refinement throughout the entire rail, not just the outer surface as in the case of as-rolled Head Hardened rails.** The result, increasing hardness and elongation compared to rail grade R200, but with even lower Carbon content. **Thanks to the higher strain and grain refinement, after only six months of service, track hardness readings increases up to 30-45 HBW due to wheel/rail interaction of cold forging.** In addition, since rolling stock wheels are associated with lower speed and low axle weight, **the actual wheels do a smooth grinding on softer steel rails, effectively helping to self-maintain embedded tracks. This is by far the best method to avoid any Rail Contact Fatigue (RCF) or head checks commonly associated with as-rolled Hardened rails.**

Today, there is currently a wide acceptance of Low Carbon Vanadium (LCV) rails by European operators and even other Rail manufacturers for being the best overall solution for tramway and LRT systems. Low Carbon Vanadium (LCV) Rails have also been independently listed at German Steel Institute VDEh with material number 1 .0542 for **Low Carbon Vanadium R200V** and with the material number 1 .0629 for **Low Carbon Vanadium Grade R260V. Both Grades being the most evaluated under current operating Tramway and LRT networks in Europe.**

As a result, ArcelorMittal proposes existing and especially NEW tramway and LRT systems to work with proven and widely available European technology in existing European City operators and test tracks.

The objective is clear: to avoid replacement of embedded Grooved by using Low Carbon Vanadium (LCV) rails with best proven performance for welding and deposit/repair welding.

# Low Carbon Vanadium (LCV) Grooved Rails

Increased performance solving Rolling Contact Fatigue / Head Checks linked with extreme Hardness levels (HBW) for City Transit networks

## New Optimized Grooved Rail Grade: R260V (Low Carbon Vanadium LCV) Steel Rail

- Same wear resistance as traditional high carbon, head hardened grade R340GHT
- Designed for best performance in low axle weight, low speed tramway and LRT operators
- **One Grade = One rail**, with no outer rail treatment for best deposit welding techniques

## New Optimized Grooved Rail Grade: R200V (Low Carbon Vanadium LCV) Steel Rail

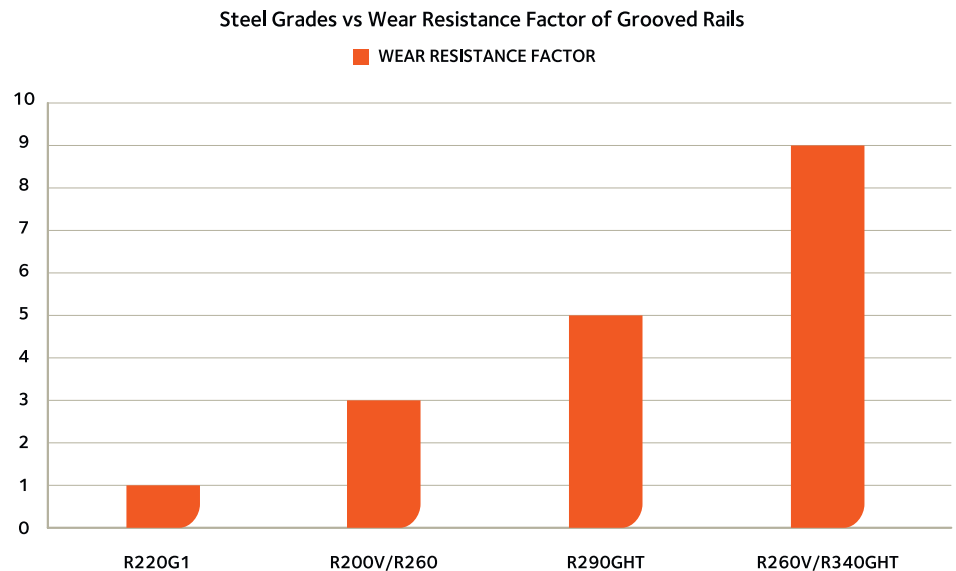
- Same wear resistance as traditional grade R260
- **Lowest C-content (0.30 – 0.48), even lower than grade R200**
- Improved performance for deposit welding even when compared to grade R200
- **One Grade = One rail**, with no outer rail treatment for best deposit welding techniques

## Clear advantages for City Operators: (when compared to Head Hardened Rails)

- **Decreased maintenance time, and costs**
- Longer service life
- Increased weldability behavior
- Increased performance solving rolling contact fatigue / head checks linked with extreme hardness levels (HBW)

As a result, low alloy rails R200V and R260V have been already placed at over 18 European transit operators successfully.

