1986

Enhancement of mechanical behavior of metals by laser coating /

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ENHANCEMENT OF MECHANICAL BEHAVIOR OF METALS
BY LASER COATING

by

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A Thesis
Presented to the Graduate Committee
of Lehigh University
in Candidacy for the Degree of
Master of Science
in
Applied Mechanics

Lehigh University
1986

This thesis is accepted and approved in partial fulfillment of the requirements for the degree of Master of Science.

January 8, 1986
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ACKNOWLEDGMENTS

I wish to express my deep gratitude and appreciation to Professor George C. Sih for his guidance and patience during the course of introducing this important subject of laser heating to the author. This work would not have been made possible without his constant encouragement and instruction.

Special thanks are due to Ching-Kong Chao for the reference work associated with analysis of the static and fatigue strength of coated cylinders. The valuable discussions with David H. Chu, Ching-Hwei Chue and Yi-Der Lee on computer programming are also acknowledged.

The friendliness of Mrs. Barbara DeLazaro and Mrs. Connie Weaver will always be remembered for the years to come. Acknowledged also is the typing of this manuscript that was done by Mrs. DeLazaro.

The support and understanding provided by my father, wife and daughter are most deeply felt when the author was away from home.

TABLE OF CONTENTS

TABLE OF CONTENTS - (CONTINUED)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES - (CONTINUED)

LIST OF FIGURES - (CONTINUED)

ABSTRACT

The objective of this work is to investigate the laser spray process by adding a coat of new material to existing specimens. This laser heating process is analyzed in terms of the radiant energy required to melt and/or vaporize solid particles of certain size. Computed are the temperatures at which phase transformation of the materials take place. The thickness of the coating is controlled by the laser power density, the time of exposure and the pressure exerted by the melted particles on the substrate which depend on the momentum transfer. Although no elaborate theoretical model is presently available for a detailed account of the laser spray process, the preliminary results are encouraging in that enhancement of the mechanical strength of solids is anticipated via surface coating.

The two systems analyzed are aluminum and steel cylinders both coated by a thin layer of titanium material with a higher yield strength. The static and fatigue strength of the cylinders are increased significantly. The thickness of coating is approximately ten percent of the cylinder radius. Further increase in coating thickness has little or no influence on the mechanical behavior.

Experiments are suggested for measuring some of the unknown parameters involved in the laser spray coating process. The thermal-mechanical interaction effects need to be analyzed both qualitatively and quantitatively before the laser coating process can be put into practice.

I. INTRODUCTION

Application of laser technology in material processing, drilling and cutting has gained increased interest to engineers and scientists in both the industrial and military sector. Energy transfer via laser radiation differs from other types in that it can be concentrated in a very narrow beam. This provides many unique properties such as high intensity of electromagnetic energy flux, high monochromaticity and high spatial and temporal coherence. Laser radiation covers a wide range of wave length from the ultraviolet to the far infrared region, i.e., approximately 0.1 to 70 μm and this range is still expanding. The power output can be of the continuous wave type or pulsating in character. These characteristics are not only of interest in application but also in fundamental research where new ideas are being continuously discovered.

Laser machining, drilling and cutting are being widely used in industry [1,2] where precision is essential. Since no comprehensive theory of laser effects has been developed, most of the applications rely on tests. High laser radiation power densities can melt and evaporate materials. Ejection of solid particles is usually observed at the very stage of exposure by laser radiation. This process can be used to change the structure, composition and properties of materials. Thermal hardening of metals can be achieved as a result of increase in the density of the structural defects such as dislocations, vacancies and their aggregates produced under radiation heating and cooling. With decreasing power density, solid particles can be melted and fused onto the surface of materials with controlled accuracy. This new layer of material can significantly alter the mechanical behavior of the solid.

The present investigation is concerned with coating materials by laser spray. An elementary theoretical basis is developed for estimating the energy density in a laser beam to propel a stream of fine solid particles onto a specimen or substrate. The rapid solidification and cooling achieved by laser fusion is beneficial because the process minimizes thermal degradation of the substrate. Hence, the resulting product can be assumed to consist of a new layer of material with different mechanical properties melted or bonded on the original specimen. Analyses are also performed to illustrate the additional static and fatigue strength gained by laser coating of cylindrical bars. Use is made of the strain energy density theory [3,4]. Particular attention is given to those parameters that control high energy laser radiation process. Overheating or the improper combination of the controlling parameters may inflict damage to the specimen instead of enhancing the material property. Obtained are the range of the controlling parameters that could be used in laser surface coating. This information is pertinent to future experimentation in establishing the methodology for industrial applications.

II. PRELIMINARIES ON LASER RADIATION

As mentioned earlier, lasers are highly monochromatic because their spectral lines are so narrow that they may be described by a single frequency and wave length. At a more refined level, the atoms, ions and/or molecules in a laser may be viewed as a quantum mechanical system that possesses discrete energy levels. Once the energy parameters, namely, the absorbed part of the incident radiation flux, the flux energy density, etc., are known, laser radiation results in heating of the object can be analyzed. Such effects can then be treated by conventional theories of heat transfer.

A. Discrete Consideration

A simple model [5] may consist of two energy levels (of ions or molecules) with E_n and E_m being respectively, the upper and lower limit. Electromagnetic radiation may be absorbed or emitted by the atoms at a characteristic frequency ν_{nm} satisfying the relation

$$\nu_{nm} = \frac{E_n - E_m}{h} \qquad (1)$$

where $h = 6.626 \times 10^{-34} J \cdot sec$ is the Planck constant.

The rate of induced emission is proportional to the energy density in units of W/m^3 of the induced field ρ with frequency ν_{nm} and the number of atoms or population of the excited state N_n. The total power induced by this process is

$$P_1 = h\nu_{nm} N_n B_{nm} \rho(\nu_{nm}) \tag{2}$$

in which $B_{mn} = B_{nm}$ is a proportionality constant. It represents the strength of the upward transition.

The total power radiated spontaneously by the collection of atoms is given by

$$P_2 = h\nu_{nm} N_n A_{nm} \tag{3}$$

where A_{nm} is also a proportionality constant. Both A_{nm} and B_{nm} are known, respectively, as the Einstein coefficients of spontaneous and induced emission. The relation between them takes the form

$$A_{nm} = \frac{8\pi h\nu_{nm}^3}{C^3} B_{nm} \tag{4}$$

where $C = 2.9979 \times 10^8$ m/sec is the velocity of light.

The power absorbed from the electromagnetic field is

$$P_3 = h\nu_{nm} B_{mn} N_m \rho(\nu_{nm}) \tag{5}$$

It is seen from equations (2) and (5) that

$$\frac{P_3}{P_1} = \frac{N_m}{N_n} \tag{6}$$

That is, the ratio of power absorbed to the power radiated through induced emission is equal to the ratio of the population of the lower state to that of the upper state.

Under thermal equilibrium, the populations of the two energy levels are related by the Boltzmann distribution:

$$\frac{N_n}{N_m} = \exp\left(- \frac{E_n - E_m}{kT}\right) \tag{7}$$

Here, k is the Boltzmann constant equal to 1.3806×10^{-23} J/°K and T is the absolute temperature in °K.

B. Laser Heating Effects

Conventional heat transfer theories [6], linear or nonlinear, may be used for analyzing heating and/or cooling of material by laser radiation provided that the pulse duration is not too small.

A complete understanding of thermal effects caused by laser radiation on material will require a knowledge of

(1) the space and time characteristics of the heat source generated by absorption of laser radiation;

(2) the solution of boundary-value problem associated with the temperature field variation on the surface and in the bulk of the material; and

(3) the development of experiments that can verify the analytical predictions.

Because of the complexity of laser heating, simplifying assumptions are necessary in order to reduce the problem to manageable proportions. Heat transfer by radiation, convection, absorption, etc., will be considered and analyzed even though a precise knowledge of many of the physical parameters is not known at present. Since the primary interest of this work is to determine the enhancement of macroscopic material strength by laser spraying, attention will be focused on the addition of a thin layer of new material onto an existing specimen. Therefore, it suffices to consider the laser energy required to propel solid particles through a prescribed distance at a given time and to form a fused layer of thin material.

III. THEORETICAL BACKGROUND: LASER SURFACE COATING

A stream of fine metallic powder can attain high velocity when injected into a beam of high energy laser*. The powder temperature is raised up to and above the melting point such that it solidifies rapidly when impinging on the substrate. This creates a hard layer of new surface material with increased homogeneity in chemical composition and microstructure. Resistance to mechanical wear and/or corrosion can thus be improved.

A. Laser Optics

In order to provide sufficient energy for driving the solid particles and for melting the solids, the laser beam must possess sufficiently high energy level. A CO_2 laser [8] can generate pulsed power up to 30% in efficiency at a wavelength of 10.6 μm being in the far infrared region of the light spectrum. The laser beam, in addition to being coherent, must be focused so that sufficient energy can be concentrated in the heat affected zone.

Referred to in Figure 1 is the so-called "Gaussian beam" [9] characterized by the parameters a(x) and b(x) which are, respectively, the beam and phase front radius defined as

$$a(x) = a_0^2 \left[1 + \left(\frac{\lambda x}{\pi a_0}\right)^2\right] \quad (8)$$

*Additional input energy can also be attained by means of radiation [7].

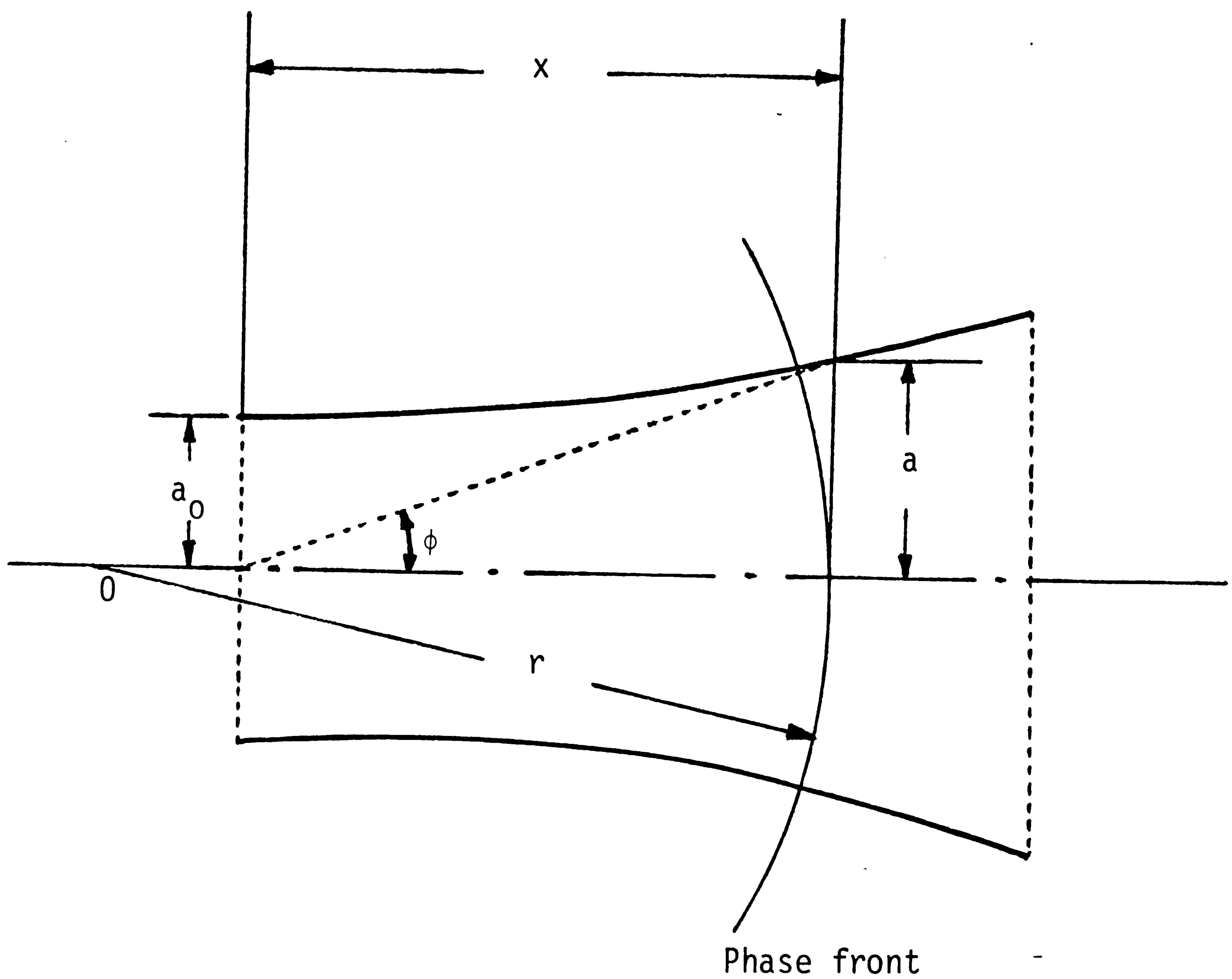

Figure 1. Schematic of Gaussian beam.

and

$$b(x) = x\left[1 + \left(\frac{\pi a_o}{\lambda x}\right)^2\right] \tag{9}$$

with x being the axial distance as shown in Figure 1 and λ is the radiation wavelength. It can be seen from equation (8) that a far field divergence angle ϕ can be defined for large x, i.e.,

$$\phi = \lim_{x\to\infty} \frac{da}{dx} = \frac{\lambda}{\pi a_o} \tag{10}$$

When a Gaussian beam is interrupted by a lens (Figure 2), the transverse field distribution is unchanged while a new beam waist is formed downstream. This alters the parameters in equations (8) and (9) as follows:

$$\frac{1}{a_2^2} = \frac{1}{a_1^2}\left(1 - \frac{d_1}{f}\right)^2 + \frac{1}{f^2}\left(\frac{\pi a_1}{\lambda}\right)^2 \tag{11}$$

and

$$d_2 - f = \frac{(d_1-f)f^2}{(d_1-f)^2+(\pi a_1^2/\lambda)^2} \tag{12}$$

with f being the focal distance.

If the far field divergence angle ϕ is small, the untransformed waist radius a_1 can be used in equation (10). Moreover, the term $[1 - (d_1/f)^2]/a_1^2$ in equation (11) becomes insignificant and a_2 can be

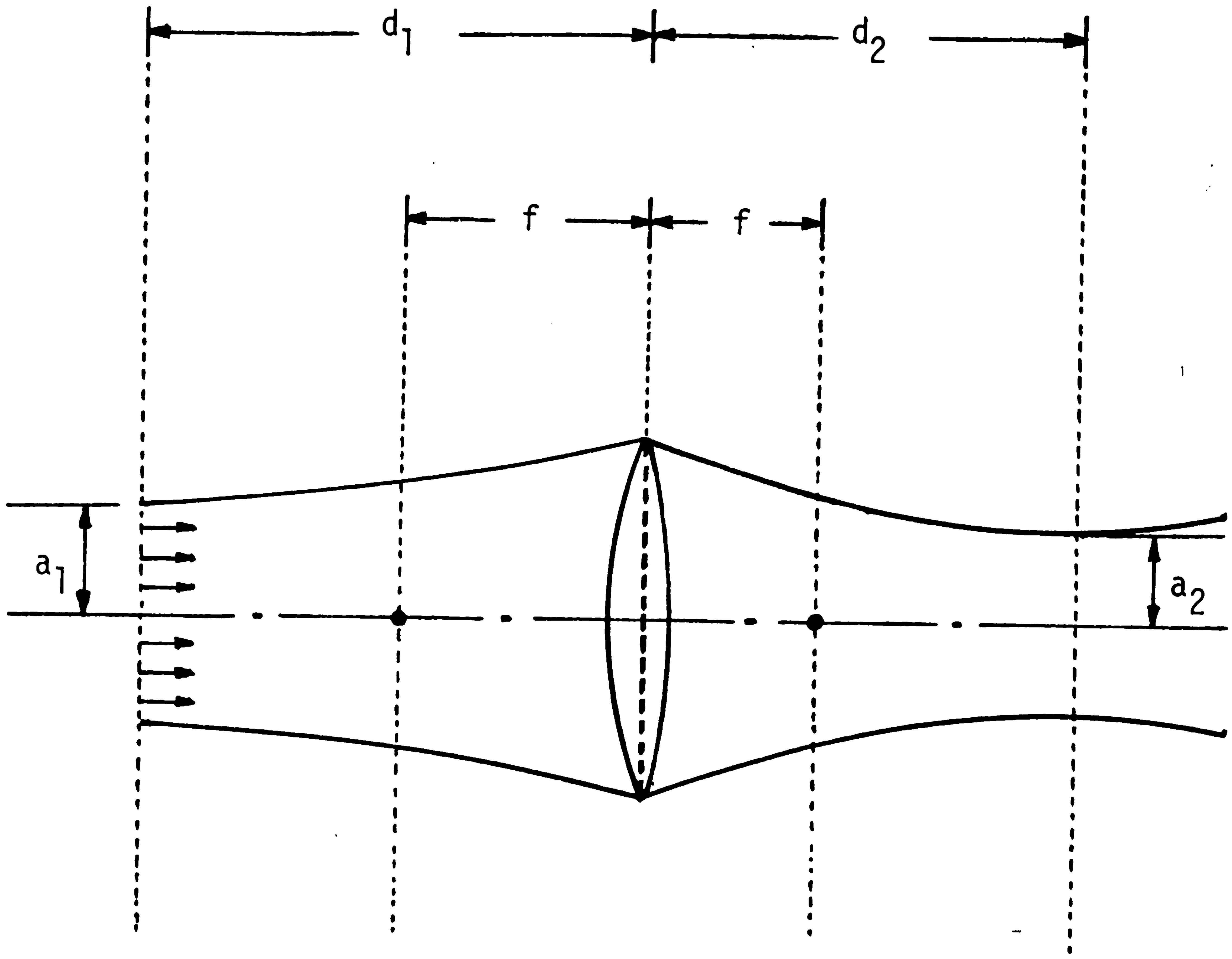

Figure 2. A Gaussian beam interrupted by lens.

approximated by

$$a_2 = f\phi = f \frac{\lambda}{\pi a_1} \tag{13}$$

The peak power density or peak intensity I_0 of the focused spot can be related to the total power P_0 as

$$P_0 = 2\pi \int_0^\infty I(r)rdr \tag{14}$$

in which

$$I(r) = I_0 \exp(-\frac{2r^2}{a_2^2}) \tag{15}$$

Substituting equation (15) into (14), it can be shown that

$$I_0 = \frac{2P_0}{\pi a_2^2} \tag{16}$$

Because of the high power density required, the focused spot is generally small in size and is difficult to measure. An indirect means of its determination can be made by defining a resultant heat affected zone whose size depends on the laser power and thermal properties of the material. Metallurgical cross-sectioning is carried out for finding the heat affected zone.

B. Energy Balance

Electrons can be raised to higher energy states when exposed to laser pulse. Heat is thus generated owing to collision of the excited electrons. The mean free collision time is typically of the order of 10^{-12} to 10^{-14} of a second. In addition to heat generation, high energy laser beams can also impart sufficient momentum to drive high density particles. Local energy balance can be applied to analyze the thermal behavior of hot particles moving rapidly in the laser beam. Classical heat transfer treatment is assumed to hold by assuming that properties such as absorptivity, emissivity, thermal conductivity, specific heat, etc., remain virtually constant during heating. These simplifying assumptions are made mainly because of the extreme lack of information on their variations with operational conditions.

For an isolated system, the change in internal energy dE is balanced by the change in heat dQ and external work dW, i.e.,

$$dQ = dE + dW \tag{17}$$

If work is done by volume change via uniform pressure P, then the change in enthalpy dH can be written as

$$dH = dE + PdV \tag{18}$$

in which $VdP = 0$. In this case, $dH = dQ$. The quantity dQ is related to dT via the heat capacity coefficient C by the relation

$$dQ = CdT \tag{19}$$

At constant pressure, C is denoted by C_p such that

$$C_p = \left(\frac{dQ}{dT}\right)_p = \left(\frac{\partial H}{\partial T}\right)_p \tag{20}$$

For particles with density ρ at temperature T, the amount of heat transfer is

$$dQ = \rho V C_p dT \tag{21}$$

The latent heat of fusion L_f (J/kg) can thus be computed by application of equation (21). This corresponds to the temperature at which the particles reach their melting point:

$$Q_f = \rho V L_f \tag{22}$$

Similarly, the latent heat of evaporation L_v can be related to Q_v as

$$Q_v = \rho V L_v \tag{23}$$

C. Melting and Vaporization Temperature

A knowledge of the temperature of the powder at which melting and/or vaporization occur is necessary before the laser spray process can be successfully applied in practice. For incident beam power densities less than $J = 10^2$ kw/cm^2, plasma effects can be neglected. The three main energy transfer mechanisms need to be considered are absorption, radiation and convection which will be denoted respectively by E_1, E_2 and E_3.

The absorbed energy rate is directly proportional to the power density of the incident beam. It can be expressed as

$$E_1 = 4\pi R^2 \eta \alpha J \tag{24}$$

Here, J has the units of W/m^2. In equation (24), α is the particle absorptivity, η the particle absorption area factor and R the particle radius in m.

The influence of radiation is governed by the 4th power temperature law of Stefan such that

$$E_2 = 4\pi R^2 \varepsilon \sigma T^4 \tag{25}$$

with ε being the emissivity coefficient that can vary with temperature and

$$\sigma = 5.668 \times 10^{-8}\ w/m^2 {}^\circ K^4 \tag{26}$$

is the Stefan-Boltzmann constant. The temperature of the particles is in degree Kelvin.

The energy loss due to convection is given by

$$E_3 = 4\pi R^2 h \tag{27}$$

in which the convective heat transfer coefficient is

$$h = \frac{k}{R}(T - T_0) \tag{28}$$

The reference temperature is T_0 and k is the thermal conductivity of the medium.

Making use of the above results, the temperature change ΔT in a small time increment can be found:

$$\Delta T = \frac{\Delta t}{\rho V C_p}(E_1 - E_2 - E_3) \tag{29}$$

In view of equations (22) and (23), the total time for the particles to melt can be obtained by adding all the time increments Δt. This gives

$$t_m = \frac{\sum_{0}^{t_m} (E_1 - E_2 - E_3)}{Q_f} \tag{30}$$

A similar equation applies to evaporation of the particles, i.e.,

$$t_v = \frac{\sum_{o}^{t_v} (E_1 - E_2 - E_3)}{Q_v} \qquad (31)$$

This completes the basic thermal treatment of the laser heating process. Numerical calculations will be given for alumina, titanium and tungsten particles.

IV. RESULTS ON POWDER MELTING AND VAPORIZATION

In what follows, equation (29) will be evaluated numerically for three different solid particles, namely $A\ell_2O_3$ (aluminum oxide), T_i (titanium) and W (tungsten). These particles are engulfed in a CO_2 laser flux with a wavelength of λ = 10.6 μm. Power densities are also taken as J = 2, 4, 6, 8 and 10 kw/cm^2. Three different particle radii R are considered. They are R = 40, 80 and 120 μm. The emissivity ε, specific heat C and thermal conductivity k are all assumed to be temperature dependent whose values can be found in Table 1. Since the amount of energy absorbed in equation (24) depends on the effective area of exposure, η is assumed to take values of 0.25, 0.50 and 1.00.

Referring to the computer program in Appendix A, temperature change ΔT corresponding to time increment Δt of laser irradiation are computed. This yields the time t_m and t_v for the particles to reach melting and vaporization, respectively. In the case of titanium, transformation from α-phase to β-phase will take place at time t_p prior to melting, i.e., $t_p < t_m$.

A. Aluminum Oxide ($A\ell_2O_3$)

Plotted in Figures 3 to 5 inclusive are the temperature-time history of $A\ell_2O_3$ particles heated by CO_2 laser irradiation with power densities J ranging from 2 to 10 kw/cm^2. Obviously, the time for $A\ell_2O_3$ to reach melting will be the smallest as J is increased with the

Table 1. Material and geometric parameters for alumina, titanium and tungsten particles

Parameters	Materials: $A\ell_2O_3$	Materials: T_i	Materials: W
Particle Radius (μm)	40 80 120	40 80 120	40 80 120
Density: ρ (kg/m^3)	3,965	4,500	19,350
Phase Transformation Point (°K)	-	1,155	-
Melting Point (°K)	2,345	1,933	3,683
Boiling Point (°K)	3,253	3,560	5,933
Latent Heat of Transformation: L_t (J/kg)	-	9.18×10^4	-
Latent Heat of Fusion: L_f (J/kg)	1.07×10^6	4.37×10^5	1.92×10^5
Latent Heat of Vaporization: L_v (J/kg)	2.90×10^7	9.83×10^6	4.68×10^6
Spectral Absorptivity α	0.29	0.30	0.70
Total Emissivity ε	0.63 @ 550°K 0.42 @ 772°K 0.26 @ 1100°K	0.73 @ 500°K 0.61 @ 1000°K 0.48 @ 1500°K	0.53 @ 500°K 0.192 @ 1500°K 0.303 @ 2500°K 0.351 @ 3500°K

Table 1 - (continued)

Materials Parameters	$A\ell_2O_3$	T_i	W
Specific Heat C (J/kg°K)	962.96 @ 298°K 1400.00 @ 1000°K	523.00 @ 298°K 824.80 @ 1800°K	133.89 @ 298°K 167.36 @ 2000°K 209.20 @ 3000°K
Thermal Conductivity k (w/m°K)	2.36 @ 273°K 2.37 @ 298°K 2.40 @ 373°K	0.224 @ 273°K 0.219 @ 298°K 0.207 @ 373°K	1.77 @ 273°K 1.73 @ 298°K 1.63 @ 373°K
Absorption Area Factor η	0.25 0.50 1.00	0.25 0.50 1.00	0.25 0.50 1.00

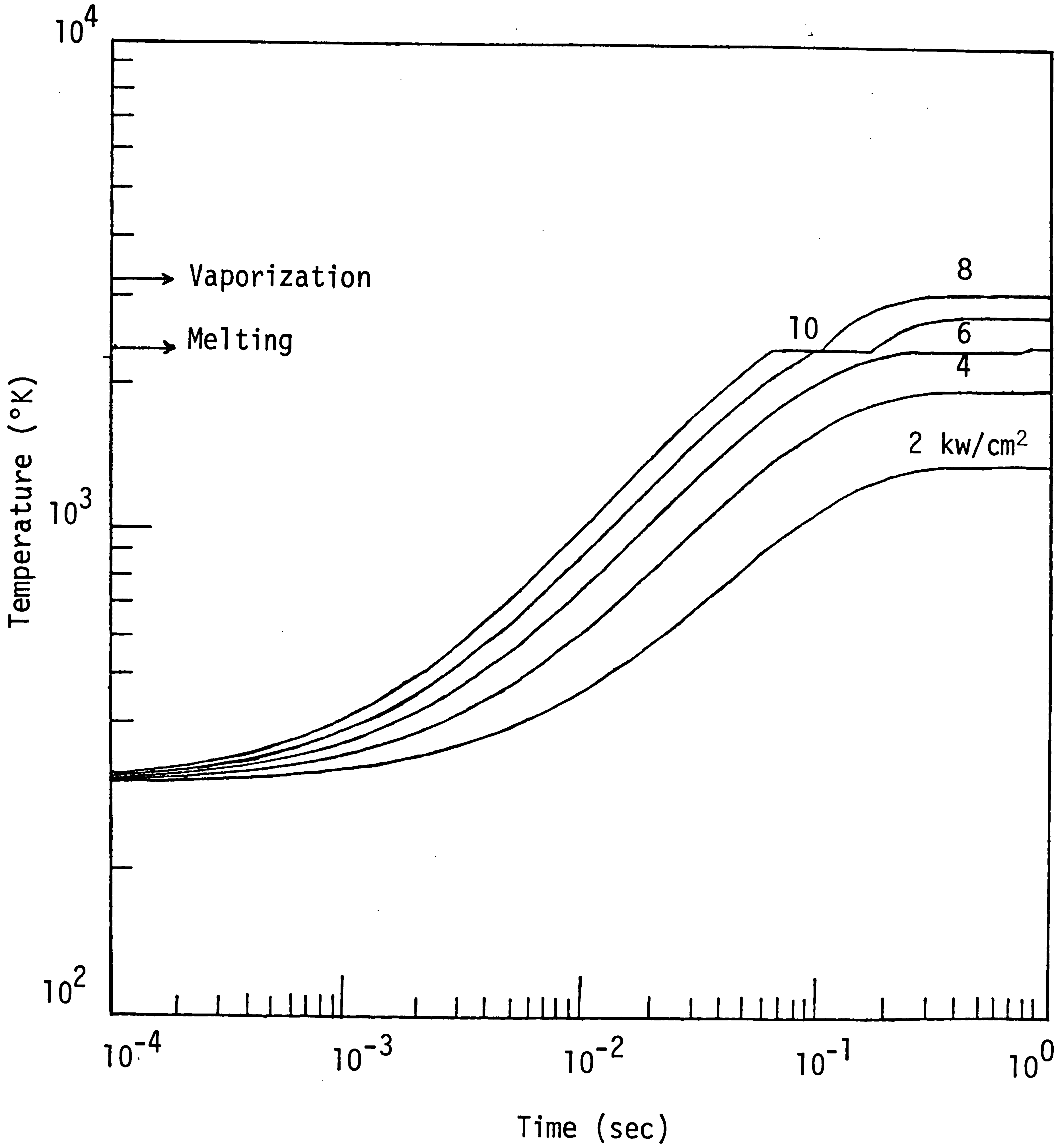

Figure 3. Temperature-time history of $A\ell_2O_3$ particles with R = 40 μm and η = 0.25 in CO_2 laser.

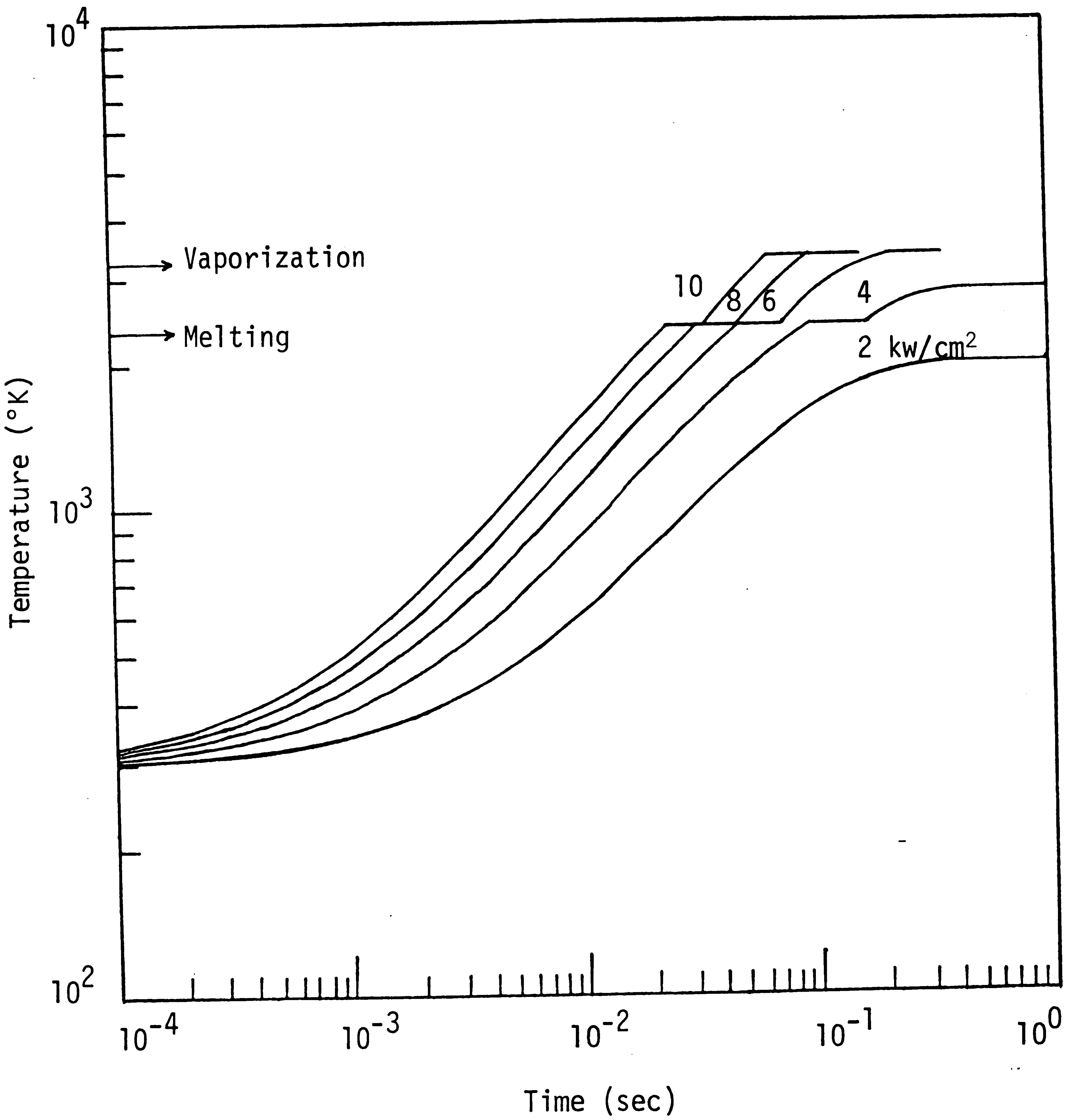

Figure 4. Temperature-time history of $A\ell_2O_3$ particles with R = 40 μm and η = 0.50 in CO_2 laser.

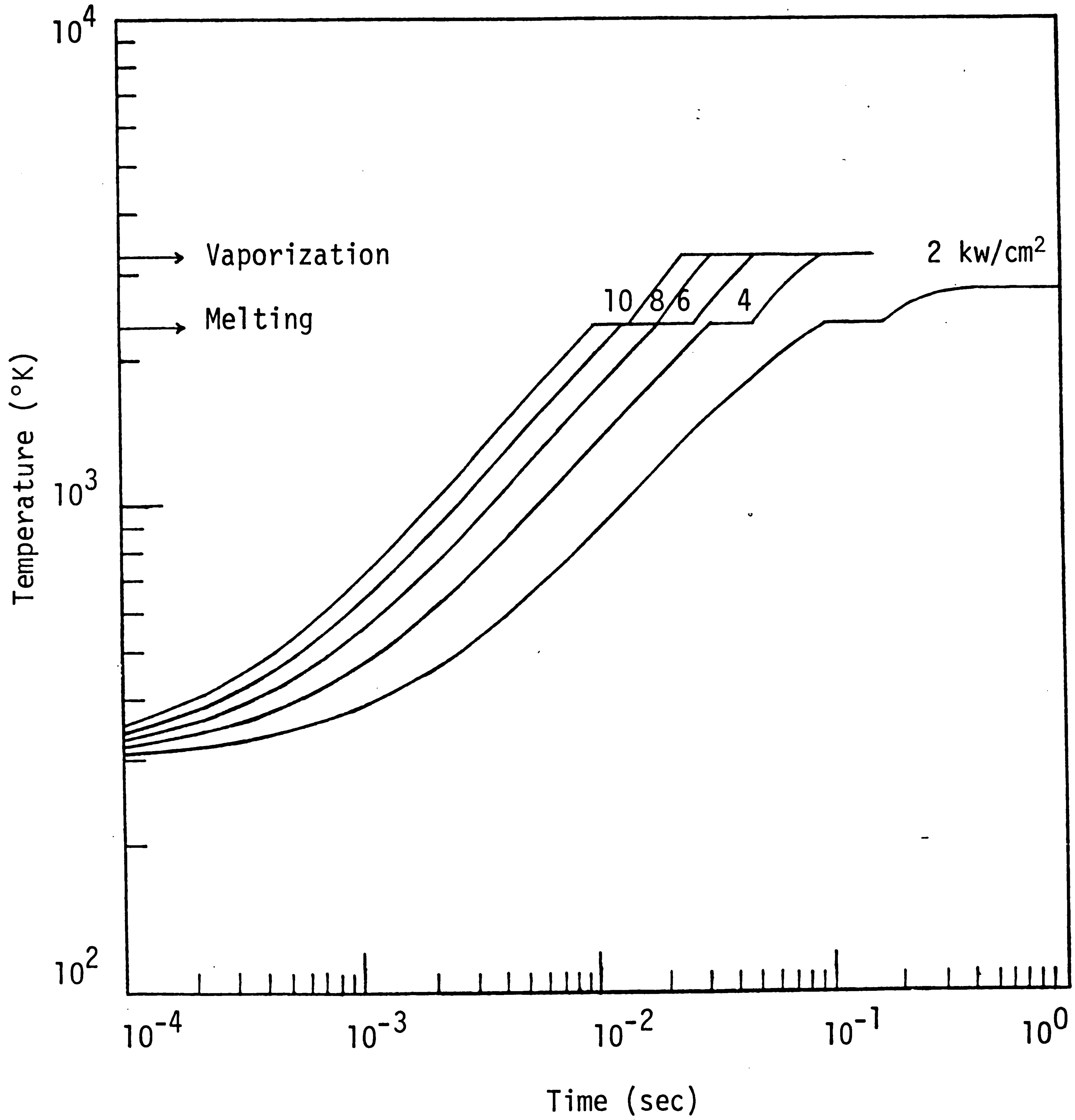

Figure 5. Temperature-time history of Al_2O_3 particles with R = 40 μm and η = 1.0 in CO_2 laser.

same size of particle, i.e., R = 40 μm. For $\eta = 0.25$, melting does not occur if J is kept under 6 kw/cm^2, Figure 3. This situation changes as the absorption area factor η is increased to 0.50. Figure 4 shows that only the case of $J = 2\ kw/cm^2$ does not reach the melting point. Further increase in η up to 1.0 is given in Figure 5. Melting occurs even when $J = 2\ kw/cm^2$.

