CHAPTER 6

SENSITIVITY ANALYSIS

6.1 Identification of significant factors for the model

To analyze whether factors have any significant effect on the rapid expansion of supercritical carbon dioxide. The estimated effects, inlet temperature, inlet pressure and inlet velocity are varied to see their effects, especially near the nozzle area which the ranges of the significant factors are shown in Table 6.1

Table 6.1 Ranges of the significant factors

Case	Inlet velocity (m/s)	Inlet temperature (K)	Inlet pressure (bar)
A	0.0	300, 340, 380	60, 70, 80, 90
B	10.0	300, 340, 380	60, 70, 80, 90
C	100.0	300, 340, 380	60, 70, 80, 90

In the identification of the significant factors, the model parameters for simulation are summarized in Table 6.2.

Table 6.2 Simulation conditions used in the simulations to find out the significant factors

Simulation conditions	
Number of grid points in the y, z directions	24 x 521
Grid size ($\Delta y, \Delta z$)	1×10^{-5}, 4×10^{-5} m
Interval time	70000
Integration step size(Δt)	1.0×10^{-12} sec.

Table 6.2 Simulation conditions used in the simulations to find out the significant factors (continue)

Simulation conditions	
Specific gas constant of CO_2	8.314*1000/44.01
Ratio of specific heat of CO_2	1.304
Prandtl number	0.710
Bed pressure of fluid	1.0 bar
Bed temperature of fluid	298.0 K
Bed density of fluid	5.30778×10^{-3} kg/m^3
Reference Temperature	293.0 K
Reference viscosity of CO_2 at Trf	1.463×10^{-4} kg/(m·s)

6.2 Effects of significant factors

The effect of the significant factors at different value of inlet velocity, inlet temperature and inlet pressure are investigated in this section. The simulation conditions for all cases are listed in Table 6.3.

Table 6.3 The simulation conditions for all cases

Case	Inlet velocity (m/s)	Inlet temperature (K)	Inlet pressure (bar)
Inlet Temperature Effect	0.0	300	80
	0.0	340	80
	0.0	380	80
	10.0	300	80
	10.0	340	80
	10.0	380	80
	100.0	300	80
	100.0	340	80
	100.0	380	80

Table 6.3 The simulation conditions for all cases (continue)

Case	Inlet velocity (m/s)	Inlet temperature (K)	Inlet pressure (bar)
Inlet velocity Effect	0.0	300	80
	10.0	300	80
	100.0	300	80
	0.0	340	80
	10.0	340	80
	100.0	340	80
	0.0	380	80
	10.0	380	80
	100.0	380	80
Inlet pressure Effect	0.0	300	60
	0.0	300	70
	0.0	300	80
	0.0	300	90
	0.0	340	60
	0.0	340	70
	0.0	340	80
	0.0	340	90
	0.0	380	60
	0.0	380	70
	0.0	380	80
	0.0	380	90
	10.0	300	60
	10.0	300	70
	10.0	300	80
	10.0	300	90
	10.0	340	60
	10.0	340	70
	10.0	340	80
	10.0	340	90
	10.0	380	60

Table 6.3 The simulation conditions for all cases (continue)

Case	Inlet velocity (m/s)	Inlet temperature (K)	Inlet pressure (bar)
Inlet pressure Effect	10.0	380	70
	10.0	380	80
	10.0	380	90
	100.0	300	60
	100.0	300	70
	100.0	300	80
	100.0	300	90
	100.0	340	60
	100.0	340	70
	100.0	340	80
	100.0	340	90
	100.0	380	60
	100.0	380	70
	100.0	380	80
	100.0	380	90

6.2.1 Effects of Inlet temperature

The effect of inlet temperature on the predicted temperature of fluid is significant at inlet pressure 80 bar and inlet velocities of 0.0, 10.0 and 100.0 m/s. Figures 6.1, 6.2 and 6.3 show the same trend of temperature profile of the flowing fluid. At the inlet temperature of 300 K, the temperature of fluid passing through the nozzle decreases slightly into the environmental temperature. For inlet temperature of 340 and 380 K, the temperature of fluid passed through the nozzle to the distance 1 D from the nozzle, decreases extremely, but from the distant 2 D from the nozzle, the temperature of fluid increase slightly into the bed temperature.

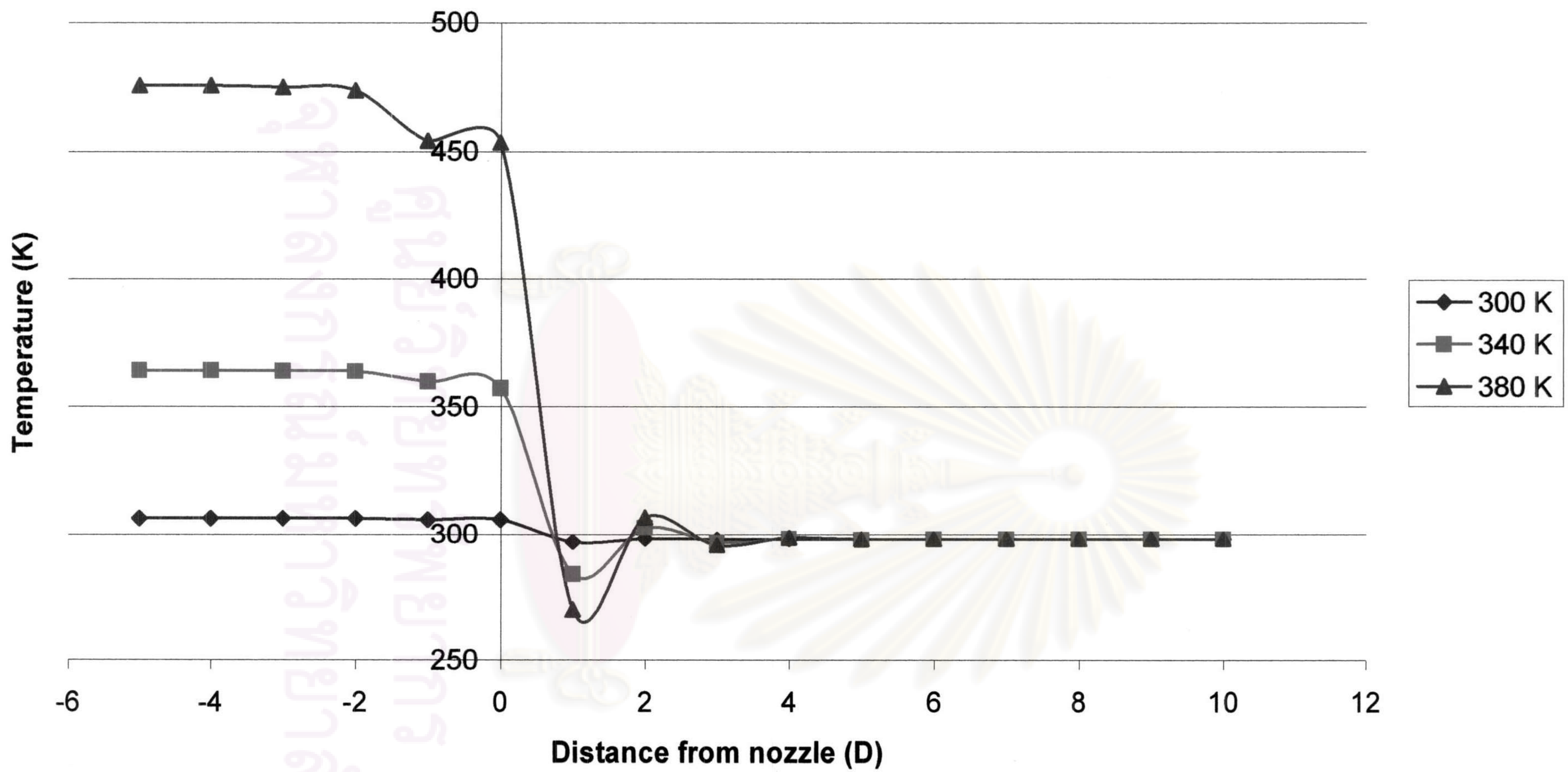

Fig 6.1 Relative graph of temperature and distance from nozzle, Inlet pressure = 80 bar and Inlet velocity = 0.0 m/s

