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The Extrusioneers

# Preventive Maintenance Program

**A structured, disciplined Preventive Maintenance (PM) program** will measure the life of the screw, barrel and valve for the resins being processed.

Every PM program should include educating employees to understand the different types of wear and the causes of that wear, plus instructions for measuring wear and guidelines for when to repair or replace components.

When running mostly reinforced resins, a PM program should be set up for inspecting every six months until wear trends have been established for the screw, barrel and valve. Non filled resins should be set up on an annual PM until wear trends for the screw, barrel and valve are established.

When it is known how long a screw should last in a given process, steps can be taken to make sure repairs or replacements can be made in a timely manner to reduce or eliminate downtime.

Understanding the wear on a component also provides the opportunity to make design changes so that replacements will run longer. PM programs provide the opportunity to track component wear life and help explain variations experienced in a process over time. As components wear, most likely changes will be seen in one or more of the following areas:

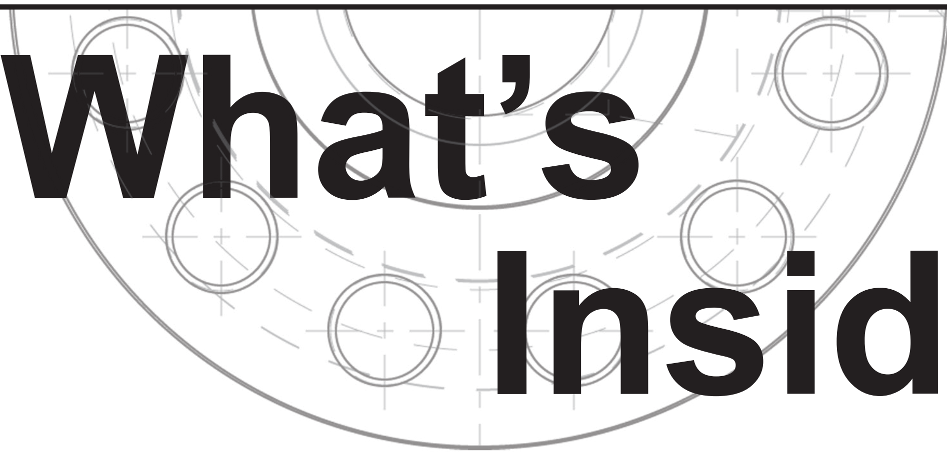
(1) Overall cycle times (standards)
(2) Scrap rates
(3) Electric consumption
(4) Downtime

Any variance in the standards set on these points can be directly related to wear on components. A strong PM program can minimize each of these.

## SPARES JUSTIFICATION PLAN

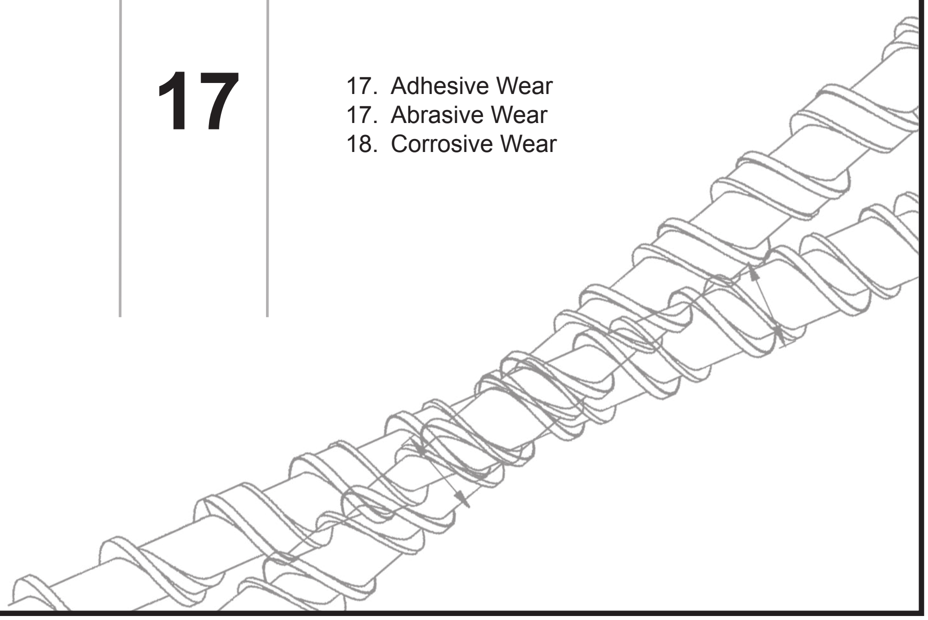
An integral part of the Preventive Maintenance Program is a plan for the maintenance of spare barrels and screws. The decision to maintain spares should be based on the economics of down time. If no spares are maintained, a decision has been made that the down time resulting from waiting on a replacement can be economically tolerated. This may be appropriate if the down time is covered by parts inventories or if part lead times are sufficiently long. Conversely, spare barrels and screws may be economically justified if:

(1) “Just-in-time” production contracts with customers cannot be met if down time occurs.
(2) Down times causes parts shortages that stops “in house” production.
(3) Lost sales during down time results in the loss of profits equal to or greater than the cost of a spare.



# What's Inside





# IMPLEMENTING A PREVENTIVE MAINTENANCE PROGRAM

Several steps are involved in the implementation of a Preventive Maintenance (PM) Program for barrels and screws including asset identification, wear measurement, materials and design considerations plus spares planning. Although the degree of applicability of each step may vary with the processing environment, all of the steps are believed to be essential to a successful program.

## ASSET IDENTIFICATION

The identification and recording of information relative to machines, barrels and screws may be accomplished manually or electronically. The essential data to be captured with each procedure is illustrated in the following pages.

