

 <p>161 Thorn Hill Road Warrendale, PA 15086-7527</p>	<p style="text-align: center;">PD 6103</p> <p style="text-align: center;">HTBoK-006/OP-1 REV. A</p> <hr/> <p>Issued 11-Sept-14</p> <p>Revised: 07-Sept-18</p> <p>Superseding: 11-Sept-14</p>
<p style="text-align: center;">BODY OF KNOWLEDGE:</p> <p>ROLE DESCRIPTION: OPERATOR/TECHNICIAN SPECIAL PROCESS: Aluminum Alloys METHOD: Performance of Aluminum Alloys Requirements</p>	
<p>All PRI QualificationSM program examinations are created using the applicable PRI QualificationSM program Body of Knowledge (BoK), which defines the baseline knowledge and experience required to be considered competent to perform the specified job role in aerospace special process manufacturing.</p> <p>All BoKs are created by subject matter experts who participate in the PRI QualificationSM Body of Knowledge Review Boards. All BoKs are updated periodically according to the latest revision of PRI QualificationSM program documentation (PD6100: Industry Managed Special Process Bodies of Knowledge) to ensure consistency with current industry practice.</p>	

1. INTRODUCTION

This document has been created by the PRI QualificationSM program Heat Treat Body of Knowledge Review Board (HT-BoKRB) according to the requirements of PD6100.

This document constitutes the PRI QualificationSM program BoK for Aluminum Alloys, Operator. It defines the baseline knowledge and experience required to be considered competent to perform this role.

Unless otherwise stated, the HT-BoKRB has followed guidelines as detailed in the current version of International Aerospace Quality Group (IAQG) Guidance PCAP 001 (Competence Management Guideline) to develop this BoK.

The information in this BoK will provide guidance for the following:

- Training providers who wish to develop training courses intended to support PRI QualificationSM program examination candidate preparation
- Heat Treat Examination Review Board (HT-ERB) for the development of PRI QualificationSM program examinations
- Candidates taking PRI QualificationSM program examinations who wish to prepare in advance

2. REFERENCES

PRI QualificationSM program documents:

PD6000	Governance & Administration of PRI Qualification SM Program
PD6100	Industry Managed Special Process Bodies of Knowledge
PD6200	Industry Managed Special Process Examinations System
IAQG documents:	IAQG Guidance PCAP 001 Competence Management Guideline

3. DEFINITIONS

Definitions described within are specific to the Special Process BoK. For program-specific definitions, please refer to either the PD 6000 or the PRI QualificationSM Dictionary.

BODY OF KNOWLEDGE (BoK): Baseline knowledge and experience required to be considered competent for a target position.

GENERAL EXAMINATION: The General Examination is designed to ascertain the candidate's general knowledge required for a particular job, role or activity. All of the questions will be derived from the corresponding BoK.

EXPERIENCE: The accumulation of knowledge or skill that results from direct participation in events or activities over a period of time.

IN-HOUSE (or IN-SOURCING): Keeping responsibility and control of key or critical processes inside an organization by using available internal resources in house control (Insourcing) is often preferred to ensure compliance of critical with specific customer or statutory requirements – The opposite of Outsourcing

KNOWLEDGE: Information / understanding acquired over a period of time. Information acquired through study and retained over that period of time (education, training, experience etc.) The combination of data and information, to which is added expert opinion, skills and experience, to result in a valuable asset which can be used to aid decision making and problem solving.

LEVEL: A class or division of a group based on education, training and experience. There are 3 levels: Operator/Technician, Planner and Owner. Please refer to the current version of PD 6000 for definitions.

METHOD: A well-defined division of a SPECIAL PROCESS widely recognised by industry. A specific area of a special process for example anodizing within Chemical Processing

NON-SPECIAL PROCESS RELATED REQUIREMENTS: Miscellaneous requirements such as Health and Safety, Environmental, etc.

OUT-SOURCED: is the contracting out of a business process to a third-party (external) supplier. It relates to both product and services

PERSONAL ATTRIBUTES: A quality or characteristic expected and required for a particular job, role or activity.

PRACTICAL EXAMINATION: The Practical Examination shall consist of a demonstration of proficiency in performing tasks that are typical of those to be accomplished in the performance of the candidate's duties. The examination content is derived from the corresponding BoK.

SERVICE PROVIDER: A company or individual that provides a service or product. Service provider is generally used to refer to external or outsourced (third party) suppliers of services and product although large organizations may have Internal Service Providers for example IT.

Examples may include Instrument calibration, Periodic Tests (TUS, SAT), analysis or testing which is outside the capability of internal resources. Service providers may also be suppliers of goods for example thermocouples pure gases etc

SKILL: Ability to perform a particular task. The quality of being able to do something that is acquired or developed through training or experience.

SPECIFIC EXAMINATION: The Specific Examination shall cover requirements and use of the specifications, codes, equipment, operating procedures and test techniques the candidate may use in the performance of his/her duties with the employer. Examination content will be derived from the corresponding BoK where applicable.

WEIGHTING: The “weighting” of each line item, using a scale of 1, 3, 7, 10, (1 being least important; 10 being most important) indicates the relative importance of that aspect of the BoK and will determine the likelihood and frequency of a question on that topic appearing in the examination

4. GUIDANCE TO EXAMINATION CANDIDATES

All PRI QualificationSM program examination candidates are recommended to read all documents referenced in section 2 of this document.

As stated in PRI QualificationSM program document PD6200, every exam question shall relate directly to and be derived from the information as detailed in the current version of the BoK.

Re-assessment to this BoK is required every 5 years, unless otherwise specified.

