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(71) Demandeur/Applicant:
THE NORDAM GROUP, INC., US
(72) Inventeurs/Inventors:
REESE, ROY JEFFERSON, JR., US;
BUTLER, WILLIAM CHRISTOPHER, US
(74) Agent: DEETH WILLIAMS WALL LLP

(54) Titre : LIAISON METALLIQUE PAR COMMANDE FLASH
(54) Title: FLASH CONTROL METAL BONDING

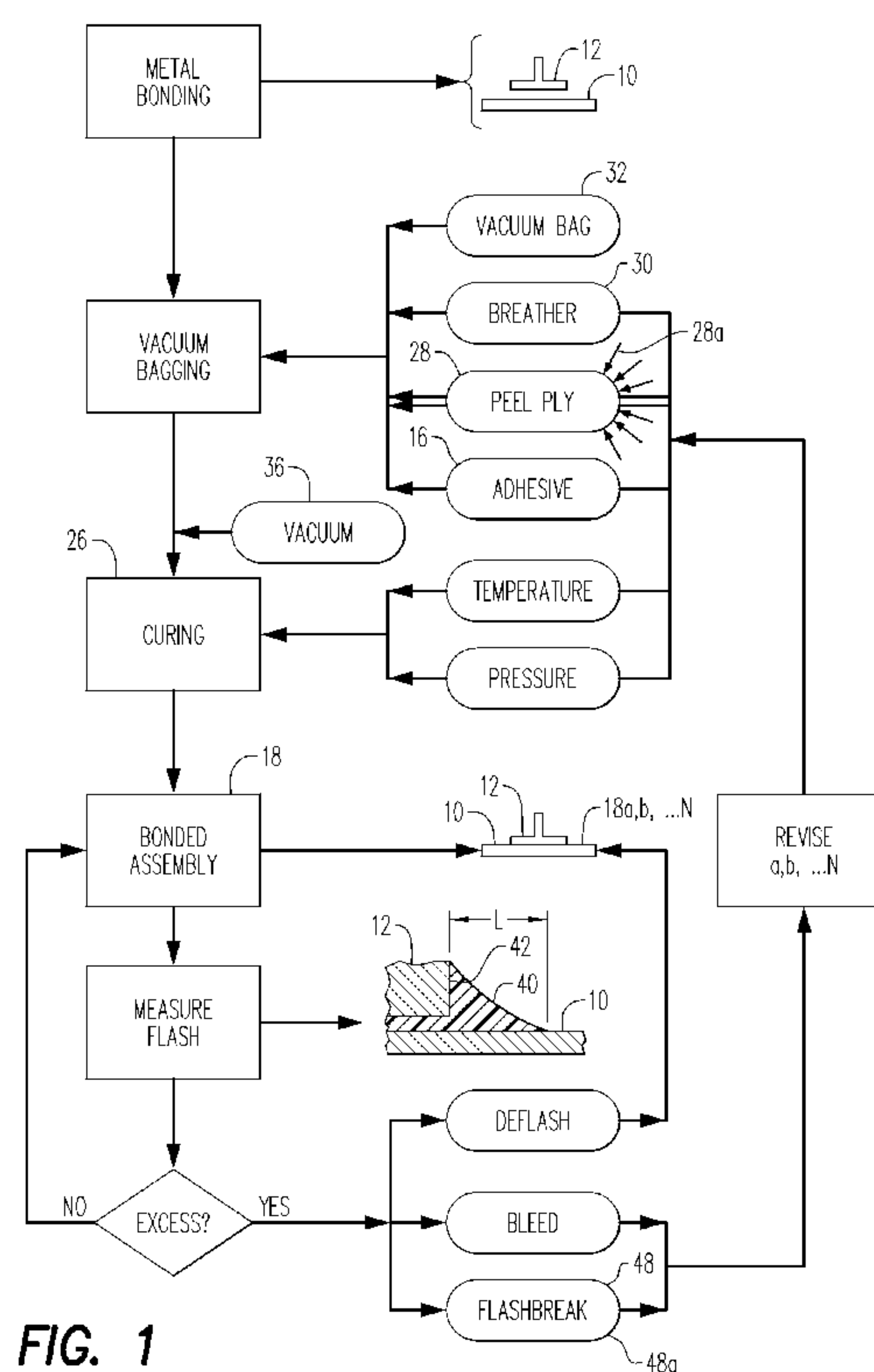


FIG. 1

(57) **Abrégé/Abstract:**

A bonding method includes vacuum bagging a second metal plate (12) atop a first metal plate (10), with a thermosetting adhesive (16) in a lap joint (22) therebetween covered in turn by a porous peel ply (28) and a porous breather ply (30); the plates (10, 12) being initially clamped together by applying vacuum through the breather ply (30); and thermally curing the adhesive (16), with the breather and peel plies (30,28) being preselected to capture adhesive seepage (38) from the lap joint (22) and removed with the plies (28,30) to correspondingly reduce cured adhesive flash (40).



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(71) Applicant: **THE NORDAM GROUP, INC.** [US/US];
6911 North Whirlpool Drive, Tulsa, OK 74117 (US).(72) Inventors: **REESE, Roy Jefferson Jr.**; 11200 E Pine
Street, Tulsa, OK 74116 (US). **BUTLER, William Chris-**
topher; 11200 E Pine Street, Tulsa, OK 74116 (US).(74) Agent: **CONTE, Francis L.**; 6 Puritan Avenue,
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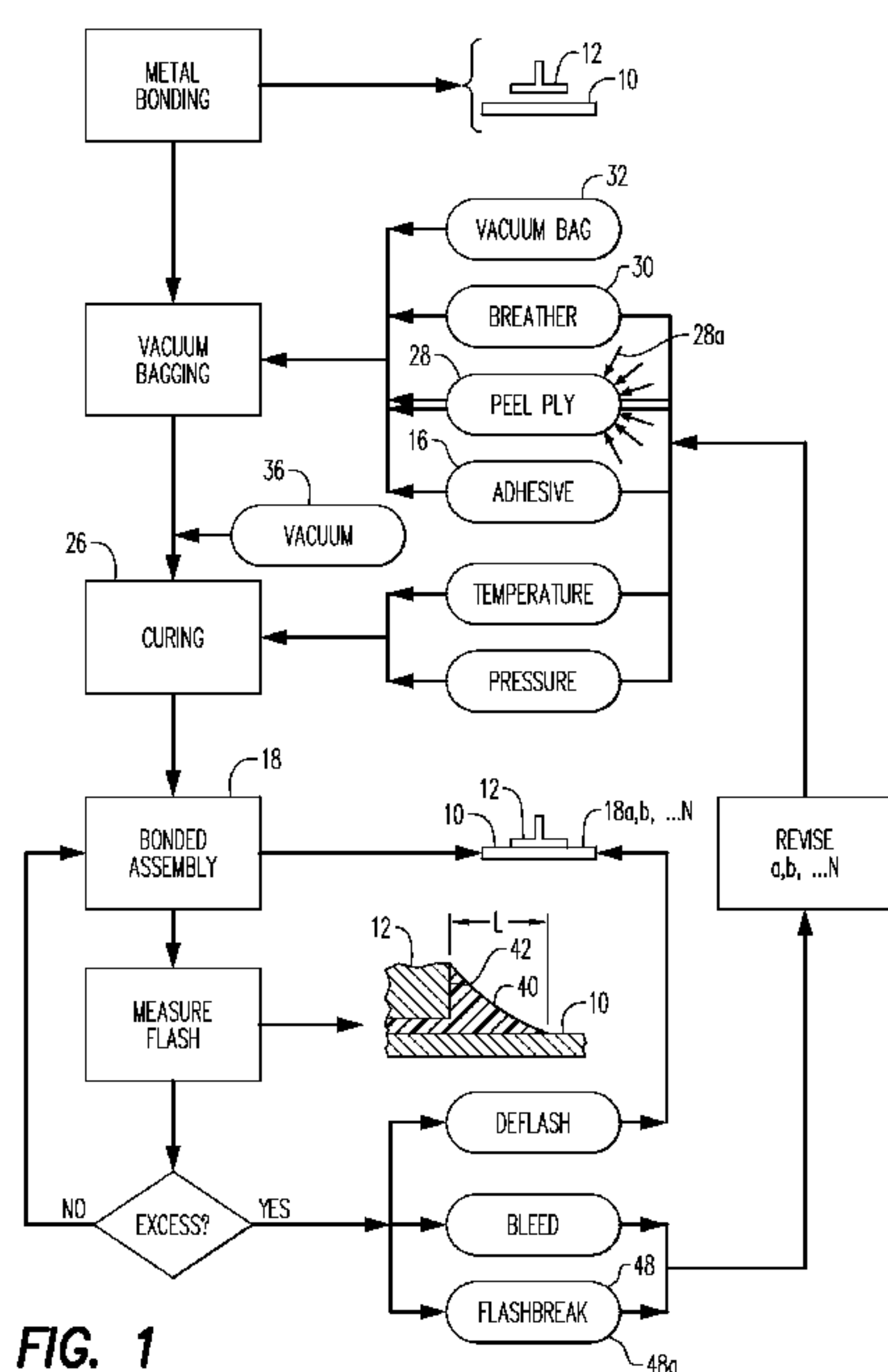


FIG. 1

(57) Abstract: A bonding method includes vacuum bagging a second metal plate (12) atop a first metal plate (10), with a thermosetting adhesive (16) in a lap joint (22) therebetween covered in turn by a porous peel ply (28) and a porous breather ply (30); the plates (10, 12) being initially clamped together by applying vacuum through the breather ply (30); and thermally curing the adhesive (16), with the breather and peel plies (30,28) being preselected to capture adhesive seepage (38) from the lap joint (22) and removed with the plies (28,30) to correspondingly reduce cured adhesive flash (40).

1 Flash Control Metal Bonding

2

3

TECHNICAL FIELD

4

5 The present invention relates generally to aircraft manufacturing, and, more
6 specifically, to adhesive metal bonding of components therein.

7

8

BACKGROUND ART

9

10 Aircraft typically included many parts and sections made from high strength aluminum
11 for reducing weight. The aluminum parts are typically bonded together mechanically by
12 fasteners and rivets, or by using high strength adhesive where appropriate.

13 Vacuum bagging is one method for adhesively bonding together metal components in
14 contrast with its common use in fabricating composite laminates of fibers in a cured resin
15 matrix.

16 In metal bonding, an adhesive film is applied between the metal parts and enclosed in
17 a vacuum bag to clamp the parts together, and then the adhesive is thermally cured in a
18 predetermined curing cycle typically conducted at elevated temperature and pressure for a
19 specified time duration.

20 The initially solid adhesive film softens during thermal curing and decreases in
21 viscosity as temperature rises. The softened adhesive may then leak from the bond area to
22 form a small fillet or flash of cured adhesive extending outwardly from the bonded joint.

23 This cured flash may be undesirable in the aircraft part for its additional weight, or
24 interference with adjoining parts, or simply for cosmetic appearance.

25 Removal of unwanted adhesive flash may therefore be accomplished by various post-
26 bonding processes, which correspondingly require suitable equipment and labor which increase
27 production time and cost. Such flash removal processes include sanding, grinding, scraping,
28 and grit blasting with wheat-starch for example, and may adversely affect the corrosion
29 protection of the underlying aluminum parts, which in turn requires rework to restore that
30 corrosion protection.

