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Case Study: Qualitative Risk Assessment of a Refrigeration System

Bio Slide

- Robert Sladek
- Asset Optimization Consultants (AOC)
- Sr. Asset Integrity Consultant
  - 30+ Years in Mechanical Integrity
  - Field of Expertise:
    - Inspection
    - RBI
    - Mechanical Integrity Management
  - Industry Involvement/Recognition:
    - Chairman for API 581 Task Group (Vice-Chair 2012-18)
    - Vice-Chair API 580 Task Group

Qualitative Risk Assessment of a Critical Refrigeration System

- RBI was used to identify scope for a refurbishment project.
  - One (1) Excel workbook used
  - Probability based on basic MI formulas
  - Consequence table was customized
  - Non-standard risk matrix was used

Background

- Fourteen (14) year old System supported
  - 2 storage rooms (-35^{o}C and +5^{o}C)
  - 1 working room (+5^{o}C)
  - 1 packaging room (+5^{o}C)
- Redundancy required to meet FDA requirements for temperature tolerance (+/-5^{o}C)
- Primary asset compliance was state requirement (not PSM).
- Recent issues with asset reliability
- Limited inspection history
- Product stored in excess of $50MM
- Secured capital funding for refurbishment

Scope

- Five (5) Compression Skids
  - 5 Exchangers
  - 5 Pressure Vessels
- Two (2) Refrigeration Skids
  - 4 Exchangers
  - 10 Pressure Vessels
- Eighteen (18) Room Evaporators
- Thirty-Three (33) Piping Circuits

Project Resourcing

This project was completed with 80 manhours of consulting / facilitation time

- Solution development
- Data review / input
- Damage assessment
- Consequence development

Site resources were used for:

- Data mining
- Consequence development
- Consequence assignment

Project Tasks

- Develop Methodology
  - Create Risk Assessment Workbook
- Circuitize Piping & Identify FE Components
- Data Gathering / Input
- Perform Damage Assessment
- Consequence Table Development
- Consequence Assignment
- Finalize / Review Risk Assessment

Probability Methodology

- Define Components
- Use ASME Code formulas for t_{min}
- Special Damage Mechanism (DM):
  - “Ice Damage”
- Use inspection/maintenance history and same/similar service where possible

Assumptions

- Copper tubing was assigned as Type ACR for the evaporators and rack piping.
- Insulation breaks per the P&ID's were correct
- No paint credit was given to insulated carbon steel assets
- CUI rate of 0.010 inches per year.
- Structural t_{min} was applied as follows:
  - Tubing = 20% of nominal thickness (t_{nom})
  - Fixed equipment and piping ≥ 2 inch diameter = 0.125 inches.
  - Piping <2 inch diameter = 0.100 inches
- Cooling water corrosion rate of 0.0021 inches per year was used for all copper tubes based on history

