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COOPERHEAT / MQS INSPECTION, INC.

TEST AND INSPECTION PROCEDURE

20.A.200 - 1998

RADIOGRAPHIC EXAMINATION OF CASTINGS

(GENERAL REQUIREMENTS)

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AUGUST 26, 2003

Reference: ASME Section V (1998 Edition)

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1.0 **SCOPE**

- 1.1 This procedure covers the general requirements for radiographic examination of metallic castings as may be required by the client's specifications and by various codes under which a component or system is being designed and manufactured.
- 1.2 The document meets the requirements of the ASME Code Section V, Article 2, Appendix VII (1998 Edition) and may be used with any other code, specification, or procedure referencing the methods for radiographic examination as defined by ASME Section V, Article 3.

2.0 **GENERAL**

- 2.1 In order to perform radiographic examination of castings to this procedure, it may be necessary for the client to provide the following information:
 - 2.1.1 Identity of the castings to be tested. This information should include the project or contract designation, purchase order number, drawing, the component serial number, part number, and heat number.
 - 2.1.2 Designate the extent of testing. This will include whether complete, partial, or sample examination is to be performed.
 - 2.1.2.1 Complete examination shall mean 100% coverage of the accessible areas.
 - 2.1.2.2 When partial examination is designated, the number, location, and size of areas will be clearly specified by the client.
 - 2.1.2.3 When sample examination is designated, the client shall identify the number of castings to be radiographed.
 - 2.1.3 The acceptance standard to be used.
 - 2.1.4 When applicable, the marking system required.
- 2.2 When radiography is performed for a manufacturer or contractor, prior to being presented to the inspector for acceptance, the radiographs shall be examined and interpreted by the manufacturer or contractor as complying with the reference Code Section. The interpretation of each radiograph and disposition of the material examined shall be recorded on a review form accompanying the radiographs.
- 2.3 The client shall be responsible for any required surface conditioning unless otherwise specified by the contract.

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3.0 **REFERENCES**

- 3.1 The following documents, of the issue in effect as called out on the purchase order or contract, have been referenced in the preparation of this procedure and are considered a part of this procedure as applicable.

American Society of Mechanical Engineers (ASME) (1998 Edition)

Section V Nondestructive Examination

American Society for Testing and Materials (ASTM)

E1114-86 Standard Method for Determining the Focal Spot Size of Iridium 192 Industrial Radiographic Sources

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SOP 4.18 Training

30.G.1 Radiation Safety and Control Program

4.0 **PERSONNEL**

- 4.1 Personnel performing radiographic examination to this procedure shall be qualified and certified in accordance with the Cooperheat / MQS Inspection, Inc. Procedure for Qualification and Certification of Personnel.

- 4.2 A Level I individual shall be qualified to perform specific setups, calibrations, and tests and to record and evaluate data by comparison with specific acceptance criteria defined in written instructions. The Level I individual shall implement these written NDE instructions under the guidance of a Level II or Level III individual. A Level I individual may independently accept the results of nondestructive examinations when the specific acceptance criteria are defined in the written instructions.

5.0 **EQUIPMENT**

- 5.1 Source of Radiation - Either x-ray or gamma-ray radiation may be used. The equipment manufacturer's or supplier's publications, such as technical manuals, decay curves, or written statements documenting the actual or maximum source size or focal spot, shall be acceptable as source size verification. For x-ray machines operating at 320 KV or less, the focal spot size may be determined by the pinhole method. For Iridium 192 sources, the focal spot size may be determined by ASTM E1114-86.

- 5.2 Film - Radiographs shall be made using industrial radiographic film.

