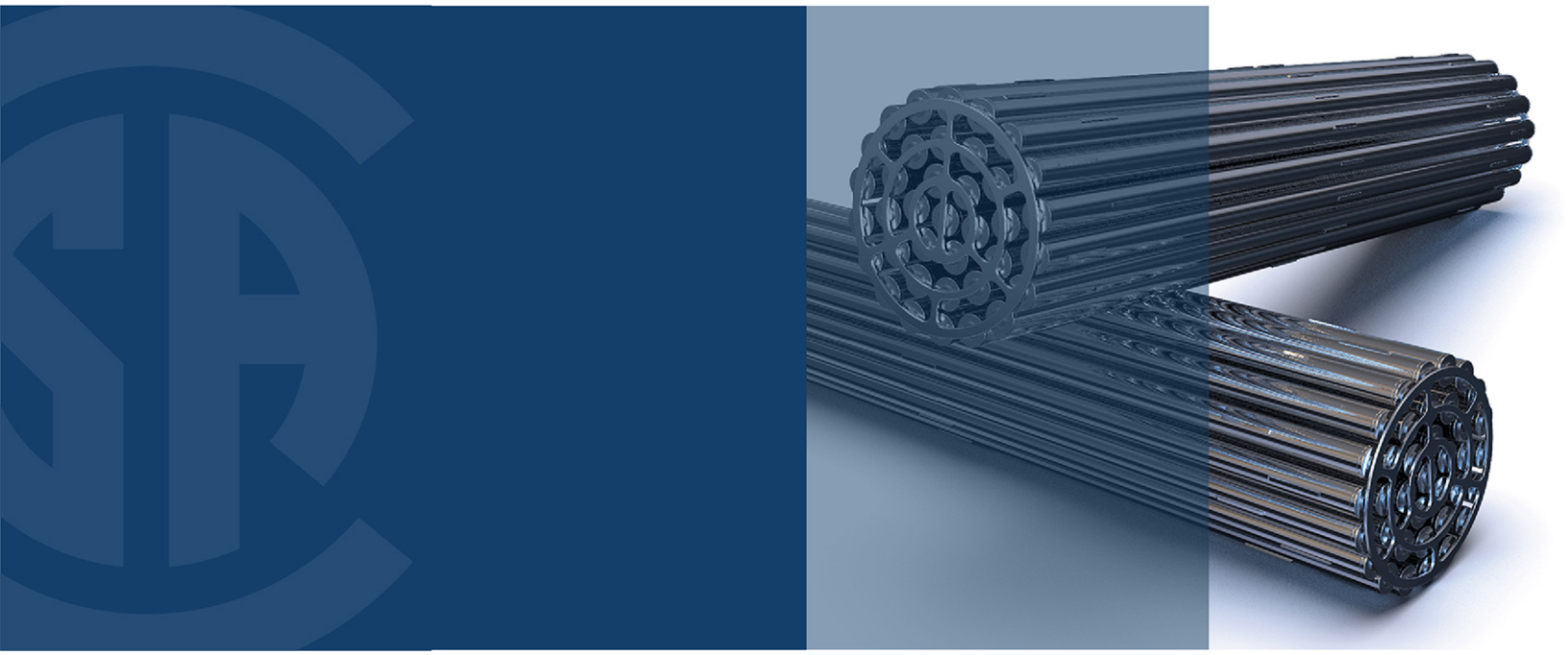
CSA N285.8:21

Technical requirements for in-service evaluation of zirconium alloy pressure tubes in CANDU reactors



Legal Notice for Standards

Canadian Standards Association (operating as "CSA Group") develops standards through a consensus standards development process approved by the Standards Council of Canada. This process brings together volunteers representing varied viewpoints and interests to achieve consensus and develop a standard. Although CSA Group administers the process and establishes rules to promote fairness in achieving consensus, it does not independently test, evaluate, or verify the content of standards.

Disclaimer and exclusion of liability

This document is provided without any representations, warranties, or conditions of any kind, express or implied, including, without limitation, implied warranties or conditions concerning this document's fitness for a particular purpose or use, its merchantability, or its non-infringement of any third party's intellectual property rights. CSA Group does not warrant the accuracy, completeness, or currency of any of the information published in this document. CSA Group makes no representations or warranties regarding this document's compliance with any applicable statute, rule, or regulation.

