Jan. 28, 1964 A. W. NELSON 3,119,149

HEAT-EXCHANGE JACKET ATTACHMENT TO EXTRUSION CYLINDER

Filed April 6, 1961 2 Sheets-Sheet 1

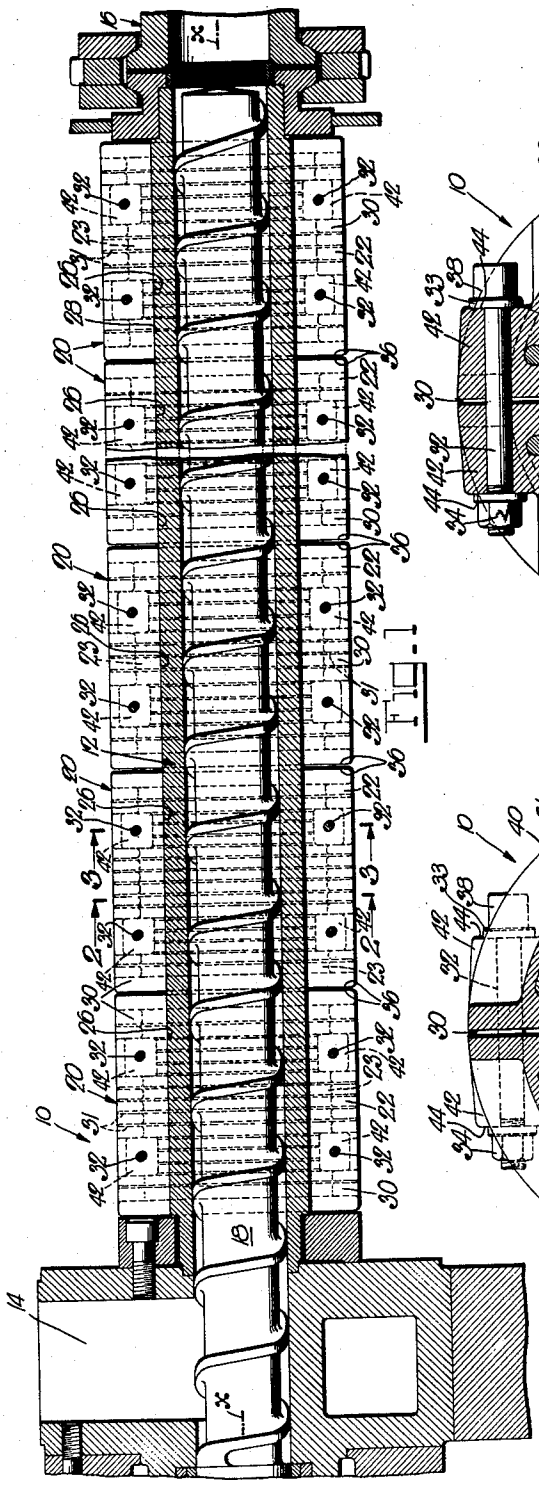


FIG. 1

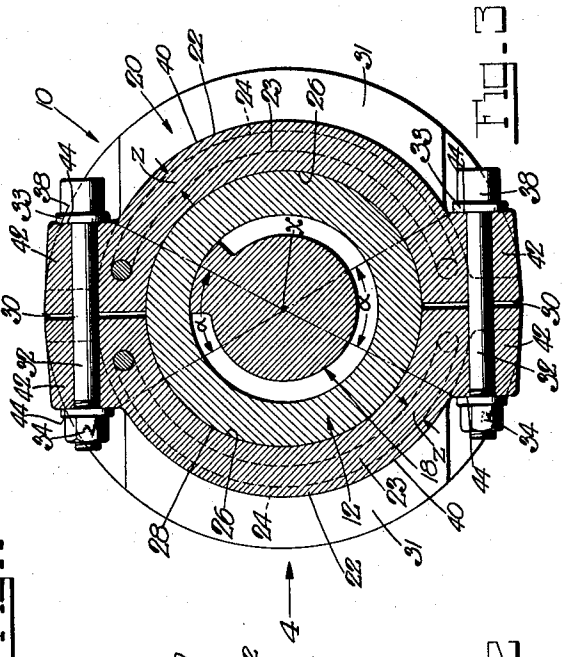


FIG. 3

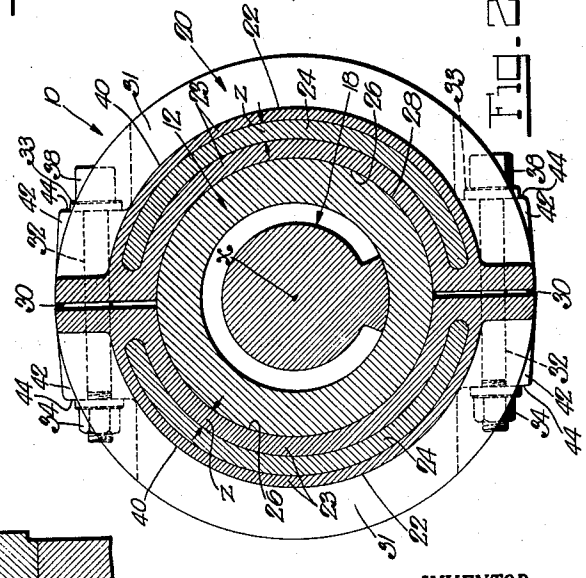


FIG. 2

INVENTOR.
Alden W. Nelson
BY
Attorney

Jan. 28, 1964 A. W. NELSON 3,119,149

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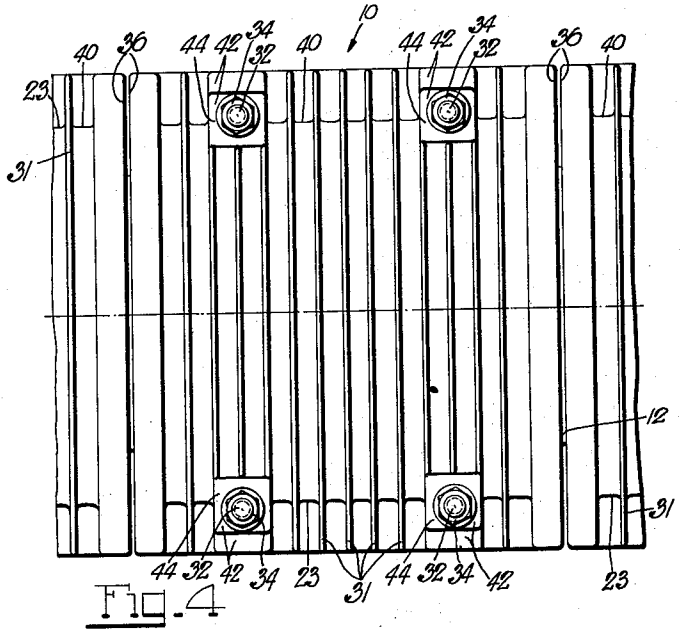



Fig. 4

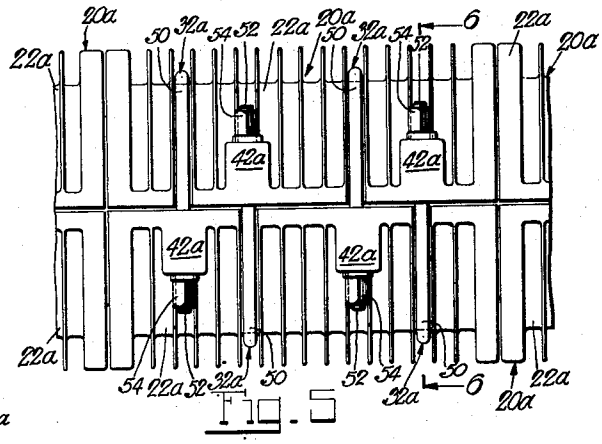



Fig. 5

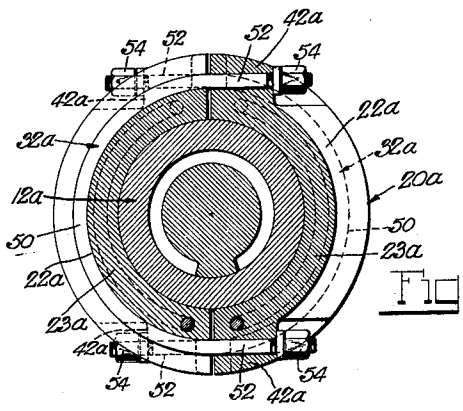



Fig. 6

INVENTOR.
Alden W. Nelson
BY
Attorney

United States Patent Office

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# 3,119,149
# HEAT-EXCHANGE JACKET ATTACHMENT TO EXTRUSION CYLINDER

Alden W. Nelson, West Mystic, Conn., assignor, by mesne assignments, to Crompton & Knowles Corporation, Worcester, Mass., a corporation of Massachusetts

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2 Claims. (Cl. 18—12)

This invention relates to extruders for plastics and the like, and more particularly to extruders with heated cylinders.

