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Review of Reliability Centered Maintenance Documents
Right-of-Way Renewals Project
Valdez Marine Terminal

RCAC Contract No: 552.02.01

Prepared by PetroTech Alaska
For the
Prince William Sound Regional Citizens' Advisory Council

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Executive Summary

Overview

The 800 mile long Trans-Alaska Pipeline System (TAPS) and Valdez Marine Terminal (VMT) has been operated and maintained by the Alyeska Pipeline Service Company (Alyeska) since its startup in June 1977. Alyeska is a separate corporation owned by a consortium of North Slope crude oil producers and exists for the sole purpose of operating and maintaining the TAPS and the VMT under a short term contract to the consortium, a contract that could be terminated in as little as 30 days. The pipeline is owned by the consortium and was built to transport liquid hydrocarbons produced on the North Slope of Alaska. The VMT was built to receive and hold the hydrocarbons from the pipeline and transfer those hydrocarbons to tanker ships.

Prior to the construction and startup of the TAPS, a series of Right-of-Way (ROW) grants and leases were obtained from federal and State of Alaska government agencies. These permits have compliance provisions controlling the way the pipeline is to be operated and maintained to help ensure the continuous environmentally safe operation of all aspects of the TAPS. These ROW and lease permits expire on Jan 22, 2004 and May 2, 2004 for the federal grants and state leases, respectively. Prior to the renewal of these permits, public and governmental regulatory agencies have the responsibility to ascertain the level of risk associated with the renewal of these permits as the pipeline and VMT continue to age. An important part of this assessment is the determination of risk posed by the physical condition and operational integrity of all the various components of the TAPS including the VMT.

The Joint Pipeline Office (JPO) is comprised of seven state and six federal agencies that have similar regulatory or management responsibilities related to common carrier pipelines in Alaska, including the TAPS. The JPO is the lead government regulatory organization that monitors the operational aspects of the TAPS and the VMT to ensure compliance with the ROW and lease permits. This report focuses on the planned Reliability Centered Maintenance (RCM) program that Alyeska, after coordination with the JPO, has researched and plans to establish as the basis upon which they expect to extend the operational life of the TAPS and the VMT indefinitely. Alyeska also expects the RCM program to assure that the operation and maintenance program for the TAPS and the VMT will comply with the ROW and lease permit provisions, if these permits are renewed for the requested 30 year extension.

One of the key objectives of the Alyeska RCM program include the establishment of methodologies to ensure that the specific maintenance “quality assurance” compliance, the construction standards, and the use of state-of-art technologies aspects of compliance with the ROW and lease permits are fully attained to help ensure the continued environmentally safe operation of the VMT during the anticipated extended period of the ROW and lease permits.

Ideally, full compliance with the ROW and lease permits in the past should have resulted in little, if any, increased risk as the age of the pipeline and VMT increased. However, over the course of the first 30 years of operation, there have been many design changes and major maintenance activities throughout the TAPS, including the VMT. Many of these changes were undoubtedly made to incorporate improvements in design and materials, improvements that have increased functionality and operational safety of the VMT; however, during the last 30 years, there has also been a significant level of local, state, and national controversy over the adequacy of the operations and maintenance programs, maintenance funding, accuracy of records, employee morale issues, and other related personnel and organization structure issues.

All pertinent changes in design and materials, and the application of new technologies that had occurred in the normal maintenance processes were required to have been recorded or otherwise documented in order for Alyeska to stay in compliance with ROW and lease permits. These permits required Alyeska to utilize new and improved materials and best practice technologies as such materials and technologies became commercially available and as maintenance needs were identified. Where and when such material or design changes occur, the TAP ROW permits also required that Alyeska maintain proper and accessible documentation of the changes that were made.

Over the years, there have been allegations that some specific materials used in the repair and replacement process did not meet original material design specifications and that the use of such materials may have resulted in increased environmental and safety risks. The JPO, other regulatory and oversight organizations, and Alyeska have conducted numerous investigations to determine the validity of these allegations; and, where appropriate, taken the action to correct deficiencies in materials used and improve the Alyeska quality assurance programs and practices.

This report makes reference to past efforts of the RCAC to discover and review historical records to ascertain whether specific “substandard” or otherwise inappropriate materials or improper design modifications have been made to equipment and operational systems at the VMT and documents a review of Alyeska’s current RCM program for the VMT. The purpose of the review was to determine adequacy of the RCM program to achieve operational and environmental safety objectives and to satisfy the ROW and Lease Grant permits requirements.

Observations

The following observations are made by the Consultant and are based on the assumption that the RCM Analyses materials provided for review are representative examples of the RCM processes being performed for Alyeska/JPO and that their detailed review, by extension, would likely represent what would be found in the detailed review of the remaining RCM Analyses.

With regard to the general applicability of the RCM process on the operations of the Valdez Marine Terminal:

> It is the opinion of the Consultant that RCM is directly applicable for the operations of the VMT in achieving the JPO objectives to ensure the safe and reliable operation of the TAPS. The RCM initiative is well intentioned as conceived and documented in the Alyeska/JPO January 2001 Memorandum of Agreement (MOA) with the exception that the MOA does not include the useful life integrity and operational effectiveness performance criteria. RCM improves the potential for Alyeska to achieve a long-term objective reducing cumulative maintenance costs. RCM can minimize effort required to maintain the functionality of the physical assets. RCM is expected to be an essential process for maintaining an aging asset at a high level which is required to assure safe operation of the asset and environmentally safe operation; both of which is operationally and economically necessary for TAPS owners to sustain profit revenues in the future through the operation of the TAPS.

With regard to the adequacy of the specific application of the RCM principles as demonstrated in the RCM Analyses on the two systems selected for expert evaluation—VMT Back Pressure Control System and VMT Vapor Recovery System Swing Compressor 2B:

> It is the opinion of the Consultant that in the two RCM Analyses reviewed, the analyses of the specific applications do not adequately follow recommended practice in RCM methodology. Further, there is a major deficiency in the lack of performance standards and expectations in the areas of safety integrity, environmental integrity, useful life integrity and operational effectiveness. As a consequence, the RCM analyses efforts do not achieve the intended goals in the two RCM Analyses reviewed.
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> It is the opinion of the Consultant that the methodology and guidelines for performance of the analysis are sound as outlined in the "Introduction to Reliability-Centered Maintenance" sections of the two RCM Analyses that were reviewed; however, the actual analyses do not fully and adequately use these guidelines and methodologies.
>
> It is the opinion of the Consultant that the RCM Analyses method used in the two analyses that were reviewed does not faithfully follow the recommended practice from the standpoint of system functions. The recommended practice asks the question "What are the functions and associated desired standards of performance of the asset <u>in its present operating context (functions)?"</u> To answer the question, the key concepts for functions include Operating Context, Primary and Secondary Functions, Function Statements, and Performance Standards should be fully understood and incorporated in the analyses.

It is the opinion of the Consultant that the key to a successful RCM process is the establishment of the appropriate operating context. There is evidence that the RCM Analyses reviewed do not faithfully follow recommended practice. The operating context should state why the system is judged critical by Alyeska/JPO in the January 2001 Memorandum of Agreement. The operating context should address the safety, environmental useful life and operational consequences of system failure. The operating context should state the historical failure frequency of the system and the expected operating performance criteria required from the standpoints of safety integrity, environmental integrity, useful life requirements and economic effectiveness. (Appropriate questions include: "What are the safety related consequences associated with system failure?"; "What are the environmental consequences associated with system failure?"; "What are the useful life consequences associated with system failure?"; "What is the economic impact of system failure?"; and, "Based on the above, what is the acceptable frequency and duration of failing to keep the backpressure in the green zone as shown on the Thompson Pass Packline-Slackline Interface elevations graphic?").

It is the opinion of the Consultant that in the two RCM Analyses reviewed, the primary and secondary functions listed in the analyses do not faithfully follow recommended practice.

It is the opinion of the Consultant that the system boundaries of the two RCM Analyses reviewed do not follow the recommended practice. Defining the appropriate system boundary is the responsibility of the RCM facilitator and should include all the facilities that are required for the system to perform its intended function. That includes the facilities that provide protection for the system. System functionality is dependent on the supply of electrical power and the sending and receipt of process variable signals to the Operations Control Center (OCC). Therefore, because electrical power and command and control signals are integral requirements for systems' function, failure of these infrastructure systems affect functionality of the system and recommended practice calls for them to be included in the analysis.

It is the opinion of the Consultant that in the two RCM Analyses reviewed, the identification of failure modes does not faithfully follow recommended practice. Recommended practice asks "what causes each system functional failure?" The best practice way to answer this question is to review all the system equipment components and ask this question: "How can this equipment failure affect the functionality of the entire system?" Equipment failures that cause system function failures are defined as critical items. Equipment in the system that does not cause an effect of system function when it fails is 'non-critical'. There is an absence of evidence to indicate that a sub-system function criticality analysis was performed even though the Alyeska/JPO January 2001 Memorandum of Agreement specifically mentions sub-system criticality analysis as work elements of the RCM initiative.

It is the opinion of the Consultant that in the two RCM Analyses reviewed, many failure modes are not analyzed as prescribed in the recommended practice. As stated previously, failures in sub-systems & utility infrastructure often affect system functionality. Remote control systems, local control systems, pressure relief protection sub-system, Bailey system, and the metering system are mentioned as failure modes but not included in the analysis. These are all critical systems and the power sub-system is backed up with the Uninterruptible

Power Supply (UPS). For example, recommended practice calls for criticality analysis of these sub-systems followed by failure mode and task analysis of critical components that impact on the VMT backpressure system functionality.