31 In order to minimize flash during the vacuum bagging bonding of metal components, a
32 specialized flashbreaker tape is available for locally masking the edge of the bond joint so that
33 the adhesive leaks atop the tape, and may be simply removed after curing by removing or
34 tearing away the tape and so captured flash.

35 Alternatively, a specialized pressure strip is also available to block adhesive seepage
36 from the bond joint during curing.

37 However, since both products are specialized, their use increases complexity of the
38 vacuum bagging process and correspondingly increases manufacturing cost, and may also

1 have adverse effects.

2 For example, the flash is torn with the removal of the flashbreaker tape, and can leave
3 an undesirable rough adhesive edge at the joint. And, the pressure strip merely dams the
4 viscous adhesive as the metal parts are compressed during curing, with the full volume of the
5 flash, and its weight, remaining in the bonded assembly.

6 Accordingly, it is desired to provide an improved vacuum bagging metal bonding
7 process which reduces formation of undesirable flash during thermal curing.

8 9 DISCLOSURE OF INVENTION

10
11 A bonding method includes vacuum bagging a second metal plate atop a first metal
12 plate, with a thermosetting adhesive in a lap joint therebetween covered in turn by a porous
13 peel ply and a porous breather ply; the plates being initially clamped together by applying
14 vacuum through the breather ply; and thermally curing the adhesive, with the breather and
15 peel plies being preselected to capture adhesive seepage from the lap joint and removed with
16 the plies to correspondingly reduce cured adhesive flash.

17 18 BRIEF DESCRIPTION OF DRAWINGS

19
20 The invention, in accordance with preferred and exemplary embodiments, together
21 with further objects and advantages thereof, is more particularly described, by way of
22 example(s) only, in the following detailed description taken in conjunction with the
23 accompanying drawings in which:

24 Figure 1 is a flowchart for the improved method of adhesively bonding together metal
25 components.

26 Figure 2 is a flowchart for exemplary metal components being bonded using a vacuum
27 bagging procedure.

28 Figure 3 is a flowchart showing exemplary details of the vacuum bagging procedure.

29 Figure 4 is a transverse sectional view through an exemplary bond joint for the metal
30 components being adhesively bonded in Figure 3, and taken along section line 4-4.

31 Figure 5 is an enlarged sectional view of a portion of the bond joint illustrated in Figure
32 4 within the circle labeled 5 during thermal curing.

33 Figure 6 is an exploded view of the bond joint shown in Figure 5 after thermal curing.

34 Figure 7 is an enlarged sectional view showing an original adhesive bond joint
35 undergoing deflashing.

36 Figure 8 is an enlarged section view of the bond joint in an alternate embodiment
37 using flashbreaker tape for removing cured flash after thermal curing.

38

The cleaned, and optionally primed, first plate 10 is supported atop a corresponding mold 20 in the form of a fixture table having a concave top mold surface which is

1 complementary to and matches the convex bottom surface of the first plate 10. In this lay-up
2 procedure, the bottom surface of the first plate 10 rests directly atop the top surface of the
3 mold 20 to ensure substantially full surface contact of the several stringer plates 12 resting
4 atop the concave top surface of the first plate 10.

5 As shown in Figure 3, the individual stringer plates 12 are accurately positioned,
6 optionally by hand, atop the first plate 10 in the lay-up procedure, with the thermosetting
7 adhesive 16 being disposed between the opposing surfaces thereof to form corresponding
8 bond or lap joints 22.

9 The lap joints 22 preferably extend both laterally and longitudinally along the full width
10 and length of the individual stringer plates 12, and are defined by the opposing top and
11 bottom surfaces of the plates 10,12 which have been initially cleaned, and optionally primed,
12 prior to applying the thermosetting adhesive, which may be first applied to the bottom surface
13 of each stringer plate 12 before being positioned atop the liner plate 10.

14 Each stringer plate 12 is accurately positioned atop the liner plate 10 as required for
15 the specific bonded assembly 18, and arcuate header ribs 24 may be joined to the several
16 stringer plates 12 to ensure accurate alignment and location thereof.

17 Figures 1-3 further illustrate schematically a vacuum bagging procedure or process
18 which is used to initially clamp the second plates 12 atop the common first plate 10 for
19 maintaining the accurate lay-up alignment therebetween.

20 As shown in Figure 2, the vacuum bagged assembly of the plates 10,12 are supported
21 atop the mold 20 and collectively transported, by forklift for example, into a conventional
22 autoclave 26. The autoclave 26 provides pressure (P) and heat to thermally cure the adhesive
23 between the metal plates in a predetermined temperature (T) cycle as specified for the
24 particular adhesive being used.

25 Vacuum bagging is a conventional process that uses a vacuum bag under negative
26 vacuum pressure to typically compress together fibrous laminates impregnated with a suitable
27 resin matrix for being thermally cured to form a hardened composite laminate.

28 Since such fibrous laminates are saturated with resin, the conventional vacuum
29 bagging procedure requires suitable release liquids or films and peel plies to prevent bonding of
30 the laminate to the supporting mold and vacuum bag itself. A breather ply is also required to
31 allow vacuum to reach the entire surface of the laminate to uniformly draw out trapped air and
32 volatiles for achieving a low void content in the cured hard composite laminate being molded.

33 However, metal-to-metal adhesive bonding is substantially different than composite
34 laminate manufacture since the metal is already solid and impervious to gas flow unlike
35 flexible fibrous laminates, and bonding adhesives are materially different than matrix resins
36 used to form the cured laminate, and are used only locally to form bonds between the solid
37 metal components.

38 Accordingly, only selected features and materials from conventional vacuum bagging

1 procedures are desired and used in optional combinations for adhesively bonding together
2 metal components while minimizing complexity and cost.

3 As initially shown in Figures 1 and 3, the lay-up procedure includes accurately
4 positioning the several stringer plates 12 atop the common supporting plate 10, with the
5 adhesive 16 being disposed therebetween.

6 As shown in detail in Figures 3 and 4, the vacuum bagging procedure then introduces
7 a porous peel ply 28 covering the entire lap joint 22, and a porous breather ply 30 covering
8 the peel ply 28 for each of the several stringer plates 12.

9 A conventional vacuum bag 32 is sealingly joined by sealant tape 34 around the full
10 perimeter thereof to the first plate 10 to cover the breather and peel plies 30,28 and the
11 second plate 12. The peel ply 28 is locally used in individual strips to cover the several lap
12 joints 22 along the opposite lateral edges of the several stringer plates 12 where the edges of
13 the adhesive 16 are exposed. Note that the upstanding T-flanges 14 need not be covered
14 with the peel ply 28, which peel ply 28 instead preferably terminates at the base thereof.

15 The breather ply 30, in contrast, extends the full extent or area of the first plate 10 on
16 which the several stringer plates 12 are mounted, and also covers in common all the individual
17 peel plies 28, as well as the upstanding T-flanges 14. The breather ply 30 conforms in extent
18 and area with that of the vacuum bag 32 for ensuring vacuum flow across the full area of the
19 vacuum bag 32 to its bonded perimeter atop the liner plate 10.

20 The vacuum bag 32 is conventionally connected by hose to a vacuum pump 36
21 shown schematically in Figures 1 and 4 for applying a vacuum, or negative pressure, through
22 the breather ply 30 to clamp the several second plates 12 atop the common first plate 10. In
23 this way, the lay-up assembly of stringer plates 12 atop the common liner plate 10 may be
24 accurately retained fixed in location during transport into the autoclave 26 for thermal curing.

25 In the autoclave 26 illustrated schematically in Figures 1 and 2, heat and pressure are
26 introduced to thermally cure the adhesive 16 to adhesively bond the second plates 12 to the
27 common first plate 10 at the corresponding lap joints 22. Each stringer plate 12 is therefore
28 adhesively bonded along its entire lower surface to the corresponding upper surface of the
29 common liner plate 10 in a full-lap bond joint 22 having maximum bonding area for increasing
30 strength and stiffness of the collective liner assembly.

31 As best shown in Figures 5 and 6, the vacuum bagging procedure is specifically
32 tailored with the breather and peel plies 30,28 being preselected to capture adhesive seepage
33 38 that flows or bleeds as a viscous liquid from the lap joints 22 during thermal curing to
34 correspondingly reduce cured adhesive flash 40 exposed on the first plate 10 at the perimeter
35 edges of the second plates 12. This flash 40 forms a visible concave adhesive fillet around
36 the perimeter of each plate 12 that visibly confirms complete surface bonding thereof to the
37 common liner plate 10.

38 By manually removing the breather and peel plies 30,28 from atop the first and

1 second plates 10,12 after thermal curing, the captured, and now cured, adhesive seepage 38
2 is removed therewith. This removal of a significant portion of the adhesive seepage may be
3 used to preferentially reduce the size of any remaining flash or fillet 40 for reducing overall
4 weight of the bonded assembly 18, and eliminating the need for post-processing deflashing of
5 the assembly.

6 In the transverse cross section of the adjoining plates 10,12 shown in Figures 4 and
7 5, each of the several second plates 12 terminates along both lateral edges at a corresponding
8 step 42, typically right-angled (90°), atop the common first plate 10 to expose the adhesive
9 otherwise hidden at the joint 22. Since both plates 10,12 are solid metal, they entrap the
10 adhesive 16 therebetween, with the only exposure of the adhesive 16 being solely along the
11 opposite perimeter steps 42 where the stringer plates 12 terminate atop the common liner
12 plate 10.

13 The peel ply 28 is locally applied directly atop both the first and second plates 10,12
14 in a bridge therebetween that drapes over and closely conforms with the down-step 42
15 directly adjacent to the exposed adhesive 16 in the joint 22. The peel ply 28 is typically
16 resilient and thus forms a small void at the step 42.

17 During thermal curing, excess adhesive 16 discharges from the joint 22 into the void
18 at the step 42 and is readily visible. Accordingly, adhesive seepage from the entire perimeter
19 of the lap joint 22 can be readily observed to correspondingly ensure complete adhesive
20 bonding over the full surface area of the stringer plate 12 atop the common liner plate 10.

21 The peel ply 28 is preselected in material definition or characteristics including material
22 composition or porosity, or both, for locally channeling or bleeding to the breather ply 30 the
23 adhesive seepage 38 along the step 42 during thermal curing.

24 Placing the mold 20 and vacuum bagged first and second plates 10,12 in the
25 autoclave 26 permits thermal curing of the adhesive 16 under heat and pressure for effecting
26 suitable viscous seepage thereof from the joint 22,

27 However, suitable viscous seepage through the peel ply 28 into the breather ply 30
28 may be obtained only by preselecting the peel ply 28 in combination with the adhesive 16,
29 breather ply 30, curing temperature T, and curing pressure P.

30 Peel and breather plies in general have specific material definitions or characteristics
31 including material compositions, properties, and performance characteristics as specified by
32 their manufacturers, and are correspondingly different as required for different methods for
33 their use.

34 Similarly, thermosetting adhesives also have specific material definitions or
35 characteristics including material compositions, properties, and performance characteristics as
36 specified by their manufacturers, and are correspondingly different as required for different
37 methods for their use. And, each thermosetting adhesive is also subject to a specified or
38 predetermined thermal curing cycle including pressure, temperature, and duration.