The effective area that absorbs energy is dependent on the laser power J. This is illustrated graphically in Figure 6. In general, η increases with J. The precise value of the slope $\Delta J/\Delta\eta$ is not known unless some additional experimental and/or analytical data are made available. Figure 7 summarizes the influence of η for $J = 2\ kw/cm^2$ and R = 40 μm in a temperature versus time plot. This corresponds to the data depicted from Figures 3 to 5. Curves similar to those in Figure 7 may also be obtained for other values of J.

As the particle size is increased to R = 80 and 120 μm, the temperature versus time curves tend to rise quicker as the absorbed energy becomes large in comparison with that dissipated. The results in Figures 8 and 9 show that melting occurs for all values of J considered as η is set at 1.0. Refer to Figure 10 where the influence of particle size on heating is more explicitly exhibited. Table 2 gives a complete summary of the thermal data for the $A\ell_2O_3$ particle. Reference can also be made to Appendix B for numerical data that correspond to each time increment.

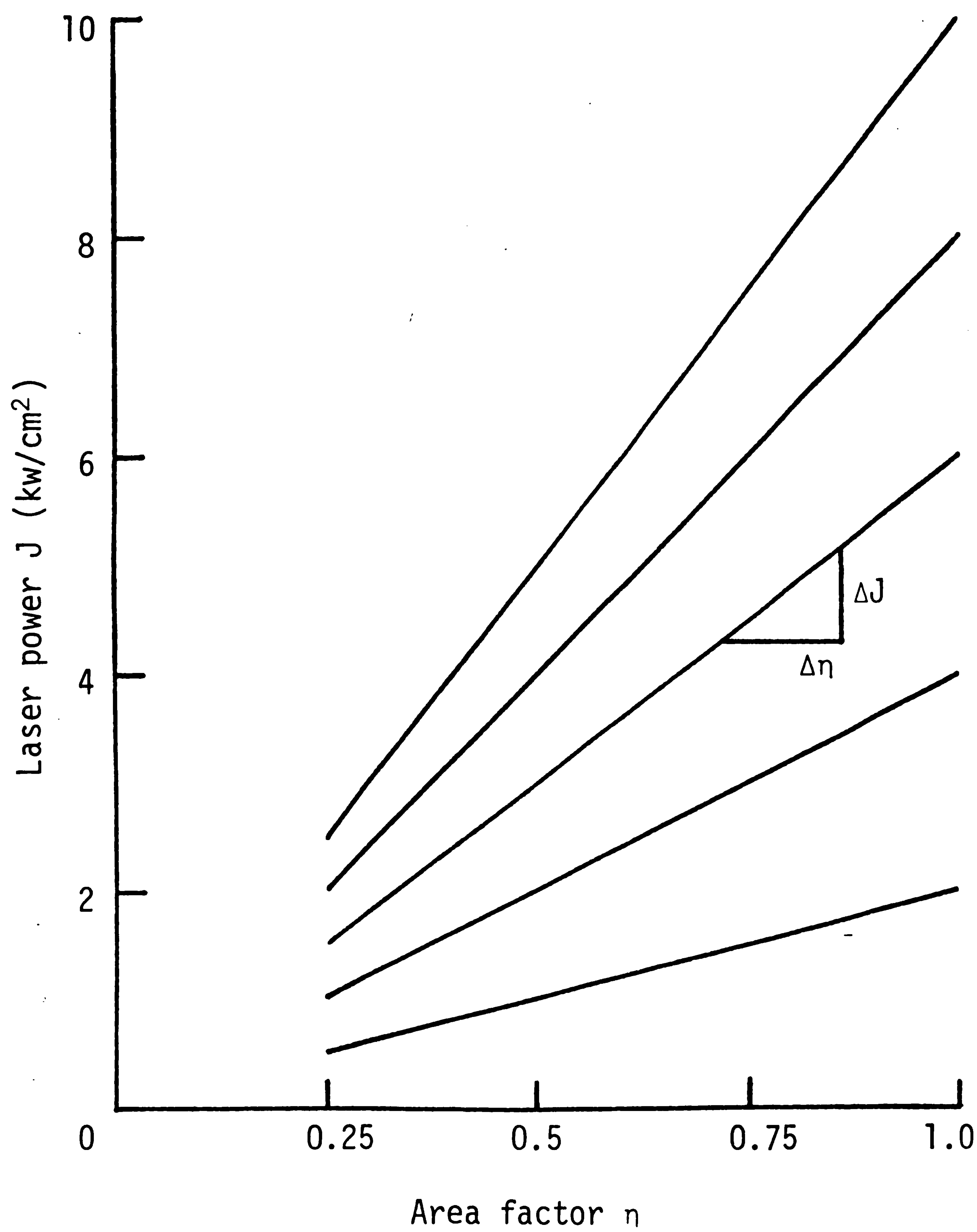

Figure 6. Influence of particle absorption area factor on laser intensity.

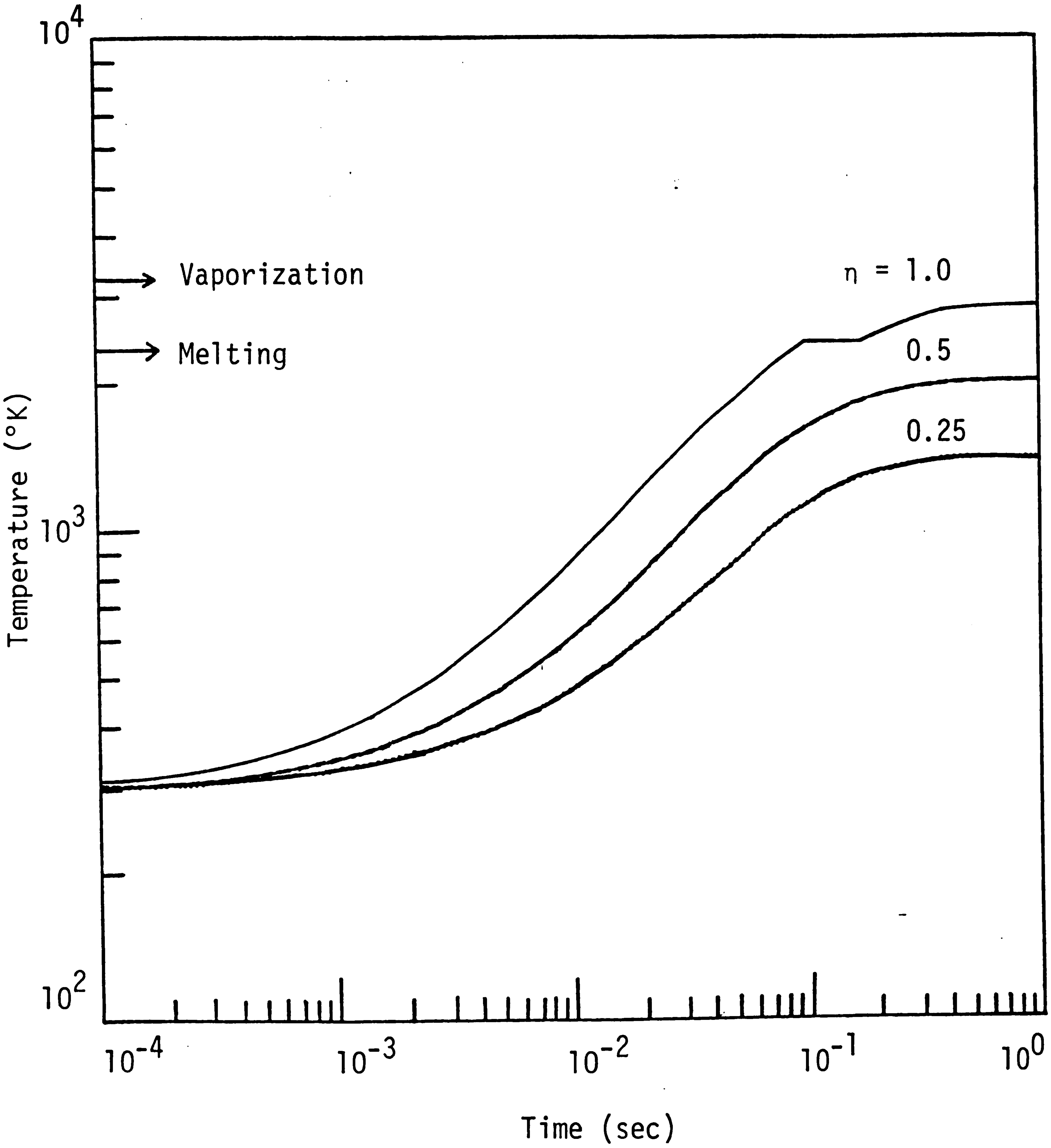

Figure 7. Influence of particle absorption area factor for $A\ell_2O_3$ particles with $J = 2$ kw/cm^2 and $R = 40$ μm in CO_2 laser.

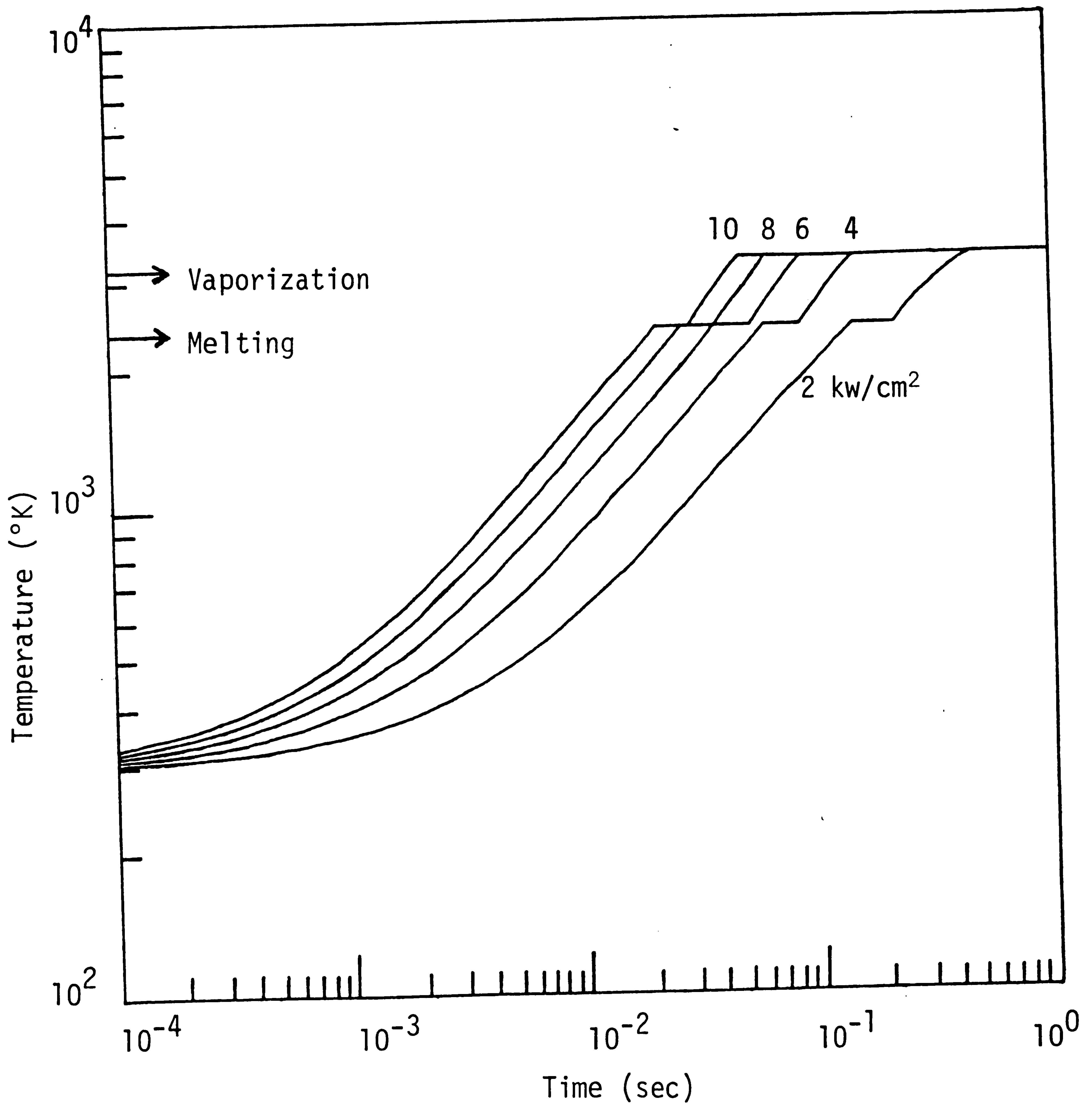

Figure 8. Temperature-time history for $A\ell_2O_3$ particles with R = 80 μm and η = 1.0 in CO_2 laser.

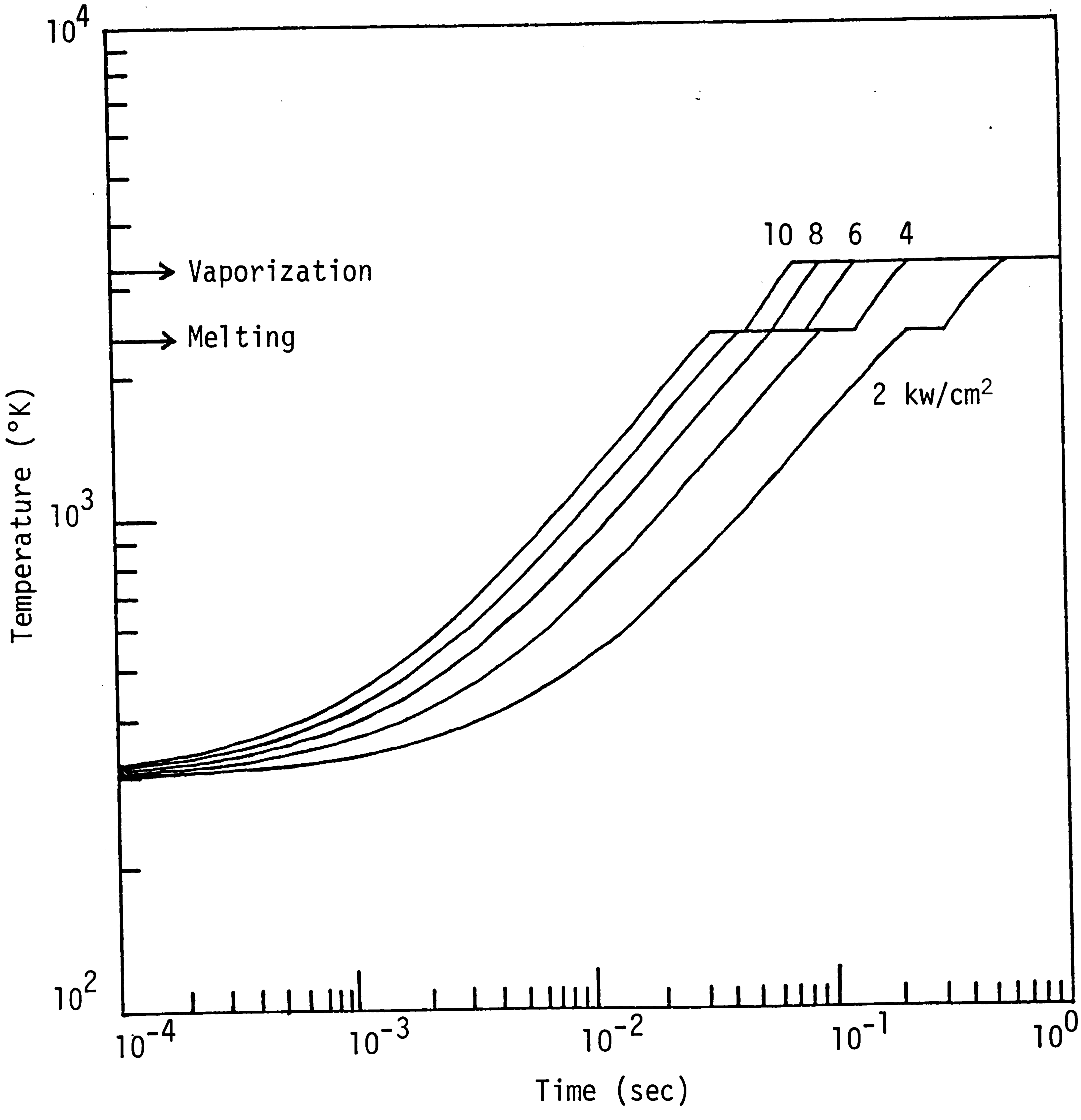

Figure 9. Temperature-time history for $A\ell_2O_3$ particles with R = 120 μm and η = 1.0 in CO_2 laser.

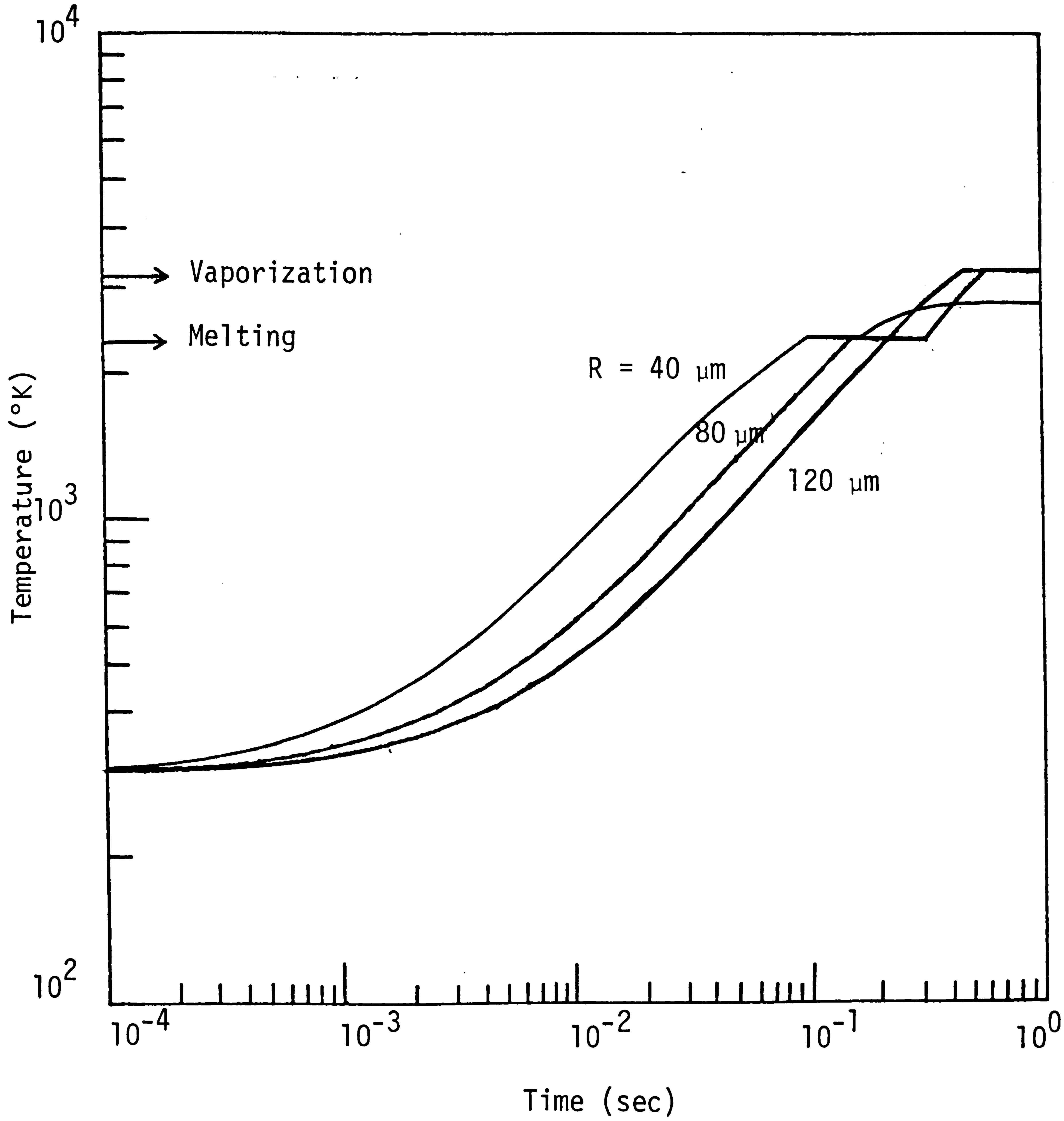

Figure 10. Temperature-time history for $A\ell_2O_3$ particles of different sizes with $J = 2$ kw/cm^2 and $\eta = 1.0$ in CO_2 laser.

Table 2. Melting (T_m = 2,345°K) and vaporization (T_v = 3,235°K) time for alumina particles under different conditions

Laser Power Density (kw/cm²)	Particle Radius (μm): 40 Melt	40 Vapor	80 Melt	80 Vapor	120 Melt	120 Vapor	Particle Absorption Area Factor
2							.25
2			.2023		.2405		.5
2	.0490		.0726	.2035	.1016	.2453	1.
4			.2023		.2405		.25
4	.0490		.0726	.2035	.1016	.2453	.5
4	.0180	.0484	.0326	.0736	.0475	.1033	1.
6	.1098		.1056		.1424		.25
6	.0261	.0986	.0450	.1069	.0647	.1449	.5
6	.0112	.0262	.0211	.0456	.0310	.0657	1.
8	.0490		.0726	.2035	.1016	.2453	.25
8	.0180	.0484	.0326	.0736	.0475	.1033	.5
8	.0081	.0182	.0156	.0331	.0230	.0482	1.
10	.0338		.0555	.1391	.0791	.1819	.25
10	.0138	.0338	.0256	.0563	.0376	.0803	.5
10	.0064	.0140	.0124	.0260	.0183	.0381	1.

Onset Condition: Melt / Vapor

B. Titanium (Ti)

The thermal-mechanical behavior of Ti differs from that of $A\ell_2O_3$ in that titanium undergoes phase transformation prior to melting. It changes from the α-phase to β-phase. For R = 40 μm and η = 0.25, Figure 11 shows that T rises with time with phase transformation taking place at T $\simeq$ 1,155°K. The curves then continue to rise until melting occurs except for the cases of insufficient power density with J = 2 and 4 kw/cm^2. As η increases to 0.5, only the curve for J = 2 kw/cm^2 did not reach melt, Figure 12. When η = 1.0, the results in Figure 13 indicate that both phase transformation and melting take place earlier and melting occurs for all J considered. The influence of particle size of titanium is displayed in Figures 14 and 15 as R is increased to 80 and 120 μm. As in the case of $A\ell_2O_3$, the temperature tends to rise quicker and higher for larger values of R. What has been traded is the particle speed as larger particles tend to travel slower for the same momentum. This may contribute to a less uniform surface coating. Hence, the optimum size of particle cannot be decided from the consideration of temperature-time history data alone.

More detailed information on the results can be found in Table 3 and Appendix B.

C. Tungsten (W)

Tungsten possesses a body-centered cubic structure in the α-phase. The β-phase prevails in the presence of oxygen. It will then become W_3O.

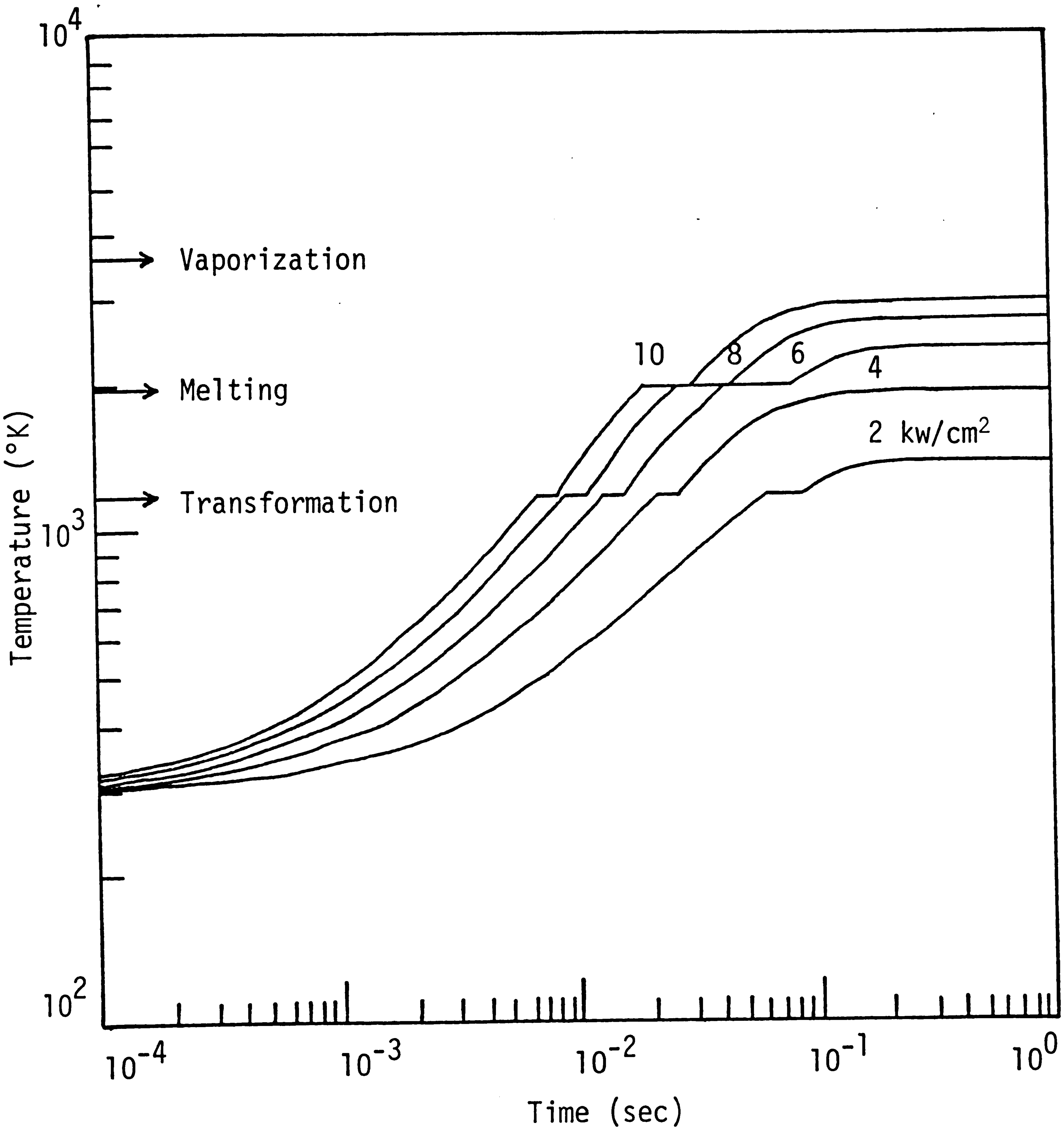

Figure 11. Temperature-time history of Ti particles with R = 40 μm and η = 0.25 in CO_2 laser.

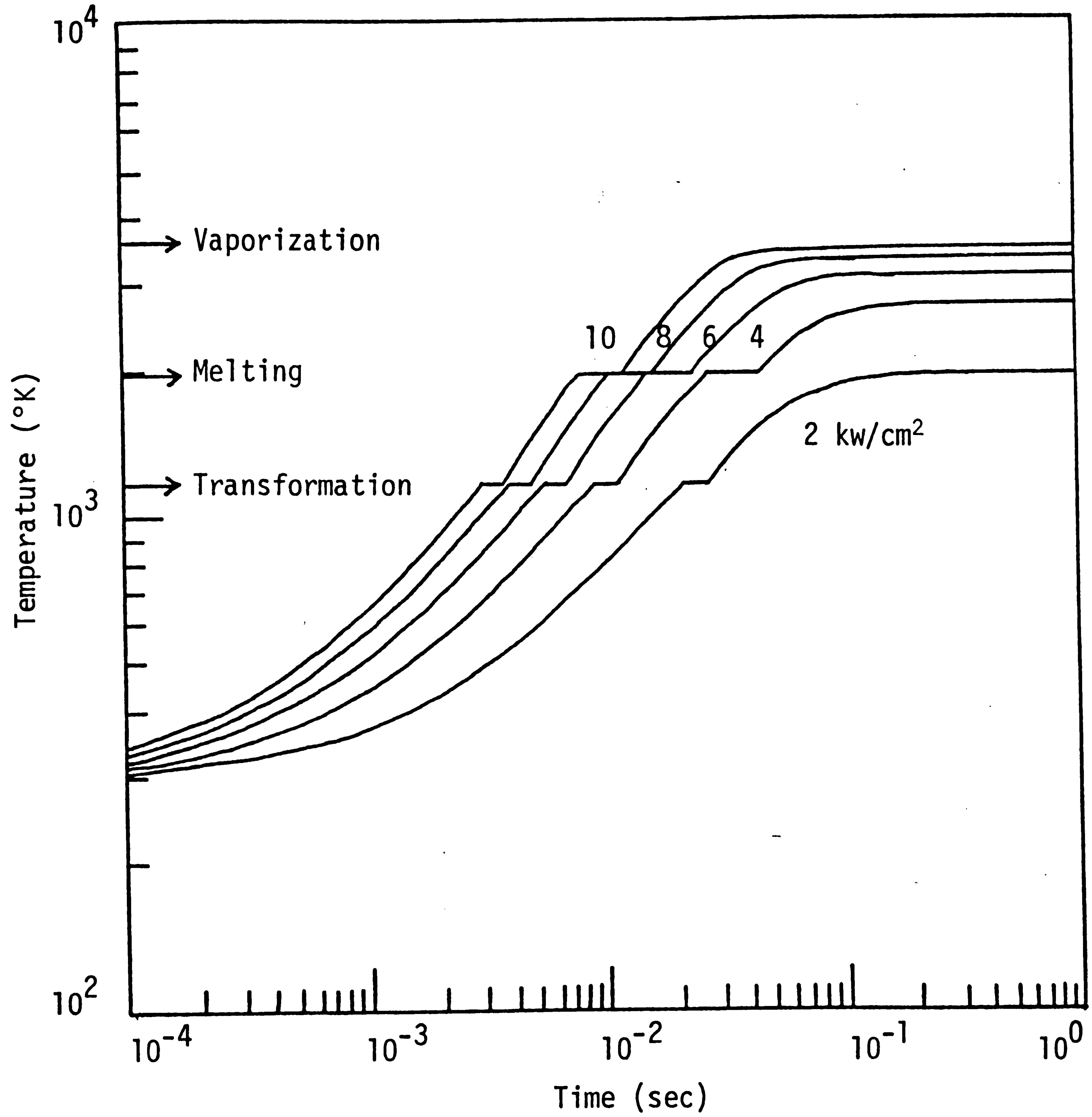

Figure 12. Temperature-time history of Ti particles with R = 40 μm and $\eta = 0.5$ in CO_2 laser.

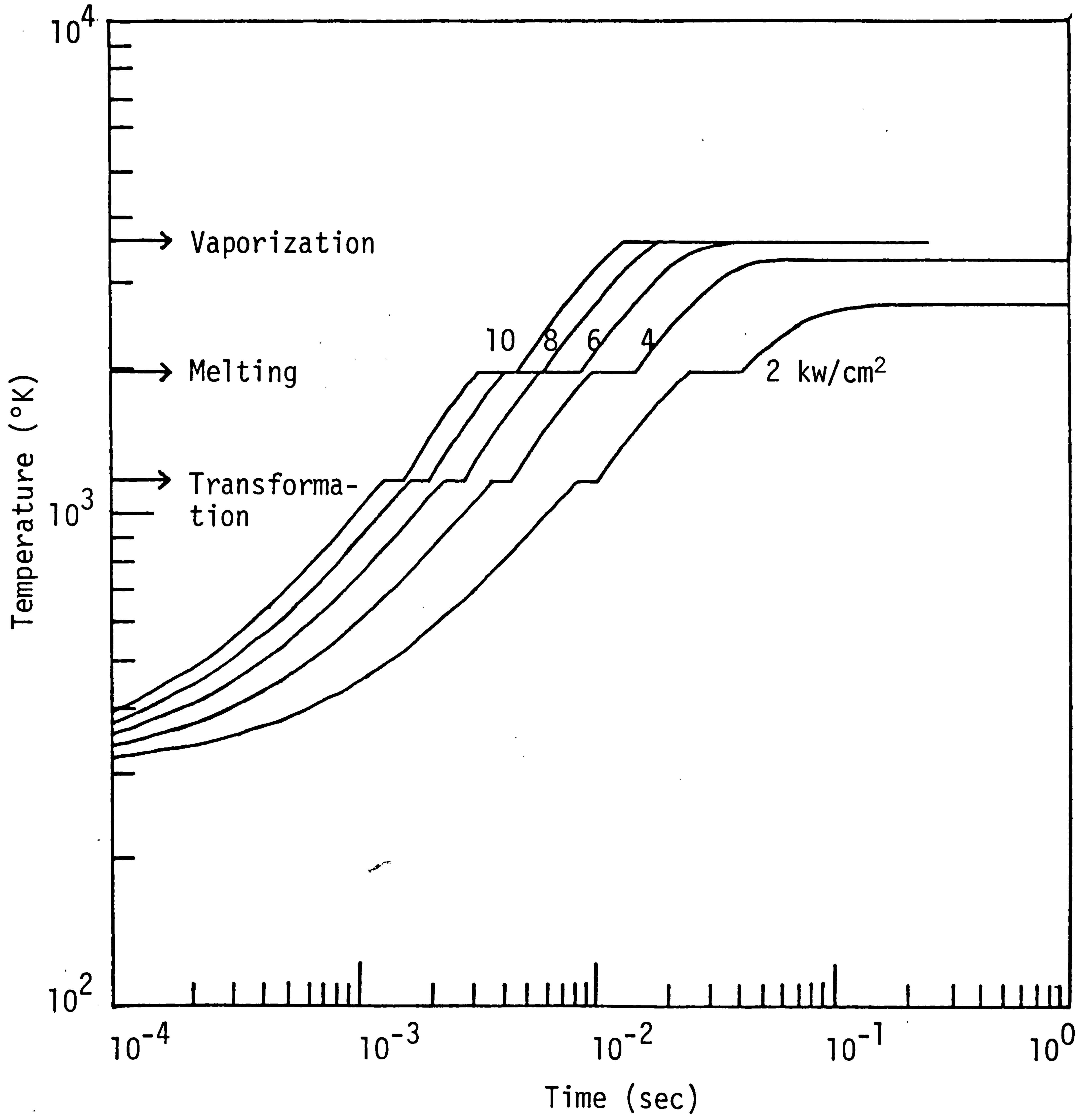

Figure 13. Temperature-time history of Ti particles with R = 40 μm and η = 1.0 in CO_2 laser.

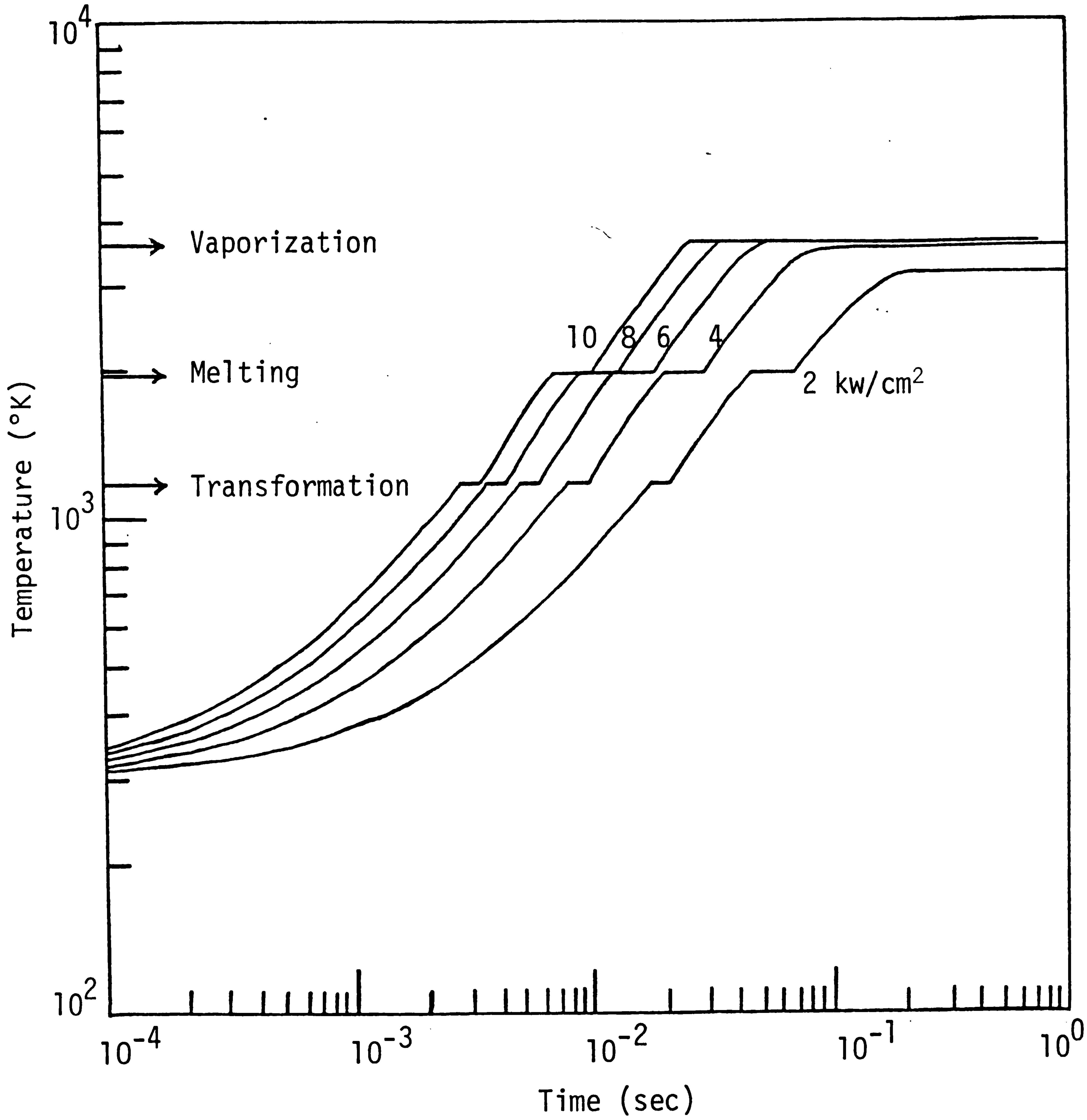

Figure 14. Temperature-time history of Ti particles with R = 80 μm and η = 1.0 in CO_2 laser.