The present invention is concerned with extruders having solid cylinders of wear and stress resistant steel, and heat-exchange jackets of a type which are cast and clamped on the cylinders and provided with internal heating means and frequently also outer cooling fins. The jackets are customarily cast in complemental, usually semi-circular, sections from suitable metals of high heat conductivity, mostly aluminum, which are of low cost and may be cast, but unfortunately have coefficients of expansion which differ widely from that of the steel of the cylinders. Accordingly, while these prior jackets are highly desirable and advantageous due to their good heat-exchange properties, low cost and easy installation and maintenance, their efficiency drops rather sharply and they even strain the operating parts of extruders at more elevated cylinder temperatures due to their different thermal expansion from that of the cylinders. Thus, despite the usual efforts to clamp these jackets to the cylinders as firmly as possible, the jackets gape locally from the cylinders, increasingly toward the bottoms thereof in the case of horizontally extending cylinders, when heating them to the higher temperatures required for certain plastics, with the result that the cylinders are, over peripheral portions thereof, sufficiently hotter than over other peripheral portions thereof to respond to their different expansion thereat by actual bowing. While this difference in temperature peripherally of the cylinders under these conditions is highly objectionable because it may well lead to a non-uniform consistency of the extrudate therein, it is even further objectionable because the ensuing bowing of the cylinders will permit the operational end pressures, usually many tons, on the feed screws therein fully to exert themselves in bending the latter to the ultimate, and thus subjecting their lands to rapid wear, if not roughing, in the cylinders.

It is the primary aim and object of the present invention to provide for the steel cylinders of extruders sectional heat-exchange jackets of cast and clamp-on type and of the same good heat-conductive metal or metals as the prior jackets of this type, which have all the aforementioned advantages, but none of the disadvantages, of these prior jackets.

It is, therefore, an object of the present invention to provide for the steel cylinders of extruders sectional heat-exchange jackets of cast and clamp-on type which, despite their formation from aluminum or other metals of similar heat conductivity and coefficients of expansion, will at all, and even the highest, operational temperatures of the cylinders gape from the latter at the most so insignificantly that there occur neither temperature differentials in the cylinders which would lead to a non-uniform consistency of the extrudate therein, nor bowing of the cylinders which would lead to rapid wear or roughing of the feed screws therein.

It is another object of the present invention to provide for the steel cylinders of extruders sectional heat-exchange jackets of the aforementioned cast and clamp-on type the complemental sections of which are at their confronting parting surfaces slightly spaced from each other when mounted on the cylinders, and these jacket sections are



firmly mounted on the cylinders by bolt-type braces of steel or other metals of similar strength and low coefficients of expansion, which are applied to the jackets in such fashion that they resist normal thermal expansion of the complemental sections thereof peripherally away from the cylinders and, instead, force them to bend and unbend on their thermal expansion and contraction to whatever extent is necessary to retain them at all operational and also non-operational temperatures in sufficiently uniform form-fit and, hence, engagement with their cylinders to preclude any significant temperature differentials peripherally of the latter.

It is a further object of the present invention to provide for the steel cylinders of extruders sectional heat-exchange jackets of this type, of which the complemental sections are machined to form-fit the cold cylinders so as to be in optimum heat-exchange relation with the latter at the very start of the heat-up cycle of an operation, and the aforementioned bolt-type steel braces are of high tensile strength and are in the assembly of the jacket sections with the cold cylinders expanded and left expanded within their elastic limit by tightening them accordingly, so that they act as springs which exert on the jacket sections even at their full operational temperatures exceedingly large clamp-on forces that contribute greatly to the aforementioned retention of the jacket sections in substantially uniform form-fit and, hence, engagement with their cylinders at all temperatures of the latter.

