



Screw and Barrel Inspection Procedure

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Introduction

Screw and barrel inspection plays a very important part in achieving exceptional production performance. The screw and barrel are major components of extrusion, injection molding and blow molding processes, and should be measured for wear at least once a year (preferably twice a year). Many U.S. companies schedule preventive maintenance (PM) during the week of Independence Day and again during the week of Christmas.

Before getting started on measuring the screw flight wear and barrel bore, it is necessary to know the standard terminology of a typical three-zone general purpose screw. Figure 1 outlines these terms.

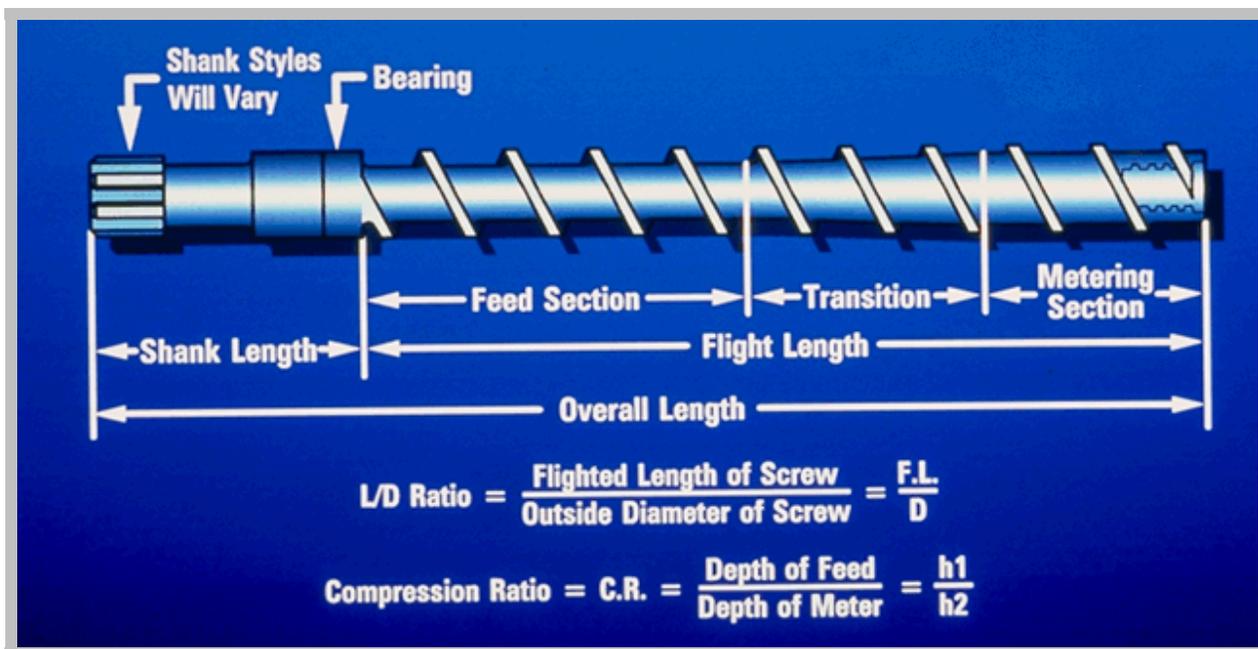


Figure 1

The graph shown in Figure 2 indicates the typical wear points for various sizes at Critical, Average or Non-critical applications. An example on this chart shows that a 3.5" screw with .020" wear will cause an average production loss of 9% on an average production process.