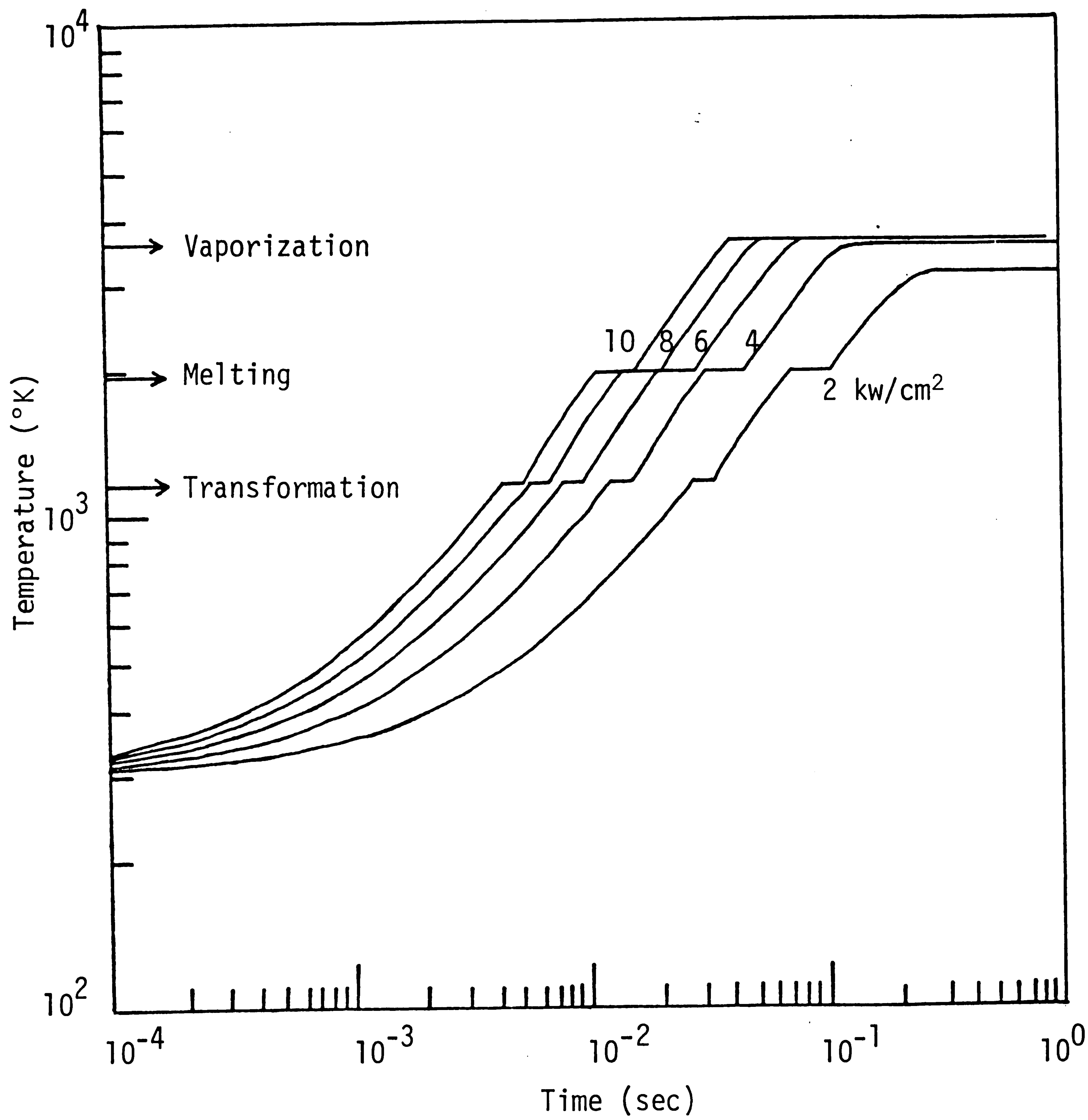

Figure 15. Temperature-time history of Ti particles with R = 120 μm and η = 1.0 in CO_2 laser.

Table 3. Melting (T'_m = 1,933°K) and vaporization (T_v = 3,560°K) time for titanium particles under different conditions

Laser Power Density (kw/cm²)	Particle Absorption Area Factor	Particle Radius 40 (μm): Melt	40: Vapor	80: Melt	80: Vapor	120: Melt	120: Vapor
		Onset Condition					
2	.25						
2	.5			.0633		.0854	
2	1.	.0153		.0266		.0384	
4	.25			.0633		.0854	
4	.5	.0153		.026		.0384	
4	1.	.0066		.0125		.0184	
6	.25	.0236		.0373		.0529	
6	.5	.0092		.0170		.0249	
6	1.	.0042		.0081	.0300	.0121	.0420
8	.25	.0153		.0266		.0384	
8	.5	.0066		.0125		.0184	
8	1.	.0031	.0119	.0061	.0205	.0090	.0296
10	.25	.0115		.0207		.0302	
10	.5	.0051		.0099	.0430	.0146	.0556
10	1.	.0025	.0087	.0048	.0158	.0072	.0230

It is evident from the data presented in Figures 16 to 18 for R = 40 μm and η = 0.25, 0.50 and 1.0 that more power is required to melt the tungsten as compared with the two previously discussed materials. Figure 16 shows that only the case J = 10 kw/cm^2 reached melting. As the affected zone of heating is increased via η, less J is needed for melting. This is exhibited by the results in both Figures 17 and 18 for η = 0.5 and 1.0. The increase in particle size or R yields the same effects as discussed earlier for titanium and needs no repetition. The results are shown in Figures 19 and 20.

Table 4 summarizes the data on melting and vaporation of tungsten powders with different sizes and power input. Additional information may be found in Appendix B.

D. Temperature Dependency

Since laser spray is a highly temperature dependent process, many of the physical parameters assumed in the thermal analysis will change as a function of temperature. The process, of course, depends on the laser power density J as indicated in Figure 21 (or Table 5) which provides a rough estimate of J versus T for the CO_2 laser, $A\ell_2O_3$, Ti and W particles. The temperature of the laser is obtained by assuming that J being proportional to the 4th power of temperature and that it behaves as a black body. The difference between the temperature of the CO_2 laser and solid particles gives an indication of loss energy as the particles are heated by laser irradiation.

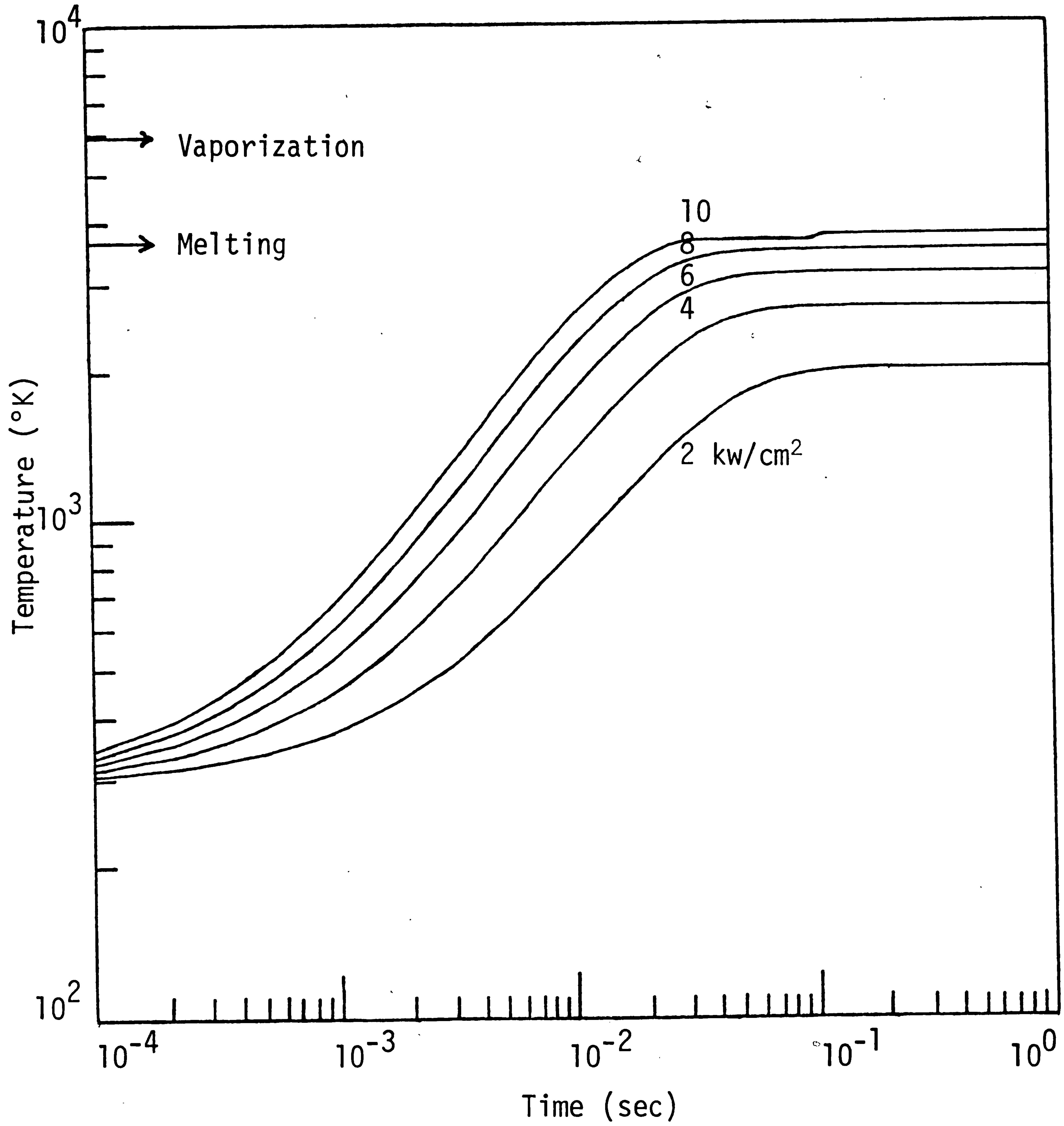

Figure 16. Temperature-time history of W particles with R = 40 μm and η = 0.25 in CO_2 laser.

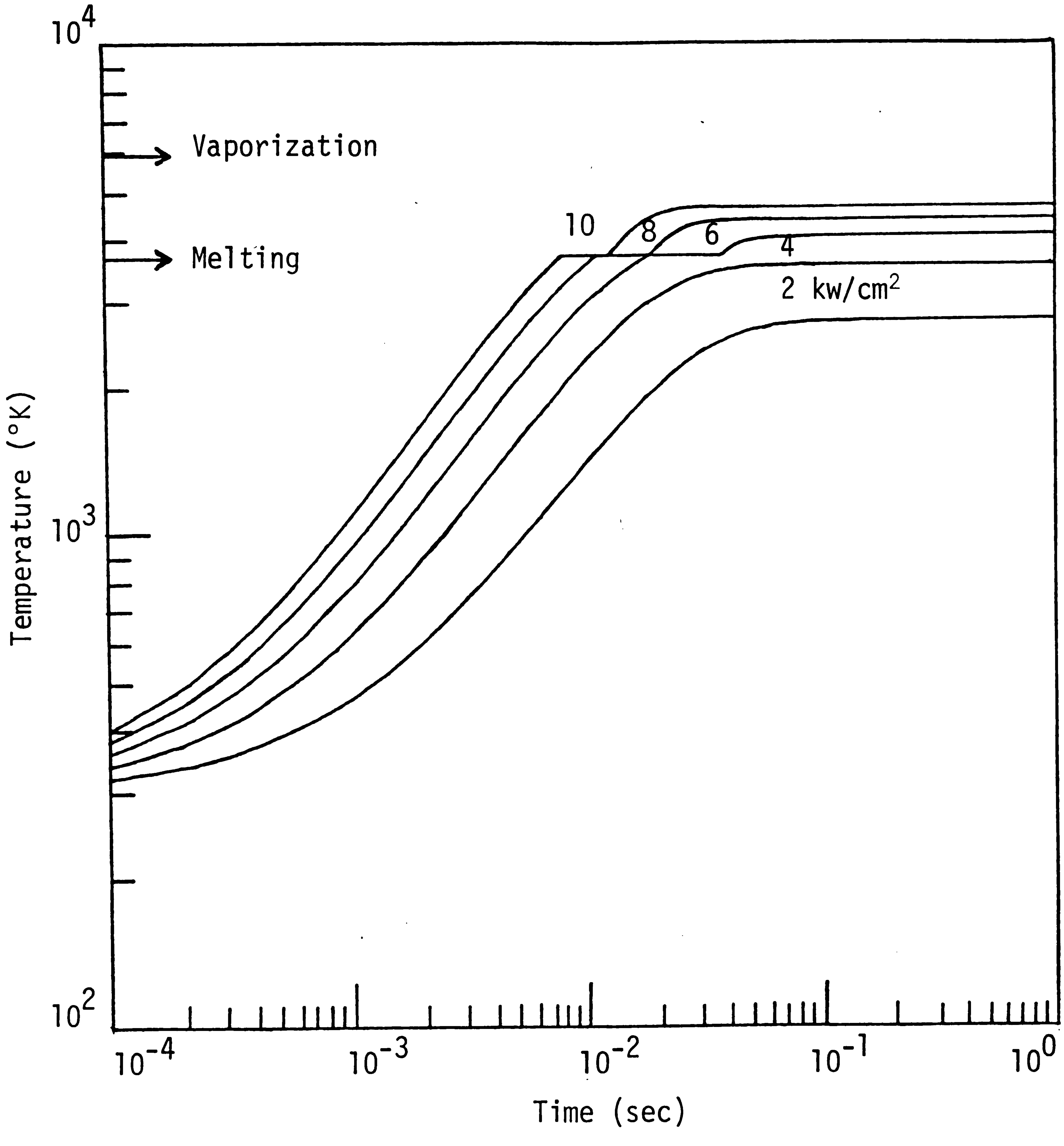

Figure 17. Temperature-time history of W particles with R = 40 μm and η = 0.5 in CO_2 laser.

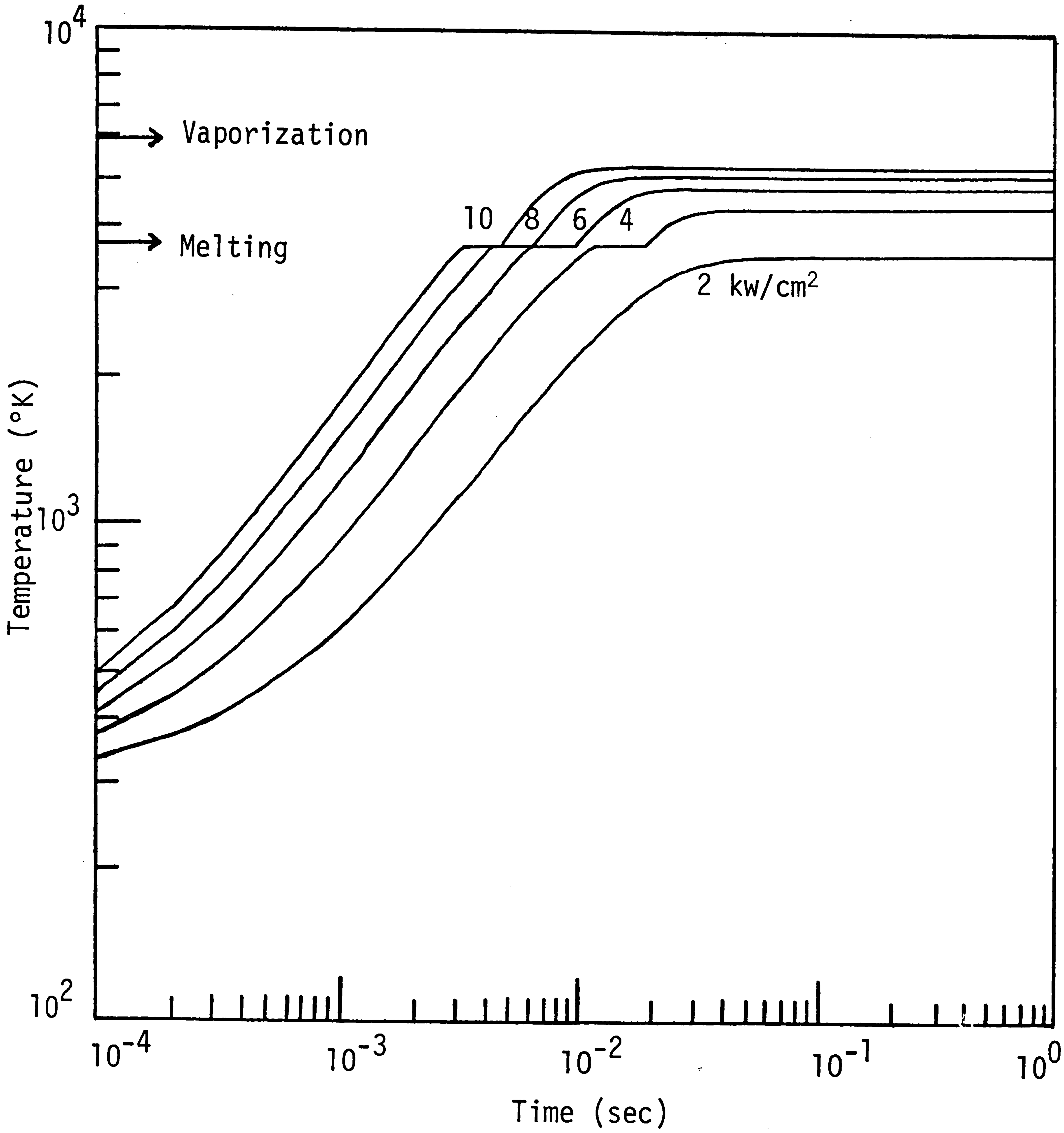

Figure 18. Temperature-time history of W particles with R = 40 μm and η = 1.0 in CO_2 laser.

Table 4. Melting (T_m = 3,683°K) and vaporization (T_V = 5,933°K) time for tungsten particles under different conditions

Laser Power Density (kw/cm^2)	Particle Absorption Area Factor	Onset Condition: Melt (Particle Radius 40 μm)	Vapor (40 μm)	Melt (80 μm)	Vapor (80 μm)	Melt (120 μm)	Vapor (120 μm)
2	.25						
2	.5						
2	1.			.0342		.0452	
4							
4	.5			.0342		.0452	
4	1.	.0072		.0128		.0186	
6	.25					.0807	
6	.5	.0113		.0184		.0262	
6	1.	.0043		.0081		.0119	
8	.25			.0342		.0452	
8	.5	.0072		.0128		.0186	
8	1.	.0031		.0059		.0087	
10	.25	.0174		.0236		.0330	
10	.5	.0054		.0099		.0145	
10	1.	.0024		.0046		.0069	

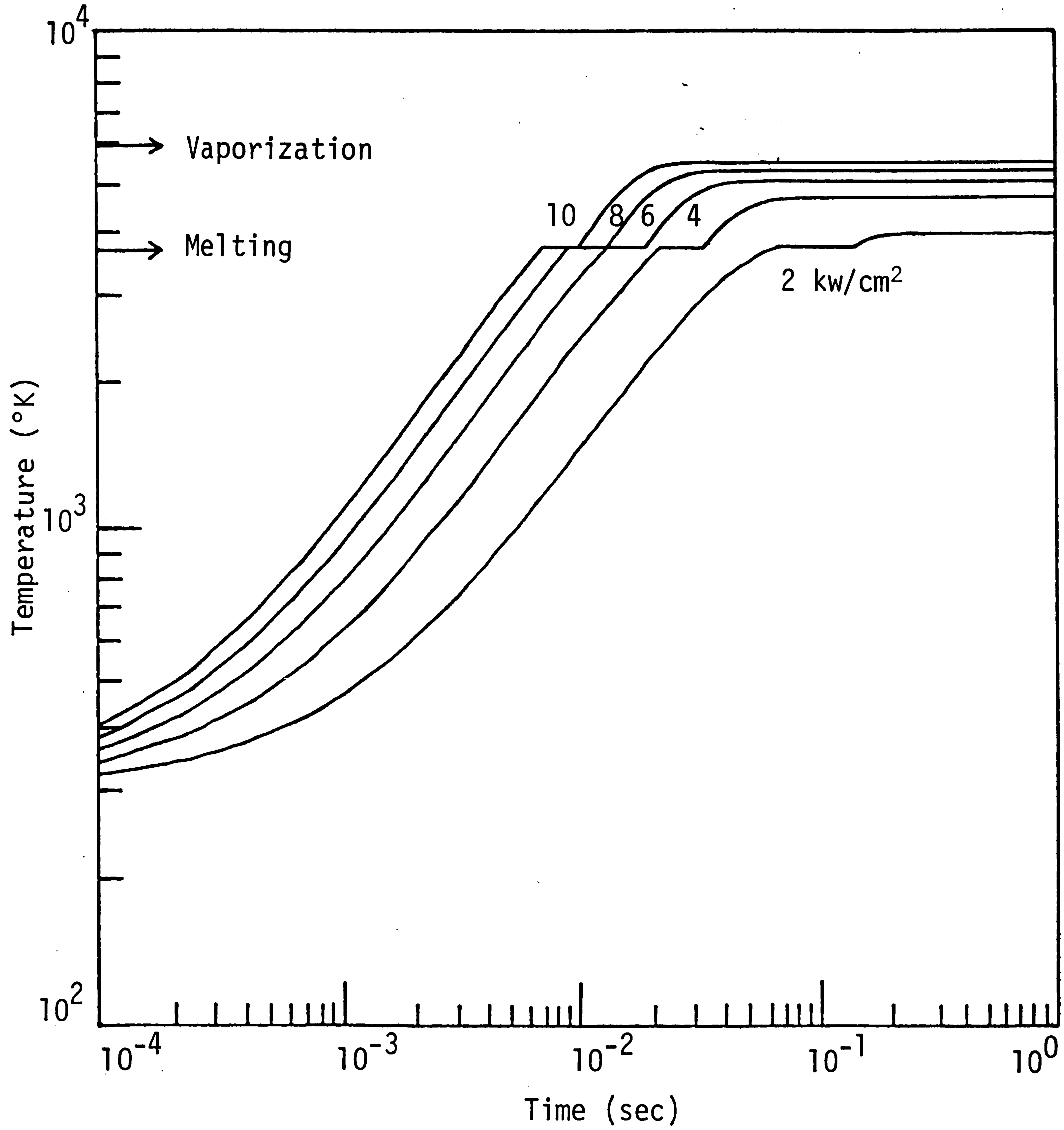

Figure 19. Temperature-time history of W particles with R = 80 μm and η = 1.0 in CO_2 laser.

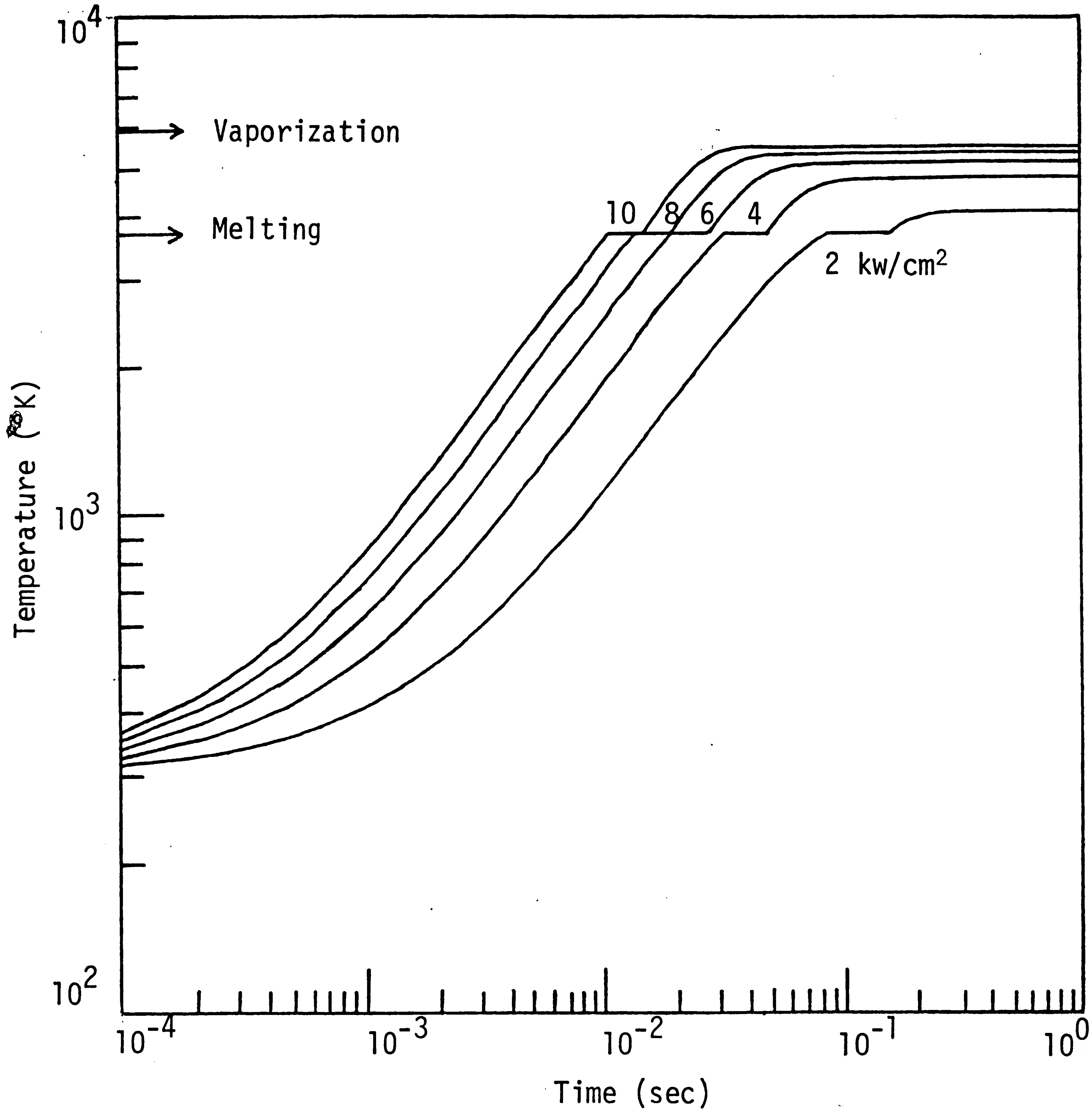

Figure 20. Temperature-time history of W particles with R = 120 μm and η = 1.0 in CO_2 laser.

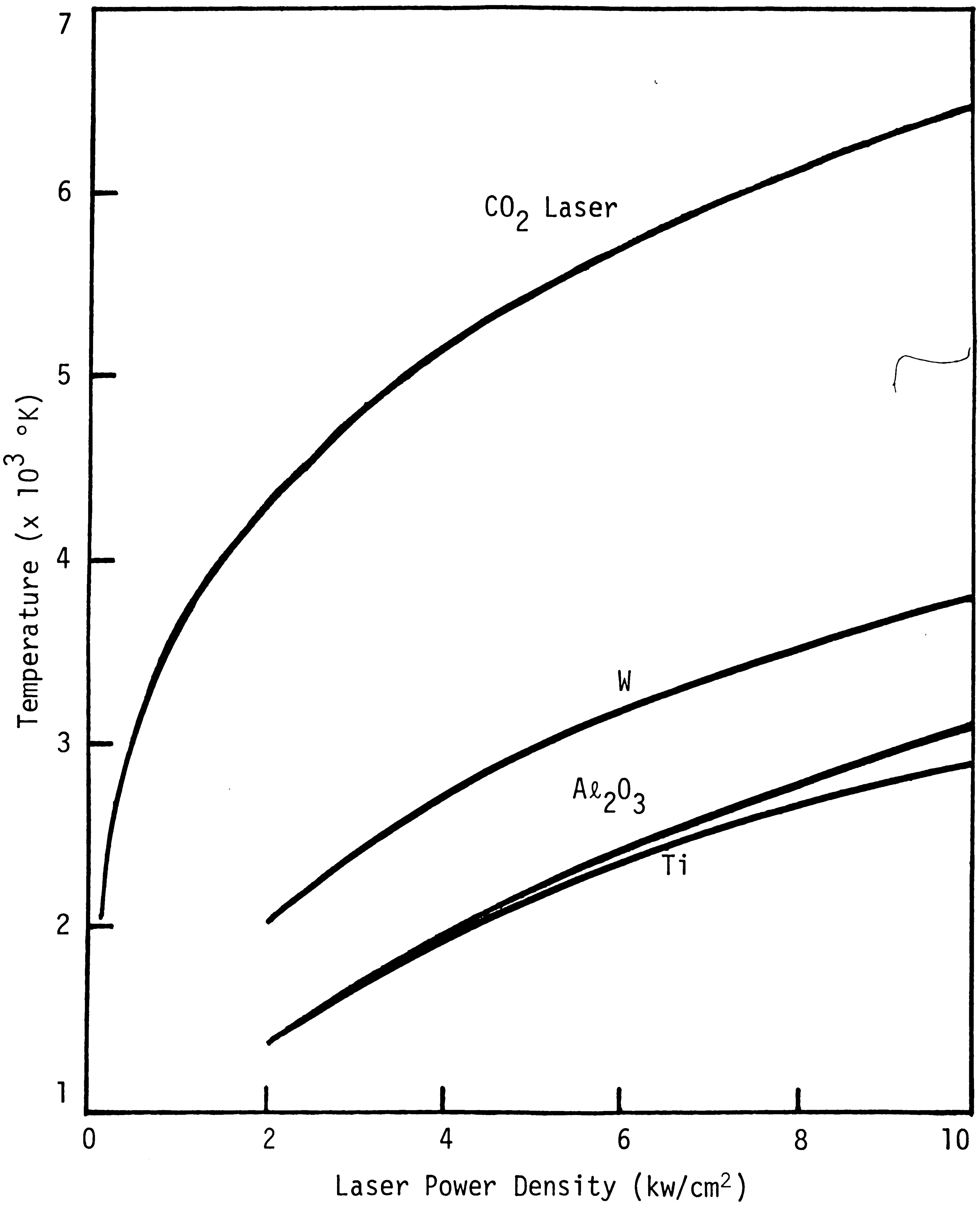

Figure 21. Estimated temperature of CO_2 laser, $A\ell_2O_3$, Ti and W particles with R = 40 μm and η = 0.25 as a function of power density.

Table 5. Equilibrium temperature in °K of material particles for different laser power J (kw/cm^2) with R = 40 μm and η = 0.25

J \ Material	CO_2 Laser*	$A\ell_2O_3$	Ti	W
1	3,645	996	-	-
2	4,334	1,385	1,382	2,035
3	4,797	1,698	-	-
4	5,154	1,967	1,931	2,713
5	5,450	2,198	-	-
6	5,704	2,406	2,349	3,170
7	5,928	2,595	-	-
8	6,129	2,770	2,663	3,518
9	6,313	2,932	-	-
10	6,481	3,084	2,888	3,795
12	6,783	3,253	-	-

*If laser is approximated as a black body, then its temperature T emitted by radiation can be estimated by application of the relation $J = \sigma T^4$.

As mentioned earlier, quantities such as specific heat, thermal conductivities, etc., are temperature dependent. Figure 22 gives an idea of how C increases with temperature for the titanium particle. A discontinuity in heat transfer is observed as the Ti structure transforms from the α-phase to the β-phase. Similarly, the case of tungsten is given in Figure 23 in which the specific heat C also rises as the temperature T is increased. These more refined conditions, however, cannot be easily introduced into the analysis without a general treatment of the thermal behavior of solids subject to high energy laser power.

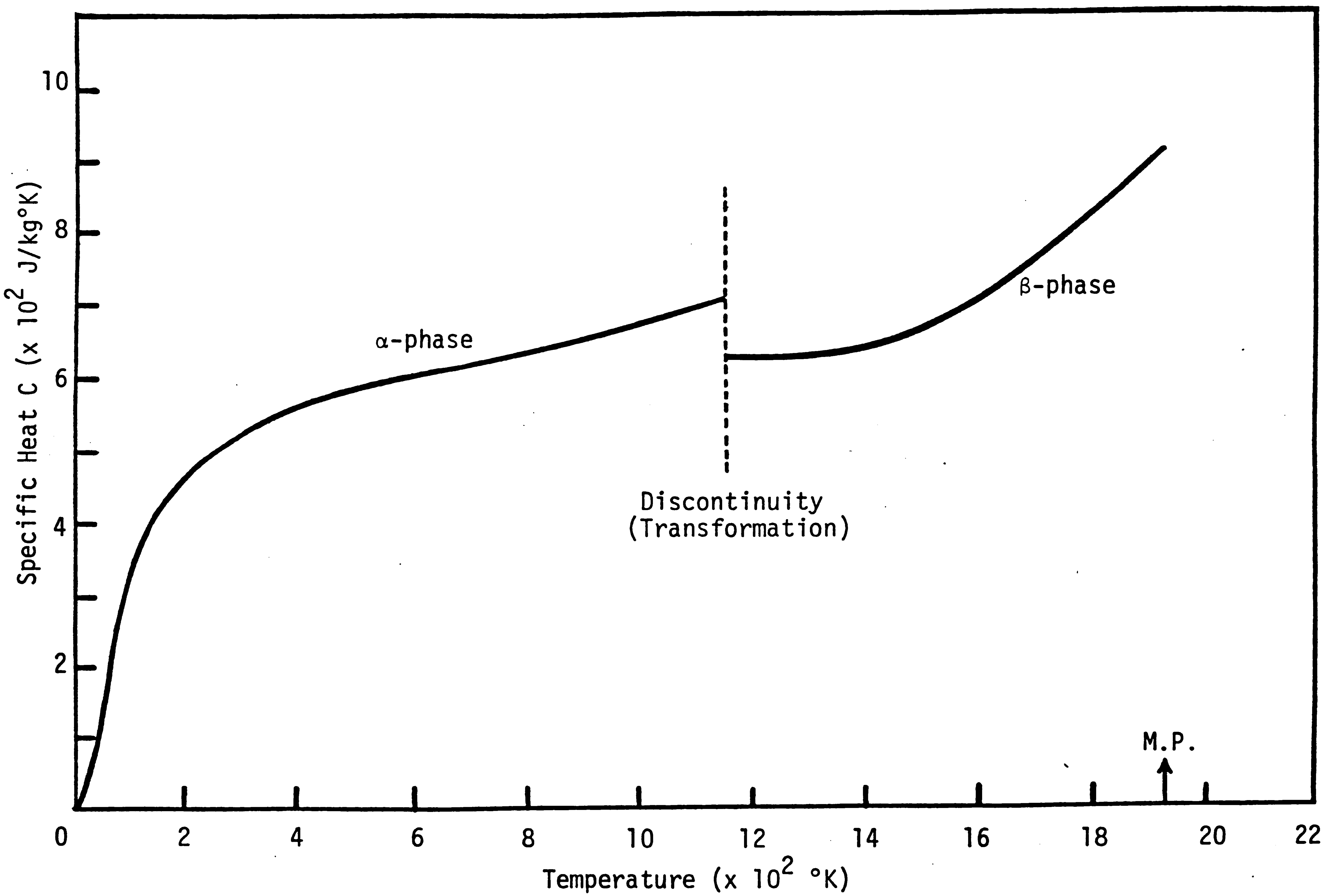

Figure 22. Discontinuity in specific heat of titanium caused by phase transformation.

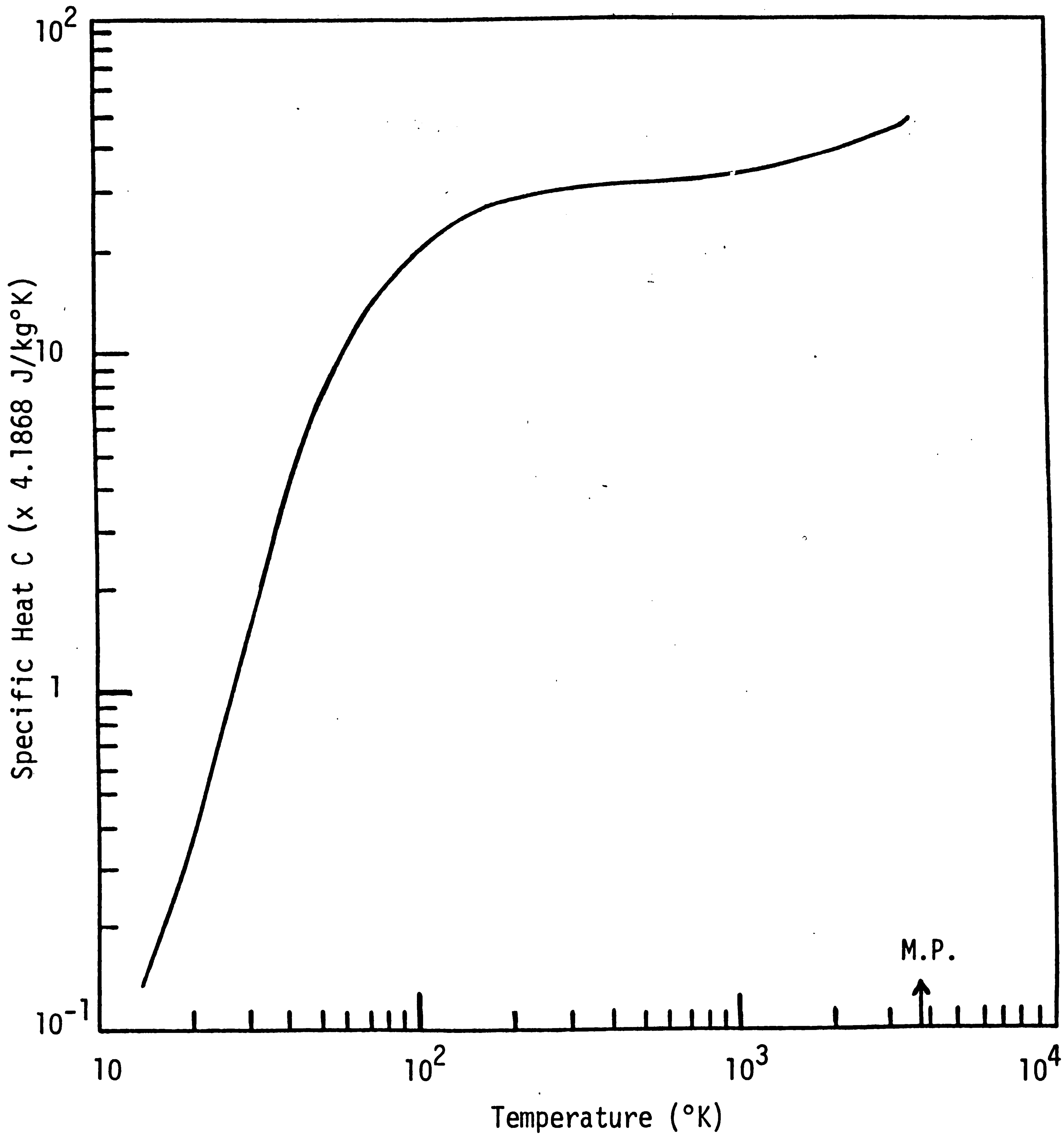

Figure 23. Specific heat of tungsten versus temperature.

