CHEMICAL ENGINEERING TRANSACTIONS
VOL. 31, 2013
Guest Editors: Eddy De Rademaeker, Bruno Fabiano, Simberto Senni Buratti

ISBN 978-88-95608-22-8; ISSN 1974-9791
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at: www.aidic.it/cet
DOI: 10.3303/CET1331030

Analysis of Root Causes for Chemical Accidents Basis on Business Process Model for Plant Maintenance

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Unintended release of material from chemical plants becomes a serious problem that may lead to a fire, explosion or human health incident. Plant maintenance is concerned, the direct cause of the unintended release can be clarified, e.g. strength decline by chemical and/or physical deterioration, imperfectness of isolation at overhaul operation, and so on. Such a direct cause of incident is brought about by a failure in any business process or failures in several business processes that constitute plant maintenance activity. To clarify these root causes for an incident, the business processes should be defined definitely, and failure is to be analyzed on the basis of that definition. However, business process of plant maintenance is managed experimentally in general, so that it was difficult to specify root causes for unintended release so far. The authors have developed a generic business process model for plant maintenance as IDEF0 (Integration DEFinition for function model) activity model. In this study, business process model based root causes analysis of incidents in plant maintenance is proposed, and an incident case is applied to illustrate effectiveness of this approach.

1. Introduction

Chemical plants treat a lot of flammable materials, so that unintended release becomes a serious problem that may lead to a fire, explosion or human health incident. Concerning to plant maintenance, the direct cause of the unintended release is the strength decline by chemical and/or physical deterioration or imperfectness of isolation at overhaul operation. However, the decline and imperfectness would be caused for the failure at various levels of plant maintenance activities. To maintain safety through the lifecycle, learning from the experienced accident is very important, and the root causes of unintended release should be identified. However, business process of plant maintenance is managed experimentally in general as same as any other engineering in the lifecycle, so that the root causes for unintended release are not identified. The failure of maintenance activities is kept intact, and only ad hoc measures are performed. To overcome this problem, business process model based analysis of root causes for incident in plant maintenance is proposed.

The plant maintenance activity is composed of various hierarchical sub-activities and interactive with other engineering activities in the lifecycle such as design and operation. The authors have developed a generic business process model for plant maintenance (Fuchino, et. al., 2010) under the cooperation of plant maintenance experts in chemical industries in Japan. IDEF0 (Integration DEFinition for Function Model) activity model was used as a modelling method. In this study, the developed activity model is applied as a reference model to analyse the root causes for experienced accident. In this study, an incident case concerning to plant maintenance was analysed to illustrate the effectiveness of the proposed approach. It is found that the root causes can be analysed exhaustively in systematic way.

Please cite this article as: Fuchino T., Takeda K., Kitajima T. and Shimada Y., 2013, Analysis of root causes for chemical accidents basis on business process model for plant maintenance, Chemical Engineering Transactions, 31, 175-180 DOI: 10.3303/CET1331030

2. Business Process Model for Plant Maintenance

In this study, root causes for any incident of plant maintenance are specified on the basis of a generic business process model. To make the generic model, a novel template approach across all principal activities was used. This template configures five types of activities, i.e. “Manage”, “Plan”, “Do”, “Evaluate”, and “Provide Resources”. The first four types represent the action, plan, do, check of PDCA cycle respectively, and the last one is to prepare information, resources and engineering standards. In this template as shown in Figure 1, “Manage” activity receives ‘Directives’, ‘Output’ and ‘Requirement’ from hierarchically upper one, and outputs sub-‘Directives’ to “Plan”, “Do” and “Evaluate” activities. These activities are activated according to the sub-‘Directives’, and output ‘Certified Output’ to these locating on their downstream. The ‘Certified Outputs’ received by “Provide Resources” are furthermore informed to “Manage” as ‘Information for Management’. “Manage” approves the results of “Plan”, “Do” and “Evaluate” activities, and outputs ‘Certified Output’ to the upper activity. The “Provide Resources” activity receives ‘Engineering Standards’, ‘Resources’ and ‘Information’, and deliver them to “Manage”, “Plan”, “Do” and “Evaluate” activities. In case of trouble in “Plan”, “Do” and “Evaluate” activities, they output ‘Change Request’ or ‘Requirement for Provide Resources’ to “Manage” via “Provide Resources” activity as ‘Information for Management’. “Manage” activity may decide to inform these requirements to the upper activity.
On the basis of the template, the business process model for plant maintenance was provided as shown in Figure 2. In this model, plant maintenance is considered as one of the engineering stages in lifecycle engineering (LCE). “A0: Perform LCE” is developed into seven sub-activities, i.e. “A1: Manage LCE”, “A2: Plan Performing LCE”, “A3: Perform Process and Plant Design”, “A4: Construct Plant”, “A5: Perform Production”, “A6: Evaluate Performance of LCE” and “A7: Provide Resources for Performing LCE”. The plant maintenance is one of the functions of production, and its activity appears on “Node A5” with “A53: Execute Production”. “A54: Perform Maintenance” is developed into “Node A54”, “Node A542” and “Node A543”, and the “Node A543” is developed into “Node A5432” and “Node A5433” as shown in Figure 2 according the template. By applying this business process model, an incident case of plant maintenance in Japan (Failure Knowledge Database) is analyzed.

