



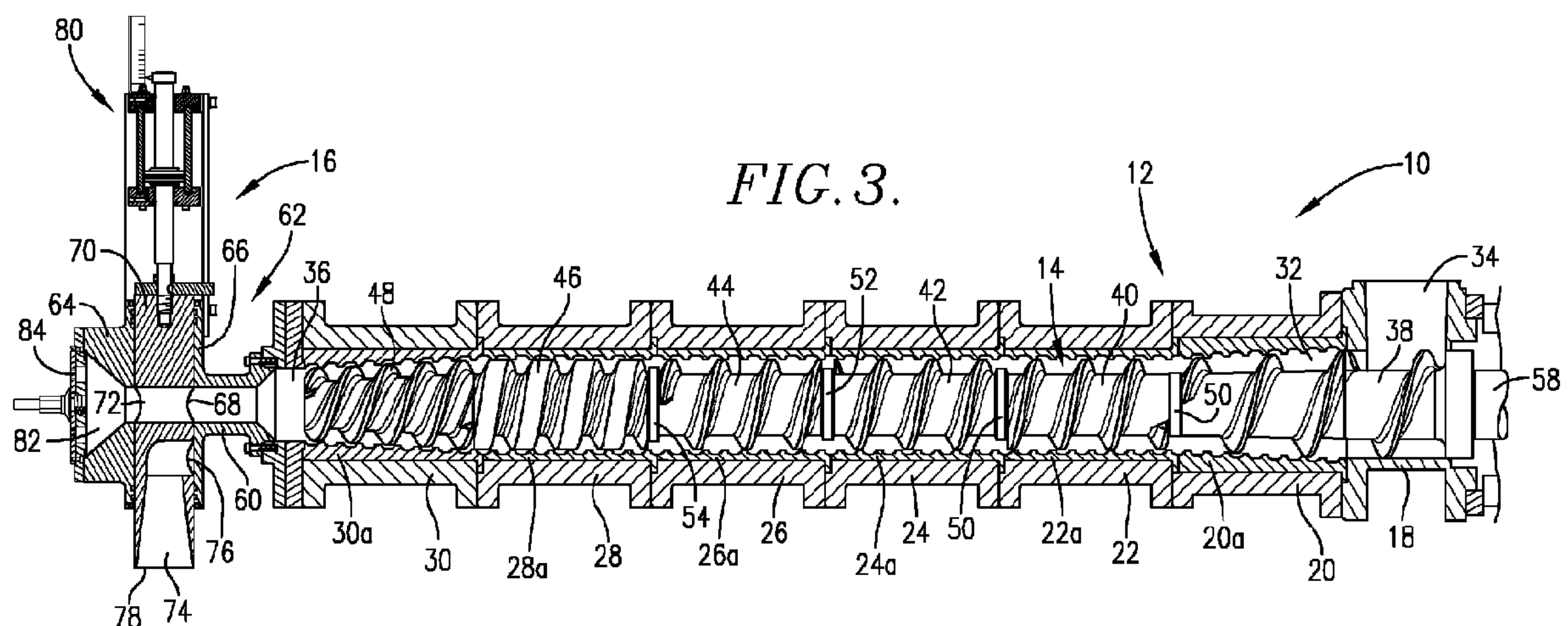
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(54) Titre : ENSEMBLE VIS D'EXTRUSION A ENERGIE MECANIQUE SPECIFIQUE ELEVEE
(54) Title: HIGH SPECIFIC MECHANICAL ENERGY EXTRUSION SCREW ASSEMBLY



(57) **Abrégé/Abstract:**

High Specific Mechanical Energy extruder screw assemblies (14, 88, 98) and complete extruders (10, 86, 96) are provided, which include wide-flight intermediate screw sections (104) having axial flight widths greater than the flight widths of the inlet and outlet screw sections (102, 106) on opposite sides of the intermediate sections (104). The intermediate sections (104) provide increased friction and shear serving to enhance the SMEs imparted to comestible food materials during processing thereof.

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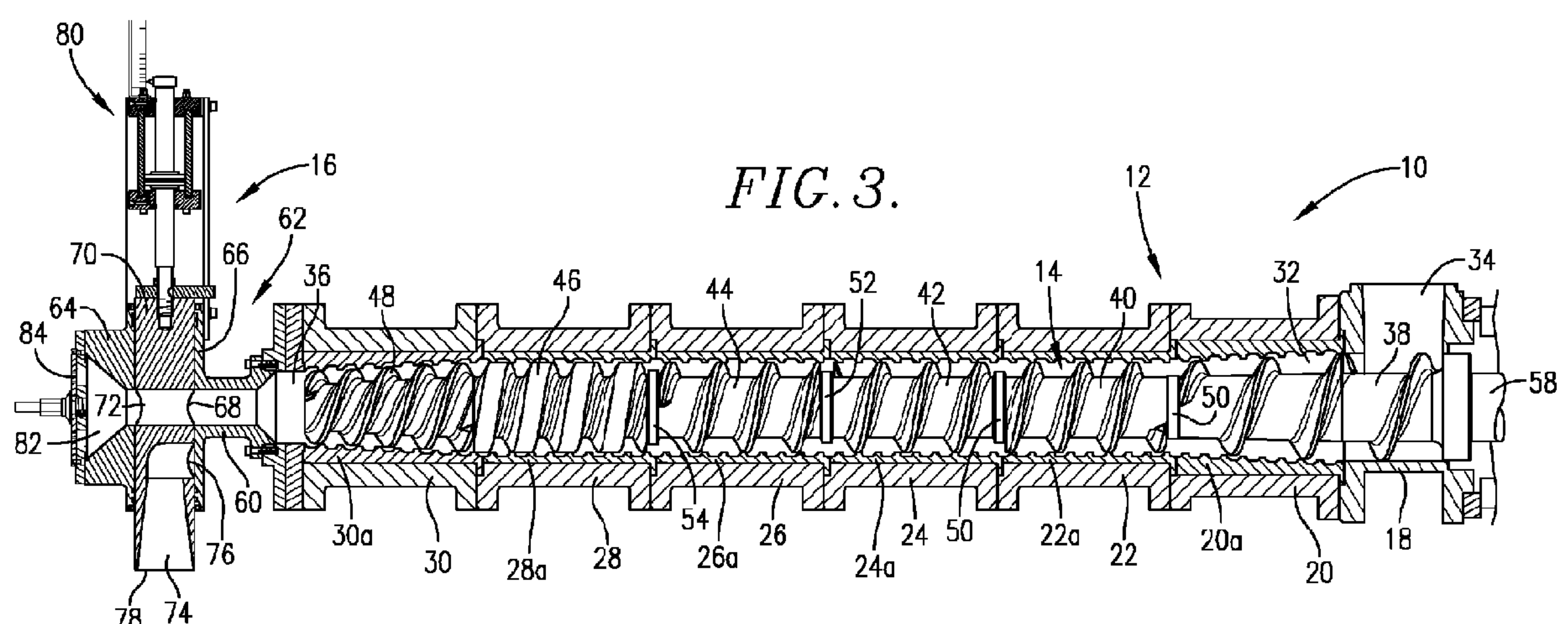
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(54) Title: HIGH SPECIFIC MECHANICAL ENERGY EXTRUSION SCREW ASSEMBLY



(57) Abstract: High Specific Mechanical Energy extruder screw assemblies (14, 88, 98) and complete extruders (10, 86, 96) are provided, which include wide-flight intermediate screw sections (104) having axial flight widths greater than the flight widths of the inlet and outlet screw sections (102, 106) on opposite sides of the intermediate sections (104). The intermediate sections (104) provide increased friction and shear serving to enhance the SMEs imparted to comestible food materials during processing thereof.

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HIGH SPECIFIC MECHANICAL ENERGY EXTRUSION SCREW ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of provisional application SN 62/513,899 filed June 1,
5 2017, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention is broadly concerned with helically flighted extrusion screw
10 assemblies and extruders which are specially designed for processing of comestible food or feed
products, such as pet and aquatic feeds. More particularly, the invention is concerned with such
equipment, and corresponding methods, wherein the extruder screw assemblies are characterized
by intermediate screw sections having relatively wide flight widths, as compared with inlet and
outlet screw sections on opposite sides of the intermediate sections. This increases the Specific
15 Mechanical Energy (SME) imparted to the products during processing thereof, which enhances
the nutritional and handling qualities of the products.