Another object of the present invention is to provide for the steel cylinders of extruders sectional heat-exchange jackets of this type of which the aforementioned bolt-type steel braces are arranged so that they not only resist most directly and with optimum force thermal expansion of the jacket sections peripherally away from their cylinders over the very peripheral portions thereof which would thermally expand the most away from the cylinders if unrestrained, but also exert optimum force on these same peripheral portions of the jacket sections to bend and unbend them on their thermal expansion and contraction for their substantially uniform form-fit and, hence, engagement with their cylinders at all temperatures of the latter. This is achieved by anchoring the bolt-type braces with their ends directly to the complemental jacket sections, and forming the braces with straight shanks which connect the complemental jacket sections across their confronting parting surfaces and are of maximum lengths at which the larger masses of the complemental jacket sections, including the heating means therein, at and near their confronting parting surfaces are confined between the braces and cylinders.

Other objects and advantages will appear to those skilled in the art from the following, considered in conjunction with the accompanying drawings.

In the accompanying drawings, in which certain modes of carrying out the present invention are shown for illustrative purposes:

FIG. 1 is a fragmentary longitudinal section through an extruder embodying the present invention;

FIGS. 2 and 3 are enlarged cross-sections through the extruder as taken on the lines 2—2 and 3—3, respectively, of FIG. 1;

FIG. 4 is a fragmentary side elevation of the extruder as viewed in the direction of the arrow 4 in FIG. 3;

FIG. 5 is a fragmentary top view of an extruder embodying the present invention in a modified manner; and

FIG. 6 is a cross-section through the modified extruder as taken on the line 6—6 of FIG. 5.

Referring to the drawings, and more particularly to FIGS. 1 to 4 thereof, the reference numeral 10 designates on extruder which comprises a cylinder 12 with a longitudinal axis $x$ having a throat 14 at one end through

which to introduce plastic material in a solid state as well as a delivery head **16** at the other end from which to discharge the plasticized material through a die aperture (not shown), and a power-driven feed screw **18** for forcing the plastic through the cylinder **12** and delivery head **16**. The cylinder **12** is provided with external heat-exchange jackets **20** which in the present instance extend substantially throughout the length of the cylinder. These jackets **20** are adapted to heat the cylinder so that the heat from the latter, and the heat generated in the plastic material by virtue of being worked by the driven screw **18**, combine to plasticize the material. Each jacket **20** comprises several, in this instance two, complemental sections **22** which are cast from a metal of good heat conductivity, with each section having a substantially semi-circular wall **23** with internal heating means which in the present instance are cast-in Calrods **24** with external terminals (not shown) for connection with a current source. The jacket sections **22** have their inner surfaces **26** machined for preferred form-fit on the outer periphery **28** of the cylinder **12**, and the mounted sections of each jacket surround the cylinder periphery except at the narrowly spaced confronting parting surfaces **30** of their walls **23**. The Calrods **24** are confined in inner, preferably part-circular, zones *z* of the walls **23** of the jacket sections **22** (FIGS. 2 and 3) and extend in usual serpentine fashion therein for substantially uniform heating of the walls of the jacket sections throughout. The jacket sections are in this instance also provided with external cooling ribs **31** which are cast integrally with the walls **23** and may be subjected to air blasts for close regulations of the heat in the cylinder under various operating conditions of the extruder. The cooling ribs **31** on the walls **23** of the complemental jacket sections **22** are preferably of the same cross-sectional dimensions throughout and equally spaced from each other. For their mount on the cylinder **12** the complemental sections **22** of each jacket are releasably clamped on the cylinder periphery **28** by rod-type braces which in this instance are bolts **32** with nuts **34**.

The cylinder **12** is customarily of wear and stress resistant steel, and the jacket sections **22** are usually of aluminum by virtue of its good heat conductivity, relatively low cost and ready casting, though these jacket sections may be cast from any other metal or metals suitable for the purpose. In any event, the metal of the jacket sections **22**, being other than steel which has grossly inadequate heat conductivity for the required heat exchange, has a coefficient of expansion which is greater than that of the steel of the cylinder, and which is twice that of the steel of the cylinder if the jacket sections are cast from aluminum as the much preferred metal. Accordingly, the cylinder **12** and the jacket sections **22** will have different thermal expansion in all directions. In order to permit differential thermal expansion of the jacket sections **22** and cylinder **12** in the direction of the cylinder axis in natural fashion, the complemental sections of each jacket **20** are merely clamped on the cylinder periphery **28** as aforementioned, and successive jackets are at their adjacent ends **36** slightly spaced from each other (FIGS. 1 and 4). However, while differential expansion of the jackets **20** and of the cylinder **12** axially of the latter is thus rendered harmless, the remaining differential expansion of these parts, principally peripherally thereof, tends to gape the complemental jacket sections **22** with their inner wall surfaces **26** away from the cylinder periphery **28** with ensuing non-uniform heating of the cylinder peripherally thereof. Thus, while peripheral thermal expansion of the cylinder **12** will result in a slightly increased radius of its periphery **28**, concurrent peripheral thermal expansion of the complemental jacket sections **22**, unless restrained from pursuing its natural course, will result in a larger increase of the radius of their inner wall surfaces **26** than that of the radius of the cylinder periphery and ensuing separation of these



inner wall surfaces from form-fit with the cylinder periphery.