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- 5.3 Screens - Except when restricted by the referencing Code Section, intensifying screens may be used. When they are used, they shall be in direct contact with the film. These screens shall be free from dirt, scratches, wrinkles, pits, and oxide coating.
- 5.4 Densitometers or step wedge comparison film shall be used for judging film density requirements. The densitometer shall be calibrated in accordance with paragraph 5 of SE-1079, using a calibrated step wedge film traceable to a national standard. The density of step wedge comparison films and densitometer calibration shall be verified by comparison with a calibrated step wedge film.
- 5.5 Film Holders shall be light-tight and shall be free of sand, dirt, or other foreign particles. A lead letter "B", with minimum dimensions of 1/2 inch in height and 1/16 inch in thickness, shall be attached to the back of each film holder as a check for backscatter.
- 5.6 Lead Identification Markers shall be of a sufficient size to be clearly visible in the finished radiograph and in quantities necessary.
- 5.7 Penetrameters shall comply with the design requirements of ASME Section V, SE-1025 or SE-747. Penetrameters shall be radiographically similar to the item under examination. Standard penetrameters shall consist of those in Table 3 or Table 4.
- 5.8 Developing Equipment - Either an automatic processor or hand tanks may be used.
- 5.9 Viewing Facilities and Equipment
- 5.9.1 Viewing facilities shall provide subdued background lighting so as not to cause reflections, shadows, or glare on the radiograph being viewed.
- 5.9.2 Film viewers shall be of the high intensity type with a variable intensity control. They shall produce sufficient illumination to view the maximum film density as required. The viewer shall have provision to prevent light from around the edge of the radiograph or light from lower density portions from interfering with the interpretation.
- 6.0 **PROCESS**
- 6.1 All radiography shall be performed in accordance with the safety requirements of the Radiation Safety and Control Program.
- 6.2 Time of Radiography - Heat treatment and thickness at the time of radiography shall be determined as required by the referencing MQS Inspection, Inc. procedure or as designated on the drawing or by the client.
- 6.3 Surface Preparation - All components shall have relatively smooth surfaces which are free of loose sand, oxides, flash, scale, slag, or other surface irregularities which would tend to mask rejectable indications.

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6.4 Film Identification

- 6.4.1 The manufacturer's symbol or name, date of the radiograph, job or heat number and, if applicable, repairs (R1, R2, R3, etc.) shall be plainly and permanently included on the radiograph.
- 6.4.2 Each radiograph shall be traceable to the contract, component, or part number, as appropriate. Traceability may be maintained by use of control numbers that are permanently included on each radiograph and on radiographic reports containing all pertinent required information.
- 6.4.3 The film identification shall not obscure the area of interest.

6.5 Location Markers

- 6.5.1 Location markers, which are to appear as radiographic images on the film, shall be placed on the part, not on the exposure holder/cassette. Their location shall be permanently marked on the surface of the part being radiographed or on a map, in a manner permitting the area of interest on a radiograph to be accurately traceable to its location on the part for the required retention period of the radiograph, and provide evidence on the radiograph that the required coverage of the region being examined has been obtained. Location markers shall be placed as follows:

(A) For single-wall viewing:

- (1) Source side location markers shall be used when radiographing the following:
 - (a) Flat or cylindrical castings
 - (b) Curved or spherical castings whose concave side is toward the source and when the source to material distance is less than the inside radius of the castings
 - (c) Curved or spherical castings whose convex side is toward the source
- (2) Film side location markers shall be used when radiographing curved or spherical castings whose concave side is toward the source and when the source to material distance is greater than the inside radius. As an alternate for source side markers in 6.5.1 (A)(1)(a), film side markers may be used when the radiograph shows coverage beyond the location markers to the extent demonstrated by Figure 1 (e) and when this alternate is documented in accordance with 6.12.

6.5.1 (Continued)

- (3) Either side location markers may be used when radiographing curved or spherical castings whose concave side is toward the source and the source to material distance equals the inside radius of the castings.

- (B) For double-wall viewing at least two location markers shall be placed on the source side surface of the castings for each radiograph.

6.5.2 When inaccessibility or other limitations prevent the placement of markers as stipulated in 6.5.1 (A) and (B), a dimensional map of the actual marker placement shall accompany the radiographs and shall show that full coverage has been obtained.

6.6 Penetrators

6.6.1 The essential hole size and thickness of penetrators or designated wire diameter shall be as specified in Table 2. A smaller hole in a thicker penetrator or a larger hole in a thinner penetrator than listed for each range may be used, provided equivalent penetrator sensitivity is maintained and all other requirements for radiography are met. The thickness on which the penetrator is based is the single wall thickness as follows:

- (A) For casting areas to be radiographed prior to finish machining, the penetrator shall be based on a thickness which does not exceed the finished thickness by more than 20% or 1/4 inch, whichever is greater. In no case shall a penetrator size be based on a thickness greater than the thickness being radiographed.
- (B) For casting areas that will remain in the as-cast condition, the penetrator shall be based on the thickness being radiographed.