Description of the Prior Art

Many comestible products such as human foods and animal feeds are produced using
20 extrusion equipment, the general configuration and operation of which is well known in the art.
During extrusion, energy is imparted to the materials being processed, by two separate
contributions, namely SME and Specific Thermal Energy (STE), the latter being accomplished by
indirect or direct application of hot water or steam. The amounts of SME and STE can be varied
depending upon the type of product desired and other processing considerations. However, certain
25 types of comestible products, such as aquatic feeds, require enhanced properties, such as increased
fat/oil uptake and retention, as well as nutritional and feeding characteristics when high levels of
SME are employed. SME is normally developed by frictional forces and associated heat during
the extrusion process.

Heretofore, attempts at making high-quality aquatic and other feeds using single screw
30 extruders has required the use of specialized tooling or other expedients in order to generate

sufficient amounts of SME. For example, it is known that mid-barrel adjustable valves can be helpful in this regard, of the type described in US Patent Publication 2007/0237850. Additionally, use has been made of non-flighted triangular or other types of plates placed between helical sections of extruder screws, as well as breaker rings, all in an effort to increase SME. However, these attempts have not been wholly satisfactory, meaning that many comestible food or feed products produced using single screw extruders have not been of optimum quality.

The following references describe various types of extruder screw assemblies known in the art: US Patents Nos. 1,677,119, 2,115,006, 2,231,357, 2,508,495, 2,686,336, 3,104,420, 3,577,494, 3,698,541, 4,277,182, 4,405,239, 4,818,206, 5,728,337, 6,599,004, 6,672,753, 7,476,096, and 8,985,034; US Patent Publication No. 2009/0016147; foreign applications Nos. CN204222133U, DE1504449A1, DE10110860B4, DE10206484A1, DE29720689U1, EP1768823B1; FR2063573A5, FR2257409A1, GB1279663A, GB1291997A, JP2010194794A, JP2011224801A, JP2013035234A, JP2014184733A, JP2016943623A, JP2016107509A, JP2016182687A, JP2016215470A, JP2016215473A, JP2016215475A, JPH03231825A, JPH11188764A, JPS5057725A, JPS6384904A, JPS62286708A, JPS63291632A, NL44896C, NL52125C, and WO8606325A1; and two product brochures.

SUMMARY OF THE INVENTION

The present invention overcomes the problems outlined above, and provides improved extruder screw assemblies and complete extruders, which are characterized by the ability to generate high levels of SME without the need for specialized tooling or other add-on equipment. Generally speaking, the extruder screw assemblies of the invention are designed for placement within an elongated extruder barrel having an inlet and a spaced outlet. The screw assemblies are helically flighted along the lengths thereof, axially rotatable, and have a total length. When placed within an extruder barrel, the screw assemblies comprise:

a helically flighted inlet section having an axial length, a pitch length, and a screw diameter, with the inlet section extending from the barrel inlet toward the barrel outlet and presenting an inlet section terminus;

a helically flighted intermediate section having an axial length, a pitch length, and a screw diameter, with the intermediate section extending from the inlet section terminus toward the barrel outlet and presenting an intermediate section terminus; and
a helically flighted outlet section having an axial length, a pitch length, and a screw diameter, with the outlet section extending from the intermediate section terminus toward the barrel outlet.

Additionally, the screw assemblies are characterized by the intermediate sections thereof having a flight width greater than the flight widths of the inlet and outlet sections. Such wide-flight intermediate sections create areas of intense friction and heat generation during processing of comestible materials, thereby increasing the SME imparted to the materials. A number of other dimensional and geometric features can be designed into the screw assemblies, depending upon the desired products to be produced. For example, optional preferred features include intermediate sections with flight widths at least about 250% greater than the flight widths of the inlet and outlet sections; intermediate section flight widths which are from about 20-80% of the pitch length of the intermediate section; and/or intermediate section flight widths which are from about 15-50% of the screw diameters of the intermediate sections. Further, other such features relating to the relative axial lengths of the inlet, intermediate, and outlet screw sections, and the pitch lengths or flight depths of these sections can be incorporated into the overall extruder screw assemblies.

The invention also pertains to methods of operating the extruders of the invention, in the processing of comestible food or feed products having starting mixtures comprising respective quantities of starch, protein, and fat, for example.

While the extruder screw assemblies of the invention are particularly useful in the context of single screw extruders, the invention is not so limited. Rather, these same types of screw assemblies can be incorporated into twin screw extruders, if desired. Moreover, while the individual screw sections described herein are preferably flighted throughout the lengths thereof, this is not strictly necessary. Individual screw sections may have unflighted regions along the lengths thereof, but preferably the sections should have at least about 75% of the lengths bearing flighting, more preferably about 90% of such lengths.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a vertical sectional view illustrating a typical prior art single screw extruder for the production of pet feeds;

Fig. 2 is a vertical sectional view illustrating a typical prior art single screw extruder for the production of aquatic feeds;

Fig. 3 is a vertical sectional view illustrating an extruder in accordance with the present invention having an intermediate wide-flight screw section;

Fig. 4 is a view similar to that of Fig. 3, but illustrating another embodiment of the invention having a different intermediate wide-flight screw section;

Fig. 5 is a view similar to that of Fig. 3, but illustrating another embodiment of the invention having a different intermediate wide-flight screw section;

Fig. 6 is a perspective exploded view illustrating the construction of portions of the Fig. 3 screw assembly;

Fig. 7 is a view similar to that of Fig. 5, but including certain important dimensional relationships pertaining to the extruder screw assembly; and

Fig. 8 is a vertical sectional view of a wide-flight screw section in accordance with the invention, illustrating features of the screw and definitions of terms relating to screw geometries.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning first to Fig. 3, an extruder 10 in accordance with the invention is illustrated, broadly made up of a tubular barrel 12, an extruder screw assembly 14 within barrel 12, and a back pressure valve assembly 16 secured to the forward outlet end of the barrel 12. The extruder 10 is designed to process comestible materials, such as edible food or feed products.

In more detail, the barrel 12 includes a total of seven tubular heads 18-30 interconnected in an end-to-end fashion to define an elongated, continuous, substantially circular in cross-section interior 32. As illustrated, inlet head 18 is equipped with a material inlet 34, whereas terminal head 30 presents a processed product outlet 36. Each of the heads 20-30 is equipped with an inner flighted sleeve 20a-30a. The sleeves 20a-28a present substantially tubular passageways, whereas terminal sleeve 30a is tapered along the length thereof. Although not shown, if desired, some or all of the barrel heads may be equipped with external jackets permitting introduction of heat

exchange media, such as steam or water; moreover, these heads could also be provided with injectors for allowing direct introduction of steam into the interior 32 of the barrel 12.

The screw assembly 14 is designed to convey material from inlet 34 along the length of barrel 12 and out the outlet 36. Moreover, the screw assembly serves to subject the materials to increasing levels of temperature and shear as material passes through the barrel, in order to cook and form the material. To this end, the assembly 14 is axially rotatable and made up of a series of interconnected, helically flighted sections, namely an inlet section 38, three conventional conveying sections 40, 42, and 44, an intermediate wide-flight section 46, and a conical terminal or outlet section 48. Ring elements 50, 52, and 54 are respectively located between sections 40 and 42, 42 and 44, and 44 and 46.

Figure 6 illustrates certain components of the screw assembly 14, namely, ring element 52, screw section 44, ring element 54, and wide flight screw section 46. As illustrated, these components, as well as all of those making up the screw assembly 14, are internally splined as at 56, and are adapted to receive a complementally splined drive shaft 58, which extends along the entire length of the drive assembly 14. The drive shaft 58 is in turn connected to a motor/gear reducer assembly (not shown) so as to rotate the screw assembly 14 during operation of extruder 10.

