REBER, Dean Howell, 1939-
A MATHEMATICAL MODEL FOR PREDICTING DYNAMIC
BEHAVIOR OF A PLASTICATING EXTRUDER.

The Ohio State University, Ph.D., 1971
Engineering, chemical

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1971

A MATHEMATICAL MODEL FOR PREDICTING DYNAMIC
BEHAVIOR OF A PLASTICATING EXTRUDER

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Dean Howell Reber, B.S., M.S

* * * * *

The Ohio State University
1971

Approved by

A handwritten signature in dark ink, appearing to read "R. E. Lyon", is written over a horizontal line.

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ACKNOWLEDGMENTS

The author wishes to express appreciation to Professors R. Emerson Lynn, Jr. and Edward J. Freeh for their guidance on this project. Thanks must go to Mike Kukla for his invaluable assistance in setting up and repairing the equipment and instrumentation. Also, appreciation is extended to the Chemical Engineering Department and the Graduate School of the Ohio State University for the financial assistance provided to the author while preparing this dissertation. Money and equipment for this work were provided by NRM Corporation, the Dow Chemical Company, the B. F. Goodrich Company, Industrial Nucleonics Corporation, and Digital Equipment Corporation.

A very special thank you is in order for my wife, Glenda, for her understanding and encouragement during this project.

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LIST OF SYMBOLS

SYMBOL	COMPUTER NOTATION	UNITS	
A_b	ABAR	ft^2	area of barrel for heat transfer
A_{bo}	ABARO	"	outside area of barrel
A_{bm}	ABARM	"	area for heat transfer between Barrel Sections 1 and 2
A_{plu}	APLU	"	area of heat transfer for small plug increments
A_s	ASCRE	"	area of screw for heat transfer
b	DEPSHR	ft	depth of shear film
BWD	BWD	"	width of solid bed
CP_b	CPBAR	btu/lb F	heat capacity of barrel
CP_p	CPPLA	"	heat capacity of polymer
CF_s	CPSCRE	"	heat capacity of screw
CD	CHDEP	in,ft	channel depth
CW	CW	ft	channel width
FM	FM		fraction of total flow to backmix region
H_b	HEAR	btu/hr ft^2 F	heat transfer coefficient between barrel and polymer
H_{bo}	HEARO	"	heat transfer coefficient between TM and Barrel Section 1

SYMBOL	COMPUTER NOTATION	UNITS	
H_{bm}	HBARM	btu/hr ft ² F	heat transfer coefficient between Barrel Sections 1 and 2
H_p	HPLA	"	heat transfer coefficient between the polymer melt and solid plug
H_s	HSCREW	"	heat transfer coefficient between polymer melt and screw
K	K		repeat unit number
K_b	KBAR	btu/hr ft F	thermal conductivity of barrel
K_p	AKPAVG	"	thermal conductivity of polymer
L	ALEN	in,ft	length of repeat unit along the barrel
Q_p	QP	lb/hr	polymer flowrate
QSHEAR	QSHEAR	btu/hr	viscous dissipation
T_b	TBAR	F	inside barrel wall temperature
T_{bm}	TBARM	"	average temperature of first lumped section of barrel
T_m	TM	"	outside barrel wall temperature
T_{melt}	MELTEM	"	melting temperature of polymer
T_p	TPLA	"	temperature of polymer melt
T_{plu}	TPLUG	"	temperature of plug
T_s	TSCREW	"	temperature of screw
V_b	VBAR	ft/min	velocity of barrel

SYMBOL	COMPUTER NOTATION	UNITS	
V_{bx}	VBARX	ft/min	velocity of barrel in x direction
VISCO	VISCO		viscosity correction par- ameter
V_{scr}	VOLSCR	ft ³	volume of screw
V_{sld}	VELSLD	ft/min	velocity of solid bed
V_t	VTOT	in ³ , ft ³	total volume of repeat unit
LAG	LAG		number of plug increments
THALAG	THALAG	hr	lag time
$\Delta\theta$	DELTHA	hr	time increment
θ	THETA	"	time
μ	VISC	lb _f sec/in ²	viscosity
ρ_b	RHOBAR	lb/ft ³	density of barrel
ρ_p	RHOPLA	"	density of polymer
ϕ	PHI	radians	helix angle

INTRODUCTION

Plasticating extruders are used throughout the field of polymers processing with the majority of all polymer production passing through an extruder at least once between polymerization and finished product. In recent years production rates from extrusion lines have been increased significantly without lowering product quality. These increases have been achieved, primarily, with better screw design, improved resins, and increased extruder barrel length to diameter ratio.

One area that has not received a lot of attention is the process control of the extrusion variables. Many extruders are operated with on-off temperature control or no feedback control at all. In many cases this type of control may be sufficient, but, as production rates increase and quality requirements become more stringent, more sophisticated control is desirable. The process computer lends itself very well to providing this type of control, having the capability to monitor and control extrusion variables with almost any desired algorithm.

The purpose of this work was to develop a mathematical

model for simulation of the dynamics of an extruder to be used for on-line computer control, or testing different control schemes off-line. Considerable work is reported in the literature describing the plasticating extrusion operation mathematically, and mathematical models have been developed for use in screw design and extruder sizing. These models are steady state models ,however, and have little value for predicting extruder dynamics.

Experimental data for developing and testing the model was obtained with a $2\frac{1}{2}$ -inch diameter extruder producing polystyrene film. The extruder temperatures and pressures were monitored with a process computer.

Chapter I

BACKGROUND

Extrusion

Basically, a plasticating extruder performs three main functions; transporting, melting and mixing. The most common extruder is a single screw machine with a three-section standard screw. The screw is divided into three geometric sections; the solids conveying section, the melting or transition section and the metering section. The solids conveying section is characterized by relatively deep flights with no taper. This enhances the movement of the relatively low bulk density solid along the barrel. As melting starts, the material flows into the tapered portion of the screw which compresses it, compensating for the increasing density of the material. Finally, the molten polymer flows into the metering section which is characterized by shallow flights with no taper. Usually the metering section is the flow limiting section in a well designed screw. It mixes the melt and determines the output from the extruder.

The actual solids conveying, melting and metering regions of an extruder rarely correspond to the geometric

sections of the screw. As is indicated in Figure 1, melting often begins before the tapered section of the screw, and it may still be taking place in the metering section. The latter is especially true when the extruder is run near capacity.

The solids conveying section of the screw has been treated in some detail by Darnell and Mole (5). The flowrate in this region is largely determined by the geometry of the screw and the coefficients of dynamic friction between the solid and the barrel, and the solid and the screw. The highest flowrate is obtained if the friction between the barrel and the solid is high, and the friction between the solid and the screw is low. Low friction between the solid and screw is often obtained by forcing a cooling fluid through the core of the screw. Flowrate in the solids conveying region is also strongly influenced by the size and geometrical shape of the solid feed material and its bulk density. The heat entering the polymer in this region comes from the barrel wall, and very little mixing takes place. The solid polymer bed moves as a plug.

The heat for melting in an extruder comes from two sources. Heat is transferred from the barrel heaters through the barrel wall into the polymer and heat is generated by the mechanical working of the polymer. The percentage

FIGURE 1 SCHEMATIC OF PLASTICATING EXTRUDER

of the total heat generated by either one of these mechanisms depends on the physical properties of the material, the geometry and speed of the screw, and the operating temperature of the barrel. A visual study of the melting process was reported by Maddock(9). He fed a water-cooled, 2-inch extruder with polyethylene pellets, 5 per cent of which contained red pigment. The extruder was operated until steady state conditions were achieved, then the screw was stopped, and the barrel rapidly cooled. The barrel was then reheated just enough to pull the screw. The melt and partially fused solids were unwrapped from the screw and cross sections were cut and photographed at different locations along the barrel. By studying these cross sections, a fairly accurate picture of how melting takes place along the barrel can be obtained. Tadmor and Klein (14) show photographs of a number of cross sections for the extrusion of different polymers. The solid bed follows along behind the trailing edge of the leading screw flight, and a thin film of newly molten material forms between the solid bed and the barrel wall. The movement of the screw past the stationary barrel sweeps the molten material off the top of the solid into a melt pool which moves between the solid bed and the leading edge of the trailing screw flight. As the solid bed moves along the screw, the individual pellets within the bed tend to fuse

together and lose their individual identity. This is especially true of amorphous materials which do not have a sharp melting point. Most of the shear heat is generated in the thin film of melt between the solid bed and the barrel wall. Interestingly, this film thickness remains fairly constant along the screw and is a function of melting rate rather than a function of axial distance along the screw. For this to be true, the solid bed must continuously be reshaped as it moves axially along the extruder barrel, and, as the solid bed becomes narrower, the melt pool becomes wider(15). Near the end of the melting region, the solid bed starts to break up into smaller pieces, and the melting mechanism changes as the area for heat transfer to the solid increases, and the thin melt film ceases to exist.

As mentioned before, the metering section of the screw usually has the greatest effect on the extruder flow characteristics. In simplest terms, the melt flow in the metering section can be broken down into two main types, drag flow and pressure flow(12). Drag flow is caused by the flights of the screw dragging the melt forward. It is a function of screw geometry and screw speed. Pressure flow is caused by the pressure gradient along the barrel and usually causes back flow in the extruder since the pressure usually increases as one proceeds toward the discharge

end of the barrel. Pressure flow is mainly a function of melt viscosity, pressure gradient, and area available for flow. The area available for flow is made up of the area between the screw flights and the clearance area between the lands of the screw and the barrel. In reality, flow in the melting section of an extruder is much more complex than the simple drag and pressure flow described above. Drag and pressure flow can be separated only with a Newtonian fluid, and, since most polymer melts are highly non-Newtonian, there is considerable interaction between the two flows. Still, the concept of drag and pressure flow is useful for a qualitative description of the metering section(10).

Figure 2 shows screw characteristics (output versus head pressure) for different types of metering sections. A deep metering section gives a relatively high flowrate at zero discharge pressure because the deep channel gives high drag flow. As discharge pressure increases, however, the flow falls off rapidly because a large area is available for pressure flow. The longer the metering section of a deep channel screw, the less reduction of flow with increasing discharge pressure(1).

For a shallow metering section, the flow at zero discharge pressure is low because the drag flow is low. As the discharge pressure is increased, the reduction in flow

FIGURE 2 THE EFFECT OF HEAD PRESSURE ON EXTRUDATE FLOW FOR DIFFERENT SCREW METERING SECTIONS

is less, because less area is available for pressure flow.

Modeling

In any modeling it is important to first define the objective of the model and use it to determine the modeling approach to be used. For example, a model to be used for predictive or adaptive computer control should contain features that will make it the most useful for this application. First, since it is to be used for process control purposes, it must predict dynamic behavior. A steady state model would have little value. Second, since the primary purpose of the model is to predict what will occur before it actually does occur, the model must be faster than real time to have any predictive value.

The type of model used for this work was a combined, lumped-parameter, unsteady-state model. A lumped-parameter model assumes no spatial gradients, which allows the use of ordinary differential equations, since only one independent variable, time, varies continuously.

A combined model consists of a number of simple interconnected flow regions and flow types. The three main flow regions usually considered are the backmix, plug, and dead-space regions. In a backmix region, perfect mixing is assumed and the properties of interest, temperature, concentration, etc., are uniform throughout the region. A plug-flow region is one in which no mixing takes place.

Each element of fluid passes through the region in single file with no mixing between the elements. In a dead-space region, the fluid is assumed to be completely stagnant(6).

The types of flow generally encountered in combined models are recycle flow, cross flow, and bypass flow. With recycle flow, some of the liquid leaving a flow region is returned to the region with the inlet feed stream. Cross flow provides for an interchange of fluid between different flow regions with no net flow. A stagnant region can be simulated using cross flow between two backmix flow regions instead of a dead space (7).

While flow in a real vessel will not correspond to any of the ideal flow regions exactly, in some cases it may be simulated fairly well by a plug-flow or backmix flow region. Usually, however, if the flow in a vessel is fairly complex, a number of flow regions and types of flow are required to adequately describe the vessel; thus the name, combined model. Figure 3 shows several lumped-parameter models with their responses to a unit step change.

The more parameters in a combined model, the greater the flexibility of the model. Increasing the number of parameters in the model has certain drawbacks, however; the mathematics becomes more cumbersome, and correspondence to physical reality usually decreases. As

FIGURE 3. SEVERAL MODELS WITH RESPONSES TO A UNIT STEP CHANGE

Levenspiel (6) states, "In fitting a real situation we should aim for the simplest model which fits the facts and whose various regions are suggested by the real vessel". The number of parameters for a combined model made up of the flow regions and flow types defined above is given in the following equation.

$$\begin{aligned} \text{Number of Parameters} = & \{(\text{Flow paths}) + \{ (\text{Flow Regions}) \\ & + \{ (\text{Cross Flow Zones}) - \{ (\text{Restrictions on Flow and} \quad (1) \\ & \text{Volume Ratios}) - 2 \end{aligned}$$

The sum of the volumes of all the flow regions is equal to the volume of the vessel, and the flow in the model at any point is equal to the flow through the vessel. Thus, the sum of flows to parallel units is equal to the flow through the vessel.

Chapter II

EXTRUDER MATHEMATICAL MODEL

The Combined Model

Since it was desired to use a combined model to simulate the dynamics of the extruder, the first step in developing a model was to determine what combination of flow regions best described the extrusion process. Based on the melting mechanism for polystyrene, described on page 6, and the fact that the solids move as a plug in the solids conveying section of the screw, the combined model shown in Figure 4 was selected.

The dotted line in Figure 4 outlines a typical repeat unit in the model. A repeat unit was made up of a backmix region and plug-flow region in parallel. The plug-flow regions represented the solid unmelted polymer and the backmix regions represented the melted polymer. Each successive plug-flow region decreased in volume and had a smaller input as more and more of the polymer melted. The converse was true for the backmix regions. In the solids conveying section, before melting began, all flow was in the plug-flow region. At the outlet end of the extruder where all the polymer was molten, all flow was

FIGURE 4 COMBINED MODEL FOR SIMULATING THE EXTRUDER

in the backmix region.

Figure 5 shows a schematic of the melting process. The backmix regions in the melting section of the screw were made up of the thin film of melt over the solid plug and the melt pool located between the solid plug and the leading edge of the trailing screw flight. The volume of a particular repeat unit was the product of the distance between the leading and trailing screw flight, the channel depth of the screw, and the length of the screw helix equivalent to the length of barrel represented by the repeat unit. The length of helix per revolution was determined from equation 2.

$$\text{HELIX LENGTH / REV.} = (a^2 + c^2)^{\frac{1}{2}}(2\pi) \quad (2)$$

where a is the helix radius and c is the pitch of the helix divided by 2π .

The heat flow in and out of a typical repeat unit in the melting section is shown in Figure 6. Figure 7 shows the differential equations for the model. These equations are developed in succeeding sections.

Backmix Flow Region

The basic melting mechanism model used for setting up a heat balance for the backmix region was that developed by Tadmor (13). Figure 5 shows the idealized channel

FIGURE 5 SCHEMATIC OF CHANNEL CROSS SECTION IN MELTING ZONE

FIGURE 6 HEAT BALANCE FOR REPEAT UNIT

FIGURE 7 DIFFERENTIAL EQUATIONS FOR DESCRIBING HEAT FLOW IN COMBINED MODEL

cross section for the model. The Y axis rises vertically from the channel with $y = 0$ at the top of the solid bed. The X axis runs perpendicular to the screw flights and the Z axis runs in the down channel direction. The assumptions made for developing the heat balance were as follows:

1. The curvature of the screw channel was neglected.
2. Melting of the solid took place only at the solid-melt interface.
3. Heat transfer into the solid plug from the melt pool was considered negligible compared to that transferred from the shear film.
4. The thickness of the film of molten polymer between the barrel and the solid plug was not a function of X.
5. Even though polystyrene (Styron 470) is an amorphous polymer which does not have a sharp melting point, it was assumed that the solid-melt interface was maintained at a constant temperature.
6. Heat transfer between the solid plug and the screw was neglected.
7. The thin film of molten polymer swept off the top of the solid plug into the melt pool had a linear velocity profile.
8. For simplicity, the barrel was assumed to turn instead of the screw.

These assumptions were in addition to those inherent in the lumped-parameter model which did not treat spatial gradients.

Equation 3 is a heat balance around the backmix region. (see Figure 6)

$$\begin{aligned} &(\text{HEAT IN WITH FLOW} - \text{HEAT OUT WITH FLOW}) + \text{HEAT IN} \\ &\text{FROM BARREL} + \text{HEAT FROM VISCOUS DISSIPATION} - \\ &\text{HEAT OUT TO SCREW} - \text{HEAT OUT TO PLUG} = \text{HEAT} \quad (3) \\ &\text{ACCUMULATION IN BACKMIX REGION} \end{aligned}$$

The first term of Equation 3 represents the difference in enthalpy between the inlet and exit streams of the backmix region. Average values for heat capacity and density were used for calculating this term.

$$\begin{aligned} &(\text{HEAT IN WITH FLOW} - \text{HEAT OUT WITH FLOW}) = \quad (4) \\ &Q_p(FM)(C_{p_p})(T_{in} - T_p) \end{aligned}$$

The second term in Equation 3 represents the flow of heat from the barrel wall into the melt. This heat flow was proportional to the temperature difference between the barrel wall and the melted plastic.

$$\text{HEAT IN FROM BARREL} = H_b(A_b)(T_b - T_p) \quad (5)$$

No attempt was made to calculate the heat transfer coefficient H_b between the barrel wall and the molten polymer.

Instead it was treated as one of the model parameters and adjusted to obtain the best fit of the model to the experimental data. The model for obtaining barrel wall temperature is treated in a later section.

The viscous dissipation term represents the heat generated due to the mechanical working of the polymer. This heat generation was difficult to determine accurately. Accurate viscosity data was difficult to obtain at the high shear rates required or unavailable at temperatures below 300 F. Also, the flow patterns for a non-Newtonian fluid in the extruder are very complex.

Viscous dissipation, per unit volume, for flow between two surfaces with a narrow gap and one surface moving is given by the following equation (3):

$$\text{SHEAR HEAT GENERATION} = \mu \left(\frac{dv}{dy} \right)^2 \quad (6)$$

Assuming a linear velocity profile

$$v = \frac{y}{b} v_b \quad (7)$$

and

$$\frac{dv}{dy} = v_b / b \quad (8)$$

Substituting into Equation 6

$$\text{SHEAR HEAT GENERATION} = \mu \left(\frac{v_b}{b} \right)^2 \quad (9)$$

In the case of shear heat generation in the melt film over the solid plug, the velocity was the difference between the barrel velocity and the velocity of the solid plug.

$$V_{bs} = V_b - V_{sld} \quad (10)$$

The volume of the shear field over the solid plug is given by:

$$\text{VOLUME OF THIN FILM} = 3.29(b)(BWD)(L) \quad (11)$$

The method for predicting melt film thickness was set up by modifying the development of Tadmor (13). The rate of heat transfer into the surface of the solid polymer was proportional to the temperature difference between the backmix region and the melting temperature of the polymer.

$$\begin{aligned} \text{HEAT TRANSFER TO SOLID PLUG SURFACE} = \\ H_p(A_p)(T_p - T_{melt}) \end{aligned} \quad (12)$$

The heat entering the solid melted some of the polymer and raised the temperature of the plug. The portion of the heat that raised the temperature of the solid is given in Equation 13.

$$\begin{aligned} \text{HEAT TO RAISE TEMPERATURE OF SOLID} = \\ (K_p/CD)(2)(A_p)(T_p - T_{plu}) \end{aligned} \quad (13)$$

The heat which actually melted the solid is given by Equation 11 - Equation 12.

$$\text{HEAT FOR MELTING} = H_p(A_p)(T_p - T_{\text{melt}}) - (K_p/CD)(2)(A_p)(T_{\text{melt}} - T_{\text{plu}}) \quad (14)$$

Because the Styron 470 had no sharp melting point it had no latent heat of fusion. The heat required to melt one pound of solid was assumed to be the heat required to raise one pound of solid from the average temperature of the solid plug to the temperature of the molten polymer in the backmix region. The rate of melting is given by Equation 14.

$$\text{RATE OF MELTING} = \frac{\text{HEAT FOR MELTING}}{CP_p(T_p - T_{\text{plu}})} \quad (15)$$

The molten polymer film is continually swept into the melt pool at a rate equal to one-half the X-direction velocity vector since a linear velocity profile was assumed.

$$\text{RATE OF FLOW INTO MELT POOL} = \frac{1}{2}(V_{bx})(b)(\rho_p)(\text{LENGTH}) \quad (16)$$

By setting Equation 14 and 15 equal, an equation for predicting film thickness can be obtained.

$$b = \frac{H_p(A_p)(T_p - T_{\text{melt}}) - (K_p/CD)(2)(A_p)(T_{\text{melt}} - T_{\text{plu}})}{\frac{1}{2}(V_{bx})(\rho_p)(CP_p)(T_p - T_{\text{plu}})(\text{LENGTH})} \quad (17)$$

In addition to the shear heat generated in the melt film, shear heat was also added to the melt in the melt

pool behind the solid bed and in the metering section of the screw where no solid polymer was present. Equation 18 was used for calculating heat generation in these areas.

$$\text{SHEAR HEAT GENERATION} = V_b^2 (\mu) (CW/CD) (1 + 3(\sin^2(\phi))) \quad (18)$$

Equation 18 is derived by Tadmor (16) with an additional term to account for screw clearance. The effect of screw clearance was neglected in Equation 18.

The fourth term of Equation 3 is the heat lost to the screw and is given by the following equation.

$$\text{HEAT OUT TO SCREW} = H_s (A_s) (T_p - T_s) \quad (19)$$

The model for predicting screw temperature is discussed in a later section.

The heat transferred to the solid plug from the backmix region, term 5 of Equation 3, is proportional to the temperature difference between the backmix region and the melting temperature of the solid polymer.

$$\text{HEAT LOST TO PLUG} = H_p (A_p) (T_p - T_{\text{melt}}) \quad (20)$$

The heat transfer coefficient, H_p , was a parameter of the model and was handled the same as H_b .

The sixth term of Equation 2 represents the accumulation of heat in the backmix region.

$$\text{HEAT ACCUMULATION} = (\rho_p)(CP_p)(FM)(V_t) \frac{dT_p}{d\Theta} \quad (21)$$

The volume of the backmix region was the product of the total volume of the repeat unit and the fraction of the total volume that was in the backmix region. It was assumed that, for a particular repeat unit, the fraction of total volume in the backmix region was equal to the fraction of total flow through that unit.

The fraction of total flow through backmix region K+1 was determined as follows.

$$FM_{(K+1)} = (\text{RATE OF MELTING})/Q_p + FM_{(K)} \quad (22)$$

The fraction of flow through a particular plug-flow region was one minus the fraction of flow through the backmix region.

Equation 23 gives the differential equation for the heat balance on the backmix region.

$$\begin{aligned} & Q_p(FM)(CP_p)(T_{in} - T_p) + H_b(A_b)(T_b - T_p) + \text{SHEAR} \\ & \text{HEAT} - H_s(A_s)(T_p - T_s) - H_p(A_p)(T_p - T_{melt}) = \\ & (\rho_p)(CP_p)(FM)(V_t) \frac{dT_p}{d\Theta} \end{aligned} \quad (23)$$

The above equation was set up as a finite difference equation for the model. The finite difference equation for backmix region K is given by Equation 24.

$$\begin{aligned}
T_{p(K, \theta + \Delta\theta)} = & \left[\Delta\theta / ((\rho_p)(C_{P_p})(F_{M(K)})(V_t)) \right] \left[(C_{P_p}) \right. \\
& (F_{M(K)})(Q_p)(T_{in} - T_{p(K, \theta)}) + Q_{SHEAR} + H_{b(K)}(A_{b(K)}) \\
& (T_{b(K, \theta + \Delta\theta)} - T_{p(K, \theta)}) - H_{p(K)}(A_{p(K)})(T_{p(K, \theta)} - \\
& T_{melt}) - Q_{SCREW} \left. \right] + T_{p(K, \theta)}
\end{aligned} \quad (24)$$

where T_{in} is the average of $T_{p(K-1, \theta)}$ and $T_{p(K-1, \theta + \Delta\theta)}$.

Plug Flow Region

The plug-flow regions were handled by dividing the plug-flow region for a particular repeat unit into small increments. The number of increments (LAG) was determined by the length of time it took for a point on the solid bed to move through the plug-flow region (θ_{LAG}).

$$\theta_{LAG} = 3.29(L) / ((V_{sld})(60)) \quad (25)$$

and

$$LAG = \theta_{LAG} / \Delta\theta \quad (26)$$

One method of handling the heat transfer into the plug was to treat each increment as a backmix region. A large number of backmix regions in series closely approximates a plug-flow region. (see Figure 8)

Setting up a heat balance around increment $\underline{n}$ of plug-flow region $\underline{K}$:

FIGURE 8 SIMULATION OF PLUG FLOW UNIT WITH BACKMIX REGIONS

$$\begin{aligned}
 &(\text{HEAT IN WITH FLOW} - \text{HEAT OUT WITH FLOW}) + \\
 &\text{HEAT IN FROM BACKMIX REGION} - \text{HEAT OUT TO SCREW} = \quad (27) \\
 &\text{HEAT ACCUMULATION IN INCREMENT } \underline{n}
 \end{aligned}$$

The first term of Equation 27 was simply the difference in enthalpy between the inlet and outlet streams.

$$\begin{aligned}
 &(\text{HEAT IN WITH FLOW} - \text{HEAT OUT WITH FLOW}) = \\
 &(1 - FM_{(K)})(Q_p)(CP_p)(T_{\text{plu}(n-1)} - T_{\text{plu}(n)}) \quad (28)
 \end{aligned}$$

The heat flow into increment $\underline{n}$ from backmix region $\underline{K}$ was

$$\begin{aligned}
 &\text{HEAT IN FROM BACKMIX REGION } K \text{ TO HEAT UP PLUG} = \\
 &(K_p/CD_{(K)})(2)(A_{\text{plu}})(T_{\text{melt}} - T_{\text{plu}(n)}) \quad (29)
 \end{aligned}$$

The term $(K_p/CD)(2)$ represents the average resistance to heat flow in the plug and T_{melt} is the temperature of the plug surface. The area for heat transfer A_{plu} is the total area for unit K divided by LAG.

The third term of Equation 27 is the heat flow out of the plug into the screw. This term was neglected because the resistance to heat transfer between the plug and the screw was large.

The accumulation term for increment $\underline{n}$ is shown in Equation 30.

$$\begin{aligned}
 &\text{HEAT ACCUMULATED} = \\
 &\rho_p(CP_p)(1 - FM_{(K)})(V_t)/LAG \left(\frac{dT_{\text{plu}(n)}}{d\theta} \right) \quad (30)
 \end{aligned}$$

Rewriting Equation 27 yields

$$\begin{aligned} & (1 - FM_{(K)})(Q_p)(CP_p)(T_{plu(n-1)} - T_{plu(n)}) \\ & + (K_p/CD_{(K)})(2)(A_{plu})(T_{melt} - T_{plu(n)}) = \\ & \rho_p(CP_p)(1 - FM_{(K)})(V_t)/LAG \frac{dT_{plu(n)}}{d\theta} \end{aligned} \quad (31)$$

Setting Equation 31 up in finite difference form gives Equation 32.

$$\begin{aligned} T_{plu(n, \theta + \Delta\theta)} = & \left[(\Delta\theta)(LAG)/((\rho_p)(CP_p)(1 - FM_{(K)})(V_t)) \right] \\ & \left[(1 - FM_{(K)})(Q_p)(CP_p)(T_{plu(n-1)} - T_{plu(n, \theta)}) + (K_p/CD_{(K)})(2)(A_{plu})(T_{melt} - T_{plu(n, \theta)}) \right] \end{aligned} \quad (32)$$

An expression for the velocity of the solid bed, used in Equation 25, can be obtained by setting up a material balance on the solid bed.

$$V_{sld} = (Q_p(1 - FM_{(K)}))/((60)(\rho_p)(CD_{(K)})(BWD_{(K)})) \quad (33)$$

In Equation 33, it was assumed that the shear film thickness was negligible and the solid plug occupied the entire depth of channel. In the model, heat transfer was reduced by 30 per cent in the plug flow region of the first repeat unit, to account for the air entrapped in the plug near the hopper. No correction was made on succeeding units.

The solid bed width $BWD_{(K)}$, for Repeat Unit K , was estimated by ratioing the channel depth and volumetric flow of solids in Unit K to the channel depth and flow of

solids in Repeat Unit 1.

$$BWD(K) = (1 - FM_{(K)})(CD_{(1)})(CW)(38)/((CD_{(K)})(\rho_p)) \quad (34)$$

The constant, 38 represents the bulk density of the feed.

Extruder Barrel Model

The extruder barrel was modeled using two lumped parameter sections in series. Heat transfer in the axial direction along the barrel was neglected. Figure 9 shows the model used for describing the barrel.

Writing heat balances around Sections 1 and 2 gives Equations 35 and 36, respectively.

$$H_{bo}(A_{bo})(T_m - T_{bm}) - H_{bm}(A_{bm})(T_{bm} - T_b) = (\rho_b)(CP_b)(V_{bar}/2) \frac{dT_{bm}}{d\theta} \quad (35)$$

$$H_{bm}(A_{bm})(T_{bm} - T_b) - H_b(A_b)(T_b - T_p) = (\rho_b)(CP_b)(V_{bar}/2) \frac{dT_b}{d\theta} \quad (36)$$

Setting up Equations 35 and 36 as finite difference equations for Repeat Unit K yields

$$T_{bm}(K, \theta + \Delta\theta) = \left[\Delta\theta / ((\rho_b)(CP_b)(V_{bar}/2)) \right] \left[H_{bo}(A_{bo})(T_m(K, \theta + \Delta\theta) - T_{bm}(K, \theta)) - H_{bm}(A_{bm})(T_{bm}(K, \theta) - T_b(K, \theta)) \right] \quad (37)$$

and for Section 2

FIGURE 9 MODEL FOR EXTRUDER BARREL

$$T_{b(K, \theta + \Delta \theta)} = \left[\Delta \theta / ((\rho_b)(C P_b)(V_{bar}/2)) \right] \left[H_{bm}(A_{bm}) (T_{bm}(K, \theta + \Delta \theta) - T_{b(K, \theta)}) - H_{b(K)}(A_b)(T_{b(K, \theta)} - T_p(K, \theta)) \right] \quad (38)$$

The barrel was divided up so that both sections had the same volume; therefore Section 2 was thicker than Section 1. The heat transfer coefficients (H_{bo} and H_{bm}) were estimated using the thermal conductivity of the metal barrel.

$$\text{HEAT TRANSFER COEFFICIENT} = K_b / (\text{METAL THICKNESS}) \quad (39)$$

The barrel liner was assumed to fit tightly in the barrel and resistance to heat transfer at the liner-barrel interface was neglected.

No attempt was made to couple the barrel zone heater temperatures to the barrel wall temperatures. Instead, the temperatures measured by the thermocouples in the barrel were used to determine the outside barrel wall temperature (T_m). These thermocouples were located one half inch deep in the barrel wall, so the areas and volumes of Sections 1 and 2 were calculated using the outside barrel diameter minus one inch.

The barrel thermocouples were spaced approximately every four and one-half inches along the top of the barrel in the gap between the zone heater sections. Since the length of barrel represented by one repeat unit was greater

than four and one-half inches, weighted averages of the temperatures measured by the thermocouples in and near a particular repeat unit were used for determining the outside barrel wall temperature for that repeat unit.

The temperature of the barrel wall was not constant during a run, especially if the temperature of one of the zone heaters was changed. This change was handled in the model by fitting the response of T_m for a particular repeat unit, as measured by the weighted averages of the barrel thermocouples, with an equation for two first order systems in series. By adjusting the time constants, the responses were simulated accurately. Appendix D gives the details for weight averaging the barrel temperatures and simulating the dynamic responses.

Angular variation of temperature around the barrel was not measured, and it was neglected in the model. The barrel zone heaters were not symmetrical, so this variation could have been significant.

Extruder Screw Model

The screw represents a large volume for storing and releasing heat. For the purposes of the model, the screw was thermally coupled only to the molten polymer. It was assumed that no heat was transferred between the solid plug and the screw, and that no heat was lost thru the core.

Setting up a heat balance for the screw yields the

following equation.

$$H_s(A_s)(T_p - T_s) = CP_s(\rho_s)(V_{scr}) \frac{dT_s}{d\theta} \quad (40)$$

Setting up a finite difference equation for repeat unit K gives Equation 41.

$$T_{s(K, \theta + \Delta\theta)} = \left[\Delta\theta / ((CP_s)(\rho_s)(V_{scr})) \right] \left[H_s(A_s)(T_{p(K, \theta)} - T_{s(K, \theta)}) \right] \quad (41)$$

The heat transfer coefficient, H_s , was a parameter in the model. This parameter had no effect on the steady state level of the model, but effected only dynamic response. The lower the value of H_s , the slower the melt temperature responded to a load change, all other things being equal.

Computer Implementation of Model

The programs used for setting up the model for the computer were written in Fortran IV computer language. While most of the development of the programs for the model was done on an IBM 360 Model 75 computer, the model was easily adaptable to a smaller computer and fit nicely on the PDP Model 15/30 computer where it is to be used eventually for on-line computer control of the extruder. The program was written to allow as much flexibility as possible, such as varying the number of repeat units in the model, or changing the size of the time increment for

the finite difference equations, etc. The model was set up using a number of subroutines to facilitate debugging and simplify modification.

The MAIN program kept track of time and initialized the variables in the subroutines. Subroutine MIX handled all calculations for the backmix regions including the calculation of shear heat and fraction of flow into the backmix and plug-flow regions. Calculations for the plug-flow regions were handled in Subroutine PLUFLO which was called from Subroutine MIX. Subroutines BARREL and SCREW, also called from Subroutine Mix, calculated the temperature of the barrel and screw. Several minor subroutines were included in the program for writing out results and punching data for subsequent runs. In the following paragraphs each of the major programs is described and flow charts are given. A statement listing of the actual programs is given in Appendix B.

The MAIN program was used mainly for reading in data, initializing variables, and keeping track of time. A step by step description of the program is given below with a flow chart shown in Figure 10. A list of variables for all the computer programs is given in Table 1.

1. The data for a particular run were read in and echoed. The data were as follows.

- a. The number of repeat units (NZONES)

FIGURE 10 FLOW CHART FOR MAIN PROGRAM

- b. The size of time increment to be used (DELTH)
 - c. The screw speed and gate pressure initially and after a load change (RPM1,RPM2,DELP1,DELP2)
 - d. The total volume of each repeat unit (VTOT)
 - e. The outside barrel wall temperature (TM)
 - f. The average channel depth for each repeat unit (CHDEP)
 - g. The length of barrel represented by each repeat unit (ALEN)
 - h. The number of plug increments to be used in each plug flow region (NPLUG)
 - i. The difference between the outside barrel wall temperature before the load change and the temperature after a new equilibrium is reached (TMDIF)
The value of TMDIF was obtained from the experimental data.
 - j. The constants for the second-order lag equation used to calculate the outside barrel wall temperature.
2. Next the variables in the model such as temperature in each backmix region, temperature in each plug-flow region, fraction of flow to each backmix region, etc. were initialized with values punched on cards during a previous run. This facilitated reaching equilibrium rapidly, before the load change was made. These values were stored in arrays separate from those used for computation.
3. The variables used for computation were set equal to the initial equilibrium values.
4. The values for the model parameters were read in and echoed. (HBAR,HPLA,VISCO)
5. Additional initializations were made. The screw speed was set equal to RPM1 and the gate pressure set equal to DELP1. The inside and outside barrel

radii were set and VBAR, VBARX, and VBARZ were calculated. The inlet temperature of the feed from the hopper was set equal to 100 F. NRACE was set equal to 1. NRACE had a value of 1 before the load change and a value of 0 after the change was made.

