Towing Vessel Safety:

Risk-based Maintenance and Inspection of Towing Vessel Machinery and Systems

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Authors:

Bartley J. Eckhardt, P.E. - Bart is President/CEO of Robson Forensic, Inc. and also heads its Marine-Industrial-Specialty Practice Group. A testifying expert himself in matters of marine and mechanical engineering, he held advanced Merchant Marine licenses and is a licensed Professional Engineer in 17 states.

Having enjoyed a 30+ year career specializing in the unusual, Bart regularly analyzes catastrophic marine and industrial incidents, particularly involving machinery, systems, rigging and marine towing. As an International Association of Marine Investigators certified marine investigator, and having completed a 40-hour course in Marine Accident Investigation by the World Maritime University, he applies principles of marine and mechanical engineering to reconstruct marine casualties.

Captain Peter D. Squicciarini - Captain Peter D. Squicciarini is a licensed Master Mariner and is currently a Marine Safety Specialist at the U.S. Coast Guard Atlantic Area Command, Portsmouth, VA. He is the Coast Guard's Uninspected Towing Vessel Safety and Compliance Coordinator for over 5000 vessels in the Atlantic Area. He has sailed on towing, passenger, and fishing vessels and was the Safety and Compliance Manager for an East Coast tug and barge company. Captain Squicciarini served in the U.S. Navy for nearly 30 years and has commanded Destroyers and Cruisers. He has published numerous maritime safety articles in industry publications, including WorkBoat Magazine. He is a graduate of the U.S. Naval Academy and now resides in Norfolk, VA.

The opinions of Captain Squicciarini contained in this paper do not necessarily reflect the opinions of the USCG. His participation in this project does not constitute a USCG endorsement of Robson Forensic, Inc.

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Bartley J. Eckhardt, P.E.
President/CEO
Robson Forensic
Lancaster, Pa USA

Captain Peter D. Squicciarini
U.S. Coast Guard,
Atlantic Area Command
Portsmouth, Va USA

Abstract

Failures of machinery and systems aboard towing vessels can have devastating consequences to the vessel, its crew, other vessels and their crews, shoreside populations and facilities, cargoes, marine transportation systems, commerce, and the environment. This paper presents a comprehensive methodology for implementing Risk-Based Maintenance and Inspections of towing vessel machinery and systems. Utilizing incident data from the United States Coast Guard (USCG) and other relevant industry information, the authors apply the principles set forth in *ANSI/API Recommended Practice 580, Risk-based Inspection* [1], as a guideline.

Relatively straightforward to implement, the methodology presented in this paper is expected to improve towing vessel safety, reduce potential dangers associated with towing operations, and provide favorable risk/benefit reward to vessel owners.

Introduction

The U.S. flag domestic cargo fleet consists of more than 38,000 vessels (mostly tugs and barges) that handle a combined total of more than one billion tons of cargo annually, and represent over $41 billion dollars in private investment in 2010[1]. [2] The USCG estimates that 6,500 of those 38,000 vessels include towing vessels greater than 26 feet in length Each year the USCG has consistently investigated several hundred incidents, some serious, involving towing vessels; ranging from collisions and allisions to fires and injuries aboard. Approximately one-third of the reported incidents can be attributed to what the USCG calls “material failures” or “component failures”, i.e. failures of machinery and equipment “not related to human performance”. Of these reported incidents, the most serious are generally those precipitated by sudden loss of maneuverability. USCG data for component failures leading to maneuverability incidents 2007-2011 are presented as Figure 3.

By their nature, towing vessels are working in close quarters in rivers, bays, and harbors; and heavy seas when working offshore. Their service is rigorous, and demands on the vessels and their crews are high. Because of this service, the consequences to persons, marine transportation systems, commerce, and the environment are potentially high in the event of a failure.

Historically, the majority of towing vessels in inland and coastwise service are classified as "uninspected vessels", and while regulated by CFR there is no requirement that they be inspected similar to the way ships are classed and inspected. The USCG has drafted *Subchapter M Proposed Regulations for Towing Vessels* [3] that, when enacted, would require the approximate 6,500 towing vessels longer than 26 feet in length to be USCG inspected.

The USCG has engaged ABSG Consulting Inc. to review the regulations, and the USCG has along with the Towing Safety Advisory Committee (TSAC,) a long established chartered Federal Advisory Committee empowered to formally represent industry to the USCG, to provide a mechanism to involve the towing industry in the development and implementation of proposed regulations and other important safety and operational issues unique to towing vessels.