Candidates are therefore advised to ensure familiarity with all aspects of the BoK as detailed in Table 1. This can be done through:

- Self-study
- Completion of internal training
- Completion of external training (a list of Approved Training Providers can be found at <https://p-r-i.org/>)

Records of all qualified personnel shall be maintained and include:

- Date of Qualification
- Results of Written Exam
- Results of Practical Exam (if applicable)
- Summary of Experience (Owner level only)

5. LEVELS

<i>Descriptors</i>	Level		
	Operator (OP)/Technician(T) <i>For descriptions, please refer to current version of PD6000</i>	Planner (PL) <i>For descriptions, please refer to current version of PD6000</i>	Owner (OW) <i>For descriptions, please refer to current version of PD6000</i>
Aluminum Alloys Specific Criteria	Basic understanding of the HT / Aluminum Alloy process including Quench and Refrigeration	In addition to knowing what the Operator does, the Planner must: Manage HT shop that contracts the service provider and reviews reports. Aluminum Alloys technician must have higher understanding; conduct TUS/SAT testing.	In addition to knowing what the Operator and Planner do, the Owner must: Manage people that perform the work and evaluate and reviews reports; must have knowledge of "how" to run the testing.
Technical Knowledge	Basic knowledge of the special process, its main processes, methods and tools.	Good level of knowledge in all aspects of the special process, all its processes, methods and tools. Ability to coach others on contents and methods in the context of their workplace.	High or extensive knowledge in all aspects of the special process, all its processes, methods and tools to assess and validate improvements. Able to contribute to set externally recognized standards. Ability to define contents and methods for using knowledge effectively in influencing and developing international processes. Ability to influence the process with one's knowledge.
Experience	Sufficient experience to deal with recurrent activity.	Has enough experience to deal with unforeseen issues.	Wide proven experience of the subject. Is recognized specialist within the special process?
Personal Attributes	Takes into consideration behavioral characteristics such as but not limited to: team working, communication, direction and purpose, innovation and problem solving, mutual trust and respect, confidentiality and trustworthiness.		
Skills	Describes the activities necessary to perform each level of job function to comply with the Body of Knowledge		
Non-Special Process Related Requirements	Health & Safety, Environmental, Quality System Requirements.		

6. Table 1

ROLE DESCRIPTION: Operator

SPECIAL PROCESS: Heat Treatment of Aluminum and Its Alloys

METHOD: Performance of Heat Treatment processes on Aluminum and its alloys to comply with customer specific/international standard requirements

REFERENCE GUIDELINE: *Addendum 1 is a list of the International Standards and Reference Documents applicable to Heat Treatment processes*

Row #	COMPETENCE	Weight (1,3,7,10)	Exam Type Written/Practical	Reference Guidelines
KNOWLEDGE:				
1.	GENERAL QUALITY SYSTEMS KNOWLEDGE:	7	Written	AS9100
2.	Knowledge and understanding of Aerospace Quality system and compliance.	7	Written	AS9100
3.	Full and complete understanding of internal work instructions as well as industry standards (see Addendum -1 of this document)	7	Written	AS9100
4.	Knowledge and understanding of how non-conformance is controlled using tools such as Root Cause Corrective Action and 5 why's.	7	Written	AS9100
5.	Knowledge and understanding of safety compliance requirements as applicable (some aluminum alloys treated in the wrong media could cause serious explosions).	10	Written	AS9100
6.	Knowledge and understanding traceability of calibration to NIST or equivalent agencies.	7	Written	AS9100
7.	GENERAL METALLURGICAL KNOWLEDGE RELATED TO HEAT TREATING ALUMINUM ALLOYS (Applicable to all specifications):			
8.	Understand the importance of compliance with Pyrometry requirements including temperature sensors, instrumentation, thermal processing equipment, system accuracy tests, and temperature uniformity surveys and including reporting of non-conformance.	7	Written	AMS2750
9.	Understanding of Heat Treatments applied to Aluminum Alloys -			
10.	<ul style="list-style-type: none"> • Solution Heat Treatment • Ageing • Annealing • Stress relieving • Quenching • Refrigeration 	7	Written	AMS2771 AMS2772 AMS 2770
11.	Understanding of the importance of meeting Quench Delay times and time to aging or to refrigeration	7	Written	AMS2771 AMS2772 AMS 2770
12.	Understanding of the definitions and importance of terms applicable to Heat Treatment of Aluminum Alloys			
13.	<ul style="list-style-type: none"> • Set temperature • Recovery time • Start of soak • End of soak • Interruptions • Quench delay • Eutectic Melting • Temp Heating Rate • Composition • Homogenization effects on Heat treat 	7	Written	AMS2771 AMS2772 AMS 2770
14.	Understanding of why adherence to set temperatures and furnace uniformity is critical especially for solution treatment	7	Written	AMS2771 AMS2772 AMS 2770
15.	Understanding of the importance of compliance with minimum and maximum treatment times, including how start and end of soak are defined and whether they are based on furnace (controller) readings or actual metal temperature (load thermocouples)	7	Written	AMS2771 AMS2772 AMS 2770
16.	Knowledge and understanding of the use of protective compounds (ammonium or sodium fluoborate, or other equivalent moisture reducing	7	Written	AMS2771 AMS2772 AMS 2770

