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San-Mou Jeng

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Date 7/26/90

An Experimental Study of Droplet Combustion

at High-Pressures

A Thesis

Presented for the

Master of Science Degree

The University of Tennessee, Knoxville

Christian M. Norton

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ABSTRACT

This thesis presents an experimental study on high-pressure suspended droplet combustion . The high-pressure combustion chamber, droplet support and temperature measurement probes, and optical imaging technique are described. Experimental results for n-Heptane droplet combustion are presented for reduced pressures ranging from $P_r = 0.178$ to $P_r = 2.305$. Primal data includes the transient internal temperature and transient droplet images, for test pressures less than 200 psia, or transient soot plume images, for test pressures greater than 200 psia. Derived measurements include mean gasification rate constants for the d^2 vaporization law and mean mass burning rates. Theoretical implications from the experimental program are discussed. Development of a droplet-on-demand generator for future free-droplet tests is described, and a discussion of future experimental plans is presented.

CONTENTS

LIST OF FIGURES

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NOMENCLATURE

English Symbols

$\overline{B}_r$	mean mass burn rate (gm/sec)
d	instantaneous droplet diameter (mm)
d_b	diameter of bead (mm)
d_i	initial drop diameter (mm)
$\overline{G}_r$	mean gasification rate (mm^2/sec)
K	degrees kelvin
m_i	initial mass of drop (gm)
P_c	critical pressure of fuel (lbs/in^2)
P_r	reduced pressure
T_b	boiling temperature (K)
T_c	critical temperature (K)

Greek Symbols

Δt	change in time (sec)
π	3.14159...
ρ	density (gm/mm^3)

CHAPTER 1

INTRODUCTION AND THEORY

1.1 INTRODUCTION

There has been and remains a special interest in the nature of high-pressure droplet combustion because of the frequently encountered near-critical and supercritical chamber pressures in practical spray combustors. This is true in both automotive and propulsion fields. In the automotive field, diesel engines reach pressures in excess of 1,000 psi, well above the critical pressure of the individual fuel components. Supercritical conditions also occur in combustors for propulsion applications. A good example is typical liquid rocket engines in which both cryogenic fuel/oxidants and hydrocarbon fuels reach supercritical pressures. In addition, it has also been proposed that gas turbines, in aircraft of the future, will run at combustion chamber pressures approaching the critical pressures of most hydrocarbon fuels. The dynamics and performance of these combustors depend on droplet life histories after injection making a physical understanding of the process very important in design and development programs.

Because droplet behavior at near-critical and supercritical pressures is a fundamental component of the spray processes involved in many different high-pressure combustors, individual droplet gasification at high ambient pressures is of a very practical nature and is the theme of this thesis. The interest in the area of supercritical combustors has continued through the years with increased understanding of the thermodynamics and fluid mechanical transports involved. But an experimentally verified description of the process has yet to appear. This unresolved issue in combustion science provides the motivation for additional experimental research.

Experimental data has been collected by very few people in the area of supercritical droplet combustion.

Faeth *et al.* (1969) have reported a fundemental study in the area of supercritical droplet combustion. There has also been additional fundamental work by Kadota and Hiroyasu (1981). The experimental work done by Faeth *et al.* was under micro-gravity conditions achieved through the use of a free falling drop chamber. They were able to show that as the critical pressure of the fuel droplet was approached, the combustion lifetime would tend toward a minimum with subsequent burn times proportional to $P^{\frac{1}{3}}$, in agreement with "puff-of-gas" theoretical models (Spalding, 1959; Rosner, 1967). Kadota and Hiroyasu (1981) performed some free-convection experiments under 1g conditions and were able to calculate the burning rate of the fuel droplets at many different pressures.

It is the intent of this work to supplement these experimental studies by examining suspended droplet free-convection combustion at elevated pressures. Transient temperature measurements and optical observations using a shadow-graph imaging technique were made. The shadow-graph technique allowed for some diameter measurements of the burning droplet at low pressures and soot plume observations at higher pressures such that mean gasification rate constants and mean mass burning rates were obtained.

The results of these tests can be used to create a data base for future work in the area of high-pressure droplet combustion. In particular, the results can be applied to theoretical submodels of droplet combustion. This could lead to further advancements in the area of high-pressure combustors. It is expected that this project along with future studies in the area of high-pressure droplet combustion will enhance our knowledge and understanding of the droplet life history in the supercritical realm.

1.2 HIGH-PRESSURE GASIFICATION THEORY

When looking at the theory of droplet vaporization at elevated pressures, the differences between the low-pressure case and the high-pressure case must be taken into consideration. The fundamental mechanisms of low-pressure droplet gasification are reasonably well understood (Faith, 1977). The present theoretical formulations employing film theory, phase equilibrium, and quasi-steady assumptions for the ideal gas have been confirmed by experimental results. Droplet gasification theory at supercritical pressures is not as well established. This is mainly due to the large degree of uncertainty and increased complexity of the physical process. The complexities encountered at elevated pressures arise mainly from thermodynamic considerations. For example, with increasing pressure, absorption of ambient gas into the liquid takes place, and real gas effects become important in determining thermophysical properties and thermodynamic phase equilibrium. Furthermore, the enthalpy of vaporization decreases with increasing pressure. These effects imply that a droplet should be capable of heating to the critical state under a sufficiently high supercritical pressure.

Fundamental effects at modeling supercritical combustion have preceeded from the assumption of the puff-of-vapor approach whereby the droplet is assumed to have undergone flash supercritical transition. Spalding (1959) initiated this approach by modeling the dense gas pocket as a point source of fuel vapor. Rosner (1967) extended this model for a distributed source of fuel vapor obtaining slightly modified results. Chervinsky (1969) added further sophistication by considering radial convection and variable properties. The basic results of the modeling efforts have concluded that the burn time is roughly proportional to $P^{\frac{1}{3}}$.

These theories have essentially been confirmed by Faeth *et al.* (1969) once the droplet has been completely vaporized. However, there has been no experimental observations of the actual process by which the droplet gasifies. Whether the liquid droplet undergoes flash transition or gasification by finite-rate regression of the droplet surface is unknown. The critical transition process demands additional laboratory investigation.

This experimental study derived from such a need. Development of comprehensive theories will continue to be hindered until definitive, experimentally based descriptions are available. The work reported in this thesis is the critical result from a broad program intended to resolve unaddressed issues and provide the needed phenomenological description.

CHAPTER 2

EXPERIMENTAL APPARATUS AND SET-UP

2.1 HIGH-PRESSURE CHAMBER

The high-pressure test chamber used for the experiments was constructed by Pressure Products Co. of Charleston, West Virginia. This chamber was designed to withstand a maximum pressure of 1000 psi and a maximum temperature of 1000 $^\circ F$, and it was tested at Pressure Products to meet the required specifications. The necessary modifications on this chamber for different phases of high-pressure droplet combustion tests were performed at the University of Tennessee Space Institute's Center for Laser Applications (CLA). The chamber walls are constructed of stainless steel and the chamber itself stands 36 inches high with an inside diameter of 2 inches. There are 2 pair of diametrically opposed quartz viewing windows built into the chamber for optical measurements. The top of the chamber can easily be removed for mounting different types of experimental probes. The chamber top has been made with a vertical positioning system so that the location of the probes can be moved to any desired location in the chamber. This ability to move the probe allows for greater flexability in experimental set-ups. A picture of the high-pressure chamber and the top of the chamber can be seen in Figures 1 and 2.

The test chamber was also equipped with a flow-through device. This allows for a wide variety of test conditions. The flow rates of many different gases can be regulated and experimental results can be obtained for the given test condition. The high-pressure gas supply can be regulated through a series of needle valves and three-way valves that have been mounted into the stainless steel gas flow tubing system. This control of the gas flow, along with a pressure transducer located in

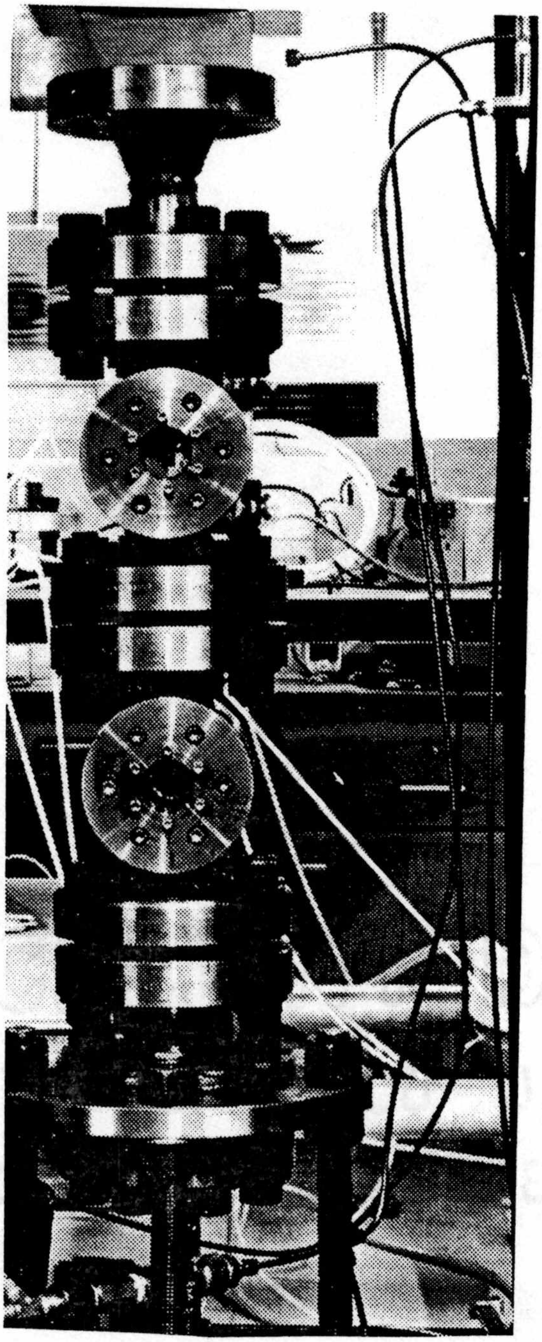

Figure 1. High-pressure test chamber

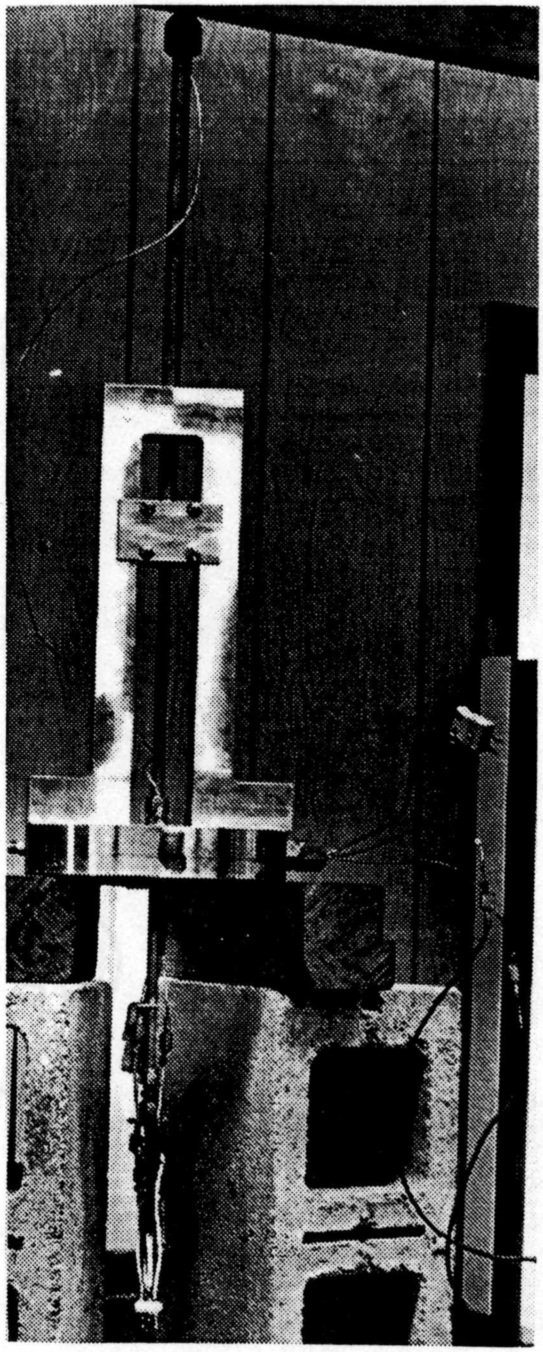

Figure 2. Chamber top and probe support with feed through wire leads

the chamber at the exit manifold, allows for very precise flow rates. The testing chamber can also be configured to emulate static conditions. If a static test were to be run, the pressure transducer allows for a very precise reading of the static pressure inside the chamber. A safety relief valve has also been connected to the chamber in case of a sudden rise in pressure that may cause damage to the chamber or to the operating personnel. This relief valve can be set to any desired pressure inside the chamber. The entire pressure vessel was mounted to a 2 inch thick aluminum plate which in turn rests on casters to allow easy positioning of the entire system. The chamber has also been surrounded by a protective enclosure. This was an added safety protection for the high operating pressures that were used.

2.2 PROBE DESIGN

The experiments that are run in the pressure vessel can be adapted to many different conditions. The type of experiment that was run and reported in this thesis required the use of a suspended drop probe. The probe was used for suspended drop combustion, but by removing the ignition source the probe can be used for evaporation experiments. In the future a second probe will be used for free falling uniform droplets, commonly referred to as a droplet-on-demand generator.

2.2.1 Suspended Drop Probe

The suspended drop probe went through many stages of development. It evolved from a very crude temporary design shown in Figure 3 to a more advanced replaceable component design shown in Figure 4. The first design was primarily used as a test to evaluate different probe design concepts and to find a probe configuration that was best for the ignition of suspended drops. The drop itself was suspended from a fiber optics rod that was drawn up at one end, by heating with

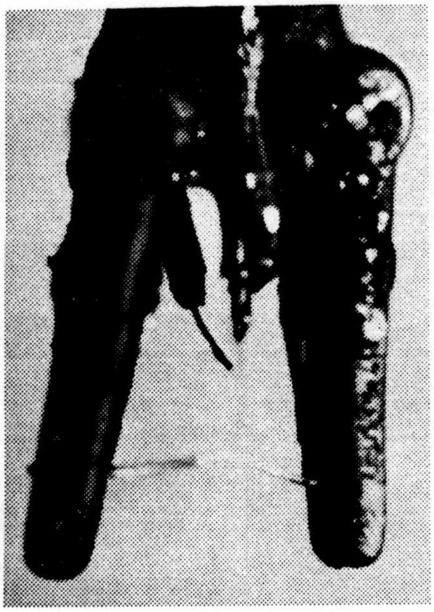

Figure 3. Preliminary suspended drop probe

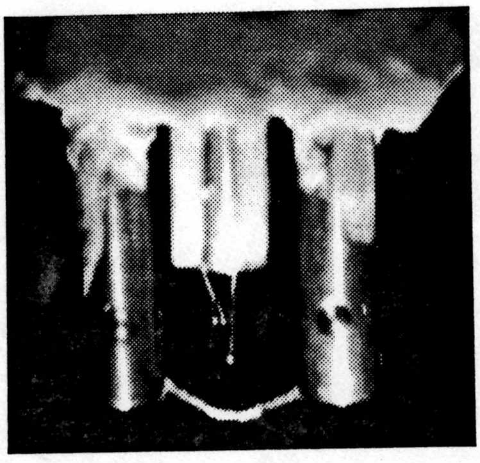

Figure 4. Final suspended drop probe

a micro-torch tip of an acetylene gas welder, to form a 0.6-1.0 mm bead. The optimum size for the bead was approximately 0.8 mm, but this could vary depending on the size of the thermocouple used.

A problem that had to be considered was the size of the suspended drop. It became apparent through testing that a drop that is too large will fall off during the ignition phase of the test. At low-pressures the drop would fall off because of the convective effects of the ignition wire. The rising heat from the wire would cause severe oscillations in the drop which in turn would cause the drop to fall off of the probe. At high-pressures the convective effects were still a problem, but the loss of surface tension in the drop compounded the troubles of keeping the drop suspended on the quartz bead. The high-pressure causes a reduction in the fuel surface tension due to the higher droplet temperature reached during the combustion phase of the test.

The probe also had an ignition source attached to the structure. The ignition source went through many different stages of development. The first type of ignition source was a spark ignition developed by Mr. Ron Litchford (1989). This was done by discharging a charge across a gap that was between two steel rods. The basic idea was to simulate a spark plug. This had little success due to the pressure wave that was created when the electrical charge discharged across the gap. The problem would get worse as the pressure was increased primarily because of the increase in the pressure wave strength due to the high pressures. The spark ignition was quickly abandoned and a hot wire was soon adopted. The hot wire concept seems to be the best method for ignition at this time. The type of wire used was 0.5 mm diameter platinum wire. The platinum wire was connected between two electrical contacts as seen in Figures 4 and 5, and when adjusted properly turned white hot as current flowed through the wire. The first source of electrical current was 60Hz AC, which

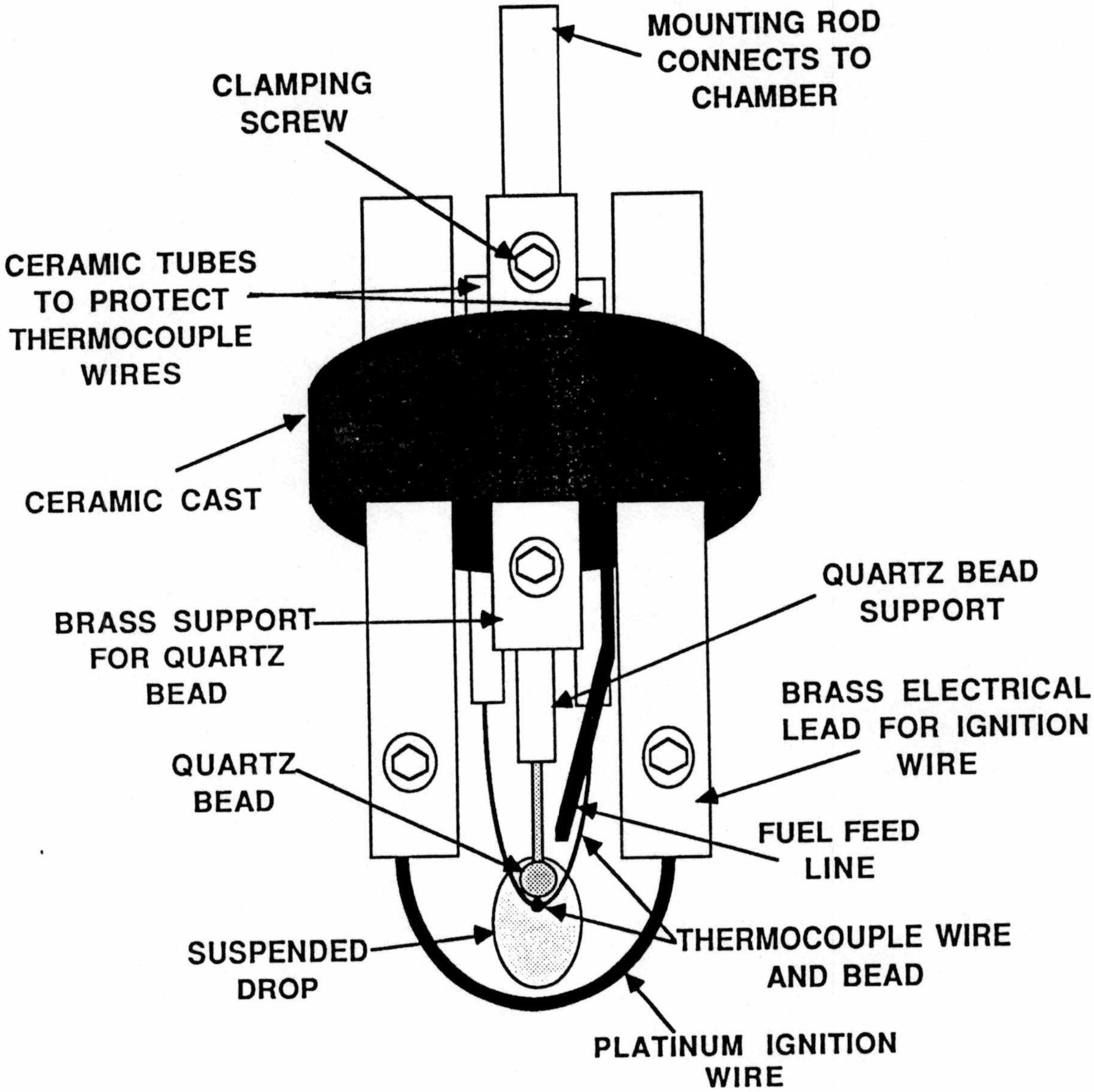

Figure 5. Schematic of final suspended drop probe

would produce a frequency response on the thermocouple. The thermocouple wires would act like an antenna and pick up the 60 Hz cycle of the AC current and reduce the signal to noise ratio. Therefore, the power source was changed from AC to DC with a finer current control which helped reduce this noise problem.

The thermocouple was another important part of the probe design. The thermocouple was placed at the tip of the quartz bead as seen in Figure 5. The thermocouple used was type K, made of nickel-chromium and nickel-aluminum, which was adequate for the temperature readings that would be taken during the combustion tests. The voltage out of the thermocouple was processed by a IBM PC based data aquisition system. The analog/digital (A/D) converter samples $1000\frac{samples}{second}$ with a resolution of $24.4\frac{\mu V}{count}$. The temperature resolution per count varied mildly depending on the temperature. The temperature reading was approximately $2.0\frac{°C}{count}$, which was good resolution for the combustion experiments that were performed. A type R thermocouple was originally used, but was found to have a much lower sensitivity. Instead of a $2.0\frac{°C}{count}$ temperature reading, the type R thermocouple would read in the range of $10\frac{°C}{count}$ which was unsatisfactory.

Once the thermocouple to be used was established, the size of the thermocouple had to be addressed. The type R thermocouple with a bead diameter of approximately 0.025 mm could easily handle the flame temperatures that would be associated with this experiment. However, a problem was encountered when the type K thermocouple with a bead diameter of approximately 0.025 mm was used. A 0.025 mm diameter thermocouple would burn up under testing conditions. It was apparent that a larger thermocouple had to be used therefore a 0.076 mm diameter thermocouple was the final choice for the experiments. This size of thermocouple has consistently demonstrated that it can handle the flame temperatures and the response time of the thermocouple is adequate for the temperature readings that were taken during the combustion tests.

The final component of the test probe was the fuel feed system. Due to the extremely small inside diameter of the chamber a simple and efficient fuel feed system had to be designed. The final set-up was a 1/4 inch steel tube that was run into the test chamber through a swagelok fitting that had been designed to withstand the elevated pressures during tests. The end of the tubing had been reduced down to a 0.010 inch inside diameter tube. This was where the fuel would exit the tubing and was squirted onto the bead. The fuel was squeezed out of the tube by applying a slightly higher pressure in the fuel feed system then in the chamber. This pressure difference was achieved by using a three way valve which allows one to change the pressure feed from the chamber to the fuel feed. After the chamber had reached the desired pressure, the valve was turned to the fuel feed line and the pressure was increased slightly. Then with the help of another three way valve the drop could be forced out of the tubing onto the bead. The end of the fuel feed system can be seen in Figure 5.

The components of the probe that were just mentioned were all permanently mounted in a ceramic rod or brass holder depending on the part. The ceramic rods and brass holders were also permanently mounted in a ceramic putty that was cured at elevated temperatures. This putty was hardened and formed a cast like shell around all the parts as seen in Figure 4 and 5. This ceramic cast was then mounted onto a steel rod that connected the assembly to the chamber cover as previously seen in Figure 2. The electrical leads for the hot wire were connected to some electrical wires that had been run through the chamber in a sealed pressure fitting as seen in Figure 2. The fitting has four electrical leads, the two remaining leads were used for the thermocouple connection.