It is the opinion of the Consultant that in the two RCM Analyses reviewed, the Pre-Analysis documentation does not follow recommended practice. RCM requires data gathering that includes accurate system configuration, up to date equipment data files including equipment inspection history, equipment failure history. It appears that a complete set of P&ID's have not been used and that special drawings were developed to show flow scenarios.

In the opinion of the Consultant, it is not good practice to perform the RCM analysis on a different basis than the equipment installed. For example, the RCM Analysis for the VMT Backpressure Control System assumed a major modification on the backpressure control value actuators had already been made. It would be more appropriate to document the poor performance as a means of demonstrating the need for the replacement and to analyze it if the projected modification would achieve the intended improvement in system functionality. If the modification is now complete, the analysis should be revisited immediately to reflect the installed design (an example of the living process of RCM). The description of the replacement actuators also indicates an electrical component. If so, those changes should be represented on the P&ID's that were used in this analysis.

It is the opinion of the Consultant that in the two RCM Analyses reviewed, failure mode details are incomplete. Complete failure mode details are an integral element of RCM because they document the need for change that results from the task selection. In addition, the failure modes details have little if any asset effectiveness and economic impacts related to them. Alyeska misses an opportunity to improve earnings when the operational and cost impacts are not included in the analysis.

It is the opinion of the Consultant that in the two RCM Analyses reviewed, task selection does not follow recommended practice. The root causes of inadequate task selection are the lack of specific requirements in the operating context and the lack of sub-system criticality analysis. It is not possible to set appropriate failure management policy for specific system components without spelling out the safety integrity, environmental integrity, useful life integrity and economic consequences of failure so that appropriate performance standards are set for the system. Each component of the system has a failure history; some of those failures affect system functionality. Criticality analysis focuses attention on critical components. RCM task selection emphasizes on-condition tasks that identify deterioration before failure occurs. System component failure data is essential in setting up failure management policy that will meet the system performance requirements. There is an absence of failure data in the analyses reviewed.

It is the opinion of the Consultant that in the two RCM Analyses reviewed, the failures recommending redesign do not follow recommended practice. The appropriate section of the analyses notes only reviews and evaluations. It does not spell out system functionality failure modes that can be mitigated with redesign of the system components. It is here that the design intent of modifications are spelled out showing the value of functional improvement in the areas of safety integrity, environmental integrity, useful life integrity &

operational effectiveness.

It is the opinion of the Consultant that in the two RCM Analyses reviewed, there is evidence that the failure modes requiring compulsory redesign do not follow recommended practice.

Presuming that the two sample RCM Analyses fairly represent the manner in which all systems will likely have get their RCM Analysis performed, the following are anticipated problems that may be encountered during the RCM implementation.

It is the opinion of the Consultant that in the two RCM Analyses reviewed, the accomplishment by Alyeska of the task items, as currently recommended in the draft analyses, could be problematical until the shortcomings in the analyses, as named above, have been corrected.

It is the opinion of the Consultant that in the two RCM Analyses reviewed, the JPO/Alyeska may possibly come under criticism by moving forward with the RCM effort as presently driven because it does not follow faithfully RCM standards. In the opinion of Consultant, environmental activist organizations intent on blocking ROW and Lease Grant permit renewals could, upon hiring a RCM expert, ask to review critical aspects of the RCM Analysis program and upon inspection, make valid claims of inadequate preparation for a maintenance program that would assure long term TAPS and specifically, VMT integrity.

It is the opinion of the Consultant that with two different RCM programs being initiated, one a “streamlined RCM” program for the pipeline and pump stations, and another, highly structured and detailed RCM II program for the VMT, that potential exists for the more detailed program to be degraded over time because it requires more time and effort to execute properly. Internal management forces may wrongly presuppose that such a streamlining effort would be more economical when it is more likely to result in higher maintenance costs and greater risk of operational failures and adverse environmental impacts.

Other Observations:

With regard to the list of critical systems that were to receive an RCM analysis, it was noted that the Control System - Operations Control Center (OCC) - is listed but the RCM analyses schedule remains unknown. It is the opinion of the Consultant that serious hidden failure modes could exist that are associated with both the hardware and the software that controls the flow of oil into, within, and from the VMT. Federal critical infrastructure security studies have identified computer control systems such as the SCADA systems that are used in pipelines, power generation systems, navigation systems, etc. as likely targets of opportunity for international terrorist organizations using readily available cyberterrorist tools. Systems isolated from the Internet can be open to risk through unauthorized software installations, actions of disgruntled employees, interdiction of radio and other control signals, and unauthorized inputs during contract specialist work on the control systems. Addition insights on potential risks can be supplied upon request.

It is the observation and understanding of the Consultant that some form of negotiated procedure was used in selecting the VMT subsystems for RCM analyses. Absent specific information in how thorough and complete the selection process was, the Consultant can offer no independent assessment as to whether all critical systems of the VMT have been or will be considered for RCM analyses.

Recommendations

The Consultant recommends that the appropriate JPO/Alyeska RCM managers re-examine the RCM initiative assisted by through services of an "outside" RCM expert, such that the following objectives could be achieved: 1) key JPO/Alyeska managers fully understand the SAE JA 1012 recommended practices and how safety and environmental risks must be weighed and standards established for failure tolerance; and, 2) understand the useful life integrity requirements that are a part of the RCM methodology.

The Consultant recommends that JPO/Alyeska RCM managers re-work the operating context for the functional systems incorporating the requirements for safety, environment, useful life and operating effectiveness.

The Consultant recommends that JPO/Alyeska senior managers take whatever action is necessary to guarantee that the appropriate JPO/Alyeska maintenance managers use RCM facilitators that will follow JPO and Alyeska management's lead as set forth above.

The Consultant recommends that JPO/Alyeska ensure each RCM team has a member that has the tacit knowledge of failure history and are well respected as knowledgeable of the system being analyzed.

The Consultant recommends that JPO/Alyeska ensure the RCM teams are trained to follow the SAE JA 1012 recommended practices and standards guidelines.

The Consultant recommends that JPO/Alyeska closely audit the ongoing initial RCM analyses team efforts to insure that relevant information is shared upward to VMT managers.

The Consultant recommends JPO/Alyeska have in place a task implementation procedure that ensures that selected tasks are implemented within 2 weeks of the RCM analysis.

The Consultant recommends JPO/Alyeska initiate an RCM Analysis on the VMT control system (OCC).

The Consultant recommends that appropriate JPO/Alyeska managers institute regular audit programs with procedures that ensure the RCM II program in effect for the VMT does not deviate with time from the SAE JA 1011 and SAE JA 1012 processes and standards, respectively; thereby helping to ensure that it does not take on the characteristics of a "streamlined RCM" program in effect for the maintenance of the pipeline and pump stations segments of the TAPS.

Review of Review of Reliability Centered Maintenance Document
Right-of Way Renewals Project
Valdez Marine Terminal

RCAC Contract No. 552.02.01
July 2002

1.0 Purpose:

The purpose of this report by the Consultant is to assist and supplement the efforts of the RCAC staff in their attempts to ascertain whether or not the current operations and maintenance practices for the facilities at the Valdez Marine Terminal (VMT) are in compliance with the Right-of-Way (ROW) permit and lease permit stipulations and requirements; and, whether the recently initiated Alyeska Pipeline Service Company (Alyeska) plans to establish a Reliability Centered Maintenance (RCM) program demonstrates a likely future ability on the part of Alyeska to operate and maintain the facilities at the VMT in an environmentally safe manner during the next 30 years span of time expected for the ROW and lease permit renewals.

This report supplements the report by the Consultant performed in 2001 which involved a review of Alyeska documents to ascertain whether sub-standard or inappropriate materials had been used in the repair of, or as part of the modifications to, the facilities at the VMT; and, if so, whether such materials are still in use, thus posing a heretofore undetermined but potential risk to the environmentally safe operation of the VMT. (See RCAC report entitled *Review of Historical Documents, Right-of-Way Renewals Project, Valdez Marine Terminal*, RCAC Contract No: 625.01.01, July, 2001).

This new report documents the general review by the Consultant, PetroTech Alaska, of various RCM Analysis documents and related files maintained at the Anchorage, AK offices of the Joint Pipeline Office (JPO), the combined federal/state organization which has regulatory jurisdiction over the operation of the Trans-Alaska Pipeline System (TAPS), including the VMT; and, the detailed specific review of two representative RCM Analyses for VMT facilities systems and equipment.

At the direction of RCAC, the review was broken into two work phases to be performed by the Consultant and the RCAC project manager.

The first phase of work included the joint Consultant/RCAC review of documents related to the RCM program being implemented by Alyeska under the supervision of an RCM specialty consulting contractor working under contract to the JPO but funded by Alyeska.

This review was accomplished by Gary J. Green, Principal Consultant of PetroTech Alaska and Dr. Thomas Kuckertz, RCAC project manager. Mr. Green has significant prior energy industry experience in Alaska and specific prior consulting experience with RCAC having been directly involved with the review of the effectiveness and efficiency of the VMT's maintenance planning, execution, and documentation programs to help assure environmentally safe operations at the VMT.

The scope of work for the first phase was to determine the general nature of the RCM related files and documents that had been generated in support of the RCM program and to select a limited number of completed RCM analyses for facilities at the VMT that were considered representative of the quality and thoroughness of the whole RCM program as it is being applied to the VMT facilities. Two specific RCM analyses were judged to be representative of the RCM process and were selected for detailed review.

The second phase of work, a detailed review of the two selected RCM analyses for facilities at the VMT began with the forwarding of these two selected RCM analyses to R. Keith Engel, an RCM expert under contract to PetroTech Alaska. Mr. Engel, as a member of the American Society for Quality (ASQ), is a Certified Reliability Engineer, Certified Quality Auditor, Certified Quality Engineer, and Certified Quality Manager. Mr. Engel was chosen because he had specific experience as an RCM analysis facilitator on a crude oil handling facility which had several critical systems and equipment analogous to those used at the VMT.

