NEW STRATEGIES FOR EP QUALIFICATION AND ENTRY INTO SERVICE

ADAPTING TO COMPETITIVE PRODUCTION LINE PRACTICE

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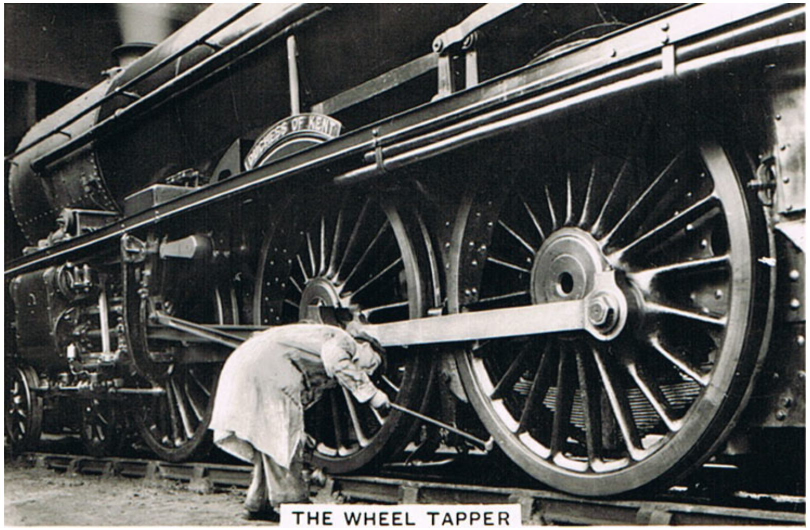
WHEEL TAPPING



Acknowledgement: Brian Thurston

Advantages:

- Simple, effective technique,
- Easily manufactured, low cost tools.
- Exploiting a sophisticated readily available, measuring instrument – the human ear.

Disadvantages:

- Time consuming and human intensive,
- No reliable prediction of failure (or not),
- High probability of major disruption when failure detected.

WHEEL TAPPING

Today's very high speed trains require quantified confidence qualification to minimize risk of catastrophic failure and facilitate competitive production.

Current methods fully exploit:

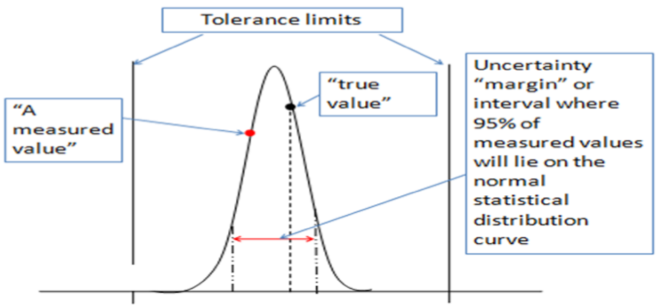
- A much better understanding of materials and advanced manufacturing processes,
- New diagnostic techniques (eg ultra-sound),
- More sophisticated design tools (CAD, FET, etc), test methods (modelling and simulation) and measurement practices (ISO17025).

To achieve:

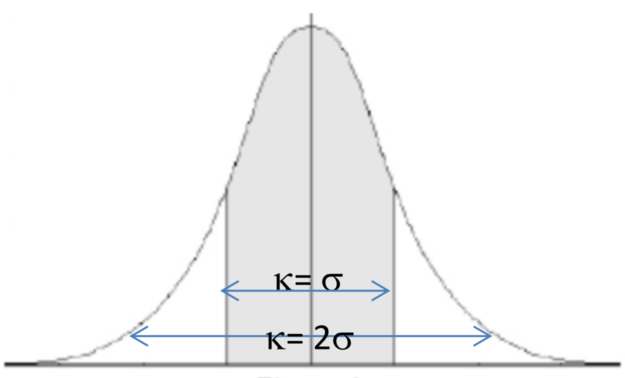
- Quantative confidence in performance, particularly reliability and endurance,
- Efficient, competitive, reliable production.

