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RELIABILITY AND RISK TREATMENT CENTERED MAINTENANCE SYSTEM

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Abstract

The authors developed a new method for applying well known tools - RCM, RBI and SIFpro. Risk-based Inspection (RBI) is an optimal maintenance process used to examine and maintain equipment. It is a widely applied strategy in processing industries (oil and gas industry, petrochemical plants) (Filimonov, Belatskiy, 1973). RBI is used to specify monitoring plans for pressure equipment, including pressure vessels and piping (Henly, Kumatoto, 1984). Safety Instrument Function process (SIFpro) is a strategy used to optimize control loop inspection intervals (Belyaev, 1969). SIFpro examines random safe and unsafe safety system failures, including emergency signals. It is used for measuring devices. SIFpro is usually preceded by HAZOP or PHA. These methods determine the areas where SIF is required. The method aims at reducing risks owing to adequate maintenance. The methodology is based on the complex use of all three methods simultaneously, not separately. The developed approach involves only one control group for reliability and risk treatment centered maintenance (RRTCM) with simultaneous use of RCM, RBI and SIFpro methods. The approach reduces the duration of engineering works. The activities were divided into five stages and structured so that to eliminate double application of the tools. The new approach helps to save 45-50% of the workload and significant financial resources. But RRTCM implementation can face some obstacles due to changes in the organizational structure, responsibilities and other business processes. RRTCM implementation difficulties can result from high demand for data input, analysis quality, maintenance, management, poor company culture, low top management support, etc.

Keywords: Maintenance; risk processing; reliability; monitoring.

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1. Introduction

At present, the industrial equipment complexity level and the amount of maintainable equipment are rather high. Efficient equipment operation and failure risk management require an adequate maintenance system. Proper preventive maintenance reduces the number of failures and serves as a tool for processing risks and failure effects. RCM (Reliability Centered Maintenance), RBI (Risk Based Inspections) and SIFpro (Safety Instrumented Function process) are important tools for improving reliability and risk processing. These well-known methods are used in RRTCM – Reliability and Risk Treatment Centered Maintenance - based on their simultaneous integrated application.

Reliability centered maintenance (RCM) is structured processes aimed at developing an optimal and economically efficient maintenance and repair system taking into account levels of risks due to equipment failures and criticality. RCM is used to develop efficient strategies for maintaining dynamic equipment and its units (Ageev, Chursin, 1981; Belyaev, 1969; Varzhapetyan, 1969; Vasilyev et al., 1997; Vensel, 1983; Dotsenko, 1983; Druzhinin, 1967; Dulesov, 1990; Klimov, 1985; Kollakot, 1989).

RCM is mainly used in processing industries and for technologically intensive equipment (Kofman et al., 1982; Kouzen, 1961; Ryabinin, 1971a). The RCM process is based on the functional failure analysis (FFA) (Ryabinin, 1969) and/or failure mode effects (FMEA) / Failure Mode Effects and Criticality Analysis (FMECA) (Ryabinin, 1971b) for criticality levels of different failures. The RCM process also differentiates explicit and implicit risks from equipment failures into operations, budget, environment, safety and product quality. At the end of the process, a proper maintenance task is specified. It decreases or at least does not aggravate failure criticality. The RCM analysis involves three or four stages (Fig.1) (Ryabinin, Kireev, 1974; Turkin, 2003).

2. Problem Statement

Risk-based Inspection (RBI) is an optimal maintenance process used to examine and maintain equipment. It is a widely applied strategy in processing industries (oil and gas industry, petrochemical plants) (Filimonov, Belatskiy, 1973). RBI is used to specify monitoring plans for pressure equipment, including pressure vessels and piping (Henly, Kumatoto, 1984). RBI examines all modes of pressure equipment failures which influence pressure equipment and piping integrity. Other modes of pressure equipment damages such as sedimentation should be analyzed using the RCM method.

Safety Instrument Function process (SIFpro) is a strategy used to optimize control loop inspection intervals (Belyaev, 1969). SIFpro examines random safe and unsafe safety system failures, including emergency signals. It is used for measuring devices. SIFpro is usually preceded by HAZOP or PHA. These methods determine the areas where SIF is required. If the risk level is reduced to the Safety Integrity Level (SIL), SIF is required.