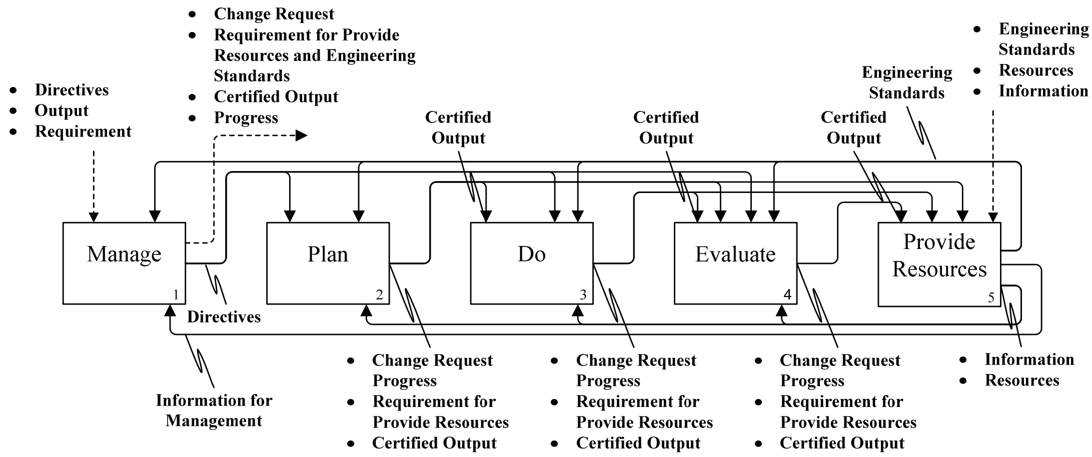

Figure 1: Template for Generalized Business Process Model

3. Incident Case

A construction work on the hydrogen sulfide line of offsite facility was carried out during a shutdown maintenance period in a certain refinery complex in Japan. An isolation valve for a pressure control valve outlet on a branched line from the hydrogen sulfide one to a flare stack was to be repaired, so that the control valve was closed and a blind plate was inserted on a wrong position of inlet of the isolation valve as shown in Figure 3. After inserting the blind plate, instrument air was cut for construction work on this instrumentation airline, and the control valve was fully opened. To inspect the isolation valve, inlet flange of this valve was loosen with the blind plate, and then the toxic hydrogen sulfide was released to the air.
Failure of isolation plan was obvious, but the toxic gas release could be prevented, if safety management in plant maintenance was performed correctly. In the next section, root causes of this incident case within plant maintenance activity are analysed by using the business process model.

