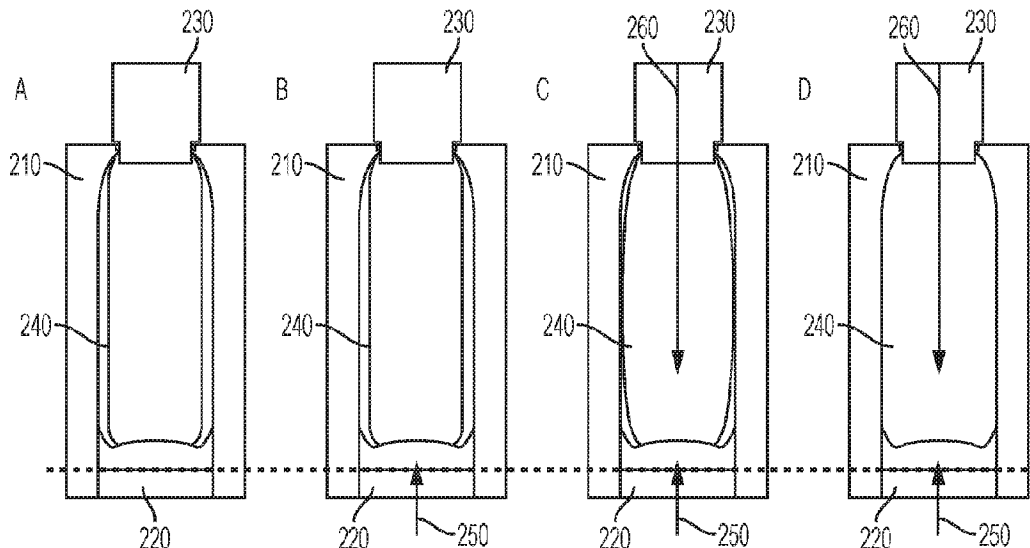




(86) Date de dépôt PCT/PCT Filing Date: 2016/05/26  
(87) Date publication PCT/PCT Publication Date: 2016/12/01  
(45) Date de délivrance/Issue Date: 2020/07/28  
(85) Entrée phase nationale/National Entry: 2017/11/03  
(86) N° demande PCT/PCT Application No.: US 2016/034214  
(87) N° publication PCT/PCT Publication No.: 2016/191513  
(30) Priorité/Priority: 2015/05/26 (US62/166,212)

(51) Cl.Int./Int.Cl. *B21D 26/053* (2011.01),  
*B21D 26/049* (2011.01)  
(72) Inventeurs/Inventors:  
CUTTER, CHRISTOPHER, US;  
LEHMAN, ROBERT, US;  
MALLORY, ROBERT WILLIAM, US;  
GO, JOHNSON, US  
(73) Propriétaire/Owner:  
NOVELIS INC., US  
(74) Agent: TORYS LLP

(54) Titre : PROCEDE DE FORMAGE PAR SOUFFLAGE A GRANDE VITESSE POUR METTRE EN FORME DES  
RECIPIENTS EN ALUMINIUM EN UTILISANT DES ALLIAGES 3XXX AVEC UNE TENEUR ELEVEE EN PRODUIT  
RECYCLE  
(54) Title: HIGH-SPEED BLOW FORMING PROCESS TO SHAPE ALUMINUM CONTAINERS USING 3XXX ALLOYS  
WITH HIGH RECYCLED CONTENT



(57) **Abrégé/Abstract:**

Provided herein is a high-speed blow forming process for shaping aluminum containers using 3xxx can body stock alloys with high recycled content, as well as articles made by that process. A process for shaping aluminum containers as described herein includes the sequential steps of blanking out a disk from a sheet of a 3xxx series aluminum alloy; forming a bottle preform by drawing, redrawing, ironing, and doming the disk; placing the preform into a mold cavity; applying an axial load to the preform; and injecting an inert gas into the interior of the preform with sufficient pressure until the preform expands to fill the mold cavity.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property  
Organization  
International Bureau



(10) International Publication Number  
**WO 2016/191513 A1**

(43) International Publication Date  
1 December 2016 (01.12.2016)

