



## *Powder Metallurgy Technologist* **CERTIFICATION PROGRAM**

### **INTRODUCTION**

The Powder Metallurgy Technologist (PMT) Certification Program was created by APMI International (APMI) to recognize individuals who possess defined bodies of knowledge encompassing the broad field of powder metallurgy and particulate materials.

APMI thanks you for your interest in becoming a certified Powder Metallurgy Technologist. This document has been prepared to assist you in preparation for this significant career accomplishment.

### **GENERAL INFORMATION**

#### **What is certification?**

Certification is formal acknowledgement by APMI that an individual has demonstrated comprehension of a specified body of knowledge encompassing the broad field of powder metallurgy and particulate materials. It promotes high professional standards within this field.

#### **Why become certified?**

With continuous growth and change in the powder metallurgy and particulate materials industries, there is need for a workforce knowledgeable in all aspects of the field. Certification identifies those individuals who have attained the required knowledge of the field and who meet high professional standards.

#### **What are the requirements to become certified?**

**PMT–Level I** certifies basic knowledge of the general principles, practices, and terminology associated with the broad field of powder metallurgy and particulate materials, as measured by a written examination, which is confined to a specified body of basic knowledge. No formal education or work experience is required. This certification opportunity is available to all persons 18 years of age or older, regardless of their status relative to the field of powder metallurgy and particulate materials.

#### **(SUSPENDED effective October 2008 )**

**PMT–Level II** is for individuals with advanced knowledge, training, and experience in powder metallurgy and particulate materials, as measured by a written examination, which is confined to a broad body of knowledge. In addition, applicants must provide evidence of specific educational accomplishments and an employment profile, at least 60 days prior to the examination date, as follows:

1. Level I certification (held for a minimum of one year) and a minimum of four years active employment (not necessarily consecutive) in a technological capacity in the powder metallurgy and/or particulate materials industry.\*

2. Successful completion of **one** of the following educational requirements:
  - a. A baccalaureate degree in a science or engineering program
  - b. An associate degree or certificate in technology-related studies
  - c. Certificates of completion in at least four home study or intensive seminar courses (3-day minimum) related directly to materials technology, at least one of which was devoted to powder metallurgy and/or particulate materials\*\*
  - d. Five or more years of active employment (not necessarily consecutive) in a technological capacity in the powder metallurgy and/or particulate materials industry\*

\* The “powder metallurgy and or particulate materials industry” shall be interpreted to include the spectrum of powder production, powder consolidation, research and development, and end-user activities, as well as activities of suppliers to the industry. Eligibility shall be determined based on written verification from an employer(s). Self-employed technologists must submit a summary record of their work history along with three references, which may be checked for verification.

\*\* Such courses must have been completed by examination. “Attendance-only” credits shall not be counted.

## THE APPLICATION PROCESS

### How to apply for certification?

Download, complete, and submit the application form along with the appropriate fee to APMI on or before the application deadline. Applicants will not be permitted to take the examination unless all fees have been paid. Applications postmarked after the deadline will be scheduled for the next planned examination. Applications submitted through a company must still be received by the deadline.

Individuals who are not members of APMI may apply for certification. Non-members will receive the option of a one-year membership upon receipt of the non-member fee. Membership becomes effective upon completion of the certification examination. If you are not currently an APMI member, but choose to join, please check the appropriate box on the application form.

The current fee schedule is listed on the application form. All fees are payable in U.S. dollars only. **There will be no refund of application fees.**

### When is the examination given?

The specific examination date and application deadline are listed on the application form.

**Where is the examination given?**

Examinations are given at pre-approved location as submitted by the examinee.

**What if the scheduled examination is missed?**

If, for any reason, an applicant fails to appear for the examination, the application must be resubmitted along with a brief letter of explanation and the applicant must await the next examination date. An additional processing fee may be charged.

**THE EXAMINATION PROCESS****How long should examination preparation take?**

Preparing for the examination varies from individual to individual since it depends on one's level of education and experience. The "Body of Knowledge" listed in this document gives the areas of knowledge which the examination questions will cover. Also included in this document is a list of reference materials. You can expand your knowledge of the areas at your own pace by referring to the materials listed. These are essential in preparing for the examination.

