CHEMICAL ENGINEERING TRANSACTIONS
VOL. 56, 2017
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Jiří Jaromír Klemeš, Peng Yen Liew, Wai Shin Ho, Jeng Shiun Lim

ISBN 978-88-95608-47-1; **ISSN** 2283-9216
DOI: 10.3303/CET1756148

Contribution of Permit to Work to Process Safety Accident in the Chemical Process Industry

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Permit to Work (PTW) is the Technical Measurement Document required to control work such as maintenance, inspection, modification and non-routine high risk activities to prevent a major accident. It is one of the elements of the Process Safety Management (PSM). The current issue of the chemical process industry (CPI) is that the accident rate has not decreased even though PSM has been widely implemented in the developed country. Statistics on the accident cases published by Chemical Safety and Hazard Investigation Board (US), European Major Accident Reporting System and Failure Knowledge Database (Japan) has revealed that PTW has significance contribution to the occurrence of accidents and is worthwhile to be studied in details. Failure in complying with PTW system has caused major accidents cases, such as Motiva Enterprise LLC (2001), Phillips Pasadena (1989) and Piper Alpha Platform (1988). Another reason for studying PTW, being that the trend of its percentage of contribution to process accident rate is not decreasing over the past two decades even though there are shared information and feedback available. In the chemical process industry, there are various types of PTW namely Hot Work, Confined Space Entry, Line breaking & vessel opening and others. Each has its own function and the percentage contribution of each PTW type is determined using data mining approach. This study is focusing on the identification of main factors of PTW-related accidents which are classified under organisation, human factors, communication, competency, procedure, supervision, tools and equipment and etc. The percentage contribution of each main factor is determined and the results are presented for sharing and learning purposes.

1. Introduction

Process related hazard could claim lives, cause injury and damage facilities which take long time to repair, resulting insufficient supplies of raw materials to the related industries. To prevent such major industrial accidents, many countries including United States of America, United Kingdom, European Union and Asian countries such as Japan, Korea and Singapore has implemented the Process Safety Management (PSM). Incidentally, PTW is one of the 14 elements of the PSM.

The UK Health and Safety Executive (UK-HSE, 2013) define a Permit to Work (PTW) as “a formal, written, safe system of work to control potentially hazardous activities”. A PTW is a document that specifies the work to be carried out and the necessary preventive actions to be taken. The key of PTW is that work can only be allowed to start provided that all potential hazards have been considered. For the successful implementation of PTW, it is greatly dependent on the strict enforcement of the procedures and practices.

A survey made by the UK-HSE showed that one third of all accidents in the UK CPI were maintenance related and the largest single being the lack of or deficiency in PTW. Failure in PTW system can cause process safety related incident categorised under explosions, fires and toxic releases, which resulted in human injury, death, damage to property and environment. Historically, there were perhaps hundreds of major safety incidents happened in the world arising from PTW failure but the following tragedies are good enough to illustrate the extent of harm (Atherton and Gil, 2008). In 1988, an explosion occurred on the Piper Alpha offshore platform of the North Sea that set off a chain of fires and explosions resulting in the loss of 167 lives

Please cite this article as: Yan C.K., Siong P.H., Kidam K., Ali M.W., Hassim M.H., Kamaruddin M.J., Kamarden H., 2017, Contribution of permit to work to process safety accident in the chemical process industry, Chemical Engineering Transactions, 56, 883-888
DOI:10.3303/CET1756148

and near total destruction of the platform. In 1989, a massive explosion followed by a major fired occurred at the Phillips Chemical Company at Pasadena, Texas. 23 workers were killed and more than 130 others injured. Property damage totalled nearly USD 750K. In 2001, an explosion and fire occurred at the sulphuric acid tank farm of Motiva Enterprises LLC, Delaware, US. One contractor was killed and eight workers injured. There was significant environment damage resulting from an estimated 375 m^3 of sulphuric acid entered the Delaware River. In 2014, a fire occurred in a petrochemical plant killing 2 contractors and injured 7 others.

