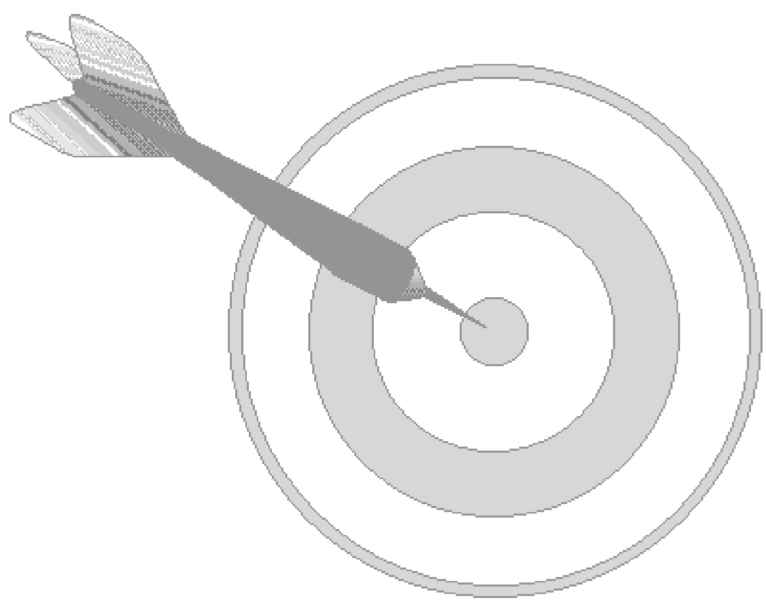
Alarm Setting Methodologies

Using

the eDART™ System

RJG, Inc.



Making Molding Simple™

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Overview

One of the important features of the Insight System™ is the ability to sort parts (or notify an operator) using a process alarm. This is done using a part diverter hooked to the alarm output (contact closure) on your eDART™ (or other RJG Process Controller). The alarm output is triggered when a summary value, such as *Peak, Cavity Pressure* falls outside a preset alarm limit. But the important questions are:

- **How do I know what value(s) to set alarms on?**

- **What should the alarm limits be?**

- **How can I be sure that my alarms are detecting my bad parts?**

This document addresses these questions.

There are several different approaches you can use, depending on the demands of your part specifications and the amount of work you can afford to put in up front. The following approaches describe the different methodologies, what they can and cannot do, and the amount of work required to implement them:

- Approach #1: Use Estimates of Alarm Settings and Tweak as You Go
  (The Simplest Way to Get Started)

- Approach #2: Alarm When the Parts May Be Different from Before
  (Keeps Process Capability High)

- Approach #3: Alarm When the Parts are Probably Bad
  (Prevents Bad Parts from being Shipped)

What follows is an introduction to alarms, a list of the summary values to use as alarms, and finally, a more detailed explanation of these three approaches. We've tried to keep them simple, but if you have any questions, call the RJG Customer Support team.

If you want to learn more about these approaches, RJG offers courses which cover setting alarm limits. These seminars teach how to set alarms, which keep the bad parts out while minimizing the number of good parts that are rejected. In some cases, you can even estimate the C_{pk} (process capability) of your parts from process data. Call (231) 947-3111 for more information.

What is an Alarm?

The eDART™ captures process information from each cycle and displays this data over time on the *Summary Graph*. An example of the summary graph is shown in Figure 1.

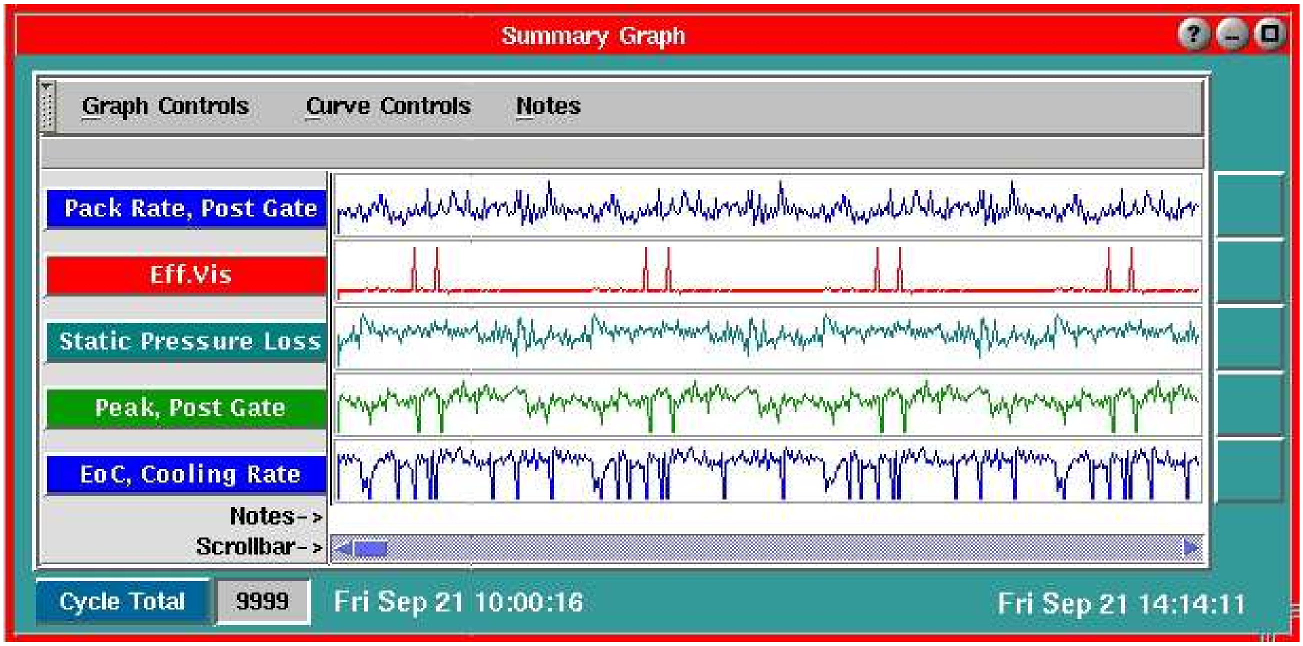


Figure 1*: Summary Graph*

On the Summary Graph, you have the option of displaying multiple summary values per sensor. (The tables on pages 10-14 show which ones to use for alarms). This powerful feature allows you to select the most important factors to monitor for your particular process.

Summary values are used in the eDART ™ System to describe parameters in the molding process. These values are calculated using cycle data and sequence input information. Summary values include a type category (e.g. Sequence Time) and a location category (e.g. Fill Time). Table 1 on page 3 shows the these available types and their most common locations. For further details refer to *Appendix E: Understanding Summary Values*.

NOTE: Some changes have been made from the DARTNet™ and DARTVision™ Systems to the eDART ™ System. For details, refer to Appendix D: Translating DARTNet™ and DARTVision™ Alarms to the eDART ™ System.

TYPE	LOCATION
Average Value	Hold Pressure, Back Pressure, Fill Flow Rate, Fill Speed, Pack Flow Rate, Pack Speed, Cycle Times, Cavity Fill Time, Cavity Pack Time, Post Gate Peak, End of Cavity Peak, Mid Cavity Peak, Barrel Temps., Mold Surface Temps., Coolant Inlet Pressure, Coolant Outlet Pressure, Coolant Diff. Pressure
Balance	Cavity Fill Time, Cavity Pack Time, Post Gate Peak, End of Cavity Peak, Mid Cavity Peak
Cooling Rate	Post Gate, Mid Cavity, End-of-Cavity
Cycle Integral	Injection Pressure, Sprue, Runner, Post Gate, End-of-Cavity, Mid Cavity, Shot Volume
Decompression	Shot Volume, Shot Stroke
Dynamic Pressure Loss	Injection to Post Gate, Post Gate to End-of-Cavity, Injection to Mid Cavity
Effective Melt Energy	Recovery
Effective Viscosity	Fill
Efficiency	Production, Machine, Mold, Cycle Time, Cavitation, Shot
Fill & Pack Integral	Post Gate, Mid Cavity, End-of-Cavity, Shot Volume
Fill Shear Rate	At Transfer
Gate Seal	Post Gate
Injection Integral	Injection Pressure, Sprue, Runner, Post Gate, Mid Cavity, End-of-Cavity, Shot Volume, Core Deflection
Mold Deflection	Post Gate, End-of-Cavity, Mid Cavity, Runner, Sprue
Pack Rate	Post Gate, Mid Cavity, End-of-Cavity
Peak	Injection Pressure, Sprue, Runner, Post Gate, End-of-Cavity, Mid Cavity, Shot Volume, Hydraulic Injection
Pressure Gradient at Cursor	Injection to Post Gate, Post Gate to End-of-Cavity, Injection to Mid Cavity
Process Metric	Match Error
Process Time	Cavity Fill, Cavity Pack, Fill Deceleration, Fill and Pack Time
Range	Cavity Fill Time, Cavity Pack Time, Post Gate Peak, End of Cavity Peak, Mid Cavity Peak
Sequence Time	Fill Time, Pack Time, Hold Time, Plastic Cooling, Injection Forward, Mold Close, Mold Open, Screw Run, Cycle Time
Static Pressure Loss	Injection to Post Gate, Post Gate to End-of-Cavity, Injection to Mid Cavity
Value at Fill -> Pack Transfer	Shot Volume, Injection Pressure, Post Gate, Mid Cavity, End-of-Cavity, Runner, Core Deflection
Value at Pack -> Hold Transfer	Shot Volume, Injection Pressure, Post Gate, Mid Cavity, End-of-Cavity, Runner, Core Deflection

***Table 1**: Summary Value Types and Locations for each Sensor*

Once you choose the summary values you want to monitor, you can then set upper and lower alarm limits on any or all of these curves. This is shown in Figure 2 where alarms are set on two summary values.

Figure 2*: Summary Graph with alarm limits set on two summary values. Note the three points that fall below the alarm limits on these curves.*

If a value falls outside an alarm limit setting for a particular shot, you can use the alarm output (contact closure) on your eDART™ to do something using an attached device. For example, a bell might ring to notify an operator or a part diverter might shift under the press to sort that shot into a different box.

Entering Alarms into the eDART™ Software

Click on the *Alarm Settings* button on the toolbar at the bottom of the screen. The Alarm Settings tool will appear (See Figure 3). For a detailed description of each function of the Alarm Settings tool, refer to the Reference section in the eDART™ Software Help Viewer.

