LANSCE target calculations

D. L. Grisham and R. D. Brown
Los Alamos National Laboratory
Los Alamos, New Mexico 87545
USA

The LANSCE target presently operates at a beam current of 30 μA. We present here the results of the finite-element calculations for the temperatures and stresses in the present target operated at 100 μA. The calculations were run using the ABAQUS finite-element code. All finite-element codes require as input both the boundary conditions for the material being heated and such material properties as the thermal conductivity, specific heat, and the elastic modulus. For the LANSCE target, the boundary conditions involve knowing the power deposition from the beam, and the heat-transfer coefficients between the tungsten-alloy cylinder and the cooling water. We believe that these numbers are quite well established.

The target material is a powder metallurgy alloy of tungsten, iron, and nickel (96.2% W, 3.8% Fe and Ni). Although the properties of pure tungsten are well known, the properties of this particular alloy have not been found in the literature. Figures 1, 2, and 3 show the available literature information on pure tungsten and a few tungsten alloys.

Calculations were run for both the steady-state and transient conditions. The former allowed us to determine the equilibrium temperature and stresses; the latter allowed us to decide whether thermal shock might be a problem. In the steady-state case, the power deposition, thermal conductivity, and the cooling rate determine the temperature. The maximum heat-up rate for the transient case is determined by the power deposition and the specific heat.

The heat-up rate in the transient calculation is far below the rate required to produce thermal shock. The thermal expansion, which is dependent on temperature and the expansion coefficient, determines the stress in the target. The calculations were done using the material properties identified in Figures 1-3 as "LANSCE CALC", and the beam parameters were 12 pulses per second with a total heat deposition of 25.78 kW in a pattern furnished by Gary Russell of LANSCE. Figure 4 shows the equilibrium temperature of 860 K calculated in the pulsing mode at the hottest point.

Figure 5 is the temperature distribution of the entire target in the steady-state condition. Figure 6 shows the steady-state stress distribution, which should be compared with the yield stress of 690 MPa. Since the highest stress value, 730 MPa, is above the yield strength but below the ultimate strength of 980 MPa, some local yielding would occur. Both strength values were furnished by the vendor. These conditions would not result in a catastrophic failure, but would probably cause some local surface cracking.

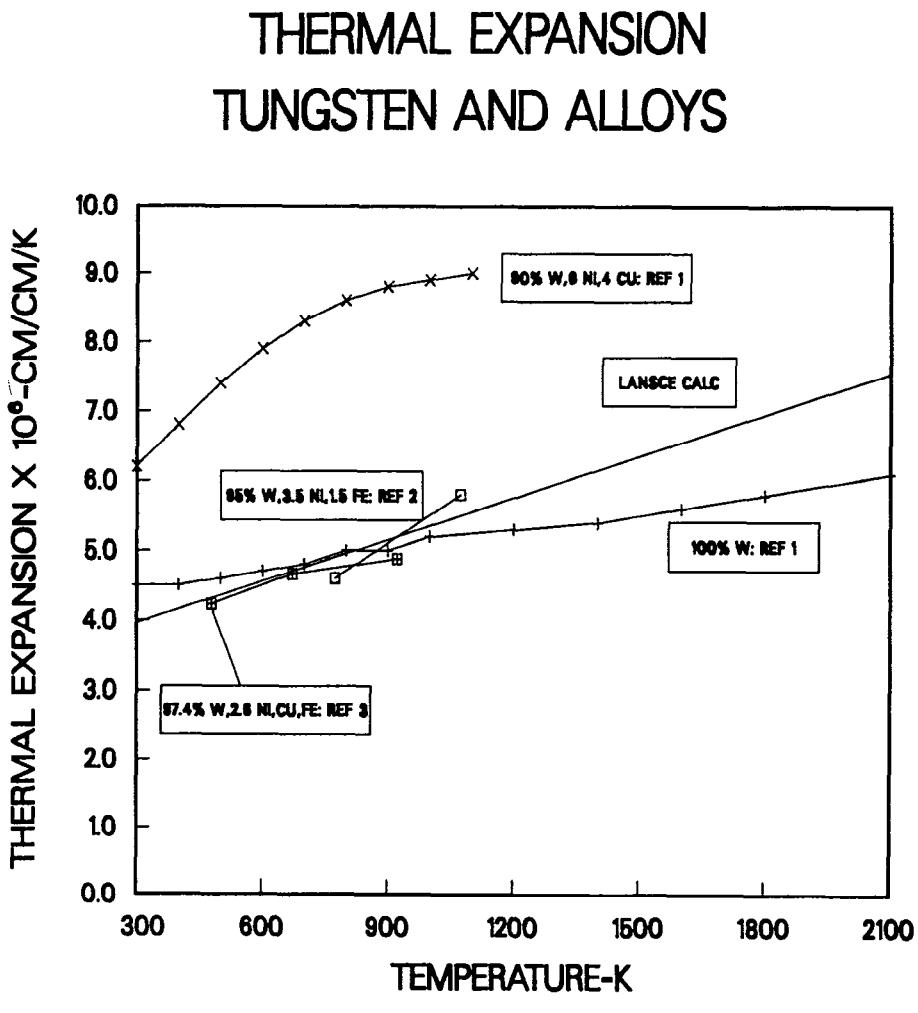

Fig. 1 Thermal expansion coefficients versus temperature for tungsten and three alloys.