1) **Prepare a Machine Inventory Listing** to assist in the identification and location of each machine with basic capacity information included. (See Page 5.)

2) **Prepare a Machine I.D. Record for each machine** which contains all of the vital information regarding its injection unit, clamp unit and essential capacity data. Repair data can optionally be added. (See Page 6.)

3) **Identify each barrel and screw** by inscribing an I.D. number in a conspicuous location on each component; on the O.D. of the nozzle end of the barrel and on the shank of the screw behind the bearing surface. Inscription may be accomplished with engraver or an air or electric scribe with a carbide tip.

   Scribes are available from most suppliers of power tools or measuring instruments. It is also helpful to color-code screws in front of the shank, identifying high compression, low compression, barrier, mixing or other types of screws.

4) **Prepare a Barrel I.D. Record** for each barrel owned, identifying the barrel by I.D. Number and relating it to the machine(s) to which it is assigned. This record lists all pertinent information, including source, dimensional data, material composition and repair data (not optional). (See Page 7.)

5) **Prepare a Screw I.D. Record** for each screw owned, identifying the screw by I.D. Number and relating it to the machine(s) to which it is assigned. The record lists source and dimensional data in addition to essential screw design and materials composition information. Repair data is also required. (See Page 7.)

When completed, the asset identification procedures described will enable:

a) the evaluation of various types of materials used in barrel lining;
b) the optimization of resin/screw design matching;
c) the establishment of repair/replacement guidelines; and
d) the rating of the services and products supplied by various vendors.

In short, identification is the first step in a Preventive Maintenance Program to achieve maximum economic benefit through asset management and control.

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# MACHINE INVENTORY LISTING

| Date | Prepared By |
|---|---|
| | |

| No | Machine ID Number | Loc Code | Manufacturer | Clamp Force (Tons) | Inject Cap (oz.) | Bore Dia (mm/in) | Year and Model No | Serial Number |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
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| 12 | | | | | | | | |
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| 20 | | | | | | | | |

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# MACHINE I.D. RECORD

| | | | |
|---|---|---|---|
| Date Acquired | Location Code | Machine No | |
| Manufacturer | Year and Model | Serial No. | |

| INJECTION UNIT | | CLAMP UNIT | |
|---|---|---|---|
| Injection Capacity (ounces/grams) | | Clamp Force (tons) | |
| Bore Diameter (inches/mm) | | Clamp Open Daylight (inches/mm) | |
| Barrel Length (inches/mm) | | Maximum Mold Thickness (inches/mm) | |
| Injection Stroke (inches/mm) | | Platen Size – H & W (inches/mm) | |
| Screw Diameter (inches/mm) | | Dist. Between Tie Bars – H X W (inches/mm) | |
| Screw L/D Ratio | | Ejector Stroke (inches/mm) | |

| GENERAL DATA | | SCREW / BARREL | |
|---|---|---|---|
| Control Type (Make & Model) | | SCREW: I.D. No. | Designed for (Resin) |
| Hydraulic Pump Motor (HP) | | | |
| Power Supply (V) | | | |
| Total Heating Wattage (KW) | | BARREL: I.D. No. | Lining Material |
| Number Heat Control Zones | | | |
| Oil Capacity (gal/liter) | | | |
| Hopper Capacity (lbs/kilos) | | | |
| Machine Weight (lbs/kilos) | | (Upsizing or other Modifications) | |
| Mach. Dimensions – LxWxH (inches/mm) | | | |

REPAIR DATA

| Date | Description | Repaired by | Down Time | Cost |
|---|---|---|---|---|
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# BARREL IDENTIFICATION RECORD

| | | |
|---|---|---|
| | | I.D. No. |
| | | Machine No. Assigned |
| Manufacturer | Bore Diameter | Capacity (Ounces) |
| Date Acquired | Supplier | Cost |
| Overall Length | Bore Length | Machine Stroke Length |
| Materials Composition – Lining (original) | | |
| Special Design Data (Bell End, Vent Hole Location, Etc.) | | |
| Date Placed in Service (Original) | Normal Production Hours | |
| Resins Being Processed & % of Each | | |

**REPAIR DATA**

| Date Repaired | Description Of Repair | Lining Materials | Down Time | Repaired By | Cost of Repair |
|---|---|---|---|---|---|
| | | | | | |
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# SCREW IDENTIFICATION RECORD

| | | | |
|---|---|---|---|
| | | I.D. No. | |
| | | Machine No. Assigned | |
| Manufacturer | Capacity (Ounces) | Diameter | L/D Ratio |
| Date Acquired | Supplier | Cost | OAL |
| Profile (Turns)<br>Feed - Transition - Meter - | Flight Depth<br>Feed | Flight Depth<br>Meter | Compression<br>Ratio |
| Special Design Data (Mixer, Barrier, Two Stage, Etc.) | | | |
| Body Material | Flight Surfacing Material | | |
| Date Placed in Service (original) | Normal Production Hours | | |
| Resins Being Processed & % of Each | | | |

**REPAIR DATA**

| Date Repaired | Description Of Repair | Repair Materials | Down Time | Repaired By | Cost of Repair |
|---|---|---|---|---|---|
| | | | | | |
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# BARREL & SCREW WEAR MEASUREMENT

Barrel and screw wear is relatively easy to measure if the necessary equipment is used. After proper cleaning and cooling to room temperature, wear can be measured and recorded on inspection reports and required repair or replacement steps can be evaluated. Inspection records should be maintained for subsequent reference and kept with the Barrel & Screw I.D. Records.

**1)** **Procure measuring equipment** from vendors including instructions on their use:

A long-range dial bore gauge is needed for measuring barrel wear. Gauges are available for various diameter ranges with various lengths depending upon machine sizes. Gauges and related literature are obtainable from several sources including Sunnen Products Company, St. Louis, Missouri (800-325-3670).

