

NOT MEASUREMENT SENSITIVE

MIL-PRF-81904C(AS)
21 November 2011
SUPERSEDING
MIL-C-81904B(AS)
31 May 1991

PERFORMANCE SPECIFICATION

COATING COMPOUND, THERMAL-INSULATION

This specification is approved for use by the Naval Air Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers asbestos-free, thermal-insulating coating compound. The thermal protection coating is used for the exterior surfaces of aircraft ordnance to delay cook-off during exposure to a liquid fuel fire (see 6.1).

1.2 Part or Identifying Number (PIN). The PINs to be used for primer coatings acquired to this specification are created as follows:

M81904	-	XXXXX	-	1
Specification		FED-STD-595		
Identifier		Color Number		

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3 and 4 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort

Comments, suggestions, or questions on this document should be addressed to: Commander, Naval Air Warfare Center Aircraft Division, Code 4L8000B120-3, Highway 547, Lakehurst, NJ 08733-5100 or emailed to michael.sikora@navy.mil . Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.daps.dla.mil .
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has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3 and 4 of this specification, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

INTERNATIONAL STANDARDIZATION AGREEMENTS

NORTH ATLANTIC TREATY ORGANIZATION (NATO)

STANAG 4240 - Liquid Fuel/External Fire, Munition Test Procedures

FEDERAL SPECIFICATION

QQ-S-698 - Steel, Sheet and Strip, Low Carbon

FEDERAL STANDARDS

FED-STD-141 - Paint, Varnish, Lacquer and Related Materials; Methods of Inspection, Sampling and Testing

FED-STD-595 - Colors Used in Government Procurement/
FED-STD-595 Color Number 36375 (Medium Gray)

COMMERCIAL ITEM DESCRIPTIONS

A-A-2787 - Enamel, (Aerosol (Low VOC)

A-A-59342 - Ethyl Alcohol (for Ordnance Use)

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-DTL-5624 - Turbine Fuel, Aviation, Grades JP-4 and JP-5

MIL-PRF-23699 - Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, Nato Code Number O-156

MIL-DTL-83133 - Turbine Fuel, Aviation, Kerosene Type, JP-8 (NATO F-34), NATO F-35, and JP-8+100 (NATO F-37)

DEPARTMENT OF DEFENSE STANDARD

MIL-STD-810 - Environmental Engineering Considerations and Laboratory Tests

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DEPARTMENT OF DEFENSE HANDBOOK

MIL-HDBK-310 - Global Climatic Data for Developing Military Products

(Copies of these documents are available online at <https://assist.daps.dla.mil/quicksearch/> or <https://assist.daps.dla.mil> or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.2.2 Other Government documents, drawings and publications. The following other Government documents, drawings and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

CODE OF FEDERAL REGULATIONS

49 CFR 171 – 178 Transportation – Hazardous Material Regulations

(Copies of this document are available online at <http://ecfr.gpoaccess.gov> or www.gpoaccess.gov/cfr/ or from the Superintendent of Documents, U.S. Government Printing Office, North Capital & “H” Streets, N.W., Washington, DC 20402-0002.)

NAVAL AIR SYSTEMS COMMAND (NAVAIR)

Drawing Number 4902393 - Bomb, General Purpose, 500 Pound, Thermally Protected, H-6 Loaded, MK 82 Mod 2

(Copies of this document are available from Naval Air Systems Command and may be obtained from the contracting officer or from Commander, Naval Air Warfare Center, Weapons Division (Code 47J270D), 1 Administration Circle M/S 6811 Bldg. 10 Room 2015, China Lake, CA 93555-6001.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

ASTM INTERNATIONAL

ASTM D1729	-	Standard Practice for Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials (DoD adopted)
ASTM D2240	-	Standard Test Method for Rubber Property—Durometer Hardness (DoD adopted)
ASTM D2247	-	Standard Practice for Testing Water Resistance of Coatings in 100 Percent Relative Humidity (DoD Adopted)

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| ASTM D3359 | - | Standard Test Method for Measuring Adhesion by Tape Test (DoD adopted) |
| ASTM D4541 | - | Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers (DoD adopted) |
| ASTM G155 | - | Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials (DoD adopted) |

(Copies of these documents are available online at <http://www.astm.org> or from ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.)

AMERICAN SOCIETY FOR QUALITY (ASQ)

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|----------|---|--|
| ASQ-Z1.4 | - | Procedures, Sampling and Tables for Inspection by Attributes (DoD Adopted) |
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(Copies of this document are available from <http://www.asq.org> or from the American Society for Quality, 600 Plankinton Avenue, Milwaukee, WI 53203.)

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

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|-----------|---|--|
| ISO 834-1 | - | Fire-resistance tests - Elements of building construction – Part 1: General Requirements (DoD Adopted) |
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(Copies of this document are available online at <http://www.iso.org> or from the International Organization for Standardization (ISO), 1.ch.de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland.)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Qualification. The coatings furnished under this specification shall be products that are authorized by the qualifying activity for listing on the applicable qualified products list (QPL) before contract award (see 4.3 and 6.3). Any change in the formulation of a qualified product shall necessitate its requalification. The material supplied under contract shall be identical, within manufacturer tolerances, to the product(s) receiving qualification.

3.2 Composition. The coating compound furnished under this specification shall consist of a sprayable resin. If the coating is supplied in two components, the volume mixing ratio shall be specified by the manufacturer.

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3.2.1 Materials. Materials used in the formulation of this coating compound shall be of such quality to produce coating compounds that meet all of the requirements of this specification.

3.2.2 Precluded material. Asbestos shall not be used in the formulation of the coating compound.

3.3 Toxicity. The material covered by this specification shall have no adverse effect on the health of the personnel when used for its intended purpose and in accordance with precautions of 3.10 through 3.10.2.

3.4 Condition in container. All components, when packaged and stored in a closed container(s) and maintained at $60 \pm 20^{\circ} \text{F}$ ($15 \pm 1^{\circ} \text{C}$) for a minimum period of six (6) months from the date of delivery to the procuring activity, shall be capable of being mixed by hand with a paddle to a smooth, homogeneous condition, free of pigmentation flotation, grit, seeds, skins, or lumps, in accordance with 4.6.2. There shall be no evidence of hard or objectionable settling which cannot be readily dispersed. The coating shall spray as specified in 3.5.2. Skinning will be permitted, provided that its removal does not affect the sprayability of the material.

3.5 Working properties.

3.5.1 Cure time. After the coating is spray applied, it shall be cured to a minimum hardness of Shore D 55 in no longer than 90 minutes.

3.5.2 Application. The coating compound shall be capable of being sprayed without sag on a vertical surface to a minimum thickness of 0.08 inch (2 mm). The coating material shall yield a smooth, uniform film at a dry-film thickness of 0.155 ± 0.020 inch (4 ± 0.5 mm). Other dry film thickness may be used if approved by the cognizant engineering authority prior to application. No orange peel (wavy appearance) shall be evident when viewed from six feet away.

3.6 Coating properties.

3.6.1 Thermal efficiency. The thermal efficiency of the coating compound shall be a minimum of 1 minute plus 1.0 second per 0.001 inch (0.025 mm) of coating to reach a backface temperature of 500°F (260°C), when tested in accordance with 4.6.4.1. For retention of qualification testing in accordance with 4.3.1, the thermal efficiency shall meet the minimum value listed above and the average shall not vary by more than ± 15 percent from the original qualification average value.

3.6.2 Color and gloss. The color and gloss of the cured coating compound, when tested in accordance with 4.6.4.2, shall be a visual match to FED-STD-595 color number 36375.

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3.6.3 Hardness. The cured coating compound, when tested in accordance with 4.6.4.3, shall have a minimum hardness of Shore D 55.