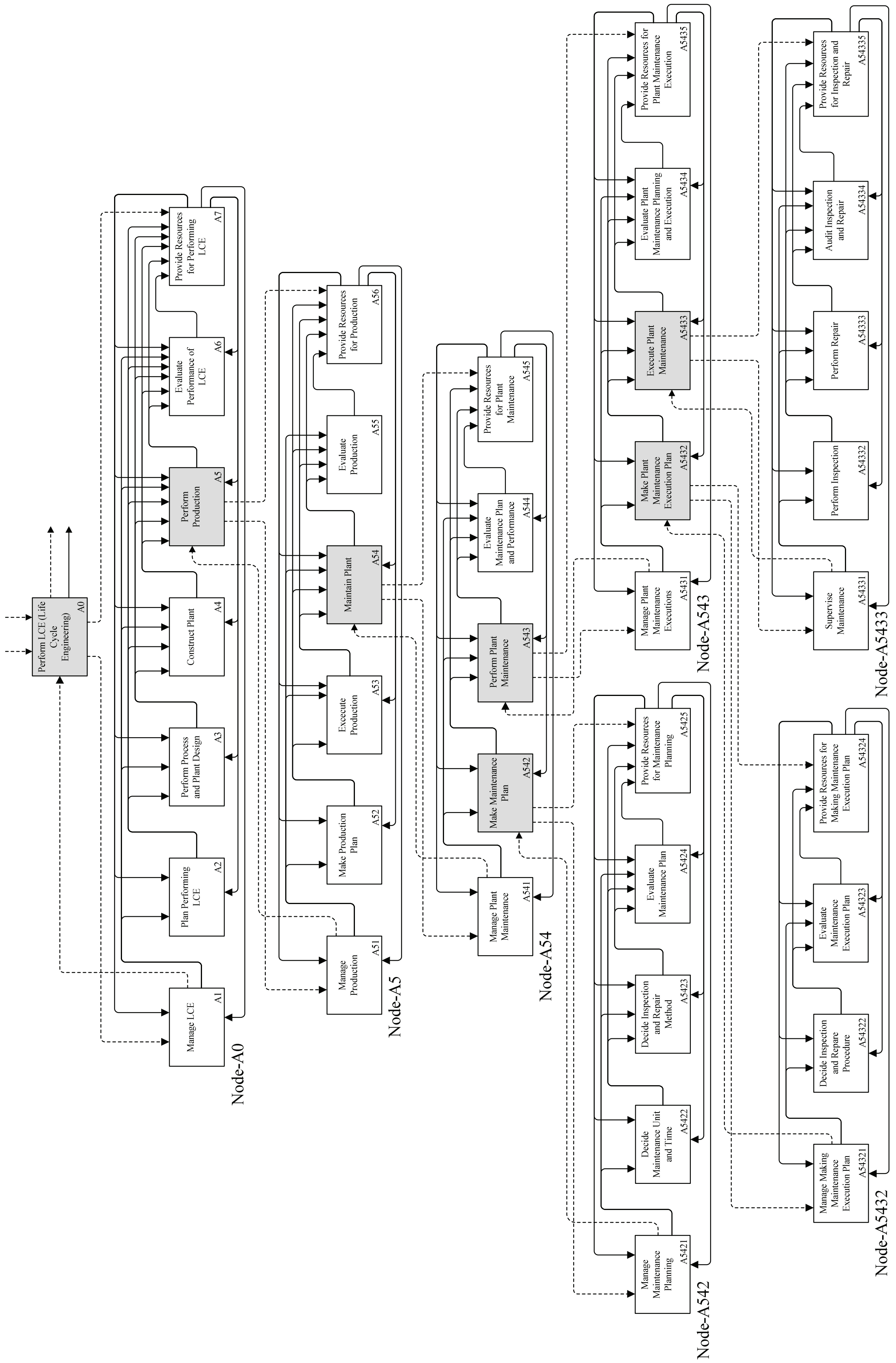

Figure 2: Overview of Business Process Model for Plant Maintenance in Lifecycle Engineering

4. Applying the Business Process Model for Root Cause Analysis

To analyze the root causes, incident case is traced back on the business process model. The analysis is started from the activity in which an incident was actualized. The incident case mentioned above was occurred during construction work for inspection of the isolation valve, so that the analysis is started form "A54332: Perform Inspection" on "Node A5433" as shown in Figure 4. "A54332: Perform Inspection" was performed on the basis of directives from "A54331: Supervise Maintenance", which implied '(1) Directive for Performing Inspection Including Inconsistent Inspection Plan with Inappropriate Isolation Plan'. In performing inspection, safety in inspection work should have been taken care, however, "A54331: Supervise Maintenance" directed inspection work on inappropriate isolation plan. If "A54331" could judge inappropriateness of isolation plan, then this incident did not occur. The engineering standard for supervising maintenance might be insufficient, and '(4) Insufficient Engineering Standard for Executing Plan Maintenance' would be the reason. Besides '(2) Directive for Executing Plan Maintenance Including Inconsistent Inspection Plan with Inappropriate Isolation Plan', "A54331: Supervise Maintenance" should originally output 'Change Request for Inspection Plan and Isolation Plan' and 'Request for Engineering Standard for Supervising Maintenance' for a hierarchically upper activity.