A Flite-Mike is a micrometer with gauge block as an integral component that is very helpful in measuring screw OD wear. They are also offered in various sizes, available from Flite Technology, Inc., Cocoa, Florida (800-327-9310).

**2)** **Measure barrel wear** and record the results on inspection reports in the following manner:

a) While hot, clean the barrel I.D. of any adhering plastic with a soft wire brush and copper or brass gauze. Allow to cool to room temperature.
b) Set the gauge to the nominal bore diameter of the barrel using a micrometer.
c) Take a gauge reading throughout the length of the barrel at 2 to 3 inch intervals. Record on an inspection record such as the one illustrated on page 9.
d) Examine and note the condition of the feed hole area for heavily worn or “washout” spots or other conditions evidencing potential need for repair (cracks, gouges, bent condition, faulty end-cap or nozzle adaptor).

**3)** **Measure screw wear** and record the results on a Screw Inspection Record using the following procedures:

a) Clean the screw while hot with a soft wire brush and copper or brass gauze, then allow to cool to room temperature. If an oven is used to clean the screw, care must be taken to avoid temperatures above 600°F. Higher temperatures, caused by an oven or the careless use of an acetylene torch, can cause the screw to warp, the chrome-plating to degrade and surface blemishes.
b) Carefully file off any burrs on flights with a file.
c) Measure the flight diameter every other flight with a micrometer and gauge block or Flite-Mike. It is preferable to mark the flights and take two measurements at opposite axis at each mark. Record the measurements on an inspection record such as the one illustrated on page 10.
d) Measure the diameter of the root between every other flight in the feed section (but not on flight radius) and in the metering section with a micrometer or caliper. Record the measurements.
e) Record the condition of the root for under-cuts or “washout”. Examine the nose thread and shank for wear requiring repair and record other information such as cracking, chipped plating and so forth. Check for straightness by rolling on flat table or surface plate.

# Barrel Inspection Report

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| | | | |
|---|---|---|---|
| Date: | | | |
| By: | | | |
| Identification Number: | Machine Number: | Manufacturer & Tonnage: | |
| Lining Material: | Date in Service: | Bore Length: | Bore Diameter: |
| Resins Processed: | Date Last Inspected: | Overall Length: | Stroke Length: |
| Condition of Bore: | | | |
| Condition of Feed Hole: | | | |

| **Measurements** | | **Measurements (continued)** | |
|---|---|---|---|
| Inches from Stroke End | Bore Diameter .000" (+/- Nominal) | Inches from Stroke End | Bore Diameter .000" (+/- Nominal) |
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Comments Regarding Wear Condition:

| | | |
|---|---|---|
| Date of Last Repair: | Done By: | Repair/Replacement Recommendation: |

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# Screw Inspection Report

| | | | |
|---|---|---|---|
| Date: | | | |
| By: | | | |
| Identification Number: | Machine Number: | Manufacturer & Tonnage: | |
| L/D Ratio: | Flight Length: | Overall Length: | Flight Diameter: |
| Shank Type: | Flight Width: | Profile: | Mixer: |
| No. of Stages: | Root Diameter Feed Zone: | Root Diameter Meter Zone: | Compression Ratio: |
| Screw Base Material: | | Screw Flight Hardsurfacing Material: | |
| Resins Run: | | Date In Service: | |
| Condition of Shank: | | Condition of Nose Threads: | |
| Condition of Root: | | Condition of Flights: | |

| Flight Diameter Measurements | | Flight Diameter Measurements (continued) | |
|---|---|---|---|
| Flight No. | Flight Diameter | Flight No. | Flight Diameter |
| | | | |
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Comments Regarding Wear Condition:

| | | |
|---|---|---|
| Date of Last Repair: | Done By: | Repair/Replacement Recommendation: |

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# REPAIR AND REPLACEMENT ALTERNATIVES

The third step in the Preventive Maintenance Program is the establishment of repair/replacement guidelines, both as to timing and component materials. The guidelines should be clear and approved by management.

**1) Establish a repair/replacement guideline** for barrels and screws based on maximum wear parameters with consideration for the types of resins being processed. Our guideline for repairing a barrel or screw is easily remembered:

***"If the combined barrel plus screw wear is twice the maximum OEM clearance, the barrel or screw (or both) should be repaired or replaced."***

The following table indicates maximum clearance dimensions for various barrel bore diameters. When processing low viscosity resins with high flow rates, minimal wear of .002" to .005" may result in inefficient production, whereas significant wear may be tolerable if non-precision parts are being processed from high viscosity resins.

**SCREW - BARREL CLEARANCE TABLE**

| Bore Diameter (Inch) | Avg. Max. Clearance (Inch) | Avg. Min. Clearance (Inch) | Repair/Repl Clearance (Inch) |
|---|---|---|---|
| 30 (1 1/4") | .009" | .006" | .015" |
| 35 (1 3/8") | .010" | .006" | .016" |
| 40 (1 1/2") | .010" | .006" | .016" |
| 45 (1 3/4") | .010" | .006" | .016" |
| 50 (2") | .010" | .006" | .016" |
| 55 (2 1/4") | .011" | .007" | .018" |
| 60 (2 3/8") | .011" | .007" | .018" |
| 65 (2 1/2") | .011" | .007" | .018" |
| 70 (3") | .012" | .008" | .020" |
| 75 (3") | .012" | .008" | .020" |
| 80 (-) | .012" | .008" | .020" |
| -- (3 1/4") | .013" | .009" | .022" |
| 90 (3 1/2") | .014" | .010" | .024" |
| 100 (4") | .015" | .011" | .026" |
| 105 (4 1/4") | .016" | .012" | .028" |
| 115 (4 1/2") | .017" | .013" | .030" |
| 125 (-) | .017" | .013" | .030" |
| -- (5 1/4") | .018" | .014" | .032" |
| 135 (-) | .018" | .014" | .032" |
| 155 (6") | .018" | .014" | .032" |

Reiloy USA has studied the maximum clearance dimensions specified by six injection molding machine manufacturers and have calculated an average of the clearance for various barrel bore diameters. Those maximum clearances are listed above. If the tolerances specified in these guidelines were applied (for both barrel and screw), the minimum clearances, as shown above, would result.