1 All these material and curing variables can therefore affect performance of thermal
2 bonding of metals using vacuum bagging procedures.

3 Further complicating bonding performance for aircraft grade structural metals are
4 design specifications mandated therefor by the aircraft manufacturer after conducting
5 extensive design and development of all components of the typical aircraft being designed.

6 Acceptable adhesive metal bonding is dependent on the specific metal parts being
7 bonded for different applications in different aircraft. The acceptability of adhesive flash is
8 similarly dependent on the particular metal parts and aircraft applications.

9 Accordingly, design constraints are typically imposed by the airframer on
10 subcontractors in manufacturing the various sub-assemblies of an aircraft, including those
11 requiring adhesive bonding of metal components.

12 One exemplary design constraint imposed upon the fabricator is the thermosetting
13 adhesive 16 specified by the airframer for bonding the specified parts.

14 In one aircraft manufacturing development program, the stringer plates 10 and liner
15 plate 12 were adhesively bonded together in an original bonding method constrained by the
16 airframer, which included vacuum bagging using an original peel ply 28a in the combination
17 shown schematically in Figure 1 to produce an initial bonded assembly 18a.

18 The size, including length L and optionally thickness, of the flash 40 is measured atop
19 the first plate 10 along the step 42 in the initial bonded assembly 18a. If the flash size is not
20 excessive for a specific design application, then the original bonding method is acceptable.

21 However, if the flash size is excessive, remedial action would be required to reduce
22 flash size.

23 For example, Figure 7 illustrates two conventional post-bonding processes that can be
24 used for removing excessive flash 40. In the original bonding method, the flash 40 had a
25 length A measured laterally outwardly from the second plate 12 of about 150 mils (3.8 mm)
26 which was deemed excessive in accordance with the design constraints.

27 Excessive flash can be formed for various reasons in the bonding process and is
28 dependent on the various materials used therein. As the excess adhesive is discharged from
29 the bond joint it can readily displace the overlying peel ply at the step 42 to form the
30 excessive flash length L directly under that peel ply.

31 In one conventional deflashing process, a hand grinder 44 may be used to grind away
32 the excessive flash 40 along the steps 42 adjoining the bonded joint. If bare metal is exposed
33 by the grinding, it is suitably cleaned and re-primed to restore corrosion resistance.

34 Alternatively, deflashing may be accomplished by using a conventional wheat-starch
35 grit blasting apparatus 46 to remove excessive flash without damaging the underlying
36 corrosion protection.

37 However, preferentially revising the metal bonding method was conducted during the
38 development program in an attempt in the first instance to avoid excess flash without the

1 need for any post-bonding deflashing.

2 Figure 1 illustrates schematically several revisions conducted during the development
3 program, including revising the bonding method for a second set of the first and second plates
4 10,12 to include at least one method difference in the vacuum bagging process and thermal
5 curing for evaluating possible solutions for flash control and amelioration.

6 The revised bonding method adhesively bonded together the second set of first and
7 second plates 10,12 to produce a second bonded assembly 18b.

8 Flash size was again measured atop the first plate 10 along the step 42 in the second
9 bonded assembly 18b.

10 The measured flash 40 in the second bonded assembly 18b may then be compared
11 with the measured flash 40 in the initial bonded assembly 18a to evaluate whether or not the
12 so revised bonding method may be effective at significantly reducing flash size.

13 The bonding method was then revised sequentially with corresponding method
14 differences to produce corresponding bonded assemblies 18a, b, ... N, until the measured
15 flash in the revised bonding method for the last (18N) bonded assembly was suitably less than
16 measured flash in one or more of the previous bonding methods.

17 For example, Figure 6 illustrates an bonding iteration in which the length B of the
18 produced flash 40 was suitably reduced from the original length A, from about 150 mils (3.8
19 mm) to about 80 mils (2.0 mm), with the reduced size being deemed non-excessive for the
20 specific metal-to-metal bond application.

21 The exemplary development program therefore uncovered a suitable peel ply 28 from
22 the many different peel plies tested which was effective for avoiding or replacing the
23 otherwise required deflashing post-operation following thermal curing of the adhesive 16 in a
24 tailored metal bonding method for the first and second plates 10,12. The so uncovered
25 satisfactory peel ply 28 is therefore different than the originally tested peel ply and may
26 therefore be subsequently used as the proven and so preselected peel ply.

27 Although the bonding method could be revised in different applications to change any
28 one or more of the peel ply 28, breather ply 30, or adhesive 16 and its corresponding
29 temperature and pressure curing cycle, revision of the peel ply itself has proven particularly
30 effective for bleeding therethrough viscous adhesive, notwithstanding the constraints imposed
31 by the airframer, including the unpermitted change of the specified thermosetting resin.

32 Accordingly, one preferred bonding method difference proven by development testing
33 includes replacing the original peel ply 28a with a different peel ply 28 having different
34 material definition defined by its material properties or characteristics.

35 In one configuration, only the peel ply difference is revised in the sequential bonding
36 methods shown in Figure 1 by sequentially testing the performance of a sequence of different
37 peel plies having different material definitions or properties to evaluate flash amelioration
38 without otherwise degrading vacuum bagging bonding of the metal plates 10,12.

1 As indicated above, flashbreaker tapes are conventionally known for masking flash,
2 but at a corresponding increase in bonding complexity and cost.

3 Flash control and reduction as disclosed above may still leave some flash along the
4 bonded joint, which may still be excessive and unacceptable for local regions of the bond joint
5 which might have close dimensional tolerances for accommodating adjacent components in
6 the aircraft construction.

7 Accordingly, the revised bonding method may optionally further include applying a
8 masking flashbreaker tape 48 directly atop the first plate 10 along the step 42 adjacent to the
9 exposed adhesive 16 prior to placement of the peel ply 28. Figure 1 schematically illustrates
10 this revision in the bonding method in combination with the preferred revision of the peel ply
11 28.

12 Figure 3 illustrates the exemplary local use of the flashbreaker tape 48 on one side of
13 one stringer plate 12 for a limited portion of the length thereof, with Figure 4 showing the
14 transverse section thereof. The amount of flashbreaker tape can be minimized as desired
15 depending upon the particular design and particular need for minimum flash production in the
16 bonded metal parts.

17 Since the flashbreaker tape 48 locally adjoins the lap joint 22 and is directly applied
18 atop the liner plate 10, the peel ply 28 is in turn directly applied atop the flashbreaker tape 48,
19 when such tape 48 is used in the step, and, optionally, the peel ply 28 extends laterally
20 oppositely from the step directly atop both the first and second plates 10,12 in the lateral
21 bridge thereacross.

22 The flashbreaker tape 48 is preferentially located typically at a suitable setback
23 distance C of about 60 mils (1.5 mm) from the edge of the stringer plate 12 as shown in more
24 detail in Figures 4 and 8.

25 The flashbreaker tape 48 is relatively thin and allows seepage thereover of the viscous
26 adhesive 16 oozing from the lap joint 22 during thermal curing. During curing, the adhesive
27 16 viscously flows or seeps both atop the flashbreaker tape 48 and through the peel ply 28 at
28 the step 42.

29 By then removing the breather and peel plies 30,28 after adhesive curing, the
30 captured adhesive seepage 38 is removed therewith as shown in Figure 6. By additionally
31 removing the flashbreaker tape 48, the flash 40 deposited thereon is torn from the cured
32 adhesive 16 in the joint 22 as shown in Figure 8.

33 The setback distance C of the flashbreaker tape 48 ensures that only the terminating
34 thin portion of the cured adhesive flash 40 atop the tape 48 is torn away from the thicker
35 portion of the torn flash 40 remaining in the step 42 as a truncated or torn adhesive fillet
36 which has a correspondingly shorter length C matching the setback distance C. And, leaving
37 only thin flash 40 atop the tape 48 reduces the tearing load or strength capability required for
38 that tape 48.

1 In this way, the flash 40 can be further reduced in size from its ablated size or length
2 B to the exemplary setback distance or length C where locally desired or required, with that
3 local size C being suitably less than the ablated size B.

4 Although flashbreaker tapes are conventional, they are also commercially available
5 with different material definitions defined by their material composition, properties, and
6 characteristics, and at different costs.

7 Figure 1 illustrates schematically that the revised bonding method may additionally
8 include using some form of flashbreaker tape 48, but synergies may be obtained by using
9 such tape in combination with the revised peel ply.

10 An original flashbreaker tape 48a may be applied atop the first plate 10 along the step
11 42 adjacent to the exposed adhesive 16 in the original bonding method for masking the first
12 plate 10 from the flash 40 in the manner illustrated in Figures 4 and 8.

13 In Figure 1, the bonding method difference may additionally include replacing the
14 original flashbreaker tape 48a with a different flashbreaker tape 48 having different material
15 definitions or characteristics. In particular, since adhesive seepage is bled through the revised
16 peel ply 28 and captured in the cooperating breather ply 30, less flash can form atop the
17 flashbreaker tape, and therefore that tape can be replaced with one having strength suitable
18 for supporting less flash, while allowing complete removal thereof without breaking or leaving
19 remnants atop the first plate 10.

20 Accordingly, the revised bonding method may achieve advantages in synergy wherein
21 both the peel ply 28 and flashbreaker tape 48 are together revised to uncover different species
22 or variations thereof effective in combination. In this embodiment, only the peel ply and
23 flashbreaker tape differences are revised in the sequential bonding methods, while the other
24 possible variables remain the same or constant during the revision process.

25 In one revision combination of peel ply and flashbreaker tape uncovered during
26 development, the original length A of flash was reduced from about 150 mils (3.8 mm) to
27 about 80 mils (2.0 mm) due to ablation capture around each stringer plate 12, and further
28 reduced locally to about 60 mils (1.5 mm) at the flashbreaker tape locations, which size
29 reductions are sufficiently small for meeting exemplary airframer specifications.

30 The use of the flashbreaker tape 48 is optional as desired for further reducing
31 excessive flash where desired, especially in local regions of the bond joint 22 between the two
32 metal plates 10,12.

33 In one of its simplest forms, the metal bonding method varies or revises solely the peel
34 ply 28 as described above to uncover and select a particular species of peel ply from the many
35 species commercially available, which uncovered species can in fact reduce the formation of
36 excessive flash during thermal curing.

37 The metal bonding method also enjoys the advantages of using in the minimum a
38 single peel ply 28 in the vacuum bonding procedure applied directly atop the first and second

1 plates 10,12 to conform with the step 42. In further combination, a single breather ply 30 is
2 applied directly atop the single peel ply 28. And, the vacuum bag 32 is then sealingly joined
3 around the perimeter thereof to the supporting first plate 10 to directly cover in turn the
4 breather and peel plies 30,28 and the full complement of second plates 12 in the particular
5 design application.

6 Particularly significant in the bonding of the metal first and second plates 10,12 is that
7 they are solid and imperforate at the lap joint 22, with the thermosetting adhesive 16 therein
8 being exposed solely along the steps 42 which bound the perimeter of the stringer plates 12.
9 The adhesive 16 is thus exposed solely at the steps 42 and is physically constrained by the
10 bounding metal plates 10,12 for locally seeping solely at the steps 42 and then directly
11 through the covering peel ply 28.