3. Research Questions

These methods contribute to optimized inspection and maintenance policy. But separate application of these methods is a significant drawback. To improve economic efficiency, they should be

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implemented simultaneously. The authors suggest a new approach (RRTCM) based on the integrated application of the described methods (RCM, RBI and SIFpro).

4. Purpose of the Study

RCM, RBI and SIFpro deal with a specific area of industrial equipment and its maintenance. The basic features of RRTCM are as follows:

- Integrated risk assessment contributing to a proper RRTM structure and simplification of relations with security services.

- Reduced work load (data can be used in other systems).

- Synergetic effects, time saving and cost reduction.

RRTCM can be used in the chemical and petrochemical industries, oil industry, heat and nuclear power stations, gas transportation and storing. It can be applied to machines and equipment such as compressors, nuclear reactors, pumps and engines, gas pipelines, coolers, and heat exchangers with control systems.

5. Research Methods

The new approach requires training a work team motivated to implement that method. RCM, RBI and SIFpro are developed for industrial equipment (technological systems, machines, machine components, measuring units, etc.). For example, the chemical industry (Figure 1) applies RCM to examine mechanical industrial equipment. RCM mainly deals with machines (rotating machines, electrical units, filters and measuring equipment) (Dotsenko, 1983). RBI is used to examine pressure equipment and pipelines subject to obligatory maintenance (towers, reactors, heat exchangers, coolers, pipelines, etc.). SIFpro is used to examine security system failures, including emergency signals. Any industrial company should use an integrated approach aimed at improving preventive maintenance. However, implementation of these methods is a challenge as it causes significant organizational changes in maintenance, production and management systems.

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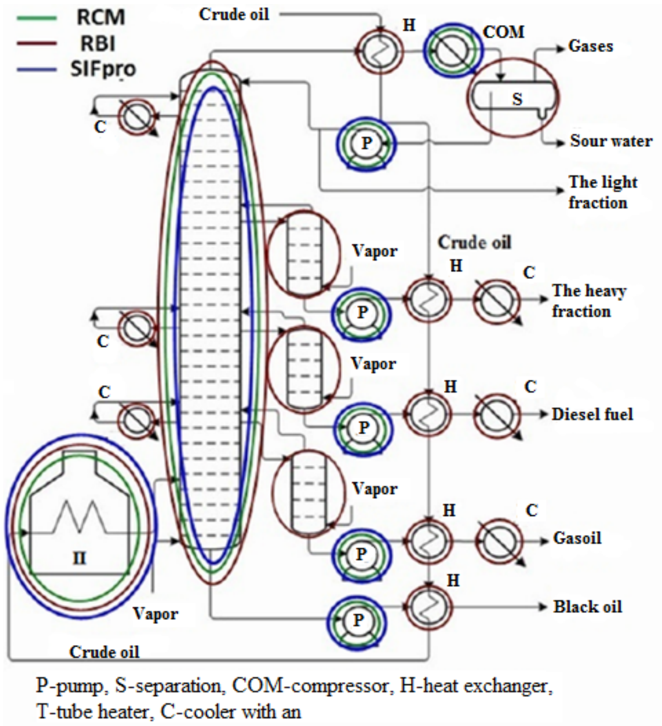

Figure 01. RCM, RBI and SIFpro application for atmospheric distillation components

Risk assessment-based decision making is an important maintenance management tool. Input RRTCM analysis is collaborative work of experts dealing with operation, maintenance, processing technology, corrosion and material science, monitoring, health and safety, electrical equipment and measuring units. The analysis contributes to the planning of the coordinated and systematized maintenance process.

6. Findings

The RRTCM process includes five stages (Table 1) which are subdivided into separate units. Each stage is a process involving several consecutive or overlapping activities (units). Stage inputs and outputs are data, forms, procedures, recommendations, etc. which are inherent components of the process. Visual identification is a special advantage (by colors: green - 100%, yellow - from 1 to 99% and red - 0% fusion).