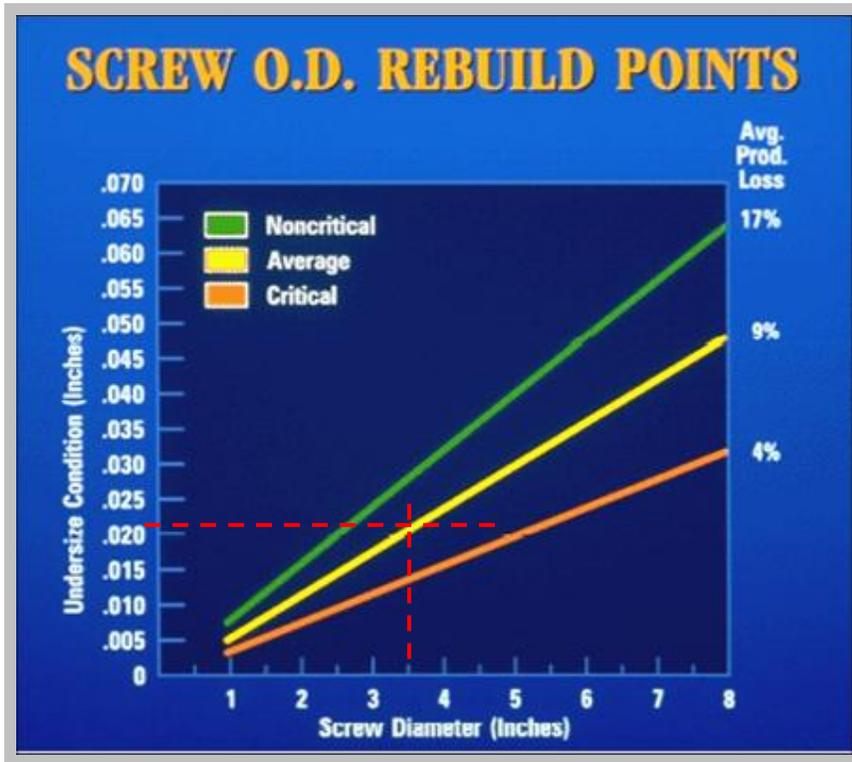


Figure 2

When a screw is worn, it also generates an increase in the melt temperature of the polymer being processed. Figure 3 shows the difference in the melt temperatures in the metering section of a screw channel between a new (normal) flight clearance vs. a worn screw with a large flight clearance.

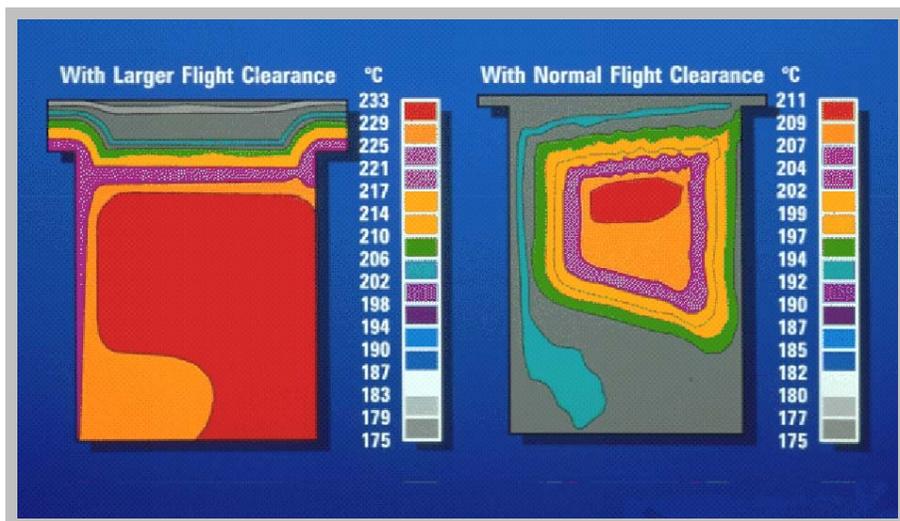


Figure 3

Also, in order to maintain their standard production throughput rates, many companies will have the machine operators increase the screw speed. As the screw speed is increased, the shear rate in the screw channel and over the flight lands also increases, causing the melt temperature to increase as well.

This is why it is very important to make sure the original screw/barrel clearance is maintained for the best overall performance of the equipment. A typical (new) total screw-to-barrel clearance, per the Society of Plastics Industry guidelines, is shown in Table 1.

Total Screw to Barrel Clearance			
<u>Screw Diameter</u> (in)	<u>Clearance</u> (in)	<u>Screw Diameter</u> (mm)	<u>Clearance</u> (mm)
1.5	.003/.005	35	.08/.11
2.0	.004/.006	50	.10/.15
2.5	.005/.007	65	.13/.18
3.0	.006/.008	75	.15/.20
3.5	.007/.010	90	.18/.25
4.5	.009/.012	115	.23/.30
5.3	.010/.014	135	.25/.35
6.0	.012/.016	150	.30/.40
8.0	.016/.021	200	.40/.50

Table 1

Procedure for Measuring Screws

The following series of photos outlines a method for measuring a screw in the field for channel profiling and also flight OD wear. Profiling a screw does not require an engineer or maintenance person, but rather, an individual who is consistent and precise. A simple sketch as shown in Figure 4 can be used to show the dimensions needed to duplicate a screw.

