CHAPTER 5

Solution of the problem

By studying the stated problem, the procedure of project execution is an important factor brings about the failure of project management. Previously, the project management has concerned and controlled in how the project was well managed and organized but has overlooked in what the quality of work should be controlled. The consequence was there were more failures as stated earlier in design phase, equipment procurement phase, and installation phase. It is true that the less the concerned quality, the more problem is occurrence. To overcome such problem, not only well organize and control the project management but also improve the quality of work simultaneously in order to ensure that the quality problem would not incur and affect others project management operations. Quality assurance system, here, is used to determine the QA activity applicable to the item during design, assembly, installation, and commissioning.

Therefore, in this research, researcher will involve the creation of the quality assurance program for making the consistency of the product quality, eliminating the quality problem, and enhancing the existing product quality. Basically, there are more specific tools or methods used for quality improvement and quality assurance system: Brainstorming, Cause and Effect diagram, Pareto, Histogram, Check sheet, and Failure Mode and Effect Analysis, for instance. In chapter 4, Brainstorming technique and Causes and Effects diagram are used to identify the problem incurred in the past projects, hence this chapter will select a suitable tool for the establishment of quality assurance system. Since the data and failures collected from the past project were mostly the subjective data, an appropriately specific technique is Failure Mode and Effect Analysis (FMEA). This specific tool can be applied to assist in establishment of the quality assurance program since FMEA is going to evaluate the existing design and process for possible ways in which whether known or potential failures are able to incur. In addition, it also eases for result assessment and is a team solving technique. The people who involve in the project management for water treatment plant are able to share their experiences either the potential problem, recommended action to prevent and/or to minimize the probability of failure or the effect of failure, or the means to prevent those problems. Basically, there are four types of FMEA comprising Design

FMEA, process FMEA, System FMEA, and Service FEMA. But in this research, FMEA will be focused on design FMEA and Process FMEA only.

5.1 Potential Failure Mode and Effect Analysis (FMEA) Technique

FMEA is an engineering technique applied to assure that the potential failure modes, potential effect of failure, and potential cause of failure have been considered and addressed. This tool also provides the systematic method used to examine the way in occurring of whether known or potential failure.

In identification, each identified failure has been estimated in what its effect on the design and process is, how often it occurs (frequently), and how the difficulty of it to be detected. For each of three elements, it can be estimated in term of level that is integer between one and ten. The severity level from one to ten is meaning that the failure gradually increases from no effect on the process and/or the final product to very slightly effect, then to slightly effect and to hazardous effect at the final. Similarly, the meaning of occurrence level from one to ten is that failure has almost never occurred, a little bit occurs, and some occur until has almost certain occurred. For the detection level, the meaning of level one is failure almost certainly detected whereas the level ten is meaning failure will not or cannot be detected. The result of multiplying among those three elements in each identified failure is called RPN, which is stand for Risk Priority Number.

5.1.1 The Procedure to conducting FMEA

The procedure to conduct the design and process FMEA is initiated from the FMEA team establishment up to brainstorming. FMEA team, of course, is established by selecting people who has involved in the project execution such as design, installation, and service functions. Appropriated team traditionally must be cross-functional and multidiscipline engineer who has skill and experience in the water treatment project. Then, team is trained in order for understanding what the FMEA is, how the FMEA works, and what the advantages of FEMA technique are.

Functional block diagram (see in figure 5.1, page 66) of individual equipment is then provided for the discussion of design FMEA whereas process flowchart is also prepared for the process FMEA discussion. The intention of providing both functional block diagram and process flowchart is to ensure that everyone in FMEA team understanding the design, process and also understanding the problem associated with design and process. In understanding the design and process, team can look on an overview and working model of the relationship and interactions of the design, process components and assemblies

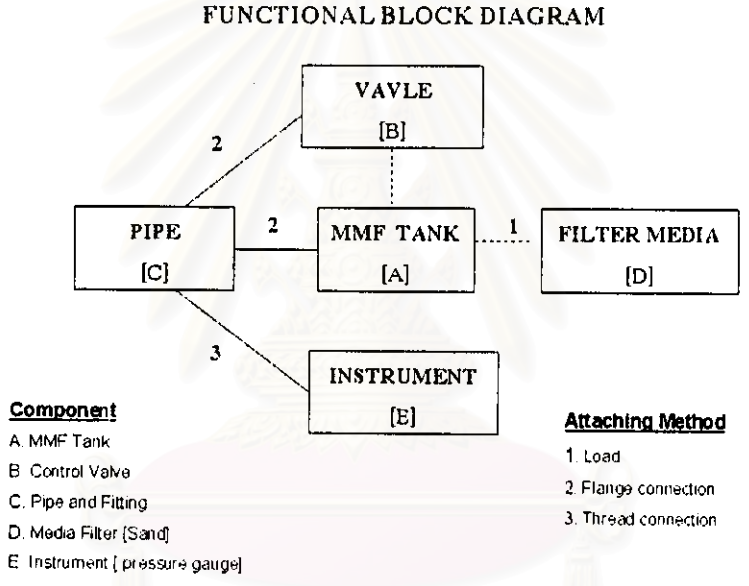

Figure 5.1 Functional Block diagram

With the brainstorming technique and Cause and Effect analysis, data of failure from each process and individual equipment were collected and appropriately categorized by FMEA team. This means that team begins to fill those data in the FEMA form as being the failure modes of the FMEA. Analysis may be qualitative or quantitative. The information of this analysis will be used to fill in the FMEA form in the relationship to the potential effects of failure, current process control, and the estimated severity, estimated occurrence, and estimated detection. In quantifying the number of severity, occurrence, and detection, each ranked number represents the criteria and effect or occurrence of failure.

Next, each RPN value of Design and Process FEMA is calculated by the multiplying among the result of Severity level, Occurrence level, and Detection level (RPN = S x O x D). The result of this calculation is certain integer from '1' to '1,000'.The next procedure is to confirm, evaluate, and measure whether the successful or failure of those results after they have been recorded. There are three basic questions assist in evaluation: Is the situation better than before? Is the situation worse than before? and Is the situation same as before? The learning of the procedure will be used in providing the recommended actions. The outcome of any recommended action is recorded in the FMEA form.

It is noted the FMEA technique is a continuous improvement philosophy, thus the FMEA action is reputably operated to assure the quality of product. However, the goals of improvement are the long-term goal and short-term goal. By mean, the long-term goal is to completely eliminate failures and the short-term goal is to minimize the failures.

5.1.2 The FMEA Team establishment

As the FMEA is a technique that cannot be done individually by any person, FMEA team is an important key of the successfully implemented FMEA. Team, therefore, must be established by selection from multifunctional people in an organization who has the extensive experience or has ever concerned in the water treatment project. In this research, there are five people who work in Engineering department joining as the FMEA team.

Name	Designation	Years of Experience
1. Mr. Pramuk Pimvern	Senior Project Engineer	12 years
2. Mr. Sataporn Lekpolkarn	Senior Service Engineer	10 years
3. Mr. Tawatchai Nawalamlert	Project Engineer	8 years
4. Mr. Wittaya Unprasert	Service Engineer	5 years
5 Mr. Poowanai Pongkaseam	Electrical Engineer	9 years

All people in team have worked in water treatment project as the number of experience shown above and also passed the training course in both overseas and/or domestic. Therefore, their experience and qualification are appropriate for joining in the FMEA team.

5.1.3 Quantifying Severity, Occurrence, and Detection value

FMEA technique was implemented into the current process of water treatment execution, from the first step, receive project requisition, up to the final step, system, commissioning. After the potential failure, potential effect, and cause of the failure for current process were identified and collected, the FMEA team has initiated to quantify the severity, occurrence, and detection value. Table 5.1 up to Table 5.6 are the evaluation criteria for both process and design FMEA that assist team in quantifying those values. Below is the explanation of how the Severity, Occurrence, and Detection value are quantified. However, the quantifying method will be explained only two failure modes since there are more failures mode and all of them are getting in the same way.

5.1.3.1 Receive Project Requisition process

There is a potential failure mode in the process of receiving project requisition that is insufficient information. Design Engineer frequently receives this form and some information for project design. It was found that project sale Engineer mostly records those data by their experience and with the different form. Without the sufficient information, the water treatment project is possibly designed by assuming some data. The consequence is the system might be inoperable and/or require more maintenance. Such failure can lead not only the customer dissatisfaction but also cause the loss of productivity in the customer manufacturing.

5.1.3.2 Study information process

After Design Engineer has received requisition and initiated the design basic process, attached information collected when sale engineer visited the customer is studied. The potential failure from this operation is misunderstanding customer

requirement and design condition. As a result of this problem, the system design cannot operate as requirement, more maintenance required, and certainly make the customer dissatisfaction.

Because of having more potential effect, team has ranked the severity level for this failure at score at 7. However, the occurrence level has been quantified at the score of 3 since this failure is isolated failures associated with similar process. For the detection ranking, an appropriate score according to FMEA team discussion is moderate, ranking 5 because the existing design aided program will control the design condition and the review procedure after design. As a result, the RPN value is equal to 7 x 3 x 5 = 105.

The collected form of process FMEA and design FMEA are shown in Appendix G and Appendix H, respectively.

Effect	Criteria (Severity of Effect)	Ranking
Hazardous Effect.	Hazardous effect. Safety -related--sudden failure. Noncompliance with government regulation.	10
Serious Effect	Potential hazardous effect. Able to stop product without mishap; safety-related; time-dependent failure. Disruption to subsequent process operations. Compliance with government regulation is in jeopardy.	9
Extreme Effect	Customer very dissatisfied. Extreme effect on process; equipment damaged. Product inoperable but safe. System inoperable.	8
Major Effect	Customer dissatisfied. Major effect on process; rework/repairs on part necessary. Product/process performance severely affected but functionable and safe. Subsystem inoperable.	7
Significant Effect	Customer experience discomfort. Product/process performance degraded, but operable and safe. Nonvital part inoperable.	6
Moderate Effect	Customer experiences some dissatisfaction. Moderate effect on product/process performance. Fault in nonvital part requires repair.	5
Minor Effect	Customer experience minor nuisance. Minor effect on product/process performance. Fault does not require repair. Nonvital fault always noticed.	4
Slight Effect	Customer slightly annoyed. Slight effect on product or process performance. Nonvital fault noticed most of the time.	3
Very Slight Effect	Customer more likely will not notice the failure. Very slight effect on product/process performance. Nonvital fault noticed sometimes.	2
No Effect	No effect on product or subsequent process.	1

Table 5.1 Severity effect criteria for Process FMEA

Source Chrysler Corporation, Ford Motor Company, General Motor Corporation, 1995

Probability of Failure	Possible Failure rates	Ranking
Very High : Failure is almost inevitable	≥ 1 in 2	10
	1 in 3	9
High : Generally associated with processes similar to Previous processes that have often failed	1 in 8	8
	1 in 20	7
Moderate : Generally associated with process similar to Previous processes which have experienced occasional Failures, but not in major proportions.	1 in 80	6
	1 in 400	5
	1 in 2,000	4
Low : Isolated failures associated with similar process	1 in 15,000	3
Very Low : Only isolated failures associated with almost Identical process	1 in 150,000	2
Remote : Failure is unlikely. No failures ever associated with Almost identical process	≤ 1 in 1,500,000	1

Table 5.2 Occurrence effect criteria for Process FMEA

Source Chrysler Corporation, Ford Motor Company, General Motor Corporation, 1995

Detection	Criteria : Likelihood the Existence of a Defect	Ranking
Almost Impossible	No know control (s) available to detect failure mode	10
Very Remote	Very remote likelihood current control (s) will detect failure mode	9
Remote	Remote likelihood current control (s) will detect failure mode	8
Very Low	Very low likelihood current control (s) will detect failure mode	7
Low	Low likelihood current control (s) will detect failure mode	6
Moderate	Moderate likelihood current control (s) will detect failure mode	5
Moderately high	Moderately high likelihood current control (s) will detect failure mode	4
High	High likelihood current control (s) will detect failure mode	3
Very High	Very high likelihood current control (s) will detect failure mode	2
Almost Certain	Current control (s) almost certain to detect the failure mode Reliability detection controls are known with similar process	1