3.6.4 Adhesion. The cured coating compound, when tested in accordance with 4.6.4.4, shall be well bonded to the surface, and shall come off in chips less than 1 inch in diameter.

3.6.5 Pull-off adhesion. The cured coating compound, when tested in accordance with 4.6.4.5, shall exhibit an average pull-off adhesion strength of 500 psi minimum.

3.6.6 Paint adhesion. Enamel applied to the cured coating compound, when tested in accordance with 4.6.4.6, shall exhibit an adhesion rating of 2B or better in accordance with ASTM D3359, indicating less than 35 percent enamel removal.

3.7 Resistance properties.

3.7.1 Lubricating oil resistance. The coating compound, when tested in accordance with 4.6.5.1, shall withstand immersion in oil for one minute at $250 \pm 4^{\circ} \text{F}$ ($121 \pm 2^{\circ} \text{C}$). Eight hours after removal, the film shall exhibit no blistering, film softening, or other film defects. Discoloration shall not be a cause for rejection.

3.7.2 Ethanol resistance. The coating compound, when tested in accordance with 4.6.5.2, shall withstand immersion in ethanol for one minute at room temperature. Eight hours after removal, the film shall exhibit no blistering, film softening, or other film defects. Discoloration shall not be a cause for rejection.

3.7.3 Aviation fuel resistance. The coating compound, when tested in accordance with 4.6.5.3, shall withstand immersion in aviation fuel for one minute at room temperature. Eight hours after removal, the film shall exhibit no blistering, film softening, or other film defects. Discoloration shall not be a cause for rejection.

3.7.4 Impact resistance. The coating compound, when tested in accordance with 4.6.6, shall require more than 40 inch-pounds (in-lbs) (3.4 Newton-meters (N-m)) average on direct (coated surface) impact and 4 in-lbs (0.5 N-m) average on reverse impact before cracking or flaking is evident.

3.7.5 Humidity resistance. The coating compound shall be tested for resistance to humidity, in accordance with 4.6.7. Upon removal from the humidity cabinet, the coating shall have a minimum Shore D hardness of 50. Pull-off adhesion strength shall not be reduced by more than 30 percent. Thermal efficiency shall not be reduced by more than 30 percent.

3.7.6 Resistance to temperature shock. The coating compound shall exhibit no evidence of cracking, loss of adhesion, or film deterioration when tested in accordance with 4.6.8. Upon completion of the test, the coating shall have a minimum Shore D

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hardness of 50. Pull-off adhesion strength shall not be reduced by more than 30 percent. Thermal efficiency shall not be reduced by more than 30 percent.

3.7.7 Weather resistance. After exposure in Xenon-arc weatherometer for 500 hours as specified in 4.6.9, the coating compound shall exhibit no evidence of cracking or loss of adhesion after exposure as specified in 4.6.9. The coatings shall have a color difference value (ΔE) of not greater than 12.0, as compared to the unexposed coating. Upon completion of the test, the coating shall have a minimum Shore D hardness of 50. Pull-off adhesion strength shall not be reduced by more than 30 percent. Thermal efficiency shall not be reduced by more than 30 percent.

3.8 Environmental performance requirements.

3.8.1 Temperature and humidity cycling. The coating compound shall exhibit no loss of adhesion nor any excessive cracking or blistering, when applied to one inert loaded MK 82, 500 pound bomb in accordance with Naval Air Systems Command Drawing Number 4902393, and when tested in accordance with 4.6.10.

3.8.2 Fast cook-off. One MK-82 bomb test shall be not less than 8 minutes to reaction when tested in accordance with 4.6.11.

3.9 Labeling. Individual cans and containers shall bear printed labels containing the following:

- a. Specification MIL-PRF-81904C(AS).
- b. Component A- Pigmented Resin, or Component B - Catalyst (as applicable).
- c. Color (name and number).
- d. Manufacturer's name and product number.
- e. Date of manufacture (month and year).
- f. Lot and batch number.
- g. Flash point.
- h. Net contents.

3.10 Container markings and packing. The container shall be as specified in the contract or order (see 6.2) and shall close by the method specified in the contract or order (see 6.2). The container shall not be distorted or bulging and there shall be no leakage or seepage of the container contents. Directions for use shall be included. All markings and directions shall be clear, legible, correct, and complete. All components shall conform to the requirements of this specification. The components shall not be missing, damaged, or defective.

3.10.1 Component A (resin) containers. All containers of toxic and hazardous chemicals and materials shall be labeled in accordance with the applicable federal, state, and municipal laws, statutes, regulations, and ordinances. In addition to the labeling specified in 49 CFR 171-178, the following labeling shall appear on each container and on each exterior shipping container:

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CAUTION
HARMFUL VAPOR.
USE ONLY WITH ADEQUATE VENTILATION.
AVOID PROLONGED BREATHING OF VAPOR.
AVOID PROLONGED OR REPEATED CONTACT WITH SKIN.
KEEP AWAY FROM HEAT AND OPEN FLAME.

3.10.2 Component B (catalyst) containers. All containers of toxic and hazardous chemicals and materials shall be labeled in accordance with the applicable federal, state, and municipal laws, statutes, regulations, and ordinances. In addition to the labeling specified in 49 CFR 171-178, the following labeling shall appear on each container and on each exterior shipping container:

CAUTION: OXIDIZING MATERIAL, STRONG IRRITANT. HARMFUL IF SWALLOWED.

- AVOID CONTACT WITH SKIN AND EYES. IN CASE OF CONTACT, FLUSH IMMEDIATELY WITH PLENTY OF WATER. FOR EYES, GET MEDICAL ATTENTION. IN CASE OF INGESTION, CALL A PHYSICIAN IMMEDIATELY. IN CASE OF CONTAINER LEAKAGE, REMOVE TO A SAFE PLACE, OUTDOORS.

3.11 Workmanship. The coating shall be processed in such a manner that produces the highest quality material necessary to meet the requirements of this specification. All components shall be free of solvents, uniform in quality and consistency after stirring, and free of agglomerates or foreign particles. There shall be no other defects present that inhibit the end product from performing its intended purpose.

4. VERIFICATION

4.1 Classification of inspection. The inspection requirements specified herein are classified as follows:

- a. Qualification inspection (see 4.3).
- b. Conformance inspection (see 4.4).

4.2 Inspection conditions. Unless otherwise stated in the test methods or paragraphs herein, all inspections shall be conducted at a room temperature of $70 \pm 10^{\circ} \text{F}$ ($21 \pm 5^{\circ} \text{C}$) and a relative humidity of 50 ± 10 percent.

4.3 Qualification inspection. Qualification inspection shall consist of all the tests and examinations specified in this specification (see 6.3).

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4.3.1 Retention of qualification. Unless otherwise specified by the qualifying activity, the time of periodic certification to retain qualification of products shall be in two-year intervals from the date of original qualification and shall be initiated by the qualifying activity. Requalification of thermal efficiency shall be by test and shall not be extended beyond five years from the previous test for acquisition of new material lots.

4.4 Conformance inspections. Conformance inspection shall consist of all examinations specified in table I and 4.4.3.

TABLE I. Conformance inspections.

Characteristic	Requirement Paragraph	Test Method Paragraph
Condition in container	3.4	4.6.2
Cure time	3.5.1	4.6.3.1
Color	3.6.2	4.6.4.2
Hardness	3.6.3	4.6.4.3
Pull-Off Adhesion	3.6.5	4.6.4.5

4.4.1 Lot formation. A lot shall consist of all the coating compound produced by one manufacturer during a period not to exceed 24 hours, at one plant, from the same materials, and under essentially the same manufacturing conditions, provided that the operation is continuous. In the event that the process is a batch operation, each batch shall constitute a lot (see 4.4.1.1).

