RANDCASTLE
EXTRUSION SYSTEMS INC.

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From the President,

When I started Randcastle in 1987, I didn't know that we would become a company that could seriously claim to have advanced the state-of-the-art of extrusion. I thought that we would innovate in small extrusion lines. That worked out and we pioneered everything from proprietary feed sections to patented surge suppression to make them work better.

Looking back, I had no idea that we would supply patented after market compounding screws for over 1,000 pounds per hour that rival, sometimes exceed, what twins can do. That might be hard for you to believe but, fortunately, we have evidence. We can show you nano materials, at 100,000 times magnification, that are well distributed. We can show you sub-micron PS globules, at 5,000 times magnification (whereas some, so called, state-of-the-art single screws are still researching with optical microscopes!). We can show you compounded wood, TPO's, and solve problems that you may not even know exist (such as reagglomeration).

Now, we're bringing new technology on-line including:

- **Micro-Batch mixers:** We're developing machinery to replace the cumbersome lab batch mixers that you're used to. You won't have to scrape hot material off rotors into a messy pile, then grind that pile and then try to mold the grindings. Instead, you'll take 100 grams of ingredients (your batch size), melt, mix and then extrude directly into a strand. Very shortly, we plan on equipment that will go one step further: In 15 minutes, you'll go from your 100 grams batch of raw ingredients to a tensile bar.
- **Injection Molding Screws:** We're installing our first molding screw. We expect to show serious property improvement.
- **Direct Extrusion:** We're already compounding directly into product at the lab scale but as this technology blossoms, the advantages of single screw compounding will let you compound while you extrude at thousands of pound per hour—saving money while you make a better product.
- **Venting:** We've invented a new venting mechanism in the single screw extruder. It's shorter than your typical two stage screw so we can fit three vents into a 36/1 single. And, since it mixes while it vents, we pretty sure it will vent better too.

One of the nice things about this business, is that I don't know where we're going. But, everyone at Randcastle looks forward—because that's our job.

Best Regards,

Keith Luker

RANDCASTLE'S

MICROTRUDERS *

Shown from left to right:
Models RCP-0375,
0500, 0625, & 0750

Single Screw Extruders

5 Grams to 75 Pounds Per Hour

**Patents: 5,486,328; 5,515,672; 5,569,429*
Other U.S. and Foreign Patents Pending

Microtruder Technology

Feed Sections[1]: Select the feed section that is right for your feed stock, output and pressure stability:

- -Standard (smooth bore)
- -Classic (smooth bore)
- -Aggressive (smooth bore)
- -Grooved Bore Series[1]
- -Roller Feed (for soft strips)
- -Melt Feed (for reactors)

Screw: Working L/D 24:1 to 50:1 in standard and custom designs including the Recirculator mixing sections (patent pending).

Barrel: Nitrided stainless steel or bi-metallic lined for corrosion or wear resistance.