	compound) when required. (Aluminum treated to high temperature in humid environments can develop porosity related to the generation of hydrogen. Entrapped water must be prevented from entering the furnace. The loading of parts directly from a water-containing quench tank (i.e., wet parts), into a furnace is prohibited by many specifications. Fluoborate compounds act as drying agents to reduce any residual moisture)			
17.	Knowledge and understanding that heat treating equipment and instruments for the heat treatment of aluminum alloys must be in accordance with all the customers' requirements	7	Written	AMS 2750
18.	Knowledge and understanding that heat treating facilities must possess the correct temperature uniformity, instrument accuracy and resolution for the heat treating of aluminum alloys in accordance with all the customers' requirements	7	Written	AMS2750
19.	Knowledge and understanding that furnaces used above 400F (200C) must be operated such that the products of combustion that could contaminate the load do not enter the heat-treating furnaces when required by specification	7	Written	AC7102/2
20.	Knowledge and understanding that salt bath must be tested periodically for pH in accordance with the applicable heat-treating specification.	7	Written	AC7102/2
21.	Racking, fixturing and spacing			
22.	Knowledge and understanding that specially designed racks and fixtures must be used for the specific parts they are designed for	7	Written	AC7102/2
23.	Knowledge and understanding that racks, fixtures and/or baskets must be free from entrapped quenchant	7	Written	AC7102/2
24.	Knowledge and understanding that parts must be spaced adequately to ensure adequate circulation of the heating medium and quenchant	7	Written	AC7102/2
25.	Quench			
26.	Knowledge and understanding that quench mechanisms must be capable of meeting the maximum quench delay provisions of the specifications	7	Written	AC7102/2
27.	Knowledge and understanding that quench delay requirements must be met and documented for each individual load	7	Written	AC7102/2
28.	Spray or forced air quench			
29.	Knowledge and understanding that spray or forced air quenching may only be used on alloys and product forms when allowed by the governing specification	7	Written	AC7102/2
30.	Knowledge and understanding that periodic electrical conductivity tests must be performed when required to verify the effectiveness of the spray and/or forced air quench	7	Written	AC7102/2
31.	Knowledge and understanding of the importance of complying with maintenance plans which assure that nozzles and jets are not blocked and are oriented at the same position as qualified	7	Written	AC7102/2
32.	Quenchant Control		Written	
33.	Knowledge and understanding that quenchant temperature must be controlled and documented	7	Written	AC7102/2
34.	Knowledge and understanding that records on or traceable to the traveler must demonstrate that quenchants have been at the specified temperature before, during and after the parts were quenched.	7	Written	AC7102/2
35.	Knowledge and understanding that quenchant agitation and/or agitation of the parts during quenching must conform to applicable specifications	7	Written	AC7102/2
36.				
37.	Water/Polymer Quenchant Solutions			
38.	Knowledge and understanding that water/polymer quenchant solutions must be checked for concentration by a method and at frequencies required by the customer?	7	Written	AC7102/2
39.	Knowledge and understanding that records must document that all the water/polymer quenchant solutions have been checked for concentration by a method and at frequencies required by the customer.	7	Written	AC7102/2
40.	Knowledge and understanding that If the concentration is checked by the refractive index, the refractometer must be periodically calibrated using standard solutions	7	Written	AC7102/2
41.	Water/Polymer Quenchant used in conjunction with the Salt Baths			
42.	Knowledge and understanding that water/polymer quenchant solutions, used in conjunction with the salt baths must be checked for salt contamination using calibrated known solutions as required by applicable specification	7	Written	AC7102/2

43.	Knowledge and understanding that records must show that the contamination does not exceed 6% and/or other requirement defined in applicable customers' specifications	7	Written	AC7102/2
44.	Refrigeration When Required by Specification			
45.	Knowledge and understanding of procedures addressing cooling requirements after quench.	7	Written	AC7102/2
46.	Knowledge and understanding that records must show that cooling after quench is in compliance with customer requirements specified in procedures or shop planning.	7	Written	AC7102/2
47.	Knowledge and understanding of time/temperature limits for retention of the "As Quenched" condition.	7	Written	AC7102/2
48.	Knowledge and understanding of the requirements to record the temperature in each refrigeration or cold storage unit.	7	Written	AC7102/2
49.	Handling Fasteners			
50.	Knowledge and understanding of customer requirements for special handling of fasteners after quenching.	7	Written	AC7102/2
51.	Aluminum Solution Heat Treating Furnaces with the Heat Source in Walls			
52.	Knowledge and understanding that radiant tubes and/or electric heating elements must be shielded or positioned to prevent the radiation heating of parts	7	Written	AC7102/2
53.	Testing			
54.	Knowledge and understanding that Hardness and/or Conductivity Testing must be performed in accordance with specification or customer requirements.	7	Written	AC7102/2
55.	Knowledge and understanding of periodic testing required by customer to verify the aluminum heat treating (e.g. monthly quench effectiveness testing - tensile testing, eutectic melting, intergranular corrosion, clad diffusion, etc.)?	7	Written	AC7102/2
56.	Knowledge and understanding that periodic testing must be performed per procedures and the customers' requirements	7	Written	AC7102/2
57.				
58.	REQUIREMENTS SPECIFIC TO PRODUCT PROCESSED (in accordance with the relevant AMS):			
59.	SPECIFIC REQUIREMENT RELATED TO HEAT TREATMENT OF WROUGHT ALUMINUM ALLOY PARTS TO AMS 2770 REQUIRED (NOT APPLICABLE IF NOT PROCESSING TO AMS 2770)			
60.	Knowledge and understanding that this specification covers the engineering requirements for heat treatment, by part fabricators (users) or their vendors or subcontractors, of parts. It also covers heat treatment by warehouses or distributors converting raw material from one temper to another temper.	7	Written	AMS2770
61.	Knowledge and understanding of the importance of compliance with work instructions as to pyrometry and furnace class (uniformity) as required by AMS 2770.	7	Written	AMS2770
62.	Refrigeration Equipment			
63.	Knowledge and understanding that refrigeration equipment must be capable of temperature recovery to within 5 °F (3 °C) of the set temperature within 20 minutes of door closing after insertion or removal of parts.	7	Written	AMS2770
64.	Cleaning Knowledge and understanding that prior to solution heat treating or annealing, parts shall be clean and visually free of contaminants such as dirt, metal residues, lubricants and solvent residues.	7	Written	AMS2770
65.	Racking and Fixturing			
66.	Knowledge and understanding that racking and fixturing must be constructed so as to preclude entrapment of water, molten salt and/or water/polymer solutions	7	Written	AMS2770
67.	Knowledge and understanding that parts must be racked or supported to permit free access of the heating and quenching media to all surfaces of parts in all portions of the load. Rivets and other small parts may be heated and soaked in baskets or in continuous furnaces. Arrangement in baskets may be either orderly or random. Parts may touch but shall not be nested in a manner that prevents free access of the quench media to most surfaces. Maximum thickness of layers of rivets or parts in baskets or on a moving belt, and minimum space between layers, shall be 2 inches (51 mm).	7	Written	AMS2770
68.	Knowledge and understanding that during Solution Heat Treating, parts, 0.250 inch (6.35 mm) and under in nominal thickness, shall be separated by not less than 1 inch (25 mm). Thicker parts shall be separated by at least 1 inch (25 mm) plus the part thickness. (Complex parts and parts of large plan form may require greater separation.)	7	Written	AMS2770