6. Computation was now started to bring the temperatures to an initial equilibrium. The time required to accomplish this varied depending on how close the initial values were. Three minutes was generally sufficient.
7. When steady state was achieved NRACE was set equal to 0 and RPM and DELP were set equal to RPM2 and DELP2 respectively. If the load change was the simulation of a zone temperature controller set point change it was handled in Subroutine BARREL. The process was now repeated and the model allowed to come to a new equilibrium. A new flowrate was calculated for each pass since it was a function of temperature. Changes in flowrate were handled with a first order lag, having a time constant of 0.01 hours.
8. After running the desired length of time, execution was terminated or data for the next run was read in and the process repeated.

Subroutine MIX handled the bulk of calculations for the model. It was set up to calculate all the heat transferred in and out of the backmix regions. Figure 11 shows a flow chart for Subroutine MIX and a description of the program follows:

1. The area of the inside barrel wall in the backmix region is calculated and the Subroutine BARREL is called and the new barrel wall temperature calculated.
2. NOMELT is compared to the value of K. If NOMELT

FIGURE 11 FLOW CHART FOR SUBROUTINE MIX

equals K , the flow in the preceding zone was all solid and all heat was transferred into Zone K thru the barrel wall. If no melting took place in this zone, $NOMELT$ was incremented by 1. Then the solid bed velocity was calculated and Subroutine $PLUFLO$ was called.

3. If $NOMELT$ was not equal to K , program flow passed to the section for calculating temperature in the backmix region.
4. The required physical properties were calculated.
5. The heat available for melting polymer was calculated to determine $FM_{(K+1)}$ and then that variable was calculated.
6. The solid bed width was calculated to determine the area for heat transfer between the backmix region and the solid plug and the velocity of the solid plug was determined.
7. The depth of the shear film over the solid plug was calculated.
8. The viscosity was determined and used to calculate the shear heat generation.
9. Subroutine $SCREW$ was called to determine the amount of heat transferred between the screw and the backmix region.
10. A new temperature at $(\theta + \Delta\theta)$ was calculated for the backmix region and then Subroutine $PLUFLO$ was called.

Subroutine $PLUFLO$ was used to calculate the temperature of the solid plug in the plug-flow region. Actually as it turned out, the temperature of the plug had little

effect on the model since the solid plug had such a low thermal conductivity. Usually the plug temperature would rise less than 10 degrees F before it was completely melted. Also, the change in plug temperature due to a load change was negligible. Often, especially during the parameter searches, the model program was used without the PLUFLO Subroutine to reduce the computer time required to set the parameters. When this was done, steady state values for plug temperatures were used in Subroutine MIX. Figure 12 gives the flow chart for Subroutine PLUFLO and a description of the program follows:

1. First the lag time and the number of plug increments in the plug-flow region were calculated.
2. The area for heat transfer was calculated. This was simply the total area for heat transfer divided by the number of increments.
3. The required physical properties were calculated.
4. The temperature of each plug increment at $\theta + \Delta\theta$ was calculated. The plug temperature matrix $TPLUG(K,J)$ was handled so that the first plug increment had the highest value of J.
5. Finally, all the plug increments (unused for this calculation) were set equal to the temperature in $TPLU(K, NOPLUG-LAG)$.

Flow charts for Subroutines BARREL and SCREW are shown in Figures 13 and 14, respectively. These two

FIGURE 12 FLOW CHART FOR SUBROUTINE PLUFLO

FIGURE 13 FLOW,CHART FOR SUBROUTINE BARREL

FIGURE 14 FLOW CHART FOR SUBROUTINE SCREW

subroutines were fairly simple so no description is given. The listings of the programs for writing out results and punching steady-state data are given in Appendix B.

Figure 15 shows the location of the model zones (repeat units) along the barrel of the extruder. The length of barrel represented by each zone was setup so that the seven melt thermocouple positions were located at the end of a model zone. The length, volume and average channel depth used for each repeat unit is given in Table 2.

TABLE 1

SIZE OF MODEL ZONES

ZONE NO.	VOLUME(in ²)	LENGTH(in)	AVG. CHANNEL DEPTH(in)
1	12.35	5.44	0.375
2	12.35	5.44	0.375
3	12.22	5.44	0.370
4	10.92	5.44	0.319
5	10.80	6.25	0.250
6	8.04	6.25	0.176
7	5.73	6.30	0.124
8	6.15	6.75	0.123
9	5.93	6.50	0.123
10	6.01	6.60	0.123

Fitting the Model Parameters

Fitting the parameters for the model was a rather arduous task, requiring considerable computer time. Most of the parameter fitting was done with a pattern search computer program written by Professor H. C. Hershey of the Chemical Engineering Department of Ohio State University. The program uses an algorithm which attempts

LEGEND

- ▼ MELT TEMPERATURE OR PRESSURE TAP
- BARREL TEMPERATURE 1/2" DEEP IN BARREL
- RESISTANCE BULB THERMOMETER

FIGURE 15 BARREL SCHEMATIC SHOWING LOCATION OF MODEL ZONES

various step sizes of all the parameters and, if one step is more successful in minimizing the function of interest, larger steps are taken with that parameter, and step sizes with the other parameters are reduced.

The parameters to be set in the model were $H\bar{B}A\bar{R}_{(K)}$, $H\bar{P}L\bar{A}_{(K)}$, and $V\bar{I}S\bar{C}O_{(K)}$. $H\bar{B}A\bar{R}$ and $H\bar{P}L\bar{A}$ are explained in a previous section. It should be emphasized that the final values of the parameters $H\bar{B}A\bar{R}$ and $H\bar{P}L\bar{A}$ do not represent the true heat transfer coefficients since their adjustment helps correct for gradients not treated in the model, etc. A shear heat correction factor ($V\bar{I}S\bar{C}O_{(K)}$) was also included as a parameter in the model. $H\bar{S}\bar{C}\bar{R}\bar{E}\bar{W}$ was set up as a model parameter but was not adjusted. It effected dynamic response only.

The parameters in the model were fit by two different methods. In the first method $H\bar{B}A\bar{R}$, $H\bar{P}L\bar{A}$, and $V\bar{I}S\bar{C}O$ for each zone were treated as separate parameters. This required the adjustment of 30 parameters. There was no experimental data for the first three model zones and a single value was used for $H\bar{P}L\bar{A}$, $H\bar{B}A\bar{R}$, and $V\bar{I}S\bar{C}O$ in these three zones. Also, $H\bar{P}L\bar{A}$ was not required beyond Zone 5 or 6 because all the polymer was molten. This further reduced the number of parameters to 18 or 19.

Fortunately, a particular zone was not effected by parameter changes in zones down stream from it, so the

parameters did not have to be fitted all at once. This permitted fitting the parameters of one zone at a time, thus reducing the maximum number of parameters to be fitted at one time to three. This was true except in the case of Zone 4 where six parameters had to be fitted, the parameters for Zone 4 plus those for Zones 1, 2, and 3. Also, the model had to be run only up to the zone in which the parameters were being fitted.

For setting the parameters by the first method, the search program was set up with the main model program as a subroutine. The conditions for a specific run were read into the computer along with the experimental melt temperatures for the zone of interest. The search program fed a set of parameter values to the model program which calculated the response. Next, the function to be minimized was calculated. This function (COST) was the sum of the squared differences between the calculated and experimental temperatures for one-half minute intervals of time, over a five minute period. The value of COST was then returned to the search program which adjusted the parameters based on its value. This procedure was repeated until no further reduction in COST could be obtained, the maximum pre-set number of iterations was completed, or computer time ran out.

Table 2 lists the values for the parameters set by

using experimental data from Run 2. The parameters were also set using experimental data from Run 1, but the model did not fit the experimental data as well for the other runs when these parameters were used.

TABLE 2

MODEL PARAMETERS SET USING RUN 2 EXPERIMENTAL DATA

ZONE	HBAR	HPLA	VISCO
1	325.	350.	2.70
2	325.	350.	2.70
3	325.	350.	2.70
4	1025.	125.	2.93
5	5600.	575.	2.80
6	750.	300.	0.40
7	665.		1.14
8	2375.		0.16
9	625.		0.84
10	560.		1.13

The second method of setting the parameters in the model consisted of tying HBAR and VISCO to the polymer temperature with a linear relationship and using a single value of HPLA for every zone. This reduced the number of parameters to the 5 shown in the following equations.

$$\text{HBAR}_{(K)} = C1 + C2(\text{TPLA}_{(K)}) \quad (42)$$

$$\text{HPLA}_{(K)} = C3 \quad (43)$$

$$\text{VISCO}_{(K)} = C4 + C5(\text{TPLA}_{(K)}) \quad (44)$$

Other relationships were tried, such as tying HPLA to the fraction melted and putting more terms in the equation

for HBAR, but the model fit was not significantly improved. With the second method, all the parameters were set at once using data from five experimental runs (Runs 2, 5, 6, 9, and 13). COST was the sum of the squared differences between the calculated and experimental temperatures for one minute intervals, over a seven minute period. In other words, COST represented the squared difference for 280 data points, eight points for each position and seven positions per run. The following equations show the values obtained for the parameters:

$$\text{HBAR}_{(K)} = 420. + 0.29(\text{TPLA}_{(K)}) \quad (45)$$

$$\text{HPLA}_{(K)} = 52. \quad (46)$$

$$\text{VISCO}_{(K)} = 1.90 + 0.00078(\text{TPLA}_{(K)}) \quad (47)$$

The value of COST, using the best set of parameters obtained by the second method, was 4817. The value of COST using the parameters obtained by the first method, with the same 280 data points, was 2422. It should be emphasized that the first method had 19 parameters and the second only 5.

A large amount of computer time was required for setting the parameters by either method. With the first method, approximately 10 minutes of IBM 360 time was required for setting the parameters in each zone. The second method,

where all the parameters were adjusted in the same run, required approximately four one-half hour 360 runs.

Chapter III

EQUIPMENT AND INSTRUMENTATION

Extruder

The extruder used was a Spacemaker model, manufactured by NRM Corporation of Akron, Ohio. It was a 2½-inch machine with an L/D ratio of 24 to 1 and was fitted with a one-piece, removable, heat-treated, steel barrel lined with Xaloy and had a working pressure rating of 10,000 psi. The barrel was flange mounted to the front end of the extruder hopper section. The barrel had four individual heating zones, with each zone consisting of two 2-KW aluminum alloy half-sections containing cast-in tubular resistance heating elements. The heaters were 12 inches long and had external radial cooling fins (Figure 16). Each heating zone was equipped with a manually operated cooling fan. Also, each zone was protected by a thermal safety switch which shut off power to the heater if the temperature exceeded 600 F. These safety switches were wired in series so that one open switch stopped power to all heating zones.

The drive system for the extruder consisted of a three

FIGURE 16 EXTRUDER BARREL ZONE HEATER

phase, 51 kva, 460/208 volt Reliance Electric Company transformer, a Reliance rectified-power, variable-speed drive unit and a 40 hp, dc motor. The motor was equipped with a $\frac{1}{2}$ hp fan to prevent over-heating at sustained low speed operation. Power was transmitted from the motor to the helical gear drive transmission by four belts. The transmission had a nominal ratio of 17/1 (17 turns of the power input pulley for one turn of the screw).

The hopper portion of the extruder had a standard 4 $\frac{3}{4}$ inch long by 2 $\frac{1}{2}$ inch wide feed opening. The feed inlet was water cooled to prevent bridging of feed material in the hopper. A five-cubic-feet-capacity spun-aluminum hopper was attached to the feed opening. The hopper was equipped with a shut-off gate.

A standard 3-section, single stage plasticating screw was used for all experimental work. The screw was machined from alloy steel, heat treated and chrome plated. Figure 17 shows the detailed dimensions of the screw. The screw was cored for heating or cooling, but neither was used for this work.

Die and Front End Arrangement

The extruder was fitted with a standard breaker plate and screen pack. The extrudate leaving the extruder passed through a Johnson sheet die. The die was heated with both tubular and strip heaters. For control purposes the die

FIGURE 17 THREE SECTION PLASTICATING SCREW

was divided into three heating zones: left, center and right. Figure 18 shows the location of the heaters and control zones on the die. The die opening which formed the sheet was adjustable. The original quick-change Handi-Clamp assembly with which the extruder was fitted was replaced with a large circular plate to which the die adapter was bolted directly.

During later runs, a valve was placed between the breaker plate and die adapter (Figure 19). The valve was used for adjusting back pressure in the extruder. A $\frac{1}{2}$ -ton chain fall was used for positioning and supporting the die (which weighed approximately 500 lbs) at the end of the extruder.

Loader

During early operation, a constant level of material was maintained in the hopper with a Conair Corporation Model 100-001 vacuum loader. The loader conveyed the virgin resin pellets from fiber drums at floor level into the feed hopper. The loader timer was set up so that the loader was on for a fixed time during each minute. If the level in the hopper was above a certain point when the cycle started, a limit switch prevented the loader from starting until the next cycle. The loader was equipped with a cloth filter to prevent dust from entering the blower. This filter was snapped automatically with high

FIGURE 18 JOHNSON SHEET DIE

CUT-AWAY SIDE VIEW

FRONT VIEW

FIGURE 19 BACK PRESSURE VALVE

pressure air to clean the filter during each cycle.

The first loader did not load regrind material satisfactorily and was replaced with a Consair Model 100-072 Flake Ratio Automatic Vacuum Hopper Loader. This unit had a wider flex throat (Figure 20) which accommodated the regrind material satisfactorily. It also was set up to load virgin and regrind material during the same cycle. The new loader operated on 115 volts and had a 1 hp blower motor. It had the same filter system that the Model 100-001 had. The loader was divided into two sections: one side for virgin material, and the other for regrind. The regrind side was equipped with an adjustable tube which could be raised or lowered to change the ratio of virgin to regrind in the feed. During an operating cycle, the virgin side filled with resin, then an automatic valve (positioned by high-pressure air) opened to permit regrind flow into the regrind side, and it filled with regrind up to the bottom of the adjustable tube. The blower then stopped, and both the virgin and regrind material were dumped through the flex throat into the hopper. A limit switch prevented the cycle from being repeated until the depth of feed in the hopper was below a certain level.

Take-off Equipment

The equipment used to "take" the sheet from the die was a converted Egan laminator. The unit had five polished

FIGURE 20 CONAIR VACUUM LOADER

rolls. The first, second, and fourth rolls in the train were driven. The drive consisted of a 5 hp Reliance dc motor and a Falk Motoreducer. The power for the motor was provided by a Reliance Adjustable Speed Control Motor Generator Unit. The speed of the driven rolls could be adjusted with a rheostat to change sheet take-off rate, but the speed of each roll could not be adjusted independently of the others. A safety shut-off cable extended across the top of the unit for emergency stops.

The second roll in the train was movable and could be positioned so that the first and second rolls could be run as nip rolls; however, the rolls were never operated in this fashion. Generally, a gap of about one inch was left between the rolls. The wind-up roll was fitted with an electro-magnetic clutch which was manually adjusted to increase the torque on the wind-up roll as the roll size increased.

The temperature of the first two rolls in the train was controlled by the circulation of hot water. A centrifugal pump driven by an Allis Chalmers 3-hp motor provided the circulation through these rolls. The water temperature was controlled by the flow of service water into the cooling water tank. The level of the tank was maintained constant, or nearly so, by manually adjusting the run-off from the tank.

The entire take-off unit, except the cooling water tank, was mounted on rollers which ran on an angle iron track. The take-off unit was moved away from the extruder to insert or remove the extruder screw. The height of the take-off unit was also adjustable. Further details and drawings of the take-off equipment are given by Kutscher (8). Figure 21 shows a photograph of the extruder and supporting equipment.

Grinder

A Flinchbaugh Products Incorporated Model 79 grinder was used for grinding the extruded film. The grinder had two rotary knives driven with belts by a 3-hp, 230 volt electric motor. The unit was always grounded during operation to reduce static electricity on the regrind.

Extruder and Die Zone Temperature Controllers

The temperature of the four extruder zone heaters and the three heating zones of the die were controlled with Harrel Incorporated Model TC-116-BB time-proportioning controllers. The measurement device for each controller was a 100 ohm platinum resistance bulb thermometer. Figures 16 and 18 show the location of the resistance bulb thermometers in the zone heaters and die, respectively. These thermometers were spring loaded so metal to metal contact was insured. The extruder heating zones also had cooling

**FIGURE 21 PHOTOGRAPH OF EXTRUDER AND SUPPORTING
EQUIPMENT IN OPERATION**

fans, but these were not tied into the controllers and had to be operated manually.

Temperature Measurement

Figure 22 shows a diagram of the extruder barrel with the locations of the thermocouples used for temperature measurement. There were eight taps along the barrel which could be used for measuring the temperature or pressure of the melt. The taps were standard extruder thermocouple taps. They were located approximately every $6\frac{1}{2}$ inches along the barrel with two taps at the extruder gate. The melt temperature was measured with exposed junction iron-constantan thermocouples (Figure 23). The tip of the thermocouple was located flush with the barrel.

In addition, $\frac{1}{8}$ inch diameter, $\frac{1}{2}$ inch deep holes were drilled in the top of the barrel every $4\frac{1}{2}$ inches (12 in all). These holes were fitted with exposed junction iron constantan thermocouples which were used to measure barrel wall temperature. The iron-constantan leads were run to a constant-temperature oven held at 59.6 C where an iron-copper junction was made. The copper-constantan wires were then run to an Auto Ref Thermocouple Junction Box manufactured by Thermo Electric Co. Incorporated of Saddle Brook, New Jersey. This junction box contained the cold junction (150 F oven) for the constantan-copper junction and had the capability of increasing or decreasing the dc

LEGEND

- ▼ MELT TEMPERATURE OR PRESSURE TAP
- BARREL TEMPERATURE 1/2" DEEP IN BARREL
- RESISTANCE BULB THERMOMETER

SCALE 8:1

FIGURE 22 LOCATION OF BARREL AND MELT THERMOCOUPLES IN EXTRUDER BARREL

FIGURE 23 EXPOSED JUNCTION THERMOCOUPLE

level of the milli-volt signal from the thermocouple. This feature permitted the full use of the computer's -10 to +10 volt range with the milli-volt signal amplified 1000 fold. From the junction box, the signal went through an amplifier to the analog-to-digital converter and on to the Digital Equipment Corporation PDP-15-30 digital computer. Further details of the temperature measurement system and calibration procedures are reported by Kutscher(8).

Pressure Measurement

Dynisco Model PT-420 liquid-filled pressure transducers were used for measuring melt pressure. The diaphragm of the transducer was located flush with the inside of the barrel wall. The transducers and thermocouples were constructed so that they could be interchanged in any of the eight positions along the barrel. Each pressure transducer had its own power supply. The milli-volt signal from the transducers was amplified 1000 times and sent to the analog-to-digital converter and the process computer.

A high-pressure hydraulic system was used for calibrating the transducers. The transducers were calibrated using a computer program which sampled the signal from the transducer. The transducer was mounted in the adapter and the hydraulic pressure was increased to the maximum pressure desired. The computer output for this pressure was marked and the pressure reduced by 200 psi and another

reading was taken. In this manner, the calibration for a particular transducer was obtained. The calibration curves for all the transducers were linear. All calibrations were carried out at room temperature. The manufacturer claims a maximum zero shift in the transducer of 15 psi per 100 F change in diaphragm temperature. Calibration curves and specifications for each transducer are given in Appendix E.

Zone Heaters

Each of the four zone heaters of the extruder was wired into a 220-volt relay. When the heater was on, the relay was closed and a 5-volt signal was sent to the computer. The data logging routine was set up to sample the signal from each heater every fraction of a second and accumulate the fraction of time during each minute cycle that the heater was on. This fraction was printed out for each heater on the teletype every minute.

Chapter IV

EXPERIMENTAL PROCEDURE

Start-up

Usually when the extruder was put into operation it was run continuously for about eight hours. The day before start-up, all the thermocouples and pressure transducers were tested and, if necessary, recalibrated. This was done by loading the data logging routine into the computer and monitoring the temperature and pressure signals. Often an amplifier had to be changed or a loose connection in the thermocouple junction box fixed.

The extruder and die zone heaters were turned on at least one hour before start-up to "heat soak" the extruder and die. This was necessary to prevent damaging the screw or generating excessive heat when the screw was started. The temperature controllers were set at 450 F during the heat-up period. During this period, the data logging routine was loaded into the computer and the temperatures were monitored.

At the conclusion of the heat soaking period, the cooling water to the hopper throat was turned on and a small amount of feed was added to the hopper. Before the screw was started, the belt guard was removed, and the

variables changed on the extruder.

Flowrate from the extruder was measured by automatically marking the sheet every minute. The marking device consisted of a grease pencil attached to the shaft of an electric motor with flexible tubing. The motor was turned on for a fraction of a second by a Flexi-pulse timer, and the grease pencil was whipped against the plastic sheet. By cutting off and weighing minute intervals of sheet, an average flowrate could be obtained for that interval. When changes were made which caused rapid variation in flowrate, such as a change in screw speed, the sheet was marked every 15 seconds.

As mentioned before, an experimental run consisted of changing one of the operating conditions of the extruder and measuring the dynamic response of temperature, pressure, and flowrate during the period that it came to a new equilibrium. When the screw speed or back pressure were changed, the change was essentially a step change, since the change was made over a period of a few seconds. Zone temperatures were varied by changing the set points of the zone temperature controllers and manually turning on the cooling fan for that zone if the temperature was to be decreased. A period of several minutes elapsed before the heater reached a new set point temperature, so a step change was not even approximated. The signals from the

resistance bulb thermometers in the zone heaters were not monitored by the computer because doing so would have altered the balance circuit of the temperature controller. The controllers had an indicator which indicated degrees Fahrenheit deviation from set point. This value was recorded during a run to determine the response of the heater temperature to the change. Turning on the cooling fan, if the zone temperature was to be lowered, brought the heater to the new set point temperature rapidly, but the zone heater temperature had to be watched very closely to prevent over-shooting the new set point.

Changing the rolls of film between runs was a three-man job. The film was cut, and one man pulled the sheet through the take-off rolls, while two others removed the full roll and replaced it with an empty one. The empty roll was pre-wrapped with dual faced masking tape to start the film.

The extruder was shut-down by turning off the vacuum loader and shutting the slide gate at the bottom of the hopper. The screw speed was reduced to 5 rpm and was run until extrudate flow stopped. When the extrudate ceased to flow, the screw was stopped and the heaters shut off. No attempt was made to clean the screw before the next start-up.

Eight hours of operation produced approximately eight

175-lb rolls of film, and took two or three days to regrind. A roll of film was mounted on the take-off wind-up roll brackets, and each minute of run was cut off, weighed, and thrown into the grinder. The regrind was stored in fiber drums.

The extruder was operated for one six-hour period using regrind material for feed. The regrind did not process as well as the virgin resin. The flowrates were lower at the same screw speeds, and it was more difficult to make smooth sheet. The poorer processing characteristics were attributed to lower bulk density and the geometric shape of the regrind. Molecular weight and viscosity measurements of the virgin and regrind material indicated that very little degradation took place from one pass through the extruder.

Data Logging

Temperature and pressure data from the extruder were logged by the PDP-15/30 computer. A Fortran program was written to sample the signals at all 20 positions on the extruder(Figure 22 shows the location of each position). In addition to temperatures and pressures, the status(on or off) of each extruder zone heater was monitored, and the fraction of time that the heater was on during a given time interval was calculated. Normally, the data was printed out on the teletype at minute intervals. If more

frequent logging was required, the data were recorded on magnetic or paper tape because the teletype was too slow. A copy of the main program and associated subroutines used for sampling and logging the data are shown in Appendix B.

Feed Material

The material used in this work was high impact polystyrene (Styron 470) supplied by the Dow Chemical Company. It is a linear thermoplastic polymer. In its commercial form, it is amorphous and is very easy to process. Polystyrene is fairly inert chemically, but softens below 100 C and tends to be brittle unless modified. Modified or impact polystyrene refers to polystyrene to which an elastomer has been added to give additional impact strength. Unmodified polystyrene is transparent while modified polystyrene is translucent (2).

Physical properties for Styron 470 are shown in Appendix A. They include viscosity, thermal conductivity, heat capacity, density, and molecular weight.

CHAPTER V

EXPERIMENTAL AND MODEL SIMULATION RESULTS

Operating Conditions

The dynamic model was developed using data taken during operation within a specified range of operating conditions. These operating conditions are shown in Table 3.

TABLE 3
EXTRUDER OPERATING CONDITIONS

OPERATING VARIABLE	RANGE		
Screw Speed rpm	75	-	105
Temperature Controller Set Points			
Zone 1 F	280	-	320
Zone 2 F	330	-	370
Zone 3 F	430	-	470
Zone 4 F	430	-	470

All of the experimental data used for setting parameters in the model were taken from runs within these ranges. The operating conditions shown in Table 3 represent reasonable operating conditions for processing high-impact polystyrene. They are not necessarily optimum conditions.

It might well be argued that the operating ranges are too small, but the author believes that these ranges represent reasonable limits for controlling the extruder

during normal operation, excluding the start-up period. Also, the possibility of developing a reasonably accurate model was better if the range of operation was kept fairly small.

Dynamic Response of Melt and Barrel Temperatures

Figure 24 shows the change in melt and barrel temperature profiles along the extruder barrel, caused by a step change in screw speed from 90 to 105 rpm. It can be observed in Figure 22 that the melt temperature drops two or three degrees between the last two positions (Positions 6 and 8 in Figure 22). This decrease has a reasonable explanation. The melt thermocouple at Position 8 was located about 1 inch beyond the last barrel wall thermocouple (Position 20) and a little more than an inch beyond the fourth zone heater. A static test (screw not turning) was made in which all the zone heaters and the die adapter heaters were turned on, and the barrel temperature measured by the thermocouple at Position 20 was maintained at a temperature over 475 F. During this test, the temperature of the barrel at a point 2 inches beyond the fourth zone heater and $\frac{1}{4}$ in deep in the barrel was found to be approximately 250 F. This rapid drop in barrel temperature could easily account for the 3 degree drop between Positions 6 and 8. Another possibility was that the underside of the barrel, the location of

FIGURE 24 EFFECT OF SCREW SPEED INCREASE ON BARREL AND MELT TEMPERATURE PROFILE

Position 8, was at a lower temperature than the top-side of the barrel. This was checked out by placing thermocouples in Positions 7 and 8 during a run with open discharge. The difference in temperature measured by these two thermocouples was less than 0.3 degrees.

The thermocouple at Position 5 was not of the exposed junction type. It was an integral part of the pressure transducer located in that position and was in contact with the metal diaphragm of the transducer.

The response of the melt thermocouple at Position 3 is not shown in the figures. The circuit handling the signal from this thermocouple was found to be faulty after the runs were completed. The thermocouple was recalibrated and found to read approximately 8 degrees too low and the signal was very erratic. The experimental data in Appendix C includes the temperatures measured by this thermocouple with 8 degrees added on, but the temperatures are questionable.

The dynamic response of several of the barrel and melt temperatures to an increase in screw speed is shown in Figures 25 and 26, respectively. The solid lines in Figure 26 show the temperature responses predicted by the model using the parameter values listed in Table 2, and the dotted lines are the responses predicted using the relationships for HBAR, HPLA, and VISCO shown in Equations 45, 46, and 47.

FIGURE 25 RESPONSE OF BARREL TEMPERATURES TO INCREASE IN SCREW SPEED

FIGURE 26 RESPONSE OF MELT TEMPERATURES TO INCREASE IN SCREW SPEED

The temperature increases at all positions along the barrel, but the size of the increase diminishes toward the outlet end of the extruder. In the case of the melt temperatures, the rise decreases from 7.2 degrees at Position 1 to 2.9 degrees at Position 8, two inches from the end of the screw. Also, the fluctuation of the temperatures from a smooth curve increases markedly moving toward the outlet end of the extruder. Whether or not these fluctuations represent real changes in melt temperature is open to question. The melt thermocouples were interchanged along the barrel and very little change in the size or frequency of the fluctuations was observed.

It should be emphasized that the thermocouple junction only "sees" the melt at the inside barrel surface and that the melt at this point is being subjected to high shear. The problem of temperature measurement of melt in plasticating extruders is treated by Tadmor (17). Obviously, temperature fluctuations of the type shown in Figure 26 can not be predicted with a lumped parameter model. The best that can be hoped for is a smooth curve that reasonably approximates the experimental data. However, these fluctuations in temperature may be important, whether real or not, if the measured temperature is used for process control.

Figures 27 and 28 show the temperature profile and

FIGURE 27 EFFECT OF SCREW SPEED DECREASE ON MELT AND BARREL TEMPERATURE PROFILE

FIGURE 28 RESPONSE OF MELT TEMPERATURE TO SCREW SPEED DECREASE

the dynamic response of the melt temperature to a decrease in screw speed from 90 to 75 rpm. The dynamic responses of melt temperature for changes in the set points of the heating zone temperature controllers are shown in Figures 29 thru 33.

Changing the control temperatures of the zone heaters had very little effect on melt and barrel temperatures outside that zone. Apparently, the change in heat transfer from the barrel was compensated for by an opposite change in the amount of shear heat generated. For example, when the barrel temperature was increased, the rise in temperature of the molten polymer lowered the viscosity and reduced the shear heat generated.

It should be pointed out that the zone heater temperatures were measured with platinum resistance bulb thermometers, located approximately $\frac{1}{2}$ inch deep in the heater, which did not give the true temperature of the interface between the heater and barrel. In a static test, with all the zone heaters controlling at 450 F, melt temperatures as high as 510 F were observed.

Figure 34 shows the response of melt temperature to a screw speed increase, coupled with the closing of the back pressure valve. Though not planned, the increase in back pressure almost exactly compensated for the increase in screw speed and the flowrate remained essentially

FIGURE 29 RESPONSE OF MELT TEMPERATURE TO DECREASE IN ZONE 1 TEMPERATURE CONTROLLER SET POINT

FIGURE 30 RESPONSE OF MELT TEMPERATURE TO INCREASE IN ZONE 3 TEMPERATURE CONTROLLER SET POINT

FIGURE 31 RESPONSE OF MELT TEMPERATURE TO INCREASE IN ZONE 2 TEMPERATURE CONTROLLER SET POINT

FIGURE 32 RESPONSE OF MELT TEMPERATURE TO INCREASE IN ZONE 4 TEMPERATURE CONTROLLER SET POINT

FIGURE 33 RESPONSE OF MELT TEMPERATURE TO INCREASE IN ZONE 1 TEMPERATURE CONTROLLER SET POINT

FIGURE 34 MELT TEMPERATURE RESPONSE TO SCREW SPEED INCREASE AND CLOSING OF BACK PRESSURE VALVE

unchanged. Additional plots of temperature responses with curves predicted by the model are shown in Appendix C.

Dynamic Response of Flowrate

The extrudate flowrate was measured by marking the sheet every minute, or more frequently when it was changing rapidly, and then weighing the sheet between these marks. The runs that exhibited a significant change in flowrate were those in which the screw speed was varied or the back pressure valve was opened or closed. Moderate changes in zone temperature set points had very little effect on flowrate.

Figure 35 shows the change in flowrate caused by an increase of screw speed from 75 to 90 rpm. The flowrate increased very rapidly to a new equilibrium value in approximately 0.4 minutes. The data show a slight overshoot of the new equilibrium flowrate. This was probably not real, since it was difficult to cut the sheet evenly "right on" the mark. This factor also accounts for the "saw tooth" nature of the data. If too much material was cut into one sample the next sample was light. Figure 36 shows the change in flowrate for a screw speed decrease from 105 to 90 rpm.

The response of flowrate to a decrease in the set point of the fourth zone temperature controller is shown in Figure 37. As with all changes in zone temperature

FIGURE 35 RESPONSE OF FLOWRATE TO INCREASE IN SCREW SPEED

FIGURE 36 RESPONSE OF FLOWRATE TO DECREASE IN SCREW SPEED

FIGURE 37 RESPONSE OF FLOWRATE TO DECREASE IN ZONE 4 TEMPERATURE
CONTROLLER SET POINT

controller set points, the change in flowrate was negligible.

Figures 38 and 39 show the response of extrudate flowrate to a change in position of the back pressure valve located between the extruder gate and the die adapter. It took between 15 and 30 seconds to adjust the back pressure valve to a new position.

Flowrate from the extruder was predicted in the model by the following equation:

$$Q_p = 0.259484 \text{ E}02 + 0.154498 \text{ E}01(\text{RPM}) - 0.927089 \text{ E}-02 (\text{DELP}) + 0.529247 \text{ E}-01(\text{TEMP}) + 0.123257 \text{ E}01(\text{DELP})^{\frac{1}{2}} \quad (48) \\ - 0.234700 \text{ E}-03(\text{RPM})(\text{DELP}) + 0.346400 \text{ E}-02(\text{RPM})^2$$

In this equation RPM is the screw speed, DELP is the gate pressure, and TEMP is the extrudate temperature at the extruder gate. The equation predicted flowrate rather well. The maximum difference between experimentally measured flowrate and predicted flowrate for 32 runs tested was 2.9 lb/hr, and the average difference was 0.89 lb/hr.

The dynamic response of the flowrate to a load change was predicted in the model using a first order lag with a time constant of 0.01 hours. The solid lines in Figures 35 thru 39 show the flowrates predicted by the model.

FIGURE 38 RESPONSE OF FLOWRATE TO CLOSING OF BACK PRESSURE VALVE

FIGURE 39 RESPONSE OF FLOWRATE TO OPENING OF BACK PRESSURE VALVE

Barrel Pressures

No attempt was made to predict pressure changes with the model, but experimental values for pressure were used in the model to predict physical properties and flowrates. The only operating variable change that produced significant variation in pressure was the closing or opening of the back pressure valve. Pressures as high as 5000 psi were attained with closed discharge, but normal operating pressure at the gate was between 950 and 1250 psi with the back pressure valve fully opened.

Analysis of Model Simulation Results

The model predictions were fairly good for the most part. The dynamic responses predicted by the model were good for almost all the runs, with little difference between the results from the model using 18 parameters and the model using five parameters. For some positions there was considerable offset from the experimental temperatures. This was particularly true for the five parameter model. For example, the temperatures predicted for Positions 1 and 4 were 5 or 6 degrees lower than the experimental values. The model using 18 parameters had less steady state offset, which would be expected since the parameters for each zone were set to reduce this offset as much as possible using the experimental data from Run 2.