The following comparative chart was prepared based on test track results on different qualities



# Low Carbon Vanadium (LCV) Vs. Grooved Heat Treatment (GHT)

## European LRT's and Tramway Operators long-term Experience.

After 30 years of European operator experience including over 10 years of test track performance, results are clear in favor of Low Carbon Vanadium (LCV) Steel Grades.

There are often concerns on the hardness depth of Grooved Heat Treatment (GHT) Grades.

EN 14811 standard only requires hardness of 270 HBW at 30mm depth. However, thanks to the specific design of the LCV grades is possible to reach a stable and robust hardness map on the entire section of the rail head. Effectively One grade = One rail without an outer skin treatment.

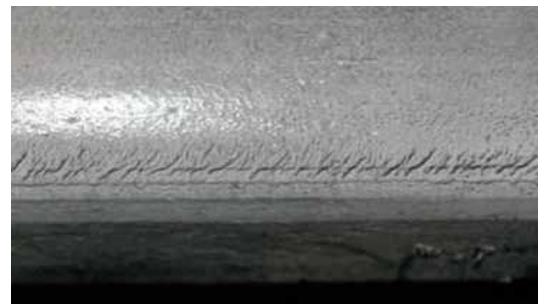
### Welding and repair welding:

In repair welding techniques, (GHT) higher carbon content upon rapid cooling can yield martensite and cracking in the Heat Affected Zone (HAZ).

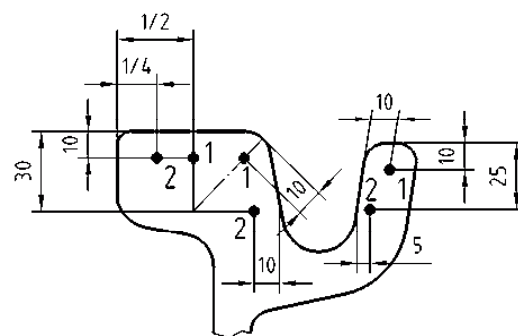
**Lower carbon content of LCV grades minimize the cracking tendency in the (HAZ) during the restoration process.**

**Lower Carbon content of Low Carbon Vanadium (LCV) grades makes them the best choice for repair welding techniques suppressing any cracking tendency in the (HAZ) during the restoration process.**

**In addition, rail bar welds of LCV grades do not loose performance at the weld point.**



Rail Contact Fatigue (RCF) on Head Hardened Grooved Rail



Hardness test positions according EN14811

|                 |  | Hardness HBW for steel grades according EN14811 |            |            |            |            |            |
|-----------------|--|---|------------|------------|------------|------------|------------|
| TEST POSITION   |  | R200  | R220G1     | R260       | R260GHT    | R290GHT    | R340GHT    |
| Running surface |  | 200 to 240                                      | 220 to 260 | 260 to 300 | 260 to 300 | 290 to 330 | 340 to 390 |
| 1               |  |   |            |            | > 260      | > 290      | > 340      |
| 2               |  |   |            |            | > 250      | > 270      | > 300      |

European City Transit operators were first in operating Tramways and LRT systems with rails placed over decades ago, have used diverse methods to extend the life of the rails including embedded Grooved rails.

### Low Carbon Rail such as Grade R200

Provides best welding and deposit-welding conditions on embedded track. Since the main objective of embedded rails is to avoid replacement. This grade provides best performance to deposit, re-surface rails while keeping maintenance cost to a minimum, since the rail/wheel interaction will by itself help regular grinding and maintenance of the rail to avoid surface micro-cracks.

#### Results:

- Best performance for welding and deposit welding.
- Best rail/wheel interaction, decrease maintenance.
- Avoidance of rail replacement by means of deposit/repair welding procedures.

