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# Martensitic Stainless Steel OCTG with Premium Connection

## 1. Introduction

In response to deterioration of oil and natural gas drilling environments (high temperature/high pressure (HPHT) due to greater depth, increases in corrosive gases such as $CO_2$ and $H_2S$, drilling in deep water, etc.) and the evolution of drilling technology (horizontal drilling, drilling with casing, etc.), more advanced and diverse performance is now required in oil country tubular goods (OCTG) and threaded joints (connections). JFE Steel is developing various products to respond to these customer needs.

## 2. Martensitic Stainless Steel Seamless Pipes

### 2.1 Product Lineup

JFE Steel's lineup of martensitic stainless steel OCTG and their respective chemical compositions are shown in **Table 1**, and their mechanical properties are shown in **Table 2** .

The main corrosion problems that occur in oil and natural gas wells are $CO_2$ corrosion (general corrosion) caused by $CO_2$ and sulfide stress cracking (SSC) caused by $H_2S$. Therefore, JFE Steel provides a lineup of steel products that can respond to various well conditions, corresponding to the $CO_2$ partial pressure and $H_2S$ partial pressure in the well concerned.

### 2.2 UHP$^{TM}$-15CR-125, UHP$^{TM}$-17CR-110

UHP$^{TM}$-15CR-125 and UHP$^{TM}$-17CR-110 are original JFE's proprietary steel grades with corrosion resistance superior to that of HP2-13CR, and were developed as substitutes for duplex steels such as 22CR and 25CR[1)]. The stable phase of the crystallographic structure of stainless steels is generally arranged by a Scheafflar diagram using the chromium equivalent ($Cr_{eq}$) and nickel equivalent ($Ni_{eq}$) (**Fig. 1**).

The main microstructure of UHP-15CR is the martensitic phase. UHP-17CR has high temperature corrosion resistance at 230°C, which was achieved by adding Cr (increasing the Cr equivalent) to UHP-15CR as the base material (**Fig. 2**), while adjusting the Ni equivalent to maintain strong, tough martensite as the stable

Table 1 Chemical composition

(wt%)

| Grade | UNS No. | C | Cr | Ni | Mo | Mn | Cu |
|---|---|---|---|---|---|---|---|
| L80-13Cr | — | 0.15-0.22 | 12.0-14.0 | Max 0.50 | — | 0.25-1.00 | Max 0.25 |
| HP2-13CR-95/110 | — | Max 0.04 | 12.0-14.0 | 4.50-5.50 | 1.80-2.50 | Max 0.60 | — |
| UHP$^{TM}$-15CR-125 | S42625 | Max 0.05 | 14.0-16.0 | 5.0-7.0 | 1.5-3.5 | Max 1.8 | 0.5-1.5 |
| UHP$^{TM}$-17CR-110 | S42825 | Max 0.05 | 16.0-18.0 | 3.0-5.0 | 1.5-3.5 | Max 1.80 | Max 3.0 |

Table 2 Mechanical properties

| Grade | YS | TS | Hardness |
|---|---|---|---|
| L80-13Cr | 80-95 ksi (552-655 MPa) | Min. 95 ksi (Min. 655 MPa) | Max. 23.0 HRC |
| HP2-13CR-95 | 95-110 ksi (655-758 MPa) | Min. 105 ksi (Min. 724 MPa) | Max. 30 HRC |
| HP2-13CR-110 | 110-130 ksi (758-896 MPa) | Min. 120 ksi (Min. 827 MPa) | Max. 32 HRC |
| UHP$^{TM}$-15CR-125 | 125-150 ksi (862-1 034 MPa) | Min. 135 ksi (Min. 931 MPa) | Max. 37 HRC |
| UHP$^{TM}$-17CR-110 | 110-130 ksi (758-896 MPa) | Min. 120 ksi (Min. 827 MPa) | Max. 33 HRC |

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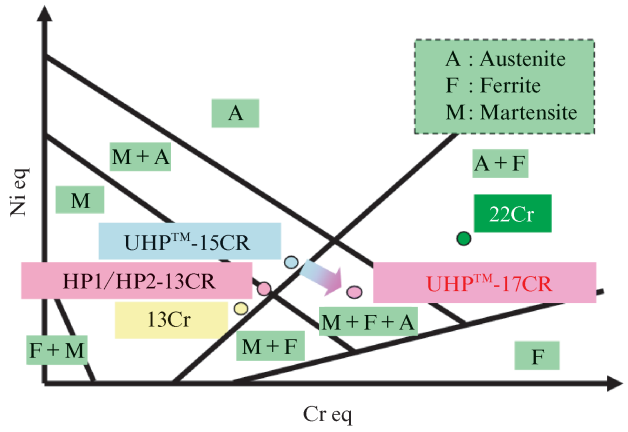