- (51) International Patent Classification:  
*B21D 26/049* (2011.01) *B21D 26/053* (2011.01)
- (21) International Application Number:  
PCT/US2016/034214
- (22) International Filing Date:  
26 May 2016 (26.05.2016)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
62/166,212 26 May 2015 (26.05.2015) US
- (71) Applicant: NOVELIS INC. [CA/US]; 3560 Lenox Road, Suite 2000, Atlanta, GA 30326 (US).
- (72) Inventors: CUTTER, Christopher; 1950 Roswell Road, Apt. 3B5, Marietta, GA 30068 (US). LEHMAN, Robert; 2744 Stillwater Lake Lane, Marietta, GA 30066 (US). MALLORY, Robert, William; 26 Laurel Branch Court, Dallas, GA 30132 (US). GO, Johnson; 898 Muirfield Trail, Marietta, GA 30068 (US).
- (74) Agents: BLACKBURN, Jennifer, L. et al.; Kilpatrick Townsend & Stockton LLP, 1100 Peachtree Street, Suite 2800, Atlanta, GA 30309 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

#### Declarations under Rule 4.17:

— of inventorship (Rule 4.17(iv))

#### Published:

— with international search report (Art. 21(3))

(54) Title: HIGH SPEED BLOW FORMING PROCESS TO SHAPE ALUMINUM CONTAINERS USING 3XXX ALLOYS WITH HIGH RECYCLE CONTENT

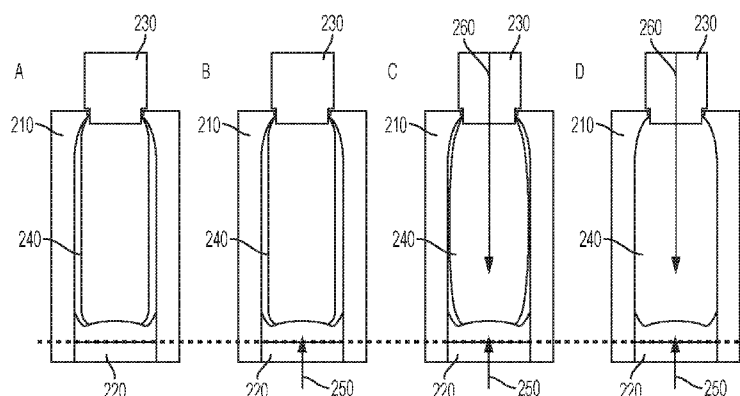


FIG. 2

(57) Abstract: Provided herein is a high-speed blow forming process for shaping aluminum containers using 3xxx can body stock alloys with high recycled content, as well as articles made by that process. A process for shaping aluminum containers as described herein includes the sequential steps of blanking out a disk from a sheet of a 3xxx series aluminum alloy; forming a bottle preform by drawing, redrawing, ironing, and doming the disk; placing the preform into a mold cavity; applying an axial load to the preform; and injecting an inert gas into the interior of the preform with sufficient pressure until the preform expands to fill the mold cavity.

**CROSS-REFERENCE TO RELATED APPLICATION**

FIELD

10 BACKGROUND

Methods of pressure forming metal containers from preforms are known in the art as described, for example, in U.S. Patent No. 8,683,837. There is a demand, however, for rapid production of aluminum containers using metal with a high recycled content.

## 20 SUMMARY

25 The terms "invention," "the invention," "this invention" and "the present invention,"  
as used in this document, are intended to refer broadly to all of the subject matter of this  
patent application and the claims below. Statements containing these terms should be  
understood not to limit the subject matter described herein or to limit the meaning or scope of  
the patent claims below. Covered embodiments of the invention are defined by the claims,  
30 not this summary. This summary is a high-level overview of various aspects of the invention

and introduces some of the concepts that are further described in the Detailed Description section below. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used in isolation to determine the scope of the claimed subject matter. The subject matter should be understood by reference to appropriate  
5 portions of the entire specification, any or all drawings and each claim.

This disclosure provides methods for high-temperature and low-temperature 3xxx series aluminum blow forming of fully or partially annealed aluminum alloy draw-and-iron (D&I) preforms. A preform is a hollow workpiece typically having an open end opposite a closed end and a generally cylindrical wall. A D&I preform is a preform made by a D&I  
10 process.

Preforms used in the methods described herein typically have a diameter of about 2.5 inches (in) to about 3.0 in, a height of about 10.0 in to about 12.5 in, a wall thickness of about 0.006 in to about 0.020 in, and a dome depth of about 0.400 in to about 1.00 in.