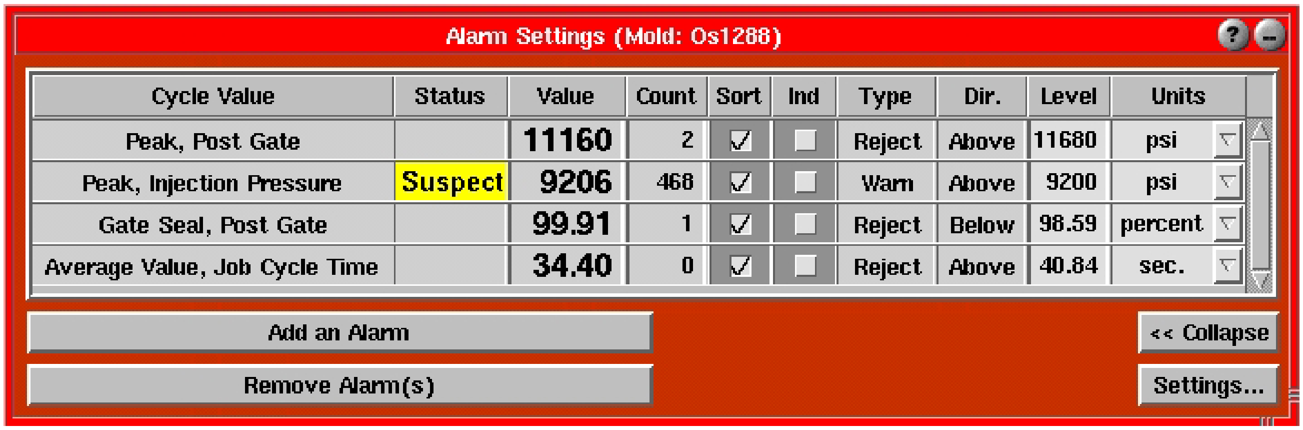


Figure 3*: Alarm Settings tool*

Click the *Add an Alarm* button.

A Select Type and Location(s) tool will appear (See Figure 4).

In the left column, choose the summary value type that you need to set alarms. In Figure 4, *Efficiency* was selected and a list of locations for that type appeared in the right column. *Cycle Time* was then selected as the location.

If you plan on adding additional types and locations, click *Apply*.

If you are finished, click *Apply & Close*.

A New Alarm Setting tool will appear (See Figure 5).

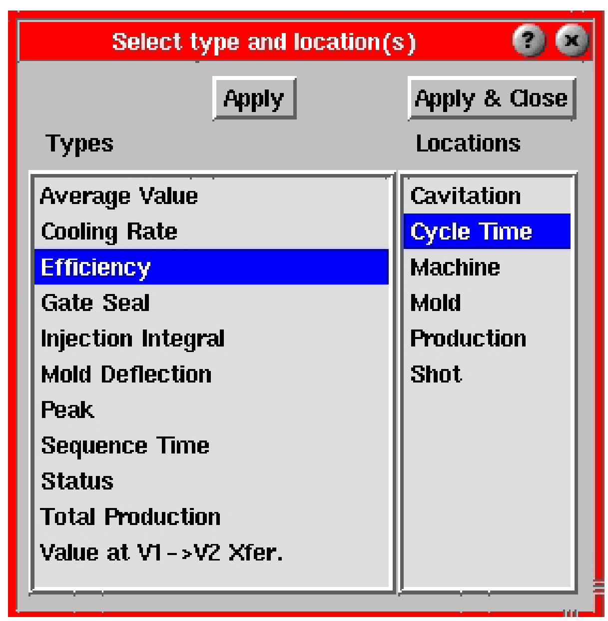
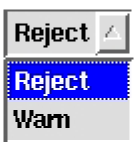


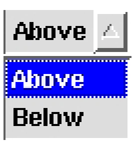
Figure 4*: Select Type and Location(s) tool*

***Figure 5**: New Alarm Setting tool*

The name of the selected (summary value) type and location is shown on the bar at the top of the screen.



Choose either to *Reject* (throw part away) or *Warn* (keep parts, but alert operator) from the combo box.



Choose either *Above* (sets a high alarm) or *Below* (sets a low alarm) from the combo box.

A suggested alarm level will appear in the value box. Check parts over a number of cycles to verify that the suggested alarm level is accurate. If you would like to change the alarm level, click inside the box and type in a new value.

Choose what type of units you would like to use from the combo box. The type of units will change depending on the summary value you are working with.

☑ Check the box(s) to enable sorting parts, enable indicators, or both.

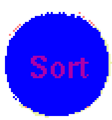
Click *Accept* to save and apply.

Repeat for each summary value you are using for alarms.

Adjusting Part Diverter Controls

Click the *Part Diverter Controls* button on the toolbar at the bottom of the screen.

A Part Divertor Controls tool will appear. (Note that this tool will not be available without a sorting output relay module.)



Click the *Sort* button to enable the sorting devices.

Viewing Alarm Lines Using the Summary Graph

Right click anywhere on the summary graph to bring up the Graph Controls menu.

Click on *Graph Options*.

Click *Show Alarm Lines* to see the new alarm levels set.

Which Summary Values Do I Use for Alarms?

When setting process alarms in the eDART™ System, one of the first things you need to do is choose which summary values to use for the alarms. This section provides some general recommendations to help you.

1. What are the types of quality issues I want my alarms to detect?

The first question to ask when setting an alarm is *"What are the types of quality issues I want my alarms to detect?"* because different cavity pressure values do a good job of checking for different quality issues. For example, "Peak, Cavity Pressure" works better for predicting flash, while "Process Time, Fill and Pack Time" (the time it took to fill and pack the part out) works better for predicting surface texture, especially in filled materials. If you want to test whether or not a value predicts part quality, see Appendix B, which describes an experiment that can be used to evaluate correlation between a cavity pressure value and part quality.

Once you have determined the quality issues you want to detect, use the tables on pages 10-14 to choose the summary values on which you would like to alarm.

2. How many alarms should I set?

The second question is *"How many alarms should I set?"* There are a couple of issues to consider when determining alarm numbers. First, how critical is the quality of the part and how difficult is it to maintain that quality? If you have a fairly easy application, you may only need to set one or more alarms. If it is a very difficult application, you may want to use more alarms - perhaps as many as six or seven. Also, if you are trying to satisfy multiple quality issues (such as dimensions and texture), additional alarms will be needed. In general, though, try to minimize the number of alarms initially and add more later if you are having trouble catching problems. Using too many alarms can cause false alarms and confusion on your part, especially if you haven't had much experience with them.

3. Which sensor location should I use?

The third question is "*Which sensor locations should I use?*". You may have more than one sensor in the cavity, or you may be asking this question before you install the sensor. In general, the best place to monitor (that is, to set alarms) is at the end-of-cavity. The case where this may not be true is if you are concerned with a potential problem that is far from the end-of-cavity.

There are a couple other issues, though, in determining sensor location. First, in most cases, you'll want the sensor in or near the Area of Influence. This is the area where the last material is flowing through the part at the end of the filling stage. To find this, you can run a clear or natural colored material and then switch to a dark or colored material. On the first shot where you see the new material, the path that it makes will be the Area of Influence. Sometimes you cannot get a sensor in that area. If not, do your best to get close to that area, and stay out of regions that stop flowing very early in the filling process.

If you have multiple sensors, it is also okay to put alarms on all of them. However, be careful to avoid over-doing it, or you may get too many false alarms.

ALSO: This was mentioned before, but it is important enough to repeat:

In general, End-of-Cavity is the best cavity pressure to set alarms on!

Summary Values for Setting Alarms

Once you have determined the quality issues you want to detect, use the following tables to help in choosing summary values for your alarms. Each table contains values to use for Strategy A (Cavity Pressure) and Strategy B (Hydraulic and Stroke), Strategy A generally being preferable. These summary values are ranked in order of preference in each table. The ones at the top of the list are usually the best at predicting part quality. Each value is listed in “Type, Location” format.

NOTE: *For Multi-cavity instrumentation, replace*:

- *Peak Cavity Pressure with Average Value, Peak Cavity Pressure*
- *Process Time, Cavity Fill with Average Value, Cavity Fill Time*
- *Process Time, Cavity Pack with Average Value, Cavity Pack Time*

Detecting Short Shots

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
Peak, End-of-Cavity (Low Alarm) - Post Gate or Mid Cavity is acceptable	Peak, Shot Volume (+/- six sigma)
Cycle Integral, End-of-Cavity (Low Alarm) - also picks up cooling - Post Gate or Mid Cavity is acceptable	Cycle Integral, Shot Volume (+/- six sigma)
Process Time, Fill and Pack Time (High Alarm) - if you don’t have End-of-Cavity (especially for thin-wall)	Effective Viscosity, Fill (High Alarm)

Detecting Sinks

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
[redacted]	
Cycle Integral, End-of-Cavity (Low Alarm) - also picks up cooling, will not pick up gate discharge	Cycle Integral, Shot Volume (+/- six sigma)
Cycle Integral, Post Gate (Low Alarm) - also picks up cooling, gate discharge, etc.	Effective Viscosity, Fill (High Alarm)
Process Time, Fill and Pack Time (High Alarm) - if you don’t have End-of-Cavity	

Detecting Flash

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
[redacted]	
Process Time, Fill and Pack Time (Low Alarm)	Cycle Integral, Shot Volume (+/- six sigma)
	Effective Viscosity, Fill (Low Alarm)

Detecting Texture

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
Process Time, Fill and Pack Time	Value at Fill -> Pack Transfer, Volume
Process Time, Pack Rate	Value at Pack -> Hold Transfer, Volume
Process Time, Cavity Fill - any or all cavity sensors	Effective Viscosity, Fill
Peak - any cavity sensor	Peak, Shot Volume (+/- six sigma)
	Cycle Integral, Shot Volume (+/- six sigma)

Detecting Dimensions

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
Cycle Integral, End-of-Cavity	Peak, Shot Volume (+/- six sigma)
Cycle Integral, Post Gate	Cycle Integral, Shot Volume (+/- six sigma)
Peak, cavity pressure	Effective Viscosity, Fill
Injection Integral, cavity pressure (if lots of mold deflection) *Should be used w/ Sequence Time, Injection Forward alarm*	Peak, Hydraulic Injection
	Value at Pack -> Hold Transfer, Injection Pressure
	Value at Fill -> Pack Transfer, Injection Pressure or Shot Volume

Detecting Check Ring Leakage

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
[redacted]	
Process Time, Fill and Pack Time	Cycle Integral, Shot Volume

Detecting Thin Wall Part Characteristics (other than texture)

