CONCLUSIONS

1. After aging at 550° the change in the physical properties of austenitic manganese steel is negligible: The precipitation stage occurs slowly.

2. Precipitation hardening occurs at a high rate at 650°, the largest changes in the physical properties occurring in the first 0.5 h. In samples from heat 3, with the highest carbon concentration, migration of carbon atoms from the matrix practically ceases after aging for 8 h, although growth of the particles continues (the electrical resistivity decreases) and the stresses that occur in the lattice with precipitation of particles decrease (the modulus of elasticity increases). For samples with a lower carbon concentration (heat 2) the rate of aging is lower, i.e., the rate of the change in the physical properties is proportional to the carbon concentration.

3. Aging at 600° for 1-8 h is accompanied by an anomalous increase in the height of the peak damping decrement of internal friction, along with cessation or slowing down of changes in electrical resistivity and modulus of elasticity. The nature of this phenomenon has not been determined and further studies are needed.

LITERATURE CITED


PERMEABILITY, DIFFUSION, AND SOLUBILITY OF HYDROGEN
IN Cr–Ni AND Cr–Mn AUSTENITIC STEELS

A. I. Gromov and Yu. K. Kovneristy

Structural materials intended for preparation of plasma chambers and blankets of thermonuclear reactors of the tokamak type must have high resistance to streams of atomic and ionized hydrogen. This requires low values of the diffusion rate, penetration of deuterium and tritium through the walls into the surrounding atmosphere, minimal sputtering with light ions, and minimal hydrogen blistering. On encountering the first wall only a small portion of the light ions (deuterium, tritium, and also helium) undergo backscattering. Most of them penetrate the wall, the depth of penetration depending on the energy of the particles. The atoms and ions of light gases, striking the material, go into solution; when saturation is reached they precipitate in the form of secondary phases (such as hydrides) or combine in bubbles that induce helium and hydrogen blistering. A study of the kinetic characteristics of the interaction of hydrogen and its isotopes with structural materials is needed for this reason. The satisfactory results of testing Cr–Ni stainless steels of the 18/10 type and alloys with a high nickel content of the Inconel and Incoloy type in fast neutrons and their good technological properties led to the selection of these materials for fittings and parts of experimental reactors of the tokamak type [1].

A. A. Baikov Institute of Metallurgy. Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 5, pp. 11-14, May, 1980.
### TABLE 1

<table>
<thead>
<tr>
<th>Steel</th>
<th>Preliminary treatment</th>
<th>Hydrogen pressure, torr</th>
<th>Permeability coeff. $P$, cm$^2$·cm/cm$^2$·sec·torr $^{-1}$</th>
<th>Diffusion coeff. $D$, cm$^2$/sec</th>
<th>Solubility coeff. $S$, cm$^3$(gas)/cm$^3$(sol. L.) x torr $^{-1}$/torr $^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>04Kh18N10 (304 L)</td>
<td>Chemical polishing</td>
<td>0.1–2</td>
<td>$0.14 \exp(-1.100/RT)$</td>
<td>$3.14 \times 10^{-1} \exp(-12.000/RT)$</td>
<td>$45 \exp(-1.100/RT)$</td>
</tr>
<tr>
<td>04Kh18N15M3 (316 L)</td>
<td>Chemical polishing</td>
<td>0.1–2</td>
<td>$0.14 \exp(-1.100/RT)$</td>
<td>$3.14 \times 10^{-1} \exp(-12.000/RT)$</td>
<td>$45 \exp(-1.100/RT)$</td>
</tr>
<tr>
<td>08Kh16Ni4M3</td>
<td>Oxidation on intake side</td>
<td>0.1–2</td>
<td>$0.14 \exp(-1.100/RT)$</td>
<td>$3.14 \times 10^{-1} \exp(-12.000/RT)$</td>
<td>$45 \exp(-1.100/RT)$</td>
</tr>
<tr>
<td>04Kh12G18AN2M</td>
<td>Chemical polishing</td>
<td>4.10–2</td>
<td>$0.14 \exp(-1.100/RT)$</td>
<td>$3.14 \times 10^{-1} \exp(-12.000/RT)$</td>
<td>$45 \exp(-1.100/RT)$</td>
</tr>
<tr>
<td>10Kh12G14N4MYu</td>
<td>Oxidation on intake side</td>
<td>0.1–2</td>
<td>$0.14 \exp(-1.100/RT)$</td>
<td>$3.14 \times 10^{-1} \exp(-12.000/RT)$</td>
<td>$45 \exp(-1.100/RT)$</td>
</tr>
<tr>
<td>04Kh16G16AMBD</td>
<td>Oxidation on intake side</td>
<td>0.1–2</td>
<td>$0.14 \exp(-1.100/RT)$</td>
<td>$3.14 \times 10^{-1} \exp(-12.000/RT)$</td>
<td>$45 \exp(-1.100/RT)$</td>
</tr>
</tbody>
</table>

Fig. 1. Schematic diagram of the apparatus for investigation of the interaction of hydrogen with metals. 1) Sample in the form of a disk; 2) RMO-4S omegatron sensor; 3) PMI-12 and PMI-2 ionization manometers; 4) measuring diaphragm; 5) PMT-6-3 resistance manometer; 6) NORD-100 magnetic discharge diode pump; 7) unit for purification of hydrogen; 8) NORD-250 magnetic discharge diode pump; 9) 2NVR-5D forevacuum pump; 10) N-IS-2 vapor-oil diffusion pump.

Fig. 2. Effect of temperature on the kinetic coefficients of the interaction of hydrogen with Cr–Ni and Cr–Mn austenitic steels. 1) 04Kh18N10 (304 L); 2) 04Kh18N15M3 (316 L); 3) 08Kh16Ni4M3; 4) 04Kh12G18AN2M; 5) 10Kh12G14N4MYu; 6) 04Kh16G16AMBD. 1, 2, 4, 5) Chemical polishing; 3, 6) oxidation.

Analyses of the swelling of steels and nickel alloys bombarded with chromium and nickel ions indicate that swelling is greatest for steels with 12–18% Ni and least for nickel-free chromium steels and alloys containing >35% Ni. Alloying of stainless steels with molybdenum, niobium, titanium, carbon, and nitrogen decreases swelling [1].

By means of a mathematically planned experiment, the six chain reactions for components of stainless austenitic steel 316SS and the radioactive isotopes formed were calculated [2]. It was found that after 20 years of operation the radiation resulting from the transformation of nickel alone becomes substantial and the nickel content of the steel (14%) should be reduced. For this reason, we selected three Cr–Ni austenitic steels of the 04Kh18N10 (304 L), 04Kh18N15M3 (316 L), and 08Kh16Ni4M3 [11] type, two Cr–Mn austenitic steels with a low nickel content of the 04Kh12G18AN2M and 10Kh12G14N4MYu type, and one steel not containing nickel —