TR 22-62 – Fracture Mechanics

TR Number	**22-62**
Primary	192.712, 192.485
Purpose	Review and develop GM as appropriate in light of Amendment 192-132; and Amendment 192-125 (from TR 19-55)
Origin/Rationale	Amdt. 192-132; Amdt. 192-125 (from TR 19-55)
Notes	Failure Analysis and remaining strength calculation; added TR 19-55 to scope.
Assigned to	IM/CORR

Note: Revisions are shown in yellow highlight and red font.

*[**Publication Note:** See edits below in blue highlight.]*

Section 192.712

{LB note: GM review note below will be revised in Addendum 4 (see underlined additions), and the entire GM note should be deleted when this TR is completed.}

~~This guide material is under review following Amendments 192-125 and 192-130.~~

{LB note: TR 22-07 proposed to add the below note (green font) regarding gathering lines, but the TR received 2 Disapproved votes in LB2-2024.}

Note: Type A gathering lines are exempt from the requirement for analysis of predicted failure pressure (§192.9(c)). Operators of Type B and Type C gathering lines do not need to comply with this section (§192.9(d) and (e)). Gathering line operators are encouraged to consider this guidance for repairs.

{Editorial Note: (All new guide material below and therefore not underlined)}

1 SUBJECT MATTER EXPERTS

(a) Dents and other mechanical damage require an operator's use of qualified SMEs in the engineering critical assessment and needs advanced planning. The SMEs considered should possess experience, qualification, and specialization in area such as engineering mechanics, stress analysis, strain-based design, finite element analysis, and fatigue life modeling to perform the analysis under §192.712(c)(3), (c)(6), (c)(7), (c)(9), and (c)(11) and confirmation under §192.712(g)(18).

(b) Cracks and crack-like defects require the estimation of the remaining life of ILI detected cracks, §192.712(d)(2)(iii), and the largest potential crack surviving a hydrotest, §192.712(d)(3). These two analyses are dependent on the SMEs referenced in §192.712(g)(18). The SMEs through prior experience are likely to drive the means and methods in an operator's use of fracture mechanics. The operator needs to consider seeking individuals with standing experience, advanced education, or certification in fields such as mechanics, metallurgy, material science, or fit-for-service analysis.

(c) The lead time to assemble the processes, procedures, personnel, software, and validation of the proposed techniques should be considered in sourcing SMEs and relative to the 90-day advance notification under §192.18.

(d) SMEs may be internal or external resources. Expected occurrence frequencies over the useful life of the pipeline system should be considered in sourcing SMEs. If external resources will be used, having contracts in place prior to an event might speed up response times.

2 FRACTURE MECHANICS

Paris' Law is the theory that a crack subject to an n^{th} loading cycle will experience a differential change in the crack dimension, **a**, and a differential change in stress intensity, **K**. When plotted log-log, this relationship presents as a line as shown in the figure below.

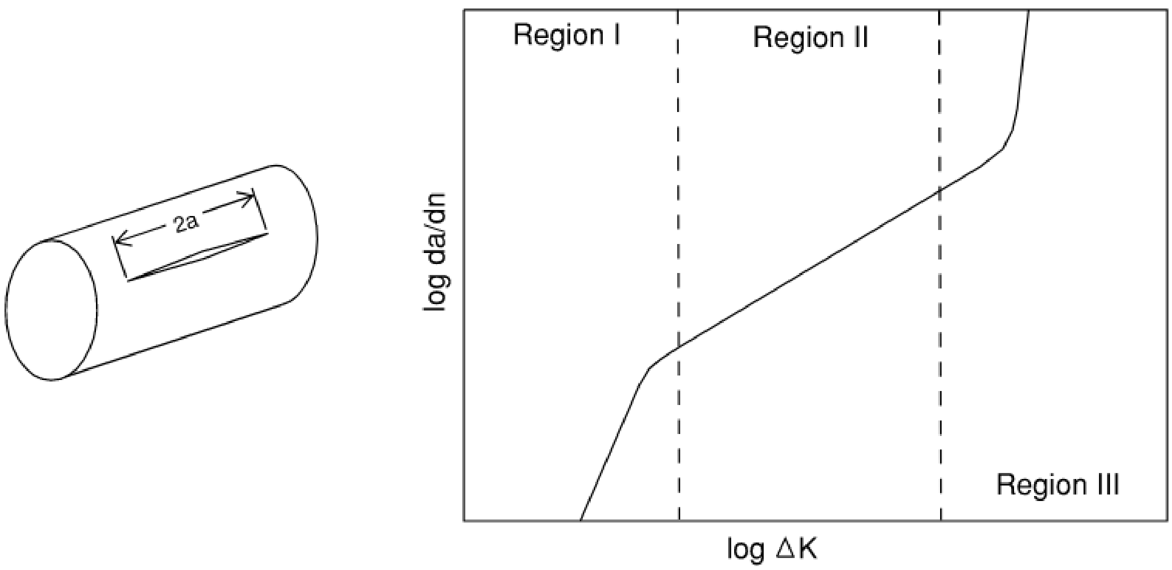

FIGURE 192.712A

Region I represents the onset of a crack. In Region II, crack growth can be regarded as predictable. The slope and intercepts of Region II are similar to material properties. In Region III, growth is less predictable with rapid propagation leading to catastrophic failure.

Fracture mechanics requires repetitive calculations of **K,** stress intensity. Expressions for **K** representing a given system can be highly complex and in instances may be derived through finite element analysis**.** The determination of cycles to failure and thus remaining life is subject to numerical integration and advanced computation techniques. Extending this to multiple anomalies becomes iterations of iterative calculations. Due to other variations of inputs or uncertainties, probabilistic techniques may be used to discern most likely outcomes.

3 FRACTURE MODELS AND SOFTWARE

PHMSA through the rulemaking process and sponsored research generated a large volume of scientific papers, articles, and other documents defining the state-of-the-art at the time of the rulemaking. Most of this literature revolves around ERW seam cracking. In the Federal Register (Vol. 87 p. 52224), PHMSA references several models or software as listed below.

(a) Newman-Raju Model.
(b) Modified Log-Secant Model.
(c) API RP 579-1 Level II or Level III.
(d) CorLAS™ software.
(e) PAFFC Model.
(f) PipeAssess PI™ software.

PRCI subsequently sponsored development of the MAT-8 model that considers compensation for brittle to ductile transitional behavior, the J-integral, and finite element techniques.

4 REFERENCES

(a) https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=390, "*Comprehensive Study to Understand Longitudinal Electric Resistance Welded (ERW) Seam Failures.*"
(b) ASTM E1049, "*Standard Practices for Cycle Counting in Fatigue Analysis.*"
(c) API 579/ASME FFS-1, "*Fitness-for-Service.*"

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1.14 OTHER DOCUMENTS (Continued)		
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API 579	Fitness-for-Service	§192.624 §192.712
...	...	...
ASTM E1049	Standard Practices for Cycle Counting in Fatigue Analysis	§192.712