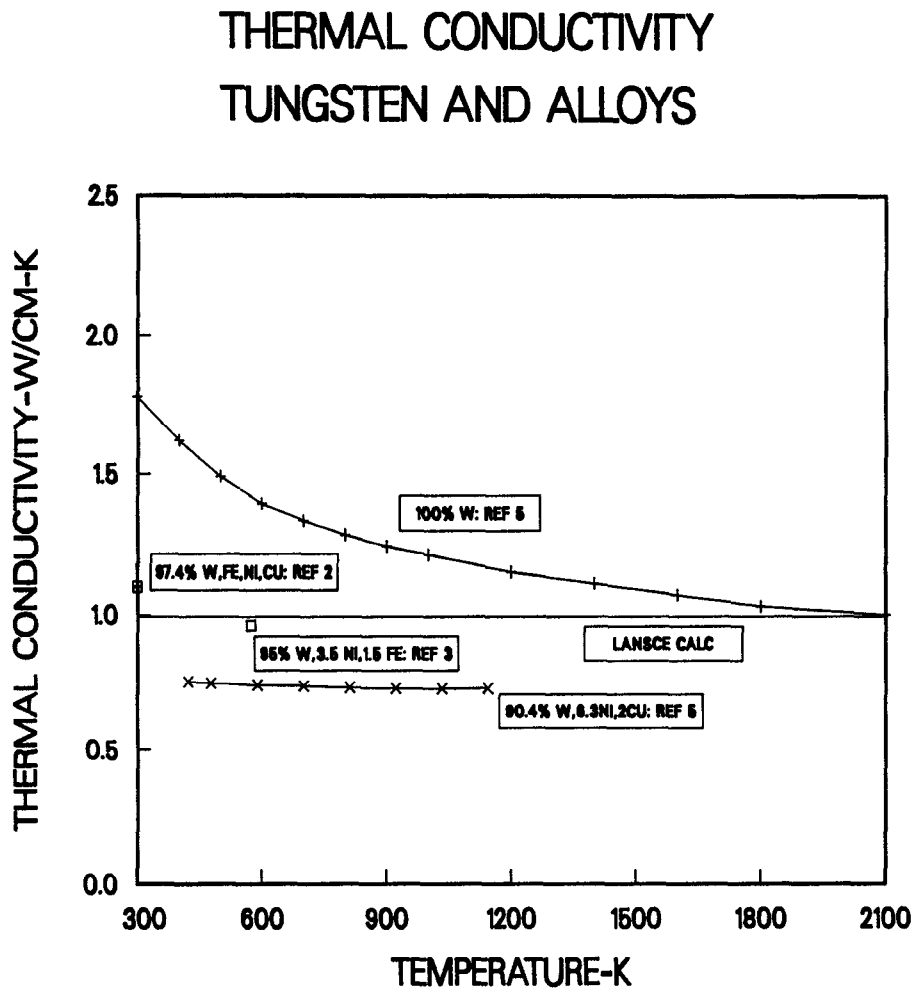

Fig. 2 The thermal conductivity for tungsten and three alloys.