Table 5.3 Detection effect criteria for Process FMEA

Effect	Criteria (Severity of Effect)	Ranking
Hazardous Without Warning	Very high severity ranking when a potential failure mode affects safe water treatment operation and/or involves noncompliance with Government regulation without warning	10
Hazardous With warning	Very high severity ranking when a potential failure mode affects safe water treatment operation and/or involves noncompliance with Government regulation with warning	9
Very High	Water treatment inoperable, with loss of primary function	8
High	Water treatment operable, but at reduced level of performance. Customer dissatisfied.	7
Moderate	Water treatment operable, but comfort/convenience item(s) inoperable. Customer experiences discomfort	6
Low	Water treatment operable, but comfort/convenience item(s) operable at Reduced level of performance. Customer experiences some dissatisfaction.	5
Very Low	Small item does not conform. Defect noticed by most customers.	4
Minor	Small item does not conform. Defect noticed by average customer	3
Very Minor	Small item does not conform. Defect noticed by discriminating customer.	2
None	No Effect	1

Table 5.4 Severity effect criteria for Design FMEA

Probability of Failure	Possible Failure rates	Ranking
Very High : Failure is almost inevitable	≥ 1 in 2	10
	1 in 3	9
High : Repeated failures	1 in 8	8
	1 in 20	7
Moderate : Occasional failures	1 in 80	6
	1 in 400	5
	1 in 2,000	4
Low : Relatively few failures	1 in 15,000	3
	1 in 150,000	2
Remote : failure is unlikely	≤ 1 in 1,500,000	1

Table 5.5 Occurrence effect criteria for Design FMEA

Detection	Criteria : Likelihood the Existence of a Defect	Ranking
Absolute Uncertainty	Design Control will not and/or can not detect a potential cause/ Mechanism and subsequent failure mode; or there is no Design Control	10
Very Remote	Very remote chance the Design Control will detect a potential cause/ Mechanism and subsequent failure mode	9
Remote	Remote chance the Design Control will detect a potential cause/ Mechanism and subsequent failure mode	8
Very Low	Very low chance the Design Control will detect a potential cause/ Mechanism and subsequent failure mode	7
Low	Low chance the Design Control will detect a potential cause/ mechanism and subsequent failure mode	6
Moderate	Moderate chance the Design Control will detect a potential cause/ Mechanism and subsequent failure mode	5
Moderately High	Moderately high chance the Design Control will detect a potential cause/ Mechanism and subsequent failure mode	4
High	High chance the Design Control will detect a potential cause/ Mechanism and subsequent failure mode	3
Very High	Very high chance the Design Control will detect a potential cause/ Mechanism and subsequent failure mode	2
Almost Certain	Design Control will almost certainty detect a potential cause/mechanism and subsequent failure mode	1

Table 5.6 Detection effect criteria for Design FMEA

5.1.4 FMEA results and confidential level identification

The result of implemented process FMEA of current water treatment execution is shown in the Table 5.7. And implemented design FMEA is indicated in the Table 5.8. From both tables, the RPN value of each potential failure is sorted and located the highest RPN value on the top of table. In this research and the result of consideration, the confidential level of the selected Risk Priority Number (RPN) is 89.5 percent. The RPN level, therefore, that can be accepted is less than a hundred and five. In calculation, the maximum of RPN is a thousand. It is the result of multiplying among the maximum level of Severity, occurrence, and detection. The eighty nine point five percent of maximum risk priority number Type I error is equal to eight hundred and ninety five. As

a result, a hundred and five comes from the minus between a thousand and eight hundred and ninety five. The considered RPN values are the risk priority numbers which since a hundred and five. In all accepted RPN value, there are some potential failures that the Severity values seem to be high, 7 and 8 value. However, most of those high Severity values are considered and prevented by the proposed quality assurance. For example, the potential failure of design the wrong equipment that had been ranked the Severity value at 8 will be prevented by equipment review checklist.

Step No.	Process	Potential Failure	Sev.	Occur	Detect	R.P.N.
1.1	Receive Project requisition	Insufficient Information	7	8	8	448
4.5	System test run	Failure of installed equipment	8	5	7	280
1.4	Design basic specification	Designed specification has error in calculation	8	4	7	224
4.4	Install control panel and wiring work	Incorrect control panel function	8	4	7	224
4.4	Install electrical control panel	Inappropriate instrument installed and calibration	8	4	6	192
4.2	Equipment installation	Lacking of parts during installation	4	8	5	160
2.3	Design detailed specification	Poor detailed design	4	6	6	144
1.4	Design basic specification	Inappropriate equipment specification is designed	8	2	8	128
2.2	Review proposed system	Failure to detect the deviated customer requirement in contract	8	4	4	128
4.3	Interconnection piping	Inappropriate route of pipe	4	8	4	128
3.3	Select vendor and subcontractor	Select inappropriate subcontractor	6	3	7	126
4.2	Equipment installation	Incorrect position of installed equipment	4	5	6	120
4.2	Equipment installation	Lacking of installation tools	4	6	5	120
3.3	Select vendor and subcontractor	Select poor performance vendor	6	3	6	108
1.2	Study Information	Misunderstanding customer requirement and design condition	7	3	5	105
2.2	Review proposed system	Project schedule and planning is poor monitored and controlled	7	3	5	105
3.5	Receive products	Poor quality of products to be received	7	3	5	105
2.5	Prepare Bill of material	Lack of parts or component	5	3	6	90
3.5	Receive products	Wrong model is delivered	5	5	3	75
2.6	Prepare procurement document	Wrong product model in ordered	7	2	5	70
1.3	Concept design	Design the wrong equipment	8	2	4	64

Table 5.7 Result of conducting process FMEA

Step No.	Process	Potential Failure	Sev.	Occur	Detect	R.P.N.
1.5	Prepare design document	Having some ambiguous data in proposal	5	6	2	60
2.6	Prepare procurement document	Vendor has changed the product model	3	4	5	60
1.4	Design basic specification	Specific equipment cannot work as requirement	8	1	7	56
1.4	Design basic specification	Material used in system has a short life time	5	2	5	50
1.3	Concept design	Design concept failure	8	2	3	48
1.5	Prepare design document and drawing	Insufficient specified information	4	6	2	48
4.5	System test run	Error of equipment function	8	3	2	48
2.3	Design detailed specification	Equipment difficult to operate	5	2	4	40
3.2	Receive quotation	Wrong specification of equipment is quoted	8	1	4	32
4.2	Equipment installation	Plan layout has been changed	4	2	4	32
1.5	Prepare design document and drawing	Error in typing	2	5	3	30
3.4	Release purchase order	Wrong model is ordered	4	2	3	24
3.1	Release request quotation	Wrong equipment model/specification is requested	5	1	2	10

Table 5.7 Result of conducting process FMEA (Continue)

Equipment No.	Equipment	Potential Failure	Sev.	Occur	Detect	R.P.N.
2	Activated carbon filter	Poor quality of treated water	6	5	4	120
3	Water softener	Operating cycle time is short	4	4	7	112
1	Multimedia Filter	Poor quality of treated water	6	3	6	108
1	Multimedia Filter	High differential pressure	5	4	5	100
1	Multimedia Filter	Media filter leakage	6	3	5	90
3	Water softener	Treated water quality higher than specification	5	2	8	80
3	Water softener	Short life time of resin	4	2	8	64
2	Activated carbon filter	High differential pressure	7	2	4	56

Table 5.8 Result of conducting design FMEA

5.1.4 The summation of implemented Process FMEA and Design FMEA

The table below is the consequence of process FMEA for the project execution that includes a potential list of failure modes ranked by RPN, its recommended action. Noted that the high RPN is addressed first and then lower until the lowest RPN of the first confidence level.

Item	Step No.	Process of work	Potential Failure Modes	Recommended Action	RPN
1	1.1	Receive project requisition	Insufficient information used for design	Control the use of modified Customer Requirement Questionnaire	448
2	4.5	System test run	Failure of installed equipment	Establish procedure to review final installation	280
3	1.4	Design basic specification	Designed specification has error in calculation	Establish equipment standard data sheet and reviewed by equipment checklist	224
4	4.4	Installation electrical control panel and wiring	Incorrect control panel Function	Establish checklist for reviewing control panel	224
5	4.4	Installation electrical control panel and wiring	Inappropriate instrument installed and calibration	Establish calibration procedure and checklist	192
6	4.2	Equipment installation	Lacking of parts during installation	Establish procedure to verify installation agreement and prepare material plan	160
7	2.3	Design detailed Specification	Poor detailed design	Establish checklist to verify designed Equipment	144

Table 5.9 Summation of implemented Process FMEA

Item	Step No	Process of work	Potential Failure Modes	Recommended Action	RPN
8	1.4	Design basic specification	Incorrect equipment specification is designed	Establish designed basic specification review checklist	128
9	2.2	Review proposed system	Failure to detect the deviated customer requirement in contract	Establish contract verification procedure and reviewed by checklist	128
10	4.3	Interconnection piping	Inappropriate route pipe	Prepare interconnection drawing and establish interconnecting pipe review checklist	128
11	3.3	Select vendor and subcontractor	Select inappropriate subcontractor	Establish procedure to assessing subcontractor	126
12	4.2	Equipment installation	Incorrect position of installed Equipment	Prepare installation drawing and establish the inspection procedure	120
13	4.2	Equipment installation	Lack of installation tools	Provide installation plan	120
14	3.3	Select vendor and subcontractor	Select poor performance vendor	Establish procedure to assessing vendor	108
15	3.5	Receive products	Poor quality of product to be received	Establish procedure to inspect items	105
16	1.2	Study information	Failure to understand customer requirement and condition of design	Establish customer requirement information review checklist	105
17	2.2	Review proposed system	Project schedule and planning is poor monitored and controlled	Establish the document to monitor and control the project execution	105

Table 5.9 Summation of implemented Process FMEA (Continue)

Item	Designed equipment	Potential Failure Modes	Recommended Action	RPN
1	Activated Carbon Filter	poor quality of treated water	Control the use of design criteria standard and review by checklist	120
2	Water Softener	Operating cycle is short	Control the use of design criteria standard and review by checklist	112
3	Multimedia Filter	Poor quality of treated water	Control the use of design criteria standard and review by checklist	108
4	Multimedia Filter	High differential pressure	Control the use of design criteria standard and review by checklist	100

Table 5.10 Summation of implemented Design FMEA

Table 5.9 and Table 5.10 are the result of Process FMEA and Design FMEA which ranking from the highest RPN to the minimum RPN of the first confidence level, respectively. From the Table above, it was found that there are seven steps of installation process; seven steps of design process, and three steps of procurement process require quality assurance activities. All recommended action comprises the establishment of both action and document to preventing the incurring of failure.

Below are the quality assurance activity for design stage that consist of:

1. The use of Customer Requirement Questionnaire for collecting information and input data for water treatment system design

2. The use of Customer Requirement Information checklist for reminding design engineer to review the critical information in order for understanding the requirements and the nature of information.

3. Preparation equipment data sheet of designed equipment during the design basic specification.

4. Review the design basic specification by checklist in order to ensure that the system and equipment designed are correctly.

5. After the company has awarded the project, the contract verification is the first design quality assurance. This activity is for reviewing the deviation between the purposed system and the contractual requirement

6. Contract verification checklist will assist design engineer to ensure that the contract is completely reviewed and comprehended the critical requirement. The deviation, if any, is listed for discussion with the customer before the detailed design execution.

7. The final quality assurance for design is reviewing detailed design.

For the quality assurance activity for procurement, there are three steps that are explained below.

1. Both assess the vendors and subcontractors' performances are important. This is because the project can be minimized the poor quality of incoming products and the poor performance of subcontractors executions.

2. In addition to assess the vendors performance, to inspect all incoming products is an activity that must be executed. Since the poor quality or defect of product, certainly, cause the project execution has faced the failures.

Seven quality assurance activities for installation stage can be categorized according to theirs characteristics into two operations.