### Low Carbon Vanadium (LCV) Steel Rails such as Grade R200V and R260V

Such grades as R200V and R260V were already developed in 1980's originally to improve weldability of crane steel rails by means of reducing C-content compared to traditional grades, while keeping same or above tensile strength, hardness and Rail elongation.

Today, this principle still stands as the primary factor to increase weldability and reduce maintenance costs. At the same time the inclusion of very low level of Vanadium (V) in the steel (up to 0.20%) allows for very beneficial effects on rail performance.

**Additionally, during numerous track tests after normal operation steel grades R200V and R260V show a high strain hardening potential. As a result, only after six months of service track hardness readings increases up to 30–45 HBW due to wheel/rail interaction of cold forging.**

#### Results:

- Increased grain refining throughout the entire rail, not just the outer surface.
- Increased tensile strength and hardness.
- Increased yield strength and elongation.
- Increased wear resistance, and deposit/repair welding to avoid embedded rail replacement.
- The entire rail: same chemistry and performance, unlike head hardened treatment.
- Avoidance of rail replacement by means of deposit welding procedures.

### Head Hardened Rails such as Grade 290GHT and R340GHT

According to European LRT operators, head hardened grades are generally used for very high weights per axle, and increased speeds such as some metro systems or mining operations.

However, high axle weights or high speed in LRT's or tramways are simply not there to provide the grind effect on the rail head. Thus, increased maintenance costs are required. In addition, deposit welding procedures are not readily compatible with a head hardening process, which as it by itself implies, it is just a treatment on the outer shell of the Rail.

#### Results:

- Potential for increased micro-cracks on rail surface which if not grinded due to the increased hardness on outer shell of the rail can grow deeper into the rail.
- Increased grinding and maintenance to eliminate micro cracks as they appear.
- Once rail outer skin is worn out, hardening treatment disappears, behaving just like a standard rail grade.
- High replacement cost of embedded rails..

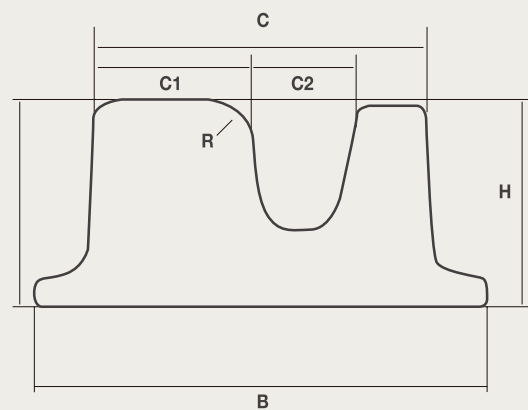
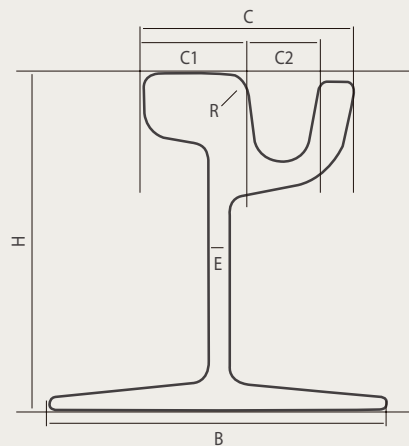
| GRADES  | MECHANICAL PROPERTIES<br>According EN14811 |       |          |         | CHEMICAL COMPOSITION |             |             |             |         |       |             |
|---------|--|-------|----------|---------|----------------------|-------------|-------------|-------------|---------|-------|-------------|
|         | HBW  | ELONG | Rm (Mpa) | Marking | C%                   | Mn%         | Si%         | Cr%         | S%      | H2ppm | V%          |
| R200    | 200 - 240                                  | ≥ 14  | ≥ 680    |         | 0.40 - 0.60          | 0.70 - 1.20 | 0.15 - 0.58 | < 0.15      | < 0.035 | < 2.5 | -           |
| R200V   | 200 - 240                                  | ≥ 15  | ≥ 690    | V       | 0.30 - 0.48          | 0.70 - 1.20 | 0.15 - 0.58 | < 0.15      | < 0.035 | < 2.5 | 0.08 - 0.20 |
| R220G 1 | 220 - 260                                  | ≥ 12  | ≥ 780    | —       | 0.50 - 0.65          | 1.00 - 1.25 | 0.15 - 0.58 | < 0.15      | < 0.025 | < 2.5 | -           |
| R260    | 260 - 300                                  | ≥ 10  | ≥ 880    | ==      | 0.62 - 0.80          | 0.70 - 1.20 | 0.15 - 0.58 | < 0.15      | < 0.025 | < 2.5 | -           |
| R260V   | 260 - 300                                  | ≥ 11  | ≥ 890    | == V    | 0.45 - 0.58          | 0.70 - 1.20 | 0.15 - 0.58 | < 0.15      | < 0.025 | < 2.5 | 0.08 - 0.20 |
| R290V   | 290 - 330                                  | ≥ 10  | ≥ 960    | === V   | 0.45 - 0.58          | 1.00 - 1.25 | 0.15 - 0.58 | < 0.15      | < 0.025 | < 2.5 | 0.08 - 0.20 |
| R320V   | 320 - 360                                  | ≥ 9   | ≥ 1080   | === V   | 0.65 - 0.85          | 0.90 - 1.30 | 0.15 - 0.58 | 0.20 - 0.80 | < 0.025 | < 2.5 | 0.05 - 0.15 |
| B1000   | 320 - 360                                  | ≥ 9   | ≥ 1080   | B1000   | 0.65 - 0.85          | 0.90 - 1.30 | 0.15 - 0.58 | 0.20 - 0.80 | < 0.025 | < 2.5 | 0.05 - 0.15 |

