การปรับปรุงประสิทธิภาพของหน่วยงานสอบเทียบอุปกรณ์เครื่องมือวัด สำหรับคลังน้ำมันและคลังปิโตรเลียมเหลว

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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาโทวิศวกรรมศาตรมหาบัณฑิต
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IMPROVING EFFICIENCY OF CALIBRATION SUPPORT UNIT FOR OIL AND LPG TESTING INSTRUMENT IN MULTI-TERMINALS

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การสอบเทียบอุปกรณ์เครื่องมือวัด มีความสำคัญในการปฏิบัติงานเกี่ยวกับการวัดเป็นอย่างมาก สำหรับหน่วยงานที่นำอุปกรณ์เครื่องมือวัดไปใช้งาน นอกจากจะต้องดำเนินการสอบเทียบอุปกรณ์เครื่องมือวัด ตามระยะเวลาที่เหมาะสมแล้ว หลังจากทำการสอบเทียบจะต้องทำการตัดสินใจว่าจากผลการสอบเทียบ เราควรนำอุปกรณ์วัดไปใช้งานต่อไปหรือไม่

วิทยานิพนธ์นี้เป็นการศึกษาการดำเนินงานของหน่วยงานสอบเทียบอุปกรณ์เครื่องมือวัด ซึ่งดำเนินการสอบเทียบอุปกรณ์เครื่องมือวัดให้กับคลังน้ำมันและคลังปิโตรเลียมเหลวทั่วประเทศ โดยหน้าที่ของหน่วยงาน นอกจากจะทำการสอบเทียบอุปกรณ์แล้ว หลังการสอบเทียบยังจะต้องทำการตัดสินใจว่าอุปกรณีเครื่องมือวัดดังกล่าวควรจะใช้งานต่อไปได้อีกหรือไม่ มีอุปกรณ์เครื่องมือวัดในขอบเขตของวิทยานิพนธ์ คือ อุปกรณ์วัดความดัน (PRESSURE GAUGE, PRESSURE TRANSMITTER, PRESSURE SWITCH) อุปกรณ์วัดอุณหภูมิ (TEMPERATURE GAUGE, TEMPERATURE ELEMENT AND TRANSMITTER, TEMPERATURE SWITCH) และ เครื่องชั่ง (WEIGHT SCALE)

ในการศึกษาเบื้องต้นพบว่า หน่วยงานยังไม่มีมาตรฐานในการกำหนดค่าความผิดพลาดที่ยอมรับได้ของอุปกรณ์เครื่องมือวัด, การยอมรับให้ใช้งานอุปกรณ์หลังการสอบเทียบ, ปัญหาค่าความไม่แน่นอนในการสอบเทียบอุปกรณ์, การดำเนินการสอบเทียบ และจัดทำรายงานผลการสอบเทียบ, และปัญหาจากการจ้างบริษัทภายนอกเข้ามาทำการสอบเทียบอุปกรณ์

จากการทดลองปรับปรุงการทำงานโดยการกำหนดวิธีการมาตรฐานในการกำหนดค่าความผิดพลาดที่ยอมรับได้ของอุปกรณ์, การควบคุมคุณสมบัติของอุปกรณ์เครื่องมือวัด ที่นำมาใช้เป็นอุปกรณ์มาตรฐานในการสอบเทียบ, การปรับปรุงกระบวนการสอบเทียบและการจัดทำรายงานผลการสอบเทียบ, และการจัดทำข้อกำหนดในการสอบเทียบอุปกรณ์สำหรับใช้ควบคุมการปฏบัติงานของบริษัทที่เข้ามาดำเนินการสอบเทียบ พบว่าสามารถลดการทำงานซ้ำได้ 25.2 %, ลดความล่าช้าในการปฏิบัติงานได้ 53.8 % อีกทั้งหน่วยงานสามารถลดค่าใช้จ่ายด้านคุณภาพ โดยเพิ่มค่าใช้จ่ายด้านการป้องกันขึ้น 39.2 % ลดค่าใช้จ่ายด้านความผิดพลาดลง 93.1% รวมลดได้ 55.4%

ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต.........	ลายมือชื่อนิสิต ....
สาขาวิชา.... การจัดการทางวิศวกรรม....................	ลายมือชื่ออาจารย์ที่ปรึกษา ....
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THANIT THINNAM: IMPROVING EFFICIENCY OF CALIBRATION SUPPORT UNIT FOR OIL AND LPG TESTING INSTRUMENT IN MULTI-TERMINAL. THESIS ADVISOR: ASSOCIATE PROFESSOR DAMRONG THAVEESAENGSAKULTHAI. COADVISOR MR. LERDSAK PORNNOPARAT. 188 pp., ISBN 974-13-0517-6.

Measuring instrument calibration is a crucial part in measurement. Apart from using instrument, the operator or working unit has to calibrate this instrument and after calibration, the instrument has to be judged whether it should be used or rejected.

Researcher studied the activities in calibration support unit which has responsibility to calibrate measuring instrument in Oil and LPG terminal all over country and after calibration, the calibration support unit has to determine that weather the calibrated instrument should be used or not. The instrument in scope of research are pressure gauge, pressure transmitter, pressure switch, temperature gauge, temperature element and transmitter, temperature switch, and weight scale.

From studied, researcher found that the problems are calibration support unit has problem in permissible error determination, calibrated instrument approval, uncertainty in calibration implementation, calibration activities and calibration report creation, and external calibrator control.

Researcher improved the calibration support unit activities by determining standard for instrument permissible error, controlling the master instrument specification, improving calibration and calibration report creation process, and controlling external calibration activities. After improvement, the rework decreased 25.2 % and the delay of calibrated instrument approval decreased 53.8 %. In addition, the calibration support unit can reduce the cost of quality about 55.4% by increasing cost of conformance 39.2 % and decreasing cost of non-conformance 93.1%.

The Regional Centre for Manufacturing Systems Engineering	Student's signature ………………..
Field of study…..Engineering Management…………………..	Advisor's signature ………………..
Academic year ….2000………………………………………..	Co- Advisor's signature …………..

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CHAPTER 1

INTRODUCTION

1.1 A GENERAL PROFILE OF OIL AND LPG INDUSTRY IN THAILAND

1.1.1 THAILAND PETROLEUM INDUSTRY: HISTORY

Thailand's petroleum industry began in 1892 when the foreign oil company imported kerosene to Thailand. It was used as fuel in lamp. Two years later lube oil was imported for use as lube oil in stream engine in rice mill. In 1902, the first gasoline was imported as fuel for bus transportation. The gasoline demand had increased continuously. In 1930 there were many foreign oil companies run business in Thailand. The major imported product were gasoline, diesel, and fuel oil. The petroleum industry became more and more important to economic situation and national security according to the increased demand. At that time, all of petroleum business had been run by foreign companies.

To prevent totally controlled by foreign oil companies, Thai government established the fuel division under the ministry of defense in 1933. It has responsibility for petroleum procurement, storage, and supply petroleum products to domestic market. To achieve this purpose, the government also established refinery in 1940. This refinery alleviated Thai people suffering from oil shortage during The World War 2 because foreign oil companies stop running their business during that time. But after the end of World War 2, the alliance countries forced Thai government to sign agreement not to sell petroleum product because it was considered to be military material. . For these reason Thai government has to sell petroleum business to foreign oil company, which is the company in the winner country.

The contract has been abolished in 1957 and Thai government decided to recover petroleum business by founding fuel organization, natural gas organization, and

Bangchak refinery. During the first time, the government petroleum business can't compete to foreign company because of lacking good management and petroleum experience. It causes Thailand still suffer from world oil crisis during 1973-1974 although having three official units taking care of energy stabilization. Finally in 1978, Thai government founded " Petroleum Authority of Thailand" [PTT], the national oil company, which has major responsibility to enhance to energy supply security in the country.

1.1.2 MARKET ENVIRONMENT

During 1978 to 1991, there were only 4 major oil companies, PTT, Shell, Esso, and Caltex, had controlled retail trade in domestic oil market. The competition among the major oil companies had not severed because the government has regulations that strictly control oil price and oil market. The oil price and oil market characteristics during this time were as follows: -

- Ex-refinery and import prices had been determined by government,
- Marketing margin had been determined by government and it was constant for many year,
- Retail prices had been determined by government and rather constant,
- Government use oil fund levy as tool to control oil price stabilizer,
- Domestic refining capacity was approximately 50% of demand and oil import were control by quota system ,
- No new entrance into oil business due to government policy,

In 1991, Thai government implemented oil price deregulation project by

- Revising criteria for issuing Article 6 of oil trading license to encourage new entrances.
- Abolish import control.
- Increase capacity in existing refineries and give permit for two new refineries construction.
- Revise regulation in order to reduce cost and time for new petrol station establishment.
- Allow refineries to sell refined product to all traders.

The oil price deregulation result increased competition in domestic oil market. From 1991, the competition in oil market has been more and more intense. There were number of oil company enter to Thai market both international company and new domestic company. The numbers of service stations have substantially increased, from four oil companies before implementation to 29 companies after implementation. Every oil companies have to improve quality in service and pay more attention in improvement in oil quality for environmental protection.

PRIVATIZATION

National Energy Policy Council [NEPC] and the Cabinet has gradually implement privatization of the energy sector over a number of years. After economic crisis, the government speeds up privatization because it help to reduce the debt of the country and attract investment to recover from crisis. According to the third letter of intend between Thai government and the IMF, there was outline for specific measure related to privatization in energy sector as follow [1]:

- In the energy sector , we will accelerate privatization and competition. As part of strategy of encouraging the entry of independent private generators to enhance competition, EGAT has initated sales of its stake in Electrity Generating (Public) Co. Limited and Powergen 2 (Ratchaburi power plant) during 1988, over longer term, we intend to split EGAT into separate generation and transmission companies, which themselvews will eventually be privatised.
- In oil sector, we will relinquish our stake in Bangchak Petroleum Company, commencing the process in June 1998. Also, we will sell a part pf PTT Exploration and Production (PTTEP), with the aim of privatizing PTT itself by the end of 1999.

The main objectives of the promotion of privatization are to:

- Increase competition in industry to bring more efficiency in industry.
- Reduce investment burden of the government by collecting fund from public sector.
- Develop capital market.
- Encourage public sector participate energy industry.
- Promote more efficient use of energy.

Privatization is one of major factor that encourages the government enterprise find the way to improve itself to compete the new entrance in the former monopoly industry.

1.1.3 COMPANY BACKGROUND

A national oil company was founded by Thai government as a state enterprise under the supervision of the Ministry of Industry on October 29th, 1978. The main objective is to conduct and support the petroleum business and other related business as well as promoting energy stability within country.

During the first period, the company's business has developed remarkably because the company got many privileges from the government, the competition in domestic market was not severe, and oil business was in the growth stage. The company did not limit activity only within Thailand but it also spread petroleum business network to neighboring countries within Asia.

When Thai government promotes free competition in domestic oil market in 1991. It has increased competition in domestic oil market. The company has to improve its capability to compete with many competitors both international and domestic oil companies.

To carry on business, the company modified mission and objective and reorganized structure many times. The organization structure in this research was one that had been in February 1996.

During the research, the company has 3 main business units, Oil Business Unit [OBU], Gas Business Unit [GBU], and International Business Unit [IBU]. These three business units have their own separated function and responsibility. In addition, the company also established Head Office who has responsibility to define and monitor the company's direction in the company's strategic level.

OBU has responsibility to internal oil and gas market. It procure Liquefied Petroleum Gas [LPG] from GBU and it procure oil form IBU and domestic refineries. OBU purchase oil and LPG from external refineries, domestic refineries, and internal Gas Separation Plants [GSP] to store in oils and gas terminal all over the country and sell products to the oils/gas station and the retailer.

Realizing that the petroleum business competition within the country will be stronger, the company has policy to establish quality, safety, health and environment management system and achieve the world class standard by the year 2000. For this reason, the company has implemented quality assurance standard [ISO 9002] and environmental management standard [ISO 14000] to oil and LPG terminal since 1997 and expanded the scope to the other terminals in later year.

1.1.3.1 PTT Vision

" To be the national energy organization conducting the fully integrated petroleum and related business with prime concern for quality, safety and the environment, aiming to provide superb quality products and services under world-class management and administration"

1.1.3.2 PTT Mission

"PTT is designed to operate the petroleum business under integration to maximize the benefits for the government and the people.

- Attaining the government policy

  - Under the conditions which do not deteriorate PTT's competitiveness.
- Meeting customers and shareholders' demand

  - Provide products and services under high quality standards and fair prices
- Organizational management

  - Continuously develop/improve the efficiency of the organizational structure and working process

  - Implement total quality management
- Human resource management

  - Development potentialities in all aspects to keep pace with business change

1.1.4 THE ROLE OF CALIBRATION SUPPORT UNIT TO ACHIEVE COMPANY MISSION AND MISSION

Instrument calibration is one of major part in quality system. It ensures that the product or process has been done according to specification that company commits to customer. Calibration is the task involving both management and technical skill. To achieve company's goal in quality system implementation, company has to have good management in calibration task. For this reason, Measurement section has been established to support calibration activities for Oil and LPG terminal. The success or fail in calibration activities effect directly to quality system in the terminal. Furthermore the success or fail in terminal's quality system effect the company's target.

1.1.5 STATEMENT OF THE PROBLEMS

The company began to implement ISO 9000 in 1997 at Ban-Rong-Poh LPG terminal [certified for LPG cylinder filling process] and to implement ISO 14000 at Songkhla Petroleum-terminal. The pilot projects were succeed so company expanded the scope of implementation to two aviation depot [citified for airplane loading process] in 1998. In that year company also implemented ISO 14000 to Lampang LPG terminal and Lampang oil terminal. The scope of implementation increases every year that is shown in table 1.1.

YEAR	SCOPE OF IMPLEMENTATION	
	ISO 9000	ISO 14000
1997	Ban Rong Po LPG Terminal	Sonkhla Petroleum Terminal
1998	Phuket Aviation Depot Kad Yai Aviation Depot	
1999	BangChak LPG Terminal Bangchak Oil Terminal Khon Kaen LPD Terminal Nakorn Sawan LPG Terminal Phrakanong Oil Terminal SonKla Petroleum Terminal Ubon Ratchathani Oil Terminal	Lampang LPG Terminal Lampang Oil Terminal Surat Thani LPG Terminal Surat Thani Oil Terminal
2000	Lampang LPG Terminal Surat Thani LPG Terminal Chiang Mai Oil Terminal Lam Lukka Oil Termimal Saraburi Oil Terminal Bangchak Oil Terminal Phuket Oil Terminal Chiang Mai Aviation Depot U-Ta-Pao Aviation depot	Phhitsanulok Oil Terminal Nakorn Sawan Oil Terminal Pak Phanang Oil Terminal

Table 1.1: ISO 9000 and ISO 14000 implementation period

Realizing that the scope of work and job quality has to be increased, but the company has to limit expenditure, especially hiring more staff, according to economic situation. So the section has to find a way to improve the efficiency in supporting calibration activities.

1.2 OBJECTIVE OF RESEARCH

The objective of this thesis is to improve efficiency of instrument calibration and testing activities which done by support unit in term of percent rework and delay date in calibration report approval.

1.3 SCOPE OF RESEARCH

1.3.1 The scope of this research focused on company's Oil and LPG terminal, which is in company's scope of quality system implementation, all over Thailand [about 25 terminals]

1.3.2 The scope of this research specify only the activities that be done by instrument working group staff and the activities that has instrument working group staff control the activities

1.3.3 The scope of this research focused on seven testing instruments as follow;

- pressure gauge
- pressure transmitter
- pressure switch
- temperature gauge
- temperature element and transmitter
- temperature switch
- weight scale

1.3.4 Quality cost will concern only quantitative data of cost of conformance and cost of non-conformance which base on number of officer in the unit.

1.4 EXPECTED BENEFITS

1.4.1 Company Benefits

- The company has the higher performance in instrument calibration and testing activities.
- The company gain reputation from customer in company's product.
- It is the primary step for the measurement section to get income from external calibration.

1.4.2 Other Benefits

- Be a clue for one or the company that has similar problem to apply this method to solve the problem.

1.5 RESEARCH METHODOLOGY

1. Survey the thesis, theory, standard and the other information that relate to instrument calibration and testing.
2. Collect the data about existing calibration and testing activities and the occurring problems.
3. Analyze the data and the effect of problems in term of cost of quality.
4. Develop the procedure(s) to improve calibrating activity.
5. Implement the procedure and data collection in term of cost of quality.
6. Analysis the result in term of comparing the cost of quality before and after the implementation.
7. Review the implementation result and suggest for further improvement
8. Prepare final thesis document.

1.6 LITERATURE SURVEY

International Standard ISO 10012-1: 1992 (E).

ISO 10012 is the international standard for quality assurance requirements for the measuring equipment. His part contains the quality assurance requirement for the supplier [In ISO context, supplier mean the manufacture or service organization who provide a product or a service] to ensure the accuracy of measurement. ISO 10012-1 also specifies the supplier about the confirmation system for measuring equipment. This part of ISO 10012 can 10012 can be applied to testing laboratory, the supplier, and the organization that use the measurement to demonstrate compliance with the requirements.

International Standard ISO/IEC GUIDE 25 : 1990 (E).

ISO/IEC Guide 25 is the general requirement for the competence of calibration and testing laboratories. It contains the set of requirement that calibration and testing laboratories has to demonstrate to achieve the quality system. ISO/IEC Guide 25 definition can be applied to both permanent locating laboratory and temporary or mobile facility.

Thai Industrial Standard มอก.1300-2537.

Thai Industrial Standard มอก.1300-2537 was announced by Thai Industrial Standard Institute for accrediting calibration and testing laboratory in Thailand. The standard is in Thai language that translates from ISO/IEC Guide 25 in identical level.

NIS 3003, The Expression of Uncertainty and Confident in Measurement, NAMAS

NIS 3000 focuses in evaluation of standard uncertainty: types A, type B and its combination. NIS 3003 expresses the evaluation in term of mathematics equation. It also has step by step procedure as an example for the determination of measurement uncertainty. In addition it has some sources of error an uncertainty in electrical, mass, temperature and dimensional calibration. Although NIS 3003 has no source of error and uncertainty in volume calibration, it help us more understanding in the overall concept and application in uncertainty calculation.

Manual of Petroleum Standards (API)

API mentions range of uncertainty in term of “confidence interval” and classify error of measurement into three groups: spurious errors, systematic errors and random errors. The first one is no mention in NAMAS. Although there are three groups of errors, API said that spurious errors should be discard because it can’t be analyst by statistic. So there remain systematic and random errors which can go along with NAMAS. API also demonstrates statistical concept and example in estimating range of uncertainty. The example is measurement of volume that could duplicate to use in metering calculation.

WARWICK MANUFACTURING GROUP, Quality Management &Technique, module document, 1999

This module document is about the management for quality. It mentions the importance of quality management in the present world and quality & management theories. It contains the detail of quality system and quality standard. In addition this document provide the tools that always be used in quality management system such as problem solving technique, SPC, QFD, and FMECA.

R.H.CERNI AND L.E. FOSTER, Instrumentation for Engineering Measurement, 1962.

This book is about instrumentation for engineering measurement. It contains principle of measuring system e.g. measurement accuracy, precision, uncertainty, source of measurement errors etc. the authors classify measuring system into three parts: primary sensor, signal conditioner, and recorder or indicator. The authors also mention measurement data in items of data transmission, data handling and processing, and data instrumentation system.

MICHEL PERIGORD, Achieving Total Quality Management, 1990

This book is about program for action in TQM. The author mentions about cost of quality as one of important topic in TQM in two chapters. Chapter 6 is “ prevention and the cost of quality “. it describe meaning of cost of quality and the importance of cost of quality. Chapter 11 is “ determining the cost of quality “. It presents the important topic for cost of quality consideration in various activities such as purchasing, marketing, research and personnel.

JOHN S. OAKLAND, Total Quality Management, 1995

This book is about improving performance through TQM. It mentions fundamental thing for TQM, the role of TQM in organization, tools for quality improvement, organization and culture, and TQM implementation. The author place cost of quality in a tool and improvement cycle part. In cost of quality chapter, the author mention about the type of cost occurring in quality management, the determination process for these cost, the benefit of quality cost, the model for develop quality cost, and the management of quality cost.

KITTISAK PLOYPANITCHAREAN, Measurement System Analysis (MSA), Technology Promotion Association (Thailand-Japan) Press, 2000.

This book has two part, Part 1 mentions about measurement system (the role of measurement in process, variation, measurement error, measurement data, etc.) and basic statistics for measurement system analysis. Part 2 mentions about accuracy analysis (bias analysis, measurement stability and linearity), precision analysis, attribute analysis, and the effect of % GR&R.

SURANIT CHALEEKARN, Controlling System of Inspection, Measuring and Test Equipment for Quality Assurance in A Phthalic Anhydride Plant, Thesis for master degree, 1996.

The objective of the research is to improve the calibration and maintenance system of measuring and test equipment in a phthalic anhydride plant by using quality assurance system requirement. The author improves calibration and maintenance jobs by generating calibration procedure, work instruction, calibration form, and support document. After implementation, the author found that the new system could reduce equipment failure by 25.5% and reduces cost of quality by 4.68% per month.

SOMSAK A. KONGKIAT, Inspection Testing and Testing Equipment Improvement for the Quality Assurance System of A Grease Manufacturing Plant, Thesis for master degree, 1995

This thesis is the studying of the problems occurring in the implementation of quality assurance system in the grease manufacturing plant, focus in inspection and testing. After investigation, the author found 4 main problems: inspection and testing for receiving incoming material, inspection and testing for in-production process, inspection and testing for final step, and measurement control and testing equipment. The author solve these problems by applying sampling technique, ABC analysis method, reference standard for testing and inspection for material such as ASTM D-4057 for sampling and ASTM E 220 for thermocouple calibration

http:///www.aiha.org/25vs9000.html

The topic of this web is “ISO Guide 25 versus ISO 9000 for laboratories”. It mentions the implementation of ISO Guide 25 and ISO 9000 to laboratory. It discuss the similarity and difference of two standard in term of semantic [accreditation, certification, registration], purpose of standard, scope of accreditation/certification, etc.

CHAPTER 2

THEORIES RELATED TO RESEARCH

2.1 BASIC TOOL OF QUALITY

2.1.1 WARWICK MANUFACTURING GROUP [2].

Process flow chart

Process flow chart is the first step in quality improvement. It helps us understand the process by using of basic picture. There is many variation of symbol used in flow-charting. There is no right or wrong way to display information because the main purpose of flow chart depend on how well we understand and use it. The standard flow-charting symbol is shown below

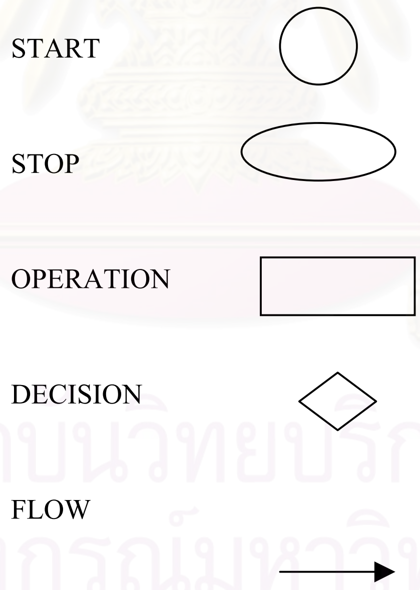


Figure 2.1: Standard flow charting symbol

Source: [2]

Cause and effect diagram

Cause and effects diagram, often-called "fishbone" diagram. It was first developed in 1943 by Kaoru Ishikawa at the University of Tokyo. It is the useful method for organizing idea, generated from brainstorming. The general format of the diagram is shown in figure 2.2.

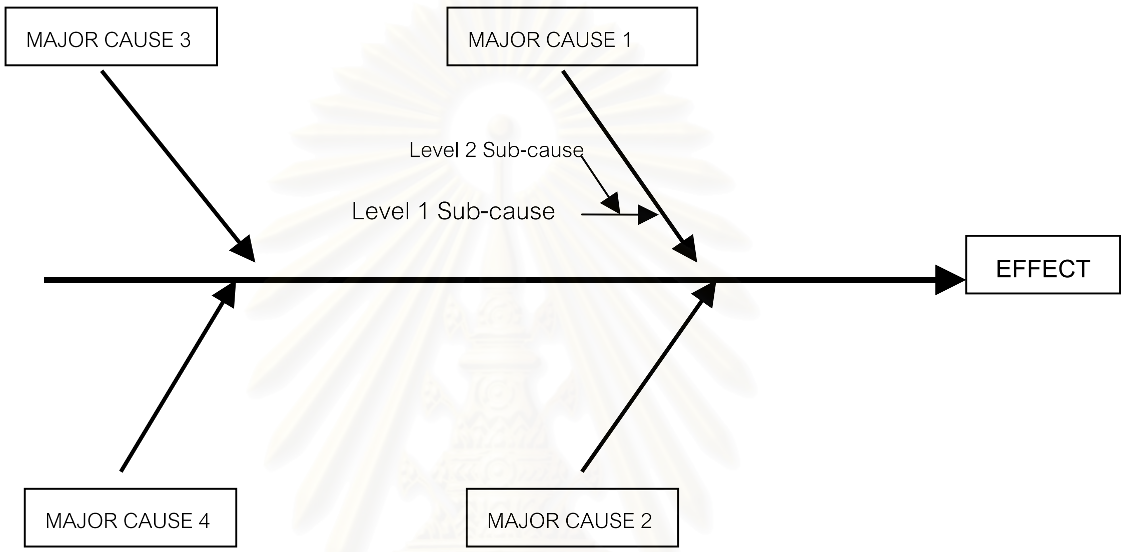


Figure 2.2:Cause Effect Diagram :1

Source: [2]

When looking in detail, Cause and Effect Diagram are classified into three basic types.

1. *Dispersion analysis type*. It is normally used when we want to know the dispersion or deviation in product's performance. The effect box normally be "product performance variation".

2. *Process classification type*. It is the diagram that follows the process. The diagram format has flow of process in the middle of diagram and factors affecting quality are identified later.

3. *Cause enumeration type*. It is the most commonly used. In this type, the possible cause will be list and categorized into five generic causes; material, method, people, equipment, and instrument.

2.1.2 SAEREE, CHAROON, DAMRONG [3].

Cause and effect diagram

Finish products from same manufacturing process are different. About 50 % of the different result from raw material, machine, and manufacturing process. Sum of slight different in material, machine and manufacturing process cause difference in product quality. Practically we will select the distinct quality characteristic such as defect rate to improve product quality.