V. MECHANICAL BEHAVIOR OF SPECIMEN WITH SURFACE COATING

When a solid is coated by a layer of new material, its overall mechanical behavior can change depending on the layer property and thickness. Such influence has been discussed [10,11] in terms of the redistribution of energy density in the surface layer. A brief account of the results obtained in [11] will be given for the case of a round circular cylinder subjected to uniaxial static and fatigue loading.

A. Overall Stress and Strain Behavior

Consider a round cylindrical bar subjected to uniaxial loading. Because of symmetry in load and geometry, it suffices to treat only one-quarter of the problem. This is given in Figure 24 with r being the radial direction and z the axial direction. The thickness of the new layer material is δ and will be normalized to the cylinder radius Δ. Two types of core materials will be considered. They are aluminum and steel with properties given in Table 6. The yield and ultimate strength are denoted respectively by σ_{ys} and σ_u while E stands for the Young's modulus. The critical strain energy density $(dW/dV)_c$ represents the area under the stress and strain curve at failure, i.e.,

$$\frac{dW}{dV} = \int_0^{\varepsilon_u} \sigma d\varepsilon \tag{32}$$

where ε_u corresponds to σ_u. The coating material is made of titanium having a higher yield strength $\hat{\sigma}_{ys}$ than the core material. Its prop-

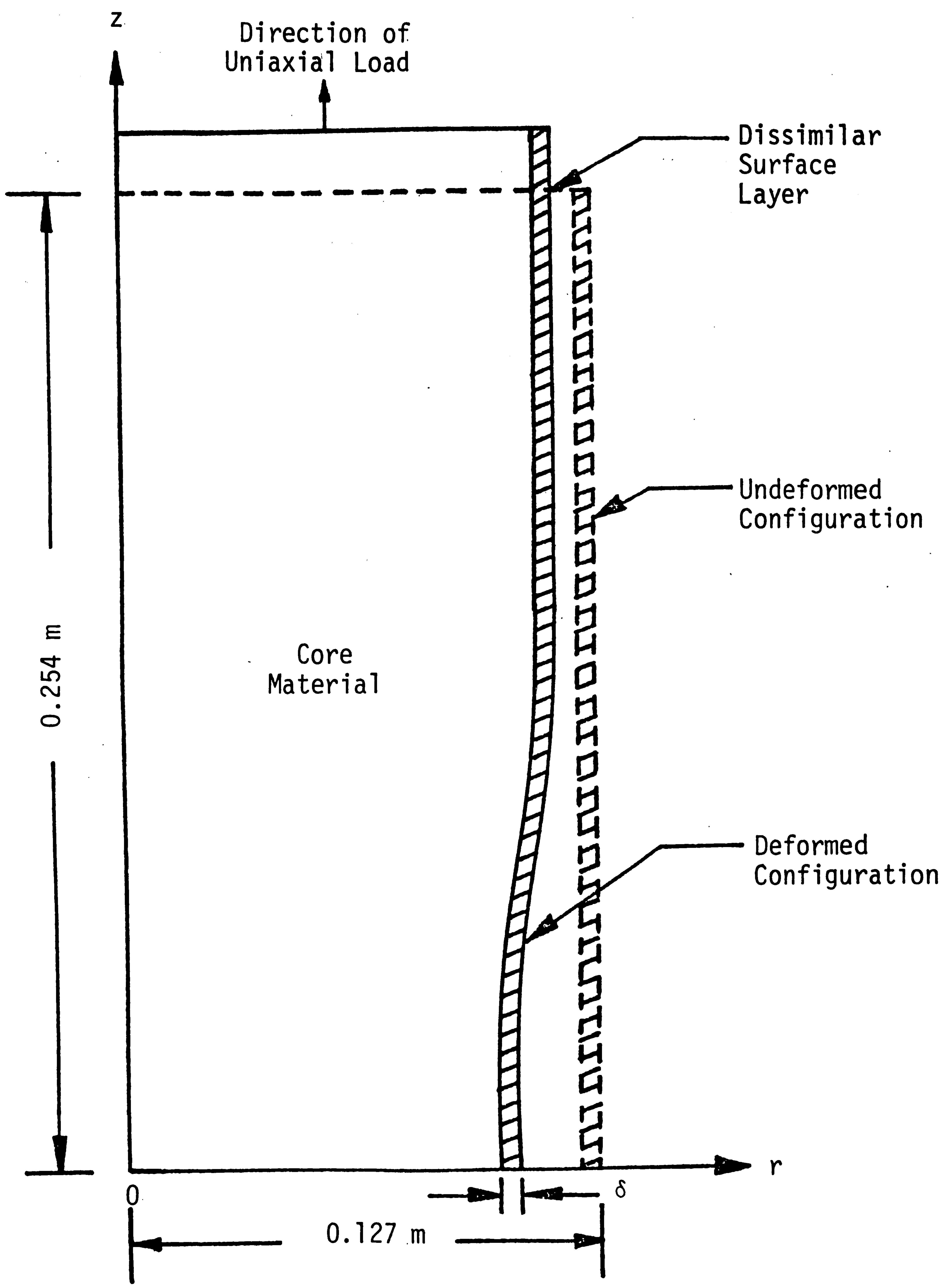

Figure 24. One-quarter symmetry of cylindrical bar specimen under uniaxial tension.

Table 6. Properties of core material: aluminum and steel

Material Type	E (MPa)	σ_{ys} (MPa)	σ_u (MPa)	$(dW/dV)_c$ (MPa)
Aluminum	6.895×10^4	413.69	620.52	3.22
Steel	2.068×10^5	517.11	1378.97	12.32

erties are given in Table 7.

Table 7. Properties of surface material: titanium

Material Type	$\hat{E}$ (MPa)	$\hat{\sigma}_{ys}$ (MPa)	$\hat{\sigma}_u$ (MPa)	$(\frac{dW}{dV})_c$ (MPa)
Titanium	1.041×10^5	620.53	1,172.12	4.70

Without going into details*, the overall stress and strain behavior for the aluminum and steel cylinder coated by titanium are shown graphically in Figures 25 and 26 for four different δ/Δ ratios. In the case of the aluminum cylinder with $\hat{\sigma}_{ys}/\sigma_{ys}$ = 1.5, the stress rises almost linearly with strain and the response becomes slightly more nonlinear as δ/Δ is increased. This is shown in Figure 25. Considerable nonlinearity in the variations of stress with strain is observed for the steel cylinder. The enhancement of mechanical strength is clearly seen to depend on δ.

*Refer to [11] with regard to the method for evaluating the stress and strain response. The finite element method is used in conjunction with the incremental theory of plasticity.

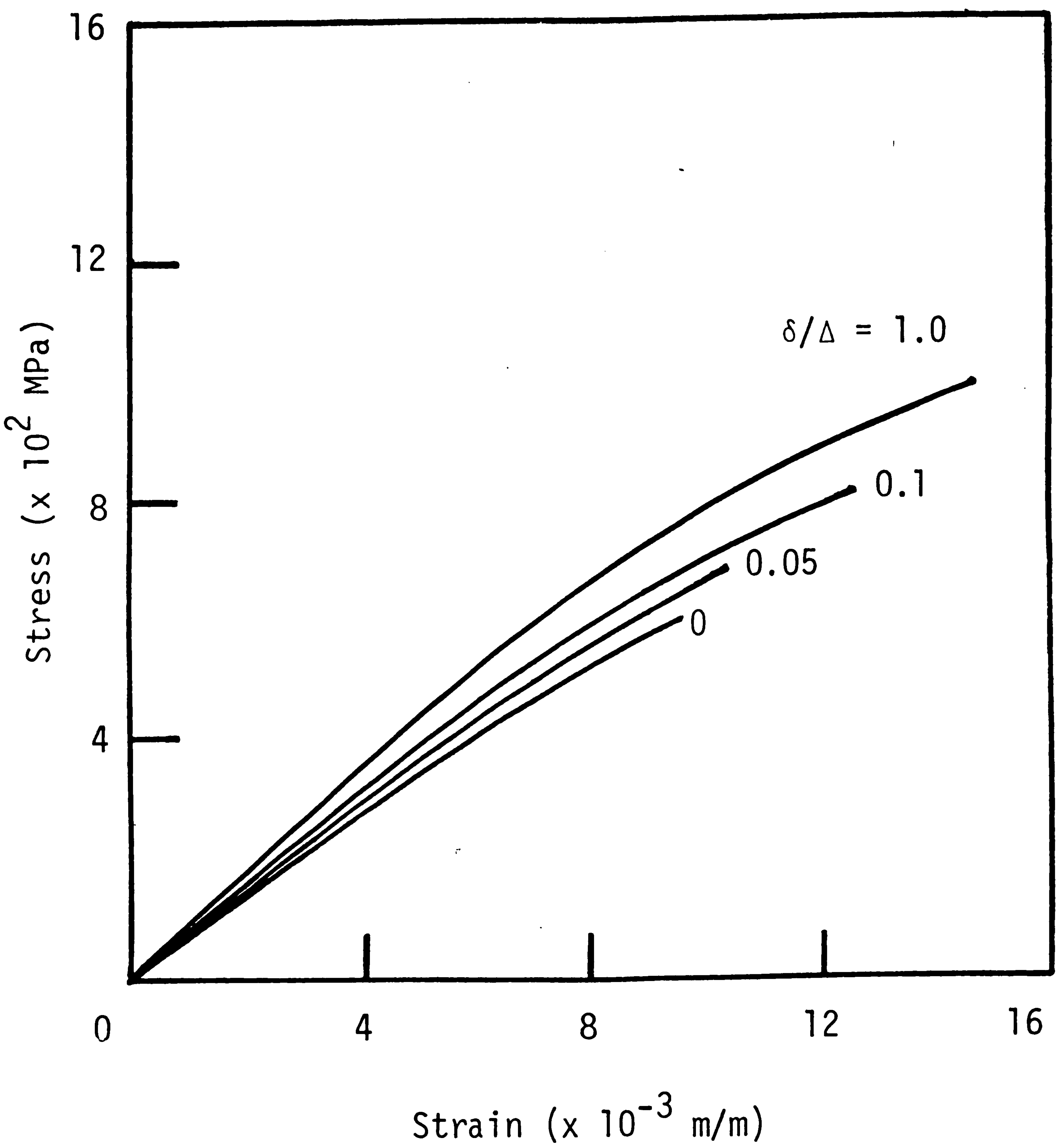

Figure 25. Overall stress and strain behavior of aluminum cylinder with titanium layer and $\hat{\sigma}_{ys}/\sigma_{ys} = 1.5$.

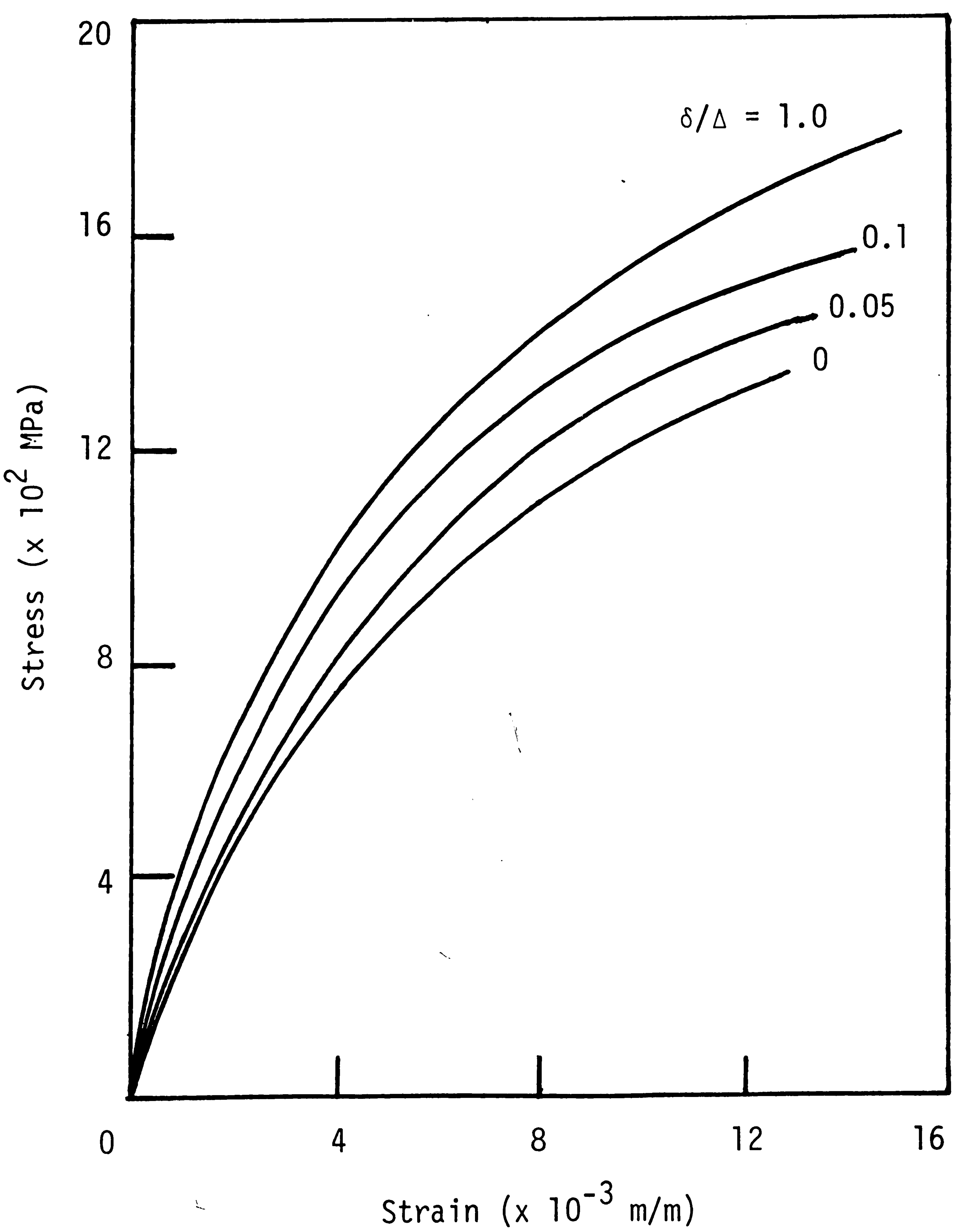

Figure 26. Overall stress and strain behavior of steel cylinder with titanium layer and $\hat{\sigma}_{ys}/\sigma_{ys} = 1.2$.

B. Static Strength and Toughness

Let $\bar{\sigma}_{ys}$, $\bar{\sigma}_u$ and $\overline{(\frac{dW}{dV})}_c$ denote the values of the yield strength, ultimate strength and critical strain energy density averaged overall the entire surface coated cylinder. It is of interest to note from Figures 27 to 29 that all the curves rise sharply up to $\delta/\Delta \simeq 1.5$ after which they level off. This implies that the overall mechanical strength and toughness of the cylinder will not change appreciably if coating thickness is raised beyond 10 to 15% of the cylinder radius. Here, toughness is associated with the critical strain energy density $(dW/dV)_c$ since [3,4]

$$\left(\frac{dW}{dV}\right)_c = \frac{S_c}{r_c} \tag{33}$$

and

$$S_c = \frac{(1+\nu)(1-2\nu)K_{1c}^2}{2\pi E} \tag{34}$$

with K_{1c} being the valid ASTM critical stress intensity factor. In equation (33), r_c is the critical ligament size at the onset of rapid fracture.

Values of $\bar{\sigma}_{ys}$, $\bar{\sigma}_u$ and $\overline{(\frac{dW}{dV})}_c$ for given ratios of δ/Δ = 0, 0.05 and 0.10 for the aluminum and steel cylinder coated by titanium can be found in Tables 8 and 9. In practice, the coating thickness is roughly 10^{-2} cm.

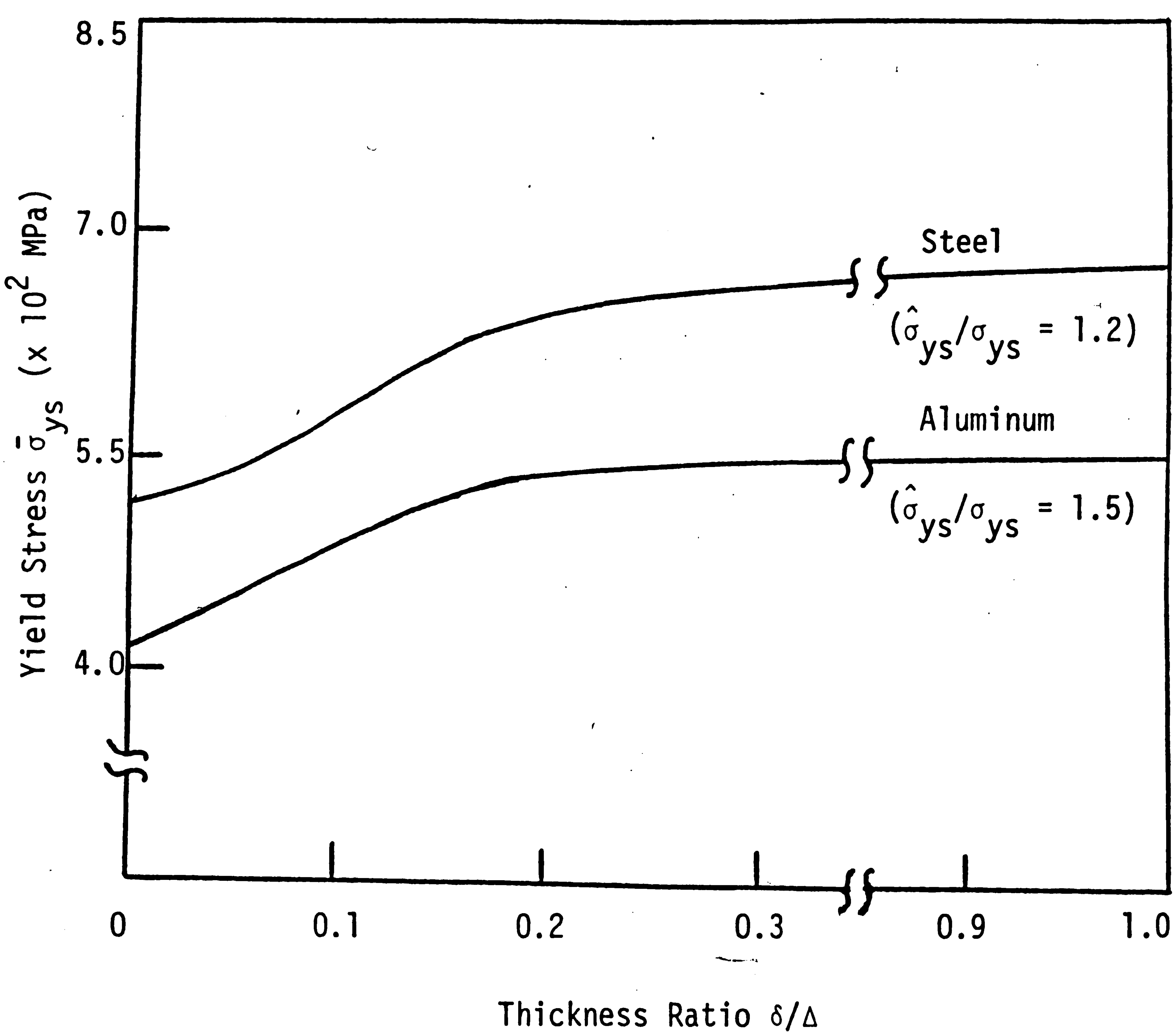

Figure 27. Overall yield stress versus thickness ratio for steel and aluminum cylinder coated with titanium.

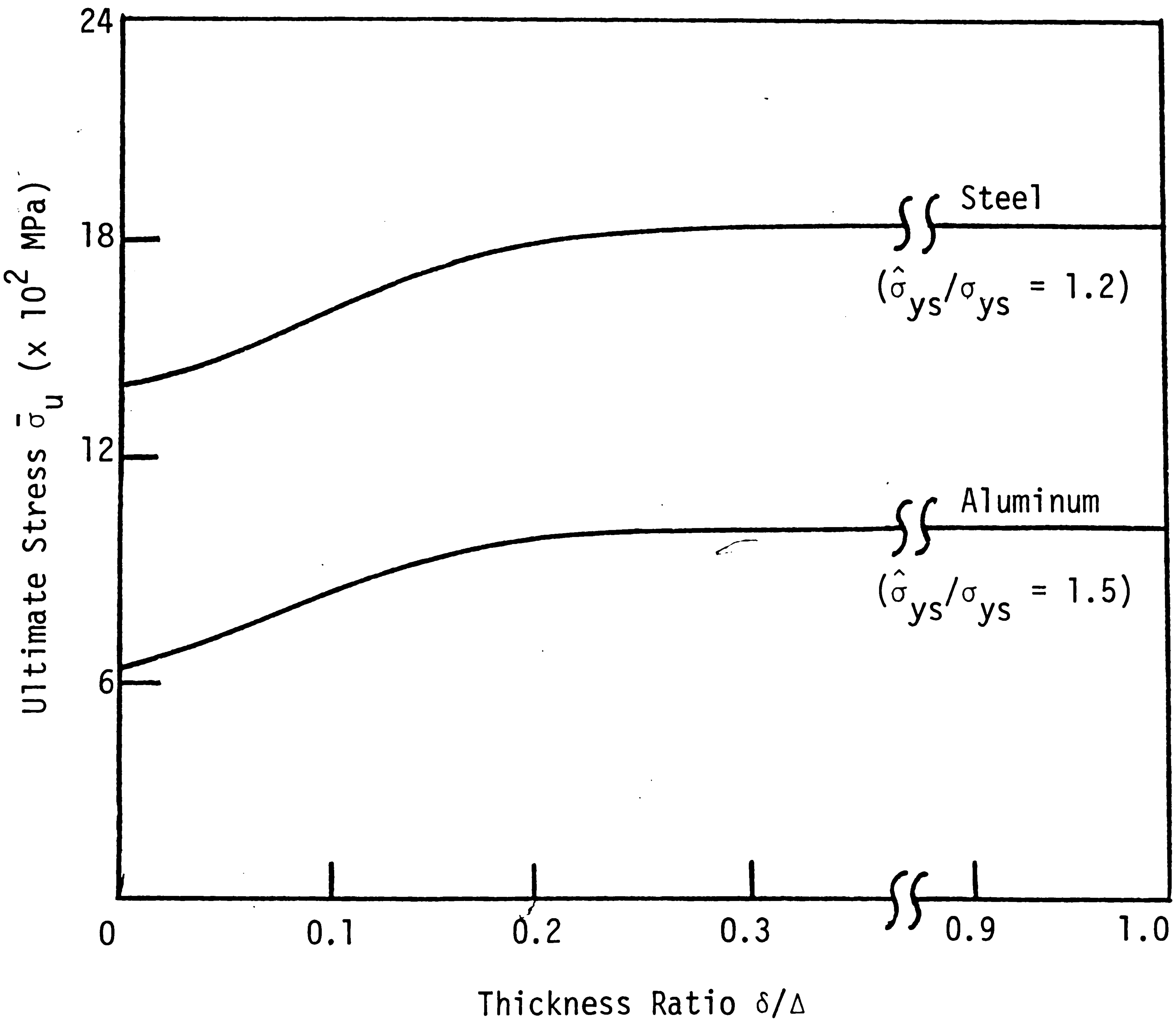

Figure 28. Overall ultimate stress versus thickness ratio for steel and aluminum cylinder coated with titanium.

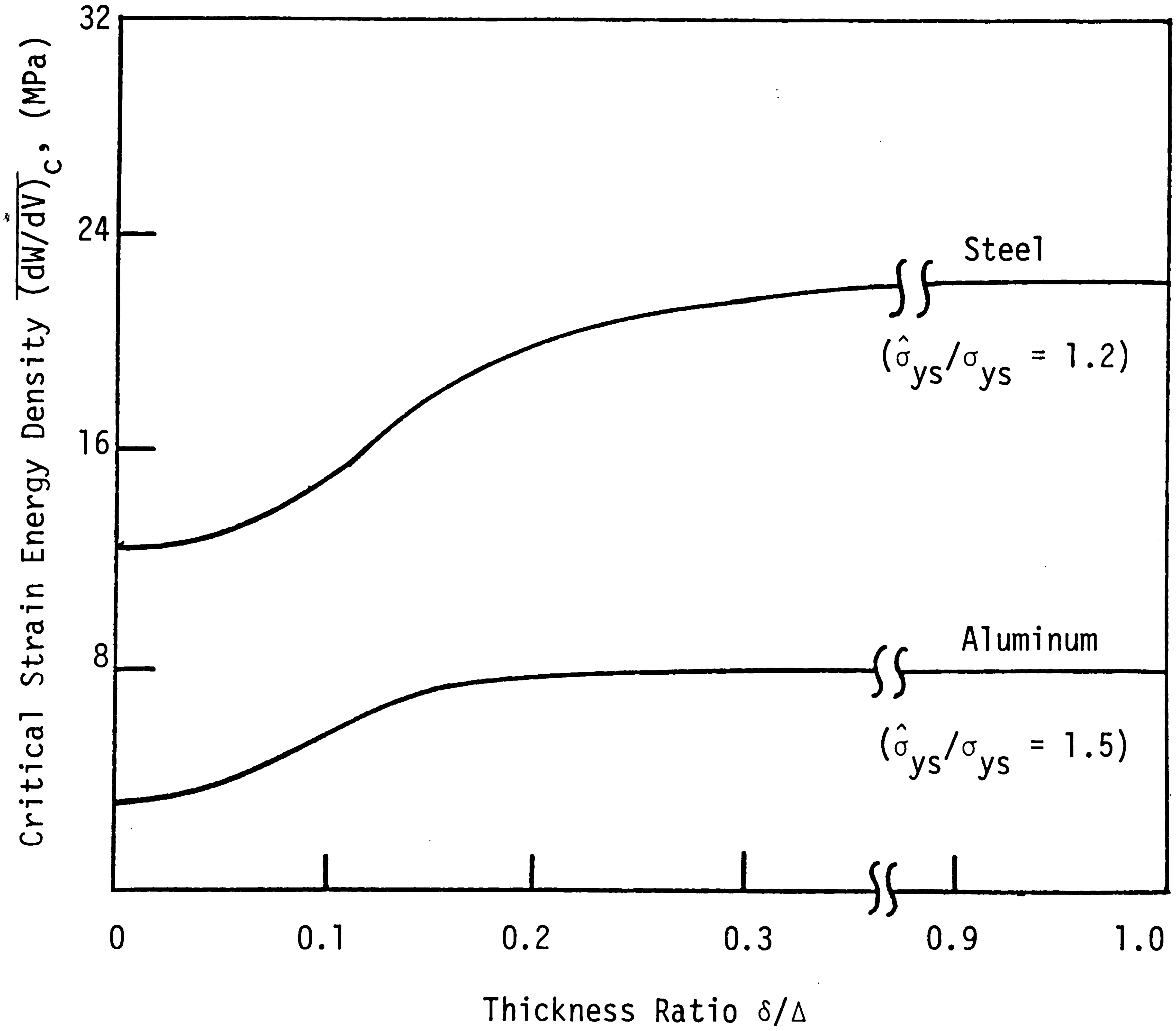

Figure 29. Overall critical strain energy density versus thickness ratio for steel and aluminum cylinder coated with titanium.

Table 8. Static strength and toughness of aluminum cylinder coated by titanium ($\hat{\sigma}_{ys}/\sigma_{ys} = 1.5$)

δ/Δ	$\bar{\sigma}_{ys}$ (MPa)	$\bar{\sigma}_u$ (MPa)	$\overline{(dW/dV)}_c$ (MPa)
0	413.69	620.52	3.22
0.05	448.15	689.47	3.73
0.10	482.63	827.36	5.68

Table 9. Static strength and toughness of steel cylinder coated by titanium ($\hat{\sigma}_{ys}/\sigma_{ys} = 1.2$)

δ/Δ	$\bar{\sigma}_{ys}$ (MPa)	$\bar{\sigma}_u$ (MPa)	$\overline{(dW/dV)}_c$ (MPa)
0	517.11	1378.97	12.32
0.05	540.23	1446.21	13.11
0.10	581.62	1565.49	15.36

C. Fatigue Strength

Since fatigue failure generally initiates from the surface where distortion dominates, it is anticipated that surface coating will also affect the fatigue strength of coated specimens. This is indeed the results found in [11]. Referring to the cylinder in Figure 24, a repeated load of the form [12]

$$\sigma = \frac{1}{2}\sigma_{ys}\,[1 - 0.6\cos(2\pi\tau)] \tag{35}$$

is applied where τ is a dimensionless time parameter. By application of the uniaxial data in Figures 25 and 26, the energy density accumulated for each load cycle is calculated until the total sum reaches the critical value $(dW/dV)_c$ at which point failure of the element is assumed to occur. Let N_f represent the number of cycles at which fatigue failure occurs near the surface layer. A plot of this quantity with δ/Δ is given in Figure 30 for the aluminum and steel cylinder. Again, significant fatigue life is gained within the range of $0 \leq \delta/\Delta \leq 0.1$. Specific percentage of increase in fatigue life can also be found in Tables 10 and 11. The results confirm that a thin coat of new material with a slightly higher yield strength can greatly improve the fatigue strength of metals.

D. Thickness Uniformity

The foregoing calculations assume that the coating is applied uniformly over the cylinder surface, a condition that is difficult to achieve in practice. From dimensional analysis, it is not difficult to deduce that δ will depend directly on the laser power J and time of exposure t and inversely on the pressure P of the melted powder exerted on the substrate, i.e.,

$$\delta = m \frac{Jt}{P} \tag{36}$$

with m being a parameter that depends on the operational condition of irradiation. While t can be set arbitrarily, the combination of m, J

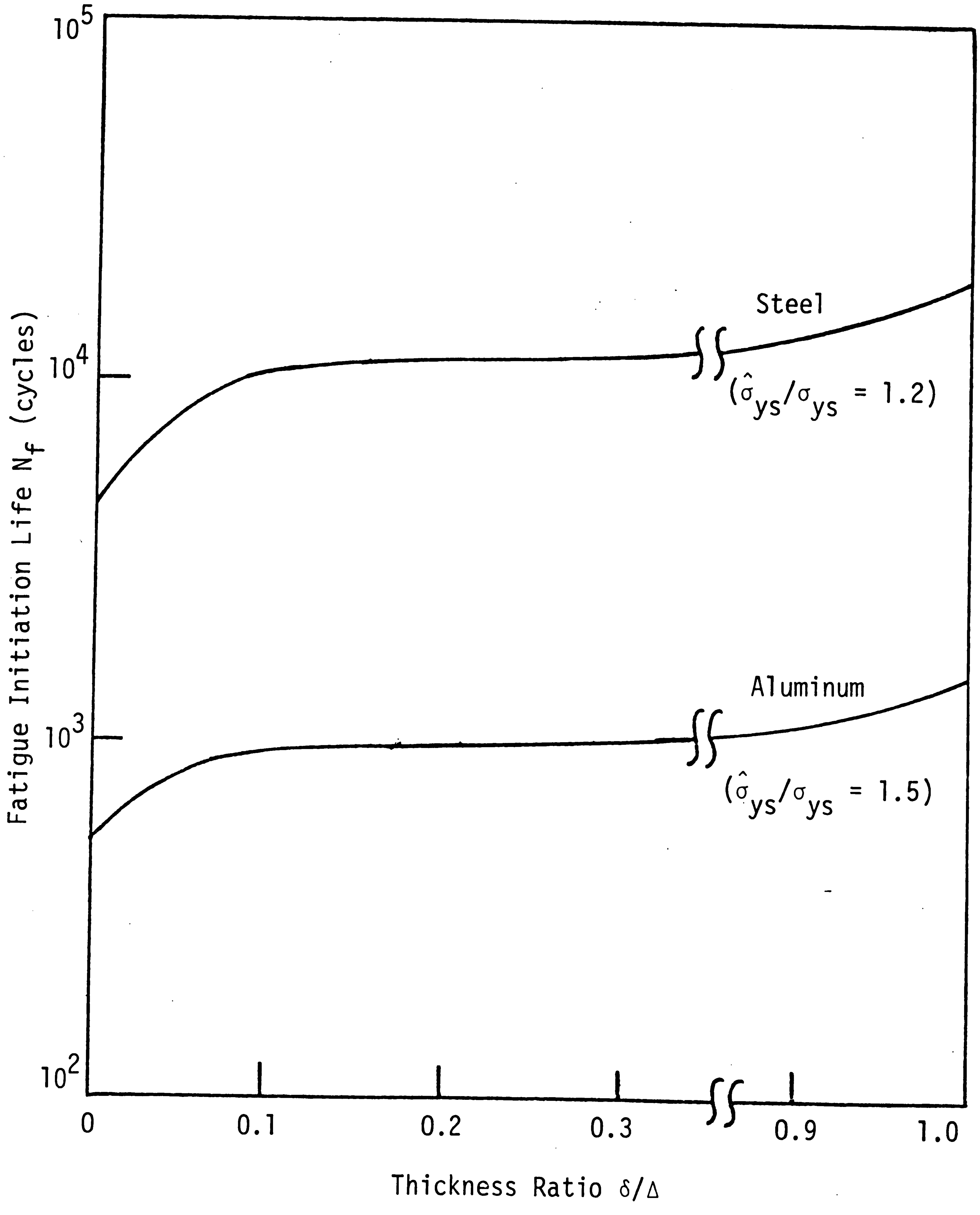

Figure 30. Fatigue initiation life versus thickness ratio for steel and aluminum cylinders coated with titanium.

Table 10. Fatigue initiation life of aluminum cylinder coated by titanium with ($\hat{\sigma}_{ys}/\sigma_{ys}$ = 1.5)

δ/Δ	N_f (Cycle)	Percent Increase (%)
0	465	0
0.05	837	80%
0.10	944	103%

Table 11. Fatigue initiation life of steel cylinder coated by titanium with ($\hat{\sigma}_{ys}/\sigma_{ys}$ = 1.2)

δ/Δ	N_f (Cycle)	Percent Increase (%)
0	3,868	0
0.05	8,765	127%
0.10	10,560	173%

and P should not vary significantly from one location of the substrate to another. Otherwise, nonuniform coating would result. At present, there exists no theory for calculating P that depends on the mass and rate of the melted powder impinging on the substrate. This quantity can also be measured experimentally.

VI. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

This work provides some preliminary considerations on the surface coating of solids by application of lasers that can be focused to give extremely high radiant power density*. Porosity or inhomogeneity of the coating, however, can arise if the fusion process is not properly understood in terms of the microstructure and the protective properties of the coating material. In addition to further refining the analytical model presented earlier, a particle pyrometry system can be developed to collect data on the thermal behavior of hot particles moving in the laser beam. Many of the unknown parameters can thus be determined.

A. Particle Transport System

Figure 31 gives a schematic of a simple particle transport system for the laser spray process. A high power CO_2 laser can act as the source such that the light beam can be reflected by a mirror and focused onto the substrate with or without the aid of a lens system. A gas carrier can be used to regulate the flow of fine powder into the laser stream. The velocity of the particles can be monitored by a camera with displacement data processed automatically with reference to time. Temperature measurement can be made by thermistors calibrated to sense small temperature changes. Alternatively, a special

*Direct surface treatment of material can also be made by changing the surface microstructure via laser heating. A more uniform layer of surface microstructure can enhance the overall mechanical behavior of the solid.