16 60 R2

## ArcelorMittal Grooved Rails

Grooved rails are manufactured at our world-class manufacturing plants in Luxembourg and Poland.

Our process complies with most demanding European requirements according to EN 14811.



57K2(LK1) and 53K2 (MSzTS52)

According to EN 14811 European standard for grooved rails, profiles shall fall into one of two tolerance group manufacturing categories: G or R.

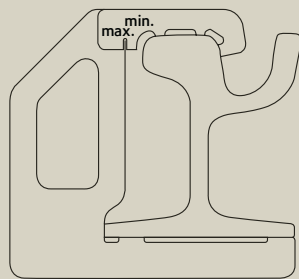
These group categories are involved in measuring rail verticality which becomes of importance for adjusting track width, embedding material interaction and to have best rail/wheel contact performance.

G group R group

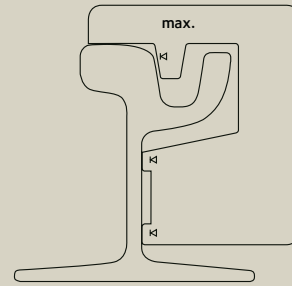
Foot and running edge asymmetry: +/-1mm +/-3mm

Web and running edge asymmetry: +/-1mm +/-3mm

G group manufacturing allows tighter tolerances in rail verticality



Foot and running edge asymmetry



Web and running edge asymmetry

**ArcelorMittal**  
100% availability  
in G tolerance

| RAIL PROFILE          | EQUIVALENT PROFILE | WEIGHT (kg/m) | TOLERANCE GROUP | HEAD RADIUS | HEAD WIDTH (mm) | GROOVE WIDTH (mm) | HEIGHT (mm) | FOOT WIDTH (mm) | WEB THICKNESS (mm) | TOTAL HEAD WIDTH (mm) |
|-----------------------|--------------------|---------------|-----------------|-------------|-----------------|-------------------|-------------|-----------------|--------------------|-----------------------|
| EN 14811 Grooved Rail |                    |               | G or R          | R           | C1              | C2                | H           | B               | E                  | C                     |
| 51R1                  | Ri52               | 51.37         | G or R          | 13/80/300   | 55.83           | 42.35             | 130.00      | 150.00          | 12                 | 113.00                |
| 53R1                  | Ri53               | 52.98         | G or R          | 13/80/300   | 55.83           | 36.34             | 130.00      | 150.00          | 12                 | 113.00                |
| 53K2                  | MSzTS52            | 53.34         | -               | 10/225      | 56.00           | 45.00             | 70.00       | 156.00          | -                  | 116.00                |
| 54G1/54R1             | 41GPU              | 54.26         | G or R          | 13/60/200   | 56.16           | 41.09             | 152.50      | 141.50          | 13                 | 116.82                |
| 54G2                  | Ri54G2             | 54.55         | G               | 13/80/300   | 55.91           | 41.55             | 152.50      | 141.50          | 13                 | 116.60                |
| 54G4                  | 41GPi              | 50.09         | G or R          | 13/60/200   | 56.22           | 40.83             | 152.52      | 141.50          | 13                 | 116.82                |
| 55G2                  | 41GP10             | 55.37         | G or R          | 10/225      | 56.23           | 40.94             | 152.50      | 141.50          | 13                 | 116.90                |
| 55G3                  | 41GP13             | 55.27         | G or R          | 13/225      | 55.61           | 40.18             | 152.50      | 141.50          | 13                 | 116.82                |