In accordance with the present invention, the rod-type braces **32**, **34** are arranged to restrain the peripheral thermal expansion of the complemental jacket sections **22** from pursuing its natural course and, instead, direct it into a different course on which the inner wall surfaces **26** remain in substantial form fit with the cylinder periphery **28** at all operational and non-operational cylinder temperatures. To this end, the present exemplary straight bolts **32** are anchored with their ends to the respective jacket sections **22** and extend across the narrowly spaced confronting parting surfaces **30** thereof and linearly therebeyond in both directions for considerable distances to their anchored ends, with the bolts having high tensile strength and a lower coefficient of expansion than the metal of the jacket sections and being under permanent longitudinal tension of such large magnitude as to clamp these jacket sections to the cylinder periphery in substantially uniform form-fit therewith at all operational and non-operational cylinder temperatures. For secure anchorage of the bolts **32** to the complemental jacket sections **22**, the latter are provided over peripheral end lengths of their walls **23** with outer integral lug formations **42** which are arranged in aligned pairs spaced axially of the cylinder (FIGS. 1 and 4) and receiving the bolts **32** with the heads **38** of the latter and the nuts **34** resting, advantageously through intermediation of large washers **33**, against the opposite surfaces **44** of the respective aligned lug formations **42**. As to the lengths of the bolts **32** between their anchored ends, i.e., between their heads **38** and their nuts **34** (FIG. 3), they are preferably of maximum lengths at which they are at their nearest approach to the cylinder axis *x* spaced somewhat farther from the latter than the heater zones *z* in these jacket sections on the one hand, and they span near optimum peripheral lengths of the jacket sections (angles $\alpha$ in FIG. 3) at which the washers **33** are spaced outwardly, but not very appreciably, from the adjacent outer wall surfaces **40** of these jacket sections on the other hand. Hence, taking into consideration the usual proportionate cross-sectional dimensions of cylinders and the walls of cast complemental heat-exchange jacket sections thereon within fairly well established limits, the bolts **32** and washers **33** will have the aforementioned preferential spacing from the cylinder axis *x* and from the outer wall surfaces **40** of the jacket sections **22**, respectively, as long as the bolts extend from either of the confronting parting surfaces **30** of the latter which they cross to their nearest anchored ends for a distance at least in excess of half the radius of the cylinder periphery **28**.

In thus arranging the bolts **32** and tightening their nuts **34**, they resist most directly and with optimum force normal peripheral thermal expansion of the walls **23** of the complemental jacket sections **22** over optimum peripheral lengths thereof which, if unrestrained, would respond to thermal expansion by separating farthest from the cylinder periphery, namely, the peripheral wall lengths spanned by the bolts **32**. In accordance with the present invention, the bolts **32** and nuts **34**, which are preferably of steel and have a coefficient of expansion smaller than that of the metal of the cast jacket sections **22**, are of sufficiently large cross-sectional dimensions and high tensile strength safely to withstand tightening of the nuts to an extent where the tension in the bolts is of such large magnitude as to compel the peripheral lengths of the jacket sections spanned by them, and with it the remaining peripheral lengths thereof, thermally to expand along and in substantially uniform engagement with the cylinder periphery, compelling the adjacent parting surfaces **30** of the jacket sections to creep toward each other and reduce the gap between them. In fact, the nuts **34** are tightened at such exceedingly high torque that the bolts **32** are at non-operational cylinder temperatures expanded within their elastic limit at least to an extent

