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# Production and Properties of Seamless Modified 9Cr-1Mo Steel Boiler Tubes

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Synopsis :

The production of seamless modified 9Cr-1Mo steel tube by the Mannesmann process was studied regarding the hot workability and heat-treatment conditions. The mechanical properties of the base metal and welded joints, and the Charpy absorbed energy and precipitation behavior after long-time aging were also investigated. The hot workability of modified 9Cr-1Mo(T91) steel was found to be inferior to that of low-alloy steel, but the steel tube and pipe can be produced by optimizing the rolling conditions and by reducing the S content. The tensile strength at elevated temperatures and the creep rupture strength of T91 steel pipe were excellent and satisfied ASME specifications. The tensile, impact, and bending properties of mechanized GTAW girth welded joints were sufficiently good. The Charpy absorbed energy of T91 steel pipe decreased after aging at 550-650 , but retained a good enough value, this decrease being most marked at 600 due to the increase in coarse (FeCr)2Mo precipitates

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heat treatment required in the production of T91 steel tube and P91 pipe, as well as various other properties.

## 2 Materials and Experimental Method

### 2.1 Materials

The chemical compositions of the steels produced

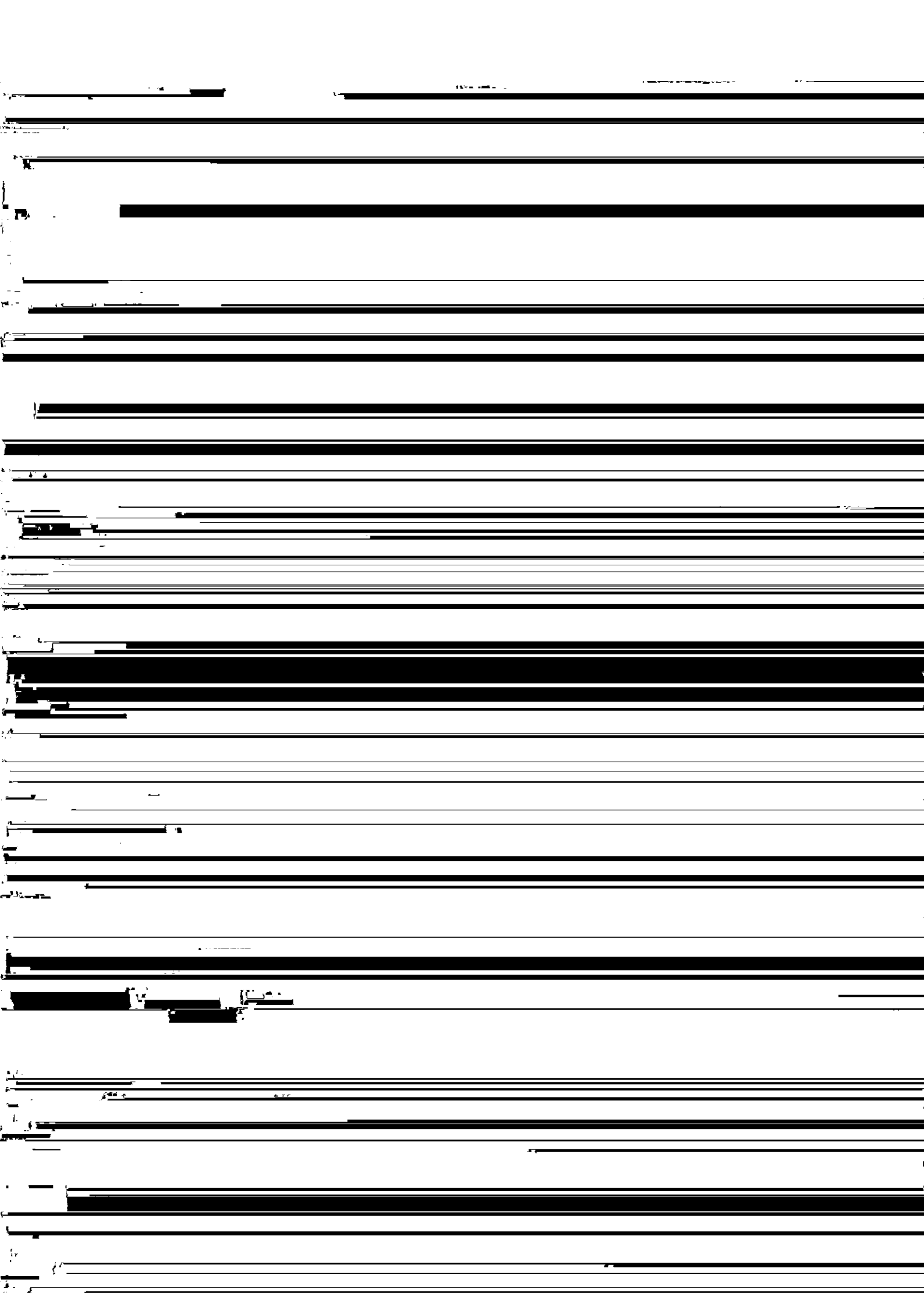
#### 2.2.2 Properties of the cold-finished tube and hot-finished pipe