A methodology used in writing this new Regulation, proposed *Subchapter M*, has been Risk-Based similar to *API Recommended Practice 580, Risk-Based Inspection* which this paper will explore. Comprehensive review and analysis of years of USCG data identified the type, frequency, and severity of incidents, in short, "risk". Significant trends were considered to be focus areas where the new Regulation could be crafted to mitigate or eliminate the identified risks through new requirements for equipment, redundancy, maintenance, operations, personnel, and of particular note, a proposed Safety Management System (SMS).

The SMS in itself has at its core Risk-Based analysis and trending. *The International Safety Management Code* (ISM) is the standard for SMS's. Other international standards, either directly or indirectly applicable to a SMS, are the *ISO 9001/14001* series which too are risk and process based. This makes the best practices of *ANSI/API Recommended Practice 580, Risk-based Inspection* quite applicable, for use in establishing and continuously improving towing vessel maintenance programs expected to be contained in an effective SMS. The result will be a reduction in material and component failures and decreased risk of sudden loss of maneuverability all of which equate to improved safety.

Analysis

The authors have analyzed the reported towing vessel incidents and put forth a methodology of Risk-based Maintenance and Inspection (RBM&I) that will help towing vessel owners and operators optimize maintenance and inspection, so that machinery and equipment failures will be reduced in a cost effective manner. It should be noted that no amount of Risk-based Maintenance and Inspection can make up for faulty design or installation; conversely risk can be reduced significantly with the application of sound principles of marine engineering, such as, providing 100 percent redundancy in critical systems or fitting spray shields around piping joints in pressurized portions of fuel and lube oil systems. RBM&I will result in less damage to towing vessels, barges, other vessels, shoreside infrastructures, and the environment; as well as increase the safety for all persons involved.

<u>API Recommended Practice 580, Risk-Based Inspection</u>

The authors have turned to the best practices of the petrochemical industry, where Risk-Based Inspection (RBI) is set forth in the 80 plus page *API Recommended Practice 580, Risk-Based Inspection*. The petrochemical industry uses RBI to target inspections of pressure-containing portions of a petrochemical plant (vessels, piping, pumps, etc.). Generally:

> The objective of RBI is to determine what incident could occur (consequence) in the event of an equipment failure, and how likely (probability) it is that the incident could happen. The accuracy of any type of RBI analysis depends on using a sound methodology, quality data, and knowledgeable personnel and is important to any type of RBI methodology selected for application.[2]
>
> The objective of RBI is to direct management's decision process of prioritizing resources to manage risk.[3]

The approach emphasizes safe and reliable operation through risk-prioritized inspection. A spectrum of complementary risk analysis approaches (qualitative through fully quantitative) can be considered as part of the inspection planning process.[4]

The expected outcome from the application of the RBI process should be the linkage of risks with appropriate inspection, process control or other risk mitigation activities to manage the risks.[5]

Risk

Risk is the combination of the probability of some event occurring during a time period of interest and the consequences, (generally negative) associated with the event. In the mathematical terms, risk can be calculated by the equation: [6]

Risk = Probability x Consequence

A logical progression for a risk analysis is:[7]

a. Collect and validate the necessary data and information
b. Identify damage mechanisms and, optionally, determine the damage mode(s) for each mechanism (e.g. general metal loss, local metal loss, pitting)
c. Determine damage susceptibility and rates
d. Determine the POF over a defined time frame for each damage mechanism
e. Determine credible failure mode(s) [e.g. small leak, large leak, rupture]
f. Identify credible consequence scenarios that will result from the failure mode(s)
g. Determine the probability of each consequence scenario, considering the POF and the probability that a specific consequence scenario will result from the failure
h. Determine the risk, including a sensitivity analysis, and review risk analysis results for consistency/reasonableness

Then the logical progression after completing the risk analysis is to develop an inspection plan and, if necessary, other mitigation actions, and evaluate the residual risk. If the risk is not acceptable, consider mitigation.[8]

Understand Risks

An objective of the RBI assessment may be to better understand the risks involved in the operation of a plant or process unit and to understand the effects that inspection, maintenance and mitigation actions have on the risks.[9]

Management of Risks

When the risks are identified, inspection actions and/or other mitigation that have a positive effect in reducing risk to an acceptable level may be undertaken. These actions may be significantly different from the inspection actions undertaken during a statutory or certification type inspection program.[10]

Risk Matrix:

For risk ranking methodologies that use consequence and probability categories, presenting the results in a risk matrix is a very effective way of communicating the distribution of risks throughout a plant or process unit without numerical values.[11]

Example of API Risk Matrix[12]:

Qualitative Risk Matrix

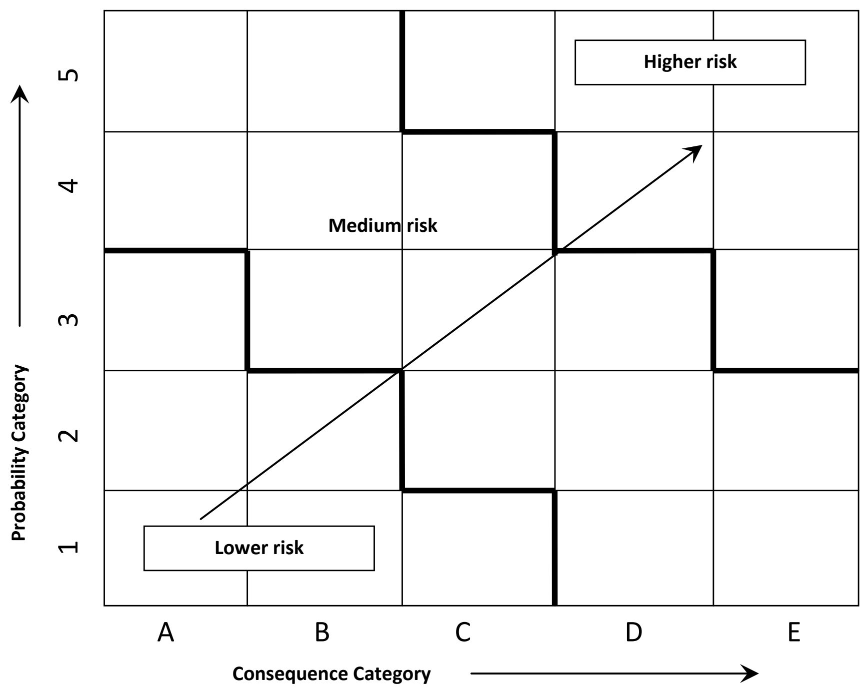


Figure 1

Qualitative Approach:

This approach requires data inputs based on descriptive information using engineering judgment and experience as the basis for the analysis of probability and Consequences of Failure (COF).[13]

…Results are typically given in qualitative terms such as high, medium, and low although numerical values may also be associated with these categories.[14]

Although the qualitative approach is less precise than more quantitative approaches it is effective in screening out units and equipment with low risk.[15]

Data Needs for Qualitative RBI:

A more qualitative approach typically does not require all of the data mentioned in section 8.2. Further, items required only need to be categorized into broad ranges or classified versus a reference point. It is important to establish a set of rules to assure consistency in categorization or classification. [16]

> Understanding equipment operations and the interaction with the process environment (both internal and external) and mechanical environment is key to identifying damage mechanisms.[17]

Qualitative Consequences Analysis:

> A qualitative method involves identification of the units, systems or equipment, and hazards present as a result of operating conditions and process fluids. On the basis of expert knowledge and experience, the consequences of failure (safety, health, environmental and financial impacts) can be estimated separately for each unit, system, equipment group or individual equipment item.[18]

The RBM&I methodology presented in this paper can be applied through the SMS to all equipment and machinery aboard a towing vessel, but pressure-containing components are among the most vulnerable to failure, and said failures can lead to catastrophic consequences.

Comprehensive Methodology Applied to Towing Vessels

RBM&I methodology, developed and presented here, is based on a consequence-driven model where,

as in API 580, Risk = Probability of Failure x Consequence

The authors have adopted an approach taken at Qatar Gas [4], where:

> A matrix approach was not implemented but instead a numeric value is obtained and the Risk ranking (Criticality) is based on this value within a given range of values (eg >15 = High, 10-15 = Medium, 5-10 = Low, <5 = Very Low). Inspection frequencies are base on the Criticality. [19]

Depicted graphically in Figure 2:

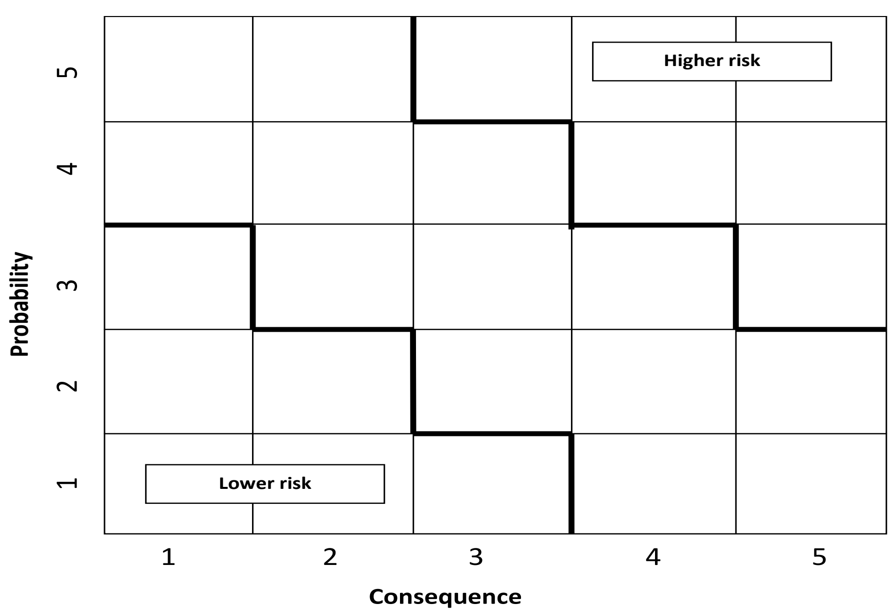


Figure 2

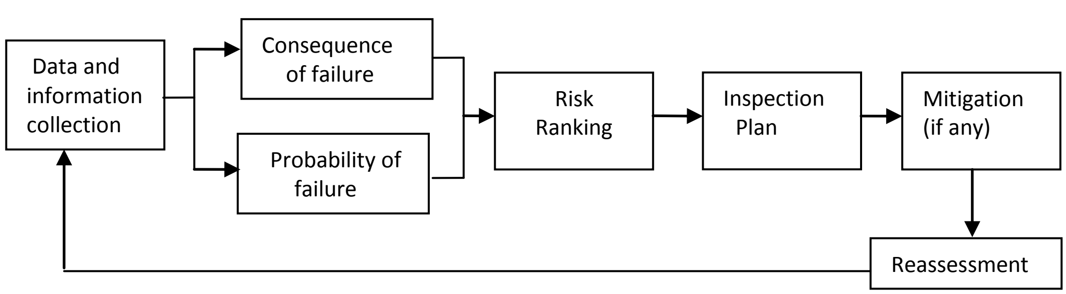
With respect to towing vessels, the probability of failure of certain equipment, machinery, and systems may be difficult to predict absent specific historical data. Accident and incident reporting via the CG-2692 form, which has strict criteria for reporting on accidents, incidents, and near misses, has been notoriously under reported or incomplete, the scope of which has not yet been quantitatively ascertained. Nevertheless, the USCG's wide data base spanning multiple years of available reporting has yielded sufficient information and vetted data to apply risk-based methodology used in the development of proposed Subchapter M and is equally sufficient to successfully apply *ANSI/API Recommended Practice 580, Risk-based Inspection.*

There are many components, equipment, and machinery aboard a towing vessel whose failure could lead to catastrophic consequences. As TSAC described it:

> Sometimes the difference between a low and high-severity incident is luck.[5][20]

The first level of assessment, and that which is described herein, is qualitative. More detailed and quantitative assessments can be carried out after the qualitative measures have been put in place, specific historical data accumulated, and effectiveness of the qualitative measures gauged. This methodology is oriented toward continuous quality improvement. As such the methodology yields the most efficient and cost-effective solution possible to vessel owners in inspecting and maintaining their towing vessels; and in complying with proposed *Subchapter M Regulations* including the SMS.

In this diagram, *API 580* depicts the RBI Planning Process that should be considered when applying this methodology[21]:



A Qualitative Risk Matrix is developed by system and presented as Figure 2, where Probability of Failure is described on a scale of 1 to 5 (with 5 being the most likely) and Consequence of Failure is described on a scale of 1 to 5 (with 5 being the most severe possible consequence). Therefore, those products of Probability of Failure (POF) and Consequence of Failure (COF) ≥15 represent the highest Risk, and warrant the first and greatest attention and resource, followed by those products of POF and COF yielding moderate Risk: 10 ≤ Risk < 15

Highest Risk

In terms of Consequence severity, those failures that can result in allisions or collisions have the highest ranking, where those failures (non-critical systems, for example) that are not likely to result in injury carry the lowest ranking. The highest consequences are sub-graded such that failures that could endanger other vessels, or people and property ashore, are considered the most severe. Generally, these are failures that result in sudden inability to maneuver the towing vessel. Component failures leading to maneuverability incidents for the period 2007 – 2011[21], as compiled by the USCG, are presented as Figure 3:

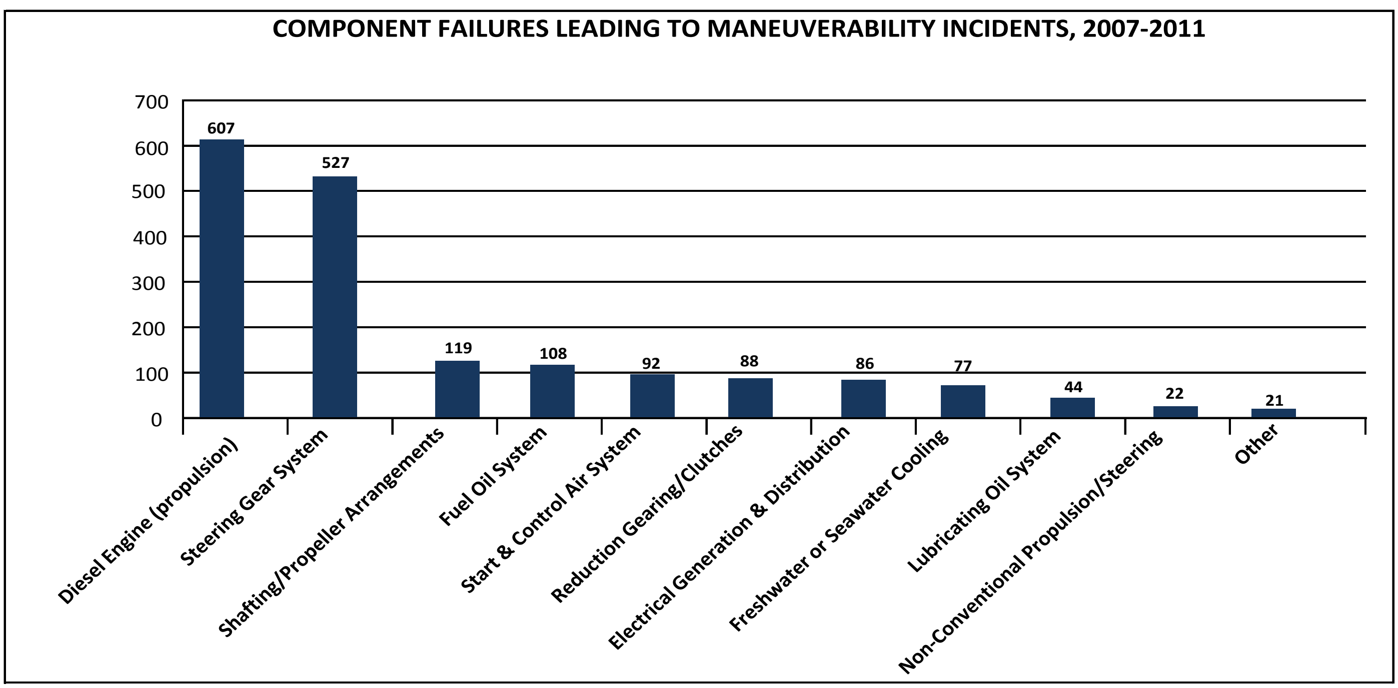


Figure 3

Many major incidents, and near misses that could have been major incidents, go unreported. Absent very detailed, complete, and accurate data sufficient to perform a rigorous probability analysis the authors recommend a more basic approach in determining Probability of Failure. Specifically:

a) That single point failures are more likely to yield a high consequence failure than an equivalent failure in a redundant system.

b) Systems that contained pressurized fuel oil, lube oil, and hydraulic fluid (i.e. for steering) are likely to fail in a manner that could not only cripple the towing vessel but lead to fire and explosion. Keeping leaks in such systems contained so that they don't mist or become exposed to competent sources of ignition is key to reducing the probability of a high consequence failure. One of the best ways to keep such leaks contained is with the use of spray shields.

Design Solutions Can Reduce Risk

Redundancy

The consequence-driven model presented herein for determining Risk is in large part predicated on the Probability of Failure leading to an undesirable or catastrophic consequence. The probability of any failure is greatly reduced when the system being evaluated for failure is 100 percent redundant.
The benefit of redundancy is intuitively obvious, and has long been applied in the design of the ships' systems in the deep sea environment, in particular warships. A curious paradox exists regarding redundancy on towing vessels. Redundancy in the deep sea environment greatly reduces the likelihood of a ship being stranded "miles from nowhere". Generally, a failure leading to the stranding of a towing vessel is not as significant as the stranding of a deep sea vessel. The consequences of machinery and equipment failures aboard towing vessels however, can endanger the broader community including shoreside populations and facilities. Yet, redundancy in towing vessels' systems has neither been required nor unilaterally applied in the historic design and typical construction of towing vessels. It is

logical, therefore, that USCG requires redundancy at least in steering systems in the proposed implementation of *Subchapter M Regulations*.