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
Fill and Pack Integral, End-of-Cavity	Peak, Shot Volume (+/- six sigma)
Fill and Pack Integral, other cavity pressure	Effective Viscosity, Fill
Peak, End-of-Cavity (other cavity sensors acceptable)	Fill and Pack Integral, Shot Volume (+/- six sigma)
Process Time, Fill and Pack Time	Value at Pack -> Hold Transfer, Injection Pressure or Shot Volume
	Value at Fill -> Pack Transfer, Injection Pressure or Shot Volume

Detecting Stresses and Molecular Orientation

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
Process Time, Fill and Pack Time	Sequence Time, Fill Time
Process Time, Cavity Fill	Value at Pack -> Hold Transfer, Shot Volume
Fill Shear Rate, At Transfer	
Static or Dynamic Pressure Loss, Post Gate to End-of-Cavity	
Static or Dynamic Pressure Loss, Injection to Post Gate	

Detecting Blocked Cavities

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
Range, Post Gate Peak	Peak, Shot Volume (+/- six sigma)
Range, End of Cavity Peak	Cycle Integral, Shot Volume
Process Time, Cavity Fill	

Detecting Mold Balance

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
Balance, Cavity Fill Time	N/A
Balance, Cavity Pack Time	
Balance, End of Cavity Peak	
Balance, other cavity peak	

Detecting Crystallinity

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
Cooling Rate, any cavity sensor (in conjunction with Gate Seal alarm)	Average Value, Mold Surface Temp. (thermocouple)
Cycle Integral, any cavity sensor	

Detecting Core Deflection

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
Peak, Core Deflection	Effective Viscosity, Fill
Cycle Integral, Core Deflection	Sequence Time, Fill Time

Detecting Warp

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
Cooling Rate, any cavity sensor	Sequence Time, Fill Time
Gate Seal, Post Gate	Sequence Time, Pack Time
Static or Dynamic Pressure Loss, Post Gate to End-of-Cavity	Sequence Time, Injection Forward
Process Time, Fill and Pack Time	
Process Time, Cavity Fill	

Detecting Mixing Consistency

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
	Average Value, Back Pressure
	Sequence Time, Screw Run

Detecting Viscosity Changes

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
Static or Dynamic Pressure Loss, Post Gate to End-of- Cavity	Effective Viscosity, Fill
Static or Dynamic Pressure Loss, Injection to Post Gate	Sequence Time, Screw Run
Value at Fill -> Pack Transfer, Post Gate	

Detecting Gate Seal

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
Gate Seal, Post Gate	Sequence Time, Injection Forward

Detecting Machine Operation Consistency

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
	Sequence Time, Fill Time
	Sequence Time, Cycle Time

Detecting Setup Consistency

Cavity Pressure (Strategy A)	Hydraulic and Stroke (Strategy B)
Cycle Integral, any cavity sensor	Sequence Time, Fill Time
Process Metric, Match Error	Sequence Time, Injection Forward
	Sequence Time, Cycle Time
	Sequence Time, Screw Run
	Value at Fill -> Pack Transfer, Volume
	Average Value, Hold Pressure
	Average Value, Back Pressure
	Average Value, Fill Flow Rate
	Average Value, Pack Flow Rate
	Decompression, Shot Volume

Determining Alarm Levels

Next, let's talk about how to choose your alarm levels. As discussed earlier, we will show you three different approaches:

- Approach #1: Use Estimates of Alarm Settings and *Tweak as You Go*
  (The Simplest Way to Get Started)

- Approach #2: Alarm When the Parts May Be *Different from Before*
  (Keeps Process Capability High)

- Approach #3: Alarm When the Parts are *Probably Bad*
  (Prevents Bad Parts from Shipping)

Approach #1: Use Estimates of Alarm Settings and *Tweak as You Go*

(The Simplest Way to Get Started)

Objective:
Start with rough estimates of your alarm settings and refine them during normal production.

What it WILL do:
This approach will allow you to get started with alarms quickly and to optimize them over time during normal production. You can use either Approaches #2 or #3 in conjunction with this approach or you can choose arbitrary alarms and optimize from there.

What it WON'T do:
This approach will not allow you to quickly get to a point where you can rely on your alarms unless either Approaches #2 or #3 are used in conjunction. Otherwise, it will take a while before your alarms are optimized. Also, it will not provide as systematic an approach as Approaches #2 or #3.

Work Required:
You will need to establish preliminary alarm limits. Usually, the reason you are taking this approach is to save time up front, so the alarm limits you choose are going to be arbitrary (although you can also use this approach with alarms set using Approaches #2 or #3). During production, you will need to monitor parts that are rejected and adjust the alarms according to the analysis of the parts.

How to do it:
Follow these steps:

1. Establish preliminary alarm limits

Determine which summary values you want to use for alarms (see the "Summary Values for Setting Alarms" section on page 10 for tips).

Set preliminary alarms on each summary value. Again, you will probably want to choose an arbitrary alarm value (This is a starting point and you'll be adjusting them as you go). Generally, it is better to set the alarms tight and gradually loosen them than to set them loose and gradually tighten them.

As mentioned, you can also use alarms from Approaches #2 or #3 as the starting point. You may ask "Why bother? I already have my alarms." The beauty of this approach is that you can verify or improve the effectiveness of your alarms by monitoring and adjusting them over time (i.e. continuous improvement).

2. Monitor alarm parts during production

Periodically check the Reject bin for alarm parts.

When parts are found in the Reject bin, inspect them (either all or a relatively large sampling). Check to see which summary values caused the alarms. These are the ones you will focus on changing.

- If none of the parts are bad, widen the alarms that went off a lot.
- If a few of the parts are bad, widen the alarms that went off a little.
- If many of the parts are bad, tighten all the alarms a little.
- If most of the parts are bad, tighten all the alarms a lot.
- If the result is somewhere between a few and many bad parts in the bin, leave the alarms alone.

Any time bad parts get into the Good bin, tighten all the alarms.

- If a few bad parts get into the Good bin, tighten the alarms a little.
- If a lot of bad parts get into the Good bin, tighten them a lot.

Keep doing this until the alarms are set somewhat tighter than the point where a few alarm parts are bad and no bad parts get into the Good bin. In the best case scenario, you want to make sure no bad parts get in the Good bin, even if you end up with a few extra good parts in the Bad bin.

NOTE*: This approach can be the quickest to begin, but can take the longest to optimize. If you want to accelerate the process, adjust the process until it causes alarms, then evaluate the parts. This can be quicker and more systematic than waiting for a mish-mash of alarms to come along. Also, you know when they are going to occur, instead of watching periodically. The choice is yours.*

One of the advantages of automatic part sorting using alarms is that you can reduce your inspection efforts since the cavity pressure sensor is doing a lot of inspection for you. However, you should keep your regular inspection efforts in place until you feel comfortable that your alarms have been fairly well optimized. Until that point, you can look a little more carefully at your alarm parts and either keep, sort, or scrap them.

Approach #2: Alarm When Parts May Be *Different from Before* *(Keeps Process Capability High)*

Objective:
If you want to sort out parts that may be different from the normal parts produced by the process, this is a good approach. In other words, this approach uses alarms when the process changes significantly.

What it WILL do:
This approach says "As long as the process hasn't changed much, the parts should be the same as they were before, but if the process changes substantially, the parts may be different." This approach will sort parts when the process changes. In most cases, it will catch short shots, flash, and in many cases it will catch dimension changes.

What it WON'T do:
This approach does not sort good parts from bad. If your normal process has a high capability (C_{pk}), this means a lot of good parts may go into the Reject bin, but hardly any bad parts will get into the Good bin. However, if your process has a low capability, you may have bad parts getting into the Good bin from time to time.

Work Required:
Identify the summary values you want to set alarms on, run approximately 100 shots on a stable process, and spend a few minutes with the software to set the alarms.

How to do it:
Follow these steps:

1. Select data from a stable process.

Dial in the process and allow it to stabilize (See Figure 6). It will take anywhere from 15 minutes to an hour for the process to stabilize in most cases. Watch the summary graph to see when stabilization occurs.

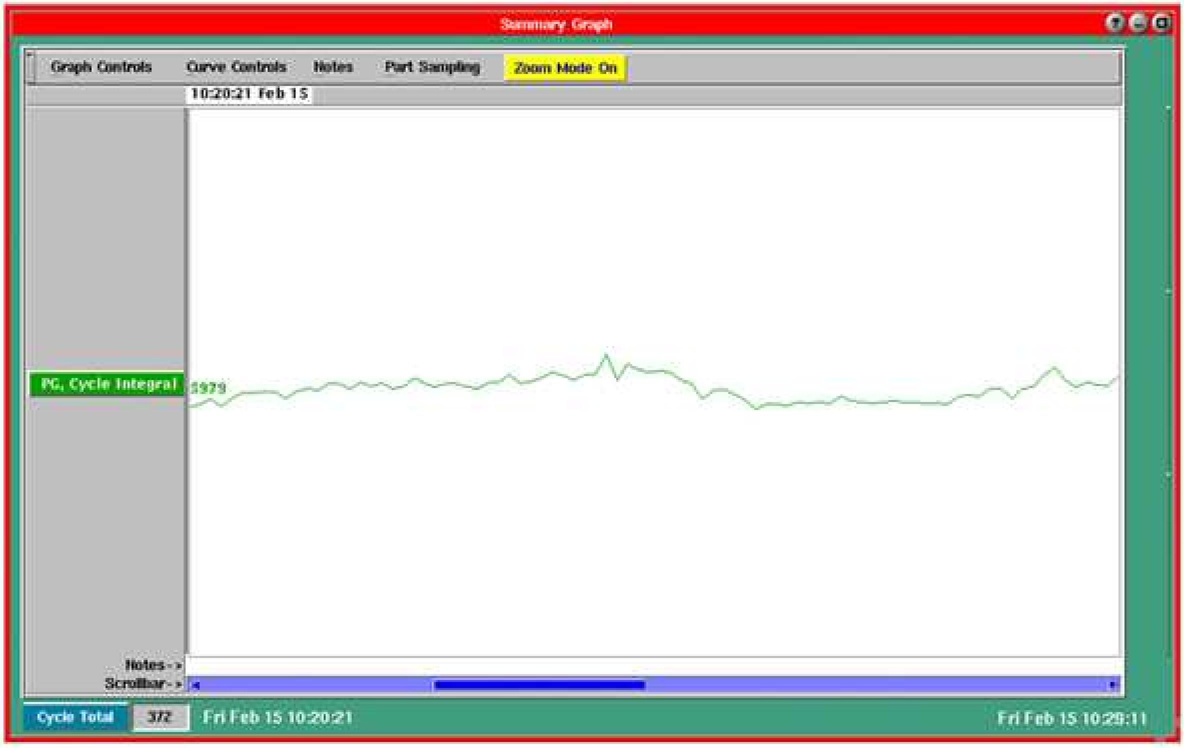


Figure 6: *Illustration of Stabilization Time*

Let the process run until there are at least 100 more datapoints. It is important that there are no “outlying” datapoints - that is, the “blips” above or below the normal process.

