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Table 1 Chemical analysis of standard materials (based on EN 10088-3) in comparison to the new material 15-5MOD

| Alloy          | C       | Si     | Mn     | P       | S       | Cr                  | Mo                | Ni                | V      | W      | Cu                | Co     | Ti     | Al     | Ta     | Nb              | N       |
|----------------|---------|--------|--------|---------|---------|---------------------|-------------------|-------------------|--------|--------|-------------------|--------|--------|--------|--------|-----------------|---------|
| Sample 15-5MOD | 0.020   | 0.25   | 0.43   | 0.020   | 0.0004  | 14.3                | 0.38              | 5.10              | 0.08   | < 0.05 | 3.18              | < 0.05 | <0.005 | 0.010  | <0.005 | <0.005          | 0.0084  |
| 15-5MOD        | < 0.050 | < 0.70 | < 1.00 | < 0.030 | < 0.010 | 14.00<br>-<br>15.50 | 0.30<br>-<br>0.60 | 4.50<br>-<br>5.50 | < 0.20 | < 0.20 | 2.50<br>-<br>4.00 | < 0.30 | < 0.05 | < 0.05 | < 0.05 | < 0.05          | < 0.05  |
| DIN 1.4313     | < 0.05  | < 0.70 | < 1.50 | < 0.040 | < 0.015 | 12.00<br>-<br>14.0  | 0.30<br>-<br>0.70 | 3.50<br>-<br>4.50 |        |        |                   |        |        |        |        |                 | ≥ 0.020 |
| DIN 1.4418     | < 0.06  | < 0.70 | < 1.50 | < 0.040 | < 0.030 | 15.0<br>-<br>17.0   | 0.80<br>-<br>1.30 | 4.0<br>-<br>6.0   |        |        |                   |        |        |        |        |                 | ≥ 0.020 |
| DIN 1.4542     | < 0.07  | < 0.70 | < 1.50 | < 0.040 | < 0.030 | 15.0<br>-<br>17.0   | < 0.60            | 3.0<br>-<br>5.0   |        |        | 3.0<br>-<br>5.0   |        |        |        |        | 5x C<br>to 0.45 |         |

Fig. 1

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Table 2 Mechanical testing of 15-5MOD in the transverse direction,  
640 x 540 mm, tempering at 520°C

| Hardening | Tempering | Block zone | Testing layer | R <sub>m</sub> [MPa] | R <sub>p0.2</sub> [MPa] | A <sub>4</sub> [%] | Z <sub>4</sub> [%] | Toughness Av (20°C) | Toughness Av (-40°C) | Delta ferrite after AMS 2315 (R-Z) [%] |
|-----------|-----------|------------|---------------|----------------------|-------------------------|--------------------|--------------------|---------------------|----------------------|----------------------------------------|
| 950°C     | 520°C     | S          | R             | 1050                 | 1022                    | 20.3               | 69.4               | 200 / 196 / 201     | 107 / 129 / 116      | 0                                      |
|           |           |            | 1/2 R         | 1048                 | 1019                    | 15.4               | 55.7               | 207 / 205 / 200     | 195 / 122 / 98       | 0                                      |
|           |           |            | Z             | 1047                 | 1016                    | 15.1               | 53.7               | 202 / 200 / 206     | 201 / 201 / 200      | 0                                      |
|           |           | M          | R             | 1037                 | 1011                    | 17.6               | 70.3               | 209 / 209 / 202     | 201 / 203 / 207      | 0                                      |
|           |           |            | 1/2 R         | 1053                 | 1022                    | 15.6               | 55.6               | 198 / 201 / 188     | 137 / 175 / 187      | 0                                      |
|           |           |            | Z             | 1046                 | 1015                    | 14.5               | 49.8               | 176 / 190 / 185     | 179 / 69 / 135       | 0                                      |
|           |           | B          | R             | 1049                 | 1016                    | 17.6               | 65.7               | 208 / 209 / 210     | 202 / 196 / 201      | 0                                      |
|           |           |            | 1/2 R         | 1041                 | 1013                    | 15.6               | 56.1               | 206 / 207 / 194     | 177 / 204 / 179      | 0                                      |
|           |           |            | Z             | 1026                 | 997                     | 15.0               | 50.1               | 199 / 206 / 191     | 189 / 179 / 191      | 0                                      |