Table 01. The RRTCM process.

Stage 1 Readiness assessment		1. Research startup	
		2. Basic research	
		3. Data collection and analysis	
		4. Workshop on implementation	
		5. Demand for human resources	
		6. Demand for professional knowledge	
		7. Contract provisions	
		8. Technical audit	
Stage 2 Preparation		9. Loss calculation	
		10. Sequencing operational systems	
		11. Adjusting analysis boundaries	
		12. Preparation for analysis	

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		13. Command generation	
		14. Analysis scheme	
		15. Device information control	
		16. Defining risk matrix	
Stage 3 Analysis		17. RCM analysis	
		18. RBI analysis	
		19. SIFpro analysis	
Stage 4 Result implementation		20. New maintenance program structure	
		21. New maintenance program	
		22. Implementation plan	
		23. Determining the scope of repair works	
Stage 5 Systems audit		24. System process updating	
		25. Changes in analysis	
		26. Key index monitoring	
		Usual (100% fusion)	
		Most often (1-99% fusion)	
		Different (0% fusion)	

At the first stage, these methods are implemented in the maintenance process of a company. Data collection by means of the technical audit and staff and management training is carried out.

Data collection and consolidation as well as coordination of the work team based on the analysis results take place during the second stage.

The third stage, analysis, is carried out based on a certain scheme to ensure complex review of analyzed industrial units and provide a standardized form of results.

Implementation of analysis results of the maintenance information system takes place during the fourth stage. New maintenance requirements (duration, works) should be implemented to take into account scheduled equipment shutdowns and legislative rules.

System process updating takes place during the fifth stage which focuses on those areas where such changes can result in analysis adjustment. The last stage also involves assessing the whole RRTCM process.

RRTCM implementation in the management structure is shown in Figure 2. The high level is an asset management process, the middle level is integration of RRTCM into the maintenance process, the low level is links to risk and reliability management software. The key RRTCM result is preventive maintenance software development.

Implementation of the updated preventive maintenance software in RRTCM reduces costs. Some other advantages of the software are as follows:

- work load reduction (use of collected data in all systems);
- specification of the maintenance policy with regard to risk management;
- equipment reliability and availability increase;
- technical integrity of equipment;
- compliance with labor protection, environment protection and industrial safety requirements;
- a uniform maintenance, inspection and safety data base;
- a continuous feedback process;
- up-to-date asset accounting;
- a uniform source for maintenance plans and decisions;

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- inspection and safety requirements;
- data reliability improvement;
- centralization of maintenance procedures;
- use of operators for performing preventive maintenance activities,
- environment of interdisciplinary groups.

Data for RRTCM (Figure 3) can be updated at appropriate intervals or when specific problems arise. In theory, the wholesale revision should be carried out for all production or equipment units once or twice a year. However, modifications can be made according to a downtime schedule.