4.4.1.1 Batch. A batch is the quantity of material which has been manufactured by some unit chemical process, or subjected to some physical mixing operation, intended to make the final product substantially uniform.

4.4.2 Sampling for tests. Conformance test samples shall consist of one gallon (3.79 liter) of the coating or coating system selected from each lot in accordance with FED-STD-141, Method 1022. Each container shall be labeled with complete information regarding the lot and batch numbers, date of sampling, contract number and applicable specification.

4.4.2.1 Sampling for examination for container fill. A random sample of filled containers shall be selected in accordance with ANSI/ASQ Z1.4, Inspection Level S-4, for examinations as specified in 4.4.3.2.1.

4.4.3 Examinations.

4.4.3.1 Tests. The conformance tests shall consist of all the tests specified in 4.4 and table I. There shall be no failures.

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4.4.3.2 Examination of container labeling, markings and packing. An examination shall be made to determine that the labeling, packing and markings comply with the requirements of 3.9 and 3.10 through 3.10.2. Samples shall be selected in accordance with 4.4.2.

4.4.3.2.1 Examination for container fill. The sample size shall be as specified in 4.4.2.1, with the exception that the sample size derived from ANSI/ASQ Z1.4 shall be rounded off to the next highest increment of five. At no time shall the sample size be less than five. If the lot consists of less than five containers, all containers shall be used to examine fill.

4.4.3.2.2 Examination of product. Conformance of the coating compound to the requirements for workmanship and any other requirements not covered by specific tests shall be determined by appropriate visual examination.

4.5 Test conditions. The laboratory testing conditions shall be in accordance with the specific test method and as described herein.

4.5.1 Test panels. This specification requires the use of two different sizes of test panels.

4.5.1.1 Small test panels. Small test panels shall be cold-rolled steel, conforming to QQ-S-698. Test panel dimensions shall be 6.0 by 3.0 by 0.031 inch (150 mm by 76 mm by 0.8 mm). Panels shall be thoroughly cleaned and lightly sanded prior to coating application. The coating compound, using appropriate spray equipment, shall be sprayed to a thickness of 0.155 ± 0.020 inch (4 ± 0.5 mm) on the prepared surface of the test panel. The actual applied coating compound thickness shall be measured (accuracy of 0.001 inch (0.025 mm)) and recorded prior to testing. Care shall be exercised to ensure a uniform coating, free from entrapped air bubbles or other film defects. The coated panels shall then be cured for a minimum of sixty minutes at room temperature.

4.5.1.2 Large test panels. Large test panels shall be prepared from low carbon steel, type 1006-1020. Prepare panels, with dimensions of 6 by 6 by 0.5 inch (152.4 mm by 152.4 mm by 12.7 mm). The test panels shall be grit blasted prior to coating application, to an approximate 2-3 mil surface profile. The coating compound shall be spray-applied to the test panels to a uniform film thickness of 0.155 ± 0.020 inch (4 ± 0.5 mm). The actual applied coating compound thickness shall be measured (accuracy of 0.001 inch (0.025 mm)) and recorded prior to testing. Care shall be exercised to ensure a uniform coating, free from entrapped air bubbles or other film defects. The coated panels shall then be cured for a minimum of sixty minutes at room temperature.

4.6 Test methods.

4.6.1 Tests. The tests contained in this specification shall be conducted in accordance with the applicable test method document or as specified herein.

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4.6.2 Condition in container. While stirring the material with a hand paddle, the material shall be observed for smoothness and homogeneity. There shall be no evidence of pigment flotation, coarse particles, or settling. The condition of the coating in the container, when examined, shall meet the requirements of 3.4.

4.6.3 Working properties.

4.6.3.1 Cure time. When the coating is applied to a thickness of 0.155 ± 0.020 in. (4 ± 0.5 mm) on the prepared surface of a test panel, it shall be examined for conformance to 3.5.1. Shore D hardness shall be tested in accordance with ASTM D2240.

4.6.4 Coating properties.

4.6.4.1 Thermal efficiency test (TET). This test exposes the coating compound to a fire environment with a total heat flux of approximately $17.6 \text{ BTU/ft}^2\text{-sec}$ (200 kW/m^2), as measured by Schmidt-Boelter heat flux gauges. The coating compound shall be prepared and applied to three test panels in accordance with 4.5.1.2.

4.6.4.1.1 Test setup. Prior to testing, five K-type thermocouples shall be welded to the back of each of three test panels in an X-pattern, with one in the center, and one approximately 1 inch from each corner. The sides and back of the test panel shall be insulated with refractory fiber insulation, nominally 6 lbs/ft^3 (96 Kg/m^3). A holder shall be used to mount the panel in a vertical plane and shall incorporate one Schmidt-Boelter heat flux gauge directly above the centerline of the top surface of the panel, with the heat flux gauge face in the same plane as the exposed surface of the panel. A propane-oxygen torch shall be used to expose the test sample to a heat flux of $17.6 \text{ BTU/ft}^2\text{-sec} \pm 1.8 \text{ BTU/ft}^2\text{-sec}$ ($200 \text{ kW/m}^2 \pm 20 \text{ kW/m}^2$). The torch shall be oriented with its face in a vertical plane to burn the flame horizontally. The elevation of the torch relative to the center of the test sample and the exact distance from the torch to the surface of the sample shall be determined by the calibration run, specified in 4.6.4.1.2; however the location shall ensure that flames impinge on the surface of the sample. A data acquisition system, with a minimum sample rate of 1 sample per second (1 hertz), shall be used to record the time, temperature, and heat flux measurements.

4.6.4.1.2 Calibration. Prior to each TET, a calibration run shall be conducted using a blank plate with a Schmidt-Boelter heat flux gauge mounted in the center. The face of the heat flux gauge shall be in the same plane as the exposed surface of the blank plate. The average heat flux measured by the gauge shall be $17.6 \text{ BTU/ft}^2\text{-sec} \pm 1.8 \text{ BTU/ft}^2\text{-sec}$ ($200 \text{ kW/m}^2 \pm 20 \text{ kW/m}^2$), once the gas flow has stabilized. The flow of gas shall then be terminated, but the location of the torch shall be maintained. The heat flux gauge specified in 4.6.4.1.1 is in addition to the gauge used for calibration and shall also be in position during the calibration run – the heat flux measured by this permanent heat flux gauge shall be monitored during the TET to confirm expected torch performance.

4.6.4.1.3 Test procedure. Upon completion of the calibration run and confirmation that the sample holder temperature is no more than 90° F (32° C), the blank

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plate shall be replaced with the test sample and the location of the propane torch from the calibration run shall be maintained. The maximum initial panel temperature, prior to fire testing, shall be 90° F (3° C). At time, T = 0, start the data acquisition system. At T = 30 seconds, the torch shall be lit. The time-temperature data for the panel back-side shall be noted and a note made of the time (in seconds) for any of the five thermocouples to reach 500° F (260° C), i.e. the first thermocouple to reach 500° F (260° C) for the thickness of the coating compound.

4.6.4.1.4 Test results. The test results shall conform to 3.6.1 and the results shall be an average of three tests.

4.6.4.2 Color. The coating compound shall be prepared and applied to test panels in accordance with 4.5.1.1. The color and gloss of the coating compound shall meet the requirements of 3.6.2, when tested in accordance with ASTM D1729.

4.6.4.3 Hardness. The coating compound shall be prepared and applied to test panels in accordance with 4.5.1.1. The Shore D hardness of the coating compound shall meet the requirements of 3.6.3, when tested in accordance with ASTM D2240.

4.6.4.4 Adhesion. The coating compound shall be prepared and applied to test panels in accordance with 4.5.1.1. An adhesion test shall be performed using a hammer and screwdriver (¼-inch to ½-inch blade width or equivalent) and the adhesion of the coating compound shall meet the requirements of 3.6.4.