69.	Knowledge and understanding that during Aging, Annealing and Stress Relieving, parts shall be separated by not less than 1 inch (25 mm) except thin parts may be nested providing thickness of nested stacks does not exceed 1 inch (25 mm) and stacks are at least 1 inch (25 mm) apart.	7	Written	AMS2770
70.	Knowledge and understanding that parts that can entrap salt shall be racked so as to preclude salt entrapment as much as practicable.	7	Written	AMS2770
71.	Soak			
72.	Knowledge and understanding that soaking time starts when all temperature control, recording and monitoring sensors reach the minimum of the uniformity tolerance range. Load sensors should not be used to determine start of soaking time.	7	Written	AMS2770
73.	Knowledge and understanding of the importance of following work instructions and maintaining documentation of minimum soak time (and maximum for alclad product)	7	Written	AMS2770
74.	Interruptions			
75.	Knowledge and understanding that during solution heat treatment, soaking must be performed without interruption.	7	Written	AMS2770
76.	Knowledge and understanding that during aging, annealing, stress relieving, and heat treatment to the O1 (formerly T411) temper, a maximum of four interruptions, with doors open for not more than 2 minutes during each, is permissible for removal or loading of parts. Door opening durations greater than 2 minutes are permitted provided the time between the door opening and recovery of furnace temperature is not included in the total time.	7	Written	AMS2770
77.	Stabilization			
78.	Knowledge and understanding of the importance of following work instructions for solution treating temperature and for stabilization of furnace prior to loading parts.	7	Written	AMS2770
79.	Prevention of Hydrogen Induced Porosity			
80.	Knowledge and understanding that entrapped water shall be prevented from entering the furnace. The loading of parts directly from a water-containing quench tank (i.e., wet parts), into a furnace is prohibited. Ammonium fluoborate, or equivalent, should be used in air furnaces as necessary; however, purging the furnace with fresh air may be necessary to prevent discoloration of subsequent loads of parts made from alclad product.	7	Written	AMS2770
81.	Knowledge and understanding that for solution heat treating of parts made from alclad product under 0.125 inch (3.18 mm) thick, the furnace recovery time shall not exceed 30 minutes and for parts made from heavier alclad product, shall not exceed 60 minutes.	7	Written	AMS2770
82.	Multiple Solution Heat Treatments of Alclad Product			
83.	Knowledge and understanding that parts made from product over 0.125 inch (3.18 mm) in nominal thickness shall be limited to two solution heat treatments in addition to any by the material producer. Parts made from product 0.020 to 0.125 inch (0.51 to 3.18 mm) in nominal thickness, shall be limited to one additional solution heat treatment in addition to any by the raw material producer. For parts made from product under 0.020 inch (0.51 mm) in nominal thickness, additional solution heat treatments are prohibited.	7	Written	AMS2770
84.	QUENCH			
85.	Quenchant Temperature Knowledge and understanding that at the start of quench, quenchant temperature shall not exceed 90 °F (32 °C) except when water quenching parts made from forgings. When quenching parts made from forgings, the start of quench water temperature shall conform to the specific requirements of AMS 2770.	7	Written	AMS2770
86.	Temperature Rise of Quenchant During Quenching Knowledge and understanding that quenchant temperature shall not exceed the maximum start-of-quench temperature by more than 10 °F (6 °C) at any time during quenching. In addition, the quenchant temperature shall not increase more than 25 °F (14 °C) from the starting temperature as a result of quenching any single load.	7	Written	AMS2770
87.	Knowledge and understanding of the importance of complying with and documenting Quench Delay Times.	7	Written	AMS2770
88.	Agitation			
89.	Knowledge and understanding that parts and/or quenchant shall be agitated during quenching. For thin parts (minimum dimension in heaviest section is under 0.105 inch (2.67 mm)), movement into the quenchant during immersion is sufficient agitation.	7	Written	AMS2770
90.	Immersion Time			
91.	Knowledge and understanding that parts racked or in baskets shall be kept immersed in the quenchant for not less than 1 minute per inch (25.4 mm) of maximum thickness, or fraction thereof, or for not less than 1 minute after all evidence of boiling ceases, whichever is longer. Sheet metal parts less than 0.125	7	Written	AMS2770