1. The first and important activity is to verify the contract and installation agreement, and then prepare installation document such as drawing. This execution is to ensure that there are not deviation of requirement whether scope of work or equipment specification. In case of having some deviation has been found, to discuss with the customer before the plant installation has started can eliminate the customer dissatisfaction problem.

2. The second is to review the performance of installation work from the placement and installation of all equipment, then the installation of piping system and electrical control panel, up to the completion of system installation. The final execution is to check all condition of equipment in order to ensure that they are ready to test the system function. The checking points cover the position of valves, the direction of water flow, and the tightening of all connections. This completion checking can prevent the failure from poor quality of installation work since any incomplete or wrong installation work will be marked and fixed before passing to the testing operation.

For the procedure of testing and commissioning in installation stage, they can be neglected in this research because there was less effect of failure from such activities in the previous projects. In addition, FMEA team agrees that equipment testing activity is individually executed at the equipment procurement stage. For example, the functional control panel is tested at the subcontractor site before it is delivered and installed at site. However, the improvement of project execution will be developing continuously, and both testing and commissioning activities will be included.

5.2 Proposed seventeen Quality Assurance (QA) activities

The descriptions below are the recommended action and the document created or modified for project execution either for collecting information or checking the operation.

5.2.1 Item 1 : Control the use of Customer Requirement Questionnaire

Used step : Receive project requisition (Step 1.1)

Potential Failure : Insufficient information used for design

Recording information by Customer Requirement Questionnaire form is importantly recommended action to prevent insufficient information for study and design. With different experience of sale engineer and different form used, data collected from customer sometimes was insufficient for basic design, and also was not able to meet the customer requirement. In order to prevent such failure and to make standard of information database, sale engineers are requested to use the existing Customer Requirement Questionnaire [F-PE-002-0] (see Fig.5.2, page 90) for collecting critical data from customer. After implementation, this document will be attached with Service requisition form and pass to engineering department for the pre-award design and make a proposal.

Basically, the following description is the content of Customer Requirement Questionnaire, which is classified according to the subjects into:

1. The general customer information that consist of company name, address, person to contact, and telephone and facsimiles number.
2. The customer supplied information and services that covers characteristic of water to be treated, result of water analysis, available space or location, and available equipment.
3. Specific requirements that describe treated water requirement or required equipment.

The existing questionnaire, which is in form of blanking form, is modified to be the secondary checklist by providing two columns on the right hand side of the second page. These two columns are used to recheck and confirm that the customer requirement both specify in individual item of treated water requirements and individual item of equipment requirements are completely supplied or included in the scope in the proposal. A word "YES" will be filled in the item that proposal has covered this requirement whereas a word "NO" will be recorded in the item that the proposal do not supply or conform with. The next proceeding is returning the proposal back to the design process and adding that loss item or insufficient specification. Until all items are specified "YES", the proposal will be submitted to the customer. On the bottom right hand side of the second page, there is a block used to fill the name of responsible person and the checked date.

5.2.2 Item 2 : Establish procedure to review final installation

Used step : System test run (Step 4.5)

Potential failure: Failure of installed equipment

The recommended action to prevent the failure of installed equipment is to establish the procedure of final equipment installation review. Each equipment, pipeline, instrument, and critical installation point in the plant will be finally reviewed before the individual equipment function test procedure has been started. This is to ensure that all equipment and parts in the plant are completely installed in the correct position, the connection of pipe is jointed or cemented, instrument is properly installed, and also no loosen of electrical wire.

However, this review process will be carried out from the first installed equipment up to the final equipment following the flow diagram. This first checking point for individual equipment is the position of that equipment in the plant, then the completion of pipe connection, then the completion of electrical wiring, and the final checking point is the position of individual valve, either open or close for testing.

F-PE-002-____-0

CUSTOMER REQUIREMENT QUESTIONNAIRE

1. GENERAL

1. Customer Name _____
2. Address _____
3. Name _____
4. Phone _____
5. Facsimile _____

2. CUSTOMER SUPPLIED INFORMATION AND SERVICE

2.1 Water tobe treated

2.1.1 Source of Water _____ (Deep Well, River, Municipal, etc.)

2.1.2 Volume available for treatment (m^3/hr) _____

2.1.3 General Appearance (Color, Clarity) _____

2.1.4 Line Pressure Min. _____ Psig, Max. _____ Psig, Avg. _____ Psig

2.2 Water Analysis

pH			
P Alkalinity	_____ ppm as $CaCO_3$	Silica	_____ ppm as $CaCO_3$
M Alkalinity	_____ ppm as $CaCO_3$	Conductivity	_____ Micro S/cm
Total Alkalinity	_____ ppm as $CaCO_3$	Turbidity	_____ NTU
Total Iron	_____ ppm as Fe	Residual Chlorine	_____ ppm
Manganese	_____ ppm as Mn	Total Solids	_____ ppm
Chloride	_____ ppm as Cl		
Sulfate	_____ ppm as SO_4		
Total Hardness	_____ ppm as $CaCO_3$		
Ca Hardness	_____ ppm as $CaCO_3$		
Mg Hardness	_____ ppm as $CaCO_3$		
Sodium	_____ ppm as Na		

2.3 Available Equipment

Do you have

____ Clarifier ____ Sand Filter ____ Carbon Filter

____ Deiron ____ Softener ____ DI system

____ Others ____ Reverse Osmosis system

Available Product Storage _____

Space Available _____ (m) Length, _____ (m) Width, _____ (m) Height

Equipment Location ____ Indoor ____ Outdoor

Figure 5.2 Customer Requirement Questionnaire

F \ PE \ 002 - _____ - 0

CUSTOMER REQUIREMENT QUESTIONNAIRE

3. CUSTOMER REQUIREMENTS	PROPOSED	
	Yes	No
1. System capacity requireme _____ m^3/hr working hours __ hrs /day	1	
2. Quality requirement		
2.1	2.1	
2.2	2.2	
2.3	2.3	
2.4	2.4	
2.5	2.5	
2.6	2.6	
2.7	2.7	
2.8	2.8	
2.9	2.9	
2.10	2.10	
3. Operation requirement ____ Automatic _____ Manual	3	
4. Additional special requirements	4	
5. Equipment requirements		
5.1	5.1	
5.2	5.2	
5.3	5.3	
6. Schematic		

Checked By
Name
.....
Signature
.....
Checked Date
.....

Figure 5.2 Customer Requirement Questionnaire (Continued)

5.2.3 Item 3 : Establish equipment standard data sheet for and review by equipment checklist

Used step : Design basic specification (Step 1.4)

Potential failure: Design specification has error in calculation

In the current procedure during design engineer carry out the conceptual design and equipment basic specification, there are three standard documents to be released. They include Designed Process Worksheet [F-PE-004-0], printed calculation sheet of computer aided design program (if any), and Engineering Design Worksheet [F-PE-005-0]. Designed process worksheet is a preliminary design worksheet drawing out the process and equipment package step by step in producing water quality from raw water up to the final water quality requirement. It also indicates capacity of individual equipment package and total system, type of necessary instruments, and pipe size. Engineering Design Worksheet is a blank document used for calculation detail. It maybe the calculation process to find out the chemical dosing requirement or consumption, the calculation of filter media requirement, or the pipe diameter calculation. For both computerized worksheet and engineering designed worksheets, they show the result and detail of calculation in term of quantity, equipment or component model, and some specific design criteria. However, this operation was found that designed specification has easily error in calculation and there maybe some critically designed criteria did not be identified and considered in those sheets. Moreover, those failures have severity effect and difficult to detect.

In order to ensure that the error in calculation and the loss of criteria description is prevented, equipment standard datasheet [F-PE-006-0] (see Fig 5.3, page 93) of individual equipment is completely created to use for collection the result of designed calculation. Equipment data sheet also serves as a guideline to ensure that crucial criterion are considered. Furthermore, the failure or problem can be traceable whenever it occurs by exploring the designed criteria or result in this sheet. In each data sheet, specific criterion of design is indicated. Design engineer will fill the result of designed calculation into the items mostly in term of the number. Anyway, individual designed data sheet will be reviewed at the activity of design output reviewing in order for ensuring that designed criteria of any specific equipment is in the limitation of practical operation. In case of having over limited specification, such item will be immediately

rectified. Finally, design check sheet of individual equipment package is also created for final checking.

F-PE-006-0

MULTIMEDIA FILTER
DATA SHEET

		SPEC	CHECKED	APPROVED
CLIENT				
PROJECT NAME				
PROJECT No.				
LOCATION		REV	BY	DATE
EQUIPMENT NAMES	*Multimedia Filter*			
INQUIRY No				
TAG No.				
P&ID No.				
QUANTITY TOTAL	WORKING / STAND BY			

SYSTEM DATA	
Type	
Operating System	*Automatic*
VESSEL DATA	
Dimensions	
- Diameter (mm)	
- Overall Height (mm)	
Internal Pressure	
- Design (Barg)	5
- Test (Barg)	7.5
Thickness	
- Sheel (mm)	
- Top Head (mm)	
- Bottom Head (mm)	
Internal Liner	
- Material	*See Specification*
- Total Thickness (mm)	*See Specification*
- Microns (dry)	*See Specification*
INTERNALS DATA (TYPE AND MATERIALS)	
Inlet Distributor	
Regenerant Distribution	
Intermediate Collector	
Underdrain Collector	
MEDIA	
Type :	Strong Acid Cation Resin
Manufacturer	
Exchange Capacity (eq/l of resin)	2
WATER DATA	
Inlet water hardness (ppm as $CaCO_3$)	
Outlet water hardness (ppm as $CaCO_3$)	
GENERAL DATA	
Indoor or Outdoor Installation	*Outdoor*
Electrical supply for control	*24 VDC/AC*

OPERATING CONDITION	
Flow Capacity (per column)	
- Normal (m^3/hr)	*12*
- Allowed max. (m^3/hr)	
Linear Velocity	
- Normal (m^3/hr)	
- Allowed max. (m^3/hr)	
Resin Volume (per column, litre)	
Bed Depth	
- Depth (mm)	
- Bed Expansion (%)	
Pressure Drop	
- Normal (kg/cm^2)	
- Allowed max. (kg/m^2)	*0.5*
Exchange Capacity (equivalent)	
(per column)	
Max. Capacity per cycle (m^3)	
(At specified exchanged hardness)	
Regenerate	
- Dosage (kgs NaCl/m^3 of resin)	*150*
- Per Cycle (Kgs)	
Hardness Leakage (ppm as $CaCO_3$)	
Regeneration Flow Rate	
- Backwash (m^3/hr)	
- Regen (m^3/hr)	
- Fast Rinse	
- Slow Rinse	
Regeneration Time	
- Backwash (min.)	
- Regen (min)	
- Fast Rinse (min.)	
- Slow Rinse (min)	
Inlet Water Pressure : Min./max (barg)	*2.0/3.0*

REMARKS

Figure 5.3 Equipment data sheet

5.2.4 Item 4 : Establish checklist for reviewing control panel function

Used step : Installation electrical control panel and wiring (Step 4.4)

Potential failure: Incorrect control panel function

There are two parts in this checklist [F-PE-027-0] (see Fig 5.4 and Fig.5.5, on page 95 and page 96): electrical control panel review checklist and cables and connection review checklist. The first part is established to review the correction of functional control that normally to be done at electrical subcontractor site before delivery to install at site. For the second part, it is created to verify the completion of cabling and wiring in order to ensure that it will not cause the wiring problem. In verification the function, all functions will be tested step by step from the first equipment up to the final equipment. Basically, there is an indicating lamp for individual function, so it is easily to verify that whether correct or incorrect of the function being check.

5.2.5 Item 5 : Establish instrument calibration procedure and checklist

Used step : Installation electrical control panel and wiring (Step no. 4.4)

Potential failure: Inappropriate instrument installed and calibration

Since the performance of equipment package and entire system can be showed by the quality of treated water detected and monitored by instruments, the accuracy of instruments is an important matter. Therefore, the procedure to calibrate of each instrument must be prepared before they are installed. In addition, a checklist [F-PE-028-0] (see Fig 5.6, on page 97) is provided to confirm that they will be completely and appropriately calibrated.