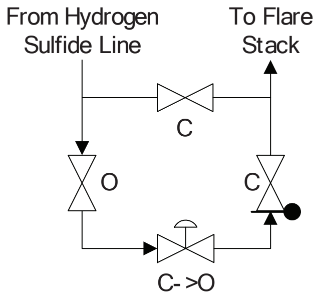

Figure 3: Flow Diagram around the Control Valve

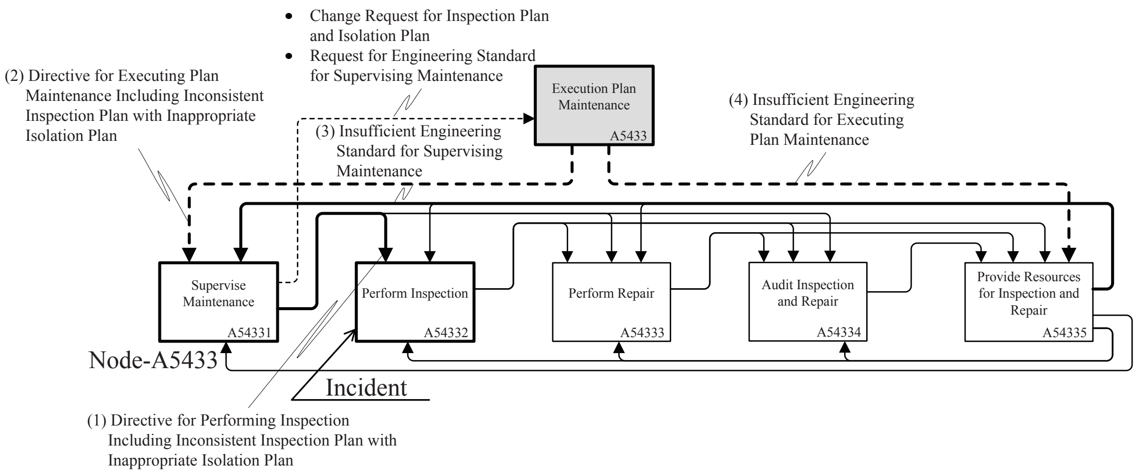

Figure 4: Tracing on Node A5433

The same analysis is carried on Node A543 and A5432 as shown in Figure 5. "A5433: Execute Plant Maintenance" received '(5) Inconsistent Inspection Plan' based on inappropriate isolation plan from "A5432: Make Plant Maintenance Execution Plan". The inconsistent inspection plan was made at "A54332: Decide Inspection and Repair Procedure" on the basis of '(7) Directive for Deciding Inspection and Repair Procedure with Inappropriate Isolation Plan', and was informed to "A54321: Manage Making Maintenance Execution Plan" via "A54324: Provide Resources for Making Maintenance Execution Plan" as information for management. "A54321: Manage Making Maintenance Execution Plan" judged the inspection plan, and certified it. If "A54321" could judge inconsistency of the inspection plan, then this incident did not occur. The error of judgment was caused by '(9) Insufficient Engineering Standard for Management of Making Maintenance Execution Plan' which were included by '(10) Insufficient Engineering Standard for Making Plant Maintenance Execution Plan'. Furthermore, the origin of '(7) Directive for Deciding Inspection and

Repair Procedure with Inappropriate Isolation Plan' was '(8) Directive for Making Plant Maintenance Execution Plan with Inappropriate Isolation Plan'.

The directives for "A5432: Make Plant Maintenance Execution Plan" and "A5433: Execute Plant Maintenance" implied inappropriate isolation plan, and the causes of malfunction in "A5431: Manage Plant Maintenance Executions" were '(11) Insufficient Engineering Standard for Managing Maintenance Executions' which were included by '(12) Insufficient Engineering Standard for Performing Plant Maintenance'. The origin of '(8) Directive for Making Plant Maintenance Execution Plan with Inappropriate Isolation Plan' and '(2) Directive for Executing Plan Maintenance Including Inconsistent Inspection Plan with Inappropriate Isolation Plan' was '(6) Directive for Executing Plan Maintenance with Inappropriate Isolation Plan'.