One problem with the model was its inability to take into account changes that occurred down stream from a particular repeat unit. A good example of this is shown by Run 13 (Figure 32) in which the set point for the Zone 4 temperature controller was increased from 430 to 450 F. For this run the temperature as measured by the thermocouple at Position 5 went from 437 to 444 F, an increase of 7 degrees. Referring to Figure 15 it can be seen that Position 5 (at the end of Repeat Unit 8) is located right at the front end of the Zone 4 barrel heater and is probably influenced much more by temperature changes in the Zone 4 barrel heater than by changes in the Zone 3 barrel heater. The majority of Zone 8 for the model is in Heater Zone 3 and weighted averages of the temperatures at Positions 16 and 17 should be used for calculating outside barrel wall temperature, however; these temperatures do not change when the temperature of the Zone 4 barrel heater is increased. This problem was partially solved by including Position 18 in the calculation of the outside barrel temperature for Model Zone 8, but, as can be seen in Figure 32, the model predicts only a three degree rise.

The model predicts flowrates well. The predicted change in flowrate for an increase in screw speed lags behind the actual change while following the change in flowrate for a decrease in screw speed accurately. This

could be corrected by using a lower time constant in the first order lag equation when predicting a flow rate increase, while keeping the existing time constant for a decreasing flowrate.

The model predicted the melt temperature response for the screw speed increase coupled with the closing of the back pressure valve accurately. This run is interesting in that it provides a method for putting more energy into the polymer while maintaining a constant flowrate. This type of information would be valuable for controlling an extruder. Theoretically, using the model, the back pressure and screw speed could be increased in such a way as to maintain a constant flowrate; thus preventing foul up of the take-off equipment.

The only advantage of using 18 versus five parameters in the model was the reduction of steady state offset. If anything, the model using five parameters gave better dynamic response. For computer control purposes, where the prediction of temperature trends is needed and steady state levels are not too important, the five parameter model would probably do as good a job as the model with more parameters. It is possible that tying the parameters to a physical variable other than model zone temperature or using basic parameters other than HBAR, HPLA, and VISCO would give a better fit. If the dynamic response of the

model is of primary importance, it would also be possible to normalize the data by subtracting the initial steady state value from the experimental data and the temperature predicted by the model before calculating the squared difference when fitting the parameters. This would yield parameter values that would give the most accurate dynamic response. The pitfall with this technique is that since the physical properties calculated in the model are dependent on temperature level, especially viscosity, the model would give accurate results only for runs that duplicated those used for fitting the parameters.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The purpose of this study was to develop an open loop model to be used for on-line computer control of a plasticating extruder. It is the belief of this author that this was accomplished and that the resulting model has real potential both for use on-line for temperature trend estimation and off-line for simulation purposes to test different control algorithms.

The conclusions that can be made from the study are as follows:

1. The experimental set up, including the extruder, sheet take-off, instrumentation and computer, used for this study was a workable system for obtaining dynamic temperature data from a plasticating extruder.
2. A lumped parameter model was developed which estimated, with fair accuracy, the dynamic response of the melt temperature of a plasticating extruder to reasonable changes (see Table 3) in screw speed, back pressure, and zone heater temperature.

3. Increasing the number of parameters in the lumped parameter model did not improve its ability to predict temperature dynamics, but did reduce the steady state error.

Recommendations

The addition of a barrel with wrapped coil heating, or better yet a barrel with cored heating zones, would greatly enhance temperature control of the extruder. The existing barrel heaters are inadequate, for an extruder being used for research purposes, both from the stand point of process control and for obtaining open loop response. The temperatures measured by the resistance bulb thermometers are not indicative of the barrel wall temperature. Also, the on-off control and manually operated cooling fans are unsatisfactory.

The method used for measuring extrudate flowrate by weighing sheet, while fairly accurate, was very cumbersome and slow and did not provide on-line information which would be useful for control purposes. A method for on-line measurement of flowrate using the integrated sheet thickness profile measured by the beta gage, along with sheet take-off rate would be desirable.

Monitoring the temperatures and pressures on the extruder with the process computer provided a good method for obtaining and logging data. This system would be even

better if a line printer were added so sampling frequency could be increased. Sampling frequency can be increased with the present system by using magnetic or paper tape, but immediate observation of temperatures and pressures is desirable especially when some of the loops are closed with the computer.

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APPENDIX A

Physical Properties for Polystyrene (Styron 470)

Heat Capacity

The heat capacity of Styron 475 as a function of temperature is shown in Figure 40(1). These data were verified by Whalen (18) for Styron 470. Equation 49 was used to determine heat capacity in the model.

$$\begin{aligned} \text{HEAT CAPACITY (btu/lb F)} = & 0.26777874 \text{ E00} - \\ & 0.16422144 \text{ E-03 (TEMP)} + 0.58071093 \text{ E-05(TEMP)}^2 \quad (49) \\ & - 0.89046243 \text{ E-08(TEMP)}^3 \end{aligned}$$

Thermal Conductivity

Figure 41 shows the variation of thermal conductivity with temperature for Styron 470 (18). These data were taken at 0 psi. Variation of thermal conductivity with pressure was neglected for this work. The expression used to obtain thermal conductivity in the model is given in Equation 50.

$$\begin{aligned} \text{THERMAL COND (btu/hr ft F)} = & 0.051 + \\ & 0.19 \text{ E-03(TEMP)} \end{aligned} \quad (50)$$

Density

Whalen(18) found that density data for Styron 470 agreed very closely with that for Styron 475 (1). Density data for Styron 475 (1) as a function of temperature and pressure is shown in Figure 42. Equation 51 was used for determining density in the model.

$$\begin{aligned} \text{DENSITY (lb/ft}^3\text{)} &= 0.66906 \text{ E}02 + 0.3067 \text{ E-}03(\text{DELP}) \\ &- 0.1522 \text{ E-}01(\text{TEMP}) + 0.148818 \text{ E-}06(\text{TEMP})(\text{DELP}) \end{aligned} \quad (51)$$

Viscosity

Figure 43 gives capillary flow data for Styron 470. The basic shear diagram was obtained from these data using the method outlined in Brodkey (4). Equation was used to predict viscosity in the model.

$$\begin{aligned} \text{LOG}_e(\text{VISCOSITY}) \text{ (lb}_f \text{ sec/in}^2\text{)} &= 0.248765 \text{ E}02 - \\ &0.9820001 \text{ E}00(\text{LOG}_e(\text{SHEAR RATE})) - 0.2403729 \text{ E-}01 \\ &(\text{LOG}_e(\text{SHEAR RATE}))^2 - 0.10309 \text{ E}00(\text{TEMP}) + \quad (52) \\ &0.10375 \text{ E-}03(\text{TEMP})^2 + 0.13982102 \text{ E-}02(\text{LOG}_e(\text{SHEAR} \\ &\text{RATE}))(\text{TEMP}) \end{aligned}$$

Viscosity data were not available for temperatures below 300 F and Equation 52 was not used for predicting viscosity below this temperature. Instead, Equation 53, which was developed by extrapolating the data, was used for estimating viscosity below 300 F.

$$\begin{aligned} \text{VISCOSITY (lb}_f \text{ sec/in}^2\text{)} &= \text{EXP}(3.99 - 0.73 \\ &(\text{LOG}_e(\text{SHEAR RATE}))) \end{aligned} \quad (53)$$

FIGURE 40 HEAT CAPACITY VERSUS TEMPERATURE FOR STYRON 470

FIGURE 41 THERMAL CONDUCTIVITY VERSUS TEMPERATURE
FOR STYRON 470

FIGURE 42 DENSITY VERSUS TEMPERATURE FOR STYRON 470

FIGURE 43 CAPILLARY FLOW DATA FOR STYRON 470

APPENDIX B
Computer Program Listings

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C      MAIN PROGRAM FOR TESTING EXTRUDER MODEL
0001      REAL NPLUG,MELTEM
0002      DIMENSION SBAR(10),SCRE(10),SFM(11),SPLA(10),SPLUG(10,100),
1SBARM(10),SBWD(10)
0003      COMMON TPLUG(10,100),FM(11),VTOT(10),TPLA(10),CHDEP(10),NPLUG(10),
1ALEN(10),TBAR(10),TM(10),HBAR(10),HPLA(10),VISCO(10),CARME(10),
2TSCREW(10),ABAR,APLA,MELTEM
0004      COMMON/A/DELTA,0,DELP,NZONES,INIT2,K
0005      COMMON/B/THETA,TIND,RPM,INIT
0006      COMMON/C/RBARI,RBARC,VBAR,VBARX,VBARZ,2P
0007      COMMON/F/NOFELT
0008      COMMON/S/BWD(10),DERIV
0009      COMMON/RAR/TMDIF(10),TAU(10),DLAY(10),TBARM(10),NRACE
0010      COMMON/NR/NRUN
0011      QPF(RPM,DELP,TEMP)=-.25948436D02+.15449893D01*RPM-.92708900D-02*DE
1LP+.5292470D-01*TEMP+.1232576D01*SQR T(DELP)-.2347D-03*RPM*DELP
2+.3464D-02* (RPM)**2
0012      100 FORMAT(' DELTA=',F12.5)
0013      101 FORMAT(I2)
0014      102 FORMAT(I2,1X,I2,5F15.6)
0015      103 FORMAT(1X,I2,4X,I2,5F15.6)
0016      104 FORMAT(8F12.4)
0017      105 FORMAT(11F7.2)
0018      106 FORMAT(1X,'STARTING NEW RUN')
0019      107 FORMAT(10F7.4)
0020      NRACE=1
0021      IN=5
0022      IO=6

```

```

C READ IN DATA, PARAMETERS, AND STEADY STATE VALUES
0023      17 READ(5,102) NRUN,NZONES,DELTH,RPM1,RPM2,DELP1,DELP2
0024      IF(NRUN .EQ.99) STOP
0025      WRITE(6,103)NRUN,NZONES,DELTH,RPM1,RPM2,DELP1,DELP2
0026      DO25 I=1,NZONES
0027      READ(5,104)VTOT(I),      TM(I),CHDEP(I),NPLUG(I),ALEN(I)
      1,TMDIF(I),TAJ(I),DLAY(I)
0028      WRITE(6,104)VTOT(I),      TM(I),CHDEP(I),NPLUG(I),ALEN(I)
      1,TMDIF(I),TAU(I),DLAY(I)
0029      VTOT(I)=VTOT(I)/1728.
0030      25 CHDEP(I)=CHDEP(I)/12.
0031      IF(NRACE.EQ.0)GOTO8
0032      27 DO23 I=1,NZONES
0033      READ(IN,104)HBAR(I),HPLA(I),VISCO(I)
0034      23 WRITE(10,104)HBAR(I),HPLA(I),VISCO(I)
0035      READ(IN,104)MELTEM
0036      WRITE(10,104)MELTEM
0037      N5=NZONES+1
0038      READ(5,107)(SBWD(I),I=1,NZONES)
0039      READ(5,105)(SBARM(I),I=1,NZONES)
0040      READ(5,105)(SBAR(I),I=1,NZONES)
0041      READ(5,105)(SCRE(I),I=1,NZONES)
0042      READ(5,105)(SFM(I),I=1,N5)
0043      READ(5,105)(SPLA(I),I=1,NZONES)
0044      WRITE(6,107)(SBWD(I),I=1,NZONES)
0045      WRITE(6,105)(SBARM(I),I=1,NZONES)
0046      WRITE(6,105)(SBAR(I),I=1,NZONES)
0047      WRITE(6,105)(SCRE(I),I=1,NZONES)
0048      WRITE(6,105)(SFM(I),I=1,N5)
0049      WRITE(6,105)(SPLA(I),I=1,NZONES)

```

```

0050      DO14I=1,50
0051      14 READ(5,105)((SPLUG(J,I),J=1,NZONES)
0052      DO15I=1,50
0053      15 WRITE(6,105)((SPLUG(J,I),J=1,NZONES)
C  INITIALIZE VARIABLES TO APPROXIMATE INITIAL STEADY STATE VALUES
0054      8 DO16J=1,NZONES
0055      TSCREW(J)=SCREW(J)
0056      FM(J)=SFM(J)
0057      TPLA(J)=SPLA(J)
0058      TBAR(J)=SBAR(J)
0059      TBARM(J)=SBARM(J)
0060      BWD(J)=SBWD(J)
0061      DO16J1=1,50
0062      16 TPLUG(J,J1)=SPLUG(J,J1)
0063      FM(N5)=SFM(N5)
0064      NRACE=1
0065      INIT=1
0066      INIT2=1
0067      DELP=DELP1
0068      RPM=RPM1
0069      3 THETA=0.0
0070      DELTHA=DELTH
0071      RBARI=1.265
0072      RBARO=2.198

```

```

C   CALCULATE BARREL VELOCITIES FOR COMPUTING SHEAR HEAT
0073   VBAR=6.283*RPM*RBARI/12.
0074   PHI=18.0/57.3
0075   VBARZ=VBAR*COS(PHI)
0076   VBARX=VBAR*SIN(PHI)
0077   21 NOMFLT=1
0078   22 TINO=100.
0079   DOZCK=1,NZONES
0080   TEMP2=TPLA(NZONES)
C   CALCULATE FLOWRATE
0081   QP=QPF(RPM,DELP,TEMP2)
0082   TA3=.01
0083   IF(NRACE.EQ.0)QP=QPF(RPM1,DELP1,TEMP1)+(1.-EXP(-THETA/TA3))*
      1(QPF(RPM,DELP,TEMP2)-QPF(RPM1,DELP1,TEMP1))
0084   Q=QP/65.
0085   20 CALL MIX
C   INCREMENT TIME
0086   THETA=THETA+DELTHA
0087   IF(THETA.LE..0500)GOTO21
0088   IF(NRACE.EQ.1)CALL PUNCH
0089   IF(NRACE.EQ.0.AND.THETA.LT..249)GOTO21
0090   IF(NRACE.EQ.0)GOTO17
0091   TEMP1=TPLA(NZONES)
C   SET UP FOR START OF RJV
0092   NRACE=0
0093   RPM=RPM2
0094   DELP=DELP2
0095   WRITE(6,106)
0096   GOTO3
0097   END

```



```

C CALL SUBROUTINE BARREL TO DETERMINE INSIDE BARREL WALL TEMPERATURE
8 CALL BARREL
  TAU2=.01
  NOPLUG=NPLUG(K)
C DETERMINE AVERAGE TEMPERATURE OF PLUG FOR ZONE K
  TPAVG=(TPLUG(K,NOPLUG)+TPLUG(K,1))/2.
  AKAVG=(AKPLAF(MELTEM)+AKPLAF(TPAVG))/2.
  CPAV1=(CPPLAF(MELTEM)+CPPLAF(TPAVG))/2.
  RHOSLD=RHOPLF(DELTA,TPAVG)
  APLA=3.29*.183*ALEN(K)/12.
  IF(K.NE.NUMELT)GOTO9
C .7 FACTOR ADDED FOR REDUCED HEAT TRANSFER DUE TO LOW BED DENSITY
C CALCULATE HEAT AVAILABLE FOR MELTING SOLID PLASTIC
  HEAT=HBAR(K)*APLA* (TBAR(K)-MELTEM)- (AKAVG/(CHDEP(K)/2.))*
  1(MELTEM-TPAVG)*APLA*.7
  FM(K+1)=(HEAT/42.)/QP
  IF(HEAT.LE.0.0)FM(K+1)=0.0
  IF(HEAT.LE.0.0)NOMELT=NOMELT+1
  TPLA2=MELTEM
  VELSLD=QP/(RHOSLD*CHDEP(1)*CW *60.)
C SINCE NO FLOW IN BACKMIX REGION IN THIS ZONE PLUFLO IS CALLED
  GOTO12
9 TINO=AVGT
  IF(K.EQ.(NOMELT+1))TINO=MELTEM
  TPLA2=TPLA(K)
  KPLA=AKPLAF(TPLA2)
  CPPLA=CPPLAF(TPLA2)
  CPAVG=(CPMELT+CPPLA)/2.
  KPAVG=(KPLA+KMELT)/2.

```

```

RHOPLA=RHOPLF(DELP,TPLA2)
APLA=3.29*BWD(K)*ALEN(K)/12.
C  CALCULATION OF HEAT FOR MELTING PLASTIC
HEAT=APLA*HPLA(K)*(TPLA(K)-MELTEM)-(AKAVG/(CHDEP(K)/2.))* (MELTEM
1-TPAVG)*APLA
FM(K+1)=(HEAT/(CPAV1*(MELTEM-TPAVG)+CPAVG*(TPLA(K)-MELTEM)))/QP+FM
1(K)
IF(FM(K).GE..95)GOTO5
IF(K.EQ.NZONES)FM(K+1)=FM(K)
C  CALCULATION OF SOLID BED WIDTH
BWD(K)=(1.-(FM(K))
)*CHDEP(1)*CW  *38./(CHDEP(K)*RHDSLD)
C  BED WIDTH CANNOT EXCEED MAXIMUM FLIGHT WIDTH
2 IF(BWD(K).GT.CW )BWD(K)=CW
C  CALCULATION OF SOLID BED VELOCITY
11 VELSLD=QP/(RHOSLD*CHDEP(1)*CW  *60.)
VBARS=VBAR-VELSLD
APLA=3.29*ALEN(K)*BWD(K)/12.
C  CALCULATE SHEAR FILM THICKNESS OVER SOLID PLUG
DEPSHK=(HPLA(K)*APLA*(TPLA(K)-MELTEM)-(AKAVG/ CHDEP(K)* 2. *APLA
1*(MELTEM-TPAVG)))/(1.5*VBARX*RHOPLA*(CPAVG*(TPLA(K)-MELTEM)+CPAV1
2*(MELTEM-TPAVG))*60.)*(ALEN(K)/12.)*3.29)
IF(DEPSHR.LE..002)DEPSHR=.002
C  CALCULATE VISCOSITY
C  CALCULATE HEAT ADDED DUE TO VISCOUS DISSIPATION
SR=VBARS/(DEPSHR*60.)
ALNSR=ALOG(SR)
IF(TPLA2.LT.300.)VISC =EXP(3.99--.73*(ALNSR))
IF(TPLA2.LT.300.)GOTO6
VISC=VISC(ALNSR,TPLA2)

```

```

VISC=EXP(VISC)
GOTO6
5 SR=VBAR/(CHDEP(K)*60.)
ALNSR=ALOG(SR)
VISC=VIS(ALNSR,TPLA2)
VISC=EXP(VISC)
QSHEAR=.012*VISC*(VBAR)**2*ALEN(K)/CHDEP(K)*VISCO(K)-(1.0-FM(K))
1 *QP*(CPMELT*(MELTEM-TPAVG)+CPAVG*(TPLA(K)-MELTEM))
IF(THETA.GE..04900.AND.NRACE.EQ.1)SHEAR(K)=QSHEAR
IF(NRACE.NE.0)GOTO21
QSHEAR=SHEAR(K)+(QSHEAR-SHEAR(K))*(1.-EXP(-THETA/TAU2 ))
21 APLA=0.0
FM(K+1)=1.0
GOTO4
6 SR1=VBAR/(CHDEP(K)*60.)
ALNSR=ALOG(SR1)
IF(TPLA2.LT.300.)VISC1=EXP(3.99-.73*(ALNSR))
IF(TPLA2.LT.300.)GOTO18
VISC1=VIS(ALNSR,TPLA2)
VISC1=EXP(VISC1)
18 CONTINUE
QSHEAR=VISCO(K)*(.55.5*VISC*BWD(K)*DEPSHR*ALEN(K)*(SR)**2)+.0533
1 *VISC1*(VBAR)**2*ALEN(K)/CHDEP(K)*(CW -BWD(K))*VISCO(K)
IF(THETA.GE..04900.AND.NRACE.EQ.1)SHEAR(K)=QSHEAR
IF(NRACE.NE.0)GOTO4
QSHEAR=SHEAR(K)+(QSHEAR-SHEAR(K))*(1.-EXP(-THETA/TAU2 ))
4 C7=PHOPLA*CPPLA*FM(K)
CB=((CPPLA+CPPLAF(TINO))/2.)*FM(K)
CALL SCREW

```

```

C  CALCULATE TEMPERATURE IN BACKMIX REGION FOR UNIT K AT PRESENT THETA
    TPLA(K)=(DELTHA/(C7*VTOT(K)))*(C8*QP*(TINO-TPLA2)+QSCREW+HBAR(K)*
1ABAR*(TBAR(K)-TPLA2)-HPLA(K)*APLA*(TPLA2-MELTEMP)-QSCREW)+TPLA2
    IF(K.EQ.NZONES)DERIV=ABS(TPLA(K)-TIP)/DELTHA
    IF(K.EQ.NZONES)TIP=TPLA(K)
    AVGT=(TPLA(K)+TPLA2)/2.
    IF(FM(K).GT..995)GOTO25
C  CALL SUBROUTINE PLUFLO TO CALCULATE PLUG TEMPERATURE FOR UNIT K
12 CALL PLUFLO
25 IF(THETA.LT..01)GOTO3
14 CONTINUE
3  OD= AMOD(THETA,.0041666)
    FA=DELTHA
    IF(THETA.GT..034)GOTO50
    IF(OD.LT.FA.AND.K.EQ.NZONES)CALL WRITE
    GOTO51
50 OD=AMOD(THETA,.0166666)
    IF(OD.LT.FA.AND.K.EQ.NZONES)CALL WRITE
102 FORMAT(15,F10.4,3F12.3)
51 RETURN
    DEBUG INIT
    END

```

```

SUBROUTINE PLUFLO
REAL NPLUG,MELTEM,KPLA
COMMON TPLUG(10,100),FM(11),VTOT(10),TPLA(10),CHDEP(10),VPLUG(10),
IALEN(10),TBAK(10),TM(10),HBAK(10),HPLA(10),VISCO(10),CARMEL(10),
2TSCREEN(10),ABAK,APLA,MELTEM
COMMON/A/DELTHA,Q,DELP,NZONES,INIT2,K
COMMON/B/THETA,TING,RPM,INIT
COMMON/C/RBARI,RBARO,VBAR,VBARX,VBARZ,QP
COMMON/I/VELSLD
CPPLAF(T2) = .267777874D00 - .16422144D-03*T2 + .58071093D-05*T
12*2 - .89046243D-08*T2**3
RHOPLF(DELP,T2) = .66906EC2 + .3(67E-03*DELP - .1522E-01*T2 + .1
148818E-06*T2 *DELP
AKPLAF(T2) = .051 + .00019*(T2)
NPLUG=NPLUG(K)
2 THALAG=ALEN(K)*3.29/(VELSLD*60.*12.)
LAG=THALAG/DELTHA
APLU=APLA/FLOAT(LAG)
IF(K.EQ.1)APLU=APLA/FLOAT(LAG)*0.7
DTEM1=TPLUG(K,NOPLUG)
IF(K.EQ.1)DTEM=TING
CPPLA=CPPLAF(DTEM1)
RHOPLA=RHOPLF(DELP,DTEM1)
AKPLA=AKPLAF(DTEM1)
AKMELT=AKPLAF(MELTEM)
AKPAVG=(AKPLA+AKMELT)/2.
AI=(1.-FM(K))*CPPLA
TPLUG(K,NOPLUG)=DELTHA/(AI*RHOPLA*VTOT(K)/FLOAT(LAG))*AI*QP*
1(DTEM-DTEM1)+(AKPAVG/(CHDEP(K)/2.)*APLU*(MELTEM-DTEM1))+DTEM1

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```

      DTEM=(DTEMI+TPLUG(K,NOPLUG))/2.
      DO5J=1,LAG
      J1=NOPLUG-J
      DTEMI=TPLUG(K,J1)
      CPPLA=CPPLAF(DTEMI)
      RHOPLA=RHOPLF(DELP,DTEMI)
      A1=(1.-FM(K))*CPPLA
      TPLUG(K,J1) =DELTHA/(A1*RHOPLA*VTOT(K)/FLOAT(LAG))*(A1*QP*
1 (DTEM-DTEMI)+(AKPAVG/(CHDEP(K)/2.)*APLU*(MELTEM-DTEMI)))+DTEMI
5 DTEM=(DTEMI+TPLUG(K,J1))/2.
      LAG1=NOPLUG-LAG-1
      J2=NOPLUG-LAG
      DO10J=1,LAG1
10 TPLUG(K,J)=TPLUG(K,J2)
      DTEM=TPLUG(K,J2)
8 CONTINUE
      RETURN
      DEBUG INIT
      END

```

```

SUBROUTINE WRITE
REAL NPLUG,MELTEM
COMMON TPLUG(10,100),FM(11),VTCT(10),TPLA(10),CHDEP(10),NPLUG(10),
1ALEN(10),TBAR(10),TM(10),HBAR(10),HPLA(10),VISCO(10),CARMEL(10),
2TSCREW(10),ABAR,APLA,MELTEM
COMMON/A/DELTA,Q,DELP,NZONES,INIT2,K
COMMON/B/THETA,TIND,RPM,INIT
COMMON/C/RBARI,RBARO,VBAR,VBARX,VBARZ,QP
COMMON/NR/NRUN
IF(THETA.LT..0001)IC=1
IF(IC.EQ.1)WRITE(6,101)NRUN
101 FORMAT(1H1,'RUN ',12,/, ' TIME FLOWRATE',36X,'MODEL ZONE',/,23X,
1'1      2      3      4      5      6      7      8      9      10
2')
THETA1=THETA*60.
WRITE(6,100)(TBAR(I),I=1,NZONES)
100 FORMAT(15X,'TBAR ',10(F6.2,1X))
WRITE(6,103)THETA1,QP,(TPLA(I),I=1,NZONES)
103 FORMAT(1X,F5.2,2X,F5.1,2X,'TPLA ',10(F6.2,1X))
WRITE(6,104)(FM(I),I=1,NZONES)
104 FORMAT(15X,'FM ',10(F6.2,1X))
IC=IC+1
IF(IC.EQ.12)IC=1
RETURN
END

```

```

SUBROUTINE BARREL
REAL NPLUG,MELTEM
COMMON TPLUG(10,100),FM(11),VTOT(10),TPLA(10),CHDEP(10),NPLUG(10),
1ALEN(10),TEAR(10),TM(10),HBAR(10),HPLA(10),VISCO(10),CARMEL(10),
2TSCREW(10),ABAR,APLA,MELTEM
COMMON/A/DELTHA,Q,DELP,NZONES,INIT2,K
COMMON/B/THETA,TINC,RPM,INIT
COMMON/BAK/TMDIF(10),TAU(10),DLAY(10),TBARM(10),NRACE
IF(IN15.EQ.14)GOTO12
RHOBAR=488.
CPBAR=.130
INI5=14
12 ABARQ=10.69*(ALEN(K))/144.
TIME=THETA*60.
TMK1=TM(K)
IF(NRACE.EQ.1)GOTO1
IF(TIME.LE.DLAY(K))GOTO1
TIME=TIME-DLAY(K)
C CALCULATE OUTSIDE BARREL WALL TEMPERATURE AT NEW THETA
TMK1=TM(K)+TMDIF(K)*(1.-EXP(-TIME/TAU(K))-TIME/TAU(K)*EXP(-TIME
1/TAU(K)))
1 ABARM=9.25*(ALEN(K))/144.
VOLBAR=4.02*(ALEN(K))/1728.
TBARM1=TBARM(K)
TBARI=TBAR(K)
TBARM(K)=(DELTHA/(RHOBAR*CPBAR*VOLBAR/2.))*(1550.*ABARQ*(TMK1-
1TBARM1))-1350.*ABARM*(TBARM1-TBARI))+TBARM1
C CALCULATE INSIDE BARREL WALL TEMPERATURE FOR UNIT K AT NEW THETA
TBAR(K)=(DELTHA/(RHOBAR*CPBAR*VOLBAR/2.))*(1350.*ABARM*(TBARM1-
1TBARI)-HBAR(K)*ABAR*(TBARI-TPLA(K)))+TBARI
14 CONTINUE
RETURN
END

```



```

SUBROUTINE SCREW
REAL NPLUG,MELTEM
COMMON TPLUG(10,100),FM(11),VTOT(10),TPLA(10),CHDEP(10),NPLUG(10),
1ALEN(10),TBAR(10),TM(10),HBAR(10),HPLA(10),VISCO(10),CARMEL(10),
2TSCREW(10),ABAR,APLA,MELTEM
COMMON/A/DELTHA,0,DELP,NZONES,INIT2,K
COMMON/B/THETA,TINO,RPM,INIT
COMMON/T/QSCREW
IF(INIT3.EQ.15)GOTO10
QSCREW=0.0
IF(K.EQ.NZONES)INIT3=15
GOTO11
10 HSCREW=100.
C CALCULATE RATE OF HEAT LOSS OR TO SCREW
QSCREW=HSCREW*.308*(TPLA(K)-TSCREW(K))
TSCREW1=TSCREW(K)
TSCREW(K)=(QSCREW*DELTHA)/.915+TSCREW1
11 RETURN
END

```

```

SUBROUTINE PUNCH
REAL NPLUG,MELTEM
-----REAL NPLUG,MELTEM
COMMON TPLUG(10,100),FM(11),VTOT(10),TPLA(10),CHDEP(10),NPLUG(10),
1ALEN(10),TBAR(10),TM(10),HBAR(10),HPLA(10),FUDGE(10),CARMEL(10),
2TSCREW(10),ABAR,APLA,MELTEM
COMMON/A/DELTHA,Q,DPLP,NZONES,INIT2,K
COMMON/BAR/TMDIF(10),TAU(10),DLAY(10),TBARM(10)
-----COMMON/S/BWD(10),DERIV
IF(J17.EQ.17)GOTO50
J17=17
N5=NZONES+1
WRITE(7,101)(BWD(I),I=1,NZONES)
WRITE(7,100)(TBARM(I),I=1,NZONES)
-----WRITE(7,100)(TBAR(I),I=1,NZONES)
WRITE(7,100)(TSCREW(I),I=1,NZONES)
WRITE(7,100)(FM(I),I=1,N5)
WRITE(7,100)(TPLA(I),I=1,NZONES)
DO14I5=1,50
14 WRITE(7,100)(TPLUG(I,I5),I=1,NZONES)
101 FORMAT(10F7.4)
100 FORMAT(11F7.2)
50 RETURN
END

```

```

5      FILE NAME EXT1 GOOD AS OF MARCH 1971
C      EXTRUDER DATA LOGGING ROUTINE
      COMMON DAT(25),ON(4),ON1(4)
      COMMON/A/IHR,IM,IS,ITS
      COMMON/B/TIME,TIME1
      COMMON/X/ FILN(2)
      WRITE(1,110)
110     FORMAT(30HENTER NAME OF DATA FILE IN 2A5)
      READ(2,201)FILN(1)
      READ(2,201)FILN(2)
201     FORMAT(A5)
      CALL ENTER(4,FILN)
      NP=1000
      LCH1=4*
      LCH2=4*
      LCH3=50
      LCH4=52
      ENP=NP
      FPC=10./(2.**17)
      WRITE(1,103)
103     CALL SSWTCH(0,J0)
      FORMAT(1H1,6X,17H EXTRUDER DATA LOG)
      IF(J0.NE.1)GOTO10
      IMA=-1
      GOTO03
20     DO001=1,4
      ON1(1)=ON(1)/.**33
      ON(1)=0.0
      TIME=0.0
      TIME1=0.0
      IF(IS.GT.57)GOTO02
      CALL HEATER(ON)
      WRITE(1,100)(ON1(K),K=1,4)
      CALL SSWTCH(2,J2)
      IF(J2.NE.1)GOTO31
      DO041=1,4
      ON(1)=0.0
      TIME=0.0
      TIME1=0.0
      WRITE(1,107)
      READ(2,106)NRUN
107     FORMAT(13H ENTER RUN NO)
106     FORMAT(I2)
      IHR=0
      IM=0
      IS=0
      ITS=0
      CALL CLOCK(IHR,IM,IS,ITS)
      CALL SSWTCH(4,J4)
      IF(J4.EQ.1)CALL HISP(NRUN)
      CALL HEATER(ON)
31     LI=0
      LCH=32

```

```

S1=0.
S2=0.
S3=0.
S4=0.
30 LCH=LCH+1
   IF(LCH.EQ.4) LCH=1
   LI=LI+1
   JS=IS
   JM=IM
   S=0.
   CALL HEATER(ON)
   DO40 I=1,NP
   CALL ADCH(LCH,JVAL)
   VAL=JVAL
   VAL=VAL*FPC
40 S=S+VAL
   DAT(LI)=S/ENP
   CALL HEATER(ON)
   DO42 I=1,50
   CALL ADCH(LCH1,JVAL1)
   CALL ADCH(LCH2,JVAL2)
   CALL ADCH(LCH3,JVAL3)
   CALL ADCH(LCH4,JVAL4)
   VAL1=JVAL1
   VAL2=JVAL2
   VAL3=JVAL3
   VAL4=JVAL4
   VAL1=VAL1*FPC
   VAL2=VAL2*FPC
   VAL3=VAL3*FPC
   VAL4=VAL4*FPC
   S1=S1+VAL1
   S2=S2+VAL2
   S3=S3+VAL3
42 S4=S4+VAL4
   CALL HEATER(ON)
   DAT(LI)=(122.+1*.2*DAT(LI))*(9./5.)+32.
   GOT050
50 IC=IS
   CALL HEATER(ON)
   IF(IM.GT.JM) IC=IC+60
   IF(JS+1.GT.IC) GOT050
   IF(LI.GE.20) GOT060
   GOT030
50 CALL SSWTCH(1,J1)
   DAT(21)=1*.+53*.1*(S1/1000.)
   DAT(22)=65.+31*.1*(S2/1000.)
   DAT(23)=100.+316.*(S3/1000.)
   DAT(24)=-100.+357.7*(S4/1000.)
100 FORMAT(6X,4F10.2/)
   CALL HEATER(ON)
   WRITE(1,101)NRUN,IHR,IM,(DAT(K),K=1,4)

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3      FILE NAME HISP
      SUBROUTINE HISP(NRUN)
      COMMON LVAL(52),S(52)
      COMMON/A/IHR,IM,IS,ITS
      FPC=10./(2.**17)
      CON=100.
5      DO40I=1,52
40     S(I)=0.0
      II=IM
      I2=IS
      DO41I=1,100
      DO47J=33,50
      CALL ADCH(J,LVAL(J))
47     S(J)=S(J)+FLOAT(LVAL(J))*FPC
      DO48J=19,23
      CALL ADCH(J,LVAL(J))
48     S(J)=S(J)+FLOAT(LVAL(J))*FPC
      J=52
      CALL ADCH(J,LVAL(52))
41     S(52)=S(52)+FLOAT(LVAL(52))*FPC
      DO49J=33,47
49     S(J)=(122.+17.2*(S(J)/CON))*(9./5.)+32.
      DO50J=19,23
50     S(J)=(122.+17.2*(S(J)/CON))*(9./5.)+32.
      S(49)=17.+539.1*(S(49)/CON)
      S(49)=65.+317.1*(S(49)/CON)
      S(50)=100.+316.*(S(50)/CON)
      S(52)=-100.+357.7*(S(52)/CON)
      WRITE(4,101)NRUN,II,I2,(S(I),I=33,47),(S(I),I=19,23),S(
101  1,S(49),S(50),S(52))
      FORMAT(3I2,20F7.1,4F6.0)
      IF(MOD(IS,15).LT.1)GOTO5
      IF(IM.GE.3)RETURN
      GOTO4
      END

```