to remain at the highest operational cylinder temperatures under sufficient tension to prevent any significant separation of the jacket sections from the cylinder periphery. The bolts **32** thus act as powerful springs which, while not counteracting peripheral thermal expansion as such of the complemental jacket sections **22**, force them to respond to their thermal expansion and contraction by bending and unbending to whatever extent is necessary to retain them at all operational and also non-operational cylinder temperatures in sufficiently uniform form-fit and, hence, engagement with the cylinder **12** to preclude any significant temperature differential peripherally of the latter. Also, the bolts **32** are over the axial extent of the complemental jacket sections **22** spaced sufficiently closely to each other to retain the latter throughout their axial lengths in substantially uniform form-fit with the cylinder periphery **28** at all operational and non-operational cylinder temperatures. Of course, the form-fit on the periphery **28** of the cold cylinder **12** of the complemental jacket sections **22** by virtue of the described machining of their inner wall surfaces **26** to this end, contributes significantly to the attainment of a substantially uniform form-fit of these jacket sections on the cylinder periphery at all cylinder temperatures, so that the jacket sections are in optimum heat-exchange relation with the cylinder uniformly throughout its periphery for heat-up in minimum time as well as during normal operation.

Of course, the dimensions of the bolts **32** and nuts **34** and their axial spacing along complemental jacket sections may vary considerably in a given extruder installation, and it would be impossible to establish any limits in these respects. Also, the bolts and nuts may be of any metal of high tensile strength, with high-grade steel being the preferred metal. Finally, the magnitude of the torque applied to the nuts for tightening them to the extent of actually expanding the bolts within their elastic limit to the described end has never been calculated, nor is it necessary to calculate such torque for a given extruder installation since it is so much easier and reliable to tighten the nuts on the bolts initially to the point where experience can pretty well foretell accomplishment of the desired end, with a check thereof being readily made on a test run of the extruder installation. Also, while the rod-type braces are in the present example bolts with nuts which are tightened on the bolts for the necessary operational tension in the latter, these rod-type braces may take other forms, such as bolts headed at both ends and introduced in a highly heated state laterally into forklike lugs on the jacket sections for shrinkage therein to the point where they will have expanded within their elastic limit to the desired extent after cooling off.

To demonstrate the remarkable and certainly unexpected high uniformity of the form-fit of the present clamped-on complemental jacket sections on the cylinder periphery at all cylinder temperatures, including the highest operational temperatures, there is given, by way of example only and by no means by way of limitation, the following data on test runs of two extruders which were alike in all respects, except that the "modified" extruder had the jacket sections mounted on the cylinder in accordance with the present invention while the "unmodified" extruder had the jacket sections mounted on the cylinder in conventional fashion. Each cylinder was of the same grade steel, and had a length of 120" and inside and outside diameters of 6" and 9.5", respectively. Both cylinders were disposed horizontally and the complemental jacket sections had their confronting parting surfaces along the tops and bottoms of the cylinders. Clamped on each cylinder were 8 heat-exchange jackets, with each jacket having two complemental cast aluminum sections of 13¾" length of which the inner and outer radii of their substantially semi-circular walls were 4¾" and 6⅛", respectively, with both of these walls form-fitting the cylinder periphery and being at their confronting parting surfaces spaced apart ¼". The mounted jackets were equally spaced apart axially of the cylinder, and all jacket sections had the same uniform external cooling fin arrangements on their walls. Each pair of complemental jacket sections had 6 clamp-on bolts of the same grade of steel and of ¾" size, with 3 bolts extending across each of the two pairs of confronting parting surfaces of these jacket sections and being spaced apart 4¼" axially of the cylinder. The bolts on the unmodified and modified installations were 2½" and 8" in length, respectively, and were spaced from the cylinder axis 7⅛" and 6¼", respectively.

On heating up both cylinders, serious thermal deflection of the cylinder of the unmodified installation was noted at approximately 500° F., while no thermal deflection of the cylinder of the modified installation was noted at the same temperature. Thus, a dial indicator placed on top of the unmodified jacketed cylinder midway of its length showed an upward deflection thereat of about ¼" at approximately 500° F., which clearly indicated more heat along the top than along the bottom of the cylinder as caused by the jacket sections gaping away from the cylinder along the bottom thereof while remaining in gravitational contact with the cylinder along the top thereof. Thermal deflection of the cylinder to this large extent also indicated early roughing of the feed screw therein under operational endthrust thereon.