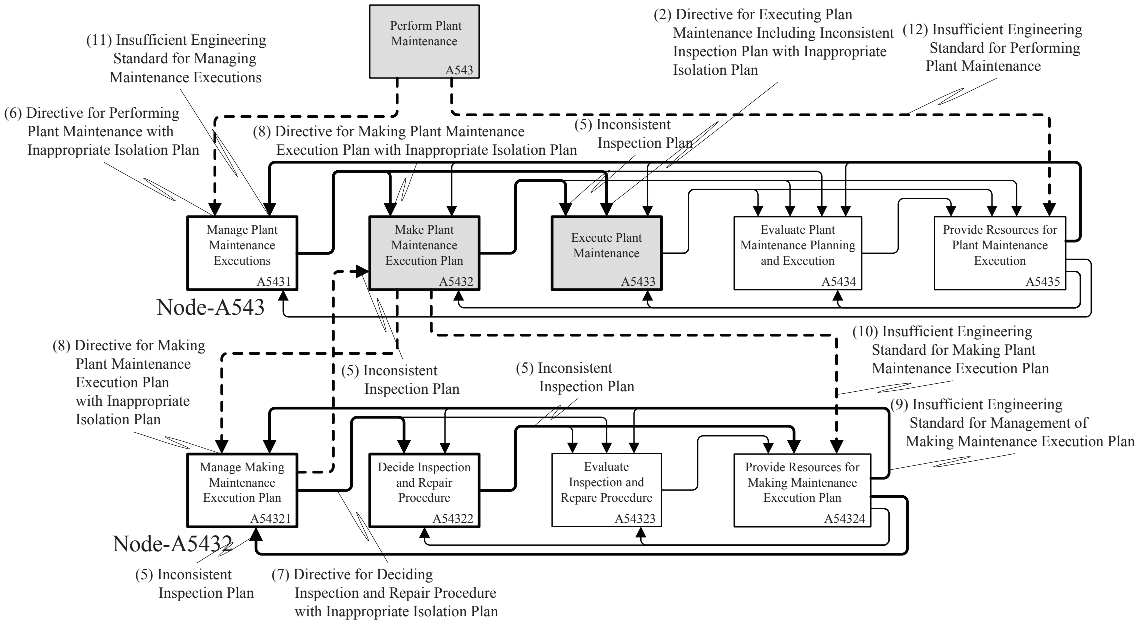

Figure 5: Tracing on Node A543 and Node A5432

Further analysis for Node A54 to A0 is shown in Figure 6. The directive for “A543: Perform Plant Maintenance” implied inappropriate isolation plan, and the cause of malfunction in “A541: Manage Plant Maintenance” were ‘(14) Insufficient Engineering Standard for Managing Plant Maintenance’, which were included by ‘(15) Insufficient Engineering Standard for Maintaining Plant’. The origin of ‘(6) Directive for Executing Plan Maintenance with Inappropriate Isolation Plan’ was ‘(13) Directive for Managing Plant Maintenance with Inappropriate Isolation Plan’.

“A54: Maintain Plant” received ‘(16) Inappropriate Isolation Plan’. This inappropriate isolation plan was made at “A53: Execute Production”, and was informed to “A51: Manage Production” via “A56: Provide Resources for Production” as information for management. “A51: Manage Production” judged the inappropriate isolation plan, and certified it. “A51: Manage Production” provided directives for “A54: Maintain Plant” on the basis of the inappropriate isolation plan. If “A51” could judge inappropriateness of the isolation plan, then this incident did not occur. The error of judgment was caused by insufficient engineering standard for managing production. “A51: Manage Production” should originally output ‘(20) Requirement for Provide Engineering Standard for Isolation’ for a hierarchically upper activity. This requirement information should have been informed to ”A1: Manage LCE” via “A7: Provide Resources for Performing LCE” as ‘(21) Information for Managing LCE’, and ”A1: Manage LCE” should have certify the request.

Consequently, malfunction of the following “Management” activities and insufficiency of engineering standards for these “Management” activities are found to be root causes.