```

3      FILE NAME HEATER
      SUBROUTINE HEATER(ON)
      DIMENSION ON(4),J(4,2)
      COMMON/A/IHR,IM,IS,ITS
      COMMON/B/TIME,TIME1
      FPC=10./(2.**17)
      A1=IS
      A2=ITS
      TIME=A1/60.+A2/600.
      DIFTIM=TIME-TIME1
      TIME1=TIME
      LCH=52
      DO10 I=1,4
      LCH=LCH+1
      CALL ADCH(LCH,JVAL)
      VAL=JVAL
      VAL=VAL*FPC
      J(1,1)=0
      C=-2.5
      IF(VAL.LT.C)J(1,1)=1
      IF(J(1,1).EQ.J(1,2).AND.J(1,1).EQ.1)ON(1)=ON(1)+DIFTIM
      IF(J(1,1).NE.J(1,2))ON(1)=ON(1)+DIFTIM/2.
10     J(1,2)=J(1,1)
      RETURN
      END

```

APPENDIX C

Tabulation of Experimental and Simulation
Results Including Plots for All Runs Not
Included in Text

Table 4 lists the runs for which experimental and simulation results are tabulated.

TABLE 4
EXPERIMENTAL AND SIMULATED RUNS

RUN NO.	CHANGE
1	Screw speed increased from 90 to 105 rpm
2	Screw speed decreased from 90 to 75 rpm
3	Screw speed decreased from 105 to 90 rpm
4	Screw speed increased from 75 to 90 rpm
5	Zone 3 temperature controller set point increased from 430 to 450 F
6	Zone 1 temperature controller set point decreased from 320 to 300 F.
7	Zone 1 temperature controller set point increased from 300 to 320 F
8	Zone 2 temperature controller set point increased from 330 to 350 F
9	Zone 2 temperature controller set point decreased from 350 to 330 F
10	Back pressure valve closed and screw speed increased from 75 to 90 rpm.
11	Back pressure valve closed
12	Back pressure valve opened
13	Zone 4 temperature controller set point increased from 430 to 450 F

TABLE 4 Continued

RUN NO.	CHANGE
14	Zone 3 temperature controller set point increased from 430 to 450 F
15	Zone 4 temperature controller set point decreased from 450 to 430 at 80 rpm
16	Zone 3 temperature controller set point decreased from 450 to 430 F at 80 rpm
17	Screw speed increased from 80 to 95 rpm

Experimental Data

RUN NO. 1 RPM INCREASED FROM 90 TO 105

STYRON 470

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-450.0

RPM- 90.

POSITION	UNITS	MINUTES AFTER CHANGE											
		0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
1	DEG F	394.0	397.3	398.8	399.5	400.2	400.5	400.7	400.9	401.0	401.1	401.0	401.1
2	DEG F	402.2	405.7	406.4	407.2	408.0	407.2	408.5	408.6	408.4	407.7	408.2	407.5
3	DEG F	405.8	408.8	407.9	408.7	409.1	408.2	409.4	410.4	409.9	409.6	409.0	408.9
4	DEG F	432.8	434.6	435.1	435.1	435.9	435.6	436.2	436.5	436.0	435.5	435.5	436.7
5	DEG F	443.4	444.6	445.5	445.7	446.4	446.4	446.8	446.6	446.9	447.3	447.2	447.1
6	DEG F	465.6	465.4	466.0	466.0	466.7	466.7	466.3	466.6	466.9	467.1	466.5	466.9
7	PSI	1191.	1192.	1200.	1207.	1189.	1195.	1193.	1187.	1198.	1193.	1190.	1181.
8	DEG F	462.1	462.7	461.9	463.6	464.3	463.0	464.0	463.4	464.6	463.7	463.6	464.8
9	DEG F	330.6	333.6	335.6	336.2	337.0	337.2	337.4	337.4	337.7	337.8	337.9	338.1
10	DEG F	368.4	371.0	372.9	373.6	374.4	374.5	374.7	374.6	374.8	374.7	374.7	375.0
11	DEG F	362.7	364.5	366.2	367.0	367.9	367.8	368.3	368.1	368.3	368.3	368.2	368.4
12	DEG F	406.9	409.2	410.7	411.4	412.0	412.4	412.8	412.8	412.6	412.5	412.6	412.6
13	DEG F	397.8	399.6	401.0	401.3	401.9	402.4	402.9	402.4	402.1	402.0	402.5	402.3
14	DEG F	408.1	409.7	411.2	411.6	412.1	412.2	412.5	412.6	412.7	412.4	412.5	412.5
15	DEG F	426.6	426.9	428.0	427.9	428.1	427.8	428.2	428.0	428.3	428.3	428.2	428.4
16	DEG F	440.9	441.6	442.6	442.7	443.2	443.1	443.3	443.4	443.6	443.7	443.7	443.8
17	DEG F	450.5	451.4	452.5	452.8	453.4	453.1	453.7	453.5	453.4	454.1	454.2	454.0
18	DEG F	469.0	469.0	469.4	469.3	469.8	469.8	470.3	470.1	470.2	469.9	469.7	469.9
19	DEG F	477.5	477.7	478.1	478.0	478.6	478.6	478.9	478.7	478.9	478.6	478.5	478.4
20	DEG F	476.8	477.0	477.6	477.8	478.2	478.2	478.7	478.7	478.8	478.7	478.6	478.5
AT DIE	DEG F	468.4	465.3	467.1	466.1	466.3	466.6	466.5	467.2	466.1	466.1	466.4	465.5

FLOWRATE LB/HR	MINUTES AFTER CHANGE							
	0.0	0.125	1.000	2.000	3.000	4.000	5.000	7.00
	172.8	184.0	205.0	202.0	200.5	202.2	202.3	202.4

RUN NO. 1 (CONTINUED)

POSITION	UNITS	MINUTES AFTER CHANGE						
		12.0	13.0	14.0	15.0	16.0	17.0	18.0
1	DEG F	400.8	401.1	401.0	401.2	401.2	401.2	401.2
2	DEG F	408.1	408.1	407.5	408.6	408.0	408.0	407.3
3	DEG F	409.9	407.7	409.1	410.5	410.4	410.7	409.5
4	DEG F	436.7	437.2	436.7	436.6	434.5	437.4	437.6
5	DEG F	447.1	447.3	447.1	447.6	447.5	447.6	447.6
6	DEG F	465.8	466.2	466.2	466.7	466.6	466.9	466.8
7	PSI	1153.	1189.	1185.	1195.	1192.	1187.	1198.
8	DEG F	463.3	464.7	464.8	463.7	464.5	464.2	464.2
9	DEG F	338.0	338.3	338.2	338.7	338.5	338.7	338.6
10	DEG F	374.9	375.1	374.8	375.1	374.8	374.9	374.7
11	DEG F	368.3	368.6	368.3	368.5	368.3	368.4	368.2
12	DEG F	412.6	412.8	412.8	413.0	413.0	413.1	413.0
13	DEG F	402.3	402.7	402.4	402.8	402.9	403.1	402.9
14	DEG F	412.3	412.5	412.3	413.1	412.9	412.8	412.9
15	DEG F	428.2	428.4	428.5	429.3	429.0	429.4	429.0
16	DEG F	443.7	444.0	444.1	444.6	444.6	444.9	444.7
17	DEG F	454.0	454.2	454.4	455.0	454.7	455.2	455.0
18	DEG F	469.8	469.9	469.7	469.8	469.8	470.1	469.8
19	DEG F	478.2	478.4	478.2	478.5	478.4	478.6	478.3
20	DEG F	478.5	478.7	478.5	478.7	478.5	478.7	478.5
AT DIE	DEG F	466.1	466.1	466.6	467.1	466.1	466.5	467.1

RUN NO. 2 RPM DECREASED FROM 90 TO 75

STYRON 47C

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-450.0

RPM- 90.

		MINUTES AFTER CHANGE											
POSITION	UNITS	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
1	DEG F	393.1	389.7	388.5	387.4	387.1	386.5	386.2	386.2	386.1	386.0	385.8	386.0
2	DEG F	402.4	399.9	399.7	398.9	398.5	398.5	397.9	398.1	397.9	397.6	397.5	398.4
3	DEG F	407.1	405.7	404.9	404.4	404.9	405.3	403.6	403.4	404.9	403.6	404.2	403.4
4	DEG F	433.9	432.8	432.5	430.7	430.0	429.6	430.5	429.1	429.4	429.8	430.3	429.1
5	DEG F	444.5	443.8	443.6	443.1	443.1	442.7	442.2	442.2	441.9	441.7	441.6	441.8
6	DEG F	465.6	465.6	465.3	465.1	464.8	464.7	464.6	464.9	464.5	464.5	464.1	464.4
7	PSI	1025.	1026.	1033.	1031.	1028.	1029.	1021.	1031.	1028.	1029.	1036.	1025.
8	DEG F	460.0	459.9	460.1	460.7	460.6	460.4	460.7	459.8	460.4	460.2	459.1	459.9
9	DEG F	328.3	324.4	323.0	321.8	321.4	320.7	320.7	320.3	320.2	320.0	319.8	319.5
10	DEG F	366.1	363.0	361.8	360.6	360.3	359.8	359.8	359.5	359.6	359.6	359.7	359.7
11	DEG F	360.8	358.3	357.0	356.0	355.9	355.1	355.1	354.9	354.9	354.8	354.8	354.8
12	DEG F	406.6	404.3	403.2	402.1	401.8	401.3	401.1	401.0	400.8	400.7	400.6	400.6
13	DEG F	398.5	396.7	396.2	395.3	395.5	394.7	394.7	394.5	394.6	394.4	394.6	394.3
14	DEG F	408.6	407.1	406.6	405.8	405.9	405.3	405.5	405.1	405.0	404.8	404.8	404.7
15	DEG F	426.7	419.0	426.2	425.4	425.6	424.9	424.8	424.2	424.3	424.4	424.6	424.6
16	DEG F	441.8	440.6	440.3	439.7	439.4	438.7	438.5	438.1	437.9	438.1	438.3	438.4
17	DEG F	451.6	450.3	450.0	449.1	449.0	448.3	448.1	447.6	447.6	447.4	447.6	447.7
18	DEG F	469.2	469.2	469.3	469.0	469.1	468.6	468.7	468.3	468.4	468.1	468.1	468.0
19	DEG F	477.7	477.3	477.5	477.1	477.2	476.8	477.0	476.6	476.6	476.4	476.4	476.4
20	DEG F	476.5	476.0	475.9	475.5	475.6	475.3	475.3	475.1	475.1	474.8	474.8	474.7
AT CIE	DEG F	467.6	469.4	470.5	469.5	470.3	470.0	470.0	469.4	469.8	469.2	469.8	469.7

		MINUTES AFTER CHANGE									
		0.0	0.125	0.850	1.125	2.500	3.500	4.500	5.50	6.50	7.50
FLOWRATE	LB/HR	174.3	160.0	152.5	149.0	149.0	146.5	147.0	149.0	145.0	147.0

RUN NO. 2 (CONTINUED)

		MINUTES AFTER CHANGE				
POSITION	UNITS	12.0	13.0	14.0	15.0	16.0
1	DEG F	385.8	386.0	385.8	386.0	385.8
2	DEG F	397.4	398.2	397.6	397.7	397.6
3	DEG F	404.2	403.4	402.9	404.0	404.2
4	DEG F	429.8	429.8	429.3	429.4	428.5
5	DEG F	441.8	442.1	441.8	441.9	441.7
6	DEG F	464.5	464.5	464.6	464.8	465.0
7	PSI	1021.	1028.	1030.	1028.	1028.
8	DEG F	458.9	459.5	459.3	459.9	458.9
9	DEG F	319.3	319.3	318.9	319.0	318.6
10	DEG F	359.6	359.9	359.6	359.8	359.5
11	DEG F	354.8	355.0	354.7	355.0	354.7
12	DEG F	400.5	400.7	400.5	400.6	400.5
13	DEG F	394.3	394.5	394.3	394.4	394.2
14	DEG F	404.9	405.0	404.7	405.0	404.7
15	DEG F	424.5	424.7	424.1	424.3	423.7
16	DEG F	438.2	438.4	437.9	437.9	437.5
17	DEG F	447.7	447.7	447.4	447.5	447.1
18	DEG F	468.1	468.3	468.4	468.7	468.5
19	DEG F	476.4	476.5	476.5	476.9	476.6
20	DEG F	474.7	474.8	474.6	475.0	474.8
AT DIE	DEG F	469.4	470.3	469.5	470.1	470.0

RUN NO. 3 RPM DECREASED FROM 105 TO 50

STYREN 470

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-430.0
RPM-105.

		MINUTES AFTER CHANGE											
POSITION	UNITS	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
1	DEG F	400.5	397.7	396.1	395.3	394.4	394.3	394.0	393.9	393.7	393.6	393.6	393.4
2	DEG F	409.5	406.3	406.2	405.2	405.7	405.0	404.5	404.5	404.3	404.4	403.7	402.6
3	DEG F	409.2	407.7	408.9	407.4	406.5	406.7	407.2	408.2	407.6	407.3	405.9	406.7
4	DEG F	435.6	434.4	433.0	431.1	431.5	431.1	432.5	431.9	432.6	432.3	433.4	431.6
5	DEG F	440.7	439.5	438.6	438.6	438.0	438.0	437.9	437.7	437.8	437.7	437.8	437.3
6	DEG F	453.3	452.8	452.1	451.7	451.3	451.3	450.9	451.4	451.2	451.4	451.4	450.8
7	PSI	1143.	1135.	1151.	1151.	1151.	1150.	1143.	1152.	1146.	1141.	1138.	1131.
8	DEG F	455.6	457.0	453.9	454.4	455.1	455.5	455.1	454.6	454.7	453.6	454.4	454.6
9	DEG F	336.5	333.5	332.2	331.5	330.8	330.6	330.2	330.2	330.0	329.9	329.6	329.5
10	DEG F	372.5	370.0	368.0	367.1	366.2	366.1	365.8	366.0	365.9	365.9	365.7	365.5
11	DEG F	366.6	364.9	362.8	362.1	361.3	361.2	360.7	361.0	360.7	360.6	360.3	360.5
12	DEG F	413.8	411.7	410.2	409.4	408.7	408.5	408.1	407.1	407.8	407.6	407.5	407.3
13	DEG F	404.7	402.9	401.7	401.2	400.4	400.7	400.3	398.2	399.8	400.1	399.7	399.3
14	DEG F	413.9	412.6	411.5	411.4	410.6	410.5	410.2	410.4	410.1	409.9	410.1	409.9
15	DEG F	427.9	427.2	426.5	426.7	426.3	426.4	426.2	426.8	426.7	426.7	426.6	426.4
16	DEG F	441.9	441.1	440.4	440.4	440.0	440.2	440.1	440.5	440.5	440.7	440.5	440.3
17	DEG F	450.8	449.5	448.8	448.7	448.1	448.3	448.1	448.3	448.2	448.5	448.1	448.1
18	DEG F	456.4	456.3	455.8	455.8	455.3	455.5	455.0	454.8	454.9	455.1	454.5	455.1
19	DEG F	462.3	462.0	461.5	461.5	461.0	461.0	460.6	460.8	460.6	460.6	460.5	460.5
20	DEG F	466.3	466.1	465.4	465.2	464.7	464.7	464.3	464.5	464.1	464.1	463.5	464.0
AT DIE	DEG F	464.2	466.1	465.8	466.5	466.3	465.9	465.0	465.2	465.3	465.5	465.2	465.9

FLOWRATE LB/HR	MINUTES AFTER CHANGE										
	0.0	0.125	0.375	0.875	1.500	2.500	3.500	4.50	5.50	6.50	7.50
	201.8	187.0	181.0	175.0	174.0	173.0	172.5	173.5	171.0	174.0	170.0

RUN NO. 3 (CONTINUED)

POSITION	UNITS	MINUTES AFTER CHANGE						
		12.0	13.0	14.0	15.0	16.0	17.0	18.0
1	DEG F	393.6	393.3	393.6	393.3	393.5	393.4	393.5
2	DEG F	404.5	403.5	403.6	404.1	403.7	402.7	403.3
3	DEG F	406.2	404.6	407.2	406.4	407.7	406.8	406.3
4	DEG F	433.3	432.4	431.5	431.9	431.8	431.8	432.0
5	DEG F	437.7	437.3	437.6	437.2	437.6	437.1	437.4
6	DEG F	451.2	451.8	451.6	451.5	451.8	451.3	451.4
7	PSI	1149.	1159.	1168.	1176.	1146.	1143.	1150.
8	DEG F	454.5	454.5	455.0	454.7	454.3	454.6	453.6
9	DEG F	329.6	329.4	329.6	329.3	329.5	329.2	329.2
10	DEG F	366.0	365.8	366.1	365.8	366.1	365.9	366.1
11	DEG F	360.8	360.5	360.8	360.4	360.9	360.6	360.7
12	DEG F	407.4	407.3	407.3	407.1	407.3	407.0	407.1
13	DEG F	399.5	399.5	399.4	398.8	399.0	398.6	398.8
14	DEG F	409.6	409.5	409.7	409.4	409.5	409.2	409.4
15	DEG F	426.0	425.8	425.8	425.6	425.9	425.7	426.1
16	DEG F	440.2	439.8	439.8	439.5	440.0	439.8	439.9
17	DEG F	447.8	447.6	447.7	447.5	447.9	447.5	447.9
18	DEG F	455.2	455.2	455.4	455.2	455.3	455.1	455.2
19	DEG F	460.7	460.7	461.0	460.8	461.1	460.7	460.9
20	DEG F	464.1	463.8	464.2	464.0	464.2	463.9	464.1
AT DIE	DEG F	465.1	465.3	466.4	464.8	465.8	465.3	465.2

RUN NO. 4 RPM INCREASED FROM 75 TO 90

STYRON 47C

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-450.0

RPM- 75.

		MINUTES AFTER CHANGE											
POSITION	UNITS	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
1	DEG F	385.9	385.1	390.5	391.2	392.0	391.9	392.7	392.5	393.0	393.0	393.0	393.2
2	DEG F	397.6	399.9	402.1	401.8	402.3	402.7	403.1	402.7	403.2	403.2	403.1	403.5
3	DEG F	405.0	404.5	406.4	406.0	406.2	405.2	405.4	405.8	405.0	406.9	406.5	406.4
4	DEG F	427.6	430.2	431.0	431.6	431.7	432.0	431.4	431.5	432.6	431.2	431.5	430.9
5	DEG F	441.6	442.1	442.2	442.5	442.9	443.1	442.3	443.1	443.3	443.2	443.3	443.2
6	DEG F	464.6	464.7	465.2	465.0	465.7	465.6	465.3	466.0	465.9	465.6	466.0	465.5
7	PSI	1119.	1113.	1127.	1137.	1121.	1109.	1123.	1105.	1099.	1092.	1103.	1099.
8	DEG F	459.9	459.9	461.2	461.1	460.6	462.2	461.2	462.2	462.9	460.1	461.5	461.7
9	DEG F	318.5	322.3	324.0	325.0	325.7	326.1	326.8	326.9	327.5	327.4	327.6	327.6
10	DEG F	359.7	362.4	363.9	364.7	365.4	365.5	365.9	365.8	366.3	366.0	366.1	366.0
11	DEG F	354.8	357.2	358.4	359.1	359.9	359.9	360.6	360.5	361.1	360.7	360.7	360.5
12	DEG F	400.6	402.6	403.9	404.7	405.4	405.8	406.2	406.1	406.5	406.5	406.8	406.8
13	DEG F	394.2	395.6	396.4	396.8	397.4	398.1	398.4	397.8	398.6	398.5	399.0	398.7
14	DEG F	404.6	406.2	406.8	407.4	407.9	407.9	408.4	408.3	408.9	408.6	409.0	408.9
15	DEG F	423.9	424.5	424.9	425.1	425.3	425.2	425.4	425.2	425.6	425.4	425.3	425.0
16	DEG F	437.7	438.8	439.2	439.6	439.9	439.7	439.9	439.8	440.0	439.7	439.6	439.2
17	DEG F	447.2	448.3	448.8	449.2	449.3	449.4	449.6	449.5	449.9	449.5	449.5	449.1
18	DEG F	468.4	468.6	468.4	468.5	468.8	468.9	469.3	469.2	469.4	469.2	469.4	469.3
19	DEG F	476.8	477.1	477.1	477.3	477.5	477.6	478.0	477.9	478.1	477.7	478.0	477.8
20	DEG F	474.9	475.4	475.7	475.9	476.1	476.2	476.5	476.6	476.8	476.6	477.0	476.7
AT DIE	DEG F	470.0	467.2	467.7	467.1	468.3	467.1	468.5	467.5	468.6	468.2	467.2	468.0

		MINUTES AFTER CHANGE											
		0.0	0.125	0.375	0.625	0.875	1.125	1.375	1.88	2.50	3.50	5.50	
FLOWRATE	LB/HR	145.7	166.8	173.0	177.0	173.7	176.4	173.0	172.2	173.0	173.0	173.0	

RUN NO. 4 (CONTINUED)

		MINUTES AFTER CHANGE						
POSITION	UNITS	12.0	13.0	14.0	15.0	16.0	17.0	18.0
1	DEG F	393.2	393.5	393.2	393.4	393.2	393.3	393.3
2	DEG F	403.5	403.2	402.8	403.4	403.4	402.3	402.6
3	DEG F	407.2	406.2	407.1	406.6	407.3	406.8	406.7
4	DEG F	430.8	431.5	432.0	431.7	432.6	432.4	432.6
5	DEG F	442.9	443.3	443.2	443.2	443.2	443.8	443.8
6	DEG F	465.5	465.9	465.2	465.7	465.7	466.0	465.6
7	PSI	1095.	1110.	1125.	1120.	1116.	1112.	1108.
8	DEG F	461.4	462.3	462.0	461.1	461.6	462.2	461.5
9	DEG F	328.0	328.2	328.4	328.6	328.7	329.1	329.0
10	DEG F	366.2	366.2	366.4	366.5	366.3	366.7	366.5
11	DEG F	360.9	360.9	361.1	361.0	361.0	361.2	361.2
12	DEG F	406.5	406.8	406.8	406.8	406.6	406.9	406.8
13	DEG F	399.0	398.6	398.4	398.6	398.0	398.5	398.4
14	DEG F	409.1	409.0	409.0	408.9	408.6	408.7	408.7
15	DEG F	425.2	425.4	425.6	425.7	426.1	426.7	426.8
16	DEG F	439.5	439.5	439.7	440.1	440.5	441.3	441.5
17	DEG F	449.4	449.4	449.7	449.8	450.1	450.6	451.0
18	DEG F	469.3	469.0	469.1	469.1	469.1	469.2	468.9
19	DEG F	477.9	477.7	477.6	477.6	477.6	477.7	477.5
20	DEG F	476.5	476.8	476.8	476.7	476.6	476.7	476.6
AT DIE	DEG F	467.7	467.6	467.3	468.2	467.5	468.4	468.0

RUN NO. 5 ZONE 3 TEMPERATURE INCREASED FROM 430 TO 450

STYRON 470

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-430.0 ZONE 4-450.0

RPM- 90.

		MINUTES AFTER CHANGE											
POSITION	UNITS	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
1	DEG F	393.9	393.9	393.9	394.1	393.8	394.1	393.9	394.1	393.6	393.9	393.7	393.8
2	DEG F	403.2	401.8	402.5	402.8	402.8	403.0	402.3	402.1	401.9	402.4	402.5	402.4
3	DEG F	404.9	403.7	406.6	406.1	406.6	406.2	406.5	407.1	406.8	408.0	406.5	406.2
4	DEG F	424.2	426.9	428.0	430.3	432.4	432.4	432.8	433.7	432.8	432.0	433.0	432.1
5	DEG F	437.9	438.0	439.0	440.3	441.2	442.3	442.5	442.9	442.9	443.2	442.9	443.3
6	DEG F	464.4	464.5	464.8	465.1	464.9	465.5	465.3	465.7	465.0	465.5	464.5	464.8
7	PSI	1120.	1129.	1111.	1117.	1113.	1109.	1121.	1095.	1121.	1112.	1112.	1121.
8	DEG F	460.1	461.1	461.7	462.1	461.1	460.9	462.4	461.4	460.5	462.2	462.5	462.3
9	DEG F	330.6	330.3	330.2	330.3	330.3	330.5	330.4	330.6	330.4	330.6	330.3	330.4
10	DEG F	368.6	368.3	368.3	368.3	368.3	368.4	368.4	368.7	368.4	368.7	368.3	368.4
11	DEG F	363.0	362.7	362.6	362.5	362.7	362.8	362.6	363.2	362.8	363.1	362.6	362.7
12	DEG F	406.9	406.8	406.8	406.9	406.7	406.6	406.5	406.6	406.5	406.7	406.6	406.3
13	DEG F	397.6	397.3	397.7	397.7	397.5	397.4	397.3	397.2	397.1	397.6	397.4	397.8
14	DEG F	407.6	407.2	407.6	407.9	408.0	408.0	407.8	408.0	407.8	408.2	407.9	408.4
15	DEG F	418.5	420.7	424.6	426.4	426.7	426.7	426.5	426.9	426.3	426.6	426.4	426.5
16	DEG F	430.7	433.0	437.1	439.4	440.2	440.7	440.9	441.3	441.0	441.1	440.8	441.0
17	DEG F	441.3	442.7	446.1	447.9	448.9	449.6	450.0	450.4	450.2	450.6	450.4	450.6
18	DEG F	466.9	466.8	467.3	467.8	468.2	468.4	468.4	468.7	468.4	468.7	468.3	468.4
19	DEG F	476.8	476.7	476.9	477.2	477.4	477.5	477.4	477.4	477.0	477.2	477.1	477.4
20	DEG F	476.2	475.9	475.9	476.3	476.5	476.6	476.6	476.8	476.6	476.6	476.5	476.6
AT DIE	DEG F	466.5	465.9	467.6	467.0	467.4	468.0	468.0	468.1	468.1	468.6	467.7	467.8

		MINUTES AFTER CHANGE									
		0.0	0.500	1.500	2.500	3.500	4.500	5.500	7.50	9.50	11.50
FLOWRATE	LB/HR	172.2	173.2	174.0	173.1	173.5	172.0	172.1	172.0	172.2	173.5

RUN NO. 6 ZONE 1 TEMPERATURE DECREASED FROM 320 TO 300

STYRON 470

TEMPERATURE SETTING ZONE 1-320.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-450.0

RPM- 90.

		MINUTES AFTER CHANGE									
POSITION	UNITS	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
1	DEG F	398.7	398.5	397.0	395.9	395.2	395.2	394.6	394.5	394.2	394.3
2	DEG F	402.9	402.8	402.8	403.2	403.3	403.5	402.5	403.2	402.9	403.3
3	DEG F	406.9	406.0	406.1	406.4	406.3	407.1	405.9	405.7	407.7	406.5
4	DEG F	432.9	434.4	433.5	433.8	433.6	432.5	432.6	433.1	433.0	433.0
5	DEG F	444.3	444.5	444.0	444.4	444.4	444.6	444.2	444.6	444.2	444.6
6	DEG F	466.1	465.8	465.8	465.9	465.6	466.0	465.4	465.7	465.7	465.8
7	PSI	1118.	1105.	1124.	1112.	1121.	1096.	1109.	1118.	1102.	1118.
8	DEG F	462.4	462.6	463.1	462.2	463.3	461.8	462.1	461.7	462.2	462.9
9	DEG F	337.1	335.8	333.3	332.2	331.8	331.8	331.5	331.6	331.1	331.3
10	DEG F	381.3	377.6	372.1	370.1	369.3	369.2	368.9	369.1	368.7	368.9
11	DEG F	373.8	370.6	366.6	364.7	364.1	363.7	363.2	363.7	363.1	363.2
12	DEG F	410.0	409.9	409.2	408.5	408.0	407.8	407.4	407.4	407.1	407.2
13	DEG F	397.8	398.1	398.4	398.2	398.1	398.6	397.9	398.2	397.7	398.0
14	DEG F	408.6	408.6	408.8	408.6	408.8	409.0	408.4	408.5	408.2	408.3
15	DEG F	427.1	426.9	427.0	427.0	427.2	427.3	426.9	427.1	426.8	426.9
16	DEG F	442.0	442.0	442.1	442.2	442.1	442.2	442.0	442.2	442.1	442.2
17	DEG F	451.4	451.3	451.5	451.4	451.6	451.6	451.6	451.9	451.6	452.0
18	DEG F	469.4	469.3	469.3	469.4	469.3	469.2	468.9	469.0	468.8	469.1
19	DEG F	477.8	477.7	477.8	477.7	477.7	477.5	477.3	477.5	477.2	477.5
20	DEG F	477.2	477.3	477.2	477.1	477.1	477.0	476.8	476.9	476.5	476.8
AT DIE	DEG F	468.9	469.0	468.7	468.1	468.8	468.1	468.2	468.1	467.9	468.2

		MINUTES AFTER CHANGE						
		0.0	0.500	1.500	2.500	3.500	4.500	6.500
FLOWRATE	LB/HR	172.0	172.0	171.8	173.9	174.0	174.0	173.1

RUN NO. 7 ZONE 1 TEMPERATURE INCREASED FROM 300 TO 320

STYRON 470

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-450.0

RPM- 90.

POSITION	UNITS	MINUTES AFTER CHANGE											
		0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
1	DEG F	393.2	393.9	395.7	396.7	396.9	397.9	397.9	398.3	398.3	398.6	398.6	398.6
2	DEG F	402.7	403.5	403.1	403.1	402.5	403.2	403.0	403.6	403.0	402.8	402.9	402.2
3	DEG F	407.1	407.1	406.8	408.4	406.7	407.1	407.5	406.9	407.3	407.0	407.1	407.1
4	DEG F	434.5	432.7	432.8	432.8	433.9	433.6	433.3	433.9	433.2	433.7	433.2	434.6
5	DEG F	444.1	444.3	444.1	443.9	443.7	444.1	444.0	444.2	444.1	444.2	444.1	444.1
6	DEG F	465.6	465.9	464.8	464.6	464.5	465.3	465.1	465.4	465.2	465.1	465.7	466.1
7	PSI	1120.	1119.	1105.	1096.	1105.	1111.	1081.	1100.	1115.	1099.	1095.	1111.
8	DEG F	462.0	462.3	462.4	462.3	461.7	461.3	461.7	462.2	462.9	461.6	462.1	462.1
9	DEG F	329.1	331.2	332.4	333.1	334.1	335.2	335.6	336.3	336.3	336.7	336.4	336.6
10	DEG F	366.1	373.9	375.2	376.0	377.5	379.1	379.8	380.5	380.5	380.9	380.6	380.9
11	DEG F	360.9	374.4	368.3	369.6	371.0	372.1	372.6	373.3	373.3	373.6	373.2	373.4
12	DEG F	406.7	406.9	408.0	408.7	408.9	409.3	409.3	409.8	409.8	410.1	409.9	410.0
13	DEG F	398.2	397.6	398.0	398.3	397.8	397.9	397.4	398.2	398.0	398.4	397.9	398.0
14	DEG F	409.1	408.9	408.8	408.9	408.7	408.7	408.7	408.9	409.0	409.0	408.7	408.9
15	DEG F	427.2	427.2	427.0	427.0	426.8	427.0	426.8	427.3	427.0	427.3	426.9	427.0
16	DEG F	442.0	442.1	442.1	442.2	442.0	442.2	441.9	442.2	441.9	442.1	441.8	441.9
17	DEG F	451.5	451.1	451.6	451.5	451.4	451.5	451.2	451.5	451.2	451.5	451.1	451.5
18	DEG F	469.3	469.0	468.2	468.0	468.4	469.1	469.0	469.2	469.0	469.3	469.1	469.2
19	DEG F	477.5	477.5	476.5	476.4	476.6	477.1	477.2	477.5	477.3	477.7	477.5	477.7
20	DEG F	476.8	477.0	476.3	476.2	476.1	476.4	476.4	476.8	476.7	476.9	476.8	477.1
AT DIE	DEG F	467.9	468.1	468.5	468.9	468.6	468.8	468.1	469.2	468.4	469.3	468.8	469.2

FLOWRATE LB/HR	MINUTES AFTER CHANGE				
	0.0	0.500	1.500	3.500	5.500
	173.5	173.6	173.6	173.3	173.5

RUN NO. 8 ZONE 2 TEMPERATURE INCREASED FROM 330 TO 350

STYRON 470

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-330.0 ZONE 3-450.0 ZONE 4-450.0

RPM- 90.

		MINUTES AFTER CHANGE											
POSITION	UNITS	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
1	DEG F	389.3	389.6	390.2	391.3	391.6	392.1	392.5	392.7	392.8	392.8	393.0	392.9
2	DEG F	396.1	397.0	400.0	401.8	402.0	402.0	402.5	403.0	402.5	402.8	402.5	402.8
3	DEG F	403.5	403.7	405.3	407.1	405.8	406.7	406.5	405.7	405.4	405.3	405.2	401.3
4	DEG F	433.1	433.6	431.7	433.2	432.8	432.4	433.3	432.6	432.9	434.0	433.8	433.4
5	DEG F	444.1	444.1	443.5	443.4	443.4	443.7	443.9	444.1	444.2	444.1	444.1	444.3
6	DEG F	464.9	464.9	463.8	464.3	463.8	464.2	465.0	465.5	465.8	465.4	465.7	465.4
7	PSI	1116.	1131.	1125.	1107.	1113.	1119.	1122.	1111.	1126.	1112.	1125.	1105.
8	DEG F	460.9	461.0	461.2	461.1	461.5	460.9	461.1	461.2	461.2	460.8	461.7	461.9
9	DEG F	326.7	327.2	326.9	327.3	327.2	327.5	327.5	327.7	327.7	327.9	328.1	328.1
10	DEG F	365.9	366.0	365.8	366.3	366.1	366.2	366.2	366.2	366.2	366.3	366.4	366.3
11	DEG F	360.1	360.6	360.1	360.4	360.3	360.3	360.5	360.6	360.7	360.8	360.8	361.0
12	DEG F	398.1	401.2	401.8	403.4	404.3	405.3	405.5	405.9	405.9	406.1	406.2	406.2
13	DEG F	387.0	402.2	394.9	396.1	396.2	397.3	397.3	397.6	397.2	397.6	397.7	397.5
14	DEG F	399.9	404.4	404.8	407.0	407.2	408.2	408.1	408.2	408.3	408.7	408.5	409.0
15	DEG F	425.3	426.5	425.9	426.5	426.3	426.7	426.3	426.6	426.5	426.8	426.8	427.2
16	DEG F	442.3	442.6	442.0	442.1	441.8	441.9	441.6	441.7	441.9	441.9	442.1	442.0
17	DEG F	452.1	451.9	451.6	451.6	451.2	451.4	451.1	451.4	451.3	451.5	451.5	451.6
18	DEG F	468.3	468.3	467.1	467.3	467.6	468.5	468.7	469.3	469.1	469.2	469.0	469.1
19	DEG F	476.8	476.8	475.5	475.8	475.9	476.8	477.0	477.4	477.4	477.5	477.6	477.5
20	DEG F	475.6	476.7	475.3	475.4	475.3	475.8	475.8	476.1	476.1	476.2	476.3	476.5
AT DIE	DEG F	466.5	466.6	466.9	468.1	467.5	467.6	467.1	468.3	467.5	468.2	467.9	468.4

		MINUTES AFTER CHANGE						
		0.0	0.500	2.000	4.000	6.000	8.000	
FLOWRATE	LB/HR	174.0	174.0	173.5	173.0	173.0	174.5	

RUN NO. 8 (CONTINUED)

POSITION	UNITS	MINUTES AFTER CHANGE	
		12.0	13.0
1	DEG F	393.2	393.1
2	DEG F	403.1	402.9
3	DEG F	406.9	406.9
4	DEG F	432.7	433.4
5	DEG F	444.8	444.2
6	DEG F	465.6	465.6
7	PSI	1120.	1104.
8	DEG F	462.5	461.7
9	DEG F	328.3	328.0
10	DEG F	366.4	366.1
11	DEG F	361.1	360.6
12	DEG F	406.5	406.4
13	DEG F	398.1	398.2
14	DEG F	409.1	408.6
15	DEG F	427.3	427.1
16	DEG F	442.1	441.9
17	DEG F	451.7	451.7
18	DEG F	469.2	469.0
19	DEG F	477.5	477.4
20	DEG F	476.5	476.4
AT DIE	DEG F	467.7	467.5

RUN NO. 9 ZONE 2 TEMPERATURE DECREASED FROM 350 TO 330

STYRON 47C

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-450.0

RPM- 90.

		MINUTES AFTER CHANGE											
POSITION	UNITS	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
1	DEG F	393.3	393.5	392.5	391.5	390.9	390.4	390.1	389.8	389.6	389.2	389.4	389.1
2	DEG F	403.9	403.7	400.0	399.1	398.1	397.5	396.3	396.3	396.1	395.4	395.1	395.2
3	DEG F	405.2	406.5	405.0	404.5	404.7	404.5	403.3	403.4	403.2	402.2	403.1	404.1
4	DEG F	430.0	432.0	430.4	431.4	432.2	432.6	432.7	432.2	432.1	433.7	433.2	433.1
5	DEG F	442.9	443.4	443.2	443.3	443.5	443.5	443.5	443.6	444.0	443.7	444.1	443.7
6	DEG F	465.7	465.9	465.7	465.5	465.6	465.1	465.3	465.1	464.7	464.6	464.5	464.4
7	PSI	1128.	1110.	1121.	1117.	1126.	1131.	1131.	1116.	1118.	1125.	1145.	1135.
8	DEG F	461.6	460.8	460.5	461.0	460.1	459.5	461.4	460.1	460.1	460.5	461.6	460.7
9	DEG F	327.8	327.9	327.5	327.5	327.4	327.4	327.3	327.1	327.1	327.1	327.1	326.5
10	DEG F	366.0	366.1	365.6	365.7	365.6	365.7	365.8	365.7	365.7	365.6	365.7	365.4
11	DEG F	360.7	360.9	360.4	360.4	360.3	360.1	360.2	360.1	360.1	360.0	360.1	359.8
12	DEG F	407.4	405.8	403.6	402.0	400.7	399.8	399.3	398.8	398.6	398.4	398.5	398.1
13	DEG F	399.2	396.9	394.0	392.0	390.3	389.4	388.6	388.0	387.8	387.4	387.5	386.9
14	DEG F	409.0	407.8	405.3	403.9	402.7	402.0	401.2	400.6	400.3	400.2	400.4	400.0
15	DEG F	424.7	425.3	424.8	425.3	425.3	425.5	425.2	425.4	425.2	425.2	425.3	425.3
16	DEG F	439.1	439.7	439.8	440.2	440.7	441.1	441.5	442.0	442.1	442.1	442.2	442.0
17	DEG F	449.2	449.8	449.6	450.3	450.4	450.9	451.2	451.5	451.6	451.8	451.9	451.7
18	DEG F	469.1	469.3	468.8	469.1	468.8	468.7	468.2	468.3	468.2	468.3	468.2	468.1
19	DEG F	477.8	478.1	477.7	477.9	477.5	477.5	477.1	477.0	476.8	476.8	476.8	476.5
20	DEG F	476.7	476.8	476.4	476.7	476.4	476.3	476.0	476.0	476.0	475.7	475.8	475.7
AT DIE	DEG F	467.5	468.0	467.7	466.7	467.3	467.4	467.5	466.9	466.9	467.1	466.8	467.5

RUN NO. 9 (CONTINUED)

POSITION	UNITS	MINUTES AFTER CHANGE						
		12.0	13.0	14.0	15.0	16.0	17.0	18.0
1	DEG F	389.2	389.0	389.2	388.9	389.0	389.2	389.2
2	DEG F	394.9	394.9	395.2	395.1	395.5	395.4	395.8
3	DEG F	403.2	404.0	403.5	402.7	402.4	403.6	403.3
4	DEG F	433.1	432.8	434.2	433.3	433.3	433.0	431.9
5	DEG F	444.0	443.6	443.8	443.9	444.0	443.9	444.1
6	DEG F	464.7	464.6	464.9	464.3	464.5	465.1	465.2
7	PSI	1151.	1134.	1121.	1123.	1116.	1116.	1121.
8	DEG F	460.2	461.5	461.1	460.5	460.0	461.4	461.0
9	DEG F	326.5	326.3	326.5	326.6	326.7	326.7	326.8
10	DEG F	365.6	365.3	365.6	365.7	365.8	365.9	365.9
11	DEG F	359.8	359.5	360.0	359.7	360.2	360.1	360.2
12	DEG F	398.3	397.9	398.0	398.0	398.0	398.1	398.1
13	DEG F	387.6	386.8	387.1	387.0	386.7	386.7	386.9
14	DEG F	400.2	399.7	399.7	399.8	399.7	399.6	399.6
15	DEG F	425.5	425.1	425.5	424.9	425.1	424.9	425.2
16	DEG F	442.3	442.1	442.4	442.0	442.1	442.2	442.4
17	DEG F	452.0	451.8	452.2	451.9	452.0	451.9	452.2
18	DEG F	468.4	468.1	468.4	468.3	468.6	468.5	468.6
19	DEG F	476.8	476.6	477.0	476.8	477.1	476.9	477.0
20	DEG F	475.7	475.5	475.7	475.6	475.7	475.8	475.8
AT DIE	DEG F	467.0	466.2	466.5	467.2	466.6	466.7	466.6

RUN NO. 10 VALVE PARTIALLY CLOSED AND RPM INCREASED FROM 75 TO 90

STYRON 470

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-450.0

RPM- 75.

		MINUTES AFTER CHANGE											