The back pressure valve assembly 16 is of the type described in US Patent No. 6,773,739, which is incorporated by reference herein in its entirety. In particular, the assembly 16 includes three interconnected components, namely an inlet transition 60, a valve unit 62, and an outlet 64. The transition 60 is secured to the butt end of barrel 12 and is in communication with barrel outlet 36. The valve unit 62 has an upright tubular segment 66 with a lateral opening 68 in alignment with transition 60. An elongated valve member 70 is situated and vertically shiftable within the segment 66. The valve unit 62 includes a somewhat triangular-shaped, laterally extending through-opening 72, as well as a product diversion passageway or channel 74 including an inlet 76 and an outlet 78. The valve unit 62 is selectively movable within segment 66 by means of a piston and cylinder assembly 80.

The outlet 64 has an outwardly diverging passageway 82 in alignment with the opening 68, and is equipped with a restricted orifice die plate 84, as shown.

Figure 4 illustrates another extruder 86 in accordance with the invention having the same barrel 12, but a modified screw assembly 88. In this instance, the screw assembly 88 differs from screw assembly 14 in that the intermediate wide flight section of the assembly 88 is made up of two interconnected wide flight screw sections 90 and 92 located within heads 26 and 28, in lieu of the single wide flight section 46 of screw assembly 14. Stated otherwise, the conveying screw section 44 of screw assembly 14 has been replaced by the wide flight screw section 90 of assembly 88, whereas the wide flight screw section 92 is identical with the previously described section 46. It will also be observed that a conventional restricted orifice die plate 94 is directly secured to the outlet end of barrel 12, such that the extruder 86 does not include the back pressure valve assembly 16 of the Fig. 3 embodiment.

Figure 5 depicts a still further extruder 96 having the previously described barrel 12 and a further modified screw assembly 98. In this instance, the screw assembly 98 has the same wide flight sections 90 and 92 of the Fig. 4 embodiment, but these are placed differently than in Fig. 4. Specifically, the wide flight screw sections 90, 92 are located within the heads 24, 26, and a conveying screw section 100 is located within head 28.

It will be appreciated from the foregoing description that the screw assemblies 14, 88, and 98 differ primarily in the length and position of the intermediate wide flight screw section(s) therein. In order to better understand these relationships, Fig. 7 is provided, which is structurally identical with Fig. 4, but has applied thereto certain identifying information. Thus, the total length (TL) of the extruder 86 is depicted, along with an inlet section 102 having a terminus 102a, an intermediate section 104 having a terminus 104a, and an outlet section 106 having a terminus 106a. The length of the inlet screw section (Inlet-L) is also illustrated, together with the length of the intermediate wide flight screw section (INT.-L), and the outlet screw section (OUT.-L). These same length relationships can also be applied to the embodiments of Figs. 3 and 5. In Fig. 3, the Inlet-L is made up of screw sections 38-44, the INT.-L is made up of screw section 46, and the OUT.-L is made up of screw section 48. Similarly, in Fig. 4, the Inlet-L is made up of screw sections 38-40, the INT.-L is made up of screw sections 90, 92, and the OUT.-L is made up of screw section 48. Finally, the Inlet-L is made up of screw sections 38 and 40, the INT.-L is made up of wide flight screw sections 90 and 92, and OUT.-L is made up of screw sections 100 and 48.

In the ensuing discussion relating to the geometries of the screw sections making up the screw assemblies 14, 88, and 98, reference will be made to certain features of the individual screw sections, each of which include a central shaft S and outwardly extending, helical flighting F. In order to better understand this discussion, reference is made to Fig. 8, which illustrates a wide flight screw section 46. As shown therein, the screw diameter (SD) is the maximum width of the screw flighting F, whereas the root diameter (RD) is the diameter of the bottom of the shaft S. Therefore, the flight depth (FLT.DPH.) is the difference between the screw diameter (SD) and the root diameter (RD). Further as illustrated in Fig. 8, the pitch length (PL) of the screw section is the axial distance between convolutions of the flighting F, and the flight angle (FA) is the leading angle of the flighting against the direction of material flow through the screw assemblies. Finally, the flight width (FW) is the axial length of the flighting F at the outer extent thereof. While these relationships have been depicted in the context of wide flight section 48, it will be appreciated that these same relationships apply equally to all of the other helically flighted sections of the described screw assemblies.

Preferred Features of the Screw Assemblies 14, 88, 98

The screw assemblies 14, 88, and 98 are all characterized by helically flighted inlet, intermediate, and outlet sections 102-106 each having respective axial lengths (Inlet-Ls, INT.-Ls, and OUT.-Ls), pitch lengths (PLs), screw diameters (SDs), root diameters (RDs), flight widths (FWs), and flight depths (FLT.DPH.s). The inlet sections 102 extend from the barrel inlet 34 toward the barrel outlets 36 and define the termini 102a. The intermediate sections 104 extend from the termini 102a toward the barrel outlet 36 and define the intermediate section termini 104a. Finally, the outlet sections 106 extend from the intermediate section termini 104a toward the barrel outlet 36.

In all of the embodiments, the flight widths of the inlet sections 102 and the outlet sections 106 are less than the flight widths of the intermediate sections 104. However, in different embodiments, the respective sections 102-106 have certain characteristics, as set forth below.

Intermediate Sections 104

- The flight widths of the intermediate sections 104 are at least about 250% greater than the flight widths of the inlet sections 102 and the outlet sections 106, e.g., from about 250-

750% greater, more preferably from about 300-600% greater, and most preferably from about 325-525% greater.

- The flight widths of the intermediate sections 104 are from about 20-80%, more preferably from about 25-55%, of the pitch lengths of the corresponding intermediate sections 104.
- 5 • The flight widths of the intermediate sections 104 are from about 15-50%, more preferably from about 20-40%, of the screw diameters of the corresponding intermediate sections 104.
- The flight angles of the sections 102-106 are from about 20-50°, and more preferably from about 25-35°.
- The axial lengths of the intermediate sections 104 are from about 10-40%, more preferably
10 from about 12-35%, of the total lengths of the corresponding screw assemblies 14, 88, 98.
- The axial lengths of the intermediate sections 104 are less than the axial lengths of the inlet sections 102 of the corresponding screw assemblies 14, 88, 98, more preferably from about 15-80%, still more preferably from about 18-75%, of the axial lengths of the inlet sections 102 of the corresponding screw assemblies 14, 88, 98.
- 15 • The pitch lengths of the intermediate sections 104 are from about 30-70%, more preferably from about 40-60%, of the screw diameters of the corresponding intermediate sections 104.
- The pitch lengths of the intermediate sections 104 are less than the pitch lengths of the inlet sections of the corresponding screw assemblies 14, 88, 98.
- The flight depths of the intermediate sections 104 are from about 8-25%, more preferably
20 from about 12-20%, of the screw diameters of the corresponding intermediate sections 104.
- The flight depths of the intermediate sections 104 are less than the flight depths of the inlet sections 102 of the corresponding screw assemblies 14, 88, 98.
- The intermediate sections 104 have substantially constant flight depths, i.e., no more than about a 15% variance in such flight depths.
- 25 • The intermediate sections 104 have substantially constant pitch lengths, i.e., no more than about a 15% variance in such pitch lengths.
- The intermediate sections 104 have substantially constant screw diameters, i.e., no more than about a 15% variance in such screw diameters.
- The intermediate sections 104 have only a single flight.

Inlet Sections 102

- The inlet sections 102 have flight widths of from about 2-15%, more preferably from about 3-12%, of the corresponding pitch lengths of the inlet sections 102.
- 5 • The inlet sections 102 have flight widths from about 0.4-7%, more preferably from about 0.5-5%, of the axial lengths of the corresponding inlet sections 102.
- The inlet sections 102 have flight widths of from about 4-9%, more preferably from about 5-7% of the screw diameters of the corresponding inlet sections 102.
- The inlet sections 102 have substantially constant flight depths, i.e., no more than about a 15% variance in such flight depths.
- 10 • The inlet sections 102 have decreasing pitch lengths along the lengths thereof.
- The inlet sections 102 have substantially constant screw diameters, i.e., no more than about a 15% variance in such screw diameters.
- The inlet sections 102 have only a single flight.