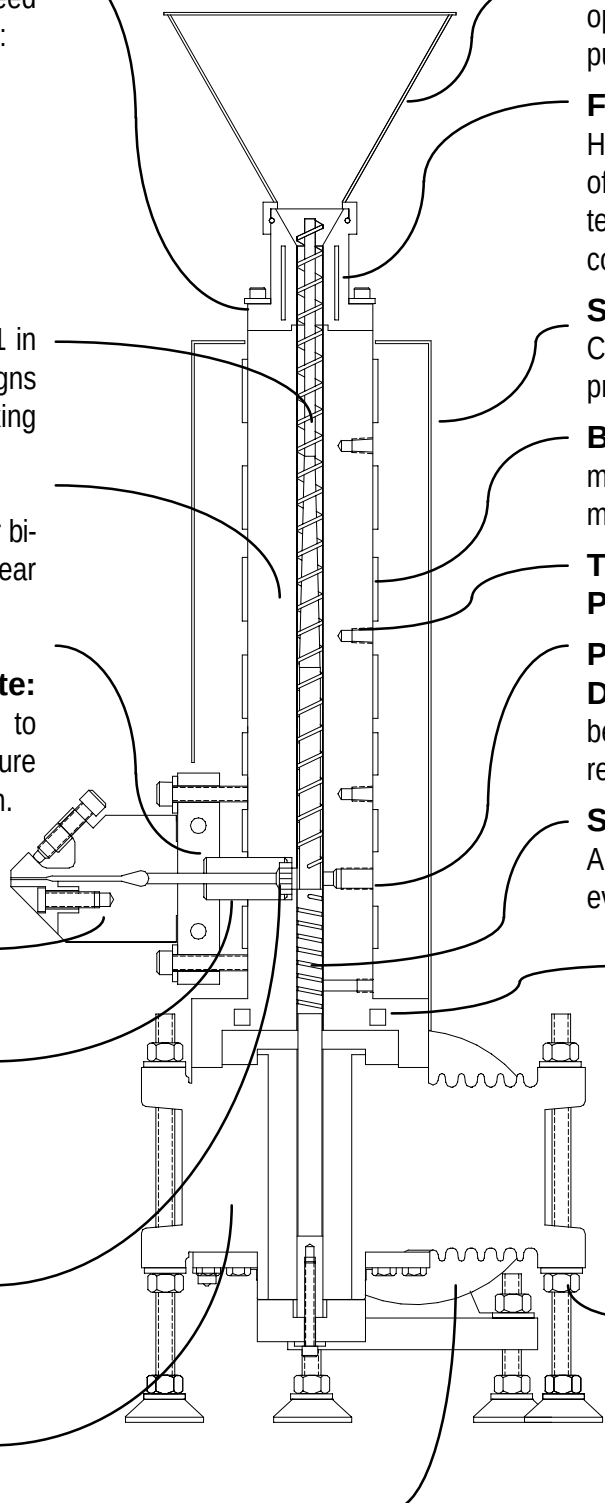
Heated Clamping Plate: Heaters provide thermal control to prevent freeze-off. Screws secure transfer tube for leak free operation.

Die: Available dies include strand, film, monofilament, coextrusion, tubing, and sheet.

Transfer Tube: Heated by the barrel and the clamping plate to eliminate cold spots, the transfer tube holds the breaker plate.

Breaker Plate: Holds the screen pack in streamlined stainless steel construction.

Gear Reducer: Double enveloping, low backlash gearing with high performance integral thrust bearings.



Hopper: Stainless steel (s.s.), optionally sealed for nitrogen purge or powdered feed stocks.

Feed Section Cooling: Hardened s.s. features (3) L/D's of directed cooling for positive temperature control of solids conveying.

Stainless Steel Cover: Cooling fans are optional for precision temperature control.

Barrel Heaters: Standard mica or high temperature mineral filled.

Type "J" Thermocouple Ports

Pressure Port & Rupture Disc[2] : Pressure measurement before the breaker plate is a recommended option.

Surge Suppressor[1]: Automatic surge reduction in every screw.

Barrel Flange: Change the extruder's output direction[3] by rotating the flange on the gearbox. Flange cooling keeps the gearbox oil cool. Assembly is shown for standard right to left operation.

Adjust Height and Level: Change the center line of the output as needed on swivel brass pads. Optional mounting systems available[3].

AC Motor: Variable uniform speed control with over amperage protection.

U. S. PATENTS: 5,486,328; 5,515,672; 5,569,429. Other U.S. and foreign patents pending.

[1] A technical bulletin or a published paper is available on this topic.
[2] Rupture discs are standard on all sizes except the 1/4 inch Microtruder.
[3] Drawings are available.

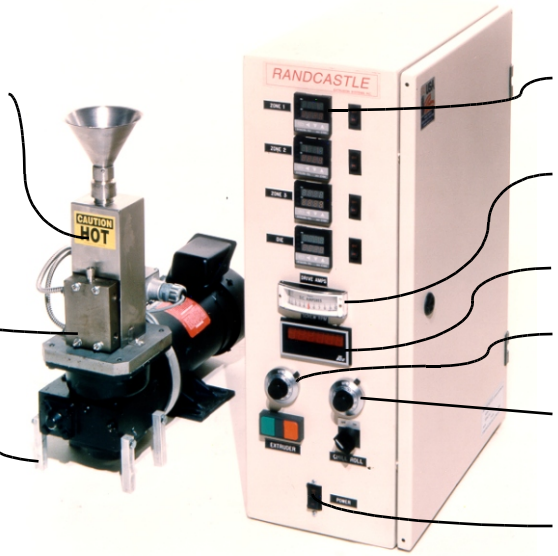
Engineering Benefits

Before we built the vertical extruder, screws smaller than 1 inch broke easily and fed poorly. The solution is the "discharge driven" Microtruder. These are some of the benefits of our state of the art technology.