Fig. 1 Sheafflar diagram

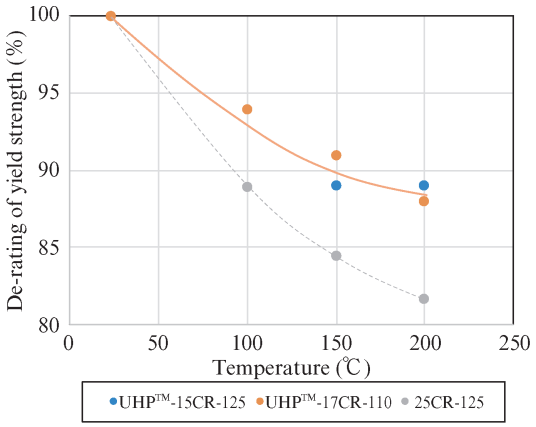


Fig. 3 Correlation between yield strength and temperature

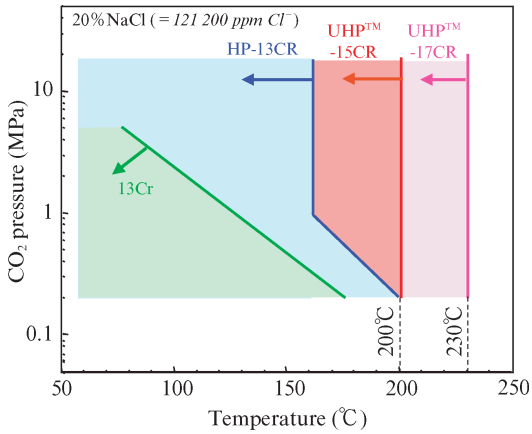


Fig. 2 $CO_2$ corrosion map

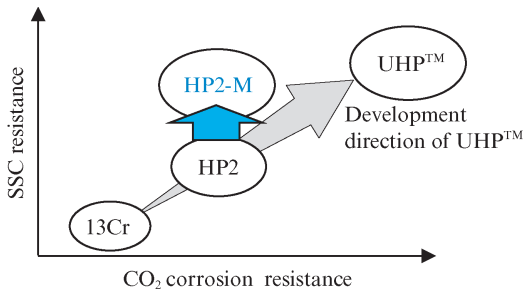


Fig. 4 Development direction of HP2-13CR-95M and HP2-13CR-110M

phase. Due to this composition, high strength of 110 to 130 ksi can be achieved in UHP-17CR at a low cost and with a comparatively short lead time, without the cold drawing processing required for duplex steels. In addition, UHP-15CR-125 and UHP-17CR-110, which do not require cold drawing, are not prone to decreased mechanical strength (yield stress) at high temperatures, which has the merit of increasing the degree of freedom in well design (**Fig. 3**).

### 2.3 HP2–13CR-95M, HP2–13CR-110M

With the diversification of well conditions, there are cases in which $CO_2$ corrosion resistance performance as high as UHP grade is not necessary, but high SSC resistance performance of the HP2 grade is required. To respond to such conditions, JFE Steel developed HP2-13CR-95M and HP2-13CR-110M with improved SSC resistance performance by adjusting the Mn and Ni components based on the existing HP2 grade, and controlling the upper limit of hardness from 30 HRC to 28 HRC at 95 ksi and from 32 HRC to 31 HRC at 110 ksi (**Fig. 4**).

## 3. Basic Design and Features of High Performance Premium Connection JFELION™

Because oil and natural gas are combustible and the leakage from a well may lead to a serious accident, the sealability of the connections used to connect OCTG during drilling is extremely important. Conventionally, the load resistance at which threaded joints can maintain sealability was lower than the load resistance of pipe body. However, the JFELION™ premium connection developed by JFE Steel has a high sealability thread that maintains sealability even under the limit load (tension, compression) and limit pressure (internal pressure, external pressure) conditions of pipe body. Although it is generally known that the high alloy steels UHP-15CR-125 and UHP-17CR-110 introduced in the previous chapter are susceptible to galling due to sliding of the seal part in the connection make-up process, JFE Steel succeeded in satisfying both galling resistance and sealability by adopting an original seal geometry developed by JFE Steel, which was optimized to suppress peak contact pressure (**Fig. 5**).

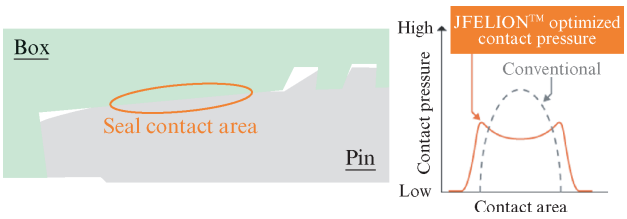


Fig. 5 Figure set and seal contact pressure of JFELION™

## 4. Conclusion

The combination of JFE's martensitic stainless steel OCTG and the JFELION™ premium connection has received a high evaluation from oil and gas companies as products that are more economical than duplex steels such as 22CR and 25CR, have excellent corrosion resistance and sealability and a low risk of galling, and can provide high running efficiency for customers. In the future, JFE Steel will continue to develop products that respond to the needs of customers.

## References

1) Ishiguro, Y. ; Enhanced Corrosion-Resistant Stainless Steel OCTG of 17Cr for Sweet and Sour Environments. NACE Corrosion. 2013, Paper no. 2436.

## For Further Information, Please Contact:

OCTG,Specialty Pipe & Tube Sec. Energy Industry Steel Products Export Dept. Tubular Business Division JFE Steel
Phone (81) 3–3597–3205 FAX (81) 3–3597–4710
Products Service & Development Sec. I Products Service & Development Dept. Chita Works JFE Steel
Phone (81) 569–24–2432 FAX (81) 569–24–2032
https://www.jfe-steel.co.jp/products/koukan/oilwell.php