2.2.2 DROPLET-ON-DEMAND PROBE

The droplet-on-demand probe is still in the developmental stages. The probe will basically be a droplet generator attached to the steel rod at the same location as the suspended drop ceramic cast. There will be no need for the ignition system, because the droplet-on-demand probe will be used to study the evaporation of free falling droplets at elevated pressures. The idea is to be able to generate uniformily sized drops and take high speed pictures of the drops behavior during evaporation in the supercritical range of pressure. The design of the droplet generator is shown in Figure 6. This design was originally conceived at Wright Patterson Air Force Base in Ohio, by Gary L. Switzer (1989). His original design was not for elevated pressures so some basic modifications have been made. The probe is currently being modified by Fred Schwartz and Newton Wright of the CLA at the University of Tennessee Space Institute. The size of the generator is very important because of the limited space inside the pressure vessel. The entire droplet generator assembly is approximately 4 inches long by 1/4 inch diameter. Droplet generation has been achieved and they are currently working on generating a wide variety of drop sizes. This change in drop size is done by changing the drive voltage on the piezoceramic and by changing the nozzle configuration. Once a method for changing drop diameter is perfected the droplet-on-demand generator will be a very useful tool in free falling droplet evaporation experiments.

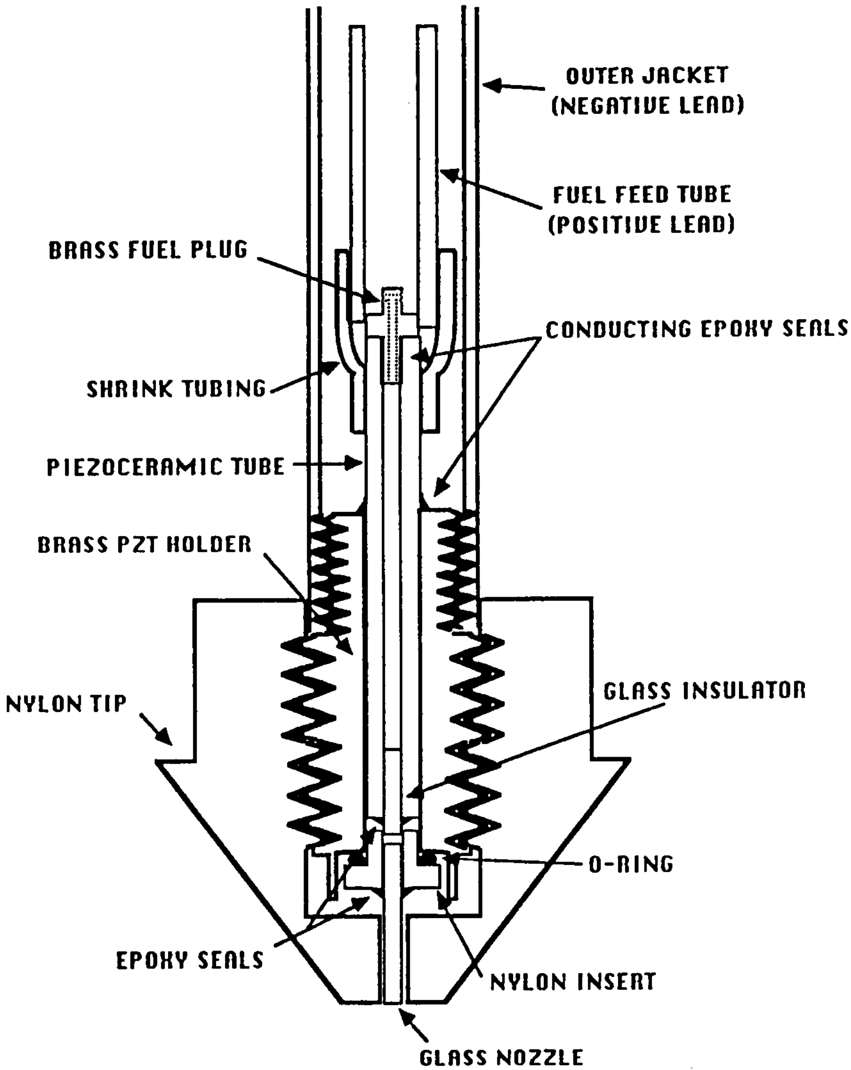

Figure 6. Schematic of droplet-on-demand generator

CHAPTER 3

EXPERIMENTAL RESULTS

3.1 TEMPERATURE RESULTS

The elevated pressure droplet combustion experiments were conducted over a wide range of pressures. The pressures varied from about 50 psia to approximately 900 psia. The fuel used was n-Heptane which has a critical pressure of 396.8 psia ($273.59 \times 10^4 \frac{N}{m^2}$) and a critical temperature of 540.3 $^\circ K$. At subcritical pressures, after ignition takes place, there is a brief heating up period. The droplet then reached what is called the steady-state of the droplet combustion, at which the rate of heat transfer from the hot environment to the droplet is the same as the heat required by evaporation of liquid from the droplet surface. This steady-state was characterised by a constant or near constant temperature reading in the center of the droplet liquid. Finally, when the droplet gasification was complete, the temperature read from the thermocouple took an abrupt turn towards the actual flame temperature. This is due to the fact that the vapor temperature and flame temperature is higher than the droplet liquid temperature. When a graph was plotted in a time verses temperature configuration the results look like those presented in Figure 7. This figure shows three different subcritical pressure tests with three different steady-state wet bulb temperatures and steady-state times. As expected, when the pressure was increased the steady-state temperature would also increase. The amount of time the droplet was at steady-state would decrease along with the actual gasification time (Faith *et al.*, 1969; Kadota and Hiroyasu, 1981).

The initial drop diameter was a very important parameter and during the course of the experiments it was found that the initial drop diameter had to be

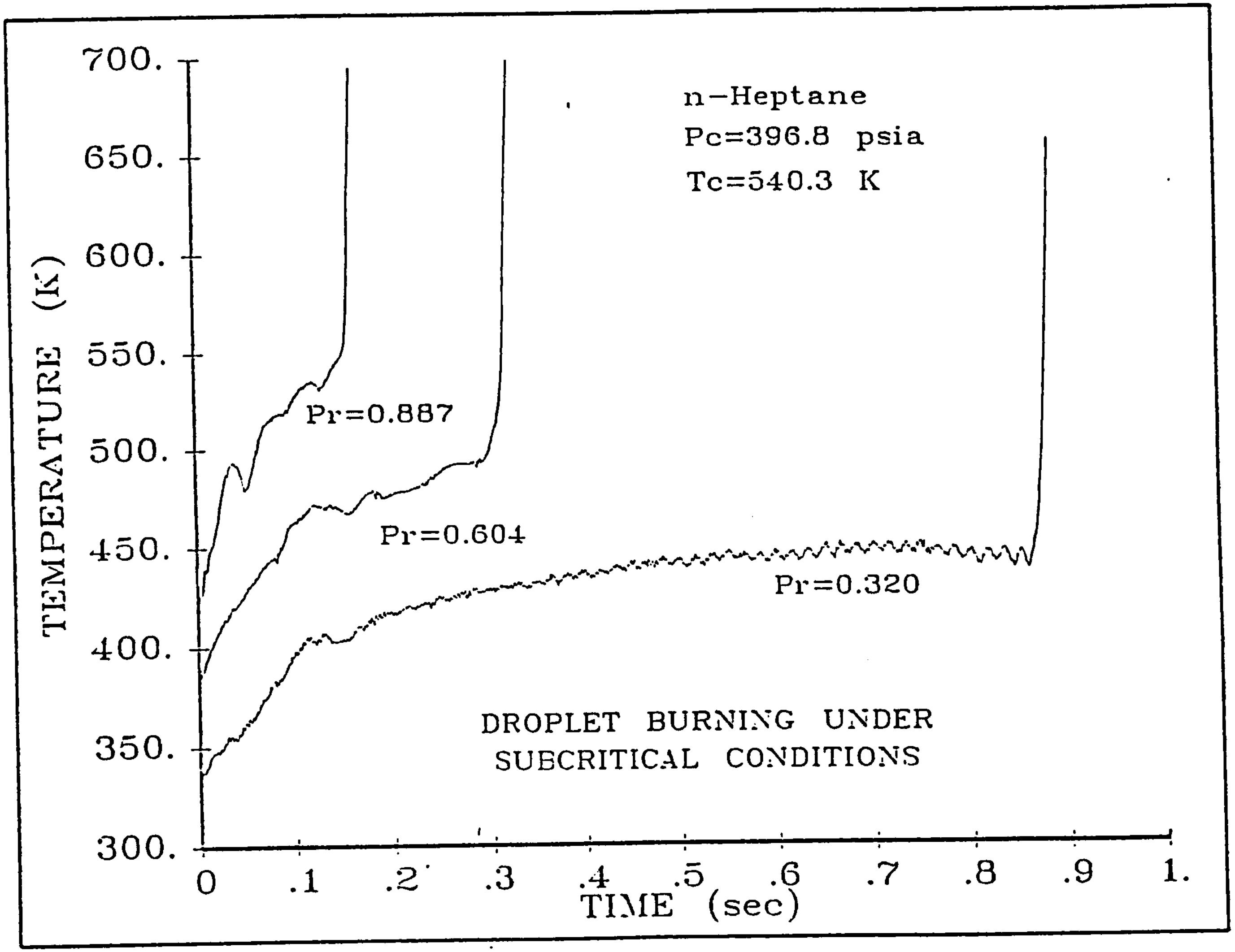

Figure 7. Temperature profile of subcritical droplet combustion tests

reduced, because of the reduced surface tension at the elevated temperatures. A drop size used at lower pressures would fall off the bead at a higher pressure. The initial droplet diameter is given on the graphs of the droplet combustion tests seen in Figures 8-21. The experimental data used for these plots can be found in the appendix. The droplet gasification time, as previously mentioned, does shorten dramatically at higher pressures. This can be attributed to the smaller initial drop diameter, but that was only a small part of the reason for the shorter gasification time. The main contributor to the short gasification time is that the gasification rate increases as the pressure increases. This will be discussed further in the next section of this chapter.

An important thing to notice about the temperature data from the supercritical pressure experiments is that they show only a slight bend in the temperature rise which suggests that at a reduced pressure (P_r) of approximately 1.5 (defined as the ratio of the ambient pressure to the critical pressure of the fuel) a droplet never reaches a steady-state evaporation. This suggests that the enthalpy loss due to evaporation is less than the heating rate going into the droplet. The supercritical burns also show very little change from one pressure to the next as seen in Figure 22. This result agrees with the results found by Kadota and Hiroyasu (1981) in an earlier study on the same subject. By careful observation of the temperature readings, a final droplet temperature can be determined. The final droplet temperature was determined from the temperature measured just as the thermocouple was noticeable in the shadow-graph pictures. Then by correlating the time that the thermocouple was visible with the time in the actual thermocouple temperature readings a final drop temperature was found. This method matches, almost perfectly, with the abrupt change in the temperature readings seen in the graphs in Figures 8-21. At the higher reduced pressures it was found that when the thermocouple bead was