Strong Screw*: An extruder screw must withstand the stress of feeding, melting, mixing, and pumping so Randcastle drives the screw through the metering section of the screw. The metering section root diameter is about 2 to 4 times as strong as the weak feed section root diameter allowing much smaller extruders.

Excellent Feeding*: A functional extruder gets the feed stock to the screw. In a typical extruder, there is a hole in the barrel, proportional to the screw diameter, that allows the feed stock to enter the screw from the hopper. The hole becomes so small in these extruders under one inch that the feed stock arches (also called "bridging" and "piping") over the hole. Once the feed becomes erratic, the extruder cannot pump uniformly. Randcastle's vertical design extends the screw *into the feed stock* to solve the problem. Attachments to the rotating screw can extend into the hopper to aid in feeding particularly difficult powders and cohesive (non-free flowing) feed stocks.

Model: RCP -0250 1/4 Inch Microtruder & Typical Control Panel (Shown with Strand Die and "Post" mounting system.)



STANDARD PANEL FEATURES

Auto Tuning Temperature Controls: (3) for the barrel & (1) for the die.

AC Motor Ammeter with automatic shut-down ammeter for "overload" conditions.

Digital Tachometer

Digital Speed Control and "Start/Stop" buttons.

Optional Controls for downstream equipment such as pelletizer, chill roll, etc..

Main Power Switch

Superior Compounding*: Mixing is important in most extrusion applications but critical in some. Pending patents for our Recirculator mixing elements demonstrate, in published peer reviewed papers, success in applications previously only possible with twin screw extruders including such high filler loadings as 40% wood flour and pellets directly into sheet.

Improved Melting*: Our patent pending melting technology makes better melted product at lower temperatures and higher extrusion rates.

Feeding Further Enhanced*: Randcastle pioneered unique smooth bore feed sections that can make for significantly better feeding and consequently more uniform pressures[1]. These feed sections can be changed in under one minute with just four clamping screws. So often, if you select the wrong screw design for an experiment, you can simply change the feed section to solve the problem *without removing the screw and cleaning it.*

Uniform Pumping*: Randcastle discovered a novel method of making extruders pump better. We named this method, "Surge Suppression" and we incorporate it into every screw we make. Essentially, if you view a surge as a wave, the Surge Suppressor stores the top part of the wave and inserts the stored material into the trough of the wave. The Surge Suppressor operates automatically giving every Randcastle screw more uniform operation.

Batch Size: Until the Microtruder, researchers were forced to make multiple expensive batches to make a single trial. Using the Microtruder, complete trials with as little as 10 grams of polymer are possible. Production applications, such as catheters and coextrusion, also benefit from the Microtruder. Extruders that are too large for the application degrade the polymer because the screw turns too slowly. This makes the residence time excessive and causes a loss of properties in the extrudate. The Microtruders permits normal screw speeds to prevent burning.

Space Savings: The vertical design has an extremely small footprint so it is readily engineered into small spaces.

* *A technical bulletin or a published paper is available on this topic.*

RANDCASTLE ***EXTRUSION SYSTEMS, INC***

Overview of
Randcastle Recirculator Screw Technology
Comparison of the Recirculator to Twin Screw

Recirculator	Twin
***No Bypass*:** All material passes through each mixer's primary elongational flow fields.	**Not available.**
Reverse Axial Flow: Increases dispersive and distributive mixing cycles.	**Not available.**
Flood Feeding: For applications where good mixing is best combined with simple operation.	**Not available.**
High Pressure Generation: Allows direct product extrusion without a gear pump.	**Not available.**
Stable Pressures: Very stable pressure generation (can be comparable to gear pump)	***Large Pressure Variation.***
Melt Separation: Melt is separated from solids to promote melting (Melt separation screws).	**Not available.**
Low Cost	***High cost***
Direct Extrusion: Without gear pump.	***Direct Extrusion:*** Requires gear pump with consequent complex operation, temperature rise, maintenance, and expense.
Single Heat History	***Two Heat Histories:*** Compounding in a twin followed by single screw extrusion.