12 As described above, development testing has been conducted to uncover revised
13 metal bonding methods which can in fact reduce excessive flash during thermal curing,
14 without otherwise adversely affecting the bonding process or bond strength or requiring post-
15 bonding rework of the workpieces.

16 Since thermal curing is dependent on the specific thermosetting adhesive used for
17 bonding the metal workpieces, the bonding method is necessarily revised specifically for any
18 different thermosetting adhesive to uncover whether or not excessive flash could in fact be
19 reduced using commercially available vacuum bagging materials, or whether custom designed
20 materials would be effective.

21 Any range or device value given herein may be extended or altered without losing the
22 effects sought, as will be apparent to the skilled person, for an understanding of the teachings
23 herein.

24 25 EXAMPLE 1 26

27 In the exemplary embodiments disclosed above, each of the first and second metal
28 plates 10,12 preferably comprises aluminum specifically configured for the several structural
29 stringers 12 being bonded to the inner surface of the fuselage liner or skin 10. In other
30 embodiments, metal plates having other material composition may also be used.

31 The specific thermosetting adhesive 16 was specified by the airframer as comprising
32 3M(TM) SCOTCH-WELD(TM) Structural Adhesive Film AF 163-2K commercially available from
33 3M Aerospace and Aircraft Maintenance Department, St. Paul, MN. This product is a
34 thermosetting modified epoxy structural adhesive in film form including 7.5-13 mil (0.19-0.33
35 mm) thickness and 0.045-0.085 Lb/ft² (220-415 g/m²) weight species.

36 In particular, the 0.060 Lb/ft² (293 g/m²) weight species of the AF 163-2K adhesive
37 film was specified, and thereby predetermined, by the airframer, with a corresponding nominal
38 film thickness of 9.5 mils (0.24 mm).

1 A predetermined thermal and pressure curing cycle is also specified by the
2 manufacturer of the adhesive, as well as by the airframer.

3 For example, the thermal curing cycle for the predetermined AF 163-2K adhesive film
4 may be conducted in the autoclave 26 under a pressure of 50 psi (345 kPa), after relieving the
5 initial vacuum in the vacuum bag 32. The adhesive is heated to about 240 degrees F (116
6 degrees C) with a rise rate of 2-4 degrees F per minute (1.1-2.2 degrees C per minute) for a
7 total cure time at temperature of 90 minutes.

8 In the original iteration of the bonding method, the breather ply 30 was Airtech
9 AIRWEAVE[®] N10 heavy weight non-woven polyester fiber breather/bleeder, 10 oz./yd² (339
10 g/m²), commercially available from Airtech Advanced Materials Group, Huntington Beach, CA
11 or its division, Airtech Europe Sarl, Luxembourg, through its U.S. distributors.

12 The original peel ply 28a tested was Airtech Release Ply Super F non-coated polyester
13 fabric having a 6.5 mil (0.165 mm) thickness, 114 g/m² weight, and fabric construction in
14 warp by fill of 354 x 252 ends/dm x picks/dm, similarly commercially available from Airtech
15 through its U.S. distributors.

16 As indicated above, this combination of adhesive, peel ply, and breather ply resulted in
17 excessive flash 40 at the bond joints 22 of about 150 mils (3.8 mm), and up to about 210
18 mils (5.3 mm), and would require post-bonding deflashing to remove the flash.

19 After many iterations or revisions of the peel ply in the bonding method shown in
20 Figure 1, an acceptable peel ply 28 was uncovered to complement the 3M(TM) AF 163-2K
21 (0.060 Lb/ft² (293 g/m²) weight species) adhesive ply 16 and Airtech N10 breather ply 30, in
22 the species of Cytec A100 white medium weight nylon woven fabric, 6.0 mils (0.152 mm)
23 thickness, 2.2 oz/yd² (75 g/m²) weight, commercially available from Cytec Industries, Inc,
24 Cytec Process Materials, Santa Fe Springs, CA through its U.S. distributors.

25 The A100 peel ply 28 was effective in the bonding method combination described
26 above to reduce the length of the ablated flash 40 to about 80 mils (2 mm).

27 28 EXAMPLE 2 29

30 Another one of the revisions in the bonding method uncovered another acceptable peel
31 ply 28 in the species of another commercially available, from Cytec Industries, Inc. of Santa
32 Fe Springs, CA, Cytec product known as Cytec A8888 green medium weight nylon open-
33 weave woven fabric, 4.5 mil (0.114 mm) thickness, 2.2 oz/yd² (75 g/m²) weight, coated with
34 heat cured silicone release solution, also effective in combination with the 3M(TM) AF 163-2K
35 (0.060 Lb/ft² (293 g/m²) weight species) adhesive 16 and the Airtech N10 breather ply 30 for
36 suitably reducing size of the flash 40 after thermal bonding.

37 The Cytec A8888 peel ply is easier to apply during lay-up and easier to remove after
38 adhesive curing than the Cytec A100 peel ply.

1

2 These two peel plies Cytec A100 and Cytec A8888 have demonstrated the capability
3 of effectively reducing size of the flash in combination with the 3M(TM) AF 163-2K (0.060
4 Lb/ft² (293 g/m²) weight species) adhesive and Airtech N10 breather in the revised metal
5 bonding method, in contrast with many other peel ply species also tested in the many
6 revisions.

7 Since many species of pre-existing peel plies and release plies are commercially
8 available from many different manufacturers for use in vacuum bagging of resin impregnated
9 fibrous laminates, they may be evaluated and tested for any efficacy in the different use for
10 adhesive metal bonding to specifically reduce flash size as disclosed herein. Or custom
11 tailored materials, including peel plies, may be newly developed for specifically reducing flash
12 size in adhesive metal bonding.

13 The Airtech company identified above commercially offers for purchase many types of
14 release fabrics and peel plies made from nylon, polyester and fiberglass for correspondingly
15 different performance, along with many types of breather and bleeder materials.

16 The Cytec company also identified above commercially offers for purchase many
17 additional types of release fabrics and peel plies made from nylon, polyester, and fiberglass for
18 correspondingly different performance, along with many types of breather materials.

19 And, other companies also offer for sale further species of breather and bleeder
20 materials, peel plies and release fabrics.

21 Accordingly, numerous commercially available vacuum bagging materials are available
22 for evaluation and testing for determining whether or not they could be specifically effective
23 for reducing flash in adhesive metal bonding as described herein without otherwise degrading
24 the bonding method, or the resulting adhesive bond.

25 Fundamental to uncovering an effective peel ply for use in vacuum bagging adhesive
26 bonding of metal components is the ability of the peel ply to cooperate with the specific
27 thermosetting adhesive and thermal cure cycle in conjunction with the covering breather ply
28 for preferentially bleeding or ablating viscous adhesive locally from the small bond joint 22 and
29 into the breather ply 30 for subsequent removal after thermal curing.

30 The peel and breather plies 28,30 must cooperate for capturing adhesive seepage,
31 which captured seepage is then thermally cured therein for removal therewith after thermal
32 curing.

33 The removal process is simply accomplished by first removing the bonded assembly
34 18 and supporting mold 20 from the autoclave 26. The vacuum bag 32 is first removed from
35 the bonded assembly, followed by removal of the breather ply 30 and the underlying peel ply
36 28 partly bonded thereto by the cured seepage 38, as shown in relevant portion in Figure 6.

37 The cured seepage is torn from the cured adhesive 16 in the bond joint 22, and thusly
38 resists removal of the breather and peel plies 30,28.

1 Accordingly, the peel ply 28 is preferably further evaluated for tear resistance with the
2 captured adhesive seepage to avoid undesirable tearing of the peel ply 28 itself upon removal
3 of the breather and peel plies 30,28 after thermal curing of the adhesive.

4 Excessive tearing of the peel ply 28 will leave remnants thereof still attached to the
5 liner plate 10 by the cured adhesive seepage. Post-bonding rework would then be required to
6 remove any such remnants, which would delay the fabrication process, and correspondingly
7 increase cost.

8 9 Examples 3 and 4

10
11 As indicated above, the revised peel ply 28 may be used in conjunction with the
12 flashbreaker tape 48 for providing synergistic reduction in flash, with corresponding reductions
13 in material and process costs.

14 The original flashbreaker tape 48a tested was 3M High Temperature Nylon Tape 855,
15 2 mil (0.051 mm) thick nylon film tape with a non-silicone rubber adhesive, commercially
16 available from 3M Industrial Tape and Specialties Division, St. Paul, MN.

17 This 3M 855 tape did not adhere adequately, was fragile, and difficult to remove after
18 thermal curing of the overlying adhesive flash.

19 Another flashbreaker tape 48b tested was BA 1844, 2 mil (0.051 mm) polyester film
20 tape with a high temperature resistant rubber based pressure sensitive adhesive tape,
21 commercially available from Bron Aerotech, Denver, CO.

22 This Bron BA 1844 tape was too fragile for effective use.

23 One revised flashbreaker tape 48c tested was Airtech FLASHBREAKER® 2R, 2 mil
24 (0.051 mm) polyester film coated with a 2 mil (0.051 mm) pressure sensitive rubber based
25 adhesive, and commercially available from Airtech Advanced Materials Group, Huntington
26 Beach, CA or its division, Airtech Europe Sarl, Luxembourg, through its U.S. distributors.

27 Another revised flashbreaker tape 48N tested was Airtech FLASHBREAKER® 5R, 5 mil
28 (0.127 mm) polyester film coated with a 2 mil (0.051 mm) pressure sensitive rubber based
29 adhesive, and commercially available from Airtech Advanced Materials Group, Huntington
30 Beach, CA or its division, Airtech Europe Sarl, Luxembourg, through its U.S. distributors.

31 These selected flashbreaker tapes 48c,N were effective for removing excess flash
32 without unacceptable tearing of the tapes that could leave behind remnants requiring
33 additional removal work.

34 35 EXAMPLES- Breathers

36
37 In addition to the Airtech N10 breather described above, other breather or bleeder plies
38 tested included Ozenberg Style 1942, an open weave cotton material, commercially available;

1 and Mochburg Style 2024, a random polyester fiber mat, commercially available.

2
3 EXAMPLES- Peel Plies

4
5 Additional peel plies tested include the Airtech Release Ply Super F described above as
6 well as:

7 1. Airtech Release Ease 234TFP-1, an open weave thin (1 mil, 0.025 mm)
8 porous PTFE (TEFLON®) coated fiberglass fabric, commercially available from Airtech as
9 identified above.

10 2. PFG Code 40000, Style 56180 FIN 060-NAT, an 8 mil (0.20 mm) nylon fiber
11 release or peel ply, 125.4 g/m² weight, commercially available from Precision Fabrics Group
12 through U.S. distributors.

13 3. PFG Code 60001, Style 56009 FIN 060-NAT, a 5 mil (0.13 mm) polyester
14 fiber release or peel ply, 84.8 g/m² weight, commercially available from Precision Fabrics
15 Group through U.S. distributors.

16 4. PFG Code 60005, Style 56116 FIN 060-NAT, a 6 mil (0.15 mm) polyester
17 fiber release or peel ply, 108.5 g/m² weight, commercially available from Precision Fabrics
18 Group through U.S. distributors.