**2) Develop guidelines for the selection of barrel component materials** based on the economics of repair/replacement and resins being processed. We believe these guidelines might take the following form:

***"Unless a new barrel is required because of structural deficiencies in the old or because of down-time constraints, reline only that portion of the barrel worn beyond tolerance levels."***

Select the barrel lining material most appropriate for the resins being processed.

Lining materials may be selected from the table on the following page.

**3) Establish guidelines for the selection of screw component materials** based on the severity of the plastic processing conditions. Most thermoplastics can be satisfactorily processed using nitrided or chrome-plated screws which have some type of hard-surfacing material on the flight O.D. As glass fibers, spheres, calcium carbonate, or other abrasive reinforcements are added, special screw materials must be selected. Special screw materials are also needed for highly corrosive thermoplastics and thermosets.

The table on page 13 sets forth basic screw materials matched to selected processing conditions.

# BARREL MATERIAL GUIDELINES

| BARREL LINING MATERIAL | HARDNESS RANGE Rc | ACCEPTABILITY FOR RESIN WEAR CONDITIONS | | | | |
|---|---|---|---|---|---|---|
| | | ABRASIVE | | | CORROSIVE | |
| | | NORMAL(1) | MODERATE(2) | SEVERE(3) | MODERATE(4) | SEVERE(5) |
| **NITRIDE: (Gas or Ion)** | | | | | | |
| 4140 or equivalent | 63-70 | Acceptable | Poor | Not acceptable | Poor | Not acceptable |
| Nitralloy 135 M or equivalent | 63-70 | Acceptable | Poor | Not acceptable | Poor | Not acceptable |
| **CAST BIMETALLICS**: | | | | | | |
| Reiloy R121 | N/A (6) | Good | Acceptable | Poor | Poor | Not acceptable |
| Reiloy R115 | N/A (6) | Good | Acceptable | Poor | Excellent | Excellent |
| Reiloy R215 | N/A (6) | Excellent | Excellent | Good | Good | Good |
| **TOOL STEELS:** | | | | | | |
| D-2 | 58-60 | Good | Acceptable | Poor | Acceptable | Not acceptable |
| PM10V | 62-64 | Excellent | Excellent | Good | Acceptable | Not acceptable |
| PM Stainless Tool Steel | 58-60 | Acceptable | Poor | Not acceptable | Excellent | Good |
| **SPECIAL ALLOYS:** | | | | | | |
| Nickel 718 (Inconel or Pyromet) | 43-45 | Acceptable | Not acceptable | Not acceptable | Excellent | Excellent |
| Monel K-500 | 37-39 | Acceptable | Not acceptable | Not acceptable | Excellent | Excellent |
| Hasstelloy C-276 | RB 87 | Acceptable | Not acceptable | Not acceptable | Excellent | Excellent |
| C-2 Tungsten Carbide | 79-81 | Excellent | Excellent | Excellent | Excellent | Good |

(1) All thermoplastics without reinforcement or abrasive fillers.
(2) Thermoplastics with abrasive reinforcement or fillers up to 30%.
(3) Thermoplastics with 30% or more reinforcements or abrasive fillers and thermosets.
(4) Cellulosics, Ionomers, Acetals and others containing corrosive additives.
(5) Fluoropolymers.
(6) Standard HRc unmeasurable due to the extreme hardness of the carbides in this matrix.

***Explanatory Notes:***

**Nitrided barrels** are offered by many original equipment manufacturers as standard equipment. Most nitrided barrels are made from Nitralloy 135M and, after nitriding, have a hardened (70+ Rc) bore diameter of .007" to .015" depth, depending upon nitriding cycle. The hardened interior surface is quite wear resistant until the nitrided depth is worn away. Thereafter, wear occurs at a fairly rapid rate.

**Bimetallic barrels** are manufactured by metallurgically bonding the lining alloy to the inner surface of a pre-machined seamless, steel-wrought tube or forging. Bonding is achieved by heating the lining alloy in the steel barrel to above its melting point and centrifugally casting it onto the steel surface. A typical bimetallic barrel has a lining thickness of 1/16$^{th}$ inch (.063"). Premium bimetallic linings are a composite of tungsten carbide particles dispersed in a nickel base alloy matrix. The high hardness of the carbides (2,080 DPH) in the premium lining indicates its potentially great wear resistance.

**Tool steel-lined barrels** are manufactured by placing a tool steel lining inside alloy steel (4130 to 4140) tubing using a press-fit or shrink-fit technique. Through-hardened tool steel linings are normally ¼" to ½" (.250" to .500") in wall thickness. The tool steels commonly used are D-2 and A-11 (10V). D-2 is a high carbon, high-chromium content tool steel which has proven wear resistance surpassing most other steels. A-11 (10V) is a tool steel with large quantities of carbon, chromium and vanadium which gives the steel remarkable wear resistance characteristics. The uniform dispersion of its fine, extremely hard (2,950 DPH) vanadium carbides accounts for its excellent resistance to adhesive and abrasive wear.