	inch (3.18 mm) thick may be removed from the quenchant as soon as all boiling ceases.			
92.	Knowledge and understanding of the importance of polymer concentration conformity, control and test methods and of avoiding salt contamination.	7	Written	AMS2770
93.	Knowledge and understanding of the importance of following refrigeration requirements after quench.	7	Written	AMS2770
94.	Knowledge and understanding of the importance of following aging times and temperatures.	7	Written	
95.	Straightening After Aging			
96.	Knowledge and understanding that during straightening of parts in certain tempers as listed in AMS 2770 is prohibited unless approved by the cognizant engineering organization:	7	Written	AMS2770
97.	Knowledge and understanding of the importance of following annealing/stress relieving work instructions.	7	Written	AMS2770
98.	O1 (Formerly T411) Temper Knowledge and understanding that parts required to be in the O1 temper shall be heated to the solution heat treating temperature and soak time specified in AMS2770, and air cooled to room temperature.	7	Written	AMS2770
99.	Knowledge and understanding of the importance of complying with hardness and conductivity sampling and testing required by AMS 2658.	7	Written	AMS2770
100.	Knowledge and understanding of the importance of complying with log requirements.	7	Written	AMS2770
101.				
102.	SPECIFIC REQUIREMENTS RELATED TO HEAT TREATMENT OF ALUMINUM ALLOY CASTINGS TO AMS 2771 (NOT APPLICABLE IF NOT PROCESSING TO AMS 2771)			
103.	Knowledge and understanding that this specification covers the engineering requirements for heat treatment of aluminum alloy castings and for parts machined from castings.	7	Written	AMS 2771
104.	Heating Media			
105.	Knowledge and understanding that media shall be air, protective atmosphere, combusted gases, molten salt bath, oil bath, or fluidized bed. Electrical heating elements and radiant tubes shall be shielded to prevent direct radiation from striking any part. The products of combustion in the furnace, and the composition and maintenance of salt baths and fluidized beds shall be such as to prevent attack or contamination of the castings. Ammonium fluoborate, or equivalent, may be used in air furnaces as necessary. Nitrate salt baths shall not be used to heat treat 520.0 alloy due to a potential explosion safety hazard.	7	Written	AMS 2771
106.	Salt Entrapment			
107.	Knowledge and understanding that castings that will entrap salt shall not be heated in a molten salt bath.	7	Written	AMS 2771
108.	Knowledge and understanding of the importance of compliance with work instructions as to pyrometry and furnace class (uniformity) as required by AMS 2771	7	Written	AMS 2771
109.	Polymer Quenchants			
110.	Knowledge and understanding that polyalkalene glycol shall meet the requirements of AMS3025. Other synthetics may be used provided that they are not detrimental to the material and that the parts meet the required specified properties in the final heat-treated condition. Polymer concentration shall be established for the particular casting configuration prior to use.	7	Written	AMS 2771
111.	Salt Contamination of Polymer Quenchants			
112.	Knowledge and understanding that contamination shall not exceed 6% by weight.	7	Written	AMS 2771
113.	Racking and Spacing			
114.	Knowledge and understanding that product shall be supported or hung and spaced to permit flow of the heating and cooling media over all surfaces to ensure that the castings will meet the specified requirements. Alternate racking methods are acceptable if tests have been performed to demonstrate that all castings so racked will meet specified requirements. Written instructions, drawings, photographs, etc. shall be used to ensure proper spacing. Small castings be heated and soaked in baskets or continuous furnaces. Care must be used to provide access for heating and quench media and to prevent damage during loading and quenching. Arrangement in baskets may be either	7	Written	AMS 2771

	orderly or random provided that the castings meet the required specified properties in the final heat-treated condition.			
115	Water Entrapment			
116	Knowledge and understanding that racks and fixtures used for solution heat treatment shall be constructed to preclude entrapment of water.	7	Written	AMS 2771
117	Loading			
118	Knowledge and understanding that the temperature of the furnace during part loading shall not exceed the solution treating temperature of the castings being heat treated	7	Written	AMS 2771
119	Knowledge and understanding of the importance of compliance with Set Temperature	7	Written	AMS 2771
120	Soaking			
121	Knowledge and understanding that soaking time starts when all temperature control sensing elements and load thermocouples (if used) are within 10 °F (6 °C) of the set or offset temperature.	7	Written	AMS 2771
122	Knowledge and understanding of interruption limits	7	Written	AMS 2771
123	Batch Furnaces			
124	Interruptions during solution treatment are permitted provided the minimum soak time is met and at least a 2-hour soak time occurs after the interruption. (A shorter soak time may be allowed when specified on the work instructions and based upon test results.) During aging and annealing treatments, a maximum of four interruptions are permitted for removal or loading of castings. The time between door opening and furnace or load thermocouple recovery is not to be counted as part of the total aging time.	7	Written	AMS 2771
125	Continuous and Semi-Continuous Furnaces			
126	During soaking, a drop-in temperature indicated by furnace instrument(s) is permissible provided (1) that temperature does not drop more than 20 °F (11 °C) below the minimum of the specified range, (2) time below the minimum of the specified range does not exceed 5 minutes, and (3) soaking is continued for not less than 10 minutes after recovery before quenching. If furnace temperature does not drop more than 20 °F (11 °C) below the minimum of the specified range, but range but does not recover to the minimum of the specified range within 5 minutes, the total soaking time, if less than 1 hour was required, shall be increased by 1/2 hour. If 1 hour or more was required, the total soaking time shall be increased by 1 hour. Load thermocouples shall be used, when needed, to determine and control metal temperature and heating time or when required by the cognizant engineering organization	7	Written	AMS 2771
127	Knowledge and understanding of the importance of compliance with log requirements	7	Written	AMS 2771
128	Cleaning			
129	Knowledge and understanding that castings shall be clean of contaminants that will react during heat treatment or cause adverse effects. Residue from heating and quenching media shall be removed from castings after solution heat treatment.	7	Written	AMS 2771
130	Solution			
131	Knowledge and understanding of the importance of compliance with set temperature requirements, start of soak, minimum soak time and end of soak	7	Written	AMS 2771
132	Quenching			
133	Quenchant Temperature			
134	Knowledge and understanding that the quenchant temperature shall not rise more than 25 °F (14 °C) at the conclusion of the quenchant contact time. To prevent excessive warpage and possible cracking, castings may be quenched in oil or water with temperature varying from cold to hot (212 °F (100 °C)) or in a polymer quenchant at room temperature providing it is substantiated that the combination of	7	Written	AMS 2771