Although machinery and equipment in certain systems aboard towing vessels may be redundant (i.e. "2" of), single point failure modes may still exist in the system and therefore vulnerability may exist in ways not fully contemplated. The methodology presented herein addresses this by recommending that all systems be traced and drawn as a first step. It is not possible to comprehensively address maintenance and inspection of a system if it is not known what the system consists of. The approach of "trace it first" has been successfully applied for decades in the training of engineering cadets by the various schoolship programs throughout the United States.

Spray Shields on Oil Lines

Engine spaces on towing vessels are notoriously tight, akin more to a naval combatant than a deep sea merchant ship. As such, there exists an extreme risk related to oil leaks, especially small opening leaks in pressurized systems such as pinholes or blown flange gaskets. When such a leak occurs, atomization, vaporization, and misting of the oil occurs; and when exposed to a competent source of ignition in close quarters, such as a red-hot turbocharger, fire and explosion occurs. Initial explosions can be similar to a particulate explosion, and fed by a continuous stream of atomized oil, the entire engine space becomes, for all intent and purpose, an open burner incinerator and a large-scale conflagration ensues. There is little recourse in effectively fighting such a fire but to secure oil flow and air into the space.

Consequence and Probability of Failure

Determining Consequence of Failure (COF)

In order to determine Risk, it is necessary to determine a Consequence of Failure (COF). Traditionally, this is a 5-point numerical scale where 1 represents negligible consequence, and 5 represents a potentially catastrophic impact.[6] The authors have develop the following suggested 5-point scale which is a variation on the traditional 5-point scale, refined to be specific to towing vessels.

Consequence Rating Used to Calculate Risk.

5	Collision/Allision resulting in fire or explosion, and/or toxic chemical release, and/or damage to critical infrastructure.
4	Collision/Allision resulting in fire and/or environmental release not immediately harmful to people and/or damage to non-critical infrastructure.
3	Fire, explosion, sinking affecting the vessel itself and pollution limited to that caused by the vessel itself.
2	Mechanical, thermal or chemical energy release affecting one or more of the vessel's crew and without harm to the environment.
1	Failure of non-critical system affecting part of the vessel itself without harm to the crew or the environment.

Table 1

Suggested Consequence Rating By System

	Column A Handling oil/chemical tank barges and/or ships of any type	Column B Not handling oil/chemical tank barges and/or ships of any kind
Steering	5	4
Propulsion	5	4
Propulsion Control	5	4
Fuel Oil Service	5	4
Fuel Oil Transfer	3	3
Compressed Air	2	2
Generator Fuel Oil	5	4
Generator Lube Oil	5	4
Generator cooling water	5	4
Firefighting	3	3
Dewatering/Bilge	3	3
Towing Machine	5	4
Deck Machinery (capstans, gypsy heads, winches)	2	2
Seawater Service	3	3
Ballast	3	3
Oily/water separation	4	4
Elevating Pilothouse	5	4
ITB Locking	5	4
Potable Water	1	1
Sanitary	1	1
Galley Equipment	3	3
HVAC	1	1
Auxiliary steam/Hot water	3	3

The Towing Safety Advisory Committee, in Appendix C of its *Report of the Working Group on Towing Vessel Inspection*, identified an Engineering Systems Matrix similar to the systems presented in Figure 4. Further considerations are offered, by system, based on the proposed *Subchapter M Regulations.*

Applying prudent principles of engineering, RBM&I will be critical to a comprehensive SMS proposed under *Subchapter M Regulations*.

Determining Probability of Failure (POF)

In order to determine risk, it is necessary to determine Probability of Failure (POF). Traditionally this is a 5-point numerical scale where 1 represents a remote possibility and 5 represents a frequent possibility. The authors have developed the following suggested 5-point scale which reflects the increased likelihood of failure due to lack of redundancy in critical systems often encountered aboard towing vessels, and the increased likelihood of a catastrophic event related to leaks in pressurized oil systems.

Probability of Failure Rating Used to Calculate Risk

5	Single point, pressure-containing, flex and threaded fittings, filters and strainers, flanged connections, or pressurized oil without spray shields.
4	Single point, pressure-containing, flanged connections, or pressurized oil with spray shields.
3	Redundant, pressure-containing, flex and threaded fittings, filters and strainers, flanged connections, or pressurized oil without spray shields.
2	Redundant, pressure-containing, flex and threaded fittings, filters and strainers, flanged connections, or pressurized oil with spray shields.
1	No pressure or energy containing.