Zoom in on the data in the stable region. To do this, put the cursor at the start of the stable region on the summary curve and right click and drag to the end of the stable region.

2. Set alarm on the 1st summary value.

Select the first summary value you want to set an alarm on (see the “Summary Values for Setting Alarms” section on page 10 for tips).

Open the Alarm Settings tool

The Alarm Settings tool automatically defaults to 6 sigma, but can be changed by clicking the *Settings* button and selecting “Adjust Suggested Levels”.

3. Repeat for each summary value you want to set alarms on.

You have just set your alarms to catch any parts if the process changes a lot from where it normally runs.

NOTES: *If you wanted to catch any small variation, you would generally set your alarms to +/- 3*Sigma. However, most molding processes are not perfectly stable - that is, they will change a bit from setup to setup, material lot to material lot, etc. If you set your alarms too tight, you will tend to get lots of alarms due to this "semi-normal" variation. Thus, we recommend setting alarms to +/- 6*Sigma to make alarms tight enough to catch variation but not so tight that you get lots of alarm parts. Where does the number 6 come from? It's based on experience with a number of molds and their variation over time. Is this the ONLY number that will work? No! It tends to work well with most applications, but for others it should be modified. If this is too wide, you can use 5, 4, or 3 sigma. Experiment and see what works for you.*

Approach #3: Alarm When the Parts are *Probably Bad* *(Prevent Bad Parts from being Shipped)*

Objective:
If you want to keep bad parts out of the good parts, this is a good approach. It does require some work up front, though.

What it WILL do:
This approach will allow you to keep unacceptable parts (those with shorts, flash, and unacceptable dimensions) out of the parts you ship to your customer. It will also help prevent too many good parts from getting into the Bad bin.

What it WON'T do:
This approach does not catch process shifts until bad parts are being produced, unless you use warning alarm limits (Note: Warning alarms can either be used to reject parts to a third bin or can be easily viewed using a light tree output).

Work Required:
A fairly simple experiment must be run. The alarms are determined and entered into the eDART ™ Software.

HELPFUL TIP: *The first couple of times you try this, only look at one thing on your parts (e.g. dimension) and only use two or three cavity pressure values (e.g. Peak Cavity Pressure and Cavity Pressure Cycle Integral).*

<u>How to do it</u>:
Follow these steps:

1. Plan the experiment.

Try to determine which machine setting will have the largest effect on the quality of the part (e.g. part measurements). In many cases, this is hold pressure. We will call this the Experimental Factor. Other common factors include fill speed, mold temperature, or melt temperature.

Determine which summary values you want to use for alarms (see the “Summary Values for Setting Alarms” section on page 10 for tips).

2. Run the Experiment.

Dial the process in to the normal process settings.

Adjust the Experimental Factor (machine setting) down until the parts are no longer acceptable. Read the values for the cavity pressure values you want to use for alarms. These values will be the lower alarm points.

Repeat the previous step, but now adjust the Experimental Factor up. Read the values for the cavity pressure values you want to use for alarms. These values will be the upper alarm points.

3. Enter alarm settings into the eDART™ Software.

You’ll want your alarms to be somewhat conservative, so you’ll probably need to make them a little tighter than your initial alarm points. As a rule of thumb, bring each of the alarm points in about 1/3 the way to the centered process. While you may still send a few good parts to the Reject bin, you want to be sure that no bad parts make it into the Good bin. For further details on this concept, refer to Appendix B.

Follow the instructions for entering alarm settings described in detail in Approach #1. The only difference is that you enter the high and low alarm settings manually.

You now have alarms that will reject parts when they are likely to be bad, but are still a bit conservative. You might send a few good parts to the Bad bin, but you shouldn’t have to sweat when your customer calls!

NOTES: *This is the simplified approach to setting these types of alarms. RJG, Inc. has a more in-depth class if you want to learn how to do this more systematically. Appendix B might help you out too.*

OPTIONAL: *Once you have set your alarms, you can verify them by adjusting the process until you get alarms on the high and low end. Have the parts checked to see how close they are to the specification limit.*

Appendix A: Devices to Use for Part Sorting or Operator Notification

Now that you have chosen summary values to set alarms on and have set alarm limits for these, you'll need to do something with them. This appendix gives a brief description of types of hardware that can use alarm outputs to either sort parts at the press or alert operators that the process is misbehaving. It also includes some ideas for making a part diverter.

Types of Devices for Diverting Parts

1. The flipper-style diverter

One of the more common diverters, this device consists of a flat sheet of metal that "flips" one direction or the other to put parts into two different boxes (see Figure A-1). It usually goes under the mold or at the end of a conveyor. These can be purchased off the shelf from automation sources or from the press manufacturer. You can also build one using a solenoid actuated air valve and a rotary style actuator.

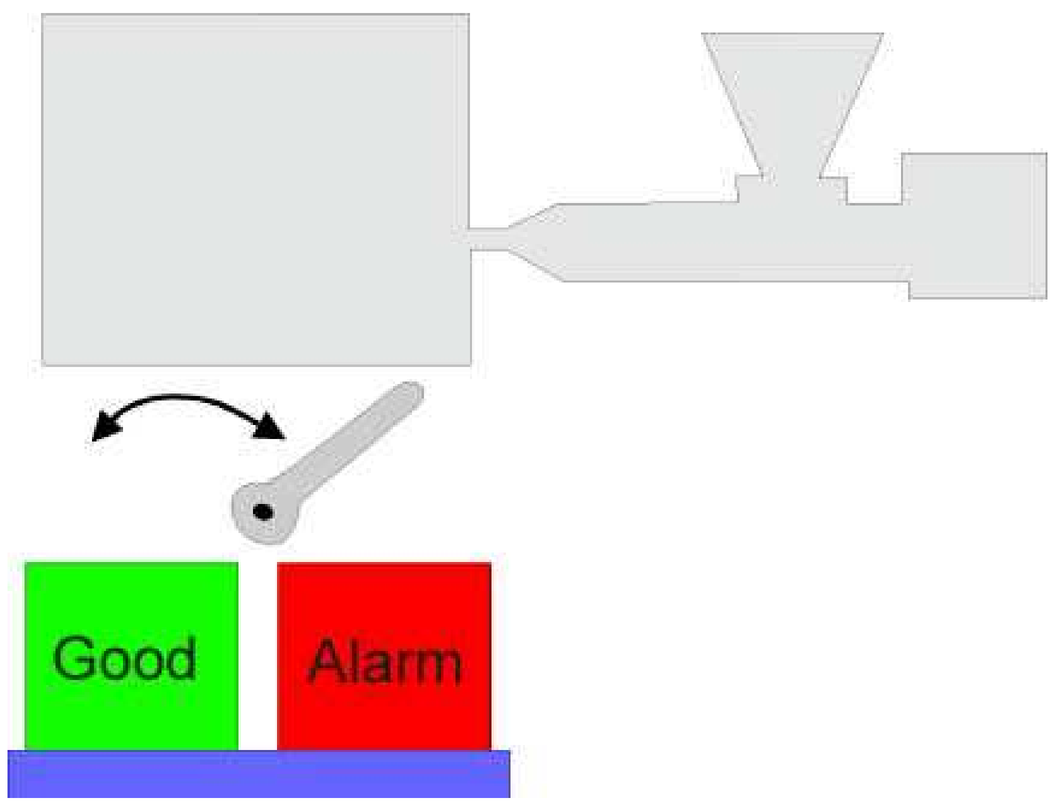


Figure A-1*: The Flipper Style Diverter*

Issues to watch for: Make sure parts can't bounce around in such a way to get into the wrong bin. If used at the end of a conveyor, a delay must be built into the alarm signal to compensate for the time the parts are on the conveyor.

2. The box shifting diverter

Another common diverter is the box shifter (Figure A-2). This is a simple side-to-side diverter that moves the position of the boxes to determine which one the parts will go in. It usually goes under the press, but can also be placed at the end of a conveyor. These are less readily purchased, but are among the easiest to build (see "Tips for Building a Part Diverter" on page 24).

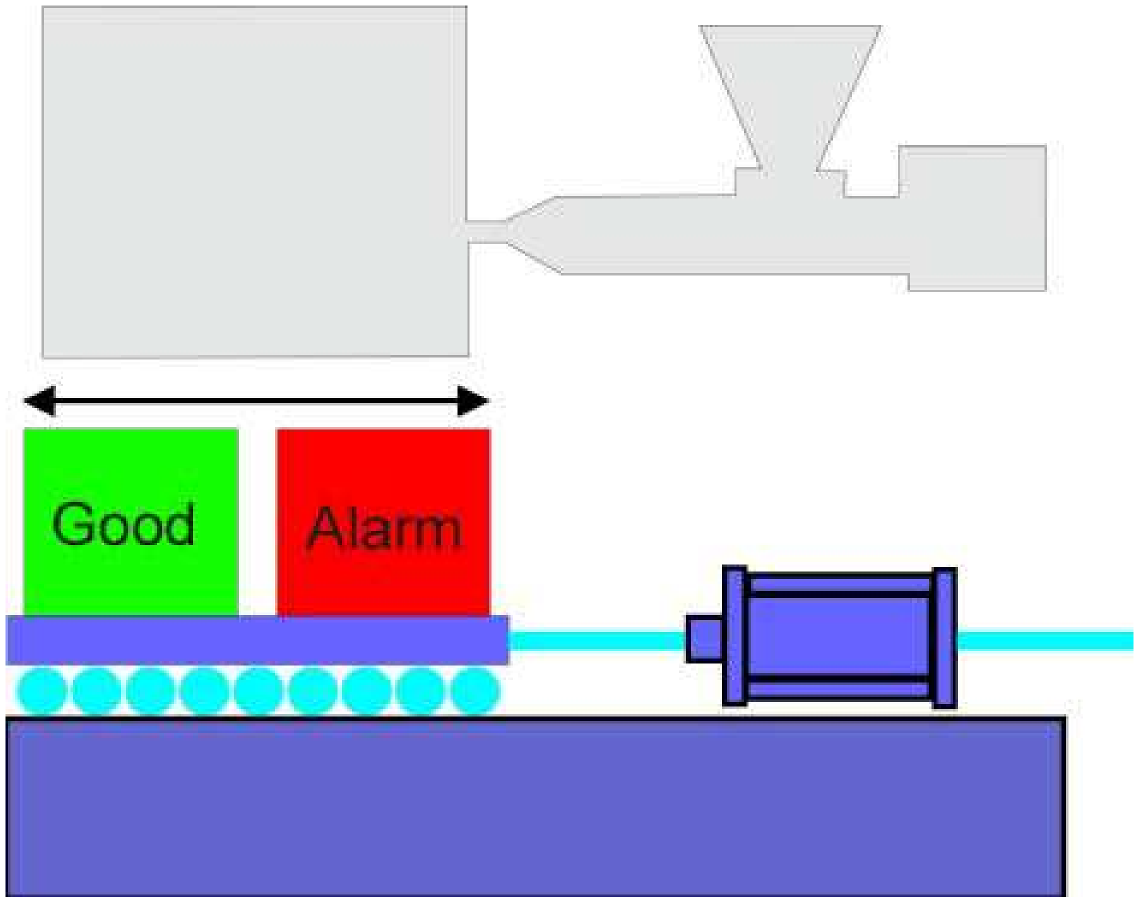


***Figure A-2**: The Box Shifting Diverter*

Issues to watch for: Make sure parts can't bounce around in such a way to get into the wrong bin. If used at the end of a conveyor, a delay must be built in to the alarm signal to compensate for the time the parts are on the conveyor. Be sure the speed at which the boxes shift is slow enough that the boxes don't go flying, yet fast enough that they shift in time to catch the parts.