Preforms used in the methods described herein can be either coated or uncoated  
15 depending on the application. For example, a conventional can coating system can be applied on the preforms. A conventional can coating system comprises inside spray, ink and over-varnish.

This disclosure provides methods for aluminum forming at temperatures ranging from ambient temperature (i.e., between about 18 °C – about 25 °C) up to about 300 °C and provides methods for preform expansion to a diameter up to 40% larger than the original  
20 preform diameter. This disclosure provides methods for a low-pressure forming operation that operates up to 420 psi ( $\approx$ 30 bars), with the use of a single segment split mold.

The methods disclosed herein are commercially valuable because they use blow-forming to expand preforms made by a D&I process. The D&I process is more efficient than  
25 the alternative impact extrusion (IE) process. The D&I process is capable of running at a considerably higher production speed than the IE process, which makes the D&I process an economical option for a high-speed, large-volume production plant. Moreover, the D&I process can be carried out on alloys having a high recycled content. Because of the large amount of deformation required, the IE process requires the use of high-purity 1xxx series  
30 aluminum alloys, which are not recycle friendly. Thus, the disclosed methods are

advantageous over conventional methods, at least because in those conventional methods aluminum bottles are manufactured by the impact extrusion (IE) process.

The blow-forming methods described herein use high pressure gas to expand an aluminum preform to fit a negative mold. The disclosed methods also could be applied to a product line employing hydroforming, which uses a liquid in place of the gas used in blow forming.

In some examples, a process for shaping aluminum containers includes the sequential steps of blanking out a disk from a sheet of a 3xxx series aluminum alloy; forming a bottle preform by drawing, redrawing, ironing, and doming the cup; placing the preform into a mold cavity; applying an axial load to the preform; and injecting an inert gas into the interior of the preform with sufficient pressure until the preform expands to fill the mold cavity. Optionally, the sheet has a thickness in the range of about 0.0150 in to about 0.0250 in. Optionally, the disk has a diameter in the range of about 6.0 in to about 9.5 in.

In some examples, the preform is heated to a forming temperature prior to injecting the inert gas. In some cases, the forming temperature is about 200 °C to about 300 °C. In some cases, the forming temperature is about 250 °C to about 255 °C, or nominally 250 °C. When the process includes heating the preform to a forming temperature, the heating may be carried out while the preform is under the axial load. That is, the heating may be carried out while the axial load is applied. The axial load prevents the preform from expanding in the axial direction, but the axial load does not compress (i.e., reduce the length of) the preform.

The inert gas is injected after a preset axial load is reached. In some examples, the preset axial load is in the range of about 100 to 250 lb/ft<sup>2</sup>. As the preform expands, the axial load decreases, so the injected gas applies pressure to the preform at a controlled rate.

In some examples, the preform may be annealed before it is placed in a mold cavity. In some cases, the annealing temperature is from about 100 °C to about 400 °C. In some cases, the annealing temperature is from about 300 °C to about 400 °C.

Also included within the scope of this disclosure are aluminum bottles made by any method disclosed herein.

The flexibility of the methods disclosed herein allows for production of elaborate designs in the aluminum bottle market, which would be difficult with other aluminum forming methods, for example mechanical shaping.

#### BRIEF DESCRIPTION OF THE FIGURES

5 Figure 1 is an illustration of a mold cavity according to the methods described herein.

Figure 2 is a schematic of a blow forming process according to the methods described herein.

Figure 3 is a graph of the forming parameters of a D&I preform upon expansion to fill a mold during a high-speed blow-forming process.

#### 10 DETAILED DESCRIPTION

The methods described herein provide shaped aluminum bottles from conventional 3xxx can body stock alloys with up to 100% recycled content. In some cases, the methods include manufacturing a preform having a wall, a closed end, and an open end by a D&I process and expanding the preform into a shaped container by high-speed blow forming.