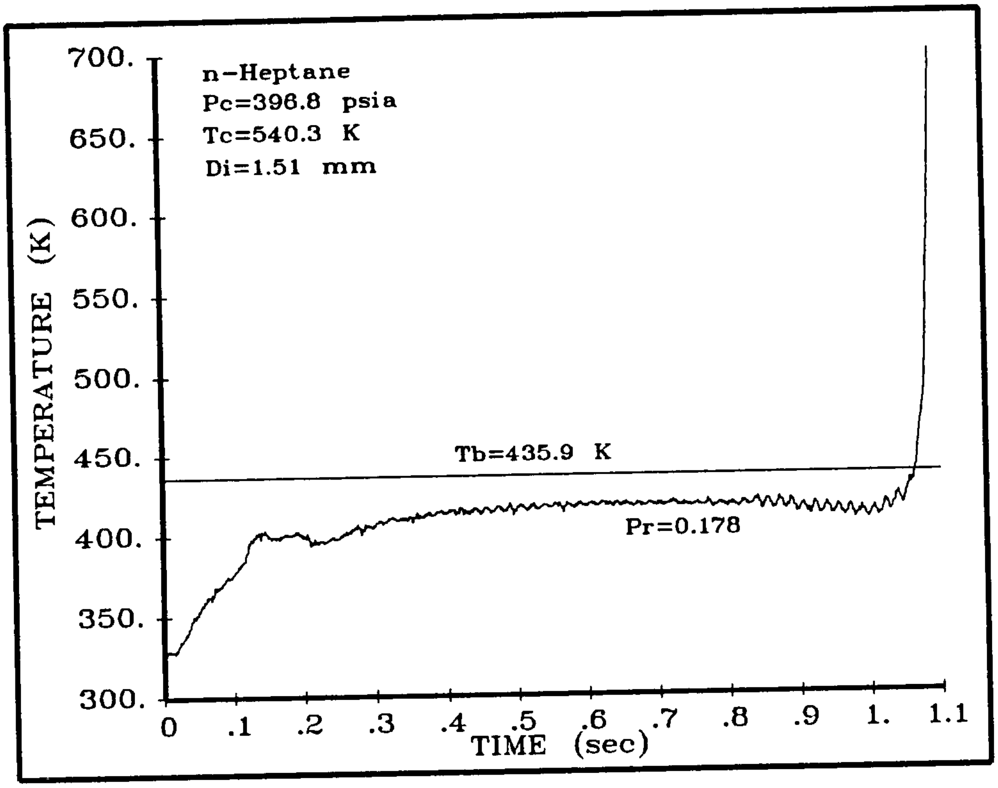

Figure 8. Temperature profile of droplet combustion test P_r=0.178

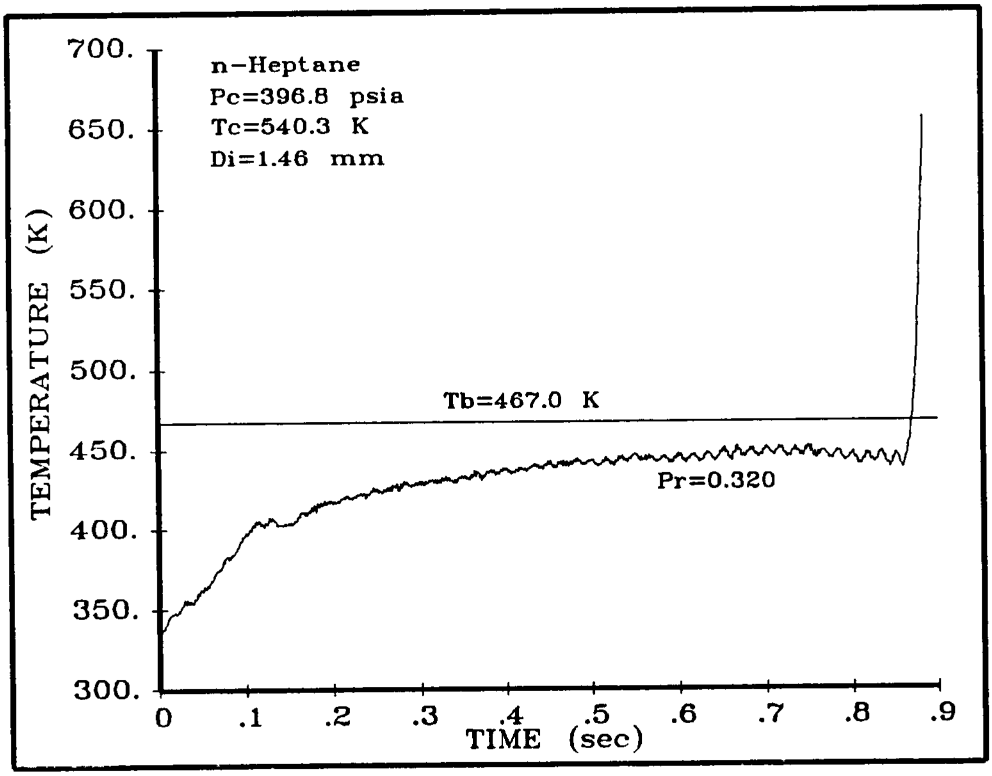

Figure 9. Temperature profile of droplet combustion test P_r=0.320

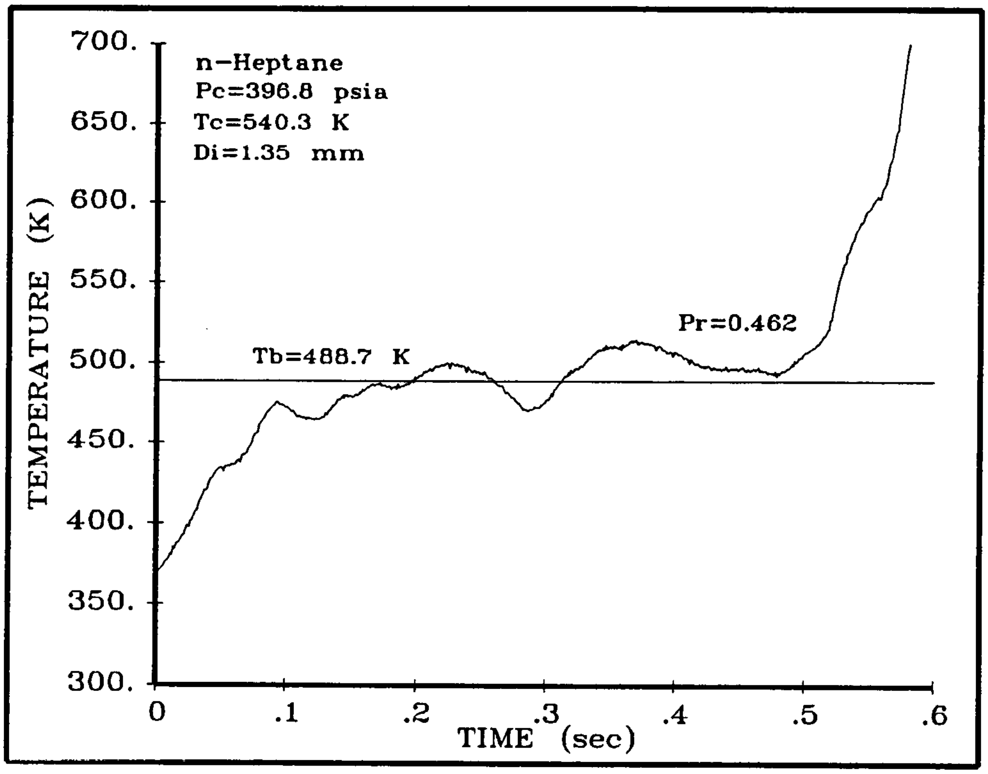

Figure 10. Temperature profile of droplet combustion test P_r=0.462

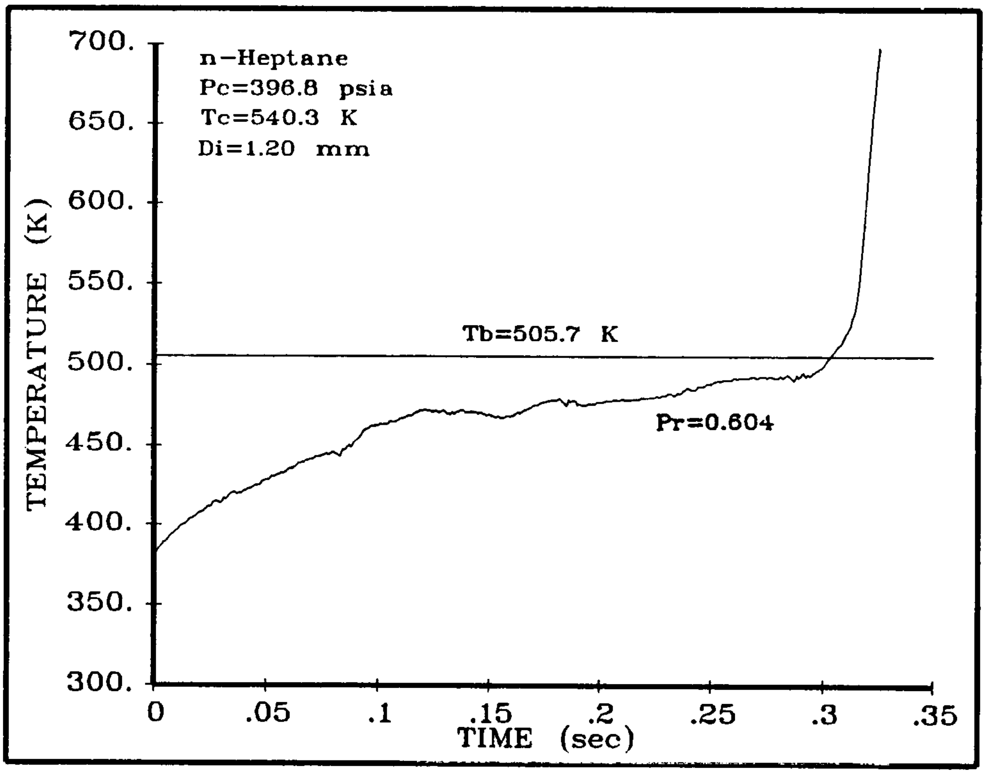

Figure 11. Temperature profile of droplet combustion test P_r=0.604

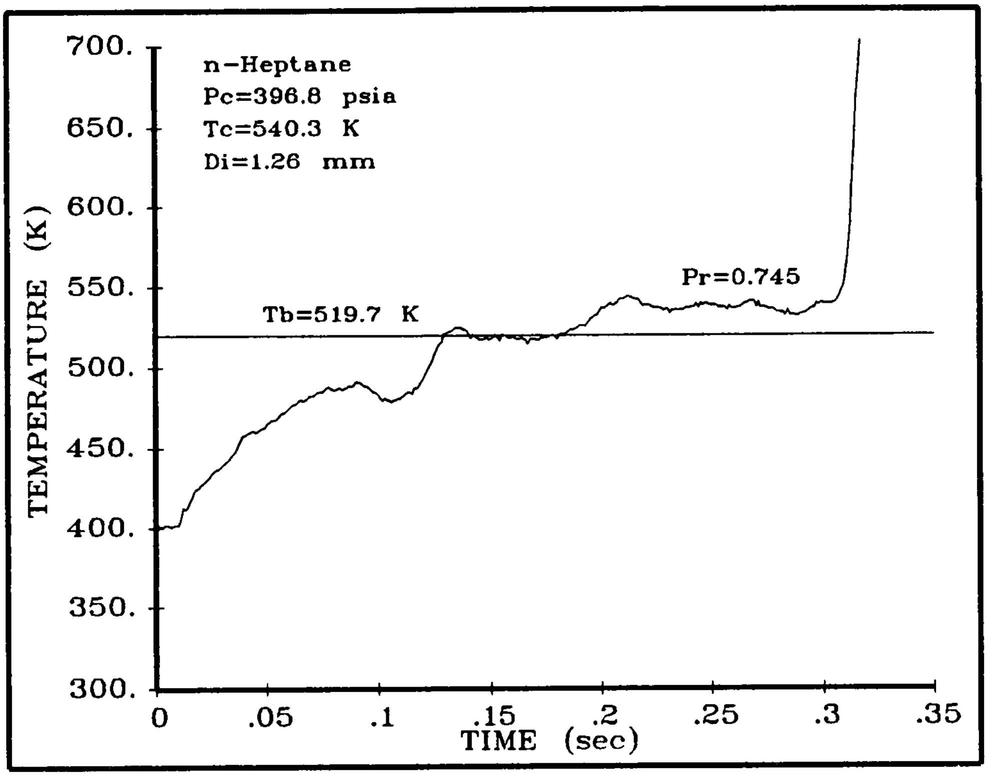

Figure 12. Temperature profile of droplet combustion test P_r=0.745

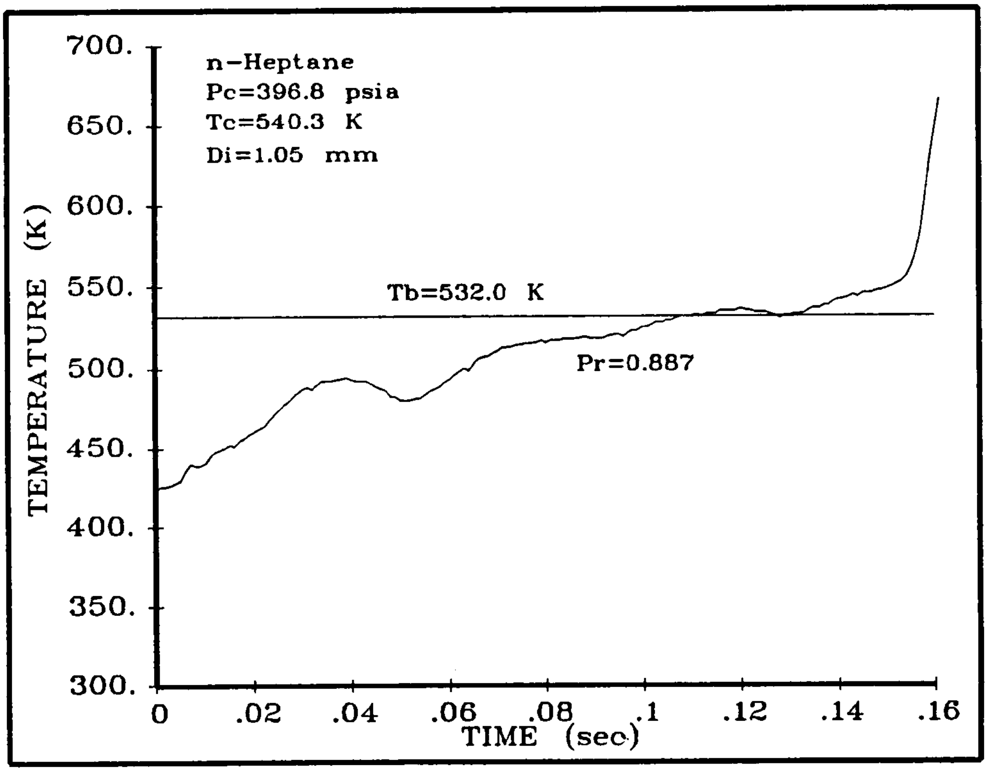

Figure 13. Temperature profile of droplet combustion test P_r=0.887

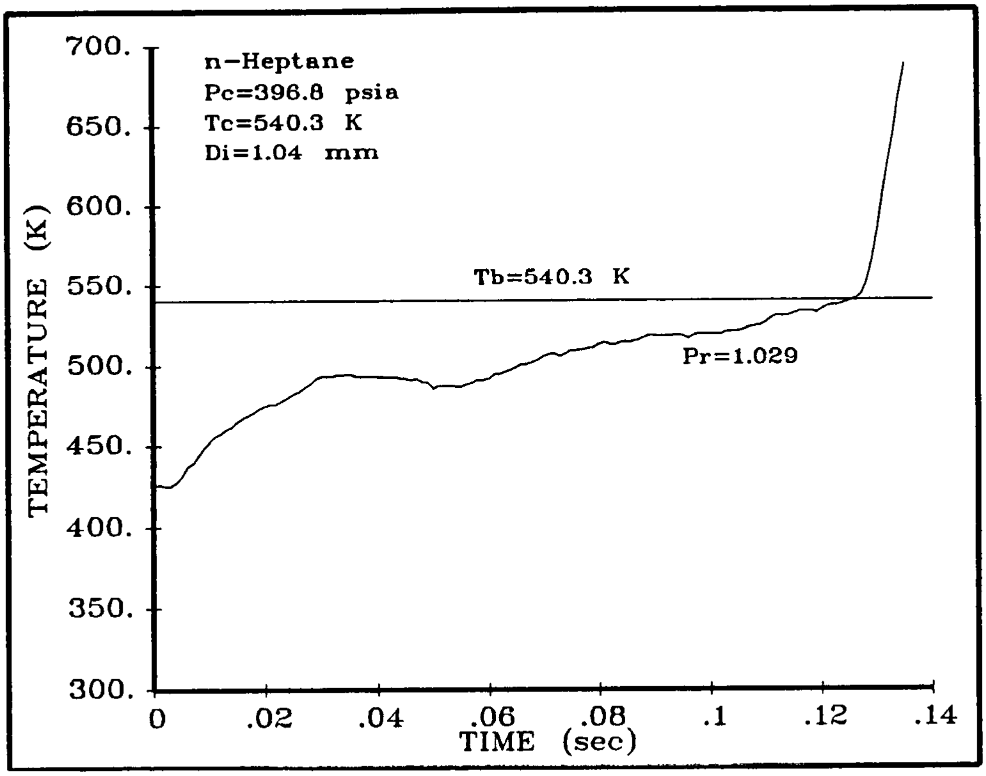

Figure 14. Temperature profile of droplet combustion test P_r=1.029

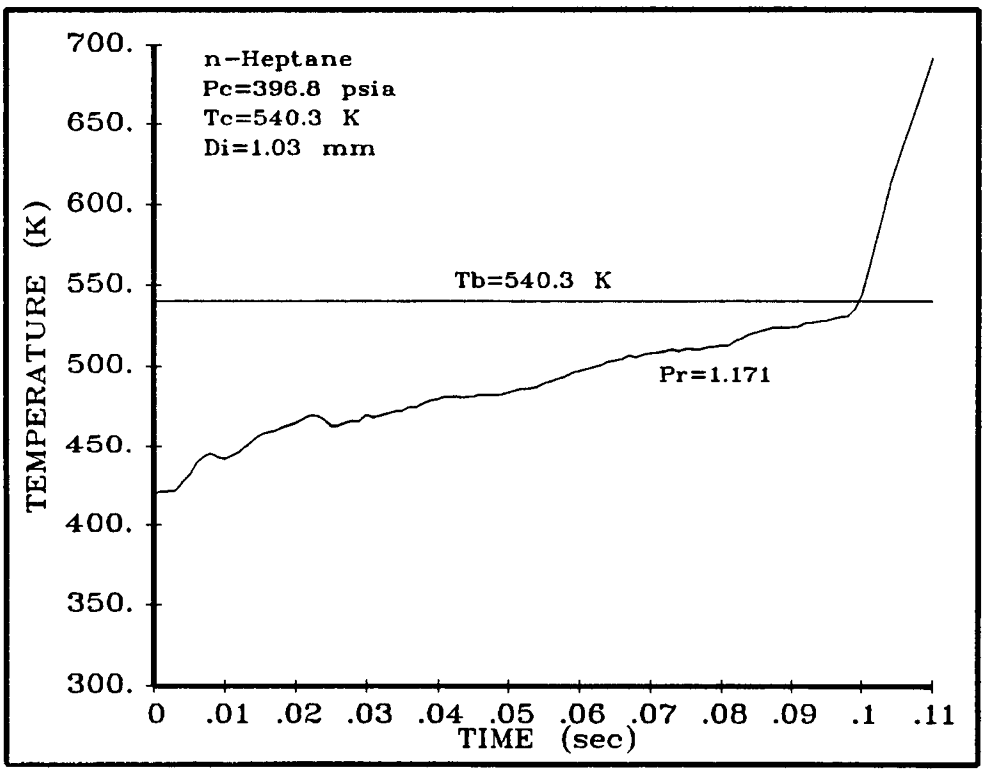

Figure 15. Temperature profile of droplet combustion test P_r=1.171

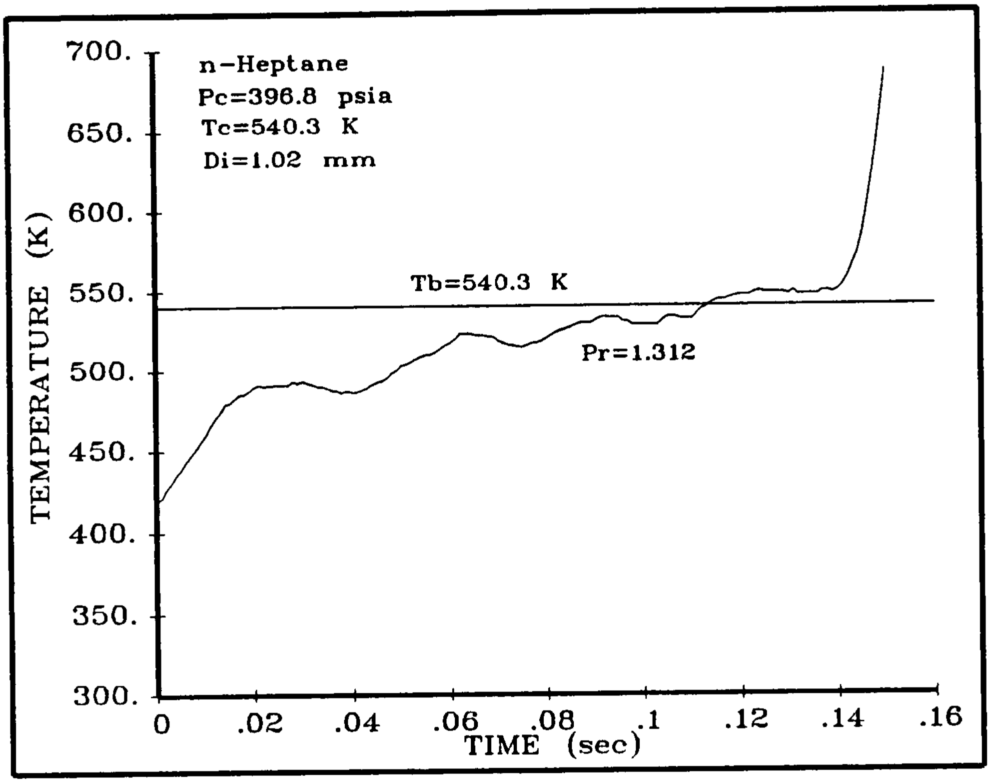

Figure 16. Temperature profile of droplet combustion test P_r=1.312

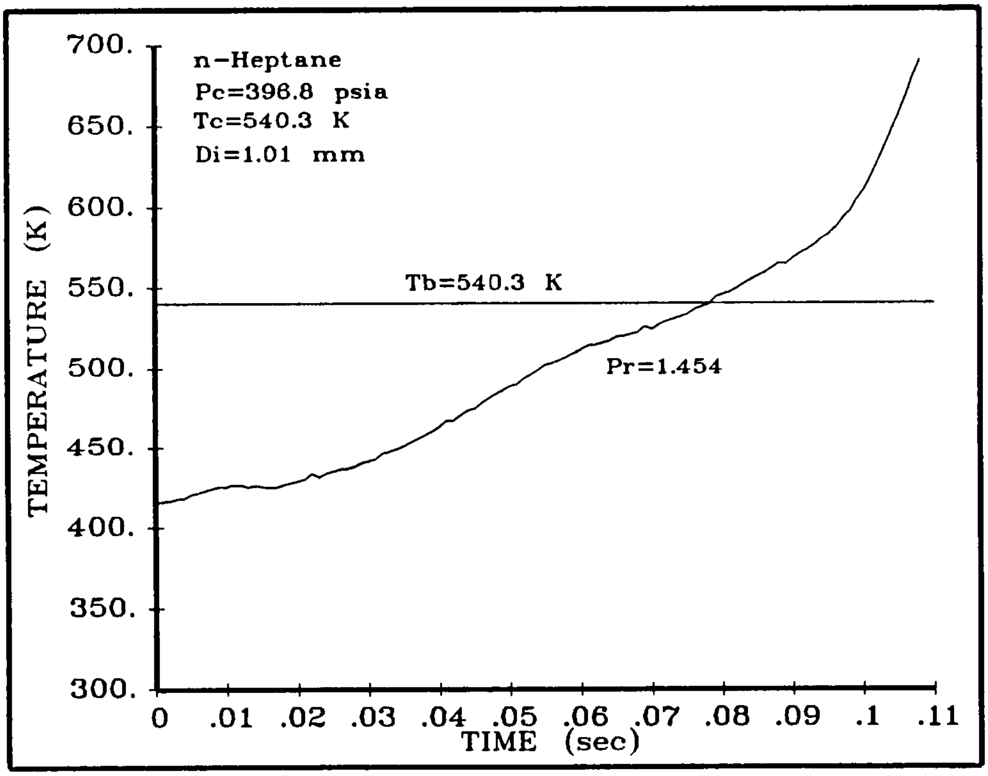

Figure 17. Temperature profile of droplet combustion test P_r=1.454

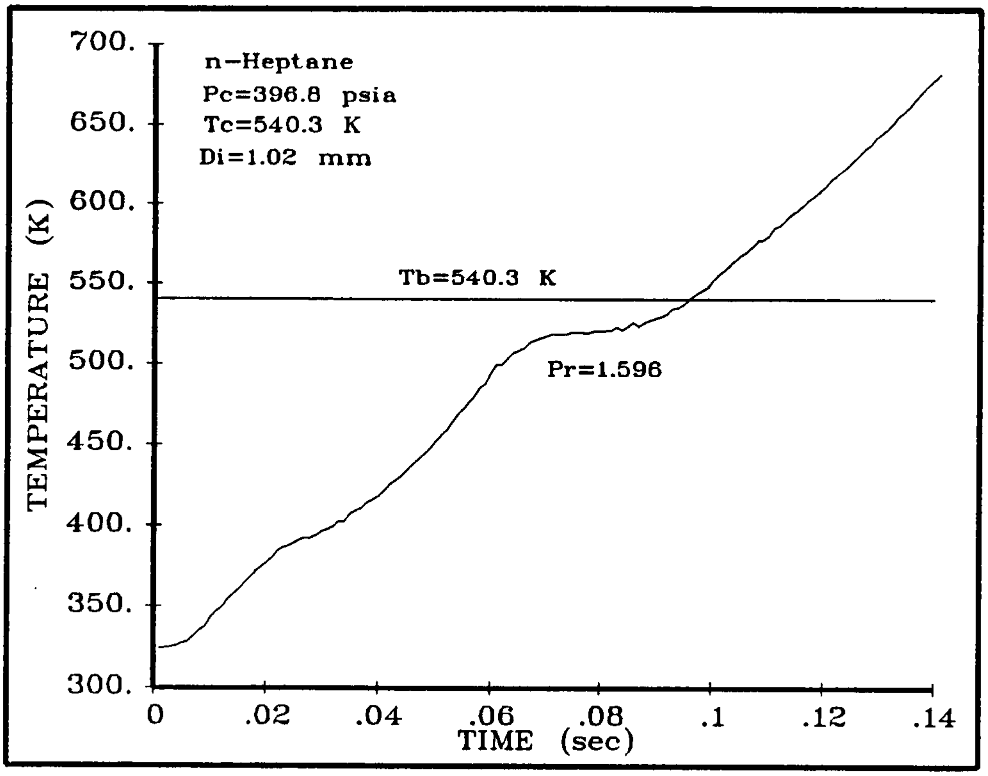

Figure 18. Temperature profile of droplet combustion test P_r=1.596

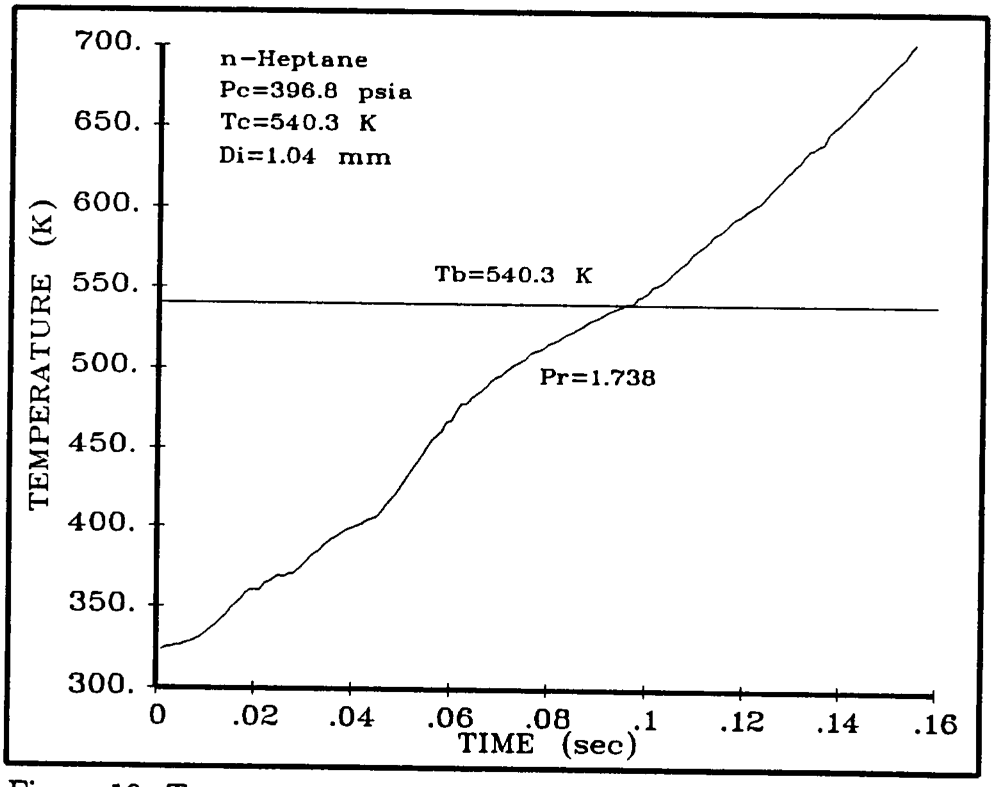

Figure 19. Temperature profile of droplet combustion test P_r=1.738

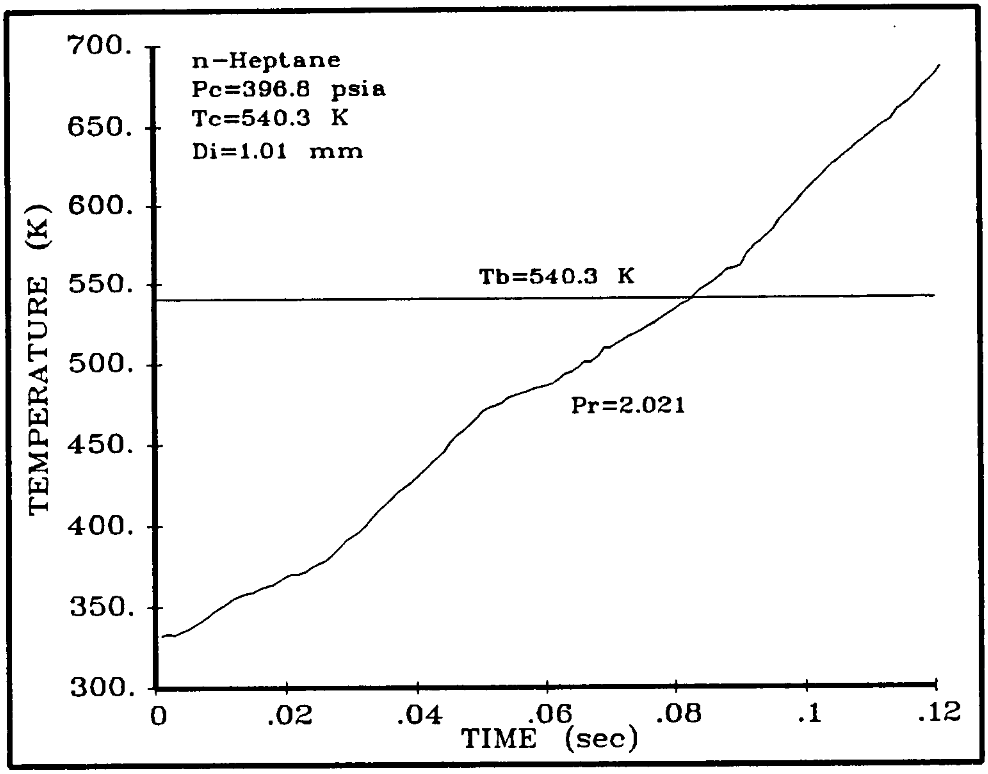

Figure 20. Temperature profile of droplet combustion test P_r=2.021

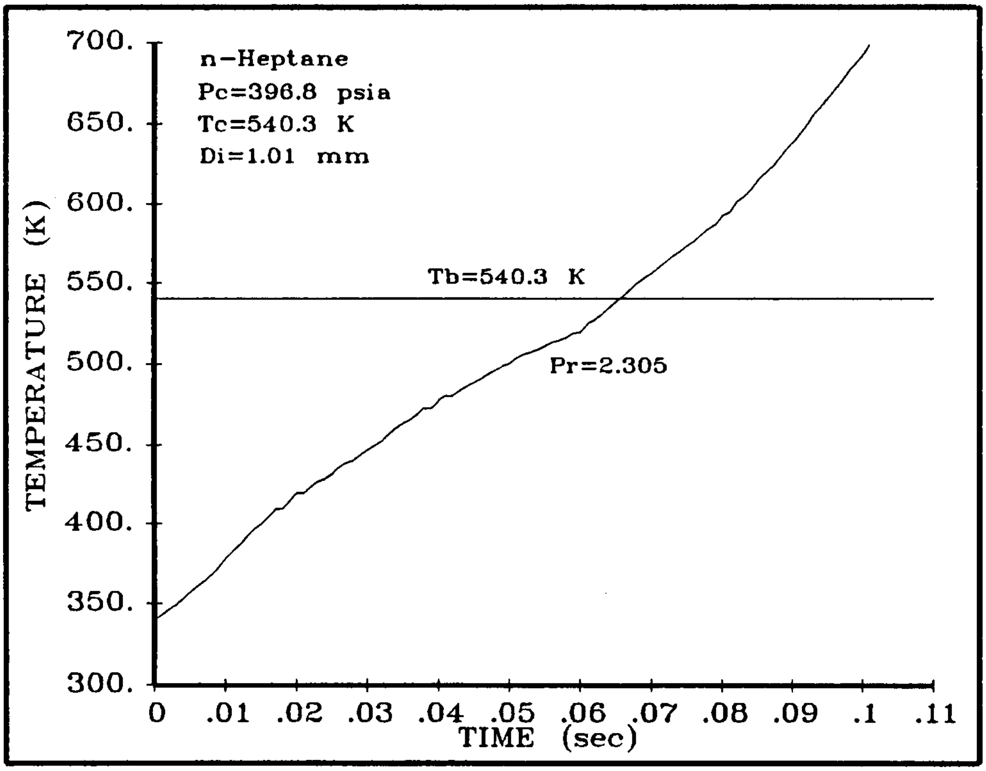

Figure 21. Temperature profile of droplet combustion test P_r=2.305

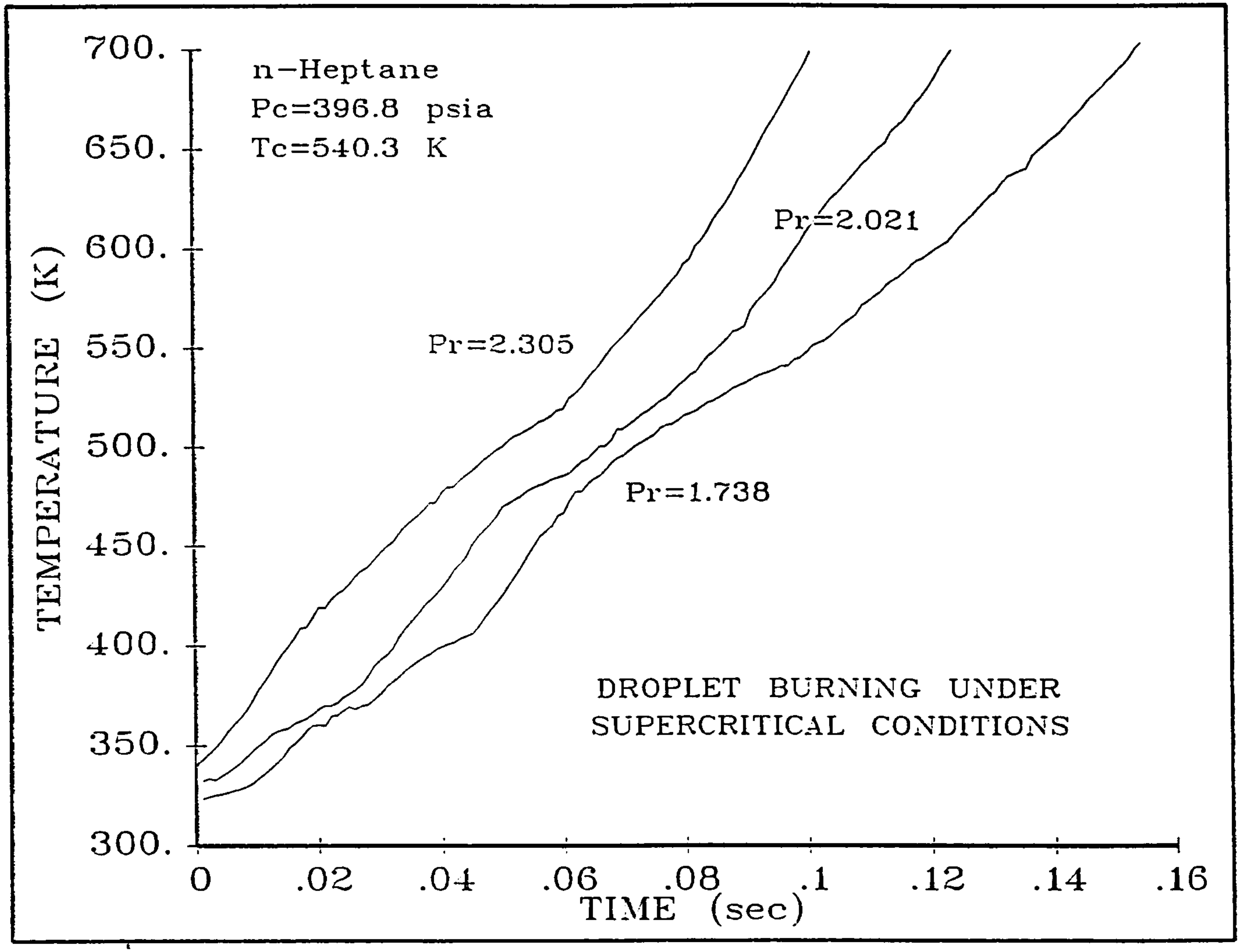

Figure 22. Temperature profile of supercritical droplet combustion test

exposed the droplet temperature was very near the critical temperature of the fuel. The slight error in this method could possibly be attributed to the response time of the thermocouple. The technique for determining the final droplet temperature was a very subjective one, but it was the best method at the time of the experiments. In Figure 23 the relationship between the final droplet temperature and pressure are shown for n-Heptane. The scatter-plot shows that as the pressure increases the final droplet temperature increases. This was true throughout the subcritical range. However, as the pressure enters the supercritical range the final droplet temperature becomes near constant. This constant was very near the critical temperature of the fuel. This result also agrees with the work done by Kadota and Hiroyasu (1981). The slight difference in the final droplet temperature and the critical temperature could possibly be because of the thermocouple bead size which affects response time. It is the writer's belief that the error actually occurs in how the final droplet temperature was attained. At supercritical pressures it was very difficult to tell when the dropet gasification stage was complete. The shadow-graph pictures were used to determine the exact time in which the thermocouple bead was exposed. The results in the low pressure tests were very accurate, because a very clear shadow-graph picture was available. As the pressure was increased the picture became more obscure due to the density gradients encountered at elevated pressures. The only thing visible at higher pressures was the carbon soot of the fuel. This problem will be looked at later on in this chapter, when droplet diameter is discussed.