6.6.2 Penetrator placement shall be as follows:

- (A) The penetrator shall be placed on the side nearest the radiation source. Where inaccessibility prevents hand placing the penetrator on the source side, the penetrator shall be placed on the film side in contact with the casting. A lead letter "F" at least as high as the identification number shall be placed adjacent to or on the penetrator, but shall not mask the essential hole.
- (B) When it is not practical to place the penetrator on the casting being examined, it may be positioned on a mounting block (or like part/product) of radiographically similar material. The block shall be essentially the same thickness as the item being radiographed and shall be positioned so that the penetrator is at the same distance from the film as it would be if placed on the source side of the item being radiographed.

6.6.3 The number of penetrameters to be used shall be as follows:

- (A) Where one or more film holders are used for an exposure, at least one penetrameter image shall appear on each radiograph except as outlined in (C).
- (B) If the requirements of paragraph 6.11.4 are met by using more than one penetrameter, one shall be representative of the lightest area of interest and the other the darkest area of interest; the intervening densities on the radiograph shall be considered as having acceptable density.
- (C) Special Cases
 - (1) For cylindrical castings where the source is placed on the axis of the component for a single exposure, at least three penetrameters are required, which shall be spaced approximately 120 degrees apart, under the following conditions:
 - (a) When a complete circumference is radiographed using one or more film holders, or;
 - (b) When a section or sections of the circumference, where the length between the ends of the outermost sections span 240 or more degrees, is radiographed using one or more film holders. Additional film locations may be required to obtain necessary penetrameter spacing.
 - (2) For cylindrical castings where the source is placed on the axis of the component for a single exposure, at least three penetrameters are required. One penetrameter shall be placed at each end of the span of the circumference radiographed and one in the approximate center of the span, under the following conditions:
 - (a) When a section of the circumference, the length of which is greater than 120 degrees and less than 240 degrees, is radiographed using just one film holder, or;
 - (b) When a section or sections of the circumference, where the length between the ends of the outermost sections span less than 240 degrees, is radiographed using more than one film holder.
 - (3) For spherical castings where the source is located at the center of the component for a single exposure, at least three penetrameters spaced approximately 120 degrees apart, are required under the following conditions:

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6.6.3(C)

Continued

- (a) When a complete circumference is radiographed using one or more film holders, or;
 - (b) When a section or sections of a circumference, where the length between the ends of the outermost sections span 240 or more degrees, is radiographed using one or more film holders. Additional film locations may be required to obtain necessary penetrameter spacing.
- (4) For spherical castings where the source is located at the center of the component for a single exposure, at least three penetrameters are required. One penetrameter shall be placed at each end of the span of the circumference radiographed and one in the approximate center of the span, under the following conditions:
- (a) When a section of a circumference, the length of which is greater than 120 degrees and less than 240 degrees, is radiographed using just one film holder, or;
 - (b) When a section or sections of a circumference, where the length between the ends of the outermost sections span less than 240 degrees is radiographed using more than one film holder.
- (5) When an array of components in a circle is radiographed, at least one penetrameter shall show on each component image.

6.6.4 In order to maintain the continuity of records involving subsequent exposures, all radiographs exhibiting penetrameters that verify the techniques permitted in accordance with paragraph 6.6.3 (C) (1) through (4) must be retained.

6.7 Geometric Unsharpness

6.7.1 When required by the referencing Code Section, geometric unsharpness of the radiograph shall not exceed the following:

<u>Material Thickness (inches)</u>	<u>Ug Maximum (inches)</u>
Under 2	0.020
2 through 3	0.030
Over 3 through 4	0.040
Greater than 4	0.070

Note: Material thickness is the thickness on which the penetrameter is based.

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6.7.2 Geometrical unsharpness of the radiograph shall be determined in accordance with:

$$U_g = Fd/D$$

where

U_g = geometrical unsharpness

F = source size, in.: the maximum projected dimension of the radiating source (or effective focal spot) in the plane perpendicular to the distance D from the casting being radiographed

D = distance, in., from source of radiation to casting being radiographed

d = distance, in., from source side of the casting being radiographed to the film

6.8 Selection of Radiation Sources

6.8.1 The radiographic technique shall demonstrate that the required radiographic sensitivity has been obtained.

6.8.2 The recommended minimum thickness for which radioactive isotopes may be used is shown in Table 1.

6.8.3 The direction of the central beam of radiation should be centered on the area of interest whenever practical.

6.9 Radiographic Technique

6.9.1 A single-wall exposure technique shall be used for radiography whenever practical. An adequate number of exposures shall be made to demonstrate that the required coverage has been obtained.