| 55R1                  | Ri55NK             | 55.45         | R               | 13/80/300   | 56.00           | 36.00             | 150.00      | 150.00          | 12                 | 113.00                |
| 57R1                  | Ph37               | 56.54         | G or R          | 9/210       | 51.92           | 60.46             | 182.00      | 150.00          | 11                 | 127.00                |
| 57K2                  | LK1                | 57.68         | -               | 13/80/300   | 56.00           | 36.00             | 72.00       | 156.00          | -                  | 115.00                |
| 59R1                  | Ri59               | 58.97         | G or R          | 10/225      | 56.00           | 42.00             | 180.00      | 180.00          | 12                 | 113.00                |
| 59R2                  | Ri59N              | 58.20         | G or R          | 13/80/300   | 55.83           | 42.35             | 180.00      | 180.00          | 12                 | 113.00                |
| 60R1                  | Ri60               | 60.59         | G or R          | 10/225      | 55.00           | 36.00             | 180.00      | 180.00          | 12                 | 113.00                |
| 60R2                  | Ri60N              | 59.75         | G or R          | 13/80/300   | 55.83           | 36.35             | 180.00      | 180.00          | 12                 | 113.00                |
| 62R1                  | NP4aM              | 62.37         | G or R          | 10/225      | 56.03           | 34.44             | 180.00      | 180.00          | 12                 | 116.00                |
| 62R2                  | NP4aS              | 61.91         | G or R          | 13/80/300   | 56.86           | 36.98             | 180.00      | 180.00          | 12                 | 116.00                |

Please, feel free to contact us if you require any other Grooved Rail profiles. ArcelorMittal strives to provide best flexibility to customers.

| EN 13674 Transport Rail |       |       | R         | C1    | H      | B      | E     |
|-------------------------|-------|-------|-----------|-------|--------|--------|-------|
| 49E1                    | S49   | 49.39 | 13/80/300 | 67.00 | 140.00 | 125.00 | 14.00 |
| 50E6                    | U50   | 50.90 | 13/60/200 | 65.00 | 153.00 | 140.00 | 15.50 |
| 54E1                    | UIC54 | 54.77 | 13/80/300 | 70.00 | 159.00 | 140.00 | 16.00 |

This Transport Rail selection represents commonly used profiles in combination with Grooved rail.

## Test Tracks

Currently, there are four test tracks actively measuring different types of track conditions such as low radius curves: 28m and below together with diverse grades and specifications including head hardened, low carbon rails and **Low Carbon Vanadium (LCV) grooved rails**. Most of these test tracks are in operation since 2007-2010.

The criteria for track measuring are being carried out in the following manner:

- 6 month intervals
- Visual inspection
- Hardness (tensile strength) measurements using EQUOTIP
- Measurement of wear on the running edge

### IFTEC, Leipzig

Grooved rail 60R2 placed in September 2006, on curved radius 27.5m, where two grades were tested: R220G1 and R260V. Results showed that rail grade R220G1 had to be build up by welding after about 1 year. When compared to grade R260V build up by welding was only needed after 4-5 years of service life.