3.2 DROPLET MEAN GASIFICATION RATE

The mean gasification rate of the fuel at different pressures was calculated and plotted on a scatter graph as seen in Figure 24. The mean gasification rate according

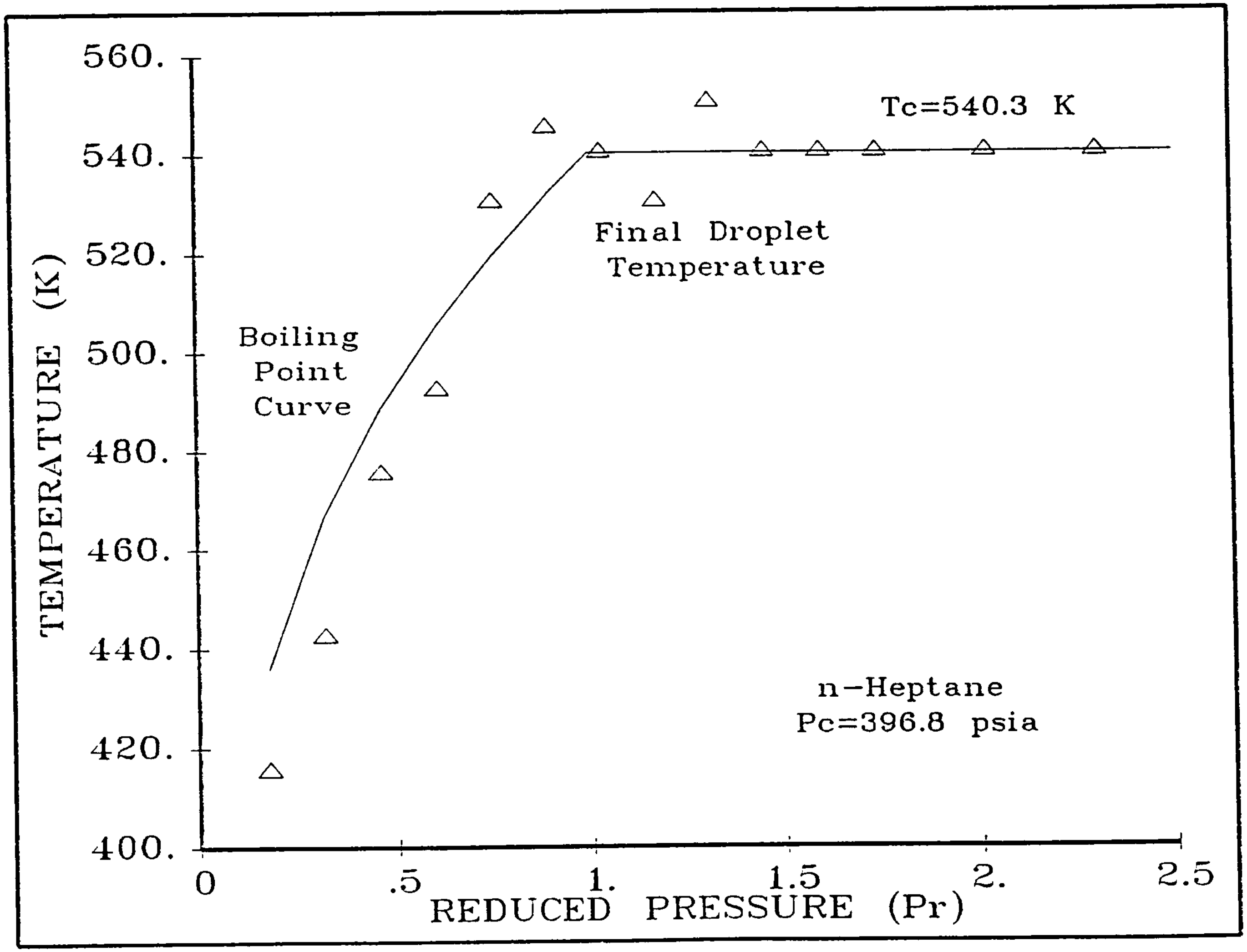

Figure 23. Final droplet temperature with respect to P_r

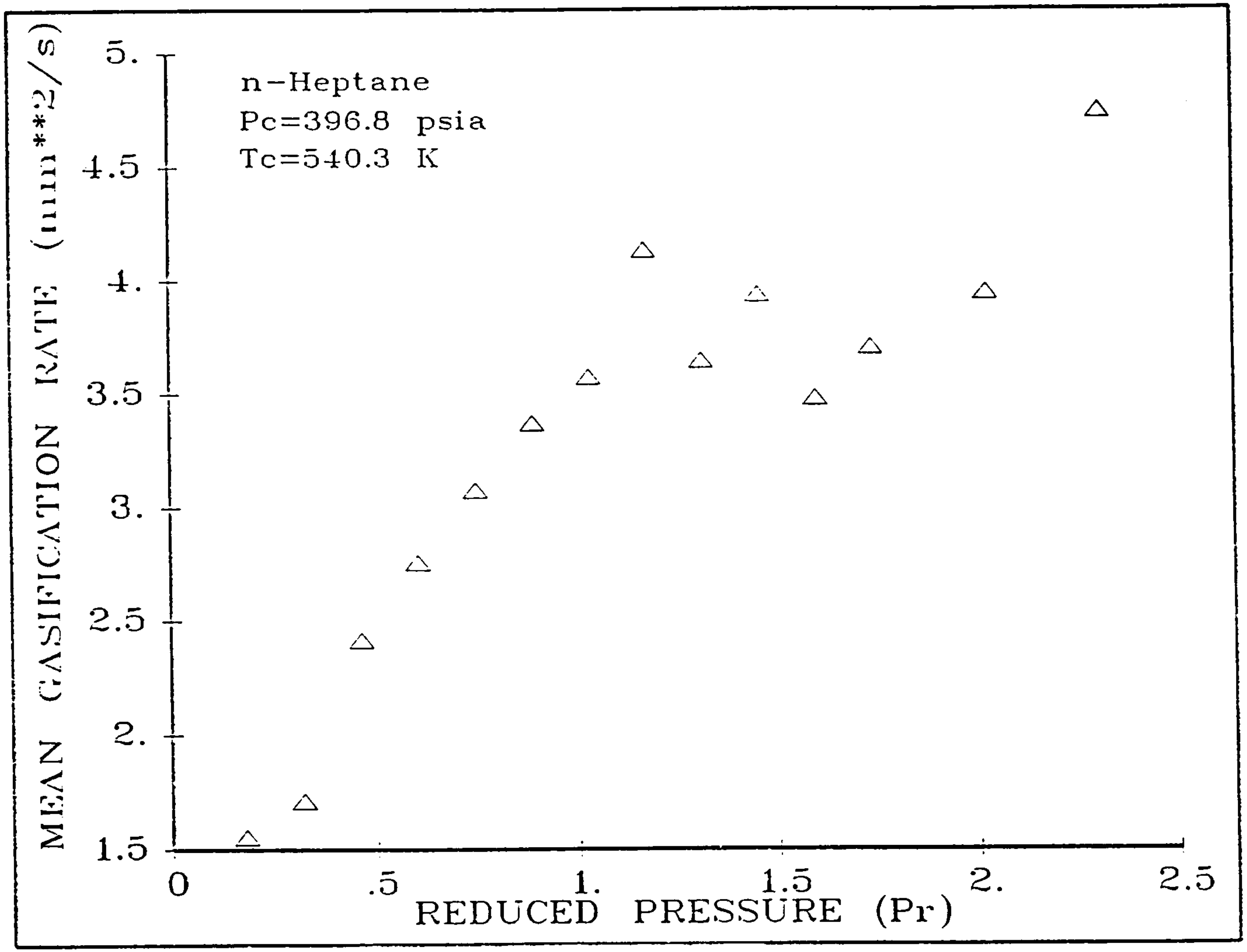

Figure 24. Gasification rate for n-Heptane

to the d^2 law is given as :

$$\overline{G}_r = \frac{d_i^2 - d_b^2}{\Delta t} \quad (1)$$

where $\overline{G}_r$ is the mean gasification rate, d_i is the initial drop diameter, d_b is the fiber optics bead diameter, and Δt is the change in time. Locating the exact ignition time is very difficult, therefore, there may be a very small error in the Δt used for the gasification rate calculations. However, this error does not affect the results in any major way. This error should also be acknowledged in the burning rate Δt that will be discussed in the next section. The mean gasification rates calculated were the rates of the tests in this thesis. The Δt is the time when the final droplet temperature was reached at the end of the gasification. The mean gasification rate constants showed a gradual increase as the pressure was increased. Then at the supercritical pressures there was a leveling off of the mean gasification rate through the reduced pressure of 1.5. From the reduced pressure of 1.5-2.2 there was a marked increase in the gasification rate. This trend was consistant with the results reported by Kadota and Hiroyasu (1981).

3.3 DROPLET MEAN MASS BURNING RATE

The mean gasification rate can only be applied if the droplet was present. In the real life case there was still a flame after the gasification was complete. This burning was due to the vapors that were still present after the drop had disappeared. If the time from ignition to the actual loss of a flame was recorded then the results would be the mean mass burn rate ($\overline{B}_r$). The mean mass burn rate was calculated by using the following equation :

$$\overline{B}_r = \frac{m_i}{\Delta t} \quad (2)$$

where :

$$m_i = \frac{4}{3}\pi\rho\left[\left(\frac{d_i}{2}\right)^3 - \left(\frac{d_b}{2}\right)^3\right] \tag{3}$$

The burning time Δt was obtained by calculating the time of complete burning of the droplet including vapors. This is done by analyzing the shadow-graph pictures and determining the time in which the flame from the burning vapors disappeared. The difference in the Δt from the gasification temperature readings to the burn temperature readings was very small at low pressures. This difference in the Δt became more pronounced as the pressure was increased to the supercritical range. This can be explained by knowing that the droplet evaporation rate will increase at the higher pressures, but the burn rate tends to decrease as the pressures increase. This decrease in burn rate was due to the reduced gas-phase diffusion rates at the elevated pressures. The molecules have a much denser atmosphere to travel through which makes it much harder for the vapor molecules to diffuse into a region where ignition can take place. Therefore, the drop would disappear due to evaporation before the vapors had completely burned. This suggests that during the final stages of droplet combustion at supercritical pressures there is a puff-of-vapor present. A mean mass burn rate could be calculated for the fuel at all the pressures tested. This burning rate is shown on the scatter plot in Figure 25.

3.4 DROPLET DIAMETER HISTORY

The droplet history was another way to verify that the gasification rate was increasing. By converting the drop diameter at a given time frame to a squared ratio, a linearized trend of the drop history could be plotted. Some of the results of the droplet history can be seen in Figures 26-29. It should be noted that the time of gasification decreased rapidly as the reduced pressure was increased. The plot line