IN NO EVENT SHALL CSA GROUP, ITS VOLUNTEERS, MEMBERS, SUBSIDIARIES, OR AFFILIATED COMPANIES, OR THEIR EMPLOYEES, DIRECTORS, OR OFFICERS, BE LIABLE FOR ANY DIRECT, INDIRECT, OR INCIDENTAL DAMAGES, INJURY, LOSS, COSTS, OR EXPENSES, HOWSOEVER CAUSED, INCLUDING BUT NOT LIMITED TO SPECIAL OR CONSEQUENTIAL DAMAGES, LOST REVENUE, BUSINESS INTERRUPTION, LOST OR DAMAGED DATA, OR ANY OTHER COMMERCIAL OR ECONOMIC LOSS, WHETHER BASED IN CONTRACT, TORT (INCLUDING NEGLIGENCE), OR ANY OTHER THEORY OF LIABILITY, ARISING OUT OF OR RESULTING FROM ACCESS TO OR POSSESSION OR USE OF THIS DOCUMENT, EVEN IF CSA GROUP HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, INJURY, LOSS, COSTS, OR EXPENSES.

In publishing and making this document available, CSA Group is not undertaking to render professional or other services for or on behalf of any person or entity or to perform any duty owed by any person or entity to another person or entity. The information in this document is directed to those who have the appropriate degree of experience to use and apply its contents, and CSA Group accepts no responsibility whatsoever arising in any way from any and all use of or reliance on the information contained in this document.

CSA Group is a private not-for-profit company that publishes voluntary standards and related documents. CSA Group has no power, nor does it undertake, to enforce compliance with the contents of the standards or other documents it publishes.

Intellectual property rights and ownership

As between CSA Group and the users of this document (whether it be in printed or electronic form), CSA Group is the owner, or the authorized licensee, of all works contained herein that are protected by copyright, all trade-marks (except as otherwise noted to the contrary), and all inventions and trade secrets that may be contained in this document, whether or not such inventions and trade secrets are protected by patents and applications for patents. Without limitation, the unauthorized use, modification, copying, or disclosure of this document may violate laws that protect CSA Group's and/or others' intellectual property and may give rise to a right in CSA Group and/or others to seek legal redress for such use, modification, copying, or disclosure. To the extent permitted by licence or by law, CSA Group reserves all intellectual property rights in this document.

Patent rights

Attention is drawn to the possibility that some of the elements of this standard may be the subject of patent rights. CSA Group shall not be held responsible for identifying any or all such patent rights. Users of this standard are expressly advised that determination of the validity of any such patent rights is entirely their own responsibility.

Authorized use of this document

This document is being provided by CSA Group for informational and non-commercial use only. The user of this document is authorized to do only the following:

If this document is in electronic form:

- load this document onto a computer for the sole purpose of reviewing it;
- search and browse this document; and
- print this document if it is in PDF format.

Limited copies of this document in print or paper form may be distributed only to persons who are authorized by CSA Group to have such copies, and only if this Legal Notice appears on each such copy.

In addition, users may not and may not permit others to

- alter this document in any way or remove this Legal Notice from the attached standard;
- sell this document without authorization from CSA Group; or
- make an electronic copy of this document.

If you do not agree with any of the terms and conditions contained in this Legal Notice, you may not load or use this document or make any copies of the contents hereof, and if you do make such copies, you are required to destroy them immediately. Use of this document constitutes your acceptance of the terms and conditions of this Legal Notice.

Standards Update Service

CSA N285.8:21
October 2021

Title: *Technical requirements for in-service evaluation of zirconium alloy pressure tubes in CANDU reactors*

To register for e-mail notification about any updates to this publication
- go to **www.csagroup.org/store/**
- click on **Product Updates**

The **List ID** that you will need to register for updates to this publication is **2429180**.

If you require assistance, please e-mail **techsupport@csagroup.org** or call 416-747-2233.

Visit CSA Group's policy on privacy at **www.csagroup.org/legal** to find out how we protect your personal information.

CSA N285.8:21
Technical requirements for in-service evaluation of zirconium alloy pressure tubes in CANDU reactors

Published in October 2021 by CSA Group
A not-for-profit private sector organization
178 Rexdale Boulevard, Toronto, Ontario, Canada M9W 1R3

To purchase standards and related publications, visit our Online Store at ***www.csagroup.org/store/***
or call toll-free 1-800-463-6727 or 416-747-4044.