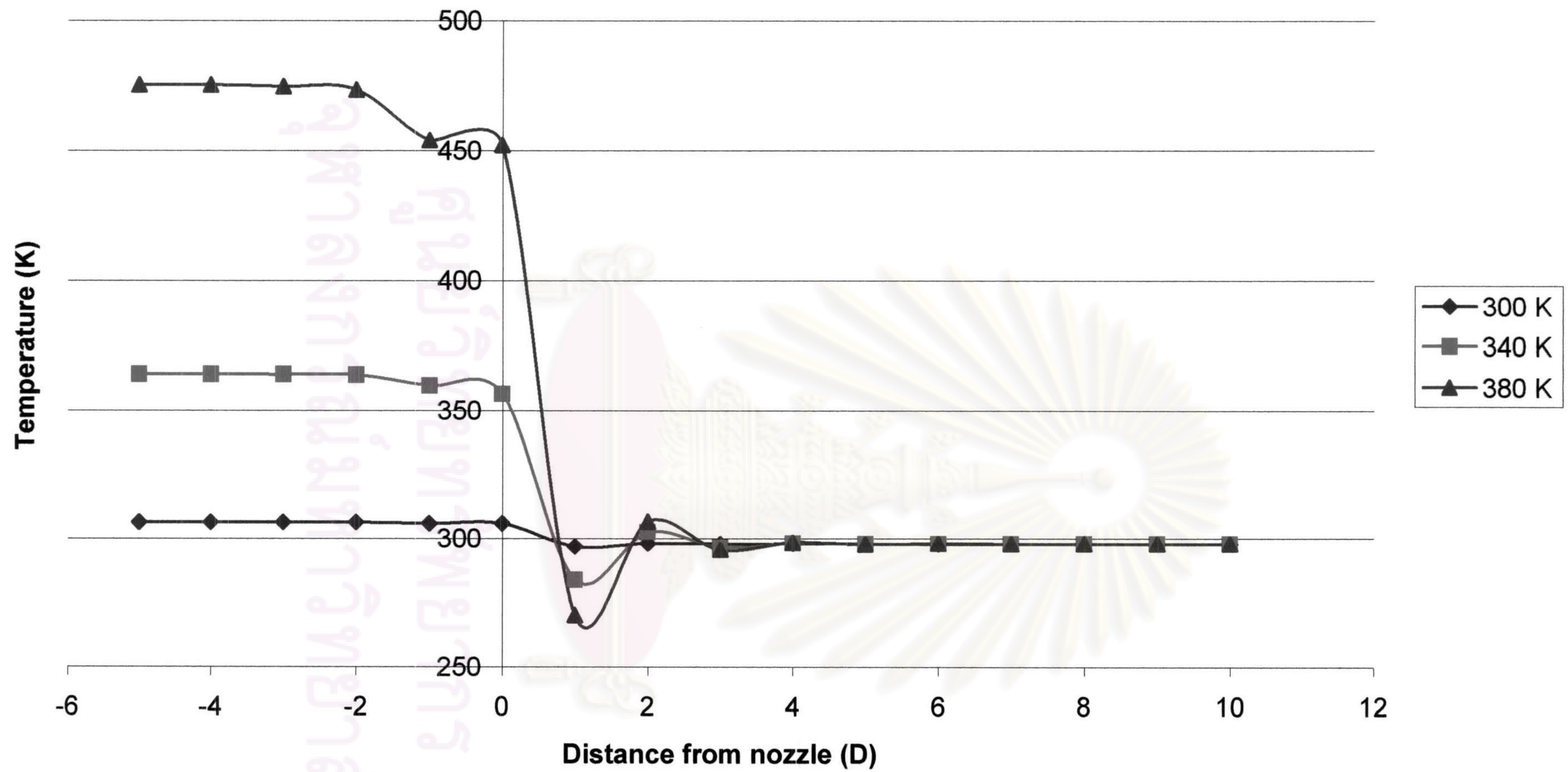

Fig 6.2 Relative graph of temperature and distance from nozzle, Inlet pressure = 80 bar and Inlet velocity = 10.0 m/s

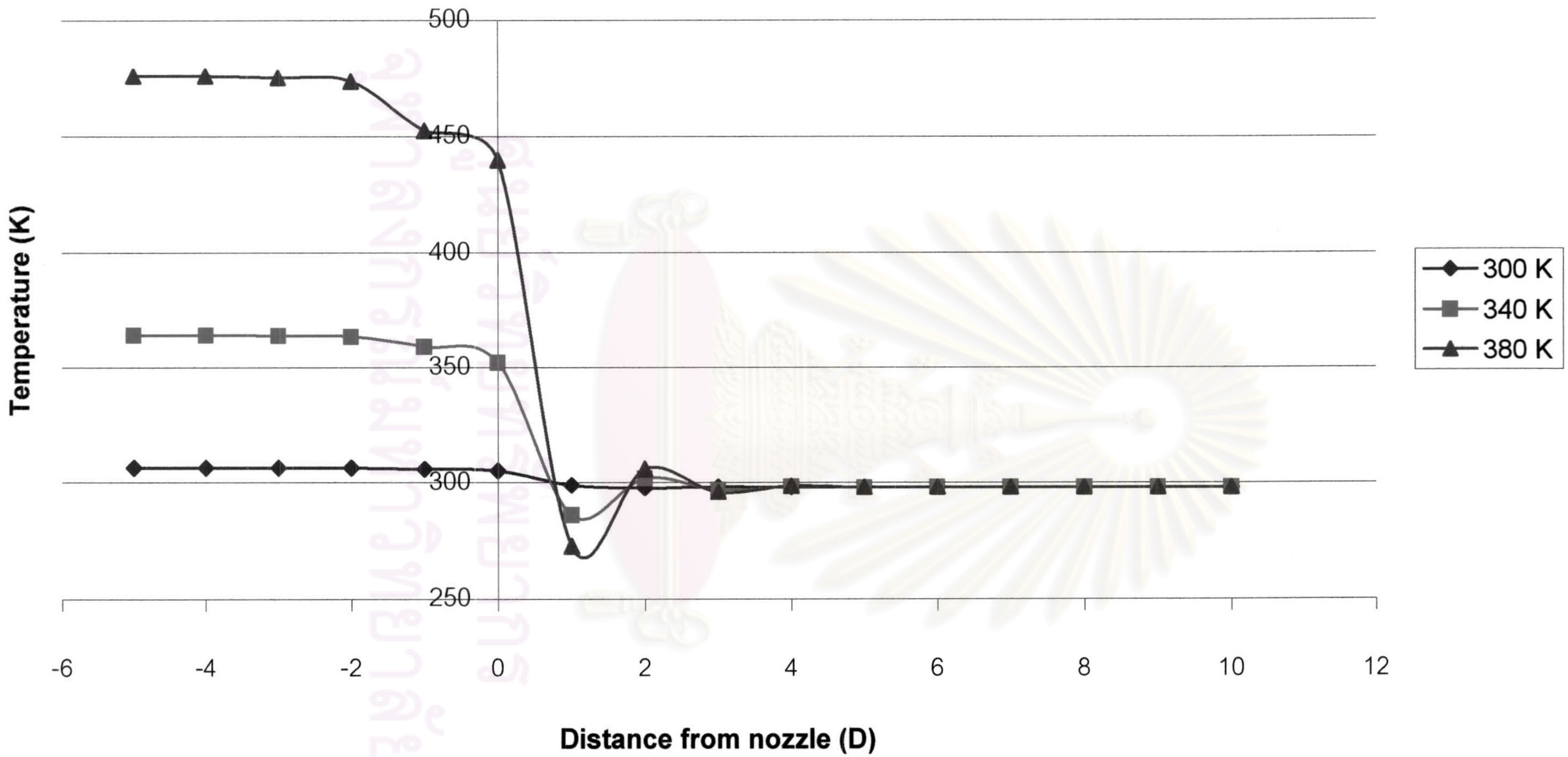

Fig 6.3 Relative graph of temperature and distance from nozzle, Inlet pressure = 80 bar and Inlet velocity = 100.0 m/s

6.2.2 Effects of Inlet velocity

From figure 6.4-6.6, the inlet velocities exhibited the significant effect on the predicted temperature of fluid under condition of inlet pressure of 80 bar and inlet temperature of 300, 340 and 380 K.