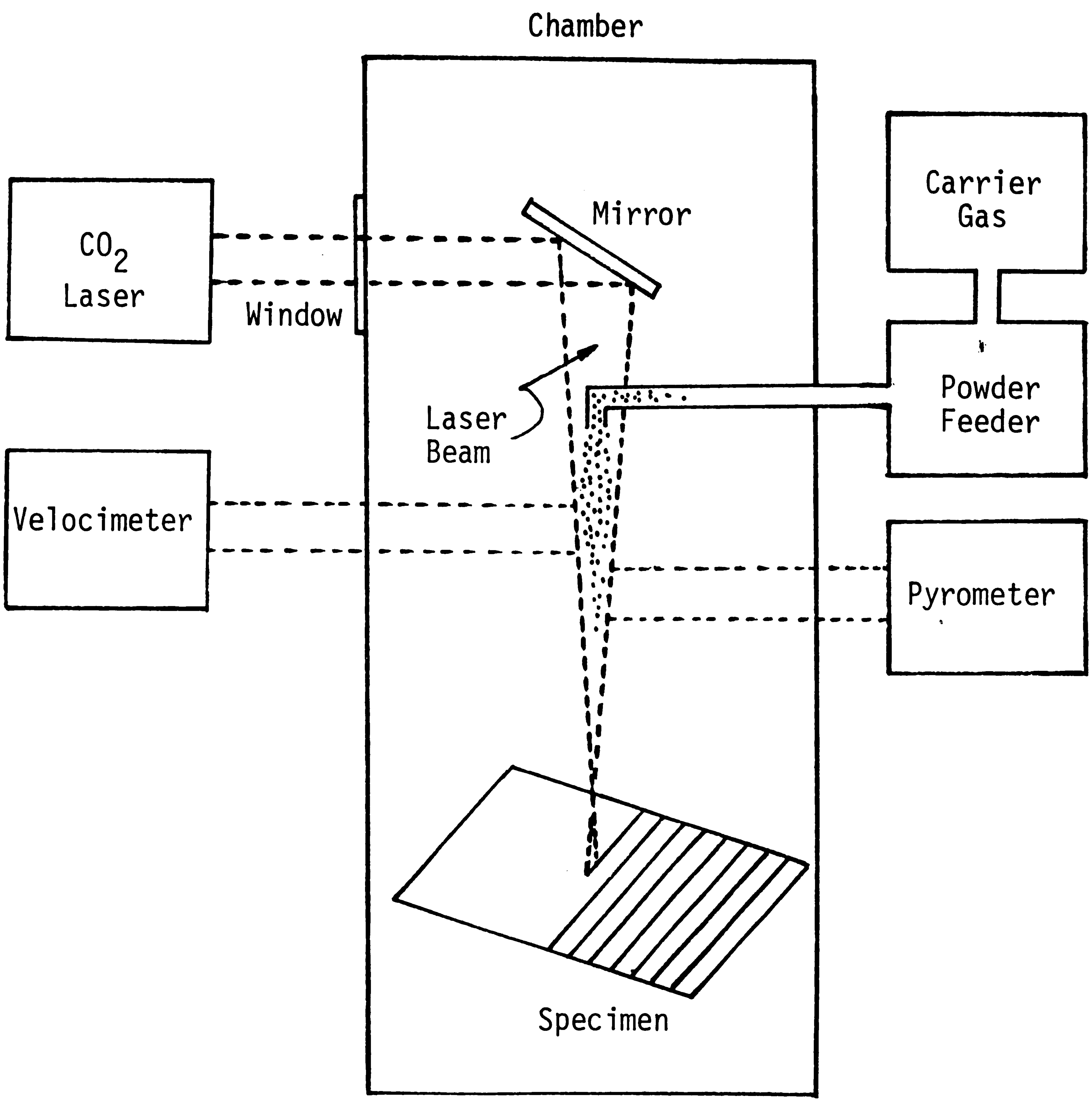

Figure 31. Schematic of particle transport system for laser spray.

pyrometry system can be designed for sensing changes that take place within short time duration. These details are beyond the scope of this discussion and are left for future considerations.

B. Rate of Solidification

Special attention should be given to the rate of powder solidification. The rate at which energy is required to fuse a unit volume of particle becomes essential. Since the substrate tends to act as a large heat sink, cooling will take place more rapidly for those melted particles that first come into contact with the solid surface. The cooling rate slows down as the thickness of the coated layer increases. This nonuniform temperature gradient should be accounted for so as to avoid large changes in the microstructure of the coating through its thickness. The thermal and mechanical interaction effects of this fusion process is not well understood at present; basically, because of the lack of a valid theoretical approach.

The recently advanced theory in [4] may be applied to analyze the phase transformation of the coating material. This approach provides a direct means of determining the thermal-mechanical interactions that occur during laser spray.

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VIII. APPENDICES: COMPUTER PROGRAM AND NUMERICAL RESULTS

Summarized below is a computer program for calculating the temperature of the powder for a specified laser power density. The accompanying numerical results are given for $A\ell_2O_3$, Ti and W with R = 40 μm, η = 1.0 and J that initiates melting.

A. Computer Program

```
      PROGRAM LASER(INPUT,OUTPUT,TAPE1=INPUT,TAPE2=OUTPUT)
      REAL MELTIME
      COMMON /TEST/ XTIME(12000), XTEMP(12000)
      TAIR = 298.00
      SIGMA = 5.668E-08
      READ (1,100) R, RHO, ALPHA, TMELT, TBOIL, MATL
  100 FORMAT (E10.2,F7.2,F4.2,2F7.2,I2)
      READ (1,125) FUSHEAT, XFMHEAT, VAPHEAT
  125 FORMAT (F10.2,F8.2,F10.2)
      AREA = 4*3.14159265*R**2
      DO 175 II= 1,3
      READ (1,150) EPSLN
  150 FORMAT (F4.2)
      IF (MATL.EQ.1) CALL AL2O3 (ALPHA, AREA, EPSLN, FUSHEAT, R,
     +                          RHO, SIGMA, TAIR, TBOIL, TMELT)
      IF (MATL.EQ.2) CALL TI (ALPHA, AREA, EPSLN, FUSHEAT, R, RHO,
     +                   SIGMA, TAIR, TBOIL, TMELT, VAPHEAT, XFMHEAT)
      IF (MATL.EQ.3) CALL W (ALPHA, AREA, EPSLN, FUSHEAT, R,
     +                      RHO, SIGMA, TAIR, TBOIL, TMELT)
      CALL ENDPLT
  175 CONTINUE
      STOP
      END


      SUBROUTINE AL2O3 (ALPHA, AREA, EPSLN, FUSHEAT, R,
     +                  RHO, SIGMA, TAIR, TBOIL, TMELT)
      REAL MELTIME
      COMMON /TEST/ XTIME(12000), XTEMP(12000)
      DELTIME = 0.0001
      SMLTEMP = 0.050
      WRITE (2,200)
  200 FORMAT (///,'DATA OF ALUMINA PARTICLE USED IN CALCULATION :')
      WRITE (2,300) R, RHO, ALPHA, EPSLN, TAIR, TMELT, TBOIL
  300 FORMAT (/,3X,'RADIUS =',E8.2,' M',4X,'DENSITY =',F8.2,' KG/M**3',
     +       4X,'ALPHA =',F4.2,4X,'AREA FACTOR = ',F4.2,4X,/,3X,
     +       'INITIAL TEMP. = ',F6.2,' K',4X,'MELTING PT. = ',F7.2,
     +       ' K',4X,'BOILING PT. = ',F7.2,' K')

      DO 1400 I= 1,5
      TEMP = 298.00
```

Computer Program - (Continued)

```
      TIME = 0.0000
      READ (1,400) POWDEN
  400 FORMAT (E10.2)
      TLASER = SQRT(SQRT(POWDEN/SIGMA))
      WRITE (2,500) POWDEN, TLASER
  500 FORMAT (//,'LASER POWER DENSITY = ',E7.2,' W/M**2',7X,
     +       'LASER TEMPERATURE = ',F8.3,' K')
      WRITE (2,600)
  600 FORMAT (//,5X,'TIME INTERVAL',6X,'TIME',9X,'TEMP. RISE',5X,
     +       'TEMPERATURE',8X,'ABSORPTION',8X,'RADIATION',7X,
     +       'CONVECTION',/)
      ABSN = ALPHA*POWDEN*AREA*EPSLN
      L = 0
      M = 0
      N = 1

      DO 1300 J= 1,6000
      EPSILON = 407.0/TEMP-0.11
      IF (EPSILON.GT.1.00) EPSILON = 1.00
      IF (EPSILON.LT.0.10) EPSILON = 0.10
      THERCON=-2.57158E-03+1.23453E-04*(TEMP/2)-1.11580E-07*(TEMP/2)**2+
     +        8.92014E-11*(TEMP/2)**3-3.65081E-14*(TEMP/2)**4+
     +        6.12873E-18*(TEMP/2)**5
      SPEHEAT = 775.2113+0.624787*TEMP
      EMIS = EPSILON*SIGMA*TEMP**4*AREA
      CONV = THERCON*(TEMP-TAIR)/R*AREA
      DELTEMP = 3.0*DELTIME*(ABSN-EMIS-CONV)/R/RHO/SPEHEAT/AREA
      TEMP = TEMP+DELTEMP
      TIME = TIME+DELTIME
      IF (TEMP.LT.TMELT) GO TO 1000
      IF (M.EQ.N) GO TO 1000

      TEMP = TMELT
      EPSILON = 407.0/TEMP-0.11
      THERCON=-2.57158E-03+1.23453E-04*(TEMP/2)-1.11580E-07*(TEMP/2)**2+
     +        8.92014E-11*(TEMP/2)**3-3.65081E-14*(TEMP/2)**4+
     +        6.12873E-18*(TEMP/2)**5
      EMIS = EPSILON*SIGMA*TEMP**4*AREA
      CONV = THERCON*(TEMP-TAIR)/R*AREA
      MELTIME = RHO*4/3*3.14159265*R**3*FUSHEAT/(ABSN-EMIS-CONV)
      TIME = TIME+MELTIME
      WRITE (2,700) TMELT
  700 FORMAT (/,/,'*** THE MELTING POINT =',F7.2,' K')
      WRITE (2,800) FUSHEAT
  800 FORMAT (4X,'THE HEAT OF FUSION =',F10.1,' J/KG')
      WRITE (2,900) MELTIME
  900 FORMAT (4X,'TIME NEEDED FOR MELTING THE PARTICLE =',F8.6,' SEC',/)
      M = M+1

 1000 WRITE (2,1100) DELTIME, TIME, DELTEMP, TEMP, ABSN, EMIS, CONV
 1100 FORMAT (7X,F7.5,8X,F7.5,8X,F8.3,8X,F8.3,10X,
     +       E10.4,7X,E10.4,7X,E10.4)
      XTIME(J) = ALOG10(TIME)
      XTEMP(J) = ALOG10(TEMP)
      NP = J
      IF (DELTEMP.LT.SMLTEMP) GO TO 1350
      IF (TEMP.LT.TBOIL) GO TO 1300
      WRITE (2,1200) TBOIL
 1200 FORMAT (/,'*** THE TEMPERATURE HAS REACHED THE BOILING POINT ',
     +       F7.2,' K',///)
      GO TO 1350
```

Computer Program - (Continued)

```
1300 CONTINUE

1350 IF (I.GT.1) GO TO 3
     CALL QIKSAX (-1,0)
     CALL PLOT (0.25,1.,-3)
     CALL QIKSET (6.,-4.,0.6,6.,2.,0.33333333)
     CALL QIKPLT (XTIME, XTEMP, NP)
     CALL PLOT (-7.,1.,-3)
     GO TO 1400
   3 CALL QLINE (XTIME, XTEMP, NP, 1)
1400 CONTINUE
     RETURN
     END

     SUBROUTINE TI (ALPHA, AREA, EPSLN, FUSHEAT, R, RHO,
    +        SIGMA, TAIR, TBOIL, TMELT, VAPHEAT, XFMHEAT)
     REAL MELTIME
     COMMON /TEST/ XTIME(12000), XTEMP(12000)
     TXFM = 1155.000
     SMLTEMP = 0.01
     WRITE (2,200)
 200 FORMAT (///,'DATA OF TITANIUM PARTICLE USED IN CALCULATION :')
     WRITE (2,300) R, RHO, ALPHA, EPSLN, TAIR, TMELT, TBOIL
 300 FORMAT (/,3X,'RADIUS =',E8.2,' M',4X,'DENSITY = ',F7.2,' KG/M**3',
    +         4X,'ALPHA =',F4.2,4X,'AREA FACTOR = ',F3.1,4X,/,3X,
    +         'INITIAL TEMP. = ',F7.2,' K',4X,'MELTING PT. = ',F8.2,' K',
    +         4X,'BOILING PT. = ',F7.2,' K')

     DO 1900 I= 1,5
     TEMP = 298.000
     TIME = 0.00000
     DELTIME = 0.0001
     READ (1,400) POWDEN
 400 FORMAT (E10.2)
     TLASER = SQRT(SQRT(POWDEN/SIGMA))
     WRITE (2,500) POWDEN, TLASER
 500 FORMAT(//,'LASER POWER DENSITY = ',E7.2,' W/M**2',7X,
    +         'LASER TEMPERATURE = ',F8.3,' K')
     WRITE (2,600)
 600 FORMAT (/,5X,'TIME-INTERVAL',6X,'TIME',9X,'TEMP. RISE',5X,
    +        'TEMPERATURE',8X,'ABSORPTION',8X,'RADIATION',7X,
    +        'CONVECTION',/)
     ABSN = ALPHA*POWDEN*AREA*EPSLN
     K = 0
     M = 0
     N = 0

     DO 1700 J= 1,12000
     EPSILON = 0.860503-3.42208E-04*TEMP+1.97891E-07*TEMP**2-
    +          1.42424E-10*TEMP**3+3.32102E-14*TEMP**4
     IF (I.EQ.1) GO TO 650
     IF (N.EQ.1) GO TO 1300
     IF (I.EQ.2) GO TO 610
     IF (I.EQ.3) GO TO 620
     IF (I.EQ.4) GO TO 630
     IF (I.EQ.5) GO TO 640
 610 IF (TEMP.GT.2790.00) TCON = 2790
     IF (TEMP.GT.2790.00) GO TO 900
     GO TO 650
```

Computer Program - (Continued)

```
 620 IF (TEMP.GT.2622.00) TCON = 2622
     IF (TEMP.GT.2622.00) GO TO 900
     GO TO 650
 630 IF (TEMP.GT.2585.00) TCON = 2585
     IF (TEMP.GT.2585.00) GO TO 900
     GO TO 650
 640 IF (TEMP.GT.2530.00) TCON = 2530
     IF (TEMP.GT.2530.00) GO TO 900
 650 IF (K.EQ.1) GO TO 800
     SPEHEAT = 320.819+0.998232*TEMP-1.31123E-03*TEMP**2+
    +          7.99335E-07*TEMP**3-1.37763E-10*TEMP**4
     IF (TEMP.LT.TXFM) GO TO 1300

     TEMP = TXFM
     EPSILON = 0.860503-3.42208E-04*TEMP+1.97891E-07*TEMP**2-
    +          1.42424E-10*TEMP**3+3.32102E-14*TEMP**4
     THERCON=-2.57158E-03+1.23453E-04*(TEMP/2)-1.11580E-07*(TEMP/2)**2+
    +         8.92014E-11*(TEMP/2)**3-3.65081E-14*(TEMP/2)**4+
    +         6.12873E-18*(TEMP/2)**5
     EMIS = EPSILON*SIGMA*TEMP**4*AREA
     CONV = THERCON*(TEMP-TAIR)/R*AREA
     XFMTIME = RHO*4/3*3.14159265*R**3*XFMHEAT/(ABSN-EMIS-CONV)
     TIME = TIME+XFMTIME
     WRITE (2,700) TXFM, XFMHEAT, XFMTIME
 700 FORMAT (/,'*** THE PHASE TRANSFORMATION TEMPERATURE = ',F7.2,' K',
    + /,4X,'TITANIUM TRANSFORMS TO BETA PHASE FROM ALPHA PHASE HERE.',
    +     /,4X,'THE HEAT OF TRANSFORMATION = ',F8.2,' J/KG',
    +     /,4X,'TIME NEEDED FOR TRANSFORMING THE PARTICLE = ',F8.6,
    +         ' SEC',/)
     K = K+1

 800 SPEHEAT = 1656.72-1.02865*TEMP-5.80073E-04*TEMP**2+
    +          7.91070E-07*TEMP**3-1.47745E-10*TEMP**4-
    +          8.94562E-15*TEMP**5
     GO TO 1000
 900 HEAT = 1656.72-1.02865*TCON-5.80073E-04*TCON**2+
    +        7.91070E-07*TCON**3-1.47745E-10*TCON**4-
    +        8.94562E-15*TCON**5
     N = N+1
     SPEHEAT = HEAT
1000 IF (TEMP.LT.TMELT) GO TO 1300
     IF (M.EQ.1) GO TO 1300

     TEMP = TMELT
     EPSILON = 0.860503-3.42208E-04*TEMP+1.97891E-07*TEMP**2-
    +          1.42424E-10*TEMP**3+3.32102E-14*TEMP**4
     THERCON=-2.57158E-03+1.23453E-04*(TEMP/2)-1.11580E-07*(TEMP/2)**2+
    +         8.92014E-11*(TEMP/2)**3-3.65081E-14*(TEMP/2)**4+
    +         6.12873E-18*(TEMP/2)**5
     EMIS = EPSILON*SIGMA*TEMP**4*AREA
     CONV = THERCON*(TEMP-TAIR)/R*AREA
     MELTIME = RHO*4/3*3.14159265*R**3*FUSHEAT/(ABSN-EMIS-CONV)
     TIME = TIME+MELTIME
     WRITE (2,1100) TMELT, FUSHEAT
1100 FORMAT (//,'*** THE MELTING POINT = ',F7.2,' K',/,
    +         4X,'THE HEAT OF FUSION = ',F10.2,' J/KG')
     WRITE (2,1200) MELTIME
1200 FORMAT (4X,'TIME NEEDED FOR MELTING THE PARTICLE =',F8.6,' SEC',/)
     M = M+1
```

Computer Program - (Continued)

```
1300 THERCON=-2.57158E-03+1.23453E-04*(TEMP/2)-1.11580E-07*(TEMP/2)**2+
    +          8.92014E-11*(TEMP/2)**3-3.65081E-14*(TEMP/2)**4+
    +          6.12873E-18*(TEMP/2)**5
      EMIS = EPSILON*SIGMA*TEMP**4*AREA
      CONV = THERCON*(TEMP-TAIR)/R*AREA
      DELTEMP = 3.0*DELTIME*(ABSN-EMIS-CONV)/R/RHO/SPEHEAT/AREA
      TEMP = TEMP+DELTEMP
      TIME = TIME+DELTIME
      WRITE (2,1500) DELTIME, TIME, DELTEMP, TEMP, ABSN, EMIS, CONV
1500 FORMAT (7X,F7.5,8X,F7.5,8X,F8.3,8X,F8.3,10X,
    +        E10.4,7X,E10.4,7X,E10.4)
      IF (TIME.GT.0.002) DELTIME = 0.00001
      XTIME(J) = ALOG10(TIME)
      XTEMP(J) = ALOG10(TEMP)
      NP = J
1550 IF (DELTEMP.LT.SMLTEMP) GO TO 1800
      IF (TEMP.LT.TBOIL) GO TO 1700


      TEMP = TBOIL
      EPSILON = 0.860503-3.42208E-04*TEMP+1.97891E-07*TEMP**2-
    +           1.42424E-10*TEMP**3+3.32102E-14*TEMP**4
      THERCON=-2.57158E-03+1.23453E-04*(TEMP/2)-1.11580E-07*(TEMP/2)**2+
    +          8.92014E-11*(TEMP/2)**3-3.65081E-14*(TEMP/2)**4+
    +          6.12873E-18*(TEMP/2)**5
      EMIS = EPSILON*SIGMA*TEMP**4*AREA
      CONV = THERCON*(TEMP-TAIR)/R*AREA
      VAPTIME = RHO*4/3*3.14159265*R**3*VAPHEAT/(ABSN-EMIS-CONV)
      TIME = TIME+VAPTIME
      DELTEMP = 0.000
      DELTIME = VAPTIME
      WRITE (2,1575) DELTIME, TIME, DELTEMP, TEMP, ABSN, EMIS, CONV
1575 FORMAT (7X,F7.5,8X,F7.5,8X,F8.3,8X,F8.3,10X,
    +        E10.4,7X,E10.4,7X,E10.4)
      XTIME(J+1) = ALOG10(TIME)
      XTEMP(J+1) = ALOG10(TEMP)
      NP = J+1
      WRITE (2,1600) TBOIL, VAPHEAT, VAPTIME
1600 FORMAT (/,'*** THE TEMPERATURE HAS REACHED THE BOILING POINT ',
    +   F7.2,' K.',/,4X,'THE HEAT OF VAPORIZATION = ',F10.2,' J/KG',/,
    +   4X,'TIME NEEDED FOR VAPORIZING THE TITANIUM = ',F8.6,' SEC')
      GO TO 1800
1700 CONTINUE

1800 IF (I.GT.1) GO TO 3
      CALL QIKSAX (-1,0)
      CALL PLOT (0.25,1.,-3)
      CALL QIKSET (6.,-4.,0.6,6.,2.,0.33333333)
      CALL QIKPLT (XTIME, XTEMP, NP)
      CALL PLOT (-7.,1.,-3)
      GO TO 1900
    3 CALL QLINE (XTIME, XTEMP, NP, 1)
1900 CONTINUE
      RETURN
      END


      SUBROUTINE W (ALPHA, AREA, EPSLN, FUSHEAT, R,
    +             RHO, SIGMA, TAIR, TBOIL, TMELT)
      REAL MELTIME
      COMMON /TEST/ XTIME(12000), XTEMP(12000)
      SMLTEMP = 0.005
```

Computer Program - (Continued)

```
      WRITE (2,200)
  200 FORMAT (///,'DATA OF TUNGSTEN PARTICLE USED IN CALCULATION :')
      WRITE (2,300) R, RHO, ALPHA, EPSLN, TAIR, TMELT, TBOIL
  300 FORMAT (/,3X,'RADIUS = ',E8.2,' M',4X,'DENSITY =',F9.2,' KG/M**3',
     +        4X,'ALPHA =',F4.2,4X,'AREA FACTOR = ',F4.2,4X,/,3X,
     +        'INITIAL TEMP. = ',F6.2,' K',4X,'MELTING PT. =',F8.2,' K',
     +        4X,'BOILING POINT = ',F7.2,' K')

      DO 1400 I= 1,5
      TEMP = 298.000
      TIME = 0.00000
      DELTIME = 0.0001
      READ (1,400) POWDEN
  400 FORMAT (E10.2)
      TLASER = SQRT(SQRT(POWDEN/SIGMA))
      WRITE (2,500) POWDEN, TLASER
  500 FORMAT (//,'LASER POWER DENSITY = ',E7.2,' W/M**2',7X,
     +        'LASER TEMPERATURE = ',F9.3,' K')
      WRITE (2,600)
  600 FORMAT(/,5X,'TIME INTERVAL',6X,'TIME',9X,'TEMP. RISE',5X,
     +       'TEMPERATURE',8X,'ABSORPTION',8X,'RADIATION',8X,
     +       'CONVECTION')
      ABSN = ALPHA*POWDEN*AREA*EPSLN
      M = 0

      DO 1200 J= 1,4000
      EPSILON = 0.28509-2.27904E-05*TEMP+1.64439E-07*TEMP**2-
     +          6.14476E-11*TEMP**3+6.81298E-15*TEMP**4
      SPEHEAT = (0.0302125+5.43353E-06*TEMP+1.05195E-10*TEMP**2+
     +          1.08512E-13*TEMP**3-3.39950E-17*TEMP**4+
     +          3.60112E-21*TEMP**5)*4186.8
      THERCON=-2.57158E-03+1.23453E-04*(TEMP/2)-1.11580E-07*(TEMP/2)**2+
     +        8.92014E-11*(TEMP/2)**3-3.65081E-14*(TEMP/2)**4+
     +        6.12873E-18*(TEMP/2)**5
      EMIS = EPSILON*SIGMA*TEMP**4*AREA
      CONV = THERCON*(TEMP-TAIR)/R*AREA
      DELTEMP = 3.0*DELTIME*(ABSN-EMIS-CONV)/R/RHO/SPEHEAT/AREA
      TEMP = TEMP+DELTEMP
      TIME = TIME+DELTIME
      IF (TEMP.LT.TMELT) GO TO 900
      IF (M.EQ.1) GO TO 900

      TEMP = TMELT
      EPSILON = 0.28509-2.27904E-05*TEMP+1.64439E-07*TEMP**2-
     +          6.14476E-11*TEMP**3+6.81298E-15*TEMP**4
      THERCON = -2.57158E-03+1.23453E-04*(TEMP/2)-
     +          1.11580E-07*(TEMP/2)**2+8.92014E-11*(TEMP/2)**3-
     +          3.65081E-14*(TEMP/2)**4+6.12873E-18*(TEMP/2)**5
      EMIS = EPSILON*SIGMA*TEMP**4*AREA
      CONV = THERCON*(TEMP-TAIR)/R*AREA
      MELTIME = RHO*4/3*3.14159265*R**3*FUSHEAT/(ABSN-EMIS-CONV)
      TIME = TIME+MELTIME
      WRITE (2,700) TMELT, FUSHEAT
  700 FORMAT (//,'*** THE MELTING POINT = ',F7.2,' K',/,
     +        '     THE HEAT OF FUSION = ',F10.2,' J/KG')
      WRITE (2,800) MELTIME
  800 FORMAT (4X,'TIME NEEDED FOR MELTING THE PARTICLE =',F9.6,' SEC',/)
      M = M+1

  900 WRITE (2,1000) DELTIME, TIME, DELTEMP, TEMP, ABSN, EMIS, CONV
```

Computer Program - (Continued)

```
1000 FORMAT(7X,F7.5,8X,F7.5,8X,F8.3,8X,F8.3,10X,
    +       E10.4,7X,E10.4,7X,E10.4)
     XTIME(J) = ALOG10(TIME)
     XTEMP(J) = ALOG10(TEMP)
     NP = J
1050 IF (DELTEMP.LT.SMLTEMP) GO TO 1300
     IF (TEMP.LT.TBOIL) GO TO 1200
     WRITE (2,1100) TBOIL
1100 FORMAT (/,'*** THE TEMPERATURE HAS REACHED THE BOILING POINT ',
    +        F7.2,' K',/)
     GO TO 1300
1200 CONTINUE

1300 IF (I.GT.1) GO TO 3
     CALL QIKSAX (-1,0)
     CALL PLOT (0.25,1.,-3)
     CALL QIKSET (6.,-4.,0.6,6.,2.,0.33333333)
     CALL QIKPLT (XTIME, XTEMP, NP)
     CALL PLOT (-7.,1.,-3)
     GO TO 1400
   3 CALL QLINE (XTIME, XTEMP, NP, 1)
1400 CONTINUE
     RETURN
     END
```

B. Numerical Results: Aluminum Oxide

DATA OF ALUMINA PARTICLE USED IN CALCULATION :

RADIUS = .40E-04 M   DENSITY = 3965.00 KG/M**3   ALPHA = .29   AREA FACTOR = 1.00
INITIAL TEMP. = 298.00 K   MELTING POINT = 2345.00 K   BOILING POINT = 3253.00 K

LASER POWER DENSITY = .20E+08 W/M**2   LASER TEMPERATURE = 4334.111 K

TIME INCREMENT	TIME	TEMP. RISE	TEMPERATURE	ABSORPTION	RADIATION	CONVECTION
.00010	.00010	11.411	309.411	.1166E+00	.8987E-05	.0000E+00
.00010	.00020	11.319	320.729	.1166E+00	.1044E-04	.8125E-04
.00010	.00030	11.228	331.957	.1166E+00	.1206E-04	.1680E-03
.00010	.00040	11.139	343.096	.1166E+00	.1384E-04	.2599E-03
.00010	.00050	11.051	354.147	.1166E+00	.1579E-04	.3568E-03
.00010	.00060	10.965	365.112	.1166E+00	.1793E-04	.4586E-03
.00010	.00070	10.880	375.992	.1166E+00	.2025E-04	.5651E-03
.00010	.00080	10.796	386.788	.1166E+00	.2215E-04	.6759E-03
.00010	.00090	10.714	397.501	.1166E+00	.2403E-04	.7911E-03
.00010	.00100	10.632	408.134	.1166E+00	.2600E-04	.9104E-03
.00010	.00110	10.552	418.686	.1166E+00	.2805E-04	.1034E-02
.00010	.00120	10.474	429.160	.1166E+00	.3019E-04	.1161E-02
.00010	.00130	10.396	439.555	.1166E+00	.3241E-04	.1291E-02
.00010	.00140	10.319	449.875	.1166E+00	.3471E-04	.1426E-02
.00010	.00150	10.244	460.119	.1166E+00	.3710E-04	.1563E-02
.00010	.00160	10.169	470.288	.1166E+00	.3956E-04	.1704E-02
.00010	.00170	10.096	480.384	.1166E+00	.4211E-04	.1848E-02
.00010	.00180	10.024	490.408	.1166E+00	.4474E-04	.1995E-02
.00010	.00190	9.952	500.360	.1166E+00	.4745E-04	.2145E-02
.00010	.00200	9.882	510.243	.1166E+00	.5025E-04	.2298E-02
.00010	.00210	9.813	520.055	.1166E+00	.5312E-04	.2453E-02
.00010	.00220	9.744	529.800	.1166E+00	.5607E-04	.2611E-02
.00010	.00230	9.677	539.476	.1166E+00	.5910E-04	.2772E-02
.00010	.00240	9.610	549.087	.1166E+00	.6221E-04	.2934E-02
.00010	.00250	9.544	558.631	.1166E+00	.6539E-04	.3100E-02
.00010	.00260	9.479	568.111	.1166E+00	.6865E-04	.3267E-02
.00010	.00270	9.415	577.526	.1166E+00	.7199E-04	.3437E-02
.00010	.00280	9.352	586.878	.1166E+00	.7540E-04	.3608E-02
.00010	.00290	9.290	596.168	.1166E+00	.7888E-04	.3782E-02
.00010	.00300	9.228	605.396	.1166E+00	.8244E-04	.3957E-02
.00010	.00310	9.167	614.563	.1166E+00	.8607E-04	.4134E-02
.00010	.00320	9.107	623.670	.1166E+00	.8978E-04	.4313E-02
.00010	.00330	9.048	632.718	.1166E+00	.9355E-04	.4494E-02
.00010	.00340	8.989	641.707	.1166E+00	.9739E-04	.4676E-02
.00010	.00350	8.931	650.638	.1166E+00	.1013E-03	.4860E-02
.00010	.00360	8.874	659.512	.1166E+00	.1053E-03	.5046E-02
.00010	.00370	8.817	668.329	.1166E+00	.1093E-03	.5233E-02
.00010	.00380	8.761	677.090	.1166E+00	.1135E-03	.5421E-02
.00010	.00390	8.706	685.797	.1166E+00	.1176E-03	.5610E-02
.00010	.00400	8.652	694.448	.1166E+00	.1219E-03	.5801E-02
.00010	.00410	8.598	703.046	.1166E+00	.1262E-03	.5993E-02
.00010	.00420	8.544	711.590	.1166E+00	.1306E-03	.6187E-02
.00010	.00430	8.491	720.081	.1166E+00	.1350E-03	.6381E-02
.00010	.00440	8.439	728.521	.1166E+00	.1395E-03	.6577E-02
.00010	.00450	8.388	736.909	.1166E+00	.1440E-03	.6773E-02
.00010	.00460	8.337	745.245	.1166E+00	.1486E-03	.6971E-02
.00010	.00470	8.286	753.532	.1166E+00	.1533E-03	.7170E-02
.00010	.00480	8.237	761.768	.1166E+00	.1580E-03	.7369E-02
.00010	.00490	8.187	769.956	.1166E+00	.1628E-03	.7570E-02

Numerical Results - (Continued)

.00010	.00500	8.138	778.094	.1166E+00	.1677E-03	.7771E-02
.00010	.00510	8.090	786.184	.1166E+00	.1726E-03	.7973E-02
.00010	.00520	8.043	794.227	.1166E+00	.1775E-03	.8176E-02
.00010	.00530	7.995	802.222	.1166E+00	.1825E-03	.8380E-02
.00010	.00540	7.949	810.171	.1166E+00	.1875E-03	.8584E-02
.00010	.00550	7.902	818.073	.1166E+00	.1926E-03	.8789E-02
.00010	.00560	7.857	825.930	.1166E+00	.1978E-03	.8995E-02
.00010	.00570	7.811	833.741	.1166E+00	.2030E-03	.9202E-02
.00010	.00580	7.766	841.507	.1166E+00	.2082E-03	.9409E-02
.00010	.00590	7.722	849.229	.1166E+00	.2135E-03	.9616E-02
.00010	.00600	7.678	856.908	.1166E+00	.2189E-03	.9825E-02
.00010	.00610	7.635	864.542	.1166E+00	.2243E-03	.1003E-01
.00010	.00620	7.592	872.134	.1166E+00	.2297E-03	.1024E-01
.00010	.00630	7.549	879.683	.1166E+00	.2352E-03	.1045E-01
.00010	.00640	7.507	887.190	.1166E+00	.2407E-03	.1066E-01
.00010	.00650	7.465	894.655	.1166E+00	.2462E-03	.1087E-01
.00010	.00660	7.424	902.079	.1166E+00	.2518E-03	.1108E-01
.00010	.00670	7.383	909.461	.1166E+00	.2575E-03	.1130E-01
.00010	.00680	7.342	916.803	.1166E+00	.2631E-03	.1151E-01
.00010	.00690	7.302	924.105	.1166E+00	.2689E-03	.1172E-01
.00010	.00700	7.262	931.368	.1166E+00	.2746E-03	.1193E-01
.00010	.00710	7.223	938.590	.1166E+00	.2804E-03	.1214E-01
.00010	.00720	7.184	945.774	.1166E+00	.2862E-03	.1236E-01
.00010	.00730	7.145	952.919	.1166E+00	.2921E-03	.1257E-01
.00010	.00740	7.107	960.025	.1166E+00	.2980E-03	.1278E-01
.00010	.00750	7.069	967.094	.1166E+00	.3039E-03	.1300E-01
.00010	.00760	7.031	974.125	.1166E+00	.3099E-03	.1321E-01
.00010	.00770	6.994	981.119	.1166E+00	.3159E-03	.1343E-01
.00010	.00780	6.957	988.076	.1166E+00	.3219E-03	.1364E-01
.00010	.00790	6.920	994.996	.1166E+00	.3279E-03	.1386E-01
.00010	.00800	6.884	1001.879	.1166E+00	.3340E-03	.1407E-01
.00010	.00810	6.848	1008.727	.1166E+00	.3401E-03	.1429E-01
.00010	.00820	6.812	1015.539	.1166E+00	.3463E-03	.1450E-01
.00010	.00830	6.777	1022.316	.1166E+00	.3525E-03	.1472E-01
.00010	.00840	6.742	1029.058	.1166E+00	.3586E-03	.1493E-01
.00010	.00850	6.707	1035.765	.1166E+00	.3649E-03	.1515E-01
.00010	.00860	6.673	1042.438	.1166E+00	.3711E-03	.1536E-01
.00010	.00870	6.638	1049.076	.1166E+00	.3774E-03	.1558E-01
.00010	.00880	6.605	1055.681	.1166E+00	.3837E-03	.1579E-01
.00010	.00890	6.571	1062.252	.1166E+00	.3900E-03	.1601E-01
.00010	.00900	6.538	1068.789	.1166E+00	.3963E-03	.1623E-01
.00010	.00910	6.505	1075.294	.1166E+00	.4027E-03	.1644E-01
.00010	.00920	6.472	1081.766	.1166E+00	.4091E-03	.1666E-01
.00010	.00930	6.440	1088.206	.1166E+00	.4155E-03	.1687E-01
.00010	.00940	6.407	1094.613	.1166E+00	.4219E-03	.1709E-01
.00010	.00950	6.375	1100.989	.1166E+00	.4284E-03	.1731E-01
.00010	.00960	6.344	1107.332	.1166E+00	.4348E-03	.1752E-01
.00010	.00970	6.312	1113.645	.1166E+00	.4413E-03	.1774E-01
.00010	.00980	6.281	1119.926	.1166E+00	.4478E-03	.1795E-01
.00010	.00990	6.250	1126.176	.1166E+00	.4543E-03	.1817E-01
.00010	.01000	6.220	1132.396	.1166E+00	.4608E-03	.1839E-01
.00010	.01010	6.189	1138.585	.1166E+00	.4674E-03	.1860E-01
.00010	.01020	6.159	1144.745	.1166E+00	.4739E-03	.1882E-01
.00010	.01030	6.129	1150.874	.1166E+00	.4805E-03	.1903E-01
.00010	.01040	6.099	1156.973	.1166E+00	.4871E-03	.1925E-01
.00010	.01050	6.070	1163.043	.1166E+00	.4937E-03	.1946E-01
.00010	.01060	6.041	1169.084	.1166E+00	.5003E-03	.1968E-01
.00010	.01070	6.012	1175.096	.1166E+00	.5070E-03	.1990E-01

Numerical Results - (Continued)