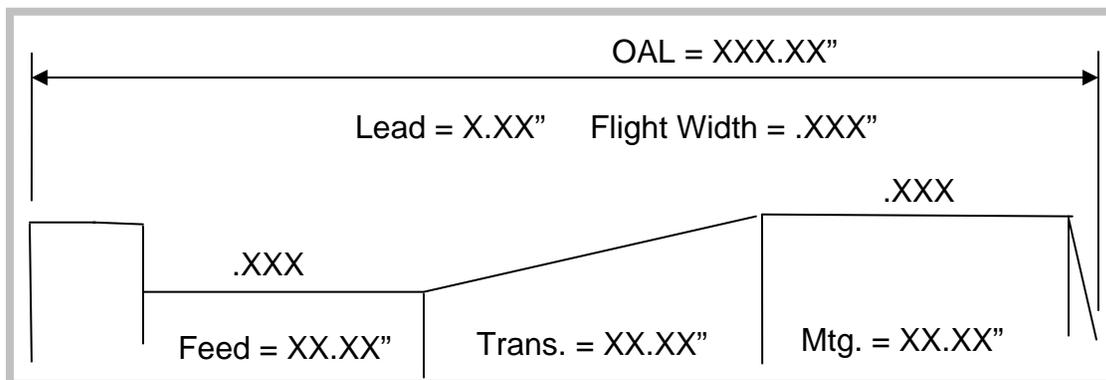


Figure 4

Feed Pocket Location and End of Shank

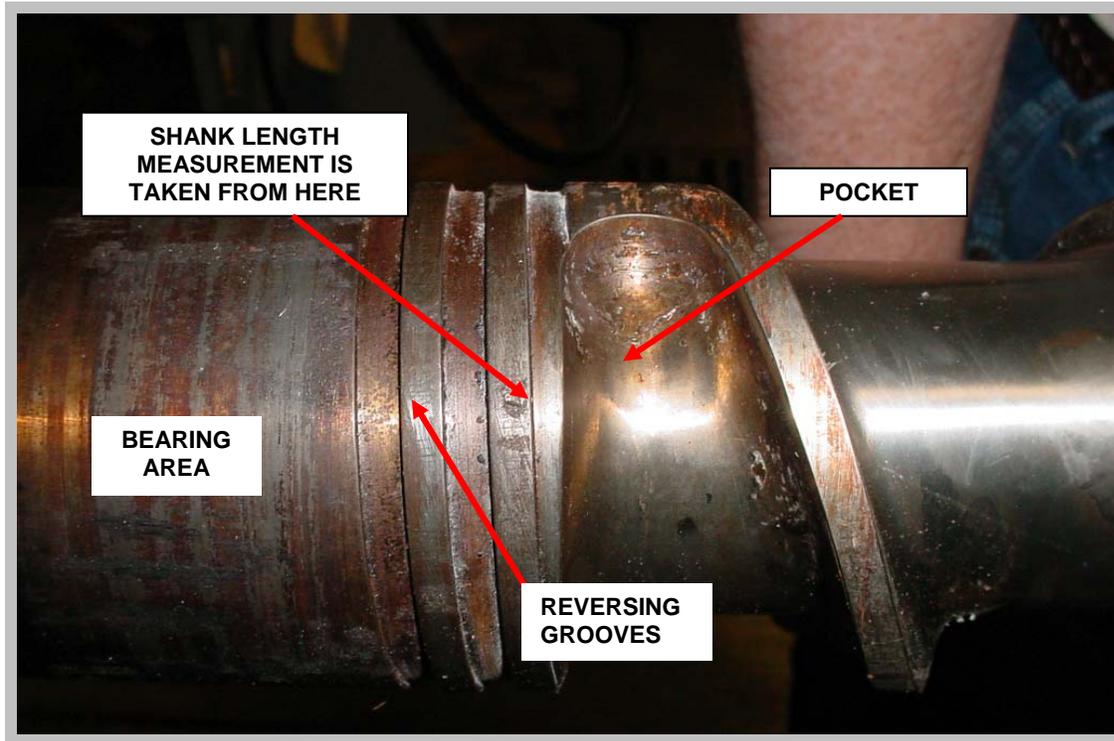


Figure 5

As shown in Figure 5, the shank (or drive) of the screw is measured from the “pocket” of the screw to the end of the shank (or drive). This overall shank length will include the “bearing area” and the drive mechanism whether or not it is a keyed drive or spline drive.

The outside diameters and lengths of the bearing area and the drive mechanism need to be recorded and inspected for wear, galling or any other such damages. Also, on most extrusion screws, the end of the screw will have a deep, drilled hole through the core of the screw so that screw cooling can be installed on the screw. This drill size and tap size also need to be detailed. The thread will typically be National Pipe Threads in the U.S. or British Straight Pipe Threads in other parts of the world.

Detailing the Drive Shank of the Screw



Figure 6

In Figure 6, the shank length is taken from the pocket back to the very end of the shank. (In this photo it is shown right to left.)

If there are plans to duplicate the existing screw, the dimensions taken must be very accurate because this portion of the screw is what fits into the drive quill of the gearbox or injection unit. The tolerances for the diameters on the drive shank will be typically $\pm .001$ " and the lengths will be $\pm 1/32$ " (.030"). If the drive has a keyed drive, these dimensions will normally be a standard key size in either Imperial or Metric units.

For spline drives, they will typically be either standard, straight-sided splines or conventional, involute splines. In the case of straight-sided splines, the number of splines, width and length is typically all that is needed. For involute splines, the number of teeth on the spline, the outside major diameter of the spline, and the length of spline are the most critical dimensions needed.

Normally, a screw designer/manufacturer can check their reference library and send the customer a reference drawing of the screw being profiled to confirm the drive dimensions.