From the results, it could be clearly seen that the inlet velocities rarely give effect on the temperature of flowing fluid passed through the nozzle. Also, inlet velocities rarely give effect to the temperature of fluid in nozzle. The predicted temperature profiles of fluid have the same trend in every values of inlet velocity which the temperature decreases extremely in the distance 1 D from the nozzle and for the distance 2 D from the nozzle, the temperature of flowing fluid increase slightly into the environment temperature.

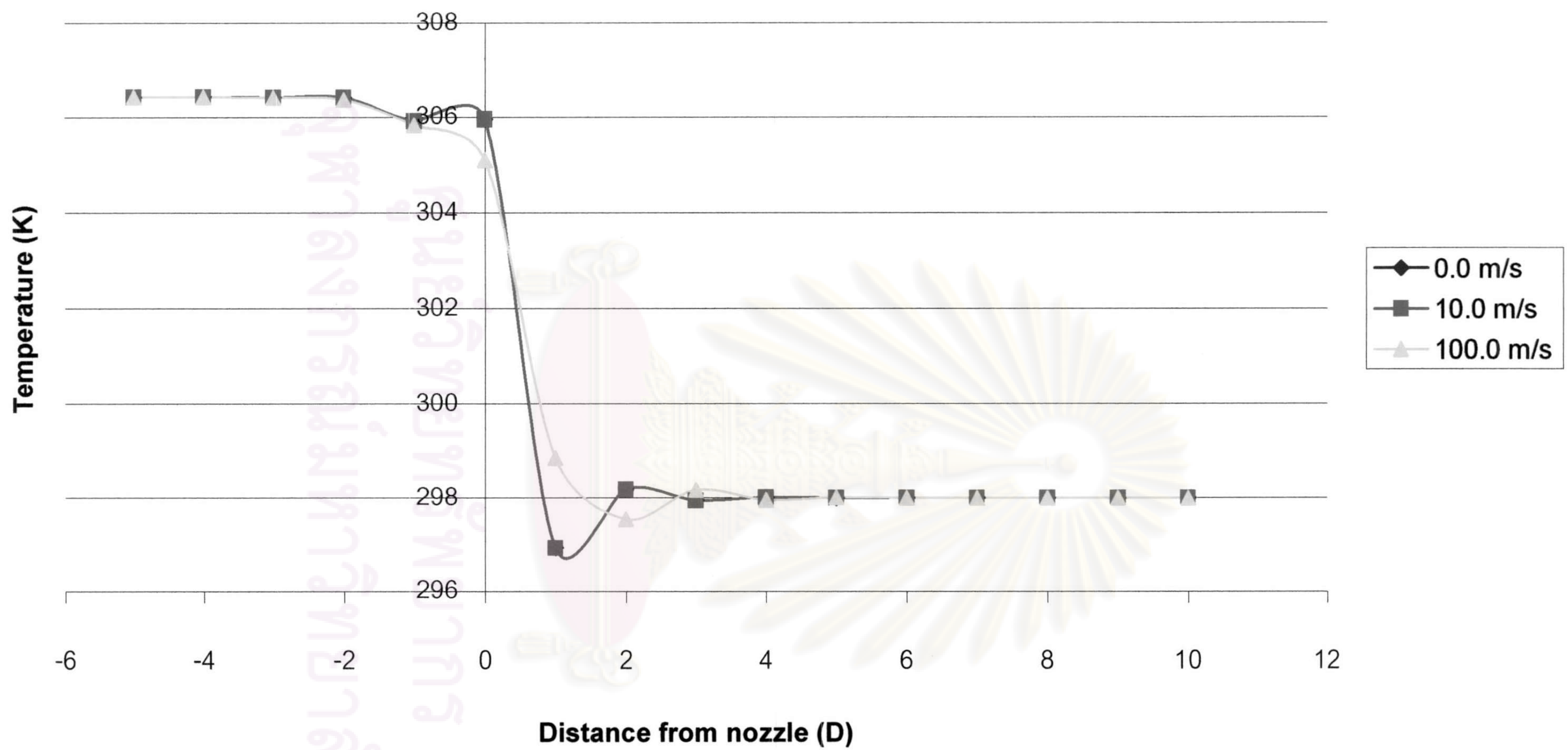

Fig 6.4 Relative graph of temperature and distance from nozzle, Inlet pressure = 80 bar and Inlet temperature = 300 K

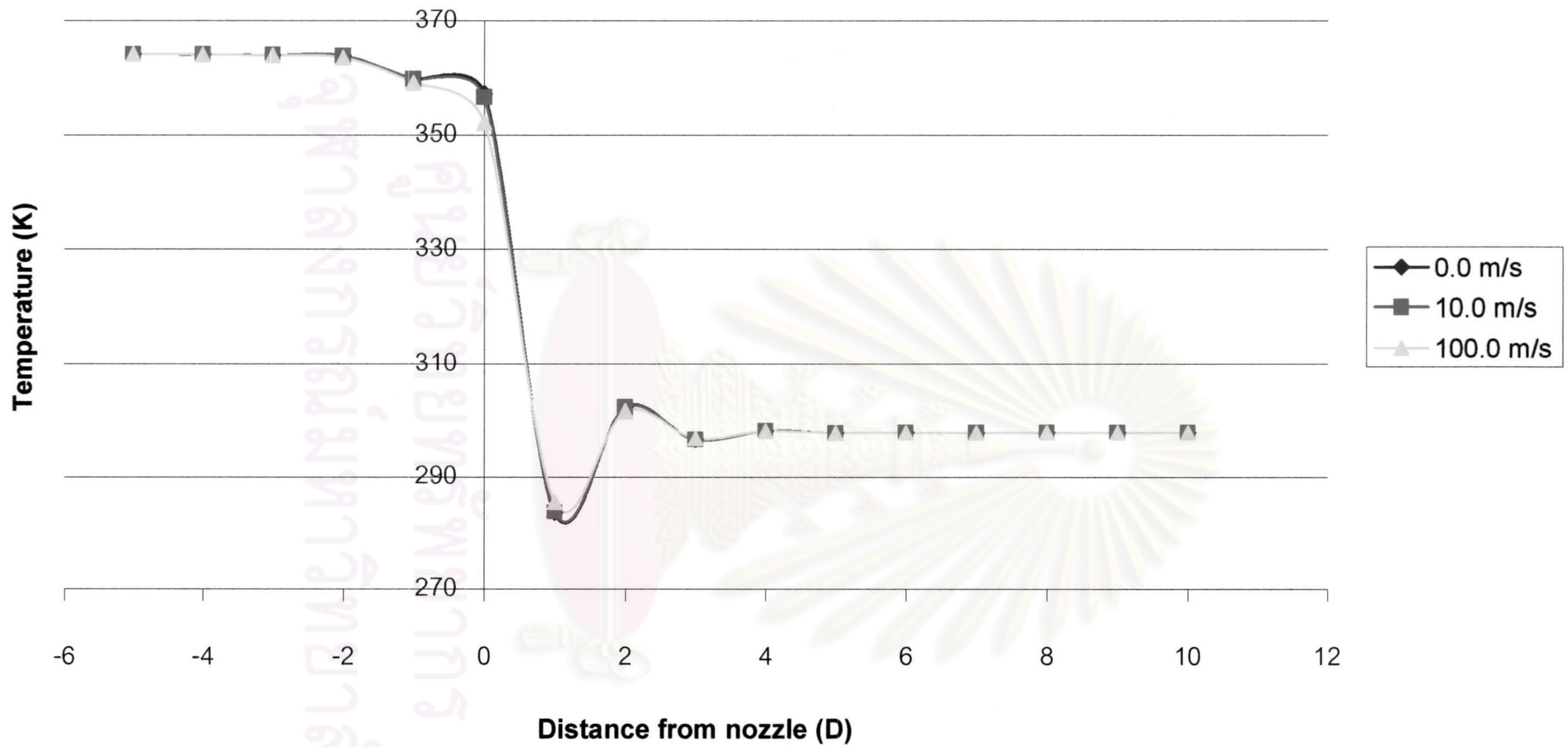

Fig 6.5 Relative graph of temperature and distance from nozzle, Inlet pressure = 80 bar and Inlet temperature = 340 K