The procedure for building cause and effect diagram is

1. Consider the quality characteristic and select one we need to improve.
2. Write the quality characteristic in the right-hand side and draw arrow from left-hand side to right-hand side.
3. Write the major cause upper and lower the arrow.
4. Write the minor cause from each major cause.

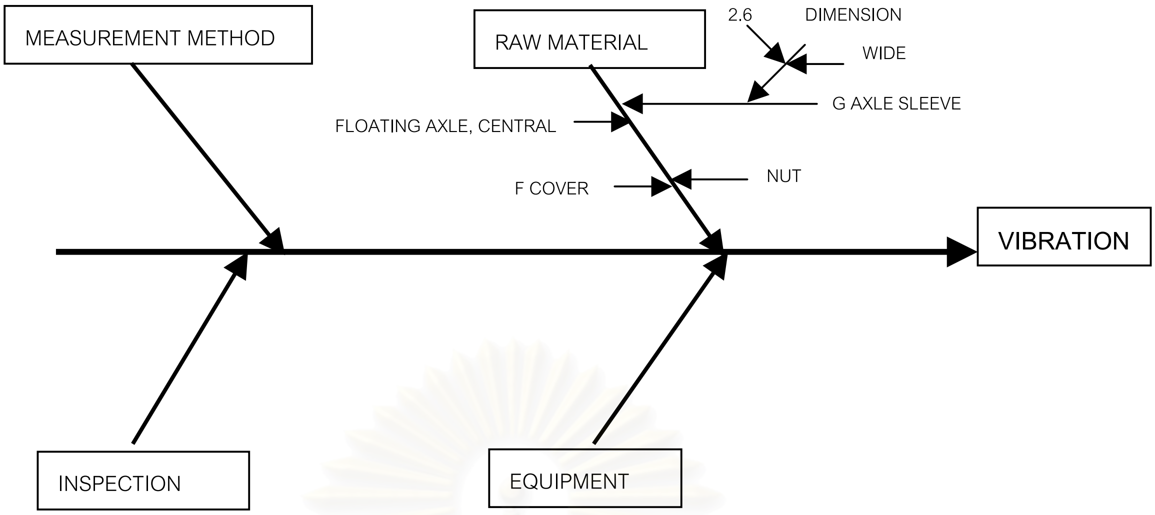


Figure 2.3:Cause Effect Diagram:2

Source: [3], p. 41.

2.2 COST OF QUALITY

The use of the measure in the form of customer satisfaction doesn't enough to indicate an effective management because it doesn't control the expenditure that company pay to achieve its. To gain customer satisfaction by providing quality product or service with minimum cost is key success in business. So costs relate to quality is suitable the degree of effective management.

2.2.1 MICHEL P'ERIGORD [4].

The cost of quality consists of four parameters: prevention, evaluation, internal failures, and external failures.

Prevention costs include the cost of all measures taken to avoid errors, defects, and failures at all activities. It involves activities such as preparatory meeting, client satisfaction studies, analysis of potential failures, reliability studies, product specification documentation, and etc.

Evaluation costs include the cost of all actions taken to confirm that product or service conforms the user's expectation. It involves activities such as verification, detection, inspection, and etc.

Internal failure costs is the cost result from product, material, and equipment do not meet the client's expectation that be found within company. The costs occurring in this phrase come from rejection and corrective action.

External failure costs is the cost result from product, material, and equipment do not meet the client's expectation that be found by customer. The costs occurring in this phrase come from return product, reimbursement, and etc.

The four parameters can be categorized into conformance and nonconformance. The cost of conformance is sum of prevention costs and evaluation costs. The cost of nonconformance is sum of internal failure costs and external failure costs. And the cost of quality is sum of conformance costs and nonconformance costs

(COQ)
The Cost of Quality
Cost of conformance = cost of prevention + cost of evaluation
Cost of nonconformance = cost of internal failures + cost of external failures
COQ = Cost of conformance + Cost of nonconformance

Table 2.1: Summarizes of COQ definition.

Source: [4], p. 76.

The cost of quality can be divided into two costs; tangible and intangible. Each of them has cost of conformance and cost of nonconformance.

Tangible cost is the cost from thing concrete, palpable and physical. To category tangible cost, the AFCIQ established a *Guide to the Cost of Quality* for small and medium-sized French companies and industries on the basis of Feigenbaum's and British standards cost that shown in table 2.2 and 2.3.

Intangible cost is the cost of everything that not concrete, palpable and physical such as intellectual work and the like. The determining of intangible cost require more complex method than tangible cost.

COST OF PREVENTION	COST OF EVALUATION
A.1 Quality management	**B.1 Industrial evaluation of the product**
A.1.1 Administration	
A.1.2 Quality engineering	**B.2 Acceptance inspection of products purchased externally**
A.1.2.1 Quality research	
A.1.2.2 Inspection method	B.2.1 Evaluation of products purchased externally
A.1.2.3 Quality audit	B.2.2 Inspection at supplier's premises
	B.2.3 Inspection of incoming good
A.2 Preparation and Implementation of Reviews	B.2.4 Cost of material expended
A.2.1 Design review	B.2.5 Data processing and analysis
A.2.2 Review of product specification documentation	
	B.3 Inspection of production
A.2.3 Review of production documentation	B.3.1 Inspection of the process
A.2.4 Review of inspection documentation	B.3.2 Inspection of production start-up
	B.3.3 Inspection of production in progress
A.3 Quality system for procurement	B.3.4 "Super inspection"
A.3.1 Evaluation of supplier	B.3.5 Inspection of packaging process
A.3.2 Inspection specification	B.3.6 Final inspection.
A.3.3 Verification of purchase order	B.3.7 Certification by official agencies
	B.3.8 Evaluation of inventory
A.4 Quality training program	B.3.9 Material expended during testing
	B.3.10 Processing of inspection data
A.5 Other prevention expenditure	B.3.11 Product quality audit
	B.4 Metrology
	B.4.1 Materiel used for inspection
	B.4.2 Material used for production

Table 2.2: The presentation of AFCIQ Grid [cost of prevention and evaluation].

Source: [4], p. 83.

COST OF INTERNAL DEFECTS	REJECTIONS
C.1 Production failures	**D.1 Claim and complaints**
C.1.1 Production failures	D.1.1 After-sale service
C.1.2 Design failures	D.1.2 Products rejected and returned
C.1.3 Failure in external procurements	D.1.3 Technical assistance/repair of rejected products
C.2 Corrective alterations	D.1.4 Replacement under warranty
C.2.1 Production failures	D.1.5 Installation defects
C.2.2 Design failures	D.1.6 Error in product application research
C.2.3 Failure in external procurements	D.1.7 Design error
	D.1.8 Civil and criminal liability
C.3 Locating of defects	
	D.2 Loss of known clientele
C.4 The rejection process	
C.5 Re-inspection of products that have been corrected	
C.6 Downgrading or terminating of product	

Table 2.3: The presentation of AFCIQ Grid [cost of internal defects and rejection].

Source: [4], p. 83.

2.2.2 JOHN S. OAKLAND [5].

A competitive product base on a balance between quality and cost factors is the principle goal of management. Quality has specified from design and the operating unit has the task to match it. The activities will incur costs can be separated into prevention costs, appraisal costs, and failure costs. Failure casts can be separated into internal and external failure.

Prevention costs are costs associate with the design, implementation, and maintenance of the quality system. It include quality planning, quality assurance, inspection equipment, training, and miscellaneous.

Appraisal costs are costs associate with the supplier's and customer's evaluation of purchase material, processes, intermediates, and final product or service ensuring that these activities conformed requirement. Appraisal costs include verification, quality audit, inspection equipment, and vendor rating.

Internal failure costs are costs occurring when the work result deviate from standard is detected before transfer product to customer. Internal failure costs include waste, scrap, rework or rectification, re-inspection, downgrading, and failure analysis.

External failure costs are costs occurring when product or service fail to reach standard is detected by customer. It include repair and servicing, warranty claim, complaints, returns, liability, and lost of goodwill.

2.2.3 DAMRONG [6].

In business, profit can be determined by the equation

$$\text{Profit} = \text{Sale} - \text{Cost}$$

To increase profit, it can be done by two methods; increase sale or decrease cost. The conception in quality cost reduction has three stages.

At 0^{th} stage, there has no process control. Most of cost occurring result from customer claim that is classified as external failure cost.

At 1^{st} stage, there has inspection in process. There are three expenditures: customer claim [external failure cost], inspection cost [appraisal cost], and rework [internal failure cost].

At 2^{nd} stage, there has prevention and inspection in process. The prevention cost is expenditure that be added to quality cost in this stage. However the quality cost at this stage should decrease.

2.3 TESTING AND MEASURING INSTRUMENTS IN QUALITY SYSTEM

2.3.1 ISO/IEC GUIDE25 [7].

According to ISO/IEC Guide 25, the laboratory should establish and maintain quality system that appropriate to the type, range and volume of calibration and testing tasks that it undertake. The quality system should be documented. The laboratory management policy and objective should be state in "quality manual" and should ensure that all element in the manual has to be follow by all involving staff under the responsibility of the quality manager.

The quality manual and related quality document should state the laboratory's policy and operation process in order to meet the requirement, it shall contain the following contents.

- The statement of quality policy, objective, and the commitment by top management.
- The organization structure of laboratory and its management, including the relevant chart between laboratory and the parent organization when laboratory is part of organization.

- The relation between management, technical operation, support unit.
- Document control and maintenance procedure.
- Staff's job description.
- Laboratory approval person identification
- Procedure for measurement traceability.
- Scope of calibration.
- The new work review process, ensuring the laboratory has appropriate facility and resource for new job.
- Referent to calibration, verification, and test procedure used.
- Instrument handling procedure in calibration and test.
- Referent to major instrument and measurement standard.
- Referent to procedure for calibration, verification, and maintenance of instrument.
- Reference to verification prove , including interlaboratory comparison.
- Procedure to follow feedback and corrective action.
- Procedure for manage the exceptionally permitting departure from procedure or standard
- Procedure for managing complaint.
- Procedure for protecting confidentially and proprietary right.
- Procedure for audit and review.

Calibration and test method

The laboratory should have documented instruction on all operation and all equipment including the handling and preparation for calibration or testing. All instruction, manual, and standard related the work of laboratory should be maintained up-to-date and be available to related staff.

The laboratory should use appropriate procedure for calibration and test task. It should be consistent with the accuracy require and standard specification. If the method used is not specified, the laboratory should select the method that has been published in reliable source such national or international reputable organization. And if there has no standard available, laboratory has to make agreement with customer about calibration and testing procedure used.

When laboratory use computer or automated equipment for capture, processing, recording, reporting, and storage data, it should ensured that the computer or automated equipment are complied with the standard.

The laboratory should establish document procedure for purchase consumable material used for all technical operation.

Measurement traceability and calibration

All measure and test equipment shall be calibrated before using. Laboratory should establish program for calibration, verification, and validation of equipment ensuring that the equipment used has not been invalidable. The measurement perform by laboratory should has to be traceable to national standard. The calibration certificate should inform the traceability, measurement result, and uncertainty of measurement.

Certificate and report

The result of calibration and testing should be reported accurately, clearly, unambiguously, and objectively. It should include the following information:

- Title such as “Calibration Certificate” and “Test Report”.
- Name and address of laboratory and calibrated location.
- Identification of the report.

- Name and address of customer
- Identification of calibrated or tested instrument.
- Characterization and condition of calibrated or tested item.
- Date of test or calibration.
- Identification of calibration or test method.
- Sampling procedure, where relevant.
- Deviation from calibration or test method.
- A statement of the estimated uncertainty of calibration or test result.
- A signature of authorized person.
- A statement to the offer that the result relates only to the item calibrated or tested, where relevant.
- A statement thet the certificate or report shall not be copied except in full without laboratory approval inn writing.

Apart from information above, laboratory has to identify more information in the certificate or test result in case of

- The certificate or test result contains the result of calibration or test performed by sub contractor.
- The statement "supplement ot calibration certificate number…" incase of there has amendment to calibration certificate or test result.
- There has defect in measuring or test equipment that will cost doubt of validity of result

When laboratory tell the result of calibration or test instrument by telephone, fax, or other electronic transmission, it has to have documented procedure ensuring the confidentially of result.

Sub-contracting of calibration or testing

When it is necessary to use sub-contractor, laboratory has to ensure that its sub-contractor has ability to perform the job complying with laboratory requirement. And laboratory has to acknowledge client in writing which part of calibrated or test activities that has been done by sub-contractor.

Outside support service and supplier

Laboratory has to select outside service and supplier that has adequate quality to sustain confidence in laboratory's calibration and test activities. If the outside support has no its assuring system, laboratory has to establish procedure to ensure that outside support unit's activities comply with laboratory requirement.

2.3.2 QUALITY ASSURANCE REQUIREMENT FOR MEASURING EQUIPMENT ISO 10012-1,[8].

To ensure that the measurement is made under specify accuracy, the International standard ISO 10012-1 present the requirement as follow: -

- Meteorological characteristic of measuring equipment [accuracy, range, resolution, etc.] shall be documented
- An effective document system for managing the confirmation and use of measuring equipment should be established
- The system should be audit and review periodically.
- Any relevant technical requirement should be reviewed for ensuring that the meteorological characteristics will be achieved.
- Uncertainty of measurement process should be identified, both that are attribute from measuring instrument, personal procedure, and the environment.

- A procedure for performing activities in the system should be documented. It should have enough information, ensuring the sufficient information for implementation and the consistency of applications.
- Measuring instrument information (maker, type , serial number, other identification, measurement standard) should be recorded. The calibration certificate and other relevant information should be available.
- Nonconform measuring instrument should be remove from the process.
- Measuring instrument should be labeled to indicate its conformation status.
- Measuring instrument should be confirmed at appropriate interval, ensuring the accuracy of instrument.
- Adjustable part that affect measuring instrument performance should be sealed or use the other guard method, preventing the adjustment from unauthorized person.
- If it is necessary to product and service from outside source, the company should make sure that the product or service from outside source has same level of quality.
- It should have system for prevention measuring instrument from receiving, handling, transporting, storing and dispatching.
- Measuring instrument should be calibrated by using master instrument that is traceable to international standard.
- Effect of uncertainty in each stage in calibration chain should be cumulative, ensuring that measuring instrument has total uncertainty within limit of permissible error.
- Measurement standard and measuring instrument should be calibrated and used in controlled environment, ensuring the accuracy of the measurement result. The environment affecting the result of measurement should be considered and if necessary, the compensation should be done.
- Suitable person should do all activity, staff with has knowledge and experience.

2.4 THE EXPRESSION OF UNCERTAINTY IN MEASUREMENT

The objective in measurement is to determine the different between true value of measurand. Generally, the measurement result is the estimate value because it contains uncertainty in the result of measurement.

True value = The average of measuring result + Uncertainty of measurement

Uncertainty of measurement is important in measurement process. When using measuring instrument, we have to know the uncertainty in our instrument, definitely we got it from calibration report of each measuring instrument. So the calibration unit has to provide uncertainty in calibration to customer.

> “ An expression of the result of a measurement is in complete unless it include a statement of the associate uncertainty…”
>
> NAMAS,NIS 3003

> “ in performing measurements and in stating and making use of the results, the supplier shall take into account all significant identified uncertainties inn the measurement process including those that are attributable to measuring equipment..”
>
> ISO10012-1

NAMAS,NIS 3003,[9], provide the expression of uncertainty and confidence in measurement for calibration. It classifies the uncertainty component according to the method of evaluation into two groups.

Group 1: Type A evaluation.

Type A is the uncertainty components that can be calculated by statistical method. It used to evaluate value from repeatability or randomness of measurement process occurs on one particular occasion. The spread in result indicates the repeatability of the measurement process. It depends on factor such as process used and sometime the calibration people. The standard deviation used to express of the result and the term standard uncertainty for type A evaluation [U_A] can be obtain from

$$U_A = \pm \sigma = \pm \frac{S_x}{\sqrt{n}}$$

Where S_x : standard deviation

n : number of measurement

Group 2: Type B evaluation

Type B is the uncertainty components that are evaluated by other method. It used to evaluate value from systematic component involving in measurement process such as the report uncertainty from the referent standard, the resolution of instrument, the effect of environmental condition, and etc.

- When it is possible to assess upper and lower limit of systematic effect on a measurand, a rectangular probability distribution ca be assumed. So if a_i is the semi-range of variation, the standard uncertainty is given by a_i is

$$U_{B1} = \frac{a_i}{\sqrt{3}}$$

- When knowing uncertainty from calibration report which the level of confidence (k) has been report, the standard uncertainty will be given by

$$U_{B2} = \frac{\text{Expanded uncertainty}}{k}$$

K VALUE	% CONFFIDENCE
1.00	68.28
1.96	95
2.00	95.45
2.58	99
3.00	99.7

Table 2.4:k value and percent of confidence

Source: [10], p. 27.

- When an instrument has been certified as conforming to specification.

  If it does not declare level of confidence, the standard uncertainty can be obtained from

$$U_{B3} = \frac{\text{Tolerance limit}}{\sqrt{3}}$$

  If it does express level of confidence, the standard uncertainty can be obtained from

$$U_{B3} = \frac{\text{Tolerance limit}}{k}$$

Combine uncertainty

We can combine uncertainty we got from group 1 and group 2 by using the formula:

$$U_T = \sqrt{U_A^2 + U_{B1}^2 + U_{B2}^2 + \ldots}$$

Expanded uncertainty

The uncertainty we got from former formula is not including level of confidence. Normally we express the term uncertainty with level of confidence so we can obtain from:

$$U = k\,U_T$$

Uncertainty ratio

Uncertainty ratio is ratio between instrument uncertainty and master instrument uncertainty. For example the Digital Multi-meter has uncertainty $\pm$ 20 PPM and master instrument we use to calibrate this Digital Multi-meter has uncertainty $\pm$ 5 PPM. So the uncertainty ratio is 4:1. The US Ministry of Defense measurement standard defines using this ratio between 4 to 10 for instrument calibration.

2.5 TRACEABILITY

The idea of traceability is that the calibrated instrument has to be tested back its result to reliable standard such as national or international standard. The accuracy of instrument in higher level we be higher than lower level. From figure 2-4, we use calibrating instrument, which has higher accuracy, to calibrate testing instrument. The calibrating instrument has to be calibrated by industrial standard and industrial standard has to be calibrated by instrument in higher level

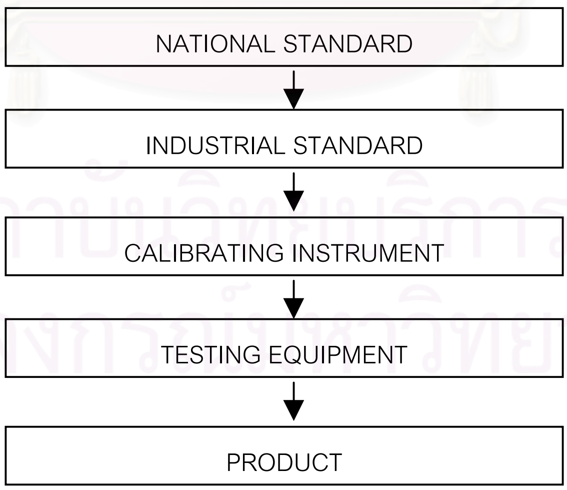


Figure 2.4: Traceability chain

Source: [11]

By traceability, every instrument that has been test back to same standard and we can compare its error. So by traceability, we can compare the instrument error although it located in different location and we also can control the product that has been product from this measuring instrument.

Accuracy ratio

As we know from traceability chain that instrument has be calibrated by the higher accuracy instrument, the ideal accuracy ratio is 10 to 1 in each level. But in reality, there has many difficulties to follow this ratio such as the available of master instrument, cost of calibration, etc. so the accuracy ratio we use is about 4 to 1 or 3 to 1.

TRACEABILITY	IDEAL RATIO	REAL RATIO
National laboratory ↓		
	10 : 1	4 : 1
Industrial primary ↓		
	10 : 1	4 : 1
Internal laboratory ↓		
	10 : 1	3 :1
Instrument		

Table 2.5 Accuracy ratio between ideal ratio and real ratio

Source: [11]

CHAPTER 3

CALIBRATION SUPPORT UNIT'S ACTIVITIES BEFORE IMPROVEMENT

3.1 ORGANIZATION CHART

Calibration support unit or instrument group in company organization chart is the working group in measurement section under Measurement section, Engineering and Measurement division. The Engineering and Measurement division, Oil terminal, and LPG terminal are under control of senior vice president terminal operation in oil business unit. The organization chart of oil business unit is shown in figure 3.1 and figure 3.2 is the organization chart in senior vice president terminal operation.

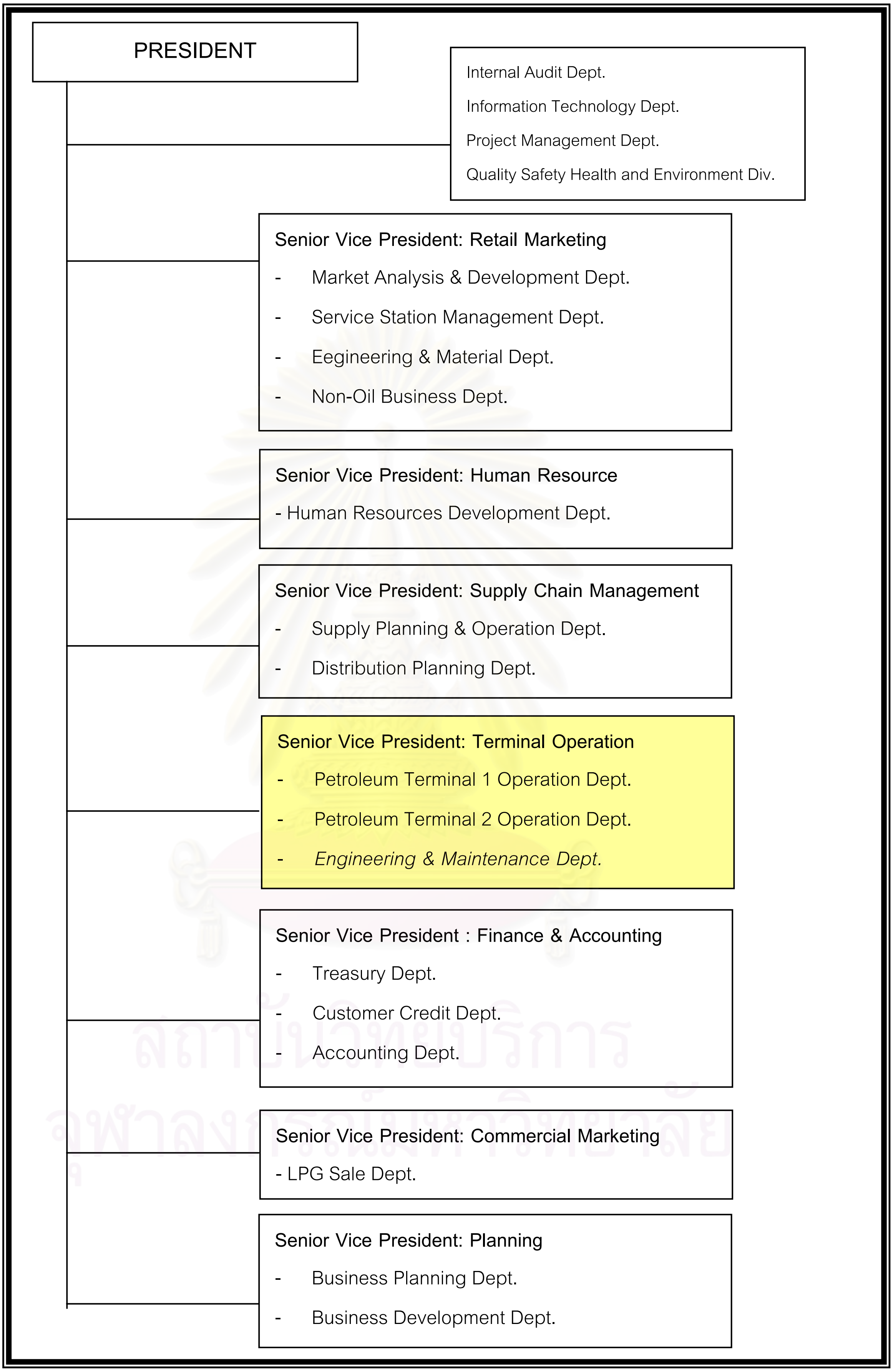


Figure 3.1: Oil business unit organization chart

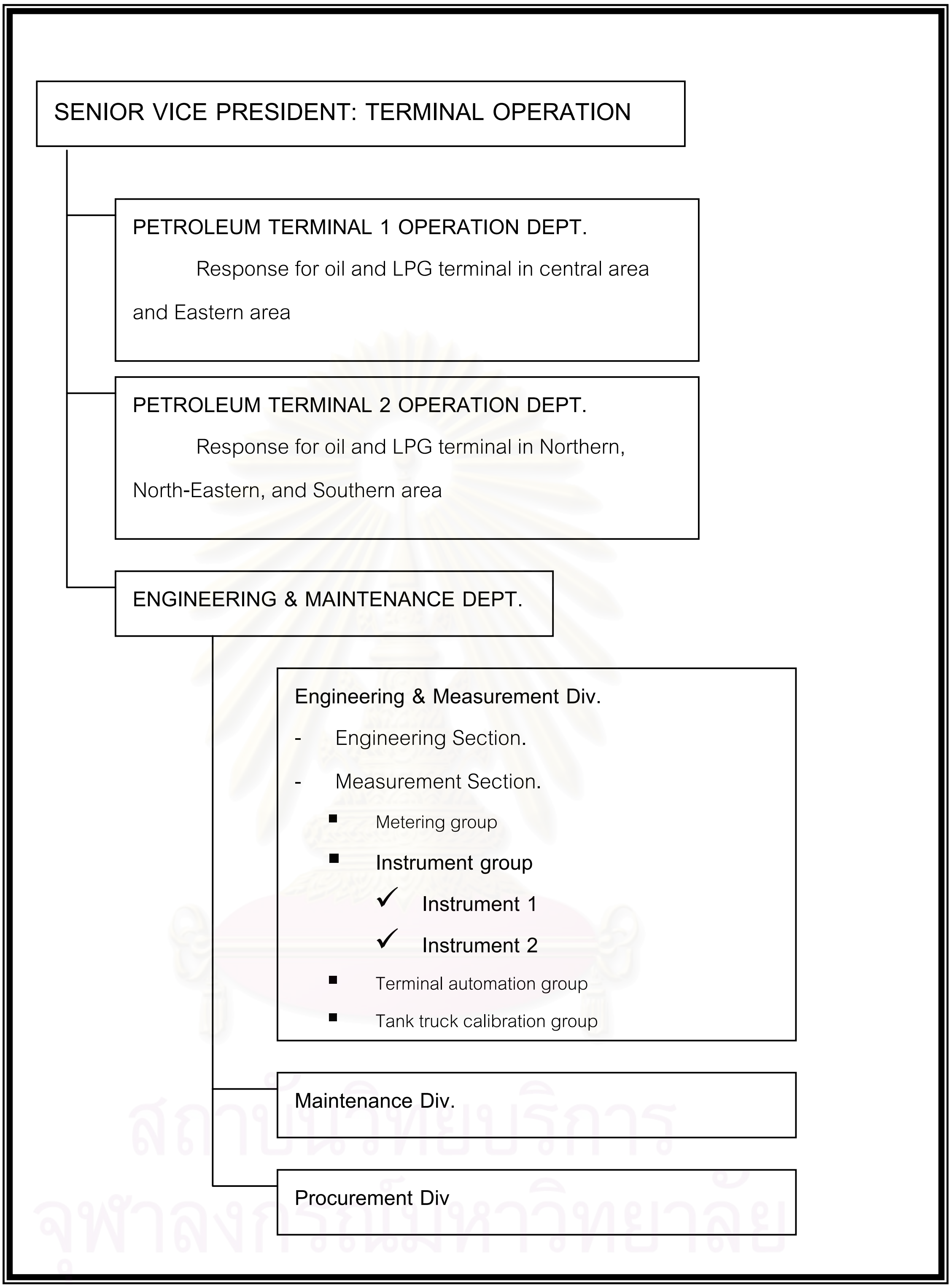


Figure 3.2: senior vice president terminal operation organization chart

Source: [12]

3.2 OIL AND LPG TERMINAL OPERATION PROCESS

Oil and LPG terminal receive products from refineries and gas separation plant by pipeline, truck, ship, and train. The terminal's activities are to receive, to store, and to distribute product. The products in oil terminal are Unleaded, Regular and Premium Gasoline, High Speed Diesel, and Jet fuel and the product in LPG terminal is liquefied petroleum gas.