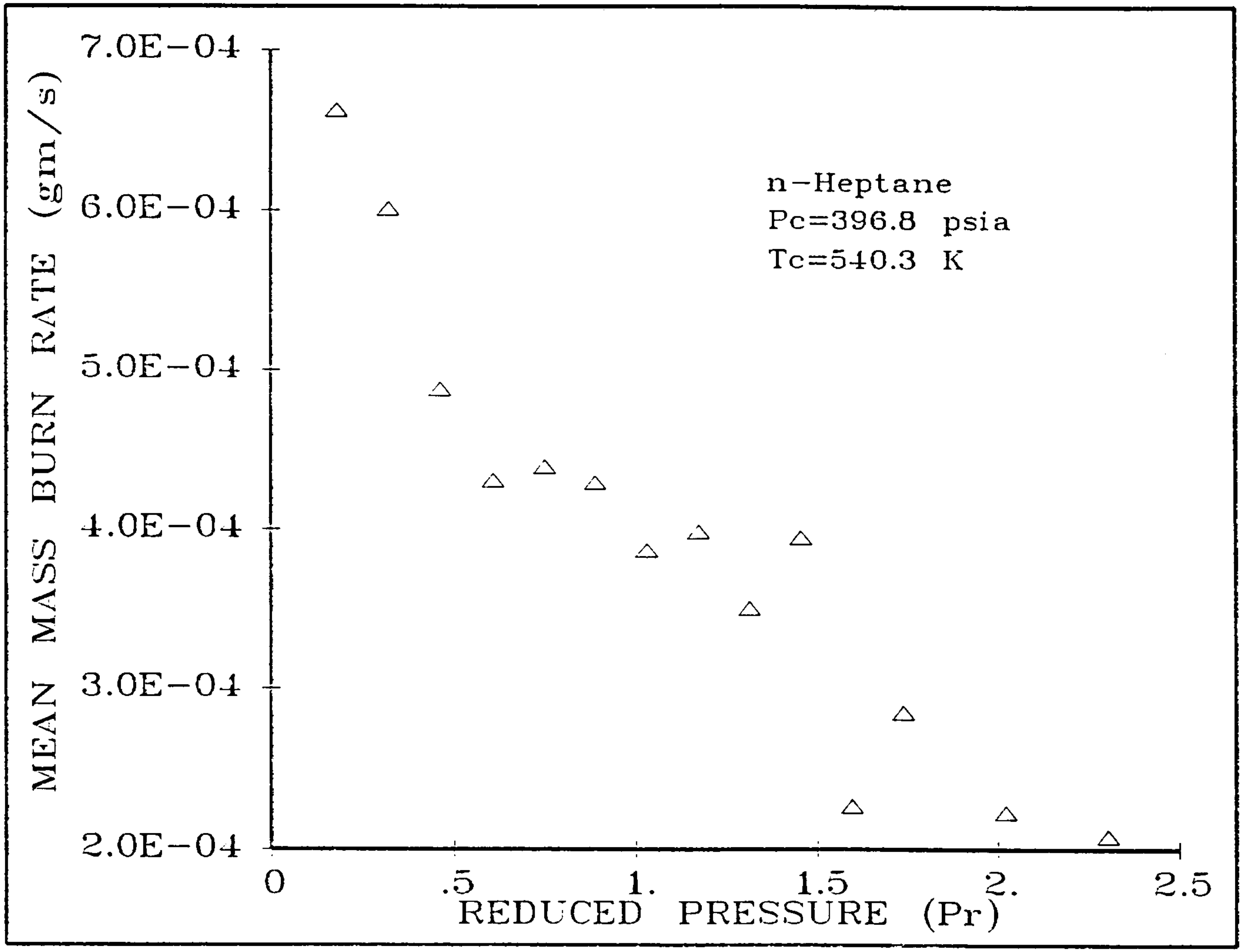

Figure 25. Mean mass burning rate for n-Heptane

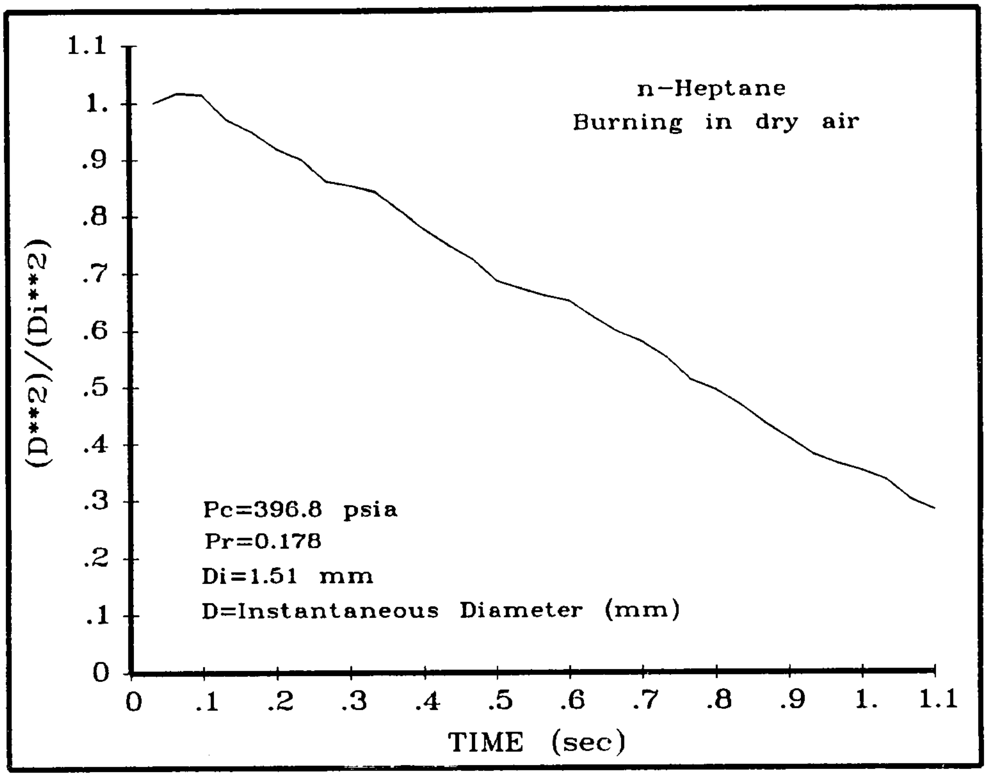

Figure 26. Droplet diameter history at P_r=0.178

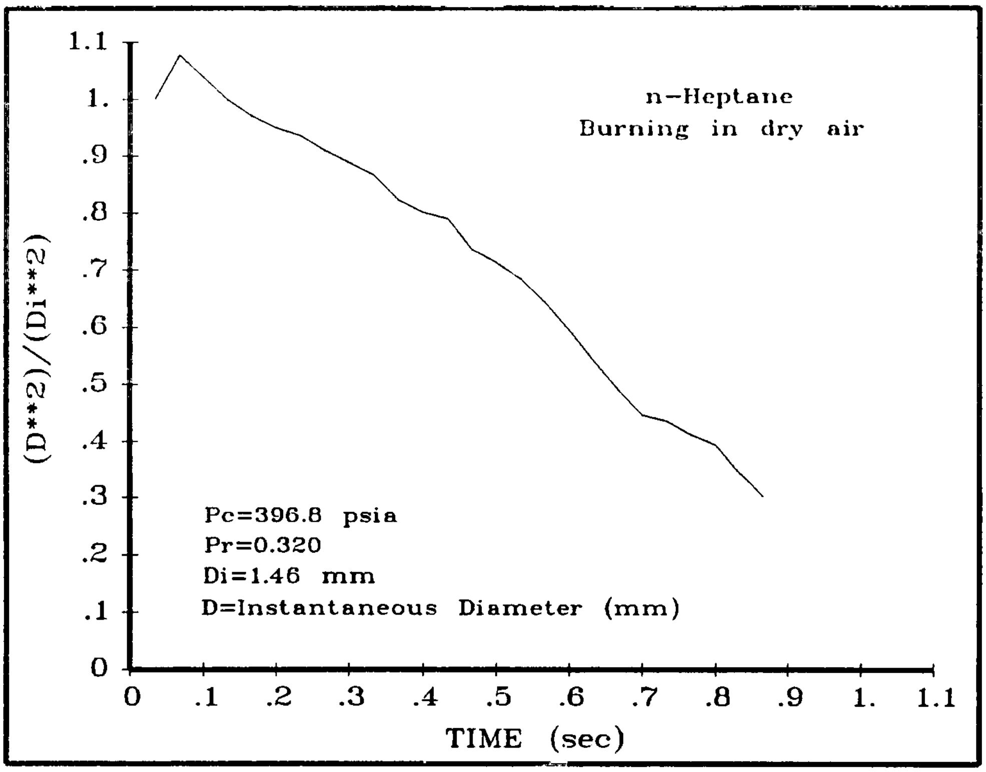

Figure 27. Droplet diameter history at P_r=0.320

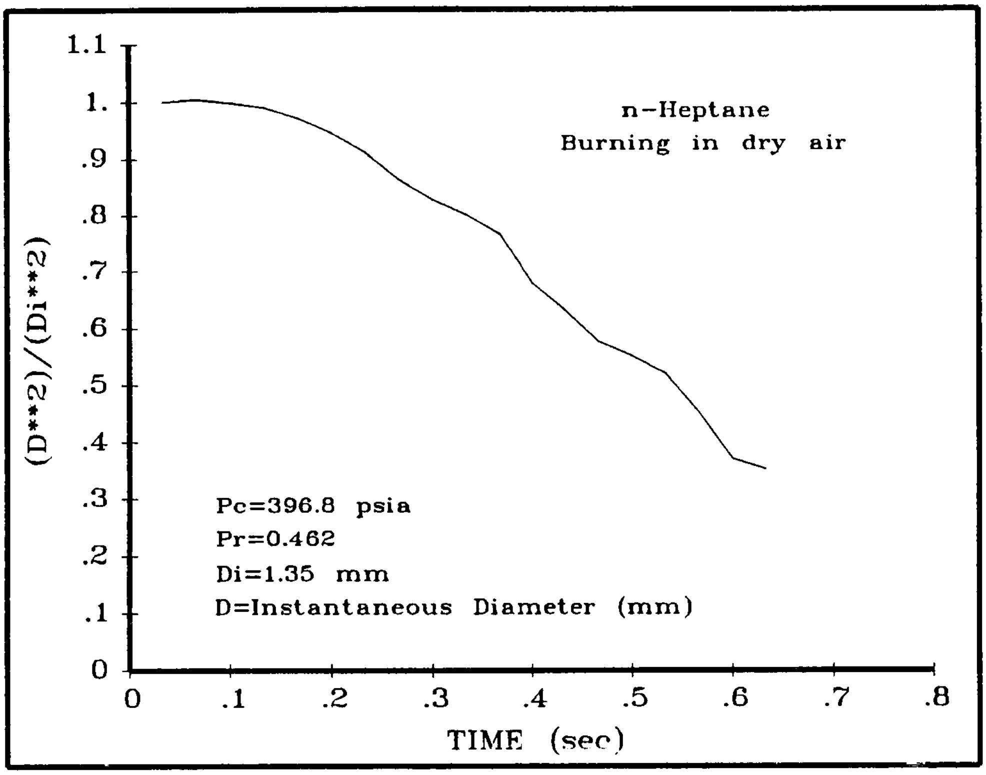

Figure 28. Droplet diameter history at P_r=0.462

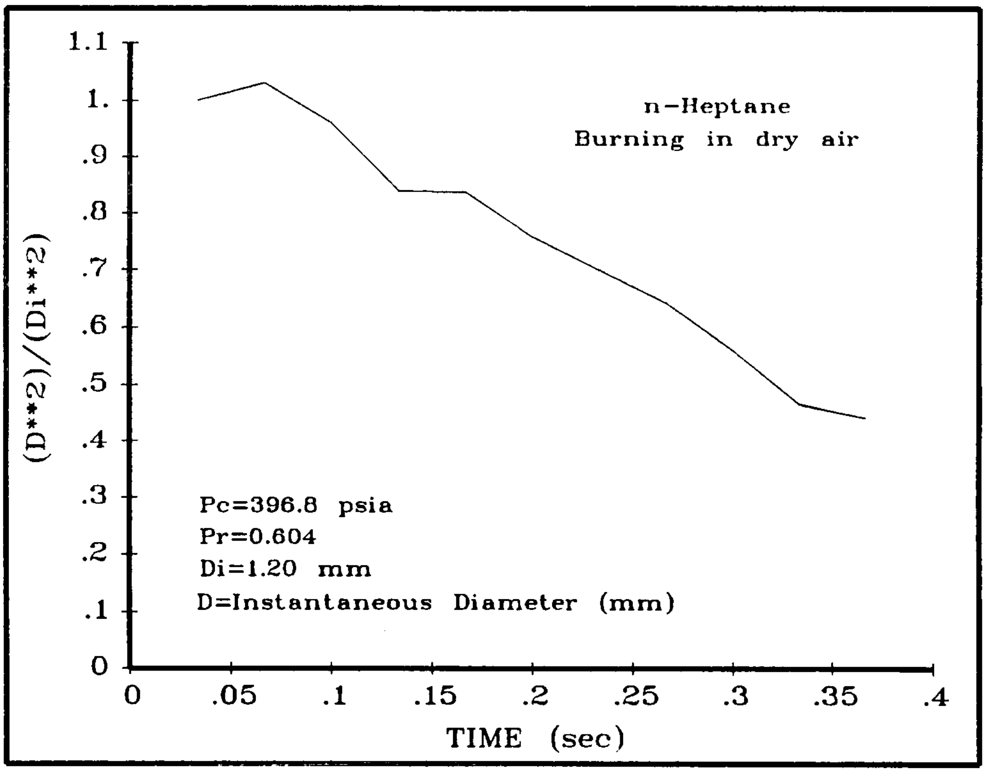

Figure 29. Droplet diameter history at P_r=0.604

stops at approximately 0.3 because that was when the fuel was completely gasified and the fiber optics bead was the only thing remaining. The diameter measurements were taken using the VICOM model VDC-1600 image processor. A typical series of droplet combustion photos can be seen in Figure 30. This shows some of the droplet combustion test running from a time t_0 to a time t_8. Since the droplets may not be a perfect sphere during their burning lifetime, the equivalent droplet diameter needs to be determined. In this report, the equivalent diameter was determined using the concept that a sphere with an equal diameter of the droplet has the same projection area as the droplet. Each frame of the gasification was digitized and an area was calculated in pixels squared. By knowing the size of the fiber optics bead, a conversion factor was found to convert the pixels squared reading to a more suitable millimeters reading. This conversion was then applied to every frame of the droplet gasification test. This gave a frame by frame drop diameter history for the duration of the test. The data used for these plots can be found in the appendix.

The highest reduced pressure that could be used was $P_r = 0.604$. This was due to the optical problems encountered at the higher pressures. A good example of the optical problems can be seen in Figures 31 and 32. The two pictures show a droplet burning at a reduced pressure less than 0.604 and a reduced pressure greater than 0.604. There was a very noticeable soot plume in the $P_r \geq 0.604$ while the picture of a burn when $P_r < 0.604$ was clear. This soot plume was what prevented the measuring of the dropet diameter at the elevated pressures.

The schematic in Figure 33 shows the basic set-up for the shadow-graph technique used for diameter measurements in all the combustion experiments.

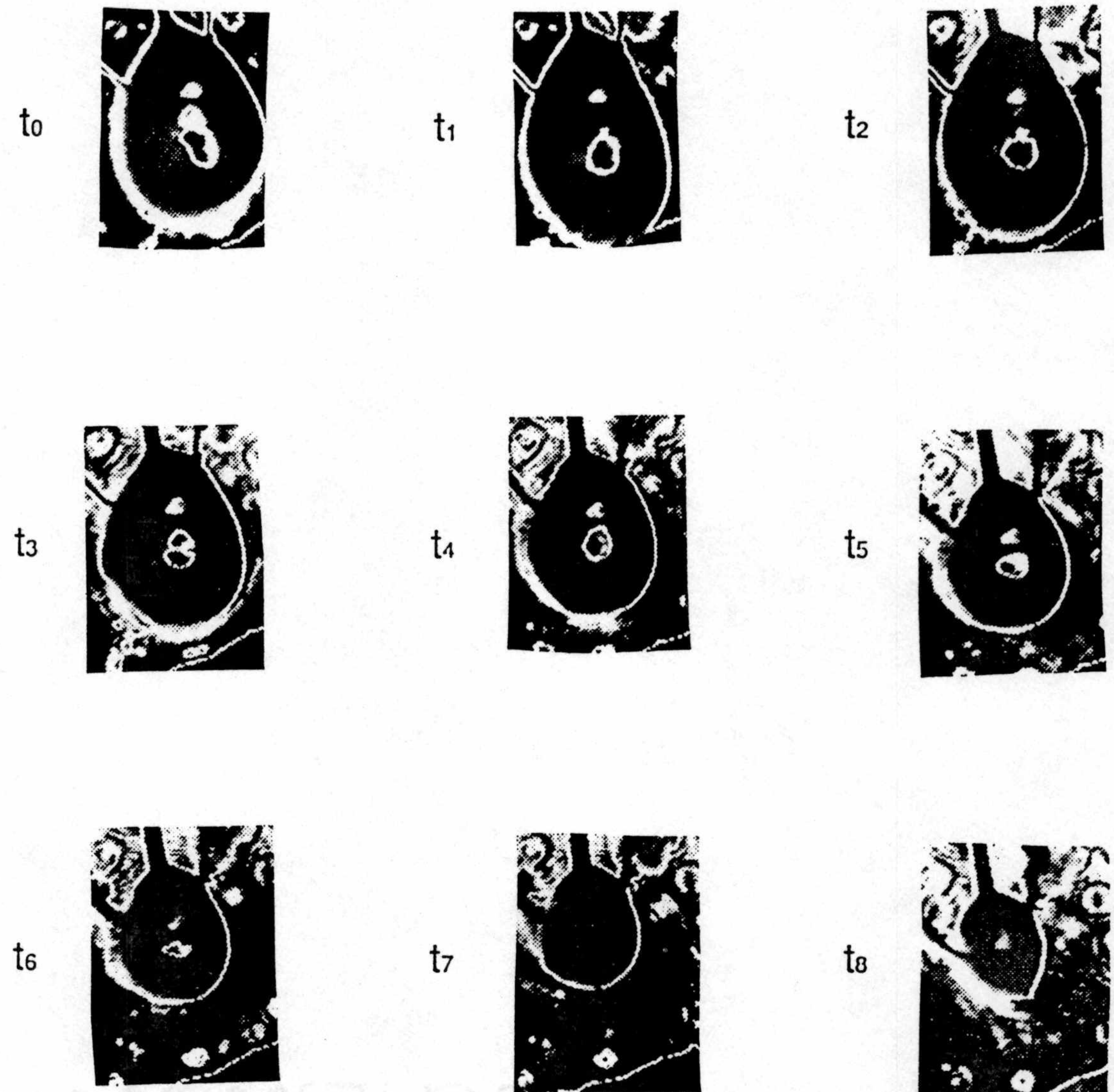

Figure 30. Series of droplet combustion pictures

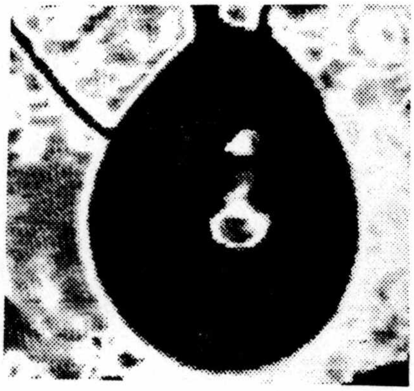

Figure 31. Droplet combustion $P_r < 0.604$

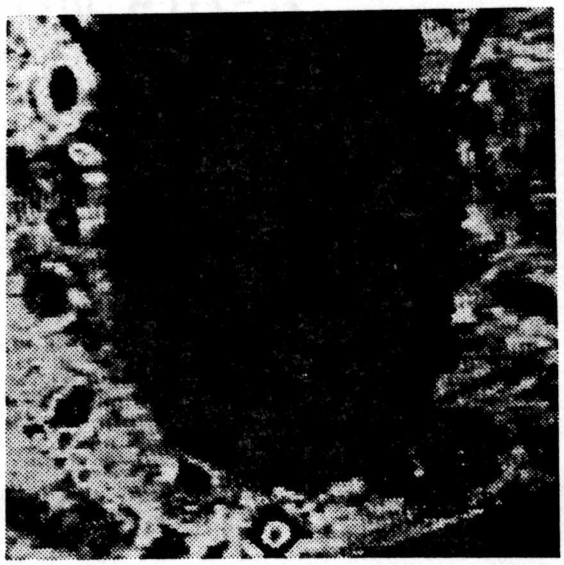

Figure 32. Droplet combustion $P_r \geq 0.604$

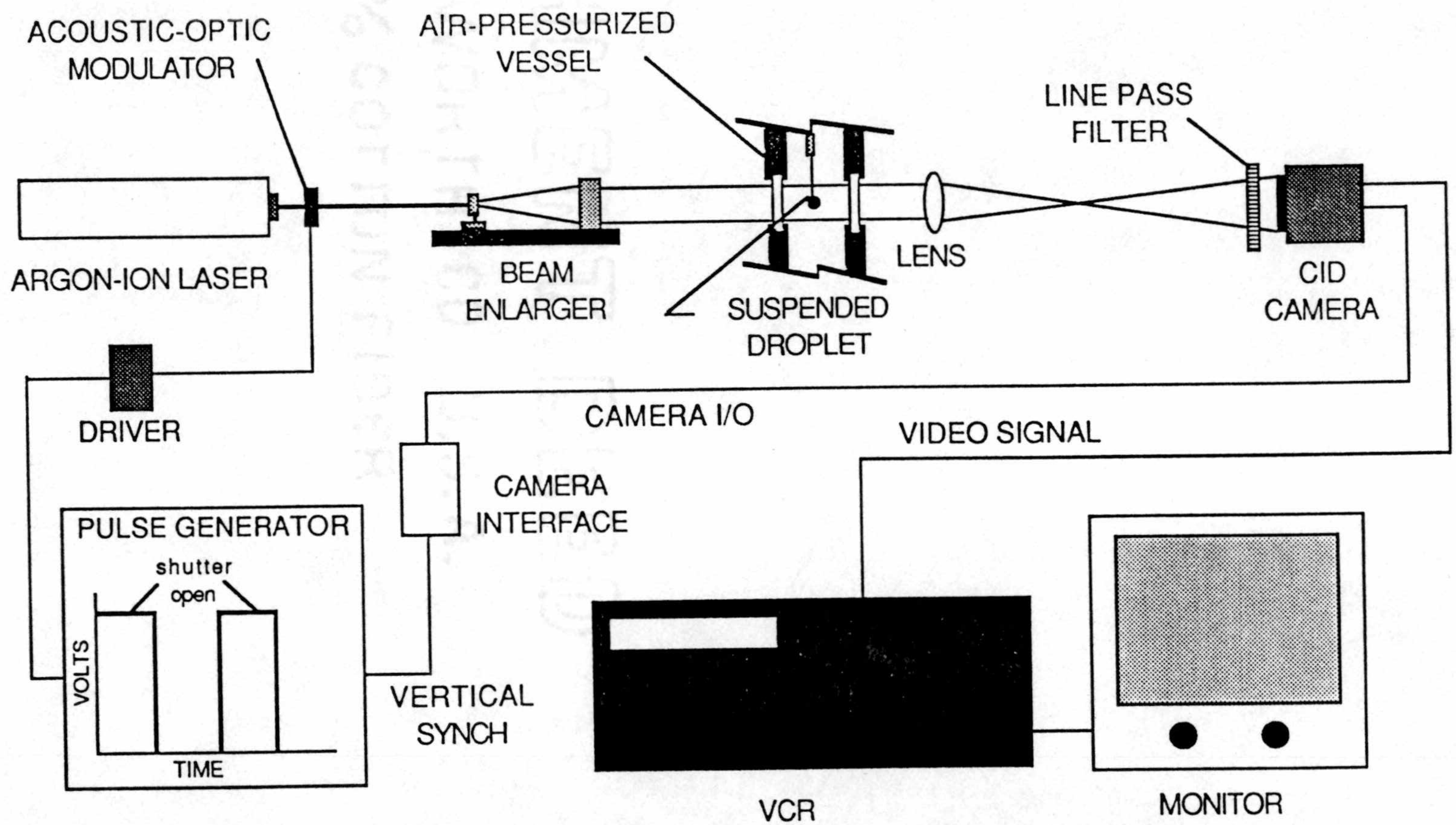

Figure 33. Shadow-graph recording set-up

CHAPTER 4

CONCLUDING REMARKS

An experimental study was made in the area of single hydrocarbon fuel droplets undergoing suspended combustion. Development of a droplet suspension probe was described along with the results of tests done with n-Heptane fuel droplets. The tests that were run allowed for the determination of droplet temperature, mean evaporation rate constants, mean mass burning rates, and some droplet diameter measurements. The tests were all conducted on a suspended drop and ignited using a hot wire source. The supercritical hydrocarbon droplet combustion was observed in a natural convection environment. The results of the tests on the n-Heptane were found to agree, for the most part, with the current theories on supercritical combustion (Kadota and Hiroyasu, 1981). Reduced pressures of up to 2.0 were reached with good temperature readings.

Formation of the soot plume, at supercritical pressures, prevented direct observation of the critical transition phenomena. However, the well defined shape and stationary behavior exhibited by the soot plume seem to indicate the droplet does not experience flash supercritical transition. If the droplet instantaneously flashed to a puff-of-gas, it seems unlikely that a plume, exhibiting behavior indicative of strong convection, would remain stationary. Finite-rate regression of the droplet surface seems more plausible at this point. Hopefully future studies on pure vaporization experiments without combustion will resolve this issue.

The final droplet temperature at the supercritical pressure was found to be close to the critical temperature of the fuel being tested. This was true throughout the supercritical range of the fuel which suggests that the ambient pressure in the supercritical realm has little effect on the final dropet temperature.

The evaporation rate of the fuel increased as the pressure was increased. This was expected because of the decrease in the surface tension of the drop as the pressure was increased. However, the burn rate decreased with the increase in ambient pressure, because the gas-phase diffusion rates at high pressures was reduced. This was explained in chapter 3 in the section on the mean mass burning rate. Therefore, the temperature results of the combustion tests on n-Heptane correlate nicely with the theories and droplet combustion tests that were run in the past (Faeth *et al.*, 1969; Kadota and Hiroyasu, 1981). It must be made clear that the mean evaporation rate constant in this thesis is the rate at which the droplet of fuel vaporizes. The mean mass burn rate is the rate at which the fuel vapors are consumed.

The one draw back to the test results was that better imaging techniques were not available. The ability to see the droplet evaporation in the higher pressure range would have been of significant importance to this study. A method to eliminate the soot plume from the shadow graph technique would be a big step toward the ability to analyse the droplet diameter during the gasification period and the critical transition process.

Further development of the droplet-on-demand generator will allow for tests on free falling uniform drops to take place in the high pressure realm. This will add to the ever-increasing data base that is being developed in the area of supercritical droplet behavior.

In conclusion, the data that was taken during this experiment is of some practical value to the confirmation of theoretical model formulations. The results of these tests show the importance of further investigations in the area of supercritical droplet combustion from both a practical and theoretical point of view.

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APPENDIX

TEMPERATURE DATA

$P_r = 0.178$

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.000	325.01	.046	351.33	.092	375.30	.138	400.53
.001	326.21	.047	351.33	.093	374.10	.139	398.13
.002	328.60	.048	350.73	.094	373.50	.140	402.94
.003	328.00	.049	350.73	.095	374.10	.141	402.34
.004	326.81	.050	353.72	.096	374.70	.142	401.14
.005	328.60	.051	353.52	.097	374.10	.143	401.74
.006	329.20	.052	353.12	.098	375.30	.144	403.54
.007	328.60	.053	354.92	.099	375.90	.145	402.94
.008	328.00	.054	357.31	.100	376.50	.146	401.14
.009	329.20	.055	357.31	.101	376.50	.147	401.14
.010	328.60	.056	356.72	.102	377.50	.148	401.14
.011	328.00	.057	357.91	.103	378.90	.149	400.53
.012	328.00	.058	359.71	.104	378.30	.150	399.33
.013	328.60	.059	359.11	.105	378.90	.151	399.93
.014	328.00	.060	359.11	.106	380.10	.152	399.33
.015	327.40	.061	359.71	.107	381.30	.153	398.90
.016	328.60	.062	362.11	.108	380.70	.154	398.13
.017	329.79	.063	360.91	.109	380.70	.155	399.33
.018	328.60	.064	362.71	.110	382.51	.156	399.33
.019	329.79	.065	362.11	.111	382.51	.157	399.33
.020	330.99	.066	362.11	.112	382.51	.158	398.73
.021	331.59	.067	362.71	.113	383.71	.159	399.33
.022	332.18	.068	360.31	.114	384.31	.160	399.33
.023	333.38	.069	364.51	.115	384.31	.161	398.13
.024	334.57	.070	363.91	.116	384.31	.162	398.73
.025	334.57	.071	362.71	.117	387.91	.163	399.33
.026	334.57	.072	364.51	.118	389.11	.164	398.73
.027	335.77	.073	368.10	.119	389.11	.165	397.53
.028	336.37	.074	368.10	.120	389.71	.166	398.73
.029	336.97	.075	366.30	.121	392.72	.167	399.93
.030	336.97	.076	368.10	.122	395.12	.168	398.73
.031	338.76	.077	368.70	.123	395.12	.169	398.73
.032	339.36	.078	368.10	.124	395.72	.170	399.93
.033	338.76	.079	367.50	.125	398.13	.171	399.93
.034	340.55	.080	368.70	.126	398.13	.172	399.93
.035	342.35	.081	369.30	.127	396.93	.173	400.53
.036	342.95	.082	368.70	.128	396.93	.174	401.14
.037	342.95	.083	368.70	.129	399.33	.175	400.53
.038	345.34	.084	370.50	.130	399.33	.176	399.93
.039	347.14	.085	371.10	.131	399.33	.177	401.14
.040	347.14	.086	371.10	.132	399.33	.178	399.93
.041	347.14	.087	371.70	.133	401.74	.179	399.93
.042	349.53	.088	372.90	.134	400.53	.180	399.93
.043	350.13	.089	373.50	.135	401.14	.181	400.53
.044	349.53	.090	373.50	.136	402.34	.182	400.53
.045	348.93	.091	374.10	.137	400.53	.183	399.93

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.184	400.53	.230	395.72	.276	404.74	.322	410.16
.185	401.14	.231	396.32	.277	405.35	.323	410.16
.186	401.14	.232	395.72	.278	404.74	.324	410.76
.187	400.53	.233	395.72	.279	403.54	.325	410.16
.188	401.74	.234	396.93	.280	402.94	.326	409.56
.189	402.94	.235	396.93	.281	399.93	.327	410.16
.190	401.74	.236	396.93	.282	404.14	.328	409.56
.191	401.14	.237	397.53	.283	403.54	.329	408.96
.192	402.94	.238	398.13	.284	402.34	.330	408.35
.193	402.34	.239	398.13	.285	402.94	.331	408.96
.194	400.53	.240	398.13	.286	406.55	.332	408.96
.195	399.93	.241	398.73	.287	405.95	.333	408.35
.196	401.14	.242	399.33	.288	404.74	.334	408.96
.197	400.53	.243	398.13	.289	405.35	.335	410.16
.198	398.73	.244	397.53	.290	405.95	.336	409.56
.199	398.73	.245	398.13	.291	405.95	.337	408.96
.200	400.53	.246	398.13	.292	404.74	.338	410.16
.201	399.33	.247	397.53	.293	404.74	.339	410.76
.202	398.73	.248	397.53	.294	405.35	.340	410.16
.203	398.13	.249	398.13	.295	405.35	.341	408.96
.204	401.14	.250	398.13	.296	404.14	.342	410.76
.205	399.93	.251	398.13	.297	404.14	.343	410.16
.206	398.13	.252	399.33	.298	405.95	.344	408.35
.207	399.33	.253	399.93	.299	405.35	.345	408.35
.208	397.53	.254	399.33	.300	405.35	.346	410.76
.209	395.72	.255	399.93	.301	406.55	.347	410.16
.210	393.32	.256	401.14	.302	407.15	.348	411.36
.211	393.32	.257	401.14	.303	407.15	.349	410.76
.212	396.32	.258	400.53	.304	407.15	.350	410.16
.213	394.52	.259	400.53	.305	408.35	.351	410.76
.214	394.52	.260	402.34	.306	408.35	.352	407.15
.215	398.13	.261	401.14	.307	407.75	.353	410.76
.216	395.72	.262	400.53	.308	407.75	.354	410.76
.217	395.12	.263	401.74	.309	408.35	.355	410.16
.218	395.12	.264	402.34	.310	407.75	.356	410.16
.219	395.72	.265	401.14	.311	406.55	.357	412.57
.220	396.32	.266	401.14	.312	407.15	.358	413.17
.221	394.52	.267	403.54	.313	407.75	.359	410.76
.222	395.72	.268	403.54	.314	407.75	.360	409.56
.223	396.93	.269	402.94	.315	407.15	.361	411.36
.224	396.93	.270	402.94	.316	408.35	.362	411.97
.225	395.72	.271	404.14	.317	408.96	.363	410.16
.226	396.93	.272	404.74	.318	408.35	.364	410.16
.227	396.93	.273	404.14	.319	409.56	.365	410.76
.228	395.72	.274	403.54	.320	410.16	.366	411.36
.229	395.12	.275	406.55	.321	409.56	.367	410.76