# SCREW MATERIAL GUIDELINES

| BASE SCREW MATERIALS | | | | ACCEPTABILITY FOR RESIN WEAR CONDITIONS | | | | |
|---|---|---|---|---|---|---|---|---|
| MATERIAL DESIGNATION | TREATMENT (1) | Rc (2) | FH (3) | ABRASIVE | | | CORROSIVE (7) | |
| | | | | NORMAL (4) | AVERAGE (5) | SEVERE 6) | MODERATE | SEVERE |
| **ALLOY STEELS:** | | | | | | | | |
| 4140 | Flame-hardened | 48-55 | no | Acceptable | Poor | Unacceptable | Unacceptable | Unacceptable |
| 4140 | Chrome-plated | 60-65 | Optional | Good | Acceptable | Unacceptable | Good | Unacceptable |
| Nitralloy 135-M | Nitrided | 63-70 | Optional | Good | Acceptable | Unacceptable | Poor | Unacceptable |
| **TOOL STEELS:** | | | | | | | | |
| PM 9V | Heat-treated | 54-56 | no | Excellent | Excellent | Good | Acceptable | Unacceptable |
| PMM4 | Heat-treated | 62-64 | no | Excellent | Good | Acceptable | Poor | Unacceptable |
| PM Stainless Tool Steel | Heat-treated | 54-56 | no | Excellent | Excellent | Good | Excellent | Good |
| **SPECIAL ALLOYS:** | | | | | | | | |
| Hastelloy C-276 | Age hardened | RB 87 | Optional | Acceptable | Unacceptable | Unacceptable | Excellent | Good |
| Nickel 718 | Age hardened | 43-45 | Optional | Acceptable | Unacceptable | Unacceptable | Excellent | Good |
| XC4000 | Carbide Encapsulated | 70+ | Optional | Excellent | Excellent | Good | Excellent | Good |
| XC1000 | Carbide Encapsulated | 70+ | Optional | Excellent | Excellent | Good | Excellent | Poor |

(1) Includes chrome-plating to .001”-.002” and gas or ion nitriding for 24+ hour cycle.
(2) Rockwell C hardness
(3) Flight hard-surfacing required
(4) Thermoplastics with no reinforcements
(5) Thermoplastics with up to 30% reinforcement.
(6) Thermoplastics with more than 30% reinforcement.
(7) Moderate includes cellulosics, acetals and others containing corrosive additives

### *Explanatory Notes:*

**The O.D**. or flight surfaces of some screws are protected against wear by a welded hard-surfacing material. The most common materials are Stellite 12, Colmonoy 56, Colmonoy 57 and Colmonoy 83. Various screw manufactures use proprietary materials specially formulated. All nitrided and chrome-plated screws (and some alloy screws) should be flight hard-surfaced.

**Ion nitriding** is preferred over gas nitriding because of its superior uniformity in depth and degree of hardness.

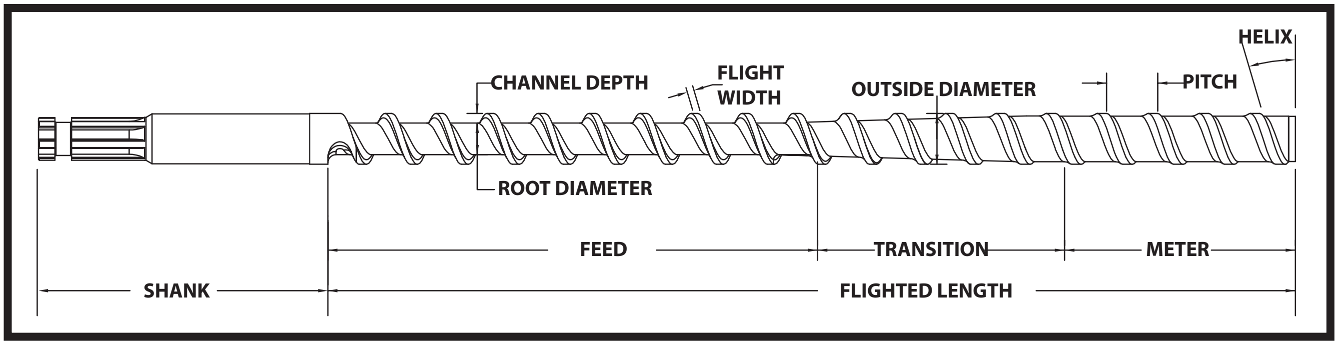
**Chrome-plating** for screws should be at least .001” depth and not “flash-chromed” which is often only .0005”.

**Screws made from tool steels** do not require flight hard-surfacing because the heat-treated steel is more wear resistant than the hard-surfacing materials.

# OPTIMIZING SCREW / RESIN MATCHING

Another important step in a Preventive Maintenance Program is the matching of screw design with resins to be processed. This matching process requires an understanding of some basic screw design concepts, the identification of resins being processed in each machine and the selection of optimum design for each resin or machine.

**1) <u>Understanding basic screw design concepts</u>** involves L/D ratio, compression ratio, screw profile and channel depth and how those factors relate to resins being processed.




a) **L/D Ratio—**The L/D ratio is the ratio of the flighted length of the screw to the outside diameter of the flights. The ratio is calculated by dividing the flighted length of the screw by its outside diameter. Although several IMM manufacturers now offer a choice of injection units, most injection screws have a 20:1 or greater L/D ratio. (The L/D ratios for extrusion screws generally range from 24:1 to 30:1 with some much longer.)

b) **Compression Ratio –** The ratio of the feed section flight depth to the meter section flight depth, referred to as “compression ratio,” typically ranges from 1.5:1 to 4.5:1 for most thermoplastic materials. Most injection screws are classified as general purpose screws having a 2.5:1 to 3.0:1 compression ratio. Where one particular plastic is to be processed continuously, it is preferable to design a screw best suited to that resin to maximize productivity and optimize part quality. In those cases, it is not unusual to deviate from the more common 2.5:1 to 3.0:1 compression .