ELECTRICAL CONTROL PANEL REVIEW CHECKLIST

CUSTOMER : *TMC*

COMPLETION DATE

ITEM	QUESTION	YES	NO	REMARKS
1	Are controls standardized?			
2	Are controls sequentially positioned?			
3	Is control spacing adequate?			
4	Is control labeling adequate?			
5	Have the proper control/display relationship been incorporated?			
6	Are the proper type of switches used?			
7	Are the controls placed according to frequency of used?			
8	Is the control panel lighting adequate?			

Checked By .....

Figure 5.4 Electrical control panel checklist

CABLES AND CONNECTION REVIEW CHECKLIST

CUSTOMER : *TMC*

COMPLETION DATE

ITEM	QUESTION	YES	NO	REMARKS
1	Are cable fabricated in removable section?			
2	Are cable routed to avoid sharp bends?			
3	Are cable routed to avoid pinching?			
4	Is cable labeling adequate?			
5	Is cable clamping adequate?			
6	Are connectors of the quick-disconnected variety?			
7	Are connectors and receptacles keyed?			
8	Are connectors and receptacles labeled?			
9	Are connectors standardized?			
10	Do the connectors incorporate provision for moisture preventation?			
11	Are connectors that are mounted on surfaces far enough apart so that they can be firmly grasped for connecting and disconnecting?			

Checked By .....

Figure 5.5 Cables and connection review checklist

INSTRUMENT CALIBRATION REVIEW CHECKLIST

CUSTOMER : *TMC*

COMPLETION DATE

ITEM	QUESTION	YES	NO	REMARKS
1	Have calibration requirement been held to minimum?			
2	Are standards available for calibration?			
3	Are calibration procedure prepared?			
4	Are which instrument is required calibration known?			
5	Have the facilities for calibration been identified?			

Checked By .....

Figure 5.6 Instrument calibration checklist

5.2.6 Item 6 : Establish procedure to verify installation agreement in contract and prepare material requirement plan

Used step : Equipment Installation (Step no. 4.2)

Potential failure: Lacking of parts during installation

The lack of parts or items during equipment installation is a potential failure that can be prevented by establishment the contract verification procedure and modifies the Bill of Material to be the material requirement (see Figure 5.7, page 100). In modification, the used date of material will be scheduled conform to the project schedule master plan. Site engineer has responsible to explore this plan everyday and to make a store issue voucher to order the items that will be used on the day after tomorrow. By this plan, items and parts is prepared before it will be used at least three days. Detail of parts and items described in the plan covers type, model, quantity, material, manufacturer, and date required.

However, at the beginning of the project and before the preparation of this plan, it is necessary for site manager and concerned person to verify an installation part of the whole contract. The subjects to be verified consist of installation requirement, Specification and Standards, material, tools, installation process, inspection and test, and commissioning.

- Installation requirement

The objective of this function is to imply a detailed consideration of the installation requirements and to verify that all involved personnel understand the requirements for the planning of installation.

- Specification and Standards

Since the Standards, basically, to be used in the water treatment will be Metric (SI) and American Standard (US), this function is performed to confirm that all applicable specifications and standards will be available to the installation staffs and of the correct issue. Unfortunately, in case of there is any shortage or ambiguous specification, the solution should be overcome before the installation activity commences.

- Material

This review is carried out to ensure that the correct materials and equipment are available and that such are suitably identified. However, in case of having the unassembled units, individual part of unit will be considered to provide match-mark in order to facilitate installation and to avoid the redo all the work to rectify the fault since there was an error in wrong location installation.

- Review tools

Tools that will be used in the project should be considered that whether the need for special installation tools or not. If there is any requirement, specialized tool will be purchased or hired.

- The installation process

Installation process will be considered that the special processes is whether required or not.

- Inspection, test, and commissioning requirement

To developing the plan for inspection, test, and commissioning, any special requirements imposed by the contract will be considered. This is because the way to arrange specialized testing and/or commissioning equipment either purchase or hire will be considered.

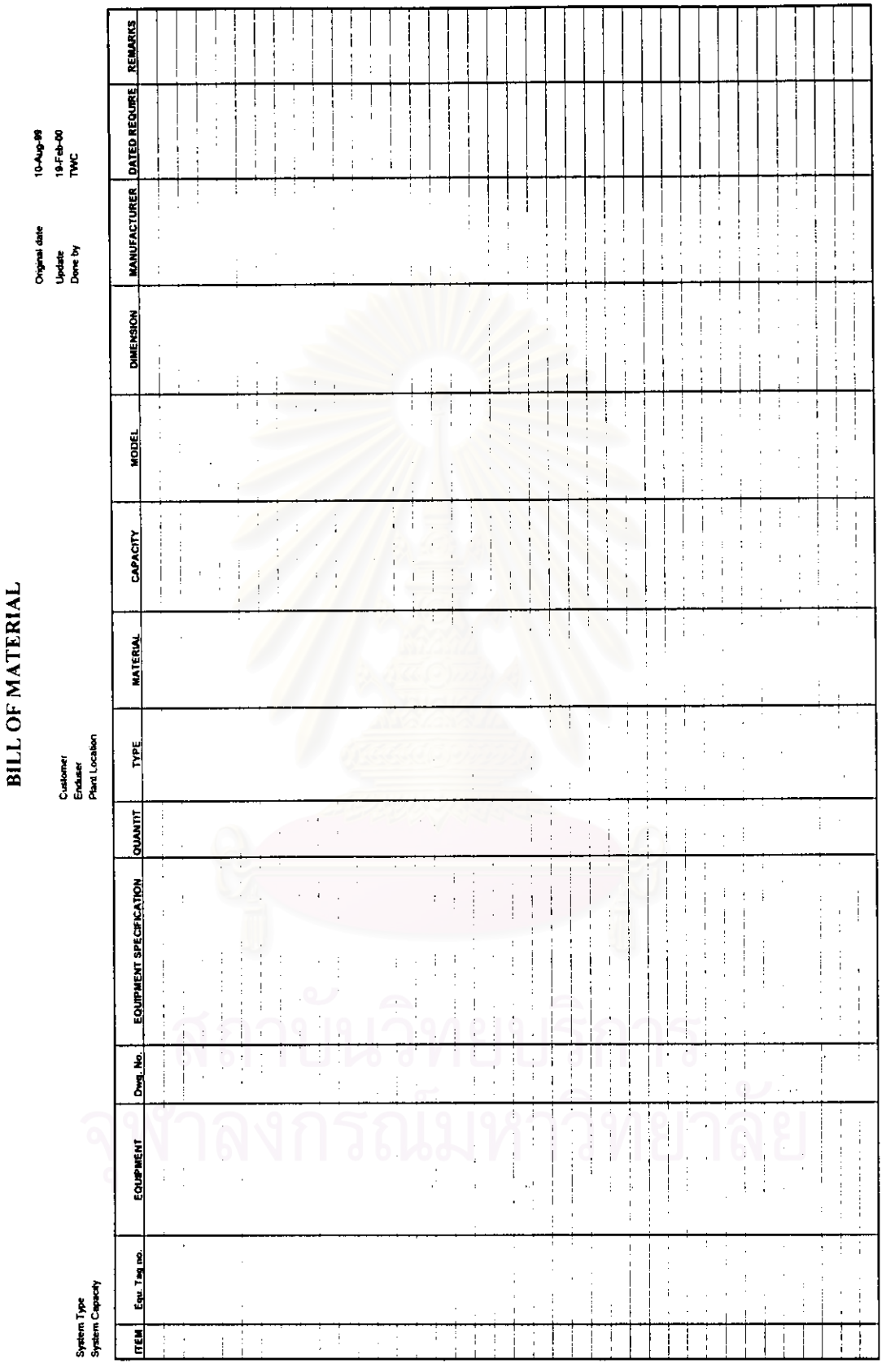

Figure 5.7 Bill of Material

5.2.7 Item 7 : Establish checklist to verify the designed equipment

Used step : Designed detail specification (step2.3)

Potential failure: Poor detailed design

This activity is to establish the checklist [F-PE-022-0] (see Fig 5.8, page 102) for reviewing detailed design system and equipment in order to ensure that designed output would meet the customer requirements and conditions, would be adequately for further installation process. In verification, this checklist serves as a guide to remind the critical and important point of detailed specification: for example, the connection type of designed valve and type of pipe or the material of equipment used for specific system.

5.2.8 Item 8 : Establish designed basic specification review checklist

Used step : Design basic specification (step 1.4)

Potential failure: Incorrect equipment specification is designed

In order to ensure that the designed basic specification would not has any designed criteria out of limitation or incomplete information and would meet the customer requirement, it must be reviewed by designed basic specification review checklist [F-PE-020-0] (see Figure 5.9, page 103) before proceeding cost estimation and proposal preparation. In case of having any incorrect designed criteria or incomplete specification, it would cause not only the project cost exaggerated estimation but also the proposal has ambiguous specification. The intention of this review is to confirm and to assure that the conceptual design is appropriately to meet the customer requirements and basic criteria of each equipment package are in the limitation. Thus, review checklist will be provided and used for both checking of the concept design and of equipment checklist. However, checklist should be provided for only equipment, which has more criteria to be considered, in order for saving time of reviewing; for example, the checklist for multimedia filter, activated carbon filter, and water softener.

DETAILED DESIGN REVIEW CHECKLIST

CUSTOMER : *TMC*

COMPLETION DATE

ITEM	QUESTION	YES	NO	REMARKS
1	Is detailed design completely met customer requirement conditions?			
2	Is detailed design met Regulatory?			
3	Is the standard of valve connection compatible with pipe standard?			
4	Have the function of individual equipment been identified?			
5	Are Standard and Codes of designed equipment compatible among the others equipment?			
6	Are the thickness of steel vessel adequate?			
7	Are equipment specification designed base on the customer requirement?			
8	Is the standard of pipe and fitting selected conforming to customer requirement?			
9	Is the material of equipment appropriately designed?			
10	Is there the basic designed for equipment?			

Checked By .....

Figure 5.8 Detailed design review checklist

DESIGN BASIC SPECIFICATION CHECKLIST

CUSTOMER : ***TMC***

COMPLETION DATE

ITEM	QUESTION	YES	NO	REMARKS
1	Has designed system been met customer requirement ?			
2	Is designed system meet regulatory ?			
3	Are the designed equipment in system currently available?			
4	Is the designed capacity of each equipment adequately for system?			
5	Is the capacity of system met the requirement ?			
6	Is the scope of requirement completely met ?			
7	Are all equipment data sheet reviewed the design criteria?			
8	Are all water quality requrements met by deisgned system?			
9	Are all equipment requirement specified in the designed system?			
10	Are there equipment data sheet support individual designed system?			
11	Have the equipment specification or catalog support individual designed equipment and component?			
12	Are the catalog or specification document updated with suppliers?			
13	Is each equipment package system verified the design criteria by equipment checklist?			

Checked By _____

Figure 5.9 Basic specification review checklist

5.2.9 Item 9 : Establish contract verification procedure and review by checklist

Used step : Reviewed proposed system (Step 2.2)

Potential failure: Fail to detect the deviated customer requirement in contract

Contract verification is an activity that carrying out to improve the performance and to prevent the failure in reviewing proposed system because the major subjects and points in contract will be carefully reviewed. In addition, the deviated requirement will be found at this step, if there is any. With the contract verification procedure, project engineer will clearly understand the nature of the project, requirements, scope of work and supplied equipment, and the means to make the project successful. In addition to the earlier mentioned point reviewed in the contract, Standards and Specifications and Design criteria are main scope to be verified. However, design criteria has already been reviewed and checked by equipment package checklist after the detailed specification design. In order to ensure that the contract verification procedure is appropriately carried out, contract verification review checklist is created to use as a guide for project engineer. The figures 5.10 on page 105 to page 106 are a contract verification review checklist.