POSITION	UNITS	0.0	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.45
1	PSI	1668.	1668.	1676.	1745.	1907.	1869.	1904.	1885.	1894.	1893.	1858.	1868.
2	DEG F	397.0	397.7	399.0	401.1	401.8	402.8	402.9	403.9	404.2	404.2	403.9	404.8
3	PSI	1813.	2011.	2194.	1991.	2320.	2119.	2291.	2051.	2198.	2384.	2359.	2200.
4	DEG F	413.7	416.4	416.2	422.5	423.9	423.7	419.7	423.1	422.5	419.9	423.4	421.8
5	DEG F	431.0	430.9	431.0	431.4	432.0	432.6	433.0	433.8	434.4	434.9	435.0	435.6
6	DEG F	461.8	462.7	462.3	465.3	465.7	466.1	466.4	467.4	468.3	468.2	469.4	469.9
7	PSI	1141.	1378.	2069.	3145.	2931.	2917.	2927.	2817.	2924.	2782.	2851.	2784.
8	DEG F	446.9	448.2	447.8	450.8	452.9	453.3	455.1	455.2	455.2	456.1	456.7	456.0
9	DEG F	317.8	317.9	319.0	320.4	322.2	324.0	325.7	327.1	328.3	329.1	329.8	330.4
10	DEG F	363.6	363.6	364.2	364.9	365.8	366.7	367.5	368.3	368.8	369.2	369.6	369.9
11	DEG F	357.6	357.5	357.8	358.4	359.3	360.1	360.9	361.7	362.4	363.0	363.3	363.8
12	DEG F	401.6	401.5	402.0	402.5	403.3	403.8	404.6	405.1	405.8	406.2	406.5	406.8
13	DEG F	393.6	393.5	393.8	394.0	394.8	395.2	395.9	396.5	397.3	397.6	397.8	397.9
14	DEG F	402.4	402.4	402.6	403.1	403.8	404.5	405.3	406.0	406.6	407.0	407.4	407.7
15	DEG F	406.2	411.6	411.9	412.3	413.0	413.8	414.5	415.3	415.9	416.4	416.8	417.3
16	DEG F	420.1	420.3	420.6	421.1	421.8	422.3	422.9	423.4	423.8	424.2	424.6	424.9
17	DEG F	429.7	429.7	429.8	430.2	430.7	431.2	431.8	432.3	433.0	433.3	433.6	433.9
18	DEG F	464.7	464.7	464.6	464.7	465.1	465.7	466.3	467.0	467.5	467.9	468.3	468.6
19	DEG F	475.2	475.2	475.2	475.4	475.8	476.5	477.1	477.7	478.2	478.6	478.8	479.0
20	DEG F	466.2	466.1	466.2	466.5	467.2	467.8	468.5	469.2	469.9	470.4	470.9	471.3

		MINUTES AFTER CHANGE									
		0.0	0.500	1.500	2.500	3.500	4.500	7.500	10.50	12.50	
FLOWRATE	LB/HR	146.0	145.0	143.0	143.5	144.2	145.0	145.0	145.0	146.0	

RUN NO.10 (CONTINUED)

POSITION	UNITS	MINUTES AFTER CHANGE									
		3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00
1	PSI	1854.	1852.	1845.	1873.	1837.	1869.	1862.	1870.	1869.	1849.
2	DEG F	405.0	405.0	406.8	406.9	407.4	408.3	407.9	407.8	407.8	406.8
3	PSI	2240.	2325.	2300.	2274.	2200.	2172.	2256.	2228.	2245.	2273.
4	DEG F	421.2	422.8	422.5	424.2	423.4	424.3	424.4	425.2	425.4	416.3
5	DEG F	436.1	437.6	438.5	439.3	439.6	440.4	440.7	441.3	441.3	441.6
6	DEG F	469.5	470.2	471.9	472.8	471.9	472.4	471.4	472.5	471.9	471.5
7	PSI	2862.	2827.	2826.	2804.	2804.	2802.	2791.	2787.	2782.	2799.
8	DEG F	457.1	457.4	460.1	460.2	461.5	462.0	462.2	463.7	462.9	463.6
9	DEG F	331.3	333.2	334.0	334.8	335.2	335.9	336.1	336.6	336.7	337.0
10	DEG F	370.5	371.5	371.7	372.1	372.0	372.4	372.2	372.4	372.2	372.3
11	DEG F	364.2	365.6	365.8	366.4	366.3	366.7	366.7	366.8	366.6	366.8
12	DEG F	407.4	408.6	409.2	409.8	410.0	410.1	410.2	410.4	410.4	410.4
13	DEG F	398.6	399.2	399.7	400.5	400.9	400.8	400.8	400.8	401.1	401.0
14	DEG F	408.3	409.6	410.1	410.9	411.1	411.5	411.5	411.7	411.6	411.8
15	DEG F	418.0	419.6	420.5	421.1	421.4	421.8	422.1	422.6	422.9	423.0
16	DEG F	425.4	427.1	427.9	428.6	428.8	429.5	430.1	430.9	431.2	431.5
17	DEG F	434.7	436.0	437.1	437.7	438.2	438.9	439.6	440.2	440.4	440.7
18	DEG F	469.1	470.3	470.8	471.1	471.2	471.6	471.7	471.8	471.7	471.8
19	DEG F	479.7	480.8	481.2	481.6	481.7	481.9	481.9	482.1	482.0	482.1
20	DEG F	472.2	473.7	474.5	475.4	475.7	476.2	476.5	476.8	476.8	477.2

RUN NO.11 VALVE PARTIALLY CLOSED

STYRON 470

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-450.0

RPM- 90.

		MINUTES AFTER CHANGE											
POSITION	UNITS	0.0	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.45
1	PSI	1649.	1654.	1656.	1695.	1744.	1819.	1860.	1823.	1845.	1852.	1888.	1817.
2	DEG F	402.5	402.1	401.7	402.2	402.6	403.1	404.0	404.5	404.2	404.3	404.9	405.1
3	PSI	1766.	1704.	1882.	2013.	1908.	2112.	2060.	2096.	2187.	2207.	2257.	2009.
4	DEG F	418.4	425.5	422.3	428.4	428.7	425.4	425.2	426.2	428.5	427.5	428.6	427.0
5	DEG F	438.3	438.3	438.2	438.4	438.5	438.5	438.7	438.9	439.2	439.7	440.1	440.4
6	DEG F	463.7	463.5	463.6	464.1	464.4	463.8	466.9	466.7	466.6	467.1	466.5	468.6
7	PSI	980.	1053.	1152.	1291.	1705.	2499.	2461.	2466.	2397.	2367.	2419.	2361.
8	DEG F	447.7	447.3	448.5	447.9	449.0	450.3	452.2	452.8	452.3	453.7	454.2	453.7
9	DEG F	328.5	328.6	328.8	329.0	329.1	329.4	329.8	330.6	331.3	332.0	332.7	333.1
10	DEG F	370.9	370.9	371.0	371.0	371.0	371.1	371.1	371.2	371.4	371.7	372.0	372.1
11	DEG F	364.1	364.0	364.2	364.4	364.2	364.3	364.3	364.5	364.6	365.0	365.0	365.7
12	DEG F	407.5	407.3	407.4	407.4	407.5	407.5	407.6	407.7	407.8	408.0	408.2	408.3
13	DEG F	396.8	396.7	396.7	397.2	397.0	396.9	397.4	397.4	397.3	397.6	397.8	398.2
14	DEG F	406.4	406.5	406.5	406.6	406.7	406.8	406.9	407.2	407.5	407.7	408.1	408.3
15	DEG F	420.6	420.8	420.9	421.0	421.0	421.2	421.5	421.9	422.5	423.0	423.6	423.9
16	DEG F	433.2	433.2	433.2	433.5	433.6	433.7	433.9	434.1	434.4	434.8	435.2	435.6
17	DEG F	441.6	441.6	441.8	441.9	441.9	441.8	441.9	442.0	442.3	442.6	442.8	443.1
18	DEG F	466.5	466.6	466.6	466.7	466.5	466.7	466.8	467.2	467.7	468.1	468.6	469.0
19	DEG F	476.0	476.0	476.1	476.2	476.1	476.1	476.4	476.8	477.1	477.5	477.9	478.3
20	DEG F	466.9	467.0	467.1	467.2	467.3	467.4	467.6	468.0	468.5	468.9	469.4	469.7

		MINUTES AFTER CHANGE									
		0.0	0.125	0.875	1.500	2.500	3.500	4.500	5.50	6.50	7.50
FLOWRATE	LB/HR	173.0	167.0	157.5	153.0	152.0	154.5	155.0	153.2	155.2	154.0

RUN NO.11 (CONTINUED)

POSITION	UNITS	MINUTES AFTER CHANGE									
		3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00
1	PSI	1824.	1794.	1832.	1810.	1838.	1821.	1810.	1837.	1804.	1783.
2	DEG F	404.5	405.0	405.2	406.1	405.7	405.7	405.5	405.9	405.7	404.6
3	PSI	2159.	2187.	2144.	2158.	2209.	2082.	2216.	2131.	2056.	2197.
4	DEG F	427.3	428.7	428.8	427.5	429.5	428.9	428.6	426.6	428.3	427.8
5	DEG F	440.8	441.7	442.4	443.0	443.0	443.5	443.5	443.6	443.5	443.3
6	DEG F	467.6	469.7	470.9	469.8	471.5	470.1	470.9	470.0	470.5	469.7
7	PSI	2355.	2336.	2353.	2320.	2320.	2320.	2306.	2332.	2290.	2290.
8	DEG F	454.2	455.6	454.9	456.0	456.3	456.7	457.1	458.5	458.9	457.4
9	DEG F	333.4	334.5	335.1	335.5	335.8	336.1	336.2	336.7	336.7	337.1
10	DEG F	372.3	372.6	372.8	373.0	373.0	373.1	373.0	373.2	373.1	373.0
11	DEG F	365.7	366.4	366.5	366.6	366.6	367.0	366.7	366.9	366.7	366.8
12	DEG F	408.4	408.8	409.1	409.2	409.3	409.4	409.4	409.4	409.4	409.4
13	DEG F	398.1	398.6	399.0	399.0	399.0	399.1	399.2	399.1	398.8	399.2
14	DEG F	408.5	409.0	409.2	409.6	409.7	410.0	409.7	410.0	409.9	410.0
15	DEG F	424.2	425.3	425.6	425.9	425.6	426.0	425.6	425.7	425.6	425.7
16	DEG F	435.9	436.8	437.2	437.5	437.6	437.7	437.5	437.5	437.4	437.4
17	DEG F	443.3	444.1	444.7	445.2	445.1	445.5	445.2	445.4	445.2	445.4
18	DEG F	469.1	470.2	470.6	471.2	471.1	471.5	471.2	471.3	470.8	470.9
19	DEG F	478.6	479.5	479.9	480.4	480.4	480.7	480.5	480.6	480.3	480.4
20	DEG F	470.3	471.3	472.0	472.7	473.0	473.4	473.5	473.6	473.6	473.7

RUN NO.12 VALVE OPENED

STYRON 47C

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-450.0

RPM- 90.

		MINUTES AFTER CHANGE											
POSITION	UNITS	0.0	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.45
1	DEG F	396.5	396.5	396.3	396.0	395.9	395.9	395.9	395.7	395.6	395.4	395.3	395.2
2	DEG F	405.5	404.2	403.2	403.1	403.5	403.5	403.9	403.3	402.5	402.3	402.1	402.4
3	DEG F	416.2	416.9	417.3	415.4	418.2	414.5	416.2	414.8	416.4	416.1	415.0	414.4
4	PSI	1719.	1438.	1313.	1297.	1251.	1242.	1242.	1271.	1194.	1312.	1275.	1165.
5	DEG F	445.1	444.8	444.7	444.3	444.0	443.7	443.4	443.1	442.9	442.7	442.4	442.2
6	PSI	1948.	1315.	1122.	1089.	1068.	1062.	1066.	1081.	1084.	1095.	1085.	1077.
7	PSI	1958.	1047.	937.	876.	899.	901.	901.	911.	914.	915.	898.	896.
8	DEG F	458.3	456.7	455.0	454.4	453.7	453.3	454.0	453.4	453.4	452.3	452.8	452.2
9	DEG F	335.0	334.7	334.2	333.6	333.0	332.6	332.1	331.8	331.4	330.9	330.7	330.3
10	DEG F	373.4	373.2	372.9	372.8	372.6	372.5	372.4	372.3	372.2	371.9	371.6	371.6
11	DEG F	366.7	366.2	366.3	366.1	365.7	365.8	365.7	365.4	365.5	365.1	365.1	365.0
12	DEG F	409.4	409.3	409.2	409.0	408.9	408.9	408.8	408.6	408.4	408.3	408.2	408.2
13	DEG F	399.3	399.1	399.3	398.7	398.7	398.6	398.4	398.2	398.1	397.9	397.6	397.6
14	DEG F	409.7	409.6	409.3	409.0	408.7	408.6	408.6	408.5	408.2	407.9	407.8	407.6
15	DEG F	425.6	427.5	427.0	426.5	426.1	425.8	425.5	425.2	424.8	424.4	424.0	423.8
16	DEG F	440.8	440.6	440.2	439.8	439.4	439.0	438.9	438.6	438.4	438.0	437.8	437.6
17	DEG F	448.5	448.3	448.0	447.8	447.6	447.5	447.5	447.4	447.2	446.8	446.4	446.2
18	DEG F	471.5	471.4	471.2	470.9	470.7	470.5	470.2	470.0	469.8	469.4	469.1	469.0
19	DEG F	480.1	480.1	479.8	479.5	479.3	479.0	478.8	478.7	478.6	478.2	477.9	477.7
20	DEG F	474.1	474.0	473.8	473.5	473.3	473.0	472.8	472.5	472.4	472.0	471.7	471.5

		MINUTES AFTER CHANGE										
		0.0	0.125	0.445	0.625	1.500	2.500	3.500	4.50	5.50	6.50	7.50
FLOWRATE	LB/HR	160.7	166.2	178.0	175.0	176.0	177.0	174.0	175.5	175.5	175.5	174.8

RUN NO.12 (CONTINUED)

POSITION	UNITS	MINUTES AFTER CHANGE								
		3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00
1	DEG F	395.2	395.1	394.7	394.8	394.5	394.8	394.7	394.9	394.7
2	DEG F	401.9	402.9	402.6	402.5	402.4	402.0	402.4	402.2	402.5
3	DEG F	411.6	412.9	412.1	412.9	412.3	411.7	411.7	411.1	411.7
4	PSI	1239.	1245.	1237.	1252.	1233.	1229.	1250.	1254.	1250.
5	DEG F	441.9	441.1	440.5	440.7	440.5	440.5	440.1	440.1	439.8
6	PSI	1074.	1094.	1092.	1102.	1095.	1098.	1076.	1078.	1100.
7	PSI	930.	914.	916.	920.	926.	934.	937.	919.	918.
8	DEG F	451.2	451.1	452.1	450.7	451.5	451.1	451.4	450.7	450.8
9	DEG F	330.0	325.5	329.1	329.0	328.6	328.7	328.7	328.8	328.6
10	DEG F	371.3	371.2	371.2	371.3	371.1	371.2	371.3	371.3	371.2
11	DEG F	364.7	364.5	364.5	364.6	364.2	364.2	364.5	364.6	364.3
12	DEG F	408.0	407.9	407.8	407.7	407.7	407.7	407.6	407.7	407.7
13	DEG F	397.3	397.4	397.3	397.2	397.4	397.2	397.5	397.4	397.2
14	DEG F	407.4	407.3	407.3	407.1	407.0	407.0	406.9	407.0	406.8
15	DEG F	423.4	422.9	422.4	422.4	422.4	422.4	422.5	422.4	422.2
16	DEG F	437.1	436.5	435.8	435.8	435.9	435.9	435.7	435.7	435.5
17	DEG F	446.0	445.2	444.8	444.6	444.6	444.5	444.3	444.2	444.1
18	DEG F	468.6	468.0	467.9	467.9	467.9	467.8	467.8	467.6	467.6
19	DEG F	477.5	477.1	476.9	476.9	477.0	477.0	476.9	476.8	476.7
20	DEG F	471.1	470.5	470.2	469.5	469.6	469.7	469.6	469.5	469.2

RUN NO.13 ZONE 4 TEMPERATURE INCREASED FROM 430 TO 450

STYRON 470

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-430.0

RPM- 90.

		MINUTES AFTER CHANGE											
POSITION	UNITS	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
1	DEG F	393.6	393.5	393.5	393.4	393.6	393.6	393.6	393.6	393.7	393.7	393.6	393.4
2	DEG F	404.0	403.1	403.0	402.7	403.9	404.0	403.1	403.6	404.2	403.9	403.8	402.9
3	DEG F	406.9	406.6	406.5	407.4	407.0	406.6	407.4	406.6	406.9	407.3	407.1	405.9
4	DEG F	431.8	432.7	432.0	430.8	432.2	432.2	433.1	432.0	431.0	432.4	430.5	431.4
5	DEG F	437.6	438.1	440.4	442.1	443.4	443.7	444.0	444.0	444.1	444.0	443.7	443.9
6	DEG F	451.4	452.9	459.9	464.1	466.5	466.8	466.6	466.4	466.4	466.2	466.4	465.7
7	PSI	1141.	1144.	1151.	1130.	1124.	1114.	1109.	1110.	1136.	1128.	1127.	1122.
8	DEG F	453.9	454.7	455.2	457.7	458.4	460.2	460.7	460.1	460.3	461.4	461.7	461.1
9	DEG F	329.4	329.2	329.3	328.9	329.2	328.9	328.9	328.7	328.7	328.5	328.4	328.3
10	DEG F	366.3	366.2	366.2	366.0	366.4	366.1	366.3	366.1	366.1	366.1	366.1	366.1
11	DEG F	360.9	360.9	361.1	360.7	361.1	360.9	361.1	360.7	360.7	360.6	360.7	360.7
12	DEG F	407.1	407.0	407.2	407.0	407.2	407.2	407.4	407.4	407.5	407.4	407.4	407.4
13	DEG F	398.3	398.4	398.7	398.4	398.8	398.8	399.1	399.2	398.9	399.0	399.3	399.0
14	DEG F	409.1	408.9	409.1	408.9	409.1	409.0	409.4	409.2	409.5	409.2	409.2	409.1
15	DEG F	425.9	425.8	426.0	425.8	426.0	425.8	426.1	425.8	426.1	425.6	425.6	425.2
16	DEG F	440.2	440.0	440.2	440.1	440.4	440.2	440.6	440.5	440.4	440.2	440.1	439.9
17	DEG F	448.0	448.0	448.6	449.0	449.8	449.8	450.2	450.1	450.3	450.1	450.3	450.0
18	DEG F	455.0	461.1	468.1	470.8	471.8	471.1	470.8	470.2	470.2	469.8	469.7	469.3
19	DEG F	460.7	466.9	474.0	477.2	478.7	478.6	478.7	478.3	478.4	478.1	478.1	477.9
20	DEG F	464.1	466.0	469.9	472.6	474.3	475.3	476.1	475.9	476.3	476.4	476.6	476.6
AT DIE	DEG F	465.4	465.8	466.4	466.6	467.1	467.7	468.0	467.9	468.1	467.4	467.5	467.7

RUN NO.13 (CONTINUED)

POSITION	UNITS	MINUTES AFTER CHANGE		
		12.0	13.0	14.0
1	DEG F	393.5	393.7	393.6
2	DEG F	403.8	403.6	403.7
3	DEG F	406.8	406.5	406.6
4	DEG F	431.6	431.7	431.5
5	DEG F	443.4	443.6	443.3
6	DEG F	466.0	466.0	465.9
7	PSI	1106.	1105.	1099.
8	DEG F	461.3	461.6	461.3
9	DEG F	328.1	328.2	327.9
10	DEG F	366.0	366.2	366.1
11	DEG F	360.8	360.9	360.6
12	DEG F	407.3	407.5	407.3
13	DEG F	399.0	399.1	399.0
14	DEG F	409.1	409.2	408.9
15	DEG F	425.0	425.3	425.1
16	DEG F	439.7	439.9	439.7
17	DEG F	449.8	449.8	449.7
18	DEG F	469.2	469.2	469.1
19	DEG F	477.8	477.9	477.8
20	DEG F	476.5	476.6	476.5
AT DIE	DEG F	467.5	467.0	467.0

RUN NC.14 ZONE 3 TEMPERATURE DECREASED FROM 450 TO 430

STYRON 47C

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-450.0

RPM- 90.

		MINUTES AFTER CHANGE											
POSITION	UNITS	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
1	DEG F	394.2	394.0	394.0	394.1	394.0	394.2	393.9	394.0	394.0	394.2	393.8	394.1
2	DEG F	403.1	402.7	401.8	402.8	402.7	403.1	402.1	402.7	403.1	403.2	401.5	403.4
3	DEG F	406.1	406.5	406.4	405.8	404.4	405.6	404.1	405.7	406.5	405.7	403.9	406.0
4	DEG F	433.8	431.5	429.3	427.6	428.2	425.5	425.3	426.7	426.7	427.5	426.7	425.8
5	DEG F	444.5	443.4	442.0	441.2	440.9	439.2	438.4	438.3	438.3	438.5	438.2	438.3
6	DEG F	465.3	464.9	465.3	464.9	464.8	464.6	464.5	465.0	464.6	465.0	464.8	465.1
7	PSI	1109.	1111.	1121.	1136.	1112.	1136.	1121.	1129.	1131.	1114.	1137.	1114.
8	DEG F	462.3	462.0	462.7	461.5	461.4	460.7	461.7	461.7	461.9	461.7	460.6	461.7
9	DEG F	331.0	330.8	330.9	330.6	330.8	330.6	330.6	330.5	330.3	330.4	330.3	330.5
10	DEG F	368.7	368.7	368.8	368.5	368.5	368.4	368.3	368.3	368.2	368.3	368.3	368.5
11	DEG F	363.1	362.8	363.1	362.6	363.0	362.7	362.7	362.6	362.3	362.5	362.4	362.7
12	DEG F	407.0	406.9	407.0	406.9	407.1	406.9	407.1	407.2	407.1	407.1	406.9	407.2
13	DEG F	398.0	397.7	397.7	397.7	398.5	397.8	398.0	398.1	397.9	397.8	397.8	398.3
14	DEG F	408.5	408.0	408.3	407.8	408.3	407.9	408.4	408.0	408.5	408.1	407.7	407.9
15	DEG F	427.0	425.0	423.8	422.6	421.9	420.9	421.3	421.5	421.5	420.7	419.9	419.4
16	DEG F	442.0	437.5	435.7	435.3	432.8	431.3	431.8	432.8	432.9	432.4	431.8	431.5
17	DEG F	451.0	446.9	447.0	445.9	433.1	442.2	442.4	442.6	442.7	442.4	442.1	441.5
18	DEG F	468.7	467.6	468.4	468.2	463.1	467.0	467.3	467.2	467.4	467.3	467.3	467.1
19	DEG F	477.5	477.1	477.4	477.1	477.0	476.9	477.1	477.1	477.2	477.1	477.0	477.0
20	DEG F	476.6	476.6	476.7	476.4	476.4	476.4	476.4	476.3	476.4	476.3	476.2	476.3
AT DIE	DEG F	468.6	467.5	467.6	467.2	467.6	467.4	467.4	466.8	467.6	467.3	466.6	466.9

MINUTES AFTER CHANGE

0.0 9.000
FLOWRATE LB/HR 174.0 174.2

RUN NO.15-ZONE 4 TEMPERATURE DECREASED FROM 450 TO 430

STYRON 470

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-430.0

RPM- 80.

POSITION	UNITS	MINUTES AFTER CHANGE											
		1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
1	DEG F	388.9	388.6	388.9	388.7	388.5	388.7	388.7	388.6	388.8	388.6	388.7	388.6
2	DEG F	399.9	399.4	400.2	400.4	399.6	399.9	399.6	399.6	400.1	400.2	399.5	399.9
3	DEG F	403.3	402.2	402.9	403.6	403.1	404.5	403.2	404.0	403.8	403.1	403.6	405.1
4	DEG F	429.6	427.4	429.1	429.1	429.6	428.4	428.8	430.1	429.0	427.1	429.4	427.8
5	DEG F	441.7	439.9	440.5	441.2	441.6	440.7	440.2	439.1	438.5	437.8	436.9	436.3
6	DEG F	465.8	462.8	461.7	464.0	464.2	462.6	460.5	458.7	457.2	455.9	454.0	453.3
7	PSI	1042.	1058.	1056.	1044.	1041.	1063.	1059.	1060.	1071.	1072.	1083.	1070.
8	DEG F	461.5	459.2	459.3	458.8	459.2	458.4	458.7	457.7	457.8	457.1	456.1	454.6
9	DEG F	307.2	307.1	307.2	307.0	307.3	307.0	307.6	307.3	307.4	307.5	307.5	307.7
10	DEG F	361.3	361.0	361.1	360.7	360.9	360.8	361.1	360.7	360.8	360.9	360.9	361.0
11	DEG F	357.2	357.0	357.1	356.7	357.0	356.9	357.1	356.6	356.9	357.1	357.0	356.9
12	DEG F	403.8	403.7	403.8	403.6	403.6	403.6	403.7	403.7	403.7	403.7	403.6	403.6
13	DEG F	396.6	396.7	396.7	396.4	396.4	396.3	396.8	396.6	396.8	396.3	396.5	396.1
14	DEG F	406.6	406.5	406.8	406.6	406.8	406.6	406.8	406.8	407.1	406.9	406.8	406.7
15	DEG F	423.2	423.2	423.8	423.9	424.3	423.7	424.1	423.7	423.6	423.2	423.1	423.3
16	DEG F	437.2	436.8	437.2	437.4	437.8	437.6	437.8	437.5	437.2	436.9	436.7	436.9
17	DEG F	446.4	445.8	446.6	446.8	447.3	446.8	447.0	446.4	446.0	445.5	445.2	445.0
18	DEG F	459.9	465.5	469.5	469.9	468.3	465.7	463.7	461.4	459.9	458.2	456.8	455.5
19	DEG F	475.8	471.7	475.5	476.2	475.3	473.0	471.1	468.9	467.2	465.5	463.9	462.5
20	DEG F	473.5	473.9	474.5	474.7	474.3	473.1	472.1	470.6	469.6	444.6	467.2	466.3
AT DIE	DEG F	469.1	468.3	469.1	469.1	468.8	468.3	468.3	468.5	468.1	467.5	467.4	467.4

FLOWRATE LB/HR	MINUTES AFTER CHANGE									
	0.0	0.500	1.500	2.500	3.500	4.500	5.500	6.50	7.50	8.50
	152.5	152.5	154.0	154.0	153.9	151.7	155.2	154.5	153.0	154.2

RUN NO.15 (CONTINUED)

		MINUTES AFTER CHANGE											
POSITION	UNITS	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0
1	DEG F	388.9	388.5	388.7	388.5	388.7	388.6	388.7	388.7	388.6	388.5	388.7	0.0
2	DEG F	398.7	400.1	400.4	399.4	399.7	400.1	400.0	399.7	400.3	400.2	400.3	399.9
3	DEG F	403.6	404.7	404.1	405.1	404.7	404.8	403.7	405.3	404.4	405.8	405.8	404.0
4	DEG F	429.8	430.0	427.7	429.4	428.7	429.6	427.8	430.6	430.7	430.4	429.5	429.9
5	DEG F	435.5	435.7	435.3	435.4	435.3	435.5	435.3	435.4	435.6	435.6	435.8	435.9
6	DEG F	451.8	451.6	450.5	450.9	450.6	451.0	450.1	450.0	450.4	450.6	451.3	450.4
7	PSI	1077.	1077.	1090.	1089.	1085.	1084.	1088.	1084.	1088.	1084.	1087.	1077.
8	DEG F	454.9	454.7	453.1	452.9	453.3	452.5	453.0	452.9	452.8	452.9	452.7	453.0
9	DEG F	307.7	307.9	307.9	308.2	307.9	308.3	308.2	308.5	308.5	308.5	308.4	308.6
10	DEG F	360.9	361.1	360.8	360.9	360.5	360.8	360.6	360.7	360.4	360.5	360.4	360.6
11	DEG F	356.8	357.2	357.0	356.8	356.5	356.8	356.7	356.8	356.4	356.6	356.3	356.8
12	DEG F	403.5	403.6	403.4	403.6	403.4	403.6	403.6	403.7	403.6	403.6	403.7	403.6
13	DEG F	396.0	396.2	395.9	396.5	396.1	396.3	396.5	396.7	396.4	396.6	396.7	396.4
14	DEG F	406.6	406.6	406.6	406.8	406.4	406.7	406.6	407.1	406.8	407.1	407.0	407.1
15	DEG F	423.6	423.9	423.7	424.0	423.9	424.2	424.1	424.7	424.6	425.0	424.7	424.5
16	DEG F	437.2	437.5	437.2	437.4	437.2	437.7	437.7	438.2	438.2	438.4	438.2	438.0
17	DEG F	445.0	445.2	445.0	445.1	444.9	445.2	445.1	445.6	445.5	445.7	445.5	445.6
18	DEG F	454.4	454.3	454.4	454.5	454.4	454.5	454.3	454.7	454.5	454.8	454.8	454.8
19	DEG F	461.2	460.8	460.6	460.7	460.3	460.4	460.1	460.4	460.2	460.6	460.4	460.5
20	DEG F	465.2	464.5	464.1	463.9	463.4	463.0	463.0	463.2	463.0	463.3	462.9	463.1
AT CIE	DEG F	466.8	466.9	466.4	467.3	467.0	467.1	466.2	467.1	466.5	466.6	466.7	467.0

RUN NO.16 ZONE 3 TEMPERATURE DECREASED FROM 450 TO 430

STYRON 470

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-450.0

RPM- 80.

		MINUTES AFTER CHANGE											
POSITION	UNITS	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
1	DEG F	389.4	389.4	389.6	389.4	389.5	389.5	389.5	389.4	389.6	389.4	389.5	389.4
2	DEG F	399.9	400.3	400.6	400.1	400.4	400.2	400.5	400.6	399.9	400.1	400.4	400.2
3	DEG F	404.3	404.6	405.2	403.5	402.6	402.2	402.4	401.7	401.6	402.6	402.0	401.8
4	DEG F	429.5	425.7	424.2	424.6	424.5	423.3	423.2	422.1	421.1	422.4	422.8	421.8
5	DEG F	442.3	439.8	439.1	438.7	438.6	438.1	437.8	437.6	437.3	437.0	436.7	436.8
6	DEG F	465.9	466.1	465.9	466.0	465.8	465.3	466.1	466.0	465.9	466.1	465.2	465.4
7	PSI	1041.	1045.	1041.	1053.	1044.	1054.	1045.	1061.	1061.	1052.	1050.	1065.
8	DEG F	460.3	459.7	459.8	459.0	460.2	459.9	459.9	459.3	458.6	459.2	459.5	459.6
9	DEG F	307.0	306.8	306.6	306.5	306.6	306.6	306.5	306.4	306.6	306.6	306.5	306.5
10	DEG F	362.2	362.0	361.8	361.7	362.1	361.8	362.0	361.8	362.0	361.9	362.0	362.1
11	DEG F	357.6	357.5	357.4	357.3	357.7	357.3	357.5	357.3	357.7	357.4	357.7	357.7
12	DEG F	404.4	404.6	404.8	404.6	404.9	404.7	404.8	404.7	404.6	404.7	404.5	404.5
13	DEG F	396.3	397.0	397.1	396.6	397.5	396.8	397.3	396.9	396.7	396.6	396.4	396.4
14	DEG F	406.9	407.0	407.4	406.9	407.2	406.9	407.0	406.6	406.7	406.5	406.5	406.3
15	DEG F	424.8	421.1	421.2	420.5	419.8	418.4	418.1	417.0	416.8	416.4	416.5	416.2
16	DEG F	439.1	432.1	432.4	432.2	431.7	430.6	429.9	429.0	428.5	428.3	428.1	427.9
17	DEG F	447.8	442.8	442.7	442.1	441.7	440.6	440.2	439.4	439.2	438.6	438.5	438.2
18	DEG F	469.3	468.8	468.9	468.7	468.9	468.4	468.7	468.6	468.7	468.1	468.1	467.9
19	DEG F	478.2	478.0	478.3	478.1	478.4	478.1	478.4	478.2	478.3	478.0	478.0	477.8
20	DEG F	475.7	475.7	475.9	475.6	475.8	475.7	475.8	475.6	475.8	475.5	475.5	475.4
AT DIE	DEG F	468.7	468.2	468.0	467.8	468.1	467.9	468.6	467.6	467.7	467.8	467.5	467.9

RUN NO.16 (CONTINUED)

PCSI TION	UNITS	MINUTES AFTER CHANGE												
		13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	
1	DEG F	389.3	389.4	389.4	389.2	389.4	389.3	389.6	389.2	389.5	389.2	389.4	389.2	389.4
2	DEG F	400.4	400.4	399.1	399.6	399.6	399.7	400.7	400.1	399.8	399.9	400.5	400.7	399.5
3	DEG F	400.0	401.6	400.9	403.0	401.7	402.6	403.0	402.0	402.0	401.7	402.8	401.0	400.7
4	DEG F	422.2	422.8	421.6	422.0	421.9	420.7	420.7	420.1	421.5	419.8	419.3	418.1	418.6
5	DEG F	436.6	436.5	436.5	436.4	436.4	436.3	436.2	436.2	436.0	435.5	435.2	434.7	434.6
6	DEG F	465.4	465.7	465.2	464.9	465.6	466.0	465.4	465.4	465.7	465.1	465.3	465.1	465.1
7	PSI	1060.	1053.	1060.	1065.	1063.	1056.	1056.	1056.	1061.	1068.	1060.	1059.	1063.
8	DEG F	458.3	459.9	459.7	459.2	458.9	458.2	459.2	459.0	459.3	459.1	459.0	459.6	459.1
9	DEG F	306.2	306.0	306.0	306.2	306.2	306.5	306.5	306.4	306.6	306.5	306.8	306.9	307.1
10	DEG F	362.0	361.9	361.8	361.9	361.7	362.0	361.8	361.8	362.0	361.8	362.0	362.1	362.3
11	DEG F	357.7	357.7	357.4	357.5	357.4	357.5	357.5	357.7	357.8	357.3	357.7	357.8	357.9
12	DEG F	404.4	404.4	404.4	404.4	404.5	404.5	404.5	404.4	404.4	404.3	404.5	404.4	404.5
13	DEG F	396.7	396.3	396.4	396.4	396.4	396.6	396.6	396.3	396.4	396.5	396.4	396.7	396.7
14	DEG F	406.3	406.3	406.2	406.2	406.2	406.3	406.3	406.1	406.3	406.2	406.4	406.3	406.4
15	DEG F	416.4	416.4	416.0	415.8	415.7	415.7	415.7	415.9	415.5	414.5	413.4	412.8	413.0
16	DEG F	427.9	428.1	427.5	427.2	427.0	427.0	427.0	426.9	426.6	425.3	424.1	423.3	423.3
17	DEG F	438.4	438.4	438.0	437.8	437.8	437.5	437.4	437.4	437.1	436.0	435.1	434.3	434.3
18	DEG F	468.0	467.9	467.8	467.8	467.8	467.8	467.9	467.9	467.8	467.6	467.6	467.4	467.3
19	DEG F	477.9	477.9	477.9	477.8	477.8	477.9	478.0	477.9	478.0	477.8	477.9	477.6	477.7
20	DEG F	475.3	475.5	475.3	475.4	475.4	475.4	475.4	475.3	475.5	475.3	475.4	475.4	475.4
AT DIE	DEG F	467.5	467.7	467.9	467.6	467.6	467.6	467.8	467.2	467.2	467.5	467.4	467.0	467.3

RUN NO.17 RPM INCREASED FROM 80 TO 95

STYRON 47C

TEMPERATURE SETTING ZONE 1-300.0 ZONE 2-350.0 ZONE 3-450.0 ZONE 4-430.0

RPM- 80.

		MINUTES AFTER CHANGE											
POSITION	UNITS	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
1	DEG F	388.7	392.0	393.4	394.3	395.2	395.2	395.7	395.7	395.9	395.8	396.2	396.2
2	DEG F	399.7	403.1	403.5	404.3	405.3	404.6	405.2	405.0	405.4	404.2	406.0	406.3
3	DEG F	404.1	406.3	407.0	407.6	406.7	406.2	407.8	407.7	408.7	407.8	408.1	407.5
4	DEG F	428.8	432.6	432.0	432.0	431.3	433.1	434.0	432.5	433.1	433.6	431.0	432.0
5	DEG F	435.7	436.3	437.0	437.4	437.8	438.1	438.4	438.4	438.5	438.3	438.4	438.3
6	DEG F	450.4	451.4	451.8	451.6	452.1	451.8	451.9	452.0	452.2	452.4	451.1	452.3
7	PSI	1169.	1185.	1167.	1164.	1168.	1165.	1159.	1161.	1169.	1168.	1169.	1177.
8	DEG F	453.5	453.7	453.5	454.3	454.0	454.8	454.8	455.2	454.6	455.2	455.3	454.7
9	DEG F	309.0	312.6	314.7	315.9	317.2	317.7	318.9	319.2	320.2	320.7	321.5	322.4
10	DEG F	360.8	363.5	365.0	365.8	366.5	366.6	367.2	366.9	367.2	367.1	367.5	367.7
11	DEG F	356.8	358.9	360.4	361.2	361.9	362.2	362.7	362.4	362.7	362.5	362.8	362.8
12	DEG F	403.7	405.9	407.3	408.0	408.6	408.9	409.4	409.6	409.9	410.0	410.0	410.0
13	DEG F	396.5	398.1	399.0	399.6	399.9	400.1	400.6	401.0	401.5	401.4	401.4	401.5
14	DEG F	407.0	408.6	409.6	409.9	410.2	410.4	411.0	411.5	411.8	411.3	411.4	411.0
15	DEG F	424.5	425.3	425.7	426.2	426.5	426.5	426.9	426.8	426.9	426.1	426.1	425.7
16	DEG F	438.2	439.3	440.0	440.2	440.9	440.9	441.2	440.8	440.9	440.4	440.4	440.2
17	DEG F	445.6	446.8	447.5	448.1	448.5	448.8	449.2	448.8	449.0	448.5	448.6	448.3
18	DEG F	454.8	455.1	455.2	455.5	455.6	455.6	455.7	455.6	456.0	455.7	455.9	455.8
19	DEG F	460.5	461.0	461.2	461.3	461.5	461.5	461.7	461.4	461.7	461.6	461.8	461.8
20	DEG F	463.1	463.6	464.1	464.3	464.6	464.5	464.8	464.6	465.0	464.8	465.2	464.9
AT DIE	DEG F	466.3	464.6	465.2	464.7	464.6	464.8	465.5	465.4	465.3	465.0	464.9	465.0

		MINUTES AFTER CHANGE										
		0.0	0.125	0.350	0.625	1.000	1.500	2.500	3.50	4.50	5.50	6.50
FLOWRATE	LB/HR	154.0	162.0	172.0	181.0	182.0	178.5	181.0	180.7	182.0	179.0	181.8

RUN NO.17 (CONTINUED)

POSITION	UNITS	MINUTES AFTER CHANGE								
		13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0
1	DEG F	396.4	396.5	396.3	396.6	396.5	396.7	396.4	396.6	396.4
2	DEG F	406.1	405.3	405.0	406.2	405.9	406.7	406.0	406.3	405.3
3	DEG F	407.8	407.9	407.7	408.3	408.2	408.4	408.2	407.9	406.9
4	DEG F	431.7	432.7	433.8	430.8	432.0	434.4	431.8	434.0	432.8
5	DEG F	438.3	438.1	438.2	438.3	438.6	438.9	438.4	438.5	438.4
6	DEG F	451.6	452.3	451.6	452.4	452.4	452.6	452.0	452.1	452.3
7	PSI	1164.	1174.	1179.	1176.	1173.	1168.	1172.	1170.	1181.
8	DEG F	456.2	455.0	454.3	454.9	455.8	455.9	453.7	454.8	454.7
9	DEG F	324.0	325.2	326.2	327.0	327.5	328.1	328.4	329.1	329.2
10	DEG F	368.0	368.2	368.2	368.5	368.3	368.5	368.3	368.7	368.6
11	DEG F	363.1	363.0	363.0	363.2	363.2	363.2	363.0	363.3	363.0
12	DEG F	410.0	410.3	410.3	410.4	410.2	410.4	410.1	410.3	410.0
13	DEG F	401.2	401.6	401.9	401.8	401.6	402.1	401.5	401.9	401.1
14	DEG F	411.2	411.3	411.7	411.8	411.6	411.8	411.6	411.8	411.4
15	DEG F	425.5	426.2	426.7	426.7	426.7	426.7	426.8	426.7	426.4
16	DEG F	440.3	440.4	440.7	440.9	440.8	440.8	440.5	440.6	440.5
17	DEG F	448.5	448.5	448.6	448.8	448.9	449.0	448.7	448.9	448.6
18	DEG F	456.0	455.8	456.0	456.0	456.0	455.7	455.7	456.0	455.7
19	DEG F	461.9	461.8	461.9	461.8	461.8	461.8	461.7	462.0	461.5
20	DEG F	465.1	465.0	465.1	465.2	465.1	465.2	465.0	465.1	465.1
AT DIE	DEG F	464.9	465.1	465.3	465.7	465.1	464.6	465.6	465.4	465.0

**Results of Model Simulations Using Parameters
Shown in Table 2**

RUN 1
TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
0.0	172.0	TBAR	239.62	312.21	365.81	384.67	399.33	409.13	431.54	446.49	467.94	448.52
		TPLA	211.00	342.83	374.39	394.13	399.44	412.74	433.32	445.32	465.96	463.11
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
0.25	182.0	TBAR	239.62	312.79	366.17	385.23	399.17	409.13	431.64	446.50	467.98	448.73