19 EXAMPLE- Adhesive

20
21 Although the 3M AF 163-2K adhesive film described above was required by the
22 airframer, another adhesive 16b was additionally tested for enhancing performance: in
23 particular, 3M(TM) SCOTCH-WELD(TM) Structural Adhesive Film AF 163-3M commercially
24 available from 3M Aerospace and Aircraft Maintenance Department, St. Paul, MN. This
25 product is a thermosetting modified epoxy structural adhesive in film form having 5.5 mil
26 (0.14 mm) thickness and 0.030 Lb/ft² (146 g/m²) weight.

27
28 Many combinations of the above listed breathers, bleeders, peel plies, and adhesives
29 were tested for exploring benefits and disadvantages thereof.

30 Reference tests were conducted without any peel ply in which an impervious film was
31 placed between the adhesive and breather resulting in maximum excess flash substantially
32 greater than with a peel ply.

33 One, two, and three plies of the release or peel materials were tested.

34 One and two plies of different release or peel materials were also tested.

35 Most testing was conducted with the common Airtech N-10 breather identified above,
36 but different breather plies were also tested in one, two, and three plies.

37 Most testing was conducted with the common 3M AF 163-2K adhesive identified
38 above, but a different adhesive was also tested.

1 In particular, the 3M AF163-3M adhesive identified above failed to provide sufficient
2 viscous flow during thermal curing resulting in unacceptable variation in flash size including
3 invisible flash locations, which in turn failed to visibly confirm complete bonding of the lap
4 joint.

5 Various disadvantages of these many combinations of testing include fundamentally
6 the failure to effectively reduce excess adhesive flash.

7 Some tests showed unacceptable variability in size of the flash or fillet along the
8 perimeter edges.

9 Some tests had local hidden flash in which no excess adhesive was discharged, and
10 therefore visible confirmation of a complete adhesive bond could not be established.

11 The multiple plies of release or peel and breather plies increased complexity of the
12 vacuum bagging bonding process, and associated cost, without suitable benefit.

13 And, some tests had unacceptable tearing of the peel ply during removal which would
14 therefore require additional post-bonding effort.

15 Accordingly, the adhesive metal bonding process disclosed above has been tested to
16 uncover and identify both unacceptable and acceptable combinations of vacuum bagging
17 materials for thermally curing the bonding adhesive, with specific combinations identified to
18 effectively reduce adhesive flash formed at the bond joint 22 between the solid metal
19 components 10,12, and thus eliminating the need for post-bonding deflashing procedures and
20 the associated time and expense therefor.

21 The elimination or reduction of excessive flash formation during the adhesive bonding
22 method now provides a new process in the manufacturing industry to supplement the
23 presently known post-bonding adhesive flash removal methods.

24 Flash control and reduction may now be more efficiently achieved with a simple
25 vacuum bagging process for metal-to-metal adhesive bonding at reduced manufacturing cost
26 rendering unnecessary post-bonding deflashing for specific applications.

27 Particularly significant in the flash control metal bonding process described above is
28 the now proven ability to effectively reduce excess flash by revising only the peel ply itself in
29 a simple, but effective, combination of single, versus multiple, plies for each of the peel ply
30 and breather ply inside the common vacuum bag. The additional use of the flashbreaker tape
31 at desired locations further reduces excess flash locally.

32 And in other applications, some or all of the variables disclosed above may be tested
33 in various combinations for evaluating efficacy of significantly reducing excess flash for
34 eliminating the otherwise required post-bonding deflashing operations known in the art.

35 Disclosed above are preferred and exemplary embodiments of the present invention in
36 which the various features thereof have been described in subject matter using general terms
37 and more specific terms, with such features being progressively combined in successive detail
38 for one or more exemplary detailed species in optional combinations as described above, and

1 as optionally recited in the appended claims.

2 Accordingly, any one or more of the described specific features may be optionally
3 combined with the corresponding general features in defining various modifications of the
4 invention in various combinations and sub-combinations in accordance with the above
5 description in its entirety. The following claims therefore may be interpreted and modified or
6 amended or supplemented with additional claims without restriction from such appended
7 claims themselves in accordance with the original subject matter presented above as being
8 merely exemplary of the true spirit and scope of the invention.

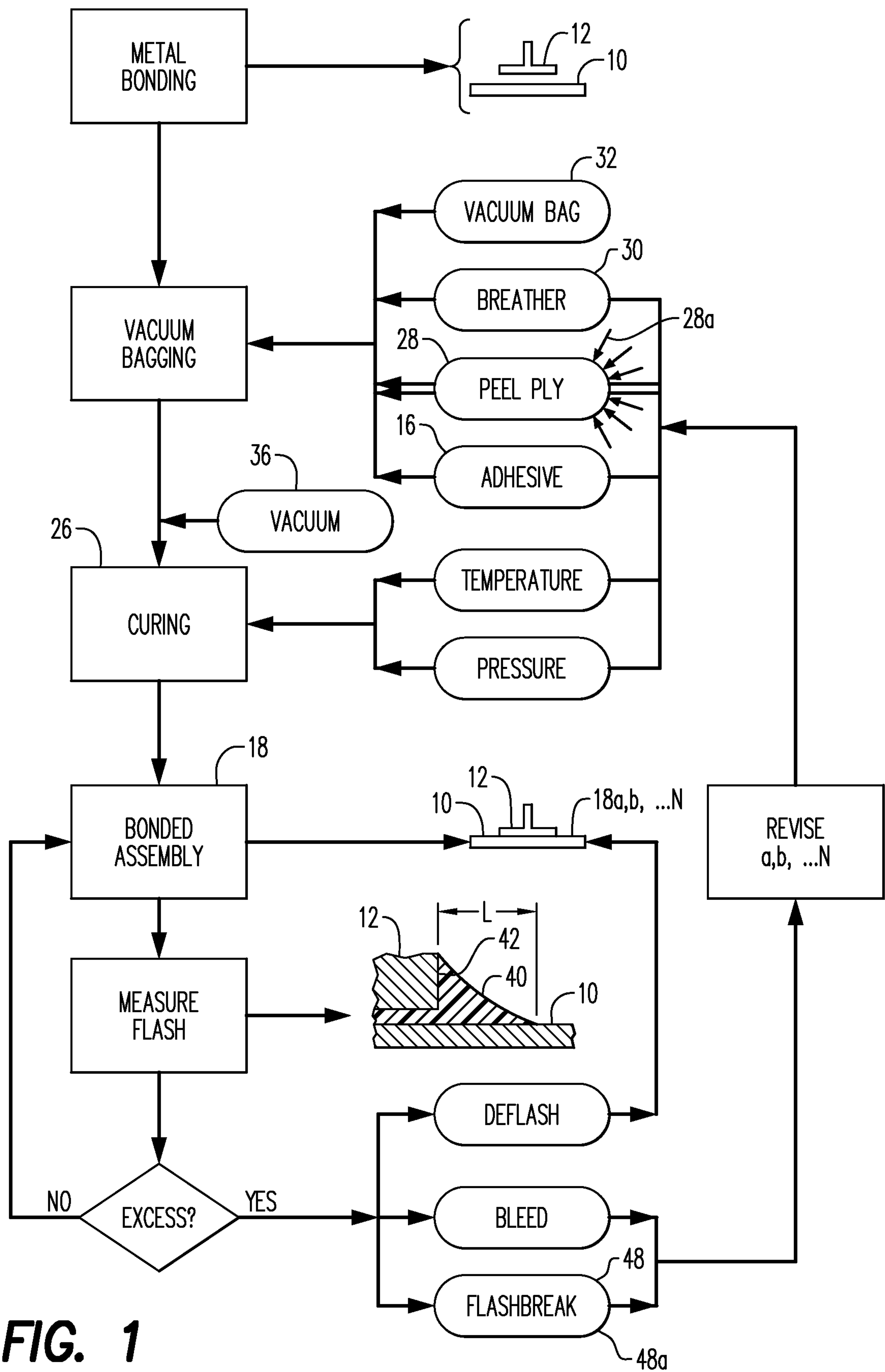
CLAIMS

1. A method of bonding together first and second metal plates (10,12) comprising:
supporting said first plate (10) atop a corresponding mold (20);
positioning said second plate (12) atop said first plate (10), with a thermosetting adhesive (16) therebetween to form a lap joint (22);
vacuum bagging said second plate (12) atop said first plate (10), with a porous peel ply (28) covering said lap joint (22) and a porous breather ply (30) covering said peel ply (28);
applying a vacuum through said breather ply (30) to clamp said second plate (12) atop said first plate (10);
thermally curing said adhesive (16) to bond said second plate (12) to said first plate (10) at said lap joint (22), with said breather and peel plies (30,28) being preselected to capture adhesive seepage (38) from said lap joint (22) during said curing to correspondingly reduce cured adhesive flash (40) exposed on said first plate (10); and
removing said breather and peel plies (30,28) from atop said first and second plates (10,12) and removing therewith said captured adhesive seepage (38).
2. A method according to claim 1 wherein:
said second plate (12) terminates at a step (42) atop said first plate (10) to expose said adhesive (16) at said joint (22);
said peel ply (28) is applied directly atop both said first and second plates (10,12) in a bridge therebetween and conforms with said step (42) adjacent to said adhesive (16) in said joint (22); and
said peel ply (28) is preselected in porosity for locally channeling to said breather ply (30) said adhesive seepage (38) along said step (42) during said curing.
3. A method according to claim 1 or claim 2 further comprising:
placing said mold (20) and vacuum bagged first and second plates (10,12) in an autoclave (26);
curing said adhesive (16) under heat and pressure in said autoclave (26) for effecting viscous seepage (38) thereof from said joint (22); and
preselecting said peel ply (28) in combination with said adhesive (16), breather ply (30), curing temperature, and curing pressure for promoting said viscous adhesive seepage (38) through said peel ply (28) into said breather ply (30).
4. A method according to any of claims 1-3 wherein said peel ply (28) is preselected to replace an otherwise required deflashing post-operation (44,46) following thermal curing of said adhesive (16) in a metal bonding method for said first and second plates (10,12) using a different peel ply (28).