	quench and solution temperature will produce mechanical properties meeting the material specification. Exceptions to the temperature rise are permitted provided that it has been demonstrated by testing and documentation that the castings meet the required specified properties in the final heat-treated condition. Unless otherwise specified in a drawing or procurement document, castings of Alloy 520.0 shall be quenched by total immersion in oil heated to 300 °F (149 °C) and castings of Alloy 242.0 shall be air-quenched.			
135	Quench Delay Time			
136	Knowledge and understanding that the quench delay time shall not exceed 15 seconds. The delay shall be measured from the time the furnace door of an air furnace starts to open, or the first portion of the load emerges from a fluidized bed or salt bath, to complete immersion of the load in the quenchant. This delay time may be exceeded providing that the cooling rate does not result in a loss of any mechanical property typically obtained by the established process for that casting configuration.	7	Written	AMS 2771
137	Agitation			
138	Knowledge and understanding that castings, quenchant, or both shall be agitated during quenching. Small parts heated and soaked in baskets may be quenched by dumping when basket loads are too heavy to allow adequate quenching by immersion of the full basket and provided that the castings are not damaged by dumping. Exceptions to the use of agitation are permitted provided that it has been demonstrated that the castings meet the required specified properties in the final heat-treated condition.	7	Written	AMS 2771
139	Quenchant Contact Time			
140	Knowledge and understanding that castings which are quenched by immersion shall be kept immersed in the quenchant for not less than 2 minutes per inch of thickness, or fraction thereof in the thickest section. Alternatively, castings shall be kept immersed in the quenchant for not less than 2 minutes after boiling ceases. Castings quenched in boiling water shall remain immersed for not less than 2 minutes. Castings quenched in an air blast shall remain in contact with the air blast until surface temperatures are reduced to 212 °F (100 °C).	7	Written	AMS 2771
141	Temper After Treatment			
142	Knowledge and understanding that all alloys are in the AQ temper immediately after quenching. After 45 minutes at room temperature or after the maximum refrigerated storage time has elapsed, they are in the W temper which is unstable, i.e., their properties are continuously changing. After an appropriate delay at room temperature, unless otherwise noted herein, the tempers shall be as shown in AMS 2771.	7	Written	AMS 2771
143	Refrigeration			
144	Knowledge and understanding that when a material specification or a fixed process agreement requires retention of the AQ condition to attain the required mechanical properties, castings shall be refrigerated within 45 minutes after quenching and storage conditions shall be documented by a temperature recorder with record of casting traceability.	7	Written	AMS 2771
145	Knowledge and understanding that when the producer determines that refrigeration is required for a casting to facilitate straightening, the castings may be refrigerated as necessary to facilitate straightening. There is no requirement for traceability records or a temperature recorder, nor pyrometry testing of the refrigeration device.	7	Written	AMS 2771
146	Aging Knowledge and understanding castings requiring aging shall be aged in accordance with work instructions derived from AMS2771 to obtain the final temper and required mechanical properties. Aging set temperature and soak time specified on the work instructions may vary from the AMS2771 requirements to obtain required properties for a specific casting configuration.	7	Written	AMS 2771
147	Annealing			
148	Knowledge and understanding that heating, soaking, and cooling parameters in AMS 2771 are recommended for annealing of castings. If a partial anneal (stress relief) is required, it shall be as specified by the cognizant engineering organization.	7	Written	AMS 2771
149	Knowledge and understanding that straightening after final heat treatment shall not be performed unless authorized by the cognizant engineering organization	7	Written	AMS 2771
150	Acceptance			

151	Knowledge and understanding that castings shall meet the hardness and tensile property requirements of the applicable material specification. When hardness or tensile properties are not specified, the test method, test specimens (i.e., separately cast specimens, integrally attached specimens, specimens machined from prolongations, or specimens machined from casting sections), and acceptance criteria shall be agreed upon by purchaser and vendor. <i>(NOTE Only operators who are approved per appropriate supplier procedures can test and/or accept product. All operators must be aware of acceptance requirements, and should bring any discrepancies to the attention of their supervisor)</i>	7	Written	AMS 2771
152	SPECIFIC REQUIREMENTS RELATED TO HEAT TREATMENT OF ALUMINUM ALLOY RAW MATERIAL TO AMS 2772 (NOT APPLICABLE IF NOT PROCESSING TO AMS 2772)	7		
153	Knowledge and understanding that this specification covers requirements and recommendations for the heat treatment of wrought aluminum alloy raw materials by producers.	7	Written	AMS 2772
154	Knowledge and understanding of the importance of following work instructions with respect to selection of equipment due to specific equipment qualification requirements.	7	Written	AMS 2772
155	Knowledge and understanding of the importance of compliance with work instructions as to pyrometry and furnace class (uniformity) as required by AMS 2772 and material specification.	7	Written	AMS 2772
156	Knowledge and understanding that heating media for solution heat treatment shall be air, protective atmosphere, combusted gases, molten salt bath, or fluidized bed. However, no protective atmosphere, combusted gas or fluidized bed environment shall be used unless it has been shown by test on the alloy/form to be heat treated, to yield product which is free from heat treat induced porosity. Composition of salt baths and fluidized beds shall be maintained to prevent attack of the product.	7	Written	AMS 2772
157	Cleanliness Knowledge and understanding that prior to heat treating, product shall be free from surface contaminants which could have a detrimental effect on the material	7	Written	AMS 2772
158	Knowledge and understanding of the importance of compliance with racking and spacing requirements due to validation requirements including load sensor placement during validation Knowledge and understanding that during solution heat treatment, product shall be supported or hung and spaced to permit flow of the heating and cooling media over all surfaces to ensure that all product will meet the specified requirements. During aging, product shall be supported or hung and spaced so that it will be heated and soaked as required to meet the specified requirements. Random racking (not nested) or layering of forgings, 1-inch (25-mm) and under in thickness is permissible for (1) solution heat treating (providing quenching is by immersion), (2) aging, and (3) annealing, providing product so racked has been demonstrated by test to meet the specified requirements. Layer thickness shall not exceed 3 inches (76 mm) and distance between layers shall be at least 3 inches (76 mm) (not required for load arrangements which have been previously validated in accordance with AMS-H-6088 or a previous issue of AMS2772).	7	Written	AMS 2772
159	Temperatures			
160	Knowledge and understanding that furnace temperatures shall be controlled so as to ensure that the metal temperature does not exceed the maximum of the range. When a load is charged into a batch furnace whose indicated temperature is higher than the maximum of the specified range, a recording load sensor, in contact with the thinnest material on the outside of the load, shall be used to verify that the metal temperature did not exceed the maximum of the range.	7	Written	AMS 2772
161	Solution Heat Treatment			
162	Knowledge and understanding that product shall be soaked, in accordance with specification requirements, within the temperature range specified and quenched as specified. Quenching directly from a furnace or salt bath is required. Extrusion press quenching and rolling mill quenching are not permitted by AMS2772.	7	Written	AMS 2772
163	Start of Soak			
164	Knowledge and understanding that soaking time shall start when the readings of all load sensors indicate that the temperature of the load has reached the minimum of the required temperature range. Alternatively, determination that the temperature of the load has reached the minimum of the required temperature range (start of	7	Written	AMS 2772

