

## Introduction

RCM (Reliability Centered Maintenance), the principle of which revolves around seven typical questions, is an efficient decision making tool for maintenance of plant. The functions of plant and equipments, the failure consequences and the measures to prevent or to cope with functional failure are focused in a systematic manner using functional failure modes and effects and criticality analysis (FMECA) and logical decision flowchart. Since operation and maintenance activities are interrelated and interact on each other, RCM which is a widely-used systematic engineering approach in industry has the potential to put the emphasis on reliable operating activities of plant while the essence of plant operation is the implementation of plant multi-level functions for safe production. From a whole point of view, the plant which is a complicated facility can be analyzed as a whole systematically in RCM logic. It is reasonable to devise operational instructions which compose the main content of operating procedures from perspective of RCM philosophy.

## Discussions on RCM Application

Modification of the seven typical questions in RCM to pay more attention to operation activities is provided as follows:

- (1) What are the functions and quantitative performance standards of the plant under different operating mode?
- (2) In what ways are the operators able to find timely that it fails to fulfill its functions?
- (3) What can cause each functional failure either directly or indirectly?
- (4) What are the actions of the operators when each failure occurs?
- (5) In what way does each failure matter considering human reliability and system interaction?
- (6) What operational actions can be done to predict or prevent each failure?
- (7) What should be done to reduce plant operation risks if a suitable proactive task cannot be found?

In contrast with a maintenance strategy to deal with the functional failures of important equipments, an operation strategy to deal with the functional failures of plant is considered along the logical passage of RCM queries. Functions of the system to support the safe stable operation or to stabilize the plant operation are focused to prepare for critical system function identification and plant functional failure mode analysis. As illustrated in fig.1, the functions of relevant systems, such as the system and associated dependent system and supporting system, cooperate to realize the required functions of plant. The functions structure of plant and the functional logical relationship will be established for functional implementation paths searching. There are various paths those lead to top-level function.

