

# ARTICLE A-4000 MATERIAL PROPERTIES

## A-4100 SCOPE

This Article provides the rules and equations for determining the material properties that are utilized in the analyses.

## (13) A-4200 FRACTURE TOUGHNESS

(a) The fracture toughness of the material is determined by two properties  $K_{Ia}$  and  $K_{Ic}$ , which represent critical values of the stress intensity factor  $K_I$ .  $K_{Ia}$  is based on the lower bound of crack arrest critical  $K_I$  values measured as a function of temperature.  $K_{Ic}$  is based on the lower bound of static initiation critical  $K_I$  values measured as a function of temperature. The  $K_{Ia}$  and  $K_{Ic}$  values used in the analysis should represent conservative values obtained preferably from the specific material and product form involved. The values so used should be justified on the basis of current technology and should take into account material variability, testing techniques, and any other variables which may lower these toughness values.

(b) Lower bound  $K_{Ia}$  and  $K_{Ic}$  versus temperature curves from tests of SA-533 Grade B Class 1, SA-508 Class 2, and SA-508 Class 3 steel are provided in Figure A-4200-1 (Figure A-4200-1M) for use if data from the actual product form are not available. The temperature scale of this data should be related to the reference nil-ductility temperature  $RT_{NDT}$ , as determined for the material prior to irradiation, according to the rules of NB-2331, or as irradiated according to A-4400. The curves in Figure A-4200-1 are intended to be very conservative since the recommended procedure is to determine the material fracture toughness from specimens of the actual material and product form in question. Analytical approximations for these curves are as follows:

(U.S. Customary Units)

$$K_{Ic} = 33.2 + 20.734 \exp[0.02 (T - RT_{NDT})]$$

$$K_{Ia} = 26.8 + 12.445 \exp[0.0145 (T - RT_{NDT})]$$

(SI Units)



22.783

$$K_{Ic} = 36.5 + 22.738 \exp[0.036 (T - RT_{NDT})]$$

$$K_{Ia} = 29.4 + 13.675 \exp[0.0261 (T - RT_{NDT})]$$

~~INSERT~~

where  $K_{Ic}$  and  $K_{Ia}$  are in units of  $\text{ksi}\sqrt{\text{in.}}$  ( $\text{MPa}\sqrt{\text{m}}$ ) and  $T$  and  $RT_{NDT}$  are in units of  $^{\circ}\text{F}$  ( $^{\circ}\text{C}$ ).

~~No material specific temperature,  $T_0$ , value determined in accordance with ASTM E1921, Standard Test Method for the Determination of Reference Temperature,  $T_0$ , for Ferritic Steels in the Transition Range, is available, a reference temperature,  $RT_{T0}$ , may be used in place of  $RT_{NDT}$ . The reference temperature,  $RT_{T0}$ , is defined as~~

~~(U.S. Customary Units)~~

$$~~RT_{T0} = T_0 + 35^{\circ}\text{F}~~$$



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Table IWD-3410-1

Acceptance Standards	Examination Category	Component and Part Examined	Acceptance Standard
	D-A	Welded attachments for vessels, piping, pumps, and valves	<del>IWB-3510</del> IWD-3510
	D-B	Pressure-retaining components	IWD-3511

**IWD-3500 Acceptance Standards**

*IWD-3510 Standards for Examination Category D-A, Welded Attachments for Vessels, Piping, Pumps, and Valves*

In the course of preparation, the requirements of IWC-3500 may be used.

**IWD-3511 Standards for Examination Category D-B, All Pressure-Retaining Components**

***IWD-3511.1 Visual Examination, VT-2.***

A component whose visual examination (IWA-5240) detects any of the following relevant conditions<sup>34</sup> shall meet IWD-3132 and IWA-5250 prior to continued service:

- (a) any through-wall or through-weld, pressure-retaining material leakage from insulated and noninsulated components
- (b) leakage in excess of limits established by the Owner from mechanical connections (such as pipe caps, bolted connections, or compression fittings) or from components provided with leakage-limiting devices (such as valve-packing glands or pump seals)
- (c) areas of general corrosion of a component resulting in leakage
- (d) discoloration or accumulated residues on surfaces of components, insulation, or floor areas that may be evidence of leakage or
- (e) leakages or flow test results from buried components in excess of limits established by the Owner

**K. Latest Ballot**

Ballot#: 11-708

Ballot Level: Board Procedural

Final Record Status: Approved

Date Opened: 03/24/11

Date Closed: 04/08/11

FYI

**ARTICLE IWD-3000**

**ACCEPTANCE STANDARDS**

**IWD-3100 EVALUATION OF EXAMINATION RESULTS**

**IWD-3110 PRESERVICE EXAMINATIONS**

In the course of preparation. The requirements of IWC-3100 may be used.