	soaking time) may be based on readings of furnace instruments providing the lag between their readings and load temperature has been determined in a similarly arranged load.			
165	Duration			
166	Knowledge and understanding that the load shall be maintained within the required temperature range for a time which has been previously shown, by tensile tests, to produce the specified properties (not required for soaking times which have been previously validated in accordance with AMS-H-6088 or a previous issue of AMS2772). Recommended soaking times are listed in Table 2 of AMS 2772.	7	Written	AMS 2772
167	<p>Knowledge and understanding of interruption limits</p> <p>During soaking in a semi-continuous air furnace, a drop-in temperature indicated by furnace instrument(s) is permissible providing that:</p> <ul style="list-style-type: none"> • The temperature indicated by any instrument does not drop more than 20 °F (11 °C) below the minimum of the specified range. • Time below the minimum of the specified range does not exceed 5 minutes. • Soaking is continued for not less than 10 minutes after recovery to the minimum of the solution heat treatment temperature range before quenching. <p>If furnace temperature does not drop more than 20 °F (11 °C) below the minimum of the specified range, but does not recover to the minimum of the specified temperature range within 5 minutes, the total soaking time within the specified range shall be increased; if less than 1 hour was required, it shall be increased by 1/2 hour; if 1 hour or more was required, it shall be increased by 1 hour.</p>	7	Written	AMS 2772
168	QUENCH			
169	Knowledge and understanding that quenchant or immersion and spray quenching shall be water or an aqueous solution of a residual stress/distortion reducing additive such as polymer. Quenchant volume, velocity, distribution and agitation (of quenchant and/or product) shall be sufficient to ensure that all products will meet specified requirements after aging.	7	Written	AMS 2772
170	Knowledge and understanding of the importance of complying with work instructions for Quench Delay (Immersion quenching shall be per specification requirements. For air blast and spray quenching, maximum allowable quench delays shall conform to those established based on tests of tensile properties and, when required, tests for susceptibility to inter-granular corrosion)	7	Written	AMS 2772
171	Rinsing		Written	
172	Knowledge and understanding that product heat treated in salt bath furnaces and product quenched in an aqueous solution of polymer shall be rinsed as necessary to ensure that it will be free from corrosion and detrimental foreign materials	7	Written	AMS 2772
173	Knowledge and understanding of the importance of complying with work instructions for quenchant temperature as specified for various product forms in AMS 2772	7	Written	AMS 2772
174	<p>Salt Contamination in Aqueous Solutions of Additives</p> <p>Knowledge and understanding that When an aqueous solution of additive is used for quenching product heat treated in a salt bath furnace, salt contamination in the quenchant shall not exceed 6% by weight.</p>	7	Written	AMS 2772
175	Quench Completion			
176	Immersion			
177	Knowledge and understanding that product under 0.250 inch (6.35 mm) in thickness shall remain in the quenchant at least until boiling emanating from the product (not the rack) ceases. Product 0.250 inch (6.35 mm) and over in thickness shall remain in the quenchant for not less than 2 minutes per inch (25 mm) of thickness, or fraction thereof, or for not less than 2 minutes after boiling ceases.	7	Written	AMS 2772
178	<p>Spray or Air Blast</p> <p>Knowledge and understanding that product quenched by spray or air blast shall remain in contact with the quenchant until the temperature of the product is below the boiling point of water.</p>	7		AMS 2772
179	<p>Knowledge and understanding of Restrictions on Alclad Products</p> <p>Heat-Up Time</p> <p>The time required for sheet material to reach the minimum of the specified temperature range shall not exceed 30 minutes for thicknesses up to 0.049 inch</p>	7	Written	AMS 2772