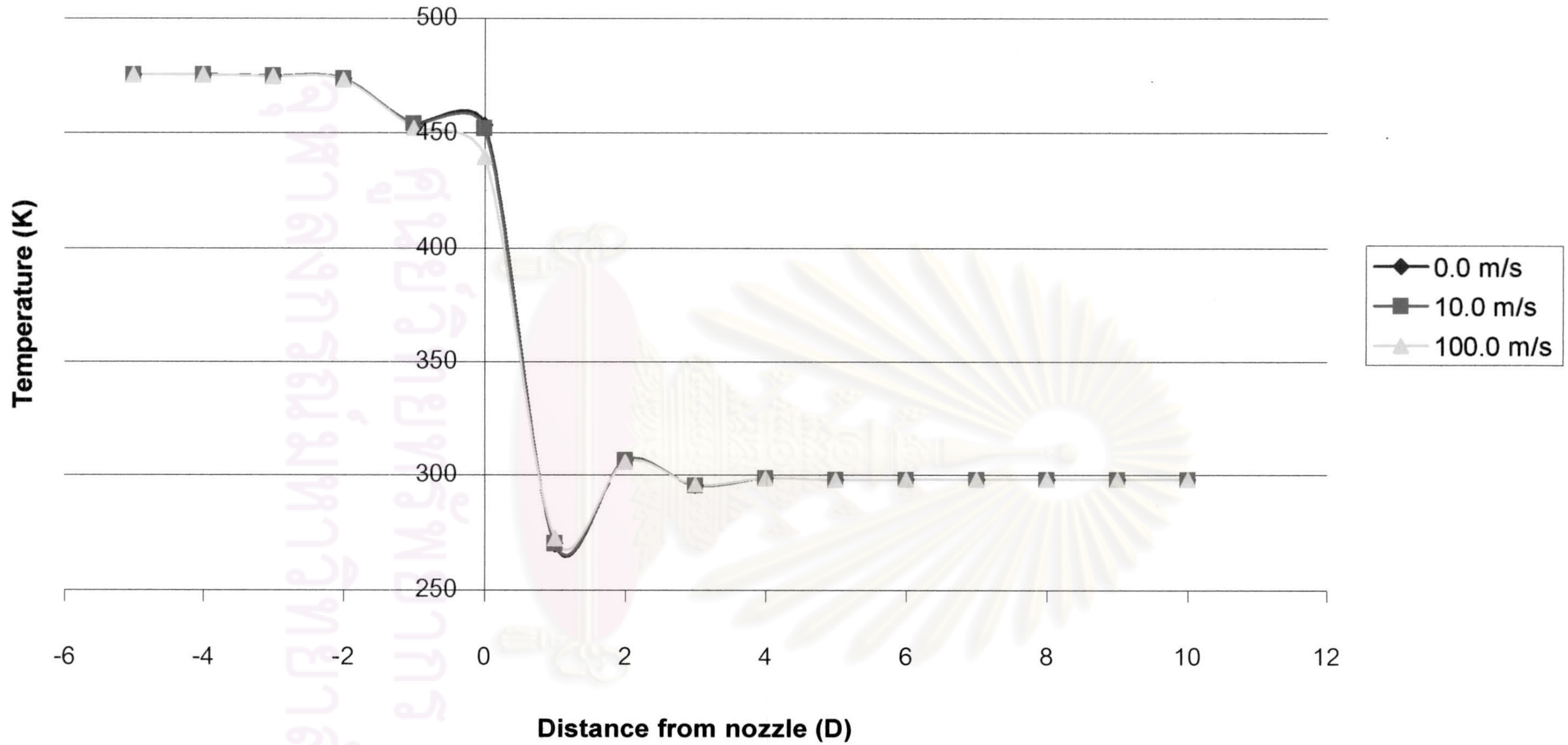

Fig 6.6 Relative graph of temperature and distance from nozzle, Inlet pressure = 80 bar and Inlet temperature = 380 K

6.2.3 Effects of Inlet pressure

Consider figure 6.8–6.16, it could be clearly seen the effects of inlet pressure on the predicted temperature of flowing fluid undergone rapid expansion of supercritical carbon dioxide under condition of inlet temperatures of 300, 340 and 380 K and inlet velocities of 0.0, 10.0 and 100.0 m/s.

From the results, the inlet pressure gives significant effect on the temperature profile along the calculating domain. The temperature of flowing fluid passing through the nozzle exhibits the same trend of a rapid decreasing along the distance of 1 D from the nozzle. For the distance of 2 D from the nozzle, the temperature of flowing fluid increases slightly and becomes lead aft at the environment temperature. These phenomena could also be implied as the Joule-Thompson effect. Moreover, the value of inlet pressure also gives impact effect to the temperature of fluid in nozzle, when pressure increases, the temperature of fluid in nozzle will decrease that be consistent with the throttling process which could be described by PT diagram

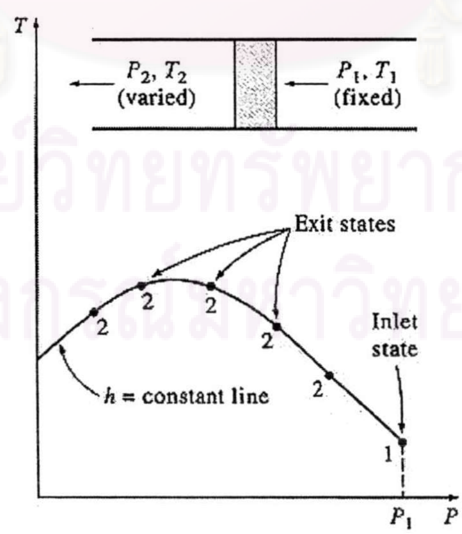

Figure 6.7 PT diagram of the throttling process

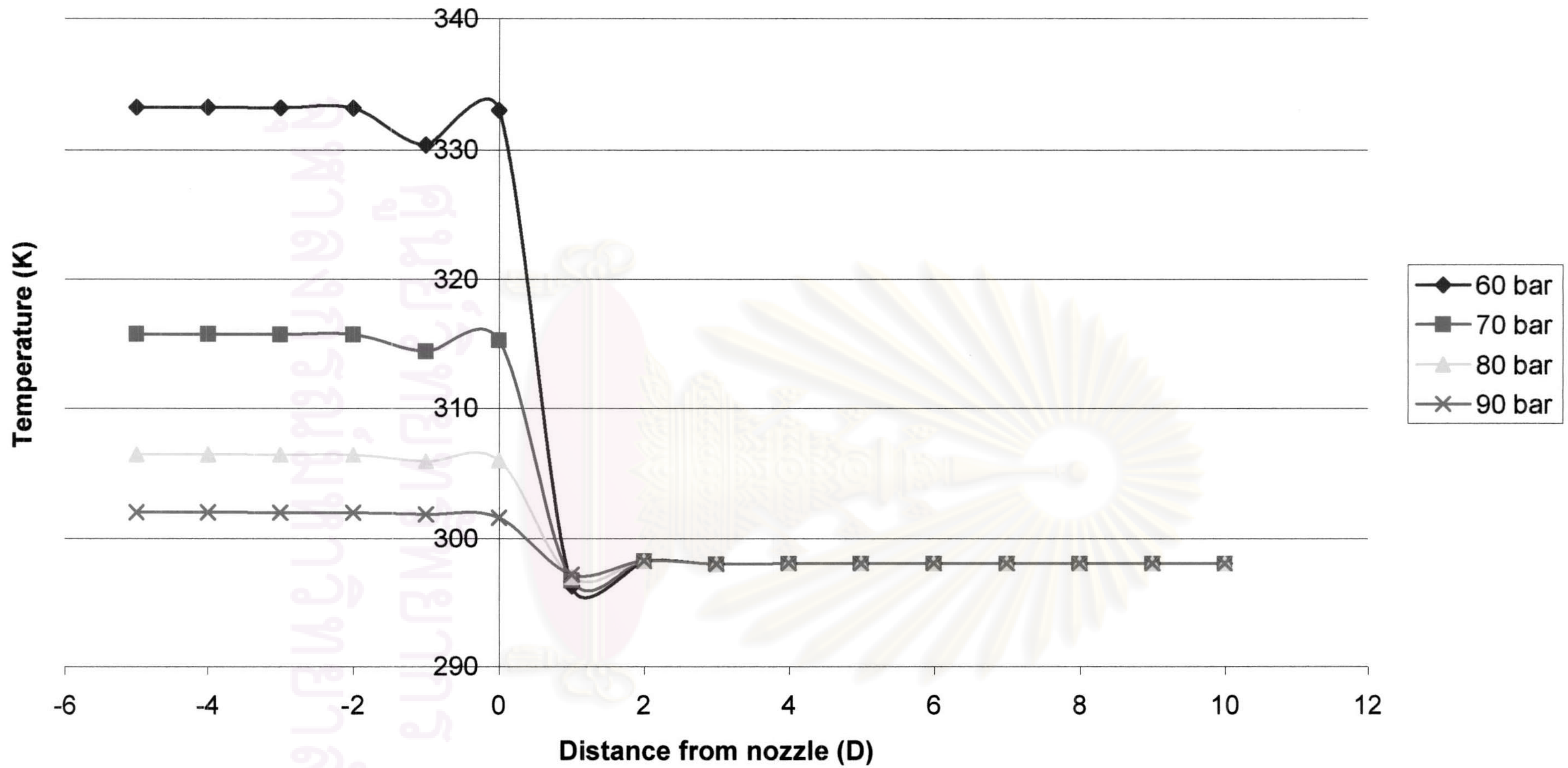

Fig 6.8 Relative graph of temperature and distance from nozzle, Inlet velocity = 0.0 m/s and Inlet temperature = 300 K