Probability Model

Componer	NB/SN	Date in Service	Material	Stress	OD	t"nom	CA	DesP	DesT	JE	Ct"min	St"min	t"min	CR-Ext	CR-INT	CR Combi	Yrs	t"act	ODM	ODM-Fx	RL	RL Factor	Probability
Shell	14193	1/1/01	SA-516-70	20000	30	0.375	0	300	300	0.7	0.317	0.125	0.317	0.01	0.00001	0.01001	14	0.23486			-8.25321422	A	A
Shell	14192	1/1/01	SA-516-70	20000	30	0.375	0	300	300	0.7	0.317	0.125	0.317	0.01	0.00001	0.01001	14	0.23486			-8.25321422	A	A
Shell	14188	1/1/01	SA-516-70	20000	30	0.375	0	300	300	0.7	0.317	0.125	0.317	0.01	0.00001	0.01001	14	0.23486			-8.25321422	A	A
Shell	14183	1/1/01	SA-516-70	20000	30	0.375	0	300	300	0.7	0.317	0.125	0.317	0.01	0.00001	0.01001	14	0.23486			-8.25321422	A	A
		1/1/01	SA-53-B	20000	1.315	0.133	0	300	450	0.85	0.012	0.100	0.100	0.01	0.00001	0.01001	14	0.09286			-0.71328671	A	A
		1/1/01	SA-53-B	20000	2.375	0.154	0	300	450	0.85	0.021	0.125	0.125	0.01	0.00001	0.01001	14	0.11386			-1.11288711	A	A
		1/1/01	SA-53-B	20000	1.9	0.145	0	300	450	0.85	0.017	0.100	0.100	0.01	0.00001	0.01001	14	0.10486			0.485514486	A	A
Channel	144722	1/1/01	SA-53-B	17100	6.625	0.28	0	150	250	0.85	0.031	0.125	0.125	0	0.019	0.019	14	0.014			-5.84210526	A	A
Channel	144721	1/1/01	SA-53-B	17100	6.625	0.28	0	150	250	0.85	0.031	0.125	0.125	0	0.019	0.019	14	0.014			-5.84210526	A	A
Channel	144720	1/1/01	SA-53-B	17100	6.625	0.28	0	150	250	0.85	0.031	0.125	0.125	0	0.019	0.019	14	0.014			-5.84210526	A	A
Channel	144718	1/1/01	SA-53-B	17100	6.625	0.28	0	150	250	0.85	0.031	0.125	0.125	0	0.019	0.019	14	0.014			-5.84210526	A	A
Channel	144719	1/1/01	SA-53-B	17100	6.625	0.28	0	150	250	0.85	0.031	0.125	0.125	0	0.019	0.019	14	0.014			-5.84210526	A	A
L4	939697DL	1/1/01	SB-75 C122	10300	1.375	0.055	0	250	100	1	0.016	0.011	0.016	0	0.00001	0.00001	14	0.05486	Ice Damage	B	3928.118227	D	B
R4	939697DR	1/1/01	SB-75 C122	10300	1.375	0.055	0	250	100	1	0.016	0.011	0.016	0	0.00001	0.00001	14	0.05486	Ice Damage	B	3928.118227	D	B
L4	939697DL	1/1/01	SB-75 C122	10300	1.375	0.055	0	250	100	1	0.016	0.011	0.016	0	0.00001	0.00001	14	0.05486	Ice Damage	B	3928.118227	D	B
R4	939697DR	1/1/01	SB-75 C122	10300	1.375	0.055	0	250	100	1	0.016	0.011	0.016	0	0.00001	0.00001	14	0.05486	Ice Damage	B	3928.118227	D	B
		1/1/01	SA-53-B	20000	2.875	0.203	0	300	450	0.85	0.025	0.125	0.125	0.01	0.00001	0.01001	14	0.16286			3.782217782	B	B
		1/1/01	SA-53-B	20000	4.5	0.237	0	300	450	0.85	0.040	0.125	0.125	0	0.019	0.019	2	0.199			3.894736842	B	B
		1/1/01	SA-53-B	20000	4.5	0.237	0	300	450	0.85	0.040	0.125	0.125	0	0.019	0.019	2	0.199			3.894736842	B	B
Tubes	144722	10/1/07	SB-75 C122	10300	0.625	0.042	0	150	250	1	0.004	0.008	0.008	0	0.0021	0.0021	8	0.0252			8.19047619	C	C
Tubes	144721	10/1/07	SB-75 C122	10300	0.625	0.042	0	150	250	1	0.004	0.008	0.008	0	0.0021	0.0021	8	0.0252			8.19047619	C	C
Tubes	144720	1/1/08	SB-75 C122	10300	0.625	0.042	0	150	250	1	0.004	0.008	0.008	0	0.0021	0.0021	7.5	0.02625			8.69047619	C	C
Tubes	144718	1/1/08	SB-75 C122	10300	0.625	0.042	0	150	250	1	0.004	0.008	0.008	0	0.0021	0.0021	7.5	0.02625			8.69047619	C	C
Tubes	144719	1/1/08	SB-75 C122	10300	0.625	0.042	0	150	250	1	0.004	0.008	0.008	0	0.0021	0.0021	7.5	0.02625			8.69047619	C	C
Shell	14190	1/1/01	SA-53-B	17100	16	0.375	0	300	250	0.85	0.159	0.125	0.159	0.01	0.00001	0.01001	14	0.23486			7.543242546	C	C
Shell	14198	1/1/01	SA-53-B	17100	16	0.375	0	300	250	0.85	0.159	0.125	0.159	0.01	0.00001	0.01001	14	0.23486			7.543242546	C	C

- Probability based on ODM and Remaining Life
  - A = < 1 year
  - B = 1 to < 5 years
  - C = 5 to < 10 years
  - D = 10 years plus

Consequence Methodology

- A 1 (high) to 5 (low) ranking system was developed for each of the following categories:
  - Safety
  - Environmental
  - System Operability
  - Cold Room Operability
- Values for the categories were assigned through consultation with the site SMEs

Consequence Model

Y	Z	AA	AD	AE	AF	AH	AI	AJ
RL	RL Fact	Probabil	Safety Impact	Environmental Impact	System Operability Impact	Cold Room Operability Impact	Total	Risk
277.3851351	D	D	3	2	3	4	2	D-2
1536	D	D	5	5	3	4	3	D-3
-5.842105263	A	A	5	5	4	4	4	A-4
8.19047619	C	C	5	5	3	4	3	C-3
277.3851351	D	D	3	2	5	5	2	D-2
1536	D	D	5	5	5	5	5	D-5
-5.842105263	A	A	5	5	4	5	4	A-4
8.19047619	C	C	5	5	3	5	3	C-3
277.3851351	D	D	3	2	5	4	2	D-2
1536	D	D	5	5	5	4	4	D-4
-5.842105263	A	A	5	5	4	4	4	A-4

"Total" consequence was rolled up based on the highest consequence (lowest number) in Column AI

Risk Results

ALL EQUIPMENT

CONSEQUENCE / PROBABILITY

Row Labe	1	2	3	4	5	Grand Total
A		4	3	5		12
B			7			7
C			12	2		14
D		16	33	9	2	60
Grand Total		20	55	16	2	93

- Top Priority - Consider design improvement prior to immediate replacement
- Mitigate and repair/replace as needed
- Perform regularly scheduled inspections

FIXED EQUIPMENT

CONSEQUENCE / PROBABILITY

Row Labe	1	2	3	4	5	Grand Total
A		4		5		9
B			4			4
C			7	2		9
D		11	20	5	2	38
Grand Total		15	31	12	2	60

PIPING / TUBING

CONSEQUENCE / PROBABILITY

Row Labe	1	2	3	4	5	Grand Total
A			3			3
B			3			3
C			5			5
D		5	13	4		22
Grand Total		5	24	4		33

Project Results

- Identified assets for immediate CUI inspection
  - (6) Pressure Vessels
  - (7) Piping circuits
- Identified assets for replacement
  - (5) Oil Coolers
  - (4) Evaporators
- Prioritized specific inspections

Presentation Finished.

Any questions?