.00010	.01080	5.983	1181.079	.1166E+00	.5136E-03	.2011E-01
.00010	.01090	5.954	1187.033	.1166E+00	.5202E-03	.2033E-01
.00010	.01100	5.926	1192.959	.1166E+00	.5269E-03	.2054E-01
.00010	.01110	5.898	1198.857	.1166E+00	.5336E-03	.2076E-01
.00010	.01120	5.870	1204.727	.1166E+00	.5402E-03	.2097E-01
.00010	.01130	5.842	1210.570	.1166E+00	.5469E-03	.2119E-01
.00010	.01140	5.815	1216.384	.1166E+00	.5536E-03	.2140E-01
.00010	.01150	5.787	1222.172	.1166E+00	.5603E-03	.2161E-01
.00010	.01160	5.760	1227.932	.1166E+00	.5670E-03	.2183E-01
.00010	.01170	5.733	1233.666	.1166E+00	.5738E-03	.2204E-01
.00010	.01180	5.707	1239.373	.1166E+00	.5805E-03	.2226E-01
.00010	.01190	5.680	1245.053	.1166E+00	.5872E-03	.2247E-01
.00010	.01200	5.654	1250.707	.1166E+00	.5940E-03	.2268E-01
.00010	.01210	5.628	1256.334	.1166E+00	.6007E-03	.2290E-01
.00010	.01220	5.602	1261.936	.1166E+00	.6074E-03	.2311E-01
.00010	.01230	5.576	1267.512	.1166E+00	.6142E-03	.2332E-01
.00010	.01240	5.551	1273.063	.1166E+00	.6210E-03	.2354E-01
.00010	.01250	5.525	1278.588	.1166E+00	.6277E-03	.2375E-01
.00010	.01260	5.500	1284.088	.1166E+00	.6345E-03	.2396E-01
.00010	.01270	5.475	1289.563	.1166E+00	.6412E-03	.2417E-01
.00010	.01280	5.450	1295.013	.1166E+00	.6480E-03	.2438E-01
.00010	.01290	5.425	1300.438	.1166E+00	.6548E-03	.2460E-01
.00010	.01300	5.401	1305.839	.1166E+00	.6615E-03	.2481E-01
.00010	.01310	5.376	1311.215	.1166E+00	.6683E-03	.2502E-01
.00010	.01320	5.352	1316.568	.1166E+00	.6751E-03	.2523E-01
.00010	.01330	5.328	1321.896	.1166E+00	.6818E-03	.2544E-01
.00010	.01340	5.304	1327.200	.1166E+00	.6886E-03	.2565E-01
.00010	.01350	5.281	1332.481	.1166E+00	.6954E-03	.2586E-01
.00010	.01360	5.257	1337.738	.1166E+00	.7021E-03	.2607E-01
.00010	.01370	5.234	1342.972	.1166E+00	.7089E-03	.2628E-01
.00010	.01380	5.211	1348.182	.1166E+00	.7157E-03	.2649E-01
.00010	.01390	5.188	1353.370	.1166E+00	.7224E-03	.2670E-01
.00010	.01400	5.165	1358.534	.1166E+00	.7292E-03	.2691E-01
.00010	.01410	5.142	1363.676	.1166E+00	.7360E-03	.2712E-01
.00010	.01420	5.119	1368.796	.1166E+00	.7427E-03	.2733E-01
.00010	.01430	5.097	1373.892	.1166E+00	.7495E-03	.2754E-01
.00010	.01440	5.074	1378.967	.1166E+00	.7562E-03	.2775E-01
.00010	.01450	5.052	1384.019	.1166E+00	.7629E-03	.2795E-01
.00010	.01460	5.030	1389.049	.1166E+00	.7697E-03	.2816E-01
.00010	.01470	5.008	1394.058	.1166E+00	.7764E-03	.2837E-01
.00010	.01480	4.987	1399.044	.1166E+00	.7831E-03	.2858E-01
.00010	.01490	4.965	1404.009	.1166E+00	.7899E-03	.2878E-01
.00010	.01500	4.944	1408.953	.1166E+00	.7966E-03	.2899E-01
.00010	.01510	4.922	1413.875	.1166E+00	.8033E-03	.2919E-01
.00010	.01520	4.901	1418.776	.1166E+00	.8100E-03	.2940E-01
.00010	.01530	4.880	1423.656	.1166E+00	.8167E-03	.2961E-01
.00010	.01540	4.859	1428.515	.1166E+00	.8234E-03	.2981E-01
.00010	.01550	4.838	1433.354	.1166E+00	.8301E-03	.3002E-01
.00010	.01560	4.818	1438.171	.1166E+00	.8368E-03	.3022E-01
.00010	.01570	4.797	1442.968	.1166E+00	.8434E-03	.3043E-01
.00010	.01580	4.777	1447.745	.1166E+00	.8501E-03	.3063E-01
.00010	.01590	4.756	1452.501	.1166E+00	.8567E-03	.3083E-01
.00010	.01600	4.736	1457.238	.1166E+00	.8634E-03	.3104E-01
.00010	.01610	4.716	1461.954	.1166E+00	.8700E-03	.3124E-01
.00010	.01620	4.696	1466.650	.1166E+00	.8766E-03	.3144E-01
.00010	.01630	4.677	1471.327	.1166E+00	.8833E-03	.3165E-01
.00010	.01640	4.657	1475.984	.1166E+00	.8899E-03	.3185E-01
.00010	.01650	4.637	1480.621	.1166E+00	.8965E-03	.3205E-01

Numerical Results - (Continued)

.00010	.01660	4.618	1485.239	.1166E+00	.9031E-03	.3225E-01
.00010	.01670	4.599	1489.837	.1166E+00	.9096E-03	.3246E-01
.00010	.01680	4.579	1494.417	.1166E+00	.9162E-03	.3266E-01
.00010	.01690	4.560	1498.977	.1166E+00	.9228E-03	.3286E-01
.00010	.01700	4.541	1503.518	.1166E+00	.9293E-03	.3306E-01
.00010	.01710	4.522	1508.040	.1166E+00	.9358E-03	.3326E-01
.00010	.01720	4.504	1512.544	.1166E+00	.9424E-03	.3346E-01
.00010	.01730	4.485	1517.029	.1166E+00	.9489E-03	.3366E-01
.00010	.01740	4.466	1521.496	.1166E+00	.9554E-03	.3386E-01
.00010	.01750	4.448	1525.944	.1166E+00	.9619E-03	.3406E-01
.00010	.01760	4.430	1530.373	.1166E+00	.9684E-03	.3425E-01
.00010	.01770	4.412	1534.785	.1166E+00	.9748E-03	.3445E-01
.00010	.01780	4.393	1539.178	.1166E+00	.9813E-03	.3465E-01
.00010	.01790	4.375	1543.554	.1166E+00	.9877E-03	.3485E-01
.00010	.01800	4.358	1547.911	.1166E+00	.9942E-03	.3505E-01
.00010	.01810	4.340	1552.251	.1166E+00	.1001E-02	.3524E-01
.00010	.01820	4.322	1556.573	.1166E+00	.1007E-02	.3544E-01
.00010	.01830	4.304	1560.878	.1166E+00	.1013E-02	.3564E-01
.00010	.01840	4.287	1565.165	.1166E+00	.1020E-02	.3583E-01
.00010	.01850	4.270	1569.434	.1166E+00	.1026E-02	.3603E-01
.00010	.01860	4.252	1573.687	.1166E+00	.1032E-02	.3622E-01
.00010	.01870	4.235	1577.922	.1166E+00	.1039E-02	.3642E-01
.00010	.01880	4.218	1582.140	.1166E+00	.1045E-02	.3661E-01
.00010	.01890	4.201	1586.341	.1166E+00	.1051E-02	.3681E-01
.00010	.01900	4.184	1590.525	.1166E+00	.1058E-02	.3700E-01
.00010	.01910	4.167	1594.692	.1166E+00	.1064E-02	.3719E-01
.00010	.01920	4.151	1598.843	.1166E+00	.1070E-02	.3739E-01
.00010	.01930	4.134	1602.976	.1166E+00	.1077E-02	.3758E-01
.00010	.01940	4.117	1607.094	.1166E+00	.1083E-02	.3777E-01
.00010	.01950	4.101	1611.195	.1166E+00	.1089E-02	.3797E-01
.00010	.01960	4.085	1615.279	.1166E+00	.1095E-02	.3816E-01
.00010	.01970	4.068	1619.348	.1166E+00	.1101E-02	.3835E-01
.00010	.01980	4.052	1623.400	.1166E+00	.1108E-02	.3854E-01
.00010	.01990	4.036	1627.436	.1166E+00	.1114E-02	.3873E-01
.00010	.02000	4.020	1631.456	.1166E+00	.1120E-02	.3892E-01
.00010	.02010	4.004	1635.460	.1166E+00	.1126E-02	.3911E-01
.00010	.02020	3.988	1639.448	.1166E+00	.1132E-02	.3930E-01
.00010	.02030	3.973	1643.421	.1166E+00	.1138E-02	.3949E-01
.00010	.02040	3.957	1647.378	.1166E+00	.1144E-02	.3968E-01
.00010	.02050	3.941	1651.319	.1166E+00	.1150E-02	.3987E-01
.00010	.02060	3.926	1655.245	.1166E+00	.1156E-02	.4006E-01
.00010	.02070	3.910	1659.155	.1166E+00	.1162E-02	.4025E-01
.00010	.02080	3.895	1663.050	.1166E+00	.1168E-02	.4043E-01
.00010	.02090	3.880	1666.930	.1166E+00	.1174E-02	.4062E-01
.00010	.02100	3.865	1670.795	.1166E+00	.1180E-02	.4081E-01
.00010	.02110	3.850	1674.644	.1166E+00	.1186E-02	.4099E-01
.00010	.02120	3.835	1678.479	.1166E+00	.1192E-02	.4118E-01
.00010	.02130	3.820	1682.298	.1166E+00	.1198E-02	.4137E-01
.00010	.02140	3.805	1686.103	.1166E+00	.1204E-02	.4155E-01
.00010	.02150	3.790	1689.893	.1166E+00	.1210E-02	.4174E-01
.00010	.02160	3.775	1693.668	.1166E+00	.1216E-02	.4192E-01
.00010	.02170	3.761	1697.429	.1166E+00	.1222E-02	.4211E-01
.00010	.02180	3.746	1701.175	.1166E+00	.1228E-02	.4229E-01
.00010	.02190	3.732	1704.907	.1166E+00	.1234E-02	.4247E-01
.00010	.02200	3.717	1708.624	.1166E+00	.1239E-02	.4266E-01
.00010	.02210	3.703	1712.327	.1166E+00	.1245E-02	.4284E-01
.00010	.02220	3.689	1716.015	.1166E+00	.1251E-02	.4302E-01
.00010	.02230	3.674	1719.690	.1166E+00	.1257E-02	.4321E-01

Numerical Results - (Continued)

.00010	.02240	3.660	1723.350	.1166E+00	.1263E-02	.4339E-01
.00010	.02250	3.646	1726.996	.1166E+00	.1268E-02	.4357E-01
.00010	.02260	3.632	1730.629	.1166E+00	.1274E-02	.4375E-01
.00010	.02270	3.618	1734.247	.1166E+00	.1280E-02	.4393E-01
.00010	.02280	3.605	1737.852	.1166E+00	.1285E-02	.4411E-01
.00010	.02290	3.591	1741.443	.1166E+00	.1291E-02	.4429E-01
.00010	.02300	3.577	1745.020	.1166E+00	.1297E-02	.4447E-01
.00010	.02310	3.564	1748.583	.1166E+00	.1302E-02	.4465E-01
.00010	.02320	3.550	1752.133	.1166E+00	.1308E-02	.4483E-01
.00010	.02330	3.537	1755.670	.1166E+00	.1313E-02	.4501E-01
.00010	.02340	3.523	1759.193	.1166E+00	.1319E-02	.4519E-01
.00010	.02350	3.510	1762.703	.1166E+00	.1325E-02	.4537E-01
.00010	.02360	3.496	1766.199	.1166E+00	.1330E-02	.4554E-01
.00010	.02370	3.483	1769.682	.1166E+00	.1336E-02	.4572E-01
.00010	.02380	3.470	1773.152	.1166E+00	.1341E-02	.4590E-01
.00010	.02390	3.457	1776.609	.1166E+00	.1347E-02	.4607E-01
.00010	.02400	3.444	1780.053	.1166E+00	.1352E-02	.4625E-01
.00010	.02410	3.431	1783.484	.1166E+00	.1358E-02	.4643E-01
.00010	.02420	3.418	1786.903	.1166E+00	.1363E-02	.4660E-01
.00010	.02430	3.405	1790.308	.1166E+00	.1368E-02	.4678E-01
.00010	.02440	3.392	1793.700	.1166E+00	.1374E-02	.4695E-01
.00010	.02450	3.380	1797.080	.1166E+00	.1379E-02	.4713E-01
.00010	.02460	3.367	1800.447	.1166E+00	.1384E-02	.4730E-01
.00010	.02470	3.355	1803.802	.1166E+00	.1390E-02	.4747E-01
.00010	.02480	3.342	1807.144	.1166E+00	.1395E-02	.4765E-01
.00010	.02490	3.330	1810.473	.1166E+00	.1400E-02	.4782E-01
.00010	.02500	3.317	1813.790	.1166E+00	.1406E-02	.4799E-01
.00010	.02510	3.305	1817.095	.1166E+00	.1411E-02	.4817E-01
.00010	.02520	3.292	1820.388	.1166E+00	.1416E-02	.4834E-01
.00010	.02530	3.280	1823.668	.1166E+00	.1421E-02	.4851E-01
.00010	.02540	3.268	1826.936	.1166E+00	.1427E-02	.4868E-01
.00010	.02550	3.256	1830.192	.1166E+00	.1432E-02	.4885E-01
.00010	.02560	3.244	1833.436	.1166E+00	.1437E-02	.4902E-01
.00010	.02570	3.232	1836.668	.1166E+00	.1442E-02	.4919E-01
.00010	.02580	3.220	1839.888	.1166E+00	.1447E-02	.4936E-01
.00010	.02590	3.208	1843.096	.1166E+00	.1452E-02	.4953E-01
.00010	.02600	3.196	1846.292	.1166E+00	.1457E-02	.4970E-01
.00010	.02610	3.184	1849.476	.1166E+00	.1462E-02	.4987E-01
.00010	.02620	3.173	1852.649	.1166E+00	.1468E-02	.5004E-01
.00010	.02630	3.161	1855.810	.1166E+00	.1473E-02	.5020E-01
.00010	.02640	3.149	1858.960	.1166E+00	.1478E-02	.5037E-01
.00010	.02650	3.138	1862.098	.1166E+00	.1483E-02	.5054E-01
.00010	.02660	3.126	1865.224	.1166E+00	.1488E-02	.5070E-01
.00010	.02670	3.115	1868.339	.1166E+00	.1493E-02	.5087E-01
.00010	.02680	3.104	1871.442	.1166E+00	.1497E-02	.5104E-01
.00010	.02690	3.092	1874.534	.1166E+00	.1502E-02	.5120E-01
.00010	.02700	3.081	1877.615	.1166E+00	.1507E-02	.5137E-01
.00010	.02710	3.070	1880.685	.1166E+00	.1512E-02	.5153E-01
.00010	.02720	3.058	1883.743	.1166E+00	.1517E-02	.5170E-01
.00010	.02730	3.047	1886.791	.1166E+00	.1522E-02	.5186E-01
.00010	.02740	3.036	1889.827	.1166E+00	.1527E-02	.5203E-01
.00010	.02750	3.025	1892.852	.1166E+00	.1532E-02	.5219E-01
.00010	.02760	3.014	1895.866	.1166E+00	.1536E-02	.5235E-01
.00010	.02770	3.003	1898.869	.1166E+00	.1541E-02	.5251E-01
.00010	.02780	2.992	1901.862	.1166E+00	.1546E-02	.5268E-01
.00010	.02790	2.982	1904.843	.1166E+00	.1551E-02	.5284E-01
.00010	.02800	2.971	1907.814	.1166E+00	.1555E-02	.5300E-01
.00010	.02810	2.960	1910.774	.1166E+00	.1560E-02	.5316E-01

Numerical Results - (Continued)

.00010	.02820	2.949	1913.723	.1166E+00	.1565E-02	.5332E-01
.00010	.02830	2.939	1916.662	.1166E+00	.1569E-02	.5348E-01
.00010	.02840	2.928	1919.590	.1166E+00	.1574E-02	.5364E-01
.00010	.02850	2.917	1922.507	.1166E+00	.1579E-02	.5380E-01
.00010	.02860	2.907	1925.414	.1166E+00	.1583E-02	.5396E-01
.00010	.02870	2.897	1928.311	.1166E+00	.1588E-02	.5412E-01
.00010	.02880	2.886	1931.197	.1166E+00	.1592E-02	.5428E-01
.00010	.02890	2.876	1934.073	.1166E+00	.1597E-02	.5444E-01
.00010	.02900	2.865	1936.938	.1166E+00	.1602E-02	.5460E-01
.00010	.02910	2.855	1939.793	.1166E+00	.1606E-02	.5476E-01
.00010	.02920	2.845	1942.638	.1166E+00	.1614E-02	.5491E-01
.00010	.02930	2.834	1945.472	.1166E+00	.1623E-02	.5507E-01
.00010	.02940	2.824	1948.296	.1166E+00	.1633E-02	.5523E-01
.00010	.02950	2.814	1951.110	.1166E+00	.1642E-02	.5538E-01
.00010	.02960	2.803	1953.913	.1166E+00	.1652E-02	.5554E-01
.00010	.02970	2.793	1956.707	.1166E+00	.1661E-02	.5569E-01
.00010	.02980	2.783	1959.490	.1166E+00	.1671E-02	.5585E-01
.00010	.02990	2.773	1962.262	.1166E+00	.1680E-02	.5600E-01
.00010	.03000	2.763	1965.025	.1166E+00	.1690E-02	.5616E-01
.00010	.03010	2.753	1967.778	.1166E+00	.1699E-02	.5631E-01
.00010	.03020	2.743	1970.520	.1166E+00	.1709E-02	.5647E-01
.00010	.03030	2.733	1973.253	.1166E+00	.1718E-02	.5662E-01
.00010	.03040	2.723	1975.975	.1166E+00	.1728E-02	.5677E-01
.00010	.03050	2.713	1978.688	.1166E+00	.1737E-02	.5693E-01
.00010	.03060	2.703	1981.391	.1166E+00	.1747E-02	.5708E-01
.00010	.03070	2.693	1984.084	.1166E+00	.1756E-02	.5723E-01
.00010	.03080	2.683	1986.768	.1166E+00	.1766E-02	.5738E-01
.00010	.03090	2.674	1989.441	.1166E+00	.1776E-02	.5753E-01
.00010	.03100	2.664	1992.105	.1166E+00	.1785E-02	.5768E-01
.00010	.03110	2.654	1994.759	.1166E+00	.1795E-02	.5783E-01
.00010	.03120	2.645	1997.404	.1166E+00	.1804E-02	.5798E-01
.00010	.03130	2.635	2000.039	.1166E+00	.1814E-02	.5813E-01
.00010	.03140	2.626	2002.665	.1166E+00	.1824E-02	.5828E-01
.00010	.03150	2.616	2005.281	.1166E+00	.1833E-02	.5843E-01
.00010	.03160	2.607	2007.887	.1166E+00	.1843E-02	.5858E-01
.00010	.03170	2.597	2010.485	.1166E+00	.1852E-02	.5873E-01
.00010	.03180	2.588	2013.073	.1166E+00	.1862E-02	.5888E-01
.00010	.03190	2.579	2015.651	.1166E+00	.1872E-02	.5902E-01
.00010	.03200	2.569	2018.220	.1166E+00	.1881E-02	.5917E-01
.00010	.03210	2.560	2020.780	.1166E+00	.1891E-02	.5932E-01
.00010	.03220	2.551	2023.331	.1166E+00	.1900E-02	.5946E-01
.00010	.03230	2.542	2025.873	.1166E+00	.1910E-02	.5961E-01
.00010	.03240	2.532	2028.405	.1166E+00	.1920E-02	.5976E-01
.00010	.03250	2.523	2030.929	.1166E+00	.1929E-02	.5990E-01
.00010	.03260	2.514	2033.443	.1166E+00	.1939E-02	.6005E-01
.00010	.03270	2.505	2035.948	.1166E+00	.1948E-02	.6019E-01
.00010	.03280	2.496	2038.444	.1166E+00	.1958E-02	.6034E-01
.00010	.03290	2.487	2040.932	.1166E+00	.1968E-02	.6048E-01
.00010	.03300	2.478	2043.410	.1166E+00	.1977E-02	.6062E-01
.00010	.03310	2.470	2045.880	.1166E+00	.1987E-02	.6077E-01
.00010	.03320	2.461	2048.340	.1166E+00	.1997E-02	.6091E-01
.00010	.03330	2.452	2050.792	.1166E+00	.2006E-02	.6105E-01
.00010	.03340	2.443	2053.235	.1166E+00	.2016E-02	.6119E-01
.00010	.03350	2.434	2055.670	.1166E+00	.2025E-02	.6134E-01
.00010	.03360	2.426	2058.095	.1166E+00	.2035E-02	.6148E-01
.00010	.03370	2.417	2060.513	.1166E+00	.2045E-02	.6162E-01
.00010	.03380	2.408	2062.921	.1166E+00	.2054E-02	.6176E-01
.00010	.03390	2.400	2065.321	.1166E+00	.2064E-02	.6190E-01

Numerical Results - (Continued)

.00010	.03400	2.391	2067.712	.1166E+00	.2074E-02	.6204E-01
.00010	.03410	2.383	2070.095	.1166E+00	.2083E-02	.6218E-01
.00010	.03420	2.374	2072.469	.1166E+00	.2093E-02	.6232E-01
.00010	.03430	2.366	2074.835	.1166E+00	.2102E-02	.6246E-01
.00010	.03440	2.357	2077.192	.1166E+00	.2112E-02	.6260E-01
.00010	.03450	2.349	2079.541	.1166E+00	.2122E-02	.6273E-01
.00010	.03460	2.341	2081.882	.1166E+00	.2131E-02	.6287E-01
.00010	.03470	2.332	2084.214	.1166E+00	.2141E-02	.6301E-01
.00010	.03480	2.324	2086.538	.1166E+00	.2150E-02	.6315E-01
.00010	.03490	2.316	2088.854	.1166E+00	.2160E-02	.6328E-01
.00010	.03500	2.308	2091.161	.1166E+00	.2170E-02	.6342E-01
.00010	.03510	2.299	2093.461	.1166E+00	.2179E-02	.6356E-01
.00010	.03520	2.291	2095.752	.1166E+00	.2189E-02	.6369E-01
.00010	.03530	2.283	2098.035	.1166E+00	.2198E-02	.6383E-01
.00010	.03540	2.275	2100.310	.1166E+00	.2208E-02	.6396E-01
.00010	.03550	2.267	2102.577	.1166E+00	.2218E-02	.6410E-01
.00010	.03560	2.259	2104.836	.1166E+00	.2227E-02	.6423E-01
.00010	.03570	2.251	2107.087	.1166E+00	.2237E-02	.6437E-01
.00010	.03580	2.243	2109.330	.1166E+00	.2246E-02	.6450E-01
.00010	.03590	2.235	2111.565	.1166E+00	.2256E-02	.6463E-01
.00010	.03600	2.227	2113.792	.1166E+00	.2266E-02	.6477E-01
.00010	.03610	2.219	2116.011	.1166E+00	.2275E-02	.6490E-01
.00010	.03620	2.211	2118.223	.1166E+00	.2285E-02	.6503E-01
.00010	.03630	2.204	2120.426	.1166E+00	.2294E-02	.6516E-01
.00010	.03640	2.196	2122.622	.1166E+00	.2304E-02	.6530E-01
.00010	.03650	2.188	2124.810	.1166E+00	.2313E-02	.6543E-01
.00010	.03660	2.180	2126.991	.1166E+00	.2323E-02	.6556E-01
.00010	.03670	2.173	2129.163	.1166E+00	.2333E-02	.6569E-01
.00010	.03680	2.165	2131.328	.1166E+00	.2342E-02	.6582E-01
.00010	.03690	2.157	2133.486	.1166E+00	.2352E-02	.6595E-01
.00010	.03700	2.150	2135.636	.1166E+00	.2361E-02	.6608E-01
.00010	.03710	2.142	2137.778	.1166E+00	.2371E-02	.6621E-01
.00010	.03720	2.135	2139.913	.1166E+00	.2380E-02	.6634E-01
.00010	.03730	2.127	2142.040	.1166E+00	.2390E-02	.6647E-01
.00010	.03740	2.120	2144.160	.1166E+00	.2399E-02	.6659E-01
.00010	.03750	2.112	2146.272	.1166E+00	.2409E-02	.6672E-01
.00010	.03760	2.105	2148.377	.1166E+00	.2418E-02	.6685E-01
.00010	.03770	2.098	2150.474	.1166E+00	.2428E-02	.6698E-01
.00010	.03780	2.090	2152.565	.1166E+00	.2437E-02	.6710E-01
.00010	.03790	2.083	2154.647	.1166E+00	.2447E-02	.6723E-01
.00010	.03800	2.076	2156.723	.1166E+00	.2456E-02	.6736E-01
.00010	.03810	2.068	2158.791	.1166E+00	.2466E-02	.6748E-01
.00010	.03820	2.061	2160.852	.1166E+00	.2475E-02	.6761E-01
.00010	.03830	2.054	2162.906	.1166E+00	.2485E-02	.6773E-01
.00010	.03840	2.047	2164.953	.1166E+00	.2494E-02	.6786E-01
.00010	.03850	2.039	2166.992	.1166E+00	.2504E-02	.6798E-01
.00010	.03860	2.032	2169.024	.1166E+00	.2513E-02	.6811E-01
.00010	.03870	2.025	2171.050	.1166E+00	.2522E-02	.6823E-01
.00010	.03880	2.018	2173.068	.1166E+00	.2532E-02	.6836E-01
.00010	.03890	2.011	2175.079	.1166E+00	.2541E-02	.6848E-01
.00010	.03900	2.004	2177.083	.1166E+00	.2551E-02	.6860E-01
.00010	.03910	1.997	2179.080	.1166E+00	.2560E-02	.6873E-01
.00010	.03920	1.990	2181.070	.1166E+00	.2570E-02	.6885E-01
.00010	.03930	1.983	2183.053	.1166E+00	.2579E-02	.6897E-01
.00010	.03940	1.976	2185.029	.1166E+00	.2588E-02	.6909E-01
.00010	.03950	1.969	2186.999	.1166E+00	.2598E-02	.6921E-01
.00010	.03960	1.962	2188.961	.1166E+00	.2607E-02	.6933E-01
.00010	.03970	1.956	2190.917	.1166E+00	.2616E-02	.6946E-01

Numerical Results - (Continued)

.00010	.03980	1.949	2192.866	.1166E+00	.2626E-02	.6958E-01
.00010	.03990	1.942	2194.808	.1166E+00	.2635E-02	.6970E-01
.00010	.04000	1.935	2196.743	.1166E+00	.2645E-02	.6982E-01
.00010	.04010	1.929	2198.672	.1166E+00	.2654E-02	.6994E-01
.00010	.04020	1.922	2200.593	.1166E+00	.2663E-02	.7005E-01
.00010	.04030	1.915	2202.509	.1166E+00	.2673E-02	.7017E-01
.00010	.04040	1.908	2204.417	.1166E+00	.2682E-02	.7029E-01
.00010	.04050	1.902	2206.319	.1166E+00	.2691E-02	.7041E-01
.00010	.04060	1.895	2208.214	.1166E+00	.2700E-02	.7053E-01
.00010	.04070	1.889	2210.103	.1166E+00	.2710E-02	.7065E-01
.00010	.04080	1.882	2211.985	.1166E+00	.2719E-02	.7076E-01
.00010	.04090	1.876	2213.861	.1166E+00	.2728E-02	.7088E-01
.00010	.04100	1.869	2215.730	.1166E+00	.2738E-02	.7100E-01
.00010	.04110	1.863	2217.592	.1166E+00	.2747E-02	.7111E-01
.00010	.04120	1.856	2219.448	.1166E+00	.2756E-02	.7123E-01
.00010	.04130	1.850	2221.298	.1166E+00	.2765E-02	.7134E-01
.00010	.04140	1.843	2223.141	.1166E+00	.2775E-02	.7146E-01
.00010	.04150	1.837	2224.978	.1166E+00	.2784E-02	.7158E-01
.00010	.04160	1.831	2226.809	.1166E+00	.2793E-02	.7169E-01
.00010	.04170	1.824	2228.633	.1166E+00	.2802E-02	.7180E-01
.00010	.04180	1.818	2230.451	.1166E+00	.2811E-02	.7192E-01
.00010	.04190	1.812	2232.263	.1166E+00	.2821E-02	.7203E-01
.00010	.04200	1.805	2234.068	.1166E+00	.2830E-02	.7215E-01
.00010	.04210	1.799	2235.867	.1166E+00	.2839E-02	.7226E-01
.00010	.04220	1.793	2237.660	.1166E+00	.2848E-02	.7237E-01
.00010	.04230	1.787	2239.447	.1166E+00	.2857E-02	.7248E-01
.00010	.04240	1.781	2241.227	.1166E+00	.2866E-02	.7260E-01
.00010	.04250	1.774	2243.002	.1166E+00	.2875E-02	.7271E-01
.00010	.04260	1.768	2244.770	.1166E+00	.2885E-02	.7282E-01
.00010	.04270	1.762	2246.532	.1166E+00	.2894E-02	.7293E-01
.00010	.04280	1.756	2248.288	.1166E+00	.2903E-02	.7304E-01
.00010	.04290	1.750	2250.038	.1166E+00	.2912E-02	.7315E-01
.00010	.04300	1.744	2251.782	.1166E+00	.2921E-02	.7326E-01
.00010	.04310	1.738	2253.520	.1166E+00	.2930E-02	.7337E-01
.00010	.04320	1.732	2255.252	.1166E+00	.2939E-02	.7348E-01
.00010	.04330	1.726	2256.978	.1166E+00	.2948E-02	.7359E-01
.00010	.04340	1.720	2258.698	.1166E+00	.2957E-02	.7370E-01
.00010	.04350	1.714	2260.412	.1166E+00	.2966E-02	.7381E-01
.00010	.04360	1.708	2262.120	.1166E+00	.2975E-02	.7392E-01
.00010	.04370	1.702	2263.823	.1166E+00	.2984E-02	.7403E-01
.00010	.04380	1.696	2265.519	.1166E+00	.2993E-02	.7414E-01
.00010	.04390	1.691	2267.210	.1166E+00	.3002E-02	.7425E-01
.00010	.04400	1.685	2268.895	.1166E+00	.3011E-02	.7435E-01
.00010	.04410	1.679	2270.574	.1166E+00	.3020E-02	.7446E-01
.00010	.04420	1.673	2272.247	.1166E+00	.3029E-02	.7457E-01
.00010	.04430	1.668	2273.914	.1166E+00	.3038E-02	.7467E-01
.00010	.04440	1.662	2275.576	.1166E+00	.3047E-02	.7478E-01
.00010	.04450	1.656	2277.232	.1166E+00	.3056E-02	.7489E-01
.00010	.04460	1.650	2278.883	.1166E+00	.3065E-02	.7499E-01
.00010	.04470	1.645	2280.528	.1166E+00	.3074E-02	.7510E-01
.00010	.04480	1.639	2282.167	.1166E+00	.3082E-02	.7520E-01
.00010	.04490	1.633	2283.800	.1166E+00	.3091E-02	.7531E-01
.00010	.04500	1.628	2285.428	.1166E+00	.3100E-02	.7541E-01
.00010	.04510	1.622	2287.050	.1166E+00	.3109E-02	.7552E-01
.00010	.04520	1.617	2288.667	.1166E+00	.3118E-02	.7562E-01
.00010	.04530	1.611	2290.278	.1166E+00	.3127E-02	.7572E-01
.00010	.04540	1.606	2291.884	.1166E+00	.3136E-02	.7583E-01
.00010	.04550	1.600	2293.484	.1166E+00	.3144E-02	.7593E-01

Numerical Results - (Continued)

.00010	.04560	1.595	2295.079	.1166E+00	.3153E-02	.7603E-01
.00010	.04570	1.589	2296.668	.1166E+00	.3162E-02	.7614E-01
.00010	.04580	1.584	2298.252	.1166E+00	.3171E-02	.7624E-01
.00010	.04590	1.578	2299.830	.1166E+00	.3179E-02	.7634E-01
.00010	.04600	1.573	2301.403	.1166E+00	.3188E-02	.7644E-01
.00010	.04610	1.568	2302.970	.1166E+00	.3197E-02	.7654E-01
.00010	.04620	1.562	2304.533	.1166E+00	.3206E-02	.7664E-01
.00010	.04630	1.557	2306.090	.1166E+00	.3214E-02	.7675E-01
.00010	.04640	1.552	2307.641	.1166E+00	.3223E-02	.7685E-01
.00010	.04650	1.546	2309.187	.1166E+00	.3232E-02	.7695E-01
.00010	.C4660	1.541	2310.728	.1166E+00	.3240E-02	.7705E-01
.00010	.04670	1.536	2312.264	.1166E+00	.3249E-02	.7715E-01
.00010	.04680	1.530	2313.794	.1166E+00	.3258E-02	.7725E-01
.00010	.04690	1.525	2315.320	.1166E+00	.3266E-02	.7734E-01
.00010	.04700	1.520	2316.840	.1166E+00	.3275E-02	.7744E-01
.00010	.04710	1.515	2318.354	.1166E+00	.3284E-02	.7754E-01
.00010	.04720	1.510	2319.864	.1166E+00	.3292E-02	.7764E-01
.00010	.04730	1.505	2321.369	.1166E+00	.3301E-02	.7774E-01
.00010	.04740	1.499	2322.868	.1166E+00	.3309E-02	.7784E-01
.00010	.04750	1.494	2324.362	.1166E+00	.3318E-02	.7793E-01
.00010	.04760	1.489	2325.851	.1166E+00	.3326E-02	.7803E-01
.00010	.04770	1.484	2327.336	.1166E+00	.3335E-02	.7813E-01
.00010	.04780	1.479	2328.815	.1166E+00	.3343E-02	.7822E-01
.00010	.04790	1.474	2330.289	.1166E+00	.3352E-02	.7832E-01
.00010	.04800	1.469	2331.758	.1166E+00	.3360E-02	.7842E-01
.00010	.04810	1.464	2333.221	.1166E+00	.3369E-02	.7851E-01
.00010	.04820	1.459	2334.680	.1166E+00	.3377E-02	.7861E-01
.00010	.04830	1.454	2336.134	.1166E+00	.3386E-02	.7870E-01
.00010	.04840	1.449	2337.584	.1166E+00	.3394E-02	.7880E-01
.00010	.04850	1.444	2339.028	.1166E+00	.3403E-02	.7889E-01
.00010	.04860	1.439	2340.467	.1166E+00	.3411E-02	.7899E-01
.00010	.04870	1.434	2341.901	.1166E+00	.3420E-02	.7908E-01
.00010	.04880	1.429	2343.331	.1166E+00	.3428E-02	.7918E-01
.00010	.04890	1.425	2344.755	.1166E+00	.3436E-02	.7927E-01

*** THE MELTING POINT = 2345.00 K
THE HEAT OF FUSION = 1071820.8 J/KG
TIME NEEDED FOR MELTING THE PARTICLE = .032509 SEC

.00010	.08151	1.420	2345.000	.1166E+00	.2190E-02	.7938E-01
.00010	.08161	1.419	2346.419	.1166E+00	.3446E-02	.7938E-01
.00010	.08171	1.414	2347.833	.1166E+00	.3454E-02	.7947E-01
.00010	.08181	1.409	2349.242	.1166E+00	.3463E-02	.7957E-01
.00010	.08191	1.404	2350.647	.1166E+00	.3471E-02	.7966E-01
.00010	.08201	1.400	2352.047	.1166E+00	.3479E-02	.7975E-01
.00010	.08211	1.395	2353.441	.1166E+00	.3488E-02	.7984E-01
.00010	.08221	1.390	2354.832	.1166E+00	.3496E-02	.7994E-01
.00010	.08231	1.386	2356.217	.1166E+00	.3504E-02	.8003E-01
.00010	.08241	1.381	2357.598	.1166E+00	.3513E-02	.8012E-01
.00010	.08251	1.376	2358.974	.1166E+00	.3521E-02	.8021E-01
.00010	.08261	1.371	2360.346	.1166E+00	.3529E-02	.8030E-01
.00010	.08271	1.367	2361.712	.1166E+00	.3537E-02	.8039E-01
.00010	.08281	1.362	2363.075	.1166E+00	.3545E-02	.8048E-01
.00010	.08291	1.358	2364.432	.1166E+00	.3554E-02	.8057E-01
.00010	.08301	1.353	2365.785	.1166E+00	.3562E-02	.8066E-01
.00010	.08311	1.348	2367.134	.1166E+00	.3570E-02	.8075E-01
.00010	.08321	1.344	2368.477	.1166E+00	.3578E-02	.8084E-01

Numerical Results - (Continued)

.00010	.08331	1.339	2369.817	.1166E+00	.3586E-02	.8093E-01
.00010	.08341	1.335	2371.151	.1166E+00	.3594E-02	.8102E-01
.00010	.08351	1.330	2372.481	.1166E+00	.3602E-02	.8111E-01
.00010	.08361	1.326	2373.807	.1166E+00	.3611E-02	.8119E-01
.00010	.08371	1.321	2375.128	.1166E+00	.3619E-02	.8128E-01
.00010	.08381	1.317	2376.445	.1166E+00	.3627E-02	.8137E-01
.00010	.08391	1.312	2377.757	.1166E+00	.3635E-02	.8146E-01
.00010	.08401	1.308	2379.065	.1166E+00	.3643E-02	.8154E-01
.00010	.08411	1.303	2380.369	.1166E+00	.3651E-02	.8163E-01
.00010	.08421	1.299	2381.668	.1166E+00	.3659E-02	.8172E-01
.00010	.08431	1.295	2382.962	.1166E+00	.3667E-02	.8180E-01
.00010	.08441	1.290	2384.252	.1166E+00	.3675E-02	.8189E-01
.00010	.08451	1.286	2385.538	.1166E+00	.3683E-02	.8198E-01
.00010	.08461	1.282	2386.820	.1166E+00	.3691E-02	.8206E-01
.00010	.08471	1.277	2388.097	.1166E+00	.3699E-02	.8215E-01
.00010	.08481	1.273	2389.370	.1166E+00	.3707E-02	.8223E-01
.00010	.08491	1.269	2390.638	.1166E+00	.3714E-02	.8232E-01
.00010	.08501	1.264	2391.903	.1166E+00	.3722E-02	.8240E-01
.00010	.08511	1.260	2393.163	.1166E+00	.3730E-02	.8249E-01
.00010	.08521	1.256	2394.418	.1166E+00	.3738E-02	.8257E-01
.00010	.08531	1.252	2395.670	.1166E+00	.3746E-02	.8266E-01
.00010	.08541	1.247	2396.917	.1166E+00	.3754E-02	.8274E-01
.00010	.08551	1.243	2398.160	.1166E+00	.3762E-02	.8282E-01
.00010	.08561	1.239	2399.399	.1166E+00	.3769E-02	.8291E-01
.00010	.08571	1.235	2400.634	.1166E+00	.3777E-02	.8299E-01
.00010	.08581	1.231	2401.864	.1166E+00	.3785E-02	.8307E-01
.00010	.08591	1.226	2403.091	.1166E+00	.3793E-02	.8316E-01
.00010	.08601	1.222	2404.313	.1166E+00	.3800E-02	.8324E-01
.00010	.08611	1.218	2405.531	.1166E+00	.3808E-02	.8332E-01
.00010	.08621	1.214	2406.745	.1166E+00	.3816E-02	.8340E-01
.00010	.08631	1.210	2407.955	.1166E+00	.3824E-02	.8348E-01
.00010	.08641	1.206	2409.161	.1166E+00	.3831E-02	.8356E-01
.00010	.08651	1.202	2410.363	.1166E+00	.3839E-02	.8365E-01
.00010	.08661	1.198	2411.561	.1166E+00	.3847E-02	.8373E-01
.00010	.08671	1.194	2412.754	.1166E+00	.3854E-02	.8381E-01
.00010	.08681	1.190	2413.944	.1166E+00	.3862E-02	.8389E-01
.00010	.08691	1.186	2415.130	.1166E+00	.3870E-02	.8397E-01
.00010	.08701	1.182	2416.311	.1166E+00	.3877E-02	.8405E-01
.00010	.08711	1.178	2417.489	.1166E+00	.3885E-02	.8413E-01
.00010	.08721	1.174	2418.663	.1166E+00	.3892E-02	.8421E-01
.00010	.08731	1.170	2419.833	.1166E+00	.3900E-02	.8429E-01
.00010	.08741	1.166	2420.998	.1166E+00	.3908E-02	.8437E-01
.00010	.08751	1.162	2422.160	.1166E+00	.3915E-02	.8444E-01
.00010	.08761	1.158	2423.318	.1166E+00	.3923E-02	.8452E-01
.00010	.08771	1.154	2424.472	.1166E+00	.3930E-02	.8460E-01
.00010	.08781	1.150	2425.623	.1166E+00	.3938E-02	.8468E-01
.00010	.08791	1.146	2426.769	.1166E+00	.3945E-02	.8476E-01
.00010	.08801	1.143	2427.912	.1166E+00	.3953E-02	.8484E-01
.00010	.08811	1.139	2429.050	.1166E+00	.3960E-02	.8491E-01
.00010	.08821	1.135	2430.185	.1166E+00	.3967E-02	.8499E-01
.00010	.08831	1.131	2431.316	.1166E+00	.3975E-02	.8507E-01
.00010	.08841	1.127	2432.443	.1166E+00	.3982E-02	.8514E-01
.00010	.08851	1.123	2433.567	.1166E+00	.3990E-02	.8522E-01
.00100	.08951	11.197	2444.764	.1166E+00	.3997E-02	.8530E-01
.00100	.09051	10.821	2455.585	.1166E+00	.4071E-02	.8606E-01
.00100	.09151	10.458	2466.043	.1166E+00	.4144E-02	.8680E-01
.00100	.09251	10.108	2476.151	.1166E+00	.4215E-02	.8752E-01
.00100	.09351	9.770	2485.921	.1166E+00	.4284E-02	.8821E-01

