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(54) METHOD FOR TEMPERING AN ALUMINUM ALLOY

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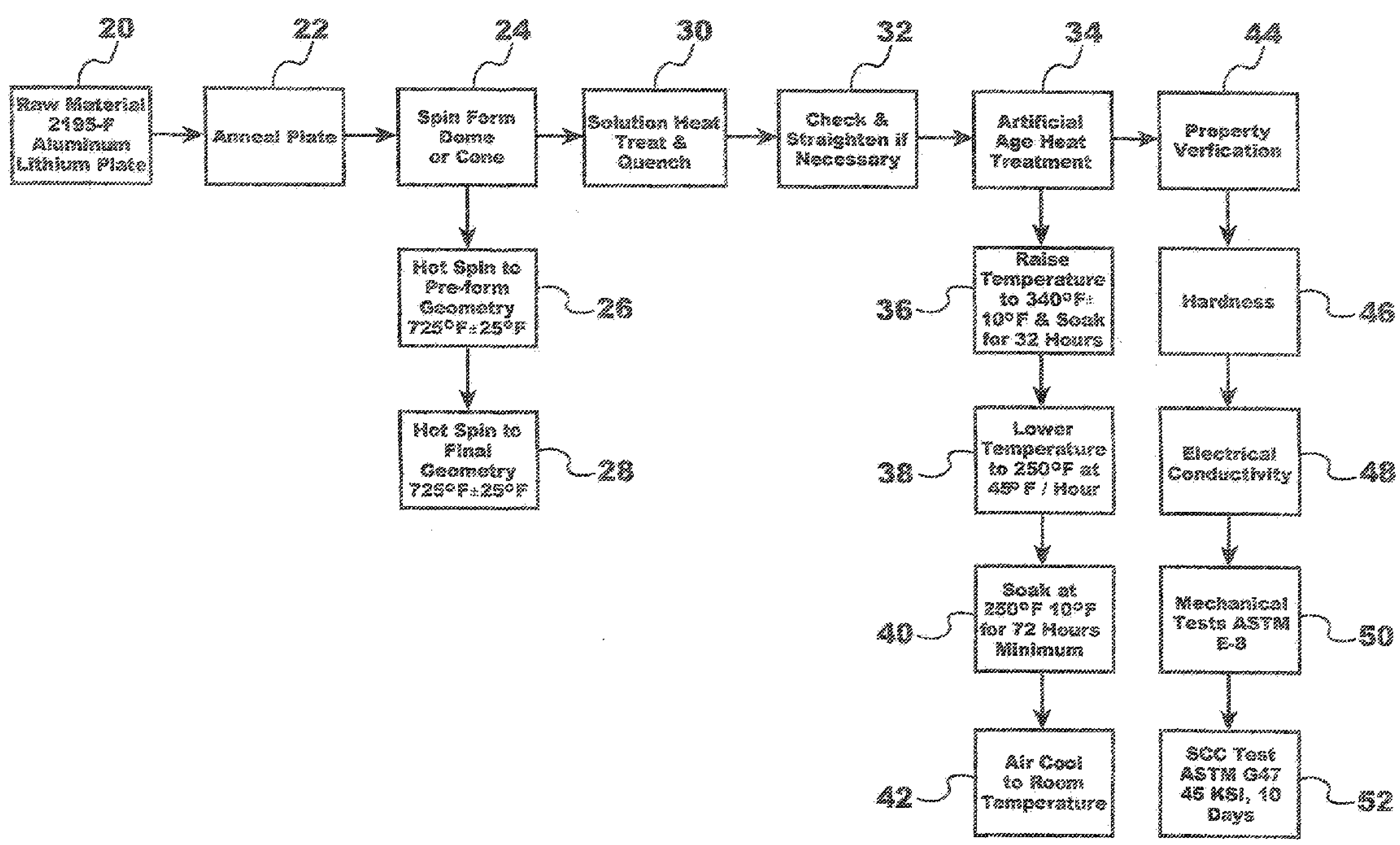
(57) **ABSTRACT**

A process for tempering large aluminum lithium alloy component parts to achieve high strength capability and resistance to stress corrosion cracking without the need for the prior art step of cold working the alloy components parts. The process achieves the desired material properties by the use of two novel soaking time periods and the use of novel controlled temperature selection at the two respective soaking times as well as carefully controlling the temperature decrease from one soaking time period to the other.