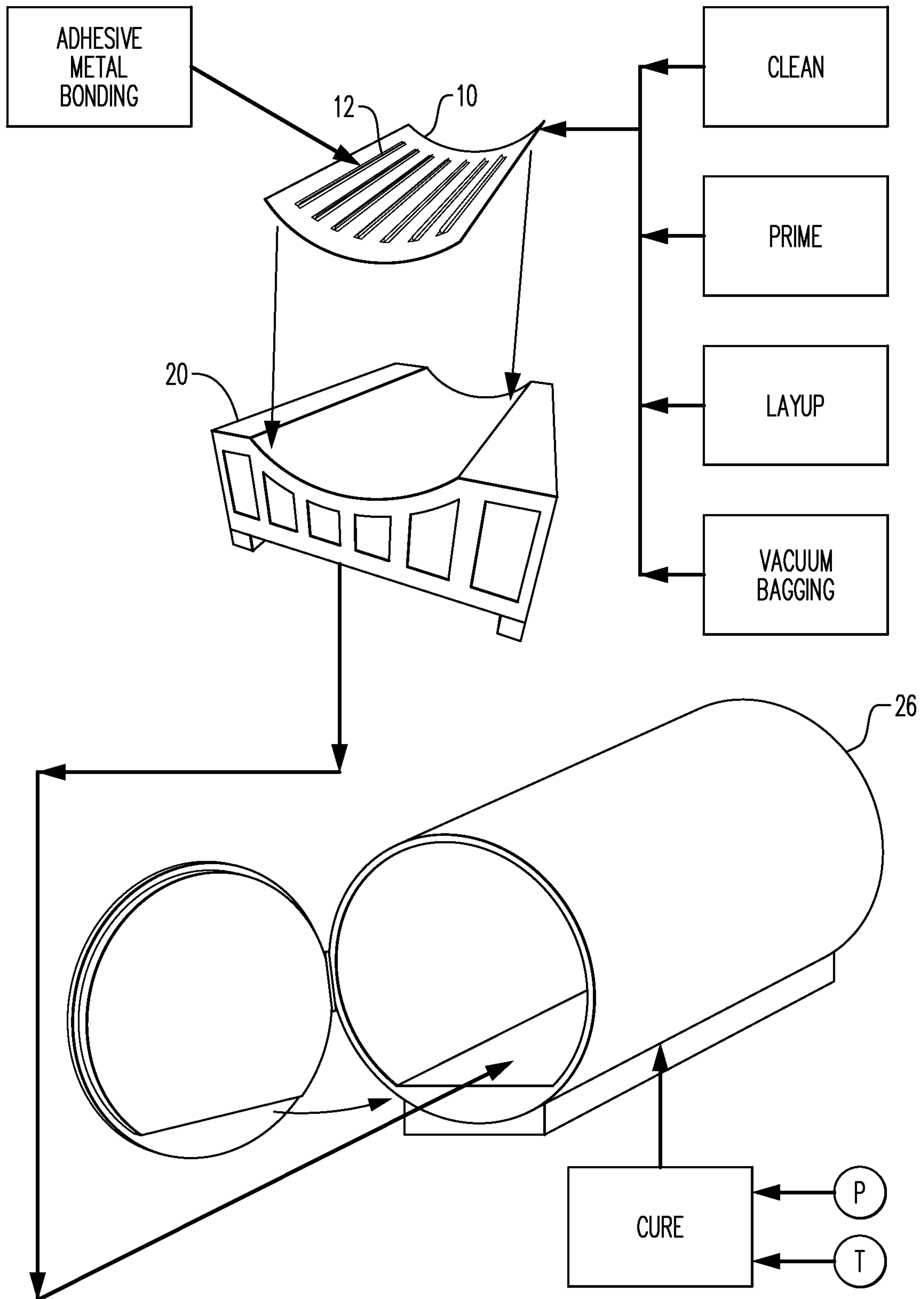
5. A method according to any of claims 1-4 further comprising:
 - applying a masking flashbreaker tape (48) atop said first plate (10) along said step (42) adjacent to said exposed adhesive (16);
 - applying said peel ply (28) directly atop said flashbreaker tape (48) in said step (42) and extending laterally oppositely directly atop both said first and second plates (10,12);
 - curing said adhesive (16) for channeling said seepage (38) both atop said flashbreaker tape (48) and through said peel ply (28) at said step (42); and
 - removing said breather and peel plies (30,28) and said captured adhesive seepage (38), and additionally removing said flashbreaker tape (48) to tear flash (40) thereon from said joint (22).
6. A method according to any of claims 1-5 wherein said peel ply (28) is selected from a plurality of different pre-existing peel plies (28) commercially available from a plurality of different manufacturers.
7. A method according to any of claims 1-6 further comprising:
 - adhesively bonding together said first and second plates (10,12) in an original bonding method including an original peel ply (28a) to produce an initial bonded assembly (18a);
 - measuring size of flash (40) atop said first plate (10) along said step (42) in said initial bonded assembly (18a);
 - revising said bonding method for a second set of said first and second plates (10,12) to include at least one method difference in said vacuum bagging process and thermal curing;
 - adhesively bonding together said second set of first and second plates (10,12) using said revised bonding method to produce a second bonded assembly (18b);
 - measuring size of flash (40) atop said first plate (10) along said step (42) in said second bonded assembly (18b); and
 - revising sequentially said difference in sequential bonding methods to produce corresponding bonded assemblies (18) until measured flash (40) in said revised bonding method is less than measured flash (40) in a previous bonding method.
8. A method according to claim 7 wherein said bonding method difference includes replacing said original peel ply (28a) with a different peel ply (28) having different characteristics.
9. A method according to claim 8 wherein only said peel ply (28) difference is revised in said sequential bonding methods.

10. A method according to any of claims 7-9 further comprising:
applying an original flashbreaker tape (48a) atop said first plate (10) along said step (42) adjacent to said exposed adhesive (16) in said original bonding method for masking said first plate (10) from said flash (40); and
said bonding method difference additionally includes replacing said original flashbreaker tape (48a) with a different flashbreaker tape (48) having different characteristics.
11. A method according to claim 10 wherein only said peel ply (28) and flashbreaker tape (48) differences are revised in said sequential bonding methods.
12. A method according to any of claims 1-11 wherein said vacuum bagging comprises:
applying a single peel ply (28) directly atop said first and second plates (10,12) to conform with said step (42);
applying a single breather ply (30) directly atop said single peel ply (28);
applying a vacuum bag (32) sealingly joined around a perimeter thereof to said first plate (10) to cover said breather and peel plies (30,28) and said second plate (12); and
said first and second plates (10,12) are imperforate at said lap joint (22), with said thermosetting adhesive (16) therein being exposed solely along said step (42) for locally seeping through said peel ply (28) at said step (42).
13. A method according to any of claims 1-12 wherein said peel ply (28) is further preselected for tear resistance with said captured adhesive seepage (38) to avoid tearing thereof upon removal of said breather and peel plies (30,28) after said thermal curing of said adhesive (16).
14. A method according to any of claims 1-13 further comprising cleaning and priming said first and second metal plates (10,12) prior to applying said thermosetting adhesive (16) in said lap joint (22).
15. A method according to any of claims 1-14 wherein:
said first and second metal plates (10,12) comprise aluminum;
said preselected breather ply (30) comprises Airtech AIRWEAVE^(®) N10 non-woven polyester fibers;
said preselected peel ply (28) is selected from the group consisting of Cytec A100 woven nylon fabric and Cytec A8888 woven nylon fabric; and
said adhesive (16) comprises 3M(TM) SCOTCH-WELD(TM) thermosetting epoxy structural adhesive film AF 163-2K (0.060 Lb/ft² (293 g/m²) weight species) having a predetermined thermal and pressure curing cycle.

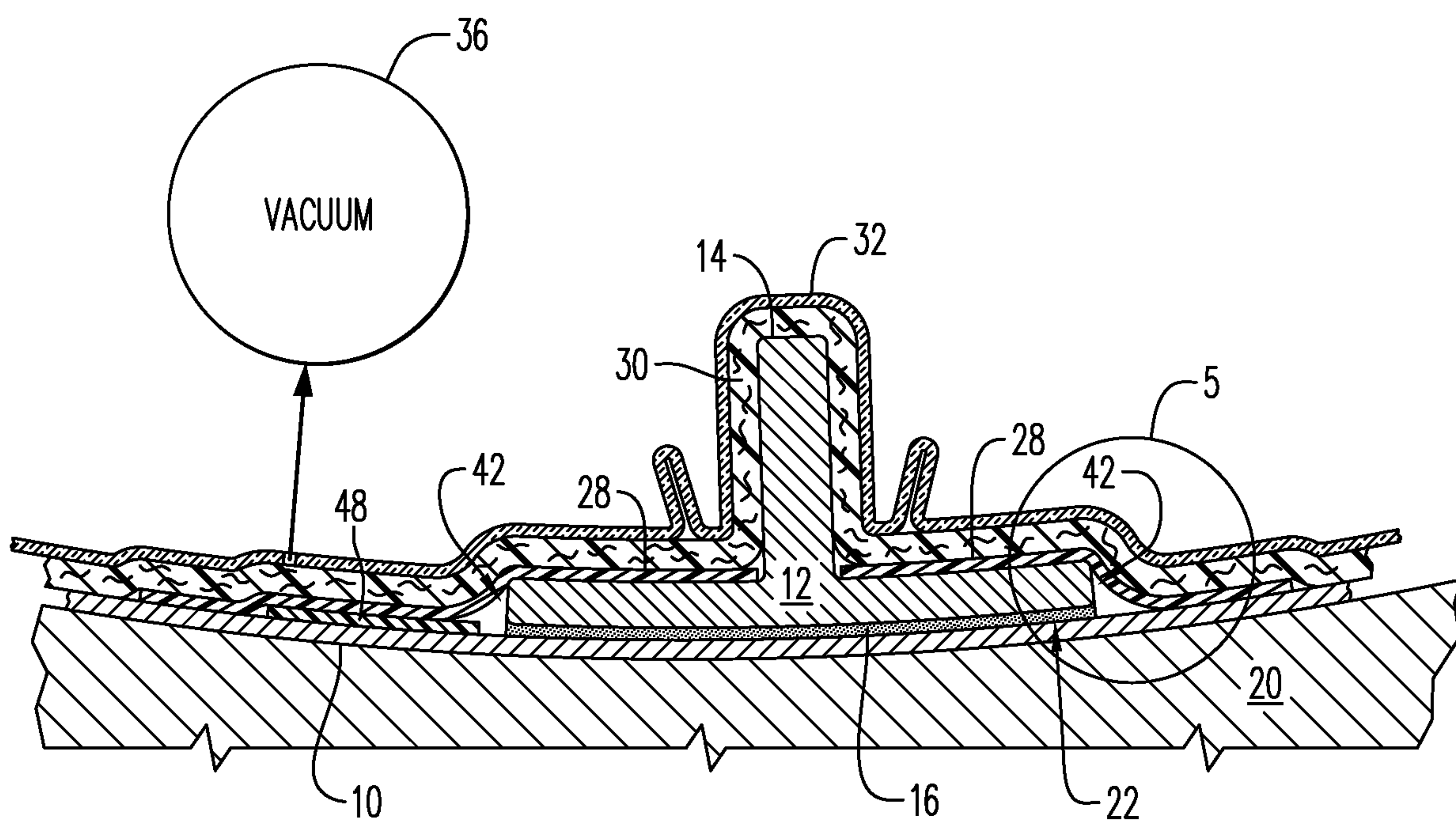
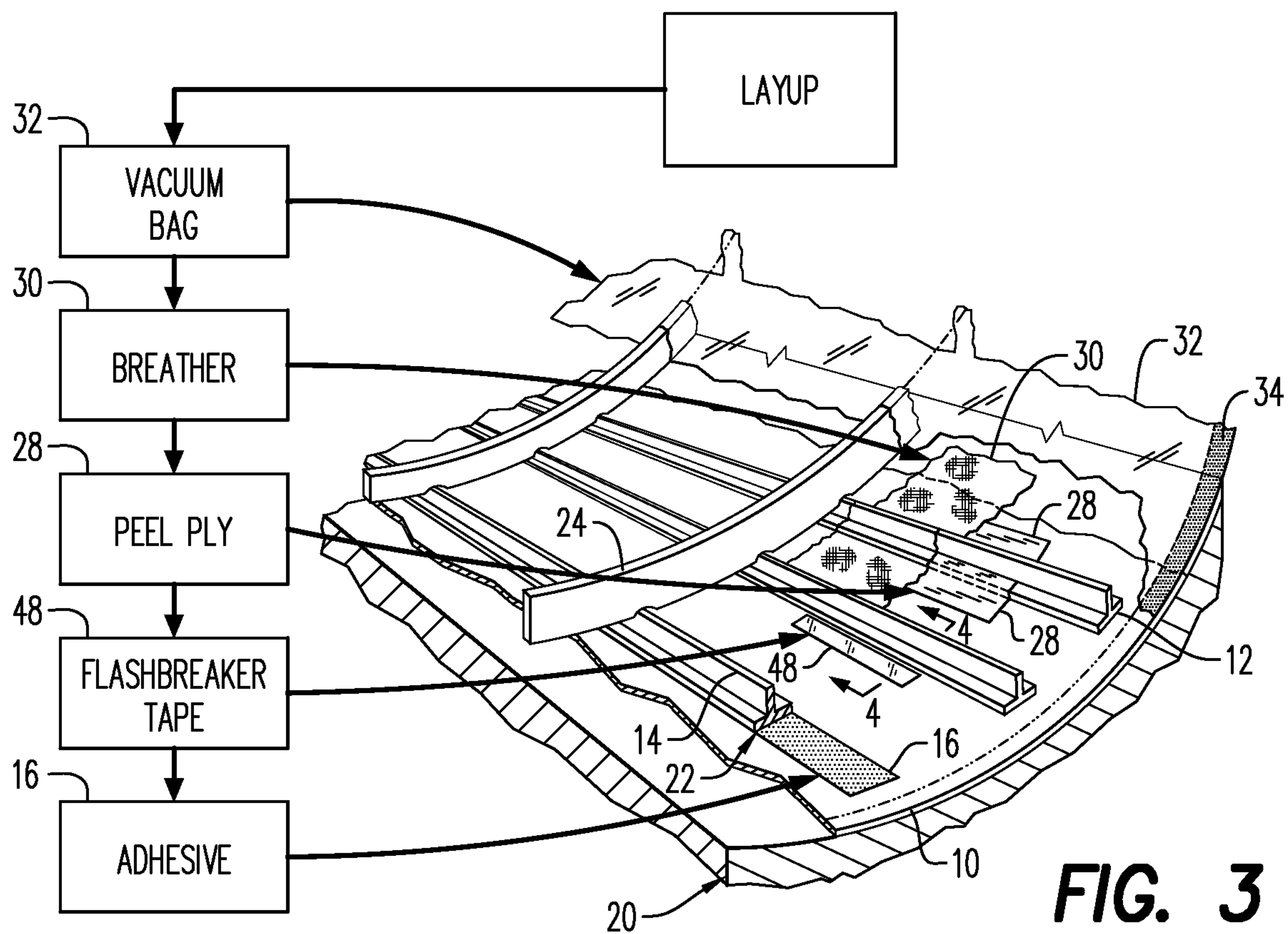
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**FIG. 1**