3. The picking robot

This is often the most elegant solution, particularly if you are already using robotics for part removal. Simply program the robot to put the parts in a different spot upon an alarm input.

4. The reversing conveyor

A less commonly used approach, the reversing conveyor reverses its direction upon an alarm signal in order to put parts in two different boxes - one at each end of the conveyor. Be sure to configure the timing of the diverter output in the Part Diverter Controls tool.

Tips for Building a Part Diverter

Figure A-3 and A-4 show a schematic for a part diverter that is relatively inexpensive and easy to build. The list of parts required is shown in Table A-1. This particular diverter is designed for a small press. For larger presses, you should be able to use the same concept - just scale it up.

The main components are a frame made of modular extruded aluminum (available from Bosch, 80-20, Quik Connect, etc.), a slide mechanism, a pneumatic cylinder to drive the slide, and a solenoid driven air valve to operate the cylinder. If you have questions on the print, you should be able to get help from your local supplier of pneumatics or extruded aluminum frame.

Tag	Part #	Description	Qty.
K	1515L	12” Lg.	2
L	1515L	20” Lg.	2
M	1515L	28” Lg.	2
I	15301L	18” Lg.	1
J	6834	15 Series long double flange high cycle linear bearing	1

***Table A-1**: List of Components for Sliding Part Diverter Frame.*
Supplier - 80/20 Inc. Phone - (219) 248-8030

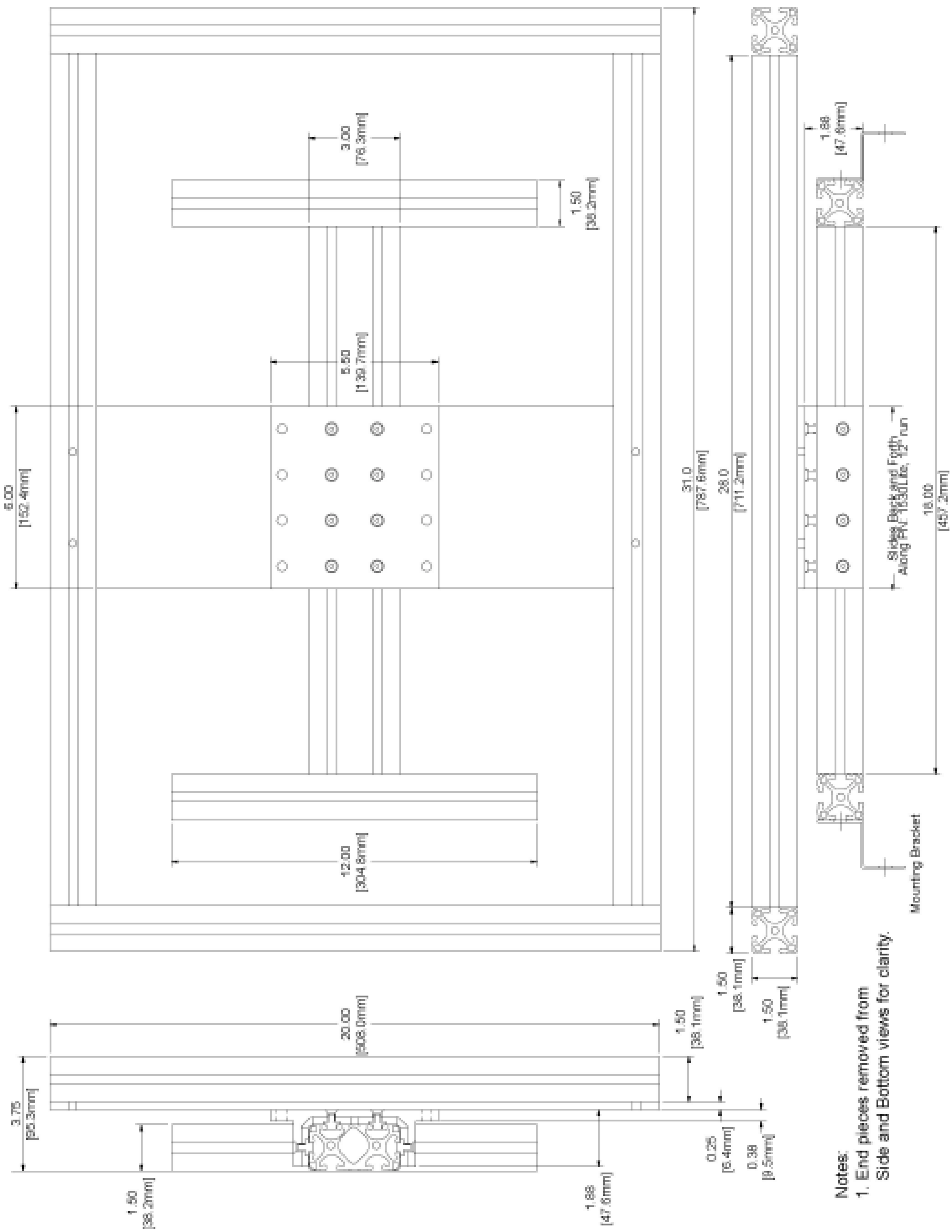


Figure A-3*: Schematic for Sliding Part Diverter*

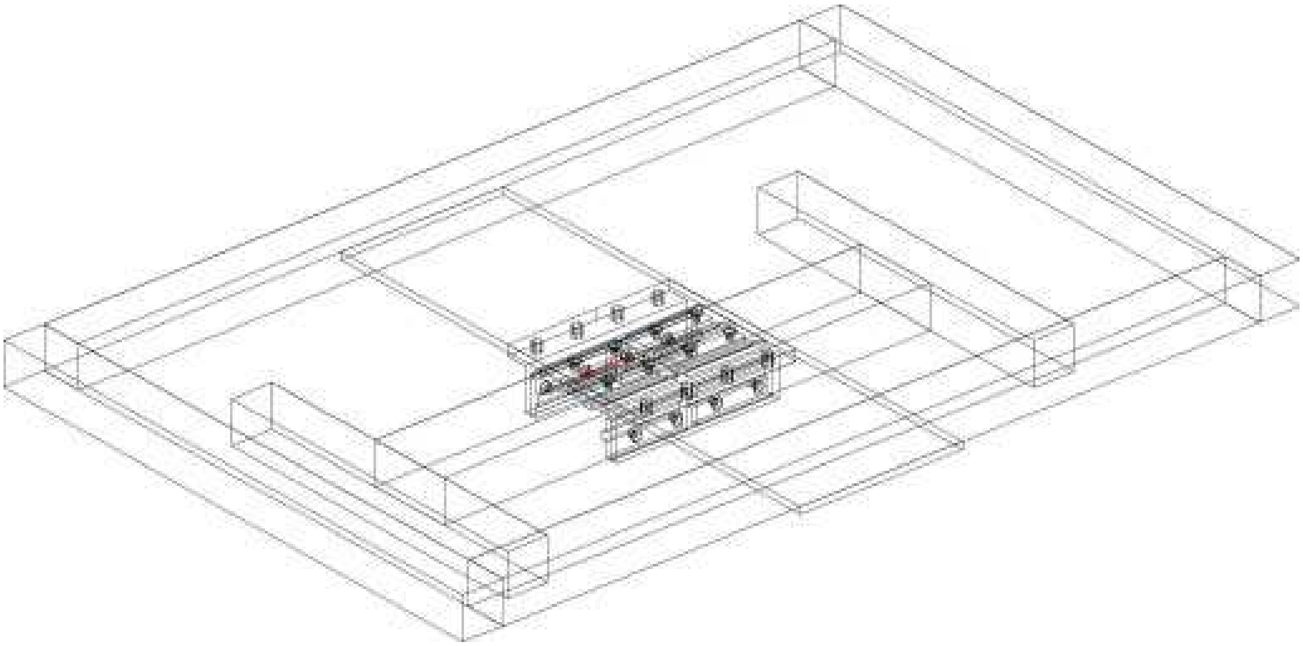


Figure A-4*: Isometric View of Sliding Part Diverter*

Types of Devices for Notifying Operators

1. The bell

This is one of the more common operator alarm devices. Usually, you can tie in to the bell already on the machine using the alarm contact closure. The bell can be rung during the entire duration of the alarm or the Diverter Controls tool can be configured to make the bell ring only instantaneously.

Issues to watch for: Bells are notoriously annoying, and operators have been known to disconnect them, temporarily or permanently! The instantaneous bell is generally much less annoying than the continuous bell, especially if it can be turned off during setup.

2. The flashing light or light stack

Similar to the bell, but usually less annoying. Many of the same issues apply. RJG now carries a light stack that can easily be connected to the eDART ™ System.

3. The central messaging system

These systems, while still relatively new to the market, can be used to announce events over a P.A., post events to a large screen, or send a message to a pager. RJG has recently released an interface to allow alarm messages to be sent out over these types of systems.

Appendix B: Theory of Alarms and an Experimental Approach to Better Alarms

One of the key assumptions behind the use of alarms is that the chosen cavity pressure value in some way predicts the quality of the parts. In other words, we assume that we can tell what the part should “look” like before we open the mold simply by looking at the cavity pressure value. All of the concepts presented in this document are founded on this assumption. The list of summary values to use for alarms is intended to identify the values, which should be the best predictors of part quality. Alarm setting Approaches #1 and #3 are designed to help quantify the levels at which we can predict that the part may be bad.