6.9.2 When it is not practical to use a single-wall technique, one of the following double-wall techniques shall be used:

(A) A technique may be used in which the radiation passes through two walls and only the casting on the film side wall is viewed for acceptance.

(B) For cylindrical castings 3-1/2 inches or less in outside diameter, a technique may be used in which the radiation passes through two walls and the material in both walls is viewed for acceptance on the same radiograph. For double-wall viewing, only a source side penetrometer shall be used.

6.10 Film Processing

6.10.1 Standard Guide for Controlling the Quality of Industrial Radiographic Film Processing SE-999 or Part III of Standard Guide for Radiographic Testing SE-94 shall be used as a guide for processing film.

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6.11 Quality of Radiographs

- 6.11.1 All film shall be free from processing or other defects which would interfere with proper interpretation of the radiograph.
- 6.11.2 Radiography shall be performed with a technique of sufficient sensitivity to display the penetrameter image and specified hole or the designated wire of a wire penetrameter. The radiographs shall also display the identifying numbers and letters.
- 6.11.3 The transmitted film density through the radiographic image of the body of the appropriate penetrameter and the area of interest shall be 1.5 minimum for single film viewing. For composite viewing of multiple film exposures, each film of the composite set shall have a minimum density of 1.0. The maximum density shall be 4.0 for either single or composite viewing. A tolerance of 0.05 in density is allowed for variations between densitometer readings.
- 6.11.4 Radiograph density through the areas of interest shall be within -15% and +30% of the density through the penetrameter and as specified in paragraph 6.11.3.
- 6.11.5 If the penetrameter image and specified hole or designated wire does not show on one radiograph in multiple film technique but does show in composite viewing, interpretation shall be permitted only by composite film viewing. Composite viewing must be approved by the client on a case by case basis.
- 6.11.6 All film not meeting the above requirements shall be discarded and the area of interest shall be radiographed again unless the subject areas are interpretable on a second film.
- 6.11.7 If a light image of the "B" (see paragraph 5.5) appears on a darker background of the radiograph, the radiograph is unacceptable and more backscatter protection is required. A dark image of the "B" on a lighter background is not cause for rejection.

6.12 Radiographic Technique Record

- 6.12.1 To aid in proper interpretation of radiographs, the details of the radiograph examination used shall accompany each group of radiographs.
- 6.12.2 To assure that all castings are radiographed consistently in the same manner, layout details shall be provided. As a minimum the layout details shall include:
- (A) Sketches of the casting, in as many views as necessary, to show the approximate position of each location marker.
 - (B) Source angles if not perpendicular to film.

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6.12.3 As a minimum, technique details information shall include:

- (A) Identification, e.g., job or heat number
- (B) Data specified in 6.5.2, when applicable
- (C) Number of exposures
- (D) Isotope or maximum x-ray voltage used
- (E) Effective focal spot size
- (F) Material type and thickness range
- (G) Single- or double-wall exposure
- (H) Minimum source-to-film distances
- (I) Maximum source-side of object to film distance
- (J) Film brand and designation
- (K) Number of films per cassette
- (L) Single- or double-wall viewing

6.13 Interpretation of Radiographs

6.13.1 An interpretation of the radiographs in accordance with the applicable acceptance standard shall be provided to the client. If requested, Cooperheat / MQS will prepare an overlay showing the location of indications of unacceptable discontinuities. The overlay will be furnished to the client who will mark the locations on the casting.

6.13.2 Viewing shall be done with subdued background lighting so as to eliminate troublesome glare, reflections, shadows, etc.