Determination of the Screw Feed Length

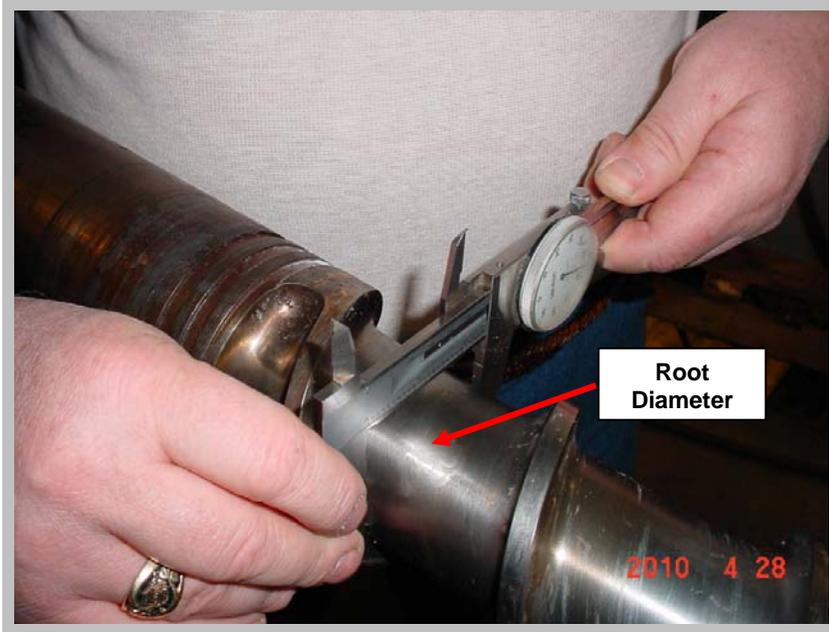


Figure 7

Using dial calipers, measure the root diameter of the screw (as shown in Figure 7) at every turn of the screw over its entire length. When measuring the root of the screw (starting in the feed section and measuring towards the nose end of the screw) the root diameter will measure very close in diameter, turn to turn (within +/- .010"). The root diameter of each turn of the screw can be marked on the root for easy reference as shown in Figure 8.

Once the root diameter is established, the channel depth of the feed section can be determined. This is done by simply subtracting the root diameter from the nominal screw outside diameter and dividing by 2 as shown in Equation 1.

$$H_f = \frac{(OD - RD_f)}{2} \quad \text{(Equation 1)}$$

Where:

- H_f = Channel depth of the feed section
- OD = Nominal outside diameter of the screw
- RD_m = Root diameter of the screw



Figure 8

At the point where the feed section ends and the transition section begins, the root diameter will start to increase in diameter. At this point, a mark needs to be made on the root of the screw. Note: To exactly determine the end of the feed section, it is advised to measure the root diameter in this area every quarter turn to precisely determine the end of the feed as shown in Figure 9.



Figure 9

Once the end of the feed section has been established, using a tape measure, measure from the end of the shank (or the beginning of the pocket -- see Figure 3) to the mark at the end of the feed. Note this length on the sketch layout.

Establishing the Metering Length

Once the feed section length and root diameter have been established, the metering length and channel depth can be determined using the same methodology, but in reverse. Starting at the end of the metering section, measure the root diameter of the screw every turn and write the dimension on the root of the screw. When the root diameter starts to get smaller, this is the area where the metering starts and the transition section ends.

Again, to accurately locate the end of transition and start of the metering section, it is advised to measure the root diameter every quarter turn in this area.

Using the tape measure, measure the distance from the end of the metering to the mark on the root where the transition section and metering section meet (as shown in Figure 10). The screw shown in Figure 10 is a two-stage screw; thus, the metering section length shown is actually the first metering section.

In the case where a two-stage screw is profiled, the vent section and the second metering section would be determined in the same manner as the first stage sections were established.