5.2.10 Item 10 : Prepare interconnection drawing and Establish Interconnecting pipe review checklist

Used step : Interconnecting piping (Step 4.3)

Potential failure: Inappropriate route pipe

After the completion of equipment installation, piping system is initiated to interconnect among equipment. In order to prevent the failure, inappropriate of piping route, the requirement for interconnecting drawing will be prepared. In such drawing, the route of pipe, material, and specific fitting is clearly indicated. However, while interconnecting pipe is installed and after completely installation, the procedure to reviewing will be done by established interconnection pipe review checklist [F-PE-026-0] (see Fig 5.11, page 107).

CONTRACT VERIFICATION CHECKLIST

CUSTOMER : *TMC*

COMPLETION DATE *05-July-1999*

ITEM	RELATED ITEM	QUESTION	YES	NO	REMARKS
1	Specification and Standards	Is the quantity of proposed items equal to contractual requirements?			
2		Is the specification of proposed system same as of contractual requirement ?			
3		Are all applicable Specifications and Standards readily available at all activity locations (e.g design stage and installation stage) ?			
4		Is the shortfall or ambiguities or incompleteness specification and Standard appropriately resolved ?			
5		Are the contractual requirements able to meet ?			
6	Scope of Work	Is the work scope of contractual requirement same as of proposed?			
7		Is the scope of work fully able to understand by all concerned?			
8	Regulatory requirement	Is there any regulatory authority involved regarding safety or environmental requirement?			

Page 1 of 2

Checked By .....

Figure 5.10 Contract verification review checklist

CONTRACT VERIFICATION CHECKLIST

CUSTOMER : *TMC*

COMPLETION DATE

ITEM	RELATED ITEM	QUESTION	YES	NO	REMARKS
9	Design Criteria	Are they all available and understand ?			
10	Materials	Are the materials and equipments available ?			
11	Tools	Is the common tools required for installation process of contractual requirement ?			
12	Installation process	Is the standard installation process required for the contractual requirement ?			
13	Organization	Is the organization structure established for and installation stage ?			
14		Is the contractual requirement able to be met by the company's resource ?			
15	Inspection plan	Is the inspection plan for special requirements imposed by contract developed ?			
16	Test plan	Is the test plan for special requirement imposed by contract developed ?			
17	Commissioning plan	Is the commissioning plan for special requirement developed ?			
18	Warrantee	Is the warantee and guarantees of contractual requirement able to be met ?			

Page 2 of 2

Checked By .....

Figure 5.10 Contract verification review checklist (Continued)

INTERCONNECTING PIPE REVIEW CHECKLIST

CUSTOMER : *TMC*

COMPLETION DATE

ITEM	QUESTION	YES	NO	REMARKS
1	Is the routed pipe conform to the original drawing?			
2	Are all components correctly installed at the identified point?			
3	Are all pipe supports installed every 1 meter as indicating in drawing?			
4	Have all check valves been installed in the correct direction?			
5	Is the pipe support fixed at both end sides of all valves?			
6	Is instrument fitting correctly installed?			
7	Is the connection of pressure gauge and fitting standardize?			
8	Have all connection points between pipe and fitting been cemented?			
9	Are all bolts and nuts tightening?			
10	Has the position of hole drilling for fastener safety for the others items?			
11	Has the walk-over been installed at the area of more intersection pipes?			
12	Has the arrow been sticked on the pipe to indicate the direction of flow?			
13	Have all equipment been identified the tag number?			

Checked By .....

Figure 5.11 Interconnecting pipe review checklist

5.2.11 Item 11 : Establish procedure to assessing subcontractor

Used step : Select vendor and subcontractor (Step 3.3)

Potential failure: Select inappropriate subcontractor

The procedure to evaluate the subcontractor is carried out by using the document of subcontractor historical records. The recorded information of subcontractor emphasizes the frequent of maintenance of fabricated equipment, the performance of the equipment, and the delay of delivery problem. However, the subcontractor who will be assessed must be in the approved subcontractor list of company.

If a subcontractor, who has already in the approved subcontractor list, has frequently made poor quality of equipment or supplied the fabricated equipment that sensitive for the quality of work in process and finished products, the procedure of inspection during fabrication will be done for that subcontractor. However, it depends on the necessity and serious of that equipment.

5.2.12 Item 12 : Prepare installation drawing and establish inspection procedure

Used step : Equipment installation (Step 4.2)

Potential failure: Incorrect position of installed equipment

In order for prevention the failure from incorrect position of installed equipment, installation drawing will be developed to show where individual equipment is installed. In the past project installation drawing used for equipment installation was plan layout only. The problem found during installation was there was no position of individual component shown in the drawing. It caused installation people to install any component by his experience. As the results, there have frequently found the wrong position of component to be installed. This improvement of installation drawing is to document the unique identification number, symbol, and material of component and pipe on the drawing.

An inspection procedure for equipment installation is, in all probability, required for both during installation and completion of the installation. Inspection for in-process inspection is required in order to ensure that the present work conforming the plan and

drawing. The document required for these inspection procedures is an inspection plan, which indicate the points of inspection, the type of acceptance, and a period of inspection per any point. For in-process inspection plan, the points of inspection should be the area that installer team can cease for verifying the acceptance of those given points. In case of the defect from installation is found warning label is suddenly created and fixed on that point, and define the solution for a responsible person to rectify it.

5.2.13 Item 13 : Establish installation plan

Used step : Equipment installation (Step 4.2)

Potential failure: Lack of installation tools

In the entire project schedule, equipment installation activity has already been explained (only the schedule of equipment to be installed). Installation plan [F-PE-019-0] (see Fig 5.12, page 110), therefore, will be established to emphasize on the others requirement including installation tools required, equipment installation procedure, special tools, and heavy machine required for the large-scale equipment.

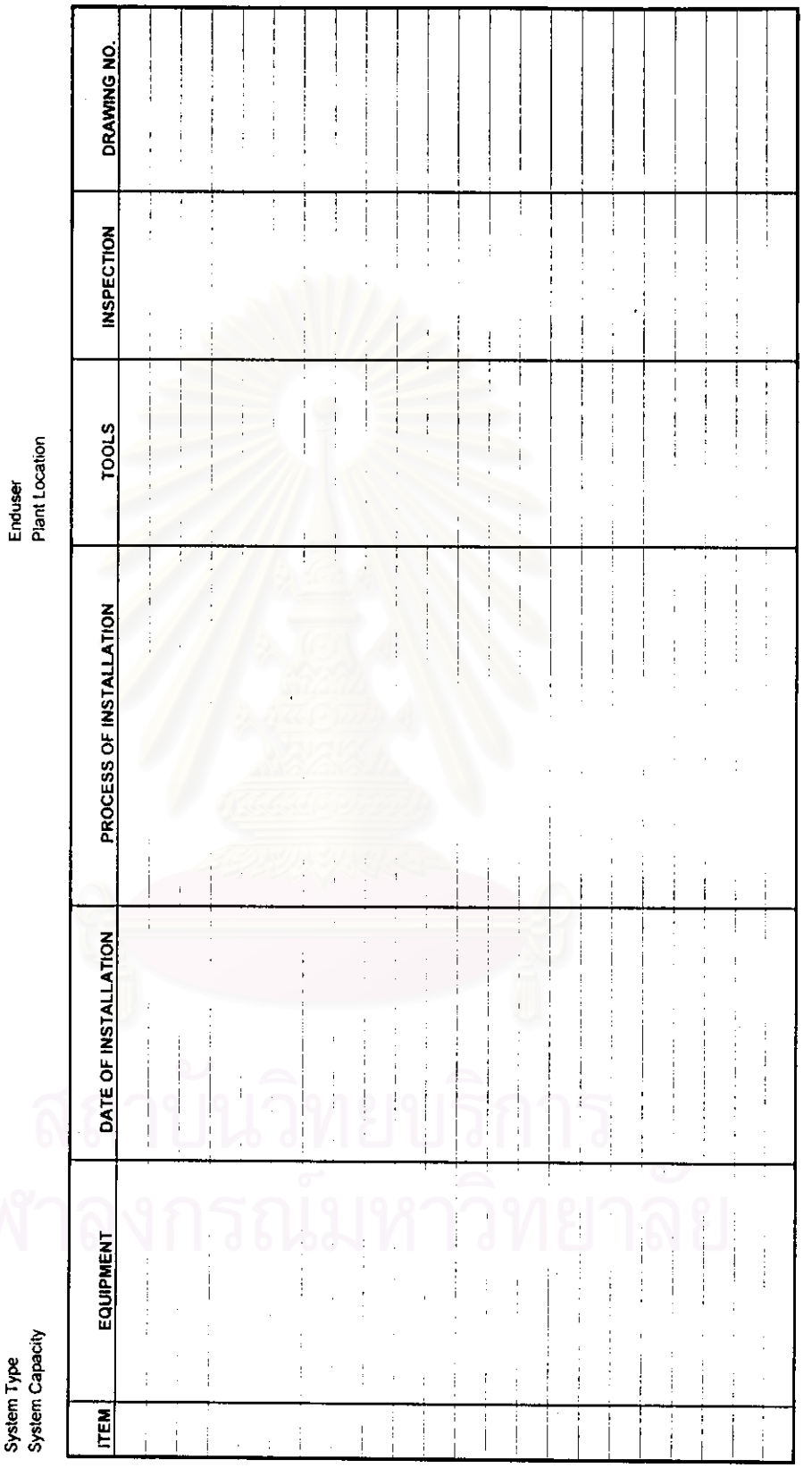

Figure 5.12 Installation plan

5.2.14 Item 14 : Establish procedure to assessing vendor

Used step : Select vendor and subcontractor (Step 3.3)

Potential failure: Select poor performance vendor

As well as subcontractor assessment procedure, the performance of vendor will be evaluated by the standard criteria. They basically are historical records that emphasize the record of poor quality of products have frequently been received, the severity of poor quality of products, and the delay of delivery. The approved vendor list will be the first screen for cutting poor quality vendors. Therefore, the procedure of vendor quality survey is an important mean to ensure the quality of vendors. The responsible people involving in this evaluation is comprised project manager, project engineer, and purchaser.

However, in case, the vendor who is in the approved vendor list has frequently delivered poor quality or supplied the products that sensitive for the quality of work in process and finished products, it might be prepared the supplier audit process. It might be to visit and review the product quality at vendor manufacturing.

5.2.15 Item 15 : Establish procedure to inspect items

Used step : Received products (Step 3.5)

Potential failure: Poor quality if product to be received

This activity is carried out to examine the acceptability and condition of received items by checking quality, identity, and also detecting the damage caused during transportation. The result of examination will be recorded in quality checking standard document and informed back to the vendors and/or subcontractor in case of quality problem has been found. Moreover, the results of failure found such as show often the equipment found the defect and what kind of defect were recorded and considered as criteria for assessment of the next project. In inspection product, purchasing order and/or packing list of overseas product are used as primary checking document. Finally the procedure to inspection both items will be set out. Since purchased items comprise both bought-out item and domestically fabricated items, the procedure and place to inspecting both items is differently. Bought-out equipment, which mainly are finished

products, is inspected on arrival whereas fabricated equipment can be inspected both during fabricating, finishing, and installing in order to prevent the defect that can be corrected at that time of meeting.

1. Bought-out equipment inspection [F-PE-023-0] (see Fig 5.13)

INSPECTION AND TEST PLAN - for Bought - out equipment

Project No. **Date**
Equipment *WATER PUMP* **Tag No.**

Inspection Point No.	Inspection Description	Inspection Characteristic To be verified	Acceptance Criteria	YES	NO	Remarks
1	Quantity					
2	Manufacturer					
3	Model					
4	Material					
5	Pipe connection					
6	Motor power					
7	Motor voltage					
8	Alignment					
9	Appearance					

Inspection person

Site Engineer _____ **Date :** _____
Store _____ **Date :** _____

This equipment follow quotation no. ..... Date .....