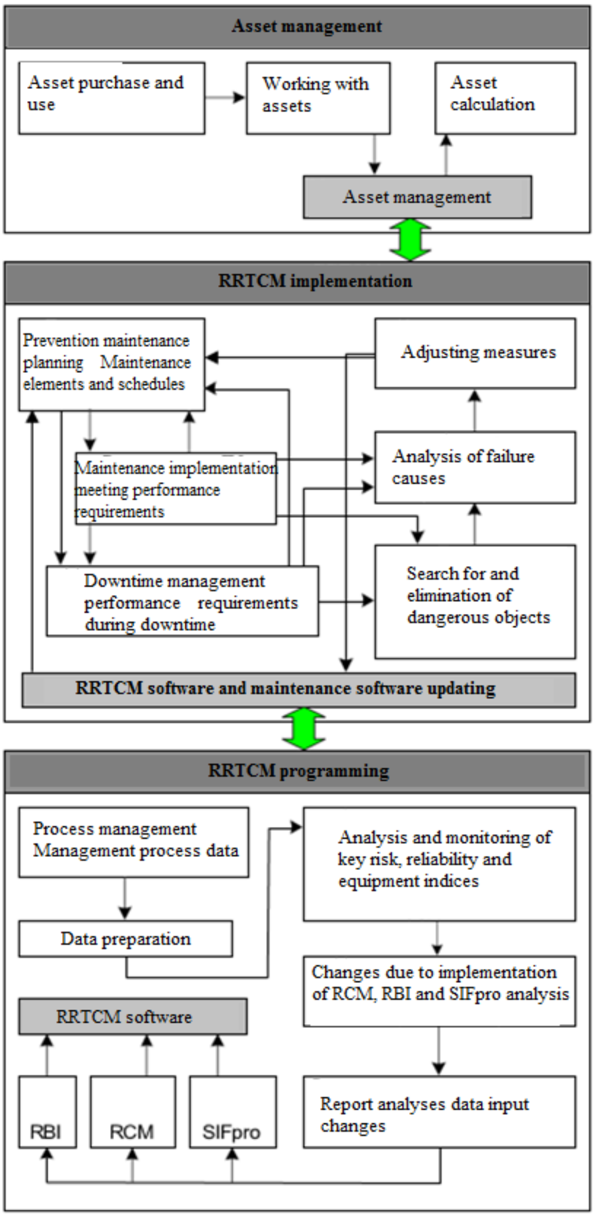

Figure 02. RRTCM inclusion in the organization structure.

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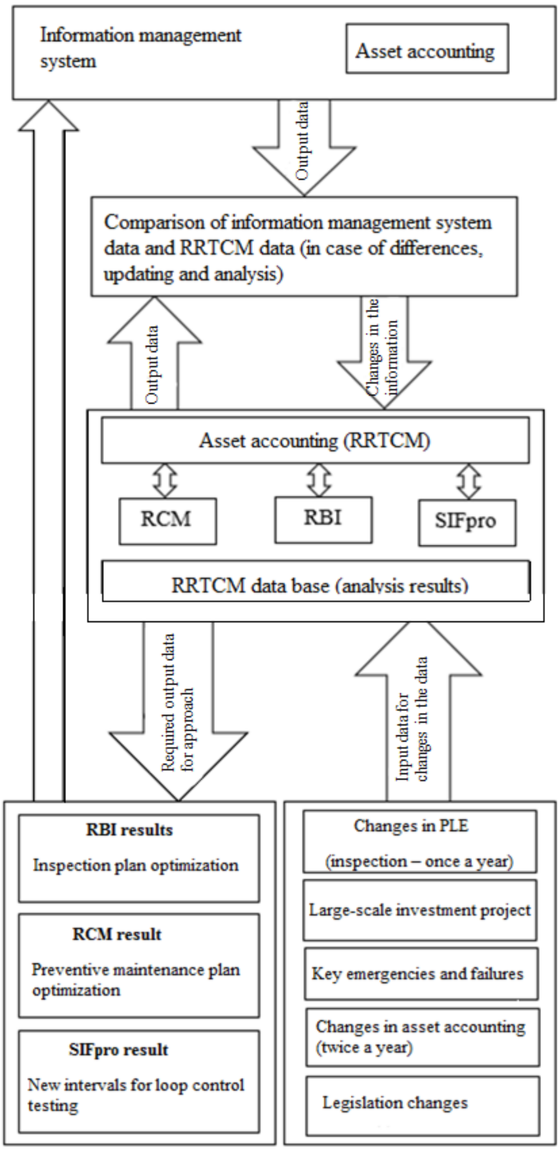

Figure 03. RRTCM updating process.

Besides, regular data modifications can be expanded due to random changes for certain equipment components where significant changes occur (without criticality identification):

- repair, reconstruction or production of new equipment (changes in asset registries, PLE, safety, etc.);
- new inspection and testing results;
- new equipment maintenance data during downtime and repair works;
- changes in legislation and standards (due maintenance);
- changes in business strategies of companies (market changes, a strategic focus, a new owner);
- production loss accounting (PLA) (large investment projects, changes in technology, etc.);
- stability and risk criteria;
- data on failures and degradation mode development;
- new research results on Hazard and Operability (HAZOP), process hazard analysis (PHA) or health, safety and environment (HSE);
- development and application of new methods or maintenance equipment;

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- new comparative / benchmarking analysis results;
- main changes in currency conversion rates.