2. Research Approach

Study was conducted using data mining method by going through data collection, data cleaning, data integration, data selection, data pre-processing, data transformation and data mining. More than 1,000 accident cases happened in the chemical process industry were searched but only about 600 are related to process safety. The database is built up on the aggregation of sources from Chemical Safety and Hazard Investigation Board (US-CSB, 2015), European Major Accident Reporting System (EMARS, 2015), Failure Knowledge Database (FKD, 2015), Central Major Accident Notification System (ZEMA, 2015) and one petrochemical plant (Malaysia) over the period from 1990 to 2015.
These accident cases are sorted under the 14 different categories of PSM elements and the percentage contribution of each element to the total accident cases is determined. Basing on the percentage contribution, the ranking of all the PSM elements is established. Subsequently, further study is conducted on the element of PTW. The different types of PTW are identified and the accident cases associated with PTW is categorised under different PTW type. Next, the percentage contribution of each PTW type to the total accident cases related with PTW is worked out and the ranking is established.

3. Results and Discussions

Though there are about 600 cases of process safety accident selected for study, the frequency occurrence of PSM element is total at 1,690 because of multiple causation, which is one accident case can cause by more than one element.

3.1 PSM Element

Out of the 1,690 frequency occurrence under study, 118 cases are related with PTW element with a contribution of 6.98 % as indicated in Table 1. Though its percentage contribution is lower than the PSM element of Operating procedure (16.86 %), Process hazard analysis (16.27 %), Employee participation (13.20 %), Training (11.01 %), Mechanical Integrity (9.17 %) and Management of Change (8.22 %), it is significant for study because trend of its percentage contribution to process accident rate is not decreasing over the past two decades even though there are shared information and feedback. Noticeably, PTW influence tends to be given less attention as evidenced by the very few research study being published. This offers an excellent opportunity in exploring this area for improvement and in accident prevention.

Table 1: Accident causation contributed by different PSM element

PSM Element	PSM Element No	PSM Element Frequency	% of contribution to accidents
Employee Participation	1	223	13.2
Process Safety Information	2	95	5.6
Process hazards analysis	3	275	16.2
Operating procedures	4	285	16.8
Training	5	186	11.0
Contractors	6	42	2.5
Pre-start-up safety review	7	27	1.6
Mechanical integrity	8	155	9.2
Hot work permit	9	118	7.0
Management of change	10	139	8.2
Incident investigations	11	67	4.0
Emergency planning and response	12	46	2.7
Compliance audits	13	18	1.0
Trade secrets	14	14	0.8
Total		1,690	100

3.2 Type of PTW

Table 2 summarises the definitions and functions of different types of PTW.

Table 2: Permit to Work Types, Definitions and Functions

Permit to Work Type	Definitions	Functions
Hot work	Any work that may produce or generate a source of ignition performed in a hazardous area	Protect personnel and equipment from any untoward incidence of fire or explosion by controlling the presence of ignition sources, combustible / flammable materials and work practices.
Line breaking & vessel opening	Dealing with separation of a process pipeline containing hazardous materials or entry into a process vessel that cannot be certified as empty and still under pressure.	Prevent fire and injury to employees working on the process pipeline and vessels.
Overhead & mobile crane	Dealing with the operating and maintenance of overhead cranes, crawler cranes and wheel mounted cranes, both truck mounted and self-propelled wheel type.	Provide a plant standard for safe lifting to prevent injury and equipment damage
Confined space entry	Any enclosure sufficiently surrounded by confining surfaces which having limited ventilation of air that are potentially accumulated with hazardous gases, mists, fumes, vapours, dusts or having oxygen deficiency / excess environment or restrictive to personnel escape.	The confined space permit is intended to prevent personnel injury/ death by controlling access to confined spaces.
Vehicle entry	Any person intending to bring vehicle into the plant process	The purpose is to control vehicle enter into the plant area with proper authorisation
Excavation	Any digging, excavation, pile-driving, setting out pegs or any other similar work carried out beyond a depth of 100 mm.	Prevent underground pipeline and cable from damage which may cause fire and explosion.
Safe work	A permit required adequate exchange of information between operating personnel and non-operating personnel who enter an operating area to perform any type of work	Ensure that operating equipment is properly prepared and in safe working conditions during repairs or temporary construction. Secondly, it is to keep operating personnel informed that non-operating personnel are in their unit and necessitate evacuation should an upset condition or emergency arises.
Hydro-blasting	The use of water and/or water additive combinations whose pressure exceed 1,000 psig in the removal of unwanted matter on various surfaces.	Ensure the safety of operator or any other person/s from injury while working with the hydro blaster.
Scaffolding	The erection of tube, coupler, frame and tower Scaffold	Provides a guideline for the erection of scaffolding to conform to standard method and specification. This is to prevent tilting and collapse.
Energized electricity	Permit required for electricians to work on energized electrical circuits or equipment with voltages greater than 120 volts but less than 1,000 volts in non-hazard classified areas of the plant.	Ensure the safety of electricians while working on the energised electrical circuits to prevent burnt and electrocution.
Flare area entry	The flare area is defined as the area within the perimeter fence of the flare stacks where there is hazard of gas release.	For protecting personnel working within the Flare-Area from heat radiation and noise induced injuries.
Radiation	When portable equipment producing ionising radiation, instruments containing sealed radioactive sources and plant containing unsealed radioactive substances are used in plant	Ensure competent person is handling the job and meet regulation.