15 By way of example, but not limitation, a disk is blanked out of an aluminum sheet. The blank may be formed by any method known in the art, such as by punching or cutting. In one embodiment an outer cutting tool cuts a 3xxx series aluminum sheet having a thickness ranging from about 0.0150 in to about 0.0250 in (e.g., 0.0150 in to 0.0200 in, 0.0180 in to 0.0200 in, 0.0180 in to 0.0250 in, or 0.0200 to 0.0250 in), into a disk, and the  
20 disk is immediately drawn into a cup. The disk may be drawn into a cup with an inner cup forming tool. The cutting and drawing is carried out by a double action press, where the first action performs disk cutting and the second action performs cup forming in a continuous motion. To provide sufficient material for aluminum bottles, including large format aluminum bottles, the cut-out disk may have a diameter ranging from about 6.0 in to about  
25 10.0 in (e.g., 6.0 in, 6.2 in, 6.5 in, 6.7 in, 7.0 in, 7.2 in, 7.5 in, 7.7 in, 8.0 in, 8.2 in, 8.5 in, 8.7 in, 9.0 in, 9.2 in, 9.5 in, 9.7 in, or 10.0 in.)

The formed cup has a fairly large diameter that requires further operation to reduce its size to a smaller diameter to facilitate subsequent operations. This is accomplished by a redraw process. A suitable redraw process for the methods described herein includes, for

example, the direct redraw process wherein the cup is drawn from inside of the cup base by using similar cup forming tools to reduce its diameter and displace the material to form a taller cup wall. Another suitable redraw process for use in the methods described herein is the reverse redraw process wherein the cup is drawn from the bottom of the cup and metal is folded in an opposite direction to form the taller cup wall. The methods disclosed herein may include either of these preform redraw processes, but are not limited to these redraw processes. Depending on machine requirements, limitations, and process requirements, there may be multiple redraw processes or combinations of redraw processes.

Once the cup is drawn to a final bottle preform diameter, an ironing tool will stretch and thin the cup wall to achieve the final preform wall thickness and length. At the end of the D&I process, a doming operation is performed wherein the bottom of the preform, i.e., the dome profile, is formed. For use in the blow forming process described herein, the final preform may have a diameter ranging from about 2.0 in to about 3.5 in (e.g., 2.0 in to 3.0 in, or 2.5 in to 3.5 in) and may be as tall as about 10.0 in to about 12.5 in (e.g., 10.0 in, 10.5 in, 11.0 in, 11.5 in, 12.0 in, or 12.5 in). The preform wall has a thickness ranging from about 0.006 in to about 0.020 in (e.g., 0.006 in, 0.007 in, 0.008 in, 0.009 in, 0.010 in, 0.012 in, 0.014 in, 0.016 in, 0.018 in, or 0.020 in). In some cases, the preform may have a constant wall thickness of about 0.010 in to about 0.020 in (e.g., 0.012 in, 0.014 in, 0.016 in, or 0.018 in). In other cases, the bottle preform may have a variable wall thickness with a thicker portion at the top of about 0.010 in to about 0.020 in (e.g., 0.010 in, 0.012 in, 0.014 in, 0.016 in, 0.018 in, or 0.020 in) and a thinner portion in the middle of about 0.006 in to about 0.012 in (e.g., 0.006 in, 0.007 in, 0.008 in, 0.009 in, 0.010 in, or 0.012 in). The preform dome has a depth from about 0.400 in to about 1.00 in (e.g., 0.400 in, 0.500 in, 0.600 in, 0.700 in, 0.800 in, 0.900 in, or 1.00 in).

During the preform forming process, the preform may be subjected to an optional annealing operation with a temperature ranging from about 100 °C to about 400 °C (e.g., 100 °C – 300 °C, 100 °C – 200 °C, 200 °C – 400 °C, 200 °C – 300 °C, or 300 °C – 400 °C for a duration ranging from about 1 minute to about 3 hours (e.g., 1 minute – 1 hour, 1 minute – 30 minutes, 5 minutes – 20 minutes, 1 hour – 3 hours, 2 hours – 3 hours, or 1 hour – 2 hours). The annealing process may be performed to improve metal formability. In certain cases, the annealing process may have a duration ranging from about 1 hour to about 3 hours. In other cases, the annealing process may range from about 1 minute up to about 30 minutes. The

annealing operation may be added during aluminum sheet production or during one or more preform production steps. The annealing process may be applied locally to a specific portion of the preform. For example, the annealing process may be applied to the neck portion of the bottle, to the body portion of the bottle, to the base portion of the bottle, or any combination thereof. The annealing process may also be applied to selective portions of the aluminum sheet before it is processed into a preform. Consequently, a gradient of mechanical properties is induced along the height of the sidewall of the preforms. Alternatively, the annealing step may be applied as an intermediate step in the necking and shaping progression operations.