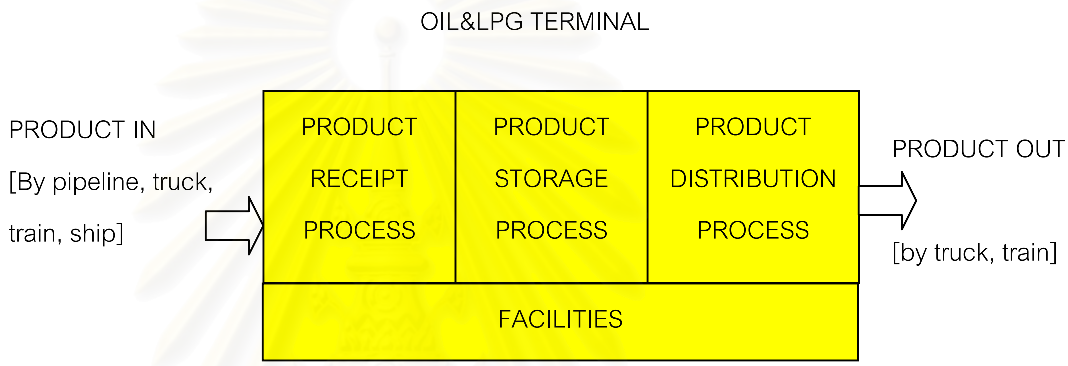


Figure 3.3 Activities in Oil and LPG terminal

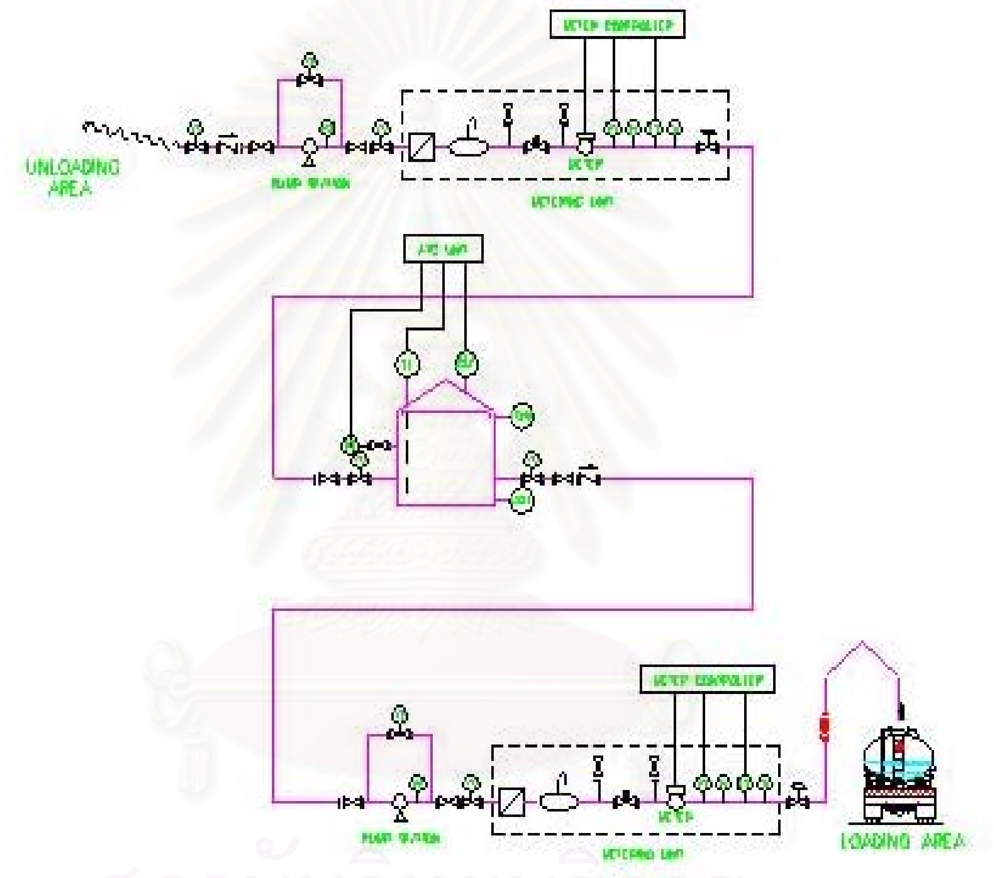


Figure 3.4: Schematic flow diagram for oil terminal

Source: Engineering and Measurement Division

3.2.1 PRODUCT RECEIVE PROCESS

As mention before that product are delivered to the terminal by pipeline, truck, train, and ship depending on the physical feature of each terminal. The terminal that receive product from pipeline and ship has no product receiving facilities because produce in pipeline has been pumped from sending area and incase if ship, it has pump to pump product to storage tank. For truck and train, the terminal has to have unloading system to unload product from transportation vehicle and send product to storage tank. This process called product unloading or product receipt process. Some terminal measure receipt volume by metering system. The other, having no metering system, measures receipts volume from Tank Gauging System in later step.

Metering system

Metering system is the group of measuring instrument. The major instrument is meter. The auxiliary instrument are pressure instrument and temperature instrument. When liquid flow through meter, meter will count liquid volume. Pressure and temperature of liquid will be measured and it is used to calculate correction factor of pressure and temperature on liquid volume. The correction factor is used to convert observe volume, read from meter, to standard volume, the volume at 0 psi and 30 ^{o}C.

The measuring instruments involving in the process are shown in table below;

SYSTEM	FUNCTION	MEASURING INSTRUMENT NAME	PURPOSE OF USING	NOTE
Unloading pump system	Unload product from transportation vehicle to storage tank	Pressure gauge	Monitor pressure. It indicate pump performance and valve condition	
Unloading pipeline	Act as media to transfer product	Pressure gauge	Monitor pressure. It indicates valve condition and LPG property in liquid and vapor line.	
Metering system	Measure the receipt quantity	Oil or LPG meter	Measure the input quantity	Not in research scope
		Pressure gauge	Monitor pressure at local area, used for cross-check with pressure in control room	
		Pressure transmitter	Measure pressure and transmit signal to control room for calculating product volume	
		Temperature gauge	Monitor temperature at local area, used for cross-check with temperature in control room	
		Temperature transmitter	Measure temperature and sent signal to control room for calculating product volume	

Table 3.1 Measuring instrument in product receive process

3.2.2 PRODUCT STORAGE PROCESS

Product pumped from unloading pump to storage tank. The measuring instruments involving in the process is tank gauging system

Tank gauging system.

Tanks gauging system measures product level in storage tank before and after receive product. The different level will be converted to volume later. The major instrument is level gauge. The auxiliary instrument are pressure instrument and temperature instrument. For example before receiving, we know that the tank contain product 2 meters high from bottom of the tank. Then we change the 2-meter high to volume by using tank table. Assuming that tank table show the 2 meters is equal to 10,000 liters. After receive, the tank has product 6 meters high from bottom of the tank and we know that the 6 meters in the tank equal to 32,000 liters. Then we know that receive volume is 32,000-10,000 = 22,000 liters. This is easy example showing how tank gauging system work. Practically it is more complicated because it has to include effect of pressure and temperature on product volume and convert to standard volume, like process in metering system. The measuring instruments involving in the process are shown in table 3.2.

SYSTEM	FUNCTION	MEASURING INSTRUMENT NAME	PURPOSE OF USING	NOTE
Tank gauging system	Measure quantity of storage product	Level gauge	Measure level in the storage tank and convert level to volume	Not in research scope
		Pressure gauge	Monitor pressure at local area, used for cross-check with pressure in control room	
		Pressure transmitter	Measure pressure and transmit signal to control room for calculating product volume.	
		Temperature gauge	Monitor temperature at local area, used for cross-check with temperature in control room.	
		Temperature transmitter	Measure temperature and sent signal to control room for calculating product volume.	

Table 3.2 Measuring instrument in product storage process

3.2.3 PRODUCT DISTRIBUTION PROCESS

Product will be pumped from storage tank to distributing vehicle, truck and train. Oil terminal use metering system to measure out-product volume. LPG terminal use weight scale to measure out-product volume. The measuring instruments involving in the process are shown in table 3.3.

SYSTEM	FUNCTION	MEASURING INSTRUMENT NAME	PURPOSE OF USING	NOTE
Loading pump system	Load product from storage tank to transportation vehicle	Pressure gauge	Same as in product receive process.	
Metering system	Measure the input quantity of product	Oil meter	Measure the oil out quantity	Not be in research scope
		Pressure gauge	Same as in product receive process.	
		Pressure transmitter	Same as in product receive process.	
		Temperature gauge	Same as in product receive process.	
		Temperature transmitter	Same as in product receive process.	
Loading pipeline		Pressure gauge	Same as in product receive process.	
Weight scale		Weight scale	Measure LPG output in weight.	

Table 3.3 Measuring instrument in product distribution process

3.2.4 FACILITY PROCESS

Apart from main processes, the terminal has facility systems such as LPG compressor system, Air compressor system, and hydro-test system.

LPG compressor

LPG compressor is used for control LPG pressure in LPG terminal. In ambient pressure and temperature, LPG is in vapor phrase but it is compressed to liquid phrase during transportation and storage so LPG terminal has to control pressure in LPG storage system, normally 5- 15 bar, by using LPG compressor. When pressure in system is lower than low limit, detected by pressure switch, compressor pump will be started to increase pressure in the system. When pressure is up to high limit, detected by pressure switch, compressor pump will be stopped. Pressure and temperature instrument is used to monitor pressure and temperature in LPG compressor.

Air compressor

The terminal use compressed air in many purposes such as a signal for open and close valve in tank farm. Air compressor system is used for generating compressed air. It works like LPG compressor. When pressure in air reservoir is lower than low limit, detected by pressure switch, compressor pump will be started to increase pressure in air reservoir. When pressure is up to high limit, detected by pressure switch, compressor pump will be stopped. Pressure and temperature instrument is used to monitor pressure and temperature in air compressor.

Hydro-test

Oil and LPG terminal do hydro-test to test pressure vessel and high-pressure instrument such as LPG cylinder and LPG hose. Hydro-test process is done by pump water to tested instrument and increase pressure up to demanded pressure. If pressure in tested instrument is constant, it means that there is no leak or deformed and it can be continuously used. Measuring instrument in hydro-test is pressure gauge.

The measuring instruments involving in these processes are shown in table 3.4.

SYSTEM	FUNCTION	MEASURING INSTRUMENT NAME	PURPOSE OF USING	NOTE
LPG compressor system	Compress LPG from vapor phrase to liquid phrase	Pressure gauge	Monitor pressure at local area, used for cross-check with pressure switch	
		Pressure switch	Control pressure in the system	
		Temperature gauge	Monitor temperature at local area, used for cross-check with temperature switch	
		Temperature switch	Control temperature in the system	
Hydro test system	Test pressure	Pressure gauge	Monitor pressure in subject that has been test eg hose.	
Air Compressor	Air supply system	Pressure gauge	Monitor pressure at local area, used for cross-check with pressure switch	
		Pressure switch	Control pressure in the system	
		Temperature gauge	Monitor temperature at local area, used for cross-check with temperature switch	
		Temperature switch	Control temperature in the system	

Table 3.4 Measuring instrument in facility system in oil and LPG terminal

3.3 CALIBRATION SUPPORT UNIT ACTIVITIES

3.3.1 QUALITY DOCUMENT SYSTEM IN ORGANIZATION

The company divide document system to 4 level as shown in table below.

LEVEL	TYPE OF DOCUMENT	MANAGE BY
1	Manual	Quality Safety and Environment Division
2	Procedure	Working Division
3	Instruction	Working Division
4	Support document/ Record/ Form	Working Division

Table 3.5 Quality document in organization

Quality manual

Quality manual is document in top level in quality system. It contains the statement of company's policy to achieve quality standard. Quality manual is written and controlled by Quality Safety and Environment Division, the division that take charge with quality system for whole organization.

Quality procedure

Quality procedure is document in a level lower than quality manual. Quality procedure tells the procedure that each section, division, and department have to do to achieve quality standard in its own scope of work. Quality procedure shows the inter-relation between section, division, and department to work a task. Every working unit has to write it own quality procedure and the procedures are managed by Quality Safety and Environment Division.

Work instruction

Work instruction is document that support quality procedure. It describes detail in each work step by step. For example the calibration support unit has calibration procedure to support oil and LPG terminal in instrument calibration in, it may has many work instruction in calibration procedure such as instruction for pressure gauge calibration weight scale calibration, etc. Working units have to write their own procedures and they are manage by Quality Safety and Environment Division.

Support document

Support document is documenting in the lowest level in document system. It is document that section, division, and department used to support their work. The support documents in calibration support unit are calibration standards, instrument manual, calibration forms, records, etc. Each working unit has to control support documents by itself.

3.3.2 CALIBRATION PROCEDURES

There are two calibration procedures used in instrument calibration.

3.2.2.1 PROCEDURE 1: CALIBRATE BY INTERNAL STAFF

STEP 1: make the list of calibrated instrument and set calibration plan.

The first step in instrument calibration procedure is to make the list of calibrate instrument and calibration schedule.

1.1 The calibration support unit staff collect information about instruments that are in scope of the unit's responsibility in each terminal by investigating the existing instrument history and asking information from terminal staff.

1.2 The calibration support unit staff discuss with terminal staff and determine instrument that need to be calibrated.

1.3 The calibration support unit staff investigate more detail in instrument that are selected in 1.2 to fulfill detail in list of calibration form. The detail that are need are location, maximum range, working range, calibration range, accuracy, etc.

1.4 The calibration support unit staff make a list of calibrated instrument and calibration plan.

1.5 The calibration support unit staff distribute lists of calibrated instruments to the terminals.

STEP 2: Confirm calibration date to terminal staff and discuss what calibrator needs supporting from terminal staff.

About 15 days before the due date, the calibrator will connect terminal staff who take care of measuring instrument in that terminal for confirm the calibration date and discuss about the thing that calibrator need support from terminal staff.

STEP 3: Instrument calibration [manuscript result]

The calibration support unit staff calibrate instrument according to work instruction. If the result is pass, the staff will attach the “calibrated” sticker. If the result isn’t pass, the staff will fix or replace the new one. The calibration person will bring manuscript result back to Bangkok and pass its to typewriter to make formal calibration report in later step.

STEP 4: Make formal calibration report.

In this step, the calibrator will bring handwriting calibration report back to Bangkok and make formal report by himself or pass the handwriting calibration report to typewriter to make formal calibration report.

STEP 5: Formal calibration reports approval.

After the formal calibration report is printed, it is passed to engineer to approve report in two categories.

5.1 To approve the completeness and correction of the report.

5.2 To make decision whether the calibrated instrument should be continuously used or not.

STEP 6: Record to calibration history sheet

After approval, the typewriter will record calibration result to calibration history sheet.

3.2.2.2 PROCEDURE 2: CALIBRATE BY EXTERNAL CALIBRATOR

STEP 1: Make the list of calibrated instrument and set calibration plan.

Step 1 is same activities as procedure 1.

STEP 2: Procurement

The calibration support unit staff contact external calibrator, discuss about calibration place, number and type of calibrated instrument.

STEP 3: Confirm calibration dates to terminal staff and discuss what calibrator needs supporting from terminal staff.

The process in this step is same as step 2 in procedure 1.

STEP 4: Supervise instrument calibration.

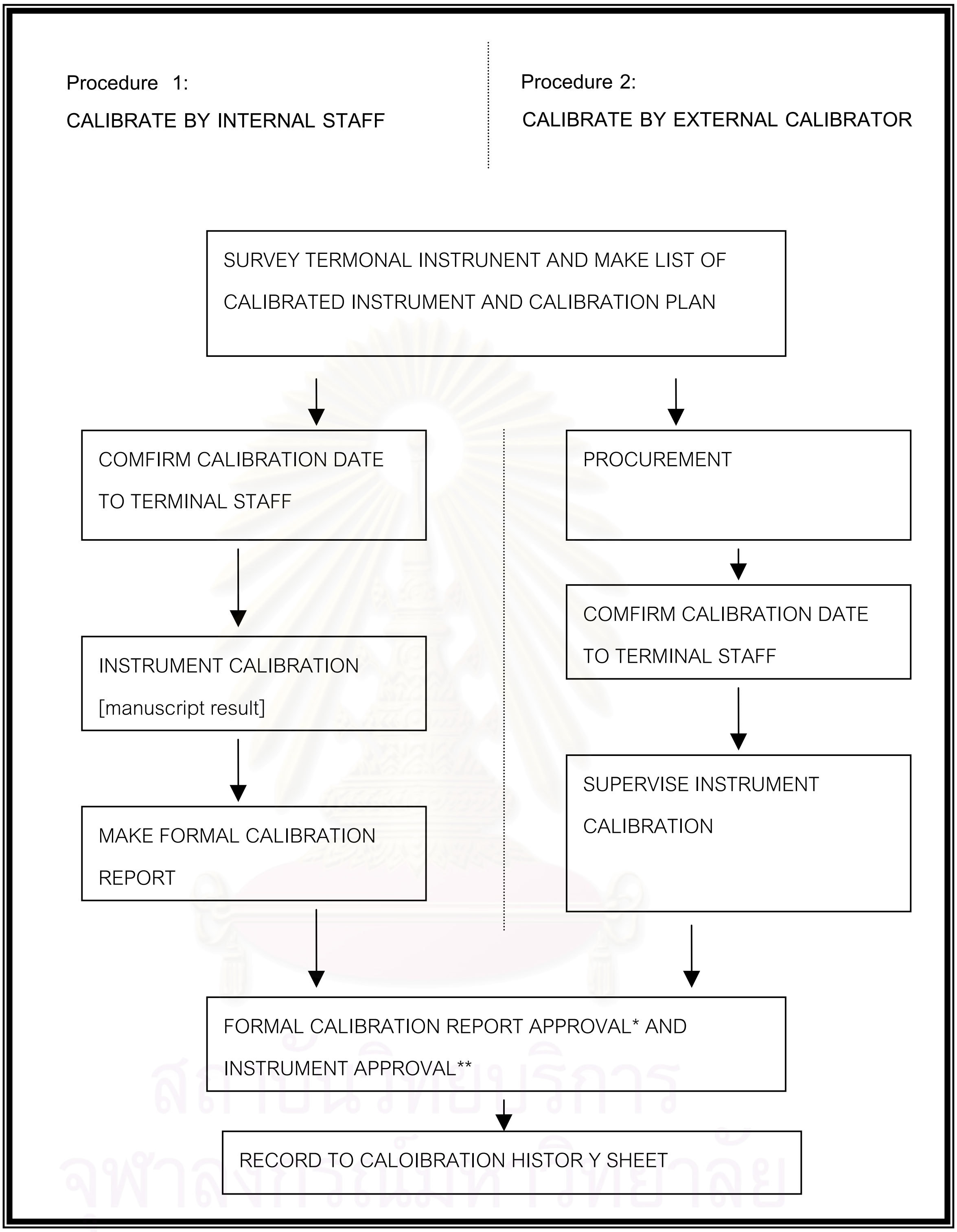
The calibration support unit staff supervise the calibration activities of external calibrator. If the result is pass, the staff will place the "calibrated" sticker. If the result isn't pass, the staff/calibrator will fix or replace the new one.

STEP 5: Formal calibration reports approval.

This step is same as in procedure 1.

STEP 6: Record to calibration history sheet.

This process is same as in procedure 1



Note * Report approval : to approve completeness and correction of report.

** Instrument approval : to make decision whether the calibrated instrument should be continuously used or not

Figure 3.5: Calibration procedure

INSTRUMENT	INTERNAL CALIBRATION	EXTERNAL CALIBRATION	EXTERNAL CALIBRATION WITH GOVERNMENT OFFICIAL
1. Pressure gauge	X	X	
2. Pressure transmitter		X	
3. Pressure switch		X	
4.Temperature gauge		X	
5. Temperature element and transmitter		X	
6. Temperature switch		X	
7. Weight scale			X

Table 3.6: Type of instrument calibration

3.3.3 INSTRUCTIONS

The calibration support unit has 5 work instructions as shown below [detail in appendix A].

3.3.3.1 The 4 kg. weight scale calibration.

3.3.3.2 The 15 kg. weight scale calibration.

3.3.3.3 The 48 kg. weight scale calibration.

3.3.3.4 The 120 kg. weight scale calibration.

3.3.3.5 The pressure gauge calibration.

3.3.4 FORMS

The calibration support unit has 6 form as shown below [detail in appendix B].

3.3.4.1 Maintenance and calibration history form.

3.3.4.2 Calibration and preventive maintenance plan form.

3.3.4.3 Instrument calibration list form.

3.3.4.4 Reject calibrated instrument form.

3.3.4.5 Weight scale calibration form.

3.3.4.6 Pressure gauge calibration form.

3.4 PROBLEMS

Although the company had implement quality system for three year and calibration support unit had supported calibration activities since the first implementation, it still has problems in calibration activities especially in calibration document such as error in calibration report form and acceptance criteria for each instrument. These problems obstruct calibration staff from finishing each calibration task within the time that it should be because the calibration staff has to solve problems time by time. Finally all problem express in form of late in calibration task [detail in appendix C].

INSTRUMENT	AVERAGE DELAY DATE IN 2000
Pressure gauge	33
Pressure transmitter	82
Pressure switch	40
Temperature gauge	81
Temperature element and transmitter	96
Temperature switch	51
Weight scale	26

Table 3.7: Delay of calibration report approval date during 2000

3.5 PROBLEM ANALYSIS FOR QUALITY IMPROVEMENT

To analyze problem occurring in section 3.4, we will use two basic tool of quality: process flow chart and cause and effects diagram.

3.5.1 PROCESS FLOW CHART

Before attempting to improve process quality, it is important to understand the process. The calibration process from calibration to calibration report approval whish express as delay in calibration report approval is shown in figure below.

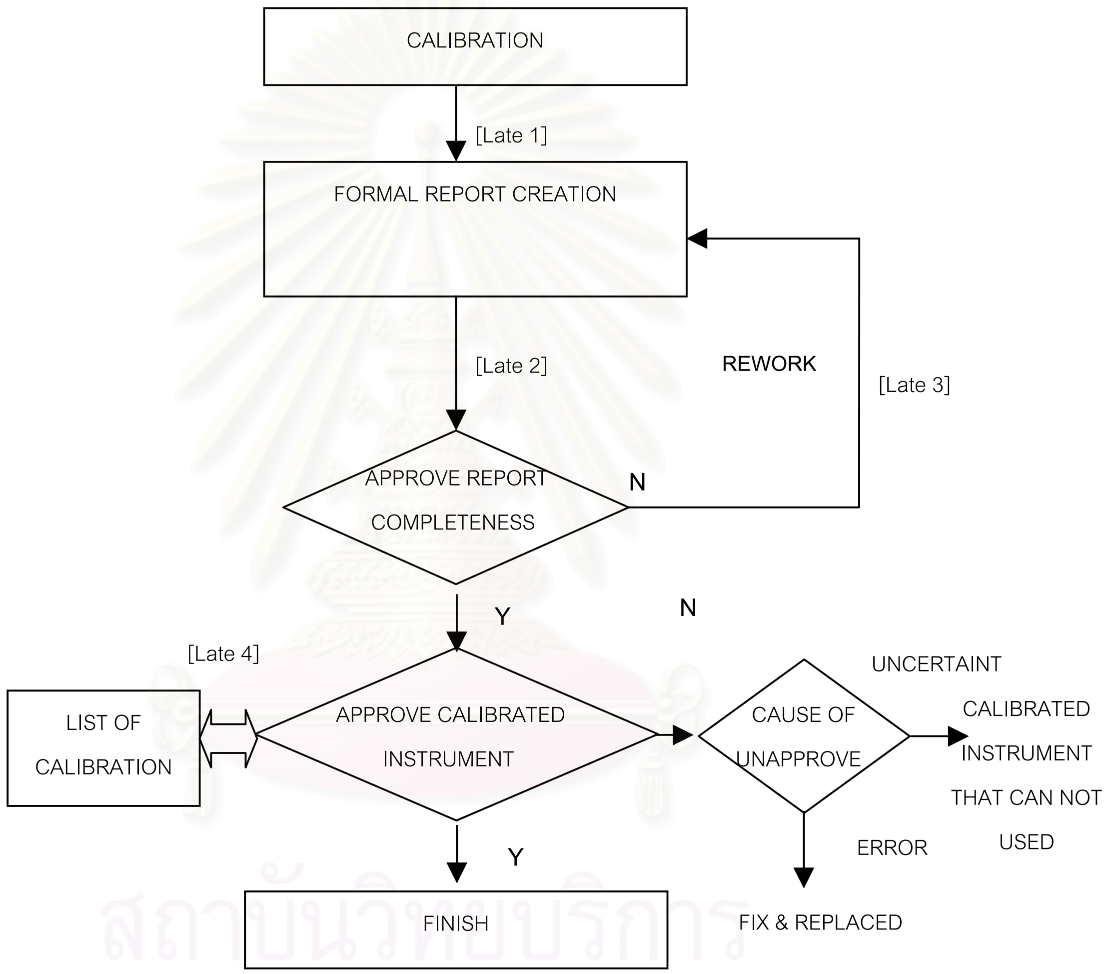


Figure 3.6: Delay of calibration report approval date model

From process flow chart we know that the problem “delay in calibration date approval” compose from 4 minor problem.