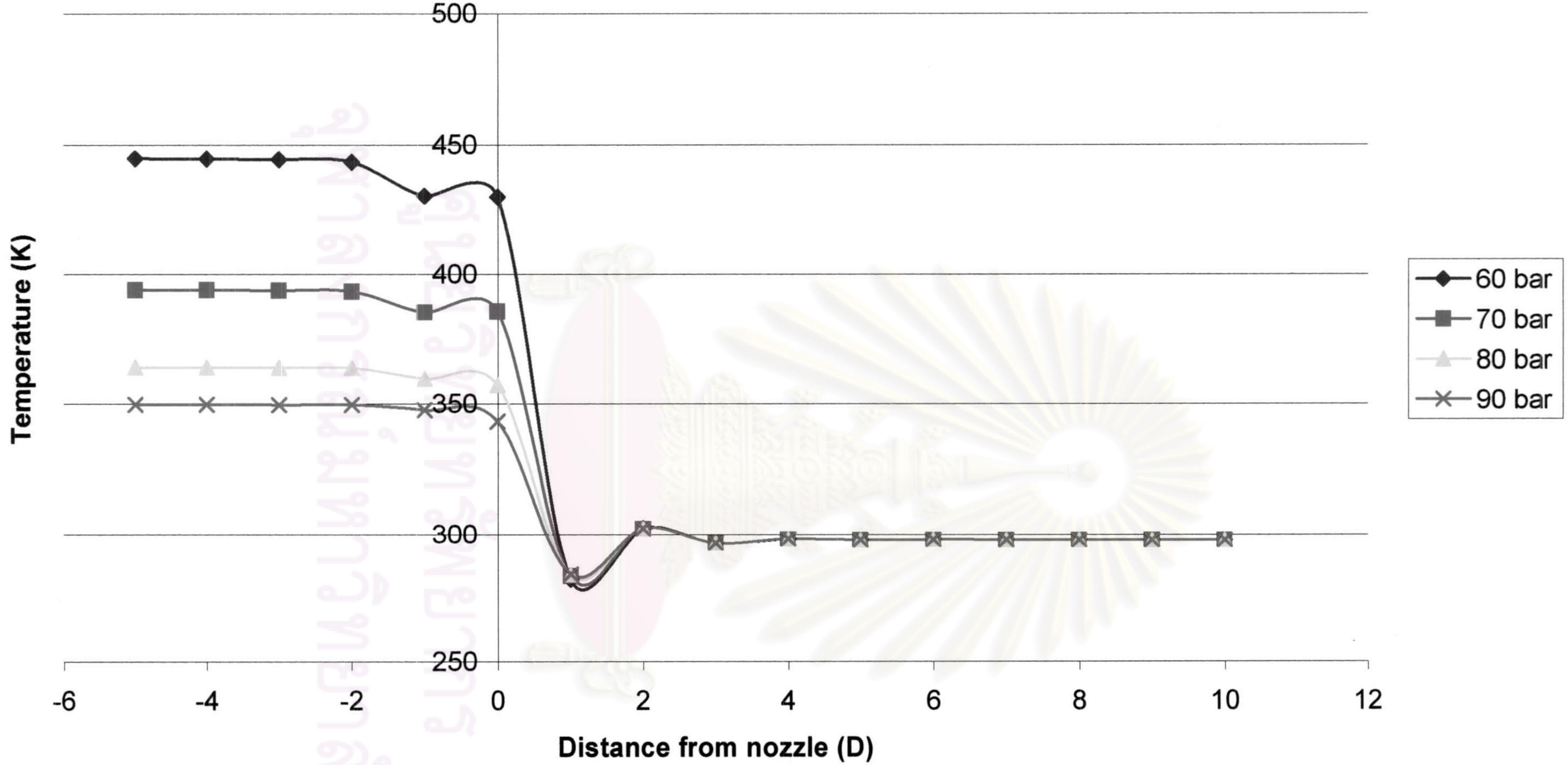

Fig 6.9 Relative graph of temperature and distance from nozzle, Inlet velocity = 0.0 m/s and Inlet temperature = 340 K

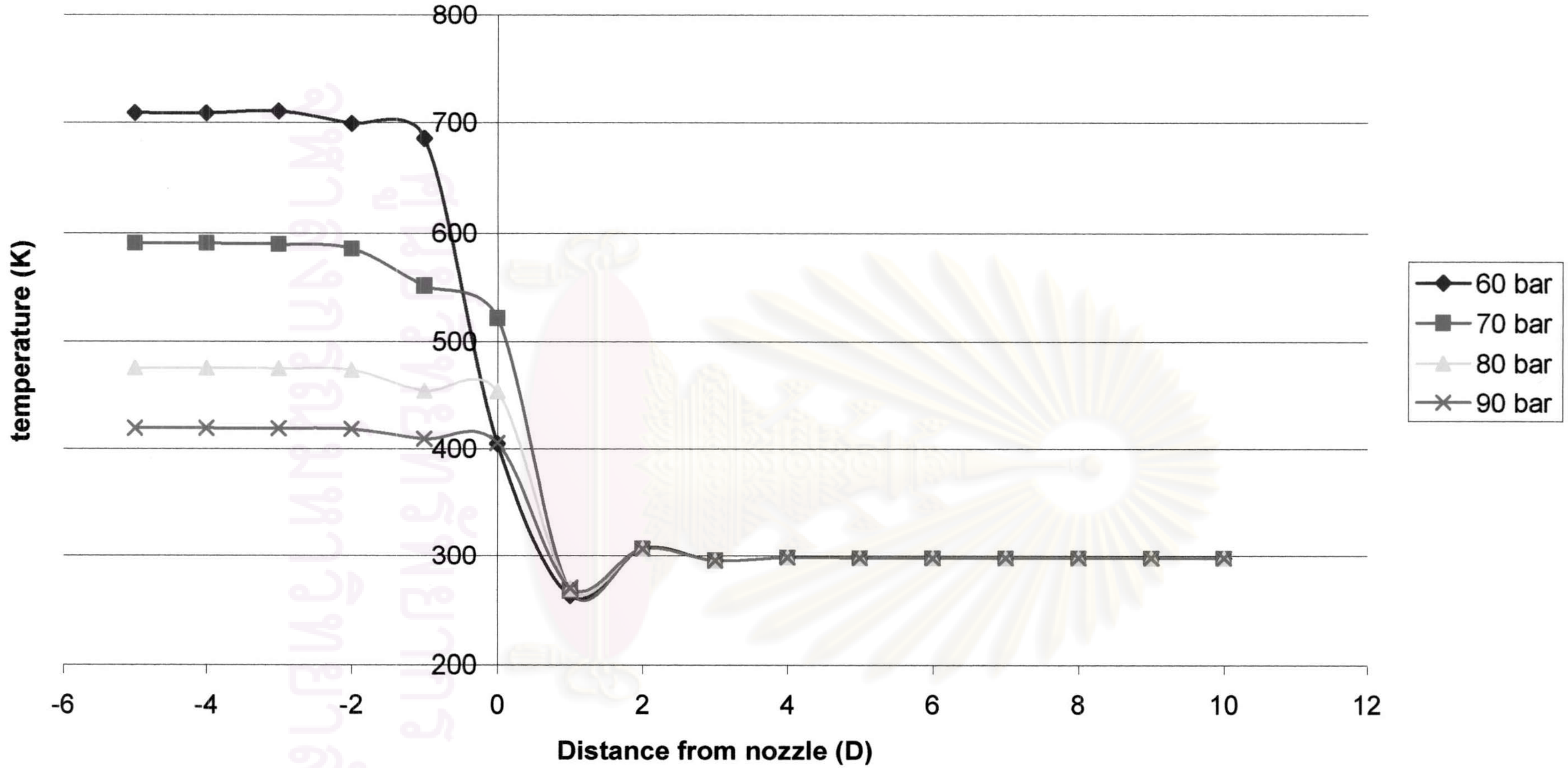

Fig 6.10 Relative graph of temperature and distance from nozzle, Inlet velocity = 0.0 m/s and Inlet temperature = 380 K