Applications: We believe the Recirculator screw has its greatest benefit:

- **Alloys**
- **Blends**
- **PLA** and **other biorenewables**—brittle materials [mixed with more rubbery materials to reduce brittleness].
- **Particulate fillers** at less than 30% concentration
- **Nano-composites**
- **Immiscible Blends** (Incompatible Mixtures): Such as PS/HDPE, EVOH/tie/PE. The principle is that by making the domains small enough, their behavior/properties improve.
- **Tubing:** Surge suppression improves the output stability so that gear pumps are not necessary for low output, precision applications e.g. medical tubing
- **TPO:** Polyethylene/Elastomer compounds.

For more information contact:

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RANDCASTLE ***EXTRUSION SYSTEMS, INC***

Overview of Randcastle Recirculator Screw Technology

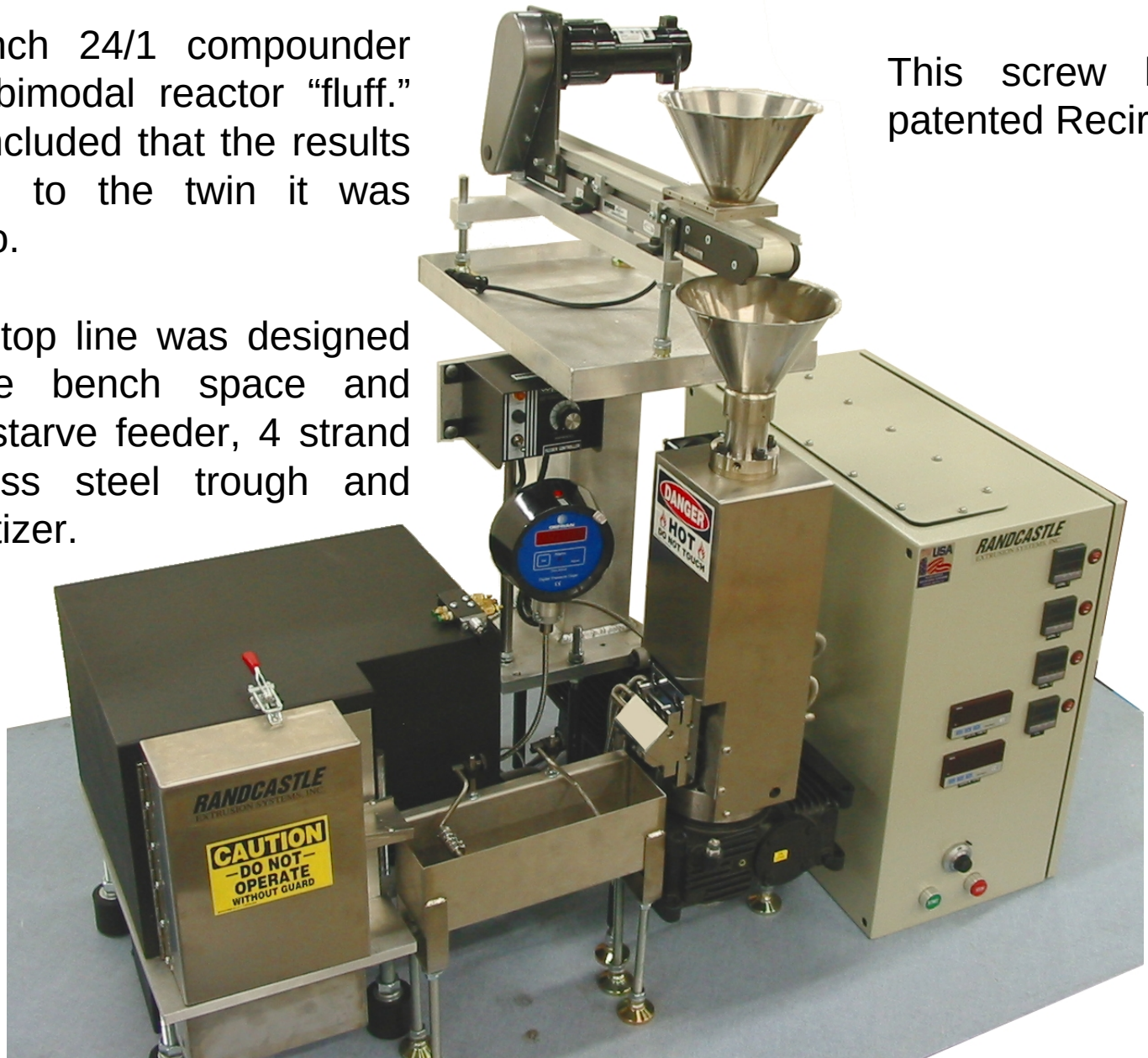
Comparison of the Recirculator To Conventional Single Screw