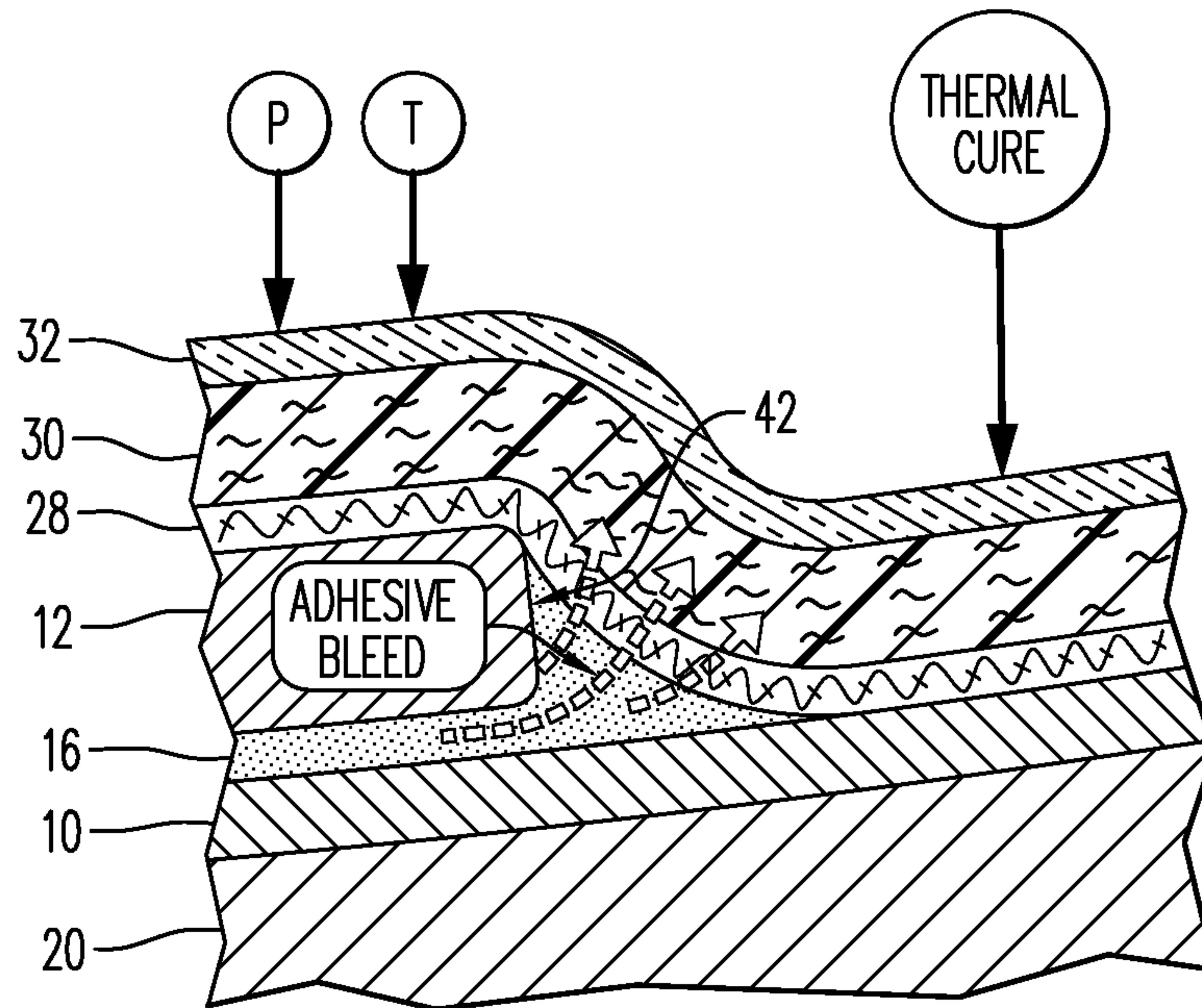
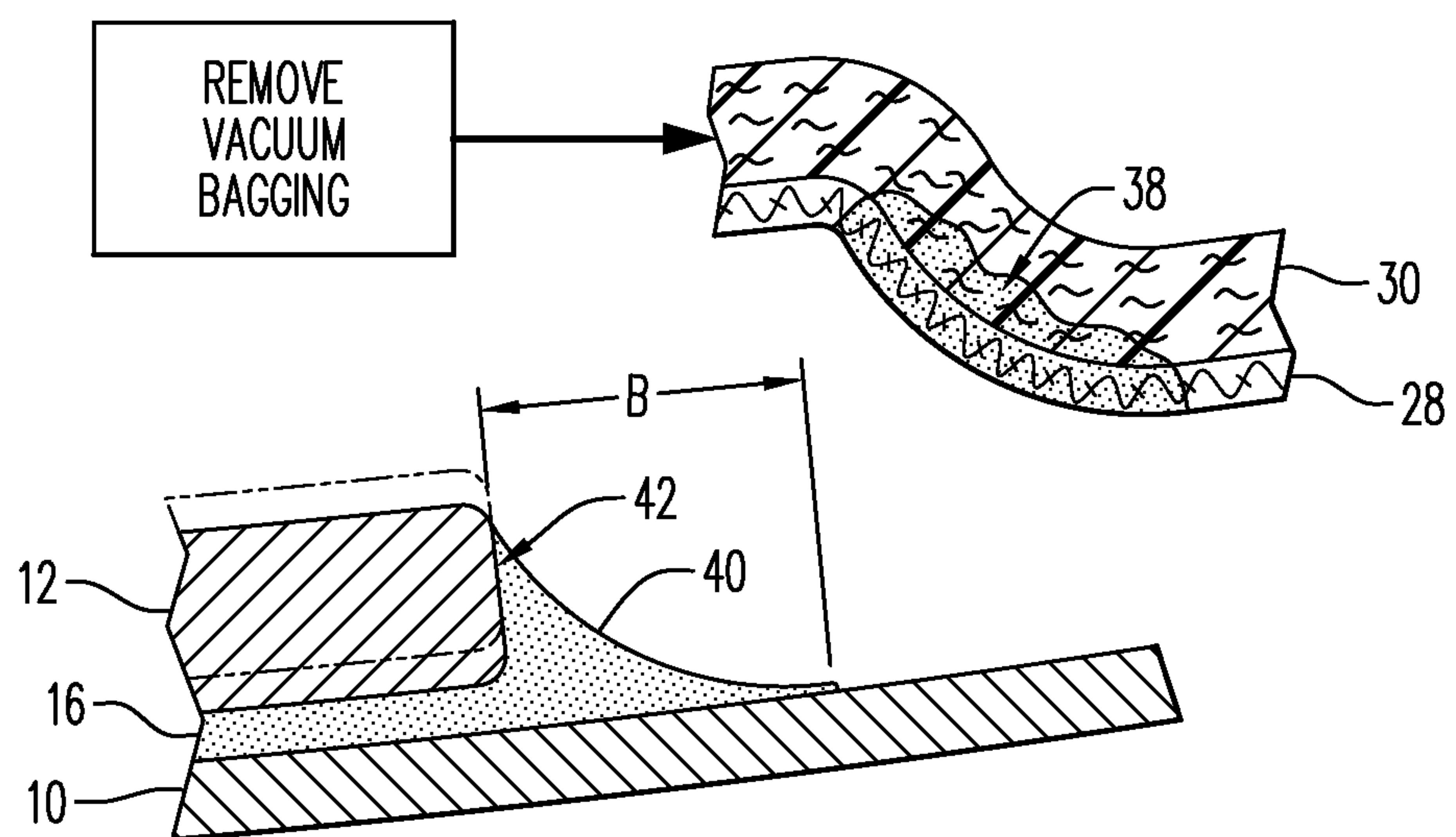
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**FIG. 2**

