



# Development of Large Diameter High Strength Line Pipes for Low Temperature Services\*

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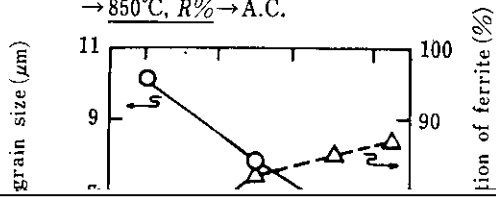
Toshihiro SEKINE\*\*\*



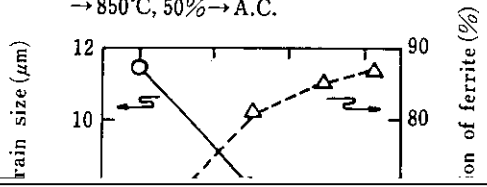
Initial austenite



1 150°C × 60 min → 1 020°C, 62.5%  
→ 850°C, R% → A.C.



1 150°C × 60 min → 1 020°C, R%  
→ 850°C, 50% → A.C.



1 150°C×60 min→1 020°C, 62.5%  
→ 950°C, 50% → 7°C, 30% → A C

1 150°C×60 min→1 020°C, 62.5%  
→ 850°C, 50% → 710°C, R<sub>2</sub> → A C

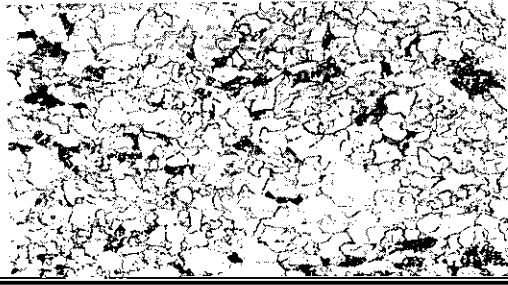


Fig. 7 shows the relation between the T.S. and the CVN 50% shear FATT when controlled-rolled by varying Ni and Mn contents in a Nb-bearing steel. Increases in Ni and Mn contents raise T.S. and, at the same time, lower the 50% shear FATT. One of the reasons for this is the lowering of the transformation temperature  $A_r_3$ , according to eq. (1) as a result of increases in these elements, because this lowering causes the austenite non-recrystallization region to ex-

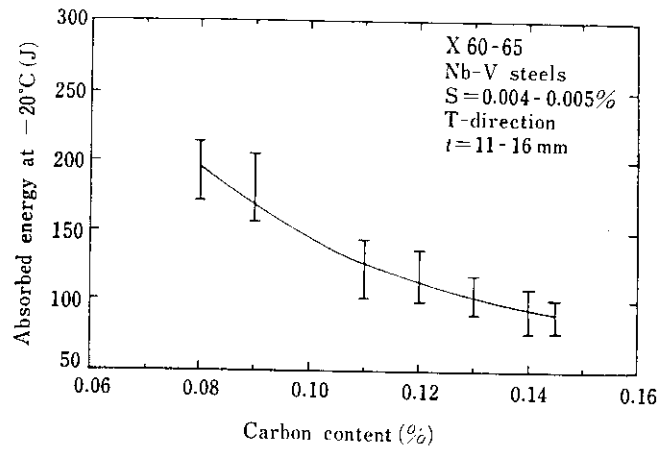


Fig. 8 Effect of carbon content on the Charpy V notch absorbed energy of X 60-65 Nb-V steels

[REDACTED]

[REDACTED]

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[REDACTED]

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CVN 50% shear FATT simultaneously. This is attri-

The EHE pipes have a Charpy impact absorbed

CVN 50% shear FATT simultaneously. This is attri-

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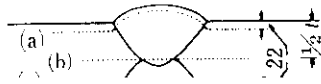
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**Table 3** Mechanical properties of line pipes for the Arctic use