- A54331: Supervise Maintenance
- A54321: Manage Making Maintenance Execution Plan
- A5431: Manage Plant Maintenance Executions
- A541: Manage Plant Maintenance
- A51: Manage Production
- A5: Manage LCE

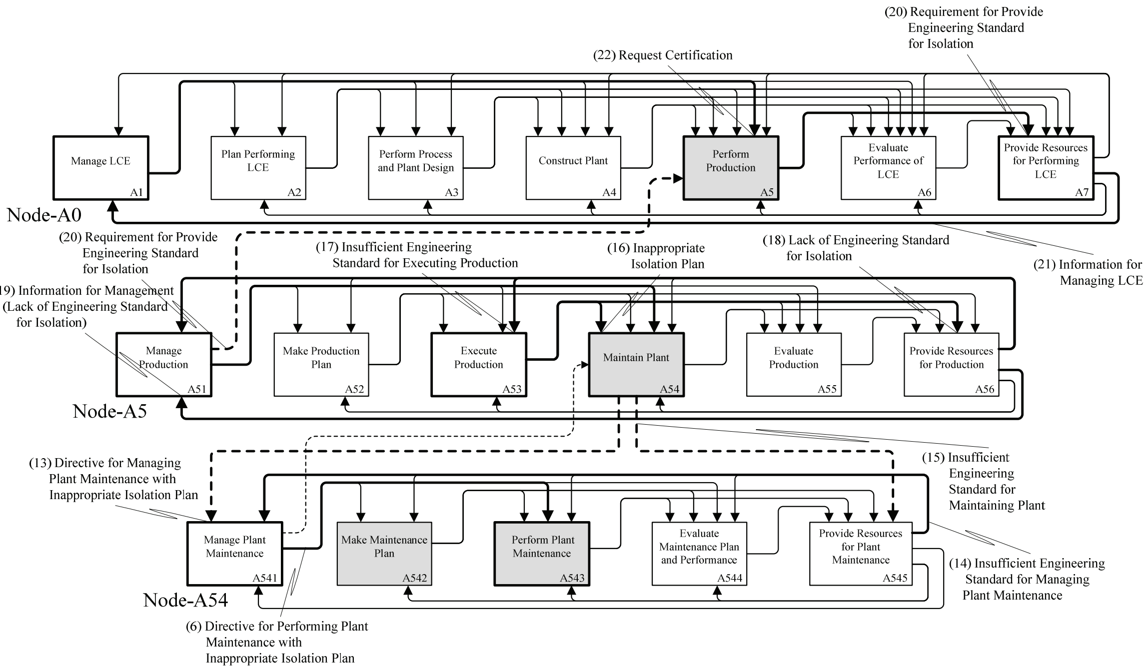

Figure 6: Tracing on Node A54 to Node A0

5. Conclusion

To maintain safety through the lifecycle, learning from the experienced incident is very important, and the root causes of unintended release should be identified. However, when the plant maintenance is concerned, business process of plant maintenance is managed experimentally in general, so that the root causes for unintended release are not identified, and the failure of maintenance activities is kept intact. The authors have developed a generic business process model for plant maintenance as IDEF0 (Integration DEFinition for function model) activity model. To overcome the above problem, business process model based root causes analysis of incidents in plant maintenance is proposed in this study, and an incident case is applied to illustrate effectiveness of this approach.
A large number of Incident reports of chemical industry suggest the three causes; i.e. (a) lack of engineering standard, (b) insufficient sharing of information between engineering stages in lifecycle, and (c) insufficient education. However, these causes are not related with business process of lifecycle, and making appropriate countermeasures is difficult.
The proposed approach, incident case is always traced back on the basis of generalized business process model, and which activity was malfunctioning and/or which information included error can be detected. Therefore, it becomes possible to make appropriate countermeasures for the experienced incident logically.

Acknowledgements

The authors are grateful to the following plant maintenance experts for their cooperation in modeling; Mr. Kazuhiro Hosoda (Fuji Oil), Mr. Shuei Ishii (Kashima Oil), Mr. Hitoshi Shinohara (Tokuyama), Mr. Shinji Takagi (Asahi Kasei Chemicals), Mr. Tsuyoshi Takehara (Toray BSF), Dr. Masazumi Miyazawa (Mitsubishi Chem. Eng.)

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