ISBN 978-1-4883-3651-5

Contents

Technical Committee on Periodic Inspection of CANDU Nuclear Power Plant Components

M. Rezaie-Manesh	Ontario Power Generation Inc., Pickering, Ontario, Canada *Category: Owner/Operator/Producer*	*Chair*
M. Venema	Bruce Power Inspection Services Department, Tiverton, Ontario, Canada *Category: Service Industry*	*Vice-Chair*
N. Azer	Kinectrics Inc., Toronto, Ontario, Canada	*Non-voting*
M. Baghbanan	OPG, Pickering, Ontario, Canada	*Non-voting*
T. Boyd	Lobo Consulting, Millgrove, Ontario, Canada *Category: General Interest*	
N. Bruns	BWXT Canada Ltd., Cambridge, Ontario, Canada *Category: Supplier/Fabricator/Contractor*	
B. Carroll	Canadian Nuclear Safety Commission (CNSC), Ottawa, Ontario, Canada *Category: Government and/or Regulatory Authority*	
D. M. Cho	Bruce Power Inc., Toronto, Ontario, Canada *Category: Owner/Operator/Producer*	
C. Dinic	Technical Standards & Safety Authority, Toronto, Ontario, Canada *Category: Government and/or Regulatory Authority*	
S. M. Fluit	BWXT Canada Ltd., Cambridge, Ontario, Canada	*Non-voting*
D. B. Graham	Kinectrics Inc., Toronto, Ontario, Canada	*Non-voting*

A. Isherwood	Ontario Power Generation Inc., Pickering, Ontario, Canada *Category: Service Industry*	
P. J. King	PJKing Consulting, Rossland, British Columbia, Canada *Category: General Interest*	
J. Lam	Ontario Power Generation Inc., Pickering, Ontario, Canada	*Non-voting*
P. Martin	NB Power-Point Lepreau Generating Station, Fredericton, New Brunswick, Canada *Category: Owner/Operator/Producer*	
W. Mayo	Canadian Nuclear Laboratories Limited (CNL), Chalk River, Ontario, Canada *Category: Service Industry*	
S. Montano	Technical Standards and Safety Authority (TSSA), Toronto, Ontario, Canada	*Non-voting*
C. Mucio	Kinectrics, Toronto, Ontario, Canada	*Non-voting*
E. Nadeau	SNC-Lavalin Nuclear Inc., Mississauga, Ontario, Canada	*Non-voting*
J. Olfert	Canadian Nuclear Laboratories, Chalk River, Ontario, Canada	*Non-voting*
E. Pakravan	Ontario Power Generation, Pickering, Ontario, Canada	*Non-voting*
W. Reinhardt	SNC-Lavalin Nuclear Inc., Mississauga, Ontario, Canada *Category: Supplier/Fabricator/Contractor*	
M. Richards	Bruce Power Inc., Tiverton, Ontario, Canada	*Non-voting*
D. A. Scarth	Kinectrics Inc., Toronto, Ontario, Canada	*Non-voting*

N. C. van den Brekel	Kinectrics Inc., Toronto, Ontario, Canada *Category: Service Industry*	
J. Weed	CANDU Owners Group Inc., Toronto, Ontario, Canada *Category: General Interest*	
R. Reipas	CSA Group, Toronto, Ontario, Canada	*Project Manager*

Subcommittee on Technical Requirements for In-Service Evaluation of Zirconium Alloy Pressure Tubes in CANDU Reactors

D. A. Scarth	Kinectrics Inc., Toronto, Ontario, Canada	*Chair*
D. M. Cho	Bruce Power Inc., Toronto, Ontario, Canada	*Vice-Chair*
W. Reinhardt	SNC-Lavalin Nuclear Inc., Mississauga, Ontario, Canada	*Vice-Chair*
N. Azer	Kinectrics Inc., Toronto, Ontario, Canada	
M. Baghbanan	OPG, Pickering, Ontario, Canada	
J. Beck	NB Power Nuclear Corp., Maces Bay, New Brunswick, Canada	
B. Carroll	Canadian Nuclear Safety Commission (CNSC), Ottawa, Ontario, Canada	
B. Chan	Technical Standards & Safety Authority, Toronto, Ontario, Canada	
H. Chaput	Canadian Nuclear Laboratories Limited (CNL), Chalk River, Ontario, Canada	
J. Cui	Kinectrics Inc., Toronto, Ontario, Canada	
M. Daymond	Queen's University, Kingston, Ontario, Canada	
M. Ducic	Canadian Nuclear Safety Commission (CNSC), Ottawa, Ontario, Canada	