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.368	410.76	.414	413.77	.460	414.37	.506	416.18
.369	412.57	.415	413.17	.461	412.57	.507	417.38
.370	412.57	.416	412.57	.462	413.17	.508	417.38
.371	411.36	.417	416.18	.463	413.77	.509	415.58
.372	412.57	.418	415.58	.464	413.17	.510	415.58
.373	413.17	.419	416.18	.465	413.17	.511	415.58
.374	413.17	.420	416.18	.466	414.37	.512	414.98
.375	411.97	.421	414.98	.467	414.37	.513	413.77
.376	413.17	.422	414.98	.468	414.98	.514	413.77
.377	412.57	.423	411.97	.469	415.58	.515	415.58
.378	411.36	.424	414.37	.470	416.78	.516	415.58
.379	411.36	.425	414.37	.471	416.78	.517	414.37
.380	411.97	.426	413.17	.472	416.78	.518	415.58
.381	411.97	.427	412.57	.473	416.78	.519	417.38
.382	411.97	.428	413.77	.474	416.78	.520	417.38
.383	411.97	.429	413.77	.475	414.98	.521	416.18
.384	413.17	.430	412.57	.476	414.98	.522	417.38
.385	413.17	.431	411.97	.477	415.58	.523	418.59
.386	413.17	.432	413.17	.478	413.77	.524	416.78
.387	413.77	.433	414.37	.479	413.77	.525	414.98
.388	413.77	.434	413.17	.480	413.17	.526	416.78
.389	413.77	.435	413.17	.481	413.77	.527	416.18
.390	413.77	.436	414.98	.482	414.37	.528	414.98
.391	413.77	.437	416.18	.483	413.77	.529	414.37
.392	414.37	.438	414.98	.484	415.58	.530	414.98
.393	413.17	.439	414.98	.485	415.58	.531	414.98
.394	412.57	.440	415.58	.486	416.78	.532	414.98
.395	413.17	.441	415.58	.487	415.58	.533	415.58
.396	413.17	.442	413.77	.488	418.59	.534	416.18
.397	412.57	.443	413.77	.489	418.59	.535	416.78
.398	412.57	.444	414.37	.490	417.38	.536	416.78
.399	412.57	.445	413.77	.491	417.38	.537	417.38
.400	412.57	.446	411.97	.492	414.98	.538	417.38
.401	413.17	.447	412.57	.493	414.98	.539	417.38
.402	413.77	.448	413.77	.494	411.36	.540	417.38
.403	414.98	.449	412.57	.495	413.77	.541	417.38
.404	413.77	.450	413.17	.496	414.37	.542	417.38
.405	414.37	.451	414.37	.497	413.77	.543	416.18
.406	414.98	.452	415.58	.498	413.17	.544	416.18
.407	414.37	.453	415.58	.499	415.58	.545	416.18
.408	414.37	.454	415.58	.500	416.78	.546	416.18
.409	414.37	.455	416.18	.501	415.58	.547	415.58
.410	414.98	.456	416.18	.502	415.58	.548	415.58
.411	412.57	.457	414.98	.503	417.38	.549	416.18
.412	411.97	.458	414.98	.504	417.99	.550	416.18
.413	413.17	.459	414.98	.505	416.78	.551	416.78

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.552	417.38	.598	417.38	.644	416.78	.690	417.99
.553	418.59	.599	416.78	.645	416.18	.691	417.99
.554	417.38	.600	416.18	.646	417.99	.692	417.99
.555	417.99	.601	417.38	.647	416.78	.693	416.78
.556	417.99	.602	417.99	.648	416.18	.694	417.38
.557	417.99	.603	417.99	.649	416.78	.695	417.38
.558	416.18	.604	417.99	.650	418.59	.696	416.78
.559	418.59	.605	418.59	.651	417.38	.697	416.18
.560	418.59	.606	418.59	.652	416.78	.698	416.78
.561	417.38	.607	417.38	.653	418.59	.699	418.59
.562	416.78	.608	417.99	.654	419.19	.700	416.78
.563	414.98	.609	418.59	.655	417.99	.701	417.99
.564	415.58	.610	417.38	.656	417.38	.702	418.59
.565	412.57	.611	416.18	.657	417.99	.703	416.78
.566	415.58	.612	417.38	.658	417.99	.704	418.59
.567	416.18	.613	417.38	.659	416.78	.705	416.18
.568	416.18	.614	416.78	.660	416.78	.706	416.78
.569	416.18	.615	416.78	.661	417.38	.707	415.58
.570	418.59	.616	417.99	.662	417.38	.708	417.38
.571	418.59	.617	417.38	.663	415.58	.709	417.38
.572	417.99	.618	417.38	.664	415.58	.710	417.38
.573	417.38	.619	418.59	.665	416.78	.711	416.78
.574	417.38	.620	419.19	.666	416.78	.712	417.38
.575	417.38	.621	418.59	.667	416.18	.713	417.99
.576	416.78	.622	418.59	.668	416.78	.714	417.99
.577	415.58	.623	418.59	.669	418.59	.715	417.38
.578	415.58	.624	418.59	.670	417.99	.716	417.38
.579	416.78	.625	416.78	.671	417.38	.717	419.19
.580	416.18	.626	417.99	.672	418.59	.718	418.59
.581	414.98	.627	418.59	.673	418.59	.719	417.99
.582	416.78	.628	417.99	.674	417.38	.720	418.59
.583	417.38	.629	416.78	.675	415.58	.721	419.79
.584	416.18	.630	417.99	.676	417.99	.722	419.19
.585	416.18	.631	418.59	.677	417.38	.723	417.99
.586	418.59	.632	417.99	.678	416.18	.724	419.19
.587	418.59	.633	417.99	.679	416.18	.725	417.99
.588	417.38	.634	416.18	.680	416.78	.726	417.99
.589	417.99	.635	417.38	.681	416.78	.727	416.18
.590	419.19	.636	415.58	.682	416.78	.728	417.38
.591	418.59	.637	417.99	.683	416.78	.729	417.38
.592	416.78	.638	418.59	.684	417.99	.730	416.78
.593	416.78	.639	417.99	.685	417.99	.731	416.18
.594	417.38	.640	417.99	.686	417.99	.732	417.38
.595	416.78	.641	418.59	.687	418.59	.733	417.38
.596	416.18	.642	419.19	.688	418.59	.734	416.18
.597	416.18	.643	417.99	.689	417.99	.735	416.18

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.736	418.59	.782	416.18	.828	415.58	.874	419.19
.737	417.99	.783	416.18	.829	415.58	.875	418.59
.738	416.78	.784	417.38	.830	416.18	.876	416.78
.739	417.38	.785	417.99	.831	416.78	.877	414.37
.740	417.99	.786	417.99	.832	416.78	.878	414.37
.741	417.38	.787	417.38	.833	416.78	.879	414.98
.742	416.18	.788	418.59	.834	417.99	.880	413.77
.743	416.78	.789	417.99	.835	418.59	.881	413.17
.744	417.38	.790	416.78	.836	419.19	.882	415.58
.745	416.18	.791	416.78	.837	420.40	.883	416.18
.746	415.58	.792	417.99	.838	420.40	.884	414.98
.747	416.18	.793	417.38	.839	420.40	.885	416.78
.748	416.78	.794	415.58	.840	419.19	.886	419.79
.749	416.18	.795	415.58	.841	421.60	.887	420.40
.750	416.18	.796	416.78	.842	419.19	.888	418.59
.751	417.38	.797	416.18	.843	417.38	.889	418.59
.752	417.38	.798	414.98	.844	417.38	.890	419.19
.753	417.38	.799	416.78	.845	413.77	.891	417.38
.754	417.38	.800	417.99	.846	415.58	.892	414.98
.755	418.59	.801	416.78	.847	413.17	.893	414.98
.756	417.38	.802	416.18	.848	413.77	.894	414.98
.757	416.78	.803	417.99	.849	414.98	.895	411.97
.758	416.78	.804	418.59	.850	417.38	.896	411.36
.759	417.38	.805	416.78	.851	416.78	.897	411.97
.760	416.78	.806	416.78	.852	418.59	.898	412.57
.761	416.18	.807	417.99	.853	419.79	.899	411.97
.762	416.78	.808	417.38	.854	419.79	.900	413.17
.763	416.78	.809	415.58	.855	420.40	.901	414.37
.764	416.18	.810	416.18	.856	419.79	.902	415.58
.765	416.18	.811	416.18	.857	418.59	.903	415.58
.766	417.38	.812	416.18	.858	416.78	.904	416.18
.767	416.78	.813	414.98	.859	417.38	.905	417.38
.768	417.38	.814	414.98	.860	416.78	.906	416.18
.769	417.99	.815	416.78	.861	414.37	.907	414.37
.770	420.40	.816	416.18	.862	413.77	.908	414.37
.771	417.99	.817	416.18	.863	414.37	.909	413.17
.772	418.59	.818	417.38	.864	414.37	.910	413.17
.773	418.59	.819	419.19	.865	413.77	.911	411.36
.774	416.18	.820	418.59	.866	414.98	.912	413.17
.775	416.78	.821	417.99	.867	416.78	.913	413.17
.776	414.98	.822	419.19	.868	417.38	.914	409.56
.777	415.58	.823	419.19	.869	417.38	.915	410.76
.778	414.37	.824	417.99	.870	419.79	.916	410.16
.779	416.78	.825	416.18	.871	421.00	.917	413.77
.780	416.18	.826	417.99	.872	419.79	.918	412.57
.781	416.18	.827	417.38	.873	418.59	.919	414.37

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.920	416.78	.966	410.16	1.012	408.35	1.058	428.83
.921	417.99	.967	410.16	1.013	410.16	1.059	431.84
.922	417.38	.968	411.97	1.014	410.16	1.060	430.04
.923	416.78	.969	414.37	1.015	409.56	1.061	430.04
.924	416.18	.970	414.37	1.016	410.76	1.062	434.25
.925	414.37	.971	414.37	1.017	412.57	1.063	438.47
.926	413.17	.972	415.58	1.018	413.77	1.064	439.68
.927	411.97	.973	414.37	1.019	414.37	1.065	443.90
.928	410.76	.974	412.57	1.020	416.78	1.066	449.93
.929	410.16	.975	410.76	1.021	418.59	1.067	452.95
.930	410.16	.976	411.36	1.022	417.38	1.068	455.96
.931	410.76	.977	410.16	1.023	416.18	1.069	460.79
.932	411.36	.978	407.15	1.024	417.38	1.070	465.01
.933	411.36	.979	408.35	1.025	415.58	1.071	468.03
.934	413.17	.980	408.35	1.026	414.37	1.072	471.65
.935	414.37	.981	409.56	1.027	411.97	1.073	476.47
.936	414.98	.982	409.56	1.028	411.97	1.074	478.89
.937	415.58	.983	411.97	1.029	412.57	1.075	481.90
.938	417.38	.984	412.57	1.030	412.57	1.076	487.33
.939	416.78	.985	410.16	1.031	413.17	1.077	493.96
.940	414.37	.986	411.97	1.032	416.18	1.078	504.81
.941	414.37	.987	411.97	1.033	416.78	1.079	519.25
.942	414.37	.988	414.98	1.034	416.78	1.080	534.88
.943	412.57	.989	412.57	1.035	418.59	1.081	552.85
.944	410.16	.990	411.97	1.036	421.60	1.082	569.56
.945	410.16	.991	411.97	1.037	421.60	1.083	587.38
.946	411.36	.992	412.57	1.038	421.60	1.084	604.50
.947	410.76	.993	409.56	1.039	422.81	1.085	619.74
.948	409.56	.994	408.96	1.040	423.41	1.086	634.29
.949	411.36	.995	408.35	1.041	421.00	1.087	650.43
.950	412.57	.996	408.35	1.042	419.19	1.088	668.66
.951	411.97	.997	407.15	1.043	418.59	1.089	684.40
.952	413.17	.998	407.75	1.044	417.38	1.090	698.25
.953	415.58	.999	408.96	1.045	415.58		
.954	416.18	1.000	408.96	1.046	415.58		
.955	414.98	1.001	410.16	1.047	417.38		
.956	414.37	1.002	412.57	1.048	419.79		
.957	414.98	1.003	412.57	1.049	419.79		
.958	413.17	1.004	412.57	1.050	422.81		
.959	411.36	1.005	414.37	1.051	423.41		
.960	410.76	1.006	414.37	1.052	426.42		
.961	411.36	1.007	411.97	1.053	427.02		
.962	410.16	1.008	411.97	1.054	427.63		
.963	408.96	1.009	411.36	1.055	431.84		
.964	408.96	1.010	410.76	1.056	428.23		
.965	410.76	1.011	408.35	1.057	428.23		

TEMPERATURE DATA

$P_r = 0.320$

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.000	335.77	.045	360.31	.090	387.91	.135	404.14
.001	335.77	.046	359.11	.091	389.11	.136	402.34
.002	336.37	.047	360.91	.092	390.31	.137	402.34
.003	337.56	.048	362.71	.093	391.52	.138	402.94
.004	337.56	.049	362.11	.094	392.12	.139	402.94
.005	337.56	.050	360.91	.095	392.12	.140	402.34
.006	339.36	.051	363.31	.096	395.12	.141	402.94
.007	339.96	.052	364.51	.097	394.52	.142	402.34
.008	340.55	.053	363.31	.098	395.12	.143	402.34
.009	342.35	.054	362.71	.099	395.72	.144	402.34
.010	344.74	.055	363.31	.100	398.13	.145	403.54
.011	345.34	.056	365.70	.101	397.53	.146	402.94
.012	345.94	.057	363.91	.102	396.32	.147	402.94
.013	346.54	.058	365.70	.103	398.13	.148	402.94
.014	347.14	.059	366.90	.104	399.33	.149	404.14
.015	347.14	.060	368.10	.105	399.93	.150	402.94
.016	347.14	.061	367.50	.106	398.73	.151	402.94
.017	347.73	.062	369.30	.107	401.74	.152	404.14
.018	348.33	.063	371.10	.108	402.94	.153	404.14
.019	347.14	.064	371.10	.109	401.74	.154	402.94
.020	347.14	.065	372.30	.110	401.74	.155	403.54
.021	348.33	.066	374.10	.111	404.14	.156	405.35
.022	349.53	.067	373.50	.112	405.35	.157	404.74
.023	348.33	.068	374.10	.113	403.54	.158	404.74
.024	349.53	.069	374.10	.114	403.54	.159	405.95
.025	351.33	.070	375.30	.115	405.35	.160	407.75
.026	351.92	.071	375.30	.116	405.35	.161	407.75
.027	351.92	.072	376.50	.117	402.34	.162	407.15
.028	353.72	.073	377.10	.118	402.94	.163	409.56
.029	356.12	.074	380.70	.119	403.54	.164	410.16
.030	354.32	.075	378.90	.120	402.34	.165	410.16
.031	353.12	.076	381.30	.121	401.14	.166	409.56
.032	356.12	.077	381.90	.122	403.54	.167	410.76
.033	355.52	.078	383.11	.123	404.14	.168	410.76
.034	353.72	.079	383.11	.124	403.54	.169	408.96
.035	353.72	.080	380.70	.125	402.94	.170	408.35
.036	354.92	.081	383.11	.126	405.35	.171	410.76
.037	354.92	.082	381.30	.127	407.15	.172	410.16
.038	353.72	.083	383.71	.128	405.95	.173	411.36
.039	353.72	.084	383.11	.129	405.35	.174	410.16
.040	356.12	.085	384.31	.130	407.15	.175	413.17
.041	356.72	.086	383.71	.131	406.55	.176	413.17
.042	356.12	.087	384.91	.132	405.95	.177	411.36
.043	356.72	.088	386.11	.133	404.74	.178	414.98
.044	359.71	.089	386.71	.134	405.35	.179	413.17

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.180	413.17	.225	419.79	.270	427.02	.315	430.04
.181	410.76	.226	419.79	.271	425.82	.316	428.83
.182	416.18	.227	421.00	.272	426.42	.317	430.04
.183	415.58	.228	421.60	.273	428.23	.318	430.64
.184	413.77	.229	421.00	.274	424.01	.319	428.83
.185	413.77	.230	421.00	.275	425.82	.320	428.83
.186	416.78	.231	422.20	.276	424.01	.321	430.04
.187	415.58	.232	422.20	.277	428.23	.322	430.64
.188	414.37	.233	421.00	.278	425.82	.323	428.83
.189	414.98	.234	421.60	.279	425.82	.324	429.43
.190	417.99	.235	422.81	.280	427.63	.325	431.84
.191	416.78	.236	421.00	.281	429.43	.326	431.24
.192	414.98	.237	419.19	.282	428.23	.327	430.04
.193	416.18	.238	421.60	.283	428.23	.328	430.64
.194	417.38	.239	422.20	.284	429.43	.329	432.45
.195	417.38	.240	421.60	.285	428.83	.330	431.24
.196	416.18	.241	421.00	.286	427.02	.331	430.04
.197	417.38	.242	422.81	.287	427.02	.332	431.84
.198	417.99	.243	424.01	.288	427.63	.333	431.84
.199	416.78	.244	424.01	.289	426.42	.334	430.04
.200	415.58	.245	423.41	.290	427.02	.335	430.04
.201	417.38	.246	425.82	.291	427.63	.336	430.04
.202	417.38	.247	425.22	.292	427.63	.337	430.04
.203	416.18	.248	424.01	.293	427.02	.338	428.83
.204	416.18	.249	424.01	.294	428.23	.339	428.83
.205	417.38	.250	425.22	.295	428.83	.340	430.64
.206	417.99	.251	424.61	.296	428.23	.341	430.04
.207	416.78	.252	422.81	.297	427.63	.342	428.83
.208	417.99	.253	423.41	.298	428.83	.343	430.04
.209	418.59	.254	424.01	.299	429.43	.344	431.84
.210	419.19	.255	423.41	.300	427.63	.345	431.84
.211	418.59	.256	422.20	.301	428.23	.346	431.84
.212	419.19	.257	423.41	.302	429.43	.347	431.84
.213	420.40	.258	424.61	.303	428.83	.348	432.45
.214	419.19	.259	424.01	.304	427.02	.349	431.84
.215	420.40	.260	423.41	.305	427.63	.350	431.84
.216	421.00	.261	425.22	.306	429.43	.351	432.45
.217	420.40	.262	425.82	.307	428.83	.352	432.45
.218	419.19	.263	424.61	.308	428.23	.353	431.24
.219	419.19	.264	424.01	.309	428.83	.354	431.24
.220	419.79	.265	426.42	.310	430.64	.355	431.84
.221	419.19	.266	426.42	.311	430.04	.356	431.24
.222	418.59	.267	424.01	.312	429.43	.357	430.64
.223	419.79	.268	427.63	.313	430.04	.358	432.45
.224	420.40	.269	426.42	.314	430.64	.359	433.65

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.360	431.84	.405	434.86	.450	440.28	.495	442.09
.361	433.05	.406	433.65	.451	440.28	.496	441.49
.362	433.05	.407	434.86	.452	442.69	.497	442.69
.363	436.06	.408	435.46	.453	440.28	.498	442.69
.364	432.45	.409	434.25	.454	438.47	.499	442.69
.365	435.46	.410	434.25	.455	437.87	.500	442.69
.366	435.46	.411	436.06	.456	439.68	.501	443.30
.367	434.25	.412	436.67	.457	437.87	.502	442.09
.368	434.25	.413	436.06	.458	438.47	.503	440.28
.369	431.84	.414	435.46	.459	437.87	.504	440.28
.370	433.05	.415	437.87	.460	441.49	.505	440.28
.371	430.04	.416	437.87	.461	440.89	.506	439.68
.372	432.45	.417	436.67	.462	440.28	.507	438.47
.373	431.84	.418	437.27	.463	442.09	.508	439.68
.374	433.05	.419	437.27	.464	440.28	.509	439.68
.375	432.45	.420	436.67	.465	441.49	.510	439.68
.376	434.25	.421	436.06	.466	438.47	.511	439.68
.377	434.86	.422	437.27	.467	442.69	.512	442.09
.378	435.46	.423	436.67	.468	441.49	.513	442.69
.379	434.25	.424	435.46	.469	439.68	.514	441.49
.380	435.46	.425	436.67	.470	439.08	.515	442.69
.381	436.67	.426	437.27	.471	442.09	.516	445.11
.382	436.06	.427	437.27	.472	440.89	.517	443.30
.383	434.86	.428	437.87	.473	438.47	.518	442.09
.384	434.86	.429	437.87	.474	439.68	.519	443.30
.385	436.06	.430	439.08	.475	442.09	.520	443.30
.386	434.25	.431	439.08	.476	440.89	.521	440.89
.387	433.05	.432	438.47	.477	439.68	.522	439.68
.388	434.25	.433	440.28	.478	441.49	.523	440.89
.389	435.46	.434	440.28	.479	442.69	.524	441.49
.390	434.25	.435	439.08	.480	442.69	.525	439.68
.391	433.65	.436	438.47	.481	441.49	.526	439.08
.392	435.46	.437	439.68	.482	443.90	.527	442.09
.393	436.67	.438	438.47	.483	443.90	.528	442.69
.394	436.06	.439	437.27	.484	442.09	.529	441.49
.395	435.46	.440	437.87	.485	442.09	.530	442.69
.396	437.87	.441	439.08	.486	442.69	.531	445.11
.397	437.27	.442	437.87	.487	441.49	.532	445.11
.398	436.06	.443	436.67	.488	440.28	.533	443.90
.399	436.67	.444	438.47	.489	440.28	.534	444.50
.400	437.87	.445	440.28	.490	440.89	.535	445.71
.401	437.27	.446	439.68	.491	440.28	.536	444.50
.402	435.46	.447	439.08	.492	439.68	.537	442.69
.403	435.46	.448	441.49	.493	440.28	.538	443.30
.404	436.06	.449	442.09	.494	441.49	.539	443.30

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.540	442.69	.585	443.90	.630	446.31	.675	445.11
.541	441.49	.586	443.90	.631	446.31	.676	445.11
.542	443.30	.587	443.90	.632	448.12	.677	446.92
.543	443.90	.588	442.69	.633	447.52	.678	448.12
.544	443.90	.589	440.89	.634	446.92	.679	447.52
.545	443.30	.590	441.49	.635	447.52	.680	448.12
.546	445.11	.591	442.69	.636	446.92	.681	449.93
.547	445.71	.592	441.49	.637	445.11	.682	450.53
.548	445.71	.593	440.89	.638	443.90	.683	449.33
.549	446.31	.594	443.30	.639	443.90	.684	449.33
.550	446.92	.595	444.50	.640	443.90	.685	450.53
.551	446.92	.596	444.50	.641	442.09	.686	448.12
.552	445.71	.597	443.90	.642	442.69	.687	446.31
.553	445.71	.598	446.31	.643	443.90	.688	446.92
.554	443.90	.599	447.52	.644	445.11	.689	446.92
.555	443.90	.600	445.11	.645	445.11	.690	445.71
.556	442.09	.601	445.71	.646	446.31	.691	444.50
.557	445.11	.602	446.92	.647	448.12	.692	446.31
.558	443.30	.603	445.71	.648	448.12	.693	446.31
.559	442.69	.604	443.30	.649	447.52	.694	446.92
.560	443.30	.605	442.69	.650	449.93	.695	445.71
.561	443.30	.606	443.90	.651	449.93	.696	449.33
.562	445.71	.607	442.69	.652	451.14	.697	449.33
.563	442.69	.608	440.89	.653	447.52	.698	449.33
.564	443.90	.609	442.09	.654	448.12	.699	450.53
.565	443.90	.610	443.90	.655	448.12	.700	451.14
.566	446.31	.611	443.90	.656	445.11	.701	450.53
.567	443.90	.612	443.30	.657	445.11	.702	449.93
.568	445.11	.613	445.11	.658	443.90	.703	449.93
.569	445.11	.614	445.71	.659	444.50	.704	448.73
.570	445.11	.615	445.71	.660	442.09	.705	447.52
.571	443.30	.616	445.71	.661	445.71	.706	447.52
.572	442.69	.617	446.31	.662	447.52	.707	447.52
.573	442.69	.618	446.92	.663	447.52	.708	446.92
.574	441.49	.619	445.11	.664	446.92	.709	445.71
.575	442.09	.620	444.50	.665	450.53	.710	446.92
.576	442.09	.621	443.90	.666	451.74	.711	448.73
.577	442.69	.622	443.90	.667	449.33	.712	448.73
.578	442.09	.623	441.49	.668	448.73	.713	449.33
.579	443.30	.624	442.09	.669	449.93	.714	449.93
.580	444.50	.625	442.69	.670	449.33	.715	451.14
.581	444.50	.626	442.69	.671	445.71	.716	450.53
.582	444.50	.627	442.69	.672	445.11	.717	449.93
.583	445.71	.628	443.90	.673	446.31	.718	451.14
.584	445.71	.629	445.71	.674	446.92	.719	449.93