Recirculator	Conventional Single
Vastly Better Mixing: Multiple elongational flow fields for dispersive and distributive mixing	**Not available.**
No Bypass**:** All material passes through each mixer's primary elongational flow fields.	**Not available.**
Upstream Axial Flow: Increases dispersive and distributive mixing	**Not available.**
Direct Extrusion: Combines compounding and high pressure capability.	**Not available**
Single Heat History*:* Mix, melt, and make better product with less energy and degradation.	***Two Heat Histories*****:** Compared to twin screw compounding for mixing followed by single screw extrusion to make a product.
Quality Continued: The Recirculator keeps a well mixed compound, mixed—by keeping domains small.	***Demixing/Reagglomeration:*** It is known that singles separate mixture components by coalescence and mechanical action increasing domain size (in one case about 8 times).
Mixing During Melting: Upstream Recirculators combine melting and mixing at the highest critical shear stress for maximum dispersion.	***Mixing After Melting****:* Shear stress is reduced by orders of magnitude.
Flood or Starve Feed: Stable pressures with the mixing advantages of starve feeding.	***Flood Feed:*** Limits mixing.
Excellent Pressure Stability: Surge suppression can make output pressure as stable as a gear pump.	***Good Pressure Stability****:* Adequate for many products.
Melt Separation At Low Pressure: Melt is separated from solids to promote melting but a low pressure to limit temperature rise.	***Melt Separation:*** Melt is separated from solids to promote mixing to promote melting but most barriers require high pressure—raising the melt temperature.
Very Wide Speed Operation: Over 350 RPM successful.	***Low Speed Operation:*** Typically less than 120 RPM.
Low Cost	***Low cost***

Compounding Line

This 5/8 inch 24/1 compounder processed bimodal reactor “fluff.” A study concluded that the results were equal to the twin it was compared to.

The bench top line was designed to minimize bench space and features a starve feeder, 4 strand die, stainless steel trough and bench pelletizer.