2.0 Background :

The 800 mile long TAPS and VMT has been operated and maintained by the Alyeska since its startup in June 1977. Alyeska is a separate corporation owned by a consortium of North Slope crude oil producers and exists for the sole purpose of operating and maintaining the TAPS and the VMT under a short term contract to the consortium, a contract that could be terminated in as little as 30 days. The pipeline is owned by the consortium and was built to transport liquid hydrocarbons produced on the North Slope of Alaska. The VMT was built to receive and hold the hydrocarbons from the pipeline and transfer those hydrocarbons to tanker ships.

Prior to the construction and startup of the TAPS, a series of ROW grants and leases were obtained from federal and State of Alaska government agencies. These permits have compliance provisions controlling the way the pipeline is to be operated and maintained to help ensure the continuous environmentally safe operation of all aspects of the TAPS. These ROW and lease permits expire on Jan 22, 2004 and May 2, 2004 for the federal grants and state leases, respectively. Prior to the renewal of these permits, public and governmental regulatory agencies have the responsibility to ascertain the level of risk associated with the renewal of these permits as the pipeline and VMT continue to age. An important part of this assessment is the determination of risk posed by the physical condition and operational integrity of all the various components of the TAPS including the VMT.

The Joint Pipeline Office (JPO) is comprised of seven state and six federal agencies that have similar regulatory or management responsibilities related to common carrier pipelines in Alaska, including the TAPS. The JPO is the lead government regulatory organization that monitors the operational aspects of the TAPS and the VMT to ensure compliance with the ROW and lease permits.

Organizations that are represented in the JPO organization include the following state agencies - Department of Natural Resources (DNR), Department of Environmental Conservation (DEC), Department of Fish and Game (DFG), Department of Labor (DOL), Division of Governmental Coordination (DGC), Alaska State Fire Marshal's Office (ASFM), Department of Transportation/Public Facilities (DOT); and the following federal agencies - Bureau of Land Management (BLM), Department of Transportation/Office of Pipeline Safety (DOT/OPS), Environmental Protection Agency (EPA), U.S. Coast Guard (USCG), U.S. Army Corps of Engineers (COE), Minerals Management Service (MMS).

Similarly, in accordance with its oversight responsibilities prescribed by OPA-90, the RCAC encourages members of Prince William Sound (PWS) communities to voluntarily bring forth their concerns about the operational practices and procedures at the VMT which might result in an increased risk to the environmentally safe operation of the VMT, or increased environmental risk to Valdez harbor and PWS. The RCAC also has a corresponding obligation to both the PWS communities and to Alyeska to investigate and determine whether concerns so raised have validity and, if so, are in need of remedies.

To fulfill these obligations, the RCAC performs specific studies and reviews designed to independently determine whether current or planned operational practices and procedures at the VMT are consistent with the intent of permits already granted or planned for re-issuance. Ideally, full compliance with the ROW and lease permits in the past should have resulted in little, if any, increased risk as the age of the pipeline and VMT increased. However, over the course of the first 30 years of operation, there have been many design changes and major maintenance activities throughout the TAPS, including the VMT. Many of these changes were made to incorporate improvements in design and materials, improvements that have increased functionality and operational safety of the VMT; however, during the last 30 years, there has also been a significant level of local, state, and national controversy over the adequacy of the operations and maintenance programs, maintenance funding, accurate record keeping, employee morale, and other related personnel and organization structure issues.

All pertinent changes in design and materials, and the application of new technologies that occurred in the normal maintenance processes were required to have been recorded, or otherwise documented, to stay in compliance with ROW and lease permits. These permits required Alyeska to utilize new and improved materials and best practice technologies as such materials and technologies became commercially available and as maintenance needs were identified. Where and when such material or design changes occur, the TAP ROW permits also required that Alyeska maintain proper and accessible documentation of the changes that were made.

Over the years, there have been allegations that some specific materials used in the repair and replacement process did not meet original material design specifications and that the use of such materials may have resulted in increased environmental and safety risks. The JPO, other regulatory and oversight organizations, and Alyeska have conducted numerous investigations to determine the validity of these allegations; and, where appropriate, taken the action to correct deficiencies in materials used and improve the Alyeska quality assurance programs and practices. It should also be noted that some of the allegations of the use of “substandard” material use have been given significant publicity in the past in the printed and broadcast news media and that since the Exxon Valdez oil spill incident, all news regarding the operations of TAPS, and the VMT in particular, continue to get the broad local and national new coverage.

Regardless of the historical efforts, anonymous allegations have continued to surface and have resulted in efforts by the JPO, Alyeska, and the RCAC to determine the validity of the allegations.

At the present time, Alyeska is in the process of getting its federal grant and state lease of Right-of-Way (ROW) and lease agreement permits renewed so that they will continue to be able to operate the TAPS and the VMT.

To put this report and the impetus for JPO and Alyeska to want to move to an RCM for the pipeline and VMT operations, it is important to put certain ROW issues in the proper context. one of the key aspects of the current Federal Agreement and Grant of Right-of-Way are the requirements on Alyeska that:

> "The quality assurance program shall be comprehensive and designed to assure the environmental and technical Stipulations of this Agreement will be fully complied with throughout all phases of construction, operation, maintenance and termination of the Pipeline System".
>
> "The following criteria shall be included in the quality assurance program, although Permittees are not limited to these criteria:
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> 1) Provide adequate and appropriate means and procedures for the detection and prompt abatement of any actual or potential condition that is susceptible to abatement by Permittees which arise out of, or could affect adversely, the construction, operation, maintenance or termination of all or any part of the Pipeline System and which at any time may cause or threaten to cause: (a) a hazard to the safety of workers or to public health or safety (including but not limited to personal injury or loss of life with respect to any person or persons) or (b) serious and irreparable harm or damage to the environment (including but not limited to areas of vegetation or timber, fish or other wildlife populations, or their habitats, or any other natural resource).
>
> 2) Provide adequate and appropriate means and procedures for the repair and replacement of improved or tangible property and the rehabilitation of natural resources (including but not limited to revegetation, restocking fish or other wildlife and reestablishing their habitats) that shall be seriously damaged or destroyed if the immediate cause of the damage or destruction arises in connection with, or results from, the construction, operation, maintenance or termination of all or any part of the Pipeline System.
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> 3) Provide for component and systems quality through adequate control management and planning, and inspection and test procedures.
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> 4) Assure that the selection of Permittees' contractors, subcontractors and contract purchases of materials and services are based upon the above quality procedures.
>
> 5) Determine quality performance by conducting surveys and field inspections of all of the facilities of Permittees' contractors and subcontractors.

6) Maintain quality determination records on all of the above procedures to insure satisfactory data identification and retrieval."

To help assure that the JPO could properly oversee the operations and maintenance of Alyeska, it wanted Alyeska to adopt a methodology that was structured, and maintenance-based in such a way as to permit JPO to have a means of continuous evaluation of the maintenance strategies with an objective of extending the useful life capacity of the TAPS. In cooperation with the JPO, Alyeska has embarked upon such a comprehensive maintenance program commonly known as Reliability Centered Maintenance (RCM) and the services of a major RCM consultant, New Dimension Solutions (formerly known as Spearhead Systems Consultants, an affiliate of Aladon) to perform RCM analyses on selected operating systems at the VMT. A less detailed, simplified form of RCM known in the maintenance management sector as Streamlined RCM (SRCM) or modified classical RCM was chosen and instituted for the pipeline operations upstream from the VMT. These programs, when properly implemented, are purported to be capable of assuring operationally safe and environmentally safe operations of facilities like the pipeline and the VMT indefinitely into the future; and thereby enabling Alyeska to be in full compliance with the referenced federal and state ROW permits.

Adopting RCM is a paradigm switch for Alyeska. As with any paradigm switch, its full understanding and proper implementation are important to both Alyeska and the JPO if RCM is to be relied upon to assure future ROW and Lease permit compliance. Therefore, in its prescribed oversight role for the VMT operations, the RCAC staff developed a plan to determine the nature of the RCM program that has been designed for, and implemented by, Alyeska in support of the VMT operations.

To put this RCM review plan in the proper perspective, it is appropriate to summarize the concepts and principles of RCM, and to relate the appropriate aspects of the development and historical use of RCM in organizations and operations which require a high degree of confidence that failure of a system or critical components within a system will not occur. It is also important to determine its specific suitability for use by Alyeska to assure future safe operations of the pipeline and the VMT, in particular.

To assure applicability of this review to the RCM program currently anticipated for the VMT, key aspects of the concepts and principles of RCM discussed in both summarized and detailed formats in this report.

Conceptually, there are multiple vendors that specialize in training and establishing RCM programs for nearly every major business sector. Alyeska and JPO agreed to use the RCM II ™, a comprehensive RCM analysis technique developed by John Moubray.

Since the Consultant's critique will be based, in part, upon how well the current Alyeska RCM program follows the concepts and principles of RCM, as set forth in the RCM contractors own materials; this report, especially in the Background section, will borrow heavily on the text and terminology used in the printed materials currently being used by Alyeska and the JPO's RCM contractor – New Dimension Solutions (formerly Spearhead System Consultants, and affiliate of Aladon Ltd.).

It is understood that JPO does not endorse any particular RCM program, but JPO does affirm that the RCM program that they want Alyeska to use should follow the concepts and principles as published in Society of Automotive Engineers (SAE) JA 1011 (August, 1999) entitled "Surface Vehicle/Aerospace Standard, Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes"; and SAE JA 1012 (January, 2002) entitled "Surface Vehicle/Aerospace Recommended Practice, A Guide to the Reliability-Centered Maintenance (RCM) Standard", both of which are recognized as the most definitive American standard for and guide to RCM. John Moubray's RCM II process and procedures are acknowledged by SAE to be among the three "most widely accepted and widely-used RCM documents available."

