Session DB 4.4
RCM
Reliability Centered Maintenance

LIFELINE DATA CENTERS

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RCM
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LIFELINE
DATA CENTERS

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Reliability Centered Maintenance

What is Reliability Centered Maintenance?

Semi-English Answer: "A maintenance methodology for systems, based on analysis of failure probability and the effects of those failures on system operation."

Reliability Centered Maintenance

What is Reliability Centered Maintenance?

Propeller-Head Answer: "A structured framework for analyzing the functions and potential failures for a physical asset (such as a generator, UPS system, or HVAC system, etc.) with a focus on preserving system functions, rather than preserving equipment. RCM is used to develop scheduled maintenance plans that will provide an acceptable level of operability, with an acceptable level of risk, in an efficient and cost-effective manner."

Source: Weibull Engineering Services

Reliability Centered Maintenance

What is Reliability Centered Maintenance?

Reliability Centered Maintenance is only worthwhile when treated as an exercise in:

- Business Alignment
- Quantified Risk Management
- Qualitative Risk Management

Reliability Centered Maintenance

What Reliability Centered Maintenance is not:

- RCM is not a prescriptive standard like TIMS (although it can be an important component of a TIMS program).

- RCM is not checklist-based – it is a dynamic and flexible framework (although there are standards which dictate what constitutes an RCM program).

Reliability Centered Maintenance

What Reliability Centered Maintenance is not:

- RCM is not an exercise in pure mathematics.

Failure Finding Interval Determination

- Probability of failure for constant failure rate is 1 minus reliability at time t defined as:

$$P = 1 - e^{-t/MTBF}$$

- Probability of multiple failure formula becomes:

$$P_{multiple\ (both)} = P_{hidden} \times P_{additional}$$

$$1 - e^{-t/MTBF_{both}} = (1 - e^{-t/MTBF_{hidden}}) \times (1 - e^{-t/MTBF_{additional}})$$

- $P_{multiple(both)} = P_{acc}$ results in:

$$P_{acc}(t) = (1 - e^{-t/MTBF_{acceptable}})$$

Reliability Centered Maintenance

A Brief History:

The first generation of jet aircraft had a crash rate that would be considered highly alarming today, and both the Federal Aviation Administration (FAA) and the airlines' senior management felt strong pressure to improve matters.

Reliability Centered Maintenance

A Brief History:

- Various reports and studies documented efforts by commercial airlines and the US Navy in the 1960s and 1970s to improve the reliability of their aircraft.
- The first formal evaluation reports on RCM were published in 1978 by United Airlines Engineers.

Reliability Centered Maintenance

A Brief History:

These studies proved that the fundamental assumption of design engineers and maintenance planners—that every airplane and every major component in the airplane (such as its engines) had a specific "lifetime" of reliable service, after which it had to be replaced (or overhauled) in order to prevent failures—was wrong in nearly every specific example in a complex modern jet aircraft.

Reliability Centered Maintenance

A Brief History:

- RCM was adopted by the U.S. military beginning in the mid-1970s.
- RCM was adopted by the U.S. commercial nuclear power industry in the late 1970s.
- RCM was adopted by Disney in 1997.

Reliability Centered Maintenance

A Brief History:

RCM is gradually finding its way into the data center industry.

Reliability Centered Maintenance

A Brief History:

- Barriers to adoption in the data center include:
    - Confusion over the relationship between TIMS & RCM – Supporters of TIMS have resisted RCM adoption.

      TIMS (Tiered Infrastructure Maintenance Standard)
        - TIMS-1: Run to Fail
        - TIMS-2: Unstructured
        - TIMS-3: Structured
        - TIMS-4: Facilitated

Reliability Centered Maintenance

A Brief History:

- Barriers to adoption in the data center include:
    - RCM is difficult. **<u>Extremely</u>** difficult.

Reliability Centered Maintenance

Because RCM is so very difficult:

Many methods sprung up that tried to reduce the difficulty of the RCM approach. The result was the propagation of many methods that called themselves RCM, yet had little in common with the original concepts. In some cases these were misleading and inefficient, while in other cases they were even dangerous.