### IFTEC, Leipzig

Rails in steel grade R260V have an approximate 4 to 5 times longer service life in comparison to steel grade R220G1 until the first build up by welding is required.

### VBZ, Zürich

In a curve with multiple radii (closest approx. 28 m) 60R2 grooved rails were laid in 2008 in both steel grades R200 and R260V. Based on achieved results, grade R260V has 7 to 8 times longer service life until the first build up by deposit welding is required.

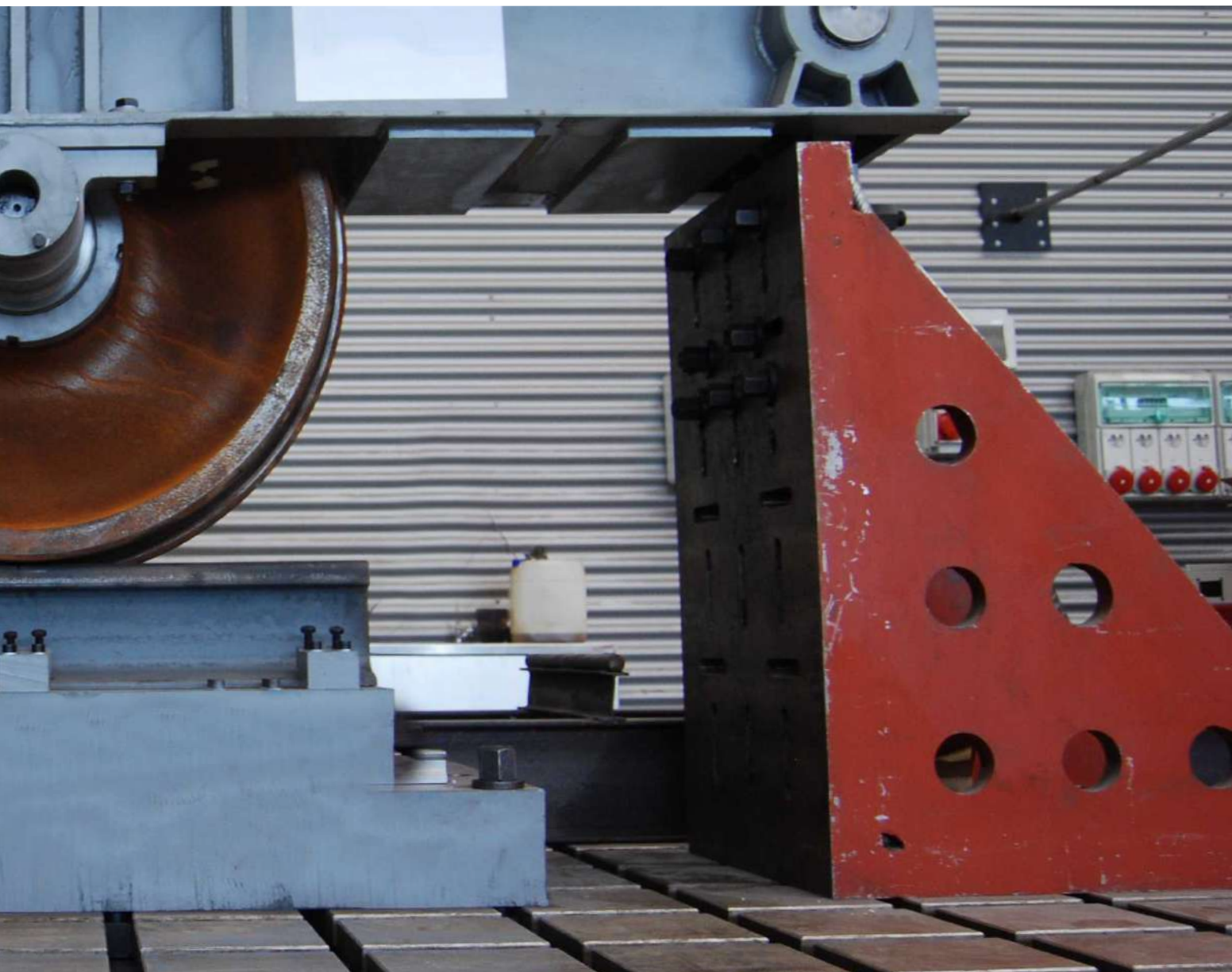
### BOGESTRA, Bochum

BOGESTRA has another short track line for selected low radii curve tracks in steel grade R260V. After years of service life, BOGESTRA had decided to continue using grade R260V based on the good performance.