Outlet Sections 106

- 15 • The outlet sections 106 have flight widths of from about 4-15%, more preferably from about 5-12%, of the corresponding pitch lengths of the outlet sections 106.
- The outlet sections 106 have flight widths from about 0.4-10%, more preferably from about 1-7.5%, of the axial lengths of the corresponding outlet sections 106.
- The outlet sections 106 have flight widths of from about 2-8%, more preferably from about 3-7% of the screw diameters of the corresponding outlet sections 106.
- 20 • The outlet sections 106 have substantially constant flight depths, i.e., no more than about a 15% variance in such flight depths.
- The outlet sections 106 have substantially constant or decreasing pitch lengths along the lengths thereof.
- 25 • The outlet sections 106 have portions thereof with decreasing screw diameters.
- The outlet sections 106 are double flighted when a conical terminal segment is employed, but otherwise have only a single flight.

It should be understood that not all of the above-described preferred features for the intermediate, inlet, and outlet sections need be present in every such section; rather, any given

intermediate, inlet, or outlet section may embody one or more of the respective preferred features. Additionally, while in some cases the screw assembly sections preferably have essentially constant screw diameters, root diameters, and flight depths, the invention is not so limited. In instances where the screw diameters, root diameters, and/or flight depths vary along the lengths of the sections, for purposes of the percentage ranges given above, the screw diameters, root diameters, or flight depths, as the case may be, should be determined as the arithmetic mean of the greatest and smallest values. For example, if a given section has a decreasing screw diameter, the maximum screw diameter is added to the minimum screw diameter, and this sum is divided by 2. This same analysis would follow for the root diameters and flight depths.

Operation

As noted previously, the extruders of the invention are designed for the production of comestible food or feed products, and are not suitable for processing of rubber and plastic materials. During operations where comestible products are prepared, starting dry mixtures, are formulated typically containing grain(s) (e.g., wheat, corn, oats, milo, soy), proteins, fats, vitamins, minerals, and the like. These mixtures are normally preconditioned by passage through known preconditioner apparatus, such as Wenger DDC or HIP preconditions, in order to moisturize and precook the mixtures. The preconditioned mixtures are then fed into the inlet of the extruder during rotation the screw assemblies therein, in order to move the materials along the length of the extruder barrels for ultimate extrusion. During such passage, the materials are subjected to increasing levels of temperature, pressure, and shear in order to fully cook the materials and allow formation thereof as self-sustaining bodies. The extruded products are then normally dried and may be coated with oil or other liquids to create the final products.

Where use is made of a backpressure valve assembly 16, the valve member 70 is normally placed in its upper position during startup of the extruder so that material from the barrel 12 will pass through the inlet 76 and out through passageway 74. As the extruder run progresses and acceptable extrudates are being produced, the valve member is shifted downwardly to the Fig. 3 position, where the through-opening 72 is in registry with the transition 60 and passageway 82. During processing, it may be necessary to adjust the backpressure exerted by the assembly 16, which involves up or down adjustment of the valve member 70 to change the effective area

presented by through-opening 82. Of course, all such movements of the valve member 70 are accomplished by actuation of piston and cylinder assembly 80.

In the context of the present invention, the materials are subjected to high levels of friction and shear in the intermediate wide-flight sections 104 of the extruders. Consequently, the products are formed with relatively high levels of SME, which enhances the physical and nutritional properties of the products. The presence of the sections 104 thus permits production of high-quality end products without the use of extraneous tools or equipment characteristic of prior art extruders of this type.

10 *Prior Art Screw Assemblies*

As indicated above, the present invention provides improved screw assemblies and extruders, which are capable of producing high-quality feeds, such as pet feeds and aquatic feeds, without the use of expedients such as mid-barrel valves, specialized mixing plates, and multiple die plate arrangements. In order to better understand the nature of the present invention as it relates to the prior art, attention is first directed to Fig. 1, which illustrates a typical single-screw extruder designed for the production of pet feeds. The extruder 108 is in many respects similar to that of extruder 10 of Fig. 3, having the same barrel 12, and a screw assembly 110 having the screw sections 38-44 and 48 of screw assembly 14. The extruder 108 has an intermediate screw section 112 having a conventional flight width, as compared with the screw section 46 of Fig. 3, as well as a restricted orifice die plate 114 without the use of backpressure valve assembly 16.

Similarly, Fig. 2 depicts a prior art extruder 116 having a barrel 12 and a screw assembly 118. The latter has the screw sections 38-42 of Fig. 3, and the screw sections 100, 48 of Fig. 5. However, the extruder 116 has an intermediate section 120 in the form of a short flighted element 122 followed by a series of mixing plates 124. Again, it is to be noted that the flight width of the element 122 is of conventional, narrow design.

Examples

The following examples set forth preferred extruder configurations and test results using these configurations. It is to be understood, however, that these examples are provided by way of

illustration only, and nothing therein should be taken as a limitation on the overall scope of the invention.

A series of comparative extruder runs for the preparation of salmon feed were carried out using two different extruder configurations, namely a standard extruder configuration as illustrated in Fig. 2 (Std.), and the wide-flight configuration illustrated in Fig. 4 (W-F). Each extruder was equipped with a back pressure valve, as illustrated in Fig. 3. In each instance, a Wenger HIP preconditioner was used to precondition the materials prior to passage into the extruders. The preconditioning was carried out identically in each run. In each test, the dry feed rate of material to the extruders was 3000 kg/hr. As the feed products exited the extruders, they were coated with oil prior to drying, and were then dried to a moisture content of about 8-9% by weight.

In each case, the salmon feed recipe was made up of 25.4% ground wheat, 30.5% soy concentrate (60%), 13.1% Menhaden fish meal, 13.2% corn gluten meal (60%), and 17.8% wheat gluten, where all percentages are by weight.

The following table sets forth the conditions used in the comparative tests, as well as the properties of the extrudates, where moisture % refers to the moisture of the products off of the extruder prior to any drying, and oil absorption is the retained oil absorption for the products after 18 hours soaking in water, followed by vacuum drying.

TABLE

Run No.	Setup	Screw Speed (rpm)	SME (kwhr/t)	Motor Load (%)	Wet Density (g/L)	Dry Density (g/L)	Cook (%)	Moisture (%)	Oil Absorption (%)
1	Std.	400	21	60	580	524	93.4	25.4	25.1
3	W-F	400	21	57	450	436	93.1	24.1	29.9
2	Std.	450	31	76	420	406	93.9	23.4	38.0
4	W-F	450	33	81	425	372	97.6	22.8	39.7

These test results confirm that the W-F extruder configuration gave the same or slightly higher cook levels, lower wet and dry bulk densities, and higher oil absorption values, as compared with the Std. configuration. The latter result is particularly important because salmon feeds produced using Std. configuration extruders tend to lose oil. The physical appearance of the feeds prepared using the W-F configuration were superior to those from the Std. configuration.

We Claim:

1. An extruder screw assembly designed for placement within an elongated extruder barrel having an inlet and a spaced outlet, said screw assembly being helically flighted, axially rotatable, having a total length, and, when placed within said barrel, comprising:
 - a helically flighted inlet section having an axial length, a pitch length, and a screw diameter, said inlet section extending from said barrel inlet toward said barrel outlet and presenting an inlet section terminus,
 - a helically flighted intermediate section having an axial length, a pitch length, and a screw diameter, said intermediate section extending from said inlet section terminus toward said barrel outlet and presenting an intermediate section terminus, and
 - a helically flighted outlet section having an axial length, a pitch length, and a screw diameter, said outlet section extending from said intermediate section terminus toward said barrel outlet,said intermediate section having a flight width which is from about 20-80% of the pitch length of the intermediate section,
the flight widths of said inlet section and said outlet section being less than the flight width of said intermediate section.
2. The screw assembly of claim 1, said intermediate section flight width being from about 25-55% of the pitch length of the intermediate section.
3. The screw assembly of claim 1, said intermediate section axial length being from about 10-40% of the total length of the screw assembly.
4. The screw assembly of claim 3, said intermediate section axial length being from about 12-35% of the total length of the screw assembly.
5. The screw assembly of claim 1, the flight width of said intermediate section being from about 15-50% of the screw diameter thereof.
6. The screw assembly of claim 5, the flight width of said intermediate section being from about 20-40% of the screw diameter thereof.
7. The screw assembly of claim 1, the axial length of said intermediate section being less than the axial length of said inlet section.
8. The screw assembly of claim 7, the axial length of said intermediate section being from about 15-80% of the axial length of said inlet section.