Reliability Centered Maintenance

Because RCM is so very difficult:

There is a tendency for (some) consulting firms to promote their respective software packages as alternative methodologies in place of the knowledge and excruciatingly detailed work required to perform analyses and execute a credible RCM program.

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Standards:

SAE JA1011-200908

This SAE Standard for Reliability Centered Maintenance (RCM) is intended for use by any organization that has or makes use of physical assets or systems that it wishes to manage responsibly. This sets out the minimum criteria for what is, and for what is not, able to be defined as RCM.

Reliability Centered Maintenance

Standards:

SAE JA1012-201108

(“A Guide to the Reliability-Centered Maintenance (RCM) Standard”) amplifies and clarifies each of the key criteria listed in SAE JA1011 (“Evaluation Criteria for RCM Processes”), and summarizes additional issues that must be addressed in order to apply RCM successfully.

Reliability Centered Maintenance

Publications:

"MIL-HDBK-2173, Department of Defense Handbook: Reliability-Centered Maintenance (RCM) Requirements for Naval Aircraft, Weapons Systems, and Support Equipment (S/S BY NAVAIR 00-25-403)". United States Department of Defense. 30 Jan 1998. Archived from the original (PDF) on 2013-10-07.

"MIL-P-24534A, Military Specification: Planned Maintenance System, Development of Maintenance Requirement Cards, Maintenance Index Pages, and Associated Documentation" (PDF). Naval Sea Systems Command. 7 May 1985.

"MIL-STD-2173, Military Standard: Reliability-Centered Maintenance (RCM) Requirements for Naval Aircraft, Weapons Systems, and Support Equipment (S/S By MIL-HDBK-2173)". United States Department of Defense. 21 Jan 1986. Archived from the original (PDF) on 2013-11-06.

"MIL-STD-3034, Military Standard: MIL-STD-3034, DEPARTMENT OF DEFENSE STANDARD PRACTICE: RELIABILITY-CENTERED MAINTENANCE (RCM) PROCESS" (PDF). United States Department of Defense. 21 Jan 2011.

"NASA Reliability Centered Maintenance (RCM) Guide for Facilities and Collateral Equipment" (PDF). NASA. FEV 2000.

"NAVAIR 00-25-403, Guidelines for the Naval Aviation Reliability-Centered Maintenance (RCM) Process)" (PDF). Naval Air Systems Command. 1 Jul 2005.

"NAVAIR S9081-AB-GIB-010, Reliability-Centered Maintenance (RCM) Handbook)" Naval Sea Systems Command. 18 Apr 2007. Archived from the original (PDF) on 2013-12-04.

"TM 5-698-2, Technical Manual: Reliability-Centered Maintenance (RCM) for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities" (PDF). United States Army. 6 Oct 2006.

Reliability Centered Maintenance

Any RCM process shall ensure that all of the following steps are performed in the sequence shown:

1. Determine the operational context and the functions and associated desired standards of performance of the asset (operational context and functions).
2. Determine how an asset can fail to fulfill its functions (functional failures).
3. Determine the causes of each functional failure (failure modes).
4. Determine what happens when each failure occurs (failure effects).
5. Classify the consequences of failure (failure consequences).
6. Determine what should be performed to predict or prevent each failure (tasks and task intervals).
7. Determine if other failure management strategies may be more effective (operational and/or design modifications).

Source: SAE JA1011 200908

Reliability Centered Maintenance

Any RCM process shall ensure that all of the following steps are performed in the sequence shown:

1. Determine the operational context and the functions and associated desired standards of performance of the asset (operational context and functions).
   - All the primary and secondary functions of the asset/system shall be identified.
   - Define the level of performance desired by the owner or user of the asset/system in its operational context (as opposed to the design capability).

Source: SAE JA1011 200908

Reliability Centered Maintenance

Any RCM process shall ensure that all of the following steps are performed in the sequence shown:

2. Determine how an asset can fail to fulfill its functions (functional failures).
    - All the failed states associated with each function shall be identified.

Source: SAE JA1011 200908

Reliability Centered Maintenance

Any RCM process shall ensure that all of the following steps are performed in the sequence shown:

3. Determine the causes of each functional failure (failure modes).
   - Failure modes shall be identified at a level of causation that makes it possible to identify an appropriate failure management policy.
   - Lists of failure modes should include any event or process that is likely to cause a functional failure (including design defects and human error whether caused by operators or maintainers) unless these events are being sufficiently addressed by processes apart from RCM.