Although there are many factors which influence the selection of a compression ratio, the molecular structure of the polymer is a major determinant. Resins are identified as **amorphous polymers** which soften gradually when heated and **crystalline polymers** which remain relatively solid to their melting point. Although there are exceptions, lower compression ratios (1.5:1 to 2.5:1) are desirable for processing amorphous polymers and higher compression ratios (3.0:1 to 5.0:1) are recommended for crystalline polymers.

c) **Screw Profile –** The standard metering screw has three processing zones: the feed zone, transition zone and meter zone. The feed zone is where the plastic first enters the screw and is conveyed forward along a constant root diameter. In the transition zone, the plastic is conveyed, compressed and melted along a root diameter that increases with a constant taper. The meter zone is where the melting of the plastic is completed and the melt is conveyed forward along a constant root diameter reaching a temperature and viscosity that is necessary to form parts.

The screw profile is described as the length, in diameters or flights, of each of the three sections of the screw. A 10-5-5 profile indicates a flighted surface with 10 diameters in the feed zone, 5 diameters in the transition zone and 5 diameters in the meter zone. General purpose screws typically have a 10-5-5 screw profile. It is not difficult for the screw manufacturer to alter this profile.

Generally, **amorphous polymers** require a long transition and lower compression ratio to avoid overheating and degrading, whereas **crystalline polymers** favor a longer feed section, shorter transition and higher compression ratio to insure pre-heating and total melting. Screw profile is frequently altered to improve feeding, melt homogenization and melt stability.

d) **Channel Depth –** The channel depth in the meter section is determined by the resin to be processed. The feed and transition zone channel depths are dependent upon the selected compression ratio and screw profile. A shallow screw channel increases the exposure of plastic to the heated barrel wall, increases the shear rate (plastic sheared between barrel and screw), generates heat and reduces throughput. Because shear rate increases as the screw channel depth becomes more shallow and/or as screw RPM increases, shear or heat sensitive materials are generally processed using a deeper screw channel and slower screw RPM. Accordingly, **amorphous polymers** are typically processed with a somewhat deeper meter depth, whereas **crystalline polymers** use more shallow flight depth in the meter section.

**2) <u>Identification of resins being processed</u>** is facilitated by reference to each Screw Identification Record illustrated on page 7. This data may be summarized in the following table.

| RESIN PROCESSING LISTING | | | | DATE: | | | | PREPARED BY: | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | Machine Manufacturer | Inject Capacity (oz) | Bore Dia (mm/in) | Resin 1 | | Resin 2 | | Resin 3 | | Others (List Type Only) |
| | | | | Type | % | Type | % | Type | % | |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |

**3) <u>Select optimum screw design</u>** for each machine based on the resins being processed. Guidelines for the proper screw design are presented in the table on page 16. ***Even with partial dedication of a machine to one or more resins, a custom-designed screw should improve cycle times, part times, part quality and reject rates.*** Conversion from existing screws to the improved designs can be accomplished as normal replacement occurs, unless improvement is anticipated to be so significant that immediate change is warranted.

Final specifications should be included in each <u>Screw Identification Record</u> and each screw should be designated on the <u>Machine I.D. Record</u> and on the processing <u>Set-Up Record</u> for each part to be produced.

# INJECTION SCREW DESIGN GUIDELINES

| RESIN | MOLECULAR TYPE | CRITICAL TEMP °F (a) | DENSITY G/cm³ | | SCREW DESIGN BASED ON | | | SELECTED TRADE NAMES |
|---|---|---|---|---|---|---|---|---|
| | | | SOLID | MELT | CHANNEL DEPTHS (b) | TRANSITION LENGTH (c) | COMPRESSION RATIO (d) | |
| ABS | Amorphous | 228 Tg | 1.08 | .97 | Deep | Long | Low | Cycolac, Magnum, Lustran |
| CA | Crystalline* | NA | 1.22 | 1.14 | Deep | Medium | Low | Tenite |
| CAB | Crystalline* | NA | 1.15 | 1.08 | Deep | Medium | Low | Tenite |
| CAP | Crystalline* | NA | 1.17 | 1.10 | Deep | Medium | Low | Tenite |
| FEP | Crystalline | 527 Tm | 2.12 | 1.49 | Medium | Short | Medium | Teflon |
| HDPE | Crystalline | 278 Tm | .95 | .73 | Medium | Medium | Medium | Dowlex, Marlex, Petrothene, Alathon |
| HIPS | Amorphous | 210 Tg | 1.05 | .97 | Deep | Long | Low | Styron, Lustrex, RTP |
| Ionomer | Crystalline | 205 Tm | .93 | .73 | Medium | Medium | Medium | Surlyn, Iatek, Formion |
| LCP | Crystalline | 525 Tm | 1.35 | Unk | Shallow | Medium | Medium | Vectra, Xydar |
| LDPE | Crystalline | 221 Tm | .92 | .76 | Medium | Medium | Medium | Petrothene, Tenite, Escorene |
| LLDPE | Crystalline | 250 Tm | .93 | .70 | Medium | Medium | Medium | Petrothene, Dowlex, Escorene, Attane |
| PA 66 | Crystalline | 500 Tm | 1.14 | .97 | Shallow | Medium | High | Zytel, Ultramid, Wellamid, Vydyne |
| PBT | Crystalline* | 470 Tm | 1.34 | 1.11 | Medium | Medium | Low | Valox, Celanex |
| PC | Amorphous | 302 Tg | 1.20 | 1.02 | Deep | Long | Low | Lexan, Makrolon, Calibre |
| PEI | Amorphous | 420 Tg | 1.27 | 1.08 | Medium | Medium | Medium | Ultem |
| PET | Crystalline** | 460 Tm | 1.40 | 1.10 | Medium | Medium | Medium | Kodapak, Petlon, Rynite (reinforced) |
| PFA | Crystalline | 582 Tm | 2.15 | Unk | Medium | Short | Medium | Teflon |
| PMMA | Amorphous | 203 Tg | 1.20 | 1.05 | Deep | Long | Low | ( Acrylic) Plexiglas, Acrylite |
| POM | Crystalline | 358 Tm | 1.42 | 1.17 | Shallow | Medium | Medium | Delrin (H); Celcon (C) |
| PP | Crystalline | 348 Tm | .90 | .75 | Medium | Medium | Medium | Marlex, Hifax, Escorene, Nortuff |
| PPE-PPO | Amorphous | unk | 1.08 | .90 | Medium | Medium | Low | Noryl, Prevex |
| PS | Amorphous | 193 Tg | 1.05 | .97 | Medium | Medium | Medium | Styron, |
| PSU | Amorphous | 374 Tg | 1.24 | 1.16 | Medium | Medium | Medium | Udel, Ultrason S |
| PVC-F | Amorphous | 194 Tg | 1.30 | 1.20 | Deep | Medium | Low | Geon |
| PVC-R | Amorphous | 188 Tg | 1.40 | 1.22 | Deep | Long | Low | Geon |
| SAN | Amorphous | 300 Tg | 1.07 | 1.00 | Medium | Medium | Medium | Lustran-SAN, Tyril, Luran |