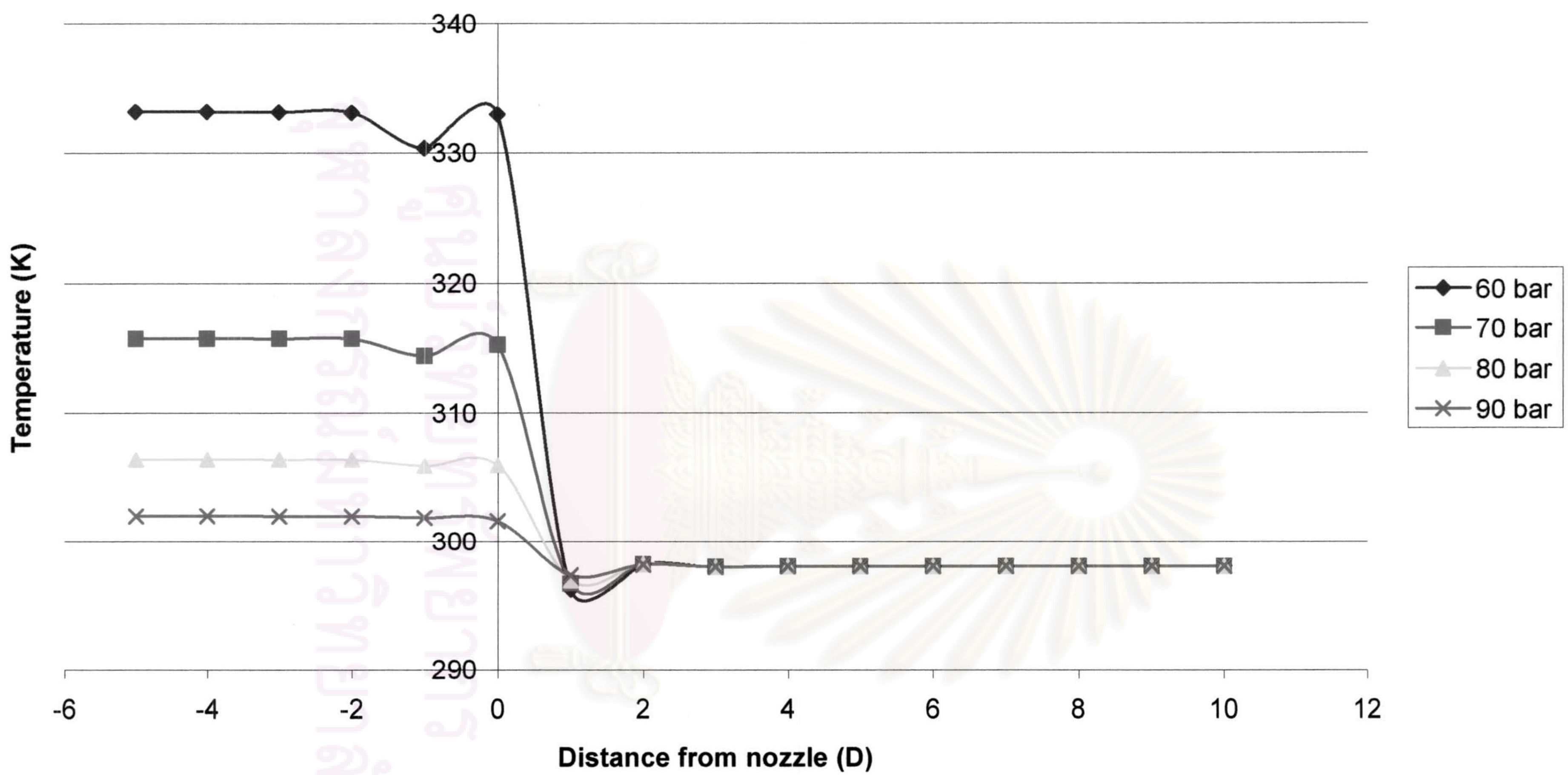

Fig 6.11 Relative graph of temperature and distance from nozzle, Inlet velocity =1 0.0 m/s and Inlet temperature = 300 K

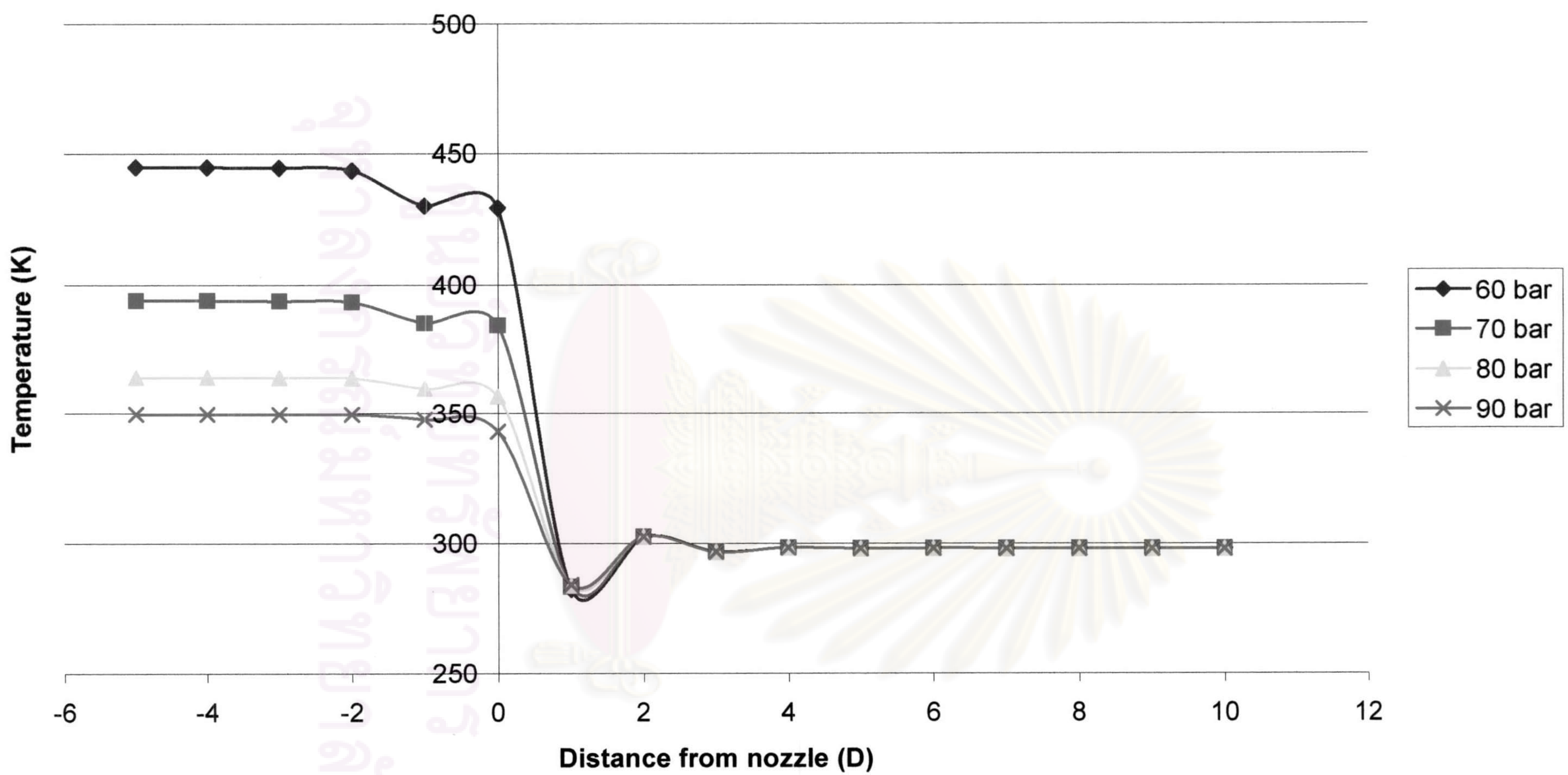

Fig 6.12 Relative graph of temperature and distance from nozzle, Inlet velocity =1 0.0 m/s and Inlet temperature = 340 K