Table 2

Step-By-Step Analysis:

Step 1 **Assign a Consequence Rating to each major system.**
Using Figure4 as a starting point, consider the service in which the towing vessel under evaluation is engaged, and assign Consequence Ratings by system from either Column A or B.

Step 2 **Draw a Flow Diagram or Piping and Instrumentation Diagram (P&ID) for each system; Identify specifics of equipment and machinery in each system.**
Trace every system aboard the vessel and generate a single line flow diagram or P&ID showing all machinery, equipment, valves, gauges and sensors in the system.

Step 3 **Identify 'single point failure' portions of each system.**
Single point failure is where there is no alternative for that system to operate in the event of a failure, rupture, leak, clog, etc.

Step 4 **Assign a Probability of Failure (POF) Rating for each system**.
Considering Steps 1-3, assign a POF for each system, or part of a system, using Table 2 as a starting point.

Step 5 **Calculate the Risk Rating by multiplying the Consequence Rating by the Probability.**
By system, multiply the POF by the COF to obtain a Risk Rating for each system and classify each system as High (Critical), Moderate, and Low.

Step 6 **Identify Critical Systems as those systems having a High Risk Rating ≥ 15, Moderate Risk Rating 10 ≤ risk <15.**

Step 7 **Devise an inspection/maintenance process and frequency addressing all areas where Risk ≥5.**
Concentrating first on High Risk ≥15, and working priority in descending order of Risk from Highest to Lowest. Under no circumstances is it acceptable to ignore all but the Highest Risk. Consider crew change intervals, manufacturer's recommendations, focusing first on strainers, filters, and flexible connections.

Applying the Methodology

Example 1 – Towing Vessel 'Alpha'

The following fictitious example is offered to show how the methodology can be applied:

M/V 'Alpha' is a 95 foot long, 2400 HP twin screw towing vessel (2 x 1200 HP) driving fixed pitch, open propellers through pneumatic-controlled clutches and reduction gears.

The 'Alpha' has two main rudders, and two flanking rudders. The 'Alpha' exclusively handles rock and gravel barges on Long Island Sound.

Step 1

Assign a Consequence Rating to each major system.
Since the M/V 'Alpha' is in a more benign service, when referring back to Figure 4, Column B (preceding) Consequence Rating applies.'

Step 2

Draw a flow diagram or P&ID for each system; Identify Specifics of Equipment and Machinery; for each system. For example: The towing vessel 'Alpha' reveals that all major systems are truly redundant and therefore carry a Failure Probability Rating of 3 or lower:

Exceptions specifically pertaining to MV 'Alpha' include:

Propulsion Control
Fuel Oil Transfer
Fuel Oil Service

Which, although redundant, have portions of their systems that constitute 'single point failure' modes.

Step 3

Identify 'Single Point Failure' Portions of Each system

Propulsion Control

Although most of the propulsion control system is redundant, i.e. port/starboard, the Propulsion Control P&ID shows that there are two (2) air compressors feeding one (1) receiver, one (1) dryer/lubricator and one threaded header. This means that these common, non-redundant portions of the pneumatic propulsion control system contain pressure and have threaded fittings.

Fuel Oil Transfer

The M/V 'Alpha' has redundant Fuel Oil Transfer pumps, but the piping between the discharge of the pumps and the Day Tank is flanged, without spray shields. A leak at one of these pressure-containing flanges could yield a mist spray of fuel oil and constitute a single point failure that could yield an explosion and/or fire.

Fuel Oil Service

The M/V 'Alpha' has a single Day Tank. Each engine is supplied fuel through dedicated piping including strainer/filter assemblies. However, leaks, inaccurate low level indication/alarms, or large quantities of dirt or water in the Day Tank could cripple the boat.

Step 4

Assign a Qualitative Probability of Failure Rating for Each System. In regards to the MV 'Alpha', Table 2 indicates: All Major systems have a Qualitative Probability of Failure Rating of '3' or below

Exceptions specifically pertaining to MV 'Alpha':

	Probability
Propulsion Control (Receiver, Filter/Dryer, Piping)	5
Fuel Oil transfer (Piping)	5
Fuel Oil Service (Day Tank)	5

Step 5

Calculate the Risk Rating by Multiplying the Consequence Rating by the Probability of Failure Rating