1. Delay in data transfer between calibration staff and calibration report creation staff [late 1].
2. Delay in calibration report creation [late 2].
3. Delay from calibration report rework result from incomplete reports [late 3].
4. Delay in calibrated instrument approval [late 4].

3.5.2 CAUSE AND EFFECT DIAGRAM

After identified the effect of problem, delay in calibration report approval, researcher arrange the meeting in calibration support unit to discuss and collect idea about cause of problem. The meeting has two sections. The first section is about idea generation by applying brainstorming procedure. After having enough idea, the ideas are group and categorize in second section by applying cause and effect diagram that shown on figure 3.7.

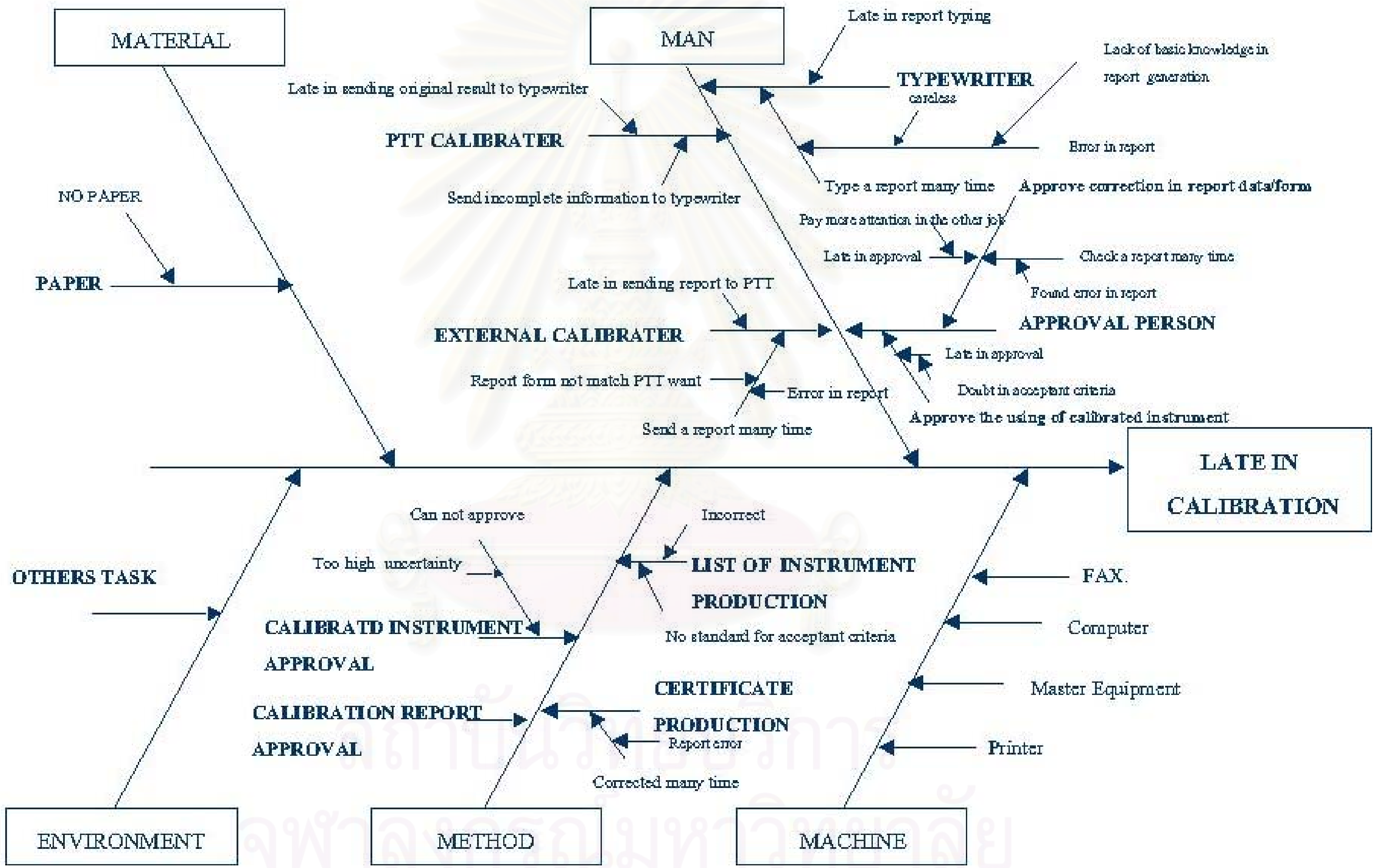


Figure 3-7: Cause and effect diagram for late in calibration

From cause and effect diagram, we classify problems into 4 problems.

3.5.2.1 Problems in acceptant criteria.

The company has no standard in acceptant criteria for calibrated instrument. Calibration support unit found that each terminal defines the acceptant criteria by itself. This causes the acceptant criteria, accuracy and uncertainty for same instrument vary from terminal to terminal. These situation cause instrument acceptant staff doubt in criteria and has question in mind such as " Is the acceptant is correct?", "Should we follow it ?", and "When the error in calibration result is more than acceptant criteria, should we expand the criteria or replace the new instrument ?. So practically, when the instrument error is more than acceptant criteria, operator hesitates to change the new one, especially the expensive instrument.

3.5.2.2 Problem in the expression of uncertainty and it's implementation.

3.5.2.2.1 The application of uncertainty in calibrated instrument approval.

Company has two criteria in calibrated instrument approval: accuracy and uncertainty.

Case 1: If both values are pass or not pass, there is no problem in approval.

Case 2: When the accuracy pass but uncertainty not pass, the acceptant personal can't determine whether the instrument should be use or not use.

CASE	CALIBRATION RESULT		ACTION
	ACCURACY	UNCERTAINTY	
1	Pass	pass	Approve
2	pass	Not pass	**Problem**
3	Not pass	Pass	Not approve
4	Not pass	Not pass	Not approve

Table 3.8: Problem in calibrated instrument acceptant criteria.

3.5.2.2.2 The uncertainty in calibration excess than limit.

As we mention before that there are two criteria in calibrated instrument approval: accuracy and uncertainty. An another problem in uncertainty is we found that the calibration result has uncertainty excess than limit.

INSTRUMENT	ACCEPTANT CRITERIA		CALIBRATION RESULT **(problem)**	
	ACCURACY	UNCERTAINTY	ACCURACY (pass)	UNCERTAINTY (not pass)
PRESSURE GAUGE	± 2.5% FS	± 0.83% FS	- 2.1% FS	**+ 4.7% FS**
			1.18% FS	**+ 0.94% FS**
			2.0% FS	**+ 1.57% FS**
PRESSURE TRANSMITTER	± 0.2% FS	± 0.06% FS	± 0.02% FS	**+ 0.145% FS**

Table 3.9: Example of problem in uncertainty application.

Month, 2000	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
REPORT[%]	6.9	18	28	20.5	6.6	10.4	60	33.3	12.5	11.9	37.3	40

Table 3.10: The calibrated instrument that can't be used result from uncertainty excess than limit

Source: [13]

3.5.2.3 Problem in calibration and calibration report.

There has no instruction for master instrument, the calibrator use it by experience. And after calibration the instrument, sometime calibrator bring draft manuscript back to Bangkok and make formal report by himself add sometime the draft manuscript has passed to typewriter to make formal report. Practically the formal report has not be done immediately after calibration. The certificate made by typewriter frequently has error so the typewriter has to bring the certificate back to fix the error. It causes the report approval process take a long time and the approval personnel have to take many times in calibration certificate approval. In addition the current certificate form has many disadvantage such as it does not mention traceability, calibration method, etc.

Month, 2000	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rework report [%]	89.7	44	98.9	54	27.4	100	64	57.8	56.3	64.4	14.9	25

Table 3.11: Number of rework calibration report.

Source: [13]

3.5.2.4 Problem from external calibrator.

Because having not enough master instrument and calibration staff, calibration support unit has to use external calibrator. When calibration support unit ask external calibration unit to calibrate instrument, the staff will contact external staff by telephone and tell the place, type and number of instrument that want to calibrate. When external calibration units finish calibration and submit calibration certificate to PTT it has problems such as incorrect detail, too high uncertainty in calibration, non standard certificate , etc. the calibration support unit has to send it back for correction. So it take long time from instrument calibration and report approval.

3.6 COST OF QUALITY

We focus only tangible costs in this research so we will implement the AFCIQ Grid to find out the items of data collection before improvement

COST OF PREVENTION	DATA COLLECTION	REASON
A.1 Quality management		
A.1.1 Administration	Yes	-
A.1.2 Quality engineering	No	It was done by another division.
A.1.2.1 Quality research	No	No activity
A.1.2.2 Inspection method	No	It was done by another division.
A.1.2.3 Quality audit	Yes	-
A.2 Preparation and Implementation of Reviews		
A.2.1 Design review	No	No activity
A.2.2 Review of product specification documentation	No	No activity
A.2.3 Review of production documentation	No	No activity
A.2.4 Review of inspection documentation	No	No activity
A.3 Quality system for procurement	No	It was done by another division
A.3.1 Evaluation of supplier		
A.3.2 Inspection specification		
A.3.3 Verification of purchase order		
A.4 Quality training program	Yes	-
A.5 Other prevention expenditure	No	No activity

Table 3.12: Prevention costs analysis

COST OF EVALUATION	DATA COLLECTION	REASON
B.1 Industrial evaluation of the product	No	No activity.
B.2 Acceptance inspection of products purchased externally	No	No activity
B.2.1 Evaluation of products purchased externally		
B.2.2 Inspection at supplier's premises		
B.2.3 Inspection of incoming good		
B.2.4 Cost of material expended		
B.2.5 Data processing and analysis		
B.3 Inspection of production	Yes	-
B.3.1 Inspection of the process		
B.3.2 Inspection of production start-up		
B.3.3 Inspection of production in progress		
B.3.4 "Super inspection"		
B.3.5 Inspection of packaging process		
B.3.6 Final inspection.		
B.3.7 Certification by official agencies		
B.3.8 Evaluation of inventory		
B.3.9 Material expended during testing		
B.3.10 Processing of inspection data		
B.3.11 Product quality audit		
B.4 Metrology	No	No activity
B.4.1 Materiel used for inspection		
B.4.2 Material used for production		

Table 3.13: Evaluation or appraisal costs analysis

COST OF INTERNAL DEFECTS	DATA COLLECTION	REASON
C.1 Production failures	No	No production process
C.1.1 Production failures		
C.1.2 Design failures		
C.1.3 Failure in external procurements		
C.2 Corrective alterations	No	No production process
C.2.1 Production failures		
C.2.2 Design failures		
C.2.3 Failure in external procurements		
C.3 Locating of defects	No	No activity
C.4 The rejection process	No	No activity
C.5 Re-inspection of products that have been corrected	Yes	-
C.6 Downgrading or terminating of product	Yes	-

Table 3.14: Internal defect or failure costs analysis

REJECTIONS	DATA COLLECTION	REASON
D.1 CLAIM AND COMPLAINTS D.1.1 After-sale service D.1.2 Products rejected and returned D.1.3 Technical assistance/repair of rejected products D.1.4 Replacement under warranty D.1.5 Installation defects D.1.6 Error in product application research D.1.7 Design error D.1.8 Civil and criminal liability	Yes	-
D.2 Loss of known clientele	No	All customer are internal customer

Table 3.15: Rejection or external failure costs analysis

In conclusion the cost of quality before improvement in the research collected from the following items.

The prevention costs are collected from

- Cost of quality coordinator [estimate from man-hour]
- Training cost [estimate from man-hour of instructor and trainee]
- Maintenance and calibration of test instrument cost

The appraisal costs are collected from

- Process quality audit [estimate from man-hour of auditor and participants]

The internal failure costs are collected from

- Calibration report rework
- Cost of calibration in instrument that the instrument that has been calibrated but can’t be used result from uncertainty in calibration excess than limited.

The internal external failure costs are collected from

- Customer complain

The cost of quality collected in research before improvement is shown in table 3.16.

Year 2000	PREVENTION COST	APPRAISAL COST	COST OF CONFORMANCE	INTERNAL FAILURE COST	EXTERNAL FAILURE COST	COST OF NON-CONFORMANCE
Jan.	1,827	0	1,827	12,250	0	12,250
Feb.	2,124	5,209	7,333	9,650	0	9,650
Mar.	12,500	0	12,500	34,850	2,698	37,548
Apr.	2,360	0	2,360	50,250	0	50,250
May.	3,540	0	3,540	4,925	0	4,925
Jun.	14,576	354	14,930	15,225	0	15,225
Jul.	6,780	0	6,780	17,050	0	17,050
Aug.	14,340	0	14,340	7,375	0	7,375
Sep.	12,295	0	12,295	4,500	0	4,500
Oct.	2,360	0	2,360	10,275	0	10,275
Nov.	3,540	0	3,540	34,950	0	34,950
Dec.	7,360	0	7,360	19,575	0	19,575
Average	6,996.8	463.6	7,430.4	18,406.3	224.8	18,631.1

Table 3.16: Cost of quality before improvement in Baht.

Source: [13]

CHAPTER 4

THE IMPROVEMENT OF CALIBRATION ACTIVITIES

The following steps below do the improvement of calibration support unit activities.

4.1 DETERMINE THE ACCEPTANT CRITERIA FOR CALIBORATED INSTRUMENT

Measuring instrument which has same propose of using should has same acceptant criteria although it located in different terminal. Normally the acceptant criteria depend on the permissible error of product. So the first step to determine acceptant criteria for measuring instrument is to determine product permissible error and then determine acceptant criteria for measuring instrument that will be used to measure product later.

4.1.1 PRODUCT PERMISSIBLE ERROR DETERMINATION

Permissible error for pressure and temperature measurement on product

Normally product permissible error determination depends on company standard, international standard, agreement between dealer and customer, and involved law or regulation. In some case, it is easy to determine instrument acceptant criteria because we had already known product permissible error. For example if we produce ball bearing that we allow maximum error for outside diameter $\pm$ 0.02 mm, we can determine the permissible error of vernier that we use to measure this work-piece. But for pressure and temperature instrument in oil and LPG terminal, it is difficult to establish maximum error because oil and LPG are measure by volume and weight. The Law and regulation related to oil and LPG are Weigh & Measure Law, Customs Law and Excise Law.. For example, Weigh and Measure law limit permissible error of $\pm$0.2% for custody transfer in metering system, Custom Law limit permissible error of ±6 mm for level gauge, range between 10-20 m, for imported and exported product.

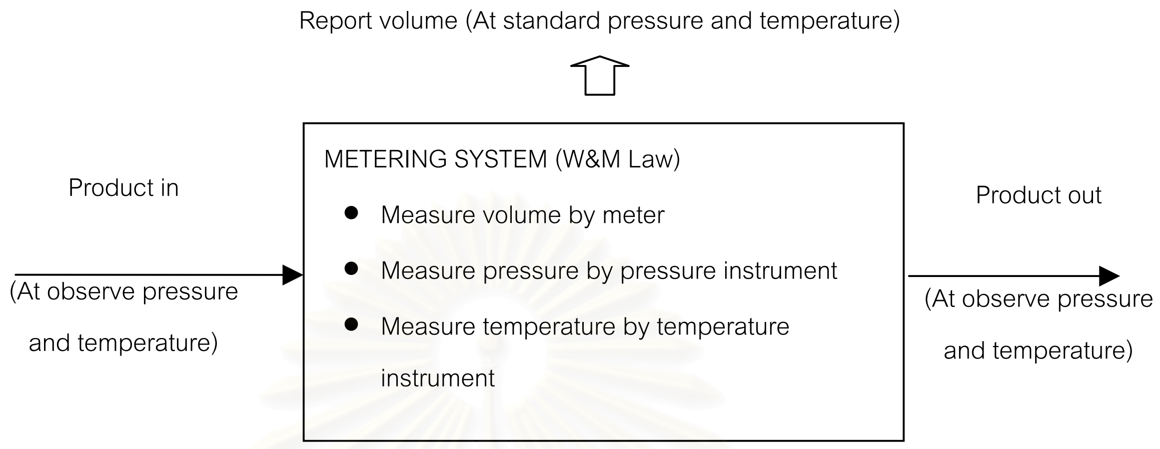


Figure 4.1: Measuring instrument in metering system

Figure 4.1 shows that in metering system, we measure product volume by meter, measure product pressure by pressure instrument, and measure product temperature by temperature instrument. But there has permissible error only in overall metering system. And there has no regulation for permissible error of each measuring instrument.

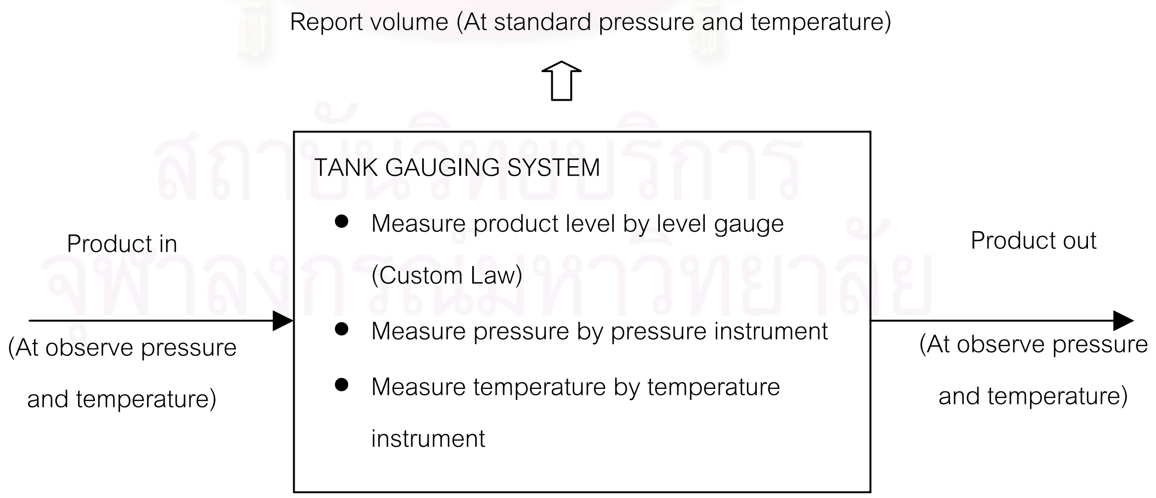


Figure 4.2 Measuring instrument in tank gauging system

Figure 4.2 show that there are three measurements in tank gauging system: level gauge, pressure instrument, and temperature instrument. There has available law only about level gauge and there has no law or regulation related to pressure and temperature instrument.

To determine permissible error for pressure and temperature in each measuring system, we have to know the effect of pressure and temperature on product volume. Researcher study the effect of pressure and temperature on product volume (detail in appendix D) and present idea for permissible error determination in pressure and temperature that effect product volume that shown in table 4.1.

ITEMS	PRODUCT PERMISSIBLE ERROR
1. Oil pressure	+/- 2 Bar
2. Oil temperature	+/- 1.2 ^{o}C
3. LPG pressure	+/- 2 Bar
4. LPG temperature in liquid phrase	+/- 0.8 ^{o}C
5. LPG temperature in vapor phrase	+/- 1.2 ^{o}C

Table 4.1: Permissible error for pressure and temperature

Permissible error for weight measurement

There has Weight &Measure Law for custody transfer by weigh so it is easier to determine permissible error that shown in table 4.2 [detail in appendix E].

ITEMS	PRODUCT PERMISSIBLE ERROR
1. 4 kg. package	80 g
2. 15 kg package	150 g
3. 48 kg package	480 g

Table 4.2: Permissible error weight indicated in package

Apart from pressure and temperature instrument used for measure pressure and temperature that effect product volume, there has other pressure and temperature instrument act as process instrument and doesn't effect product quantity so we will discuss about these instrument in later step.

4.1.2 MEASURING INSTRUMENT PERMISSIBLE ERROR DETERMINATION

After determine product permissible error, the next step is to determine measuring instrument permissible error. We know that instrument permissible error should be less than product permissible error. Normally it expresses in ratio between product permissible error and instrument permissible error. The higher ratio, the better instrument used in process. But it is limited by instrument cost and the availability of master instrument to calibrate this instrument. Then the ratio 5:1 is the popular one. Assume that we use ratio 5:1 between product permissible error and instrument permissible error, we will get instrument permissible error that shown in table 4.3.

ITEMS	PRODUCT PERMISSIBLE ERROR	INSTRUMENT PERMISSIBLE ERROR [when applying ratio 1:5]
1. Oil pressure	+/- 2 Bar	+/- 0.4 Bar
2. Oil temperature	+/- 1.2 ^{o}C	+/- 0.24 ^{o}C
3. LPG pressure	+/- 2 Bar	+/- 0.4 Bar
4. LPG temperature in liquid phrase	+/- 0.8 ^{o}C	+/- 0.16 ^{o}C
5. LPG temperature in vapor phrase	+/- 1.2 ^{o}C	+/- 0.24 ^{o}C
6. 4 kg. package	80 g	16 g
7. 15 kg package	150 g	30 g
8. 48 kg package	480 g	96 g

Table 4.3: Instrument permissible error determination (1)

Apart form instrument in Table 4.3, terminal has another type of measuring instrument. These instruments are installed in operation process and not involving in product quantity so there has no product permissible error. However the measurement should has instrument error. Researcher studies its purpose of using and instrument selection from design phrase. Finally determine permissible error for these instrument that shown in table 4.4[detail in appendix F]

INSTRUMENT	INSTRUMENT PERMISSIBLE ERROR
1. Pressure gauge	+/- 0.5 Bar
2. Temperature gauge	
Range 100 °C	+/- 2 °C
Range 200 °C	+/- 4 °C
Range 300 °C	+/- 6 °C
3. Pressure switch	+/- 0.5 Bar
4. Temperature switch	+/- 5 °C

Table 4.4 Instrument permissible error determination (2)

When consider from calibration report, there are two criteria involving in instrument permissible error: error and uncertainty. However we can correct instrument error by plus or minus the value differ between master instrument and measuring instrument.

Standard [Bar]	UUT Reading [Bar]	Error[Bar]
….	….	….
10.1	10.0	- 0.1
….	….	….

Figure 4.3: Error in calibration report

For example when we use pressure gauge to measure product pressure at 10 bar and we know from calibration report that at 10 bar, pressure gauge indicates pressure less than standard value 0.1 bar. We can correct pressure reading from pressure gauge by plus 0.1 bar to pressure gauge reading at 10 bar.

Practically the use or not use of correction value depends on operator and company’s policy. The use of correction value will make operator more difficulty in his/her routine job but it help company save money from changing measuring instrument frequency result from instrument error.

An another criterion is uncertainty in calibration. When we calibrate instrument it has uncertainty in instrument calibration result from calibration process and instrument we use in calibration process. Uncertainty can't be eliminated. But we can decrease uncertainty by controlling uncertainty component.

4.1.3 MASTER INSTRUMENT SPECIFICATION DETERMINATION

From Chapter 2, it mention two criteria in master instrument specification determination; accuracy ratio and uncertainty ratio. When we apply accuracy ration 3:1 and uncertainty ratio 4:1 to terminal measuring instrument, we will get master instrument specification that shown in table 4.5

INSTRUMENT	INSTRUMENT PERMISSIBLE ERROR	MASTER INSTRUMENT SPECIFICATION [ACCURACY]	MASTER INSTRUMENT SPECIFICATION [UNCERTAINTY]
1. Pressure instrument that measure oil pressure	+/- 0.4 Bar	+/- 0.13 Bar	+/- 0.1 Bar
2.Temperature instrument that measure oil temperature	+/- 0.24 °C	+/- 0.08 °C	+/- 0.06 °C
3. Pressure instrument that measure LPG pressure	+/- 0.4 Bar	+/- 0.13 Bar	+/- 0.1 Bar
4.Temperature instrument that measure LPG temperature in liquid phrase	+/- 0.16 °C	+/- 0.05 °C	+/- 0.04 °C
5. Temperature instrument that measure LPG temperature in vapor phrase	+/- 0.24 °C	+/- 0.08 °C	+/- 0.06 °C
6. Weight scale for 4 kg. package	16 g	5.3 g	4 g
7. Weight scale for 15 kg package	30 g	10 g	7.5 g
8. Weight scale for 48 kg package	96 g	32 g	24 g
9. Pressure gauge	+/- 0.5 Bar	+/- 0.17 Bar	+/- 0.13 Bar
10. Temperature gauge [Range 100 °C]	+/- 2 °C	+/- 0.7 °C	+/- 0.5 °C
11. Temperature gauge [Range 200 °C]	+/- 4 °C	+/- 1.4 °C	+/- 1 °C
12. Temperature gauge [Range 300 °C]	+/- 6 °C	+/- 2 °C	+/- 1.5 °C
13. Pressure switch	+/- 0.5 Bar	+/- 0.17 Bar	+/- 0.13 Bar
14. Temperature switch	+/- 5 °C	+/- 1.7 °C	+/- 1.3 °C

Table 4.5 Instrument permissible error determination.

We will use table 4.5 as a guide to control master instrument specification that we use in calibration process.

4.1.4 CALIBRATION PERIOD

Measuring instrument needs to be calibrated at suitable interval ensuring that they are used under specify permissible error. The determination of calibration period depend on many factors such as the standard operating manual, frequency of using, measuring environment, and etc. User has to decide the suitable calibration interval by himself because he is the people who work closely to measuring instrument.

The calibration period has to be review ensuring that the company suitable calibration interval. If it is found that the measuring instrument performance doesn't conform company specification, company has to solve problem by adjust the calibration period that can be done by the following procedure [14, pp.108-109.]

1. If in the first time, we set calibration period for pressure transmitter according to the manufacturer recommendation, assume that 4 months. After 4 months, the calibration results before adjustment show that the error still be in limit. We can expand the calibration period by multiply 1.5 to the current calibration period so the next calibration period is 6 months.

2. If the calibration result in 1 show that the error higher than limit. We should reduce calibration period by multiply 0.5 to the current calibration period so the next calibration period is 2 mouths.

4.2 THE CALIBRATED INSTRUMENT APPROVAL PROCEDURE

After calibration, we have to check the calibration report for two purposes; check reports completeness and make decision whether the calibrated instrument should be continuously used or not.