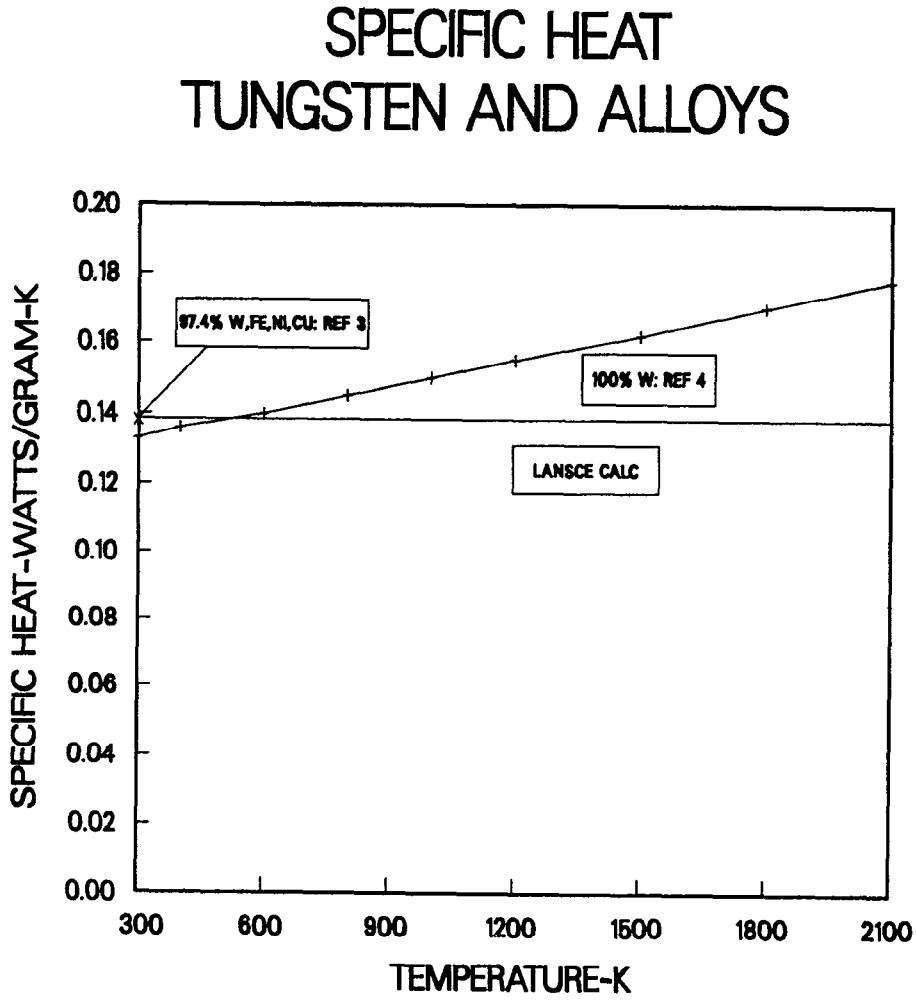

Fig. 3 The specific heat for tungsten and a single alloy.

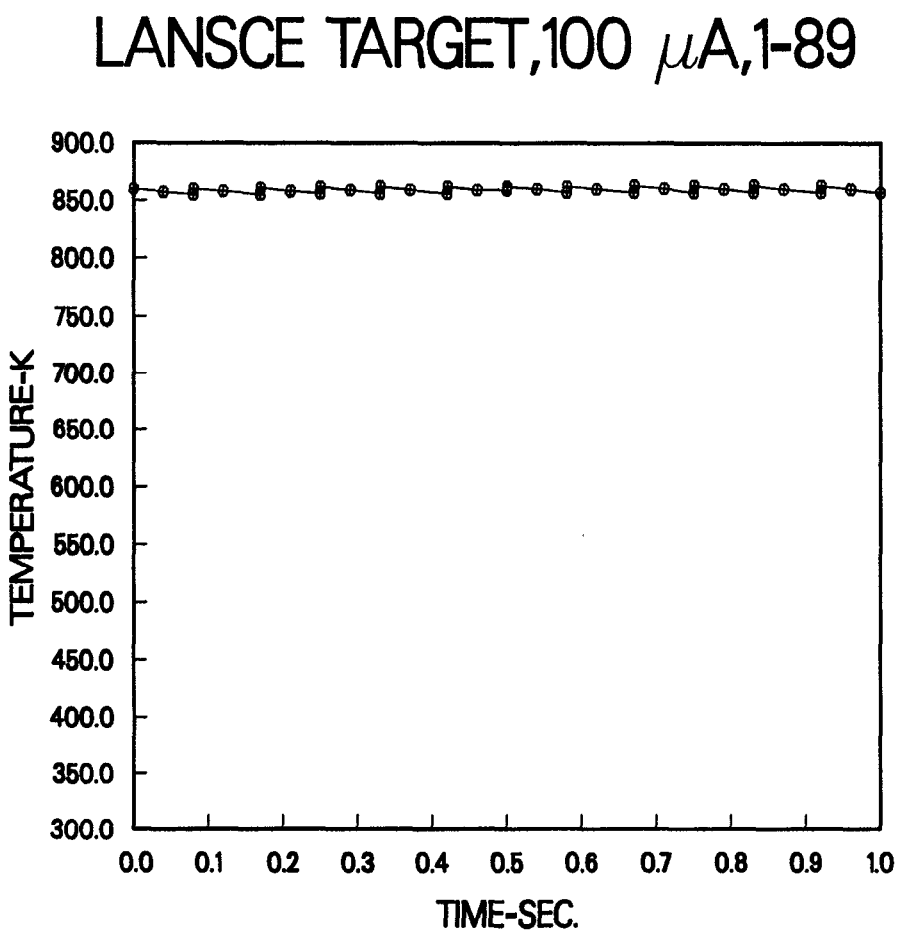

Fig. 4 The maximum target temperature near equilibrium for the transient (pulsed) calculation.