Fig. 2

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Table 3 Mechanical testing of 15-5MOD in the transverse direction, 640 x 540 mm, tempering at 485°C

| Hardening | Tempering | Block zone | Testing layer | R <sub>m</sub> [MPa] | R <sub>p0.2</sub> [MPa] | A <sub>4</sub> [%] | Z <sub>4</sub> [%] | Toughness Av (20°C) | Toughness Av (-40°C) | Delta ferrite after AMS 2315 (R-Z) [%] |
|-----------|-----------|------------|---------------|----------------------|-------------------------|--------------------|--------------------|---------------------|----------------------|----------------------------------------|
| 950°C     | 485°C     | S          | R             | 1133                 | 1094                    | 16.9               | 63.8               | 183 / 181 / 175     | 174 / 136 / 99       | 0                                      |
|           |           |            | 1/2 R         | 1137                 | 1095                    | 15.6               | 56.3               | 178 / 147 / 185     | 120 / 100 / 71       | 0                                      |
|           |           |            | Z             | 1137                 | 1096                    | 14.8               | 55.9               | 173 / 170 / 182     | 146 / 116 / 83       | 0                                      |
|           |           | M          | R             | 1105                 | 1105                    | 14.1               | 60.9               | 167 / 160 / 184     | 160 / 175 / 188      | 0                                      |
|           |           |            | 1/2 R         | 1103                 | 1103                    | 15.2               | 55.8               | 159 / 171 / 179     | 71 / 100 / 82        | 0                                      |
|           |           |            | Z             | 1101                 | 1101                    | 14.1               | 47.1               | 165 / 160 / 170     | 97 / 123 / 100       | 0                                      |
|           |           | B          | R             | 1141                 | 1098                    | 16.5               | 62.2               | 173 / 178 / 162     | 166 / 129 / 100      | 0                                      |
|           |           |            | 1/2 R         | 1132                 | 1092                    | 14.2               | 58.6               | 167 / 176 / 171     | 122 / 118 / 156      | 0                                      |
|           |           |            | Z             | 1119                 | 1077                    | 14.8               | 51.1               | 160 / 172 / 163     | 109 / 147 / 123      | 0                                      |

Fig. 3

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Table 4 Mechanical testing of DIN 1.4418, 640 x 540 mm, in the transverse direction

| Hardening | Tempering | Block zone | Testing layer | R <sub>m</sub><br>[MPa] | R <sub>p0.2</sub><br>[MPa] | A <sub>4</sub><br>[%] | Z <sub>4</sub><br>[%] | Toughness<br>A <sub>v</sub><br>(20°C) | Toughness<br>A <sub>v</sub><br>(-40°C) | Delta ferrite after<br>AMS 2315 (R-Z) [%] |
|-----------|-----------|------------|---------------|-------------------------|----------------------------|-----------------------|-----------------------|---------------------------------------|----------------------------------------|-------------------------------------------|
| 950°C     | 515°C     | S          | R<br>Z        | 1067<br>1089            | 1025<br>1014               | 18.5<br>18.0          | 65.0<br>56.3          | 145 / 147 / 160<br>133 / 163 / 154    | 131 / 137 / 136<br>79 / 69 / 87        | 0<br>1.5                                  |
|           |           | M          | R<br>Z        | 1108<br>1108            | 1042<br>1021               | 21.7<br>22.3          | 61.7<br>64.1          | 154 / 144 / 145<br>155 / 161 / 150    | 123 / 114 / 98<br>86 / 75 / 38         | 0<br>0.5                                  |
|           |           | B          | R<br>Z        | 1042<br>1006            | 1016<br>1016               | 18.2<br>17.3          | 63.2<br>62.1          | 152 / 137 / 156<br>158 / 146 / 146    | 119 / 122 / 113<br>115 / 114 / 111     | 0<br>0.2                                  |

Fig. 4

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Table 5 Mechanical testing of DIN 1.4313, 640 x 540 mm, in the transverse direction

| Hardening | Tempering | Block zone | Testing layer | R <sub>m</sub> [MPa] | R <sub>p0.2</sub> [MPa] | A <sub>4</sub> [%] | Z <sub>4</sub> [%] | Toughness Av (20°C) | Toughness Av (-40°C) | Delta ferrite after AMS 2315 (R-Z) [%] |
|-----------|-----------|------------|---------------|----------------------|-------------------------|--------------------|--------------------|---------------------|----------------------|----------------------------------------|
| 950°C     | 475°C     | S          | R             | 1108                 | 976                     | 20.6               | 67.0               | 227 / 229 / 220     | 26 / 35 / 87         | 0                                      |
|           |           |            | 1/2 R         | 1100                 | 975                     | 19.3               | 67.1               | 220 / 217 / 215     | 25 / 16 / 18         | 0                                      |
|           |           |            | Z             | 1086                 | 936                     | 20.9               | 67.4               | 217 / 219 / 227     | 24 / 22 / 48         | 0                                      |
|           |           | M          | R             | 1114                 | 955                     | 22.2               | 72.6               | 235 / 233 / 234     | 16 / 14 / 16         | 0                                      |
|           |           |            | 1/2 R         | 1121                 | 975                     | 20.0               | 64.9               | 224 / 137 / 230     | 17 / 20 / 12         | 0                                      |
|           |           |            | Z             | 1121                 | 974                     | 18.7               | 64.7               | 100 / 211 / 169     | 10 / 14 / 34         | 0                                      |
|           |           | B          | R             | 1093                 | 941                     | 22.2               | 73.2               | 212 / 199 / 222     | 22 / 38 / 14         | 0                                      |
|           |           |            | 1/2 R         | 1100                 | 956                     | 20.7               | 66.7               | 224 / 223 / 225     | 16 / 20 / 12         | 0                                      |
|           |           |            | Z             | 1114                 | 968                     | 20.2               | 65.0               | 244 / 165 / 235     | 30 / 16 / 22         | 0                                      |