4.2.1 CHECK REPORT COMPLETENESS

Check report completeness mean check the correction of detail in calibration report such as instrument name, instrument identification, location, company name, unit used in calibration, etc and check the information shown in report. According to international standard ISO/IEC Guide 25, the calibration report include the following information:

- Title such as "Calibration Certificate" and "Test Report".
- Name and address of laboratory and calibrated location.
- Identification of the report.
- Name and address of customer
- Identification of calibrated or tested instrument.
- Characterization and condition of calibrated or tested item.
- Date of test or calibration.
- Identification of calibration or test method.
- Sampling procedure, where relevant.
- Deviation from calibration or test method.
- A statement of the estimated uncertainty of calibration or test result.
- A signature of authorized person.
- A statement to the offer that the result relates only to the item calibrated or tested, where relevant.
- A statement that the certificate or report shall not be copied except in full without laboratory approval in writing.

4.2.2 CALIBRATED INSTRUMENT APPROVAL

After calibration, company has to consider that whether the calibrated instrument should be continuously used or not. This step can be done by comparing calibration result with instrument permissible error. However it doesn't easy process when includes uncertainty in calibration in calibrated instrument approval process.

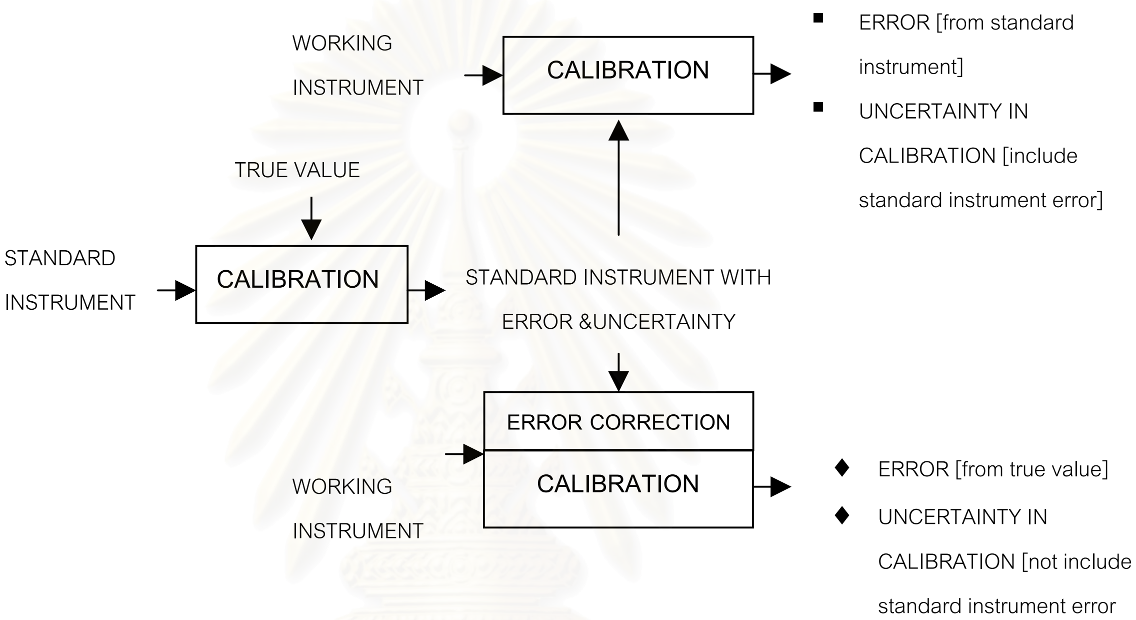


Figure 4.4: Model of error and uncertainty in calibration

Figure 4.4 show model of error and uncertainty that express in calibration report. At first calibration, we compare standard instrument with true value. Then we know standard instrument error and uncertainty in calibration standard instrument. When we bring standard instrument to calibrate working instrument, it can be done by two methods.

In the first method, we compare working instrument with standard instrument directly. Then we got error between standard instrument and working instrument.

The uncertainty in calibration in the first method has to include standard instrument error as a part of uncertainty component.

In the second method, we correct standard instrument error by plus or minus standard instrument reading before calibration. Then the error from second method is error between true value and working instrument. The uncertainty in calibration in this method has not to include standard instrument error as a part of uncertainty component. The second method is more complicated than the first method but it help us reducing uncertainty in calibration. When we use second method and eliminate error by error correction, then the instrument permissible equal to uncertainty. We will use this procedure in calibrated instrument approval.

4.3 DOCUMENT IMPLEMENTATION

The document improvement is calibration report form, work instruction, and calibration specification.

4.3.1 CALIBRTION REPORT FORMS

Calibration report forms are improved by applying ISO/IEC Guide 25. The improvements are adding calibration procedure, traceability, physical report standardization, etc. The improved forms are shown in appendix G.

4.3.2 WORK INSTRUCTIONS

Work instructions are improved by adding instruction about calibration report creation, instruction for the use of master instrument, pressure transmitter calibration, temperature transmitter calibration, etc. The work instruction is shown in appendix H.

4.3.3 CALIBRATION SPECIFICATIONS

Calibration specifications are developed for solving problem from external calibrator. It is used to control external calibrator. The specification specify master instrument permissible error, report form, calibration process, etc. The calibration specification has detail in appendix I.

4.4 DATA COLLECTION AFTER IMPROVEMENT

4.4.1 COST OF QUALITY

By using the same analytical method as data collection before improvement. The cost of quality after improvement collected from items below.

The prevention costs are collected from

- Cost of quality coordinator [estimate from man-hour]
- Meeting between calibration support unit staff and external calibrator [estimate from man-hour]
- Training cost [estimate from man-hour of instructor and trainee]
- Maintenance and calibration of test instrument cost

The appraisal costs are collected from

- Process quality audit [estimate from man-hour of auditor and participants]
- On site inspection [estimate from man-hour and traveling allowance expenditure]

The internal failure costs are collected from

- Calibration report rework
- Cost of calibration in instrument that the instrument that has been calibrated but can't be used result from uncertainty in calibration excess than limited.

The internal external failure costs in the table are collected from

- Customer complain

The cost of quality after improvement is shown in table below.

Year 2001	PREVENTION COST	APPRAISAL COST	COST OF CONFORMANCE	INTERNAL FAILURE COST	EXTERNAL FAILURE COST	COST OF NON-CONFORMANCE
Jan.	12,826	2,660	15,486	3,075	0	3,075
Feb.	6,674	707	7,381	700	0	700
Mar.	7,340	825	8,165	75	0	75
Average	8,946.7	1,397.4	10,344.1	1,283.3	0	1,283.3

Table 4.6: Cost of quality after improvement in Baht.

Source: [13]

4.4.2 DELAY OF CALIBRATION REPORT APPROVAL

The delay date of calibration report approval has detail in appendix J.

INSTRUMENT	AVERAGE DELAY DATE
Pressure gauge	13
Pressure transmitter	40
Pressure switch	21
Temperature gauge	30
Temperature element and transmitter	43
Temperature switch	No data
Weight scale	12

Table 4.7: Delay date in calibrated instrument during Jan -Mar 2001

4.4.3 NUMBER OF REWORK REPORT

The number of report rework is shown in table below.

Month, 2001	Jan	Feb	Mar
Rework report[%]	47.3	9	2.1

Table 4-8: Number of report rework report during Jan -Mar 2001

Source: [13]

4.4.4 NUMBER OF CALIBRATED INSTRUMENT THAT CAN'T BE USED [result from uncertainty higher than limit]

Month, 2000	Jan	Feb	Mar
REPORT[%]	0	1.5	0

Table 4-9: The calibrated instrument that can't be used result from uncertainty excess than limit

Source: [13]

CHAPTER 5

CONCLUSION AND SUGGESTION

5.1 COMPARISON OF BEFORE AND AFTER IMPROVEMENT

5.1.1 COST OF QUALITY

The cost of quality decreases 55.4 % that shown in table 5.1.

ITEMS	AVERAGE COST OF QUALITY [in Bath]	
	BEFORE	AFTER
PREVENTION COSTS	6,966.8	8,946.7
APPRAISAL COSTS	463.6	1,397.4
COST OF CONFORMANCE	**7,430.4**	**10,344.1**
INTERNAL FAILURE COSTS	18,406.3	1,283.3
EXTERNAL FAILURE COSTS	224.8	0
COST OF NONCONFORMANCE	**18,631.1**	**1,283.3**
COST OF QUALITY	**26,061.5**	**11,627.4**

Table 5.1: Cost of quality between before and after implementation

5.1.2 DELAY OF CALIBRATION REPORT APPROVAL

The delay dates in report approval decrease between 47.5 to 63 % that shown in table below.

INSTRUMENT	DELAY DATE		DECREASE
	BEFORE	AFTER	[%]
Pressure gauge	33	13	60.6
Pressure transmitter	82	40	51.2
Pressure switch	40	21	47.5
Temperature gauge	81	30	63
Temperature element and transmitter	96	43	55.2
Temperature switch	51	No data*	-
Weight scale	26	12	53.8

Table 5.2: Delay of calibration report approval before and after implementation

Note *: There is no schedule for temperature switch calibration during Jan –Mar 2001

5.1.3 NUMBER OF REPORT REWORK

The report rework decreases about 25% that shown in table 5.3.

REWORK [%]		
BEFORE	AFTER	DECREASE
58.4	33.2	25.2

Table 5.3: Number of report rework before and after implementation

5.1.4 NUMBER OF CALIBRATED INSTRUMENT THAT CAN'T BE USED [result from uncertainty in calibration higher than limit]

Number of calibrated instrument that can't be used result from uncertainty in calibration higher than limit decrease about 18.5 % that shown in table 5.4 below.

CALIBRATED INSTRUMENT THAT CAN'T BE USED [%]		
BEFORE	AFTER	DECREASE
18.8	0.27	18.5

Table 5.4: Number of calibrated instrument that can't be used before and after implementation

5.2 CONCLUSION OF THE RESEARCH

The summary of improvement is control input in calibration process and improve calibration process that has detail below.

5.2.1 CONTROL INPUT IN CALIBRATION PROCESS

Input in calibration process that we control is master instrument. Table 5.5 shows specification of master instrument that we control. For internal calibration, we can reduce uncertainty in calibration master instrument by calibration our master instrument with higher level in traceability chain.

For example, the calibration support unit has precision pressure calibrator model PPC 70 BAR manufacture by Ametek USA. In year 2000, it was sent to be calibrated at MMC Thailand LTD laboratory, which is a laboratory in company level. In a year later, the calibration support unit tries to reduce uncertainty by sending instrument to be calibrated at TECHNOLOGY PROMOTION INSTITUTE, a laboratory in national level. The different in uncertainty is shown in table below.

UNIT	UNCERTAINTY [at confidence level 95%]	
	YEAR 2000[calibrated by MMC Thailand laboratory, certificate number MMC/M1920]	YEAR 2001[Calibrated by TECHNOLOGY PROMOTION INSTITUTE laboratory, certificate number 01P23].
Bar	+/- 0.047	+/- 0.015
Kg/cm^2	+/- 0.032	+/- 0.015
psi	+/- 1.503	+/- 0.22

Table 5.5: Uncertainty different between different laboratory level in traceability chain

For external calibration, we can control master instrument specification by developing calibration specification that mention in section 4.3.3.

5.2.2 IMPROVE CALIBRATION PROCESS BY IMPROVING WORK INSTRUCTION AND FORM.

The detail is in section 4.3.1and 4.3.2.

5.2.3 IMPROVE CALIBRATED INSTRUMENT APPROVAL PROCESS

The process of report completeness approval has been discussed before in section 4.2.1. For calibrated instrument approval, it start from determine instrument permissible error, detail in section 4.1, and after calibration, we compare calibration result to permissible error. However there are two terms in permissible error, accuracy and uncertainty and the idea for calibration and approval process that has minimum uncertainty are

- Correct master instrument value before calibration, and
- Focus on uncertainty in calibrated instrument approval.

The summary for improvement is shown in figure 5.1

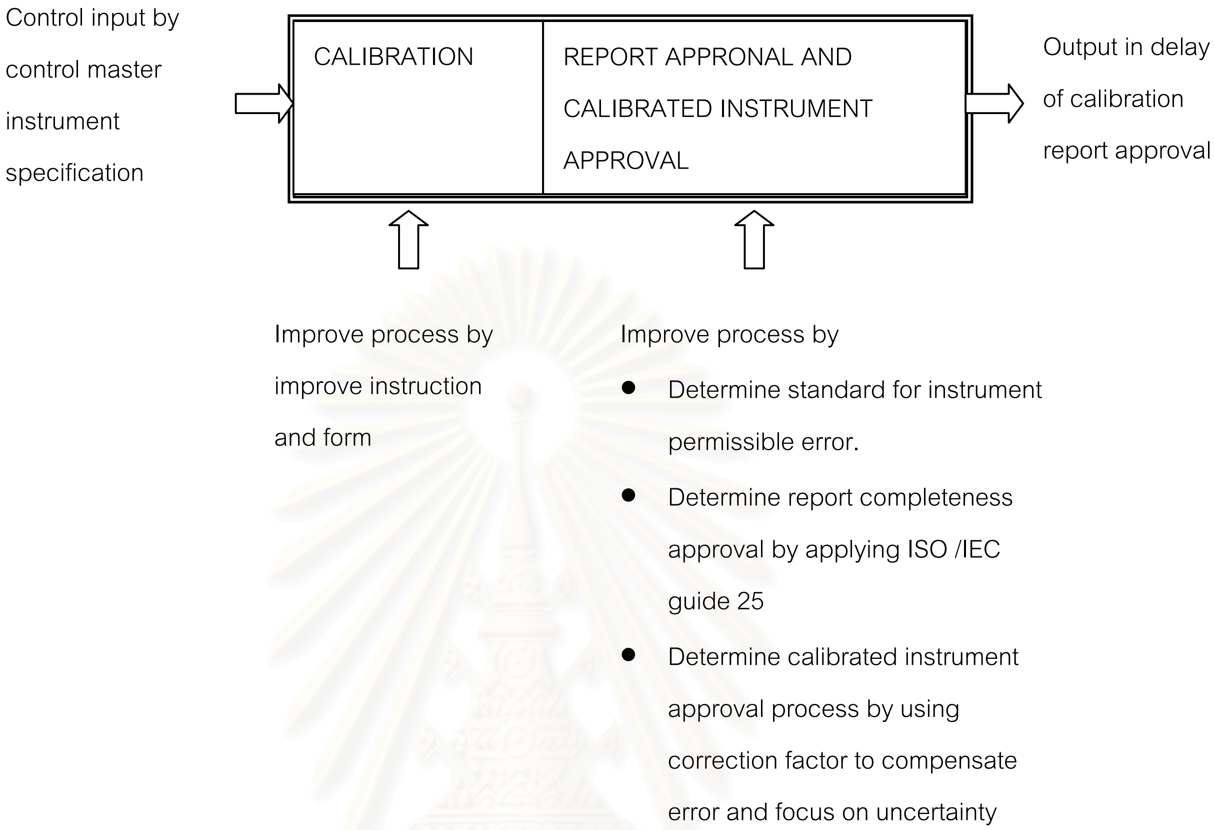


Figure 5.1: model of improvement

5.2.4 IMPROVE COMMUNICATION BETWEEN COMPANY AND SUPPLIER

Because of having limit in master instrument and staff, company has to employ external calibrator. Researcher found that the communication through telephone and calibration is not enough because we don’t know how well the external calibrator understands the company demand. So it is important to arrange meeting between supplier and company and transfer what the company want to supplier and to discuss the supplies difficulty to achieve the task.

5.2.5 RESULT SUMMARY

Cost of quality

Cost of prevention after implementation increase results from company arrange meeting between supplier and company to discuss calibration detail. The meeting has been arranged two times in January and February. After ensure that supplier understands the scope of work then company not establishes meeting on the later month. In addition part of prevention come from training work instruction training.

Appraisal cost increase result from the company engineer go to investigate calibration activities at Saraburi oil terminal which is done by external calibrator and controlled by company technician.

Failure costs reduce because the number of report rework and calibrated instrument that can't be used after calibration decrease result from paying more attention in calibration process and acceptant criteria modification.

5.3 SUGGESTION

1. The calibration support unit should expand the scope of the instrument permissible error determination to cover all measuring instruments. It help calibration support unit has same standard for all measuring instrument.
2. Normally we can't reduce uncertainty in calibration that effect from master instrument immediately because it takes time in master instrument calibration. The company has to establish long schedule, at lease 6 months, in master instrument calibration.
3. In one measuring system, it has more than one instrument. For example the metering system has three measuring instruments. These instruments have been take care by different workgroup. Management level has to establish the

communication system between the workgroup ensuring that all workgroup working with same standard.

4. The person that supervise activities in calibration support unit should has well mathematics background because there has mathematics relayed to many activities.

5.4 PROBLEMS FOUND WHILE DOING THE RESEARCH AND COMMENT

5.4.1 DATA COLLECTION

5.4.1.1 DATA COLLECTION FROM INTERNAL SOURCE

Data collection from internal source means the data that can be collect from within calibration support unit. Researcher found that although data are quite well organized but it still consumes much time in data collection because of large amount of data. The implement of computer database management system will help company reducing time when company wants to pull some data from big cabinet.

5.4.1.2 DATA COLLECTION FROM EXTERNAL SOURCE

External source mean oil and LPG terminal. Because all of instrument located at the terminal, researcher has to ask information from terminal staff. Researcher found that there no resembles answer although researcher ask question about same instrument. Finally researcher has to investigate answer from standard operating manual.

5.4.2 DOCUMENT IMPLEMENTATION AND THESIS PREPARATION

All of document preparing for implementation has been written in Thai language but it has to be written in English in thesis preparation. It takes quite much time in preparing both two languages document.

5.5 RECOMMEND FOR FURTHER RESEARCH

When looking into calibration support unit activities, it was found that there are many items that should be studied for improvement both developing from this thesis and studying new items. The further research recommendations are

- The study of permissible error of the other measuring instrument such as oil meters.
- The study for improvement about data base management in calibration support unit.
- The study about suitable ratio between work load and resource available[in term of number of staff]
- The study for reducing uncertainty in calibration apart from control master instrument.

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APPENDICES

APPENDIX A

CURRENT WORK INSTRUCTION

WORK INSTRUCTION	DIVISION/DEPARTMENT: ENGINEERING AND MAINTENANCE DIVISION
TOPIC : WEIGHT SCALE CALIBRATION [4 KG]	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 1 **OF** **3**

WRITE BY : POSITION :

ANNOUNCE BY : [SIGNATURE]

NAME :

POSITION :

THIS WORK INSTRUCTION IS THE COPY NUMBER:

MODIFICATION SUMMARY

NO	PAGE	DETAIL	BY

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : WEIGHT SCALE CALIBRATION [4 KG]	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 2 **OF** 3

1. OBJECTIVE:

   To be used as instruction for 4 kg weight scale calibration [range 20 kg.]

2. SCOPE:

   This instruction is used for calibrate instrument in PTT oil and LPG terminal.

3. REFERENCES:

   Weight scale calibration form.

4. DEFINITION: -

5. INSTRUCTION:

   ***Before calibration*: prepare standard weight, one of 5 kg , one of 10 kg,**

   Calibration process:

1. Check the scale indicator, adjust to zero point. Record the result.
1. Place 5 kg. standard weight in the scale. Record the result.
2. Take the standard weight out
3. Place 10 kg. standard weight in the scale. Record the result.
4. Take the standard weight out..
5. Place 15 kg. standard weight in the scale. Record the result
6. Take the standard weight out.
7. Place 20 kg. standard weight in the scale. Record the result
8. Take the standard weight out.
9. Do step 6,7 /4,5/2,3 again.
10. If the error is more than limit, adjust the scale until the result is in limit.

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : WEIGHT SCALE CALIBRATION [4 KG]	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 3 **OF** 3

6 SUPPLEMENT:

Instrument: Standard weight, approved by Ministry of Commerce.

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : WEIGHT SCALE CALIBRATION [15 KG]	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 1 **OF** 3

WRITE BY : POSITION :

ANNOUNCE BY : [SIGNATURE]

NAME :

POSITION :

THIS WORK INSTRUCTION IS THE COPY NUMBER:

MODIFICATION SUMMARY

NO	PAGE	DETAIL	BY

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : WEIGHT SCALE CALIBRATION [15 KG]	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 2 **OF** 3

1. OBJECTIVE:

To be used as instruction for 15 kg weight scale calibration [range 30 kg.]

2. SCOPE:

This instruction is used for calibrate instrument in PTT oil and LPG terminal.

3. REFERENCES:

Weight scale calibration form.

4. DEFINITION: -

5. INSTRUCTION:

Before calibration: prepare standard weight, one of 5 kg , one of 10 kg, and one of 20 kg..

Calibration process:

1. Check the scale indicator, adjust to zero point. Record the result.
2. Place 5 kg. standard weight in the scale. Record the result.
3. Take the standard weight out.
4. Place 10 kg. standard weight in the scale. Record the result.
5. Take the standard weight out.
6. Place 15 kg. standard weight in the scale. Record the result
7. Take the standard weight out.
8. Place 20 kg. standard weight in the scale. Record the result
9. Take the standard weight out.
10. Place 25 kg. standard weight in the scale. Record the result

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : WEIGHT SCALE CALIBRATION [15 KG]	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE 3 OF** 3

11. Take the standard weight out.

12.Place 30 kg. standard weight in the scale. Record the result

13.Take the standard weight out.

14. Do step 10,11 again

15. Do step 8,9 again

16.Do step 6,7 again.

17.Do step 4,5 again.

18.Do step 2,3 again

19.If the error is more than limit, adjust the scale until the result is in limit.

6 SUPPLEMENT:

Instrument: Standard weight, approved by Ministry of Commerce.

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : WEIGHT SCALE CALIBRATION [48 KG]	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 1 **OF 3**

WRITE BY : POSITION :

ANNOUNCE BY : [SIGNATURE]

NAME :

POSITION :

THIS WORK INSTRUCTION IS THE COPY NUMBER:

MODIFICATION SUMMARY

NO	PAGE	DETAIL	BY

WORK INSTRUCTION	DIVISION/DEPARTMENT: ENGINEERING AND MAINTENANCE DIVISION
TOPIC : WEIGHT SCALE CALIBRATION [48 KG]	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 2 **OF** 3

1. OBJECTIVE:

To be used as instruction for 48 kg weight scale calibration [range 60 kg.]

2. SCOPE:

This instruction is used for calibrate instrument in PTT oil and LPG terminal.

3. REFERENCES:

Weight scale calibration form.

4. DEFINITION: -

5. INSTRUCTION:

Before calibration: prepare standard weight, one of 5 kg , one of 10 kg, and three of 20 kg..

Calibration process:

1. Check the scale indicator, adjust to zero point. Record the result.
2. Place 15 kg. standard weight in the scale. Record the result.
3. Take the standard weight out.
4. Place 30 kg. standard weight in the scale. Record the result.
5. Take the standard weight out.
6. Place 45 kg. standard weight in the scale. Record the result
7. Take the standard weight out.
8. Place 60 kg. standard weight in the scale. Record the result
9. Take the standard weight out.
10. Do step 6,7 / 4,5 / 2,3 again.

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : WEIGHT SCALE CALIBRATION [48 KG]	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 3 **OF 3**

11. If the error is more than limit, adjust the scale until the result is in limit

6 SUPPLEMENT:

Instrument: Standard weight, approved by Ministry of Commerce.

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : WEIGHT SCALE CALIBRATION [120 KG]	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 1 **OF** 3

WRITE BY : POSITION :

ANNOUNCE BY : [SIGNATURE]

NAME :

POSITION :

THIS WORK INSTRUCTION IS THE COPY NUMBER:

MODIFICATION SUMMARY

NO	PAGE	DETAIL	BY

WORK INSTRUCTION	DIVISION/DEPARTMENT: ENGINEERING AND MAINTENANCE DIVISION
TOPIC : WEIGHT SCALE CALIBRATION [120 KG]	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 2 **OF** 3

1. OBJECTIVE:

To be used as instruction for 120 kg weight scale calibration [range 120 kg.]

2. SCOPE:

This instruction is used for calibrate instrument in PTT oil and LPG terminal.

3. REFERENCES:

Weight scale calibration form.

4. DEFINITION: -

5. INSTRUCTION:

Before calibration: prepare standard weight, two of 10 kg, and five of 20 kg..

Calibration process:

1. Check the scale indicator, adjust to zero point. Record the result.
2. Place 30 kg. standard weight in the scale. Record the result.
3. Take the standard weight out.
4. Place 60 kg. standard weight in the scale. Record the result.
5. Take the standard weight out.
6. Place 90 kg. standard weight in the scale. Record the result
7. Take the standard weight out.
8. Place 120 kg. standard weight in the scale. Record the result
9. Take the standard weight out.
10. Do step 6,7 / 4,5 / 2,3 again.

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : WEIGHT SCALE CALIBRATION [120 KG]	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 3 **OF** 3

11.If the error is more than limit, adjust the scale until the result is in limit

6 SUPPLEMENT:

Instrument: Standard weight, approved by Ministry of Commerce.

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : PRESSURE GAUGE CALIBRATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 1 **OF** 3

WRITE BY : POSITION :

ANNOUNCE BY : [SIGNATURE]

NAME :

POSITION :

THIS WORK INSTRUCTION IS THE COPY NUMBER:

MODIFICATION SUMMARY

NO	PAGE	DETAIL	BY

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : PRESSURE GAUGE CALIBRATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 2 **OF** 3

1. OBJECTIVE:

For celibate pressure gauge.

2. SCOPE:

This instruction is used for calibrate instrument in PTT oil terminal, LPG terminal , and aviation terminal.

3. REFERENCES:

Pressure gauge calibration form.

4. DEFINITION: -

5. INSTRUCTION:

Calibration process:

1. Clean & visual check the pressure gauge.
2. Fill the gauge detail in the calibration form.
3. Connect the gauge to hand pump and pressure calibrator. Fill hydraulic oil to the system, ensure that it doesn't has air in the system.
4. Set pressure at 0% of calibration range and record the result.
5. Increase pressures to about 25% of calibration range and record the result.
6. Increase pressures to about 50% of calibration range and record the result.
7. Increase pressures to about 75% of calibration range and record the result.
8. Increase pressures to 100% of calibration range and record the result.
9. Reduce pressures to about 75% of calibration range and record the result.
10. Reduce pressures to about 50% of calibration range and record the result.
11. Reduce pressures to about 25% of calibration range and record the result

WORK INSTRUCTION	DIVISION/DEPARTMENT: ENGINEERING AND MAINTENANCE DIVISION
TOPIC : PRESSURE GAUGE CALIBRATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 3 **OF** 3

12. Reduce pressures to 0% of calibration range and record the result

13. If the error is more than limit, adjust the scale do step 4 to 12 again.

6 SUPPLEMENT:

Instrument: Pressure calibrator, Hand pump, Connector, Hydraulic hose, Base plate for presure gauge, Cover & Needle removal, screwdriver, and wrench

.