Source: SAE JA1011 200908

Reliability Centered Maintenance

Any RCM process shall ensure that all of the following steps are performed in the sequence shown:

4. Determine what happens when each failure occurs (failure effects).
   - Failure effects shall describe what would happen assuming the failure mode and corresponding functional failure actually occurs.
   - Failure effects shall include all the information needed to support the evaluation of the consequences of the failure, such as:
     - What evidence (if any) that the failure has occurred (in the case of hidden functions, what would happen if a multiple failure occurred).
     - What it does (if anything) to kill or injure someone, or to have an adverse effect on the environment.
     - What it does (if anything) to have an adverse effect on production or operations.
     - What physical damage (if any) is caused by the failure.
     - What (if anything) must be done to restore the function of the system after the failure.

Source: SAE JA1011 200908

Reliability Centered Maintenance

Any RCM process shall ensure that all of the following steps are performed in the sequence shown:

5. Classify the consequences of failure (failure consequences).
   - The consequences of every failure mode shall be formally categorized as follows:
     - The consequence categorization process shall separate hidden failure modes from evident failure modes.
     - The consequence categorization process shall clearly distinguish events (failure modes and multiple failures)that have safety and/or environmental consequences from those that only have economic consequences (operational and non-operational consequences).
     - The assessment of failure consequences shall be carried out as if no specific task is currently being done to anticipate, prevent, or detect the failure.

Source: SAE JA1011 200908

Reliability Centered Maintenance

Any RCM process shall ensure that all of the following steps are performed in the sequence shown:

6. Determine what should be performed to predict or prevent each failure (tasks and task intervals).
    - The failure management strategy selection process shall take account of the fact that the conditional probability of various failure modes will increase, not change, or even decrease with age or exposure to stress.
    - All scheduled tasks shall be applicable and effective and the means by which this requirement will be satisfied are set out in Step 7.
    - If two or more proposed failure management strategies are applicable and effective, the rationale for selecting one over another shall be recorded.
    - The selection of failure management policies shall be carried out as if no specific task is currently being done to anticipate, prevent, or detect the failure.

Source: SAE JA1011 200908

Reliability Centered Maintenance

Any RCM process shall ensure that all of the following steps are performed in the sequence shown:

7. Determine if other failure management strategies may be more effective (operational and/or design modifications).
   - Scheduled Tasks
   - On-Condition Tasks
     - There shall exist a clearly defined potential failure.
     - There shall exist an identifiable P-F interval (or failure development period).
     - The task interval shall be less than the shortest likely P-F interval.
   - Failure-Finding Tasks
     - The task shall confirm that all components covered by the failure mode description are functional.

Source: SAE JA1011 200908

Reliability Centered Maintenance

The output of the seven mandatory steps is a FMECA, or Failure Mode, Effects, & Criticality Analysis.

- A critically important deliverable from the FMECA is an in-depth ranking of failure modes according to the combination of severity and the probability of that failure mode occurring (Criticality Analysis).

Reliability Centered Maintenance

The output of the seven mandatory steps is a FMECA, or Failure Mode, Effects, & Criticality Analysis.

- FMECA production is an iterative process, annually, at least.
- FMECAs should be included in the design process.

Reliability Centered Maintenance

The FMECA data can then be processed through a Quantified Residual Risk Rating model:

Impact ✖ **Likelihood** = **Risk** – **Control** = **Residual Risk Rating**

Rating	Risk Likelihood	Business Impact
Low (L)	**Low Likelihood –** Occurrence greater than 3 years for the organization and/or the industry; occurrence is very rare. The control environment is well defined and is based on multi-layered controls, it is well documented, there has been testing and/or assessments within the last six months, and it has been independently audited by risk, compliance or internal audit within the last year	**Low Impact –** Insignificant financial loss (including remediation, current and future customer loss); little to no process disruption (operational); little to no reputation damage (brand); little to no fines, penalties, regulatory consequence, civil prosecution (contractual and compliance); little to no bodily harm (health and safety); little to no environmental damage (environmental)
Medium (M)	**Medium Likelihood –** Occurrence between 1 month and 3 years for the organization and/or industry; occurrence is relatively infrequent. The control environment is well defined and is based on multi-layered controls, it is well documented, there has been testing and/or assessments within the last six months, and it has been independently audited by risk, compliance or internal audit within the last year	**Medium Impact –** Moderate financial loss between (including remediation, current and future customer loss); minor process disruption (operational); minor reputation damage (brand); minor fines, penalties, regulatory consequence, civil prosecution (contractual and compliance) and bodily harm (health and safety); minor environmental damage (environmental)
High (H)	**High Likelihood –** Occurrence once a month or more frequent for the organization and/or industry; occurrence if relatively frequent. The control environment is not well understood well, it is not documented, there has been no testing and/or assessments within the last six months, and it has not been independently audited by risk, compliance or internal audit within the last year	**High Impact –** Significant financial loss (including remediation, current and future customer loss); major process disruption (operational) ; significant reputation damage (brand); large fines, penalties, regulatory consequence, criminal prosecution (contractual and compliance); loss of human life (health and safety); significant environmental damage (environmental)

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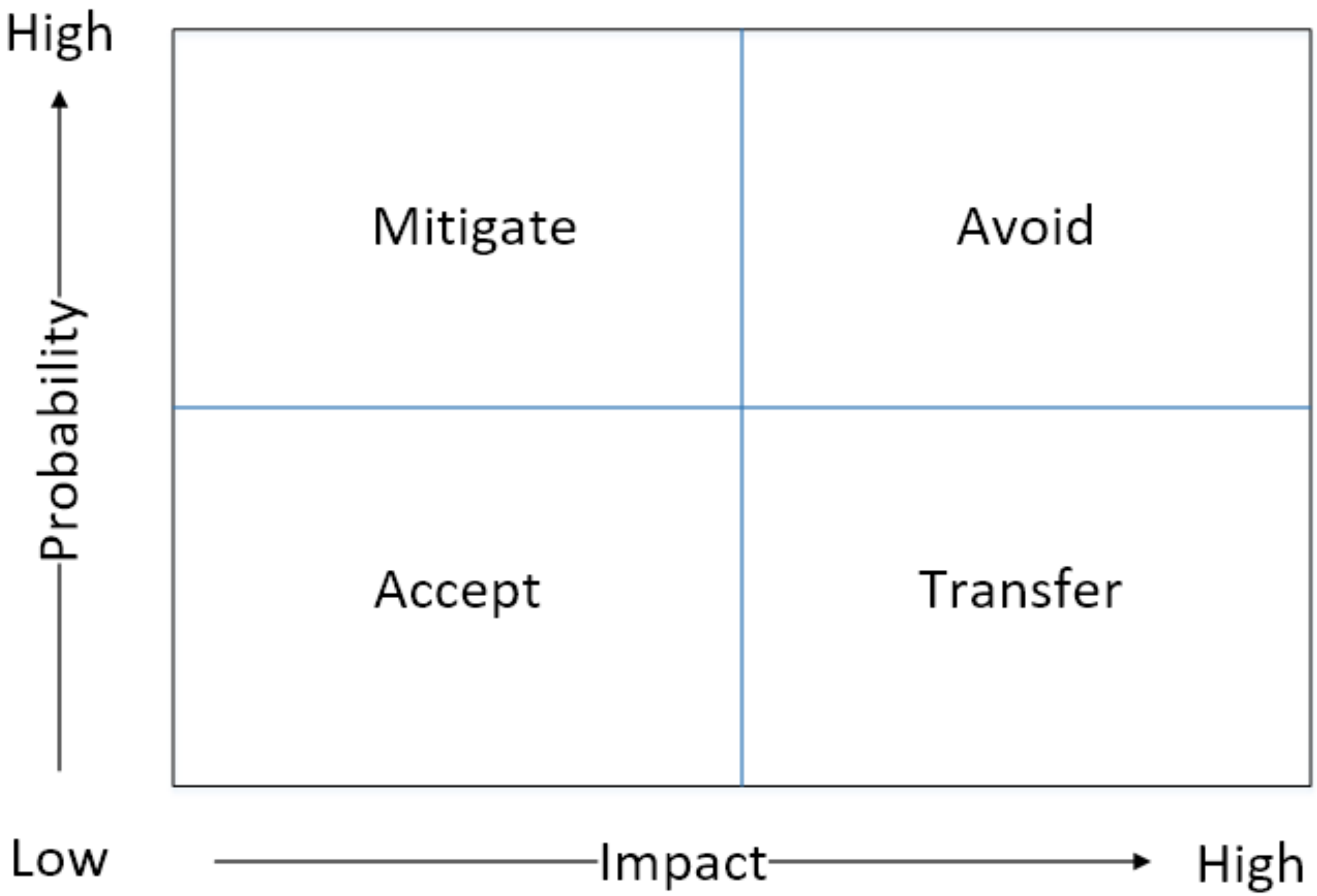
The quantified risk data from the FMECA can also be illustrated in quadrant format:



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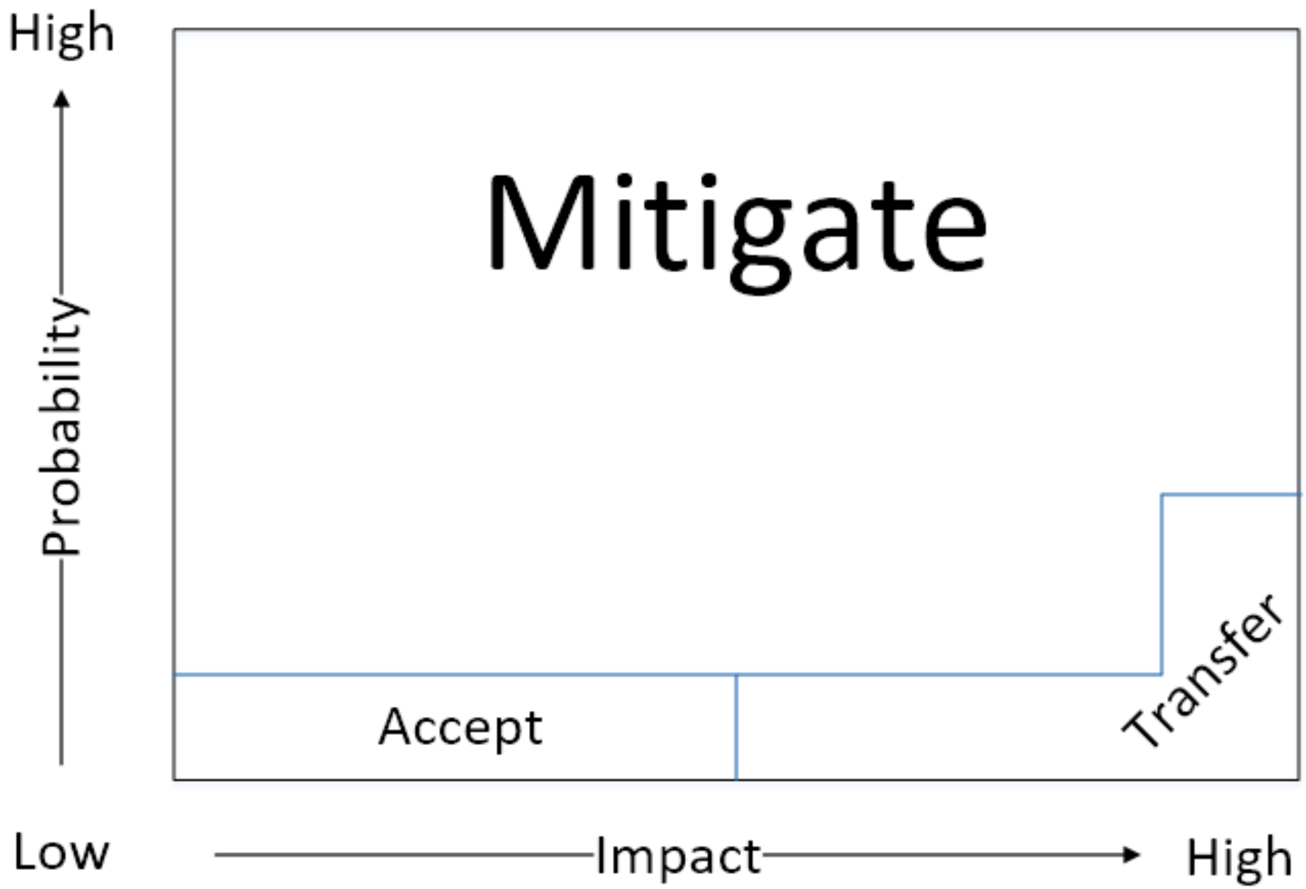
Although the data center business is the business of risk mitigation:



Reliability Centered Maintenance

RCM integrates with:

- ISO-9000: A Quality Management System – Uptime/Reliability = Quality.
- Six Sigma: Disciplined & Data-Driven process improvement. RCM provides reliable data, iteratively and over time.
- TIMS: You cannot achieve TIMS-4 (Fully Facilitated Maintenance) without RCM.*

* Presenter Opinion

Reliability Centered Maintenance

RCM can come into conflict with some data center standards (TIA-942, BICSI, UTI):

- One of the major tenets of RCM in practice is rigorous application of stress-reducing operating practices.

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The following are NOT stress-reducing operating practices.

- Circuit Breaker Injection Testing (with the possible exception of during data center commissioning).

- Generator set testing with load banks.

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Another major tenet of RCM is “Failure Finding” tasks - Scheduled tasks used to determine whether a specific hidden failure has occurred.

Good Example: Exercising a main power disconnect to make sure the sequence, timing, and load surges associated with a utility feed loss function as designed.

Bad Example: Running a generator on a load bank at 100% capacity when the system design dictates the generator would never run over 60% capacity in operation.

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A Mini Case Study; Scroll Compressor Slide Failures:

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A Mini Case Study; Scroll Compressor Slide Failures:

Why did we choose this technology?

- They sound great (95db!).
- Archimedean spirals are cool.
- **Infinitely variable throughout range of operation.**

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A Mini Case Study; Scroll Compressor Slide Failures:

- There is an assembly in scroll compressors called a “slide”.
- We were experiencing slide failures every 90 days PER REFRIGERANT UNIT.
- This was a minimum of a two-day outage per failure.

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A Mini Case Study; Scroll Compressor Slide Failures:

Was this a maintenance or service shortcoming?

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A Mini Case Study; Scroll Compressor Slide Failures:

No!

This was a combination of design and operational considerations – the variability of the compressor, the very reason we selected the technology, was also its greatest weakness.

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A Mini Case Study; Scroll Compressor Slide Failures:

In order to reduce the workload on the slides, we installed global mixing loops to reduce temperature variability in the returning coolant

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A Mini Case Study; Scroll Compressor Slide Failures:

The addition of mixing loops reduced the failure frequency by half.

Next, we upsized a refrigerant supply pipe on the high side of the chiller barrels.

The pipe size modifications further eased the workload on the slide assemblies. Failure frequency was again greatly reduced.

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A Mini Case Study; Scroll Compressor Slide Failures:

Continuing iterative FMECA analysis showed we still needed to reduce temperature variability. In the Spring of 2013 we:

- Increased the +/- water temperature tolerance in the cooling loops servicing ICT areas by 4° Fahrenheit; +2°/-2°
- added special solenoids which allowed us to run the compressors as unloaded, half-loaded, or fully-loaded.

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A Mini Case Study; Scroll Compressor Slide Failures:

We have not replaced a slide assembly in a scroll compressor since…

Reliability Centered Maintenance

RCM in the real world, properly executed:

- Improves the bottom line by eliminating downtime and superfluous maintenance.
- Improves uptime, reliability, and accordingly, customer satisfaction.
- Dazzles corporate risk managers from existing and prospective customers.

TRANSITION SLIDE TITLE

3 Key Things You Have (Hopefully) Learned During this Session

1. What Reliability-Centered Maintenance is and what it is not.
2. How RCM integrates with Six Sigma, ISO 9001, and TIMS.
3. The role of RCM throughout the Design-Build-Maintain cycle.

Thank you!

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Thank you

Speaker information & contact info (if interested in providing)

Company Logo Ok

Let's talk!

Questions & Hopefully, Answers.