### BLT Baselland, Basel

Different rail grades were placed during mid 2010 in the course of track measurements at the VBZ in Zurich. After close examination, it is yet to see any significant running edge wear on grade R260V.





| CITY TRANSPORT AUTHORITY / OPERATOR   | COUNTRY     | GRADE           | YEAR SINCE USED |
|---------------------------------------|-------------|-----------------|-----------------|
| BUDAPEST VERKEHRS AG                  | Hungary     | R260V           | 2000            |
| IFTEC, Leipzig                        | Germany     | R260V           | 2006            |
| VBZ, Zürich                           | Switzerland | R200V and R260V | 2008            |
| BLT BASSELLAND, Basel                 | Switzerland | R260V*          | 2010            |
| BOGESTRA, Bochum                      | Germany     | R260V           | 2011            |
| ZET, Zagreb                           | Croatia     | R260V           | 2012            |
| RNV, Mannheim                         | Germany     | R260V           | 2012            |
| BSVAG, Braunschweig                   | Germany     | R260V           | 2013            |
| JENAER NAHVERKEHR-GESSELLSCHAFT, Jena | Germany     | R260V           | 2013            |
| EVAG, Erfurt                          | Germany     | R260V*          | 2014            |
| Maulbeerallee                         | Germany     | R260V           | 2014            |
| BBVG, Bielefeld                       | Germany     | R260V           | 2015            |
| Baseler Verkehrs-Betriebe (BVB)       | Germany     | R200            | 2014            |

\* Test Track also includes Head Hardened Grades

# ArcelorMittal

## Our Company

ArcelorMittal with over 220,000 employees across 60 countries and industrial locations in 19 countries is the world's leading steel and mining company.

**ArcelorMittal is one of the world's largest rail producers with a capacity of 1 million tons of annual rail production with true global presence; supplying rails for railways, metro, tramway, light tracks, crossings, crane rails and rail components.**

ArcelorMittal has implemented a quality assurance system that meets the requirements of international standards ISO 9001, 14001, 18001. ArcelorMittal is member of IQNet international network of agencies for the quality systems evaluation and certification.

### Quality Products and Service

**The high quality of our rails, linked with awarded customer quality certificates and approvals at a global scale, are the reasons for which our products have experienced an important increase in the global market in the recent years.**

ArcelorMittal Rails quality policy is focused on ensuring our customers the quality of our products supply, adapted specifically to their needs.

Our quality assurance system policy is intended for the production of rail and rendering of services to meet the changing needs of our customers to meet or exceed their expectations.

Customer satisfaction is our main objective and the prevailing condition for permanent success of our rail facilities and product reliability.

**ArcelorMittal is one of the few world manufacturers able to produce 120m rail lengths (up to 30m in grooved rail).**





## ArcelorMittal Global R&D

ArcelorMittal is leader in all major global steel markets, with leading R&D dedicated centers. Rail manufacturing at ArcelorMittal is supported by Global R&D Rail Competence Center located in Aviles, Spain and supported by ArcelorMittal Global R&D network, where continuous improvement in Railway Systems Engineering and Research takes place.