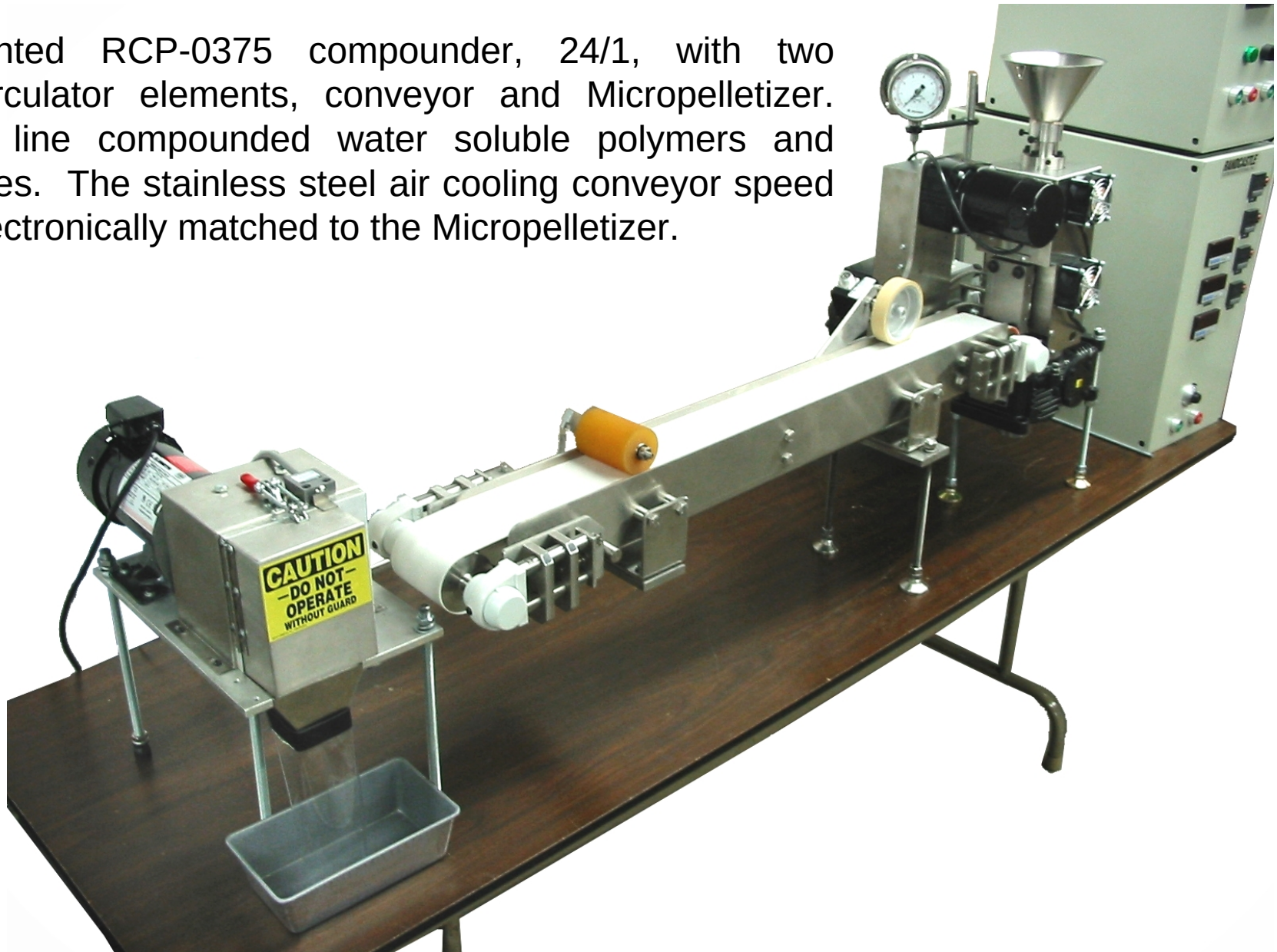


This screw had two patented Recirculators.

Compounding Line

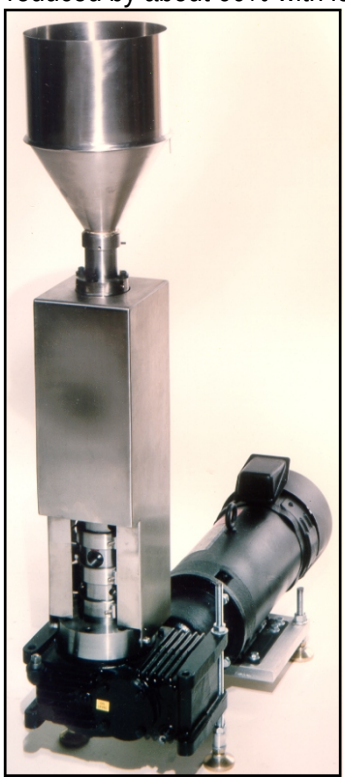
Micro Pelletizing Line

Patented RCP-0375 compounder, 24/1, with two Recirculator elements, conveyor and Micropelletizer. This line compounded water soluble polymers and actives. The stainless steel air cooling conveyor speed is electronically matched to the Micropelletizer.