In some cases, we need either more assurance that we can actually predict part quality or we need to do a better job of predicting where our alarm limits should be set. The objective of this section is to explain some of the theory behind the setting of alarms and to use that theory to build an experiment you can use to determine alarm levels. Although this may sound intimidating, in principle, we are doing almost the same thing as Approach #3. Here is how it works:

An Example Using Approach #3

In Approach #3, we adjusted something on the machine to make parts out of specification on the high and low end of the alarm limits (for example, dimensions too large at a high pressure and too small at a low pressure). Then we read off the values for the cavity pressure values at the high and low settings, and used these to set alarms. If you recall, alarms were set a little tight - just in case.

Let’s look at an example using Approach #3. The table below shows some data on the hold pressure used, and the resulting part dimensions and cavity pressure.

Part Length Specification: 100 +/- 0.5 mm.

Hold Pressure	Part Length (mm)	Peak Cavity Pressure (PSI)
4000	99.5	3100
5000	100.0	3980
6000	100.5	5150

Table B-1*: Data from Approach #3 Example*

As you can see, the parts are within the specification limits when the Peak Cavity Pressure is between 3100 and 5150 PSI. But factors other than hold pressure (the only factor studied here) may also affect the parts differently (such as melt temperature). For example, if we changed the melt temperature a little and hit a Peak Cavity Pressure of 5150, the parts may be a little bigger or smaller. Since we want to be safe, we set our alarms 1/3 of the way to the center, giving us alarms around 3400 and 4800 PSI.

While some good parts might get into the Suspect bin, no bad parts should get into the Good bin.

A Different Analysis for the Same Data

Now let's look at the same example, only using a graph to illustrate. Figure B-1 shows the Part Length plotted against the Peak Cavity Pressure.

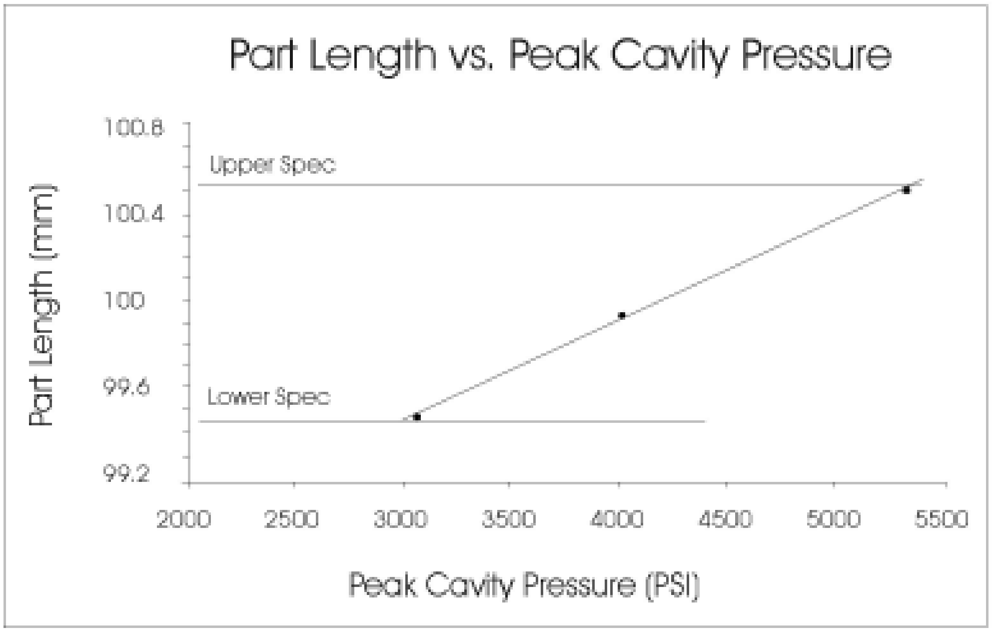


Figure B-1*: Data from Approach #3 Example*

The three points in Figure B-1 correspond to the three runs from Table B-1. When we draw a line through the three datapoints, we find a good fit. That means if we know the Peak Cavity Pressure, we can predict the part length fairly accurately.

Next, let's estimate how much variation in part length could occur if the Peak Cavity Pressure didn't change. This could be due to a change in other process conditions (melt temperature, fill speed, etc.), normal process variation, or the accuracy of the sensors (mainly in cases where very small variations are important). For the sake of our current example, let's say we feel confident that the parts would not change more than 0.3 mm if the Peak Cavity Pressure stays the same (you can figure out the width of your own prediction bands by using your part standard deviation data and some simple statistics).

Let's apply this to the graph. Instead of a single straight line to predict part dimensions, we will have a prediction band. This is shown in Figure B-2.

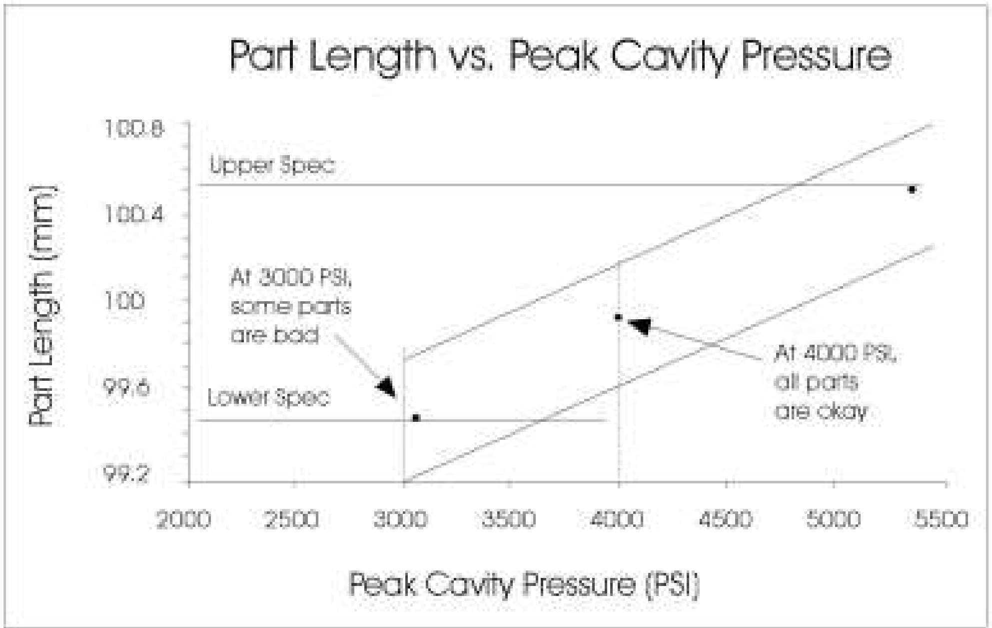


Figure B-2*: The Prediction Band*

The prediction band allows us to predict the range of part measurements we could expect at any given Peak Cavity Pressure. For example, if Peak Pressure is 3000 PSI, we expect that the part length would be anywhere between 99.2 mm and 99.8 mm (99.5 +/- 0.3).

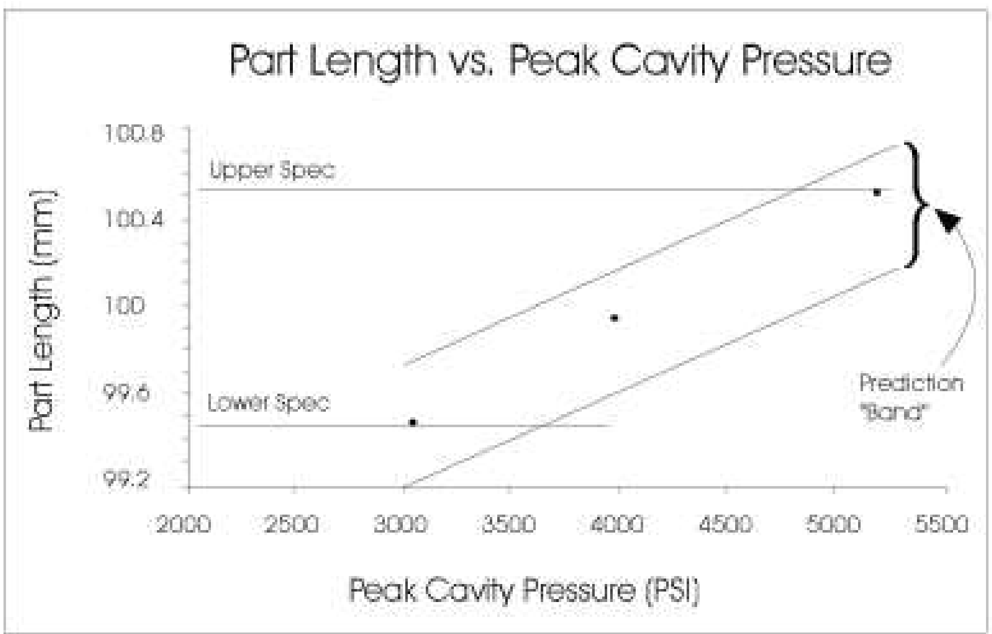


Figure B-3*: Applying the Prediction Band*

In Approach #3, we said we wanted to set our alarms conservatively so that no bad part ever got into the good bin. The prediction band allows us to determine just how conservative we need to be. Figure B-3 illustrates this. Let's say you set your lower alarm at 3000 PSI. We're running our process and get a pressure of 3001 PSI - just inside the alarm limits. The prediction band says the part may be okay, but there's a very good chance that the part is going to be too small. So we set our lower alarm to 4000 PSI. Now let's say we get a shot with a Peak of 3999. This causes an alarm. However, there's not even a chance that this part is bad - it's definitely well within the specification limits!

Setting Alarms Using the Graph

So where do we set the alarm so that we don't get bad parts in the Good bin, but also don't throw away good parts unnecessarily? The setting for the alarm we are looking for is at the intersection of the Specification Limit and the innermost edge of the prediction band. This is shown in Figure B-4. Here, for the lower alarm, the best setting is around 3600 PSI. For the upper alarm, it is around 4500 PSI. Notice that this is not too far off from the numbers reached using Approach #3 (3800 and 4800 PSI)!