Numerical Results - (Continued)

.00100	.09451	9.444	2495.365	.1166E+00	.4352E-02	.8889E-01
.00100	.09551	9.129	2504.493	.1166E+00	.4419E-02	.8955E-01
.00100	.09651	8.824	2513.318	.1166E+00	.4484E-02	.9018E-01
.00100	.09751	8.531	2521.848	.1166E+00	.4547E-02	.9080E-01
.00100	.09851	8.247	2530.095	.1166E+00	.4609E-02	.9140E-01
.00100	.09951	7.973	2538.067	.1166E+00	.4670E-02	.9198E-01
.00100	.10051	7.708	2545.775	.1166E+00	.4729E-02	.9254E-01
.00100	.10151	7.452	2553.228	.1166E+00	.4787E-02	.9309E-01
.00100	.10251	7.205	2560.433	.1166E+00	.4843E-02	.9362E-01
.00100	.10351	6.966	2567.399	.1166E+00	.4898E-02	.9413E-01
.00100	.10451	6.736	2574.135	.1166E+00	.4951E-02	.9463E-01
.00100	.10551	6.513	2580.648	.1166E+00	.5004E-02	.9511E-01
.00100	.10651	6.298	2586.946	.1166E+00	.5054E-02	.9558E-01
.00100	.10751	6.090	2593.035	.1166E+00	.5104E-02	.9603E-01
.00100	.10851	5.889	2598.924	.1166E+00	.5152E-02	.9647E-01
.00100	.10951	5.694	2604.618	.1166E+00	.5199E-02	.9690E-01
.00100	.11051	5.506	2610.124	.1166E+00	.5245E-02	.9731E-01
.00100	.11151	5.325	2615.449	.1166E+00	.5289E-02	.9771E-01
.00100	.11251	5.149	2620.599	.1166E+00	.5333E-02	.9810E-01
.00100	.11351	4.980	2625.579	.1166E+00	.5375E-02	.9847E-01
.00100	.11451	4.816	2630.394	.1166E+00	.5416E-02	.9883E-01
.00100	.11551	4.657	2635.052	.1166E+00	.5456E-02	.9919E-01
.00100	.11651	4.504	2639.556	.1166E+00	.5494E-02	.9953E-01
.00100	.11751	4.356	2643.912	.1166E+00	.5532E-02	.9986E-01
.00100	.11851	4.213	2648.125	.1166E+00	.5569E-02	.1002E+00
.00100	.11951	4.075	2652.200	.1166E+00	.5604E-02	.1005E+00
.00100	.12051	3.941	2656.140	.1166E+00	.5639E-02	.1008E+00
.00100	.12151	3.811	2659.952	.1166E+00	.5672E-02	.1011E+00
.00100	.12251	3.686	2663.638	.1166E+00	.5705E-02	.1014E+00
.00100	.12351	3.565	2667.203	.1166E+00	.5737E-02	.1016E+00
.00100	.12451	3.448	2670.652	.1166E+00	.5767E-02	.1019E+00
.00100	.12551	3.335	2673.987	.1166E+00	.5797E-02	.1022E+00
.00100	.12651	3.226	2677.213	.1166E+00	.5826E-02	.1024E+00
.00100	.12751	3.120	2680.333	.1166E+00	.5855E-02	.1026E+00
.00100	.12851	3.018	2683.351	.1166E+00	.5882E-02	.1029E+00
.00100	.12951	2.919	2686.270	.1166E+00	.5908E-02	.1031E+00
.00100	.13051	2.823	2689.094	.1166E+00	.5934E-02	.1033E+00
.00100	.13151	2.731	2691.825	.1166E+00	.5959E-02	.1035E+00
.00100	.13251	2.642	2694.466	.1166E+00	.5983E-02	.1037E+00
.00100	.13351	2.555	2697.021	.1166E+00	.6007E-02	.1039E+00
.00100	.13451	2.472	2699.493	.1166E+00	.6030E-02	.1041E+00
.00100	.13551	2.391	2701.884	.1166E+00	.6052E-02	.1043E+00
.00100	.13651	2.312	2704.196	.1166E+00	.6073E-02	.1045E+00
.00100	.13751	2.237	2706.433	.1166E+00	.6094E-02	.1047E+00
.00100	.13851	2.164	2708.597	.1166E+00	.6114E-02	.1048E+00
.00100	.13951	2.093	2710.690	.1166E+00	.6134E-02	.1050E+00
.00100	.14051	2.025	2712.714	.1166E+00	.6153E-02	.1052E+00
.00100	.14151	1.958	2714.673	.1166E+00	.6171E-02	.1053E+00
.00100	.14251	1.894	2716.567	.1166E+00	.6189E-02	.1055E+00
.00100	.14351	1.832	2718.400	.1166E+00	.6206E-02	.1056E+00
.00100	.14451	1.773	2720.172	.1166E+00	.6223E-02	.1057E+00
.00100	.14551	1.715	2721.887	.1166E+00	.6239E-02	.1059E+00
.00100	.14651	1.659	2723.546	.1166E+00	.6255E-02	.1060E+00
.00100	.14751	1.605	2725.150	.1166E+00	.6270E-02	.1061E+00
.00100	.14851	1.552	2726.702	.1166E+00	.6285E-02	.1062E+00
.00100	.14951	1.501	2728.204	.1166E+00	.6300E-02	.1064E+00
.00100	.15051	1.452	2729.656	.1166E+00	.6313E-02	.1065E+00
.00100	.15151	1.405	2731.061	.1166E+00	.6327E-02	.1066E+00

Numerical Results - (Continued)

.00100	.15251	1.359	2732.420	.1166E+00	.6340E-02	.1067E+00
.00100	.15351	1.315	2733.735	.1166E+00	.6353E-02	.1068E+00
.00100	.15451	1.272	2735.007	.1166E+00	.6365E-02	.1069E+00
.00100	.15551	1.230	2736.237	.1166E+00	.6377E-02	.1070E+00
.00100	.15651	1.190	2737.428	.1166E+00	.6388E-02	.1071E+00
.00100	.15751	1.151	2738.579	.1166E+00	.6399E-02	.1072E+00
.00100	.15851	1.114	2739.693	.1166E+00	.6410E-02	.1073E+00
.00100	.15951	1.077	2740.770	.1166E+00	.6420E-02	.1073E+00
.00100	.16051	1.042	2741.813	.1166E+00	.6431E-02	.1074E+00
.00100	.16151	1.008	2742.821	.1166E+00	.6440E-02	.1075E+00
.00100	.16251	.975	2743.796	.1166E+00	.6450E-02	.1076E+00
.00100	.16351	.944	2744.740	.1166E+00	.6459E-02	.1077E+00
.00100	.16451	.913	2745.653	.1166E+00	.6468E-02	.1077E+00
.00100	.16551	.883	2746.536	.1166E+00	.6477E-02	.1078E+00
.00100	.16651	.854	2747.390	.1166E+00	.6485E-02	.1079E+00
.00100	.16751	.826	2748.217	.1166E+00	.6493E-02	.1079E+00
.00100	.16851	.800	2749.016	.1166E+00	.6501E-02	.1080E+00
.00100	.16951	.773	2749.790	.1166E+00	.6508E-02	.1081E+00
.00100	.17051	.748	2750.538	.1166E+00	.6516E-02	.1081E+00
.00100	.17151	.724	2751.262	.1166E+00	.6523E-02	.1082E+00
.00100	.17251	.700	2751.962	.1166E+00	.6530E-02	.1082E+00
.00100	.17351	.677	2752.639	.1166E+00	.6536E-02	.1083E+00
.00100	.17451	.655	2753.295	.1166E+00	.6543E-02	.1083E+00
.00100	.17551	.634	2753.929	.1166E+00	.6549E-02	.1084E+00
.00100	.17651	.613	2754.542	.1166E+00	.6555E-02	.1084E+00
.00100	.17751	.593	2755.135	.1166E+00	.6561E-02	.1085E+00
.00100	.17851	.574	2755.709	.1166E+00	.6566E-02	.1085E+00
.00100	.17951	.555	2756.265	.1166E+00	.6572E-02	.1086E+00
.00100	.18051	.537	2756.802	.1166E+00	.6577E-02	.1086E+00
.00100	.18151	.520	2757.322	.1166E+00	.6582E-02	.1087E+00
.00100	.18251	.503	2757.824	.1166E+00	.6587E-02	.1087E+00
.00100	.18351	.486	2758.311	.1166E+00	.6592E-02	.1087E+00
.00100	.18451	.471	2758.781	.1166E+00	.6597E-02	.1088E+00
.00100	.18551	.455	2759.236	.1166E+00	.6601E-02	.1088E+00
.00100	.18651	.440	2759.677	.1166E+00	.6606E-02	.1088E+00
.00100	.18751	.426	2760.103	.1166E+00	.6610E-02	.1089E+00
.00100	.18851	.412	2760.515	.1166E+00	.6614E-02	.1089E+00
.00100	.18951	.399	2760.914	.1166E+00	.6618E-02	.1089E+00
.00100	.19051	.386	2761.299	.1166E+00	.6622E-02	.1090E+00
.00100	.19151	.373	2761.673	.1166E+00	.6625E-02	.1090E+00
.00100	.19251	.361	2762.034	.1166E+00	.6629E-02	.1090E+00
.00100	.19351	.349	2762.383	.1166E+00	.6632E-02	.1091E+00
.00100	.19451	.338	2762.721	.1166E+00	.6636E-02	.1091E+00
.00100	.19551	.327	2763.048	.1166E+00	.6639E-02	.1091E+00
.00100	.19651	.316	2763.364	.1166E+00	.6642E-02	.1091E+00
.00100	.19751	.306	2763.670	.1166E+00	.6645E-02	.1092E+00
.00100	.19851	.296	2763.966	.1166E+00	.6648E-02	.1092E+00
.00100	.19951	.286	2764.252	.1166E+00	.6651E-02	.1092E+00
.00100	.20051	.277	2764.529	.1166E+00	.6654E-02	.1092E+00
.00100	.20151	.268	2764.797	.1166E+00	.6656E-02	.1092E+00
.00100	.20251	.259	2765.056	.1166E+00	.6659E-02	.1093E+00
.00100	.20351	.251	2765.307	.1166E+00	.6662E-02	.1093E+00
.00100	.20451	.243	2765.550	.1166E+00	.6664E-02	.1093E+00
.00100	.20551	.235	2765.784	.1166E+00	.6666E-02	.1093E+00
.00100	.20651	.227	2766.011	.1166E+00	.6669E-02	.1093E+00
.00100	.20751	.220	2766.231	.1166E+00	.6671E-02	.1094E+00
.00100	.20851	.213	2766.444	.1166E+00	.6673E-02	.1094E+00
.00100	.20951	.206	2766.649	.1166E+00	.6675E-02	.1094E+00

Numerical Results - (Continued)

.00100	.21051	.199	2766.848	.1166E+00	.6677E-02	.1094E+00
.00100	.21151	.192	2767.041	.1166E+00	.6679E-02	.1094E+00
.00100	.21251	.186	2767.227	.1166E+00	.6681E-02	.1094E+00
.00100	.21351	.180	2767.407	.1166E+00	.6682E-02	.1095E+00
.00100	.21451	.174	2767.581	.1166E+00	.6684E-02	.1095E+00
.00100	.21551	.169	2767.750	.1166E+00	.6686E-02	.1095E+00
.00100	.21651	.163	2767.913	.1166E+00	.6688E-02	.1095E+00
.00100	.21751	.158	2768.071	.1166E+00	.6689E-02	.1095E+00
.00100	.21851	.153	2768.223	.1166E+00	.6691E-02	.1095E+00
.00100	.21951	.148	2768.371	.1166E+00	.6692E-02	.1095E+00
.00100	.22051	.143	2768.514	.1166E+00	.6694E-02	.1095E+00
.00100	.22151	.138	2768.652	.1166E+00	.6695E-02	.1096E+00
.00100	.22251	.134	2768.786	.1166E+00	.6696E-02	.1096E+00
.00100	.22351	.129	2768.915	.1166E+00	.6698E-02	.1096E+00
.00100	.22451	.125	2769.040	.1166E+00	.6699E-02	.1096E+00
.00100	.22551	.121	2769.161	.1166E+00	.6700E-02	.1096E+00
.00100	.22651	.117	2769.278	.1166E+00	.6701E-02	.1096E+00
.00100	.22751	.113	2769.392	.1166E+00	.6702E-02	.1096E+00
.00100	.22851	.110	2769.501	.1166E+00	.6703E-02	.1096E+00
.00100	.22951	.106	2769.607	.1166E+00	.6704E-02	.1096E+00
.00100	.23051	.103	2769.710	.1166E+00	.6706E-02	.1096E+00
.00100	.23151	.099	2769.809	.1166E+00	.6707E-02	.1096E+00
.00100	.23251	.096	2769.905	.1166E+00	.6707E-02	.1097E+00
.00100	.23351	.093	2769.998	.1166E+00	.6708E-02	.1097E+00
.00100	.23451	.090	2770.088	.1166E+00	.6709E-02	.1097E+00
.00100	.23551	.087	2770.175	.1166E+00	.6710E-02	.1097E+00
.00100	.23651	.084	2770.259	.1166E+00	.6711E-02	.1097E+00
.00100	.23751	.081	2770.340	.1166E+00	.6712E-02	.1097E+00
.00100	.23851	.079	2770.419	.1166E+00	.6713E-02	.1097E+00
.00100	.23951	.076	2770.495	.1166E+00	.6713E-02	.1097E+00
.00100	.24051	.074	2770.569	.1166E+00	.6714E-02	.1097E+00
.00100	.24151	.071	2770.640	.1166E+00	.6715E-02	.1097E+00
.00100	.24251	.069	2770.709	.1166E+00	.6716E-02	.1097E+00
.00100	.24351	.067	2770.776	.1166E+00	.6716E-02	.1097E+00
.00100	.24451	.065	2770.840	.1166E+00	.6717E-02	.1097E+00
.00100	.24551	.062	2770.903	.1166E+00	.6717E-02	.1097E+00
.00100	.24651	.060	2770.963	.1166E+00	.6718E-02	.1097E+00
.00100	.24751	.058	2771.022	.1166E+00	.6719E-02	.1097E+00
.00100	.24851	.057	2771.078	.1166E+00	.6719E-02	.1097E+00
.00100	.24951	.055	2771.133	.1166E+00	.6720E-02	.1098E+00
.00100	.25051	.053	2771.186	.1166E+00	.6720E-02	.1098E+00
.00100	.25151	.051	2771.237	.1166E+00	.6721E-02	.1098E+00
.00100	.25251	.050	2771.287	.1166E+00	.6721E-02	.1098E+00
.00100	.25351	.048	2771.335	.1166E+00	.6722E-02	.1098E+00
.00100	.25451	.046	2771.381	.1166E+00	.6722E-02	.1098E+00
.00100	.25551	.045	2771.426	.1166E+00	.6723E-02	.1098E+00
.00100	.25651	.043	2771.469	.1166E+00	.6723E-02	.1098E+00
.00100	.25751	.042	2771.511	.1166E+00	.6724E-02	.1098E+00
.00100	.25851	.041	2771.552	.1166E+00	.6724E-02	.1098E+00
.00100	.25951	.039	2771.591	.1166E+00	.6724E-02	.1098E+00
.00100	.26051	.038	2771.629	.1166E+00	.6725E-02	.1098E+00
.00100	.26151	.037	2771.666	.1166E+00	.6725E-02	.1098E+00
.00100	.26251	.036	2771.701	.1166E+00	.6725E-02	.1098E+00
.00100	.26351	.034	2771.736	.1166E+00	.6726E-02	.1098E+00
.00100	.26451	.033	2771.769	.1166E+00	.6726E-02	.1098E+00
.00100	.26551	.032	2771.801	.1166E+00	.6726E-02	.1098E+00
.00100	.26651	.031	2771.833	.1166E+00	.6727E-02	.1098E+00
.00100	.26751	.030	2771.863	.1166E+00	.6727E-02	.1098E+00

Numerical Results - (Continued)

.00100	.26851	.029	2771.892	.1166E+00	.6727E-02	.1098E+00
.00100	.26951	.028	2771.920	.1166E+00	.6728E-02	.1098E+00
.00100	.27051	.027	2771.947	.1166E+00	.6728E-02	.1098E+00
.00100	.27151	.026	2771.974	.1166E+00	.6728E-02	.1098E+00
.00100	.27251	.026	2771.999	.1166E+00	.6729E-02	.1098E+00
.00100	.27351	.025	2772.024	.1166E+00	.6729E-02	.1098E+00
.00100	.27451	.024	2772.048	.1166E+00	.6729E-02	.1098E+00
.00100	.27551	.023	2772.071	.1166E+00	.6729E-02	.1098E+00
.00100	.27651	.022	2772.094	.1166E+00	.6729E-02	.1098E+00
.00100	.27751	.022	2772.115	.1166E+00	.6730E-02	.1098E+00
.00100	.27851	.021	2772.136	.1166E+00	.6730E-02	.1098E+00
.00100	.27951	.020	2772.156	.1166E+00	.6730E-02	.1098E+00
.00100	.28051	.020	2772.176	.1166E+00	.6730E-02	.1098E+00
.00100	.28151	.019	2772.195	.1166E+00	.6730E-02	.1098E+00
.00100	.28251	.018	2772.213	.1166E+00	.6731E-02	.1098E+00
.00100	.28351	.018	2772.231	.1166E+00	.6731E-02	.1098E+00
.00100	.28451	.017	2772.248	.1166E+00	.6731E-02	.1098E+00
.00100	.28551	.017	2772.265	.1166E+00	.6731E-02	.1098E+00
.00100	.28651	.016	2772.281	.1166E+00	.6731E-02	.1098E+00
.00100	.28751	.016	2772.297	.1166E+00	.6731E-02	.1098E+00
.00100	.28851	.015	2772.312	.1166E+00	.6732E-02	.1098E+00
.00100	.28951	.015	2772.326	.1166E+00	.6732E-02	.1098E+00
.00100	.29051	.014	2772.340	.1166E+00	.6732E-02	.1098E+00
.00100	.29151	.014	2772.354	.1166E+00	.6732E-02	.1098E+00
.00100	.29251	.013	2772.367	.1166E+00	.6732E-02	.1098E+00
.00100	.29351	.013	2772.380	.1166E+00	.6732E-02	.1098E+00
.00100	.29451	.012	2772.392	.1166E+00	.6732E-02	.1099E+00
.00100	.29551	.012	2772.404	.1166E+00	.6733E-02	.1099E+00
.00100	.29651	.012	2772.416	.1166E+00	.6733E-02	.1099E+00
.00100	.29751	.011	2772.427	.1166E+00	.6733E-02	.1099E+00
.00100	.29851	.011	2772.438	.1166E+00	.6733E-02	.1099E+00
.00100	.29951	.010	2772.448	.1166E+00	.6733E-02	.1099E+00
.00100	.30051	.010	2772.458	.1166E+00	.6733E-02	.1099E+00
.00100	.30151	.010	2772.468	.1166E+00	.6733E-02	.1099E+00

Numerical Results: Titanium

DATA OF TITANIUM PARTICLE USED IN CALCULATION:

RADIUS = .40E-04 M   DENSITY = 4500.00 KG/M**3   ALPHA = .30   AREA FACTOR = 1.00
INITIAL TEMP. = 298.00 K   MELTING POINT = 1933.00 K   BOILING POINT = 3560.00 K

LASER POWER DENSITY = .20E+08 W/M**2   LASER TEMPERATURE = 4334.111 K

TIME INCREMENT	TIME	TEMP. RISE	TEMPERATURE	ABSORPTION	RADIATION	CONVECTION
.00010	.00010	19.159	317.159	.1206E+00	.6943E-05	.0000E+00
.00010	.00020	18.858	336.017	.1206E+00	.8852E-05	.1400E-03
.00010	.00030	18.583	354.600	.1206E+00	.1108E-04	.2946E-03
.00010	.00040	18.331	372.931	.1206E+00	.1366E-04	.4629E-03
.00010	.00050	18.098	391.029	.1206E+00	.1661E-04	.6442E-03
.00010	.00060	17.882	408.911	.1206E+00	.1996E-04	.8377E-03
.00010	.00070	17.682	426.592	.1206E+00	.2373E-04	.1043E-02
.00010	.00080	17.494	444.086	.1206E+00	.2795E-04	.1259E-02
.00010	.00090	17.318	461.404	.1206E+00	.3264E-04	.1486E-02
.00010	.00100	17.152	478.556	.1206E+00	.3782E-04	.1722E-02
.00010	.00110	16.994	495.550	.1206E+00	.4352E-04	.1968E-02
.00010	.00120	16.845	512.395	.1206E+00	.4977E-04	.2223E-02
.00010	.00130	16.703	529.098	.1206E+00	.5658E-04	.2488E-02
.00010	.00140	16.566	545.664	.1206E+00	.6398E-04	.2760E-02
.00010	.00150	16.435	562.099	.1206E+00	.7199E-04	.3040E-02
.00010	.00160	16.309	578.408	.1206E+00	.8062E-04	.3329E-02
.00010	.00170	16.186	594.594	.1206E+00	.8992E-04	.3624E-02
.00010	.00180	16.067	610.662	.1206E+00	.9988E-04	.3927F-02
.00010	.00190	15.952	626.613	.1206E+00	.1105E-03	.4237E-02
.00010	.00200	15.839	642.452	.1206E+00	.1219E-03	.4553E-02
.00010	.00210	15.728	658.179	.1206E+00	.1340E-03	.4876E-02
.00010	.00220	15.618	673.798	.1206E+00	.1468E-03	.5204E-02
.00010	.00230	15.511	689.309	.1206E+00	.1604E-03	.5539E-02
.00010	.00240	15.405	704.713	.1206E+00	.1748E-03	.5879E-02
.00010	.00250	15.299	720.013	.1206E+00	.1900E-03	.6225E-02
.00010	.00260	15.195	735.207	.1206E+00	.2060E-03	.6575E-02
.00010	.00270	15.090	750.298	.1206E+00	.2227E-03	.6931E-02
.00010	.00280	14.987	765.284	.1206E+00	.2404E-03	.7291E-02
.00010	.00290	14.883	780.167	.1206E+00	.2588E-03	.7656E-02
.00010	.00300	14.779	794.947	.1206E+00	.2781E-03	.8025E-02
.00010	.00310	14.676	809.623	.1206E+00	.2982E-03	.8398F-02
.00010	.00320	14.572	824.194	.1206E+00	.3192E-03	.8775E-02
.00010	.00330	14.467	838.662	.1206E+00	.3410E-03	.9156E-02
.00010	.00340	14.363	853.024	.1206E+00	.3637E-03	.9540E-02
.00010	.00350	14.257	867.281	.1206E+00	.3872E-03	.9927E-02
.00010	.00360	14.151	881.433	.1206E+00	.4116E-03	.1032E-01
.00010	.00370	14.045	895.478	.1206E+00	.4369E-03	.1071E-01
.00010	.00380	13.938	909.416	.1206E+00	.4630E-03	.1111E-01
.00010	.00390	13.830	923.246	.1206E+00	.4899E-03	.1151E-01
.00010	.00400	13.722	936.968	.1206E+00	.5177E-03	.1191E-01
.00010	.00410	13.613	950.580	.1206E+00	.5464E-03	.1231E-01
.00010	.00420	13.503	964.083	.1206E+00	.5758E-03	.1271E-01
.00010	.00430	13.393	977.476	.1206E+00	.6060E-03	.1312E-01
.00010	.00440	13.282	990.757	.1206E+00	.6371E-03	.1353E-01
.00010	.00450	13.170	1003.927	.1206E+00	.6689E-03	.1394F-01
.00010	.00460	13.058	1016.985	.1206E+00	.7016E-03	.1435E-01
.00010	.00470	12.945	1029.930	.1206E+00	.7349E-03	.1476E-01
.00010	.00480	12.832	1042.762	.1206E+00	.7690E-03	.1518E-01
.00010	.00490	12.718	1055.481	.1206E+00	.8039E-03	.1559E-01

Numerical Results - (Continued)

.00010	.00500	12.605	1068.085	.1206E+00	.8394E-03	.1600E-01
.00010	.00510	12.490	1080.576	.1206E+00	.8757E-03	.1642E-01
.00010	.00520	12.376	1092.952	.1206E+00	.9126E-03	.1683E-01
.00010	.00530	12.261	1105.213	.1206E+00	.9502E-03	.1725E-01
.00010	.00540	12.146	1117.359	.1206E+00	.9884E-03	.1767E-01
.00010	.00550	12.032	1129.391	.1206E+00	.1027E-02	.1808E-01
.00010	.00560	11.917	1141.307	.1206E+00	.1067E-02	.1850E-01
.00001	.00561	1.180	1142.488	.1206E+00	.1107E-02	.1891E-01
.00001	.00562	1.179	1143.667	.1206E+00	.1111E-02	.1895E-01
.00001	.00563	1.178	1144.845	.1206E+00	.1115E-02	.1900E-01
.00001	.00564	1.177	1146.021	.1206E+00	.1119E-02	.1904E-01
.00001	.00565	1.176	1147.197	.1206E+00	.1123E-02	.1908E-01
.00001	.00566	1.174	1148.372	.1206E+00	.1127E-02	.1912E-01
.00001	.00567	1.173	1149.545	.1206E+00	.1131E-02	.1916E-01
.00001	.00568	1.172	1150.717	.1206E+00	.1135E-02	.1920E-01
.00001	.00569	1.171	1151.888	.1206E+00	.1139E-02	.1924E-01
.00001	.00570	1.170	1153.058	.1206E+00	.1143E-02	.1928E-01
.00001	.00571	1.169	1154.227	.1206E+00	.1147E-02	.1933E-01
.00001	.00572	1.168	1155.394	.1206E+00	.1151E-02	.1937E-01

*** THE PHASE TRANSFORMATION TEMPERATURE = 1155.00 K
THE HEAT OF TRANSFORMATION = 91800.00 J/KG
TIME NEEDED FOR TRANSFORMING THE PARTICLE = .001106 SEC

.00001	.00684	1.312	1156.312	.1206E+00	.1154E-02	.1939E-01
.00001	.00685	1.312	1157.624	.1206E+00	.1158E-02	.1944E-01
.00001	.00686	1.312	1158.936	.1206E+00	.1163E-02	.1949E-01
.00001	.00687	1.312	1160.247	.1206E+00	.1168E-02	.1953E-01
.00001	.00688	1.311	1161.559	.1206E+00	.1172E-02	.1958E-01
.00001	.00689	1.311	1162.870	.1206E+00	.1177E-02	.1963E-01
.00001	.00690	1.311	1164.181	.1206E+00	.1181E-02	.1967E-01
.00001	.00691	1.311	1165.492	.1206E+00	.1186E-02	.1972E-01
.00001	.00692	1.311	1166.802	.1206E+00	.1191E-02	.1977E-01
.00001	.00693	1.310	1168.113	.1206E+00	.1195E-02	.1981E-01
.00001	.00694	1.310	1169.423	.1206E+00	.1200E-02	.1986E-01
.00001	.00695	1.310	1170.733	.1206E+00	.1205E-02	.1991E-01
.00001	.00696	1.310	1172.043	.1206E+00	.1209E-02	.1995E-01
.00001	.00697	1.310	1173.352	.1206E+00	.1214E-02	.2000E-01
.00001	.00698	1.309	1174.662	.1206E+00	.1219E-02	.2005E-01
.00001	.00699	1.309	1175.971	.1206E+00	.1224E-02	.2010E-01
.00001	.00700	1.309	1177.280	.1206E+00	.1228E-02	.2014E-01
.00010	.00710	13.086	1190.366	.1206E+00	.1233E-02	.2019E-01
.00010	.00720	13.057	1203.422	.1206E+00	.1281E-02	.2066E-01
.00010	.00730	13.020	1216.443	.1206E+00	.1331E-02	.2114E-01
.00010	.00740	12.977	1229.420	.1206E+00	.1381E-02	.2162E-01
.00010	.00750	12.928	1242.348	.1206E+00	.1432E-02	.2210E-01
.00010	.00760	12.872	1255.220	.1206E+00	.1484E-02	.2258E-01
.00010	.00770	12.810	1268.029	.1206E+00	.1538E-02	.2307E-01
.00010	.00780	12.741	1280.771	.1206E+00	.1592E-02	.2356E-01
.00010	.00790	12.667	1293.438	.1206E+00	.1647E-02	.2404E-01
.00010	.00800	12.587	1306.025	.1206E+00	.1702E-02	.2454E-01
.00010	.00810	12.502	1318.527	.1206E+00	.1759E-02	.2503E-01
.00010	.00820	12.412	1330.939	.1206E+00	.1816E-02	.2552E-01
.00010	.00830	12.318	1343.257	.1206E+00	.1874E-02	.2601E-01
.00010	.00840	12.218	1355.475	.1206E+00	.1932E-02	.2650E-01
.00010	.00850	12.115	1367.591	.1206E+00	.1991E-02	.2700E-01
.00010	.00860	12.009	1379.600	.1206E+00	.2051E-02	.2749E-01
.00010	.00870	11.899	1391.498	.1206E+00	.2111E-02	.2798E-01

Numerical Results - (Continued)

.00010	.00880	11.786	1403.284	.1206E+00	.2172E-02	.2847E-01
.00010	.00890	11.670	1414.954	.1206E+00	.2233E-02	.2896E-01
.00010	.00900	11.552	1426.505	.1206E+00	.2294E-02	.2945E-01
.00010	.00910	11.432	1437.937	.1206E+00	.2355E-02	.2993E-01
.00010	.00920	11.310	1449.247	.1206E+00	.2417E-02	.3042E-01
.00010	.00930	11.187	1460.433	.1206E+00	.2479E-02	.3090E-01
.00010	.00940	11.062	1471.496	.1206E+00	.2542E-02	.3138E-01
.00010	.00950	10.937	1482.433	.1206E+00	.2604E-02	.3186E-01
.00010	.00960	10.811	1493.244	.1206E+00	.2667E-02	.3233E-01
.00010	.00970	10.685	1503.929	.1206E+00	.2729E-02	.3281E-01
.00010	.00980	10.559	1514.487	.1206E+00	.2792E-02	.3328E-01
.00010	.00990	10.432	1524.919	.1206E+00	.2854E-02	.3374E-01
.00010	.01000	10.306	1535.225	.1206E+00	.2917E-02	.3421E-01
.00010	.01010	10.180	1545.406	.1206E+00	.2980E-02	.3467E-01
.00010	.01020	10.055	1555.461	.1206E+00	.3042E-02	.3513E-01
.00010	.01030	9.931	1565.392	.1206E+00	.3105E-02	.3559E-01
.00010	.01040	9.807	1575.200	.1206E+00	.3167E-02	.3604E-01
.00010	.01050	9.685	1584.885	.1206E+00	.3229E-02	.3649E-01
.00010	.01060	9.564	1594.448	.1206E+00	.3291E-02	.3693E-01
.00010	.01070	9.443	1603.891	.1206E+00	.3353E-02	.3738E-01
.00010	.01080	9.324	1613.216	.1206E+00	.3415E-02	.3782E-01
.00010	.01090	9.207	1622.422	.1206E+00	.3477E-02	.3825E-01
.00010	.01100	9.091	1631.513	.1206E+00	.3538E-02	.3869E-01
.00010	.01110	8.976	1640.489	.1206E+00	.3599E-02	.3911E-01
.00010	.01120	8.863	1649.351	.1206E+00	.3660E-02	.3954E-01
.00010	.01130	8.751	1658.102	.1206E+00	.3720E-02	.3996E-01
.00010	.01140	8.641	1666.743	.1206E+00	.3781E-02	.4038E-01
.00010	.01150	8.532	1675.275	.1206E+00	.3841E-02	.4080E-01
.00010	.01160	8.425	1683.700	.1206E+00	.3901E-02	.4121E-01
.00010	.01170	8.320	1692.020	.1206E+00	.3960E-02	.4162E-01
.00010	.01180	8.216	1700.237	.1206E+00	.4019E-02	.4203E-01
.00010	.01190	8.115	1708.351	.1206E+00	.4078E-02	.4243E-01
.00010	.01200	8.014	1716.366	.1206E+00	.4137E-02	.4283E-01
.00010	.01210	7.916	1724.281	.1206E+00	.4195E-02	.4322E-01
.00010	.01220	7.819	1732.100	.1206E+00	.4253E-02	.4362E-01
.00010	.01230	7.723	1739.823	.1206E+00	.4311E-02	.4401E-01
.00010	.01240	7.629	1747.452	.1206E+00	.4369E-02	.4439E-01
.00010	.01250	7.537	1754.989	.1206E+00	.4426E-02	.4477E-01
.00010	.01260	7.447	1762.436	.1206E+00	.4482E-02	.4515E-01
.00010	.01270	7.358	1769.794	.1206E+00	.4539E-02	.4553E-01
.00010	.01280	7.270	1777.064	.1206E+00	.4595E-02	.4590E-01
.00010	.01290	7.184	1784.248	.1206E+00	.4651E-02	.4627E-01
.00010	.01300	7.100	1791.348	.1206E+00	.4707E-02	.4664E-01
.00010	.01310	7.017	1798.365	.1206E+00	.4762E-02	.4701E-01
.00010	.01320	6.935	1805.301	.1206E+00	.4817E-02	.4737E-01
.00010	.01330	6.855	1812.156	.1206E+00	.4871E-02	.4772E-01
.00010	.01340	6.777	1818.933	.1206E+00	.4926E-02	.4808E-01
.00010	.01350	6.700	1825.632	.1206E+00	.4980E-02	.4843E-01
.00010	.01360	6.624	1832.256	.1206E+00	.5034E-02	.4878E-01
.00010	.01370	6.549	1838.805	.1206E+00	.5087E-02	.4913E-01
.00010	.01380	6.476	1845.281	.1206E+00	.5140E-02	.4947E-01
.00010	.01390	6.404	1851.686	.1206E+00	.5193E-02	.4981E-01
.00010	.01400	6.333	1858.019	.1206E+00	.5246E-02	.5015E-01
.00010	.01410	6.264	1864.283	.1206E+00	.5298E-02	.5049E-01
.00010	.01420	6.196	1870.479	.1206E+00	.5350E-02	.5082E-01
.00010	.01430	6.129	1876.608	.1206E+00	.5402E-02	.5115E-01
.00010	.01440	6.063	1882.671	.1206E+00	.5453E-02	.5148E-01
.00010	.01450	5.998	1888.669	.1206E+00	.5505E-02	.5180E-01

Numerical Results - (Continued)