To better understand the nature of the observations and recommendations being made as a result of the RCM process reviews conducted by the Consultant, it is necessary to provide a basis upon which the report can be better understood. This is accomplished by providing summarized information on the RCM process, and using the same definitions and concepts that are believed to have been used in setting up the Alyeska RCM program.

<u>Reliability Centered Maintenance – Definition, Concept, History, Evolution, and Application</u>
A review of recent JPO documents prepared as part of the JPO's Comprehensive Monitoring Program defined a generic RCM program as "a highly prescriptive process used to identify the maintenance needs of a physical asset to ensure operational safety, environmental responsibility, and functional reliability. The RCM analysis involves the asset operators, maintainers, and responsible engineering resources in a comprehensive and interactive manner." The definition provided on the Aladon Company website is as follows:

> "Reliability-centered Maintenance: a process used to determine what must be done to ensure that any physical asset continues to do what its users want it to do in its present operating context." (http://www.aladon.co.uk/10intro.html)

RCM has its origins in the aircraft industry but is now recognized as a best practice preventive maintenance methodology in nearly every major, capital intensive industry, especially those that also involve significant human safety and environmental considerations. The following brief history of RCM is taken from the Aladon Company website.

> "The initial development work was done by the North American civil aviation industry. It came into being when the airlines at that time began to realize that many of their maintenance philosophies were not only too expensive but also actively dangerous. This realization prompted the industry to put together a series of "Maintenance Steering Groups" to re-examine everything they were doing to keep their aircraft airborne. These groups consisted of representatives of the aircraft manufacturers, the airlines and the FAA.
>
> The first attempt at a rational, zero-based process for formulating maintenance strategies was promulgated by the Air Transport Association in Washington DC in 1968. The first attempt is now known as MSG 1 (from the first letters of Maintenance Steering Group). A refinement - now known as MSG 2 - was promulgated in 1970.
>
> In the mid-1970's the US Department of Defense wanted to know more about the then state of the art in aviation maintenance thinking. They commissioned a report on the subject from the aviation industry. This report was written by Stanley Nowlan and Howard Heap of United Airlines. They gave it the title "Reliability Centered Maintenance". The report was published in 1978, and it is still one of the most important documents - if not the most important - in the history of physical asset management. It is

> available from the US Government National Technical Information Service, Springfield, Virginia.
>
> Nowlan and Heap's report represented a considerable advance on MSG 2 thinking. It was used as a basis for MSG 3, which was promulgated in 1980. MSG 3 has since been revised twice. Revision 1 was issued in 1988 and revision 2 in 1993. It is used to this day to develop prior-to-service maintenance programs for new aircraft types (recently including the Boeing 777 and Airbus 330/340).
>
> Nowlan and Heap's report and MSG 3 have since been used as a basis for various military RCM standards, and for non-aviation derivatives. Of these, by far the most widely used is RCM 2." (http://www.aladon.co.uk/10intro.html)

RCM systematically considers system functions, identifies and considers the way functions can fail, and gives a priority-based consideration of safety and economics that identifies the most applicable and effective preventive maintenance (PM) tasks to maintain the functions and purpose of the system.

The RCM process seeks to accomplish its objectives by systematically asking and obtaining precise and detailed answers to the following seven questions:

1. What are the functions and associated performance standards of the asset in its present operating context?
2. In what ways does it fail to fulfill its functions?
3. What causes each functional failure?
4. What happens when each failure occurs?
5. In what way does each failure matter?
6. What can be done to predict or prevent each failure?
7. What if a suitable proactive task cannot be found? (http://www.aladon.co.uk/10intro.html)

Applying the RCM process to determine what must be done to keep the asset functioning as expected, the asset manager needs to ascertain what the users, those who actually operate the asset, want that asset to do and to confirm that it is properly designed or sized to do it.

Therefore, the first step in the RCM process is "to define the functions of each asset in its operating context, together with the associated desired standards of performance. What users expect assets to be able to do can be split into two categories:

1. primary functions, which summarize why the asset was acquired in the first place. This category of functions covers issues such as speed, output, carrying or storage capacity, product quality, and customer service.
2. secondary functions, which recognize that every asset is expected to do more than simply fulfill its primary functions. Users also have expectations in areas such as safety, control, containment, comfort, structural integrity, economy, protection, efficiency of operation, environmental compliance and even the appearance of the asset." (http://www.aladon.co.uk/10intro.html

The primary objective of maintenance is to keep an asset functioning according to its design and purpose. It becomes essential to be able understand what events can cause the asset to fail to perform as expected. This implies that the way to obtain the best performance of an asset is to use this understanding of failure causes and to manage the asset in a manner which keeps it from unpredictable functional failures and minimizes the cost to keep the asset performing according to expectations.

"The RCM process does this at two levels:

1. by identifying what circumstances amount to a failed state; and,
2. by asking what events can cause the asset to get into a failed state. "

(http://www.aladon.co.uk/10intro.html)

The RCM analysis process then attempts to identify all known and probable events that could reasonably cause the functional failure of an asset. The RCM process calls these events "failure modes". The process of identifying these events requires both historical knowledge of past failures of the same or similar equipment being used in the same context; and, engineering knowledge or training on the design limitations and material properties of the components of the asset.

Human factors (acts or omissions by operators or personnel responsible for maintaining the asset) should also be considered. These factors are a major reason why engineers and operators or "maintainers," who are closest to the actual operation of the asset, should be involved in the RCM analysis process from the beginning.

After the RCM process has identified the functions of an asset, its potential functional failures, and the ways it might fail (failure mode), it is imperative that the effect(s) of each potential failure mode be identified. Again, an engineer with a "big picture" view of the asset and its intra-asset role and functions, along with the operator who has intimate knowledge of the actual way that the asset functions need to be involved in identifying the potential effects of asset failure. Four questions that need to be asked to determine "what" happens when a failure occurs are:

1. What evidence (if any) that the failure has occurred in what ways (if any) it poses a threat to safety or the environment;
2. What ways (if any) does the failure affect production or operations;
3. What physical damage (if any) is caused by the failure; and,
4. What must be done to repair the failure.

(http://www.aladon.co.uk/10intro.html)

The "what happens" as the result of a failure then needs to be analyzed to determine whether or not there are serious "consequences". Failure "effects" can range from insignificant to critical to operations. According to Aladon, one of the great strengths "of RCM is that it recognizes that the consequences of failures are far more important than their technical characteristics. In fact, it recognizes that the only reason for doing any kind of proactive maintenance is not to avoid failures per se, but to avoid or at least to reduce the consequences of failure. The RCM process classifies these consequences into four groups, as follows:

1. *Hidden failure consequences*: Hidden failures have no direct impact, but they expose the organization to multiple failures with serious, often catastrophic, consequences.
2. *Safety and environmental consequences*: A failure has safety consequences if it could injure or kill someone. It has environmental consequences if it could breach a corporate, regional, national or international environmental standard.
3. *Operational consequences*: A failure has operational consequences if it affects production (output, product quality, customer service or operating costs in addition to the direct cost of repair)
4. *Non-operational consequences*: Evident failures that fall into this category affect neither safety nor production, so they involve only the direct cost of repair." (http://www.aladon.co.uk/10intro.html)

"RCM uses these categories as the basis of a strategic framework for maintenance decision-making. By forcing a structured review of the consequences of each failure in terms of the above categories, it integrates the operational, environmental and safety objectives of the maintenance function. This helps to bring safety and the environment into the mainstream of maintenance management.

The consequence evaluation process also shifts emphasis away from the idea that all failures are bad and must be prevented. In so doing, it focuses on the maintenance activities that have most effect on the performance of the organization, and diverts energy away from those that have little or no effect. It also encourages us to think more broadly about different ways of managing failure, rather than to concentrate only on failure prevention. Failure management techniques are divided into two categories:

1. *proactive tasks*: tasks undertaken before failure occurs, in order to prevent the item from getting into a failed state. They embrace what is traditionally known as 'predictive' and 'preventive' maintenance, although we see later that RCM uses the terms scheduled restoration, scheduled discard and on-condition maintenance

2. *default actions*: these deal with the failed state, and are chosen when it is not possible to identify an effective proactive task. Default actions include failure-finding, redesign and run-to-failure." (http://www.aladon.co.uk/10intro.html)

With regard to proactive tasks, "many people still believe that the best way to optimize plant availability is to do some kind of proactive maintenance on a routine basis. Second Generation wisdom suggested that this should consist of overhauls or component replacements at fixed intervals." (http://www.aladon.co.uk/10intro.html) Old maintenance paradigms held that extensive records about failure should provide the information necessary to take preventive action shortly before the item is due to fail at some point in the future. For certain types of simple items, and for some complex items with dominant age-related failure modes, the old paradigm may still apply. Wear-out characteristics are often found where equipment comes into direct contact with the product, where there is flexure induced fatigue, where there is operation in corrosive environments, and when a component of the asset is subject to evaporation. (simple example of abrasion – the leading edge of a shovel).

"However, equipment in general is far more complex than it was thirty years ago. This has led to startling changes in patterns of failure". (http://www.aladon.co.uk/10intro.html)

"Unless there is a dominant age-related failure mode, age limits do little or nothing to improve the reliability of complex items. In fact, scheduled overhauls often increase overall failure rates by introducing infant mortality into otherwise stable systems.

An awareness of these facts has led some organizations to abandon the idea of proactive maintenance altogether. In fact, this can be the right thing to do for failures with minor consequences. But when the failure consequences are significant, something must be done to prevent or predict the failures, or at least to reduce the consequences.