Keep in mind that all certification candidates are responsible for their own study mode and preparation for the examination. There are no particular courses or study materials required for taking the examination. In addition, APMI does not guarantee passing the certification examination as a result of completing a specific course or studying specific materials.

**THE EXAMINATION****Are reference materials permitted in the examination?**

No, examinations are entirely "closed book." Other than a conventional non-programmable calculator, no electronic devices are permitted in the examination. Calculators may not be shared. Scratch paper will be provided by the examination proctor, but must be turned in along with the examination booklet and answer sheet at the conclusion of the examination.

**What are the primary recommendations about taking the examination?**

- Your preparation should begin well in advance of, not after, the submission of your application.
- Carefully evaluate the "Body of Knowledge" and focus on studying the areas in which you feel the least educated and experienced, although all areas should be reviewed.
- About a week prior to the examination, conduct an overall review of all of the areas, which you have studied. Do not attempt to cram information at the last minute.
- Be sure you have at least two well-sharpened No. 2 pencils with good erasers and a pocket calculator with extra batteries. No one will be permitted to share materials during the examination.

- Be well rested. It is important to get a good night's rest so you are alert for the examination.
- Arrive at the examination location at least a half-hour before the scheduled start time. This allows you extra time to check in, prepare your work space, and relax before the examination begins.
- Be sure to read carefully all instructions before proceeding with the examination.
- During the examination, work first on the questions you can do with confidence, then return to those you skipped. Do not guess at answers. No score will be given for unanswered questions, but a scoring penalty will be assessed for wrong answers.

## **EXAMINATION FORMAT, SCORING AND SAMPLE QUESTIONS**

### **Level I**

The Level I examination consists of 100 multiple-choice questions. The examination score shall be equal to the number of correct answers minus 0.25 times the number of incorrect answers. Unanswered questions shall receive no score. The minimum passing score shall be 70.

Following are examples of questions for the Level I examination.

1. Inside a sintering furnace, a reducing gas atmosphere is capable of:
  - a. forming a layer of oxide on the top of a steel PM part
  - b. maintaining a pre-existing oxide layer on the top of a PM part
  - c. removing an oxide layer from a PM part
  - d. none of the above
2. The addition of copper to iron powder has the following effect on sintered properties:
  - a. improves strength
  - b. lowers hardness
  - c. increases ductility
  - d. all of the above
3. To maintain dimensional control in self-lubricating bronze bearings, they are:
  - a. sized
  - b. machined
  - c. oil impregnated
  - d. copper infiltrated
4. In a compressibility curve, you plot:
  - a. apparent density vs. compaction pressure
  - b. tap density vs. compaction pressure
  - c. green density vs. compaction pressure
  - d. sintered density vs. compaction pressure

5. The technology called metal injection molding (MIM) involves the use of:
  - a. standard metal powders
  - b. subsieve metal powders
  - c. oxidized metal powders
  - d. heavily lubricated metal powders
  
6. The type of powder particles that yield the lowest green strength can be described as:
  - a. irregular
  - b. spherical
  - c. spongy
  - d. dendritic
  
7. The most common iron-based powders used by the PM industry are produced by:
  - a. oxide reduction
  - b. water atomization
  - c. electrolysis
  - d. chemical reduction
  
8. The apparent density of a metal powder is influenced by:
  - a. its particle size distribution
  - b. its particle shape
  - c. its chemical composition
  - d. all of the above
  
9. The furnace atmosphere gas with the highest percentage of hydrogen is:
  - a. endogas
  - b. exogas
  - c. inert gas
  - d. dissociated ammonia
  
10. Double action pressing is:
  - a. compacting two different powders
  - b. compacting the same piece twice
  - c. compacting the part from the top and bottom simultaneously
  - d. compacting the part from the sides

**Level I Answers;** 1(c), 2(a), 3(a), 4(c), 5(b), 6(b), 7(b), 8(d), 9(d), 10(c)

**(SUSPENDED effective October 2008 )**

**Level II**

The Level II examination consists of two parts. Part A consists of 60 multiple-choice questions, which constitute 60% by weight of the total score. Part B consists of 6 non-multiple-choice problems. The candidate must attempt to answer 4 of the 6 questions. Part B constitutes 40% by weight of the total score.

For Part A, the examination score shall be equal to the number of correct answers minus 0.25 times the number of incorrect answers.

For Part B, each of the 4 questions constitutes a maximum weighting of 10%. Partial credit may be given.