**ArcelorMittal leads the efforts to continuously improve Rail steel production by studying on-track Real performance, its hardness and wear behavior to fatigue including weldability.** Although the welding technology of conventional pearlitic rails is much consolidated with aluminothermic welding and flash-butt welding techniques, the increasing interest in new grades entails increasingly demanding requirements for similar and dissimilar welding. To face this need **ArcelorMittal has installed a world class welding pilot plant at Gbbal R&D Asturias Center. Rail Welding Competence Unit will allow to progress beyond it through the development of specific procedures to improve Flash Butt Welding and aluminothermicwelding of today's rails.**

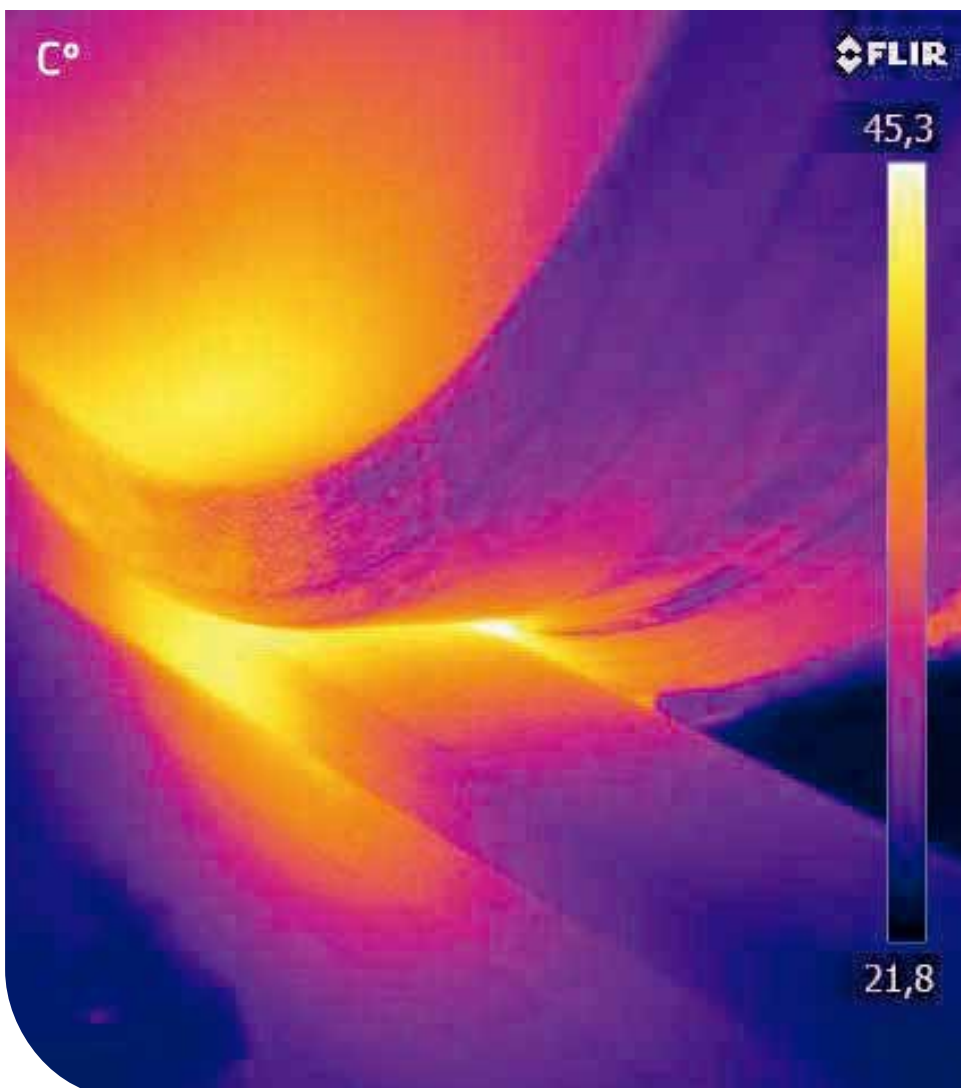
Areas of expertise at Global Rail R&D facility include but are not limited to:

- Full-size Welding Pilot Plant
- Modelling of rail manufacturing process and in-use performance.
- Tribology testing for wearing and Rolling Contact Fatigue (RCF). Twin Disk
- Full-Size wearing and RCF bench
- Characterization laboratory for validation and qualification tests
- Associated welding and reparability laboratory
- Mechatronics laboratory for inspection systems development

**Additional information can be found on:**

<http://rails.arcelormittal.com>

January 2018



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**transforming tomorrow**