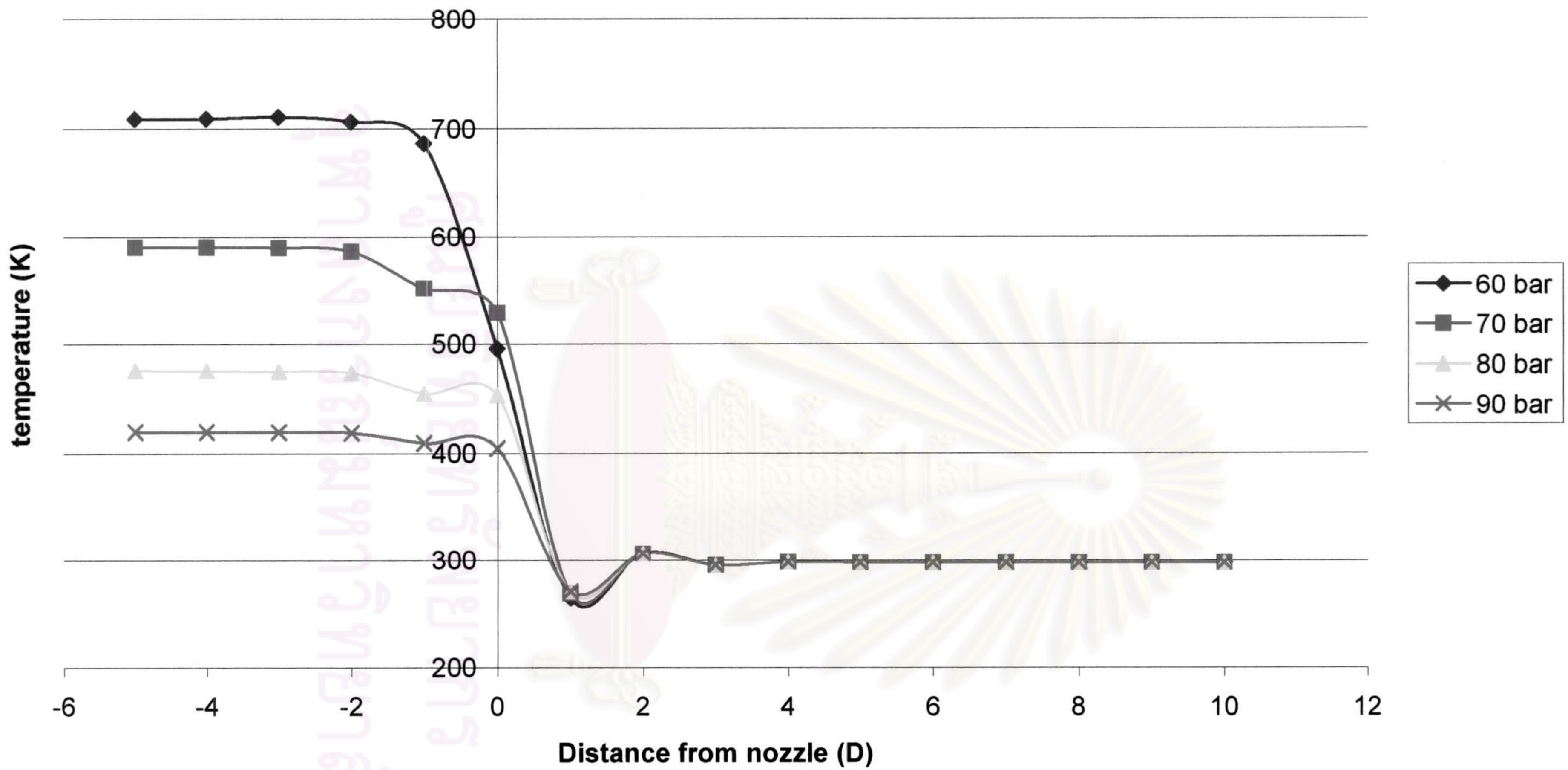

Fig 6.13 Relative graph of temperature and distance from nozzle, Inlet velocity =1 0.0 m/s and Inlet temperature = 380 K

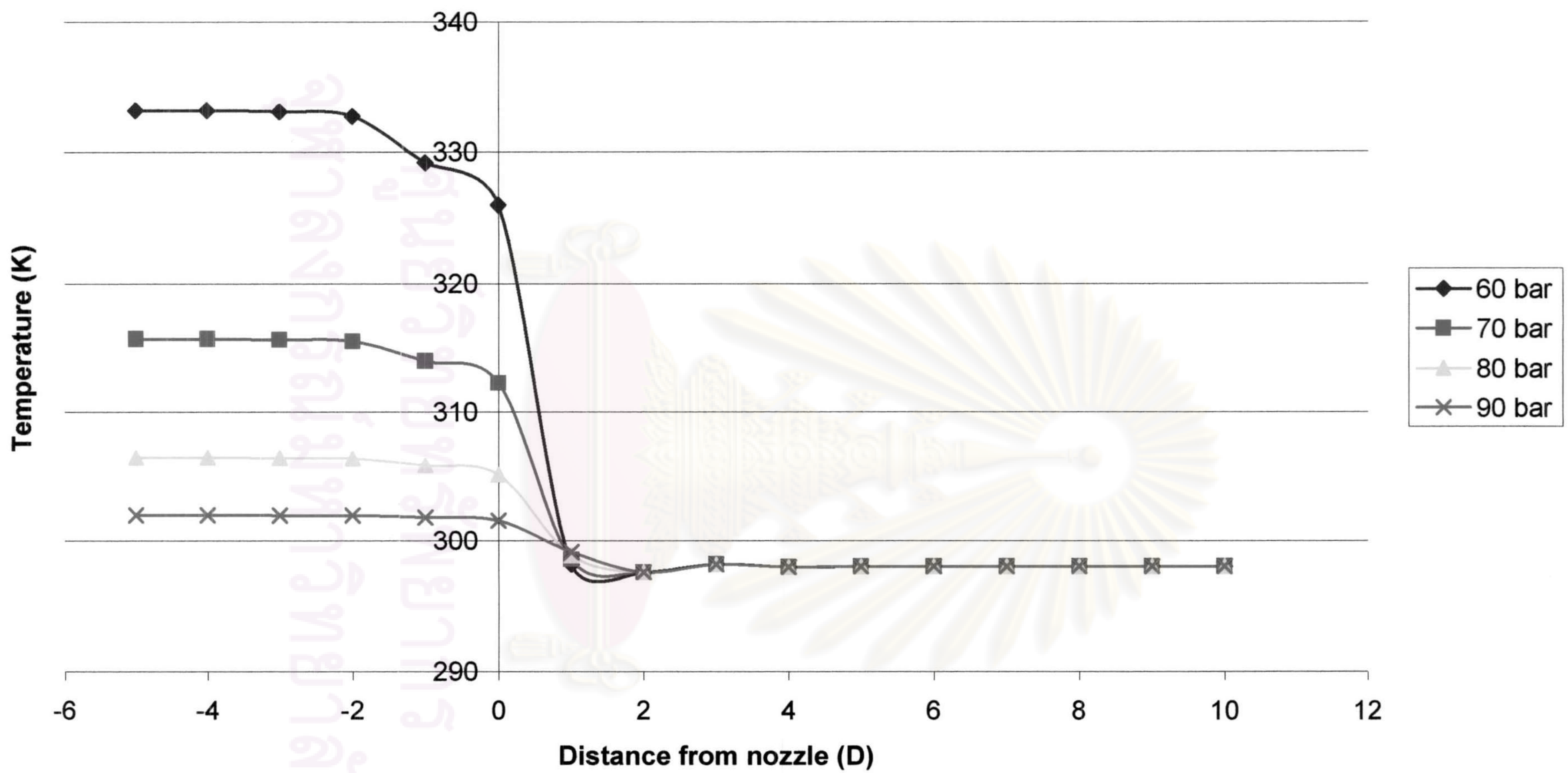

Fig 6.14 Relative graph of temperature and distance from nozzle, Inlet velocity = 100.0 m/s and Inlet temperature = 300 K