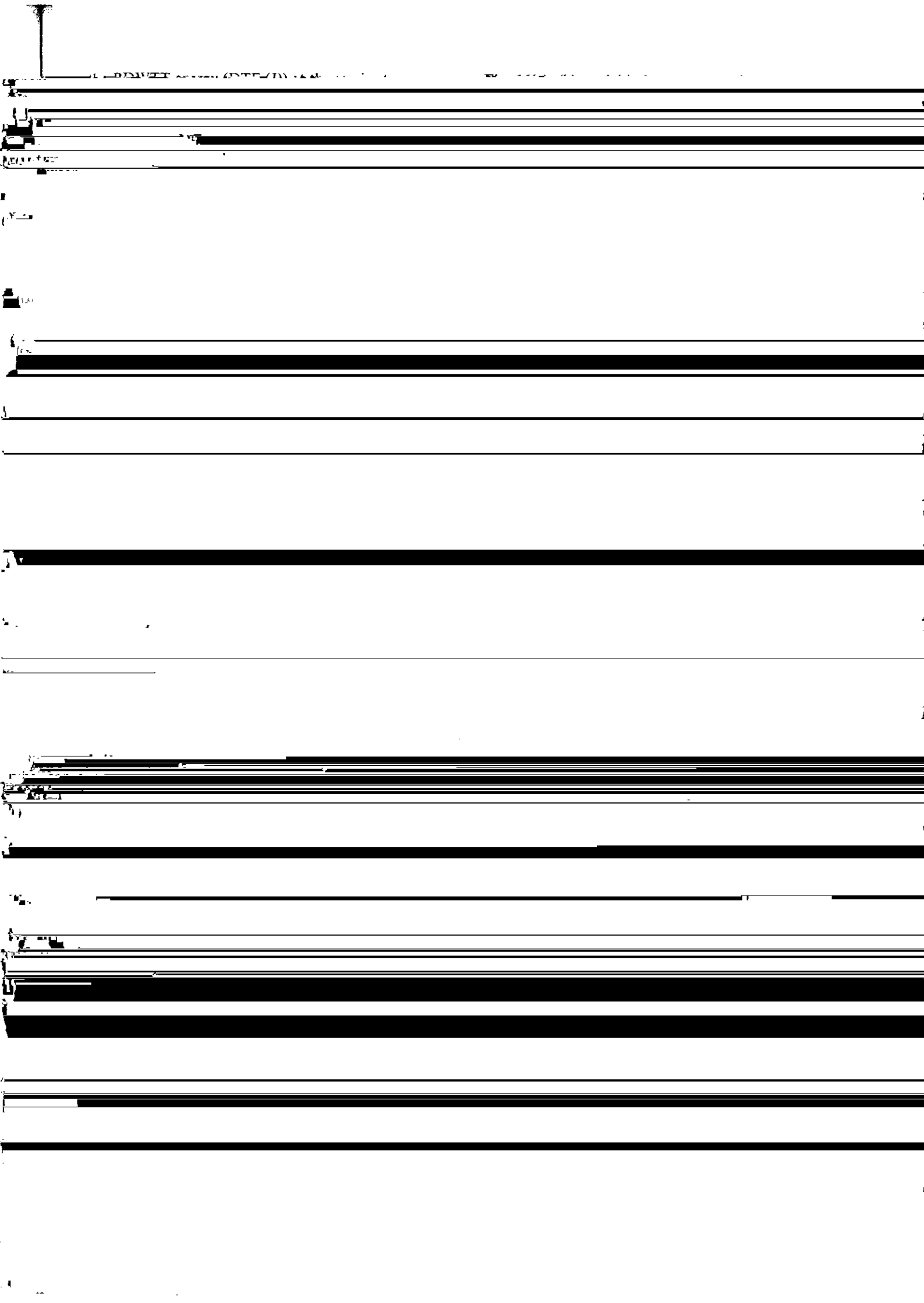
(1) Grade X65 and X70 pipes with high Charpy absorbed energy for service temperature of  $-25^{\circ}\text{C}$  (High Energy Pipe)

Grade		X65		X70	
Type		A		B	
Thickness	Yield strength	Tensile strength	Charpy	Tensile strength	Charpy
6	355	455	100	455	100
8	355	455	100	455	100
10	355	455	100	455	100
12	355	455	100	455	100
14	355	455	100	455	100
16	355	455	100	455	100
18	355	455	100	455	100
20	355	455	100	455	100
22	355	455	100	455	100
24	355	455	100	455	100
26	355	455	100	455	100
28	355	455	100	455	100
30	355	455	100	455	100
32	355	455	100	455	100
34	355	455	100	455	100
36	355	455	100	455	100
38	355	455	100	455	100
40	355	455	100	455	100
42	355	455	100	455	100
44	355	455	100	455	100
46	355	455	100	455	100
48	355	455	100	455	100
50	355	455	100	455	100
52	355	455	100	455	100
54	355	455	100	455	100
56	355	455	100	455	100
58	355	455	100	455	100
60	355	455	100	455	100
62	355	455	100	455	100
64	355	455	100	455	100
66	355	455	100	455	100
68	355	455	100	455	100
70	355	455	100	455	100
72	355	455	100	455	100
74	355	455	100	455	100
76	355	455	100	455	100
78	355	455	100	455	100
80	355	455	100	455	100
82	355	455	100	455	100
84	355	455	100	455	100
86	355	455	100	455	100
88	355	455	100	455	100
90	355	455	100	455	100
92	355	455	100	455	100
94	355	455	100	455	100
96	355	455	100	455	100
98	355	455	100	455	100
100	355	455	100	455	100



softened zones and the fusion line of heat-affected zone gave a CVN 50% shear FATT of  $-80^{\circ}\text{C}$ .

Pipes of (3) are thick-walled with the service tem.



to have sufficient resistance to unstable ductile fracture if CVT and DTE satisfy the required energy. Namely HF pipes are considered to have sufficient

(5) Increases in Ni and Mn contents of CR steel raise tensile strength and simultaneously lower the impact fracture appearance transition temp.

ductile fracture arrestability under normal operation pressure of  $\sigma_H = 0.6$  to  $0.72 \sigma_{SMYS}$ . The EHE pipes have room for ductile fracture arrestability even under  $\sigma_H = 0.72 \sigma_{SMYS}$ , and are considered to be able to play satisfactorily the role of the so-called "crack arrester pipe" even under more severe operating conditions. For instance, compare that economy is given with the

perature. This is attributable to fine-grained bainite that is grown in place of pearlite, besides fine-grained ferrite.

(6) When Nb-bearing steel is controlled-rolled, reheated at a temperature slightly lower than  $A_{r3}$  point and then quenched and tempered (CR + QT), the yield strength and tensile strength are improved.

[The following text is heavily obscured by horizontal black bars and is largely illegible. It appears to be a list of items or a table of contents.]

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4. Discussion

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