		TPLA	211.00	345.38	375.88	395.38	399.23	412.59	433.56	445.31	466.05	463.91
		FM	0.0	0.32	0.59	0.76	0.81	1.00	1.00	1.00	1.00	1.00
0.50	188.5	TBAR	239.62	313.30	366.67	385.91	399.22	409.22	431.82	446.61	468.05	449.00
		TPLA	211.00	346.20	376.57	396.28	399.24	412.44	433.77	445.40	466.18	464.57
		FM	0.0	0.31	0.57	0.75	0.79	1.00	1.00	1.00	1.00	1.00
0.76	192.9	TBAR	239.62	313.72	367.17	386.47	399.36	409.40	432.03	446.79	468.16	449.23
		TPLA	211.00	346.58	376.94	396.88	399.33	412.36	433.96	445.56	466.32	465.06
		FM	0.0	0.30	0.56	0.74	0.78	1.00	1.00	1.00	1.00	1.00
1.01	195.7	TBAR	239.62	314.13	367.68	386.97	399.57	409.64	432.26	447.00	468.28	449.43
		TPLA	211.00	346.82	377.21	397.34	399.50	412.38	434.16	445.75	466.48	465.43
		FM	0.0	0.30	0.56	0.73	0.78	1.00	1.00	1.00	1.00	1.00
1.26	197.6	TBAR	239.62	314.52	368.19	387.42	399.82	409.93	432.49	447.23	468.41	449.60
		TPLA	211.00	346.98	377.43	397.72	399.70	412.48	434.36	445.96	466.65	465.73
		FM	0.0	0.29	0.55	0.73	0.77	1.00	1.00	1.00	1.00	1.00
1.50	198.8	TBAR	239.62	314.88	368.65	387.82	400.06	410.22	432.71	447.45	468.52	449.74
		TPLA	211.00	347.11	377.61	398.04	399.92	412.62	434.56	446.17	466.80	465.96
		FM	0.0	0.29	0.55	0.73	0.77	1.00	1.00	1.00	1.00	1.00
1.75	199.6	TBAR	239.62	315.22	369.10	388.21	400.32	410.53	432.94	447.67	468.64	449.87
		TPLA	211.00	347.21	377.79	398.34	400.14	412.80	434.77	446.38	466.95	465.16
		FM	0.0	0.29	0.55	0.73	0.77	1.00	1.00	1.00	1.00	1.00
2.00	200.1	TBAR	239.62	315.53	369.51	388.54	400.56	410.82	433.14	447.87	468.74	449.98
		TPLA	211.00	347.30	377.94	398.60	400.35	413.00	434.97	446.58	467.09	466.34
		FM	0.0	0.29	0.55	0.72	0.77	1.00	1.00	1.00	1.00	1.00
3.00	201.0	TBAR	239.62	316.40	370.68	389.52	401.30	411.71	433.76	448.49	469.05	450.29
		TPLA	211.00	347.55	378.38	399.34	401.02	413.71	435.60	447.19	467.53	466.81
		FM	0.0	0.29	0.54	0.72	0.77	1.00	1.00	1.00	1.00	1.00
4.01	201.2	TBAR	239.62	316.87	371.31	390.05	401.72	412.23	434.12	448.85	469.24	450.46
		TPLA	211.00	347.68	378.64	399.76	401.42	414.17	435.99	447.56	467.80	467.08
		FM	0.0	0.29	0.54	0.72	0.77	1.00	1.00	1.00	1.00	1.00

PUN 1

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	317.09	371.61	390.31	401.94	412.49	434.30	449.03	469.34	450.55
5.00	201.2	TPLA	211.00	347.75	378.78	399.98	401.62	414.42	436.21	447.75	467.95	467.23
		FM	0.0	0.29	0.54	0.72	0.77	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	317.20	371.75	390.44	402.04	412.62	434.39	449.13	469.39	450.59
6.01	201.2	TPLA	211.00	347.78	378.85	400.10	401.72	414.56	436.33	447.86	468.05	467.32
		FM	0.0	0.29	0.54	0.72	0.77	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	317.24	371.81	390.50	402.10	412.68	434.43	449.18	469.42	450.62
7.01	201.2	TPLA	211.00	347.80	378.89	400.16	401.77	414.63	436.40	447.92	468.10	467.37
		FM	0.0	0.29	0.54	0.72	0.77	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	317.26	371.84	390.53	402.12	412.71	434.46	449.20	469.43	450.63
8.00	201.2	TPLA	211.00	347.81	378.91	400.19	401.80	414.67	436.43	447.95	468.12	467.40
		FM	0.0	0.29	0.54	0.72	0.77	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	317.27	371.85	390.55	402.13	412.72	434.47	449.22	469.44	450.64
9.01	201.2	TPLA	211.00	347.82	378.92	400.21	401.81	414.69	436.46	447.97	468.14	467.42
		FM	0.0	0.29	0.54	0.72	0.77	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	317.28	371.86	390.55	402.14	412.73	434.47	449.23	469.44	450.65
10.01	201.2	TPLA	211.00	347.82	378.92	400.22	401.82	414.70	436.47	447.98	468.15	467.44
		FM	0.0	0.29	0.54	0.72	0.77	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	317.28	371.86	390.56	402.14	412.73	434.48	449.23	469.45	450.65
11.00	201.2	TPLA	211.00	347.82	378.93	400.22	401.82	414.70	436.48	447.98	468.16	467.44
		FM	0.0	0.29	0.54	0.72	0.77	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	317.28	371.86	390.56	402.14	412.73	434.48	449.23	469.45	450.65
12.01	201.2	TPLA	211.00	347.82	378.93	400.23	401.82	414.71	436.48	447.98	468.16	467.45
		FM	0.0	0.29	0.54	0.72	0.77	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	317.28	371.86	390.56	402.15	412.74	434.48	449.23	469.45	450.65
13.01	201.2	TPLA	211.00	347.82	378.93	400.23	401.82	414.71	436.48	447.99	468.16	467.45
		FM	0.0	0.29	0.54	0.72	0.77	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	317.28	371.86	390.56	402.15	412.74	434.48	449.23	469.45	450.65
14.00	201.2	TPLA	211.00	347.82	378.93	400.23	401.82	414.71	436.48	447.99	468.16	467.45
		FM	0.0	0.29	0.54	0.72	0.77	1.00	1.00	1.00	1.00	1.00

2

TIME FLOW RATE

TIME FLOWRATE		MODEL ZONE										
		1	2	3	4	5	6	7	8	9	10	
0.0	174.3	YBAR	239.62	311.01	363.88	383.35	399.25	409.45	431.76	447.03	468.14	448.47
		TPLA	211.00	342.46	373.48	393.11	399.25	412.83	433.41	445.79	466.17	463.16
		FM	0.0	0.33	0.61	0.78	0.82	1.00	1.00	1.00	1.00	1.00
0.25	164.3	YBAR	239.62	310.39	363.52	382.80	399.45	409.47	431.66	447.03	468.12	448.27
		TPLA	211.00	339.76	371.95	391.91	399.50	412.99	433.19	445.81	466.10	462.41
		FM	0.0	0.35	0.63	0.81	0.85	1.00	1.00	1.00	1.00	1.00
0.50	157.9	YBAR	239.62	309.80	362.98	382.08	399.46	409.37	431.45	446.92	468.04	448.00
		TPLA	211.00	338.81	371.21	390.05	399.56	413.00	432.92	445.72	466.00	461.76
		FM	0.0	0.37	0.65	0.82	0.86	1.00	1.00	1.00	1.00	1.00
0.76	153.7	YBAR	239.62	309.31	362.45	381.48	399.38	409.14	431.18	446.71	467.94	447.76
		TPLA	211.00	338.40	370.84	390.29	399.53	412.95	432.62	445.54	465.85	461.25
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
1.01	151.0	YBAR	239.62	308.83	361.91	380.93	399.22	408.83	430.87	446.46	467.82	447.55
		TPLA	211.00	338.16	370.58	389.77	399.40	412.60	432.29	445.30	465.70	460.86
		FM	0.0	0.38	0.67	0.84	0.88	1.00	1.00	1.00	1.00	1.00
1.26	149.1	YBAR	239.62	308.37	361.36	380.43	399.00	408.49	430.56	446.19	467.70	447.37
		TPLA	211.00	338.00	370.37	389.33	399.22	412.30	431.98	445.04	465.53	460.55
		FM	0.0	0.39	0.68	0.85	0.88	1.00	1.00	1.00	1.00	1.00
1.50	148.0	YBAR	239.62	307.95	360.87	379.99	398.78	408.18	430.28	445.93	467.58	447.22
		TPLA	211.00	337.88	370.18	388.97	399.03	412.02	431.69	444.80	465.38	460.31
		FM	0.0	0.39	0.68	0.85	0.88	1.00	1.00	1.00	1.00	1.00
1.75	147.2	YBAR	239.62	307.55	360.39	379.57	398.54	407.86	430.00	445.68	467.47	447.09
		TPLA	211.00	337.77	370.00	388.63	398.81	411.73	431.42	444.55	465.23	460.10
		FM	0.0	0.39	0.68	0.85	0.88	1.00	1.00	1.00	1.00	1.00
2.00	146.7	YBAR	239.62	307.19	359.95	379.19	398.31	407.58	429.75	445.44	467.36	446.97
		TPLA	211.00	337.68	369.83	388.33	398.60	411.46	431.17	444.32	465.09	459.93
		FM	0.0	0.39	0.69	0.85	0.88	1.00	1.00	1.00	1.00	1.00
3.00	145.8	YBAR	239.62	306.15	358.68	378.12	397.60	406.73	429.02	444.74	467.05	446.55
		TPLA	211.00	337.42	369.32	387.48	397.94	410.66	430.44	443.63	464.67	459.47
		FM	0.0	0.40	0.69	0.85	0.89	1.00	1.00	1.00	1.00	1.00
4.01	145.6	YBAR	239.62	305.59	358.00	377.53	397.18	406.26	428.62	444.34	466.87	446.68
		TPLA	211.00	337.28	369.03	387.00	397.54	410.19	430.00	443.23	464.41	459.22
		FM	0.0	0.40	0.69	0.85	0.89	1.00	1.00	1.00	1.00	1.00

RUN 2

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	305.33	357.67	377.24	396.97	406.03	428.42	444.14	466.78	446.39
5.00	145.6	TPLA	211.00	337.21	368.86	386.75	397.33	409.94	429.77	443.01	464.25	459.07
		FM	0.0	0.40	0.69	0.85	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	305.21	357.52	377.10	396.86	405.91	428.31	444.03	466.73	446.34
6.01	145.6	TPLA	211.00	337.17	368.78	386.62	397.22	409.81	429.63	442.89	464.17	458.99
		FM	0.0	0.40	0.69	0.85	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	305.15	357.45	377.03	396.81	405.85	428.25	443.98	466.70	446.31
7.01	145.6	TPLA	211.00	337.15	368.73	386.55	397.17	409.74	429.56	442.83	464.13	458.94
		FM	0.0	0.40	0.69	0.85	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	305.13	357.42	377.00	396.78	405.83	428.23	443.95	466.69	446.30
8.00	145.6	TPLA	211.00	337.14	368.71	386.51	397.14	409.70	429.52	442.80	464.10	458.91
		FM	0.0	0.40	0.69	0.85	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	305.12	357.40	376.98	396.77	405.82	428.22	443.94	466.68	446.29
9.01	145.6	TPLA	211.00	337.13	368.70	386.49	397.13	409.68	429.50	442.78	464.08	458.89
		FM	0.0	0.40	0.69	0.85	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	305.12	357.40	376.98	396.76	405.81	428.21	443.93	466.68	446.29
10.01	145.6	TPLA	211.00	337.13	368.69	386.48	397.12	409.66	429.48	442.77	464.07	458.88
		FM	0.0	0.40	0.69	0.85	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	305.11	357.40	376.97	396.76	405.81	428.21	443.92	466.68	446.29
11.00	145.6	TPLA	211.00	337.13	368.68	386.47	397.12	409.65	429.47	442.77	464.07	458.87
		FM	0.0	0.40	0.69	0.85	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	305.11	357.39	376.97	396.75	405.80	428.21	443.92	466.67	446.28
12.01	145.6	TPLA	211.00	337.13	368.68	386.47	397.11	409.65	429.47	442.76	464.06	458.87
		FM	0.0	0.40	0.69	0.85	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	305.11	357.39	376.97	396.75	405.80	428.21	443.92	466.67	446.28
13.01	145.6	TPLA	211.00	337.13	368.68	386.47	397.11	409.65	429.47	442.76	464.06	458.87
		FM	0.0	0.40	0.69	0.85	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	305.11	357.39	376.97	396.75	405.80	428.21	443.92	466.67	446.28
14.00	145.6	TPLA	211.00	337.13	368.68	386.47	397.11	409.65	429.46	442.76	464.05	458.87
		FM	0.0	0.40	0.69	0.85	0.89	1.00	1.00	1.00	1.00	1.00

RUN 3

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	316.15	370.05	389.62	403.02	413.60	433.27	444.62	458.01	440.12
0.0	201.6	TPLA	211.00	347.44	378.19	399.42	402.55	415.42	435.89	443.92	459.57	457.83
		FM	0.0	0.29	0.54	0.72	0.77	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.59	369.69	389.07	403.15	413.64	433.21	444.60	457.94	439.91
0.25	191.5	TPLA	211.00	344.97	376.68	398.26	402.73	415.57	435.73	443.91	459.36	457.02
		FM	0.0	0.30	0.56	0.74	0.79	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.10	369.19	388.39	403.11	413.63	433.10	444.53	457.81	439.61
0.50	184.9	TPLA	211.00	344.13	375.99	397.38	402.75	415.99	435.62	443.85	459.15	455.32
		FM	0.0	0.31	0.58	0.76	0.80	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	314.71	368.71	387.83	402.97	413.50	432.96	444.42	457.67	439.34
0.76	180.5	TPLA	211.00	343.76	375.65	396.79	402.66	416.15	435.50	443.75	458.95	455.78
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	314.34	368.21	387.31	402.75	413.27	432.80	444.28	457.52	439.10
1.01	177.6	TPLA	211.00	343.56	375.41	396.32	402.49	416.14	435.34	443.62	458.76	455.36
		FM	0.0	0.33	0.60	0.77	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	313.99	367.72	386.83	402.47	412.98	432.62	444.13	457.37	438.89
1.26	175.7	TPLA	211.00	343.42	375.22	395.93	402.26	416.02	435.16	443.47	458.58	455.02
		FM	0.0	0.33	0.60	0.78	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	313.67	367.27	386.41	402.18	412.68	432.46	443.98	457.23	438.72
1.50	174.5	TPLA	211.00	343.32	375.06	395.59	402.02	415.84	434.99	443.33	458.42	454.76
		FM	0.0	0.33	0.61	0.78	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	313.36	366.83	386.01	401.89	412.36	432.29	443.84	457.10	438.56
1.75	173.7	TPLA	211.00	343.24	374.90	395.29	401.75	415.63	434.80	443.19	458.27	454.53
		FM	0.0	0.33	0.61	0.78	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	313.09	366.43	385.65	401.60	412.07	432.14	443.70	456.99	438.42
2.00	173.1	TPLA	211.00	343.16	374.76	395.01	401.50	415.42	434.63	443.05	458.13	454.34
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	312.31	365.28	384.61	400.73	411.15	431.67	443.29	456.64	438.04
3.00	172.2	TPLA	211.00	342.97	374.34	394.23	400.70	414.63	434.09	442.63	457.72	453.84
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.89	364.65	384.05	400.23	410.63	431.40	443.05	456.44	437.84
4.01	172.0	TPLA	211.00	342.87	374.09	393.79	400.23	414.14	433.76	442.37	457.48	453.55
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

RUN 3

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
5.00	172.0	TBAR	239.62	311.69	364.36	383.77	399.97	410.37	431.27	442.92	456.34	437.73
		TPLA	211.00	342.81	373.96	393.57	399.99	413.88	433.57	442.24	457.34	453.40
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
6.01	172.0	TBAR	239.62	311.60	364.23	383.64	399.84	410.24	431.19	442.86	456.29	437.68
		TPLA	211.00	342.79	373.89	393.45	399.87	413.74	433.47	442.16	457.26	453.30
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
7.01	172.0	TBAR	239.62	311.56	364.16	383.57	399.78	410.18	431.16	442.82	456.27	437.65
		TPLA	211.00	342.77	373.85	393.38	399.81	413.67	433.41	442.12	457.22	453.25
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
8.00	172.0	TBAR	239.62	311.54	364.14	383.54	399.75	410.15	431.14	442.80	456.25	437.63
		TPLA	211.00	342.77	373.83	393.35	399.78	413.53	433.38	442.10	457.19	453.22
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
9.01	172.0	TBAR	239.62	311.53	364.12	383.53	399.74	410.13	431.13	442.79	456.25	437.63
		TPLA	211.00	342.76	373.82	393.33	399.76	413.50	433.35	442.09	457.18	453.20
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
10.01	172.0	TBAR	239.62	311.53	364.12	383.52	399.73	410.13	431.13	442.79	456.24	437.62
		TPLA	211.00	342.76	373.81	393.32	399.75	413.59	433.35	442.08	457.17	453.19
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
11.00	172.0	TBAR	239.62	311.53	364.12	383.52	399.73	410.12	431.12	442.79	456.24	437.62
		TPLA	211.00	342.76	373.81	393.32	399.75	413.59	433.34	442.08	457.17	453.18
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
12.01	172.0	TBAR	239.62	311.53	364.12	383.51	399.72	410.12	431.12	442.78	456.24	437.62
		TPLA	211.00	342.76	373.81	393.32	399.75	413.58	433.34	442.07	457.16	453.18
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
13.01	172.0	TBAR	239.62	311.53	364.12	383.51	399.72	410.12	431.12	442.78	456.24	437.62
		TPLA	211.00	342.76	373.81	393.31	399.75	413.58	433.34	442.07	457.16	453.17
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
14.00	172.0	TBAR	239.62	311.53	364.12	383.51	399.72	410.12	431.12	442.78	456.24	437.62
		TPLA	211.00	342.76	373.81	393.31	399.75	413.58	433.34	442.07	457.16	453.17
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

RUN 4

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	305.05	357.63	377.21	397.00	405.85	428.35	444.15	466.73	446.49
0.0	144.9	TPLA	211.00	337.18	369.02	386.82	397.40	409.76	429.68	443.00	464.22	459.10
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	305.69	357.98	377.77	396.77	405.87	428.46	444.14	466.75	446.70
0.25	154.5	TPLA	211.00	339.93	370.48	388.05	397.11	409.73	429.97	442.97	464.27	459.90
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	306.29	358.52	378.51	396.78	406.06	428.69	444.25	466.81	446.97
0.50	160.8	TPLA	211.00	340.82	371.19	389.03	397.07	409.90	430.30	443.06	464.36	460.56
		FM	0.0	0.36	0.64	0.81	0.85	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	306.82	359.07	379.13	396.87	406.33	428.97	444.43	466.89	447.20
0.76	165.0	TPLA	211.00	341.24	371.57	389.69	397.13	410.12	430.62	443.23	464.48	461.03
		FM	0.0	0.35	0.63	0.80	0.84	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	307.34	359.64	379.69	397.04	406.65	429.26	444.65	466.98	447.38
1.01	167.7	TPLA	211.00	341.50	371.85	390.20	397.25	410.35	430.93	443.44	464.61	461.39
		FM	0.0	0.35	0.62	0.80	0.84	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	307.85	360.20	380.20	397.25	406.97	429.55	444.88	467.08	447.54
1.26	169.5	TPLA	211.00	341.68	372.09	390.63	397.43	410.52	431.21	443.66	464.75	461.57
		FM	0.0	0.34	0.62	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	308.30	360.72	380.64	397.46	407.28	429.81	445.10	467.17	447.67
1.50	170.6	TPLA	211.00	341.83	372.29	390.98	397.61	410.86	431.47	443.87	464.88	461.89
		FM	0.0	0.34	0.62	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	308.75	361.22	381.07	397.68	407.58	430.06	445.32	467.26	447.78
1.75	171.4	TPLA	211.00	341.95	372.47	391.31	397.81	411.11	431.72	444.09	465.01	462.07
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	309.15	361.68	381.45	397.89	407.86	430.30	445.53	467.34	447.88
2.00	172.0	TPLA	211.00	342.06	372.64	391.59	398.00	411.35	431.94	444.29	465.13	462.22
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.29	362.99	382.53	398.55	408.69	430.98	446.13	467.60	448.15
3.00	172.8	TPLA	211.00	342.35	373.13	392.41	398.61	412.09	432.62	444.89	465.50	462.63
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.90	363.69	383.12	398.93	409.15	431.36	446.48	467.74	448.30
4.01	173.0	TPLA	211.00	342.51	373.41	392.86	398.97	412.53	433.03	445.25	465.73	462.85
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

RUN 5

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	312.19	365.94	384.78	399.10	408.43	424.43	439.45	464.78	447.46
0.0	172.8	TPLA	211.00	342.78	374.33	394.21	399.21	412.17	428.70	438.62	461.55	460.95
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	312.20	365.94	384.78	399.09	408.44	424.52	439.52	464.80	447.46
0.25	172.7	TPLA	211.00	342.80	374.34	394.20	399.20	412.19	428.74	438.69	461.68	460.97
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	312.20	365.94	384.77	399.09	408.48	424.86	439.94	464.91	447.50
0.50	172.7	TPLA	211.00	342.81	374.34	394.20	399.20	412.21	428.94	438.98	461.82	461.03
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	312.20	365.94	384.75	399.08	408.53	425.37	440.33	465.09	447.55
0.76	172.7	TPLA	211.00	342.81	374.34	394.18	399.19	412.25	429.24	439.43	462.06	461.14
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	312.20	365.94	384.73	399.08	408.60	425.96	440.91	465.31	447.63
1.01	172.7	TPLA	211.00	342.82	374.34	394.17	399.18	412.29	429.59	439.96	462.35	461.27
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	312.20	365.94	384.71	399.07	408.67	426.57	441.50	465.53	447.71
1.26	172.7	TPLA	211.00	342.82	374.33	394.16	399.18	412.33	429.96	440.51	462.66	461.42
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	312.20	365.94	384.67	399.07	408.73	427.13	442.05	465.75	447.78
1.50	172.7	TPLA	211.00	342.82	374.33	394.14	399.17	412.37	430.31	441.02	462.95	461.56
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	312.21	365.94	384.67	399.06	408.79	427.69	442.59	465.96	447.86
1.75	172.7	TPLA	211.00	342.83	374.33	394.13	399.16	412.41	430.65	441.53	463.24	461.71
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	312.21	365.94	384.66	399.05	408.84	428.19	443.09	466.16	447.93
2.00	172.8	TPLA	211.00	342.83	374.33	394.12	399.16	412.45	430.97	441.99	463.52	461.35
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	312.21	365.94	384.61	399.04	409.00	429.66	444.56	466.75	448.16
3.00	172.8	TPLA	211.00	342.84	374.33	394.09	399.14	412.56	431.92	443.38	464.37	462.29
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	312.21	365.94	384.58	399.03	409.09	430.46	445.38	467.10	448.30
4.01	172.8	TPLA	211.00	342.84	374.33	394.07	399.13	412.62	432.47	444.18	464.88	462.57
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

RUN 5
TIME FLOWRATE

		MODEL ZONE									
		1	2	3	4	5	6	7	8	9	10
5.00	172.8	TBAR	239.62	312.21	365.94	384.57	399.02	409.13	430.85	445.80	467.28
		TPLA	211.00	342.85	374.32	394.05	399.12	412.55	432.76	444.60	465.17
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00
6.01	172.8	TBAR	239.62	312.21	365.94	384.56	399.02	409.15	431.04	446.01	467.37
		TPLA	211.00	342.85	374.32	394.05	399.12	412.57	432.91	444.81	465.33
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00
7.01	172.8	TBAR	239.62	312.21	365.94	384.56	399.02	409.16	431.12	446.11	467.42
		TPLA	211.00	342.85	374.32	394.05	399.11	412.58	432.99	444.92	465.43
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00
8.00	172.8	TBAR	239.62	312.21	365.94	384.56	399.02	409.16	431.16	446.16	467.44
		TPLA	211.00	342.85	374.32	394.04	399.11	412.68	433.03	444.98	465.48
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00
9.01	172.8	TBAR	239.62	312.21	365.94	384.56	399.02	409.16	431.18	446.18	467.46
		TPLA	211.00	342.85	374.32	394.04	399.11	412.68	433.05	445.01	465.51
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00
10.01	172.8	TBAR	239.62	312.21	365.94	384.56	399.02	409.16	431.19	446.20	467.45
		TPLA	211.00	342.85	374.32	394.04	399.11	412.68	433.06	445.03	465.52
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00
11.00	172.8	TBAR	239.62	312.21	365.94	384.56	399.02	409.16	431.20	446.21	467.47
		TPLA	211.00	342.85	374.32	394.04	399.11	412.68	433.07	445.04	465.53
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00
12.01	172.8	TBAR	239.62	312.21	365.94	384.56	399.02	409.16	431.20	446.21	467.47
		TPLA	211.00	342.85	374.32	394.04	399.11	412.68	433.07	445.04	465.54
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00
13.01	172.8	TBAR	239.62	312.21	365.94	384.56	399.02	409.16	431.20	446.21	467.47
		TPLA	211.00	342.85	374.32	394.04	399.11	412.68	433.08	445.05	465.54
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00
14.00	172.8	TBAR	239.62	312.21	365.94	384.56	399.02	409.16	431.20	446.21	467.47
		TPLA	211.00	342.85	374.32	394.04	399.11	412.68	433.08	445.05	465.55
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00

RUN 6

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
0.0	172.9	TBAR	239.62	315.38	375.37	391.63	400.21	409.60	432.09	447.28	468.37	448.76
		TPLA	211.00	343.43	377.50	399.18	400.43	413.31	433.80	446.06	466.45	463.43
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
0.25	172.9	TBAR	239.62	315.34	375.25	391.55	400.20	409.60	432.10	447.29	468.38	448.76
		TPLA	211.00	343.44	377.47	399.13	400.42	413.32	433.81	446.07	466.46	463.45
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
0.50	172.9	TBAR	239.62	315.19	374.77	391.20	400.16	409.60	432.10	447.29	468.38	448.77
		TPLA	211.00	343.41	377.31	398.89	400.37	413.31	433.82	446.07	466.47	463.46
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
0.76	172.9	TBAR	239.62	314.97	374.06	390.69	400.10	409.60	432.10	447.30	468.38	448.77
		TPLA	211.00	343.37	377.07	398.53	400.30	413.30	433.82	446.08	466.47	463.47
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.01	172.9	TBAR	239.62	314.71	373.24	390.10	400.04	409.59	432.10	447.30	468.38	448.77
		TPLA	211.00	343.32	376.81	398.12	400.22	413.28	433.81	446.08	466.48	463.48
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.26	172.9	TBAR	239.62	314.45	372.40	389.50	399.97	409.58	432.10	447.30	468.39	448.78
		TPLA	211.00	343.27	376.55	397.70	400.14	413.25	433.81	446.08	466.48	463.49
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.50	172.9	TBAR	239.62	314.21	371.63	388.95	399.90	409.57	432.09	447.30	468.39	448.78
		TPLA	211.00	343.23	376.30	397.31	400.06	413.23	433.80	446.08	466.49	463.49
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.75	172.9	TBAR	239.62	313.97	370.86	388.40	399.84	409.56	432.09	447.30	468.39	448.78
		TPLA	211.00	343.19	376.06	396.93	399.99	413.20	433.79	446.08	466.49	463.50
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
2.00	172.9	TBAR	239.62	313.75	370.18	387.91	399.78	409.55	432.09	447.30	468.39	448.78
		TPLA	211.00	343.15	375.84	396.58	399.92	413.18	433.79	446.08	466.49	463.51
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
3.00	172.9	TBAR	239.62	313.14	368.18	386.46	399.60	409.52	432.08	447.30	468.39	448.79
		TPLA	211.00	343.03	375.19	395.54	399.71	413.11	433.76	446.08	466.50	463.52
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
4.01	172.9	TBAR	239.62	312.80	367.11	385.67	399.49	409.50	432.07	447.30	468.39	448.79
		TPLA	211.00	342.97	374.81	394.94	399.58	413.06	433.75	446.08	466.50	463.53
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

RUN 6

TIME FLOWRATE

MODEL ZONE

	1	2	3	4	5	6	7	8	9	10
TBAR	239.62	312.65	366.60	385.28	399.44	409.48	432.07	447.30	468.39	449.79
TPLA	211.00	342.94	374.61	394.63	399.51	413.03	433.74	446.08	466.51	463.54
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	312.58	366.37	385.09	399.40	409.48	432.07	447.30	468.40	449.79
TPLA	211.00	342.92	374.51	394.46	399.48	413.01	433.73	446.08	466.51	463.54
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	312.55	366.26	385.00	399.39	409.47	432.07	447.30	468.40	449.80
TPLA	211.00	342.92	374.45	394.38	399.46	413.00	433.73	446.08	466.51	463.54
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	312.53	366.22	384.96	399.38	409.47	432.06	447.30	468.40	448.80
TPLA	211.00	342.91	374.43	394.34	399.44	413.00	433.73	446.08	466.51	463.54
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	312.53	366.20	384.94	399.37	409.47	432.06	447.30	468.40	448.80
TPLA	211.00	342.91	374.42	394.32	399.44	413.00	433.72	446.08	466.51	463.54
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	312.52	366.19	384.93	399.37	409.47	432.06	447.30	468.40	448.80
TPLA	211.00	342.91	374.41	394.30	399.44	412.99	433.72	446.08	466.51	463.54
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	312.52	366.18	384.93	399.37	409.47	432.06	447.30	468.40	448.80
TPLA	211.00	342.91	374.40	394.30	399.43	412.99	433.72	446.08	466.51	463.54
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	312.52	366.18	384.92	399.37	409.47	432.06	447.30	468.40	448.80
TPLA	211.00	342.91	374.40	394.29	399.43	412.99	433.72	446.08	466.51	463.54
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	312.52	366.18	384.92	399.36	409.47	432.06	447.30	468.40	448.80
TPLA	211.00	342.91	374.40	394.29	399.43	412.99	433.72	446.08	466.51	463.54
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	312.52	366.18	384.92	399.36	409.47	432.06	447.30	468.40	448.80
TPLA	211.00	342.91	374.40	394.29	399.43	412.99	433.72	446.08	466.51	463.54
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	312.52	366.18	384.92	399.36	409.47	432.06	447.30	468.40	448.80
TPLA	211.00	342.91	374.40	394.29	399.43	412.99	433.72	446.08	466.51	463.54
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	312.52	366.18	384.92	399.36	409.47	432.06	447.30	468.40	448.80
TPLA	211.00	342.91	374.40	394.29	399.43	412.99	433.72	446.08	466.51	463.54
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

RUN 7

TIME FLOWRATE

MODEL 70VE

	1	2	3	4	5	6	7	8	9	10
TBAR	239.62	311.41	364.01	383.49	399.24	409.73	432.14	447.27	458.29	448.58
TPLA	211.00	342.61	373.67	393.26	399.29	413.06	433.76	446.05	466.39	463.31
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	311.47	364.15	383.59	399.24	409.72	432.13	447.28	468.29	448.59
TPLA	211.00	342.64	373.71	393.33	399.28	413.06	433.76	446.05	466.40	463.32
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	311.67	364.73	384.00	399.27	409.71	432.12	447.28	468.29	448.59
TPLA	211.00	342.69	373.90	393.61	399.32	413.07	433.76	446.06	466.40	463.33
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	311.96	365.58	384.60	399.32	409.68	432.11	447.28	468.29	448.59
TPLA	211.00	342.76	374.18	394.03	399.39	413.03	433.75	446.06	466.40	463.34
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	312.30	366.55	385.29	399.39	409.65	432.09	447.28	468.30	448.60