In some examples, the methods provide high-speed blow forming processes for shaping D&I preforms of conventional 3xxx can body stock alloys with high recycled content. The recycled content may be present in an amount of up to 100 wt. % of the alloy. In some cases, the recycled content may be present from 50 wt. % to 100 wt. % of the alloy (e.g., 50 wt. %, 55 wt. %, 60 wt. %, 65 wt. %, 70 wt. %, 75 wt. %, 80 wt. %, 85 wt. %, 90 wt. %, 95 wt. %, or 100 wt. %).

In one example, standard AA3104 can body stock alloys are used. Other non-limiting alloys that may be used in the methods disclosed herein are AA3003, AA3004, AA3105, and AA3204.

In one non-limiting example, a preform optionally is annealed in a box furnace prior to blow-forming. After optional annealing, the preform is placed in a mold cavity for blow forming. The mold cavity typically has a long axis. The preform also has a long axis and is disposed substantially coaxially within the mold cavity. Optionally, the mold cavity is part of a split mold, i.e., a mold made up of two or more mating segments around the periphery of the mold cavity, separable for removal of the formed container. With a split mold, the defined shape may be asymmetric about the long axis of the cavity.

In one example, a high-speed blow forming process uses an ambient or heated mold cavity. In the case of the heated mold cavity, a controlled temperature gradient may be used, such that the temperature of the mold cavity varies about 5 °C to 10 °C (e.g., 5 °C, 6 °C, 7 °C, 8 °C, 9 °C, or 10 °C) from the top to the bottom of the preform. In practice, the top and bottom of the mold cavity are heated to temperatures from about 200 °C to 300 °C (e.g., 200 °C, 220 °C, 240 °C, 260 °C, 280 °C, or 300 °C), with the bottom being 5 °C to 10 °C higher than the top. In some examples, a mold apparatus includes a split mold having two halves

(left and right), a backing ram (bottom), and a preform seal (top). In addition to the mold cavity being heated, the backing ram and preform seal may also be heated. When the backing ram and seal are heated, the backing ram is generally heated to a temperature from about 215 °C to about 335 °C (215 °C, 225 °C, 235 °C, 245 °C, 255 °C, 265 °C, 275 °C, 285 °C, 295 °C, 305 °C, 315 °C, 325 °C, or 335 °C), and the preform seal is generally heated to a temperature similar to the upper portion of the mold cavity, for example, to about 180 °C to 320 °C (e.g., 180 °C, 200 °C, 220 °C, 240 °C, 260 °C, 280 °C, 300 °C, or 320 °C). Figure 1 is a schematic of a mold cavity showing one half of a split mold 110 and a backing ram 120.

Figure 2 is a schematic of a blow-forming process. During a blow-forming process, a mold cavity 210, a backing ram 220, and a preform seal 230 enclose a preform 240 as shown in Fig. 2, panel A. The backing ram 220 places an axial load indicated by arrow 250 on the preform 240 while the preform 240 is heated to its forming temperature, as shown in Fig. 2, panel B. The axial load typically is in the range of 100 lb/ft<sup>2</sup> to 250 lb/ft<sup>2</sup> (e.g., 100 lb/ft<sup>2</sup>, 125 lb/ft<sup>2</sup>, 150 lb/ft<sup>2</sup>, 175 lb/ft<sup>2</sup>, 200 lb/ft<sup>2</sup>, 225 lb/ft<sup>2</sup>, or 250 lb/ft<sup>2</sup>). Although the backing ram 220 exerts a load on the preform 240, there is no significant compression, or reduction in length, of the preform. The displacement of the backing ram 220 is about 0 in to about 0.050 in (e.g., 0.025 in – 0.05 in). The backing ram 220 is essentially stationary once in place in contact with the preform dome and during the molding process.

Once the forming temperature is reached, the preform 240 is pressurized with an inert gas 260, such as nitrogen, until the preform 240 expands to completely fill the mold cavity 210, as shown in Fig. 2, panels C and D. The blowing pressure is applied to the preform at a controlled rate. As the preform 240 expands, the axial load decreases.

