



Standard Guide for Steam Treatment of Ferrous Powder Metallurgy (PM) Materials¹

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^{ε1} NOTE—P/M was changed to PM editorially in December 2009.

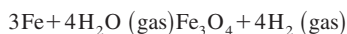
1. Scope

1.1 This guide is intended as an aid in establishing and maintaining a procedure for the steam treatment, also referred to as steam blackening, of sintered ferrous PM materials and the appropriate use and evaluation of these materials. Additional information concerning the effect of this process on ferrous PM material properties is contained in [Appendix X1](#).

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Summary of Guide

2.1 A normal sequence of steps is: (1) preheat the load; (2) introduce a superheated steam-rich atmosphere; (3) heat the load to the processing temperature and maintain the temperature for the duration of the processing cycle; and (4) cool the load to a temperature suitable for handling. This process will produce a layer of black iron oxide (magnetite) on the surface of the parts and on the surfaces of the interconnected porosity by the reaction.



3. Significance and Use

3.1 The performance and quality of steam-treated materials depends upon the surface cleanliness of the material prior to steam treatment and the adequacy of the processing. Steam treatment can be used as a decorative coating, producing a blue-gray to a blue-black appearance. It can reduce the susceptibility of ferrous PM materials to further oxidation and corrosion, thus providing better shelf life. More significantly, improvements in apparent hardness, compressive strength,

wear characteristics, and some mechanical properties (see [Appendix X1](#)) can be observed due to steam treatment. The hardness of magnetite (Fe_3O_4) formed during steam treatment is typically equivalent to 50 HRC, and when present in sintered materials, their wear resistance can be improved significantly. Steam treatment is also used to seal parts or provide a base material for additional coatings. Steam treated ferrous PM materials are used in many industries, including automotive, marine, home appliances and lawn and garden applications.

4. Apparatus

4.1 The material can be processed in either a batch-type furnace or a continuous belt-type furnace. The furnace must be capable of heating the load, maintaining it at the processing temperature, and maintaining a steam atmosphere free of air leaks. Both batch type and continuous furnaces must meet the same criteria described in the following procedure section. When both batch and continuous furnaces are operated to meet the same processing times, temperatures, and atmosphere, the results should be similar.

5. Procedure

5.1 Place the load in the furnace and heat in air until the temperature of the entire load is above 100°C (212°F) without exceeding 430°C (800°F).

5.2 Once the load is preheated, introduce superheated steam into the furnace until all of the air is purged from the furnace or processing zone. This steam atmosphere must be maintained until the processing cycle is complete.

NOTE 1—The temperature of the parts must be in excess of 100°C (212°F) before the superheated steam is introduced. If it is not, water will condense on the parts and rust spots will form. The temperature must not exceed 430°C (800°F) before the superheated steam is introduced or the parts will be covered with a smooth even coating of rust caused by air in the furnace atmosphere.

5.3 Raise the temperature of the furnace to the processing temperature of between 430°C (800°F) and 590°C (1100°F) while maintaining the atmosphere of superheated steam.

NOTE 2—The processing temperature depends on the desired properties. Lower temperatures result in deeper oxide penetration while higher temperatures produce a thicker surface oxide layer.

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NOTE 3—Processes that decrease the amount or the size of the interconnected porosity such as copper infiltration, grinding, vibratory finishing, sizing, machining, burnishing, shot peening, or polishing will reduce the effectiveness of the steam treatment by limiting the ability of steam to penetrate the part. Increasing the density reduces the pore size, which reduces penetration unless sufficiently large porosity is available to maintain a pathway for the steam. Copper infiltration also coats the surface of iron particles with copper, which prevents steam from reacting with the iron and decreases the effectiveness of steam treatment as a surface treatment.

5.4 Hold the load at the processing temperature for 30 to 120 min depending on the desired properties. Steam treatment builds an oxide layer on pore surfaces and gradually restricts the access of the steam to the interior of the part. Higher temperature causes the metal to be more reactive, producing a thicker surface layer and limiting the penetration of the oxide into the part. Lower temperature produces deeper penetration with a thinner surface layer.

NOTE 4—A discussion of sealing method is recommended for parts requiring additional surface treatments (plating, painting, and so forth).

5.5 The oxide produced by steam treatment is slightly porous, which can allow corrosive material to penetrate to non-oxidized iron. While the oxide provides improved shelf and handling life by itself, oil impregnation, an oil dip, or rust preventatives are recommended for applications requiring additional corrosion protection.