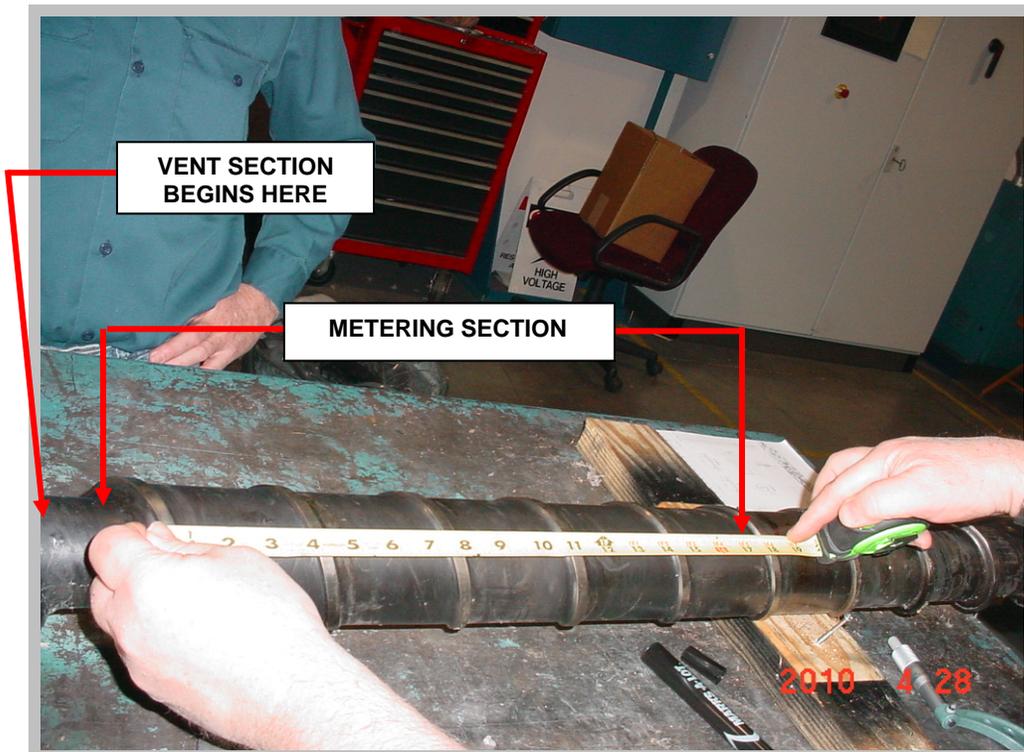


Figure 10

Just as the feed depth was determined, the metering section channel depth will be determined as shown in Equation 2:

$$H_m = \frac{(OD - RD_m)}{2} \quad \text{(Equation 2)}$$

Where:

- H_m = Channel depth of the metering section
- OD = Nominal Outside Diameter of the Screw
- RD_m = Root Diameter of the Screw

Establishing the Transition Section Length

Once the feed section length and metering length have been established, the length of the transition section can be determined. First, measure from the pocket to the end of the first metering to verify the length of the first stage. Next, subtract the length of the feed and metering sections from the length to determine the transition length as shown in Equation 3.

$$T_l = FL - (F_l + M_l) \quad \text{(Equation 3)}$$

Where:

T_l = Transition Length

FL = Flighted Length

F_l = Feed Length

M_l = Metering Length

Additional Details

Often times screws are more complex than a simple single-stage, general purpose design, (especially in the extrusion industry) with the use of barrier sections and various mixing devices. Many times, to detail these complex geometries, it is necessary to have a person who is “knowledgeable in the art” of screw designing/manufacturing measure the geometry.

As shown in Figure 11, the transition between the first metering and the vent section is done in this case with a 45° angle between the differentials of the root diameters, with a large and generous radius at the root of the angle in the vent section. The large radius is necessary to reduce the stress concentration and to avoid polymer degradation in this area.

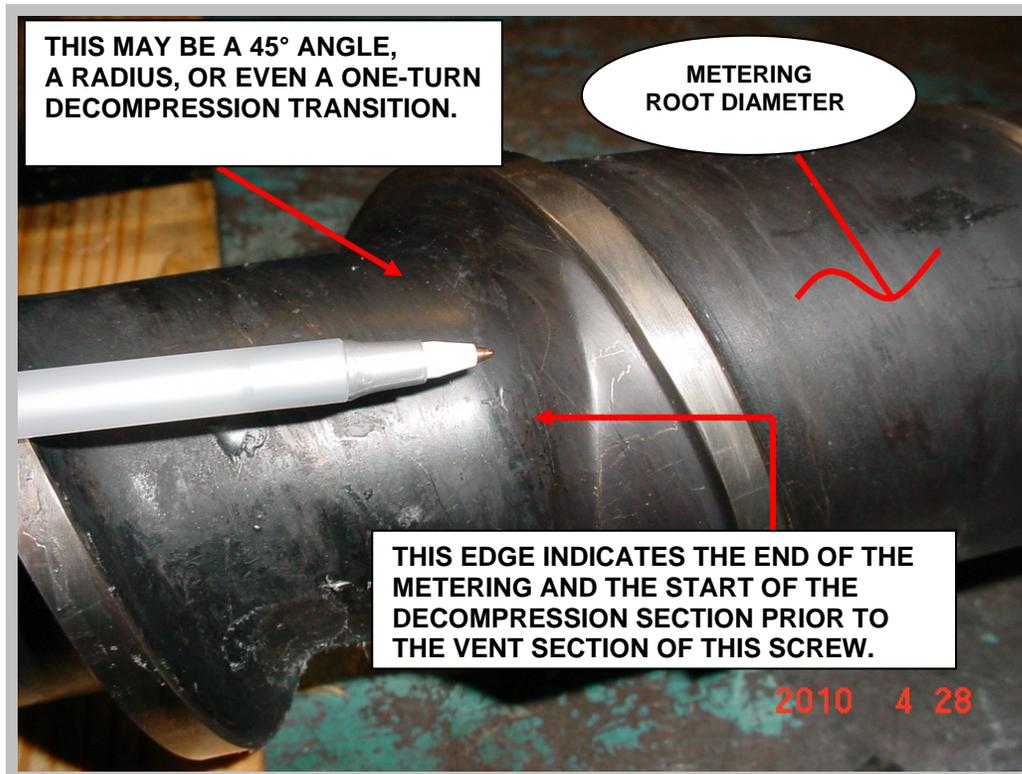


Figure 11

Many times a one-turn decompression transition is used instead of a 45° angle between the end of the metering and the beginning of the vent section. Also, there are possibilities where either a blister ring or a slotted blister is placed at the end of the metering to help in the devolatilization of the polymer as it enters the vent section of the screw.