Figure 5.13 Bought –out Inspection checklist

2. Domestically fabricated equipment inspection

As state above, the fabricated equipment will be inspected either during fabricating or before installation. In making an inspection plan [F-PE-024-0] (see Fig 5.14, page113), inspection point should be determined and inspection requirements of each specified inspection point will be detailed. The details of any required special equipment and qualify experienced inspector will be indicated as well. Furthermore, the acceptance and/or rejection criteria will be indicated

INSPECTION AND TEST PLAN - for Assembled Equipment

Project No. **Date**

Equipment *WST Steel Tank* **Tag No.**

Inspection Point No.	Inspection Description	Inspection Characteristic To be verified	Acceptance Criteria	YES	NO	Remarks
1	Diamension					
2	Type of support					
3	Welding					
4	Lug					
5	Inlet and Outlet					
6	Painting					

Inspection person

Site Engineer ..... **Date :** .....

Store ..... **Date :** .....

This equipment follow quotation no. ..... Date .....

Figure 5.14 Assembled Equipment Checklist

5.2.16 Item 16 : Establish Customer Requirement information review checklist

Used step : Study information (step 1.2)

Potential failure: Failure to understand customer requirement and condition of design

This checklist [F-PE-019-0] (see Fig. 5.15, page 114 to page 115.) is created to help design engineer in reminding and ensuring that critical information such as customer requirement and supplied-information (raw water quality) are completely studied and understood. This is to prevent the potential failure either misunderstands customer requirement or condition of design or the poor performance of designed system.

CUSTOMER REQUIREMENT INFORMATION CHECKLIST

CUSTOMER : *TMC*

COMPLETION DATE

ITEM	QUESTION	YES	NO	REMARKS
1	Is the raw water analysis fully described and reviewed the nature of the water?			
2	Is the capacity of system requirement reviewed?			
3	Is the water resource and water quality compatible?			
4	Is the scope of customer supplied verified?			
5	Are there any customer supplied drawing, sketches, or plan? If yes, Are those document clearly understood?			
6	Is the plant location reviewed?			
7	Is the scope of work reviewed and understood?			
8	Is the scope of supplied equipment reviewed and understood?			
9	Is the requireed system operation reviewed and understood?			
10	Are the treated water quality verified and able to meets?			
11	Are the treated water quality required compatible with the system required?			
12	Is the company able to supply the equipment brandname as the customer requirements?			

Page 1 of 2

Checked By .....

Figure 5.15 Customer Requirement Information review Checklist

CUSTOMER REQUIREMENT INFORMATION CHECKLIST

CUSTOMER : *TMC*

COMPLETION DATE

ITEM	QUESTION	YES	NO	REMARKS
13	Can all required equipment and scope of work be supplied and done by the company capability only?			
14	Are the customer requirement fully understand and no need to have further discussion with customer?			
15	Are the customer requirement out of scope of mandatory requirements ?			
16	Has the special equipment described and rechecked?			

Page 2 of 2

Checked By .....

Figure 5.15 Customer Requirement Information review Checklist (Continued)

5.2.17 Item 17 : Establish the document to monitor and control the project execution

Used step : Review proposed system (Step 2.2)

Potential failure: Project schedule and planning is poor monitored and controlled

In the past project, after the project has been scheduled and planned resources were assigned to each planned task. The project was carried out from the first task, designed the detailed specification of equipment, up to the commissioning. Project manager was less information of the project progress to compare with the project planing. Therefore, the overtime sometimes was needed for the task overscheduled. This was because Project did not know that task prior to the overtime requirement.

The project monitoring document such as diary report (see in Figure 5.16, page 117) is developed to use for diary progress of project execution both in design phase and installation phase. The contents in report include the task to be done, the progression of that task, task due date, and next planned task. Project manager has received and evaluated the status of project easier. Furthermore, any task that has less progress and nearly due date will be assigned more resources to carry out for finishing closely plan as much as possible.

DIALY REPORT

Project : _____

Date : _____

Inspector : _____

Task	Progress	Task Due date
1. PE Tank installation	100 % completion	28-Otc-99

Next Plan

Figure 5.16 Diary Report

5.3 Improvement of the Existing Project execution

As a study was conducted into the work out of the project execution and the implemented FMEA results, it was found that the existing project execution was too poor to control and unable to verify. Therefore, the proposed quality assurance activity (recommended actions) established from conducting the FMEA technique is implemented into the current processes. Also, the necessary standard documents both the form and checklist is established and applied to the working process.

5.3.1 The improvement of design control procedure

On a further investigation of current design process revealed that there was insufficient design control procedure. In development, the recommended action will put on the existing design procedure that has already set out the certain flow chart. As stated earlier, design procedure is divided into two stages comprising design for pre-awarded project and for award project.

5.3.1.1 Improved design process control for pre-awarded project

The Figure 5.17 is the improved design flow chart shown the design control procedure for the pre-awarded project. From the chart, there are four design activities implemented to control the design procedure. They include to control the used of Customer Requirement Questionnaire for customer information collection, to review the study of customer information, to prepare equipment data sheet, and to review designed basic specification. The description below is the improved design control procedure for pre-awarded project.

Step 1.1 Improved Receive Project Requisition activity

1. Preparation of Customer Requirement Questionnaire

The improvement point of this activity is the use of Customer Requirement Questionnaire [F-PE-002-0] for collecting information from customer. In the past

project poor communication between customer and sale engineer was frequently occurred that caused the design basis information was insufficient. As the results, the designed specification could not meet the customer requirement and had to be redesigned. By the use of this document, of course, basic information will be completely and adequately for the design. Moreover, this modified document is used to recheck the completion of proposal both the scope of work and supplied equipment before submission to customer.

Step 1.2 Improved Study information activity

1. Review the study of customer requirement information

An improvement point of general information study process is the use of Customer Requirement Questionnaire review Checklist [F-PE-019-0] to remind design engineer to study the critical information appropriately. This is because checklist will assist design engineer to ensure that critically collected information has been studied and understood. This proper information study can prevent the poor performance of designed system and make the conceptual design to meet the customer requirement. Information that will be reviewed, of course, is a critical information covering customer requirement and limited customer-supplied service and information. In case of less information, however, discussion with customer will be required.

Step 1.4 : Improved Design basic specification activity

For the Design basic specification process, there are two improvement points comprising to prepare standard equipment data sheet for individual equipment [F-PE-006-0] and to review basic designed specification

1. Preparation equipment standard data sheet

The Standard equipment data sheet is served for recording the important and critical design criteria for individual equipment, and is also used for tractability when the technical problem incurs. This data sheet will be rechecked the criteria to prevent the failure or problem caused of design error.

2. Review designed basic specification

After design basic specification activity has finished, Design Basic specification review checklist [F-PE-020-0] will be used as a guide to review the basic specification document. This is because to confirm that equipment specification would correct and appropriate for operation, meet the customer requirements, and would not be any incomplete specification or ambiguous information. Since the basic specification will be used for the cost estimation and proposal preparation, if the specification is unclear, it would cause not only the project cost exaggerated estimation but also the proposal has ambiguous specification.