(a) Tm = Melting Point     Tg = Glass Transition Point (mean of temps)
(b) Degree of meter channel depth. Example: Medium for 2" (50 mm) diameter .100" to .125".
(c) Short = 4D or less; Medium = 5D to 7D; Long = 8D or more
(d) Low - less than 2.5:1; Medium - 2.5 to 3.4:1; High - 3.5:1 and above

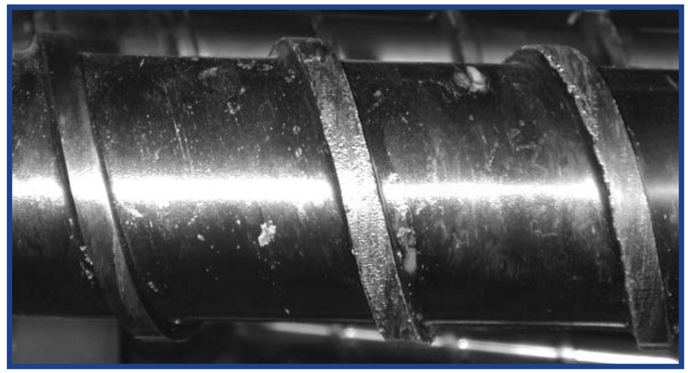
* Processes like amorphous
** Bottle grade material
H = Homopolymer   C = Copolymer

# COMPONENT WEAR

There are three types of wear that occur in barrels, screws, valves and other components. An understanding of the nature and causes of adhesive, abrasive and corrosive wear is essential to the selection and use of these components. Knowledge of wear sources can help in its prevention.

**1. <u>Adhesive Wear</u> -** Adhesive wear occurs when two metals rub together with sufficient force to cause the removal of material from the less wear resistant surface. If the two metals have a comparable chemical analysis and hardness, a galling action can occur when one metal is actually welded to the other causing high and low spots where material is added or removed.

The screw and barrel can come into contact with each other during operation. The screw is cantilevered in the barrel and is supported only at its shank and by the plastic in the barrel. When conditions cause excessive contact between the two components, adhesive wear and/or galling will occur on the screw flight OD and the barrel walls.



Severe Adhesive Wear

There are several ***causes*** of adhesive wear and/or galling, all of which can be prevented through the proper design, manufacture and use of the machinery components.

**a. Improper Screw Design -** If the design of the screw is not adequate to generate the necessary melting capacity, the unmelted resin can result in an uneven plugging of the flow in the screw channels, causing the screw to deflect against the barrel wall. This condition will occur more readily with new rather than old components that have considerable wear. The same condition can occur with a properly designed screw running in a barrel with an improper heat profile as described.

Moderate Adhesive Wear

**b. Wrong Component Materials** - To avoid adhesive wear and/or galling, the chemical analysis and/or hardness of the screw and barrel materials must be different. This ‘compatibility’ of materials must be considered when selecting screw and barrel materials.

**c. Incorrect Heat Profile -** In an effort to process resins at their lowest melt temperatures, low heater band settings in the transition and feed zones can cause the resin to melt almost solely from shear heat generated by the screw. If the shear heat is not uniform, the same restrictive condition described above in item (a) will occur, causing screw deflection and consequent adhesive wear and/or galling.

**d. Poor Manufacturing Workmanship -** Inferior plating, flight hard-surfacing or nitriding of screws, improper heat treatment of components or lack of straightness in the barrel or screw can cause adhesive wear and/or galling.

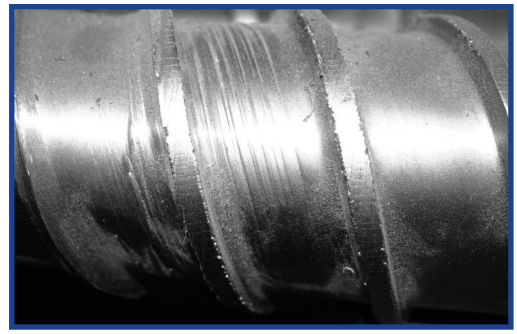
**e. Improper Machine Alignment -** An injection molding machine or extruder can be found to be out of alignment causing continual contact between the barrel and screw. Although this may be the last item to be checked, misaligned components can and do occur. Laser alignment may be required.