Measuring the Lead of the Flight and Flight Width

Normally as a rule, the flight lead is equal to the screw diameter. This is referred to as the screw having a “square” lead. For example, a 3.5” screw would have a 3.5” flight lead. As shown in Figure 12, measuring from the leading edge of one flight to the leading edge of the next flight will determine the distance at which the flight travels as it makes one full turn of the screw. This is the case of a single-flighted screw.

In the case of a screw that is double, triple or even quad flighted, the distance the flight travels as it makes one full turn is its “lead”. In the case of a screw that is double flighted, the distance between the first flight and the next flight is referred to as its “pitch”. In the case of a 3.5” double-flighted screw, the “lead” could be 3.5” and its “pitch” would be 1.75”.

One must carefully measure “barrier-type” screws because the distance between the flights will not be equal. This is done by design on barrier screws.

As for the flight width of a screw, the flight width, designated by the letter (e), is typically 10% of the screw diameter. In the case of our 3.5" screw example, the flight width would be .350". This is also shown in Figure 12.

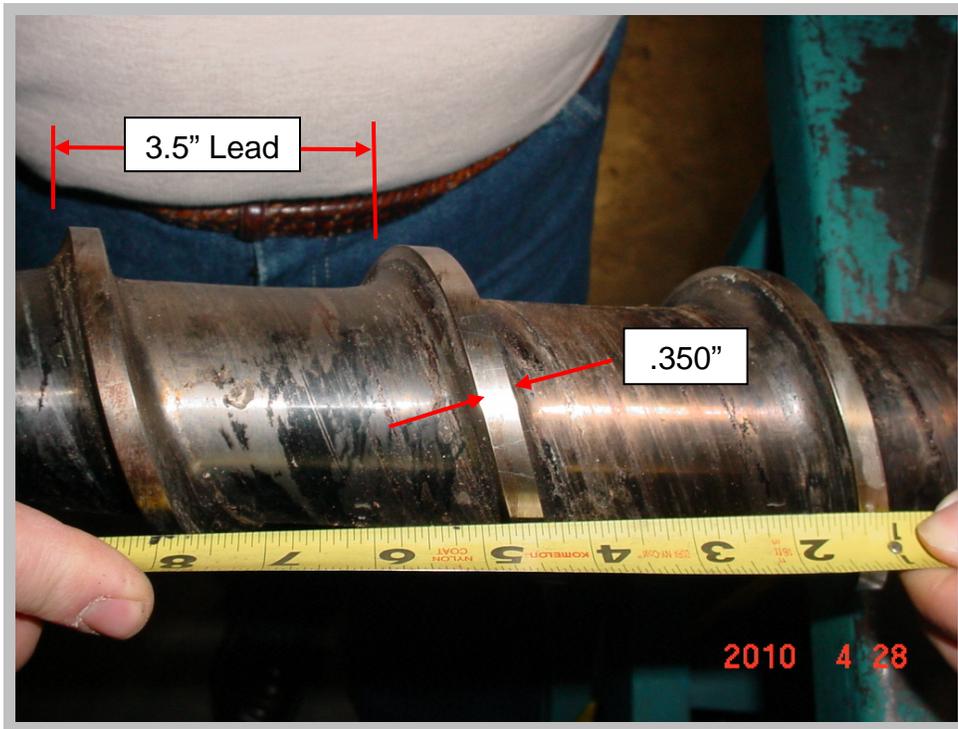


Figure 12

Measuring the Outside Diameter (OD) of the Screw Flights

Measuring the screw flight OD is the most critical and also the most difficult task when profiling a screw. As shown in Figure 13, it is necessary to use a micrometer and a parallel bar to gather this information.

The typical procedure for measuring the flight OD is as follows:

- Place the parallel bar across the flight surface beginning at the pocket, making sure the bar is spanning at least three (3) flights.
- Measure each flight by adjusting the micrometer to locate the true flight surface and outside diameter.
- Always locate the parallel bar and micrometer as close to the screw centerline in order to obtain a consistent measurement.
- Note the micrometer reading and subtract the thickness of the parallel bar.

Example:

- The micrometer reading is 3.959" and the parallel bar is .500" thick. The screw diameter is 3.459".
 - Referencing the normal size for a 3.5" from Table 1, the OD of a new 3.5" screw should be 3.492"
 - Therefore, the screw is worn .033" ($3.492" - 3.459" = .033"$)
- Repeat this for each flight section, moving the parallel bar one section at a time.