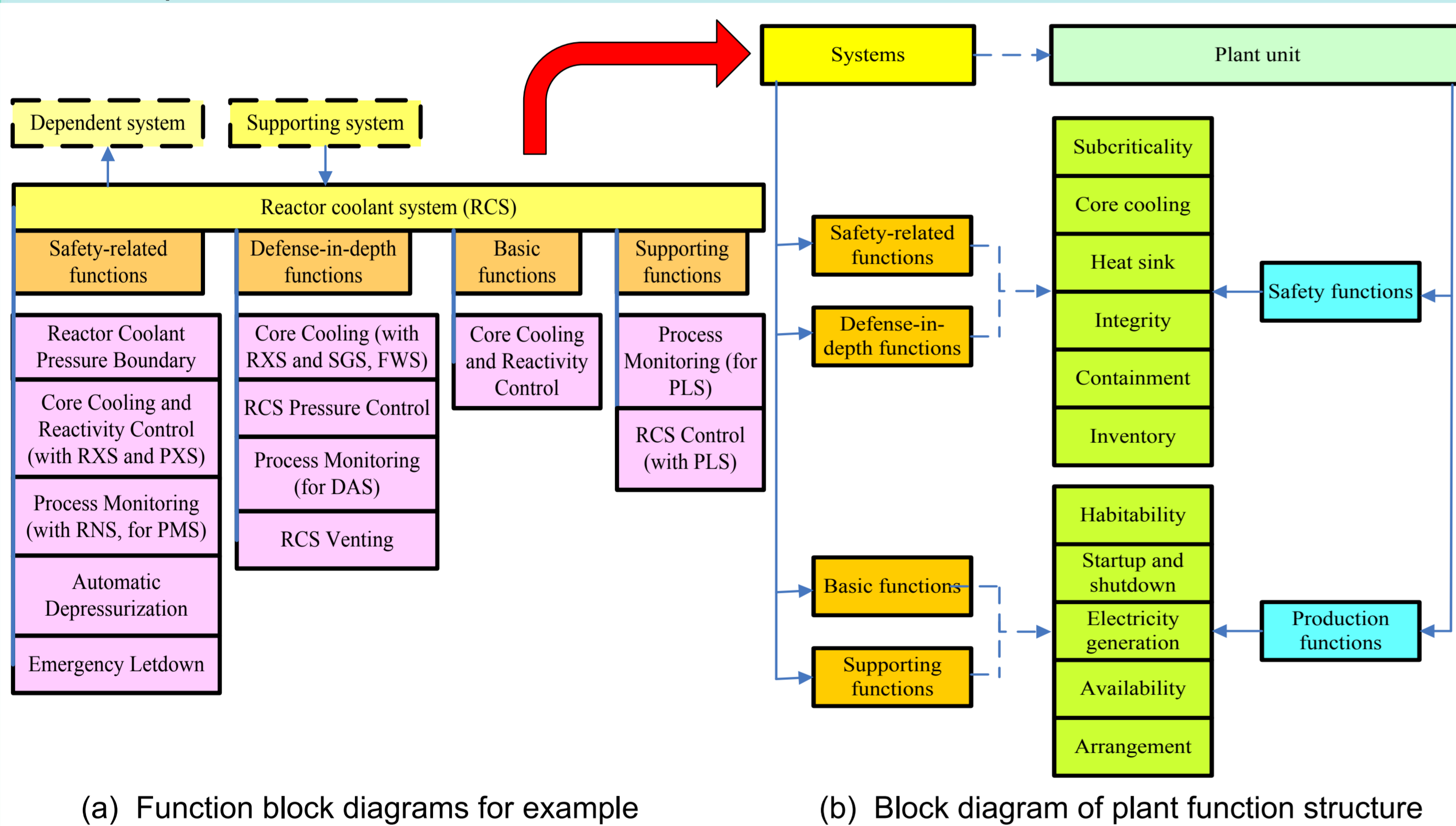


Fig. 1 Simple function block diagram

While the mainly concern of operation task is to maintain the stable production function until the safety function is threatened. Identification of the operators' action steps along the functional implementation paths will contribute a lot to the operating procedure development. A table for functional information collection such as the following one is convenient in analysis case.

Table 1 Table of functional information collection

Basic information		Function realization		Relevant systems		Relevant function sequence			
System	Function	Modes or conditions	Performance criteria	Action steps	Supporting systems	Dependent systems	Higher-level function	Lower-level function	Goal-function

The performance standards of the plant can be indicated by system operating parameters and limit conditions of operation. When abnormal failure attacks of varying degrees occur, the task of operation is to control the symptoms and to pull the deviated state variables back as soon as possible. The functional failures may be caused by the failures or accidents associated with its components or other systems. Based on the plant functional failure modes and system failure effects and path criticality analysis, optimum task selection is able to be performed.

There is a defense-in-depth mechanism penetrating operating process, as well as the design of function hierarchy. When failures of different severities occur, the operators take design-support steps to prevent the situation from deteriorating and to avoid the worst failures which might lead to the loss of all the essential safety functions of plant.

A type of general decision logic is showed in fig. 2 to support operating procedures development in RCM view. The decision logic diagram can be utilized to identify the requirement of operating procedures development among various specific paths to achieve functional goals. Nevertheless the concrete steps of each specific task should be specified according to special action logic. The task should be evaluated for the necessity of being part of procedure, and the interface of various activities for plant performance should be clearly defined first.