This brings us back to the question of proactive tasks. As mentioned earlier, RCM divides proactive tasks into three categories, as follows: *scheduled restoration tasks; scheduled discard tasks; scheduled on-condition tasks*.

Scheduled restoration entails remanufacturing a component or overhauling an assembly at or before a specified age limit, regardless of its condition at the time. Similarly, *scheduled discard* entails discarding an item at or before a specified life limit, regardless of its condition at the time. Collectively, these two types of tasks are now generally known as preventive maintenance. They used to be by far the most widely used form of proactive maintenance. However for the reasons discussed above, they are much less widely used than they were twenty years ago.

For on-condition tasks, the continuing need to prevent certain types of failure, and the growing inability of classical maintenance techniques to do so, are the reasons behind the growth of new types of failure management. The majority of these techniques rely on the fact that most failures give some warning of the fact that they are about to occur. These warnings are known as potential failures, and are defined as identifiable physical conditions which indicate that a functional failure is about to occur or is in the process of occurring.

The new techniques are used to detect potential failures so that action can be taken to reduce or eliminate the consequences which could occur if they were to degenerate into functional failures. They are called *on-condition tasks*, and include all forms of condition-based maintenance, predictive maintenance and condition monitoring.)

Used appropriately, on-condition tasks are a very good way of managing failures, but they can also be an expensive waste of time. RCM enables decisions in this area to be made with particular confidence." (http://www.aladon.co.uk/10intro.html)

In order to be meaningful and effective as a maintenance management process, RCM must result in actions that achieve the objectives of the enterprise. There are three "action" categories recognized as necessary in the RCM process 1) "failure finding" that leads to establishing "powerful, risk-focused rules for establishing whether, how often and by whom" maintenance tasks will be performed; 2) "redesign" that makes a changes to the capability of a system through modification to equipment and/or procedures. "The RCM process considers the maintenance requirements of each asset before asking whether it is necessary to change the design". 3) "no scheduled maintenance" which is essentially a conscious, process driven 'no action required' decision. The decision results when it determined that it is best to simply allow a failure to occur and then repair it – also known as " run-to-failure". Obviously, an RCM run-to-failure maintenance decision would not be reached for any critical system upon which the capacity of the enterprise would be reduced. (example: a non-critical headlight in a field maintenance vehicle would be a "run to failure" maintenance item.)

By focusing on the most important functions of the systems, and avoiding or removing maintenance actions that are not justified, a properly implemented RCM program can increase the total reliability of the operation while reducing total maintenance costs, both of which are understandably important considerations in any profit and loss enterprise, especially those that could realize substantial costs as the result of an unscheduled disruption of the business processes.

"A great strength of RCM is the way it provides precise and easily understood criteria for deciding which (if any) of the proactive tasks is technically feasible in any context, and if so for deciding how often and by whom they should be done.

Whether or not a proactive task is technically feasible is governed by the technical characteristics of the task and of the failure that it is meant to prevent. Whether it is worth doing is governed by how well it deals with the consequences of the failure. If a proactive task cannot be found that is both technically feasible and worth doing, then suitable default action must be taken. The essence of the task selection process is as follows:

- for hidden failures, a proactive task is worth doing if it reduces the risk of the multiple failure associated with that function to a tolerably low level. If such a task cannot be found then a scheduled failure-finding task must be prescribed. If a suitable failure-finding task cannot be found, then the secondary default decision is that the item may have to be redesigned (depending on the consequences of the multiple failure).

- for failures with safety or environmental consequences, a proactive task is only worth doing if it reduces the risk of that failure on its own to a very low level indeed, if it does not eliminate it altogether. If a task cannot be found that reduces the risk of the failure to a tolerable level, the item must be redesigned or the process must be changed.

- if the failure has operational consequences, a proactive task is only worth doing if the total cost of doing it over a period of time is less than the cost of the operational consequences and the cost of repair over the same period. In other words, the task must be justified on economic grounds. If it is not justified, the initial default decision is no scheduled maintenance. (If this occurs and the operational consequences are still unacceptable then the secondary default decision is again redesign).

- if a failure has non-operational consequences a proactive task is only worth doing if the cost of the task over a period of time is less than the cost of repair over the same period. So these tasks must also be justified on economic grounds. If it is not justified, the initial default decision is again no scheduled maintenance, and if the repair costs are too high, the secondary default decision is once again redesign.

This approach means that proactive tasks are only specified for failures that really need them, which in turn leads to substantial reductions in routine workloads. Fewer tasks also means that the remaining tasks are more likely to be done properly. This together with the elimination of counterproductive tasks leads to more effective maintenance.

Compare this with the traditional approach to the development of maintenance policies. Traditionally, the maintenance requirements of each asset are assessed in terms of its real or assumed technical characteristics, without considering the consequences of failure. The resulting schedules are used for all similar assets, again without considering that different consequences apply in different operating contexts. This results in large numbers of schedules that are wasted, not because they are 'wrong' in the technical sense, but because they achieve nothing." (http://www.aladon.co.uk/10intro.html)

There is ample anecdotal evidence from the aircraft manufacturing, airline, National Aeronautics and Space Administration (NASA), U. S. Navy, and the nuclear power industries which can lead to significant improvements in maintenance management effectiveness. It stands to reason, however, that such anecdotal evidence originates in properly implemented RCM programs.

As with any new program that involves change, one of the most important initial steps is "thorough planning".

"RCM should be applied first to systems where it is likely to yield the highest returns relative to the effort required in any or all of the above areas. If these systems are not self-evident, it may be necessary to prioritize RCM projects (analyses) on a more formal basis. When this has been done, it is then essential to plan each project in detail."

"The key elements of the planning process are as follows:

- Define the scope and boundaries of each project
- Define and wherever possible quantify the objectives of each project (now state and desired end state)
- Estimate the amount of time (number of meetings) needed to review the equipment in each area
- Identify project manager and facilitator(s)
- Identify participants (by title and by name)
- Plan training for participants and facilitators
- Plan date, time and location of each meeting
- Plan management audits of RCM recommendations
- Plan to implement the recommendations (maintenance tasks, design changes, changes to operating procedures) "(http://www.aladon.co.uk/10intro.html)

As discussed above, a core aspect of the RCM process is determining the answers to seven basic questions. But who is best suited to determine the "right" answers?

"In practice, maintenance people simply cannot answer all these questions on their own. This is because many (if not most) of the answers can only be supplied by production or operations people. This applies especially to questions concerning functions, desired performance, failure effects and failure consequences.

For this reason, a review of the maintenance requirements of any asset should be done by small teams". (http://www.aladon.co.uk/10intro.html) To be sure that the answers are all in the proper context, those who know the most about the purpose, design, capacity, function, and maintenance history of the equipment or system for which the RCM analysis is being performed should be on that small team.

"Each group member should also have been trained in RCM". "(http://www.aladon.co.uk/10intro.html) (this means the specific RCM version being implemented)

"The use of these groups enables management to gain access to the knowledge and expertise of each member of the group on a systematic basis, while the members themselves learn a great deal about how the asset works." (http://www.aladon.co.uk/10intro.html)

In order to be effective and stay on point during RCM analyses, it is imperative that the team be guided and facilitated by a highly trained specialist in RCM.

"The facilitators are the most important people in the RCM review process. Their role is to ensure that:

- the RCM analysis is carried out at the right level, that system boundaries are clearly defined, that no

important items are overlooked and that the results of the analysis are properly recorded
- (the) RCM (process and principles) are correctly understood and applied by the group
- the group reaches consensus in a brisk and orderly fashion, while retaining their enthusiasm and commitment
- the analysis progresses as planned and finishes on time.

Facilitators also work with RCM project managers or sponsors to ensure that each analysis is properly planned and receives appropriate managerial and logistic support.

If it is applied in the manner suggested above, an RCM analysis results in three tangible outcomes, as follows:

- schedules to be done by the maintenance department
- revised operating procedures for the operators of the asset
- a list of areas where one-time changes must be made to the design of the asset or the way in which it is operated to deal with situations where the asset cannot deliver the desired performance in its current configuration.

A less tangible but very valuable outcome is that participants in the process tend to start functioning much better as multidisciplinary teams.

After the review has been completed for each asset, senior managers with overall responsibility for the equipment must satisfy themselves that the review is sensible and defensible. This entails deciding whether they agree with the definition of functions and performance standards, the identification of failure modes and the description of failure effects, the assessment of failure consequences and the selection of tasks.

Once the RCM review has been audited and approved, the final step is to implement the tasks, procedures and one-time changes. The revised tasks and procedures must be documented in a way that ensures that they will be easily understood and performed safely by the people who do the work.

The maintenance tasks are then fed into suitable maintenance planning and control systems, while revised operating procedures are usually incorporated into standard operating procedure manuals. Proposals for modifications are dealt with by the engineering or project management function in most organizations.

Desirable as they are, the outcomes listed above should only be seen as a means to an end. Specifically, they should enable the maintenance function to fulfill all the expectations listed above. How they do so is summarized in the following paragraphs:

- Greater safety and environmental integrity: RCM considers the safety and environmental implications of every failure mode before considering its effect on operations. This means that steps are taken to minimize all identifiable equipment-related safety and environmental hazards, if not eliminate them altogether. By integrating safety into the mainstream of maintenance decision-making, RCM also improves attitudes to safety.