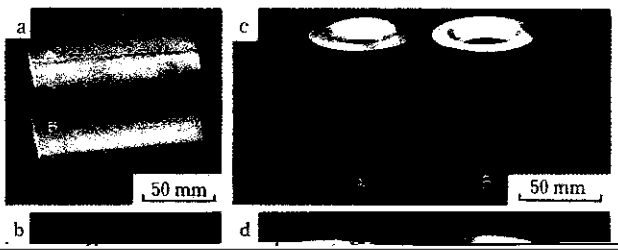
Various tests were performed: cross sectional

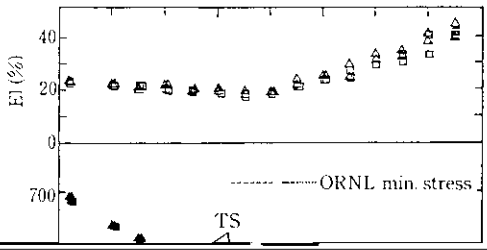
temperature tension and creep rupture tests with round bar of 6-mm diameter and 30-mm GL test pieces taken

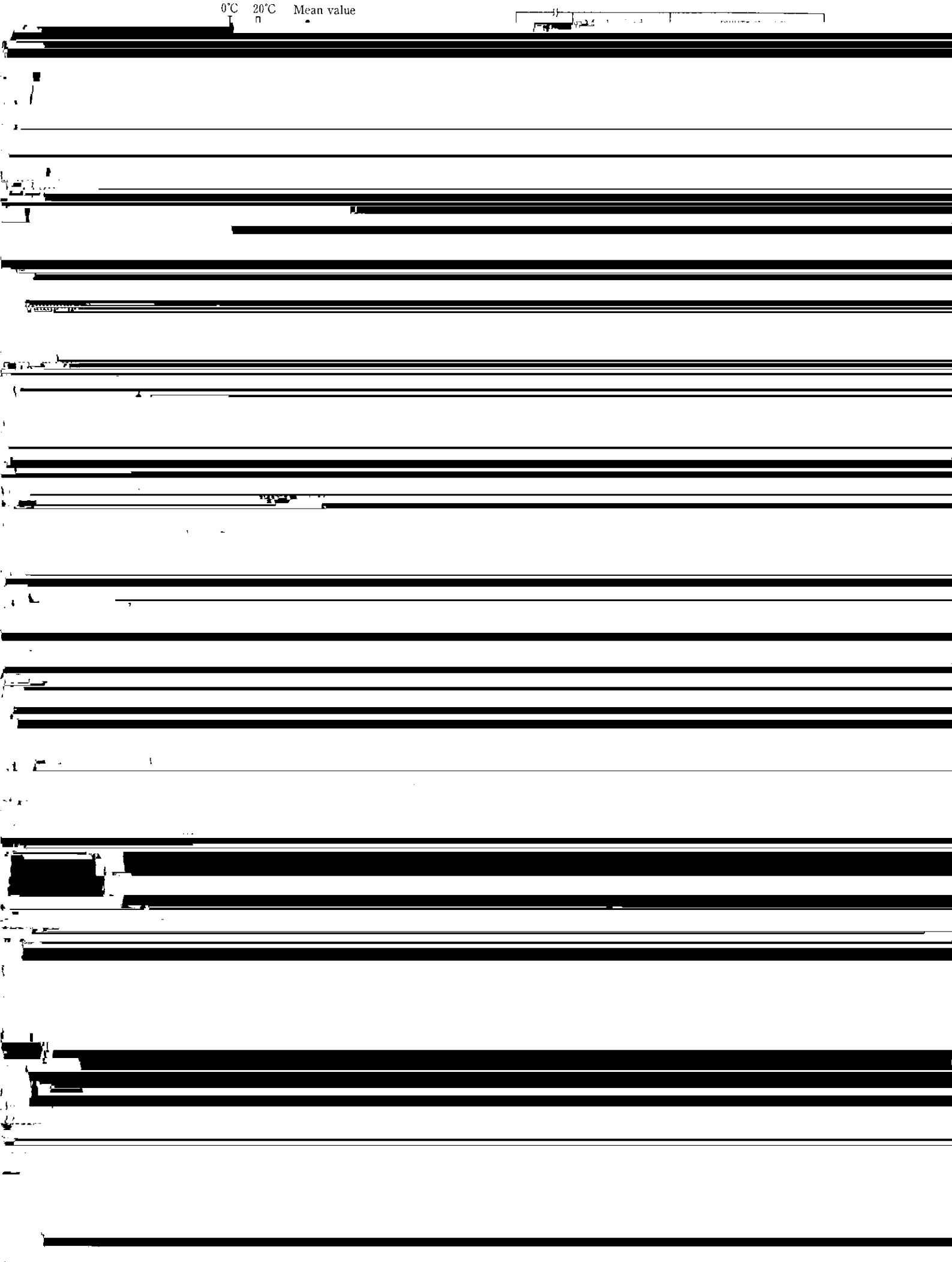
Table 4 Chemical compositions of base metal and welding material for similar and dissimilar joints (mass %)