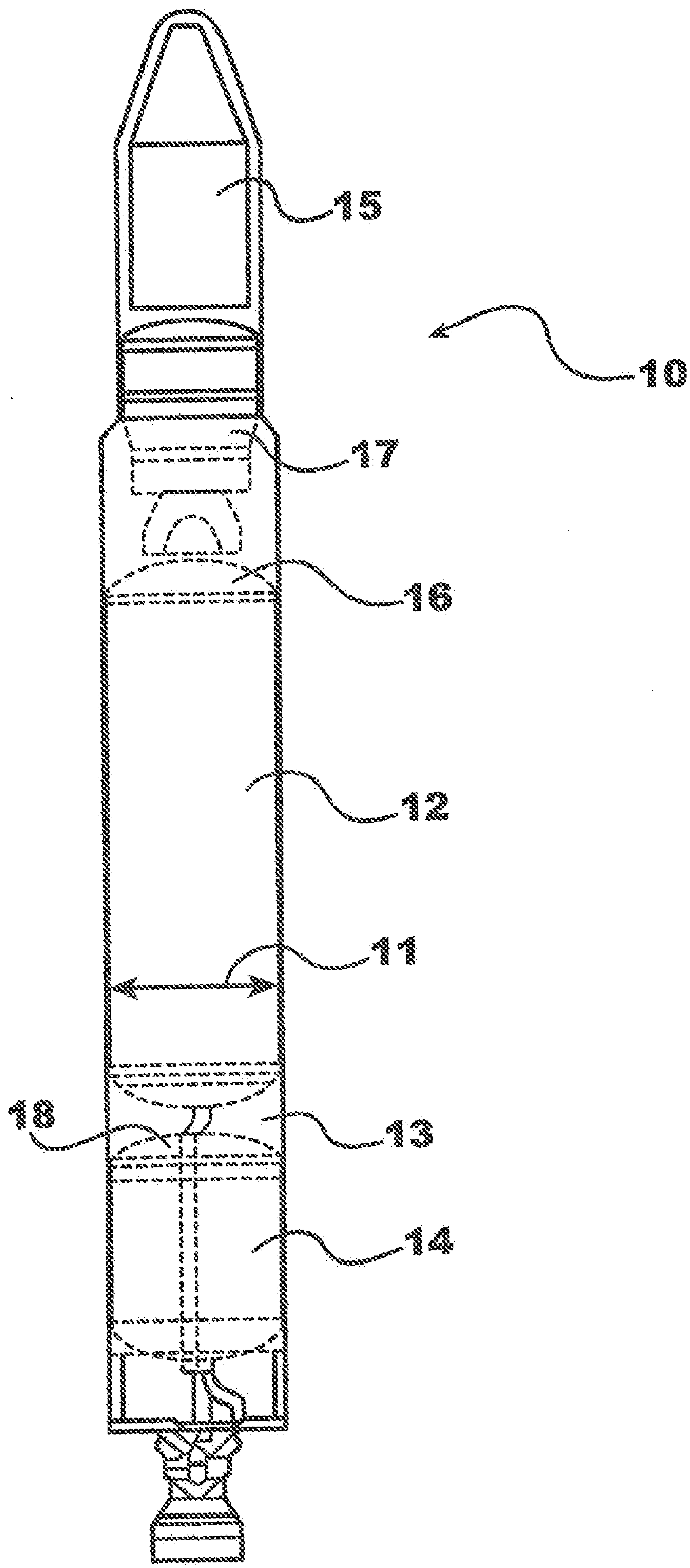


Fig. 1

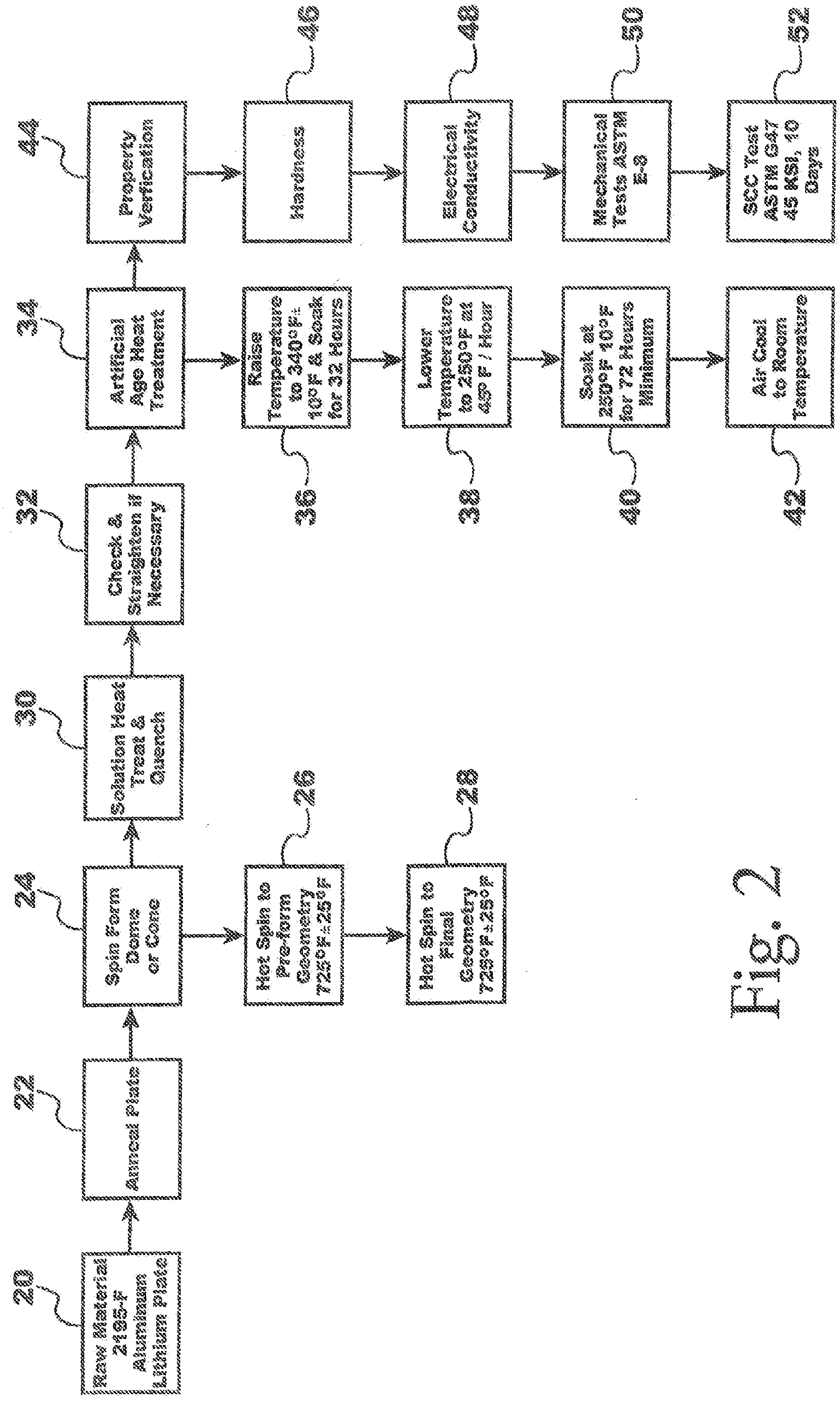

20
Raw Material 2195-F Aluminum Lithium Plate
22
Anneal Plate
24
Spin Form Dome or Cone
26
Hot Spin to Pre-form Geometry 725°F ±25°F
28
Hot Spin to Final Geometry 725°F ±25°F
30
Solution Heat Treat & Quench
32
Check & Straighten if Necessary
34
Artificial Age Heat Treatment
36
Raise Temperature to 340°F± 10°F & Soak for 32 Hours
38
Lower Temperature to 250°F at 45°F / Hour
40
Soak at 250°F 10°F for 72 Hours Minimum
42
Air Cool to Room Temperature
44
Property Verification
46
Hardness
48
Electrical Conductivity
50
Mechanical Tests ASTM E-8
52
SCC Test ASTM G47 45 KSI, 10 Days

Fig. 2

Fig. 3

Data Comparison	Mechanical Properties Data							Stress Corrosion Data	
Industry Standard Vs. Spincraft	Thickness Range		Orientation	UTS KSI	YTS .2% KSI	% Elongation		Stress KSI	Duration Days
SAE Aerospace Material Spec. AMS 4472 TABLE 3A	1.5	2.3	L	77.0	73.0	6.0%			
	1.5	2.3	LT	80.0	72.0	5.0%			
	1.5	2.3	ST	81.0	69.0	2.0%		45.0	30
SPINCRAFT DATABASE	1.0	1.8	L	80.4	71.2	10.3%			
	1.0	1.8	LT	78.4	70.7	7.9%			
	1.0	1.8	ST	75.0	68.1	6.4%		45.0 & 55.0	10

METHOD FOR TEMPERING AN ALUMINUM ALLOY

[0001] This application is a continuation-in-part of U.S. application Ser. No. 12/387,966 filed May 8, 2008 that claims priority from Provisional Application Serial No. 61/133,207 filed Jun. 26, 2008.