Following are examples of questions and problems for the Level II examination.

**Part A**

1. A powder with an apparent density of  $3.11 \text{ g/cm}^3$  is to be compacted into a single-level part 8 mm thick, with a green density of  $6.60 \text{ g/cm}^3$ . Assuming perfectly rigid dies and punches, and a single-direction pressing (from the top only), the distance the upper punch must travel into the die during pressing is:
  - a. 17 mm
  - b. 5 mm
  - c. 21 mm
  - d. 9 mm
  
2. The particle size distribution of an atomized molten metal will be affected by:
  - a. the liquid metal viscosity
  - b. superheat
  - c. the liquid metal flow rate
  - d. all of the above
  
3. Which of the following procedures are used commercially in the first stage debinding of metal injection molded parts?
  - a. thermal
  - b. catalytic
  - c. solvent
  - d. all of the above
  
4. A PM part made to the MPIF material specification FN0205-35 means that it is made from an alloy containing 2 wt.% Ni and 0.5 wt.% C and has:
  - a. a minimum yield strength of 35,000 psi
  - b. a minimum ultimate tensile strength of 35,000 psi
  - c. a minimum hardness of 35 HRB
  - d. a minimum transverse rupture strength of 35,000 psi

5. Endothermic gas is the product of a chemical reaction between:
  - a. water vapor and hydrogen
  - b. hydrogen and nitrogen
  - c. a hydrocarbon fuel gas and air
  - d. none of the above
  
6. In hot isostatic pressing (HIP), the dominant densification mechanism at densities near the pore-free density of a metal powder is:
  - a. dislocation glide
  - b. vapor phase transport
  - c. diffusional creep
  - d. interstitial diffusion

**Level II Part A Answers;** 1(d), 2(d), 3(d), 4(a), 5(c), 6(c)

### Part B

1. Two different tungsten powders (theoretical density =19.3 g/cm<sup>3</sup>) are analyzed for particle size using a streaming technique and found to have an equivalent mean size of 5 μm. Other properties are different, as noted below:

	<u>Powder A</u>	<u>Powder B</u>
specific surface area (m <sup>2</sup> /g)	0.26	0.12
apparent density (g/cm <sup>3</sup> )	2.30	4.50
tap density (g/cm <sup>3</sup> )	4.60	8.10

- (a) Explain why there might be a difference in surface areas.
  - (b) What equivalent spherical diameter would give the same surface area for each powder?
  - (c) What differences might explain the packing properties?
  - (d) What additional information would be useful?
  
2. Two different powders of essentially the same composition are given equivalent pressing and sintering cycles. It is found that the sintered powders exhibit different mechanical properties. Explain briefly three factors that could contribute to this difference.
  
3. A 10 mm diameter final dimension is needed with a final (sintered) density of 85% of theoretical, which is formed from a compact with 82% of theoretical green density. What die diameter is needed for this process?

## Level II Part B Answers;

1. (a) Powder B has a higher apparent density and tap density and a lower surface area compared with powder A. These facts suggest that powder A has a spongy or agglomerated particle structure.
- (b) Equivalent spherical diameter =  $6/S\rho_m$   
where S is the specific surface area  
 $\rho_m$  = theoretical density  
 $D_A = 1.2 \mu\text{m}$      $D_B = 2.6 \mu\text{m}$
- (c) The packing characteristics are similar with respect to the ratio of tap density to apparent density ( $\cong 2$ ). However, powder A has a much lower apparent density and tap density, as would be expected from an agglomerated powder. This is consistent with the higher surface area, but equal agglomerate size.
- (d) Most useful would be an optical or scanning electron micrograph. Also, assuming the surface was measured by the BET technique, an air permeability surface area should be different from the listed value for A, but not for B. This would again confirm the agglomerated nature of powder A.
2. Most probable effects are related to powder characteristics:
- Particle size—affects compressibility and sintering response
  - Particle structure—especially internal pores; these are hard to remove if present in one powder (but not the other)
  - Particle size distribution—for example, if one powder has a bimodal distribution, then smaller particles will improve density and bonding during sintering
  - Particle shape—affects packing and density; in turn, density controls mechanical properties
  - Particle contamination—if one powder has surface segregation or contamination, then differences in particle bonding are expected