- Improved operating performance (output, product quality and customer service): RCM recognizes that all types of maintenance have some value, and provides rules for deciding which is most suitable in every situation. By doing so, it helps ensure that only the most effective forms of maintenance are chosen for each asset, and that suitable action is taken in cases where maintenance cannot help. This much more tightly focused maintenance effort leads to quantum jumps in the performance of existing assets where these are sought. RCM was developed to help airlines draw up maintenance programs for new types of aircraft before they enter service. As a result, it is an ideal way to develop such programs for new assets, especially complex equipment for which no historical information is available. This saves much of the trial and error that is so often part of the development of new maintenance programs – trial that is time-consuming and frustrating, and error that can be very costly.

- Greater maintenance cost-effectiveness: RCM continually focuses attention on the maintenance activities that have most effect on the performance of the plant. This helps to ensure that everything spent on maintenance is spent where it will do the most good. In addition, if RCM is correctly applied to existing maintenance systems, it reduces the amount of routine work (in other words, maintenance tasks to be undertaken on a cyclic basis) issued in each period, usually by 40% to 70%. On the other hand, if RCM is used to develop a new maintenance program, the resulting scheduled workload is much lower than if the program is developed by traditional methods.

- Longer useful life of equipment, due to carefully focused emphasis on the use of on-condition maintenance.

- A comprehensive database: An RCM review ends with a comprehensive and fully documented record of the maintenance requirements of all the significant assets used by the organization. This makes it possible to adapt to changing circumstances (such as changing shift patterns or new technology) without having to reconsider all maintenance policies from scratch. It also enables equipment users to demonstrate that their maintenance programs are built on rational foundations (the audit trail required by more and more regulators). Finally, the information stored on RCM worksheets reduces the effects of staff turnover with its attendant loss of experience and expertise.

- An RCM review of the maintenance requirements of each asset also provides a much clearer view of the skills required to maintain each asset, and for deciding what spares should be held in stock.

- Greater motivation of individuals, especially people who are involved in the review process. This is accompanied by much wider ‘ownership’ of maintenance problems and their solutions. It also means that solutions are more likely to endure.

- Better teamwork: RCM provides a common, easily understood technical language for everyone who has anything to do with maintenance. This gives maintenance and operations people a better understanding of what maintenance can (and cannot) achieve and what must be done to achieve it.

All of these issues are part of the mainstream of maintenance management, and many are already the target of improvement programs. A major feature of RCM is that it provides an effective step-by-step framework for tackling all of them at once, and for involving everyone who has anything to do with the equipment in the process.” (http://www.aladon.co.uk/10intro.html)

RCM is a comprehensive and scientifically based technique for developing a unique PM program for a particular asset or group of assets that must work simultaneously and cooperatively to achieve a specific purpose. To be a successful technique, RCM relies on a reasonable presumption that the inherent reliability of an asset or piece of equipment is a function of both the adequacy of the technical design of and the quality of materials used to construct that piece of equipment. An effective PM program ensures that the inherent reliability is realized in its specific operational/functional application.

Going to RCM is a paradigm switch. Its full understanding and proper implementation is important to both the APSC and the JPO in assuring future ROW and Lease permit compliance.

<u>Phase I – Review Of JPO Files And Reports On The Alyeska RCM Program</u>

During the period from May 16-22, 2002, Consultant and Dr. Thomas Kuckertz, RCAC Project Manager jointly conducted a review of RCM related documents and materials on file in the JPO offices in Anchorage, AK.

Prior to the document review, Gary J. Green, Principal Consultant of PetroTech Alaska and Dr. Kuckertz met with two senior JPO officials, Gary Reimer, Deputy Authorized Officer and James Lusher, Engineering Manager, and Peter Stock, Vice President – Consulting, New Dimension Solutions (Formerly Spearhead System Consultants), the RCM expert working under contract to develop the RCM program for Alyeska. The purpose of these meetings was to personally explain the RCAC's intent in conducting the review and to coordinate the logistics of the actual review of the materials.

The following documents subsequently provided by Mr. Reimer and Mr. Lusher were reviewed by Mr. Green and Dr. Kuckertz to provide background information on recent events and insights to the JPO's current approach to their Comprehensive Monitoring Program:

- Joint Pipeline Office Comprehensive Monitoring Program Reports – Evaluation of Alyeska Pipeline Service Company's Operation of the Trans-Alaska Pipeline 1999-2000 dated February, 2001; Trans-Alaska Pipeline Construction Program 1999-2000 dated January 2001; and Trans-Alaska Pipeline Maintenance Program 1999-2000 dated January, 2001;
- A Comprehensive Monitoring Program Report – Examining Grant & Lease Compliance dated April, 2002;
- Joint After-Action Report for the TAPS Bullet Hole Response dated February 8, 2002;
- Spearhead Systems Consultants (US) Ltd. publication entitled Maintenance Management 21;
- Society of Automotive Engineers, Inc. publication on RCM standards entitled "SAE JA 1011, Surface Vehicle/Aerospace Standard, issued August, 1999;
- Society of Automotive Engineers, Inc. publication on RCM recommended practices entitled "SAE JA 1012, Surface Vehicle/Aerospace Recommended Practice, issued January, 2002; and,
- RCM II, Reliability Centered Maintenance, by John Moubray, May, 2000 edition.

Additionally, Mr. Reimer and Mr. Lusher authorized Mr. Green and Dr. Kuckertz access to active JPO files containing completed, ongoing, and planned RCM analyses concerning the facilities and systems associated with the Valdez Marine Terminal. RCM Analyses of major concern were those considered "complex, and/or critical" and therefore priority ranked for completion.

The following are complex (critical) systems associated with the operation of the VMT that were identified as priorities for the initial RCM analyses:

- Back Pressure Control (RCM analyses completed)
- Pressure Relief (RCM analyses completed)
- Ballast Water Treatment (RCM analyses completed)
- Control System (Operations Control Center (OCC) (RCM analyses schedule unknown)
- Leak Detection System (RCM analyses schedule unknown)
- Combustible Gas Detection (RCM analyses schedule unknown)
- Hazardous Gas Detection (RCM analyses schedule unknown)
- Tanks

Mr. Reimer and Mr. Lusher also coordinated with other appropriate JPO staff to facilitate building, document, and work space access . The document review took place in the JPO's Anchorage office. .

JPO staff subsequently provided immediate document access to the RCM files associated with the following systems:

PS5 Pressure Relief – Hydraulic Skid;
PS5 Pressure Relief – Valve;
PS5 Pressure Relief – Tank;
PS9 Manifold Building - Fire, Gas, and Halon Detection;
PS9 Pump Building - Fire, Gas, and Halon Detection;
PS9 MLU - Fire, Gas, and Halon Detection;
PS9 Primary Generator Bldg - Fire Detect and Halon Supp;
PS4 MLU - Fire, Gas, and Halon Detection;
PS4 Garrett Fire Detection & Suppression;
PS4 Emergency Ventilation;
Berth 4 No. 1 Loading Arm;
Chicksan Hydraulic;
Berth 5 Fenwal Safety System;
Berth 5 Servomex Oxygen Analyzer;
Berth 5 Vapor Collection System;
Waste Gas Incinerator;
Berth 5, Vapor Collection Arm;
Berth 4 Fire System PMO Pilot;
P/V Compressed Air System;
P/V Nitrogen Generation System;
BWT Bio-Treatment Tanks;
Back Pressure Control System;
V/R Berth Compressor 2A;
BWT BETX Analyzer
V/R Tank Farm Compressor;
P/V Inert Gas Coolers;
V/R Swing Compressor 2B;
Fenwal Safety System Review;

It was noted that only the last eighteen (18) of these twenty-eight (28) RCM Analyses files were related to the facilities and systems in operation at the VMT. The 10 non-related files were not reviewed.

Each of these 18 VMT related RCM Analyses files were reviewed by Mr. Green and Dr. Kuckertz to gain an understanding of the complexity and detail involved with the RCM II Analysis process as it is currently being applied to specific systems at the VMT; and, to select a few representative RCM II Analyses as candidates for more detailed reviews by an outside RCM expert. The two representative files selected were:

- Trans-Alaska Pipeline System Valdez Marine Terminal Back Pressure Control System, June, 2001; and,
- Trans-Alaska Pipeline System VMT – Vapor Recovery System Swing Compressor (2B), November, 2001.

<u>Phase II – Detailed Review Of Two RCM Analyses On VMT Systems/Facilities</u>

The RCM Analyses of the Trans-Alaska Pipeline System Valdez Marine Terminal Back Pressure Control System, June, 2001 and the Trans-Alaska Pipeline System VMT – Vapor Recovery System Swing Compressor (2B), November, 2001 were selected by Mr. Green and Dr. Kuckertz for a detailed review by R. Keith Engel, an RCM expert under contract to PetroTech Alaska. Mr. Engel, is a member of the American Society for Quality (ASQ), is a Certified Reliability Engineer, Certified Quality Auditor, Certified Quality Engineer, and Certified Quality Manager.

The purpose of the review by Mr. Engel of these two RCM Analyses is to assist and supplement the efforts of the RCAC staff in support of their specific oversight responsibilities as the certified alternative voluntary advisory group for Prince William Sound as required under the Oil Pollution Act of 1990 (OPA-90).

RCM, as currently proposed for implementation, is characterized as an important aspect of the means by which Alyeska will maintain compliance with the anticipated renewal of its ROW and grant permits, and the means by which JPO will monitor and measure Alyeska's compliance with these permits. For these reasons, the RCAC's assessment of the RCM initiative undertaken by Alyeska and the JPO for the VMT is believed to be consistent with the RCAC's oversight responsibilities to help assure that the operations of the VMT do not consitute an unacceptable environmental risk to the Port of Valdez and Prince William Sound.

No expert observations reported or recommendations subsequently made in this report are intended to be used as the sole basis for determining whether there has been any specific non-compliance relative to the current TAPS Right-of-Way or Lease Grant permits; nor constitute the basis for determining any compliance issue relative to any specific local, state, or federal occupational, health, and safety regulations.