**2. <u>Abrasive Wear</u> -** Abrasive wear occurs when abrasive particles in the resin come into contact with the screw or barrel. The scouring effect of the hard particles wears away the metal in the screw or barrel, most often in the transition section. Foreign particles such as screw flight particles, chrome plating and other objects can also gouge the barrel or screw or even break segments out of the screw flights.

Abrasive particles in the resin can be reinforcements, such as glass fibers or spheres, calcium carbonate and powdered metals or ceramics. All cause abrasive wear, especially if the components are not made from high quality wear resistant materials.

Severe Abrasive Wear

Abrasive wear can also occur when processing non-reinforced resins if too much of the energy required to melt the resin is generated by shear. Cold pellets moving into the transition section of the screw are compressed and sheared causing a scrubbing action resulting in abrasive wear.



Moderate Abrasive Wear

Although the processing of heavily reinforced resins will inevitably result in abrasive wear to the barrel and screw, many of the causes of this type of wear can be delayed or prevented. The ***causes of abrasive wear*** include:

**a. Improper Component Materials -** The failure to use wear resistant materials in barrel linings and on screw surfaces allows abrasive wear at a much more rapid rate.

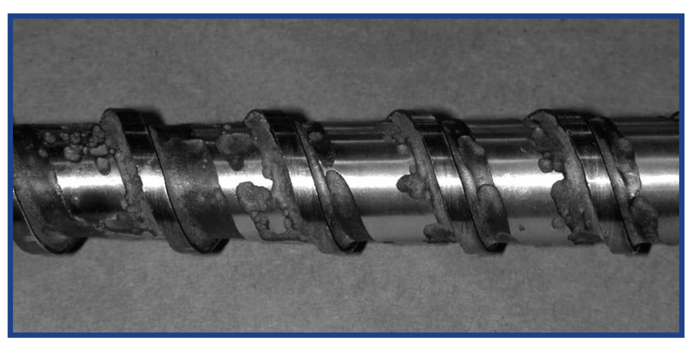
**b. Inadequate Screw Design -** A screw design that is too aggressive (compression ratio too high or transition section too short) can contribute to premature abrasive wear. An overly aggressive screw design can cause excessive shearing of the resin contributing to the scouring effect of abrasive, reinforced resins.

**c. Incorrect Heat Profile -** Heater band settings that are too low in the feed and transition zones can cause too much shear in melting the resin. The excessive shear causes abrasive wear on the root and flight radii of the screw and on the barrel lining. The same condition can result from heater band failure where inadequate conductive heat is used to melt the resin. For this reason, many molders of reinforced resin use a ‘reverse’ or ‘hump’ heat profile.

**d. Excessive Back Pressure or Head Pressure -** In some cases, back pressure is used to compensate for an improper screw design in an effort to complete the melting of the resin. Excessive back pressure increases the scouring effect of the resins (especially reinforced resins) against the screw and barrel. It can also segregate modifiers or fillers in a resin, creating a part with inferior physical properties.

**e. Failure to Use Magnets -** Another form of abrasive wear occurs when foreign particles enter the barrel. The use of magnets, screens or filters can prevent gouging and fracturing of components caused by processing nuts, bolts and the like.

**3. <u>Corrosive Wear</u>-** Corrosive wear results from acids that are generated in plastics processing which attack the surfaces of barrels and screws. Corrosive wear is characterized by pitting and usually occurs in the last few flights of the transition zone and in the metering zone. The pits can also collect melt, burn or degrade it and result in black or burned particles in the parts.



Corrosive Wear

There are several resins that can generate acidic gases at high temperature. They include polyvinyl chloride (which releases hydrochloric acid), acetals (formic acid), fluoroplastics (hydrofluoric acid) and cellulosics (acetic, butyric and propionic acids).

In addition, flame retardants, coupling agents and some foaming agents release acids, including bromic and sulphuric acids.

Despite their acid-generating characteristics, these resins can be successfully processed using the proper screw designs and corrosion-resistant component materials. The ***causes of corrosive wear*** include:

**a. Improper Component Materials -**Corrosion-resistant materials are available for barrel linings and screws. Stainless steels in a hardened condition, nickel alloys, special flight hardsurfacing materials and iron-free barrel linings all help avoid corrosive wear.

**b. Incorrect Shut-down and Start-up** - Shut-down and start-up procedures that permit the soaking of the resin at operating temperatures for an extended time will ultimately cause corrosive wear. This is especially true if any moisture is allowed to permeate the resin. Shutting down without cleaning the barrel of plastic and without leaving the screw in the forward position not only encourages corrosion but can also contribute to cold start-up breakage.

**c. Inadequate Screw Design -** Screw designs that cause excessive shear heat also contribute to corrosive wear. Some resins that do not conduct heat as well as others (shear sensitive) can be burned or degraded, allowing corrosion to occur.

**d. Inadequate Moisture Removal -** Hygroscopic resins absorb moisture readily and must be dried before processing. They include: ABS, PMMA, FEP, PA, PBT, PC, PET, POM, PPO, PVC, SAN, PSU and PEI. If moisture is allowed to remain in the resin, it can unite with other elements to produce corrosives at operating temperatures.

**e. Incorrect Heat Profile -** The same conditions that can result from improper screw design (excessive shear heat) can also result from an improper heat profile or runaway heater bands. These conditions contribute to corrosive wear.

**f. Excessive Residence Time -** If the shot size is very small relative to the shot capacity of the machine, lengthy residence times will result. The over-soaking of the resin at high temperatures can encourage corrosion in some resins.

As you evaluate wear in your processing environment, keep one important consideration in mind: **All of the causes of excessive wear can be prevented!**

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