TPLA	211.00	342.83	374.48	394.51	399.47	413.09	433.74	446.06	466.41	463.35
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	312.64	367.57	386.00	399.46	409.63	432.07	447.28	468.30	448.60
TPLA	211.00	342.90	374.80	395.00	399.55	413.10	433.74	446.06	466.41	463.35
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	312.96	368.50	386.65	399.53	409.60	432.05	447.28	468.30	448.60
TPLA	211.00	342.96	375.09	395.45	399.63	413.11	433.73	446.06	466.41	463.36
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	313.26	369.41	387.29	399.60	409.58	432.03	447.28	468.30	448.59
TPLA	211.00	343.03	375.37	395.90	399.72	413.12	433.73	446.06	466.42	463.36
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	313.55	370.24	387.88	399.66	409.55	432.02	447.28	468.30	448.60
TPLA	211.00	343.08	375.64	396.31	399.79	413.13	433.72	446.06	466.42	463.37
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	314.36	372.64	389.59	399.87	409.50	431.97	447.29	468.30	448.61
TPLA	211.00	343.26	376.44	397.56	400.03	413.17	433.71	446.06	466.43	463.38
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
TBAR	239.62	314.79	373.93	390.54	399.99	409.47	431.95	447.29	468.30	448.61
TPLA	211.00	343.36	376.91	398.29	400.17	413.20	433.71	446.07	466.43	463.39
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

RUN 7

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	315.00	374.55	391.01	400.06	409.46	431.94	447.29	468.31	448.61
5.00	173.1	TPLA	211.00	343.41	377.16	398.68	400.25	413.22	433.71	446.07	466.44	463.40
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.09	374.83	391.24	400.09	409.46	431.94	447.29	468.31	448.62
6.01	173.1	TPLA	211.00	343.43	377.29	398.88	400.30	413.23	433.71	446.07	466.44	463.40
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.13	374.96	391.35	400.11	409.46	431.94	447.29	468.31	448.62
7.01	173.1	TPLA	211.00	343.44	377.35	398.98	400.32	413.24	433.71	446.07	466.44	463.41
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.15	375.01	391.40	400.13	409.46	431.94	447.29	468.31	448.62
8.00	173.1	TPLA	211.00	343.45	377.39	399.03	400.33	413.25	433.71	446.07	466.44	463.41
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.16	375.04	391.42	400.13	409.46	431.94	447.29	468.31	448.62
9.01	173.1	TPLA	211.00	343.45	377.41	399.06	400.34	413.25	433.72	446.07	466.44	463.41
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.16	375.05	391.44	400.14	409.46	431.94	447.29	468.31	448.62
10.01	173.1	TPLA	211.00	343.46	377.42	399.08	400.35	413.25	433.72	446.07	466.44	463.41
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.16	375.05	391.44	400.14	409.46	431.94	447.29	468.31	448.62
11.00	173.1	TPLA	211.00	343.46	377.42	399.09	400.35	413.25	433.72	446.07	466.44	463.41
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.16	375.06	391.45	400.14	409.46	431.94	447.29	468.31	448.62
12.01	173.1	TPLA	211.00	343.46	377.42	399.09	400.35	413.25	433.72	446.07	466.44	463.41
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.16	375.06	391.45	400.14	409.46	431.94	447.29	468.31	448.62
13.01	173.1	TPLA	211.00	343.46	377.43	399.10	400.35	413.25	433.72	446.07	466.44	463.41
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.16	375.06	391.45	400.14	409.46	431.94	447.29	468.31	448.62
14.00	173.1	TPLA	211.00	343.46	377.43	399.10	400.35	413.25	433.72	446.07	466.44	463.41
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

185

RUN 8
TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	310.25	363.59	381.55	392.19	401.09	429.89	446.46	467.44	447.77
0.0	172.9	TPLA	211.00	342.37	373.49	392.00	392.93	405.33	430.02	444.89	465.46	462.48
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.26	363.59	381.57	392.29	401.18	429.89	446.45	467.45	447.78
0.25	172.9	TPLA	211.00	342.38	373.49	392.00	393.03	405.38	430.03	444.89	465.46	462.49
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.30	363.61	381.65	392.68	401.58	429.97	446.47	467.47	447.81
0.50	173.0	TPLA	211.00	342.40	373.49	392.05	393.38	405.70	430.15	444.92	465.49	462.52
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.35	363.63	381.78	393.22	402.19	430.11	446.51	467.52	447.85
0.76	173.0	TPLA	211.00	342.41	373.49	392.12	393.86	406.21	430.37	444.98	465.53	462.56
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.40	363.66	381.93	393.82	402.91	430.27	446.56	467.57	447.89
1.01	173.0	TPLA	211.00	342.43	373.50	392.21	394.39	406.81	430.63	445.05	465.59	462.61
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.46	363.69	382.08	394.43	403.65	430.45	446.61	467.63	447.94
1.26	173.0	TPLA	211.00	342.44	373.50	392.30	394.93	407.44	430.92	445.13	465.65	462.66
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.51	363.72	382.22	395.00	404.34	430.62	446.66	467.68	447.98
1.50	173.0	TPLA	211.00	342.45	373.51	392.39	395.43	408.03	431.18	445.21	465.70	462.70
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.57	363.74	382.36	395.55	405.02	430.78	446.72	467.74	448.03
1.75	173.0	TPLA	211.00	342.47	373.52	392.47	395.92	408.52	431.46	445.28	465.76	462.75
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.61	363.77	392.48	396.06	405.65	430.94	446.77	467.79	448.07
2.00	173.0	TPLA	211.00	342.48	373.53	392.55	396.37	409.17	431.71	445.36	465.82	462.80
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.75	363.84	382.85	397.53	407.48	431.42	446.93	467.94	448.19
3.00	173.1	TPLA	211.00	342.51	373.55	392.78	397.69	410.83	432.51	445.60	466.00	462.94
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.82	363.87	383.05	398.35	408.50	431.70	447.04	468.02	448.26
4.01	173.1	TPLA	211.00	342.53	373.56	392.91	398.43	411.80	433.01	445.76	466.12	463.04
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

100

RUN 8

TIME FLOWRATE

MODEL ZONE

	1	2	3	4	5	6	7	8	9	10
5.00 173.1	TBAR 239.62 310.96 363.89 383.14 398.76 409.01 431.86 447.11 468.07 448.30									
	TPLA 211.00 342.55 373.57 392.98 398.80 412.32 433.29 445.85 466.19 463.09									
	FM 0.0 0.33 0.61 0.79 0.83 1.00 1.00 1.00 1.00 1.00 1.00									
6.01 173.1	TBAR 239.62 310.87 363.90 383.19 398.95 409.26 431.94 447.15 468.10 448.32									
	TPLA 211.00 342.55 373.57 393.01 398.98 412.50 433.45 445.91 466.23 463.13									
	FM 0.0 0.33 0.61 0.79 0.83 1.00 1.00 1.00 1.00 1.00 1.00									
7.01 173.1	TBAR 239.62 310.88 363.90 383.21 399.04 409.38 431.99 447.17 468.11 448.33									
	TPLA 211.00 342.55 373.57 393.03 399.07 412.74 433.55 445.94 466.25 463.15									
	FM 0.0 0.33 0.61 0.79 0.83 1.00 1.00 1.00 1.00 1.00 1.00									
8.00 173.1	TBAR 239.62 310.88 363.90 383.22 399.09 409.43 432.01 447.19 468.12 448.33									
	TPLA 211.00 342.56 373.57 393.04 399.11 412.82 433.60 445.96 466.27 463.15									
	FM 0.0 0.33 0.61 0.79 0.83 1.00 1.00 1.00 1.00 1.00 1.00									
9.01 173.1	TBAR 239.62 310.89 363.90 383.23 399.11 409.45 432.03 447.19 468.12 448.34									
	TPLA 211.00 342.56 373.57 393.04 399.13 412.86 433.64 445.97 466.28 463.17									
	FM 0.0 0.33 0.61 0.79 0.83 1.00 1.00 1.00 1.00 1.00 1.00									
10.01 173.1	TBAR 239.62 310.89 363.90 383.23 399.12 409.48 432.03 447.20 468.12 448.34									
	TPLA 211.00 342.56 373.57 393.04 399.14 412.89 433.65 445.98 466.29 463.17									
	FM 0.0 0.33 0.61 0.79 0.83 1.00 1.00 1.00 1.00 1.00 1.00									
11.00 173.1	TBAR 239.62 310.89 363.90 383.23 399.13 409.48 432.04 447.20 468.13 448.34									
	TPLA 211.00 342.56 373.57 393.05 399.15 412.90 433.67 445.99 466.29 463.18									
	FM 0.0 0.33 0.61 0.79 0.83 1.00 1.00 1.00 1.00 1.00 1.00									
12.01 173.1	TBAR 239.62 310.89 363.90 383.23 399.13 409.49 432.04 447.20 468.13 448.34									
	TPLA 211.00 342.56 373.57 393.05 399.15 412.91 433.67 445.99 466.29 463.18									
	FM 0.0 0.33 0.61 0.79 0.83 1.00 1.00 1.00 1.00 1.00 1.00									
13.01 173.1	TBAR 239.62 310.89 363.90 383.23 399.13 409.49 432.04 447.20 468.13 448.34									
	TPLA 211.00 342.56 373.57 393.05 399.15 412.91 433.68 445.99 466.29 463.18									
	FM 0.0 0.33 0.61 0.79 0.83 1.00 1.00 1.00 1.00 1.00 1.00									
14.00 173.1	TBAR 239.62 310.89 363.90 383.23 399.13 409.49 432.04 447.21 468.13 448.34									
	TPLA 211.00 342.56 373.57 393.05 399.15 412.92 433.68 445.99 466.29 463.18									
	FM 0.0 0.33 0.61 0.79 0.83 1.00 1.00 1.00 1.00 1.00 1.00									

RUN 9
TIME FLOWRATE

TIME FLOWRATE			MODEL ZONE									
			1	2	3	4	5	6	7	8	9	10
0.0	172.8	TBAR	239.62	310.79	363.76	383.48	399.89	409.92	430.09	445.39	467.76	448.53
		TPLA	211.00	342.49	373.59	393.25	399.87	413.39	432.58	444.27	465.46	462.95
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
0.25	172.8	TBAR	239.62	310.79	363.76	383.45	399.74	409.82	430.10	445.42	467.76	448.52
		TPLA	211.00	342.50	373.58	393.22	399.72	413.30	432.57	444.29	465.46	462.95
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
0.50	172.8	TBAR	239.62	310.77	363.76	383.35	399.28	409.38	430.11	445.49	467.76	448.50
		TPLA	211.00	342.50	373.57	393.15	399.30	412.93	432.47	444.34	465.49	462.95
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
0.76	172.8	TBAR	239.62	310.73	363.76	383.20	398.65	408.71	430.11	445.60	467.77	448.46
		TPLA	211.00	342.50	373.57	393.06	398.73	412.35	432.30	444.41	465.51	462.94
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.01	172.8	TBAR	239.62	310.69	363.76	383.03	397.95	407.93	430.10	445.71	467.79	448.41
		TPLA	211.00	342.49	373.56	392.95	398.10	411.68	432.11	444.49	465.55	462.93
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.26	172.8	TBAR	239.62	310.65	363.76	382.86	397.25	407.13	430.09	445.83	467.80	448.37
		TPLA	211.00	342.49	373.56	392.84	397.47	410.97	431.90	444.56	465.58	462.92
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.50	172.8	TBAR	239.62	310.61	363.75	382.71	396.61	406.38	430.07	445.93	467.81	448.32
		TPLA	211.00	342.49	373.55	392.75	396.90	410.32	431.70	444.63	465.51	462.90
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.75	172.8	TBAR	239.62	310.58	363.75	382.56	395.98	405.64	430.05	446.03	467.82	448.28
		TPLA	211.00	342.48	373.55	392.65	396.34	409.67	429.49	444.69	465.54	462.89
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
2.00	172.9	TBAR	239.62	310.54	363.75	382.42	395.42	404.97	430.03	446.13	467.83	448.24
		TPLA	211.00	342.48	373.55	392.56	395.84	409.07	431.30	444.75	465.55	462.88
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
3.00	172.9	TBAR	239.62	310.44	363.75	382.02	393.77	402.99	429.95	446.38	467.86	448.13
		TPLA	211.00	342.47	373.54	392.30	394.37	407.26	430.70	444.90	465.73	462.84
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
4.01	172.9	TBAR	239.62	310.39	363.75	381.80	392.87	401.90	429.88	446.50	467.87	448.07
		TPLA	211.00	342.46	373.54	392.15	393.55	406.21	430.32	444.07	465.77	462.82
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

RUN 9

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	310.37	363.75	381.60	392.43	401.36	429.83	446.56	467.88	448.04
5.00	172.8	TPLA	211.00	342.46	373.53	392.07	393.14	405.65	430.09	444.99	465.79	462.81
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.36	363.75	381.64	392.21	401.39	429.79	446.58	467.88	448.02
6.01	172.8	TPLA	211.00	342.46	373.53	392.03	392.94	405.35	429.96	444.99	465.79	462.82
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.35	363.75	381.61	392.11	400.96	429.77	446.58	467.88	448.02
7.01	172.8	TPLA	211.00	342.46	373.53	392.01	392.84	405.19	429.88	444.99	465.79	462.80
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.35	363.75	381.60	392.06	400.90	429.75	446.58	467.88	448.02
8.00	172.8	TPLA	211.00	342.46	373.53	392.00	392.80	405.11	429.84	444.98	465.79	462.80
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.35	363.75	381.60	392.03	400.87	429.74	446.58	467.88	448.02
9.01	172.8	TPLA	211.00	342.46	373.53	391.99	392.77	405.06	429.81	444.98	465.79	462.80
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.35	363.75	381.60	392.02	400.85	429.73	446.58	467.88	448.01
10.01	172.8	TPLA	211.00	342.46	373.53	391.90	392.76	405.03	429.79	444.98	465.79	462.79
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.35	363.75	381.59	392.02	400.84	429.73	446.58	467.88	448.01
11.00	172.8	TPLA	211.00	342.46	373.53	391.99	392.75	405.02	429.78	444.97	465.79	462.79
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.35	363.75	381.59	392.01	400.84	429.73	446.58	467.88	448.01
12.01	172.8	TPLA	211.00	342.46	373.53	391.99	392.75	405.01	429.77	444.97	465.79	462.79
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.35	363.75	381.59	392.01	400.84	429.73	446.57	467.88	448.01
13.01	172.8	TPLA	211.00	342.46	373.53	391.99	392.75	405.01	429.77	444.97	465.79	462.79
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.35	363.75	381.59	392.01	400.84	429.73	446.57	467.88	448.01
14.00	172.8	TPLA	211.00	342.46	373.53	391.99	392.75	405.00	429.77	444.97	465.79	462.79
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

160

RUN 10

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
0.0	144.4	TBAR	239.62	304.75	360.23	379.06	397.01	403.72	413.75	431.44	461.11	442.33
		TPLA	211.00	337.22	369.97	388.20	397.52	408.28	419.74	430.71	456.83	453.93
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
0.25	144.7	TBAR	239.62	305.64	360.90	379.96	398.10	403.99	414.15	431.67	461.32	442.31
		TPLA	211.00	340.85	372.93	390.17	398.85	408.91	420.69	431.02	457.40	454.81
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
0.50	145.0	TBAR	239.62	306.60	361.86	381.16	399.28	404.65	415.12	432.29	461.84	442.89
		TPLA	211.00	342.20	374.66	391.82	400.14	409.78	421.88	431.69	458.15	455.77
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
0.76	145.2	TBAR	239.62	307.54	362.77	382.14	400.22	405.44	416.33	433.12	462.51	443.57
		TPLA	211.00	342.92	375.66	392.95	401.12	410.54	423.07	432.53	458.97	456.69
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
1.01	145.3	TBAR	239.62	308.48	363.66	383.01	401.02	406.27	417.63	434.03	463.23	444.28
		TPLA	211.00	343.40	376.36	393.82	401.93	411.46	424.23	433.43	459.80	457.55
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
1.26	145.4	TBAR	239.62	309.41	364.51	383.80	401.71	407.10	418.93	434.95	463.96	444.98
		TPLA	211.00	343.76	376.91	394.54	402.62	412.24	425.33	434.35	460.50	458.34
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
1.50	145.5	TBAR	239.62	310.25	365.27	384.48	402.30	407.85	420.12	435.80	464.63	445.61
		TPLA	211.00	344.04	377.34	395.12	403.19	412.93	426.31	435.19	461.31	459.03
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
1.75	145.6	TBAR	239.62	311.06	366.01	385.12	402.85	408.59	421.27	436.63	465.28	446.23
		TPLA	211.00	344.27	377.72	395.65	403.72	413.59	427.25	436.01	462.02	459.69
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
2.00	145.6	TBAR	239.62	311.79	366.67	385.69	403.33	409.25	422.32	437.40	465.87	446.78
		TPLA	211.00	344.48	378.04	396.12	404.19	414.19	428.11	436.77	462.65	460.29
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
3.00	145.7	TBAR	239.62	313.88	368.55	387.31	404.68	411.17	425.36	439.64	467.61	448.40
		TPLA	211.00	345.02	378.95	397.42	405.49	415.97	430.65	439.02	464.57	462.06
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
4.01	145.8	TBAR	239.62	315.00	369.57	388.20	405.42	412.24	427.03	440.92	468.58	449.31
		TPLA	211.00	345.32	379.45	398.16	406.21	417.00	432.14	440.33	465.72	463.13
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00

RUN 10

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	315.53	370.05	388.63	405.80	412.77	427.87	441.57	469.08	449.77
5.00	145.8	TPLA	211.00	345.47	379.72	398.54	406.57	417.56	432.95	441.03	466.36	463.73
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.77	370.28	388.85	405.98	413.04	428.28	441.91	469.33	450.01
6.01	145.9	TPLA	211.00	345.54	379.86	398.75	406.76	417.87	433.40	441.40	466.72	464.08
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.88	370.38	388.95	406.08	413.16	428.48	442.08	469.46	450.13
7.01	145.9	TPLA	211.00	345.58	379.94	398.86	406.85	418.03	433.64	441.59	466.92	464.28
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.92	370.43	389.01	406.12	413.23	428.57	442.17	469.52	450.19
8.00	145.9	TPLA	211.00	345.60	379.98	398.92	406.90	418.12	433.77	441.70	467.04	464.40
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.94	370.45	389.03	406.15	413.26	428.62	442.21	469.56	450.23
9.01	145.9	TPLA	211.00	345.61	380.01	398.95	406.93	418.17	433.85	441.76	467.11	464.48
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.95	370.46	389.04	406.16	413.28	428.65	442.24	469.58	450.25
10.01	145.9	TPLA	211.00	345.62	380.02	398.97	406.94	418.20	433.89	441.79	467.15	464.52
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.96	370.46	389.05	406.17	413.29	428.66	442.25	469.59	450.26
11.00	145.9	TPLA	211.00	345.62	380.03	398.98	406.95	418.21	433.92	441.81	467.17	464.55
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.96	370.47	389.05	406.17	413.29	428.67	442.26	469.59	450.26
12.01	145.9	TPLA	211.00	345.62	380.03	398.98	406.96	418.22	433.94	441.82	467.19	464.56
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.96	370.47	389.06	406.17	413.29	428.67	442.27	469.60	450.27
13.01	145.9	TPLA	211.00	345.62	380.03	398.99	406.96	418.23	433.94	441.83	467.20	464.57
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.96	370.47	389.06	406.17	413.30	428.68	442.27	469.60	450.27
14.00	145.9	TPLA	211.00	345.62	380.04	398.99	406.96	418.23	433.95	441.83	467.20	464.58
		FM	0.0	0.40	0.69	0.86	0.89	1.00	1.00	1.00	1.00	1.00

RUN 11

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	311.16	367.16	385.47	398.57	407.50	426.05	440.90	464.64	444.17
0.0	174.3	TPLA	211.00	342.55	374.52	394.62	398.73	411.34	429.40	439.97	461.95	459.05
		FM	0.0	0.33	0.61	0.78	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.34	367.39	385.72	399.46	407.69	426.21	441.05	464.78	444.23
0.25	167.6	TPLA	211.00	343.10	375.51	395.18	399.81	411.39	429.83	440.19	462.34	459.15
		FM	0.0	0.35	0.62	0.80	0.84	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.66	367.72	386.07	400.30	408.07	426.58	441.37	465.09	444.46
0.50	163.2	TPLA	211.00	343.43	376.21	395.63	400.75	412.52	430.36	440.54	462.81	459.40
		FM	0.0	0.35	0.64	0.81	0.85	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	312.05	368.04	386.38	400.91	408.46	427.01	441.75	465.48	444.79
0.76	160.4	TPLA	211.00	343.68	376.70	396.06	401.43	413.03	430.84	440.94	463.28	459.71
		FM	0.0	0.36	0.65	0.82	0.85	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	312.46	368.35	386.65	401.38	408.82	427.45	442.15	465.90	445.17
1.01	158.5	TPLA	211.00	343.88	377.04	396.35	401.93	413.46	431.28	441.35	463.74	460.06
		FM	0.0	0.37	0.65	0.82	0.86	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	312.88	368.63	386.89	401.74	409.16	427.89	442.54	466.31	445.56
1.26	157.3	TPLA	211.00	344.03	377.31	396.58	402.32	413.82	431.69	441.74	464.17	460.42
		FM	0.0	0.37	0.65	0.83	0.86	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	313.26	368.88	387.09	402.02	409.46	428.29	442.90	466.58	445.92
1.50	156.5	TPLA	211.00	344.16	377.50	396.77	402.61	414.12	432.04	442.09	464.56	460.75
		FM	0.0	0.37	0.66	0.83	0.86	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	313.63	369.12	387.28	402.26	409.74	428.67	443.25	467.05	446.27
1.75	156.0	TPLA	211.00	344.27	377.67	396.94	402.85	414.39	432.37	442.44	464.92	461.09
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	313.95	369.33	387.44	402.46	409.99	429.01	443.57	467.38	446.60
2.00	155.6	TPLA	211.00	344.36	377.80	397.09	403.05	414.53	432.67	442.75	465.26	461.39
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	314.90	369.92	387.91	402.97	410.72	430.01	444.49	468.33	447.55
3.00	155.1	TPLA	211.00	344.60	378.15	397.48	403.56	415.32	433.55	443.66	466.23	462.33
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	315.40	370.23	388.16	403.23	411.11	430.56	445.01	468.87	448.09
4.01	155.1	TPLA	211.00	344.73	378.33	397.70	403.81	415.72	434.06	444.19	466.81	462.91
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00

RUN 11

TIME FLOWRATE

MODEL ZONE

	1	2	3	4	5	6	7	8	9	10
5.00 155.1	TBAR 239.62	315.64	370.38	388.29	403.35	411.31	430.83	445.28	469.13	448.36
	TPLA 211.00	344.80	378.43	397.82	403.93	415.93	434.34	444.47	467.13	463.23
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
6.01 155.1	TBAR 239.62	315.75	370.45	388.35	403.42	411.41	430.97	445.42	469.27	448.50
	TPLA 211.00	344.83	378.48	397.88	404.00	416.05	434.50	444.62	467.31	463.42
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
7.01 155.1	TBAR 239.62	315.79	370.48	388.39	403.45	411.46	431.03	445.48	469.33	448.57
	TPLA 211.00	344.85	378.50	397.91	404.03	416.11	434.58	444.70	467.40	463.52
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
8.00 155.1	TBAR 239.62	315.82	370.50	388.40	403.46	411.48	431.07	445.52	469.37	448.60
	TPLA 211.00	344.86	378.52	397.93	404.05	416.14	434.63	444.74	467.46	463.58
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
9.01 155.1	TBAR 239.62	315.82	370.50	388.40	403.47	411.49	431.08	445.54	469.39	448.62
	TPLA 211.00	344.86	378.53	397.94	404.06	416.16	434.66	444.76	467.49	463.62
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
10.01 155.1	TBAR 239.62	315.83	370.51	388.41	403.48	411.50	431.09	445.55	469.40	448.63
	TPLA 211.00	344.86	378.53	397.94	404.06	416.17	434.68	444.78	467.51	463.64
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
11.00 155.1	TBAR 239.62	315.83	370.51	388.41	403.48	411.50	431.10	445.55	469.40	448.63
	TPLA 211.00	344.86	378.54	397.95	404.06	416.18	434.68	444.78	467.52	463.65
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
12.01 155.1	TBAR 239.62	315.83	370.51	388.41	403.48	411.51	431.10	445.56	469.40	448.64
	TPLA 211.00	344.86	378.54	397.95	404.07	416.18	434.69	444.79	467.53	463.66
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
13.01 155.1	TBAR 239.62	315.83	370.51	388.41	403.48	411.51	431.10	445.56	469.41	448.64
	TPLA 211.00	344.86	378.54	397.95	404.07	416.19	434.69	444.79	467.53	463.67
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
14.00 155.1	TBAR 239.62	315.83	370.51	388.41	403.48	411.51	431.10	445.56	469.41	448.64
	TPLA 211.00	344.86	378.54	397.95	404.07	416.19	434.70	444.79	467.54	463.67
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00

RUN 12

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
0.0	160.7	TBAR	239.62	314.60	370.22	387.99	402.50	411.04	431.50	447.42	470.08	448.72
		TPLA	211.00	344.04	377.43	397.24	402.88	415.35	434.46	446.36	468.17	463.91
		FM	0.0	0.36	0.64	0.82	0.85	1.00	1.00	1.00	1.00	1.00
0.25	165.7	TBAR	239.62	314.46	370.04	387.79	401.80	410.90	431.37	447.29	469.97	448.68
		TPLA	211.00	343.62	376.64	396.81	402.03	414.98	434.14	446.17	467.87	463.85
		FM	0.0	0.35	0.63	0.81	0.84	1.00	1.00	1.00	1.00	1.00
0.50	168.9	TBAR	239.62	314.23	369.77	387.51	401.16	410.63	431.09	446.98	469.70	448.51
		TPLA	211.00	343.39	376.11	396.43	401.31	414.53	433.74	445.83	467.49	463.67
		FM	0.0	0.34	0.62	0.80	0.84	1.00	1.00	1.00	1.00	1.00
0.76	171.0	TBAR	239.62	313.94	369.50	387.27	400.68	410.33	430.75	446.58	469.36	448.27
		TPLA	211.00	343.22	375.77	396.14	400.79	414.13	433.36	445.43	467.08	463.42
		FM	0.0	0.34	0.62	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.01	172.4	TBAR	239.62	313.64	369.25	387.05	400.32	410.04	430.39	446.16	469.00	447.98
		TPLA	211.00	343.10	375.53	395.92	400.40	413.79	433.00	445.02	466.67	463.13
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.26	173.3	TBAR	239.62	313.33	369.00	386.85	400.03	409.76	430.04	445.73	468.63	447.69
		TPLA	211.00	343.00	375.35	395.73	400.10	413.49	432.67	444.61	466.28	462.84
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.50	173.9	TBAR	239.62	313.05	368.79	386.69	399.81	409.52	429.73	445.35	468.29	447.42
		TPLA	211.00	342.92	375.21	395.58	399.87	413.24	432.39	444.24	465.92	462.57
		FM	0.0	0.33	0.61	0.78	0.82	1.00	1.00	1.00	1.00	1.00
1.75	174.3	TBAR	239.62	312.78	368.59	386.53	399.62	409.29	429.42	444.98	467.97	447.15
		TPLA	211.00	342.86	375.09	395.45	399.68	413.01	432.12	443.89	465.58	462.29
		FM	0.0	0.33	0.61	0.78	0.82	1.00	1.00	1.00	1.00	1.00
2.00	174.5	TBAR	239.62	312.54	368.40	386.39	399.46	409.09	429.15	444.64	467.67	446.90
		TPLA	211.00	342.80	375.00	395.34	399.52	412.81	431.89	443.56	465.28	462.04
		FM	0.0	0.33	0.61	0.78	0.82	1.00	1.00	1.00	1.00	1.00
3.00	174.9	TBAR	239.62	311.85	367.89	385.99	399.04	408.52	428.36	443.65	466.80	446.18
		TPLA	211.00	342.65	374.74	395.02	399.11	412.27	431.20	442.61	464.36	461.27
		FM	0.0	0.33	0.60	0.78	0.82	1.00	1.00	1.00	1.00	1.00
4.01	175.0	TBAR	239.62	311.46	367.61	385.78	398.83	408.21	427.93	443.10	466.32	445.77
		TPLA	211.00	342.57	374.61	394.84	398.90	411.97	430.80	442.07	463.83	460.80
		FM	0.0	0.33	0.60	0.78	0.82	1.00	1.00	1.00	1.00	1.00

RUN 12

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	311.30	367.48	385.68	398.72	408.05	427.72	442.82	466.08	445.56
5.00	175.0	TPLA	211.00	342.53	374.54	394.75	398.80	411.81	430.59	441.79	463.53	460.53
		FM	0.0	0.33	0.60	0.78	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.22	367.42	385.63	398.67	407.98	427.61	442.68	465.96	445.45
6.01	175.0	TPLA	211.00	342.51	374.50	394.70	398.75	411.72	430.47	441.64	463.37	460.38
		FM	0.0	0.33	0.60	0.78	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.19	367.39	385.60	398.64	407.94	427.56	442.61	465.90	445.40
7.01	175.0	TPLA	211.00	342.50	374.48	394.68	398.72	411.68	430.41	441.56	463.28	460.29
		FM	0.0	0.33	0.60	0.78	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.17	367.38	385.59	398.63	407.92	427.53	442.57	465.87	445.37
8.00	175.0	TPLA	211.00	342.49	374.47	394.66	398.71	411.65	430.38	441.52	463.23	460.24
		FM	0.0	0.33	0.60	0.78	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.17	367.38	385.58	398.62	407.92	427.52	442.55	465.85	445.36
9.01	175.0	TPLA	211.00	342.49	374.47	394.66	398.70	411.64	430.36	441.50	463.20	460.21
		FM	0.0	0.33	0.60	0.78	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.16	367.37	385.58	398.62	407.91	427.51	442.54	465.84	445.35
10.01	175.0	TPLA	211.00	342.49	374.46	394.65	398.70	411.63	430.34	441.49	463.18	460.20
		FM	0.0	0.33	0.60	0.78	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.16	367.37	385.58	398.62	407.91	427.51	442.54	465.84	445.35
11.00	175.0	TPLA	211.00	342.49	374.46	394.65	398.70	411.63	430.34	441.48	463.17	460.19
		FM	0.0	0.33	0.60	0.78	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.16	367.37	385.58	398.62	407.91	427.51	442.54	465.84	445.34
12.01	175.0	TPLA	211.00	342.49	374.46	394.65	398.69	411.62	430.33	441.48	463.16	460.18
		FM	0.0	0.33	0.60	0.78	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.16	367.37	385.58	398.62	407.91	427.51	442.53	465.84	445.34
13.01	175.0	TPLA	211.00	342.49	374.46	394.65	398.69	411.62	430.33	441.47	463.16	460.17
		FM	0.0	0.33	0.60	0.78	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.16	367.37	385.58	398.62	407.91	427.51	442.53	465.84	445.34