In one non-limiting example, for a preform nominal temperature of 250 °C, the upper portion of the mold cavity is heated to 250 °C and the bottom portion of the mold cavity is heated to 255 °C. The seal is heated to 250 °C and the backing ram is heated to 275 °C. During the forming process, the four parts (i.e., the two halves of the mold, the backing ram, and the seal) enclose the preform. An axial load of about 200 lb/ft<sup>2</sup> is placed on the preform while the preform is heated to its forming temperature. Once the forming temperature is reached, the preform is pressurized with nitrogen until the mold cavity is filled.

Optionally, a blow forming method may be carried out at ambient temperatures, i.e., without heating the mold apparatus. When forming under ambient temperature conditions,

for example 23 °C, the preform is immediately pressurized with an inert gas once the preset axial load is reached. The pressurization rate is approximately 1 second and the pressure is held until the blow formed preform completely fills the mold cavity.

5 The split mold expansions increase in diameter up to 40% larger than the original diameter (e.g., 15 %, 20%, 25%, 30%, 35%, or 40%). The forming temperature ranges from ambient temperature, for example about 23 °C, to about 300 °C (e.g., 23 °C – 100 °C, 23 °C – 200 °C, 100 °C – 300 °C, or 200 °C – 300 °C).

Figure 3 is a graph showing change in forming parameters over time as a D&I  
10 preform was expanded to a straight wall mold in a high-speed blow forming process. The fully formed bottle had a 40% expansion (to 2.933 in final diameter). This bottle was formed at a nominal temperature of 250 °C with a 5 °C temperature gradient from the top to the bottom of the preform, i.e., the temperature at the top of the preform was 250 °C and the temperature at the bottom of the preform was 255 °C. As shown in Figure 3, the entire forming process for making the straight wall container took approximately 5 seconds.

15 The shaped aluminum containers described herein may be used for beverages including, but not limited to, soft drinks, water, beer, wine, energy drinks, and other beverages.

It should be understood that the foregoing relates only to  
20 preferred embodiments of the present invention and that numerous modifications or alterations may be made therein without departing from the spirit and the scope of the present invention.

WHAT IS CLAIMED IS:

1. A process for shaping aluminum containers comprising the sequential steps of:  
blanking out a disk from a sheet of a 3xxx series aluminum alloy;  
forming a bottle preform by drawing, redrawing, ironing, and doming the disk;  
placing the bottle preform into a mold cavity and enclosing the bottle preform in the mold cavity using a preform seal;  
applying an axial load to the bottle preform using a backing ram, wherein application of the axial load does not reduce a height of the bottle preform, and wherein the backing ram is held essentially stationary while applying the axial load, undergoing a displacement of between 0 inches and 0.05 inches; and  
injecting an inert gas into an interior of the bottle preform with pressure until the bottle preform expands to fill the mold cavity.
2. The process of claim 1, wherein the sheet has a thickness ranging from about 0.0150 in to about 0.0250 in.
3. The process of claim 1, wherein the sheet has a thickness ranging from about 0.0180 in to about 0.025 in.
4. The process of claim 1, wherein the sheet has a thickness ranging from about 0.0200 in to about 0.025 in.
5. The process of any one of claims 1 to 4, wherein the disk has a diameter ranging from about 6.0 in to about 10.00 in.
6. The process of claim 1, wherein the disk has a diameter ranging from about 6.0 in to about 7.0 in.
7. The process of claim 1, wherein the disk has a diameter ranging from about 8.0 in to about 9.50 in.