3.3 PTW System Failures

Basing on the results of percentage contribution for the 12 different PTW types tabulated in Table 3, the top 5 ranked PTW types in descending order that contribute to the process safety accident are Hot Work (27.12 %), Line breaking and vessel opening (16.95 %), Overhead & mobile crane (11.86 %) and Confined space entry (10.17 %). These 4 PTW types themselves constitute 66.10 % of the overall PTW related accidents because they are the major risked activities with job complexity in hazardous environment during plant maintenance, turnaround and shutdown. Their works and hazards will be briefly explained for better understanding.

3.3.1 Hot work

Hot work includes welding, burning, use of industrial non-flame proof electrical equipment, internal combustion engines, use of pneumatic chippers, hammers and rock drills. The recognised hazards are the presence of flammable gases & vapours in the surrounding atmosphere, the flammable and combustible materials in the item to be worked on.

3.3.2 Line breaking and vessel opening

This permit is critical in dealing with the isolation and separation of process pipeline or vessel using blind flange. The risks are the residual hazardous materials, hydrocarbon and trapped pressure in the pipeline and vessel.

3.3.3 Overhead and mobile crane

It covers the operating and maintenance of overhead cranes, crawler cranes, wheel mounted cranes. The recognised hazards are that the engine can generate sparks, congested plant environment with many blind spots, swinging boom and soggy ground that cannot withstand the load limit of crane.

3.3.4 Confined space entry

According to Kletz (1982), confined space can be categorised to “any absorber, boiler, culvert, drain, flue, gas purifier, sewer, still, tank, tower, vitriol chamber or other place where there is reason to apprehend the presence of dangerous gas or fume”. The hazards are limited ventilation of air, hazardous gases, mists, fumes, vapours, dusts or having oxygen deficiency / excess environment, inadequate illumination, restriction to safe access for escape.

Table 3: Incident causation according to PTW Type (CSB, FKD, EMARS, ZEMA & one petrochemical plant in Johor, Malaysia) (1990 - 2015)

PTW Type	No	Frequency of Occurrence	% of contribution to incidents
Hot work	1	32	27.1
Line breaking & vessel opening	2	20	17.0
Overhead & mobile crane	3	14	12.0
Confined space entry	4	12	10.2
Vehicle entry	5	10	8.5
Excavation	6	6	5.1
Scaffolding	7	6	5.1
Safe work	8	6	5.1
Hydro-blasting	9	6	5.1
Energized electricity	10	4	3.4
Flare area entry	11	2	1.7
Radiation	12	0	0
Total		118	100

3.4 Main factors of PTW failure

The frequent PTW failure is caused by not checking system adequately, not identifying hazards adequately, unclear of correct type of personal protective equipment needed, poor isolation of energy source and inadequate formal hand back of plant upon completion of maintenance work.

From the study on the investigation reports, the main factors contributed to each PTW type failure are identified and summarised in Table 4. There are all together 7 main factors classified as organisation, communication, human factor, procedure, tools and equipment, supervision and competency. All are of important even though communication, human factor and procedure are present in all the PTW type failure.