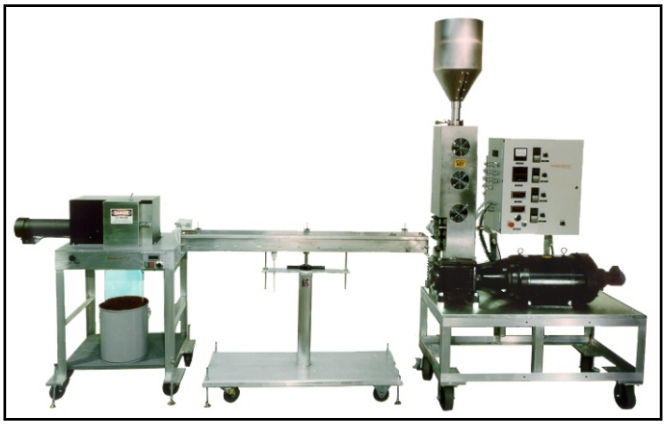
Microtruder Features & Specifications

All standard Microtruders include the extruder and a control panel. The standard extruder includes a 24:1 working L/D ratio 4140 hardened screw, removable water cooled feed sections made from hardened stainless steel (s.s.), a 1750 RPM DC motor, 15:1 gear reducer with integral thrust bearings and keyed drive quill, nitrided s.s. barrel with mica band heaters, s.s. barrel cover, rupture disc [1], and a s.s. breaker plate. The standard control panel includes (3) auto tuning temperature controllers for the barrel and (1) for the die, a variable speed AC motor control with 1000:1 speed range and overload amperage protection, digital motor amme ter, and a digital screw speed readout. Bench mounting is standard and includes height and leveling adjustment (shown on the RCP -1000 below). Typical dimensions are given on page 7. Detailed assembly drawings available. Outputs in the following chart[1] can be reduced by about 60% with low output screws and increased about 300% with Recirculator Technology.



Left: RCP-1000 with standard mounting. The barrel is shown assembled so that the output is away from the motor. The barrel can be rotated in 30 degree increments.

MODEL NUMBER	MICROTRUDER SCREW SIZE (In Inches)	OUTPUT PER HOUR	FEED STOCK (Max[3]. Inches)
RCP-0250	0.250	10 to 115 grams	0.03
RCP-0375	0.375	29 to 352 grams	0.06
RCP-0500	0.500	82 to 983 grams	0.13[4]
RCP-0625	0.625	168 to 2040 grams	0.15
RCP-0750	0.750	0.5 to 6 pounds	0.18
RCP-1000	1.000	1 to 18 pounds	0.19
RCP-1250	1.250	1.9 to 35 pounds	0.21



Right: A 1.25 inch model RCP-1250 model Microtruder shown in a floor model pelletizing line with 5 foot water trough and 2 inch wide pelletizer.

MODEL NUMBER	MOTOR HP	~SCREW VOLUME[5]	HOPPER VOLUME
RCP-0250	0.33	1.3 cm^3	460 cm^3
RCP-0375	0.75	5 cm^3	1,925 cm^3
RCP-0500	1.0	15 cm^3	1,925 cm^3
RCP-0625	1.5	34 cm^3	1,925 cm^3
RCP-0750	2.0	74 cm^3	325 in^3
RCP-1000	3.0	107 cm^3	700 in^3
RCP-1250	5.0	283 cm^3	1,600 in^3

[1] Standard on all Microtruders except the RCP-0250. Technical bulletin available.
[2] Output depends on many factors. This information is only a guide. Output tests used for this chart were for LLDPE at mininum speeds of 10 RPM and maximum speeds of 120 RPM for the RCP -0250 to the RCP-0625. Maximum output of the RCP-0750 and larger were using Recirculator Technology or grooved feed section and HIPS. Output of other materials may vary.
[3] If this dimension is close to the maximum feed stock dimension, lab testing might be prudent to insure performance. Maximum size is also dependent on specific screw design.
[4] A standard RCP-0500 screw will accept most conventional "1/8 inch" pellets.
[5] The volume of low output screws is about 60% less and the free volume of high output 50:1 L/D Recirculator screws about twice as high.

Right: A 50:1 L/D RCP -0500 compounder with (4) Recirculator mixing elements in a coextrusion system with a 24/1 RCP-0250 extruder to make bi-component fibers or rods. An optional starve feeder is shown that increases compounding flexibility.