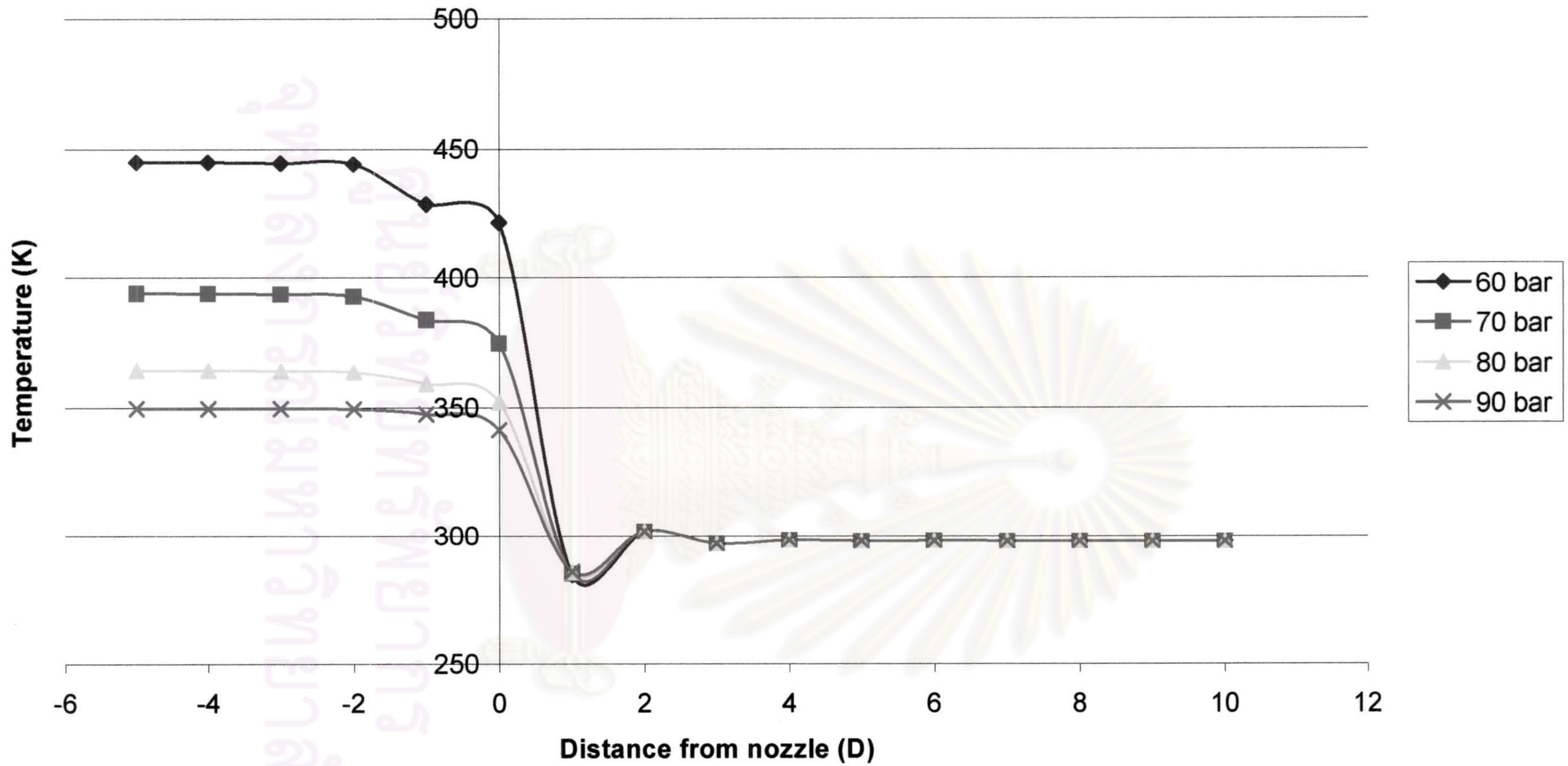

Fig 6.15 Relative graph of temperature and distance from nozzle, Inlet velocity = 100.0 m/s and Inlet temperature = 340 K

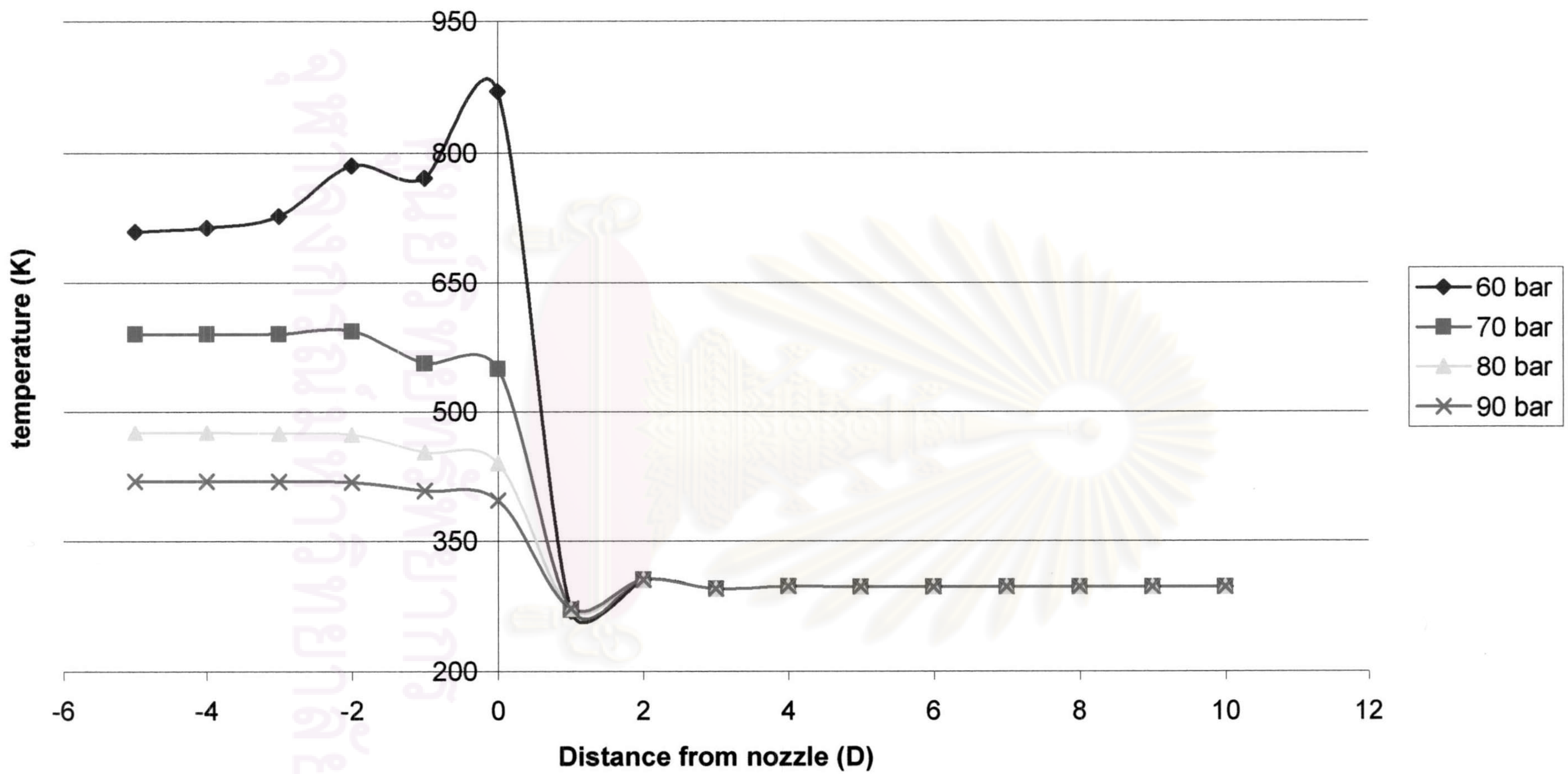

Fig 6.16 Relative graph of temperature and distance from nozzle, Inlet velocity =10 0.0 m/s and Inlet temperature = 380 K