APPENDIX B

CURRENT FORM

MAINTENANCE/CALIBRATION HISTORY

INSTRUMENT DESCRIPTION **Sheet :** ....

Instrument Name : .... **Model :** .... **Manufacture :** ....

Type : .... **Serial No. :** .... **Tag No. :** ....

Area : .... **Installation Date. :** .... **Casing Material :** ....

Flange To Flange Dimention : .... **Flange Class :** .... **Maximum Range :** ....

Working Range : .... **Operating Temp. :** .... **Operating Pressure :** ....

Resolution : ....

Cal. Criteria **Tolerance :** .... **Repeatability :** ....

Remarks : ....

MAINTENANCE/CALIBRATION DETAIL

No.	Date	Cal. Result				Main. Detail	By.
		Due Date	Cert. No.	Cal. Place	Pass/Not Pass		

CALIBRATION AND PREVENTIVE MAINTENANCE PLAN FOR ……. TERMINAL YEAR ………………

page …..of……..

No	Name	Brand	Location	JAN.	FEB.	MAR	APR.	MAY	JUN.	JUL.	AUG	SEP.	OCT.	NOV.	DEC.

Legend	PREPARE&REVISED BY	APPROVED BY
- Plan Calibration Preventive maintenance Calibration and maintenance - Actual	(　　　　) Engineer DATE : / /	(　　　　) Manager DATE : / /

REV.3 FQP-EM-001-002

LIST OF CALIBRATION | Page..of..

TERMINAL

	NAME OF EQUIPMENT	BRAND	S/N/TAG NO.	MOC	LOCATION	FREQUENCY	SIZE	RANGE	WORKING / CAL. RANGE	ACCEPTANT CRITERIA			NOTE
										TOLERANCE	REPEATABILITY	UNCERTAINTY	

PREPARE&REVISE BY	APPROVED BY
( )	( )
/ /	/ /

REV.5 FQP-EM-001-003

REJECT INSTRUMENT RECORD

Page…….of……..

LOCATION ______________________

No	TAG NO.	SERIAL NO.	BRAND	ITEM	DATE	CAUSE	NOTE

REV. 2 FQP-EM-002-001

WEIGHT SCALE CALIBRATION REPORT

CERT NO.__________

LOCATION :

Page_____of_____

WEIGHT SCALE DATA (Kg.)			
BRAND/MODEL :	**TYPE :**	**SERIAL NUMBER**	
MAX.CAPACIY (Kg.)	**DIVISION (d)**	**MPE (= +/-)**	

PERFORMANCE TEST								
STEP	**STANDARD WEIGHT (P)**	**SCALE INDICATION (I)**				**ERROR (E) = I-P**		
		BEFORE		**AFTER CALIBRATION**		**BEFORE/AFTER**		**REMARK**
		INCREASED	**DECREASED**	**INCREASED**	**DECREASED**	**INCREASED**	**DECREASED**	
MAX.ERROR OF INDICATION								

CALIBRATED BY	**WITHNESSED BY**	**APPROVED BY**
( )	( )	( )
DATE :	**DATE :**	**DATE :**

MASTER EQUIPMENT : STANDARD WEIGHT

NOTE : The uncertainty of weight scale measurement was +

The reported uncertainty is based on a standard uncertainty multiplied by a coverage factor of k = 2

providing a level of confidence of approximately 95 %

REV.3 **FWI-EM.-001-001**

THE PETROLEUM AUTHORITY OF THAILAND

2 ARD-NARONG RD. PHRAKHANONG BANGKOK 10250 TEL.. 712-2000

CALIBRATION REPORT

CERT.NO …………

UNIT UNDER TEST (UUT)

EQUIPMENT : PRESSURE GAUGE

MANUFACTURER :

MODEL :

SERIAL NO. :

TAG NO. :

RESOLUTION :

RANGE :

WORKING RANGE :

LOCATION :

DEPOT :

TOLERANCE :

REFERENCE STANDARD INSTRUMENT

EQUIPMENT :

MANUFACTURER :

MODEL :

SERIAL NO. :

CERT. NO. :

DUE DATE :

UNCERTAINTY :

RESOLUTION :

CALIBRATION RESULTS

UUT PRESSURE (KG/CM^2)	STANDARD APPLIED PRESSURE				MAXIMUM ERROR (KG/CM^2)	% ERROR (OF FULL SCALE)
	BEFORE ADJUST		AFTER ADJUST			
	INCREASED	DECREASED	INCREASED	DECREASED		

THE UNCERTAINTY OF PRESSURE MEASUREMENT WAS +/- % OF FULL SCALE

THE REPORTED UNCERTAINTY OF MEASUREMENT WAS BASED ON A STANDARD UNCERTAINTY MULTIPLIED BY A COVERANGE FACTOR k=2 ,PROVIDING A LEVEL OF CONFIDANCE OF APPROXIMATELY 95 %

CALIBRATION DATE.

CALIBRATED BY.

( )

TECHNICIAN

DATE :

APPROVED BY.

( )

ENGINEER

DATE :

APPENDIX C

DATA COLLECTION FOR LATE DATE BETWEEN CALIBRATION DATE AND REPORT APPROVAL DATE

1. PRESSURE GAUGE

REPORT NUMBER	TERMINAL	QUANTITY	CAL. DATE	REPORT APPROVAL DATE	LATE DATE
PG001/43 - PG044/43	Nakhon Sawan LPG	44	11/01/2000	8/03/2000	56
PG045/43 - PG103/43	Nakhon Sawan LPG	59	11/01/2000	15/03/2000	63
PG104/43 - PG109/43	Surat Thani Oil.	6	28/01/2000	15/03/2000	46
PG110/43	Workshop	1	8/02/2000	16/03/2000	37
PG111/43 - PG152/43	Bangchak LPG	42	8/02/2000	20/04/2000	72
PG153/43 - PG167/43	Chiang Mai Oil	15	8/03/2000	5/06/2000	89
PG168/43 - PG184/43	Phuket Oil	17	23/03/2000	3/04/2000	12
PG185/43 - PG213/43	Phuket Aviation	29	25/03/2000	18/06/2000	85
PG214/43 - PG305/43	Khon Kaen LPG	92	5/04/2000	11/05/2000	36
PG306/43 - PG321/43	U-Ta-Pao Aviation	16	24/04/2000	6/06/2000	43
PG325/43 - PG402/43	Sonkhla Petroleum	78	26/04/2000	6/06/2000	41
PG403/43 - PG423/43	Surat Thani Oil	21	25/05/2000	6/06/2000	12
PG424/43 - PG501/43	Surat Thani LPG	78	27/05/2000	16/06/2000	20
PG502/43 - PG516/43	Lampang Oil	15	10/06/2000	20/6/2000	10
PG517/43 - PG626/43	Lampang LPG	110	13/06/2000	5/7/2000	22
PG627/43 - PG633/43	Phitsanulok Aviation	7	11/07/2000	21/07/2000	10
PG634/43 - PG641/43	Phitsanulok Oil	8	14/07/2000	21/07/2000	7
PG642/43 - PG652/43	Pak Phanang Oil	11	2/08/2000	14/08/2000	12
PG656/43 - PG680/43	Ubon Ratchathani Oil.	25	18/08/2000	23/08/2000	5
PG681/43 - PG697/43	Hat Yai Aviation	17	11/09/2000	18/09/2000	7
PG698/43 - PG712/43	Udon Thani Oil	15	20/09/2000	9/10/2000	19
PG719/43 - PG794/43	Ban Rongpo LPG	76	2/10/2000	23/10/2000	20
PG796/43 - PG804/43	Khon Kaen Aviation	9	17/10/2000	31/10/2000	14
PG805/43 - PG819/43	Khon Kaen Oil	15	14/10/2000	31/10/2000	16
PG820/43 - PG829/43	Ubon Ratchathani Aviation	10	14/11/2000	25/11/2000	11
PG830/43 - PG835/43	Nakornphanom Aviation	6	17/11/2000	27/11/2000	10
PG836/43 - PG849/43	Udon Thani Aviation	14	16/11/2000	25/11/2000	9
PG850/43 - PG869/43	Denchai Oil	20	20/11/2000	27/11/2000	7

Table C-1: Late date in pressure gauge calibration during 2000

REPORT NUMBER	**TERMINAL**	**QUANTITY**	**CAL. DATE**	**REPORT APPROVAL DATE**	**LATE DATE**
PG871/43 - PG873/43	Denchai Aviation	3	23/11/2000	8/01/2001	46
PG874/43 - PG895/43	Chiang Mai Aviation	22	14/12/2000	8/01/2001	25
PG896/43 - PG900/43	Chiang Rai Aviation	5	12/12/2000	8/01/2001	28
AVERAGE LATE DATE					**33**

Table C-1: Late date in pressure gauge calibration during 2000 (Cont.)

2. PRESSURE TRANSMITTER

REPORT NUMBER	TERMINAL	QUANTITY	CAL. DATE	REPORT APPROVAL DATE	LATE DATE
D 1525	Nakhon Sawan LPG	1	3/01/2000	7/08/2000	206
D1742-4	Bangchak LPG	3	8/02/2000	24/06/2000	137
D1749	WORKSHOP	1	8/02/2000	7/08/2000	181
D2066-D2074	Lam Lukka Oil	9	24/04/2000	31/05/2000	37
D2176,9	Sonkhla Petroleum	2	28/04/2000	23/08/2000	117
D2177,2180	Sonkhla Petroleum	2	28/04/2000	7/08/2000	100
D2511,2	Lampang LPG	2	20/06/2000	31/07/2000	41
AVERAGE LATE DATE					**82**

Table C-2: Late date in pressure transmitter calibration during 2000

3. PRESSURE SWITCH

REPORT NUMBER	TERMINAL	QUANTITY	CAL. DATE	REPORT APPROVAL DATE	LATE DATE
D2489-2510	Lampang LPG	22	21/06/2000	31/07/2000	40
D3330-3347	Khon Kaen LPG	18	6/12/2000	16/01/2001	41
AVERAGE LATE DATE					**40**

Table C-3: Late date in pressure switch calibration during 2000

3. TEMPERATURE GAUGE

REPORT NUMBER	TERMINAL	QUANTITY	CAL. DATE	REPORT APPROVAL DATE	LATE DATE
D1527-31	Nakhon Sawan LPG	5	10/01/2000	9/02/2000	30
D1745-6	Bangchak LPG	2	8/02/2000	23/08/2000	197
D1748	WORKSHOP	1	22/02/2000	7/08/2000	167
D2289-96	Surat Thani LPG	8	30/05/2000	23/08/2000	85
D2515-25	Lampang LPG	11	11/03/2000	31/07/2000	142
D2577-9	Ban Rongpo LPG	3	9/08/2000	19/09/2000	41
D3303-3318	Khon Kaen LPG	16	6/12/2000	16/01/2000	41
AVERAGE LATE DATE					**81**

Table C-4: Late date in temperature gauge calibration during 2000

5. TEMPERATURE ELEMENT AND TRANSMITTER

REPORT NUMBER	TERMINAL	QUANTITY	CAL. DATE	REPORT APPROVAL DATE	LATE DATE
D1747	WORKSHOP	1	22/02/2000	7/08/2000	167
D2075-95	Lam Lukka Oil	21	14/03/2000	31/05/2000	78
D2146,48,50,52,54,56,58,60,62,64,66,68,72	Sonkhla Petroleum	11	28/04/2000	23/08/2000	117
D2589,90,91,3359,3360	Ban Rongpo LPG	5	28/7/2000	22/1/2001	178
D3297-3302	Khon Kaen LPG	6	6/12/2000	16/01/2001	41
AVERAGE LATE DATE					**96**

Table C-5: Late date in temperature element and transmitter calibration during 2000

6. TEMPERATURE SWITCH

REPORT NUMBER	TERMINAL	QUANTITY	CAL. DATE	REPORT APPROVAL DATE	LATE DATE
D2299-2304	Surat Thani LPG	6	31/05/2000	3/08/2000	64
D2526-28	Lampang LPG	3	20/06/2000	31/07/2000	41
D2529-34	Lam Lukka Oil	6	21/06/2000	22/08/2000	62
D3319-3329	Khon Kaen LPG	11	6/12/2000	16/1/2001	41
AVERAGE LATE DATE					**51**

Table C-6: Late date in temperature switch calibration during 2000

7. WEIGHT SCALE

REPORT NUMBER	TERMINAL	QUANTITY	CAL. DATE	REPORT APPROVAL DATE	LATE DATE
PKW040-041/2000	Lube House	2	30/5/2000	14/6/2000	15
PKW081-083/2000	Lube House	3	13/7/2000	27/7/2000	14
PKW107-111/2000	Nakhon Sawan LPG	5	9/11/2000	14/12/2000	35
PKW112-114/2000	Sonkhla Petroleum	3	20/11/2000	14/12/2000	24
PKW115-120/2000	Surat Thani LPG	6	30/11/2000	14/12/2000	14
PKW138-142/2000	Khon Kaen LPG	5	7/12/2000	23/1/2001	47
PKW144-149/2000	Lampang LPG	6	18/12/2000	10/1/2001	23
AVERAGE LATE DATE					**26**

Table C-7: Late date in weight scale calibration during 2000

APPENDIX D

THE DETERMINATION OF PERMISSIBLE ERROR FOR PRESSURE AND TEMPERATURE INSTRUMENT THAT EFFECT OIL AND LPG VOLUME.

THE DETERMINATION OF PERMISSIBLE ERROR FOR PRESSURE AND TEMPERATURE INSTRUMENT THAT EFFECT OIL AND LPG VOLUME.

Before calibration instrument, first we have to know the purpose of using of calibrated instrument then we can estimate the instrument permissible error. It is important because it relate to master instrument specification that we will use to calibrate instrument.

Knowing that the terminal use pressure and temperature instrument to measure pressure and temperature to calculate correction factor. The factors are used to convert observe product volume to standard product volume, at 0 psi and 30 °C. We can calculate the effect of pressure and temperature to product volume by step shown below.

1 EFFECT OF PRESSURE AND TEMPERATURE ON OIL

To convert oil volume from observe pressure and temperature to standard pressure and temperature, we have to multiply oil volume at observe pressure and temperature by two correction factors.

1.1 CORRECTION FACTOR THE EFFECT OF TEMPERATURE IN LIQUID [Ctl]

Volume at observe temperature [V_T] can converted to volume at standard temperature [V_O]by using formula

$$V_O = V_T \times C_{tl}$$

C_{tl} is temperature correction factor. Correction factor from any temperature to 30 °C , calculated by

$$C_{tl30} = \frac{e^{[-\alpha_T \times \Delta_T \times (1+0.8 \times \alpha_T \times \Delta_T)]}}{e^{[-\alpha_T \times 15 \times (1+0.8 \times \alpha_T \times 15)]}}$$

$$\Delta T = T - 15^0 C$$

$$\alpha = \frac{K_0}{\rho_{15}^{2}} + \frac{K_1}{\rho_{15}}$$

When ρ is product density [kg/m^3]

K_0 , K_1 , K_2 can obtain from ASTM D1250 (1980) in table below

PRODUCT TYPE	DENSITY (kg/m^3)	K_0	K_1	K_2
Fuel oil	838.50 – 1075.00	186.9696	0.4862	0
Jet group	788.00 – 838.50	594.5418	0.0	0
Between Jet Aud Gasoline	770.50 – 787.50	2680.3206	0	-0.00336312
Gasoline group	653.00 – 770.00	346.4228	0.4388	0

Table D-1: Constant value for temperature correction factor

Source: Werasak Wisuttatham, Satit Chusuwan, Mateta Neamprame, Calculation in volume calibration, Central Bureau of Weight & Measures, page24.

1.2 CORRECTION FACTOR THE EFFECT OF PRESSURE IN LIQUID [Cpl]

Volume at observe temperature [V_P]can converted to volume at standard temperature [V_O]by using formula below

$$V_O = V_P \times C_{pl}$$

C_{pl} is pressure correction factor. Correction factor from any pressure to 0 psig can calculated by

$$C_{pl} = \frac{1}{1 - PF}$$

when P is gauge pressure on liquid

F is compressibility facter for liquid can calculated from

$$F = e^{(-1.60280 + 0.0002159T + 0.87096/\rho152+ 0.0042092T/\rho152)}$$

$$\times 10^{-6} / K_{pa}$$

T is liquid temperature [^{0}C]

ρ_{15} is product density at 15^{0}C [g/cm^3]

1.3 CORRECTION FACTOR THE EFFECT OF PRESSURE AND TEMPERATURE ON LIQUID

Practically observe condition differ from standard condition in both pressure and temperature, so normal formula we use to convert volume from observe condition [V_{TP}] to standard condition [V_O] is

$$V_O \quad = \quad V_{TP} \times C_{tl} \times C_{pl} \qquad **[1]$$

In oil terminal, normal pressure and temperature is 5 BAR and30^0C. The pressure range is 2 – 8 BAR and temperature range is 20 – 50^0C. Company has two groups of product: Jet and gasoline. From calculation procedure above we found the effect of pressure and temperature on oil volume as shown below

For Jet group (average density 0.8133 kg/l)

- Volume change about 0.009% when pressure vary 1 BAR
- Volume change about 0.092% when temperature vary 1^0C

For gasoline group (average density 0.7115 kg/l)

- *Volume change about 0.014% when pressure vary 1 BAR*
- *Volume change about 0.134% when temperature vary 1^0C*

Because effect of pressure and temperature on gasoline group is higher than Jet group, so we use effect of pressure and temperature on gasoline group for further consideration.

Knowing that pressure and temperature instrument are auxiliary instrument in metering system, We use Weigh and Measure Law in custody transfer by metering, permissible error is $\pm$ 0.2%as criteria in consideration permissible error for pressure and temperature instrument in metering system.

In metering system, we measure oil volume [by meter], pressure, and temperature then we know that

Permissible error in metering custody transfer [ME] is the combination of volume error [M], pressure error [P], and temperature error [T].

Volume error [from meter]

Researcher discuss about meter error to metering workgroup and found that practically metering work group will control meter error in calibration within $\pm$ 0.1 %. The information, collected from Lumlukka and Saraburi oil terminal is shown below

SUMMARY OF LOADING GANTRY METER CALIBRATION: LUMLUKKA OIL DEPOT

SERIAL NUMBER	REPORT NUMBER	ACCURACY
RM 13317 GLJH	P.K.M949/2000	-0.036
RM 13319 GLJH	P.K.M950/2000	-0.038
RM 13316 GLJH	P.K.M951/2000	-0.019
RM 13314 GLJH	P.K.M952/2000	-0.021
RM 13315 GLJH	P.K.M953/2000	-0.027
RM 13318 GLJH	P.K.M954/2000	-0.039
RM 13313 GLJH	P.K.M955/2000	-0.028
RM 13328 GLJH	P.K.M956/2000	-0.040
RM 13330 GLJH	P.K.M957/2000	-0.014
RM 13331 GLJH	P.K.M958/2000	-0.042
RM 13329 GLJH	P.K.M959/2000	-0.001
RM 13327 GLJH	P.K.M960/2000	-0.022
RM 13324 GLJH	P.K.M961/2000	-0.046
RM 13326 GLJH	P.K.M962/2000	-0.032
RM 13325 GLJH	P.K.M963/2000	-0.021
RM 13322 GLJH	P.K.M964/2000	-0.030
RM 13323 GLJH	P.K.M965/2000	-0.022
RM 13320 GLJH	P.K.M966/2000	-0.038
RM 13321 GLJH	P.K.M967/2000	-0.000

Table D-2: Summary of loading gantry metering calibration: Lumlukka oil terminal

SUMMARY OF LOADING GANTRY METER CALIBRATION: SARABURI OIL DEPOT

SERIAL NUMBER	REPORT NUMBER	ACCURACY
13354 SA	P.K.M828/2000	-0.009
13335 SA	P.K.M829/2000	-0.031
13355 SA	P.K.M830/2000	-0.041
13336 SA	P.K.M831/2000	-0.022
13339 SA	P.K.M832/2000	-0.050
13358 SA	P.K.M833/2000	-0.008
13360 SA	P.K.M834/2000	-0.044
13342 SA	P.K.M835/2000	-0.016
13362 SA	P.K.M836/2000	-0.053
13343 SA	P.K.M837/2000	-0.014
13346 SA	P.K.M838/2000	-0.024
13365 SA	P.K.M839/2000	-0.016
13367 SA	P.K.M840/2000	-0.017
13348 SA	P.K.M841/2000	-0.022
13351 SA	P.K.M842/2000	-0.029
13370 SA	P.K.M843/2000	-0.041
13371 SA	P.K.M844/2000	-0.030
13350 SA	P.K.M845/2000	-0.033
13353 SA	P.K.M846/2000	-0.017
13352 SA	P.K.M847/2000	-0.000
13373 SA	P.K.M848/2000	-0.009
13372 SA	P.K.M849/2000	-0.017

Table D-3: Summary of loading gantry metering calibration: Saraburi oil terminal

Pressure and temperature error

The use of statistic method to combine error

Although error combination by plus and minus is the easy method, but it is done under assumption that all error occur simultaneously. Practically it does not happen and each error will mitigate total error by plus and minus each other. So normally, we combine error by statistic method: root sum square. .

$$ME = \sqrt{M^2 + T^2 + P^2}$$

Knowing from Weigh & Measure Law that

$$ME = \pm 0.2\ \%$$

The metering workgroup will control meter error within $\pm$ 0.1 % so we place the value in equation.

$$0.2 = \sqrt{(0.1)^2 + T^2 + P^2}$$

To make it easy in calculation, we assume that P is equal to P [T = P =X], then

$$0.04 = 0.01 + 2X^2$$

$$X = 0.122$$

Then we got permissible error of pressure and temperature about $\pm$0.122 %. Then we convert $\pm$0.122 % into pressure and temperature.

$$\text{Permissible error for pressure} = \frac{0.122}{0.014} = \pm 8.7\ \text{BAR}$$

$$\text{Permissible error for temperature} = \frac{0.122}{0.134} = \pm 0.9\ ^0\text{C}$$

This is preliminary step when we assume that effect of pressure and temperature to liquid is equal. We will adjust this value later before implementation.

2 EFFECT OF PRESSURE AND TEMPERATURE ON LPG

Pressure and temperature also effect LPG volume. In LPG tank, product has two phrase: liquid and vapor. We have to measure product pressure, temperature in liquid phrase, and temperature in vapor phrase. According to Bang Chak LPG terminal calculation sheet, LPG quantity can calculated from the equation

LPG in storage tank (metric ton) = LPG quantity [liquid] + LPG quantity [vapor]

LPG quantity in liquid phrase = $VL \times FL \times WL$

VL : Volume of Liquid

FL : Factor Liquid [Table 54]

WL : Liquid Weight [Table 56]

LPG quantity in vapor phrase = $$\frac{VV \times 273 \times (1.033+PV) \times M \times WL}{(273+TV) \times 23139.2 \times DL}$$

VV : Volume of Vapor

PV : Vapor Pressure

M : Molecular Weight

WL : Liquid Weight

TV : Vapor Temp

DL : Density at 15 ^{0}C

In LPG terminal, normal pressure and temperature is about 7.5 BAR and 30^{0}C. The pressure range is 5 – 10 BAR and temperature range is 20 – 50^{0}C. From calculation procedure above we found the effect of pressure and temperature on LPG quantity as shown below

- Volume change about 0.053% when pressure vary 1 BAR
- Volume change about 0.202% when TL vary 1^{0}C
- Volume change about 0.001% when TV vary 1^{0}C

Knowing that pressure and temperature instrument are auxiliary instrument in tank gauging system, We use same criteria with metering system, permissible error is ± 0.2%, in consideration permissible error for pressure and temperature instrument in tank gauging system. By using same criteria, terminal can cross check between receipt volume and storage volume.

In tank gauging system, we measure product level [by level gauge], pressure, and temperature then we know that

Permissible error in tank gauging system [TE] is the combination of level gauge error [L], pressure error [P], temperature error on liquid phrase [Tl], and temperature error on vapor phrase [Tv].

Level gauge error

Researcher discuss about level gauge error to staff who take care of level gauge calibration and found that practically level gauge error has to controlled within ± 3 mm. We have to convert this error into volume.

Because LPG tank has sphere shape, the different 3 mm. in each level effect different volume, the maximum volume is in the middle of sphere. From sphere calibration report, we know that the maximum ± 3 mm is about 0.058% of LPG volume

TERMINAL	TANK	LEVEL (mm)	Diff. Vol (lts)	Vol 100% (lts)	% Error ± 3mm
Bangchak LPG	D201	7629-7641	2,307.15	2,005,623.00	0.058
	D202	7619-7631	2,307.88	2,006,911.00	0.057
Ban Rong Po LPG	D301	7699-7711	2,312.01	2,008,938.00	0.058
	D302	7549-7661	2,307.19	2,006,187.00	0.058
	D303	7619-7631	2,308.29	2,007,561.00	0.057
Khonkaen LPG	D401	7619-7631	2,306.63	2,005,676.00	0.058
	D402	7599-7611	2,307.56	2,007,358.00	0.057

Table D-4: Maximum effect of + 3 mm to LPG volume in sphere tank.