4.6.4.5 Pull-off adhesion. The coating compound shall be prepared and applied to three test panels in accordance with 4.5.1.2. The coating shall be tested using a 0.79 inch (20mm) dolly and the coating shall be scored down to base metal around the dolly prior to testing. The average of the three readings of pull-off strength of the coating compound shall meet the requirements of 3.6.5, when tested in accordance with ASTM D4541 Method E.

4.6.4.6 Paint adhesion.

4.6.4.6.1 Panel preparation. The coating compound shall be prepared and applied to test panels in accordance 4.5.1.1. After the coating compound is cured, enamel in accordance with A-A-2787 shall be applied to the coated panel in two coats. The enamel coating thickness shall be 1.0 to 1.5 mils.

4.6.4.6.2 Adhesion test. After the enamel is fully cured, the adhesion of the enamel to the coating compound shall be tested in accordance with ASTM D3359, method B. Two sets of 6 cuts (1 mm apart) each shall be scribed 90 degrees to each other. Place tape over the grid area, and within 90 ±30 seconds of application, remove the tape by pulling it back on itself. Evaluate the enamel removal in accordance with ASTM D3359. The adhesion of the enamel shall meet the requirements of 3.6.6.

4.6.5 Resistance properties.

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4.6.5.1 Lubricating oil resistance. The coating compound shall be prepared and applied to test panels, in accordance with 4.5.1.1. The test panels shall then be immersed in lubricating oil, conforming to MIL-PRF-23699, at a temperature of $250 \pm 4^{\circ}\text{F}$ ($121 \pm 2^{\circ}\text{C}$) for one minute. Eight hours after removal from the lubricating oil, the test panels when examined, shall meet the requirements of 3.7.1.

4.6.5.2 Ethanol resistance. The coating compound shall be prepared and applied to test panels, in accordance with 4.5.1.1. The test panels shall then be immersed in a solution of 95% ethanol, 5% water, conforming to A-A-59342, at room temperature for one minute. Eight hours after removal from the ethanol, the test panels when examined, shall meet the requirements of 3.7.2.

4.6.5.3 Aviation fuel resistance. The coating compound shall be prepared and applied to test panels, in accordance with 4.5.1.1. The test panels shall then be immersed in aviation fuel, conforming to MIL-DTL-5624, at room temperature for one minute. Eight hours after removal from the aviation fuel, the test panels when examined, shall meet the requirements of 3.7.3.

4.6.6 Impact resistance. Place one test panel prepared in accordance with 4.5.1.1 coating side up, over the hole of the cylindrical base of a Gardner Heavy-Duty Impact Tester IG-1120. Determine the maximum impact resistance at which no failures occur. Repeat the test on the reverse side of another panel prepared in accordance with 4.5.1.1, with the coating side down. The test panels, when examined, shall meet the requirements of 3.7.4.

4.6.7 Humidity resistance. Two test panels shall be prepared as specified in 4.5.1.2. The coated test panels shall be tested for humidity resistance in accordance with ASTM D2247. Exposure time shall be 336 hours and exposure levels shall be $120 \pm 10^{\circ}\text{F}$ (49°C) and 95 ± 5 percent relative humidity. After removal from the humidity cabinet, the coating compound on both panels shall be tested for hardness in accordance with 4.6.4.3. The coating shall be tested for pull-off adhesion strength on one panel in accordance with 4.6.4.5. The coating may be spot repaired after adhesion testing if coating is removed to the base metal. Both panels of the coating shall be tested for thermal efficiency changes in accordance with 4.6.4.1. The coating properties shall meet the requirements of 3.7.5.

4.6.8 Resistance to temperature shock. Two test panels shall be prepared in accordance with 4.5.1.2. The coating compound shall meet the requirements of 3.7.6, when tested in accordance with MIL-STD-810, Method 503.5, with the following exceptions:

- a. The internal hot-chamber temperature shall be maintained at 160°F (71°C) and 95 percent relative humidity.
- b. The Internal cold-chamber temperature shall be maintained at -65°F (-54°C).
- c. Panels shall be cycled every 24 hours, in lieu of 4 hours.

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- d. The complete test period shall be 28 days.

After removal from the test chamber, the coating compound shall be tested for hardness on both panels in accordance with 4.6.4.3. The coating shall be tested for pull-off adhesion strength on one panel in accordance with 4.6.4.5. The coating may be spot repaired after adhesion testing if the coating is removed to the base metal. Both panels of the coating shall be tested for thermal efficiency change in accordance with 4.6.4.1. The coating properties shall meet the requirements of 3.7.6.

4.6.9 Weather resistance. Prepare three test panels in accordance with 4.5.1.2. One test panel shall be used as the control. The other two test panels shall be exposed for 500 hours in a Xenon-arc weatherometer (Atlas Electric Devices Company or equivalent as approved by the qualifying activity) that cycles between 102 minutes of light only and 18 minutes of light and water spray. The following conditions shall apply when testing in accordance with ASTM G155, type BH:

- a. Black body temperature in cabinet: $145 \pm 5^{\circ} \text{F}$ ($63 \pm 3^{\circ} \text{C}$).
- b. Relative humidity in cabinet: 50 ± 5 percent.
- c. Intensity (spectral irradiance) of Xenon-arc: 0.35 ± 0.01 Watts/meter² (W/m²) at a wavelength of 340 nm.
- d. Cabinet temperature: $108 \pm 5^{\circ} \text{F}$ ($42 \pm 3^{\circ} \text{C}$).

After exposure, measure the color difference (ΔE) value of the exposed panels and the control and examine the coating compound for conformance to 3.7.7. After removal from the test chamber, the coating compound shall be tested for hardness on both exposed panels in accordance with 4.6.4.3. The coating shall be tested for pull-off adhesion strength on one exposed panel in accordance with 4.6.4.5. The coating may be spot repaired after adhesion testing if coating is removed to the base metal. Both panels of the coating shall be tested for thermal efficiency change in accordance with 4.6.4.1. The coating compound properties shall meet the requirements of 3.7.7.

4.6.10 Temperature and humidity cycling. The coating compound shall meet the requirements of 3.8.1 when tested to the 28-day temperature and humidity test of MIL-HDBK-310. For the 28-day temperature and humidity cycling test, the temperature range shall be -65 to $+160^{\circ} \text{F}$ (-54 to $+71^{\circ} \text{C}$).

4.6.11 Fast cook-off. The coating compound shall meet the requirements of 3.8.2, when tested to the fast cook-off test in accordance with STANAG 4240, except as modified herein. In addition, the following shall apply:

- a. The quantity of fuel shall be sufficient to cause reaction of the ordnance or to ensure a 15-minute fire (approximately a 2.5 inch (64 mm) depth of fuel), whichever is greater. Test fuel shall be JP-5 conforming to MIL-DTL-5624, or JP-8 conforming to MIL-DTL-83133.
- b. The test pit shall be a minimum of 24 feet by 24 feet (7.3 meters by 7.3 meters) or a circular pit with a minimum diameter of 28 feet (8.5 meters).

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- c. Flame temperature shall reach 1000° F (538° C) within 30 seconds after fire ignition, as measured by thermocouples in accordance with STANAG 4240.
- d. The bomb shall be suspended from its suspension lugs with its center 35 ± 5.0 in. (0.89 ± 0.13 meter) above the fuel. The bomb shall be placed with its longest axis along the diagonal of the test pit, when applicable, as shown on figure 1.
- e. The test shall not be performed when the wind velocity exceeds 5 knots (9.2 Km/hr).
- f. The test shall not be performed when ambient temperatures are below 40° F (5° C).
- g. The energetic material used in the MK 82 bomb shall be PBXN-109.