Next, only one unmodified jacket and one modified jacket were mounted on the respective cylinders midway of their lengths so as to observe the heating effects of these single jackets on the cylinders. The results were most revealing. Thus, the unmodified jacket required 136 minutes to heat its cylinder to 500° F. while the modified jacket required only 76 minutes to heat its cylinder to the same temperature. Gaps between each jacket and its cylinder were also probed with feeler gauges at 500° F. cylinder temperatures. Thus, considering the tops and bottoms of the cylinders to be the 12 o'clock and 6 o'clock points, respectively, of a time dial, the clearance between the unmodified jacket and its cylinder was found to be a maximum of .015" at 11:30 and 12:30 o'clock and a maximum of .034" at 5:30 and 6:30 o'clock, while the clearance between the modified jacket and its cylinder was found to be a maximum of .008" at 11:30 and 12:30 o'clock and a maximum of .009" at 5:30 and 6:30 o'clock. The clearances just given were measured as the cylinders reached 500° F. on their heat up. As the heat of the cylinders was ironed out at 500° F., the clearance between the unmodified jacket and its cylinder decreased to .012" at the top and to .025" at the bottom, while the clearance between the modified jacket and its cylinder decreased to .006" at top and bottom. The temperature differential at the top and bottom of the cylinder with the unmodified jacket near the ends of the latter was found to be a maximum of 35° F. which decreased to 20° F. after the cylinder reached 500° F., while the temperature differential at the top and bottom of the cylinder with the modified jacket near the ends of the latter was found to be a maximum of 5° F. which decreased to 0 after the cylinder reached 500° F.

It follows from the preceding that, as to both, heating and cooling these cylinders, the rate of heat-transfer between the unmodified jacket and its cylinder and between the modified jacket and its cylinder is in the ratio of 76 minutes to 136 minutes or 1 to 1.8, meaning that the heating and cooling capacity of the modified jacket is approximately 80% greater than that of the unmodified jacket.

Reference is now had to FIGS. 5 and 6 which show different braces **32***a* for clamping the complemental sections **22***a* of heat-exchange jackets **20***a* on a cylinder **12***a*. The present braces **32***a* are of strap-type, having semicircular intermediate lengths **50** and straight end-lengths **52**, of which the intermediate length **50** of each

brace embraces the semicircular wall 23*a* of a jacket section 22*a* and extends with its endlengths 52 through lug formations 42*a* on the opposite jacket section to receive therebeyond nuts 54. The jackets 20*a* of the exemplary length shown in FIG. 5 are clamped on the cylinder 12*a* by four of these strap-type braces 32*a* of which two embrace the part-circular wall of one jacket section and the other two embrace the part-circular wall of the other jacket section. The arrangement of the straight end lengths 52 of these strap-type braces 32*a* in relation to the jacket sections 22*a* is similar to the described arrangement of the straight bolt-type braces 32 in relation to the jacket sections 22 (FIG. 3), and the nuts 54 are similarly tightened to such an extent that the braces will be longitudinally expanded within their elastic limit so as to retain the complemental jacket sections 22*a* in substantially uniform form-fit with the outer periphery of the cylinder 12*a* at all operational and also non-operational cylinder temperatures.

The invention may be carried out in other specific ways than those herein set forth without departing from the spirit and essential characteristics of the invention, and the present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive, and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

What is claimed is:

1. In an extruder, the combination with a steel cylinder having an axis and an outer periphery concentric with said axis, of heat-exchange jackets on said cylinder substantially throughout its length, each jacket having two cast complemental sections of a metal of better heat conductivity and of a larger coefficient of expansion than the steel of the cylinder, with each section having a substantially semi-circular wall with an inner surface and heating means within an internal zone of said wall over the greater part of its semi-circular extent, and said complemental sections fitting with the inner surfaces of their walls said cylinder periphery and having narrowly spaced



confronting parting surfaces; and straight rod-type metal braces each anchored with its opposite ends to the complemental sections, respectively, of a jacket and extending across said confronting parting surfaces of their walls at a greater distance thereat from the cylinder axis than said inner zones of said sections, and further extending beyond each of said parting surfaces for a distance of over half the radius of said cylinder periphery, said metal braces solely securing said complemental jacket sections to the cylinder and having a smaller coefficient of expansion than the metal of said jacket sections, and said metal braces being longitudinally expanded within their elastic limit when the cylinder is non-heated, whereby said section walls are forced to bend in peripheral expansion into substantially uniform form-fit with said cylinder periphery at all operational cylinder temperatures.

2. The combination in an extruder as set forth in claim 1, in which the wall of each jacket section is formed with integral outer cooling fins substantially over its semi-circular extent.

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