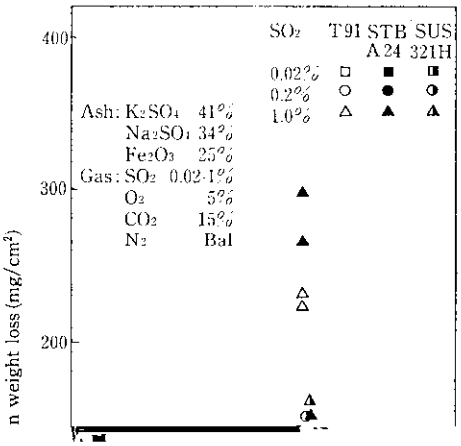
| Tested material | C | Si | Mn | P | S | Cr | Mo | Ni | Nb | V | N (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SA 213 T 91 #1 | 0.10 | 0.30 | 0.39 | 0.008 | 0.002 | 8.46 | 1.01 | 0.10 | 0.078 | 0.195 | 490 |

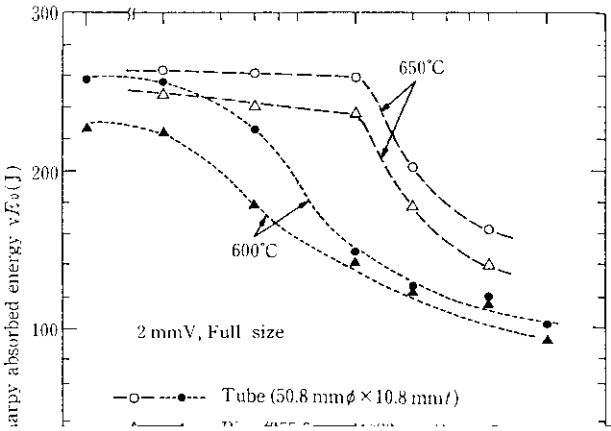


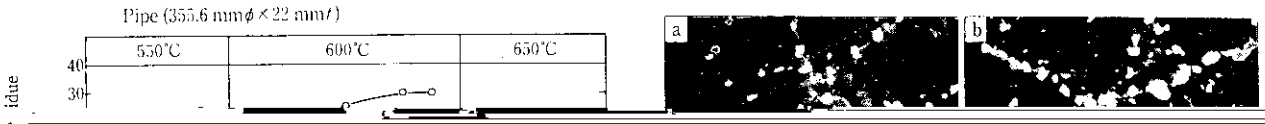

a
b
50 mm
c
d
50 mm


40
20
0
El (%)
700
ORNL min. stress
TS

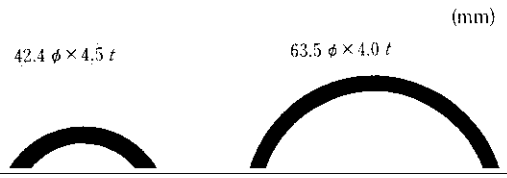

0°C
20°C
Mean value

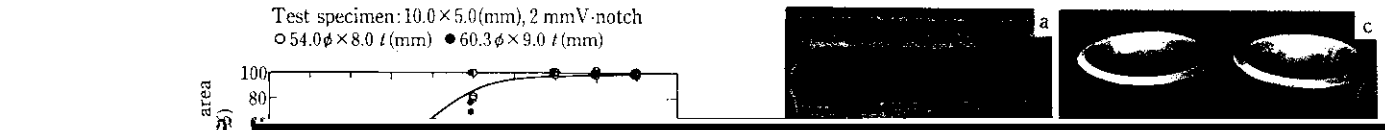

SO₂ T91 STB SUS
A 24 321H
0.02%
0.2%
1.0%
Ash: K₂SO₄ 41%
Na₂SO₄ 34%
Fe₂O₃ 25%
Gas: SO₂ 0.02-1%
O₂ 5%
CO₂ 15%
N₂ Bal
400
300
200
n weight loss (mg/cm²)


300
200
100
650°C
600°C
2 mmV, Full size
Tube (50.8 mmφ × 10.8 mmt)


Pipe (355.6 mmϕ × 22 mmt)
530°C
600°C
650°C
40
30
idue
a
b

tempered martensitic structure and hardness from long-term aging, while the formation and coarsening of the $(FeCr)_2Mo$ intermetallic compound reduced the absobed energy. However, the Charpy energy exceeded about 100J even after $10^4$h, and this figure is high




Test specimen: 10.0×5.0(mm), 2 mmV-notch
○54.0φ×8.0 t(mm) ●60.3φ×9.0 t(mm)
100
80
area
(%)
a
c