3. f = final (sintered) condition  
g = initial (green) condition

$$D_f = 10 \text{ mm}$$

$$\rho_f = 85\%$$

$$\rho_g = 82\%$$

$$D_g = ?$$

$$\rho_f = \frac{\rho_g}{(1 - \Delta D/D_g)^3} \quad \therefore \Delta D/D_g = 1 - (\rho_g/\rho_f)^{1/3} \quad \text{where } \Delta D = D_g - D_f$$

$$\Delta D = D_g (1 - (\rho_g/\rho_f)^{1/3}) = D_g - D_f$$

$$\text{rearrange: } D_g = D_f / (\rho_g/\rho_f)^{1/3} = 10 / (82/85)^{1/3} = 10.12 \text{ mm}$$

### How are examination locations and proctors selected?

Examinations will be held at locations where appropriate sites and proctors are available. You must indicate your preferred location for taking the examination on your application form.

Examinations will be monitored by proctors who have been approved by APMI.

Proctors are responsible for checking in applicants at the examination location, monitoring the room during the examination, and submitting all completed examinations to APMI headquarters for scoring and recording. Upon applying for the certification examination, applicants automatically acknowledge the confidentiality of the examination. They agree to follow the proctor's instructions and to not discuss the examination questions with any individual other than the proctor. Any problems which

arise on the content or the administration of the examination should be reported immediately to the proctor who will notify APMI headquarters of the situation. Proctors are not permitted to answer any technical questions in reference to the examination. Examinees or proctors must not copy any examination questions or answers on the examination. If any of the situations cited is suspected, the examinee will be disqualified and will be ineligible to become certified by APMI.

## **FOLLOWING THE EXAMINATION**

### **When will results be announced?**

Applicants will be notified in writing within 30 days following the examination concerning their status. APMI realizes that timely notification is important to candidates and will do its best to give results as soon as possible. The examination results will be provided only in writing and only to the applicant.

### **What recognition is given to those that pass the examination?**

Upon notification, you will receive a congratulatory letter, and a personalized certificate suitable for framing will be sent to you or your local APMI chapter for official presentation.

### **What happens to those not passing the examination?**

Unsuccessful applicants will receive written indication of their areas of weakness on the examination. It will also be necessary for them to re-apply to take the examination again. Re-application must be for a time at least one full calendar year from the time of the first examination.

### **What is required to maintain certification?**

In order to retain certification, currency must be demonstrated for certification renewal every five years.

- For recertification at PMT Level I, there are two options:
  - a) Accumulate a minimum of 15 professional credits every five years as defined below, or
  - b) Retake and pass the Level I examination.
- For recertification at PMT Level II, there are two options:
  - a) Accumulate a minimum of 35 professional credits every five years as defined below, or
  - b) Accumulate a minimum of 15 professional credits and retake and pass the Level II examination.

Credits are subject to the following stipulations:

- Credits cannot be banked for the next renewal period. Only 15 credits will be accepted in a five-year period for Level I PMTs. Any credits accumulated in excess of 15 will be deleted once currency is granted.
- Eligible professional credits will be based on activities/accomplishments occurring **after** the date the candidate passed the examination.
- Activities must be technological in character, and must have a relationship to the field of powder metallurgy and/or particulate materials.
- Acceptable forms of evidence include a receipt or certificate from a seminar, school transcripts, or a letter from an organization or school documenting activities. For MPIF-sponsored functions, list the date and event only; no proof is needed.

Return the PMT Recertification Professional Credit Submission Form prior to February 1 of your recertification year.

**Professional Credit(s)**

**Continuing Work Experience** ..... 2/year

**CODE**

**Activity/Accomplishment**

- 1 APMI member ..... 0.5/year
- 2 APMI chapter officer ..... 0.5/year

**Continuing Education**

- 3 Regional Technical Programs/seminars/short courses.... 1/full-day, 0.5/half-day
- 4 In-house (internal)/customer-site training courses .....0.5/full-day
- 5 Home study courses ..... 3/course
- 6 College level course .....\*
- 7 Professional industry meeting attendance ..... 0.1/meeting\*\*

- 8 Professional industry speaker/ internal or customer-site training speaker  
..... 0.5/meeting, full day\*\*
- 9 Seminar instructor .....2/day

