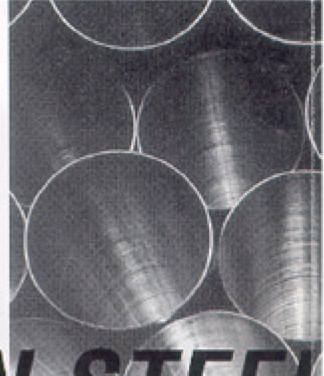
Dillinger Offshore Letter



DILLINGER HÜTTE GTS - EXPERIENCE IN STEEL FOR SOUR SER

More than 300000 t of plates and slabs for sour gas pipelines in 1993

Cheap energy is one of the very fundamental foundations that our industrialized part of the world is based upon.

After a first decade of enthusiasm, at least since Chernobyl 8 years ago, the acceptance of nuclear power plants has drastically decreased and does not seem to be the future solution to energy supply. Until renewable energy, including hydrogen technology, will be made cheaply available and in greater quantities, energy production for industy and individual users will mainly rely on fossil fuels - oil, gas and coal despite their contribution to green house effect.

The most accessible oil and gas fields are located in areas quite far away from consumers requiring transportation as shown in Fig. 1. For long distances tankers will be the most economic transportation system, but up to some 1000 miles and for land crossing pipelines are the most reasonable solution to fill the gap. Today 75% of all natural gas is transported via hundreds of thousands miles of pipelines connecting us to the energy resources and keeping our way of life and comforts.

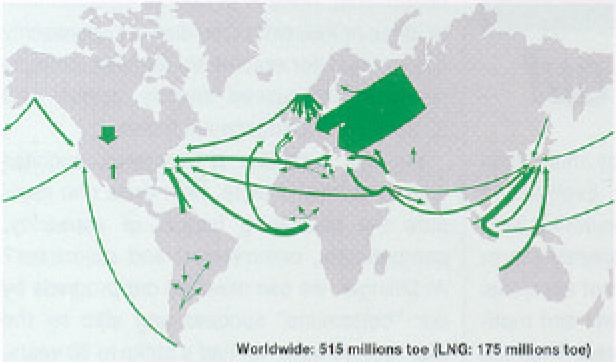
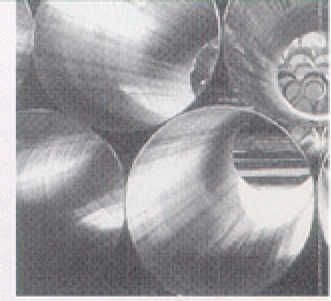


Fig. 1: Forecast of major gas exchanges (year 2020)

From "Natural gas in the world, outlook to 2000" (Edition Technip)

Special steels, special plate processing, rolling and welding were developed for large diameter pipelines. To be able to increase pipe diameters and pressures, the yield strength of the steel was raised from X52 to X80 (API 5L) during the last 20 years and plates up to 5200mm wide are available. At the same time toughness and weldability could be improved by sophisticated steel making and plate rolling procedures.

The developments in steel making and plate rolling have also allowed for the production of pipes with high resistance to hydrogen induced cracking (HIC) permitting safe transport of media containing H_2S. Expensive stainless, cladded or duplex pipes can now be restricted to severe corrosive media where the cost can be justified.



The sour gas resistance of steel is mostly tested according to NACE HIC- and SSCC (sulphide stress corrosion cracking) procedures and standards. Reduced carbon content, extremely low sulphur content and extra low levels of inclusions associated with a homogeneous structure are of the essence to achieve steel with the best sour gas resistance.

Two large deliveries of Dillinger Hütte (DH) illustrate briefly our technical know how to produce sour gas resistant plates for line pipe:

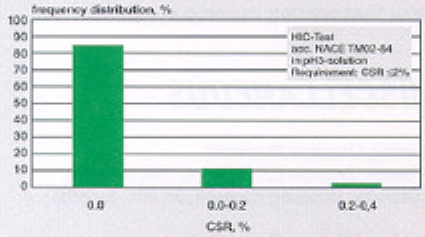


Fig. 2: HIC test results of NIOC X65 sour service steel plates

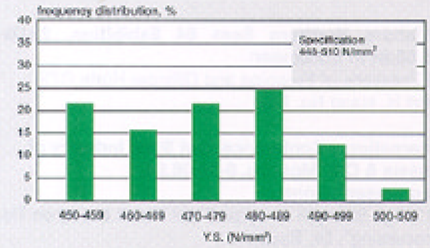


Fig. 3: Yield strength distribution on pipe base material

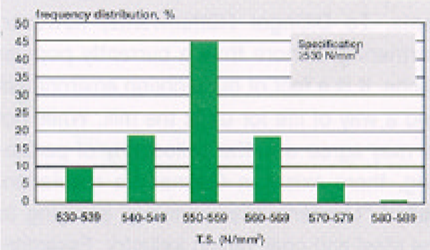


Fig. 4: Tensile strength distribution on pipe base material

■ Tensile test requirements in transverse direction:

	plate	pipe
Y.S.0.5	475-558 N/mm²	448-510 N/mm² 20% up to 538 N/mm²
T.S.	≥ 530 N/mm2	≥ 530 N/mm²
Y.S./T.S.	≤ 0.93	≤ 0.90
El. 2"	≥ 26%	≥ 23.5%

■ BDWTT requirements:
at 0°C ≥ 90% shear (single value)

■ Ch-V requirements in transverse direction:
Ch-V at 0°C ≥ 97 J (single value)

■ HIC-Test according NACE TM 02-84 with solution according NACE TM01-77 (pH=3):
Criterium CSR < 2%

■ SSCC- 4 point bending test with solution according NACE TM 01-77:
Criterium "no SSC-cracks"

■ Vickers hardness:
max. 248HV10

Table 1: Requirement profile for NIOC X65 HIC plates

L PLATE PRODUCTION VICE LINEPIPES

1. TM-steels with high wall thickness for sour service pipes

One challenging project in the field of modern linepipe was for X65, in 1993 for Iran. 130,000 mt of X65 for sour service with wall thicknesses ranging from 21.6 mm up to 31.8 mm were ordered from DH.