8. The process of any one of claims 1 to 7, further comprising heating the bottle preform to a forming temperature prior to injecting the inert gas.
9. The process of claim 8, wherein the forming temperature is from about 200° C to about 300° C.
10. The process of claim 9, wherein the forming temperature is from about 250° C to about 255° C.
11. The process of claim 8, wherein the bottle preform has a top and a bottom, wherein the forming temperature comprises a temperature gradient from the top to the bottom of the bottle preform, and wherein the forming temperature at the bottom of the bottle preform is from 5° C to 10° C higher than the forming temperature at the top of the bottle preform.
12. The process of any one of claims 8 to 11, wherein the heating is carried out while the axial load is applied.
13. The process of any one of claims 1 to 12, wherein the inert gas is injected after the axial load reaches a preset axial load.
14. The process of any one of claims 1 to 13, wherein the 3xxx series aluminum alloy is selected from the group consisting of AA3104, AA3003, AA3004, and AA3105.
15. The process of any one of claims 1 to 14, wherein the 3xxx series aluminum alloy includes at least 50 wt. % recycled material.
16. The process of any one of claims 1 to 15, further comprising fully or partially annealing the bottle preform prior to placing the bottle preform in the mold cavity.
17. The process of claim 16, wherein an annealing temperature is from about 100° C to about 400° C.
18. The process of claim 17, wherein the annealing temperature is from about 300° C to about 400° C.

19. The process of any one of claims 1 to 18, wherein the bottle preform has:  
a diameter of about 2.5 in to about 3.0 in;  
the height of about 10.0 in to about 12.5 in;  
a wall thickness of about 0.006 in to about 0.020 in; and  
a depth of dome from about 0.400 in to about 1.00 in.