**Seminar/Conference Activity**

- 10 Paper authorship ..... 3
- 11 Conference attendance (technical sessions)..... 2/conference
- 12 Exhibit attendance only (may not be added to same-conference  
technical session attendance) ..... 0.5/conference

\* equal to 2 x of credits given by the particular school for that course

\*\* includes technical meetings only; does not include social events or golf outings

**BODY OF KNOWLEDGE**

**Level I**

- PM Materials, Applications and Finished Properties
- Powder Manufacturing Methods and Principles
  - ferrous, nonferrous
  - e.g., atomization, oxide reduction, electrolytic production, blending
- Powder Characterization
  - e.g., particle size, apparent density, flowability, compressibility, green strength, chemical composition
- Compaction
  - e.g., basic principles, methods, tooling schemes, press types
- Sintering
  - e.g., basic principles, furnaces, atmospheres, solid-state, liquid-phase
- High-Density and Specialty Processing
  - e.g., P/F, MIM, HIP, CIP, plasma spraying, controlled porosity
- Secondary Operations
  - e.g., sizing, machining, heat treating, plating, deburring, joining, coining, carburizing, impregnation, steam treating

## Level II

- PM Materials, Applications and Finished Properties
  - SPC/SQC
- Powder Manufacturing Methods and Principles
  - ferrous, nonferrous
  - e.g., atomization, oxide reduction, electrolytic production, blending
- Powder Characterization
  - e.g., particle size, apparent density, flowability, compressibility, green strength, chemical composition
- Compaction
  - e.g., basic principles, methods, tooling schemes, press types
- Sintering
  - e.g., basic principles, furnaces, atmospheres, solid-state, liquid-phase
- High-Density and Specialty Processing
  - e.g., P/F, MIM, HIP, CIP, Ceracon, ROC, plasma spraying, controlled porosity
- Secondary Operations
  - e.g., sizing, machining, heat treating, plating, deburring, joining, coining, carburizing, impregnation, steam treating

## REFERENCE MATERIALS

### Level I

- *Fundamentals of Powder Metallurgy*, Leander F. Pease III & William G. West, 2002, MPIF
- Standard Test Methods for Metal Powders and Powder Metallurgy Products, current edition, MPIF.
- Standard 35, Materials Standards for P/M Structural Parts, current edition, MPIF.
- *Powder Metallurgy & Particulate Materials Processing*, Randall M. German, 2005, MPIF.
- ASM (MEI) homestudy course/seminar, "Fundamentals and Applications of Powder Metallurgy"
- MPIF instructional video, "Basic Powder Metallurgy", D.W. Smith, 1993
- ASM Handbook Powder Metal Technologies and Applications, Volume 7, 1998
- MPIF video, "Powder Metallurgy", 1990
- MPIF Powder Metallurgy Equipment Manual (out of print).
- *P/M Design Manual*, 1998, MPIF.
- Powder Metallurgy Design Solutions, 1999, MPIF.
- MPIF Basic P/M Short Course

## Level II

The reference list for the Level II examination includes the references listed for the Level I examination **with the addition of the following:**

- *Powder Metallurgy of Iron and Steel*, Randall M. German, 1998, John Wiley & Sons, Inc.
- *Sintering Theory and Practice*, Randall M. German, 1996, John Wiley & Sons, Inc.
- *Introduction to Powder Metallurgy*, F. Thummler and R. Oberacker, 1994, The Institute of Materials.
- *Powder Injection Molding*, Randall M. German, 1990, MPIF. (out of print)
- *Injection Molding of Metals & Ceramics*, 1997, MPIF.
- *Powder Forging*, Howard A. Kuhn and B. Lynn Ferguson, 1990, MPIF.
- *Atomization: The Production of Metal Powders*, Alan Lawley, 1992, MPIF.
- Statistical Process Control Manual, 1995, Automotive Industry Action Group.
- MPIF Advanced Powder Metallurgy Short Course.
- *International Atlas of Powder Metallurgical Microstructures*, P. Beiss, K. Dalal & R. Peters, 2002, MPIF

All reference materials are available for sale through the MPIF Publications department (except the Statistical Process Control Manual). For information contact:  
MPIF Publications (609) 945-0009, FAX (609) 987-8523 or E-Mail: [plebedz@mpif.org](mailto:plebedz@mpif.org).

To order the Statistical Process Control Manual, call AIAG at (248) 358-3570.