Fig. 5

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Table 6 Mechanical testing of DIN 1.4252, dimensions 520 x 280 mm, in the transverse direction

| Hardening | Tempering | Block zone | Testing layer   | R <sub>m</sub> [MPa] | R <sub>p0.2</sub> [MPa] | A <sub>4</sub> [%]   | Z <sub>4</sub> [%]   | Toughness Av (20°C)                          | Toughness Av (-40°C)                  | Delta ferrite after AMS 2315 (R-Z) [%] |
|-----------|-----------|------------|-----------------|----------------------|-------------------------|----------------------|----------------------|----------------------------------------------|---------------------------------------|----------------------------------------|
| 950°C     | 580°C     | M          | R<br>1/2 R<br>Z | 1120<br>1121<br>1115 | 1051<br>1012<br>993     | 20.6<br>17.1<br>17.4 | 52.7<br>44.4<br>44.0 | 29 / 26 / 24<br>22 / 19 / 16<br>14 / 14 / 13 | 10 / 8 / 7<br>11 / 8 / 7<br>6 / 8 / 5 | < 0.5                                  |

Fig. 6

Table 7 Mechanical testing of sample 15-5MOD in the transverse direction, 640 x 540 mm, hardening at 450°C

| Hardening | Tempering | Block zone | Testing layer | R <sub>m</sub> [MPa] | R <sub>p0.2</sub> [MPa] | A <sub>4</sub> [%] | Z <sub>4</sub> [%] | Toughness Av (-40°C)         | Delta ferrite after AMS 2315 (R-Z) [%] |
|-----------|-----------|------------|---------------|----------------------|-------------------------|--------------------|--------------------|------------------------------|----------------------------------------|
| 950°C     | 450°C     | S          | 1/2 R         | 1309<br>1303         | 1190<br>1177            | 15.1<br>15.2       | 65.5<br>71.0       | 20 / 27 / 33<br>49 / 63 / 78 | < 0.5                                  |

Fig. 7

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Table 8 Resistance to erosion corrosion:

Tensile test values of the tested samples and mass loss

Medium: boiling 20% ethanoic acid, test duration 24 h,

PH = 1.6 (acidified with H<sub>2</sub>SO<sub>4</sub>)

| Material       | Rm   | Rp0.2% | A4   | Z    |
|----------------|------|--------|------|------|
| DIN 1.4313     | 1113 | 942    | 19.3 | 69.1 |
| DIN 1.4418     | 1085 | 984    | 18.7 | 44.7 |
| 15-5MOD, 485°C | 1119 | 1071   | 19.3 | 73.3 |
| 15-5MOD, 520°C | 1056 | 1006   | 17.2 | 67.1 |
| DIN 1.4542     | 1108 | 1068   | 16.8 | 68.4 |

| Material       | Mass before testing (g) | Mass after testing (g) | Mass loss [g] | Result in gm <sup>2</sup> h |
|----------------|-------------------------|------------------------|---------------|-----------------------------|
| DIN 1.4313     | 23.10668                | 22.63705               | 0.46963       | 11.01                       |
|                | 23.07869                | 22.59528               | 0.48341       | 11.18                       |
| DIN 1.4418     | 23.97674                | 23.97674               | 0.00000       | 0.00                        |
|                | 23.72929                | 23.72836               | 0.00093       | 0.02                        |
| 15-5MOD, 485°C | 23.31939                | 23.31901               | 0.00038       | 0.01                        |
|                | 23.68716                | 23.68672               | 0.00044       | 0.01                        |
| 15-5MOD, 520°C | 23.65176                | 23.64894               | 0.00372       | 0.09                        |
|                | 23.28609                | 23.28269               | 0.00340       | 0.08                        |
| DIN 1.4542     | 22.65869                | 22.65829               | 0.00040       | 0.01                        |
|                | 22.70889                | 22.70855               | 0.00034       | 0.01                        |

Fig. 8