9. The screw assembly of claim 8, the axial length of said intermediate section being from about 18-75% of the axial length of said inlet section.

10. The screw assembly of claim 1, said inlet and outlet section flight widths each being from about 2-15% of the corresponding pitch length of the inlet and outlet sections, respectively.

11. The screw assembly of claim 10, said inlet and outlet section flight widths each being from about 3-12% of the corresponding pitch length of the inlet and outlet sections, respectively.

12. The screw assembly of claim 1, said inlet and outlet section flight widths each being from about 0.4-7% of the corresponding axial length of the inlet and outlet sections, respectively.

13. The screw assembly of claim 12, said inlet and outlet section flight widths each being from about 0.5-5% of the corresponding axial length of the inlet and outlet sections, respectively.

14. The screw assembly of claim 1, the flight width of said inlet and outlet sections each being from about 2-8% of the corresponding screw diameter of the inlet and outlet sections, respectively.

15. The screw assembly of claim 14, the flight width of said intermediate section being from about 3-7% of the corresponding screw diameter of the inlet and outlet sections, respectively.

16. The screw assembly of claim 1, the flight depth of said intermediate section being from about 8-25% of the screw diameter thereof.

17. The screw assembly of claim 16, the flight depth of said intermediate section being from about 12-20% of the screw diameter thereof.

18. The screw assembly of claim 1, said intermediate section having a substantially constant flight depth.

19. The screw assembly of claim 1, said intermediate section having a substantially constant pitch length.

20. The screw assembly of claim 1, said intermediate section having a substantially constant screw diameter.

21. The screw assembly of claim 1, said intermediate section having only a single flight.
22. The screw assembly of claim 1, said intermediate section having a pitch length of from about 30-70% of the screw diameter of the intermediate section.
23. The screw assembly of claim 1, said intermediate section having a pitch length of from about 40-60% of the screw diameter of the intermediate section.
24. The screw assembly of claim 1, the screw diameter of said outlet section being tapered along the length thereof.
25. The screw assembly of claim 1, the pitch length of said intermediate section being less than the pitch length of said inlet section.
26. The screw assembly of claim 1, the flight depth of said intermediate section being less than the flight depth of said inlet section.

27. An extruder screw assembly designed for placement within an elongated extruder barrel having an inlet and a spaced outlet, said screw assembly being helically flighted, axially rotatable, having a total length, and, when placed within said barrel, comprising:

an elongated, helically flighted, axially rotatable screw assembly having a total length and, when placed within said barrel, including --

a helically flighted inlet section having an axial length, a pitch length, and a screw diameter, said inlet section extending from said barrel inlet toward said barrel outlet and presenting an inlet section terminus,

a helically flighted intermediate section having an axial length, a pitch length, and a screw diameter, said intermediate section extending from said inlet section terminus toward said barrel outlet and presenting an intermediate section terminus, and

a helically flighted outlet section having an axial length, a pitch length, and a screw diameter, said outlet section extending from said intermediate section terminus toward said barrel outlet,

said intermediate section having a flight width which is from about 15-50% of the screw diameter thereof,

the flight widths of said inlet section and said outlet section being less than the flight width of said intermediate section.

28. The screw assembly of claim 27, the flight width of said intermediate section being from about 20-40% of the screw diameter thereof.

29. The screw assembly of claim 27, said intermediate section flight width being from about 25-55% of the pitch length of the intermediate section.

30. The screw assembly of claim 27, said intermediate section axial length being from about 10-40% of the total length of the screw assembly.

31. The screw assembly of claim 30, said intermediate section axial length being from about 12-35% of the total length of the screw assembly.

32. The screw assembly of claim 27, the axial length of said intermediate section being less than the axial length of said inlet section.

33. The screw assembly of claim 27, the axial length of said intermediate section being from about 15-80% of the axial length of said inlet section.

34. The screw assembly of claim 33, the axial length of said intermediate section being from about 18-75% of the axial length of said inlet section.

35. The screw assembly of claim 27, said inlet and outlet section flight widths each being from about 2-15% of the corresponding pitch length of the inlet and outlet sections, respectively.

36. The screw assembly of claim 34, said inlet and outlet section flight widths each being from about 3-12% of the corresponding pitch length of the inlet and outlet sections, respectively.

37. The screw assembly of claim 27, said inlet and outlet section flight widths each being from about 0.4-7% of the corresponding axial length of the inlet and outlet sections, respectively.

38. The screw assembly of claim 37, said inlet and outlet section flight widths each being from about 0.5-5% of the corresponding axial length of the inlet and outlet sections, respectively.

39. The screw assembly of claim 27, the flight width of said inlet and outlet sections each being from about 2-8% of the corresponding screw diameter of the inlet and outlet sections, respectively.

40. The screw assembly of claim 39, the flight width of said intermediate section being from about 3-7% of the corresponding screw diameter of the inlet and outlet sections, respectively.

41. The screw assembly of claim 27, the flight depth of said intermediate section being from about 8-25% of the screw diameter thereof.

42. The screw assembly of claim 41, the flight depth of said intermediate section being from about 12-20% of the screw diameter thereof.

43. The screw assembly of claim 27, said intermediate section having a substantially constant flight depth.

44. The screw assembly of claim 27, said intermediate section having a substantially constant pitch length.

45. The screw assembly of claim 27, said intermediate section having a substantially constant screw diameter.

46. The screw assembly of claim 27, said intermediate section having only a single flight.

47. The screw assembly of claim 27, said intermediate section having a pitch length of from about 30-70% of the screw diameter of the intermediate section.

48. The screw assembly of claim 47, said intermediate section having a pitch length of from about 40-60% of the screw diameter of the intermediate section.

49. The screw assembly of claim 27, the screw diameter of said outlet section being tapered along the length thereof.

50. The screw assembly of claim 27, the pitch length of said intermediate section being less than the pitch length of said inlet section.

51. The screw assembly of claim 27, the flight depth of said intermediate section being less than the flight depth of said inlet section.

52. An extruder, comprising:
an elongated barrel having an inlet and an outlet;
an elongated, helically flighted, axially rotatable screw assembly within said barrel having a total length, including --
a helically flighted inlet section having an axial length, a pitch length, and a screw diameter, said inlet section extending from said barrel inlet toward said barrel outlet and presenting an inlet section terminus,
a helically flighted intermediate section having an axial length, a pitch length, and a screw diameter, said intermediate section extending from said inlet section terminus toward said barrel outlet and presenting an intermediate section terminus, and
a helically flighted outlet section having an axial length, a pitch length, and a screw diameter, said outlet section extending from said intermediate section terminus toward said barrel outlet,
said intermediate section having a flight width which is from about 20-80% of the pitch length of the intermediate section,
the flight widths of said inlet section and said outlet section being less than the flight width of said intermediate section.
53. The extruder of claim 52, said intermediate section flight width being from about 25-55% of the pitch length of the intermediate section.
54. The extruder of claim 52, said intermediate section axial length being from about 10-40% of the total length of the screw assembly.
55. The extruder of claim 54, said intermediate section axial length being from about 12-35% of the total length of the screw assembly.
56. The extruder of claim 52, the flight width of said intermediate section being from about 15-50% of the screw diameter thereof.
57. The extruder of claim 56, the flight width of said intermediate section being from about 20-40% of the screw diameter thereof.
58. The extruder of claim 52, the axial length of said intermediate section being less than the axial length of said inlet section.