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.720	447.52	.765	448.73	.810	439.68	.855	442.09
.721	446.92	.766	448.12	.811	439.68	.856	440.28
.722	447.52	.767	449.33	.812	442.69	.857	439.68
.723	446.31	.768	448.73	.813	443.90	.858	438.47
.724	444.50	.769	447.52	.814	442.69	.859	437.27
.725	446.31	.770	446.92	.815	445.11	.860	439.08
.726	446.31	.771	446.31	.816	447.52	.861	442.09
.727	445.71	.772	445.71	.817	446.92	.862	444.50
.728	445.11	.773	443.90	.818	445.71	.863	446.31
.729	447.52	.774	444.50	.819	446.92	.864	449.33
.730	449.33	.775	445.11	.820	446.92	.865	452.95
.731	448.73	.776	443.90	.821	443.90	.866	454.15
.732	448.73	.777	443.30	.822	442.69	.867	456.57
.733	451.14	.778	445.71	.823	443.30	.868	462.00
.734	451.14	.779	446.31	.824	443.30	.869	466.22
.735	448.73	.780	446.92	.825	441.49	.870	471.04
.736	448.12	.781	447.52	.826	440.89	.871	478.89
.737	449.33	.782	449.33	.827	442.09	.872	486.12
.738	447.52	.783	448.73	.828	442.69	.873	492.15
.739	445.71	.784	448.12	.829	442.69	.874	499.38
.740	445.71	.785	448.73	.830	444.50	.875	511.43
.741	448.12	.786	448.12	.831	446.31	.876	524.06
.742	446.31	.787	445.71	.832	447.52	.877	537.28
.743	445.11	.788	444.50	.833	447.52	.878	549.86
.744	446.92	.789	444.50	.834	448.12	.879	565.39
.745	450.53	.790	443.90	.835	448.12	.880	583.23
.746	448.73	.791	442.09	.836	446.31	.881	597.43
.747	450.53	.792	442.09	.837	444.50	.882	613.31
.748	451.74	.793	442.69	.838	445.71	.883	634.87
.749	451.74	.794	443.30	.839	442.09	.884	656.16
.750	449.93	.795	443.30	.840	441.49		
.751	447.52	.796	444.50	.841	440.28		
.752	451.74	.797	446.31	.842	440.89		
.753	448.12	.798	446.31	.843	440.28		
.754	445.71	.799	445.71	.844	437.87		
.755	444.50	.800	446.92	.845	439.68		
.756	448.12	.801	448.12	.846	439.68		
.757	446.31	.802	446.31	.847	443.90		
.758	443.90	.803	443.90	.848	442.69		
.759	445.11	.804	445.11	.849	445.11		
.760	448.12	.805	443.90	.850	446.31		
.761	446.92	.806	441.49	.851	447.52		
.762	445.71	.807	439.68	.852	446.31		
.763	448.12	.808	441.49	.853	445.71		
.764	448.12	.809	440.89	.854	443.90		

TEMPERATURE DATA

$P_r = 0.462$

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.000	369.90	.045	430.64	.090	472.85	.135	471.04
.001	369.90	.046	431.84	.091	473.46	.136	472.85
.002	370.50	.047	432.45	.092	475.27	.137	473.46
.003	371.10	.048	433.05	.093	475.87	.138	473.46
.004	372.30	.049	433.65	.094	475.27	.139	474.66
.005	372.90	.050	434.25	.095	474.06	.140	476.47
.006	374.70	.051	433.65	.096	474.06	.141	477.08
.007	375.90	.052	431.84	.097	474.06	.142	477.08
.008	376.50	.053	434.86	.098	474.06	.143	478.28
.009	377.70	.054	434.86	.099	472.85	.144	480.09
.010	378.90	.055	434.86	.100	472.25	.145	477.68
.011	381.30	.056	435.46	.101	472.25	.146	480.09
.012	380.10	.057	434.86	.102	471.65	.147	479.49
.013	385.51	.058	436.06	.103	470.44	.148	478.89
.014	383.71	.059	436.06	.104	469.84	.149	479.49
.015	386.11	.060	436.06	.105	469.23	.150	479.49
.016	387.31	.061	436.06	.106	469.84	.151	478.89
.017	387.91	.062	437.87	.107	468.03	.152	478.89
.018	389.11	.063	438.47	.108	466.82	.153	480.09
.019	390.92	.064	439.08	.109	466.22	.154	480.09
.020	392.72	.065	437.27	.110	466.82	.155	480.09
.021	392.72	.066	441.49	.111	466.22	.156	480.09
.022	394.52	.067	442.09	.112	465.61	.157	481.90
.023	396.93	.068	442.09	.113	465.61	.158	481.30
.024	398.73	.069	442.69	.114	465.61	.159	483.71
.025	397.53	.070	443.30	.115	465.61	.160	482.50
.026	401.14	.071	445.71	.116	464.41	.161	483.11
.027	401.74	.072	446.92	.117	465.01	.162	484.31
.028	403.54	.073	448.12	.118	465.61	.163	484.92
.029	404.74	.074	449.93	.119	465.01	.164	484.92
.030	406.55	.075	452.95	.120	465.01	.165	485.52
.031	407.75	.076	454.76	.121	464.41	.166	486.12
.032	410.76	.077	455.36	.122	464.41	.167	486.73
.033	413.17	.078	455.96	.123	464.41	.168	486.12
.034	414.37	.079	460.79	.124	465.01	.169	486.12
.035	416.18	.080	461.39	.125	464.41	.170	486.73
.036	417.99	.081	462.60	.126	464.41	.171	486.73
.037	420.40	.082	463.81	.127	465.01	.172	486.73
.038	420.40	.083	465.01	.128	465.61	.173	487.33
.039	420.40	.084	466.82	.129	465.61	.174	485.52
.040	424.01	.085	468.63	.130	466.22	.175	486.12
.041	425.82	.086	469.23	.131	468.63	.176	486.12
.042	427.02	.087	469.84	.132	467.42	.177	485.52
.043	427.63	.088	471.04	.133	469.23	.178	484.92
.044	428.83	.089	472.25	.134	469.84	.179	485.52

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.180	485.52	.225	496.37	.270	481.90	.315	492.15
.181	483.71	.226	499.99	.271	480.70	.316	492.15
.182	484.31	.227	499.99	.272	479.49	.317	494.56
.183	484.92	.228	499.38	.273	478.89	.318	492.76
.184	485.52	.229	498.78	.274	478.89	.319	495.77
.185	483.71	.230	498.78	.275	477.68	.320	494.56
.186	487.33	.231	499.38	.276	476.47	.321	494.56
.187	484.92	.232	498.18	.277	475.87	.322	496.37
.188	484.92	.233	498.18	.278	475.27	.323	496.37
.189	485.52	.234	497.58	.279	475.27	.324	496.37
.190	485.52	.235	498.18	.280	473.46	.325	496.37
.191	485.52	.236	498.18	.281	472.25	.326	497.58
.192	486.73	.237	496.97	.282	471.04	.327	498.18
.193	486.73	.238	494.56	.283	471.04	.328	498.18
.194	486.73	.239	497.58	.284	471.04	.329	499.38
.195	487.33	.240	496.37	.285	470.44	.330	500.59
.196	487.93	.241	495.77	.286	469.84	.331	501.19
.197	489.74	.242	494.56	.287	470.44	.332	502.40
.198	487.93	.243	494.56	.288	471.04	.333	503.00
.199	491.55	.244	495.17	.289	470.44	.334	503.00
.200	490.34	.245	495.17	.290	471.04	.335	504.20
.201	491.55	.246	493.96	.291	472.85	.336	505.41
.202	492.15	.247	494.56	.292	471.65	.337	505.41
.203	492.15	.248	494.56	.293	472.25	.338	506.61
.204	492.15	.249	493.36	.294	472.25	.339	507.22
.205	493.96	.250	493.96	.295	472.25	.340	508.42
.206	494.56	.251	492.76	.296	474.06	.341	507.82
.207	494.56	.252	494.56	.297	474.06	.342	508.42
.208	494.56	.253	493.96	.298	474.66	.343	508.42
.209	495.77	.254	492.15	.299	475.27	.344	509.62
.210	496.37	.255	490.95	.300	476.47	.345	508.42
.211	495.17	.256	490.34	.301	477.08	.346	511.43
.212	495.17	.257	490.95	.302	477.08	.347	509.02
.213	496.97	.258	490.34	.303	478.89	.348	509.62
.214	497.58	.259	489.14	.304	481.30	.349	510.23
.215	497.58	.260	487.93	.305	479.49	.350	510.23
.216	497.58	.261	487.93	.306	483.11	.351	509.62
.217	497.58	.262	486.73	.307	483.71	.352	510.83
.218	498.18	.263	486.12	.308	484.92	.353	510.23
.219	498.78	.264	485.52	.309	486.12	.354	510.23
.220	498.78	.265	485.52	.310	486.73	.355	509.62
.221	498.78	.266	486.12	.311	487.93	.356	509.62
.222	499.38	.267	483.71	.312	488.53	.357	510.83
.223	499.99	.268	481.90	.313	490.34	.358	508.42
.224	499.38	.269	481.30	.314	491.55	.359	512.03

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.360	510.23	.405	504.81	.450	496.37	.495	503.00
.361	510.83	.406	503.60	.451	496.97	.496	503.60
.362	511.43	.407	503.00	.452	497.58	.497	503.60
.363	511.43	.408	503.60	.453	496.37	.498	504.81
.364	512.63	.409	503.00	.454	495.77	.499	506.01
.365	513.24	.410	501.80	.455	495.17	.500	506.61
.366	513.84	.411	499.99	.456	496.37	.501	506.61
.367	513.24	.412	502.40	.457	495.77	.502	507.22
.368	513.84	.413	501.80	.458	495.17	.503	508.42
.369	513.84	.414	500.59	.459	495.77	.504	508.42
.370	513.84	.415	499.99	.460	496.37	.505	509.02
.371	512.03	.416	499.38	.461	496.37	.506	509.62
.372	512.63	.417	499.99	.462	495.77	.507	509.62
.373	512.63	.418	499.38	.463	496.37	.508	510.83
.374	513.24	.419	498.78	.464	497.58	.509	511.43
.375	512.63	.420	498.18	.465	495.17	.510	512.03
.376	512.03	.421	498.18	.466	495.77	.511	513.24
.377	512.03	.422	497.58	.467	495.17	.512	514.44
.378	512.63	.423	497.58	.468	495.17	.513	515.64
.379	512.03	.424	497.58	.469	495.17	.514	516.85
.380	512.03	.425	498.18	.470	495.17	.515	516.85
.381	511.43	.426	498.78	.471	493.96	.516	518.65
.382	511.43	.427	497.58	.472	493.96	.517	520.46
.383	511.43	.428	496.37	.473	493.96	.518	521.06
.384	510.83	.429	496.37	.474	493.96	.519	526.47
.385	508.42	.430	497.58	.475	493.96	.520	526.47
.386	510.83	.431	496.97	.476	493.36	.521	531.87
.387	510.83	.432	496.37	.477	495.17	.522	536.08
.388	510.23	.433	496.37	.478	492.15	.523	539.67
.389	509.02	.434	496.37	.479	494.56	.524	543.87
.390	508.42	.435	496.97	.480	493.36	.525	548.06
.391	508.42	.436	495.77	.481	493.96	.526	551.65
.392	507.82	.437	496.37	.482	495.17	.527	554.05
.393	506.61	.438	496.37	.483	495.17	.528	557.03
.394	506.61	.439	498.18	.484	495.17	.529	560.02
.395	506.61	.440	496.37	.485	495.17	.530	562.41
.396	507.22	.441	495.77	.486	496.37	.531	562.41
.397	506.61	.442	495.77	.487	496.97	.532	568.37
.398	504.20	.443	496.37	.488	496.97	.533	568.97
.399	507.22	.444	496.37	.489	498.18	.534	570.75
.400	506.61	.445	496.37	.490	499.99	.535	573.13
.401	506.61	.446	496.37	.491	498.78	.536	575.51
.402	505.41	.447	496.97	.492	501.80	.537	576.70
.403	505.41	.448	496.37	.493	500.59	.538	579.08
.404	505.41	.449	495.77	.494	501.19	.539	582.05

TIME	TEMP
.540	583.23
.541	584.42
.542	586.20
.543	588.57
.544	587.97
.545	589.75
.546	592.12
.547	594.48
.548	595.07
.549	595.66
.550	596.25
.551	598.02
.552	599.79
.553	600.97
.554	602.15
.555	603.32
.556	604.50
.557	603.32
.558	602.74
.559	606.27
.560	609.20
.561	610.96
.562	613.89
.563	616.82
.564	620.33
.565	624.41
.566	627.32
.567	630.81
.568	636.03
.569	641.23
.570	645.26
.571	646.41
.572	655.01
.573	660.72
.574	667.53
.575	673.18
.576	679.36
.577	685.51
.578	691.62
.579	696.60
.580	700.45
.581	705.37
.582	708.10

TEMPERATURE DATA

$P_r = 0.604$

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.000	382.51	.045	424.61	.090	452.95	.135	471.04
.001	383.11	.046	424.61	.091	454.15	.136	471.04
.002	384.91	.047	425.22	.092	455.96	.137	471.65
.003	386.71	.048	427.02	.093	458.38	.138	472.25
.004	388.51	.049	427.63	.094	460.19	.139	470.44
.005	389.11	.050	428.23	.095	460.19	.140	470.44
.006	390.92	.051	428.23	.096	460.79	.141	470.44
.007	392.72	.052	430.04	.097	462.00	.142	471.04
.008	393.92	.053	430.64	.098	462.00	.143	471.04
.009	395.12	.054	430.64	.099	462.60	.144	470.44
.010	396.32	.055	431.24	.100	462.60	.145	469.84
.011	398.13	.056	431.84	.101	463.20	.146	470.44
.012	399.33	.057	432.45	.102	463.20	.147	469.84
.013	399.93	.058	432.45	.103	463.20	.148	469.23
.014	400.53	.059	433.05	.104	463.20	.149	468.63
.015	402.34	.060	434.25	.105	465.01	.150	469.23
.016	403.54	.061	435.46	.106	465.01	.151	468.63
.017	404.14	.062	434.86	.107	465.01	.152	468.03
.018	404.74	.063	436.06	.108	465.01	.153	467.42
.019	406.55	.064	437.27	.109	465.61	.154	468.03
.020	407.15	.065	438.47	.110	466.82	.155	467.42
.021	407.75	.066	438.47	.111	466.82	.156	467.42
.022	408.35	.067	439.08	.112	467.42	.157	467.42
.023	410.16	.068	440.28	.113	468.03	.158	468.63
.024	411.36	.069	440.28	.114	468.63	.159	468.03
.025	411.36	.070	440.89	.115	468.63	.160	468.03
.026	413.17	.071	440.89	.116	469.84	.161	468.63
.027	414.37	.072	442.09	.117	470.44	.162	469.23
.028	414.37	.073	442.69	.118	471.04	.163	470.44
.029	413.77	.074	442.69	.119	471.65	.164	469.84
.030	413.77	.075	443.30	.120	471.65	.165	471.04
.031	416.78	.076	443.90	.121	472.25	.166	471.65
.032	415.58	.077	444.50	.122	471.65	.167	472.25
.033	417.99	.078	443.90	.123	471.65	.168	472.85
.034	419.19	.079	444.50	.124	471.04	.169	473.46
.035	419.79	.080	445.71	.125	471.04	.170	474.66
.036	420.40	.081	444.50	.126	471.65	.171	475.27
.037	419.19	.082	443.90	.127	470.44	.172	475.27
.038	419.79	.083	442.69	.128	471.04	.173	475.87
.039	419.79	.084	447.52	.129	471.65	.174	476.47
.040	421.00	.085	446.92	.130	471.04	.175	477.08
.041	421.60	.086	448.73	.131	469.84	.176	477.08
.042	422.20	.087	450.53	.132	469.23	.177	477.68
.043	422.81	.088	449.33	.133	471.04	.178	477.68
.044	423.41	.089	451.74	.134	469.23	.179	478.28

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.180	477.68	.225	480.09	.270	492.15	.315	540.27
.181	478.28	.226	480.70	.271	492.15	.316	552.25
.182	479.49	.227	480.09	.272	492.76	.317	565.99
.183	477.68	.228	481.30	.273	492.76	.318	583.83
.184	476.47	.229	480.70	.274	492.76	.319	602.15
.185	474.66	.230	481.30	.275	492.15	.320	619.74
.186	478.89	.231	482.50	.276	492.76	.321	637.76
.187	477.08	.232	482.50	.277	492.76	.322	653.87
.188	477.68	.233	481.30	.278	492.15	.323	669.23
.189	477.68	.234	481.30	.279	492.15	.324	683.84
.190	475.27	.235	483.11	.280	492.15	.325	698.25
.191	475.87	.236	481.90	.281	493.36		
.192	475.27	.237	483.71	.282	492.15		
.193	475.27	.238	484.31	.283	492.76		
.194	475.27	.239	485.52	.284	493.96		
.195	475.87	.240	486.12	.285	492.76		
.196	475.87	.241	484.92	.286	491.55		
.197	475.87	.242	484.92	.287	490.34		
.198	475.87	.243	484.92	.288	493.96		
.199	477.08	.244	486.73	.289	492.15		
.200	477.08	.245	486.73	.290	493.96		
.201	476.47	.246	486.73	.291	495.17		
.202	477.08	.247	486.73	.292	492.76		
.203	477.68	.248	487.93	.293	493.96		
.204	477.68	.249	488.53	.294	493.36		
.205	477.68	.250	487.93	.295	494.56		
.206	477.68	.251	489.14	.296	495.17		
.207	478.28	.252	489.74	.297	496.37		
.208	478.28	.253	490.34	.298	496.97		
.209	477.68	.254	489.74	.299	498.18		
.210	478.89	.255	490.34	.300	499.38		
.211	478.89	.256	490.95	.301	501.80		
.212	478.28	.257	490.95	.302	503.60		
.213	478.28	.258	490.95	.303	505.41		
.214	478.28	.259	490.95	.304	507.22		
.215	478.89	.260	492.15	.305	509.02		
.216	478.89	.261	491.55	.306	510.83		
.217	478.89	.262	491.55	.307	512.03		
.218	478.89	.263	492.15	.308	513.24		
.219	479.49	.264	492.15	.309	516.85		
.220	479.49	.265	492.15	.310	519.25		
.221	479.49	.266	492.15	.311	521.06		
.222	479.49	.267	492.15	.312	524.06		
.223	480.09	.268	492.76	.313	528.87		
.224	480.09	.269	492.76	.314	533.67		

TEMPERATURE DATA

$P_r = 0.745$

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.000	400.53	.045	459.58	.090	490.95	.135	524.66
.001	401.14	.046	460.19	.091	490.95	.136	524.66
.002	401.14	.047	461.39	.092	490.34	.137	524.06
.003	400.53	.048	462.00	.093	489.14	.138	523.46
.004	401.74	.049	462.60	.094	488.53	.139	522.86
.005	401.74	.050	464.41	.095	488.53	.140	521.06
.006	401.14	.051	465.61	.096	487.33	.141	518.05
.007	400.53	.052	467.42	.097	485.52	.142	520.46
.008	401.14	.053	467.42	.098	484.92	.143	519.25
.009	401.74	.054	467.42	.099	484.31	.144	518.05
.010	401.14	.055	468.63	.100	483.11	.145	517.45
.011	404.74	.056	470.44	.101	481.30	.146	516.85
.012	412.57	.057	471.65	.102	479.49	.147	517.45
.013	411.97	.058	471.65	.103	481.30	.148	518.05
.014	411.97	.059	472.85	.104	480.09	.149	517.45
.015	415.58	.060	474.66	.105	479.49	.150	517.45
.016	419.19	.061	475.87	.106	478.89	.151	518.05
.017	422.20	.062	476.47	.107	479.49	.152	520.46
.018	424.01	.063	477.08	.108	480.09	.153	518.65
.019	424.61	.064	478.28	.109	480.70	.154	516.25
.020	426.42	.065	480.09	.110	480.70	.155	520.46
.021	427.63	.066	479.49	.111	481.90	.156	519.85
.022	428.83	.067	479.49	.112	483.11	.157	519.25
.023	430.04	.068	480.09	.113	484.31	.158	518.65
.024	431.24	.069	481.90	.114	484.92	.159	518.05
.025	433.65	.070	482.50	.115	483.71	.160	518.65
.026	434.86	.071	482.50	.116	487.33	.161	518.65
.027	436.06	.072	483.11	.117	486.73	.162	517.45
.028	436.67	.073	484.31	.118	488.53	.163	517.45
.029	437.27	.074	484.92	.119	490.34	.164	518.05
.030	439.08	.075	484.92	.120	492.76	.165	517.45
.031	440.28	.076	486.12	.121	495.77	.166	516.85
.032	441.49	.077	487.33	.122	498.78	.167	514.44
.033	442.69	.078	487.93	.123	501.80	.168	517.45
.034	445.11	.079	486.73	.124	504.20	.169	517.45
.035	446.31	.080	486.12	.125	507.82	.170	517.45
.036	448.12	.081	486.12	.126	511.43	.171	516.85
.037	451.14	.082	486.73	.127	513.84	.172	516.85
.038	453.55	.083	487.33	.128	515.04	.173	518.05
.039	457.17	.084	486.12	.129	521.06	.174	518.05
.040	457.77	.085	486.73	.130	521.06	.175	518.65
.041	458.38	.086	487.33	.131	521.66	.176	518.65
.042	458.98	.087	488.53	.132	522.26	.177	519.25
.043	460.19	.088	488.53	.133	522.86	.178	519.85
.044	460.79	.089	488.53	.134	524.06	.179	519.25

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.180	517.45	.225	536.68	.270	537.28	.315	666.40
.181	519.85	.226	536.68	.271	540.27	.316	686.07
.182	520.46	.227	536.08	.272	536.68	.317	702.09
.183	521.06	.228	534.88	.273	537.28		
.184	521.06	.229	535.48	.274	536.68		
.185	521.66	.230	536.08	.275	536.08		
.186	522.86	.231	533.67	.276	535.48		
.187	523.46	.232	535.48	.277	536.08		
.188	523.46	.233	534.88	.278	535.48		
.189	524.06	.234	535.48	.279	534.28		
.190	525.27	.235	534.88	.280	534.28		
.191	525.87	.236	535.48	.281	533.67		
.192	525.87	.237	535.48	.282	534.28		
.193	525.27	.238	536.08	.283	531.87		
.194	527.67	.239	536.68	.284	535.48		
.195	529.47	.240	536.08	.285	532.47		
.196	530.67	.241	537.28	.286	532.47		
.197	531.87	.242	537.28	.287	532.47		
.198	532.47	.243	539.08	.288	531.87		
.199	534.28	.244	536.68	.289	531.87		
.200	536.08	.245	539.67	.290	533.07		
.201	536.68	.246	538.48	.291	533.07		
.202	536.68	.247	539.08	.292	533.67		
.203	537.88	.248	539.08	.293	534.28		
.204	539.67	.249	538.48	.294	535.48		
.205	538.48	.250	538.48	.295	536.68		
.206	538.48	.251	538.48	.296	536.08		
.207	539.67	.252	538.48	.297	539.67		
.208	541.47	.253	537.28	.298	538.48		
.209	542.07	.254	537.28	.299	539.67		
.210	542.07	.255	537.28	.300	539.08		
.211	542.67	.256	537.28	.301	539.08		
.212	543.87	.257	535.48	.302	539.08		
.213	543.27	.258	537.88	.303	539.08		
.214	542.67	.259	536.08	.304	539.08		
.215	542.07	.260	536.08	.305	539.67		
.216	542.07	.261	536.68	.306	540.87		
.217	541.47	.262	536.68	.307	543.27		
.218	539.08	.263	537.28	.308	547.46		
.219	537.88	.264	538.48	.309	551.06		
.220	538.48	.265	539.08	.310	560.02		
.221	538.48	.266	539.67	.311	567.78		
.222	537.88	.267	540.27	.312	586.79		
.223	537.28	.268	540.87	.313	613.89		
.224	536.68	.269	540.87	.314	641.23		