Mr. Engel was asked to provide his expert opinion including comment on the following three areas:

1. The general applicability of the RCM process on the operations of the Valdez Marine Terminal;
2. The adequacy of specific application of the RCM principles on the two systems selected for expert evaluation (VMT Back Pressure Control System & VMT Vapor Recovery System Swing Compressor 2B); and,
3. The identification of potential future problems that might be anticipated with Alyeska's implementation of the RCM program, presuming that the two sample RCM analyses represent the manner in which all other systems scheduled for RCM analyses will be analyzed at the VMT.

<u>Document Review Methodology.</u>

In an effort to provide a view of the Alyeska RCM II program as initiated at the VMT, two representative RCM II Analyses were furnished by the JPO. To assure that these documents were understood in the proper context, the Consultant, PetroTech Alaska, with the consent of the RCAC, contracted the services of R. Keith Engel d.b.a. SAGETHINK , Inc. because he had direct recent work experience with RCM and predictive maintenance practices within the energy industry business sector.

Mr. Engel reviewed and analyzed the documents and files provided to him through the auspices of the RCAC after Mr. Green, the primary PetroTech Consultant and Dr. Kuckertz, the RCAC project manager had determined that the selected RCM II Analyses were representative of the manner and methods by which the other RCM II analyses for the VMT were or were being completed by New Dimensions Solutions, the RCM II consulting contractor working for the joint JPO and Alyeska RCM project.

As the basis for his review and comments, Mr. Engel used the principles and RCM methodologies espoused in 1) the Society of Automotive Engineers, Inc. publication on RCM standards entitled "SAE JA 1011, Surface Vehicle/Aerospace Standard, issued August, 1999; 2) the Society of Automotive Engineers, Inc. publication on RCM recommended practices entitled "SAE JA 1012, Surface Vehicle/Aerospace Recommended Practice, issued January, 2002; and, 3) the book RCM II, Reliability Centered Maintenance, by John Moubray, May, 2000 edition.

<u>Documents and Files Collected and Reviewed.</u>

1) Draft Report Revision 1 (5-5-02) –Joint Pipeline Office--Comprehensive Monitoring Program-TAPS Maintenance and Sustained Useful Life- January 2001 – April 2002. The 52-page draft report covers Alyeska and JPO activities for the 16-month period. The RCM initiative was launched during this period. The report includes nine attachments. Attachments 1,2,3,4, and 6 were received and reviewed. The other attachments deal with non-VMT assets and the joint agreement between Alyeska and JPO dated April 2002. The attachments to the report contain specific information pertinent to the RCM assessment and are detailed below:
    a) Attachment 1 — Memorandum of Agreement between the Joint Pipeline Office and Alyeska Pipeline Service Company — In the matter of critical system integrity review of the Trans Alaska Pipeline System. A total of 14 points were agreed upon. Key points were that JPO was to lead the RCM analysis using the RCM II methodology. Attachment A of the agreement notes that the VMT Ballast Water Treatment was selected as the pilot project for RCM analysis and lists an 8-step project execution plan. The following VMT systems are listed as in critical service:

        - Back-Pressure Control
        - Pressure Relief
        - Ballast Water Treatment
        - Control System (Operations Control Center)
        - Leak Detection System (Operations Control Center & East Metering)
        - Fire Protection System
        - Hazardous Gas Detection System
        - Tanks

    The RCM process for each of the VMT critical systems includes the following work elements:

- RCM Analysis Planning (Objectives, Operating context, resource selection, RCM process training, meeting schedules)
- Sub-systems Criticality Analysis (Criticality shall be based upon consequences to the environment and human safety in the event of subsystem functional failure)
- Conduct RCM Analysis of Critical Sub-Systems
- RCM report for Alyeska/JPO Management Review and Validation of Recommendations
- Implementation Plan for APWSC/JPO Approved RCM Recombination
- RCM Recommendation Implement (maintenance work orders. Operating procedures. Redesign where compulsory)

b) Attachment 2—SAE Standard JA1011-Issued August 1999-Evaluation Criteria for Reliability Centered Maintenance (RCM) Processes—SAE International-The Engineering Society for Advancing Mobility Land Sea Air and Space. The 11-page standard is based on documents including "Reliability-Centered Maintenance (RCM 2)" by John Moubray. The standard provides historical perspective, scope applicability and definitions that form the criteria for effective use of RCM methods.

c) Attachment 3-- SAE Standard JA1012-Issued January 2002—A guide to the Reliability Centered Maintenance (RCM) Standard—SAE International-The Engineering Society for Advancing Mobility Land Sea Air and Space. The 57-page standard supplements the SAE JA1011 RCM Criteria standard as it "amplifies and where necessary clarifies, those key concepts and terms, especially those that are unique to RCM." It is the opinion of the PetroTech Alaska that this standard provides a basis of recommended practices for RCM.

d) Attachment 4—A 6-page summary of the Hidden, Safety or Environmental failure Modes on the VMT Back-pressure Control System

e) Attachment 6—A 23-page graphical summary of the RCM Task Breakdown findings from the Biological Treatment Tanks RCM analysis.

2) Trans-Alaska Pipeline System-Valdez Marine Terminal-Back Pressure Control System-RCM2 Analysis-Draft-June 2001. The published results of the detailed RCM analysis of this system.

3) Trans-Alaska Pipeline System-VMT-Vapor Recovery System-Swing Compressor (2B)-RCM2 Analysis-Draft-November 2001. The published results of the detailed RCM analysis of this system.

Key Observations:

The following observations are made by PetroTech Alaska and R. Keith Engel (d.b.a. SAGETHINK , Inc.), and are based on the assumption that the referenced RCM Analyses materials provide examples of the RCM processes being performed for Alyeska/JPO.

1) With regard to the general applicability of the RCM process on the operations of the Valdez Marine Terminal:

    a) It is the opinion of PetroTech Alaska and R. Keith Engel that RCM is directly applicable for the operations of the VMT in achieving the JPO objectives to ensure the safe and reliable operation of the TAPS. RCM also improves the potential for Alyeska to achieve a long-term objective reducing cumulative maintenance costs. RCM can minimize effort required to maintain the functionality of the physical assets. RCM is expected to be an essential process for maintaining an aging asset at a necessarily high level, an asset upon which TAPS owners can expect a continued flow of earnings. The RCM initiative is well intentioned as conceived and documented in the Alyeska/JPO January 2001 Memorandum of Agreement with the exception that it does not include the useful life integrity and operational effectiveness performance criteria.

2) With regard to the adequacy of the specific application of the RCM principles on the two systems selected for expert evaluation—VMT Back Pressure Control System and VMT Vapor Recovery System Swing Compressor 2B:

    a) It is the opinion of PetroTech Alaska and R. Keith Engel that the analyses of the specific applications do not follow recommended practice in RCM methodology and are inadequate. It is the opinion of the consultant that the major deficiency is the lack of performance standards and expectations in the areas of safety integrity, environmental integrity, useful life integrity and operational effectiveness. As a consequence, the RCM analysis efforts do not achieve the intended goals. The VMT Backpressure Control System is used here to explain deficiencies; a similar list of issues would result if the VMT Vapor Recovery System Swing Compressor were used.

    b) It is the opinion of PetroTech Alaska and R. Keith Engel that the methodology and guidelines for performance of the analysis are sound as outlined in the "Introduction to Reliability-Centered Maintenance section included in the VMT Backpressure Analysis report:
        - Gather the necessary data for the analysis effort
        - Set up a multi-disciplined team with inherent know-how of the area of analysis
        - Train the team on RCM principles
        - Follow the SAE standard's recommended practice
        - Perform the analysis
        - Implement the tasks identified
        - Create & sustain a living RCM process that adapts with feedback loops

    c) It is the opinion of PetroTech Alaska and R. Keith Engel that the analyses method does not follow the recommended practice from the standpoint of system functions. Reference SAE JA1012 Section 6. Functions:
        - The recommended practice asks this question "What are the functions and associated desired standards of performance of the asset in its present operating context (functions)?" Key concepts for functions include:
            - Operating Context

- Primary & secondary functions
- Function statements
- Performance standards

d) It is the opinion of PetroTech Alaska and R. Keith Engel that the key to the RCM process is establishing the appropriate operating context. The backpressure system operating context does not follow the recommended practice. Reference SAE JA1012 Section 6.1 Operating Context

- The operating context should state why the system is judged critical by Alyeska/JPO in the January 2001 Memorandum of Agreement.
- The operating context should address the safety, environmental useful life and operational consequences of system failure.
- The operating context should state the historical failure frequency of the system and the expected operating performance criteria required from the standpoints of safety integrity, environmental integrity, useful life requirements and economic effectiveness.

- In this instance the following are appropriate questions:
  - "What are the safety related consequences associated with system failure?"
  - "What are the environmental consequences associated with system failure?"
  - "What are the useful life consequences associated with system failure?"
  - "What is the economic impact of system failure?"
  - "Based on the above, what is the acceptable frequency and duration of failing to keep the backpressure in the green zone as shown on the Thompson Pass Packline-Slackline Interface elevations graphic?"