59. The extruder of claim 58, the axial length of said intermediate section being from about 15-80% of the axial length of said inlet section.

60. The extruder of claim 59, the axial length of said intermediate section being from about 18-75% of the axial length of said inlet section.

61. The extruder of claim 52, said inlet and outlet section flight widths each being from about 2-15% of the corresponding pitch length of the inlet and outlet sections, respectively.

62. The extruder of claim 61, said inlet and outlet section flight widths each being from about 3-12% of the corresponding pitch length of the inlet and outlet sections, respectively.

63. The extruder of claim 52, said inlet and outlet section flight widths each being from about 0.4-7% of the corresponding axial length of the inlet and outlet sections, respectively.

64. The extruder of claim 63, said inlet and outlet section flight widths each being from about 0.5-5% of the corresponding axial length of the inlet and outlet sections, respectively.

65. The extruder of claim 52, the flight width of said inlet and outlet sections each being from about 2-8% of the corresponding screw diameter of the inlet and outlet sections, respectively.

66. The extruder of claim 52, the flight width of said intermediate section being from about 3-7% of the corresponding screw diameter of the inlet and outlet sections, respectively.

67. The extruder of claim 52, the flight depth of said intermediate section being from about 8-25% of the screw diameter thereof.

68. The extruder of claim 67, the flight depth of said intermediate section being from about 12-20% of the screw diameter thereof.

69. The extruder of claim 52, said intermediate section having a substantially constant flight depth.

70. The extruder of claim 52, said intermediate section having a substantially constant pitch length.

71. The extruder of claim 52, said intermediate section having a substantially constant screw diameter.

72. The extruder of claim 52, said intermediate section having only a single flight.

73. The extruder of claim 52, including a restricted orifice die adjacent the outlet end of said barrel.

74. The extruder of claim 52, including a variable backpressure valve assembly adjacent the outlet end of said barrel, the valve assembly having a restricted orifice die outlet.

75. The extruder of claim 52, said intermediate section having a pitch length of from about 30-70% of the screw diameter of the intermediate section.

76. The extruder of claim 52, said intermediate section having a pitch length of from about 40-60% of the screw diameter of the intermediate section.

77. The extruder of claim 52, the screw diameter of said outlet section being tapered along the length thereof.

78. The extruder of claim 52, the pitch length of said intermediate section being less than the pitch length of said inlet section.

79. The extruder of claim 52, the flight depth of said intermediate section being less than the flight depth of said inlet section.

80. An extruder, comprising:
an elongated barrel having an inlet and an outlet;
an elongated, helically flighted, axially rotatable screw assembly within said barrel having a total length, including --
a helically flighted inlet section having an axial length, a pitch length, and a screw diameter, said inlet section extending from said barrel inlet toward said barrel outlet and presenting an inlet section terminus,
a helically flighted intermediate section having an axial length, a pitch length, and a screw diameter, said intermediate section extending from said inlet section terminus toward said barrel outlet and presenting an intermediate section terminus, and
a helically flighted outlet section having an axial length, a pitch length, and a screw diameter, said outlet section extending from said intermediate section terminus toward said barrel outlet,
said intermediate section having a flight width which is from about 15-50% of the screw diameter thereof,
the flight widths of said inlet section and said outlet section being less than the flight width of said intermediate section.
81. The extruder of claim 80, the flight width of said intermediate section being from about 20-40% of the screw diameter thereof.
82. The extruder of claim 80, said intermediate section flight width being from about 25-55% of the pitch length of the intermediate section.
83. The extruder of claim 80, said intermediate section axial length being from about 10-40% of the total length of the screw assembly.
84. The extruder of claim 83, said intermediate section axial length being from about 12-35% of the total length of the screw assembly.
85. The extruder of claim 80, the axial length of said intermediate section being less than the axial length of said inlet section.
86. The extruder of claim 85, the axial length of said intermediate section being from about 15-80% of the axial length of said inlet section.

87. The extruder of claim 86, the axial length of said intermediate section being from about 18-75% of the axial length of said inlet section.

88. The extruder of claim 80, said inlet and outlet section flight widths each being from about 2-15% of the corresponding pitch length of the inlet and outlet sections, respectively.

89. The extruder of claim 88, said inlet and outlet section flight widths each being from about 3-12% of the corresponding pitch length of the inlet and outlet sections, respectively.

90. The extruder of claim 80, said inlet and outlet section flight widths each being from about 0.4-7% of the corresponding axial length of the inlet and outlet sections, respectively.

91. The extruder of claim 90, said inlet and outlet section flight widths each being from about 0.5-5% of the corresponding axial length of the inlet and outlet sections, respectively.

92. The extruder of claim 80, the flight width of said inlet and outlet sections each being from about 2-8% of the corresponding screw diameter of the inlet and outlet sections, respectively.

93. The extruder of claim 92, the flight width of said intermediate section being from about 3-7% of the corresponding screw diameter of the inlet and outlet sections, respectively.

94. The extruder of claim 80, the flight depth of said intermediate section being from about 8-25% of the screw diameter thereof.

95. The extruder of claim 94, the flight depth of said intermediate section being from about 12-20% % of the screw diameter thereof.

96. The extruder of claim 80, said intermediate section having a substantially constant flight depth.

97. The extruder of claim 80, said intermediate section having a substantially constant pitch length.

98. The extruder of claim 80, said intermediate section having a substantially constant screw diameter.

99. The extruder of claim 80, said intermediate section having only a single flight.

100. The extruder of claim 80, including a restricted orifice die adjacent the outlet end of said barrel.

101. The extruder of claim 80, including a variable backpressure valve assembly adjacent the outlet end of said barrel, the valve assembly having a restricted orifice die outlet.

102. The extruder of claim 80, said intermediate section having a pitch length of from about 30-70% of the screw diameter of the intermediate section.

102. The extruder of claim 102, said intermediate section having a pitch length of from about 40-60% of the screw diameter of the intermediate section.

104. The extruder of claim 80, the screw diameter of said outlet section being tapered along the length thereof.

105. The extruder of claim 80, the pitch length of said intermediate section being less than the pitch length of said inlet section.

106. The extruder of claim 80, the flight depth of said intermediate section being less than the flight depth of said inlet section.

107. An extruder screw assembly designed for placement within an elongated extruder barrel having an inlet and a spaced outlet, said screw assembly being helically flighted, axially rotatable, having a total length, and, when placed within said barrel, comprising:

a helically flighted inlet section having an axial length, a pitch length, and a screw diameter, said inlet section extending from said barrel inlet toward said barrel outlet and presenting an inlet section terminus,

a helically flighted intermediate section having an axial length, a pitch length, and a screw diameter, said intermediate section extending from said inlet section terminus toward said barrel outlet and presenting an intermediate section terminus, and

a helically flighted outlet section having an axial length, a pitch length, and a screw diameter, said outlet section extending from said intermediate section terminus toward said barrel outlet,

the flight width of said intermediate section being at least about 250% greater than the flight widths of said inlet and outlet sections.

108. The screw assembly of claim 107, said flight width of said intermediate section being from about 250-750% greater than the flight widths of said inlet and outlet sections.

109. The screw assembly of claim 108, said flight width of said intermediate section being from about 300-600% greater than the flight widths of said inlet and outlet sections

110. The screw assembly of claim 107, said intermediate section flight width being from about 20-80% of the pitch length of the intermediate section.

111. The screw assembly of claim 107, said intermediate section axial length being from about 10-40% of the total length of the screw assembly.

112. The screw assembly of claim 111, said intermediate section axial length being from about 12-35% of the total length of the screw assembly.

113. The screw assembly of claim 107, the flight width of said intermediate section being from about 15-50% of the screw diameter thereof.

114. The screw assembly of claim 113, the flight width of said intermediate section being from about 20-40% of the screw diameter thereof.

115. The screw assembly of claim 107, the axial length of said intermediate section being less than the axial length of said inlet section.

116. The screw assembly of claim 115, the axial length of said intermediate section being from about 15-80% of the axial length of said inlet section.