TEMPERATURE DATA

$P_r = 0.887$

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.000	422.81	.045	488.53	.090	518.65	.135	536.68
.001	425.22	.046	487.33	.091	518.05	.136	536.08
.002	425.22	.047	486.12	.092	518.65	.137	537.88
.003	425.82	.048	482.50	.093	519.85	.138	538.48
.004	427.02	.049	481.90	.094	520.46	.139	540.27
.005	428.83	.050	480.09	.095	521.06	.140	541.47
.006	435.46	.051	479.49	.096	519.25	.141	542.07
.007	439.68	.052	480.09	.097	521.66	.142	542.67
.008	438.47	.053	480.70	.098	523.46	.143	544.47
.009	438.47	.054	481.30	.099	523.46	.144	543.27
.010	440.28	.055	483.11	.100	525.27	.145	545.07
.011	444.50	.056	485.52	.101	525.27	.146	545.67
.012	447.52	.057	486.73	.102	527.07	.147	545.67
.013	448.73	.058	488.53	.103	528.27	.148	546.87
.014	449.93	.059	490.95	.104	527.67	.149	547.46
.015	451.74	.060	492.76	.105	529.47	.150	548.06
.016	451.14	.061	495.77	.106	529.47	.151	549.26
.017	454.15	.062	497.58	.107	530.67	.152	551.06
.018	455.96	.063	499.99	.108	531.87	.153	552.25
.019	458.38	.064	498.78	.109	531.87	.154	555.24
.020	460.19	.065	503.00	.110	531.87	.155	560.62
.021	462.00	.066	505.41	.111	533.07	.156	569.56
.022	463.81	.067	506.61	.112	531.87	.157	583.83
.023	467.42	.068	507.22	.113	533.07	.158	603.91
.024	471.04	.069	509.02	.114	533.67	.159	629.07
.025	473.46	.070	510.83	.115	533.67	.160	646.41
.026	476.47	.071	512.63	.116	534.88	.161	665.83
.027	478.89	.072	512.63	.117	534.88	.162	681.04
.028	481.90	.073	513.24	.118	534.88	.163	694.94
.029	484.31	.074	513.84	.119	534.88		
.030	486.73	.075	514.44	.120	536.08		
.031	487.93	.076	515.04	.121	535.48		
.032	486.73	.077	515.04	.122	534.88		
.033	489.74	.078	515.64	.123	534.28		
.034	491.55	.079	516.85	.124	534.28		
.035	492.15	.080	515.64	.125	534.28		
.036	492.15	.081	517.45	.126	533.07		
.037	492.76	.082	517.45	.127	532.47		
.038	493.36	.083	517.45	.128	530.67		
.039	493.96	.084	518.05	.129	532.47		
.040	492.76	.085	518.05	.130	532.47		
.041	492.15	.086	518.05	.131	533.07		
.042	492.15	.087	518.65	.132	533.07		
.043	492.15	.088	519.25	.133	533.67		
.044	490.34	.089	518.65	.134	535.48		

TEMPERATURE DATA

$P_r = 1.029$

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.000	424.61	.045	491.55	.090	518.05	.135	687.74
.001	425.82	.046	490.95	.091	518.05		
.002	425.22	.047	491.55	.092	518.05		
.003	424.61	.048	489.74	.093	518.05		
.004	427.02	.049	489.14	.094	518.65		
.005	430.64	.050	485.52	.095	518.05		
.006	436.67	.051	487.33	.096	516.25		
.007	439.08	.052	487.33	.097	518.65		
.008	443.30	.053	487.33	.098	519.25		
.009	448.12	.054	486.73	.099	519.25		
.010	452.34	.055	486.73	.100	519.25		
.011	455.36	.056	487.93	.101	519.25		
.012	457.17	.057	489.14	.102	519.25		
.013	459.58	.058	490.95	.103	520.46		
.014	461.39	.059	490.95	.104	521.06		
.015	464.41	.060	491.55	.105	521.06		
.016	466.82	.061	493.96	.106	521.66		
.017	468.63	.062	494.56	.107	523.46		
.018	470.44	.063	495.77	.108	524.06		
.019	472.85	.064	496.97	.109	524.66		
.020	474.66	.065	498.78	.110	526.47		
.021	475.87	.066	500.59	.111	528.87		
.022	475.87	.067	500.59	.112	530.67		
.023	477.68	.068	501.80	.113	530.07		
.024	480.09	.069	503.00	.114	530.67		
.025	481.90	.070	505.41	.115	531.87		
.026	483.71	.071	506.61	.116	533.07		
.027	486.12	.072	507.22	.117	533.67		
.028	488.53	.073	505.41	.118	533.67		
.029	491.55	.074	507.22	.119	532.47		
.030	493.36	.075	509.02	.120	534.28		
.031	493.36	.076	509.02	.121	536.08		
.032	493.36	.077	509.62	.122	537.28		
.033	493.96	.078	510.23	.123	537.28		
.034	493.96	.079	510.83	.124	538.48		
.035	494.56	.080	512.63	.125	539.67		
.036	493.36	.081	513.84	.126	540.87		
.037	492.76	.082	512.63	.127	543.27		
.038	493.36	.083	512.63	.128	550.46		
.039	493.36	.084	513.84	.129	564.80		
.040	492.76	.085	514.44	.130	585.01		
.041	492.76	.086	514.44	.131	606.27		
.042	492.76	.087	515.04	.132	627.32		
.043	492.76	.088	516.85	.133	647.56		
.044	492.15	.089	518.65	.134	668.66		

TEMPERATURE DATA

$P_r = 1.171$

TIME	TEMP	TIME	TEMP	TIME	TEMP
.000	419.19	.045	481.30	.090	524.06
.001	421.00	.046	482.50	.091	524.66
.002	421.00	.047	482.50	.092	526.47
.003	421.60	.048	481.90	.093	527.07
.004	427.02	.049	482.50	.094	527.67
.005	431.84	.050	483.71	.095	528.27
.006	439.08	.051	484.92	.096	529.47
.007	442.69	.052	486.12	.097	530.67
.008	445.11	.053	486.12	.098	531.27
.009	442.69	.054	486.73	.099	534.88
.010	441.49	.055	489.14	.100	543.87
.011	443.30	.056	490.34	.101	560.02
.012	445.71	.057	492.15	.102	577.30
.013	449.93	.058	493.36	.103	593.89
.014	454.15	.059	495.77	.104	612.14
.015	457.77	.060	496.97	.105	625.58
.016	458.98	.061	498.18	.106	638.92
.017	460.19	.062	499.38	.107	651.58
.018	462.00	.063	500.59	.108	664.70
.019	463.20	.064	502.40	.109	678.80
.020	465.01	.065	503.60	.110	691.62
.021	466.82	.066	504.20		
.022	469.23	.067	506.61		
.023	469.23	.068	505.41		
.024	466.82	.069	507.22		
.025	463.20	.070	507.82		
.026	463.20	.071	508.42		
.027	465.01	.072	509.02		
.028	466.22	.073	510.23		
.029	466.22	.074	509.02		
.030	469.84	.075	510.83		
.031	468.03	.076	510.23		
.032	469.23	.077	510.23		
.033	470.44	.078	511.43		
.034	471.65	.079	512.03		
.035	472.25	.080	512.63		
.036	474.66	.081	512.63		
.037	474.66	.082	515.64		
.038	477.08	.083	517.45		
.039	478.89	.084	519.85		
.040	479.49	.085	521.06		
.041	481.30	.086	522.26		
.042	481.30	.087	523.46		
.043	480.70	.088	524.06		
.044	480.70	.089	524.06		

TEMPERATURE DATA

$P_r = 1.312$

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.000	418.59	.045	492.15	.090	530.67	.135	547.46
.001	421.00	.046	492.76	.091	532.47	.136	547.46
.002	426.42	.047	494.56	.092	533.67	.137	549.26
.003	430.64	.048	497.58	.093	533.07	.138	549.26
.004	434.86	.049	499.38	.094	533.07	.139	548.06
.005	438.47	.050	502.40	.095	533.07	.140	549.86
.006	443.30	.051	503.60	.096	530.67	.141	552.85
.007	446.92	.052	504.81	.097	530.07	.142	558.23
.008	451.14	.053	506.61	.098	528.27	.143	565.99
.009	455.36	.054	508.42	.099	527.67	.144	572.54
.010	459.58	.055	509.02	.100	528.27	.145	584.42
.011	465.01	.056	509.62	.101	528.27	.146	600.38
.012	469.84	.057	510.83	.102	528.27	.147	620.33
.013	474.06	.058	513.24	.103	527.67	.148	642.38
.014	478.89	.059	515.04	.104	531.27	.149	664.13
.015	479.49	.060	516.85	.105	533.07	.150	686.07
.016	481.90	.061	519.25	.106	533.67	.151	707.01
.017	484.31	.062	522.86	.107	533.07	.152	725.32
.018	484.92	.063	522.86	.108	531.87		
.019	486.73	.064	522.86	.109	532.47		
.020	489.14	.065	522.26	.110	531.87		
.021	490.95	.066	521.66	.111	535.48		
.022	489.74	.067	521.66	.112	537.88		
.023	490.34	.068	521.06	.113	539.67		
.024	490.34	.069	520.46	.114	541.47		
.025	490.95	.070	518.05	.115	543.27		
.026	490.95	.071	516.85	.116	543.87		
.027	490.34	.072	515.64	.117	543.87		
.028	492.76	.073	515.04	.118	545.07		
.029	491.55	.074	514.44	.119	546.27		
.030	492.76	.075	513.84	.120	546.87		
.031	491.55	.076	515.04	.121	546.87		
.032	490.95	.077	516.25	.122	546.87		
.033	489.74	.078	516.85	.123	548.66		
.034	489.74	.079	518.05	.124	549.26		
.035	488.53	.080	519.85	.125	548.66		
.036	487.33	.081	521.66	.126	548.66		
.037	486.73	.082	523.46	.127	548.66		
.038	485.52	.083	524.66	.128	548.66		
.039	486.73	.084	525.27	.129	548.06		
.040	486.12	.085	526.47	.130	547.46		
.041	486.12	.086	527.67	.131	549.26		
.042	487.33	.087	528.87	.132	546.87		
.043	488.53	.088	529.47	.133	547.46		
.044	490.34	.089	528.87	.134	547.46		

TEMPERATURE DATA

$P_r = 1.454$

TIME	TEMP	TIME	TEMP	TIME	TEMP
.000	414.98	.045	474.66	.090	567.78
.001	415.58	.046	478.28	.091	570.75
.002	416.18	.047	481.30	.092	573.13
.003	417.38	.048	483.71	.093	576.11
.004	417.99	.049	486.12	.094	579.67
.005	420.40	.050	488.53	.095	582.64
.006	421.00	.051	489.74	.096	586.79
.007	422.81	.052	493.36	.097	592.12
.008	424.01	.053	495.77	.098	596.25
.009	425.22	.054	498.78	.099	603.91
.010	425.22	.055	501.80	.100	609.79
.011	426.42	.056	503.00	.101	617.99
.012	426.42	.057	504.81	.102	627.32
.013	424.61	.058	507.22	.103	637.18
.014	425.82	.059	509.02	.104	646.99
.015	425.22	.060	511.43	.105	657.30
.016	424.61	.061	513.84	.106	668.10
.017	424.61	.062	514.44	.107	680.48
.018	426.42	.063	515.64	.108	690.51
.019	427.63	.064	516.85		
.020	428.83	.065	519.25		
.021	430.04	.066	519.85		
.022	433.65	.067	521.06		
.023	431.24	.068	522.26		
.024	433.65	.069	525.87		
.025	434.86	.070	524.06		
.026	436.06	.071	527.07		
.027	436.67	.072	528.87		
.028	437.87	.073	530.67		
.029	439.68	.074	531.87		
.030	440.89	.075	533.67		
.031	442.09	.076	536.08		
.032	445.71	.077	537.88		
.033	446.92	.078	539.67		
.034	448.73	.079	543.87		
.035	450.53	.080	545.67		
.036	453.55	.081	546.87		
.037	455.96	.082	549.26		
.038	458.38	.083	552.25		
.039	460.79	.084	554.64		
.040	463.81	.085	557.03		
.041	467.42	.086	558.83		
.042	467.42	.087	561.81		
.043	470.44	.088	564.80		
.044	473.46	.089	564.20		

TEMPERATURE DATA

$P_r = 1.596$

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.000	324.40	.045	433.65	.090	528.27	.135	660.15
.001	324.42	.046	437.27	.091	529.47	.136	664.70
.002	324.42	.047	440.28	.092	531.27	.137	668.10
.003	325.01	.048	443.30	.093	534.28	.138	672.05
.004	325.61	.049	446.92	.094	534.88	.139	675.43
.005	327.40	.050	451.14	.095	537.28	.140	678.24
.006	328.00	.051	455.36	.096	540.87	.141	681.60
.007	330.99	.052	458.38	.097	543.27	.142	685.51
.008	334.57	.053	463.20	.098	545.07	.143	688.85
.009	336.97	.054	468.03	.099	547.46	.144	692.18
.010	342.95	.055	471.65	.100	551.65	.145	694.94
.011	345.94	.056	475.87	.101	555.24	.146	699.35
.012	348.93	.057	480.09	.102	558.23	.147	703.19
.013	353.12	.058	484.92	.103	561.81	.148	706.46
.014	356.72	.059	487.33	.104	564.80		
.015	359.71	.060	494.56	.105	567.78		
.016	363.31	.061	499.38	.106	570.16		
.017	366.90	.062	499.38	.107	573.13		
.018	371.10	.063	503.60	.108	577.30		
.019	373.50	.064	506.61	.109	577.89		
.020	376.50	.065	507.82	.110	580.27		
.021	379.50	.066	509.62	.111	585.01		
.022	383.71	.067	512.63	.112	586.79		
.023	386.11	.068	514.44	.113	590.34		
.024	387.31	.069	515.64	.114	593.30		
.025	389.11	.070	516.85	.115	595.66		
.026	390.92	.071	518.05	.116	598.61		
.027	392.12	.072	518.65	.117	601.56		
.028	392.12	.073	518.05	.118	604.50		
.029	393.92	.074	518.65	.119	607.44		
.030	396.32	.075	519.85	.120	610.38		
.031	397.53	.076	519.85	.121	614.48		
.032	399.33	.077	519.25	.122	617.41		
.033	402.34	.078	519.25	.123	620.33		
.034	402.34	.079	520.46	.124	623.24		
.035	407.15	.080	520.46	.125	626.74		
.036	408.96	.081	520.46	.126	630.23		
.037	410.76	.082	521.06	.127	633.71		
.038	413.77	.083	522.86	.128	636.60		
.039	415.58	.084	521.06	.129	640.65		
.040	417.99	.085	523.46	.130	643.53		
.041	421.60	.086	525.87	.131	646.41		
.042	425.22	.087	523.46	.132	649.86		
.043	427.63	.088	525.87	.133	654.44		
.044	430.04	.089	527.07	.134	656.73		

TEMPERATURE DATA

$P_r = 1.738$

TIME	TEMP	TIME	TEMP	TIME	TEMP	TIME	TEMP
.000	323.22	.045	405.95	.090	531.87	.135	638.92
.001	323.22	.046	409.56	.091	533.67	.136	640.07
.002	324.42	.047	413.77	.092	535.48	.137	646.41
.003	325.01	.048	417.99	.093	536.68	.138	649.28
.004	325.61	.049	421.60	.094	537.88	.139	651.58
.005	326.21	.050	425.82	.095	539.08	.140	654.44
.006	327.40	.051	430.64	.096	540.87	.141	656.73
.007	328.00	.052	434.86	.097	540.87	.142	660.15
.008	329.20	.053	439.68	.098	543.87	.143	663.56
.009	330.99	.054	445.11	.099	545.07	.144	666.40
.010	333.38	.055	449.93	.100	547.46	.145	669.79
.011	335.77	.056	454.76	.101	551.06	.146	673.74
.012	338.16	.057	457.17	.102	552.25	.147	676.56
.013	341.15	.058	460.19	.103	553.45	.148	679.36
.014	344.14	.059	465.61	.104	555.84	.149	682.72
.015	348.33	.060	466.82	.105	558.83	.150	685.51
.016	350.73	.061	472.85	.106	561.81	.151	688.85
.017	353.72	.062	477.68	.107	564.20	.152	691.62
.018	357.31	.063	477.68	.108	566.58	.153	694.94
.019	359.71	.064	481.30	.109	571.35	.154	699.90
.020	360.31	.065	483.71	.110	573.13	.155	703.19
.021	359.71	.066	485.52	.111	575.51	.156	705.92
.022	364.51	.067	488.53	.112	577.89	.157	709.18
.023	365.10	.068	492.15	.113	581.45		
.024	367.50	.069	494.56	.114	583.83		
.025	369.30	.070	495.77	.115	585.60		
.026	368.10	.071	498.18	.116	587.97		
.027	369.90	.072	500.59	.117	591.52		
.028	370.50	.073	502.40	.118	593.89		
.029	372.90	.074	504.20	.119	595.07		
.030	375.90	.075	506.01	.120	597.43		
.031	379.50	.076	509.02	.121	599.79		
.032	381.90	.077	510.83	.122	601.56		
.033	384.31	.078	511.43	.123	603.32		
.034	387.31	.079	513.24	.124	606.85		
.035	389.71	.080	515.64	.125	610.38		
.036	392.12	.081	516.85	.126	613.31		
.037	393.92	.082	518.05	.127	616.24		
.038	395.72	.083	520.46	.128	619.74		
.039	398.13	.084	522.26	.129	622.66		
.040	399.33	.085	523.46	.130	626.16		
.041	400.53	.086	525.27	.131	628.48		
.042	401.74	.087	527.07	.132	632.55		
.043	403.54	.088	529.47	.133	636.03		
.044	404.74	.089	530.67	.134	637.18		

TEMPERATURE DATA

$P_r = 2.021$

TIME	TEMP	TIME	TEMP	TIME	TEMP
.000	332.18	.045	450.53	.090	560.62
.001	332.18	.046	454.76	.091	568.97
.002	333.38	.047	457.77	.092	573.13
.003	332.78	.048	461.39	.093	576.11
.004	334.57	.049	465.01	.094	579.67
.005	336.37	.050	469.84	.095	583.83
.006	338.76	.051	471.65	.096	589.75
.007	341.15	.052	473.46	.097	593.89
.008	344.14	.053	475.27	.098	598.61
.009	347.14	.054	477.68	.099	602.74
.010	349.53	.055	479.49	.100	608.03
.011	351.92	.056	480.70	.101	612.14
.012	354.92	.057	481.90	.102	616.24
.013	356.72	.058	483.71	.103	620.33
.014	357.91	.059	484.92	.104	624.41
.015	358.51	.060	485.52	.105	627.32
.016	360.91	.061	486.73	.106	630.81
.017	362.11	.062	489.74	.107	634.29
.018	363.31	.063	492.76	.108	637.76
.019	365.70	.064	493.96	.109	641.23
.020	368.10	.065	496.97	.110	644.11
.021	369.90	.066	500.59	.111	647.56
.022	369.90	.067	500.59	.112	650.43
.023	371.10	.068	503.60	.113	652.72
.024	374.10	.069	509.02	.114	658.44
.025	375.90	.070	509.02	.115	661.29
.026	377.70	.071	511.43	.116	664.13
.027	380.70	.072	513.84	.117	668.66
.028	384.91	.073	516.25	.118	673.18
.029	389.71	.074	518.05	.119	676.56
.030	392.72	.075	520.46	.120	680.48
.031	395.12	.076	522.86	.121	685.51
.032	398.73	.077	524.66	.122	691.07
.033	404.14	.078	527.67	.123	695.49
.034	408.35	.079	530.67	.124	699.90
.035	411.97	.080	533.07	.125	705.92
.036	415.58	.081	536.08	.126	711.90
.037	419.79	.082	537.88		
.038	422.81	.083	542.07		
.039	425.82	.084	545.67		
.040	429.43	.085	548.06		
.041	433.05	.086	551.06		
.042	437.87	.087	554.05		
.043	440.89	.088	558.23		
.044	444.50	.089	558.83		

TEMPERATURE DATA

$P_r = 2.305$

TIME	TEMP	TIME	TEMP	TIME	TEMP
.000	339.96	.045	487.93	.090	638.34
.001	342.95	.046	490.34	.091	643.53
.002	345.94	.047	493.36	.092	649.28
.003	348.93	.048	495.77	.093	655.58
.004	352.52	.049	498.18	.094	660.72
.005	356.72	.050	499.99	.095	665.83
.006	360.31	.051	503.00	.096	670.92
.007	363.31	.052	505.41	.097	676.56
.008	367.50	.053	506.61	.098	682.16
.009	372.30	.054	508.42	.099	687.18
.010	377.70	.055	510.23	.100	692.18
.011	381.90	.056	512.63	.101	698.80
.012	386.11	.057	513.84		
.013	391.52	.058	515.64		
.014	395.72	.059	518.65		
.015	399.33	.060	519.25		
.016	403.54	.061	524.66		
.017	408.35	.062	527.07		
.018	408.96	.063	530.07		
.019	413.77	.064	534.28		
.020	419.19	.065	537.88		
.021	418.59	.066	541.47		
.022	422.81	.067	545.67		
.023	425.82	.068	549.86		
.024	427.63	.069	552.85		
.025	430.64	.070	555.84		
.026	434.25	.071	559.42		
.027	437.27	.072	563.01		
.028	439.08	.073	566.58		
.029	442.69	.074	569.56		
.030	446.31	.075	573.13		
.031	449.33	.076	576.11		
.032	451.74	.077	580.27		
.033	455.96	.078	583.83		
.034	459.58	.079	586.79		
.035	462.60	.080	592.12		
.036	465.01	.081	594.48		
.037	468.03	.082	600.97		
.038	472.25	.083	603.91		
.039	472.25	.084	608.62		
.040	477.08	.085	614.48		
.041	480.09	.086	618.57		
.042	480.09	.087	622.66		
.043	483.11	.088	627.90		
.044	485.52	.089	633.71		

DROPLET DIAMETER DATA

Pr=0.178		Pr=0.320		Pr=0.462		Pr=0.604	
TIME	RATIO	TIME	RATIO	TIME	RATIO	TIME	RATIO
0.03	1.000	0.03	1.000	0.03	1.000	0.03	1.000
0.06	1.016	0.06	1.077	0.06	1.004	0.06	1.030
0.10	1.013	0.10	1.038	0.10	0.998	0.10	0.959
0.13	0.971	0.13	0.998	0.13	0.990	0.13	0.839
0.17	0.949	0.17	0.969	0.17	0.971	0.17	0.836
0.20	0.919	0.20	0.950	0.20	0.945	0.20	0.758
0.23	0.900	0.23	0.936	0.23	0.911	0.23	0.699
0.27	0.860	0.27	0.909	0.27	0.863	0.27	0.641
0.30	0.853	0.30	0.889	0.30	0.827	0.30	0.559
0.33	0.842	0.33	0.867	0.33	0.802	0.33	0.466
0.37	0.810	0.37	0.823	0.37	0.765	0.37	0.442
0.40	0.776	0.40	0.801	0.40	0.678		
0.43	0.748	0.43	0.789	0.43	0.630		
0.47	0.725	0.47	0.736	0.47	0.575		
0.50	0.686	0.50	0.712	0.50	0.550		
0.53	0.672	0.53	0.684	0.53	0.519		
0.57	0.660	0.57	0.642	0.57	0.450		
0.60	0.651	0.60	0.594	0.60	0.369		
0.63	0.622	0.63	0.540	0.63	0.351		
0.67	0.597	0.67	0.492				
0.70	0.578	0.70	0.446				
0.73	0.551	0.73	0.436				
0.77	0.511	0.77	0.411				
0.80	0.494	0.80	0.394				
0.83	0.467	0.83	0.342				
0.87	0.435	0.87	0.302				
0.90	0.408						
0.93	0.379						
0.97	0.362						
1.00	0.350						
1.03	0.334						
1.06	0.300						
1.10	0.282						

VITA

Christian Michael Norton attended many different schools throughout the United States and Japan because his father was enlisted in the United States Air Force. He graduated with honors from high school in Gwinn, Michigan and started college at Northern Michigan University on a basketball scholarship. After completing the first year, he transferred to Middle Tennessee State University and received a B.S. degree in Aerospace Technology. In 1988 he applied to the University of Tennessee Space Institute to pursue a Master's degree in Aerospace Engineering. In 1989, he was awarded a NASA Graduate Student Researcher Fellowship for one year of graduate study and research at UTSI. This fellowship was awarded by Marshall Space Flight Center in Huntsville, Alabama. The M.S. degree was awarded in 1990.

The author was a member of the Middle Tennessee State University Baseball team which won 2 Ohio Valley Conference Championships and participated in 2 College World Series Regional playoffs. He set career pitching records in the conference and at Middle Tennessee State University. He earned the Athletic Director's Scholarship Achievement Award and made the Ohio Valley Conference Achedemic Team. He has served as Vice-President in charge of Finance for the Space Institute Student Government Association (SISGA). As of this writing, Mr. Norton has accepted a job with McDonnell Douglas Space Systems Company in Huntsville, Alabama. He resides at the University of Tennessee Space Institute's Student Center.