- Of particular importance are evident failure modes with safety and environmental consequences, reference SAE JA1012 Section 12.1, the asset owner must spell out the acceptable levels of risk tolerance.

e) It is the opinion of PetroTech Alaska and R. Keith Engel that primary and secondary functions listed do not follow recommended practice, reference SAE JA1012 Section 6.2 List of Functions:

- The analysis report lists 30 functions for the backpressure control system. It is the opinion of the Consultant that recommended practice would produce a total of 9.
- The primary function reference SAE JA1012 Section 6.2.1 Primary Functions. The primary function of the VMT Back Pressure Control System is to control the pipeline backpressure in the green zone as shown on the Thompson Pass Packline-Slackline Interface elevations graphic.
- Secondary Functions- This is a list of 8 functions not the 32 shown in the report, reference SAE JA1012 Section 6.2.2 Secondary functions:

- Maintain environmental integrity by insuring the pipeline pressure envelope is not breeched
- Maintain structural integrity of the asset—prevent high vibration at the Thompson Pass Packline-Slackline Interface
- Maintain the safety of the pipeline so no people are killed or injured
- Maintain the useful life of the asset by controlling pressure so vibration is reduced to minimize the probability of fatigue failure.
- Maintain Containment—same as environmental integrity above
- Maintain comfort for Heiden View residents who are disturbed by the vibrations
- Maintain protection of the pipeline system from safety, environmental, and economic impacts
- Maintain economy and effectiveness of the pipeline system by preventing failures that disrupt flow or cause high operating cost due to repairs (This very important function appears to be ignored in the analysis effort—RCM is not complete until this area is addressed---As a consequence, Alyeska is missing the opportunity to improve the asset earnings stream)

f) It is the opinion of PetroTech Alaska and R. Keith Engel that the system boundaries do not follow the recommended practice. Defining the appropriate system boundary is the responsibility of the RCM facilitator (reference Reliability-Centered Maintenance, by John Moubray page 270).

- A system boundary should include all the facilities that are required for the system to perform its intended function. That includes the facilities that provide protection for the system.
- For example the backpressure control system would include the safety relief section, which is installed to protect the VMT pressure envelope from rupturing by exceeding the maximum allowable working pressure. The relief section functionality is dependent on the hydraulic supply system providing the motive force to move the relief valves. The hydraulic system functionality is dependent of supply of electrical power to provide motive power transferred into hydraulic pressure.
- Similarly, the control system that takes the process variable signal to the Operations Control Center (OCC) and returns a control signal to the backpressure valves should be part of the system.
- Electrical power is an integral requirement for system function. Failure of these infrastructure systems affect functionality of the system and the recommended practice calls for them to be included in the analysis.

g) It is the opinion of PetroTech Alaska and R. Keith Engel that identification of failure modes does not follow recommended practice. The recommended practice asks "what causes each system functional failure?" The best practice for answering this question is to review all the system equipment components and ask this question: "How can this equipment failure affect the functionality of the entire system?" Equipment failures that cause system function failures are defined as critical items. Equipment in the system that does not cause an effect of system function when it fails is non-critical. The maintenance tasks for critical items will be more precise than for non-critical equipment, which can be run to failure.

- There is no evidence in the reports that a sub-system function criticality analysis was performed.
- In addition, the Alyeska/JPO January 2001 Memorandum of Agreement-Attachment A-Paragraphs 1.1.2 and 1.2.3 specifically mention sub-system criticality analysis as work elements of the RCM initiative.

h) It is the opinion of PetroTech Alaska and R. Keith Engel that many failure modes are not analyzed as prescribed in the recommended practice. As stated previously, failures in sub-systems & utility infrastructure often affect system functionality. Remote control systems, local control systems, pressure relief protection sub-system, Bailey system, and the metering system are mentioned as failure modes but not included in the analysis. These are all critical systems and the power sub-system is backed up with the Uninterruptible Power Supply (UPS). Recommended practice calls for criticality analysis of these sub-systems followed by failure mode and task analysis of critical components that impact on the VMT backpressure system functionality.

i) It is the opinion of PetroTech Alaska and R. Keith Engel that Pre-Analysis documentation does not follow recommended practice. RCM requires data gathering that includes accurate system configuration, up to date equipment data files including equipment inspection history, equipment failure history. It appears that a complete set of P&ID's are not included in the backpressure system analysis. The P&ID's are also marked up. Special drawings were developed to show flow scenarios.

j) The VMT Backpressure Control System report states that the analysis was made on a different basis than the equipment installed. The analysis assumed a major modification on the backpressure control value actuators had already been made. It is the opinion of PetroTech Alaska and R. Keith Engel that this is not good practice. It would be more appropriate to document the poor performance as a means of demonstrating the need for the replacement and to analyze if the projected modification would achieve the intended improvement in system functionality. If the modification is complete, the analysis should be revisited immediately to reflect the installed design (an example of the living process of RCM). The description of the replacement actuators indicates an electrical component. If so those changes should be represented on the P&ID's that were used in this analysis.

k) It is the opinion of PetroTech Alaska and R. Keith Engel that failure mode details are incomplete. Complete failure mode details are an integral element of RCM because they document the need for change that results from the task selection. In addition, the failure modes details have little if any asset effectiveness and economic impacts related to them. Alyeska misses the opportunity to improve earnings when the operational and cost impacts are not included in the analysis.

l) It is the opinion of PetroTech Alaska and R. Keith Engel that task selection does not follow recommended practice. The root causes of inadequate task selection are the lack of specific requirements in the operating context and the lack of sub-system criticality analysis. It is not possible to set appropriate failure management policy for specific system components without spelling out the safety integrity, environmental integrity, useful life integrity and economic consequences of failure so that appropriate performance standards are set for the system. Each component of the system has a failure history; some of those failures effect system functionality. Criticality analysis focuses attention on critical components. RCM task selection emphasizes on-condition tasks that identify deterioration before failure occurs, reference SAE JA1012 Section 13.1. System component failure data is essential in setting up failure management policy that will meet the system performance requirements. The analysis contains no failure data.

m) It is the opinion of PetroTech Alaska and R. Keith Engel that the failures recommending redesign do not follow recommended practice. This section of the report notes only reviews and evaluations. It does not spell out system functionality failure modes that can be mitigated with redesign of the system components. It is here that the design intent of modifications are spelled out showing the value of functional improvement in the areas of safety integrity, environmental integrity, useful life integrity & operational effectiveness. Reference SAE JA1012 Section 14.

- The Draft VMT backpressure Control System RCM Analysis Report list of hidden, safety or environmental failure modes does not agree the attachment 4 of the JPO Comprehensive Monitoring Program draft.
- A number of failure modes with these consequences will likely require redesign when Alyeska sets the acceptable level of risk of failure.

n) It is the opinion of the Consultant that the failure modes requiring compulsory redesign do not follow recommended practice.

- The report contains a page with an error message in the system and sub-system blocks. No statements are made regarding compulsory redesign issues.

3) Presuming that the two sample RCM Analyses fairly represent the manner in which all systems will have get their RCM Analysis, the following are anticipated problems that are likely to be encountered during the RCM implementation:

a) It is the opinion of PetroTech Alaska and R. Keith Engel that accomplishment by Alyeska of the task items, as currently recommended in the draft analyses, could be problematical until the shortcomings in the analyses have been corrected.
b) It is the opinion of PetroTech Alaska and R. Keith Engel that JPO/Alyeska may come under criticism by moving forward with the RCM effort as presently driven. In the opinion of PetroTech Alaska, environmental activist organizations intent on blocking ROW and Lease Grant permit renewals could, upon hiring a RCM expert, ask to review critical aspects of the RCM Analysis program and make valid claims of inadequate preparation for a maintenance program that would assure long term TAPS and specifically, VMT integrity.

Other Observations:

With regard to the list of critical systems that were to receive an RCM analysis, it was noted that the Control System - Operations Control Center (OCC) - is listed but the RCM analyses schedule remains unknown. It is the opinion of PetroTech Alaska serious hidden failure modes could exist that are associated with both the hardware and the software that controls the flow of oil into, within, and from the VMT. Federal critical infrastructure security studies have identified computer control systems (SCADA) in pipelines, power generation systems, navigation systems, etc. as likely targets of opportunity for international terrorist organizations using readily available cyberterrorist tools. Systems isolated from the Internet can be open to risk through unauthorized software installations, disgruntled employees, and contract specialists working without adequate background security investigations being allowed to work on the system. Addition insights on potential risks can be supplied upon request.

Recommendations

The Consultant recommends that the appropriate JPO/Alyeska RCM managers re-examine the RCM initiative assisted by through services of an “outside” RCM expert, such that the following objectives could be achieved: 1) key JPO/Alyeska managers fully understand the SAE JA 1012 recommended practices and how safety and environmental risks must be weighed and standards established for failure tolerance; and, 2) understand the useful life integrity requirements that are a part of the RCM methodology.

The Consultant recommends that JPO/Alyeska RCM managers re-work the operating context for the functional systems incorporating the requirements for safety, environment, useful life and operating effectiveness.

The Consultant recommends that JPO/Alyeska senior managers take whatever action is necessary to guarantee that the appropriate JPO/Alyeska maintenance managers use RCM facilitators that will follow JPO and Alyeska management’s lead as set forth above.

The Consultant recommends that JPO/Alyeska ensure each RCM team has a member that has the tacit knowledge of failure history and are well respected as knowledgeable of the system being analyzed.

The Consultant recommends that JPO/Alyeska ensure the RCM teams are trained to follow the SAE JA 1012 recommended practices and standards guidelines.

The Consultant recommends that JPO/Alyeska closely audit the ongoing initial RCM analyses team efforts to insure that relevant information is shared upward to VMT managers.

The Consultant recommends that JPO/Alyeska have in place a task implementation procedure that ensures that selected tasks are implemented within 2 weeks of the RCM analysis.

The Consultant recommends that JPO/Alyeska initiate an RCM Analysis on the VMT control system (OCC).

The Consultant recommends that appropriate JPO/Alyeska managers institute regular audit programs with procedures that ensure the RCM II program in effect for the VMT does not deviate with time from the SAE JA 1011 and SAE JA 1012 processes and standards, respectively; thereby helping to ensure that it does not take on the characteristics of a "streamlined RCM" program in effect for the maintenance of the pipeline and pump stations segments of the TAPS.