4.6.11.1 Fast cook-off instrumentation. In addition to the instrumentation required by STANAG 4240, six plate thermometers (PTs) shall be included in the fast cook-off test to record the fire exposure for comparison and verification with the intended thermal exposure described in 4.6.11.2. PTs shall be constructed in accordance with ISO 834-1. A description of PT construction is provided in appendix A. Each PT shall be aged in a pre-heated oven at 1832° F (1000° C) for one hour prior to its first use. Figure 1 and figure 2 illustrate the positioning of the PTs.

4.6.11.1.1 Description of bomb faces. In 4.6.11.1.1 – 4.6.11.2, the following descriptions shall be applied: the right and left faces of the bomb specify a vertical plane that is tangent to the widest diameter of the bomb, on the right and left sides of the bomb, respectively. The front face of the bomb specifies a vertical plane that is tangent to the nose of the bomb. The rear face of the bomb is specified as a vertical plane that is tangent to the ends of the tail fins.

4.6.11.1.2 PT A location and orientation. PT A, the front PT, shall be placed with its metal surface facing forward and parallel to the front face of the bomb. PT A shall be spaced 6.0 in. (152 mm) from the right face of the bomb and 6.0 in. (152 mm) from the front face of the bomb.

4.6.11.1.3 PT B location and orientation. PT B, the bottom PT, shall be placed with its metal face at the same height as the bottom of the bomb, facing downward. PT B shall be spaced 6.0 in. (152 mm) from the right face of the bomb and 6.0 in. (152 mm) to the front of the minor axis centerline of the bomb.

4.6.11.1.4 PT C location and orientation. PT C, the right side PT, shall be placed with its metal surface facing to the right and parallel to the right face of the bomb. PT C shall be spaced 12.0 in (305 mm) from the right face of the bomb and 6.0 in. (152 mm) to the rear of the minor axis centerline of the bomb.

4.6.11.1.5 PT D location and orientation. PT D, the left side PT, shall be placed with its metal surface facing to the left and parallel to the left face of the bomb. PT D shall be spaced 12.0 in (305 mm) from the left face of the bomb and 6.0 in (152 mm) to the front of the minor axis centerline of the bomb.

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4.6.11.1.6 PT E location and orientation. PT E, the top PT, shall be placed with its metal face at the same height as the top of the bomb, facing upward. PT E shall be spaced 6.0 in. (152 mm) from the left face of the bomb and 6.0 in. (152 mm) to the rear of the minor axis centerline of the bomb.

4.6.11.1.7 PT F location and orientation. PT F, the rear PT, shall be placed with its metal surface facing in the rear direction and parallel to the rear face of the bomb. This PT shall be spaced 6.0 in. (152 mm) from the left face of the bomb and 6.0 in. (152 mm) to the rear of the rear face of the bomb.

4.6.11.1.8 PT measurements. All PT location reference measurements shall be within ± 0.5 in. (13 mm) of that specified herein. Measurements from all PTs shall be taken every one second or less (1 Hz). When not in use, PTs shall be sheltered from the weather in order to protect the PT components from absorbing water. Prior to a test, each PT shall be tested to verify it is in proper working order by using a torch to quickly heat the metal face.

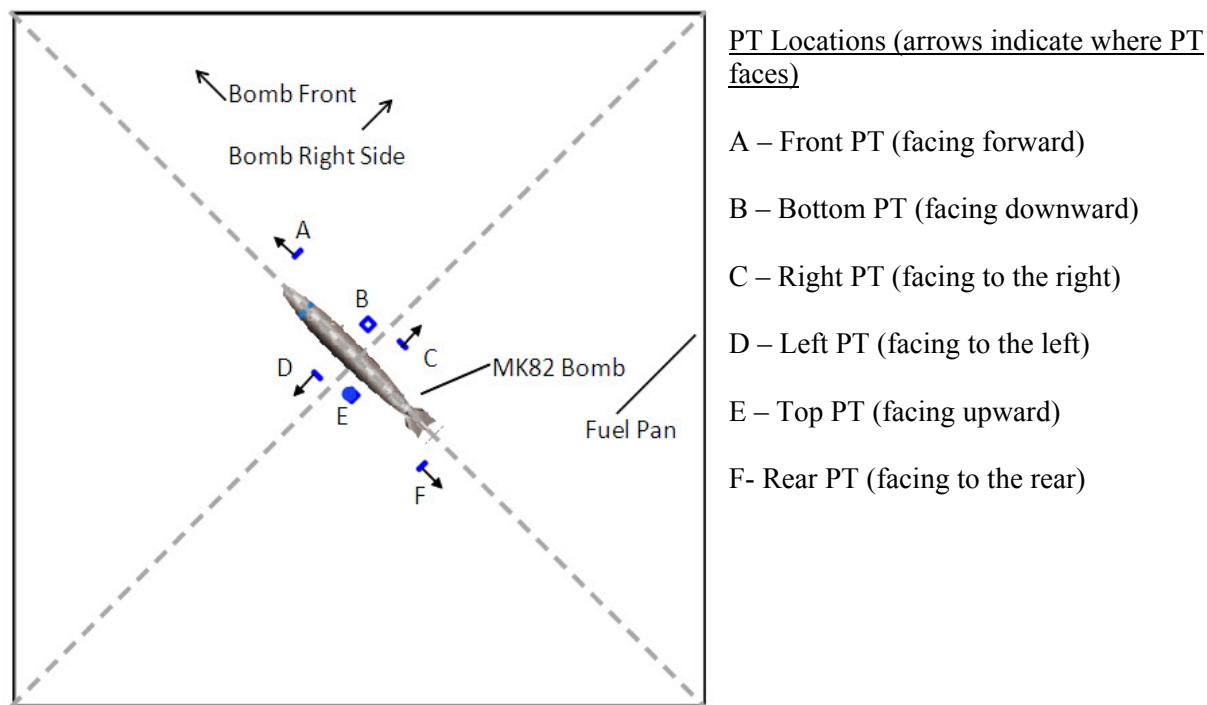


FIGURE 1. Illustration of the placement of PTs fast cook-off test, plane view.

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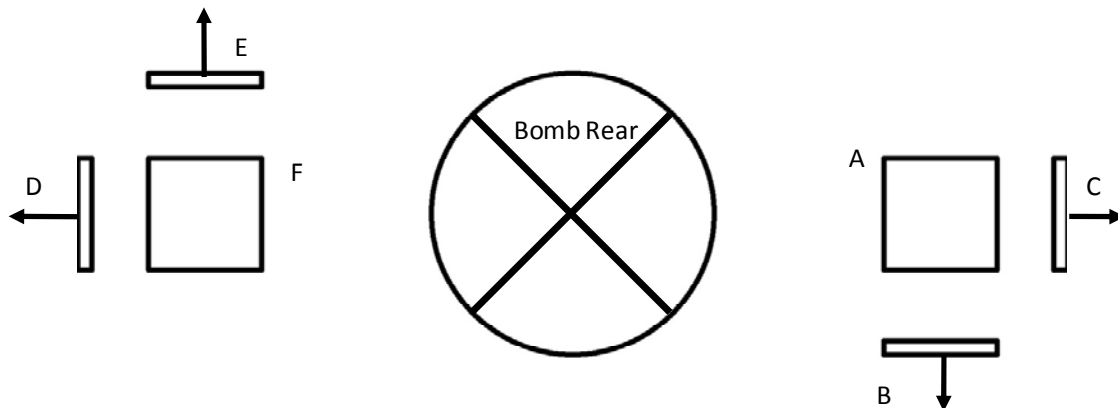


FIGURE 2. Illustration of the placement of PTs in fast cook-off test, rear elevation view (see figure 1 legend).

4.6.11.1.9 Supports for fast cook-off test instrumentation. For the fast cook-off test, the instrumentation shall be supported using thin, rigid supports. Examples of supports include steel pipe, bars, or angle iron. The supports shall be minimal and shall not interfere with the thermal exposure to the bomb.