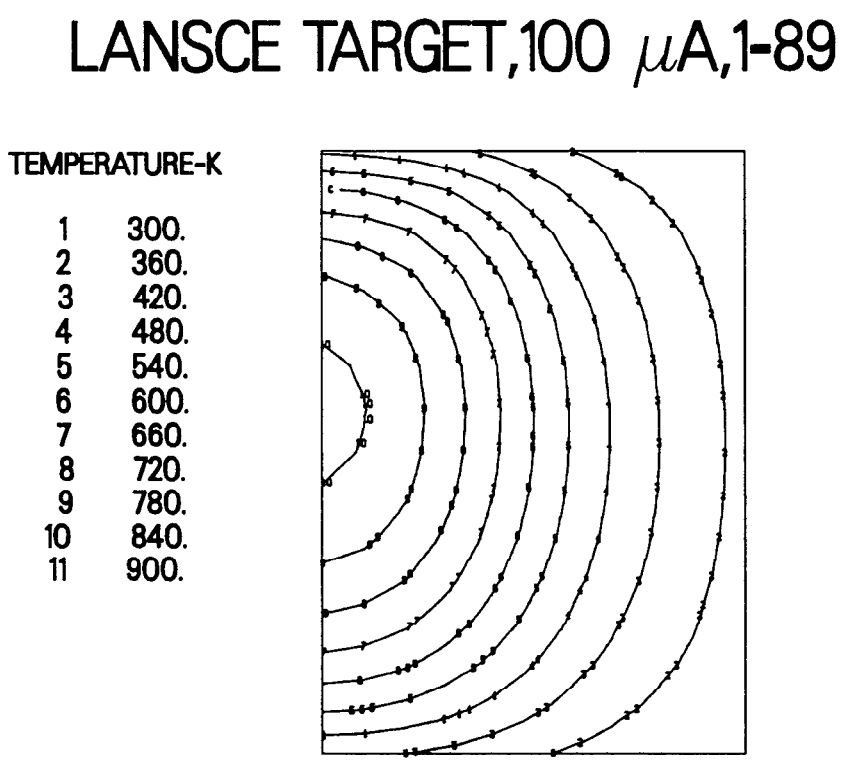

Fig. 5 The steady-state temperature distribution for the entire target.

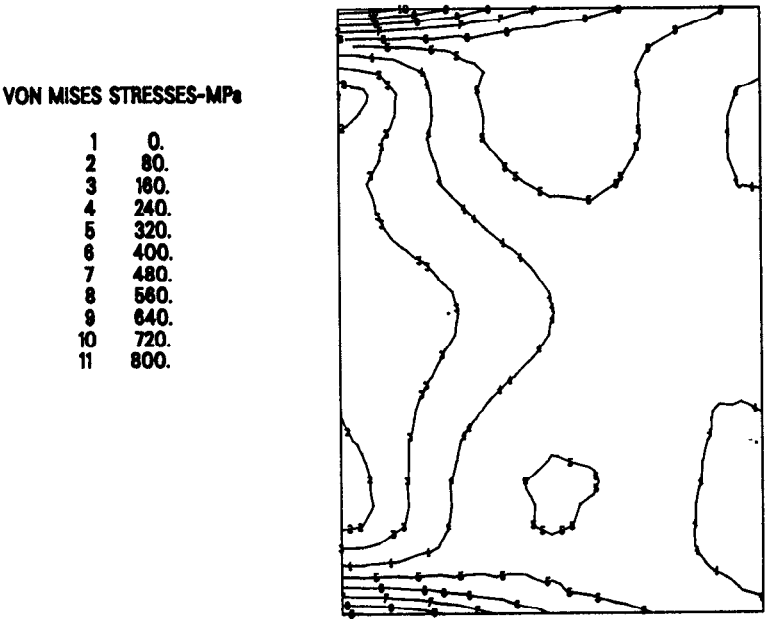

Fig. 6 The steady-state distribution for the entire target. The cylinder axis is the left vertical side, with the beam centered on this axis. The maximum stresses occur at the cooled end faces.

These calculations are done with both physical and thermal properties that have not been determined for the particular alloy being used. LANSCE is now preparing to have the real properties measured, at which point the calculations will be redone using the measured properties. Only at that point can the effect of the 100-μA beam current on the existing LANSCE target be properly determined.

References

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