1/2

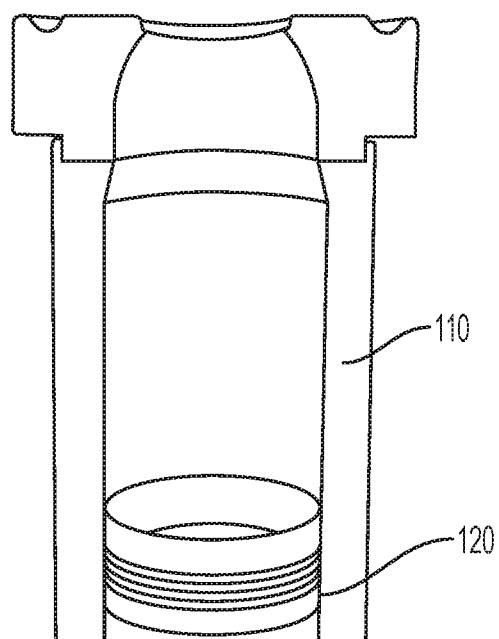


FIG. 1

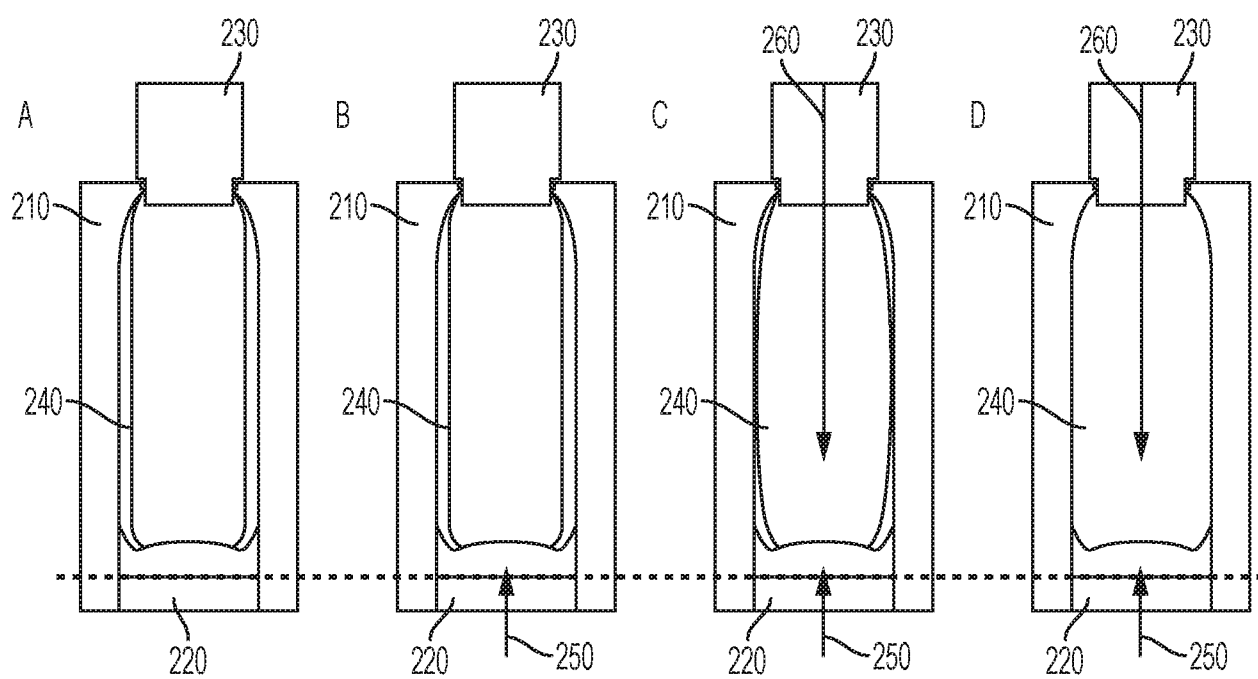


FIG. 2

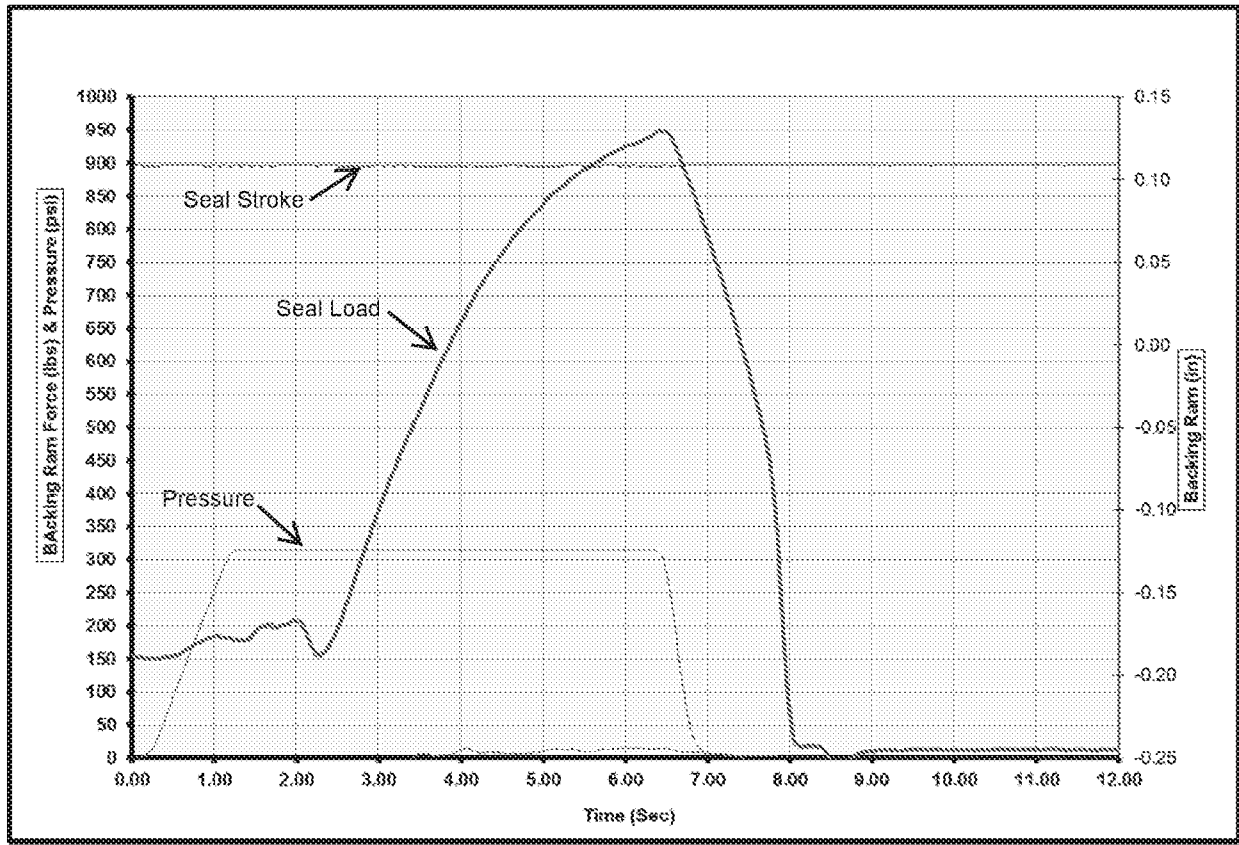


FIG. 3

