Usefulness of reliability test information for production assurance and reliability management

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Objectives

It's important to have <u>strong input data</u> for reliability estimation (ISO/TR 12489:2013)

> To identify and discuss different challenges related to the test information collected and to be used in reliability estimation for production assurance and reliability management (ISO 20815:2018).

A focus on the reliability of modified technology.

- ISO/TR 12489 (2013). Petroleum, petrochemical and natural gas industries — Reliability modelling and calculation of safety systems.
- ISO 20815 (2018). Petroleum, petrochemical and natural gas industries — Production assurance and reliability management.

Background

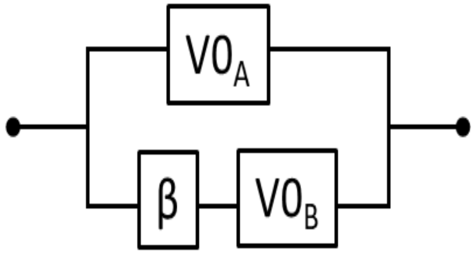
- A solenoid valve V1 is considered, as part of a well integrity verification system.
- The system builds on NORSOK D-010 (2021), AWES recommended practise 3362-01 and field specific safety requirements.
- Reliability performance in focus, but one of several aspects tested in qualification.

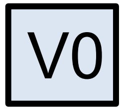
> Replace the earlier model V0 with the new model V1?

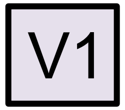
- NORSOK D-010: 2021. Well integrity in drilling and well operations. Edition 5. Standards Norway.
- AWES (Advanced Well Equipment Standards Group): 2016. 3362-01, Recommended Practice For the Qualification of Downhole Instrumentation/Sensors. https://awes-group.com/?mdocs-file=478

Decision alternatives

- Two V0s in a 1-o-o-2 structure with estimated reliability R=0.993
- One V1 in a 1-o-o-1 structure only if estimated reliability R>0.993.







V1 reliability target

Reliability target: 0.995 with 95% confidence for V1 surviving 10,000 cycles.

The intention is to verify a significant improvement compared with the reliability of V0.

Basis for test design and reliability estimation – V0 history

As basis for the test design and estimation, information about the aging process can be deduced from V0 experience; despite a ‘less developed’ design, representing a field-proven technology with extensive operational experience.

V0 experience give information about failure rate λ, aging process, failure modes, and the beta-factor. E.g., wear issues will not appear before at least 250,000 cycles.

Basis for reliability estimation – V1 testing

A semi-accelerated test design:

i) V1 accelerated testing; and

ii) V1 cycle endurance testing.

i) Accelerated V1 testing

A Weibull distribution is assumed, with the stressor expressed using a traditional Arrhenius relationship, i.e., an Arrhenius Weibull reliability model.

Reliability at the use case temperature is (when shape factor is k=1) :

$R(t_0) = e^{-\frac{t_{use}}{\lambda}} = e^{-\frac{t_1 A}{\lambda}}$, where A is the acceleration of failures

- 5 solenoid valves
- One-month accelerated test with temperature stressor (150 deg C elevated) to validate a reliability level of minimum 0.990 at 95% confidence. Simulates 28 years in use case conditions.
- Probability of zero failures (criterion), if the reliability is less than 0.990, is 3.5%.

What is the minimum number of cycles needed for verification?

Reliability ≥ 0.995 with CL=95%?

Number of valves to test for 10,000 cycles:

Reliability	Confidence level			
	99 %	98 %	95 %	90 %
0.995	919	780	598	459
0.994	765	650	498	383
0.993	656	557	426	328
0.992	573	487	373	287
0.991	509	433	331	255
0.990	458	389	298	229

High cost

Aspects relevant for estimation quality

Reliability target (requirements)

Selection of analytic method

"HARKing" - Hypothesizing After the Results are Known" (snooping, p-hacking, data fishing, data mining, …)

Estimation quality

Modelling assumptions

Censoring & reporting

"the file drawer problem"

…

A way to test fewer valves

Hypothesis testing; H_1: Reliability ≥ 0.995

Run the five valves to failure, or to 598 x 10,000 cycles, whatever comes first.

And censor for wear-out failures occurring after t=250,000 cycles.

Example numbers

The 5 valves tested fails after a total of three million cycles.

All failures are due to wear-out issues.

This only gives a 95 % confidence for a reliability of at least 0.990

To reach the reliability target, additional valves can be tested in the same manner and added to the total number of cycles, until the target is reached.

> A somewhat flexible test, can optimize output, and minimize cost.

Ways to mitigate and effects

- Stronger and less flexible requirements with more attention to process validation

  > Different industrial needs could motivate flexibility

- Use of independent parties in design and analysis, and involvement of end-user.

  > Could still be an economical motivation (budget constraints)

- Adequate documentation and argumentation (e.g., key assumptions)

  > Argumentation and logic could be difficult to challenge

- Show the confidence in the results

  > It depends on the design and analytic premise

- Bayesian analysis?

  > Could be bias in the prior belief

Concluding remarks

- Potential barriers of high estimation quality related to the trade-off between the cost of testing and to demonstrate acceptable levels with high confidence.
- HARKing and the file drawer problem are two relevant challenges to be aware of.
- It is difficult to avoid biased designs and analysis without loosing some flexibility.

Thank you for the attention!

Selvik J.T., Lohne, H.P. (2021). **Challenges in reliability estimation of modified technology using information from accelerated reliability testing – An offshore well integrity solenoid valve case**. In: Proceedings of the 31st European Safety and Reliability Conference - ESREL 2021, Angers (France) 19-23 September 2021. https://www.rpsonline.com.sg/proceedings/9789811820168/html/233.xml