Risk Rating Chart

	Consequence Rating ×	Probability of Failure Rating =	Qualitative Risk
Steering	4	3	12
Propulsion	4	3	12
Propulsion Control	**4**	**5**	**20**
Fuel Oil Service	**4**	**5**	**20**
Fuel Oil Transfer	**3**	**5**	**15**
Compressed Air	2	3	6
Generator Fuel Oil	4	3	12
Generator Lube Oil	4	4	16
Generator cooling water	4	4	16
Firefighting	3	3	9
Dewatering/Bilge	3	3	9
Towing Machine	4	4	16
Deck Machinery (capstans, gypsy heads, winches)	2	2	4
Seawater Service	3	3	9
Ballast	3	3	9
Oily/water separation	4	4	16
Elevating Pilothouse	4	4	16
ITB Locking	4	4	16
Potable Water	1	1	1
Sanitary	1	1	1
Galley Equipment	3	3	9
HVAC	1	1	1
Auxiliary steam/Hot water	3	3	9

Step 6

Identify Critical Systems

Critical Systems aboard the M/V 'Alpha' are Propulsion Control, Fuel Oil Transfer, and Fuel Oil Service.

Step 7

Devise an Inspection/Maintenance Process and Frequency Focusing first on those three systems that carry a Qualitative Risk Rating ≥ 15:

Propulsion Control:

Task	Frequency
• Verify pressure rating, ASME VIII U-stamp, ASME stamp safety valve, inspection dates	Annual
• Recertify vessel and safety valve	Every 5 years or as specified
• Exercise safety valve, inspect for corrosion/deterioration	At crew change, every 1-3 weeks
• Blow down Dryer/Lubricator	Daily or as specified
• Check for leaks	Daily or as specified
• Replace filter element	As specified

Fuel Oil Transfer:

Install Spray Shield to reduce QPFR to 4.

Fuel Oil Service:

Task	Frequency
• Muck out and inspect Day Tank	At yard interval, Subchapter
• Verify low level indication/alarm	At crew change, every 1-3 weeks
• Blow down Day Tank/Recirc through	Weekly, or as specified

Conclusion

Reducing machinery and equipment failures aboard towing vessels is critical to reducing the number and scale of accidents resulting in fatalities, injuries, and property loss and damage associated with towing vessels. It is also economically important to vessel operating costs, availability and sustainability to meet customer demands, underwriter's requirements, and overall business profits-bottom line. The methodology set forth herein dovetails with, and supports the *Proposed USCG Subchapter M Regulations for Towing Vessels*, including for quality assurance, continuous quality improvement, and Safety Management Systems (SMS).

This paper describes a how-to methodology to implement Risk-based Maintenance and Inspection of towing vessel systems, machinery, and equipment. This methodology assures that resources brought to bear mitigate the greatest and most serious risks, in the most efficient and cost-effective manner. The methodology is rooted in real and sound engineering, and draws on well-established principles of the petrochemical industry.

ENDNOTES

1. http://www.marad.dot.gov/ships
2. API Recommended Practice 580, Second Edition page 16
3. Ibid., page 22
4-5. Ibid., page 1
6. Ibid., page 12
7. Ibid, page 13
8. Ibid., page 14
9-10. Ibid., page 26
11. Ibid., page 61
12. Ibid., page 62
13-15. Ibid., page 18
16. Ibid., page 34
17. Ibid., page 39
18. Ibid , page 47
19. Patel, Risk Based inspection, page 7.
20. TSAC Report Appendix C. Page 4
21 API Recommended Practice 580, Second Edition page 20
21. Figure 3: .US Coast Guard's files, vessel inspection data bases, and incident investigations.

REFERENCES

[1] American Petroleum Institute. (2009). Risk-Based Inspection: “API Recommended Practice 580”, Second Edition. Washington, D.C. API Publishing Services (Endnote 2-18, 20)

[2] United States Department of Transportation Maritime Administration. *U.S. Flag Waterborne Domestic Trade and Related Programs*. (Endnote 1)

[3] Subchapter M Proposed Regulations. Department of Homeland Security and USCG (2006). Proposed Rule Making: “Inspection of Towing Vessels.” Docket No. USCG-2006-24412.

[4]Patel, Ramesh (2005) Risk Based Inspection. *Middle East Nondestructive Testing Conference and Exhibition.* www.ndt.net (Endnote 19)

[5]Towing Safety Advisory Committee, “Report of the Working Group on Towing Vessel Inspection.”7, September, 2006.

[6] U.S. Coast Guard, Human Element and Ship Design Division:. *Marine Operations Risk Guide, A Guide to Improving Marine Operations by Addressing Risk.*(2004) *http://www.uscg.mil/hq/cg5/cg5211/docs/morg.pdf*