D. B. Graham Kinectrics Inc., Toronto, Ontario, Canada

L. Gutkin Kinectrics Inc., Toronto, Ontario, Canada

T. Hunt Kinectrics Inc., Toronto, Ontario, Canada

M. Ip Bruce Power Inc., Toronto, Ontario, Canada

T. Janathasing Candu Owners Group, Toronto, Ontario, Canada

D. Jobba Ontario Power Generation Inc., Pickering, Ontario, Canada

M. Jyrkama Waterloo, Ontario, Canada

J. Lam Ontario Power Generation Inc., Pickering, Ontario, Canada

S. Laxman Canadian Nuclear Safety Commission (CNSC), Ottawa, Ontario, Canada

C. Liu Kinectrics Inc., Toronto, Ontario, Canada

C. Manu Kinectrics Inc., Toronto, Ontario, Canada

D. Mok Kinectrics Inc., Toronto, Ontario, Canada

E. Nadeau SNC-Lavalin Nuclear Inc., Mississauga, Ontario, Canada

J. Robertson Kinectrics Inc., Toronto, Ontario, Canada

G. Shek Kinectrics Inc., Toronto, Ontario, Canada

K. Tsembelis	Canadian Nuclear Safety Commission (CNSC), Ottawa, Ontario, Canada	
W. R. Tyson	Natural Resources Canada, Ottawa, Ontario, Canada	
N. C. van den Brekel	Kinectrics Inc., Toronto, Ontario, Canada	
Y. Wang	Canadian Nuclear Safety Commission (CNSC), Ottawa, Ontario, Canada	
B. Williams	Natural Resources Canada, CanmetMATERIALS, Hamilton, Ontario, Canada	
S. Xu	Kinectrics Inc., Toronto, Ontario, Canada	
R. Reipas	CSA Group, Toronto, Ontario, Canada	*Project Manager*

Preface

This is the fourth edition of CSA N285.8, *Technical requirements for in-service evaluation of zirconium alloy pressure tubes in CANDU reactors*. It supersedes the previous editions, published in 2010, 2005, and 2015.

This Standard specifies mandatory technical requirements and non-mandatory evaluation procedures for fitness-for-service assessments. Pressure tubes in Canadian CANDU® nuclear power plants are inspected in accordance with CSA N285.4, *Periodic inspection of CANDU nuclear power plant components*. When a detected flaw indication does not satisfy the criteria of acceptance by examination, or when pressure tube to calandria tube contact is detected or predicted, Clause 12 of CSA N285.4 permits a fitness-for-service assessment to determine acceptability. Also, Clause 12 of CSA N285.4 requires evaluation of the results of specified material property surveillance measurements.

Note: *CANDU (CANada Deuterium Uranium) is a registered trademark of Atomic Energy of Canada Limited.*

The major changes to this edition include the following:

a) removed provision in Clause 5.4.3.2 c) that exempts a Level A overload evaluation;
b) updated Annex C to be consistent with current methods used in the industry for probabilistic core assessments and probabilistic leak before break (Clauses C.3 and C.4);
c) revised Clause D.8 to support use of equation for fracture initiation toughness for higher *Heq* concentrations;
d) added new Clause 6.5 for evaluation of pressure tube to calandria tube (PT-CT) contact to improve clarity of requirements, and to address observed spacer movement;
e) updated the definition of fitness-for-service (FFS) evaluation to use "…in a degraded condition that was not considered in the design…" to avoid using the terminology "beyond design basis";
f) evaluated use of the term "structural integrity" and revised the Standard as appropriate;
g) included the recently published p_C statistical equation into Annex D;
h) included the recently published F_{NR} for non-ratcheting flaw assessments; and
i) updated the maximum allowable operating interval (Δt_{max}) for operation of tubes left in contact (Clause 6.3) accounting for improved knowledge of deuterium ingress rates.

This Standard is one of a series of CSA N285 Standards that provide consistent rules for the design, fabrication, installation, inspection, and assessment of pressure-retaining systems and components in CANDU nuclear power plants. The series outlines requirements that are particularly applicable to nuclear power plants in Canada and references the appropriate requirements of the ASME *Boiler and Pressure Vessel Code*. Users of this Standard are reminded that the site selection, design, manufacture, construction, installation, commissioning, operation, and decommissioning of nuclear facilities in Canada are subject to the *Nuclear Safety and Control Act* and its Regulations. The Canadian Nuclear Safety Commission might impose additional requirements to those specified in this Standard.