4.6.11.2 Thermal exposure. The thermal exposure to the munition shall be measured by the PTs specified in 4.6.11.1. In order for the fast cook-off test to be a valid test, all of the following criteria shall be met:

- a. All PTs shall reach 650° C within 150 seconds maximum.
- b. The time averaged temperature measured by each PT for the remainder of the test shall be within the following ranges:
 - i. PTs A and F: 850° C \pm 100° C
 - ii. PTs C and D: 850° C \pm 100° C
 - iii. PT B: 800° C \pm 100° C
 - iv. PT E: 800° C \pm 100° C

5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When packaging of materiel is to be performed by DoD or in-house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the military service's system commands. Packaging data retrieval is available from the managing Military

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Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

6. NOTES

(This section contains information of a general or explanatory nature that may be may be helpful, but is not mandatory.)

6.1 Intended use. The thermal-insulating coating compound is intended for use as an exterior, protective coating on explosive-loaded ordnance items. A list of ordnance items that currently utilize this coating compound is provided in 6.6. This coating is formulated to preclude the use of asbestos, to meet applicable environmental conditions, and to delay an explosive reaction when the coated ordnance item is exposed to high-flux thermal environments.

6.2 Acquisition requirements. Acquisition documents should specify the following:

- a. Title, number, and date of this specification.
- b. FED-STD-595 color number and name (see 1.2).
- c. Toxicological information (see 3.3 and 6.4).
- d. Type of container and method of closure (see 3.10).
- e. If a retention sample is required and where to send it (see 4.3.1 and 6.3.3).
- f. Batch information (4.4.1 and 4.4.1.1).
- g. Quantity and size of containers.
- h. Packaging requirements (see 5.1).

6.3 Qualification. With respect to products requiring qualification, awards will be made only for products which are, at the time of award of contract, qualified for inclusion in Qualified Products List QPL No. whether or not such products have actually been so listed by that date. The attention of the contractors is called to these requirements, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. Information pertaining to qualification of products may be obtained from Commander, Naval Air Warfare Center Weapons Division, Code 4.3.4.1, Building 02466, MS6213, China Lake, CA 93555-6106. An online listing of products qualified to this specification may be found in the Qualified Products Database (QPD) at <https://assist.daps.dla.mil>.

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6.3.1 Qualification inspection samples. The test samples should consist of a minimum of one two-quart kit consisting of the following FED-STD-595 color: 36375. The material should be furnished in the type of containers to be used in filling contract orders. Samples should be identified as follows and forwarded to the laboratory designated in the letter of authorization.

Qualification inspection samples

Specification MIL-PRF-81904C;

“Coating Compound, Thermal-Insulation”

Manufacturer's name and product number

Submitted by (name and date) for qualification testing in accordance with authorization (reference authorizing letter)

6.3.2 Inspection, and other information. In addition to the qualification test samples, the qualifying activity will request the manufacturer to submit to the qualification activity: (a) one copy of the MSDS (see 6.4); (b) a certified test report showing that the material conforms to the requirements of this specification and (c) certification that asbestos is not used in the formulation of this coating.

6.3.3 Retention of qualification for formulation modifications. Manufacturers must request formulation modifications in writing. The request is reviewed and approval is determined by the preparing activity. The approval process may include limited testing of the modified material, complete qualification testing, and/or laboratory data and certification of the performance properties by the manufacturer.

6.4 Material Safety Data Sheet (MSDS). 29 CFR 1910.1200 requires that the MSDS for each hazardous chemical used in an operation must be readily available to personnel using the material. Contracting officers should identify the activities requiring copies of the MSDS.

6.5 Material storage. The recommended storage temperature range for both components should be recommended by the manufacturer, however it is recommended that the components be stored below 80° F, and storage at the lower end of the recommended storage temperature range should aid in extending storage life. It is recommended that the components be stored in their original, unopened, containers. A three-month inventory, combined with the practice of rotation of stock is recommended.

6.6 Thermally protected bombs. The following is a listing of identified Naval Air Systems Command drawing numbers of ordnance items that utilize thermal protection coatings:

4902393 Body Assy. Bomb. GP. 500 lb. TP. MK B2-2. Ld

923ASI00 Body Assy. Bomb. GP. 500 lb. TP. MK 82-2. Inert Ld

923AS554 Body Assy. Bomb. GP. 500 lb. TP. MK 82-3. H-6 Ld

923AS555 Body Assy. Bomb. GP. 500 lb. TP. MK 82-4. H-6 Ld

923AS761 Bomb, General Purpose, 500 Pounds BLU-111C/B, Loaded, Thermally Protected

923AS755 Bomb, General Purpose, Low Collateral Damage, 500 Pound, Loaded, Thermally Protected, BLU-126/B

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923AS759 Bomb, General Purpose, Low Collateral Damage, 500 Pound, Loaded, Thermally Protected, BLU-126A/B49020B9 Body Assy. Bomb. GP. 1000 lb. TP. MK 83-5. H-6 Ld
923AS109 Body Assy. Bomb. GP. 1000 lb. TP. MK 83-5. Inert Ld
923AS763 Bomb, General Purpose, 1000 Pounds BLU-110C/B Loaded, Thermally Protected
923AS110 Body Assy. Bomb. GP. 2000 lb. TP. MK 84-5. Inert Ld
4902049 Body Assy. Bomb. GP. 2000 lb. TP. MK 84-3. H-6 Ld
923AS107 Body Assy. Bomb. GP. 2000 lb. TP. MK 84-5. H-6 Ld
923AS520 Body Assy. Bomb. GP. 2000 lb. TP. MK 84-6. Inert Ld
923AS519 Body Assy. Bomb. GP. 2000 lb. TP. MK 84-6. H-6 Ld
923AS616 Body Assy. Bomb. Practice. 500 lb. TP. BDU-45/B. Inert Ld
923AS654 Body Assy. Bomb. GP. 1000 lb. TP. BLU-110A/B. PBXN-109. Ld

6.7 Non-spray application of thermal insulation coating. This coating compound may be applied by a hand-trowel method for "touch-up" applications. The exact mixing ratio is highly dependent upon the conditions under which this material is applied and should be identified by the manufacturer. Mix only that amount that can be applied in less than ten (10) minutes.

6.8 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

6.9 Subject term (key word) listing.

Aircraft ordnance
High-flux thermal environment
Protection

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APPENDIX A

FAST COOK-OFF TEST CHANGES

A.1 SCOPE

A.1.1 Scope. This appendix discusses the rationale behind the changes in 4.6.11 and 4.6.4.1. Two new subsections were added to 4.6.11 including fast cook-off instrumentation and thermal exposure evaluation. Edits were also made to the permitted ambient conditions at the time of testing. Several new subsections were added to 4.6.4.1 including the test setup, the severity of the thermal exposure and the test methodology itself. This appendix is not a mandatory part of the specification. The information contained herein is intended for guidance

A.2 FAST COOK-OFF TEST CHANGE NOTES

A.2.1 The fast cook-off test used in this specification is a slight modification of the fast cook-off test found in STANAG 4240. STANAG 4240 is used to determine a munition's Insensitive Munition (IM) classification based on cook-off severity. While a cook-off time is reported in STANAG 4240, it is not a pass-fail criterion. The fast cook-off test in STANAG 4240 only controls the thermal exposure sufficiently to characterize the cook-off severity. The fast cook-off test in this specification is used to evaluate a munition coating (not the munition) and is concerned with the time to reaction. Therefore, additional measurements and regulation of the fire exposure conditions are required. Observations and records taken during the fast cook-off test described in this specification are expected to be consistent with the requirements of NATO STANAG 4240.