FIELD OF THE INVENTION

[0002] This present invention relates to the manufacture of metallic domes and conical components used in launch vehicles, and in particular, components produced using the aluminum lithium alloy known as 2195.

BACKGROUND OF THE INVENTION

[0003] Aluminum lithium alloy, 2195, is used in launch vehicle applications where its lower density, higher modulus and comparable strength, and desirable cryogenic service properties make it attractive. When components are manufactured to industry guidelines for this material, the 2195 aluminum lithium alloy also possesses resistance to stress corrosion cracking. As the mass for launch vehicle payloads continues to grow, use of this alloy for fuel tanks and vehicle structures has become a requirement by NASA and other launch vehicle service providers. In supporting this requirement, it becomes necessary to supply 2195 alloy in its highest strength condition and possessing resistance to stress corrosion cracking.

[0004] To achieve the high strength capability and resistance to stress corrosion cracking of this material, manufacturers solution heat treat the material which is then followed by a rapid quenching in water or in a solution of glycol and water. After the quench, the material is uniformly cold worked. The cold working process is typically a stretching operation that is controlled from 1 to 3 percent. Upon completing the cold working operation, the component is then artificially aged to achieve high strength and resistance to stress corrosion cracking. The thermal treatment and cold working parameters are well known and have been established as the industry standard practice by 2195 material producers to achieve ideal conditions for 2195 aluminum lithium alloy. This ideal condition would be defined as temper designation T8X where the 2195 material is solution heat treated, quenched, cold worked (stretched) 1% to 3% to an intermediate temper T3X, and artificially aged to T8X. For some launch vehicle tank and structural components, it is not possible to uniformly apply the cold work that is required to achieve the desired characteristics of 2195 aluminum lithium alloy due to the size and geometric shape of the parts. Single piece tank domes and cones produced from a 2195 aluminum lithium plate/blank using the metal spinning process fall into this category. It is in the manufacture of these components that current manufacturing methods fall short.

[0005] One possible solution is to manufacture metal spinning equipment capable of uniformly applying the cold work necessary to achieve the high strength and resistance to stress corrosion cracking of 2195 aluminum lithium alloy. However, it is unlikely that metal spinning manufacturers will invest in this equipment given the relatively low volume of parts. There is also the question as to whether cold work using compressive forces developed from metal spinning is likely to yield the desired condition given that industry data is based on cold work using tension forces. The unfavorable return on investment and questionable success of this solution make this an unattractive option.

[0006] A method of manufacturing these components and achieving the high strength and resistance to stress corrosion cracking without the addition of cold work after solution heat treatment and quench is not known in the art. Parts produced using 2195 material without the post quench cold work would carry the T62 temper designation for which there is no published industry standard for strength and resistance to stress corrosion cracking requirements.

SUMMARY OF THE INVENTION

[0007] The invention is a method of manufacturing domes and cones using the metal spinning process and alternative heat treatment parameters to achieve the same properties attainable as if the part were cold worked although this step has been eliminated. The preferred embodiment of the method includes the steps of forming and heat treating 2195 aluminum lithium alloy domes and cones.

[0008] It is an aspect of the invention to provide a method of treating 2195 aluminum lithium alloy in order to achieve the same favorable properties obtained using prior art methods requiring cold working of the produced part.

[0009] It is another aspect of the invention to provide a method of treating 2195 aluminum lithium alloy that can be used with extremely large parts requiring spinning techniques to manufacture such parts.

[0010] It is still another aspect of the invention to provide a method of treating 2195 aluminum lithium alloy that possesses high tensile and yield strengths.

[0011] It is another aspect of the invention to provide a method of treating 2195 aluminum lithium alloy that has a high resistance to stress corrosion cracking

[0012] Finally, it is an aspect of the invention to provide a method of treating 2195 aluminum lithium alloy that provides parts for launch vehicles which meet performance parameters yet can be made using existing manufacturing equipment.

[0013] These aspects of the invention are not meant to be exclusive and other features, aspects, and advantages of the present invention will be readily apparent to those of ordinary skill in the art when read in conjunction with the following description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. **1** is an illustration of a multi-stage rocket, which shows the type of components that can be made using the process taught by the invention.

[0015] FIG. **2** is a flow chart of the preferred embodiment of the method in accordance with the present invention.

[0016] FIG. **3** is a table of material properties that have been achieved by producing parts in accordance with the present invention compared to material produced with the cold work outlined in a published industry material standard.