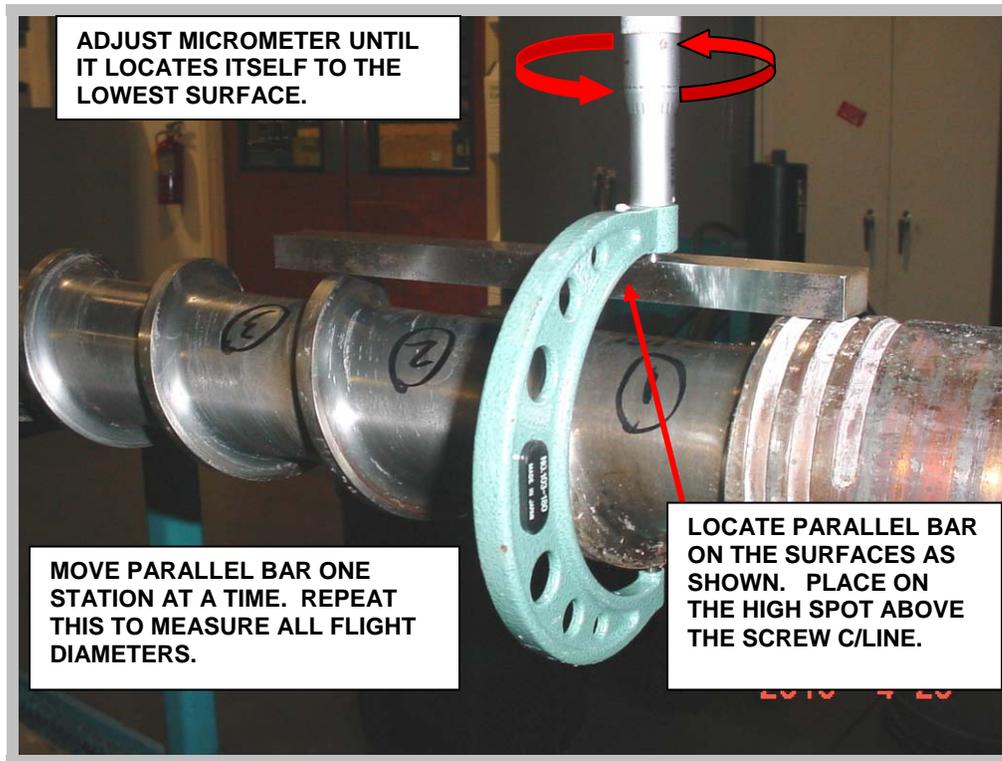


Figure 13

As mentioned earlier, it does not take an engineer or maintenance person to profile and measure a screw. It requires a person who is methodical and who accurately collects the data.

Tools Required to Profile and Measure a Screw

The following list outlines the required tools to accurately measure and profile screws in the field:

- Dial caliper
- 0-7" micrometers (for measuring up to 6" diameter screws)
- .500" thick parallel bar
- 25' tape measure
- Magic marker
- Inspection Report (Figure 14)



Screw Wear Inspection



Date _____
 Xaloy Job # _____
 Part # _____
 PO # _____

Dia _____
 L/D _____
 Make _____
 Ship Date _____

FLIGHT NUMBER (keyway in 12:00 position)	FACTORY SPECS (diameter of each flight)	COMMENTS:
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
M1		
M2		

Previous rebuild numbers:

Figure 14

Barrel Bore Measurements

Introduction

Measuring the bore of a barrel is not as complex as measuring the OD of a screw, but it requires as much accuracy. The primary area of concern when measuring a barrel is the amount of wear in the bore of the barrel. On extrusion barrels, most generally, the wear area is in the middle of the barrel or in other words, where the melting of the polymer takes place.

For injection molding barrels, the wear area is most often at the end of the barrel where the non-return valve is reciprocating. This wear area will mainly be in the last 4 to 5 diameters of the barrel.

In Figure 15, a bore gauge is used. A bore gauge only measures the variance of the bore.