**IWD-3120 INSERVICE EXAMINATIONS**

(a) In the course of preparation. The requirements of IWC-3120 may be used.

(b) Components whose examination reveals flaws that do not meet the standards of IWD-3400 shall be subjected to supplemental examination, or to a repair/replacement activity. Requirements for evaluation are described in IWD-3600.

Visual examinations that detect relevant conditions may be supplemented by other examinations (IWA-2220, IWA-2230, or IWA-2240) to determine the need for corrective measures, analytical evaluation, or repair/replacement activities.

**IWD-3200 SUPPLEMENTAL EXAMINATIONS**

~~In the course of preparation. The requirements of IWC-3200 may be used.~~

**IWD-3410 ACCEPTANCE STANDARDS**

The acceptance standards referenced in Table IWD-3410-1 shall be applied to determine acceptability for service.

**IWD-3400 STANDARDS**

~~In the course of preparation. The requirements of IWC 3400 may be used.~~

**IWD-3500 ACCEPTANCE STANDARDS**

In the course of preparation. The requirements of IWC-3500 may be used.

TABLE IWD-3410-1  
ACCEPTANCE STANDARDS

Examination Category	Component and Part Examined	Acceptance Standard
D-A	Welded attachments for vessels, piping, pumps, and valves	IWD-3510
D-B	Pressure retaining components	IWD-3511



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**IWD-3100 EVALUATION OF EXAMINATION RESULTS**

**IWD-3110 PRESERVICE EXAMINATIONS**

In the course of preparation. The requirements of IWC-3100 may be used.

**IWD-3120 INSERVICE EXAMINATIONS**

(a) In the course of preparation. The requirements of IWC-3120 may be used.

(b) Components whose examination reveals flaws that do not meet the standards of IWD-3400 shall be subjected to supplemental examination, or to a repair/replacement activity. Requirements for evaluation are described in IWD-3600.

**IWD-3200 SUPPLEMENTAL EXAMINATIONS**

In the course of preparation. The requirements of IWC-3200 may be used.

**IWD-3400 STANDARDS**

In the course of preparation. The requirements of IWC-3400 may be used.

**IWD-3500 ACCEPTANCE STANDARDS**

~~In the course of preparation. The requirements of IWC-3500 may be used.~~

**IWD-3600 ANALYTICAL EVALUATION OF FLAWS**

**IWD-3610 ACCEPTANCE CRITERIA FOR FERRITIC COMPONENTS**

In the course of preparation. The requirements of IWC-3610 may be used.

**IWD-3510 Standards for Examination Category D-A, Welded Attachments for Vessels, Piping, Pumps, and Valves**

In the course of preparation. The requirements of IWC-3500 may be used.

**IWD-3511 Standards for Examination Category D-B, All Pressure Retaining Components**

**IWD-3511.1 Visual Examination, VT-2.** A component whose visual examination (IWA-5240) detects any of the following relevant conditions<sup>1</sup> shall meet IWD-3132 and IWA-5250 prior to continued service:

- (a) any through-wall or through-weld, pressure-retaining material leakage from insulated and noninsulated components;
- (b) leakage in excess of limits established by the Owner from mechanical connections (such as pipe caps, bolted connections, or compression fittings) or from components provided with leakage limiting devices (such as valve packing glands or pump seals);
- (c) areas of general corrosion of a component resulting in leakage;
- (d) discoloration or accumulated residues on surfaces of components, insulation, or floor areas that may be evidence of leakage; or
- (e) leakages or flow test results from buried components in excess of limits established by the Owner.

<sup>1</sup> Relevant conditions are defined in IWA-9000; they do not include conditions that result in condensation on components, normal collection of fluid in sumps.