The CSA N-Series of Standards provides an interlinked set of requirements for the management of nuclear facilities and activities. CSA N286 provides overall direction to management to develop and implement sound management practices and controls, while the other CSA Group nuclear Standards provide technical requirements and guidance that support the management system. This Standard works in harmony with CSA N286 and does not duplicate the generic requirements of CSA N286; however, it might provide more specific direction for those requirements.

This Standard is based in part on fitness-for-service guidelines developed by a Technical Task Team formed by the CANDU Owners Group (COG).

In order to facilitate adoption by the authority having jurisdiction, this Standard includes some regulatory provisions.

This Standard was prepared by the Subcommittee on Technical Requirements for In-Service Evaluation of Zirconium Alloy Pressure Tubes in CANDU Reactors, under the jurisdiction of the Technical Committee on Periodic Inspection of CANDU Nuclear Power Plant Components and the Strategic Steering Committee on Nuclear Standards, and has been formally approved by the Technical Committee.

Notes:

1) *Use of the singular does not exclude the plural (and vice versa) when the sense allows.*
2) *Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.*
3) *This Standard was developed by consensus, which is defined by* CSA Policy governing standardization — Code of good practice for standardization *as "substantial agreement. Consensus implies much more than a simple majority, but not necessarily unanimity". It is consistent with this definition that a member may be included in the Technical Committee list and yet not be in full agreement with all clauses of this Standard.*
4) *To submit a request for interpretation of this Standard, please send the following information to inquiries@csagroup.org and include "Request for interpretation" in the subject line:*
   a) *define the problem, making reference to the specific clause, and, where appropriate, include an illustrative sketch;*
   b) *provide an explanation of circumstances surrounding the actual field condition; and*
   c) *where possible, phrase the request in such a way that a specific "yes" or "no" answer will address the issue.*

   Committee interpretations are processed in accordance with the CSA Directives and guidelines governing standardization *and are available on the* Current Standards Activities *page at standardsactivities.csa.ca.*
5) *This Standard is subject to review within five years from the date of publication. Suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to inquiries@csagroup.org and include "Proposal for change" in the subject line:*
   a) *Standard designation (number);*
   b) *relevant clause, table, and/or figure number;*
   c) *wording of the proposed change; and*
   d) *rationale for the change.*

CSA N285.8:21
Technical requirements for in-service evaluation of zirconium alloy pressure tubes in CANDU reactors

0 Introduction

This Standard consists of a mandatory main body and eight non-mandatory annexes. The main body contains the mandatory rules and acceptance criteria for in-service evaluation of zirconium alloy pressure tubes in CANDU reactors. The non-mandatory annexes are as follows:

- Annex A — Procedures for the evaluation of pressure tube flaws;
- Annex B — Procedures for the evaluation of pressure tube to calandria tube contact;
- Annex C — Procedures for the assessment of a reactor core;
- Annex D — Material properties and derived quantities;
- Annex E — Notification of in-service evaluation form;
- Annex F — Guidance on calculating the maximum allowable pressure tube failure frequencies for use in probabilistic assessments for the reactor core;
- Annex G — Uncertainty analysis in probabilistic evaluations; and
- Annex H — Acceptable number of simulations for probabilistic assessments performed by repeated random sampling.

Annexes A to C contain evaluation procedures that may be used to demonstrate compliance with the acceptance criteria in the main body of the Standard. Annex D contains the material properties and derived quantities that are required when performing an evaluation in accordance with Annexes A to C. Annex E contains a form for providing notification of the evaluation to the authority having jurisdiction (AHJ). Annexes F, G, and H are used in conjunction with probabilistic assessments of the reactor core that are performed within the scope of Clause 7 and Annex C. Annex F provides a method for calculating the maximum allowable pressure tube failure frequency. Annex G provides a methodology for performing uncertainty analyses of the probabilistic calculation results. Annex H provides a convergence criterion for the probabilistic calculations.

This Standard assumes that the typical evaluation process consists of

- pressure tube inspection;
- evaluation of the inspection results;
- documentation of the inspection results and evaluation;
- notification of the AHJ regarding the inspection and evaluation; and
- acceptance by the AHJ of the disposition of pressure tubes prior to returning the reactor to service.

1 Scope

1.1

This Standard specifies the technical requirements for the owner/operator to evaluate cold-worked Zr-2.5 wt% Nb alloy pressure tubes in operating CANDU reactors for continued operation. Clause 13 of CSA N285.0/N285.6 Series requires that when in-service inspection results or material surveillance results do