.00010	.01460	5.935	1894.603	.1206E+00	.5556E-02	.5213E-01
.00010	.01470	5.872	1900.475	.1206E+00	.5606E-02	.5245E-01
.00010	.01480	5.811	1906.286	.1206E+00	.5657E-02	.5276E-01
.00010	.01490	5.750	1912.036	.1206E+00	.5707E-02	.5308E-01
.00010	.01500	5.691	1917.727	.1206E+00	.5757E-02	.5339E-01
.00010	.01510	5.632	1923.359	.1206E+00	.5807E-02	.5370E-01
.00001	.01511	.557	1923.917	.1206E+00	.5856E-02	.5401E-01
.00001	.01512	.557	1924.474	.1206E+00	.5861E-02	.5404E-01
.00001	.01513	.556	1925.030	.1206E+00	.5866E-02	.5407E-01
.00001	.01514	.556	1925.586	.1206E+00	.5871E-02	.5410E-01
.00001	.01515	.555	1926.141	.1206E+00	.5876E-02	.5413E-01
.00001	.01516	.555	1926.696	.1206E+00	.5881E-02	.5416E-01
.00001	.01517	.554	1927.250	.1206E+00	.5885E-02	.5419E-01
.00001	.01518	.554	1927.803	.1206E+00	.5890E-02	.5422E-01
.00001	.01519	.553	1928.356	.1206E+00	.5895E-02	.5425E-01
.00001	.01520	.552	1928.909	.1206E+00	.5900E-02	.5428E-01
.00001	.01521	.552	1929.461	.1206E+00	.5905E-02	.5431E-01
.00001	.01522	.551	1930.012	.1206E+00	.5910E-02	.5434E-01
.00001	.01523	.551	1930.563	.1206E+00	.5915E-02	.5438E-01
.00001	.01524	.550	1931.113	.1206E+00	.5920E-02	.5441E-01
.00001	.01525	.550	1931.662	.1206E+00	.5925E-02	.5444E-01
.00001	.01526	.549	1932.212	.1206E+00	.5929E-02	.5447E-01
.00001	.01527	.549	1932.760	.1206E+00	.5934E-02	.5450E-01
.00001	.01528	.548	1933.308	.1206E+00	.5939E-02	.5453E-01

*** THE MELTING POINT = 1933.00 K
THE HEAT OF FUSION = 437101.92 J/KG
TIME NEEDED FOR MELTING THE PARTICLE = .008766 SEC

.00001	.02405	.548	1933.548	.1206E+00	.5941E-02	.5454E-01
.00001	.02406	.547	1934.095	.1206E+00	.5946E-02	.5457E-01
.00001	.02407	.547	1934.641	.1206E+00	.5951E-02	.5460E-01
.00001	.02408	.546	1935.188	.1206E+00	.5956E-02	.5463E-01
.00001	.02409	.546	1935.733	.1206E+00	.5961E-02	.5466E-01
.00001	.02410	.545	1936.278	.1206E+00	.5966E-02	.5469E-01
.00001	.02411	.544	1936.823	.1206E+00	.5970E-02	.5472E-01
.00001	.02412	.544	1937.367	.1206E+00	.5975E-02	.5475E-01
.00001	.02413	.543	1937.910	.1206E+00	.5980E-02	.5478E-01
.00001	.02414	.543	1938.453	.1206E+00	.5985E-02	.5481E-01
.00001	.02415	.542	1938.995	.1206E+00	.5990E-02	.5484E-01
.00001	.02416	.542	1939.537	.1206E+00	.5995E-02	.5487E-01
.00001	.02417	.541	1940.078	.1206E+00	.6000E-02	.5490E-01
.00001	.02418	.541	1940.619	.1206E+00	.6004E-02	.5493E-01
.00001	.02419	.540	1941.159	.1206E+00	.6009E-02	.5496E-01
.00001	.02420	.540	1941.698	.1206E+00	.6014E-02	.5499E-01
.00001	.02421	.539	1942.237	.1206E+00	.6019E-02	.5502E-01
.00001	.02422	.539	1942.776	.1206E+00	.6024E-02	.5505E-01
.00001	.02423	.538	1943.314	.1206E+00	.6029E-02	.5508E-01
.00001	.02424	.537	1943.851	.1206E+00	.6033E-02	.5511E-01
.00001	.02425	.537	1944.388	.1206E+00	.6038E-02	.5514E-01
.00001	.02426	.536	1944.925	.1206E+00	.6043E-02	.5517E-01
.00001	.02427	.536	1945.461	.1206E+00	.6048E-02	.5520E-01
.00001	.02428	.535	1945.996	.1206E+00	.6053E-02	.5523E-01
.00001	.02429	.535	1946.531	.1206E+00	.6057E-02	.5526E-01
.00001	.02430	.534	1947.065	.1206E+00	.6062E-02	.5529E-01
.00010	.02440	5.337	1952.402	.1206E+00	.6067E-02	.5532E-01
.00010	.02450	5.285	1957.687	.1206E+00	.6115E-02	.5561E-01

Numerical Results - (Continued)

.00010	.02460	5.233	1962.920	.1206E+00	.6163E-02	.5590E-01
.00010	.02470	5.182	1968.102	.1206E+00	.6211E-02	.5620E-01
.00010	.02480	5.132	1973.234	.1206E+00	.6259E-02	.5649E-01
.00010	.02490	5.083	1978.317	.1206E+00	.6306E-02	.5677E-01
.00010	.02500	5.034	1983.351	.1206E+00	.6353E-02	.5706E-01
.00010	.02510	4.986	1988.338	.1206E+00	.6400E-02	.5734E-01
.00010	.02520	4.939	1993.277	.1206E+00	.6447E-02	.5762E-01
.00010	.02530	4.893	1998.170	.1206E+00	.6494E-02	.5790E-01
.00010	.02540	4.848	2003.018	.1206E+00	.6540E-02	.5818E-01
.00010	.02550	4.803	2007.821	.1206E+00	.6586E-02	.5845E-01
.00010	.02560	4.758	2012.579	.1206E+00	.6632E-02	.5873E-01
.00010	.02570	4.715	2017.294	.1206E+00	.6678E-02	.5900E-01
.00010	.02580	4.672	2021.966	.1206E+00	.6724E-02	.5927E-01
.00010	.02590	4.630	2026.596	.1206E+00	.6769E-02	.5953E-01
.00010	.02600	4.588	2031.184	.1206E+00	.6814E-02	.5980E-01
.00010	.02610	4.547	2035.731	.1206E+00	.6860E-02	.6006E-01
.00010	.02620	4.507	2040.238	.1206E+00	.6904E-02	.6032E-01
.00010	.02630	4.467	2044.705	.1206E+00	.6949E-02	.6058E-01
.00010	.02640	4.428	2049.132	.1206E+00	.6994E-02	.6084E-01
.00010	.02650	4.389	2053.521	.1206E+00	.7038E-02	.6110E-01
.00010	.02660	4.351	2057.872	.1206E+00	.7083E-02	.6135E-01
.00010	.02670	4.313	2062.185	.1206E+00	.7127E-02	.6161E-01
.00010	.02680	4.276	2066.461	.1206E+00	.7171E-02	.6186E-01
.00010	.02690	4.239	2070.700	.1206E+00	.7215E-02	.6211E-01
.00010	.02700	4.203	2074.903	.1206E+00	.7259E-02	.6235E-01
.00010	.02710	4.168	2079.071	.1206E+00	.7302E-02	.6260E-01
.00010	.02720	4.132	2083.203	.1206E+00	.7346E-02	.6284E-01
.00010	.02730	4.098	2087.301	.1206E+00	.7389E-02	.6309E-01
.00010	.02740	4.064	2091.365	.1206E+00	.7432E-02	.6333E-01
.00010	.02750	4.030	2095.394	.1206E+00	.7475E-02	.6357E-01
.00010	.02760	3.997	2099.391	.1206E+00	.7518E-02	.6381E-01
.00010	.02770	3.964	2103.355	.1206E+00	.7561E-02	.6404E-01
.00010	.02780	3.931	2107.286	.1206E+00	.7604E-02	.6428E-01
.00010	.02790	3.899	2111.185	.1206E+00	.7647E-02	.6451E-01
.00010	.02800	3.868	2115.053	.1206E+00	.7689E-02	.6474E-01
.00010	.02810	3.836	2118.889	.1206E+00	.7731E-02	.6497E-01
.00010	.02820	3.806	2122.695	.1206E+00	.7774E-02	.6520E-01
.00010	.02830	3.775	2126.470	.1206E+00	.7816E-02	.6543E-01
.00010	.02840	3.745	2130.215	.1206E+00	.7858E-02	.6566E-01
.00010	.02850	3.715	2133.930	.1206E+00	.7900E-02	.6588E-01
.00010	.02860	3.686	2137.616	.1206E+00	.7941E-02	.6611E-01
.00010	.02870	3.657	2141.273	.1206E+00	.7983E-02	.6633E-01
.00010	.02880	3.628	2144.902	.1206E+00	.8025E-02	.6655E-01
.00010	.02890	3.600	2148.502	.1206E+00	.8066E-02	.6677E-01
.00010	.02900	3.572	2152.074	.1206E+00	.8109E-02	.6699E-01
.00010	.02910	3.545	2155.619	.1206E+00	.8149E-02	.6720E-01
.00010	.02920	3.517	2159.136	.1206E+00	.8190E-02	.6742E-01
.00010	.02930	3.490	2162.626	.1206E+00	.8231E-02	.6763E-01
.00010	.02940	3.464	2166.090	.1206E+00	.8272E-02	.6784E-01
.00010	.02950	3.437	2169.527	.1206E+00	.8313E-02	.6805E-01
.00010	.02960	3.411	2172.939	.1206E+00	.8354E-02	.6826E-01
.00010	.02970	3.386	2176.324	.1206E+00	.8395E-02	.6847E-01
.00010	.02980	3.360	2179.684	.1206E+00	.8436E-02	.6868E-01
.00010	.02990	3.335	2183.019	.1206E+00	.8476E-02	.6889E-01
.00010	.03000	3.310	2186.329	.1206E+00	.8517E-02	.6909E-01
.00100	.03100	32.853	2219.182	.1206E+00	.8557E-02	.6929E-01
.00100	.03200	30.453	2249.635	.1206E+00	.8971E-02	.7133E-01
.00100	.03300	28.296	2277.931	.1206E+00	.9376E-02	.7324E-01

Numerical Results - (Continued)

.00100	.03400	26.343	2304.274	.1206E+00	.9775E-02	.7504E-01
.00100	.03500	24.564	2328.838	.1206E+00	.1017E-01	.7673E-01
.00100	.03600	22.932	2351.770	.1206E+00	.1055E-01	.7832E-01
.00100	.03700	21.429	2373.199	.1206E+00	.1093E-01	.7983E-01
.00100	.03800	20.038	2393.238	.1206E+00	.1130E-01	.8124E-01
.00100	.03900	18.746	2411.984	.1206E+00	.1167E-01	.8258E-01
.00100	.04000	17.542	2429.526	.1206E+00	.1203E-01	.8384E-01
.00100	.04100	16.416	2445.942	.1206E+00	.1238E-01	.8502E-01
.00100	.04200	15.361	2461.303	.1206E+00	.1272E-01	.8614E-01
.00100	.04300	14.371	2475.674	.1206E+00	.1306E-01	.8719E-01
.00100	.04400	13.441	2489.115	.1206E+00	.1338E-01	.8818E-01
.00100	.04500	12.565	2501.680	.1206E+00	.1370E-01	.8911E-01
.00100	.04600	11.741	2513.421	.1206E+00	.1401E-01	.8999E-01
.00100	.04700	10.964	2524.385	.1206E+00	.1430E-01	.9081E-01
.00100	.04800	10.233	2534.617	.1206E+00	.1459E-01	.9158E-01
.00100	.04900	9.543	2544.160	.1206E+00	.1486E-01	.9230E-01
.00100	.05000	8.894	2553.054	.1206E+00	.1512E-01	.9297E-01
.00100	.05100	8.283	2561.337	.1206E+00	.1538E-01	.9361E-01
.00100	.05200	7.708	2569.045	.1206E+00	.1562E-01	.9420E-01
.00100	.05300	7.167	2576.212	.1206E+00	.1584E-01	.9475E-01
.00100	.05400	6.659	2582.872	.1206E+00	.1606E-01	.9526E-01
.00100	.05500	6.183	2589.055	.1206E+00	.1627E-01	.9574E-01
.00100	.05600	5.736	2594.791	.1206E+00	.1646E-01	.9618E-01
.00100	.05700	5.318	2600.109	.1206E+00	.1665E-01	.9660E-01
.00100	.05800	4.926	2605.035	.1206E+00	.1682E-01	.9698E-01
.00100	.05900	4.560	2609.595	.1206E+00	.1698E-01	.9734E-01
.00100	.06000	4.219	2613.814	.1206E+00	.1713E-01	.9767E-01
.00100	.06100	3.900	2617.714	.1206E+00	.1728E-01	.9798E-01
.00100	.06200	3.603	2621.318	.1206E+00	.1741E-01	.9826E-01
.00100	.06300	3.327	2624.645	.1206E+00	.1754E-01	.9852E-01
.00100	.06400	3.070	2627.715	.1206E+00	.1765E-01	.9877E-01
.00100	.06500	2.832	2630.547	.1206E+00	.1776E-01	.9899E-01
.00100	.06600	2.611	2633.158	.1206E+00	.1786E-01	.9920E-01
.00100	.06700	2.405	2635.563	.1206E+00	.1796E-01	.9939E-01
.00100	.06800	2.215	2637.779	.1206E+00	.1805E-01	.9957E-01
.00100	.06900	2.039	2639.818	.1206E+00	.1813E-01	.9973E-01
.00100	.07000	1.877	2641.695	.1206E+00	.1820E-01	.9988E-01
.00100	.07100	1.726	2643.421	.1206E+00	.1827E-01	.1000E+00
.00100	.07200	1.587	2645.008	.1206E+00	.1834E-01	.1001E+00
.00100	.07300	1.459	2646.467	.1206E+00	.1839E-01	.1003E+00
.00100	.07400	1.341	2647.808	.1206E+00	.1845E-01	.1004E+00
.00100	.07500	1.232	2649.040	.1206E+00	.1850E-01	.1005E+00
.00100	.07600	1.131	2650.171	.1206E+00	.1855E-01	.1006E+00
.00100	.07700	1.039	2651.210	.1206E+00	.1859E-01	.1006E+00
.00100	.07800	.954	2652.163	.1206E+00	.1863E-01	.1007E+00
.00100	.07900	.875	2653.039	.1206E+00	.1867E-01	.1008E+00
.00100	.08000	.803	2653.842	.1206E+00	.1870E-01	.1009E+00
.00100	.08100	.737	2654.579	.1206E+00	.1873E-01	.1009E+00
.00100	.08200	.676	2655.254	.1206E+00	.1876E-01	.1010E+00
.00100	.08300	.620	2655.874	.1206E+00	.1879E-01	.1010E+00
.00100	.08400	.568	2656.443	.1206E+00	.1881E-01	.1011E+00
.00100	.08500	.521	2656.964	.1206E+00	.1883E-01	.1011E+00
.00100	.08600	.478	2657.442	.1206E+00	.1885E-01	.1011E+00
.00100	.08700	.438	2657.880	.1206E+00	.1887E-01	.1012E+00
.00100	.08800	.402	2658.281	.1206E+00	.1889E-01	.1012E+00
.00100	.08900	.368	2658.649	.1206E+00	.1890E-01	.1012E+00
.00100	.09000	.337	2658.987	.1206E+00	.1892E-01	.1013E+00
.00100	.09100	.309	2659.296	.1206E+00	.1893E-01	.1013E+00

Numerical Results - (Continued)

.00100	.09200	.283	2659.579	.1206E+00	.1894E-01	.1013E+00
.00100	.09300	.259	2659.838	.1206E+00	.1895E-01	.1013E+00
.00100	.09400	.238	2660.076	.1206E+00	.1896E-01	.1014E+00
.00100	.09500	.218	2660.294	.1206E+00	.1897E-01	.1014E+00
.00100	.09600	.199	2660.493	.1206E+00	.1898E-01	.1014E+00
.00100	.09700	.183	2660.676	.1206E+00	.1899E-01	.1014E+00
.00100	.09800	.167	2660.843	.1206E+00	.1900E-01	.1014E+00
.00100	.09900	.153	2660.997	.1206E+00	.1900E-01	.1014E+00
.00100	.10000	.140	2661.137	.1206E+00	.1901E-01	.1014E+00
.00100	.10100	.129	2661.266	.1206E+00	.1901E-01	.1014E+00
.00100	.10200	.118	2661.384	.1206E+00	.1902E-01	.1015E+00
.00100	.10300	.108	2661.491	.1206E+00	.1902E-01	.1015E+00
.00100	.10400	.099	2661.590	.1206E+00	.1903E-01	.1015E+00
.00100	.10500	.090	2661.681	.1206E+00	.1903E-01	.1015E+00
.00100	.10600	.083	2661.764	.1206E+00	.1904E-01	.1015E+00
.00100	.10700	.076	2661.840	.1206E+00	.1904E-01	.1015E+00
.00100	.10800	.069	2661.909	.1206E+00	.1904E-01	.1015E+00
.00100	.10900	.064	2661.973	.1206E+00	.1905E-01	.1015E+00
.00100	.11000	.058	2662.031	.1206E+00	.1905E-01	.1015E+00
.00100	.11100	.053	2662.084	.1206E+00	.1905E-01	.1015E+00
.00100	.11200	.049	2662.133	.1206E+00	.1905E-01	.1015E+00
.00100	.11300	.045	2662.178	.1206E+00	.1905E-01	.1015E+00
.00100	.11400	.041	2662.219	.1206E+00	.1906E-01	.1015E+00
.00100	.11500	.038	2662.256	.1206E+00	.1906E-01	.1015E+00
.00100	.11600	.034	2662.291	.1206E+00	.1906E-01	.1015E+00
.00100	.11700	.031	2662.322	.1206E+00	.1906E-01	.1015E+00
.00100	.11800	.029	2662.351	.1206E+00	.1906E-01	.1015E+00
.00100	.11900	.026	2662.377	.1206E+00	.1906E-01	.1015E+00
.00100	.12000	.024	2662.401	.1206E+00	.1906E-01	.1015E+00
.00100	.12100	.022	2662.424	.1206E+00	.1906E-01	.1015E+00
.00100	.12200	.020	2662.444	.1206E+00	.1907E-01	.1015E+00
.00100	.12300	.019	2662.462	.1206E+00	.1907E-01	.1015E+00
.00100	.12400	.017	2662.479	.1206E+00	.1907E-01	.1015E+00
.00100	.12500	.016	2662.495	.1206E+00	.1907E-01	.1015E+00
.00100	.12600	.014	2662.509	.1206E+00	.1907E-01	.1015E+00
.00100	.12700	.013	2662.522	.1206E+00	.1907E-01	.1016E+00
.00100	.12800	.012	2662.534	.1206E+00	.1907E-01	.1016E+00
.00100	.12900	.011	2662.545	.1206E+00	.1907E-01	.1016E+00
.00100	.13000	.010	2662.555	.1206E+00	.1907E-01	.1016E+00

Numerical Results: Tungsten

DATA OF TUNGSTEN PARTICLE USED IN CALCULATION:

RADIUS = .40E-04 M   DENSITY = 19350.00 KG/M**3   ALPHA = .70   AREA FACTOR = 1.00
INITIAL TEMP. = 298.00 K   MELTING POINT = 3683.00 K   BOILING POINT = 5933.00 K

LASER POWER DENSITY = .40E+08 W/M**2   LASER TEMPERATURE = 5154.156 K

TIME INCREMENT	TIME	TEMP. RISE	TEMPERATURE	ABSORPTION	RADIATION	CONVECTION
.00010	.00010	81.401	379.401	.5630E+00	.2618E-05	.0000E+00
.00010	.00020	80.163	459.564	.5630E+00	.7011E-05	.7118E-03
.00010	.00030	78.930	538.495	.5630E+00	.1544E-04	.1696E-02
.00010	.00040	77.707	616.201	.5630E+00	.2985E-04	.2918E-02
.00010	.00050	76.495	692.696	.5630E+00	.5259E-04	.4346E-02
.00010	.00060	75.298	767.994	.5630E+00	.8642E-04	.5954E-02
.00010	.00070	74.116	842.110	.5630E+00	.1344E-03	.7723E-02
.00010	.00080	72.951	915.061	.5630E+00	.2002E-03	.9633E-02
.00010	.00090	71.802	986.863	.5630E+00	.2873E-03	.1167E-01
.00010	.00100	70.671	1057.534	.5630E+00	.4001E-03	.1382E-01
.00010	.00110	69.556	1127.090	.5630E+00	.5427E-03	.1607E-01
.00010	.00120	68.458	1195.548	.5630E+00	.7196E-03	.1842E-01
.00010	.00130	67.376	1262.924	.5630E+00	.9355E-03	.2085E-01
.00010	.00140	66.310	1329.234	.5630E+00	.1195E-02	.2336E-01
.00010	.00150	65.258	1394.493	.5630E+00	.1502E-02	.2594E-01
.00010	.00160	64.221	1458.714	.5630E+00	.1863E-02	.2859E-01
.00010	.00170	63.198	1521.912	.5630E+00	.2280E-02	.3131E-01
.00010	.00180	62.188	1584.100	.5630E+00	.2759E-02	.3407E-01
.00010	.00190	61.190	1645.290	.5630E+00	.3303E-02	.3690E-01
.00010	.00200	60.204	1705.494	.5630E+00	.3916E-02	.3977E-01
.00010	.00210	59.229	1764.724	.5630E+00	.4602E-02	.4269E-01
.00010	.00220	58.266	1822.989	.5630E+00	.5364E-02	.4565E-01
.00010	.00230	57.312	1880.301	.5630E+00	.6205E-02	.4864E-01
.00010	.00240	56.368	1936.670	.5630E+00	.7127E-02	.5168E-01
.00010	.00250	55.434	1992.104	.5630E+00	.8131E-02	.5474E-01
.00010	.00260	54.510	2046.614	.5630E+00	.9221E-02	.5783E-01
.00010	.00270	53.594	2100.207	.5630E+00	.1040E-01	.6095E-01
.00010	.00280	52.687	2152.894	.5630E+00	.1166E-01	.6409E-01
.00010	.00290	51.788	2204.682	.5630E+00	.1301E-01	.6725E-01
.00010	.00300	50.898	2255.579	.5630E+00	.1445E-01	.7043E-01
.00010	.00310	50.016	2305.595	.5630E+00	.1597E-01	.7362E-01
.00010	.00320	49.142	2354.737	.5630E+00	.1759E-01	.7681E-01
.00010	.00330	48.276	2403.013	.5630E+00	.1928E-01	.8002E-01
.00010	.00340	47.418	2450.431	.5630E+00	.2107E-01	.8323E-01
.00010	.00350	46.569	2497.000	.5630E+00	.2293E-01	.8645E-01
.00010	.00360	45.727	2542.727	.5630E+00	.2488E-01	.8966E-01
.00010	.00370	44.893	2587.620	.5630E+00	.2691E-01	.9287E-01
.00010	.00380	44.068	2631.688	.5630E+00	.2902E-01	.9608E-01
.00010	.00390	43.250	2674.938	.5630E+00	.3120E-01	.9928E-01
.00010	.00400	42.441	2717.379	.5630E+00	.3346E-01	.1025E+00
.00010	.00410	41.640	2759.019	.5630E+00	.3579E-01	.1057E+00
.00010	.00420	40.846	2799.865	.5630E+00	.3818E-01	.1088E+00
.00010	.00430	40.062	2839.927	.5630E+00	.4064E-01	.1120E+00
.00010	.00440	39.285	2879.212	.5630E+00	.4317E-01	.1151E+00
.00010	.00450	38.517	2917.728	.5630E+00	.4575E-01	.1182E+00
.00010	.00460	37.757	2955.485	.5630E+00	.4839E-01	.1213E+00
.00010	.00470	37.005	2992.490	.5630E+00	.5109E-01	.1244E+00
.00010	.00480	36.262	3028.751	.5630E+00	.5384E-01	.1275E+00
.00010	.00490	35.527	3064.278	.5630E+00	.5664E-01	.1305E+00

Numerical Results - (Continued)

.00010	.00500	34.800	3099.079	.5630E+00	.5948E-01	.1335E+00
.00010	.00510	34.083	3133.161	.5630E+00	.6237E-01	.1365E+00
.00010	.00520	33.373	3166.534	.5630E+00	.6529E-01	.1395E+00
.00010	.00530	32.672	3199.207	.5630E+00	.6826E-01	.1424E+00
.00010	.00540	31.980	3231.187	.5630E+00	.7125E-01	.1453E+00
.00010	.00550	31.296	3262.483	.5630E+00	.7428E-01	.1482E+00
.00010	.00560	30.621	3293.104	.5630E+00	.7734E-01	.1511E+00
.00010	.00570	29.954	3323.058	.5630E+00	.8043E-01	.1539E+00
.00010	.00580	29.296	3352.354	.5630E+00	.8354E-01	.1567E+00
.00010	.00590	28.646	3381.000	.5630E+00	.8667E-01	.1594E+00
.00010	.00600	28.005	3409.006	.5630E+00	.8982E-01	.1622E+00
.00010	.00610	27.373	3436.379	.5630E+00	.9298E-01	.1649E+00
.00010	.00620	26.749	3463.128	.5630E+00	.9616E-01	.1675E+00
.00010	.00630	26.134	3489.262	.5630E+00	.9935E-01	.1702E+00
.00010	.00640	25.527	3514.788	.5630E+00	.1026E+00	.1728E+00
.00010	.00650	24.929	3539.717	.5630E+00	.1058E+00	.1753E+00
.00010	.00660	24.339	3564.056	.5630E+00	.1090E+00	.1779E+00
.00010	.00670	23.758	3587.815	.5630E+00	.1122E+00	.1803E+00
.00010	.00680	23.186	3611.000	.5630E+00	.1154E+00	.1828E+00
.00010	.00690	22.622	3633.622	.5630E+00	.1186E+00	.1852E+00
.00010	.00700	22.067	3655.689	.5630E+00	.1218E+00	.1876E+00
.00001	.00701	2.152	3657.841	.5630E+00	.1250E+00	.1900E+00
.00001	.00702	2.147	3659.988	.5630E+00	.1253E+00	.1902E+00
.00001	.00703	2.141	3662.129	.5630E+00	.1256E+00	.1904E+00
.00001	.00704	2.136	3664.265	.5630E+00	.1259E+00	.1907E+00
.00001	.00705	2.131	3666.396	.5630E+00	.1263E+00	.1909E+00
.00001	.00706	2.125	3668.521	.5630E+00	.1266E+00	.1911E+00
.00001	.00707	2.120	3670.641	.5630E+00	.1269E+00	.1914E+00
.00001	.00708	2.115	3672.756	.5630E+00	.1272E+00	.1916E+00
.00001	.00709	2.109	3674.865	.5630E+00	.1275E+00	.1918E+00
.00001	.00710	2.104	3676.969	.5630E+00	.1278E+00	.1920E+00
.00001	.00711	2.099	3679.068	.5630E+00	.1281E+00	.1923E+00
.00001	.00712	2.094	3681.161	.5630E+00	.1285E+00	.1925E+00

*** THE MELTING POINT = 3683.00 K
THE HEAT OF FUSION = 191755.44 J/KG
TIME NEEDED FOR MELTING THE PARTICLE = .004127 SEC

.00001	.01126	2.088	3683.000	.5630E+00	.1290E+00	.1929E+00
.00001	.01127	2.084	3685.084	.5630E+00	.1290E+00	.1929E+00
.00001	.01128	2.078	3687.162	.5630E+00	.1294E+00	.1931E+00
.00001	.01129	2.073	3689.235	.5630E+00	.1297E+00	.1934E+00
.00001	.01130	2.068	3691.303	.5630E+00	.1300E+00	.1936E+00
.00001	.01131	2.063	3693.366	.5630E+00	.1303E+00	.1938E+00
.00001	.01132	2.057	3695.423	.5630E+00	.1306E+00	.1940E+00
.00001	.01133	2.052	3697.476	.5630E+00	.1309E+00	.1943E+00
.00001	.01134	2.047	3699.523	.5630E+00	.1312E+00	.1945E+00
.00001	.01135	2.042	3701.565	.5630E+00	.1316E+00	.1947E+00
.00001	.01136	2.037	3703.601	.5630E+00	.1319E+00	.1949E+00
.00001	.01137	2.032	3705.633	.5630E+00	.1322E+00	.1952E+00
.00001	.01138	2.026	3707.659	.5630E+00	.1325E+00	.1954E+00
.00001	.01139	2.021	3709.680	.5630E+00	.1328E+00	.1956E+00
.00001	.01140	2.016	3711.696	.5630E+00	.1331E+00	.1958E+00
.00010	.01150	20.109	3731.806	.5630E+00	.1334E+00	.1960E+00
.00010	.01160	19.594	3751.400	.5630E+00	.1366E+00	.1983E+00
.00010	.01170	19.088	3770.487	.5630E+00	.1397E+00	.2004E+00
.00010	.01180	18.590	3789.077	.5630E+00	.1428E+00	.2026E+00

Numerical Results - (Continued)

.00010	.01190	18.100	3807.177	.5630E+00	.1459E+00	.2047E+00
.00010	.01200	17.620	3824.797	.5630E+00	.1490E+00	.2068E+00
.00010	.01210	17.148	3841.945	.5630E+00	.1520E+00	.2088E+00
.00010	.01220	16.684	3858.629	.5630E+00	.1550E+00	.2108E+00
.00010	.01230	16.229	3874.858	.5630E+00	.1580E+00	.2128E+00
.00010	.01240	15.783	3890.642	.5630E+00	.1610E+00	.2147E+00
.00010	.01250	15.345	3905.987	.5630E+00	.1639E+00	.2166E+00
.00010	.01260	14.916	3920.903	.5630E+00	.1669E+00	.2184E+00
.00010	.01270	14.496	3935.399	.5630E+00	.1697E+00	.2202E+00
.00010	.01280	14.084	3949.483	.5630E+00	.1725E+00	.2220E+00
.00010	.01290	13.680	3963.163	.5630E+00	.1753E+00	.2237E+00
.00010	.01300	13.285	3976.447	.5630E+00	.1781E+00	.2254E+00
.00010	.01310	12.898	3989.346	.5630E+00	.1808E+00	.2271E+00
.00010	.01320	12.520	4001.865	.5630E+00	.1834E+00	.2287E+00
.00010	.01330	12.150	4014.015	.5630E+00	.1861E+00	.2303E+00
.00010	.01340	11.788	4025.803	.5630E+00	.1887E+00	.2318E+00
.00010	.01350	11.434	4037.237	.5630E+00	.1912E+00	.2333E+00
.00010	.01360	11.089	4048.325	.5630E+00	.1937E+00	.2348E+00
.00010	.01370	10.751	4059.077	.5630E+00	.1962E+00	.2362E+00
.00010	.01380	10.422	4069.499	.5630E+00	.1986E+00	.2376E+00
.00010	.01390	10.100	4079.599	.5630E+00	.2009E+00	.2390E+00
.00010	.01400	9.787	4089.386	.5630E+00	.2033E+00	.2404E+00
.00010	.01410	9.481	4098.867	.5630E+00	.2055E+00	.2417E+00
.00010	.01420	9.183	4108.050	.5630E+00	.2078E+00	.2429E+00
.00010	.01430	8.892	4116.943	.5630E+00	.2100E+00	.2442E+00
.00010	.01440	8.609	4125.552	.5630E+00	.2121E+00	.2454E+00
.00010	.01450	8.334	4133.886	.5630E+00	.2142E+00	.2465E+00
.00010	.01460	8.065	4141.951	.5630E+00	.2162E+00	.2477E+00
.00010	.01470	7.804	4149.755	.5630E+00	.2182E+00	.2488E+00
.00010	.01480	7.550	4157.305	.5630E+00	.2202E+00	.2499E+00
.00010	.01490	7.303	4164.608	.5630E+00	.2221E+00	.2509E+00
.00010	.01500	7.063	4171.671	.5630E+00	.2239E+00	.2519E+00
.00010	.01510	6.829	4178.500	.5630E+00	.2257E+00	.2529E+00
.00010	.01520	6.602	4185.102	.5630E+00	.2275E+00	.2539E+00
.00010	.01530	6.382	4191.484	.5630E+00	.2292E+00	.2548E+00
.00010	.01540	6.168	4197.651	.5630E+00	.2309E+00	.2557E+00
.00010	.01550	5.960	4203.611	.5630E+00	.2325E+00	.2566E+00
.00010	.01560	5.758	4209.369	.5630E+00	.2341E+00	.2574E+00
.00010	.01570	5.562	4214.932	.5630E+00	.2357E+00	.2583E+00
.00010	.01580	5.373	4220.305	.5630E+00	.2372E+00	.2591E+00
.00010	.01590	5.189	4225.493	.5630E+00	.2387E+00	.2599E+00
.00010	.01600	5.010	4230.503	.5630E+00	.2401E+00	.2606E+00
.00010	.01610	4.837	4235.340	.5630E+00	.2415E+00	.2613E+00
.00010	.01620	4.669	4240.010	.5630E+00	.2428E+00	.2620E+00
.00010	.01630	4.507	4244.517	.5630E+00	.2441E+00	.2627E+00
.00010	.01640	4.350	4248.867	.5630E+00	.2454E+00	.2634E+00
.00010	.01650	4.198	4253.064	.5630E+00	.2466E+00	.2640E+00
.00010	.01660	4.050	4257.114	.5630E+00	.2478E+00	.2646E+00
.00010	.01670	3.907	4261.022	.5630E+00	.2489E+00	.2652E+00
.00010	.01680	3.769	4264.791	.5630E+00	.2501E+00	.2658E+00
.00010	.01690	3.636	4268.427	.5630E+00	.2511E+00	.2664E+00
.00010	.01700	3.506	4271.933	.5630E+00	.2522E+00	.2669E+00
.00010	.01710	3.382	4275.315	.5630E+00	.2532E+00	.2674E+00
.00010	.01720	3.261	4278.575	.5630E+00	.2542E+00	.2680E+00
.00010	.01730	3.144	4281.719	.5630E+00	.2552E+00	.2684E+00
.00010	.01740	3.031	4284.750	.5630E+00	.2561E+00	.2689E+00
.00010	.01750	2.922	4287.672	.5630E+00	.2570E+00	.2694E+00
.00010	.01760	2.816	4290.488	.5630E+00	.2578E+00	.2698E+00

Numerical Results - (Continued)

.00010	.01770	2.715	4293.203	.5630E+00	.2587E+00	.2702E+00
.00010	.01780	2.616	4295.819	.5630E+00	.2595E+00	.2707E+00
.00010	.01790	2.521	4298.340	.5630E+00	.2603E+00	.2711E+00
.00010	.01800	2.429	4300.770	.5630E+00	.2610E+00	.2714E+00
.00010	.01810	2.341	4303.110	.5630E+00	.2618E+00	.2718E+00
.00010	.01820	2.255	4305.366	.5630E+00	.2625E+00	.2722E+00
.00010	.01830	2.173	4307.538	.5630E+00	.2632E+00	.2725E+00
.00010	.01840	2.093	4309.632	.5630E+00	.2638E+00	.2728E+00
.00010	.01850	2.016	4311.648	.5630E+00	.2645E+00	.2732E+00
.00010	.01860	1.942	4313.590	.5630E+00	.2651E+00	.2735E+00
.00010	.01870	1.871	4315.461	.5630E+00	.2657E+00	.2738E+00
.00010	.01880	1.802	4317.262	.5630E+00	.2662E+00	.2741E+00
.00010	.01890	1.735	4318.997	.5630E+00	.2668E+00	.2743E+00
.00010	.01900	1.671	4320.668	.5630E+00	.2673E+00	.2746E+00
.00010	.01910	1.609	4322.277	.5630E+00	.2679E+00	.2749E+00
.00010	.01920	1.549	4323.826	.5630E+00	.2684E+00	.2751E+00
.00010	.01930	1.492	4325.318	.5630E+00	.2688E+00	.2753E+00
.00010	.01940	1.436	4326.754	.5630E+00	.2693E+00	.2756E+00
.00010	.01950	1.383	4328.137	.5630E+00	.2697E+00	.2758E+00
.00010	.01960	1.331	4329.468	.5630E+00	.2702E+00	.2760E+00
.00010	.01970	1.282	4330.749	.5630E+00	.2706E+00	.2762E+00
.00010	.01980	1.234	4331.983	.5630E+00	.2710E+00	.2764E+00
.00010	.01990	1.188	4333.170	.5630E+00	.2714E+00	.2766E+00
.00010	.02000	1.143	4334.313	.5630E+00	.2718E+00	.2768E+00
.00100	.02100	11.002	4345.316	.5630E+00	.2721E+00	.2770E+00
.00100	.02200	6.860	4352.176	.5630E+00	.2756E+00	.2787E+00
.00100	.02300	4.259	4356.434	.5630E+00	.2778E+00	.2798E+00
.00100	.02400	2.636	4359.071	.5630E+00	.2792E+00	.2805E+00
.00100	.02500	1.629	4360.700	.5630E+00	.2800E+00	.2809E+00
.00100	.02600	1.006	4361.706	.5630E+00	.2806E+00	.2811E+00
.00100	.02700	.620	4362.326	.5630E+00	.2809E+00	.2813E+00
.00100	.02800	.383	4362.709	.5630E+00	.2811E+00	.2814E+00
.00100	.02900	.236	4362.944	.5630E+00	.2812E+00	.2815E+00
.00100	.03000	.145	4363.090	.5630E+00	.2813E+00	.2815E+00
.00100	.03100	.090	4363.179	.5630E+00	.2813E+00	.2815E+00
.00100	.03200	.055	4363.235	.5630E+00	.2814E+00	.2815E+00
.00100	.03300	.034	4363.269	.5630E+00	.2814E+00	.2815E+00
.00100	.03400	.021	4363.290	.5630E+00	.2814E+00	.2815E+00
.00100	.03500	.013	4363.303	.5630E+00	.2814E+00	.2815E+00
.00100	.03600	.008	4363.311	.5630E+00	.2814E+00	.2816E+00
.00100	.03700	.005	4363.315	.5630E+00	.2814E+00	.2816E+00

VITA

Mr. Patrick Y. K. Chang, son of Mr. and Mrs. Jida and Pingmann P. Chang, was born in Taipei, Taiwan, the Republic of China, on December 11, 1952. He graduated from the Department of Mechanical Engineering at the Chung Cheng Institute of Technology, Taoyuan, Taiwan, in 1976. He served in the Chinese Armed Forces for eight years and was awarded the "One Star Medal of Merit" and six National Defense Citations in recognition of his distinguished services.

Mr. Chang is married to Karen and they have a daughter named Clare. The family resides in the suburb of Taipei together with his father. He was admitted as a graduate student to Lehigh University in the Department of Mechanical Engineering and Mechanics. Upon completion of the Master degree in Applied Mechanics, he shall return to the Republic of China and attempt to continue his research work that was initiated in the United States of America.