To achieve better RRTCM implementation results and gain benefits, well-defined organizational arrangement with specified roles and responsibilities is required. The RRTCM structure is shown in Figure 3. The structure is divided into four parts:

- prevention,
- technical equipment integrity management (TEIM),
- emergency situation / reaction,
- management and control.

Prevention shows the position of RRTCM among other reliability improvement measures (e.g., RCA) and is used to calculate and control key performance indices (KPI). TEIM focuses on technical equipment integrity management based on RBI researches (operation of production units, data exchange, operating constraint monitoring IOW). A committee consisting of managers of a company make decisions on future actions and work done.

As can be seen from Figure 3, to solve reliability / integrity tasks, except for a management committee, a communication ‘officer’ is required. The officer provides support for RRTCM commands during maintenance and inspection plan assessment.

RRTCM implementation is less time-consuming compared to separate implementation of the RCM, RBI and SIFpro methods. Implementation time is shown in Table 2. The table shows only time reduction for the second, third and fourth stages. Stages 1 and 5 are omitted since they refer to the company as a whole. During RRTCM implementation, labor intensity was calculated in man/hours for each phase of the second, third and fourth stages. For future comparison, it was expressed as percentage. During RCM, RBI and SIFpro implementation, labor intensity was also calculated as percent of RRTCM labor intensity.

According to the pessimistic RRTCM scenario, cost-effectiveness can be 44.4%. According to the optimistic scenario, cost-effectiveness can be 50.5%..

7. Conclusion

RRTCM implementation can face some obstacles due to changes in the organizational structure, responsibilities and other business processes. RRTCM implementation difficulties result from:

- high demand for data input,
- analysis quality,
- maintenance management,
- poor company culture, low top management support, etc.

RRTCM approach combines separately applied RCM, RBI and SIFpro methods. To be efficient, the approach should be supported by top managers of a company. The diagrams in Figure 6 show that the RRTCM approach involves almost all levels and departments of the company.

Time saving results due to integrated implementation of the RCM, RBI and SIFpro methods are presented in Table 2. The rightmost column in Table 2 shows that labor intensity due to the use of the RRTCM approach is 100% man/hours. Implementation time reduction due to the use of the RRTCM

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approach is 44.4-50.5%. RRTCM benefits depend on the size of a company, RRTCM work groups' performance, absolute labor intensity (in man/hours) for separate and integrated RCM, RBI and SIFpro implementation, labor force cost (in ruble/man/hours). The main purpose of the RRTCM approach is to reduce time for RCM, RBI and SIFpro implementation, develop an optimal reliability and risk treatment centered maintenance strategy and improve efficiency of investment in physical assets and their maintenance.

Table 02. Comparison of RRTCM implementation time and time for separate implementation of RCM, RBI and SIFpro (labor capacity, %).

		Labor intensity (% man/hours)								
		RCM		RBI		S		Total		RRTCM
Type		P	O	P	O	P	O	P	O	
9.		10	10	10	10	100	10	300	300	100
10.		10	10	10	10	100	10	300	300	100
11.		70	90	40	60	20	30	130	180	100
12.		50	70	50	70	70	80	170	220	100
13.		90	10	90	10	90	10	270	300	100
14.		10	10	10	10	100	10	300	300	100
15.		50	70	50	70	30	40	130	180	100
16.		10	10	10	10	100	10	300	300	100
17.		100	100	0	0	0	0	100	100	100
18.		0	0	100	100	0	0	100	100	100
19.		0	0	0	0	100	10	100	100	100
20.		50	60	50	60	20	30	120	150	10
21.		50	60	50	60	20	30	120	150	10
22.		50	70	60	70	30	40	140	180	10
23.		50	70	50	70	20	30	120	170	10
Mean value								180	202	10
Labor intensity reduction (%)								**100 * (180-100) 180**	**100 * (202-100) 202**	

P – Pessimistic RRTCM scenario
O – Optimistic RRTCM scenario
applied for all methods
partially applied
applied for one method

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