117. The screw assembly of claim 116, the axial length of said intermediate section being from about 18-75% of the axial length of said inlet section.

118. The screw assembly of claim 107, said inlet and outlet section flight widths each being from about 2-15% of the corresponding pitch length of the inlet and outlet sections, respectively.

119. The screw assembly of claim 118, said inlet and outlet section flight widths each being from about 3-12% of the corresponding pitch length of the inlet and outlet sections, respectively.

120. The screw assembly of claim 107, said inlet and outlet section flight widths each being from about 0.4-7% of the corresponding axial length of the inlet and outlet sections, respectively.

121. The screw assembly of claim 120, said inlet and outlet section flight widths each being from about 0.5-5% of the corresponding axial length of the inlet and outlet sections, respectively.

122. The screw assembly of claim 107, the flight width of said inlet and outlet sections each being from about 4-9% of the corresponding screw diameter of the inlet and outlet sections, respectively.

123. The screw assembly of claim 122, the flight width of said intermediate section being from about 5-7% of the corresponding screw diameter of the inlet and outlet sections, respectively.

124. The screw assembly of claim 107, the flight depth of said intermediate section being from about 8-25% of the screw diameter thereof.

125. The screw assembly of claim 124, the flight depth of said intermediate section being from about 12-20% of the screw diameter thereof.

126. The screw assembly of claim 107, said intermediate section having a substantially constant flight depth.

127. The screw assembly of claim 107, said intermediate section having a substantially constant pitch length.

128. The screw assembly of claim 107, said intermediate section having a substantially constant screw diameter.

129. The screw assembly of claim 107, said intermediate section having only a single flight.

130. The screw assembly of claim 107, said intermediate section having a pitch length of from about 30-70% of the screw diameter of the intermediate section.

131. The screw assembly of claim 107, said intermediate section having a pitch length of from about 40-60% of the screw diameter of the intermediate section.

132. The screw assembly of claim 107, the screw diameter of said outlet section being tapered along the length thereof.

133. The screw assembly of claim 107, the pitch length of said intermediate section being less than the pitch length of said inlet section.

134. The screw assembly of claim 107, the flight depth of said intermediate section being less than the flight depth of said inlet section.

135. An extruder screw assembly designed for placement within an elongated extruder barrel having an inlet and a spaced outlet, said screw assembly being helically flighted, axially rotatable, having a total length, and, when placed within said barrel, comprising:

an elongated, helically flighted, axially rotatable screw assembly having a total length and, when placed within said barrel, including --

a helically flighted inlet section having an axial length, a pitch length, and a screw diameter, said inlet section extending from said barrel inlet toward said barrel outlet and presenting an inlet section terminus,

a helically flighted intermediate section having an axial length, a pitch length, and a screw diameter, said intermediate section extending from said inlet section terminus toward said barrel outlet and presenting an intermediate section terminus, and

a helically flighted outlet section having an axial length, a pitch length, and a screw diameter, said outlet section extending from said intermediate section terminus toward said barrel outlet,

the flight width of said intermediate section being at least about 250% greater than the flight widths of said inlet and outlet sections.

136. The screw assembly of claim 135, the flight width of said intermediate section being from about 20-40% of the screw diameter thereof.

137. The screw assembly of claim 135, said intermediate section flight width being from about 25-55% of the pitch length of the intermediate section.

138. The screw assembly of claim 135, said intermediate section axial length being from about 10-40% of the total length of the screw assembly.

139. The screw assembly of claim 138, said intermediate section axial length being from about 12-35% of the total length of the screw assembly.

140. The screw assembly of claim 135, the axial length of said intermediate section being less than the axial length of said inlet section.

141. The screw assembly of claim 135, the axial length of said intermediate section being from about 15-80% of the axial length of said inlet section.

142. The screw assembly of claim 141, the axial length of said intermediate section being from about 18-75% of the axial length of said inlet section.

143. The screw assembly of claim 135, said inlet and outlet section flight widths each being from about 2-15% of the corresponding pitch length of the inlet and outlet sections, respectively.

144. The screw assembly of claim 142 said inlet and outlet section flight widths each being from about 3-12% of the corresponding pitch length of the inlet and outlet sections, respectively.

145. The screw assembly of claim 135, said inlet and outlet section flight widths each being from about 0.4-7% of the corresponding axial length of the inlet and outlet sections, respectively.

146. The screw assembly of claim 145, said inlet and outlet section flight widths each being from about 0.5-5% of the corresponding axial length of the inlet and outlet sections, respectively.

147. The screw assembly of claim 135, the flight width of said inlet and outlet sections each being from about 4-9% of the corresponding screw diameter of the inlet and outlet sections, respectively.

148. The screw assembly of claim 147, the flight width of said intermediate section being from about 5-7% of the corresponding screw diameter of the inlet and outlet sections, respectively.

149. The screw assembly of claim 135, the flight depth of said intermediate section being from about 8-25% of the screw diameter thereof.

150. The screw assembly of claim 149, the flight depth of said intermediate section being from about 12-20% of the screw diameter thereof.

151. The screw assembly of claim 135, said intermediate section having a substantially constant flight depth.

152. The screw assembly of claim 135, said intermediate section having a substantially constant pitch length.

153. The screw assembly of claim 135, said intermediate section having a substantially constant screw diameter.

154. The screw assembly of claim 135, said intermediate section having only a single flight.

155. The screw assembly of claim 135, said intermediate section having a pitch length of from about 30-70% of the screw diameter of the intermediate section.

156. The screw assembly of claim 155, said intermediate section having a pitch length of from about 40-60% of the screw diameter of the intermediate section.

157. The screw assembly of claim 135, the screw diameter of said outlet section being tapered along the length thereof.

158. The screw assembly of claim 135, the pitch length of said intermediate section being less than the pitch length of said inlet section.

159. The screw assembly of claim 135, the flight depth of said intermediate section being less than the flight depth of said inlet section.

160. A method of processing comestible material comprising the step of passing said material through the extruder of claim 52 during rotation of said screw assembly.

161. The method of claim 160, including the step of injecting moisture into said material during passage thereof through said extruder.

162. The method of claim 160, said comestible material comprising respective quantities of starch and protein.

163. A method of processing comestible material comprising the step of passing said material through the extruder of claim 80 during rotation of said screw assembly.

164. The method of claim 163, including the step of injecting moisture into said material during passage thereof through said extruder.

165. The method of claim 163, said comestible material comprising respective quantities of starch and protein.

166. A method of processing comestible material comprising the step of passing said material through the extruder of claim 135 during rotation of said screw assembly.

167. The method of claim 166, including the step of injecting moisture into said material during passage thereof through said extruder.