	(1.24 mm), 60 minutes for thicknesses from 0.050 to 0.101 inch (1.27 to 2.57 mm) and 120 minutes for thicker sheet or for plate. Soaking Time To ensure all lots will develop specified properties after aging, soaking time shall be established in accordance with specification requirements. However, the total soaking time used for any lot (single or multiple solution heat treatments) should be limited to the minimum necessary to ensure that the product will meet the specified requirements. Re-Solution Heat Treatment of Alclad 2xxx and 7xxx Sheet and Plate Product thinner than 0.020 inch (0.51 mm) shall not be re-solution heat treated. Sheet thicknesses from 0.020 to 0.125 inch (0.51 to 3.18 mm) inclusive shall not be re-solution heat treated more than once. Product thicker than 0.125 inch (3.18 mm) shall not be re-solution heat treated more than twice. NOTE These restrictions are not applicable to any lot of product which is tested to ensure conformance to the alclad thickness requirement of the material specification.			
180	Aging			
181	Knowledge and understanding that recommended aging temperatures and times are shown AMS 2772. Alternate temperatures and times may be used provided the aged material meets the specified requirements.	7	Written	AMS 2772
182	Knowledge and understanding of Recommended Annealing Times, Temperatures and Cooling Rates	7	Written	AMS 2772
183	Knowledge and understanding that Processing to -O1 Temper Shall consist of heating product to the temperature range shown in Table 1 of AMS 2772 followed by an air cool.	7	Written	AMS 2772
SKILLS:				
The skills required to perform a particular special process task				
		7		
184	Has knowledge and understanding to be able to recognize and report in real time deviations from process parameters or other events which may have a negative impact on product quality.	7	Written	General Industry
185	Read and understand written instructions:	7	Written	General Industry
186	Ability to understand specification requirements and customer flow-down requirements	7	Written	General Industry
187	Recognition of the importance of following work instructions	7	Written	General Industry
188	Understands the safety concerns involved with heat treatment including the proper use of handling tools and personal protective equipment	7	Written	General Industry
189	Understands precautions to be taken when handling thermocouples to avoid damage	7	Written	General Industry
190	Capable of generating and maintaining accurate and complete records required to demonstrate compliance with customer requirements including <ul style="list-style-type: none"> • Set temperature • Soak Time • Quench delay time • Quench concentration • Quench temperature before and after quench • Cooling after quench including refrigeration temperature • Periodic and lot acceptance test requirements and results 	7	Written	AC7102/2, AMS2770, AMS2771, AMS2772
191	If properly delegated, ability to review and approve heat treatment processing records	7	Written	AC7102
192	Has knowledge and understanding of the proper operation, maintenance and calibration requirements for equipment used for testing, evaluation and acceptance (e.g., hardness, conductivity)	7	Written	AC7102/5
193	Knowledge and understanding of the Preventive Maintenance Program	7	Written	General Industry
194	Sequencing			
195	Has an appropriate understanding of where this process falls in the sequence of events.	10	Written	General Industry
PERSONAL ATTRIBUTES:				
<i>Are statements that will enable judgment of the person's personal attributes</i>				
<i>Define within the following rows statements from the Body of Knowledge or statements from Company sources that will enable judgment of the person's personal attributes</i>				
196	Willingness to train and mentor co-workers	7	Written	

197	Good communicator at all levels	7	Written	
198	Takes responsibility to challenge work instructions that do not appear to conform to specification or customer requirements.	10	Written	
199	Personal integrity	7	Written	
200	Attentive to details	7	Written	
EXPERIENCE:				
<i>Are the minimum experience requirement expected to demonstrate their competence.</i>				
<p>NOTE: ARP 1962 (Aerospace Recommended Practice -Training and Approval of Heat-Treating Personnel) requires that suppliers have a documented personnel training program including documented training to an established outline and initial and periodic evaluation of the competency. Evaluation to the requirements of this program should be used in completing this section. The following are recommendations and would be superseded by the supplier's specific documented program. The supplier program may define alternative criteria, waivers and equivalences.</p>				
201	Recommended Minimum Classroom Training			
202	Heat Treatment – 80 hours Paperwork – 40 hours Test, Inspection, Maintenance – 40 hours	10	Written	ARP 1962
203	Recommended Minimum On-the-Job-Training			
204	Air atmosphere – 9 months Sat bath – 9 months Aluminum Alloys (aging and stress relief only) – 12 months Aluminum Alloys (all other processes) – 24 months	10	Written	ARP 1962
205	Testing and Evaluation			
206	Initial and periodic evaluation of personnel is required. The type of frequency of the evaluation shall be determined by the company employing the individual, except that each individual shall be evaluated at least every 5 years. This shall be defined in the formal written program. Evaluation may consist of any combination of written or oral examination or testing, structured checklist review, employee performance appraisal, company employee specific audit program or other appropriate methodology defined in the formal written program.	10	Written	ARP 1962
NON-SPECIAL PROCESS RELATED REQUIREMENTS: Defined within these rolls are other general or pre-requisite needed				
207	Must have a thorough understanding of general Quality Systems.	7	Written	AS9100 or equivalent
208	Must have a thorough understanding of customer specific requirements.	7	Written	Customer specifications
209	Must have a thorough understanding of Control of Non-Conformance for equipment and product including containment, customer notification and disposition.	7	Written	AS9100 or equivalent

7. DOCUMENT REVISION HISTORY

REVISION DATE	SUMMARY
23 April 2018	Updated template, updated color scheme, new logo, updated web address
7 September 2018	BoK reviewed and updated by eQualified Content Developer
4 December 2019	Editorial revision to update program name from eQualified to PRI Qualification SM .

ADDENDUM 1

LIST OF INTERNATIONAL STANDARDS & REFERENCE DOCUMENTS FOR ALUMINUM ALLOYS SERVICE

SPECIAL PROCESS	DOCUMENT TITLE	DOCUMENT NUMBER
Heat Treating	Baseline Nadcap Audit Criteria for Aluminum Heat Treating	AC7102/2
Heat Treating	Baseline Nadcap Audit Criteria for Hardness and/or Conductivity Testing for Heat Treating	AC7102/5
Heat Treating	Nadcap Audit Criteria For Heat Treating Pyrometry	AC7102/8
Heat Treating	SAE Aerospace Materials Specification – Pyrometry	AMS 2750
Heat Treating	SAE Aerospace Materials Specification – Heat Treatment of Wrought Aluminum Alloy Parts	AMS 2770
Heat Treating	SAE Aerospace Materials Specification – Heat Treatment of Aluminum Alloy Castings	AMS 2771
Heat Treating	SAE Aerospace Materials Specification – Heat Treatment of Aluminum Alloy Raw Materials	AMS 2772
Heat Treating	SAE Aerospace Recommended Practice - Training and Approval of Heat-Treating Personnel	ARP 1962
Quality	AS9100 Quality Management Systems - Requirements for Aviation, Space and Defense Organizations	AS 9100
Quality	Quality Standards	ISO9001