The requirement profile for this steel is illustrated in Table 1. To produce these plates with a combination of BDWTT-, HIC- and SSCC- requirements respectively, DH used a 4-stage TM-rolling combined with a 2-stage-cooling both between rolling stage 3 and 4 and a final accelerated cooling after rolling stage 4.

The plates with the higher wall thicknesses 29.5 mm and 31.8 mm were formed into pipe at the BERGROHR SIEGEN pipe mill.

The results illustrated in Fig. 2 to 5 show a very consistent distribution of HIC and mechanical properties respectively, indicating a well defined balance between the steel treatment in the steel plant and the sophisticated rolling and cooling procedures in the plate mill.

ChV-results on pipe have fulfilled the specified requirements as it shown in Fig. 6 both for Base Material (BM) and heat affected zone (HAZ).

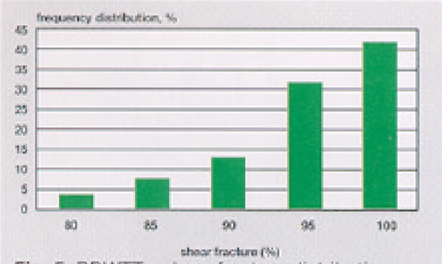


Fig. 5: BDWTT - shear fracture distribution tested at -20 C°

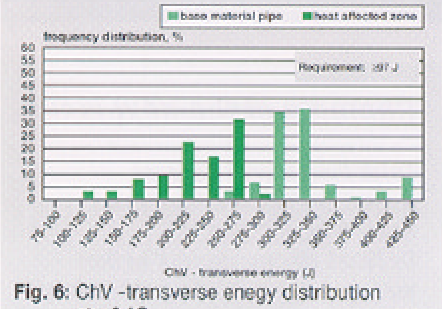


Fig. 6: ChV -transverse enegy distribution at ±0 °C

2. TM-steels for sour service under extreme arctic conditions

The know how to produce X65/X70 steel plates for artic conditions and sour service linepipe steels had to be combined for an artic pipeline project.

The maximum wall thickness for this order was 16.3mm, with the main part of the order however having a wall thickness of 12.7 mm. The complete requirement profile is illustrated in Table 2.The type of chemistry for all items is shown in Table 3.

The requirement was to perform the HIC-test in pH 5 test solution in accordance with NACE TM02-84. Typical CSR (CSR = Crack Sensitivity Ratio) values of zero have been found. In addition to this official requirement, DH tested also the plates, for research purposes, in pH 3 solution according to NACE TM01-77, which is much more severe, with satisfactory results.

The mechanical properties for tensile testing and BDWTT are shown in Fig. 7 and 8 respectively. The tensile properties exhibit a very narrow scatter band and BDWTT-results show excellent values for shear area even tested at -60°C.

As a next step we will try to realize HIC and BDWTT requirements in X70 of increasing plate thicknesses.

Dr. J. Bauer (Research & Development),
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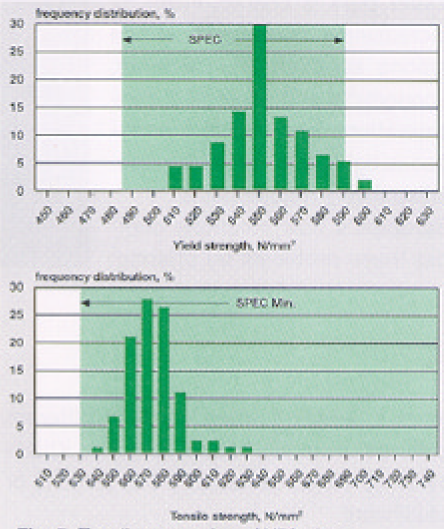

Fig. 7: Tensile properties of X70 plates for sour service

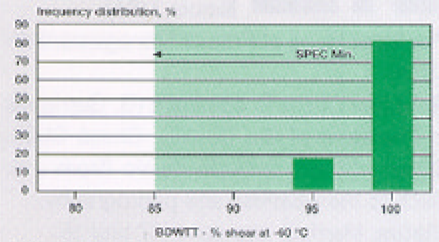

Fig. 8: BDWTT - results on X70 sour service steel

Y.S.	485-590 N/mm²
T.S.	≥ 531 N/mm²
Ch-V transverse (-46°C)	100/110J (single/average) 80/95% shear (single/average)
BDWTT	for 12.7 and 11.3mm at -60°C: ≥ 85% shear for 16.25mm at -30°C: ≥ 95% shear
HIC-test NACE TM 02-84 (pH: 5)	CLR ≤ 5%, CSR ≤ 1%

Table 2: Requirements for X65/X70 sour service steel plates

Steel type:	**CMnNbVTi**
C	≤ 0.06
Mn	≤ 1.55
S	≤ 0.001
P_{CM} (typical)	≤ 0.14
CE_{IIW} (typical)	≤ 0.32
Nb + V + Ti	≤ 0.12
Ca - treated	

Table 3: Type of chemistry for X70 sour service steel