DETAILED DESCRIPTION OF THE INVENTION

[0017] As shown in FIG. **1**, the illustration of the multi-stage rocket **10** is a typical structure that has parts that can be made using the method taught herein. Payload **15** is placed within the payload fairing structure. Second stage rocket engine **17** powers payload **15** during the final leg of the journey to achieve a successful orbit. In the first stage of rocket **10**, note that primary tank **12** and secondary tank **14**

have a domed top and bottom **16** and **18** respectively. These tanks have an extremely large diameter **11** and are particularly well suited to be manufactured using the present invention. The thrust cone **17** (typically composite materials) is also a component part that would be preferably made using the method disclosed herein.

[0018] Referring now to FIG. **2**, the flow chart showing process **54** for tempering 2195 aluminum lithium alloy is described. The starting material form **20** is in the mill temper known as the F condition. The material plate **20** is annealed in step **22** in accordance SAE Aerospace Material Specification AMS 2770 for 2XXX aluminum alloy. The dome or cone forming is done in step **24** by a spinning process. The dome or cone forming is performed in steps **26**, **28** at a controlled temperature of 725° F.±25° F. using the metal spinning process and/or the stretch forming process developed as disclosed in U.S. Pat. No. 6,199,419. Upon completing the forming operation, the component is solution heat treated, in accordance with SAE Aerospace Material Specification AMS 2770 using a set temperature of 950° F.±10° F. for a time in accordance with AMS 2770 Table 3 and then rapid quenched in either water or glycol water solution as indicated in step **30**. If necessary, the component may be straightened after solution heat treatment to remove minor distortion resulting from the rapid quench, step **32**. The component is then artificially aged in step **34**. In step **36**, the component temperature is raised to 340° F.,±5° F. The component is then "soaked" (industry term of art meaning to allow it to remain at that temperature) for 32 hours±5 minutes. Then, in step **38**, the component temperature is lowered to 250° F.±5° F. at a decreasing rate of 45° F. per hour. Then, the component part is "soaked" again for 72 hours±5 minutes in step **40**. Finally, in step **42**, the component part is air cooled to room temperature. After the completion of the above referenced steps, the component part carries the T62 temper designation and is tested for its properties beginning in step **44**. The various parameters that are tested are hardness, step **46**; electrical conductivity, step **48**; minimums achieved when practicing the invention, step **50** and, finally in step **52**, a SCC Test as specified.

[0019] Although the present invention has been described with reference to certain preferred embodiments thereof, other versions are readily apparent to those of ordinary skill in of the preferred embodiments contained herein.

What is claimed is:

1. A process for tempering an aluminum alloy blank to achieve high strength capability and resistance to stress corrosion cracking, said process comprising the steps of:

annealing said alloy blank in accordance with Aerospace Material Specification AMS 2770 for 2XXX aluminum alloy;

hot spinning the annealed alloy blank into a desired shape at a first controlled temperature;

solution heat treating said desired shape in accordance with SAE Aerospace Material Specification AMS 2770 using a set temperature of 950° F.±10° F. for a time in accordance with AMS 2770 Table 3;

rapidly quenching said desired shape in a liquid;

a first aging said desired shape to a second controlled temperature;

a first soaking of said desired shape at a first predetermined length of time;

lowering the second controlled temperature of said desired shape at a predetermined rate of decrease to a third controlled temperature;

a second soaking of said desired shape at a second predetermined length of time; and

air cooling said desired shape until said desired shape reaches room temperature.

2. The process of claim **1** comprising the additional step after said quenching step of:

straightening said desired shape to remove minor distortions that may be introduced by said quenching step.

3. The process of claim **1** comprising the additional step of:

testing said desired shape to determine the properties of said desired shape.

4. The process of claim **3** wherein said testing step has a least one test selected from the group of tests consisting of hardness, electrical conductivity, mechanical ASTM test, and a SCC test.

5. The process of claim **1** wherein said quenching liquid is water.

6. The process of claim **1** wherein said quenching liquid is a glycol water solution.

7. The process of claim **1** wherein said first controlled temperature is in the range of 725 degrees F.

8. The process of claim **1** wherein said second controlled temperature is in the range of 340 degrees F.

9. The process of claim **1** wherein said third controlled temperature is in the range of 250 degrees F.

10. The process of claim **1** wherein said temperature rate of decrease is in the range of 45 degrees F. per hour.

11. The process of claim **1** wherein said first soaking time is in the range of 32 hours.

12. The process of claim **1** wherein said soaking time is in the range of 72 hours.

13. The process of claim **1** wherein said aluminum alloy blank is made from 2195 aluminum lithium alloy.

14. The process of claim **1** wherein said desired shape is a domed top of a rocket.

15. The process of claim **1** wherein said desired shape is a thrust cone of a rocket.

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