A.2.2 Plate thermometers (PTs) have been added as instrumentation for the fast cook-off test (see 4.6.11.1). Typical thermocouples only measure either the gas temperature (convective heat transfer) or a surface temperature. When measuring gas temperature, a thermocouple does not adequately measure radiative heating. This is because the size of the thermocouple bead is very small compared to the flame. In a large pool fire the heat transfer to objects within the flame is approximately 90 percent radiative (Quintiere). The total of the radiative and convective heat transfers to an object constitute the total thermal exposure from the fire. PTs provide a quantified measurement of the thermal exposure: the adiabatic surface temperature. This measurement captures the total thermal exposure to the object due to both radiative and convective heat transfer (Wickstrom and Ingason). The use of total heat flux gauges (e.g. Schmidt-Boelter heat flux sensors) was considered but ultimately not used for two primary reasons. First, with heat flux gauges there is a need to thermally protect the cooling water supply and data acquisition lines while the unit is fully engulfed by the flames; there is no such requirement for the PT because as constructed it can be safely exposed to the flames. Second, the cost of a heat flux gauge is significantly more than a PT, and it is likely that all instrumentation will be destroyed by the bomb's cook-off.

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A.2.2.1 PT placement. Six PTs were placed in various locations around the test bomb. Four were placed around the center section of the bomb and one at each end of the bomb, as described in section 4.6.11.1. The PTs were located such that their placement would minimally interfere with the flow around the bomb and minimally block incident radiation to the bomb. PTs were also located in positions such that they would not interfere with each other (i.e., the thermal exposure to each PT).

Researchers have shown that the thermal exposure to an object in large pool fires varies depending on location within the flames (Beyler, Russell and Canfield, Blanchat and Figueroa). A comparatively narrow range of thermal exposures (expressed as either heat flux or temperature) is observed in the lower 40 percent of the flame height in the area surrounding the centerline; in particular within a half of the radius away from the centerline. The exposure is diminished significantly near the edges of the flame. For the pit size and configuration in this specification, the bomb and instrumentation are located within the comparatively uniform thermal exposure region. Four of the six PTs are placed around the center section of the bomb so as to document the most severe thermal exposure. The other two PTs are placed near the respective ends of the bomb in order to determine the lower bound of the thermal exposure. Also, these end PTs will help detect if wind is significantly changing the exposure to one or both ends of the bomb.

A.2.2.2 Effects of wind on the thermal exposure in a pool fire. The effects of wind on the thermal exposure in a pool fire were examined. It was found that the existing limitation of a maximum wind speed of 5 knots is appropriate, because that wind is not anticipated to dramatically alter the thermal exposure to the MK 82 bomb in a pool fire that is 28 ft (8.5 m) in diameter.

A.2.2.3 PT construction as referenced from ISO-834-1.

A.2.2.3.1 Plate thermometers. Plate thermometers comprise an assembly of a folded metal plate, the thermocouple fixed to it and containing insulation material. The plate part must be constructed from 150 ± 1 mm long by 100 ± 1 mm wide by 0.7 ± 0.1 mm thick nickel alloy sheet strips folded to the design as shown on figure 3.

A.2.2.3.2 The measuring junction. The measuring junction must consist of nickel chromium/nickel aluminum (type K) wire, contained within mineral insulation in a heat-resisting steel alloy sheath of nominal diameter 1 mm, the hot junctions being electrically insulated from the sheath. The thermocouple hot junction must be fixed to the geometric centre of the plate in the position shown in figure 1 by a small steel strip made from the same material as the plate. The steel strip can be welded to the plate or may be screwed to it to facilitate replacement of the thermocouple. The strip must be approximately 18 mm by 6 mm if it is spot welded to the plate, and nominally 25 mm by 6 mm if it is to be screwed to the plate. The screw must be 2 mm in diameter.

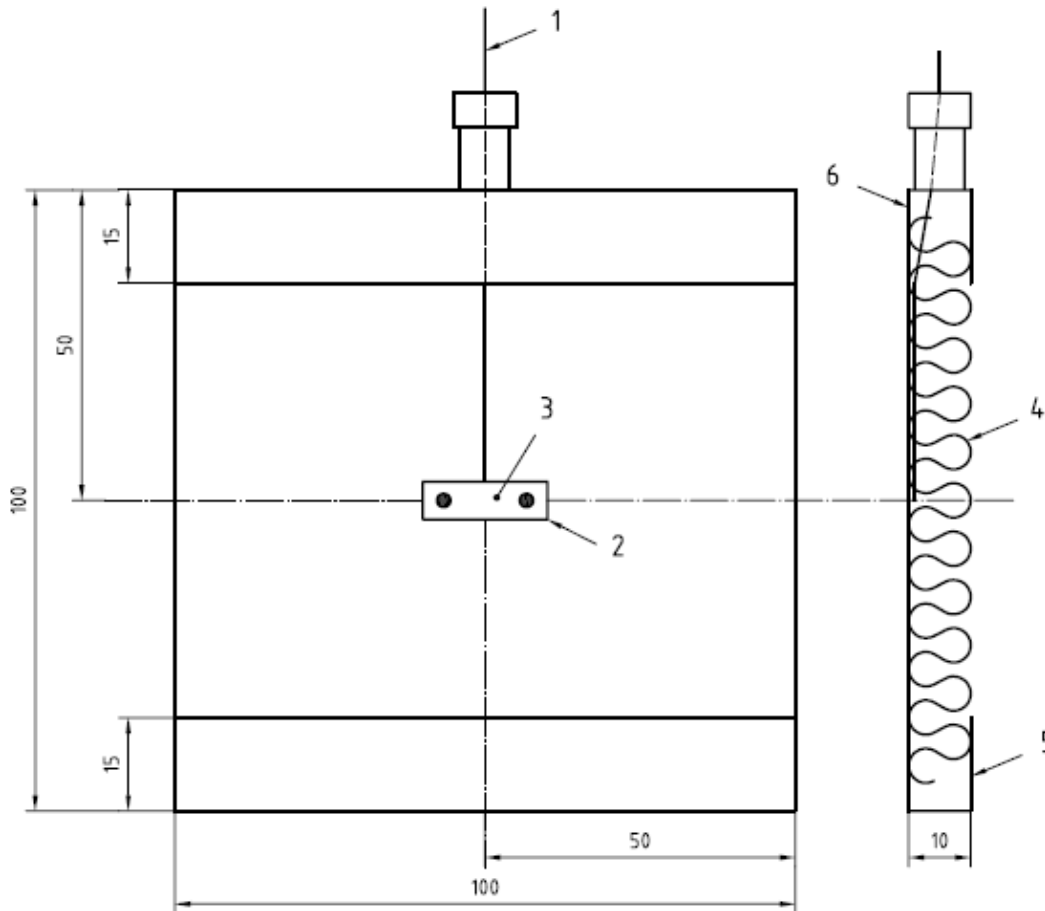
A.2.2.3.3 Inorganic insulation material. The assembly of plate and thermocouple must be fitted with a pad of inorganic insulation material nominally 97 ± 1 mm by 97 ± 1 mm by 10 ± 1 mm thick, density 280 ± 30 kg/m³.

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A.2.2.3.4 Plate thermometer aging. Before the plate thermometers are first used, the complete plate thermometer must be aged by immersing in a pre-heated oven at 1000 °C for 1 hour.

A.2.2.3.5 Thermocouple and the insulation pad replacement. The thermocouple and the insulation pad must be replaced after 50 hours of exposure.

**Key**

- 1 Sheathed thermocouple with insulated hot junction
- 2 Spot-welded or screwed steel strip
- 3 Hot junction of thermocouple
- 4 Insulation material
- 5 Nickel alloy strip $0.7 \pm 0,1$ mm thick
- 6 Face A

NOTES:

- 1. Drawing dimensions are in millimeters.