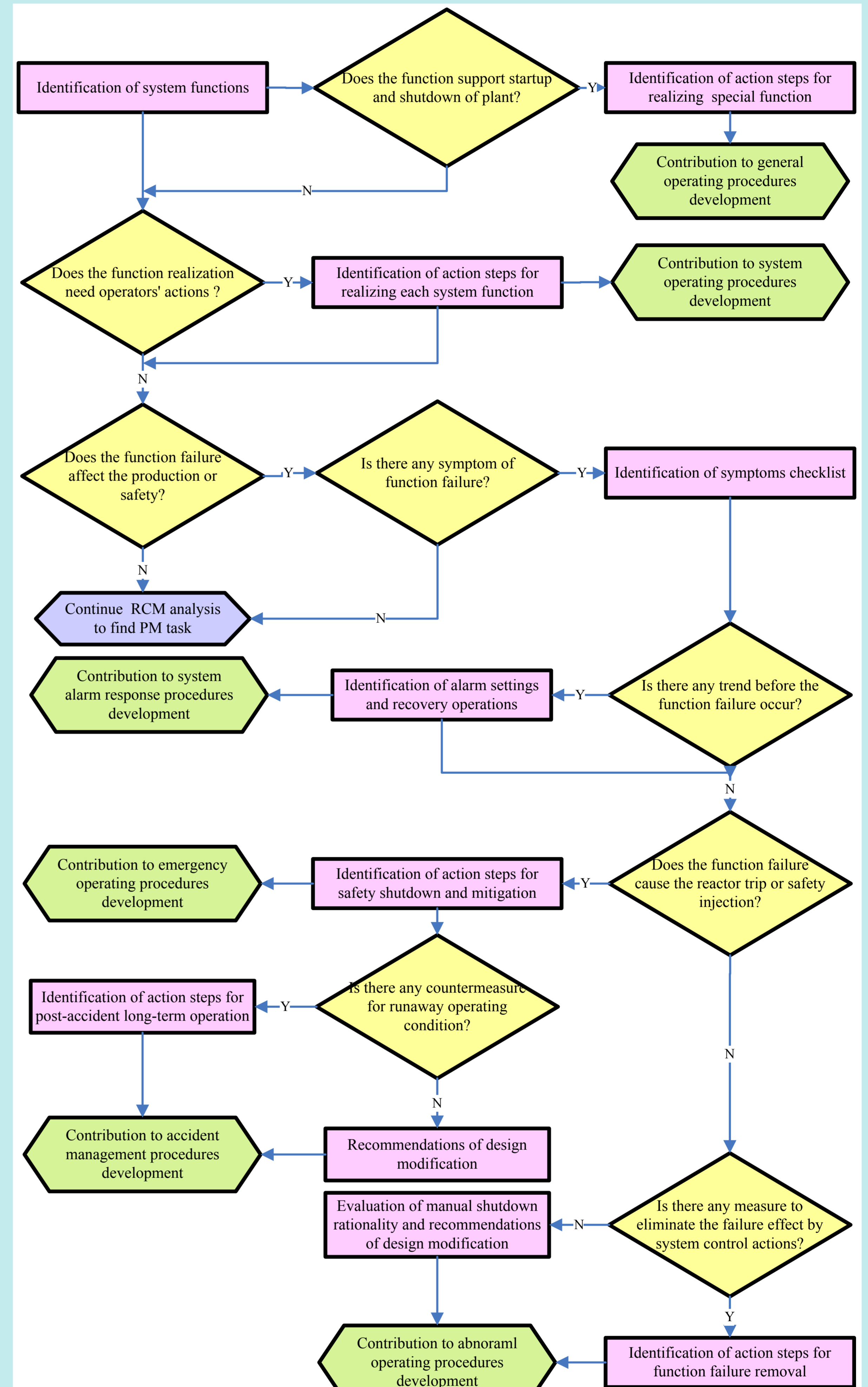


Fig. 2 A decision logic diagram for operating procedures development

## Implementing Recommendations and Benefits

Participation of plant operators is required to bring an operational analysis process together during RCM implementation meanwhile. An operation analysis and improvement group could be incorporated. Standing on viewpoint of the plant owner, the interaction will enhance functional implementation image and operational relationship understanding of operators for continually improving the operation through a systematic approach.

On the other side, an reliability centered approach for procedures development can be introduced from the perspective of NPPs engineering design. Pyramid-style function structure establishment and path-search analysis will strengthen functional interfaces analysis which is good for system design. The process can benefit system operating procedures development more than the top-down functional analysis in human engineering process. Some initiating events which may contribute to probabilistic safety analysis can also be identified as the outcomes of functional failure analysis.

## Conclusions

Based on the workflow and the logic of RCM analysis, a systematic approach to develop operating procedures can be provided. The implementation process can be team up with RCM analysis for procedures development, and do both benefit to the design and operation of the plant. Although the outcomes of function and operation analysis process theoretically can contribute a lot to operating procedures development in view of RCM, the practical process implementation is needed for deeper reasoning and improvement. And it is necessary to use analytical tools and to add functional information systematically to procedure development database because the function structure establishment is troublesome and time-consuming. Since some operating procedures are imported directly, the process can also be used for procedure optimization task.