Acknowledgments: Alain Stoll, Luchini RS Group and Vyska Steel Works

OBSERVATION OR CONFIDENCE

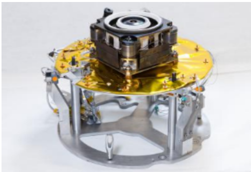


Modelled/measured Results Distribution

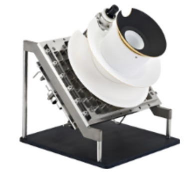


Combined Estimated Standard Uncertainty Distribution

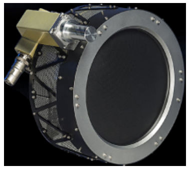
- Model and measurement distributions (observed):
  - Modelling:
    - Model results distribution,
    - Estimate modelling uncertainties.
  - Measurement:
    - Measured results distribution,
    - Estimate measurement uncertainty.
- Estimated Standard Uncertainty distributions (predicted);
  - Modelling:
    - Derive Combined Standard Uncertainty distribution (Monte-Carlo?).
  - Measurement:
    - Derive Combined Standard Uncertainty distribution.
- Confidence:
  - Apply coverage (κ) at σ, 2σ, 3σ etc for (quantified) confidence that future results be within a determined range.

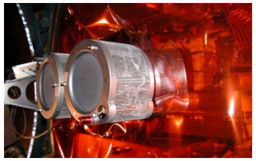


EP QUALIFICATION



- EP qualification also requires:
  - Qualification to high (quantified) levels of confidence,
  - Increasingly efficient, competitive (mass) production.
- Qualification requirements are a successful demonstration of:
  - Performance (thrust, Isp, efficiency): at a single operating point, multiple operating points or over a complete operating envelope,
  - Compatibility with parent spacecraft and associated equipments (mass, volume, thermal and power budgets; EMC, exhaust plume effects, etc)
  - Robustness: the ability to withstand the mechanical, thermal, vacuum, radiation environments and other hazards (eg micro-meteoroids),
  - Endurance: the total impulse (lifetime) required for the mission(s),
  - Reliability: consistent achievement of performance and endurance.





CHALLENGES AND STRATEGIES

- Challenges:
  - Demonstrate the equipment will meet all specified requirements,
  - Competitive (development amortised) recurring costs.
- Strategies:
  - Scoping:
    - Match performance demonstration to agreed requirements (eg agreed operating point(s)),
    - Match compatibility and robustness design to target platforms and orbits,
  - Optimise the efficiency of endurance and reliability demonstration in terms of time, cost and confidence.
- Here focus on thrusters and EP systems because:
  - Qualification practice for electronics, pointing mechanisms, pipework and harnesses is equally critical but well established,
  - Thruster reliability and endurance qualification cost and schedule.

ENDURANCE AND RELIABILITY TRADE-OFFS

- Successful single life test gives:
  - Some confidence design is capable of required total impulse,
  - Low confidence (sample of one) in repeatability,
  - Significantly extends qualification programme and very costly.
- Multiple life tests (probably needs 10 for a reasonable sample size):
  - High confidence in design and repeatability,
  - Unacceptably expensive except for very small systems.
- Proto-flight:
  - Reduces need for ground total impulse test,
  - May require longer in-orbit operation to be judged successful and in-orbit performance more difficult to monitor,
  - Infrequent opportunities and not necessarily representative of (main) target application.
- Multiple limited endurance tests:
  - Increases sample size and therefore confidence,
  - Can significantly reduce time and costs,
  - Not a continuous, full life (total impulse) demonstration,
  - Has the potential for high confidence at lower cost and shorter schedule.

MULTIPLE LIMITED ENDURANCE TEST OPTIMISATION

- Objectives:
  - High confidence that:
    - Design is capable of required total impulse,
    - Performance and total impulse is repeatable.
  - Cost and schedule minimized.
- Challenges:
  - Agree confidence levels and methodology with customers,
  - Optimize trade-offs between materials research, modelling and testing for cost and schedule.
  - Fully exploit all sources of evidence:
    - Materials behaviour under operating conditions,
    - Modelling both structural and performance properties,
    - Ensuring all test results contribute fully.
  - Configure performance, compatibility and robustness proving as contributory elements for reliability and endurance qualification.

MULTIPLE LIMITED ENDURANCE TEST FOUNDATIONS

- Precise build standard management:
  - Models,
  - Equipment under test and test facility/configuration.
- ISO 17025 measurement practice to give:
  - A methodology to validate modelling with test data,
  - Quantified confidence levels in modelled and measured performance.
- Managing customer expectation and trust through:
  - Realising benefits of lower cost and shorter schedule,
  - Engaging in realistic confidence level determination.

THE CHOICES

- Observed or Predicted:
  - Qualification based on observed (mainly test) results – "*past performance is not (necessarily) a guide to the future* ", or,
  - Qualification using proven engineering performance prediction methods – "*quantified confidence in future performance*".
- Test or Model:
  - Qualification based only on test results,
  - Qualification based on models validated by test results.