FIGURE 3. Illustration of a plate thermometer from ISO 834-1.

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A.2.3 Thermal exposure. An intended thermal exposure has been specified in order to verify that the test was valid. Test parameters were more rigidly specified in order to make the test more repeatable, which is inherently difficult with an outdoor liquid pool fire.

A.2.4 Minor changes to reduce the variability in fast cook-off testing. Some minor changes were made to the test configuration as previously outlined in 4.6.11. The changes were made in order to reduce the variability in fast cook-off testing. These include the following:

- a. The test fuel was limited to “JP-5 or JP-8” instead of “JP-4 or JP-5.” JP-4 was removed primarily for personnel safety reasons, and JP-8 was added as an option for instances when JP-5 is not readily available. The anticipated ambient test temperatures are above the JP-4 flashpoint, which could present a potential safety hazard in the form of a low-lying vapor cloud that spreads from the test pit. Ambient test temperature is expected to be below the JP-5 and JP-8 flashpoint temperatures and therefore reduces the risk to test personnel.
- b. The energetic fill in the MK 82 test bomb must be the same (to within production specifications) from test to test. The nature of the energetic material greatly impacts the time to reaction for an individual bomb. Regulating this parameter in this specification will allow for more repeatable tests.
- c. A lower bound of 40° F (5° C) was placed on the ambient temperature. Ambient temperatures below this threshold can cause the sub-fuel water layer to potentially freeze. In addition, conducting fast cook-off tests over too wide a range of ambient temperatures could start to affect the resulting thermal exposure, especially the time to reach a benchmark temperature in the early stages of the fire.

A.2.5 Temperature readings to calculate an estimate of the total heat flux. It is possible to use the temperature readings from the plate thermometer to calculate an estimate of the total heat flux that would have been measured by a heat flux gauge (e.g. Schmidt-Boelter gauge) in the same location.

A.2.5.1 Single value of the total incident heat flux. A water cooled Schmidt-Boelter type heat flux gauge placed into the flame would measure a single value of the total incident heat flux, which includes both the radiative and convective portions of the heat flux.

A.2.5.2 Convective heat flux component. An implicit component of the reported heat flux gauge measurements is that the convective heat flux component is being determined based on the temperature difference between the “hot” gases impacting the face of the heat flux gauge and the “cool” water flowing behind the gauge face. Since it is extremely difficult to determine and track the actual temperature of the bomb itself in the FCO test, a water temperature has been assumed in the PT temperature to heat flux conversion proposed in this section; this gives a reasonable approximation of what would

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be measured by a heat flux gauge. The hot gas temperature should be an average of the temperatures measured by the thermocouples that are specified by STANAG 4240.

A.2.5.3 Equation for estimating the total heat flux. Utilizing the formula proposed by Wickstrom (2010) for the incident radiant heat flux and considering the discussions above for the convective heat flux, an equation for estimating the total heat flux that would be measured by a heat flux gauge is presented in Eq. (1):

$$\dot{q}_{THF} = \frac{\varepsilon \sigma T_s^4 + (h + K_{cond})(T_s - T_g) + \rho c \delta \frac{\Delta T_s}{\Delta t}}{\varepsilon} + h(T_g - T_w) \quad \text{Eq. (1)}$$

Where:

- \dot{q}_{THF} = Total incident heat flux (W/m²)
- ε = Surface Emissivity (0.9)
- σ = Stephan-Boltzman Constant (5.67 x 10⁻⁸ W/m²-K⁴)
- h = Convective Heat Transfer Coefficient (10 W/m²-K)
- K_{cond} = Total Conduction Loss Coefficient (0 W/m²-K)
- ρ = Inconel Plate Density (8110 kg/m³)
- c = Inconel Specific Heat Capacity (448 J/kg-K)
- δ = Inconel Plate Thickness (0.0007 m)
- Δt = Measurement Time Step (sec)
- ΔT_s = Change in Plate Temperature over Time Step t (K)
- T_w = Heat Flux Gauge Cooling Water Temperature (30 °C = 303 K)
- T_g = Gas (average of STANAG 4240 thermocouples) Temperature (K)
- T_s = Measured Plate Thermometer Temperature (K)

A.2.5.4 Reduced equation. Inserting the material properties and coefficients listed above, Eq. (1) is reduced to Eq. (2):

$$\dot{q}_{THF} = (5.67 \times 10^{-8})T_s^4 + 11.1T_s - 1.1T_g - 3030 + 2825 \frac{\Delta T_s}{\Delta t} \quad \text{Eq. (2)}$$

A.3 THERMAL EFFICIENCY TEST CHANGE NOTES.

A.3.1 Fire tests in MIL-PRF-81904. MIL-PRF-81904 includes two fire tests, the thermal efficiency test (TET) and a fast cook-off test (FCO). There is currently no established link between performance in the TET and performance in the FCO. Furthermore, there is no established correlation between the pass/fail criteria described in this specification for the two tests. Therefore, while it is generally expected that coatings performing poorly in the TET will not pass the FCO, this has not been rigorously studied. Additionally, it is not known whether passing the TET is an indication that a coating will pass the FCO. All new coatings are required to pass the FCO (see 4.6.11) in order to get on the qualified products list (QPL).

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A.3.2 TET. The TET is used in MIL-PRF-81904 for two purposes:

- a. To screen out inferior new candidate coatings, and thereby minimize the conductance of costly fast cook off tests for candidate coatings that would ultimately fail.
- b. For periodic requalification of products; no FCO is required for requalification.

A.3.3 Thermal exposure used in the TET. The thermal exposure used in the TET was increased to 200 kW/m². This value was taken from UL 1709, an industry fire standard used to evaluate the exposure of structural members to hydrocarbon fuel fires. The summary of heat flux measurements for objects in hydrocarbon pool fires in the literature (Beyler) indicates that 200 kW/m² is at the very upper range of the expected exposure and is a conservative value.

A.3.4 Total heat flux gauge addition. A total heat flux gauge was permanently added to the test setup, and a calibration run was included in the test procedure. These steps were taken to increase the repeatability of the thermal exposure from one test to the next.

A.3.5 Accounting for the thickness of the steel panel used in the testing. The test pass/fail criterion stated in 3.6.1 was also revised to account for the specified increase in the thickness of the steel panel used in the testing. The panel thickness was increased to more closely approximate the body of a MK-82 series bomb.

A.4 APPLICABLE RESOURCE DOCUMENTS.

Beyler, C. *Fire Hazard Calculations for Large, Open Hydrocarbon Fires*. SFPE Handbook, 3rd Ed. Quincy, MA: 2003.

Blanchat, T and Figueroa, V. *Large-Scale Open Pool Experimental Data and Analysis for Fire Model Validation and Development*. Fire Safety Science- Proceedings of the Ninth International Symposium. Pp. 105-116. 2008.

Quintiere, J. *Fundamentals of Fire Phenomena*. John Wiley and Sons. West Sussex, England: 2007.

Russell, and Canfield, *Experimental Measurement of Heat Transfer to a Cylinder Immersed in a Large Aviation-Fuel Fire*. Journal of Heat Transfer, pp397 – 404: August 1973.

Wickstrom, U., *The Plate Thermometer for Measuring Fire Exposure in Terms of Adiabatic Surface Temperature*, 4th International Symposium on Tunnel Safety and Security, Frankfurt, Germany, March 17-19, 2010.

Wickstrom, U., and Ingason, H., *Measuring Incident Radiant Heat Flux Using the Plate Thermometer*, Fire Safety Journal 42 (2007), pp 161 – 166.

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CONCLUDING MATERIAL

Custodian:
Navy - AS

Preparing activity:
Navy - AS

(Project 8030-2011-002)

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at <https://assist.daps.dla.mil>.