Communication is to ensure no misunderstanding and neglect of essential precautions between operating and maintenance when plant was handed from production to maintenance workers. Information on the work to be done, the correct equipment and its readiness for handing over is transpired and agreed by both parties during the communications.
Every permit must have written procedure and work instruction no matter how simple or complicated the permit is. Common violations are by passing the or not following the correct sequence of the work steps. Without procedure or no complying to it can be very costly.

Table 4: Link of main factors to PTW type failure

PTW type	Main factor							
	Organisation	Communication	Human factor	Procedure	Tools / Equip-ment	Supervision	Comp-etency	Total
Hot work	1	1	1	1	1	1	1	7
Line breaking & vessel opening	1	1	1	1	1	1	1	7
Overhead & mobile crane	1	1	1	1	1	1	1	7
Confined space entry	1	1	1	1	1	1	1	7
Vehicle entry		1	1	1	1	1	1	6
Excavation	1	1	1	1	1	1	1	7
Scaffolding	1	1	1	1	1	1	1	7
Safe work		1	1	1				3
Hydro-blasting	1	1	1	1	1	1	1	7
Energised electricity	1	1	1	1	1	1	1	7
Flare area entry		1	1	1				3
Total	8	11	11	11	9	9	9	68

Negative attitude, negligence, carelessness, physical fatigue and non-attentiveness are among the common human factors that can result in PTW failure.
Tools and equipment must be in sound conditions or else can have severe impact on the safe implementation of PTW. Gas detectors that are not calibrated, exposed cable of the electrical tools, defective high pressure hoses, inappropriate personal protective equipment, wrong scaffold material specification and substandard fittings are examples that can cause accident but the examples are not exhaustive. As a thumb of rule, all tools and equipment must be inspected and certified fit before they are used.
Supervision is always critical in activities involving hot work, line breaking and vessel opening, confined space entry, overhead and mobile crane, hydro blasting, excavation, scaffolding, vehicle entry and energised electricity. Supervision can be continuous as in the case of confined space entry.
Competency means skilled, knowledgeable and experienced personnel. Typical examples are the gas tester, welder, crane supervisor and welder, electrical charge-man, radiography officer, safety officer and so on and so forth. Their competency must be checked and verified by the Safety Department before any work execution is allowed.
Organisation plays a major role to ensure the successful implementation of PTW by showing strong management commitment and exercise firm enforcement.

4. Conclusions

This paper is part of an on-going study to give more insight into how PTW can be a causal factor in major accident in the chemical process industries. In this study, the extent of influence on different PTW type to the process safety accidents in CPI has been established. The study on the accident reports enhances the identification of the main factors of PTW type failure. The study provides a better understanding of PTW system and different types of PTW. This information is useful for sharing and learning with the chemical process plant practitioners. However, there is further in-depth study on-going to determine the root causes with preventive actions in improving process safety.

References

Atherton J., Gil F., 2008, Incidents that Define Process Safety, Center for Chemical Process Safety, AIChE, New York, United States.

EMARS, 2015, European Major Accident Reporting System, Major Accident Hazards Bureau <emars.jrc.ec.europa.eu> accessed 20.06.2015.

JST, 2015, Failure Knowledge Database, Japan and Science Technology Agency <shippai.jst.go.jp/en/search> accessed 10.03.2015.

Kletz T.A., 1982, Hazards in chemical system maintenance- permits in Safety and Accident Prevention in Chemical Operations, Eds. Fawcett H.H., Wood W.S, 2nd Ed., Wiley-Interscience, New York, United States.

UK-HSE, 2013, UK Health & Safety Executive, Report on Isolation and permits to work - Safe maintenance <www.hse.gov.uk/safemaintenance/permits.htm> accessed 17.03.2015.

US-CSB, 2015, US Chemical Safety and Hazard Investigation Board, Completed Investigation <www.csb.gov/investigations/completed-investigations> accessed 17.03.2015.

ZEMA, 2015, Umwelt Bundesamt (Federal Environmental Agency) <www.infosis.uba.de /index.php/de/site/12981/zema/index.html> accessed 15.08.2015.