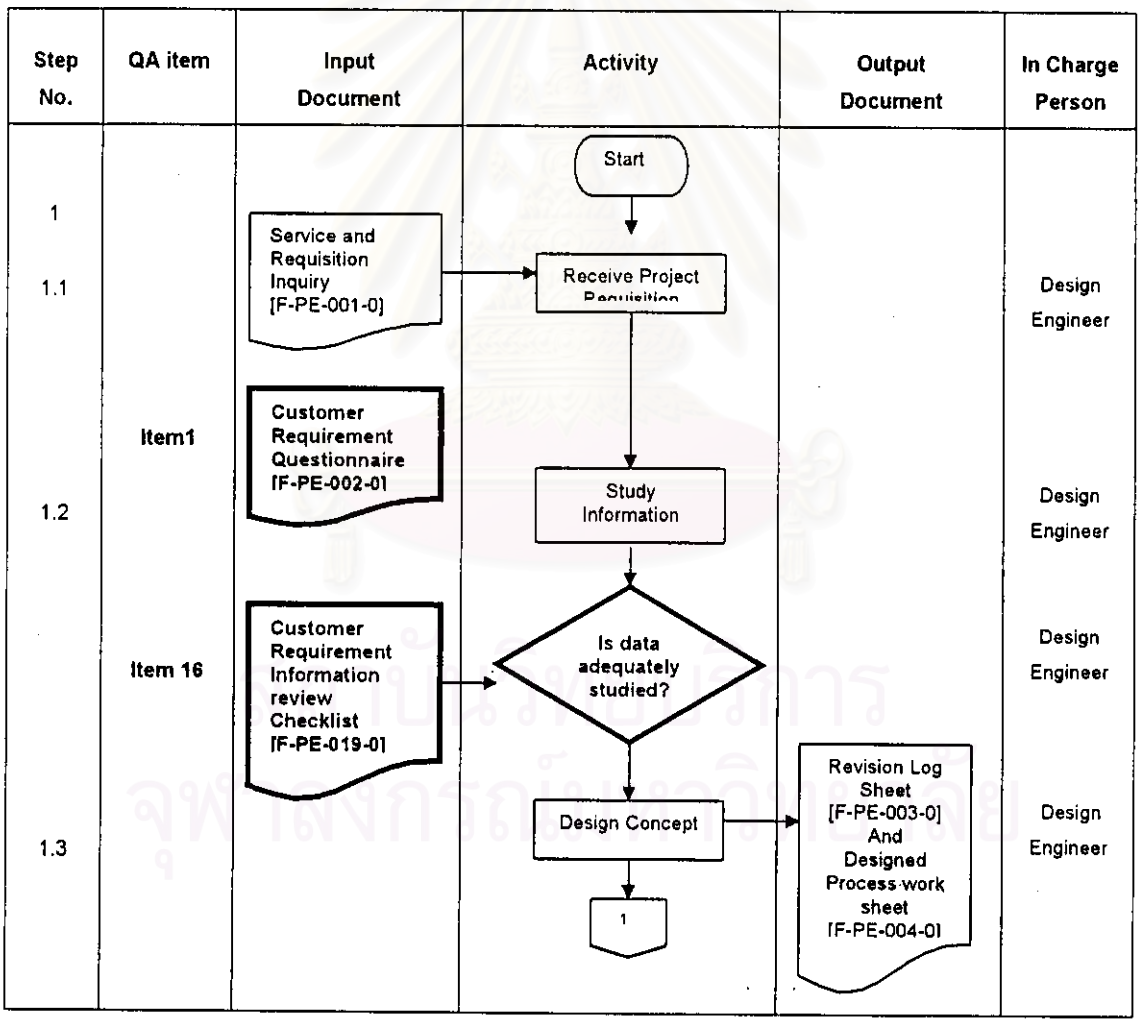

Figure 5. 17 Improved design control procedure for pre-awarded project

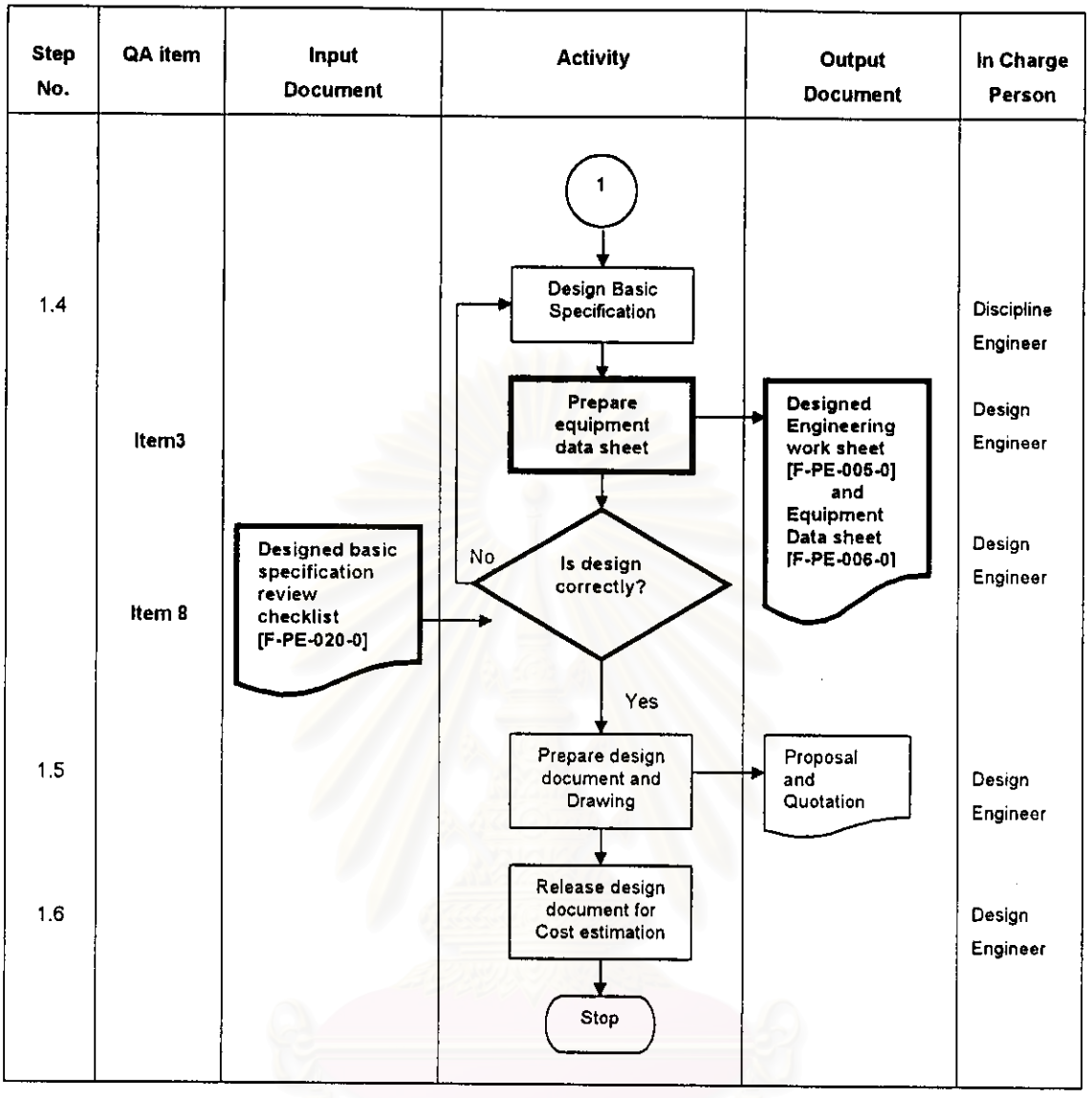

Figure 5. 17 Improved design control procedure for pre-awarded project (Continued)

5.3.1.2 Improved design process control for awarded project

Generally, procedure for awarded project has been started from Engineering Manager to assign a project engineer up to procurement document preparation. The objective of this procedure is to provide the system conform to the customer requirement, to terminate the design failure, to avoid the conflict with customer during and after the equipment installation, and to facilitate in project management. The improved flow chart of design control procedure for awarded project is indicated in the Figure 5.18. From this chart three improved activities are added for control the design procedure. These activities are contract verification and reviewing the result of contract

verification, establishment the document do monitor and control the project execution, and preparation the designed basic specification review checklist.

Step 2.2 : Improved review proposed system activity

1. Contract verification and reviewed by checklist

In practical, after a Project Engineer is assigned, the contract will be verified for understanding; the customer requirement, the scope of work, equipment specification, Standard and Codes of equipment, and the customer supplied-service or products (if any). While the contract has been reviewed, project execution has been scheduled and planned simultaneously. By this mean, the failure from proposed system will be prevented at a certain level. This is because this activity will ensure that the proposed equipment could be completely installed and operated without the failure and defects. The system can produce the water quality that meet the customer requirement. Moreover, this review will also ensure that installed equipment can be inspected, tested, and maintained in a way of customer satisfaction. Moreover, the scope of this review covers the verification of deviated requirement describing in the contract. The contract review checklist [F-PE-021-0] is created for this operation to assist project engineer for more clearly understand the contractual requirements. In case of there are deviated items, the corrective action will be performed immediately, either to revise proposed system conform to the contract or to contact the customer for an agreement conforming the final proposed system.

2. Preparation the document to monitor and control the project

With the less monitor and control project execution in the past project, the diary report is created for monitoring the activity to be done, next planned, and the task due date. This document will help project manager to monitor and control the progress of project. By reviewing the report, Project Manager can assign the team to do the overtime for the work that overscheduled, if necessity.

Step 2.3 : Improved design detailed specification

Equipment detailed design will be reviewed by detailed design checklist [F-PE-022-0] in order to ensure that there are no wrong or error. If the incorrect specifications are found, they will be corrected before the process of drawing and Bill of Material.

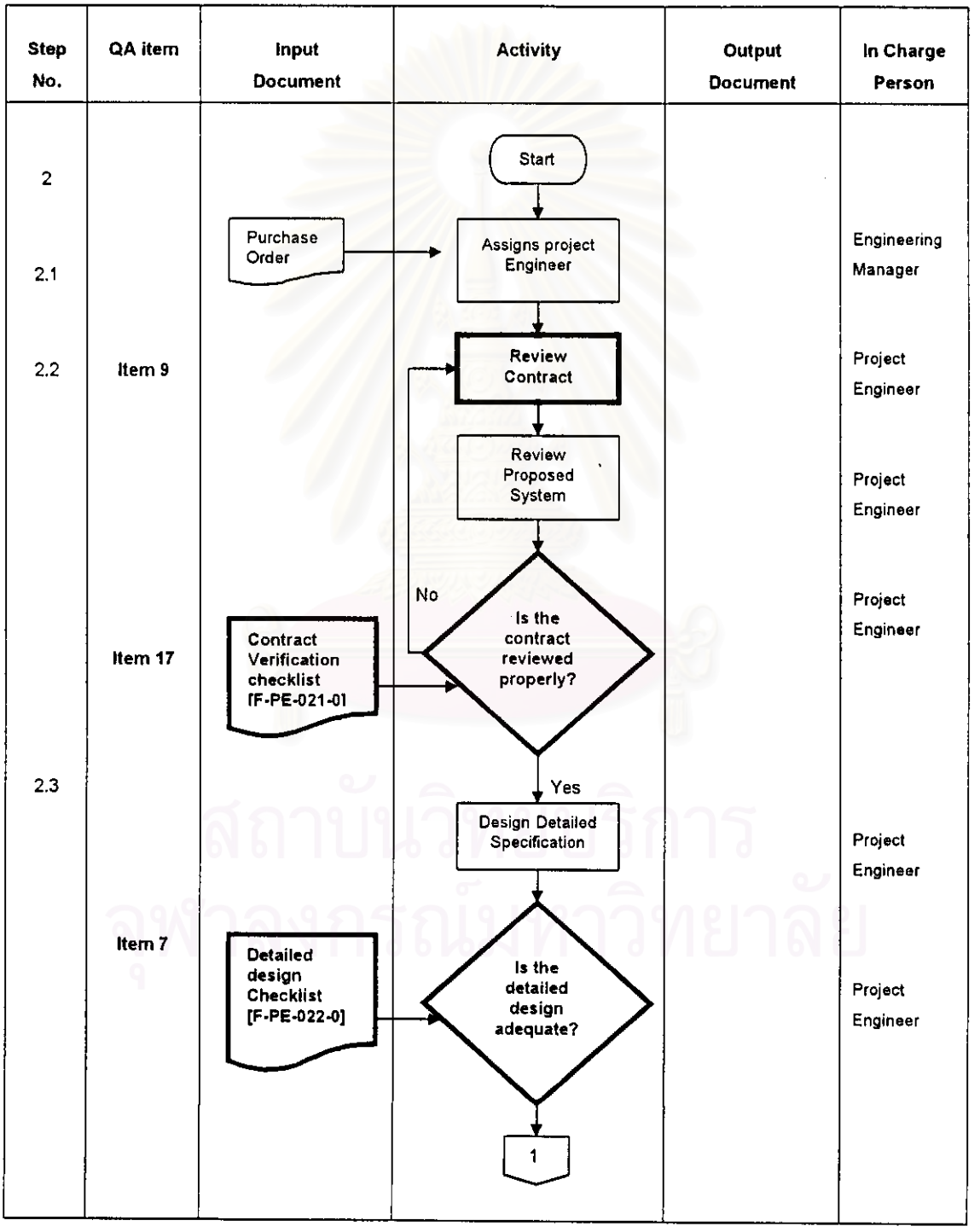

Figure 5.18 Improved procedure for awarded project in design control

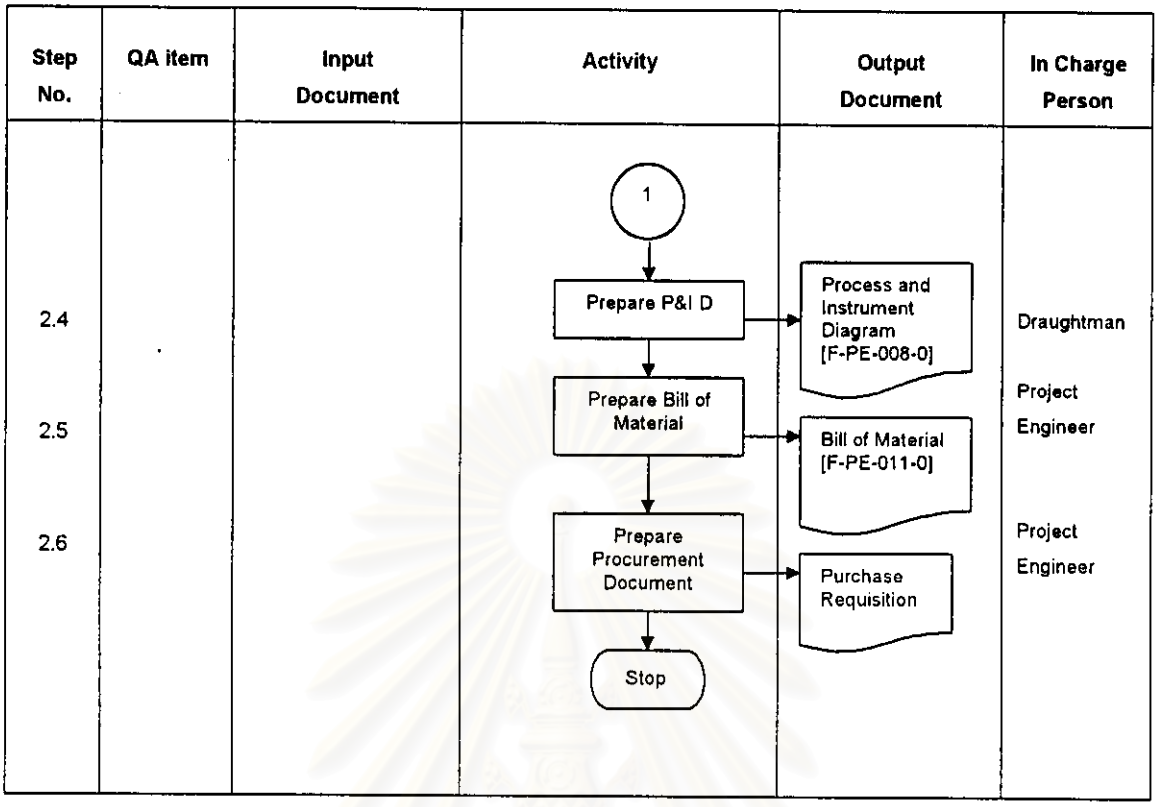

Figure 5.18 Improved procedure for awarded project in design control (continued)

5.3.2 Improvement of equipment procurement procedure

Step 3.3 : Improved vendor and subcontractor selection activity

The improvement point for the vendor and subcontractor selection is to establish the quality survey for vendor and subcontractor list preparation. Detail of reviewing point between vendor and subcontractor is different. The detail for vendor includes the frequent of poor quality to be delivered and the severity of that poor quality. The detail for subcontractor emphasizes the frequent of maintenance and the delay of delivery.