6. Interferences

6.1 The surface of the material to be steam-treated should be free of contaminants including red rust, soot, and dirt. Steam treatment cannot reduce existing rust. Soot and dirt attract moisture, which causes rust to form during steam treatment. The soot and dirt will remain as surface blemishes after steam treatment.

6.2 Since steam treatment builds an iron oxide layer on the pore surfaces, it tends to restrict access to the non-oxidized interior iron, causing the reaction to slow until further treatment has little effect on the thickness of the oxide layer.

7. Hazards

7.1 Hydrogen is generated as a by-product of the steam treatment process. This hydrogen must be flushed from the furnace and air ingress must be prevented. Prior to opening a

batch-type furnace, the furnace should be flushed with nitrogen or an inert gas unless the parts and furnace are cooled to below the auto ignition point of hydrogen while still in the steam atmosphere.

7.2 Foreign material can interfere with steam treatment and possibly pose a serious health threat. Some chemical compounds, for example, chlorinated hydrocarbons, decompose into products that cause materials to rust during processing. All cutting fluids, lubricants, coolants, and so forth should be removed prior to steam treatment. This may be done during the preheating stage of the steam treatment process. However, the effect of the contaminant and by-products must be considered to ensure they are compatible with the steam treatment process and do not create a hazardous condition.

8. Testing and Evaluation

8.1 Fe_3O_4 can be deposited either heavily on the external part surface or uniformly at the surface and in the porosity. Depending on the objective of the steam treatment, the methods used for evaluation may need to be changed.

8.2 A simple visual inspection is sufficient for many decorative applications. Density or the change in mass measure the amount of Fe_3O_4 formed. Apparent hardness gives an indication of the surface condition. Metallographic evaluation is recommended to determine the extent of oxide penetration. Microindentation and file hardness testing are not recommended.

8.3 No single test will indicate the effectiveness of steam treatment for all potential applications. It is recommended that the producer and user agree on test procedures to evaluate parts early in the part development process.

8.4 Steam treatment changes the chemical composition and the mechanical properties of the material. Testing for compliance with material specifications should therefore be performed prior to steam treatment unless it is agreed that the part is to be tested in the steam-treated condition.

9. Keywords

9.1 blackening; black oxide; ferrous PM parts; iron oxide; magnetite; steam

APPENDIX

(Nonmandatory Information)

X1. TYPICAL PROPERTIES OF STEAM-TREATED MATERIALS

X1.1 **Table X1.1** summarizes data for various materials and process cycles. Data are included for material in the as-sintered and for the steam-treated condition (AS = as-sintered;

ST = steam-treated). The data should not be taken as a specification or minimum or maximum results that should be expected from steam treatment.

TABLE X1.1 Comparison of Properties Before (AS) and After Steam Treatment (ST)

Sintered Grade ^A	UTS			% Elongation			TRS			Unnotched Charpy Impact			Macro (Apparent) Hardness			Density		
	10 ⁻³ psi			In 1 in.			10 ⁻³ psi			ft-lbf			HRB			g/cm ³		
	AS	ST	% Chg.	AS	ST	% Chg.	AS	ST	% Chg.	AS	ST	% Chg.	AS	ST	Net Chg.	AS	ST	Net Chg.
F-0000-10	20.0	22.2	+11	6.5	1.5	-77	48	58	+21	4.0	2.0	-50	37	86	+49	6.20	6.50	+0.30
F-0000-15	19.1	19.8	+4	3.5	0.5	-86	57	75	+32	4.5	2.0	-56	52	89	+37	6.93	7.09	+0.16
F-0008-25	30.6	18.1	-41	1.5	0.5	-67	66	64	-3	2.5	1.5	-40	69	107	+38	6.26	6.60	+0.34
F-0008-30	39.5	28.0	-29	1.5	0.5	-67	96	102	+6	3.0	2.0	-33	87	109	+22	6.78	6.96	+0.18
FC-0208-40	48.0	30.0	-38	1.0	0.5	-50	99	97	-2	3.5	2.0	-43	87	111	+24	6.27	6.53	+0.26
FC-0208-50	66.8	57.2	-14	1.5	1.0	-33	138	143	+4	6.5	4.5	-31	95	109	+14	6.85	6.97	+0.12

^A The materials listed are sponge iron powder-based, except for the F-0008-30, a water granulated iron powder-based, the FC-0208-50 and F-0000-15 are water atomized powder-based materials.

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