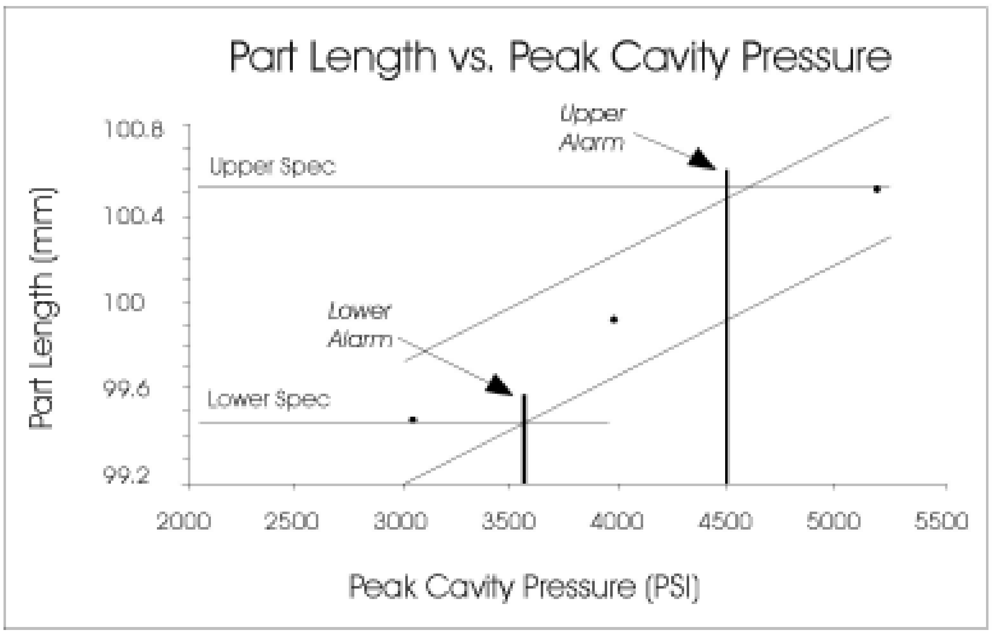


Figure B-4: *Choosing Alarm Limits*

Let's look at our new lower alarm of 3600 PSI. If we get a shot that falls slightly outside this alarm - say 3500 PSI, it is very likely that the part is good, but there is a small chance that the part is bad. However, since we are trying to keep all bad parts out of the Good bin, this is a necessary trade-off.

Understanding Why We Can't Tell Good Parts from Bad

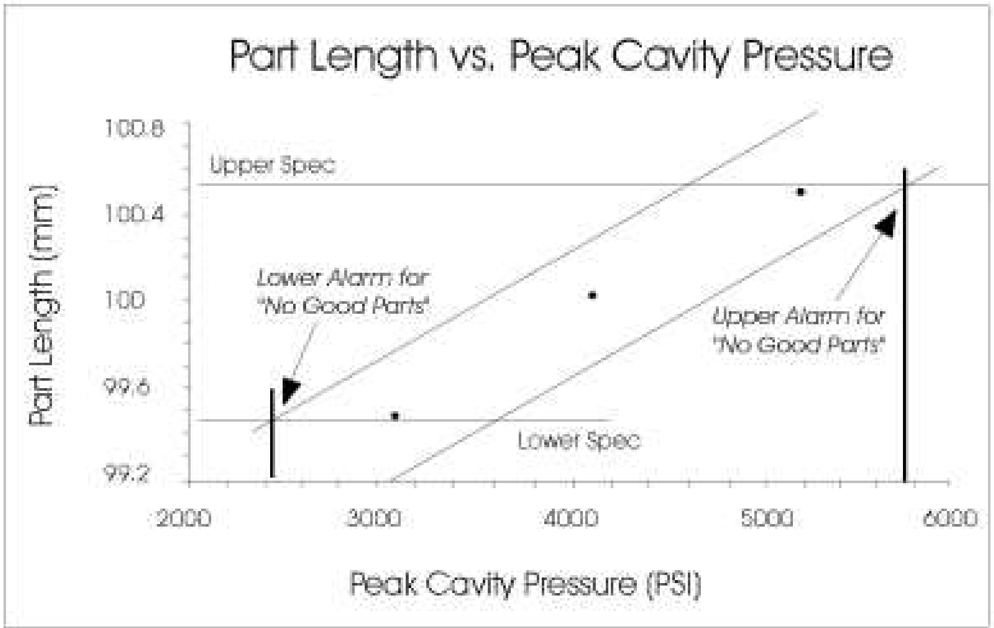


***Figure B-5**: Alarms if We Want to Know the Part is Bad*

Let's say we decided that we wanted to find out where we definitely knew the part was bad. Where would we set the alarm? With a little thought, we can see that we need to set the alarm at the outermost intersections of the prediction band and the specification limits. This is shown in Figure B-5. Are these good places to set alarms? Definitely not!

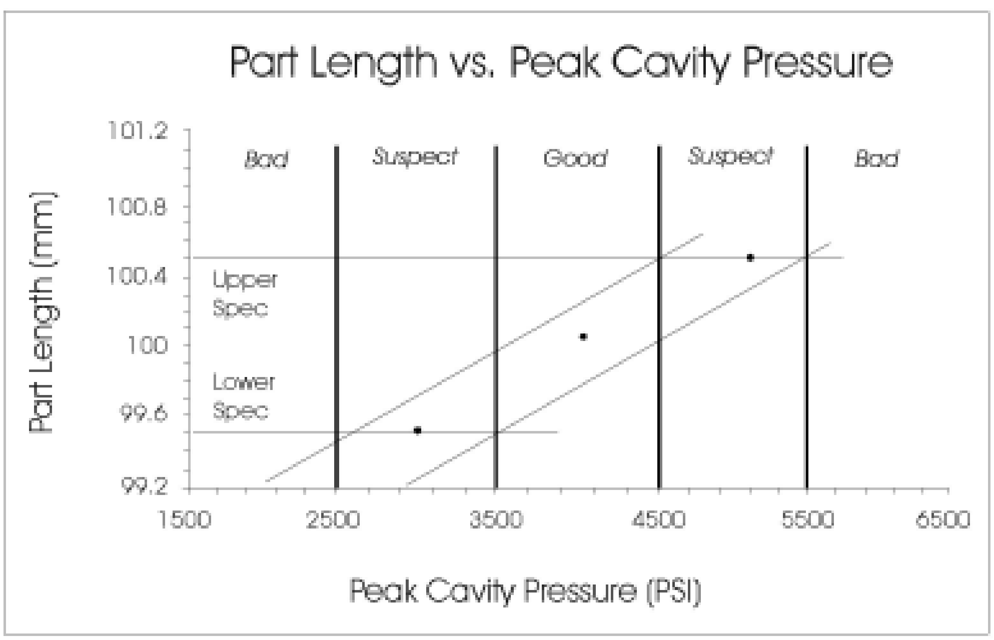


***Figure B-6**: The Three Regions of Alarms - Good, Bad, and Suspect*

You can see that in all cases, there are three regions on the graph: a region where the parts are definitely good, a region where they may be either good or bad (in other words suspect), and a region where they are definitely bad. This is illustrated in Figure B-6.

Using one alarm, we usually choose to sort good parts into one bin and suspect or bad parts into another bin. Notice we can never really sort good parts into one bin and bad parts into another because of the suspect parts. However, the more we do up front to understand the correlation between cavity pressure and part dimensions, the more we can narrow the prediction band and, therefore, the width of the suspect region. This makes our alarms more meaningful and helps us do a better job of keeping the bad parts out of the Good bin without putting too many good parts in the Bad bin.

And the more you understand this theory of how alarms are set, the better you will become at setting effective alarms, even if you are using the simple approaches described earlier in the document.

Appendix C: A Note About Integrals

Many of you may ask “What is an Integral?,” let alone “What is a Cycle Integral or any other type of Integral?” First, let’s define the word Integral: An Integral is nothing more than an area under a curve. Let’s repeat this point:

An Integral is an Area Under a Curve

In this case, we are interested in the area under the cavity pressure curve, hydraulic pressure curve, or whatever measurement we are looking at.

What are the Different Kinds of Integrals?

The Cycle Integral

The Cycle Integral is the most common Integral we use. This means that we are looking at the area under the curve for the whole cycle (see Figure C-1). This is usually used for cavity pressure, and sometimes for hydraulic pressure or stroke. Basically, if anything changes in the process, the shape of the curve will change, and thus, the area under the curve will change. Therefore, the Cycle Integral is a good measurement for catching any change.

***Figure C-1**: The Cycle Integral*

The Injection Integral

The Injection Integral measures only the area under the curve during Injection Forward (See Figure C-2). There are times when we don't care so much about changes after the end of injection forward. For example, some dimensions are only affected by cavity pressure during injection forward - after that, the pressure can change, but the parts won't. For these types of parts, the Injection Integral is a better predictor of part dimensions.