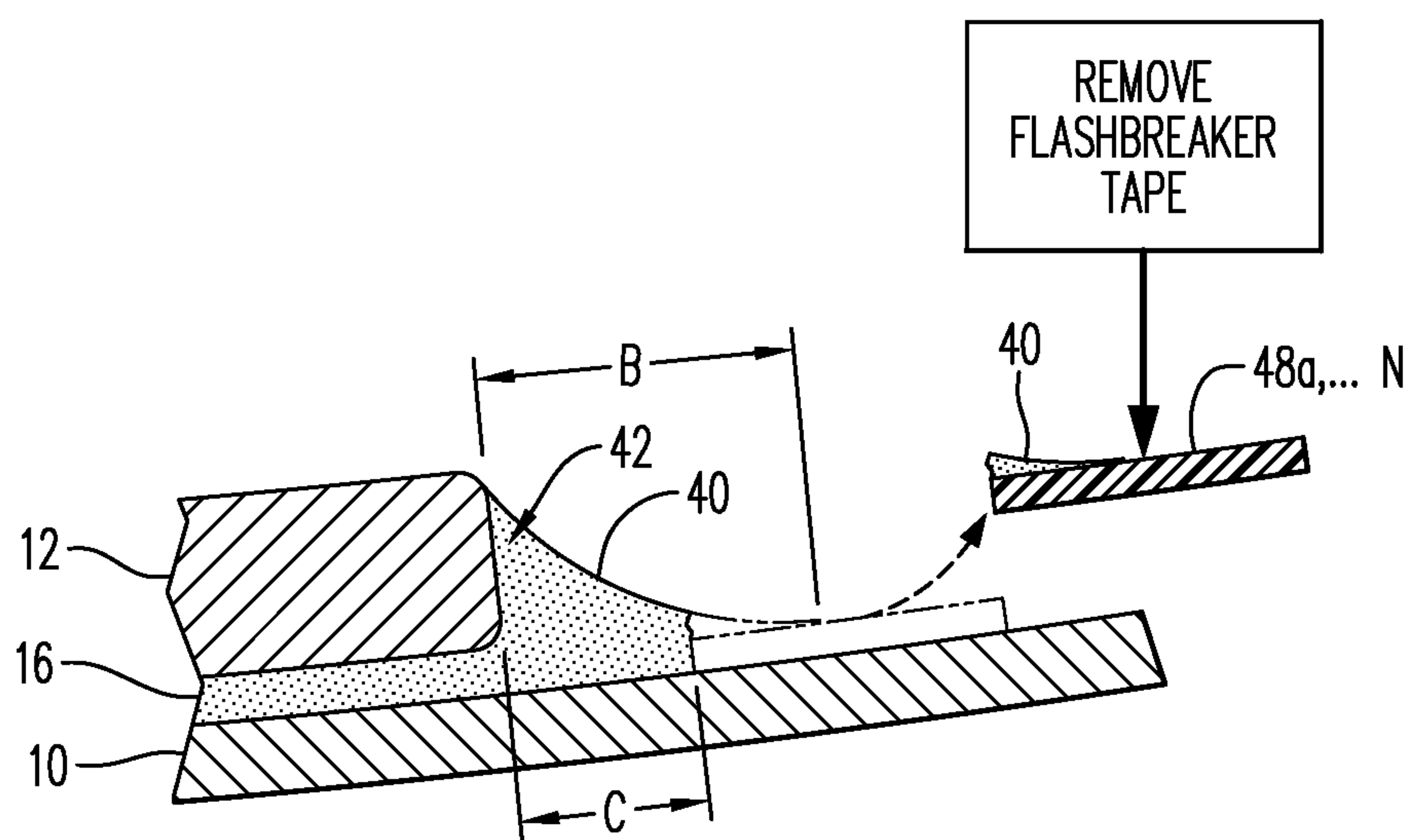
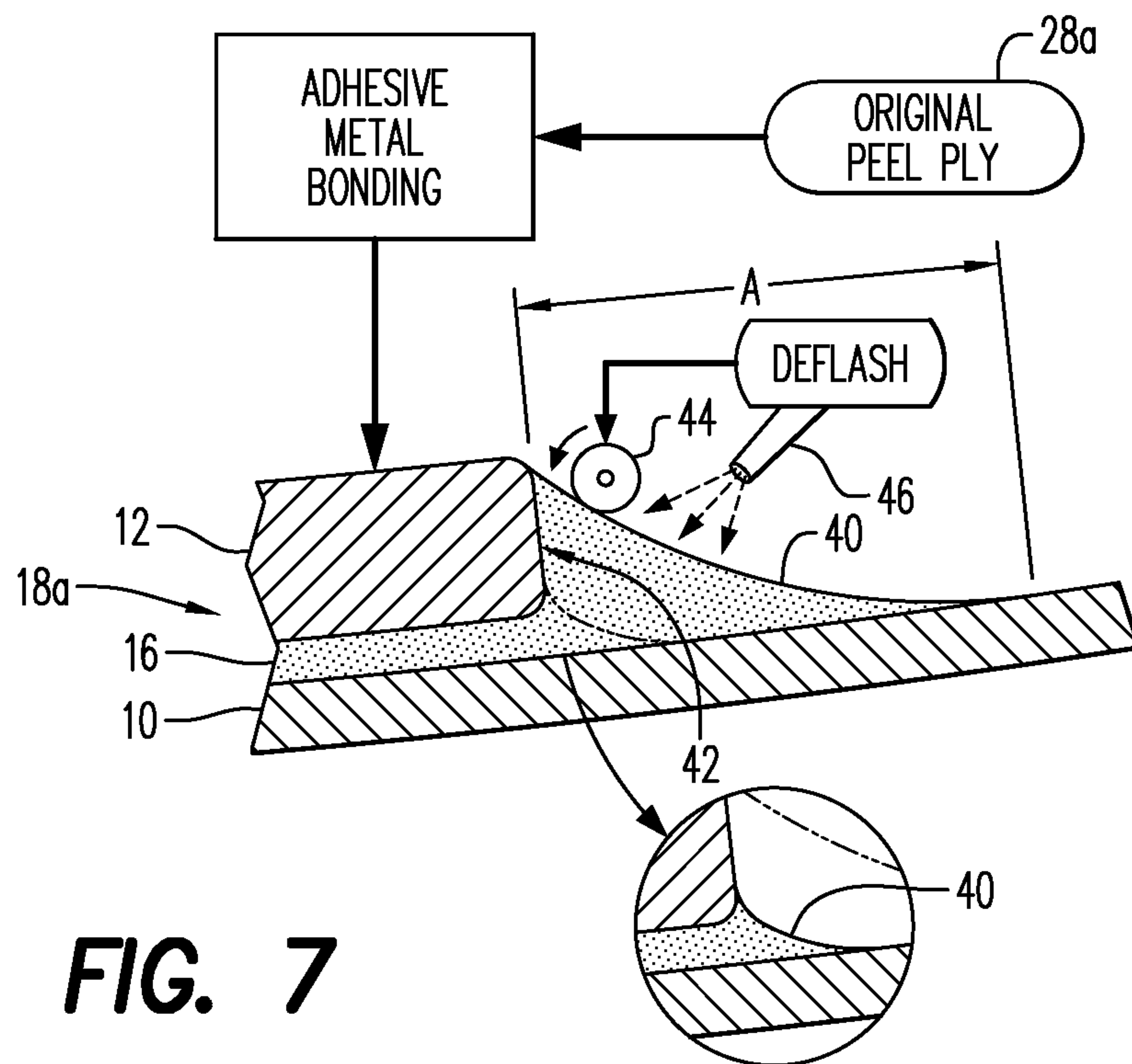
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**FIG. 5****FIG. 6**

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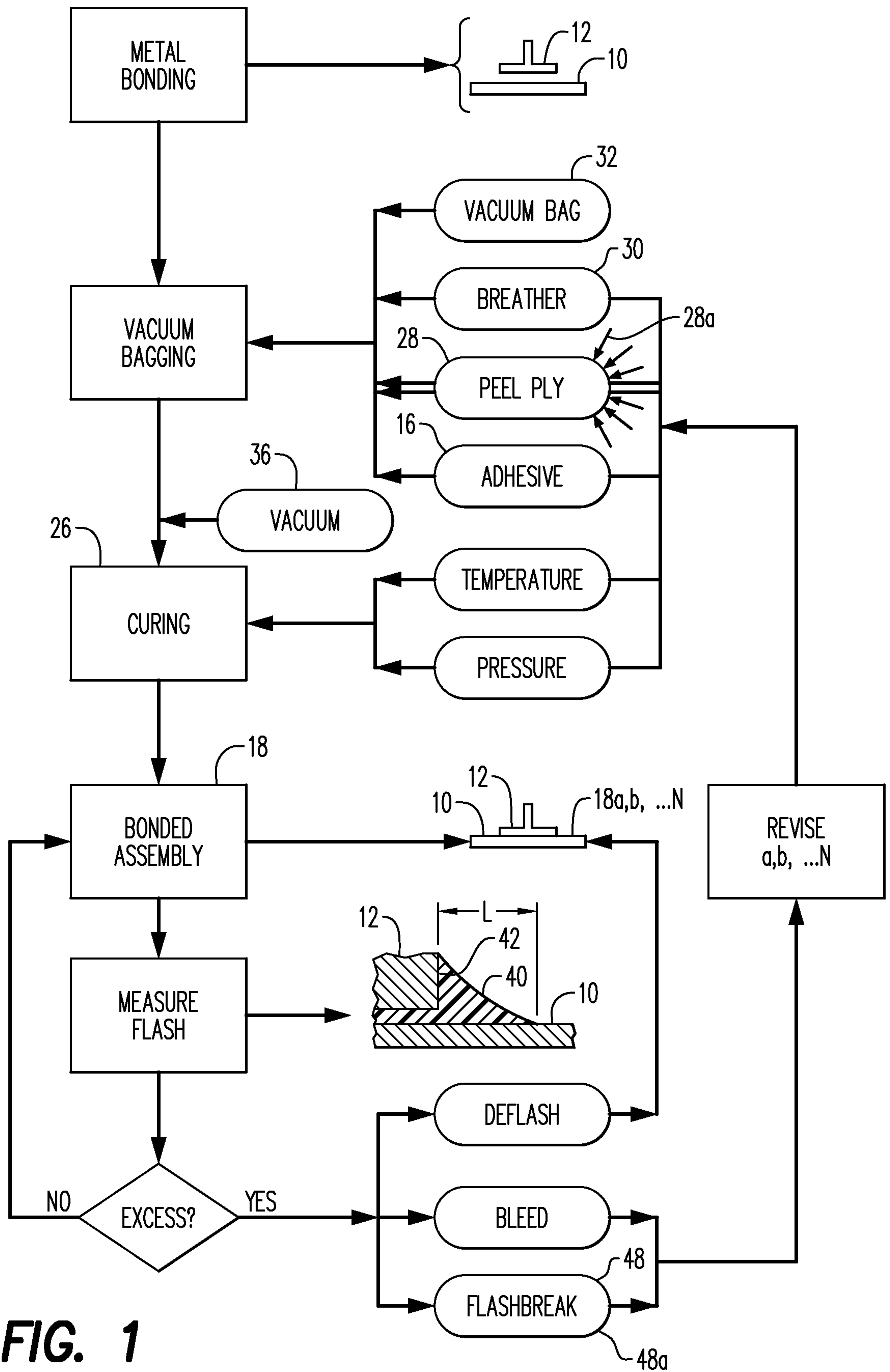


FIG. 1