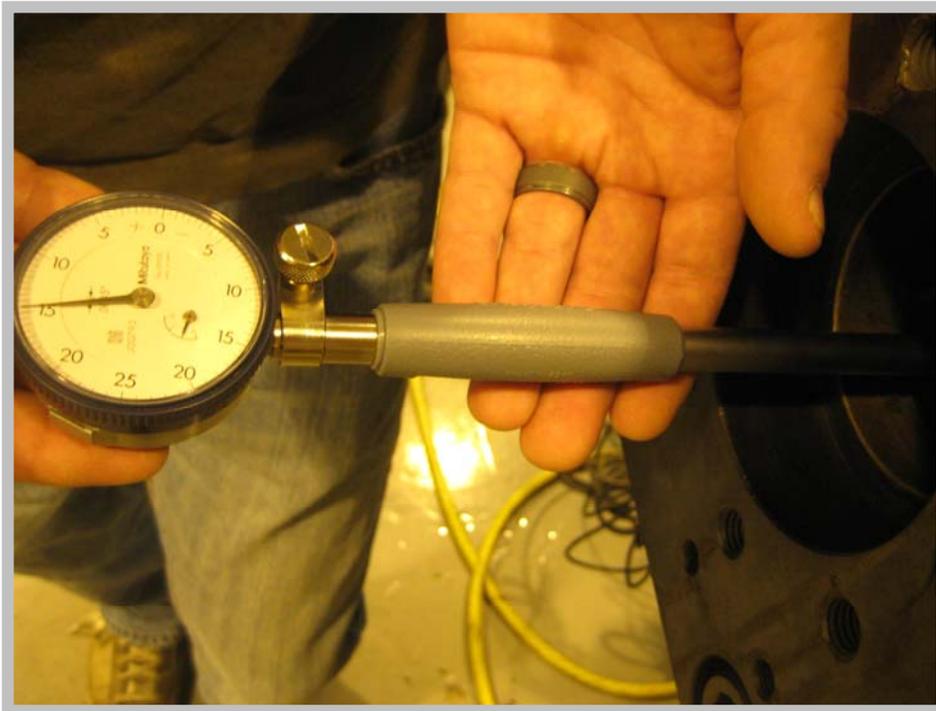


Figure 15

Therefore, the gauge first needs to be set up for the barrel bore size being measured. Most generally the last ½" (12mm) of a barrel typically does not see any wear in either an extrusion or injection barrel. Therefore, by using an inside micrometer or a tubular bore snap gauge and an outside diameter micrometer, the bore can be measured. The bore gauge can then be set up accordingly. The use of a tubular bore snap gauge is shown in Figure 16.

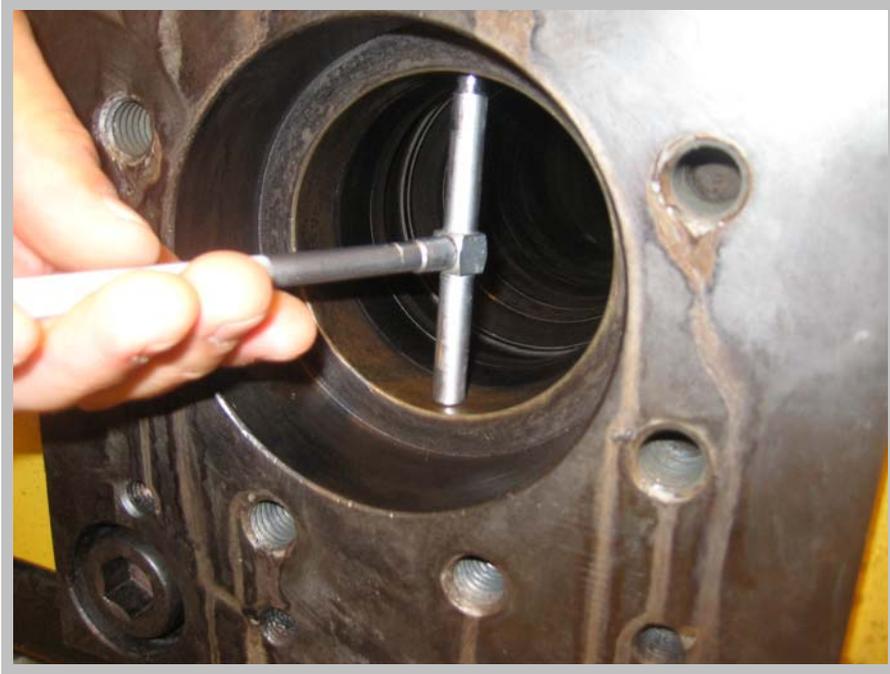


Figure 16

Once the bore has been “snapped” with the tubular bore snap gauge at the entrance of the barrel discharge opening, the outside diameter micrometers can be used to determine the bore size. (See Figure 17)



Figure 17

Once the exact bore size has been determined, this dimension should be recorded and used to set the dial indicator on the bore gauge to zero. Once this is done, the variation in the bore diameter can be measured and recorded.

When measuring the barrel bore, most generally, the bore should be measured every diameter of the barrel. For example, if the barrel is a 3.5" diameter, a bore measurement should be taken every 3.5". This can be seen on the tape measure attached to the bore gauge. If while taking the measurements there is a location that shows a significant change in the bore variance that is in between the designated measure points (and in this case every 3.5"), this location needs to be noted, and the maximum variance must be recorded. The form shown in Figure 18 can be used for data collection.

XALOY
entry pellet knows our name

Barrel Wear Inspection

Discharge End

Feed End

14	13	12	11	10	9	8	7	6	5	4	3	2	1
----	----	----	----	----	---	---	---	---	---	---	---	---	---

Customer _____
 Job Number _____
 Nominal ID _____
 Overall Length _____

Comments _____

Note: Give Position of Feed Port and Vent Port if they exist in the barrel.
 Feed Port _____ Vent Port _____

Figure 18

The tools required to measure a barrel bore for wear are:

- Extended bore gauge with tape measure attached to the extension
- Internal micrometers or outside micrometers and tubular snap gauges
- Inspection Report Form

Using the information presented in this paper as a guideline, anyone with mechanical ability can measure screws and barrels for profiling and wear. This process requires the correct tools and the patience to accurately collect the essential information.