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7.0 DOCUMENTATION

- 7.1 A radiographic report shall be prepared and furnished to the client. A standard radiographic report form will be used unless otherwise requested by the client.
- 7.2 The report, as a minimum, shall contain the following:
- (A) Name of the company and the radiographic technician, level of certification, the contract number, job number, and the date of exposure
 - (B) Number of films
 - (C) The data specified in 6.4 and 6.5.2
 - (D) Film interpretation noting unacceptable discontinuities and their location and acceptable discontinuities
 - (E) Details of radiographic technique
 - (F) Density readings through penetrameters and area of interest
- 7.3 The final radiographs shall be submitted to the client for evaluation and acceptance. The client shall review the interpretation of all radiographs and shall have the final authority and responsibility for acceptance or rejection. The final radiographs will be submitted to the client for appropriate storage.

8.0 ACCEPTANCE CRITERIA

- 8.1 Acceptance standards shall be determined as required by the referencing Cooperheat / MQS Inspection, Inc. procedure.
- 8.2 The client shall have the final authority and responsibility for the interpretation and acceptance of all radiographic examination results and reports submitted by Cooperheat / MQS Inspection, Inc.

TABLE 1**MINIMUM MATERIAL THICKNESS FOR ISOTOPE RADIOGRAPHY**

<u>MATERIAL</u>	<u>MINIMUM THICKNESS</u>	
	<u>Iridium 192</u>	<u>Cobalt 60</u>
Steel	0.75 in.	1.50 in.
Copper or High Nickel	0.65 in.	1.30 in.
Aluminum	2.50 in.	

TABLE 2**IQI SELECTION**

Penetrameter						
Single-Wall Material Thickness Range, in.	Source Side			Film Side		
	Hole Type Designation	Essential Hole	Wire Diameter, in.	Hole Type Designation	Essential Hole	Wire Diameter, in.
Up to 0.25, include	12	2T	0.008	10	2T	0.006
Over 0.25 through 0.375	15	2T	0.010	12	2T	0.008
Over 0.375 through 0.50	17	2T	0.013	15	2T	0.010
Over 0.50 through 0.75	20	2T	0.016	17	2T	0.013
Over 0.75 through 1.00	25	2T	0.020	20	2T	0.016
Over 1.00 through 1.50	30	2T	0.025	25	2T	0.020
Over 1.50 through 2.00	35	2T	0.032	30	2T	0.025
Over 2.00 through 2.50	40	2T	0.040	35	2T	0.032
Over 2.50 through 4.00	50	2T	0.050	40	2T	0.040
Over 4.00 through 6.00	60	2T	0.063	50	2T	0.050
Over 6.00 through 8.00	80	2T	0.100	60	2T	0.063
Over 8.00 through 10.00	100	2T	0.126	80	2T	0.100
Over 10.00 through 12.00	120	2T	0.160	100	2T	0.126
Over 12.00 through 16.00	160	2T	0.250	120	2T	0.160
Over 16.00 through 20.00	200	2T	0.320	160	2T	0.250

TABLE 3**HOLE TYPE IQI DESIGNATION, THICKNESS,
AND HOLE DIAMETERS, IN.**

Penetrant Designation	Penetrant Thickness	1T Hole Diameter	2T Hole Diameter	4T Hole Diameter
5	0.005	0.010	0.020	0.040
7	0.0075	0.010	0.020	0.040
10	0.010	0.010	0.020	0.040
12	0.0125	0.0125	0.025	0.050
15	0.015	0.015	0.030	0.060
17	0.0175	0.0175	0.035	0.070
20	0.020	0.020	0.040	0.080
25	0.025	0.025	0.050	0.100
30	0.030	0.030	0.060	0.120
35	0.035	0.035	0.070	0.140
40	0.040	0.040	0.080	0.160
45	0.045	0.045	0.090	0.180
50	0.050	0.050	0.100	0.200
60	0.060	0.060	0.120	0.240
80	0.080	0.080	0.160	0.320
100	0.100	0.100	0.200	0.400
120	0.120	0.120	0.240	0.480
160	0.160	0.160	0.320	0.640
200	0.200	0.200	0.400	---

TABLE 4**WIRE PENETRANT DESIGNATION AND WIRE DIAMETERS (in inches)**

ASTM SET	WIRE DIAMETER
A	0.032 0.004 0.005 0.0063 0.008 0.010 0.013 0.016 0.020 0.025 0.032 0.040 0.050 0.063 0.080 0.100 0.126 0.160 0.200 0.250 0.320
B	
C	
D	

FIGURE 1

ID AREA PLACEMENT MARKER DRAWING