Then we combine error by statistical method

$$TE = \sqrt{L^2 + Tv^2 + Tl^2 + P^2} \qquad **[2]$$

Assuming that tank gauging system error equal to metering error

$$TE = \pm 0.2\ \%$$

The level gauge error is + 0.058 % [from table A4-1-4]

$$L = \pm 0.058\ \%$$

To make it easy in calculation, we assume that P is equal to Tv,Tl [P=Tv=Tl=X]

$$0.2^2 = \sqrt{0.058^2 + X^2 + X^2 + X^2}$$

$$0.4 = 0.058^2 + 3X^2$$

$$X = 0.111$$

So we got permissible error of pressure and temperature instrument about ±0.111 %. Then we convert ±0.111 % into pressure and temperature then we got

$$\text{Permissible error for Tl} = \frac{0.111}{0.202} = \pm 0.5\ {}^0C$$

$$\text{Permissible error for Tv} = \frac{0.111}{0.001} = \pm 111\ {}^0C$$

$$\text{Permissible error for P} = \frac{0.111}{0.053} = \pm 2.1\ \text{BAR}$$

This is preliminary value when we assume that effect of pressure and temperature to liquid is equal. Then we will adjust this value and group it together for easy in calibration and maintenance by following this procedure

1. Fix permissible error for pressure instrument both in oil and LPG to =± 2 BAR.
2. Calculate permissible error for temperature instrument

   For oil , Pressure vary 2 BAR cause volume change 0.028% then we put these value in equation [1]

$$0.2 = \sqrt{(0.1)^2 + (0.028)^2 + T^2}$$

$$0.4 = 0.01 + 0.00784 + T^2$$

$$T = 0.171\%$$

We convert T to temperature $= \dfrac{0.171}{0.134} =$ **1.2 ^{0}C**

<u>For LPG,</u> Pressure vary 2 BAR cause volume change 0.106% and we know that effects of Tv to LPG volume is very little. Assume that permissible error for Tv is **1.2 ^{0}C**. When Tv vary 1.2 ^{0}C , LPG volume change 0.001% . Then we put these value to equation B.

$$0.2 = \sqrt{(0.058)^2 + (0.106)^2 + (0.001)^2 + Tl^2}$$

$$0.4 = \sqrt{0.003364 + 0.011236 + 0.00001 + Tl^2}$$

$$Tl = 0.159\ \%$$

We convert Ti to temperature

$$= \frac{0.159}{0.202} = \mathbf{0.8\ ^0C}$$

APPENDIX E

PERMISSIBLE ERROR FOR WEIGHT

PERMISSIBLE ERROR FOR WEIGHT

For weight scale, we determine permissible error by following Weigh & Measure Law

INDICATE AMOUNT IN PACKAGE	PERMISSIBLE ERROR [%]
Not over 200 g	6
Over 200 g but not over 1 kg.	3
Over 1 kg. But not over 5 kg.	2
Over 5 kg.	1

Table E-1: Weight & Measure permissible error for product in package

PTT has three type of package 4 kg., 15 kg., and 48 kg. Then the permissible error is shown in table E-2 below.

INDICATE AMOUNT IN PACKAGE	PERMISSIBLE ERROR [%]	PERMISSIBLE ERROR [g]
4 kg.	2	80
15 kg.	1	150
48 kg.	1	480

Table E-2: Permissible error for PTT product in package.

APPENDIX F

THE DETERMINATION OF PERMISSIBLE ERROR FOR PRESSURE AND TEMPERATURE INSTRUMENT THAT EFFECT PRODUCT VOLUME.

THE DETERMINATION OF PERMISSIBLE ERROR FOR PRESSURE AND TEMPERATURE INSTRUMENT THAT EFFECT PRODUCT VOLUME.

1. PRSSURE GAUGE

The purpose of using pressure gauge in oil and LPG terminal are

- Monitor pressure at air compressor
- Monitor pressure at LPG compressor
- Monitor pressure at LPG pump
- Monitor pressure at loading arm
- Monitor pressure at filling hall
- Monitor pressure at hydro-test system
- Monitor pressure at evacuation unit
- Monitor pressure at oil pump
- Etc.

According to terminal design, these pressure gauge are considered as instrument in process and designer select pressure gauge that has +/-1.5% of full scale accuracy [from Technical&Maintenance Manual Chapter 3. Vendor Instruction Manual- Ban Rong Po]. When looking in detail, we found pressure gauge working range that shown in table F-1.

PURPOSE OF USING	RANGE [Bar]	ERROR 1.5 % FS. [in Bar]
Monitor pressure at air compressor.	0-4 , 0-10 , 0-16	0.06 , 0.15 , 0.24
Monitor pressure at LPG compressor.	0-25	0.375
Monitor pressure at LPG pump.	0-35	0.525
Monitor pressure at loading arm.	0-25 , 0-35	0.375 , 0.525
Monitor pressure at filling hall.	0-16 , 0-25 , 0-30	0.24 , 0.375 , 0.525
Monitor pressure at hydro-test system.	0-60	0.9
Monitor pressure at evacuation unit.	-1 –10	0.165
Monitor pressure at oil pump.	-1 –9 , -1 –10	0.15 , 0.15

Table F-1: Pressure working range

It is difficult to control pressure gauge permissible error in term of percent of full scale especially when apply uncertainty in calibration to calibrated instrument approval criteria because of two reasons.

Reason 1 : the uncertainty in calibration usually be shown in term of pressure not in term of full scale. This includes uncertainty in master instrument calibration.

Reason 2: although we calibrate pressure gauge by using same calibration process and same master instrument, uncertainty in term of full scale it is unequal if the calibrated instrument has different range.

By these reasons, we found that it is easier to inspect calibrated instrument when we determine permissible error in pressure unit and from table F-1 the value +/-0.5 Bar is the appropriate permissible error for these pressure instrument.

2. TEMPERATURE GAUGE

The purpose of using temperature gauge in oil and LPG terminal are

- Monitor temperature in storage tank
- Monitor temperature at LPG compressor
- Monitor temperature at air compressor
- Etc.

According to terminal design, temperature gauge has specification of +/-2% of full scale. When looking in detail, we found temperature gauge working range that shown in table F-2.

PURPOSE OF USING	RANGE [^{0}C]	ERROR 1.5 % FS.[^{0}C]
Monitor temperature at LPG Tank. Monitor temperature at LPG compressor. Monitor temperature at air compressor.	-30 –100 ^{0}C -30 –100 ^{0}C , 0-200 ^{0}C 0-100 ^{0}C , 0-300 ^{0}C	2.6 ^{0}C 2.6 ^{0}C , 4 ^{0}C 2 ^{0}C , 6 ^{0}C

Table F-2: Temperature working range

It is difficult to control temperature gauge permissible error in term of percent of full scale by same reason as pressure gauge. Then we determine permissible error for temperature gauge by using working range and it specification. The permissible error for temperature gauge is shown in table F-3

RANGE [^{0}C]	PERMISSIBLE ERROR [+/- ..^{0}C]
About 100 ^{0}C About 200 ^{0}C About 300 ^{0}C	2 ^{0}C 4 ^{0}C 6 ^{0}C

Table F-3: Permissible error for temperature gauge

3. PRESSURE SWITCH

Pressure switch is used in air and LPG compressor, research found that it has no pressure switch accuracy in air and LPG compressor specification so we have to determine its permissible error from its working process.

3.1 PRESSURE SWITCH IN LPG COMPRESSOR

In LPG compressor, it has pressure switch high [PSH] and pressure switch low [PSL].

Pressure switch low [PSL]

The PSL control LPG pressures in system not lower than set point. If LPG pressure is lower than atmospheric pressure, the O_2 from outside will flow into LPG system, if it has leak in pipeline or flange connection. When it has suitable air fuel ratio, in this case is O_2 and LPG, the combustion has opportunity to occur if it has spark point in the system. Normally the terminal set PSL about 1.5-2.5 Bar so permissible error for PSL should not be more than 0.5 Bar, the different between 1.5 Bar and atmospheric pressure.

Pressure switch high [PSH]

The PSH control LPG pressures in system not higher than set point for safety purpose. Normally the terminal set PSH about 15.5-18.5 Bar and when LPG pressure in system is up to 19.5, relieve valve will blow pressure out so permissible error for PSH should not be more than 1 Bar, the different between 18.5 Bar and 19.5 Bar.

3.2 PRESSURE SWITCH IN AIR COMPRESSOR

In air compressor, it has pressure switch high [PSH] , pressure switch low [PSL], and pressure switch alarm .

Pressure switch high [PSH] and pressure switch low [PSL]

Normal pressure in air reservoir is 6-7 Bar. When pressure lower than 6 Bar PSL will start pump and build up pressure. When pressure is increased to 8.5 Bar PSH activate pump to free run stage for a while before stop.

Pressure switch low [alarm]

PSL[alarm] in air compressor detect low pressure in air compressor and activate alarm low bottom, normally it is set to 5.5 Bar. If operator not pay attention in this situation and let pressure low to 4.5 Bar, the PSLL will shut down air compressor system.

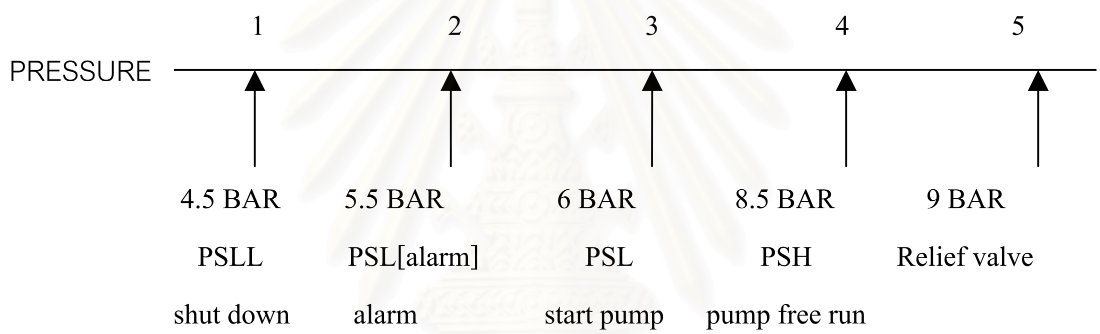

Figure F-1: Pressure switch pattern in air compressor

Figure F-1 show that the pressure interval between each point are 0.5 – 2.5 Bar. We found that it is difficult for operator in calibration if we determine permissible error vary from point to point. Then we determine one permissible error by considering it from the minimum pressure interval, we will get permissible error for pressure switch +/- 0.5 Bar.

Having many permissible errors in one instrument will cause operator has difficulty in operation process, then we unite pressure switch permissible error by determining permissible error from minimum value. So the permissible error for pressure switch is +/- 0.5 Bar.

4 TEMPERATURE SWITCH

Temperature switch in LPG compressor and air compressor have same purpose of using, safety purpose. They are use to control temperature not higher than limit. Like pressure switch, there has no temperature switch accuracy in manual. However from experience of calibrator, it is difficult to adjust pressure close to set point and the value +/- 5 ^{o}C is acceptable.

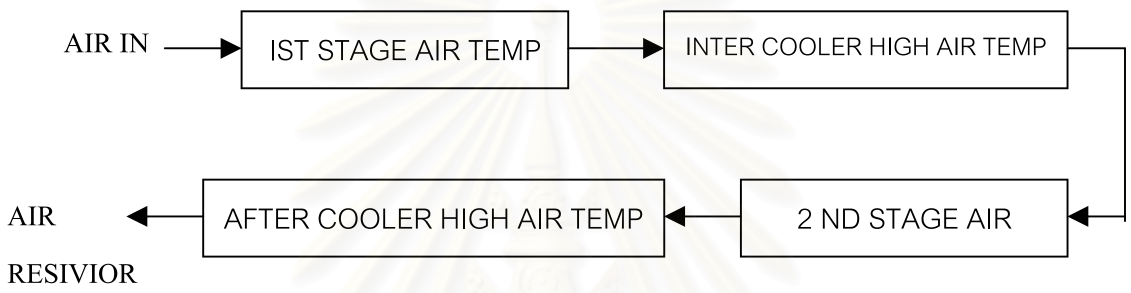

Figure F-2: Schematic diagram for air compressor

In manual, temperature switch are set at 190^{0}C, 60^{0}C, 195^{0}C, and 60^{0}C for each stage and we found that the error +/- 5 ^{o}C in each stage is acceptable because it is within compressor maximum range.

APPENDIX G

NEW FORM

Page..of…

LIST OF CALIBRATION

TREMINAL :

No	NAME OF EQUIPMENT	BRAND	S/N/TAG NO.	MOC: Number	LOCATION	FREQUENCY	SIZE	RANGE	WORKING / CAL. RANGE	ACCEPTANT CRITERIA				NOTE
										ACCURACY	REPEATABILITY	UNCERTAINTY	TOLERANCE	

PREPARE&REVISE BY	APPROVE BY
……………………………………………..	…………………………………………..
( )	( )
/ /	/ /

REV.6 FQP-EM-001-003

THE PETROLEUM AUTHORITY OF THAILAND

2 ARD-NARONG RD. PHRAKHANONG BANGKOK 10250 TEL.. 239-7537-8

CALIBRATION REPORT

CERT.NO ………..

UNIT UNDER TEST (UUT)

EQUIPMENT : WEIGHT SCALE

MANUFACTURER :

MODEL :

SERIAL NO. :

TAG NO. :

RESOLUTION :

RANGE :

WORKING RANGE :

LOCATION :

DEPOT :

MPE :

DIVISION :

PROCEDURE USED :

REFERENCE STANDARD INSTRUMENT

EQUIPMENT :

MANUFACTURER :

MODEL :

SERIAL NO. :

CERT. NO. :

DUE DATE :

UNCERTAINTY :

RESOLUTION :

THE RESULT OF TEST WAS FOUND ACCURATE AS SHOWN ON DATE AND PLACE OF TEST ONLY

THE CERTIFICATION IS TRACABLE TO :

CALIBRATION RESULTS

STD WEIGHT ( )	SCALE INDICATION				MAXIMUM ERROR ( )	REMARK
	BEFORE ADJUST		AFTER ADJUST			
	INCREASED	DECREASED	INCREASED	DECREASED		

THE UNCERTAINTY OF PRESSURE MEASUREMENT WAS +/- THE REPORTED UNCERTAINTY OF MEASUREMENT WAS BASED ON A STANDARD UNCERTAINTY MULTIPLIED BY A COVERANGE FACTOR k=2 ,PROVIDING A LEVEL OF CONFIDANCE OF APPROXIMATELY 95 %

CALIBRATION DATE.

CALIBRATED BY. APPROVED BY.

( ) ( )

DATE : DATE :

THE PETROLEUM AUTHORITY OF THAILAND

2 ARD-NARONG RD. PHRAKHANONG BANGKOK 10250 TEL.. 239-7537-8

CALIBRATION REPORT

CERT.NO……

UNIT UNDER TEST (UUT)

EQUIPMENT :

MANUFACTURER :

MODEL :

SERIAL NO. :

TAG NO. :

RESOLUTION :

RANGE :

WORKING RANGE :

LOCATION :

DEPOT :

TOLERANCE :

PROCEDURE USED :

REFERENCE STANDARD INSTRUMENT

EQUIPMENT :

MANUFACTURER :

MODEL :

SERIAL NO. :

CERT. NO. :

DUE DATE :

UNCERTAINTY :

RESOLUTION :

THE RESULT OF TEST WAS FOUND ACCURATE AS SHOWN ON DATE AND PLACE OF TEST ONLY

THE CERTIFICATION IS TRACABLE TO :

CALIBRATION RESULTS

UUT PRESSURE ( )	STANDARD APPLIED PRESSURE				MAXIMUM ERROR
	BEFORE ADJUST		AFTER ADJUST		
	INCREASED	DECREASED	INCREASED	DECREASED	

THE UNCERTAINTY OF PRESSURE MEASUREMENT WAS +- THE REPORTED UNCERTAINTY OF MEASUREMENT WAS BASED ON A STANDARD UNCERTAINTY MULTIPLIED BY A COVERANGE FACTOR k=2 ,PROVIDING A LEVEL OF CONFIDANCE OF APPROXIMATELY 95 %

CALIBRATION DATE.

CALIBRATED BY.

( )

DATE :

APPROVED BY.

( )

DATE :

REV.3

FWI-EM-012-001

APPENDIX H

NEW WORK INSTRUCTION

WORK INSTRUCTION	DIVISION/DEPARTMENT: ENGINEERING AND MAINTENANCE DIVISION
TOPIC : CALIBRATION REPORT CREATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 1 **OF** 3

WRITE BY : POSITION :

ANNOUNCE BY : [SIGNATURE]

NAME :

POSITION :

THIS WORK INSTRUCTION IS THE COPY NUMBER:

MODIFICATION SUMMARY

NO	PAGE	DETAIL	BY

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : CALIBRATION REPORT CREATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 2 **OF** 3

1. OBJECTIVE:

To be instruction for calibration reports creation.

2. SCOPE:

This instruction is used for calibrate instrument in PTT oil terminal, LPG terminal, and aviation terminal.

3. REFERENCES:

Calibration report form

4. DEFINITION: -

5. INSTRUCTION:

The calibrator has to response the completeness of formal calibration report. The report should finished within 7 days after calibration date. The calibrator can create calibration by himself or pass manuscript to type writer to create the formal calibration report by following step below.

1. Check form revision, ensuring that it is the up-to-date revision.
2. Print data from manuscript into report form.
3. Before print out report, it has to check
   - The data between manuscript and report.
   - Table and line.
   - The unit, it has to be same unit in report.
   - The sign for example there has to have +/- in front of uncertainty value, there has to have – between range, etc.

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : CALIBRATION REPORT CREATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 3 **OF** 3

- The number of digit after point [.] has to equal to resolution of instrument.
- Check calibration date, name of calibrator, name of approval person.
- Check report number.

4. After print out report, it has to be sent to related person to sign report immediately

6 SUPPLEMENT: -

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : PRESSURE MODULE INSTRUCTION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 1 **OF** 3

WRITE BY : POSITION :

ANNOUNCE BY : [SIGNATURE]

NAME :

POSITION :

THIS WORK INSTRUCTION IS THE COPY NUMBER:

MODIFICATION SUMMARY

NO	PAGE	DETAIL	BY

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : PRESSURE MODULE INSTRUCTION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 2 **OF** 3

1. OBJECTIVE:

To be instruction for pressure module in pressure gauge calibration.

2. SCOPE:

This instruction is used for calibrate instrument in PTT oil terminal, LPG terminal, and aviation terminal.

3.REFERENCES:

3.1 instruction for uses Model PPC all standard versions.

3.2 Druck DPI 601 Portable pressure indicator/calibrator user manual.

4. DEFINITION: -

5. INSTRUCTION:

5.1 Instruction for AMETREK pressure module

1. Fill hydraulic oil to oil reservoir about 2/3 of receiver capacity.
2. Connect pressure gauge to pressure module.
3. Turn needle valve counter clockwise until it is full open.
4. Pump hand pump until there is full oil in connector then tighten connector.
5. Press on button “on” in pressure module.
6. Pump hand pump until there has no bubble in oil reservoir.
7. Press “zero” button for zero adjustment.
8. Turn needle valve clockwise until it is full close.
9. Increase pressure by pumping hand pump to demanded pressure.
10. Fine turn pressure by turning “vernier knob”.
11. After calibration, turn needle open needle valve to release pressure in system.

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : PRESSURE MODULE INSTRUCTION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 3 **OF** 3

5.2 Instruction for DRUCK pressure module

1. Press button "on" and select unit in calibration.
2. Connect pressure module and pressure gauge to hand pump. Open bleed valve on pressure gauge side.
3. Turn shut-off valve counter clockwise.
4. Turn screw press clockwise.
5. Pump hydraulic oil until the oil leak from bleed valve.
6. Close bleed valve or tighten pressure gauge connector in case of no bleed valve.
7. Turn screw press counter clockwise.
8. Close shut off valve.
9. Set zero.
10. Turn screw press to adjust pressure.
11. After calibration, turn screw press counterclockwise and open shut off valve to release pressure in system.

6 SUPPLEMENT: -

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : PRESSURE TRANSMITTER CALIBRATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 1 **OF** 4

WRITE BY : POSITION :

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POSITION :

THIS WORK INSTRUCTION IS THE COPY NUMBER:

MODIFICATION SUMMARY

NO	PAGE	DETAIL	BY

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : PRESSURE TRANSMITTER CALIBRATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 2 **OF** 4

1. OBJECTIVE:

To be instruction for pressure transmitter calibration.

2. SCOPE:

This instruction is used for calibrate instrument in PTT oil terminal, LPG terminal, and aviation terminal.

3.REFERENCES:

Calibration report form

4. DEFINITION: -

5. INSTRUCTION:

5.1 Pressure transmitter calibration.

Simulate electrical signal 4 , 8 , 12 , 16 , 20, 16, 12, 8, 4 mA. to transmitter input. Read and record transmitter electrical output. When the error is more than permissible error, adjust transmitter by setting Zero – Span and then simulate signal and record result again.

5.2 Loop test

Simulate pressure 0% , 25% , 50% , 75% , 100% , 75% , 50% , 25% , 0% of span to transmitter. Read and record pressure at control room.

WORK INSTRUCTION	DIVISION/DEPARTMENT: ENGINEERING AND MAINTENANCE DIVISION
TOPIC : PRESSURE TRANSMITTER CALIBRATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 3 **OF** 4

6 SUPPLEMENT: -

6.1 Instruction for reading tank pressure at control room at Lumlukka and Saraburi oil terminal

At ATG [ENTIS] cmputer

1. Press X enter
2. Input Passward CHGAUG enter
3. Press W enter
4. Press C enter
5. Press 1 enter
6. Press U enter
7. Press Ctrl I [in case of not display the address]
8. Input Address and BZP1 enter , the the pressure is displayed.
9. Do step 8 continuously until pressure is stable.

6.2 Instruction for reading pump pressure at control room at Lumlukka and Saraburi oil terminal .

At control room computer

1. Enter screen Xvision Sever
2. Click mouse [right button] at demanded area to enlarge the screen.
3. Select pump by click mouse
4. Click mouse [right button] at demanded pressure.
5. Member tags No. of pressure transmitter Ex PT-201A , PT-201B and PLC Address at and host Ex N9 : 0 offset 504 , 505
6. Double click at Quit.
7. Enter screen ABS. EXE

WORK INSTRUCTION	DIVISION/DEPARTMENT: ENGINEERING AND MAINTENANCE DIVISION
TOPIC : PRESSURE TRANSMITTER CALIBRATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 4 **OF** 4

8. Press F3 enter
9. Input User name xxxxxx enter [SRBPTT for Saraburi terminal]
10. Press F3 enter
11. Input Password xxxxxx enter [SRBPTT for Saraburi terminal]
12. Press F1 enter
13. Press F2 enter
14. Search Add./sym : Input Tag No. enter
15. Monitor and record pressure

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : TEMPERATURE TRANSMITTER CALIBRATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 1 **OF** 4

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MODIFICATION SUMMARY

NO	PAGE	DETAIL	BY

WORK INSTRUCTION	DIVISION/DEPARTMENT: ENGINEERING AND MAINTENANCE DIVISION
TOPIC : TEMPERATURE TRANSMITTER CALIBRATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 2 **OF** 4

1. OBJECTIVE:

To be used as instruction for temperature transmitter calibration.

2. SCOPE:

This instruction is used for calibrate instrument in PTT oil terminal, LPG terminal , and aviation terminal.

3.REFERENCES: -

4. DEFINITION: -

5. INSTRUCTION:

5.1 Temperature element [RTD] calibration.

- Place RTD in temperature bath.
- Increase temperature 0% , 25% , 50% , 75% , 100% , 75% , 50% , 25% , 0% of calibration range.
- Record the result.

5.2 Temperature transmitter calibration. [Loop test]

- Connect resistance box [decade box] to input of transmitter.
- Simulate resistance at 0% , 25% , 50% , 75% , 100% , 75% , 50% , 25% , 0% of calibration range.
- Record the result.
- If the error is higher than permissible error, adjust the indicator and re-calibration

WORK INSTRUCTION	DIVISION/DEPARTMENT: ENGINEERING AND MAINTENANCE DIVISION
TOPIC : TEMPERATURE TRANSMITTER CALIBRATION	**DOCUMENT CODE :** WI-0P-XXX
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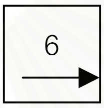
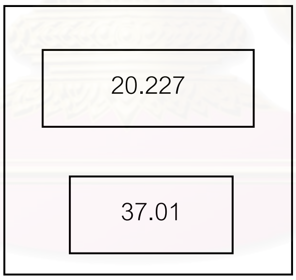
6 SUPPLEMENT: -

6.1 Instruction for reading loading gantry thermometer and BLC loop test.

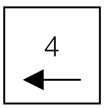
1. Select master BLC [observe from the blue cable under BLC box]
2. Press test button for a while until screen display “Test”.
3. Press 

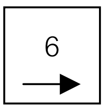
or 

until screen display “Arm” then press enter. Enter
4. Press 0 Enter
5. The screen will display “go to no” , then input “37” Enter
6. Screen will display



The upper box display temperature the lower box display mode and arm number . The picture mean in mode 37 arm no. 1, temperature is 20.227 °C. Normally arm 1 is dummy, the working arm start from arm 2. We can monitor temperature in the other arm by press button



or


7. Start loop test by disconnects cable between RTD and transmitter and connect decade box instead.

WORK INSTRUCTION	DIVISION/DEPARTMENT: ENGINEERING AND MAINTENANCE DIVISION
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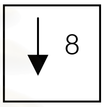
8. Simulate signal from decade box [ohm] and read temperature at BLC [^{0}C]

9. If we need indicator adjustment, we can do by go to mode 38 [by press button 

or 

10. and check default at mode 38. If it is not 100 , we have to change it to 100 by

    10.1 At mode 38 press cal button for a while until screen display "cal" then press enter.

    10.2 Input 100 Enter

    10.3 Input 00 [number after zero point .] Enter

    10.4 Simulate ohm at 30^{0}C if BLC indicate 30.018, we have to reduce 0.018 from default. Then the new value is 100-0.018 = 99.982.

    10.5 Input new default by following step 9.1 – 9.3.

11. Re-calibration

12. Go out from program by press clear button.

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : PRESSURE SWITCH CALIBRATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 1 **OF** 2

WRITE BY : POSITION :

ANNOUNCE BY : [SIGNATURE]

NAME :

POSITION :

THIS WORK INSTRUCTION IS THE COPY NUMBER:

MODIFICATION SUMMARY

NO	PAGE	DETAIL	BY

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : PRESSURE SWITCH CALIBRATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 2 **OF** 2

1. OBJECTIVE:

To be instruction for pressure switch calibration.

2. SCOPE:

This instruction is used for calibrate instrument in PTT oil terminal, LPG terminal, and aviation terminal.

3. REFERENCES: -

4. DEFINITION: -

5. INSTRUCTION:

5.1 Pressure switch high calibration

- Input pressure to pressure switch. Start from pressure lower than set point and then increase pressure until pressure switch is activated. Record the result.
- If pressure switch doesn't be activated at set point, adjust pressure switch and re-calibration.

5.2 Pressure switch low calibration

- Input pressure to pressure switch. Start from pressure higher than set point and then decrease pressure until pressure switch is activated. Record the result.
- If pressure switch doesn't be activated at set point, adjust pressure switch and re-calibration.

6 SUPPLEMENT: -

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : TEMPERATURE SWITCH CALIBRATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 1 **OF** 2

WRITE BY : POSITION :

ANNOUNCE BY : [SIGNATURE]

NAME :

POSITION :

THIS WORK INSTRUCTION IS THE COPY NUMBER:

MODIFICATION SUMMARY

NO	PAGE	DETAIL	BY

WORK INSTRUCTION	**DIVISION/DEPARTMENT:** ENGINEERING AND MAINTENANCE DIVISION
TOPIC : TEMPERATURE SWITCH CALIBRATION	**DOCUMENT CODE :** WI-0P-XXX
DATE : XX/XX/XX	**PAGE** 2 **OF** 2

1. OBJECTIVE:

To be used as instruction for temperature switch calibration.