168. The method of claim 166, said comestible material comprising respective quantities of starch and protein.

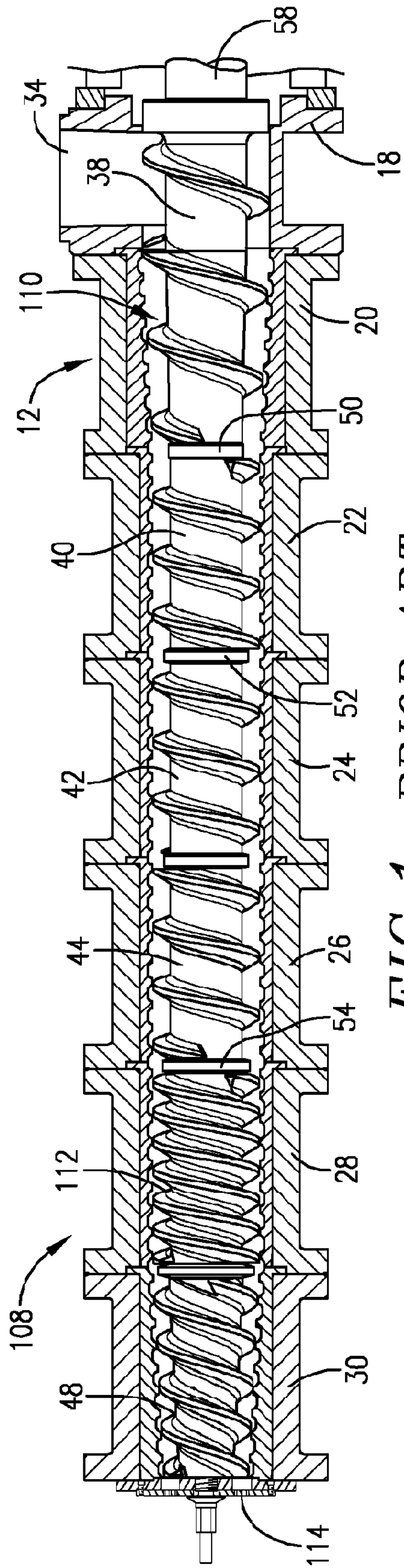


FIG. 1. PRIOR ART

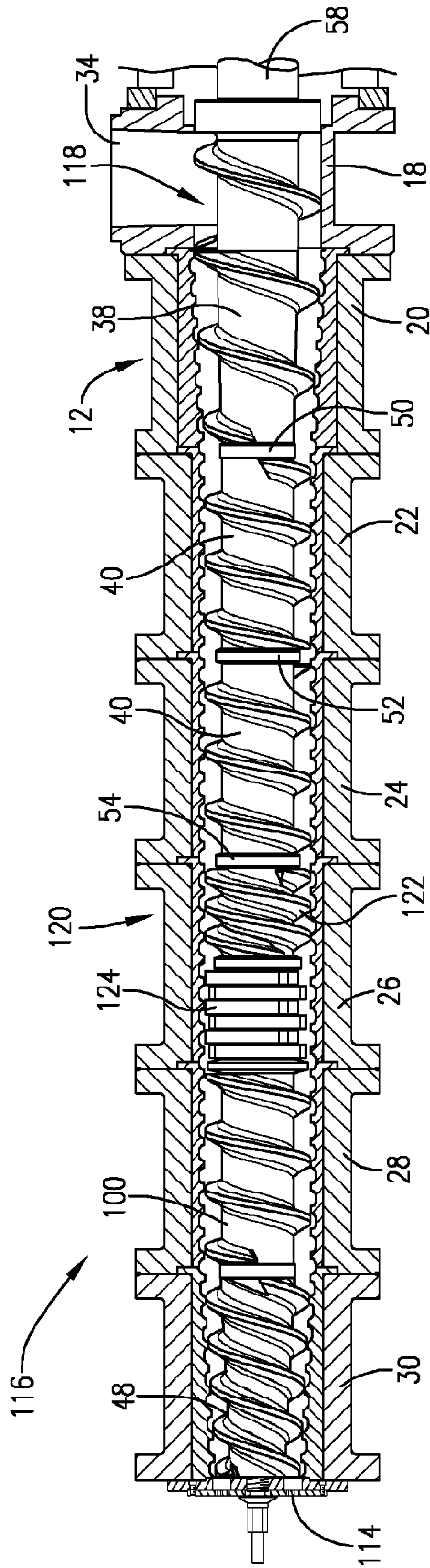


FIG. 2. PRIOR ART

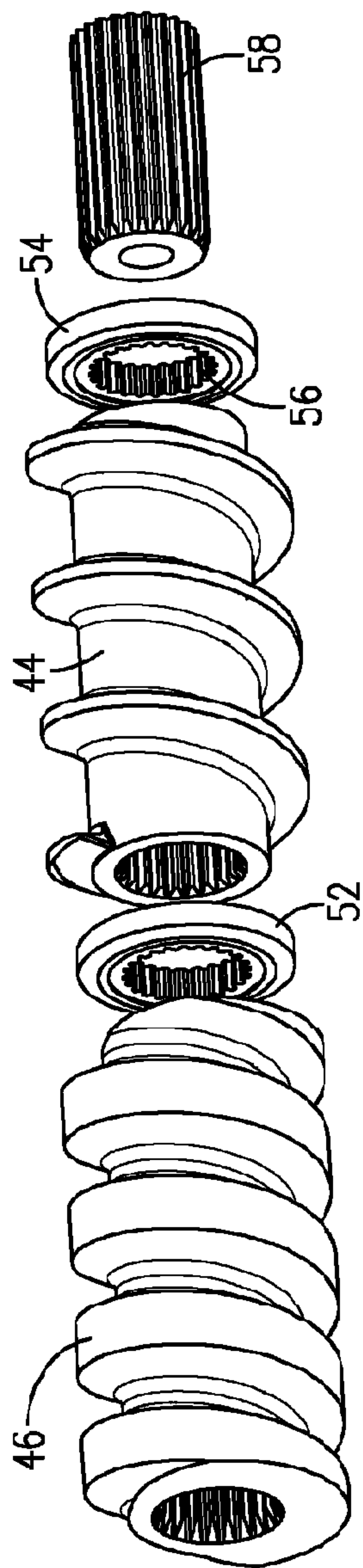


FIG. 6.

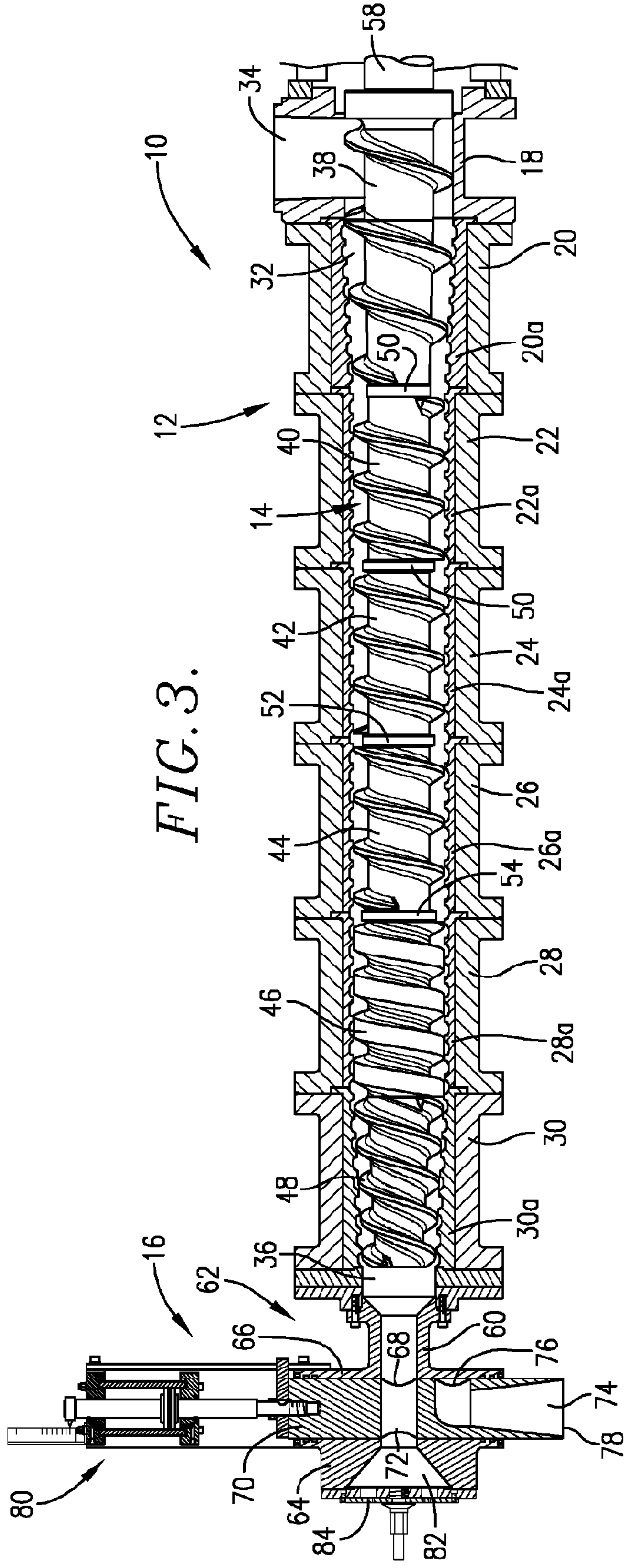


FIG. 3.