14.00	175.0	TPLA	211.00	342.49	374.46	394.65	398.69	411.62	430.33	441.47	463.16	460.17
		FM	0.0	0.33	0.60	0.78	0.82	1.00	1.00	1.00	1.00	1.00

RUN 13

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	311.58	364.23	383.60	399.50	409.79	431.05	442.92	456.18	437.65
0.0	172.1	TPLA	211.00	342.69	373.83	393.39	399.56	413.22	433.15	442.19	457.33	453.45
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.57	364.19	383.59	399.48	409.79	431.04	442.96	456.31	437.76
0.25	172.3	TPLA	211.00	342.69	373.81	393.37	399.53	413.22	433.14	442.21	457.39	453.50
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.53	364.16	383.58	399.48	409.79	431.01	443.10	456.88	438.27
0.50	172.4	TPLA	211.00	342.68	373.78	393.36	399.52	413.22	433.12	442.33	457.73	453.86
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.47	364.13	383.57	399.49	409.79	430.96	443.31	457.75	439.05
0.76	172.5	TPLA	211.00	342.67	373.75	393.34	399.52	413.22	433.10	442.51	458.28	454.46
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.40	364.10	383.57	399.50	409.80	430.91	443.56	458.75	439.97
1.01	172.6	TPLA	211.00	342.65	373.73	393.33	399.53	413.23	433.07	442.71	458.93	455.18
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.33	364.07	383.56	399.52	409.80	430.85	443.81	459.79	440.92
1.26	172.7	TPLA	211.00	342.64	373.71	393.32	399.54	413.23	433.04	442.92	459.62	455.95
		FM	0.0	0.34	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.26	364.04	383.56	399.54	409.80	430.82	444.05	460.76	441.82
1.50	172.7	TPLA	211.00	342.63	373.69	393.31	399.55	413.24	433.01	443.12	460.27	456.68
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.20	364.01	383.55	399.56	409.81	430.77	444.28	461.72	442.70
1.75	172.8	TPLA	211.00	342.61	373.67	393.30	399.57	413.25	432.99	443.32	460.92	457.41
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.14	363.98	383.55	399.57	409.81	430.73	444.49	462.59	443.50
2.00	172.8	TPLA	211.00	342.60	373.65	393.29	399.58	413.26	432.96	443.49	461.52	458.09
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.97	363.90	383.53	399.62	409.82	430.61	445.10	465.13	445.88
3.00	173.0	TPLA	211.00	342.57	373.60	393.26	399.61	413.28	432.89	444.02	463.33	460.19
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.89	363.86	383.52	399.65	409.82	430.55	445.44	466.51	447.19
4.01	173.0	TPLA	211.00	342.55	373.57	393.24	399.63	413.29	432.85	444.31	464.40	461.45
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

RUN 13

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	310.84	363.84	383.52	399.66	409.83	430.51	445.60	467.19	447.85
5.00	173.1	TPLA	211.00	342.55	373.56	393.24	399.64	413.30	432.83	444.46	464.96	462.15
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.82	363.83	383.52	399.67	409.83	430.50	445.68	467.52	448.17
6.01	173.1	TPLA	211.00	342.54	373.55	393.23	399.64	413.30	432.82	444.54	465.26	462.53
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.81	363.83	383.51	399.67	409.83	430.49	445.72	467.67	448.33
7.01	173.1	TPLA	211.00	342.54	373.54	393.23	399.64	413.30	432.81	444.58	465.42	462.74
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.81	363.83	383.51	399.67	409.83	430.49	445.74	467.74	448.41
8.00	173.1	TPLA	211.00	342.54	373.54	393.23	399.64	413.31	432.81	444.60	465.50	462.86
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.81	363.82	383.51	399.67	409.83	430.49	445.75	467.78	448.44
9.01	173.1	TPLA	211.00	342.54	373.54	393.23	399.64	413.31	432.81	444.60	465.55	462.93
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.81	363.82	383.51	399.67	409.83	430.49	445.75	467.80	448.46
10.01	173.1	TPLA	211.00	342.54	373.54	393.23	399.64	413.31	432.81	444.61	465.58	462.97
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.81	363.82	383.51	399.67	409.83	430.49	445.75	467.80	448.48
11.00	173.1	TPLA	211.00	342.54	373.54	393.22	399.64	413.30	432.81	444.61	465.59	462.99
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.81	363.82	383.51	399.67	409.83	430.49	445.76	467.81	448.43
12.01	173.1	TPLA	211.00	342.54	373.54	393.22	399.64	413.30	432.81	444.61	465.60	463.01
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.81	363.82	383.51	399.67	409.83	430.49	445.76	467.81	448.48
13.01	173.1	TPLA	211.00	342.54	373.54	393.22	399.64	413.30	432.81	444.61	465.61	463.02
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.81	363.82	383.51	399.67	409.83	430.49	445.76	467.81	448.49
14.00	173.1	TPLA	211.00	342.54	373.54	393.22	399.64	413.30	432.81	444.61	465.61	463.02
		FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

RUN 14

TIME FLOWRATE

MODEL ZONE

	1	2	3	4	5	6	7	8	9	10
0.0 173.0	TBAR 239.62	312.42	366.02	384.85	399.32	409.34	431.94	447.08	467.84	448.45
	TPLA 211.00	342.81	374.34	394.24	399.40	412.93	433.56	445.85	466.03	453.10
	FM 0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
0.25 173.0	TBAR 239.62	312.42	366.02	384.85	399.32	409.34	431.85	446.99	467.82	448.44
	TPLA 211.00	342.83	374.34	394.24	399.40	412.84	433.52	445.77	466.00	463.09
	FM 0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
0.50 173.0	TBAR 239.62	312.41	366.02	384.85	399.32	409.31	431.51	446.55	467.70	448.42
	TPLA 211.00	342.83	374.34	394.24	399.39	412.83	433.32	445.46	465.84	463.04
	FM 0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
0.76 173.0	TBAR 239.62	312.40	366.02	384.84	399.31	409.27	430.99	446.13	467.51	448.37
	TPLA 211.00	342.84	374.34	394.24	399.39	412.81	433.31	444.98	465.58	452.93
	FM 0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.01 172.9	TBAR 239.62	312.38	366.02	384.84	399.31	409.23	430.39	445.52	467.28	448.31
	TPLA 211.00	342.84	374.34	394.24	399.39	412.79	432.65	444.42	465.27	452.80
	FM 0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.26 172.9	TBAR 239.62	312.36	366.02	384.84	399.31	409.18	429.78	444.90	467.03	448.25
	TPLA 211.00	342.84	374.34	394.24	399.39	412.76	432.28	443.84	464.94	452.66
	FM 0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.50 172.9	TBAR 239.62	312.34	366.02	384.84	399.31	409.13	429.20	444.32	466.80	448.18
	TPLA 211.00	342.84	374.34	394.24	399.38	412.73	431.93	443.30	464.63	462.52
	FM 0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
1.75 172.9	TBAR 239.62	312.32	366.02	384.84	399.31	409.09	428.64	443.74	466.58	448.12
	TPLA 211.00	342.84	374.34	394.23	399.38	412.71	431.58	442.77	464.31	462.37
	FM 0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
2.00 172.9	TBAR 239.62	312.30	366.02	384.84	399.31	409.05	428.13	443.22	466.37	448.05
	TPLA 211.00	342.84	374.34	394.23	399.38	412.68	431.27	442.28	464.02	462.24
	FM 0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
3.00 172.9	TBAR 239.62	312.26	366.02	384.84	399.30	408.93	426.65	441.67	465.74	447.86
	TPLA 211.00	342.84	374.34	394.23	399.38	412.51	430.31	440.82	463.12	461.80
	FM 0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
4.01 172.9	TBAR 239.62	312.23	366.02	384.84	399.30	408.87	425.84	440.81	465.38	447.74
	TPLA 211.00	342.84	374.34	394.23	399.38	412.57	429.75	439.98	462.57	451.52
	FM 0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

RUN 14

TIME FLOWRATE

MODEL ZONE

	1	2	3	4	5	6	7	8	9	10
THAR	239.62	312.22	366.02	384.84	399.30	408.84	425.45	440.37	465.19	447.67
TPLA	211.00	342.84	374.34	394.23	399.37	412.55	429.47	439.54	462.26	461.36
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
THAR	239.62	312.22	366.02	384.84	399.30	408.84	425.25	440.16	465.09	447.63
TPLA	211.00	342.85	374.34	394.23	399.37	412.54	429.32	439.32	462.09	461.26
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
THAR	239.62	312.21	366.02	384.84	399.30	408.82	425.18	440.05	465.04	447.60
TPLA	211.00	342.85	374.34	394.23	399.37	412.54	429.24	439.20	461.99	461.20
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
THAR	239.62	312.21	366.02	384.84	399.30	408.81	425.14	440.00	465.01	447.59
TPLA	211.00	342.85	374.34	394.23	399.37	412.54	429.20	439.14	461.94	461.15
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
THAR	239.62	312.21	366.02	394.84	399.30	408.81	425.12	439.97	465.00	447.58
TPLA	211.00	342.85	374.34	394.23	399.37	412.53	429.19	439.11	461.91	461.14
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
THAR	239.62	312.21	366.02	384.84	399.30	408.81	425.11	439.96	464.99	447.58
TPLA	211.00	342.85	374.34	394.23	399.37	412.53	429.17	439.09	461.89	461.12
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
THAR	239.62	312.21	366.02	384.84	399.30	408.81	425.10	439.95	464.99	447.57
TPLA	211.00	342.85	374.34	394.23	399.37	412.53	429.16	439.08	461.88	461.11
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
THAR	239.62	312.21	366.02	384.84	399.30	408.81	425.10	439.94	464.98	447.57
TPLA	211.00	342.85	374.34	394.23	399.37	412.53	429.16	439.07	461.87	461.10
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
THAR	239.62	312.21	366.02	384.84	399.30	408.81	425.10	439.94	464.98	447.57
TPLA	211.00	342.85	374.34	394.23	399.37	412.53	429.16	439.07	461.87	461.10
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00
THAR	239.62	312.21	366.02	384.84	399.30	408.81	425.10	439.94	464.98	447.57
TPLA	211.00	342.85	374.34	394.23	399.37	412.53	429.16	439.07	461.87	461.10
FM	0.0	0.33	0.61	0.79	0.83	1.00	1.00	1.00	1.00	1.00

RUN 15

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	299.93	357.45	379.57	398.36	407.80	428.25	441.93	461.26	445.38
0.0	154.6	TPLA	211.00	337.51	369.46	388.98	398.55	411.66	430.37	441.06	460.00	457.76
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	299.94	357.45	379.55	398.36	407.81	428.27	441.92	461.18	445.26
0.25	154.5	TPLA	211.00	337.52	369.45	388.96	398.56	411.67	430.38	441.05	459.94	457.67
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	299.98	357.43	379.53	398.36	407.83	428.32	441.88	460.89	444.82
0.50	154.4	TPLA	211.00	337.54	369.44	388.94	398.56	411.69	430.41	441.02	459.74	457.35
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	300.04	357.41	379.50	398.36	407.86	428.39	441.83	460.45	444.14
0.76	154.3	TPLA	211.00	337.55	369.44	388.91	398.56	411.71	430.46	440.98	459.45	456.86
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	300.10	357.38	379.47	398.36	407.89	428.43	441.78	459.94	443.36
1.01	154.3	TPLA	211.00	337.57	369.43	388.89	398.56	411.73	430.52	440.93	459.11	456.29
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	300.16	357.35	379.44	398.36	407.92	428.57	441.72	459.42	442.55
1.26	154.2	TPLA	211.00	337.58	369.42	388.86	398.56	411.75	430.58	440.89	458.76	455.68
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	300.22	357.32	379.42	398.36	407.95	428.66	441.67	458.93	441.80
1.50	154.2	TPLA	211.00	337.60	369.41	388.84	398.56	411.77	430.64	440.85	458.43	455.12
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	300.28	357.30	379.39	398.36	407.98	428.74	441.62	458.45	441.05
1.75	154.1	TPLA	211.00	337.61	369.41	388.82	398.56	411.79	430.70	440.81	458.10	454.55
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	300.34	357.27	379.37	398.36	408.00	428.82	441.58	458.02	440.38
2.00	154.1	TPLA	211.00	337.62	369.40	388.80	398.56	411.81	430.75	440.78	457.80	454.03
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	300.49	357.20	379.29	398.36	408.08	429.04	441.44	456.75	438.40
3.00	154.0	TPLA	211.00	337.66	369.38	388.74	398.56	411.87	430.91	440.67	456.90	452.44
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	300.57	357.17	379.26	398.36	408.12	429.15	441.37	456.06	437.31
4.01	154.0	TPLA	211.00	337.68	369.37	388.71	398.56	411.90	431.00	440.62	456.37	451.50
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00

RUN 15
TIME FLOWRATE

TIME		FLOWRATE	MODEL ZONE									
			1	2	3	4	5	6	7	8	9	10
5.00	153.9	TBAR	239.62	300.61	357.15	379.23	398.36	408.14	429.22	441.34	455.72	436.77
		TPLA	211.00	337.69	369.36	388.69	398.56	411.92	431.05	440.59	456.09	450.98
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
6.01	153.9	TBAR	239.62	300.63	357.14	379.22	398.36	408.15	429.25	441.32	455.55	436.50
		TPLA	211.00	337.70	369.36	388.68	398.55	411.93	431.08	440.58	455.94	450.70
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
7.01	153.9	TBAR	239.62	300.64	357.14	379.22	398.36	408.15	429.26	441.32	455.48	436.38
		TPLA	211.00	337.70	369.36	388.68	398.55	411.94	431.09	440.57	455.85	450.55
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
8.00	153.9	TBAR	239.62	300.64	357.13	379.22	398.36	408.15	429.27	441.31	455.44	436.32
		TPLA	211.00	337.70	369.36	388.67	398.55	411.94	431.10	440.57	455.81	450.46
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
9.01	153.9	TBAR	239.62	300.64	357.13	379.22	398.36	408.15	429.27	441.31	455.42	436.29
		TPLA	211.00	337.70	369.36	388.67	398.55	411.94	431.10	440.57	455.79	450.41
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
10.01	153.9	TBAR	239.62	300.64	357.13	379.22	398.36	408.15	429.27	441.31	455.41	436.27
		TPLA	211.00	337.70	369.36	388.67	398.55	411.94	431.11	440.57	455.78	450.38
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
11.00	153.9	TBAR	239.62	300.64	357.13	379.22	398.36	408.16	429.27	441.31	455.41	436.27
		TPLA	211.00	337.70	369.36	388.67	398.55	411.94	431.11	440.57	455.77	450.37
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
12.01	153.9	TBAR	239.62	300.64	357.13	379.22	398.36	408.16	429.27	441.31	455.41	436.26
		TPLA	211.00	337.70	369.36	388.67	398.55	411.94	431.11	440.57	455.76	450.36
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
13.01	153.9	TBAR	239.62	300.64	357.13	379.22	398.36	408.16	429.27	441.31	455.41	436.26
		TPLA	211.00	337.70	369.36	388.67	398.55	411.94	431.11	440.57	455.76	450.35
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
14.00	153.9	TBAR	239.62	300.64	357.13	379.22	398.36	408.16	429.27	441.31	455.41	436.26
		TPLA	211.00	337.70	369.36	388.67	398.55	411.94	431.11	440.57	455.76	450.35
		FM	0.0	0.38	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00

RUN 16

TIME FLOWRATE

	MODEL ZONE									
	1	2	3	4	5	6	7	8	9	10
0.0 154.8	TDAR 239.62	299.77	358.09	379.87	398.23	407.95	429.65	445.38	467.75	447.64
	TPLA 211.00	337.46	369.63	389.19	398.44	411.72	431.28	444.20	465.29	460.91
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
0.25 154.7	TDAR 239.62	299.77	358.08	379.86	398.23	407.94	429.51	445.24	467.72	447.63
	TPLA 211.00	337.47	369.62	389.17	398.44	411.72	431.20	444.07	465.25	460.90
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
0.50 154.7	TDAR 239.62	299.77	358.08	379.85	398.25	407.91	428.97	444.72	467.56	447.60
	TPLA 211.00	337.47	369.61	389.16	398.45	411.71	430.88	443.58	465.02	460.81
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
0.76 154.6	TDAR 239.62	299.77	358.08	379.85	398.27	407.87	428.17	443.93	467.30	447.54
	TPLA 211.00	337.48	369.60	389.15	398.47	411.59	430.38	442.85	464.55	460.67
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
1.01 154.6	TDAR 239.62	299.77	358.08	379.84	398.29	407.82	427.24	443.01	466.98	447.46
	TPLA 211.00	337.48	369.60	389.14	398.49	411.56	429.81	441.99	464.20	460.49
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
1.26 154.6	TDAR 239.62	299.77	358.08	379.83	398.31	407.76	426.29	442.06	466.64	447.38
	TPLA 211.00	337.48	369.59	389.13	398.51	411.64	429.21	441.10	463.73	460.30
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
1.50 154.6	TDAR 239.62	299.77	358.08	379.83	398.33	407.71	425.40	441.18	466.33	447.30
	TPLA 211.00	337.48	369.59	389.12	398.52	411.61	428.65	440.28	463.28	460.11
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
1.75 154.5	TDAR 239.62	299.78	358.07	379.83	398.35	407.66	424.53	440.31	466.01	447.22
	TPLA 211.00	337.48	369.58	389.11	398.54	411.58	428.10	439.46	462.83	459.92
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
2.00 154.5	TDAR 239.62	299.78	358.07	379.82	398.36	407.62	423.74	439.51	465.72	447.14
	TPLA 211.00	337.48	369.58	389.11	398.55	411.56	427.59	438.70	462.42	459.73
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
3.00 154.5	TDAR 239.62	299.78	358.07	379.81	398.41	407.49	421.43	437.16	464.85	446.89
	TPLA 211.00	337.48	369.56	389.09	398.60	411.49	426.06	436.46	461.13	459.15
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00
4.01 154.5	TDAR 239.62	299.78	358.07	379.81	398.44	407.41	420.18	435.84	464.35	446.74
	TPLA 211.00	337.49	369.56	389.08	398.62	411.45	425.18	435.17	460.34	458.77
	FM 0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00	1.00

RUN 16

TIME FLOWRATE

		MODEL ZONE									
		1	2	3	4	5	6	7	8	9	10
5.00	154.5	TBAR	239.62	299.78	358.07	379.80	398.45	407.38	419.57	435.18	464.09
		TPLA	211.00	337.49	369.55	389.07	398.63	411.43	424.71	434.50	459.90
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00
6.01	154.5	TBAR	239.62	299.78	358.07	379.80	398.46	407.36	419.27	434.84	463.95
		TPLA	211.00	337.49	369.55	389.07	398.64	411.41	424.47	434.15	459.64
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00
7.01	154.4	TBAR	239.62	299.78	358.07	379.80	398.46	407.36	419.14	434.68	463.87
		TPLA	211.00	337.49	369.55	389.06	398.64	411.41	424.34	433.97	459.50
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00
8.00	154.4	TBAR	239.62	299.78	358.06	379.80	398.46	407.35	419.07	434.60	463.83
		TPLA	211.00	337.49	369.55	389.06	398.64	411.41	424.27	433.97	459.47
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00
9.01	154.4	TBAR	239.62	299.78	358.06	379.80	398.47	407.35	419.04	434.55	463.81
		TPLA	211.00	337.49	369.55	389.06	398.64	411.41	424.24	433.92	459.38
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00
10.01	154.4	TBAR	239.62	299.78	358.06	379.80	398.47	407.35	419.03	434.53	463.80
		TPLA	211.00	337.49	369.55	389.06	398.64	411.41	424.22	433.79	459.35
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00
11.00	154.4	TBAR	239.62	299.78	358.06	379.80	398.47	407.35	419.02	434.52	463.79
		TPLA	211.00	337.49	369.55	389.06	398.64	411.41	424.20	433.78	459.33
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00
12.01	154.4	TBAR	239.62	299.78	358.06	379.80	398.47	407.35	419.02	434.51	463.79
		TPLA	211.00	337.49	369.55	389.06	398.64	411.41	424.20	433.77	459.32
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00
13.01	154.4	TBAR	239.62	299.78	358.06	379.80	398.47	407.35	419.02	434.51	463.79
		TPLA	211.00	337.49	369.55	389.06	398.64	411.41	424.19	433.77	459.31
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00
14.00	154.4	TBAR	239.62	299.78	358.06	379.80	398.47	407.35	419.02	434.51	463.79
		TPLA	211.00	337.49	369.55	389.06	398.64	411.41	424.19	433.76	459.31
		FM	0.0	0.37	0.66	0.83	0.87	1.00	1.00	1.00	1.00

RUN 17

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.62	300.81	357.45	379.36	398.53	408.09	429.30	441.46	455.47	436.43
0.0	153.0	TPLA	211.00	337.80	369.72	388.94	398.77	411.92	431.17	440.74	456.10	450.83
		FM	0.0	0.38	0.67	0.83	0.87	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	301.52	357.85	379.93	398.32	408.10	429.40	441.47	455.52	436.64
0.25	162.6	TPLA	211.00	340.57	371.26	390.18	398.51	411.85	431.47	440.75	456.25	451.65
		FM	0.0	0.36	0.64	0.81	0.85	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	302.36	358.49	380.67	398.34	408.26	429.58	441.57	455.62	436.92
0.50	169.0	TPLA	211.00	341.50	372.03	391.15	398.48	411.92	431.75	440.84	456.43	452.31
		FM	0.0	0.34	0.62	0.79	0.83	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	303.26	359.18	381.28	398.47	408.50	429.79	441.70	455.74	437.16
0.76	173.2	TPLA	211.00	341.97	372.47	391.81	398.56	412.05	432.01	440.97	456.59	452.79
		FM	0.0	0.33	0.61	0.78	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	304.20	359.92	381.83	398.46	408.80	429.99	441.86	455.85	437.37
1.01	175.9	TPLA	211.00	342.30	372.82	392.32	398.71	412.22	432.25	441.13	456.74	453.15
		FM	0.0	0.33	0.60	0.78	0.82	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	305.14	360.66	382.34	398.89	409.11	430.19	442.03	455.97	437.54
1.26	177.7	TPLA	211.00	342.57	373.11	392.75	398.91	412.44	432.48	441.29	456.88	453.42
		FM	0.0	0.33	0.60	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	305.99	361.33	382.79	399.13	409.42	430.38	442.18	456.08	437.68
1.50	178.9	TPLA	211.00	342.78	373.37	393.11	399.12	412.66	432.69	441.45	457.00	453.62
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	306.83	361.99	383.21	399.38	409.72	430.56	442.34	456.18	437.81
1.75	179.7	TPLA	211.00	342.97	373.61	393.45	399.33	412.89	432.89	441.67	457.12	453.80
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	307.58	362.59	383.59	399.61	410.00	430.72	442.48	456.27	437.92
2.00	180.2	TPLA	211.00	343.14	373.83	393.74	399.55	413.12	433.07	441.74	457.22	453.94
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	309.75	364.31	384.68	400.33	410.86	431.21	442.92	456.54	438.22
3.00	181.0	TPLA	211.00	343.63	374.49	394.59	400.21	413.87	433.64	442.18	457.54	454.31
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	310.91	365.24	385.28	400.75	411.35	431.49	443.17	456.69	438.38
4.01	181.2	TPLA	211.00	343.90	374.87	395.06	400.61	414.34	433.99	442.45	457.73	454.51
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00

RUN 17

TIME FLOWRATE

MODEL ZONE

			1	2	3	4	5	6	7	8	9	10
		TBAR	239.52	311.46	365.68	385.57	400.96	411.59	431.64	443.30	456.77	438.47
5.00	181.2	TPLA	211.00	344.03	375.07	395.32	400.81	414.59	434.18	442.59	457.84	454.62
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.71	365.89	385.72	401.07	411.71	431.71	443.37	456.81	438.51
6.01	181.2	TPLA	211.00	344.10	375.17	395.45	400.91	414.73	434.29	442.67	457.90	454.68
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.82	365.98	385.78	401.12	411.77	431.75	443.40	456.83	438.53
7.01	181.2	TPLA	211.00	344.14	375.23	395.52	400.97	414.80	434.35	442.71	457.93	454.72
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.87	366.02	385.82	401.15	411.80	431.77	443.42	456.84	438.54
8.00	181.2	TPLA	211.00	344.16	375.26	395.55	400.99	414.84	434.39	442.73	457.95	454.74
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.89	366.04	385.83	401.16	411.81	431.78	443.43	456.85	438.55
9.01	181.2	TPLA	211.00	344.17	375.27	395.57	401.01	414.86	434.41	442.75	457.96	454.75
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.90	366.04	385.84	401.16	411.82	431.78	443.44	456.85	438.55
10.01	181.2	TPLA	211.00	344.17	375.28	395.59	401.01	414.87	434.42	442.75	457.97	454.76
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.90	366.05	385.85	401.17	411.82	431.79	443.44	456.85	438.55
11.00	181.2	TPLA	211.00	344.17	375.28	395.59	401.02	414.88	434.43	442.76	457.97	454.77
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.90	366.05	385.85	401.17	411.82	431.79	443.44	456.85	438.55
12.01	181.2	TPLA	211.00	344.17	375.29	395.59	401.02	414.88	434.43	442.76	457.97	454.77
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.90	366.05	385.85	401.17	411.83	431.79	443.44	456.85	438.55
13.01	181.2	TPLA	211.00	344.18	375.29	395.60	401.02	414.88	434.43	442.76	457.97	454.77
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00
		TBAR	239.62	311.90	366.05	385.85	401.17	411.83	431.79	443.44	456.85	438.55
14.00	181.2	TPLA	211.00	344.18	375.29	395.60	401.02	414.88	434.43	442.76	457.97	454.77
		FM	0.0	0.32	0.59	0.77	0.81	1.00	1.00	1.00	1.00	1.00

**Plots of Experimental Data and Model Results
for Runs Not Shown in Text**

FIGURE 44 RESPONSE OF MELT TEMPERATURE TO DECREASE IN SCREW SPEED

FIGURE 45 RESPONSE OF MELT TEMPERATURE TO SCREW SPEED INCREASE

FIGURE 46 RESPONSE OF MELT TEMPERATURE TO ZONE 2 SET POINT CHANGE

FIGURE 47 RESPONSE OF MELT TEMPERATURE TO CLOSING OF BACK PRESSURE VALVE

FIGURE 48 RESPONSE OF MELT TEMPERATURE TO OPENING OF BACK PRESSURE VALVE

FIGURE 49 RESPONSE OF MELT TEMPERATURE TO DECREASE IN
 ZONE 3 TEMPERATURE CONTROLLER SET POINT

FIGURE 50 RESPONSE OF MELT TEMPERATURE TO DECREASE
 IN ZONE 4 TEMPERATURE CONTROLLER SET POINT

FIGURE 51 RESPONSE OF MELT TEMPERATURE TO DECREASE IN ZONE 3 TEMPERATURE CONTROLLER SET POINT

FIGURE 52 RESPONSE OF MELT TEMPERATURE TO INCREASE IN SCREW SPEED

APPENDIX D

Outside Barrel Wall Temperatures for Model

Weighted Barrel Wall Temperatures

Table 5 gives the weighted average experimental barrel temperatures used for determining the outside barrel wall temperatures for the model (TM). Computer program listings for calculating the weighted temperatures for each repeat unit are shown in Appendix B.

TABLE 5

WEIGHTINGS USED TO DETERMINE OUTSIDE
BARREL WALL TEMPERATURES FOR MODEL

REPEAT UNIT	WEIGHTING
1	$TM = 250.$
2	$TM = 0.634(\text{POSITION } 9) + 91.5$
3	$TM = 0.849(\text{POS } 10) + 0.151(\text{POS } 9)$
4	$TM = 0.244(\text{POS } 12) + 0.708(\text{POS } 11) +$ $0.048(\text{POS } 10)$
5	$TM = 0.90(\text{POS } 13) + 0.10(\text{POS } 12)$
6	$TM = 0.048(\text{POS } 15) + 0.708(\text{POS } 14) +$ $0.244(\text{POS } 13)$
7	$TM = 0.263(\text{POS } 16) + 0.737(\text{POS } 15)$
8	$TM = 0.710(\text{POS } 16) + 0.290(\text{POS } 18)$
9	$TM = 0.209(\text{POS } 19) + 0.698(\text{POS } 18) +$ $0.093(\text{POS } 17)$
10	$TM = 0.39(\text{POS } 20) + 0.39(\text{POS } 19) + 68.8$

Dynamic Response of TM

The outside barrel wall temperature was handled in the model by reading the initial value of TM (at time 0) into the MAIN program for each repeat unit. Also, the difference between the initial value and the value after a new equilibrium had been reached (TMDIF) was read in. The dynamic change of outside barrel wall temperature was determined with Equation 54.

$$TM(K,\theta) = TM(K,0) + TMDIF(K) \left[1 - \exp(-\theta/TAU(K)) - \frac{\theta}{TAU(K)} \exp(-\theta/TAU(K)) \right] \quad (54)$$

In most cases a value of 1.0 for TAU fit the experimental data fairly well (with θ in minutes).

APPENDIX E
Pressure Transducer Calibration Curves

Pressure Transducer Specifications

Figures 53, 54, 55 and 56 show calibration curves for the Dynisco Pressure Transducers, manufactured by the Microdot Company of Westwood, Mass. All calibrations were carried out at room temperature using a hydraulic pump and a Heise gage. The manufacturer's specifications for the transducers are as follows:(11)

Excitation - 6 volts recommended (8 volts maximum)

Zero Balance - $\pm 5\%$ F.S.(full scale) (the maximum output voltage from the transducer with no pressure or force applied)

Combined Error - $\pm 0.5\%$ F.S. (the maximum difference between any point on the ascending or descending calibration curve and the corresponding point on a straight line drawn between the zero and full scale points)

Repeatability - 0.1% F.S. (the maximum difference between two readings taken under the same conditions)

Maximum Bulb Temperature - 160 F

Maximum Diaphragm Temperature - 750 F

Maximum Zero Shift Due to Diaphragm Temperature Change - 15 psi/100 F

Maximum Pressure - 2 times F.S.

Mounting Torque - 500 inch lbs with no zero shift or change in performance

FIGURE 53 PRESSURE TRANSDUCER CALIBRATION CURVE

FIGURE 54 PRESSURE TRANSDUCER CALIBRATION CURVE

FIGURE 55 PRESSURE TRANSDUCER CALIBRATION CURVE

FIGURE 56 PRESSURE TRANSDUCER CALIBRATION CURVE