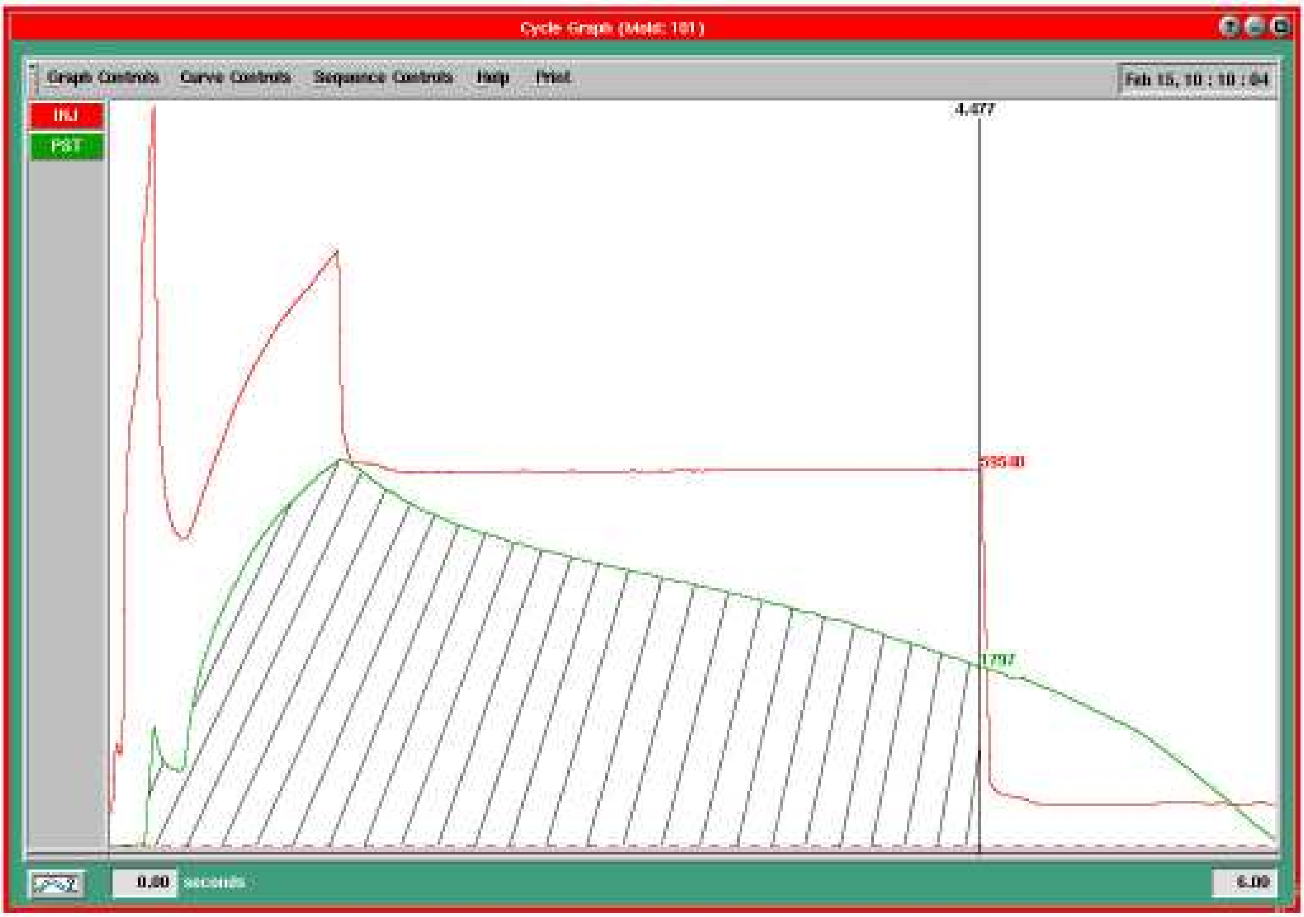


Figure C-2: The Injection Integral

The Fill and Pack Integral

The Fill and Pack Integral is used largely by thin-wall parts. This is the area under the first portion of the curve. Here, pack ends when the cavity pressure reaches 98% of Peak Post Gate Pressure or at the point that you define in the Sequence Settings tool.

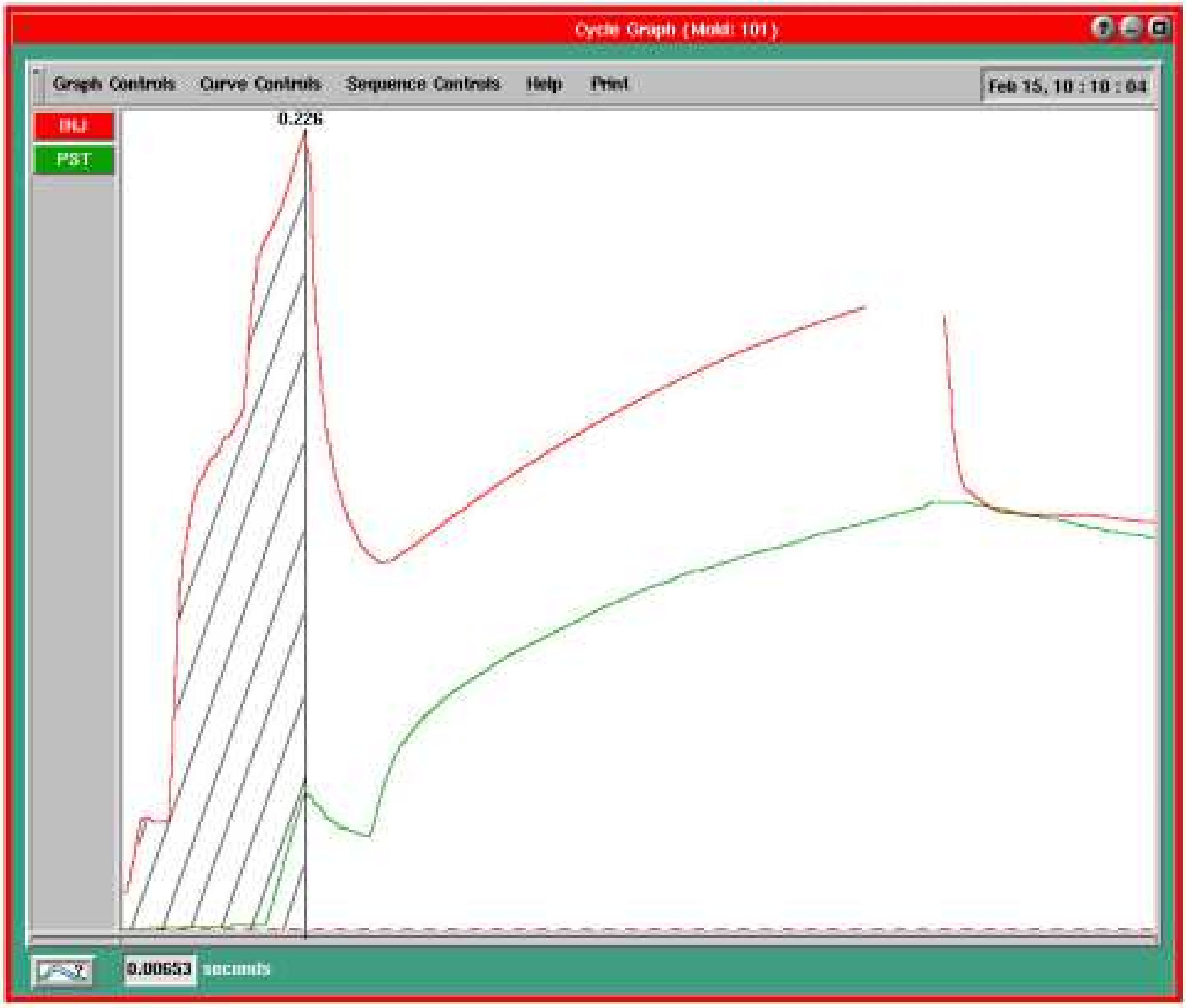


Figure C-3: *The Fill and Pack Integral*

Appendix D: Translating DART*Net*™ and DART*Vision*™ Alarms to the eDART™ System

For those who are familiar with the DART*Net*™ and DART*Vision*™ systems, upgrading to the eDART ™ System can be a big change. Despite the added advantages of the eDART ™ System, some of the changes can be confusing. For example, if you had alarms set on "Time to Peak" in the DART*Vision*™ system, you will not find this in the eDART ™ software's list of summary values. This and other values still exist, however, they have been repackaged in the eDART ™ System.

Listed below are the most common summary values that have changed and some notes on other differences in the systems.

<u>Fill Integral</u>
The DART*Vision*™ Fill Integral was almost exclusively used with hydraulic data to monitor viscosity. However, the term "Hydraulic Fill Integral" is one that most people don't immediately associate with viscosity, so we've renamed it "Effective Viscosity, Fill". Here, the type of value is "Effective Viscosity" and the location is "Fill". This is because we are measuring viscosity during the filling stage only, and since we are not measuring true viscosity, we've called it "Effective Viscosity" instead. Also, the actual calculation is slightly different, so you probably won't be able to bring over your alarm settings exactly as you had them in DART*Vision*™.

However, this means you will not be able to monitor the Fill Integral for any other sensors (e.g. cavity pressure). If you are one of the very few molders who have a use for this, give us a call - we will do our best to help you.

<u>Screw Run Integral</u>
Like Fill Integral, the Screw Run Integral was used with hydraulic data because we couldn't directly measure back pressure and screw rotation speed. In the eDART ™ System, we do not measure screw rotation speed directly, but we do measure back pressure. So, in place of the Hydraulic Screw Run Integral, the eDART ™ System now offers "Average Value, Back Pressure" and "Sequence Time, ScrewR". Here, "Sequence Time, ScrewR" is the screw run time, which gives you a good estimate for screw rotation speed in most cases.

<u>Integral to Peak</u>
The Integral to Peak in DART*Vision*™ was the area under the curve between the start of injection and the peak pressure. This was most commonly used with cavity pressures, or with hydraulic data to get a fill integral if a fill trigger was not available. In the eDART ™ System, the "Effective Viscosity, Fill" value takes the place of the Hydraulic Integral to Peak, since the eDART ™ calculates the end of fill (sometimes using Hydraulic Time to Peak, if no better data is available).

For Cavity Pressure Integral to Peak, the eDART ™ System now uses the Fill & Pack Integral. This is slightly different than the Integral to Peak in that the Fill & Pack Integral is calculated from the start of Fill until the point where the cavity pressure reaches 98% of its peak value. By ending at 98% of peak, the Fill & Pack Integral is more consistent than the Integral to Peak This is especially true in flat-topped curves where the time to peak varied greatly, whereas the time to 98% of peak is fairly consistent (See "Time to Peak").

Time to Peak

In DART*Vision*™, "Time to Peak" was a common summary value. In cases where you didn't have a fill trigger, Hydraulic Time to Peak was available as an alternative to Fill Time. Also, when used with a cavity pressure sensor, the Time to Peak gave a good measure of packing time, as well as check ring variation.

In the eDART ™ software, several values have replaced Time to Peak. For a fill time replacement, the eDART ™ automatically computes fill time from Hydraulic Time to Peak if a better signal is not already available.

For cavity pressure packing time, several new values are available. The most direct replacement is "Process Time, Fill & Pack Time". This is slightly different from Time to Peak in that it measures the time to reach 98% of peak. This prevents the large variations in Time to Peak seen with flat-topped curves. Another value for looking at packing rate is "Process Time, Cavity Pack", which only measures the time from when the cavity filled until the pressure reaches 98% of the peak.

For check ring balance, "Process Time, Fill & Pack" will still work. However, a new value type, "Process Time, Cavity Fill" is probably more accurate. This measures the time taken for the cavity to finish filling (that is, where the dogleg occurs).

One difference between "Process Time, Fill & Pack" and "Time to Peak" is that only one Process Time, Fill & Pack is calculated per cavity. That is, if you have both a post gate and an end of cavity sensor, the Fill & Pack Time is calculated off only of one of these. The sensor used is chosen in the Sequence Settings tool on the Cavity Pack tab.

Trigger Times

In DART*Vision*™, triggers could be hooked up on one of four trigger inputs. It was possible to measure the time each of these signals stayed on and set alarms around these.

In the eDART ™ software, trigger times are called "Sequence Times". This may be easier to understand if you've never used the DART*Vision*™ system, but may take some time to adjust to if you're familiar with triggers.

Another difference with triggers is that they are all listed under the same summary value type, "Sequence Times". So, if you want to set a fill time alarm, you choose "Sequence Time, Fill Time." Note that this may be calculated if a signal is not available directly from the machine. If you ONLY want to use a machine sequence signal, you can choose "Machine Sequence, Fill Time."