2. SCOPE:

This instruction is used for calibrate instrument in PTT oil terminal, LPG terminal, and aviation terminal.

3.REFERENCES:

Calibration report form

4. DEFINITION: -

5. INSTRUCTION:

Temperature switch high calibration

- Place temperature sensor in temperature bath that has temperature lower than set point and then increase temperature until temperature switch is activated. Record the result.
- If temperature switch doesn't be activated at set point, adjust temperature switch and re-calibration.

6 SUPPLEMENT: -

Instrument: Temperature bath and temperature sensor

APPENDIX I

CALIBRATION SPECIFICATION

CALIBRATION SPECIFICATION FOR PRESSURE GAUGE

1. Objective : Petroleum Authority of Thailand [PTT] require external calibration unit for pressure gauge calibration at …………..terminal.

2. Calibration specification

The calibration unit has to calibrate pressure gauge according to condition below

2.1 Master instrument has to be calibrated and has calibration certificate that can be traceable to national or international standard in same unit with under-test instrument. The uncertainty in master instrument calibration is no more than $\pm$ 0.13 BAR and master instrument accuracy should no more than $\pm$ 0.17 BAR. The calibration unit has to submit master instrument calibration certificate to PTT for approval before calibration.

2.2 The calibration unit has to have transportation procedure, ensuring that the master instrument accuracy has not effect by transportation.

2.3 The calibration unit has to calibrate instrument by using standard procedure. If there has no standard procedure, the calibration unit has to submit calibration procedure to PTT for approval before calibration.

2.4 The calibration unit has to calibrate instrument cover calibration range.

2.5 PTT not allow calibration unit using sub-contractor unless having PTT agreement.

2.6 When calibration result is more than permissible error, the calibration unit has to adjust instrument and calibrate again.

2.7 The calibration certificate has to contain these informations

- Header such as “calibration certificate” or “ calibration report” etc.
- Name and address of calibration unit.
- Calibration certificate identification.
- Name and address of customer in form “PETROLEUM AUTHORITY OF THAILAND: terminal name “
- Calibration date.
- Calibration procedure.
- Calibration environment and additional information.

- Calibration results, before and after adjusts.
- Estimated uncertainty.
- Signatures of authorize personnel.
- Statement " A statement to the offer that the result relate only to the item calibrated or tested, where relevant.
- A statement thet the certificate or report shall not be copied except in full without laboratory approval inn writing.
- Traceability in calibration.

2.8 Calibration unit has to review the detail in caliraation certificate, ensuring that it match to detail in list of instrument before submit to PTT.

3. Working condition

3.1 The calibration unit has to response to any damage in PTT treasure occurring from the calibration unit staff or sub-contractor.

3.2 The calibration unit can ask for more information from Engineering and Measurement Division, Engineering and Maintenance Department.

3.3 The calibration unit has to submit calibration report to Engineering and Measurement Division within 15 days after calibration date.

3.4 The calibration unit has to submit request letter, with copy of staff personnel identify card, to terminal before starting operation.

4. Bidding specification.

4.1 The calibration unit has to be company in PTT approved vendor list.

4.2 The calibration unit has no record about having been terminate job by government agencies.

5. Payment.

PTT will pay an installment within 30 days after acceptant committee already inspected the job.

CALIBRATION SPECIFICATION FOR PRESSURE TRANSMITTER

1. Objective : Petroleum Authority of Thailand [PTT] require external calibration unit for pressure transmitter calibration at ………….terminal.

2. Calibration specification

The calibration unit has to calibrate pressure gauge according to condition below

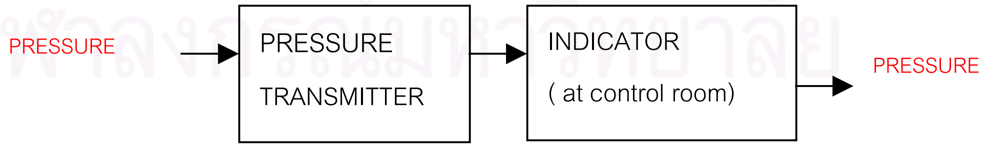
2.1 Master instrument has to be calibrated and has calibration certificate that can be traceable to national or international standard in same unit with under-test instrument. The uncertainty in master instrument calibration is no more than $\pm$ 0.1 BAR and master instrument accuracy should no more than $\pm$ 0.13 BAR. The calibration unit has to submit master instrument calibration certificate to PTT for approval before calibration.

2.2 The calibration unit has to have transportation procedure, ensuring that the master instrument accuracy has not effect by transportation.

2.3 The calibration unit has to calibrate instrument by using standard procedure. If there has no standard procedure, the calibration unit has to submit calibration procedure to PTT for approval before calibration.

2.3.1 In pressure transmitter calibration, the calibration unit has to simulate input and measure output in form of electrical signal.

2.3.2 In loop test, the calibration unit has to simulate input and measure output in form of pressure.



2.4 The calibration unit has to calibrate instrument cover calibration range.

2.5 PTT not allow calibration unit using sub-contractor unless having PTT agreement.

2.6 When calibration result is more than permissible error, the calibration unit has to adjust instrument and calibrate again.

2.7 The calibration certificate has to contain these informations

- Header such as "calibration certificate" or " calibration report" etc.
- Name and address of calibration unit.
- Calibration certificate identification.
- Name and address of customer in form "PETROLEUM AUTHORITY OF THAILAND: terminal name "
- Calibration date.
- Calibration procedure.
- Calibration environment and additional information.
- Calibrations result before and after adjust in same unit between master and under-test instrument and it has to be working unit. The calibration result has to express input value on the left-hand side and output value on the right-hand side. And the different in term of electrical signal has to convert to pressure.
- Estimated uncertainty, both in pressure transmitter and loop test.
- Signature of authorizes personnel.
- Statement " A statement to the offer that the result relate only to the item calibrated or tested, where relevant.
- A statement thet the certificate or report shall not be copied except in full without laboratory approval inn writing.
- Traceability in calibration.

2.8 Calibration unit has to review the detail in caliraation certificate, ensuring that it match to detail in list of instrument before submit to PTT.

3 Working condition

3.1 The calibration unit has to response to any damage in PTT treasure occurring from the calibration unit staff or sub-contractor.

3.2 The calibration unit can ask for more information from Engineering and Measurement Division, Engineering and Maintenance Department.

3.3 The calibration unit has to submit calibration report to Engineering and Measurement Division within 15 days after calibration date.

3.4 The calibration unit has to submit request letter, with copy of staff personnel identify card, to terminal before starting operation.

4 Bidding specification.

4.1 The calibration unit has to be company in PTT approved vendor list.

4.2 The calibration unit has no record about having been terminate job by government agencies.

5 Payment

PTT will pay an installment within 30 days after acceptant committee already inspected the job.

CALIBRATION SPECIFICATION FOR PRESSURE SWITCH

1. Objective : Petroleum Authority of Thailand [PTT] require external calibration unit for pressure switch calibration at …………..terminal.

2. Calibration specification

The calibration unit has to calibrate pressure gauge according to condition below

2.1 Master instrument has to be calibrated and has calibration certificate that can be traceable to national or international standard in same unit with under-test instrument. The uncertainty in master instrument calibration is no more than $\pm$ 0.13 BAR and master instrument accuracy should no more than $\pm$ 0.17 BAR. The calibration unit has to submit master instrument calibration certificate to PTT for approval before calibration.

2.2 The calibration unit has to have transportation procedure, ensuring that the master instrument accuracy has not effect by transportation.

2.3 The calibration unit has to calibrate instrument by using standard procedure. If there has no standard procedure, the calibration unit has to submit calibration procedure to PTT for approval before calibration.

2.4 The calibration unit has to calibrate instrument cover calibration range.

2.5 PTT not allow calibration unit using sub-contractor unless having PTT agreement.

2.6 When calibration result is more than permissible error, the calibration unit has to adjust instrument and calibrate again.

2.7 The calibration certificate has to contain these informations

- Header such as "calibration certificate" or " calibration report" etc.
- Name and address of calibration unit.
- Calibration certificate identification.
- Name and address of customer in form "PETROLEUM AUTHORITY OF THAILAND: terminal name "
- Calibration date.
- Calibration procedure.
- Calibration environment and additional information.

- Calibrations result before and after adjust.
- Estimated uncertainty.
- Signature of authorizes personnel.
- Statement " A statement to the offer that the result relate only to the item calibrated or tested, where relevant.
- A statement thet the certificate or report shall not be copied except in full without laboratory approval inn writing.
- Traceability in calibration.

2.8 Calibration unit has to review the detail in caliraation certificate, ensuring that it match to detail in list of instrument before submit to PTT.

3 Working condition

3.1 The calibration unit has to response to any damage in PTT treasure occurring from the calibration unit staff or sub-contractor.

3.2 The calibration unit can ask for more information from Engineering and Measurement Division, Engineering and Maintenance Department.

3.3 The calibration unit has to submit calibration report to Engineering and Measurement Division within 15 days after calibration date.

3.4 The calibration unit has to submit request letter, with copy of staff personnel identify card, to terminal before starting operation.

4 Bidding specification.

4.1 The calibration unit has to be company in PTT approved vendor list.

4.2 The calibration unit has no record about having been terminate job by government agencies.

5 Payment

PTT will pay an installment within 30 days after acceptant committee already inspected the job.

CALIBRATION SPECIFICATION FOR TEMPERATURE GAUGE

1. Objective: Petroleum Authority of Thailand [PTT] require external calibration unit for temperature gauge calibration at …………..terminal.

2. Calibration specification

The calibration unit has to calibrate pressure gauge according to condition below

2.1 Master instrument has to be calibrated and has calibration certificate that can be traceable to national or international standard in same unit with under-test instrument. The uncertainty in master instrument calibration is no more than $\pm$ 0.5 °C [range 0-100°C], $\pm$ 1.0 °C [range 0-200°C], and $\pm$ 1.5 °C [range 0-300°C] . Master instrument accuracy should no more than $\pm$ 0.7 °C [range 0-100°C], $\pm$ 1.4 °C [range 0-200°C], and $\pm$ 2.0 °C [range 0-300°C] The calibration unit has to submit master instrument calibration certificate to PTT for approval before calibration.

2.2 The calibration unit has to have transportation procedure, ensuring that the master instrument accuracy has not effect by transportation.

2.3 The calibration unit has to calibrate instrument by using standard procedure. If there has no standard procedure, the calibration unit has to submit calibration procedure to PTT for approval before calibration.

2.4 The calibration unit has to calibrate instrument cover calibration range.

2.5 PTT not allow calibration unit using sub-contractor unless having PTT agreement.

2.6 When calibration result is more than permissible error, the calibration unit has to adjust instrument and calibrate again.

2.7 The calibration certificate has to contain these informations

- Header such as “calibration certificate” or “ calibration report” etc.
- Name and address of calibration unit.
- Calibration certificate identification.
- Name and address of customer in form “PETROLEUM AUTHORITY OF THAILAND: terminal name “
- Calibration date.

- Calibration procedure.
- Calibration environment and additional information.
- Calibration result before and after adjust.
- Estimated uncertainty.
- Signature of authorize personnel.
- Statement " A statement to the offer that the result relate only to the item calibrated or tested, where relevant.
- A statement that the certificate or report shall not be copied except in full without laboratory approval inn writing.
- Traceability in calibration.

2.8 Calibration unit has to review the detail in calibration certificate, ensuring that it match to detail in list of instrument before submit to PTT.

3. Working condition

3.1 The calibration unit has to response to any damage in PTT treasure occurring from the calibration unit staff or sub-contractor.

3.2 The calibration unit can ask for more information from Engineering and Measurement Division, Engineering and Maintenance Department.

3.3 The calibration unit has to submit calibration report to Engineering and Measurement Division within 15 days after calibration date.

3.4 The calibration unit has to submit request letter, with copy of staff personnel identify card, to terminal before starting operation.

4. Bidding specification.

4.1 The calibration unit has to be company in PTT approved vendor list.

4.2 The calibration unit has no record about having been terminate job by government agencies.

5. Payment.

PTT will pay an installment within 30 days after acceptant committee already inspected the job.

CALIBRATION SPECIFICATION FOR TEMPERATURE ELEMENT AND TRANSMITTER

1. Objective: Petroleum Authority of Thailand [PTT] require external calibration unit for temperature element and transmitter calibration at ....terminal.

2. Calibration specification

The calibration unit has to calibrate pressure gauge according to condition below

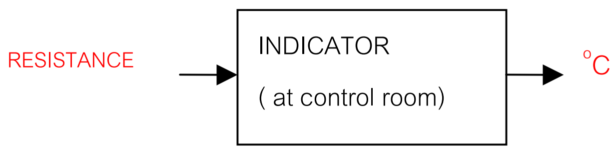
2.1 Master instrument has to be calibrated and has calibration certificate that can be traceable to national or international standard in same unit with under-test instrument. The uncertainty in master instrument calibration is no more than $\pm$ 0.04 ^{o}C [for calibrate instrument in LPG liquid phrase] and $\pm$ 0.06 ^{o}C [for calibrate instrument in oil, LPG vapor phrase]. Master instrument accuracy should no more than $\pm$ 0.05 ^{o}C [for calibrate instrument in LPG liquid phrase] and $\pm$ 0.08^{o}C [for calibrate instrument in oil, LPG vapor phrase]. The calibration unit has to submit master instrument calibration certificate to PTT for approval before calibration.

2.2 The calibration unit has to have transportation procedure, ensuring that the master instrument accuracy has not effect by transportation.

2.3 The calibration unit has to calibrate instrument by using standard procedure. If there has no standard procedure, the calibration unit has to submit calibration procedure to PTT for approval before calibration.

2.3.1 In pressure temperature element calibration, the calibration unit has to simulate input in degree C and measure output in form of resistance.

2.3.2 In loop test, the calibration unit has to simulate input in form of resistance and measure output in form of degree C.



2.4 The calibration unit has to calibrate instrument cover calibration range.

2.5 PTT not allow calibration unit using sub-contractor unless having PTT agreement.

2.6 When calibration result is more than permissible error, the calibration unit has to adjust instrument and calibrate again.

2.7 The calibration certificate has to contain these informations

- Header such as “calibration certificate” or “ calibration report” etc.
- Name and address of calibration unit.
- Calibration certificate identification.
- Name and address of customer in form “PETROLEUM AUTHORITY OF THAILAND: terminal name “
- Calibration date.
- Calibration procedure.
- Calibration environment and additional information.
- Calibrations result before and after adjust in same unit between master and under-test instrument and it has to be working unit. The calibration result has to express input value on the left-hand side and output value on the right-hand side. And the different in term of electrical signal has to convert to temperature.
- Estimated uncertainty, both in pressure transmitter and loop test.
- Signature of authorizes personnel.
- Statement ” A statement to the offer that the result relate only to the item calibrated or tested, where relevant.
- A statement thet the certificate or report shall not be copied except in full without laboratory approval inn writing.
- Traceability in calibration.

2.8 Calibration unit has to review the detail in caliraation certificate, ensuring that it match to detail in list of instrument before submit to PTT.

3. Working condition

3.1 The calibration unit has to response to any damage in PTT treasure occurring from the calibration unit staff or sub-contractor.

3.2 The calibration unit can ask for more information from Engineering and Measurement Division, Engineering and Maintenance Department.

3.3 The calibration unit has to submit calibration report to Engineering and Measurement Division within 15 days after calibration date.

3.4 The calibration unit has to submit request letter, with copy of staff personnel identify card, to terminal before starting operation.

4. Bidding specification.

4.1 The calibration unit has to be company in PTT approved vendor list.

4.2 The calibration unit has no record about having been terminate job by government agencies.

5. Payment

PTT will pay an installment within 30 days after acceptant committee already inspected the job.

CALIBRATION SPECIFICATION FOR TEMPERATURE SWITCH

1. Objective: Petroleum Authority of Thailand [PTT] require external calibration unit for temperature switch calibration at …………..terminal.

2. Calibration specification

The calibration unit has to calibrate pressure gauge according to condition below

2.1 Master instrument has to be calibrated and has calibration certificate that can be traceable to national or international standard in same unit with under-test instrument. The uncertainty in master instrument calibration is no more than $\pm$ 1.3 °C and master instrument accuracy should no more than $\pm$ 1.67 °C. The calibration unit has to submit master instrument calibration certificate to PTT for approval before calibration.

2.2 The calibration unit has to have transportation procedure, ensuring that the master instrument accuracy has not effect by transportation.

2.3 The calibration unit has to calibrate instrument by using standard procedure. If there has no standard procedure, the calibration unit has to submit calibration procedure to PTT for approval before calibration.

2.4 The calibration unit has to calibrate instrument cover calibration range.

2.5 PTT not allow calibration unit using sub-contractor unless having PTT agreement.

2.6 When calibration result is more than permissible error, the calibration unit has to adjust instrument and calibrate again.

2.7 The calibration certificate has to contain these informations

- Header such as “calibration certificate” or “ calibration report” etc.
- Name and address of calibration unit.
- Calibration certificate identification.
- Name and address of customer in form “PETROLEUM AUTHORITY OF THAILAND: terminal name “
- Calibration date.
- Calibration procedure.
- Calibration environment and additional information.

- Calibrations result before and after adjust.
- Estimated uncertainty.
- Signature of authorizes personnel.
- Statement " A statement to the offer that the result relate only to the item calibrated or tested, where relevant.
- A statement that "the certificate or report shall not be copied except in full without laboratory approval inn writing".
- Traceability in calibration.

2.8 Calibration unit has to review the detail in calibration certificate, ensuring that it match to detail in list of instrument before submit to PTT.

3. Working condition

3.1 The calibration unit has to response to any damage in PTT treasure occurring from the calibration unit staff or sub-contractor.

3.2 The calibration unit can ask for more information from Engineering and Measurement Division, Engineering and Maintenance Department.

3.3 The calibration unit has to submit calibration report to Engineering and Measurement Division within 15 days after calibration date.

3.4 The calibration unit has to submit request letter, with copy of staff personnel identify card, to terminal before starting operation.

4. Bidding specification.

4.1 The calibration unit has to be company in PTT approved vendor list.

4.2 The calibration unit has no record about having been terminate job by government agencies.

5. Payment

PTT will pay an installment within 30 days after acceptant committee already inspected the job.

CALIBRATION SPECIFICATION FOR WEIGHT SCALE

1. Objective: Petroleum Authority of Thailand [PTT] require external calibration unit for filling hall scale and truck scale at ………….terminal.

2. Calibration specification

The calibration unit has to calibrate pressure gauge according to condition below

2.1 The calibration unit has to use master instrument approved by MOC or use master instrument has to be calibrated and has calibration certificate that can be traceable to national or international standard in same unit with under-test instrument. The uncertainty in master instrument calibration is

- $\pm$ 4 g for 4 kg filling hall scale calibration,
- $\pm$ 7.5 g for 15 kg filling hall scale calibration,
- $\pm$ 24 g for 48 kg filling hall scale calibration,

And accuracy in master instrument is

- $\pm$ 5.3 g for 4 kg filling hall scale calibration,
- $\pm$ 10 g for 15 kg filling hall scale calibration,
- $\pm$ 32 g for 48 kg filling hall scale calibration,

The calibration unit has to submit master instrument calibration certificate to PTT for approval before calibration.

2.2 The calibration unit has to have transportation procedure, ensuring that the master instrument accuracy has not effect by transportation.

2.3 The calibration unit has to calibrate instrument by using standard procedure. If there has no standard procedure, the calibration unit has to submit calibration procedure to PTT for approval before calibration.

2.4 The calibration unit has to calibrate instrument cover calibration range.

2.5 PTT not allow calibration unit using sub-contractor unless having PTT agreement.

2.6 When calibration result is more than permissible error, the calibration unit has to adjust instrument and calibrate again.

2.7 The calibration certificate has to contain these informations

- Header such as “calibration certificate” or “ calibration report” etc.
- Name and address of calibration unit.
- Calibration certificate identification.
- Name and address of customer in form “PETROLEUM AUTHORITY OF THAILAND: terminal name “
- Calibration date.
- Calibration procedure.
- Calibration environment and additional information.
- Calibrations result before and after adjust.
- Estimated uncertainty.
- Signature of authorizes personnel.
- Statement ” A statement to the offer that the result relate only to the item calibrated or tested, where relevant.
- A statement that “the certificate or report shall not be copied except in full without laboratory approval inn writing”.
- Traceability in calibration.

2.8 Calibration unit has to review the detail in calibration certificate, ensuring that it match to detail in list of instrument before submit to PTT.

3. Working condition

3.1 The calibration unit has to response to any damage in PTT treasure occurring from the calibration unit staff or sub-contractor.

3.2 The calibration unit can ask for more information from Engineering and Measurement Division, Engineering and Maintenance Department.

3.3 The calibration unit has to submit calibration report to Engineering and Measurement Division within 15 days after calibration date.

3.4 The calibration unit has to submit request letter, with copy of staff personnel identify card, to terminal before starting operation.

4. Bidding specification.

4.1 The calibration unit has to be company in PTT approved vendor list.

4.2 The calibration unit has no record about having been terminate job by government agencies.

5. Payment

PTT will pay an installment within 30 days after acceptant committee already inspected the job.

APPENDIX J

DATA COLLECTION FOR LATE DATE BETWEEN CALIBRATION DATE AND REPORT APPROVAL DATE AFTER IMPROVEMENT

DATA COLLECTION FOR LATE DATE BETWEEN CALIBRATION DATE AND REPORT APPROVAL DATE AFTER IMPROVEMENT

1. PRESSURE GAUGE

REPORT NUMBER	TERMINAL	QUANTITY	CAL. DATE	REPORT APPROVAL DATE	LATE DATE
PG003/44 - PG047/44	Saraburi Oil	45	29/01/2001	12/02/2001	14
PG048/44 – PG58/44	Chiang Mai Oil	11	28/02/2001	9/03/2001	9
PG059/44 – PG069/44	Phuket Oil	11	21/03/2001	27/03/2001	6
PG070/44 - PG098/44	Phuket Aviation	29	21/03/2001	28/03/2001	7
D3378-95	Nakhon Sawan Oil	18	13/01/2001	25/01/2001	12
D3396-3481	Nakhon Sawan LPG	86	10/01/2001	25/01/2001	15
D3577,81-82,86-91,3610	Bangchak LPG	10	7/02/2001	1/03/2001	22
D3620	Bangchak LPG	1	13/02/2001	13/03/2001	28
D3579,80,97-00,3611-19	Bangchak LPG	15	14/02/2001	1/03/2001	15
D3578,83-85,92-96,3601-09	Bangchak LPG	18	24/04/2000	1/03/2001	14
D3875	Bangchak LPG	1	13/02/2001	13/03/2001	28
AVERAGE LATE DATE					**13**

Table J-1: Late date in pressure gauge calibration during Jan.-Mar 2001.

1. PRESSURE TRANSMITTER

REPORT NUMBER	TERMINAL	QUANTITY	CAL. DATE	REPORT APPROVAL DATE	LATE DATE
D 3482	Nakhon Sawan LPG	1	10/01/2001	31/01/2001	21
D3682,84,…,04	Saraburi Oil	12	29/01/2001	13/03/20001	43
D3858-68,71-74	Saraburi Oil	15	29/01/2001	13/03/20001	43
D3869	Saraburi Oil	1	29/01/2001	26/03/2001	56
D3870	Saraburi Oil	1	5/02/2001	13/03/20001	46
D3622,4,6	Bangchak LPG	3	13/02/2001	1/03/2001	16
D3627	Workshop	1	13/02/2001	1/03/2001	16
AVERAGE LATE DATE					**40**

Table J-2: Late date in pressure transmitter calibration during Jan.-Mar 2001.

3. PRESSURE SWITCH

REPORT NUMBER	TERMINAL	QUANTITY	CAL. DATE	REPORT APPROVAL DATE	LATE DATE
D3486-94	Nakhon Sawan LPG	9	10/01/2001	31/01/2001	21
AVERAGE LATE DATE					**21**

Table J-3: Late date in pressure switch calibration during Jan.-Mar 2001.

1. TEMPERATURE GAUGE

REPORT NUMBER	TERMINAL	QUANTITY	CAL. DATE	REPORT APPROVAL DATE	LATE DATE
D3495-99	Nakhon Sawan LPG	5	10/01/2001	25/01/2001	15
D3706-12	Saraburi Oil	7	29/01/2001	13/03/2001	43
D3634-5	Bangchak LPG	2	7/02/2001	1/03/2001	22
AVERAGE LATE DATE					**30**

Table J-4: Late date in temperature gauge calibration during Jan.-Mar 2001.

5. TEMPERATURE ELEMENT AND TRANSMITTER

REPORT NUMBER	TERMINAL	QUANTITY	CAL. DATE	REPORT APPROVAL DATE	LATE DATE
D3713,15,19,21,23,25,29,31,33,34,35,37,39,41,43,47	Saraburi Oil	16	29/01/2001	13/03/2001	43
D3717,27,30,45,3838	Saraburi Oil	5	29/01/2001	26/03/2001	56
D3806,08,10,12,14,16,18,20,22,24,26,28,30,32,34,36,40,42,44,46,48,49,51,52,24,55,56,57	Saraburi Oil	28	29/01/2001	13/03/2001	43
D3631-33	Truck calibration tower	3	6/02/2001	13/03/2001	35
D3637	Workshop	1	13/02/2001	13/03/2001	28
AVERAGE LATE DATE					**43**

Table J-5: Late date in temperature element and transmitter calibration during Jan.-Mar 2001.

6. WEIGHT SCALE

REPORT NUMBER	TERMINAL	QUANTITY	CAL. DATE	REPORT APPROVAL DATE	LATE DATE
PKW00201	Bangchak LPG	1	26/01/2001	19/02/2001	24
PKW003/01	Bangchak LPG	1	25/01/2001	19/02/2001	25
PKW026/01-032/01	Ban Rong Po LPG	7	20/03/2001	28/03/2001	8
AVERAGE LATE DATE					**12**

Table J-6: Late date in weight scale calibration during Jan.-Mar 2001.

BIOGRAPHY

Mr. Thanit Thinnam was born on October 4, 1972 in Nakornsrithammarat. He graduated Bachelor Degree from the Department of Mechanical Engineering, Faculty of Engineering, King Mongkut Institute of Technology Lardkrabang in 1994. Since then, he has worked for Petroleum Authority of Thailand in Engineering and Maintenance Division. In 1998, he continued his studies for Master Degree in Engineering Management, the Regional Centre for Manufacturing Systems Engineering, Chulalongkorn University.