Step 3.5 : Improved received product process

1. Prepare bought-out and assembled equipment inspection checklist

An improvement for product receiving activity is to establish inspection procedure and to create inspection checklist for both bought-out [F-PE-023-0] and

assembled equipment [F-PE-024-0]. For the bought-out items Site engineer has responsible for inspecting the identified point, acceptable specification, and the damage of items. For fabricated equipment inspection is carried out both during fabrication and finish fabrication. The visiting date for inspection at the manufacturing will be planned to conform to the project schedule. In case of finding quality problem it will be rectified before the completion of items.

5.3.3 Improvement of installation control procedure

In the past project installation work did not beware of the quality of work both during process and final project completion. The execution did not concern much on the quality such as inspection of the component from vendor, verification of equipment during installation, and verification the completion of installation for finished equipment. The quality problem then easily occurred in the project installation. In order to improve and to ensure, therefore, the quality of final project completion proposed installation control activity would be developed into the existing installation flow chart. In addition to the control activity improvement, the installation document will also be developed to support the activity of installation control procedure.

The proposed installation procedure has covered the addition of installation agreement verification activity, material requirement plan preparation, installation plan, electrical control panel verification, instrument calibration review, in-process inspection, and final inspection.

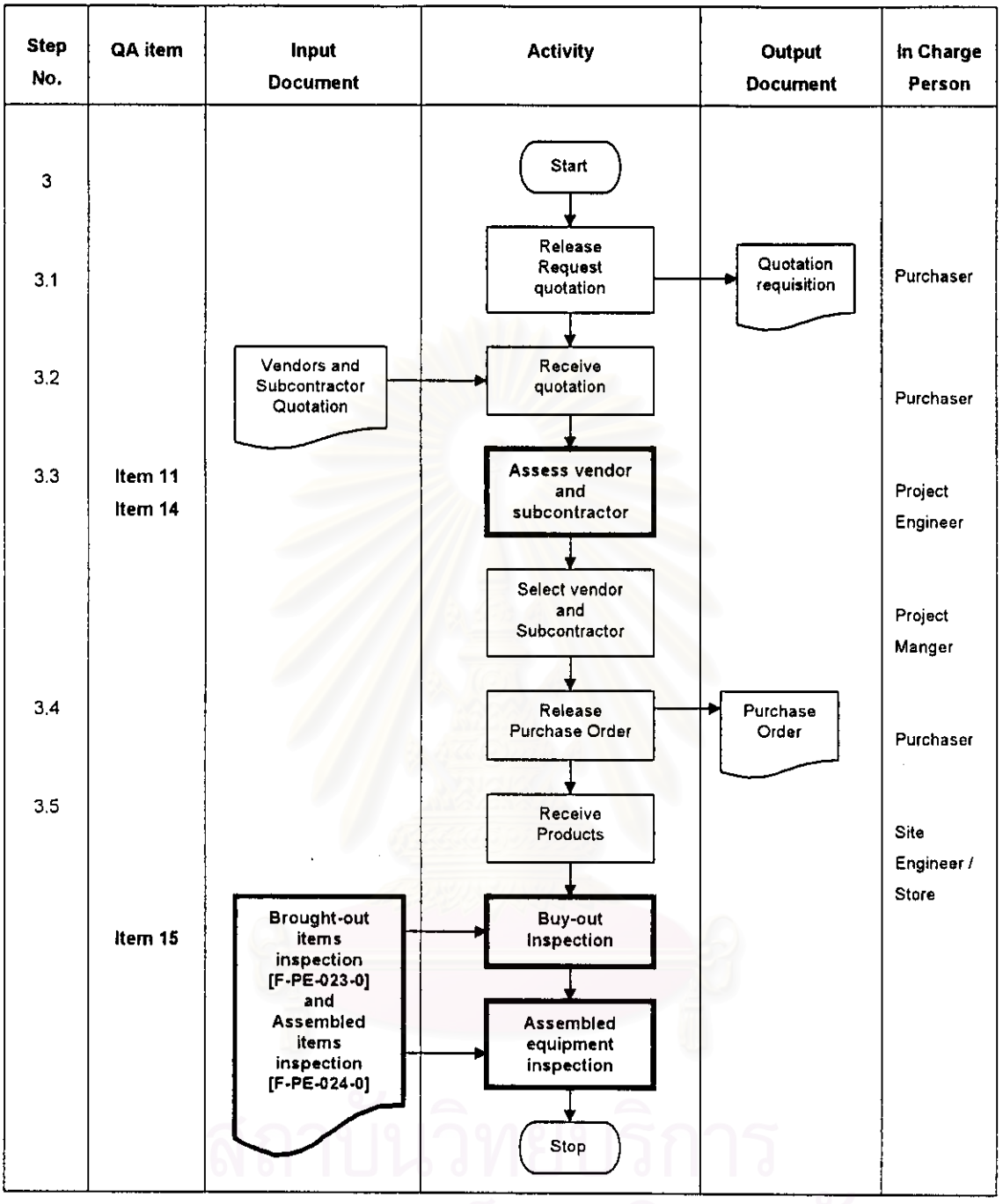

Figure 5.19 Improved equipment procurement procedure

Step 4.2 : Improved equipment installation procedure

1. Verify installation agreement and prepare material plan

The initiated improvement of installation control procedure is to verify an installation agreement in contract before installation document preparation. The

objective of review is for understanding in installation requirement, ensuring that required material and tools are available, and assisting in preparation of necessary installation document. In addition, it is also exploring the contract and verifying in order to ensure that the missing or ambiguous information found has been followed up and satisfactorily closed out by the responsible person. After review completion, installation plan [F-PE-019-0] and material requirement will be created and modified to assist equipment installation procedure in order to prevent the lack of material and the failure from equipment installation.

2. Prepare equipment installation drawing and procedure

The improved point for this step is to prepare installation drawing that includes plan layout and section view of installed equipment. In the inspection, the requirement and the procedure for inspection during installation should be indicated. The quality control person at site will describe the points where the installer would cease pending an intermediate check to verify acceptance. Therefore, the type of acceptance checks and test should be prior defined. The complete acceptance check or test of each activity would be reported in the document, such as installation checklist. However, before calling on the inspector to verify for acceptance, installers themselves should be responsible for checking their own work.

Step 4.3 : Improved interconnection piping

1. Provide piping installation drawing and checklist

This step is improved by making an interconnecting pipe drawing to assist technician installing piping work in order to prevent the failure or incorrect of pipe installation. In the drawing, equipment tag number, material, pipe size, dimension, and direction of pipe route are indicated. Another activity to prevent the failure is to create the Piping installation checklist [F-PE-026-0] used for inspecting both in-process pipe installation and the completion of piping work. By this improvement point, the failure of piping work will be rectified before they are used for system testing.

Step 4.4 : Improved electrical panel and wiring work installation

1. Provide electrical control panel function inspection

The improved point for this step is to verify the control panel function. Electrical engineer uses the checklist [F-PE-027-0] for reviewing the operation of control panel in order to ensure that the function will perform correctly.

2. Provide instrument calibration procedure and verify calibration procedure

This improved point is to provide instrument calibration. Instrument engineer calibrates instrument following the procedure and verifies its by Checklist [F-PE-027-0] created for confirming that calibration procedure is appropriately execution.

Step 4.6 : Improved system test run

1. Provide Final installation checking procedure

Before the system will be test run, the final review procedure is carried out in order to ensure that individual equipment, piping system, and electrical control panel and wiring work in the plant are completely installed and ready to be test. In reviewing, final installation checklist [F-PE-028-0] will be used as a guideline to remind engineer to check all critical points in the system. Site engineer and project engineer will be in charge for responsible to perform this operation. This approved activity will help in prevention of the damage of equipment and/or parts from the wrong and improper of installation. In case of finding of any equipment or parts are incorrect or inappropriate installations, it will be immediately corrected. System test run procedure is carried on after all equipment and parts are passed from verification.

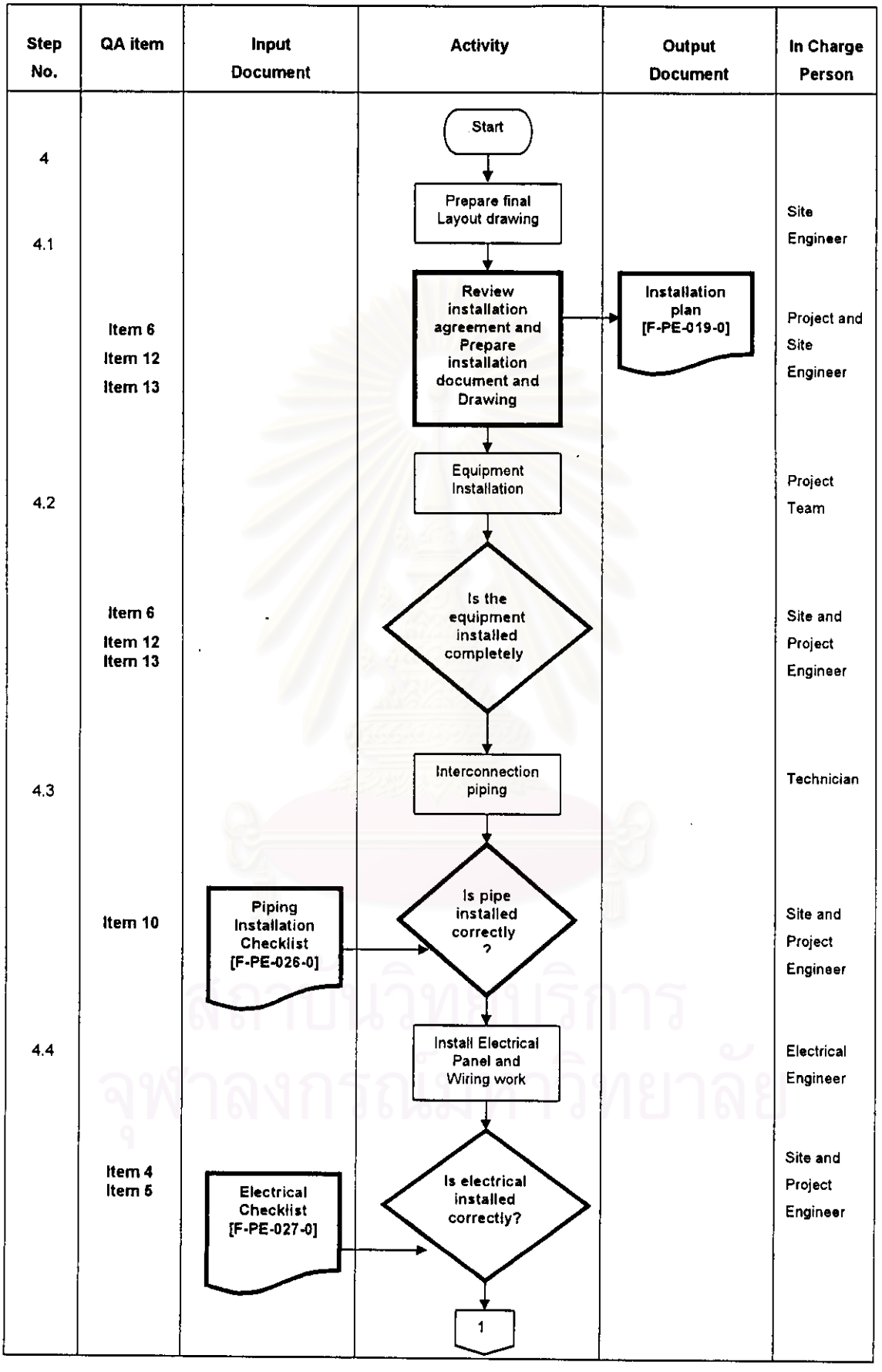

Figure 5.20 Improved installation control procedure

Step No.	QA item	Input Document	Activity	Output Document	In Charge Person
	Item 2	Final Installation Checklist [F-PE-028-0]	1 Check all equipment Is equipment ready to test? Yes System test run Commissioning Stop		Site and Project Engineer Site and Project Engineer
4.5					Site Engineer
4.6					Project Engineer

Figure 5.20 Improved installation control procedure (Continued)