

THE EVALUATION OF LEAKAGE IN UNDERGROUND STORAGE TANK AT PETROL STATION

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BIODATA

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*Member MSNT (Malaysia Society for Nondestructive Testing).

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*DBT (DOSH Brain Team).





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* Content.

- * Background.
- * Accidents in Petrol Station.
- * Federal Government Gazette.
- * Gua Musang Mishap.
- * DOSH Activities.
- * Issues on Underground Storage Tank (UST).
- * Definition of leakage.
- * Problem Statements.
- * Research Objectives and Research Questions.
- * Research Methodology.
- * Conclusion and Research Contributions.



Background 1



Petro Teguh
Malaysia Sdn Bhd



No. of petrol stations in Malaysia;

1. PETRONAS : 1070

2. SHELL : 956

3. PETRON : 580

4. CALTEX : 432

4. BHP : 337

5. Others

(Buroq Oil (249) , Petro Teguh (27) , Smart Stream (44) , Haz Capital (16) and Other (8))

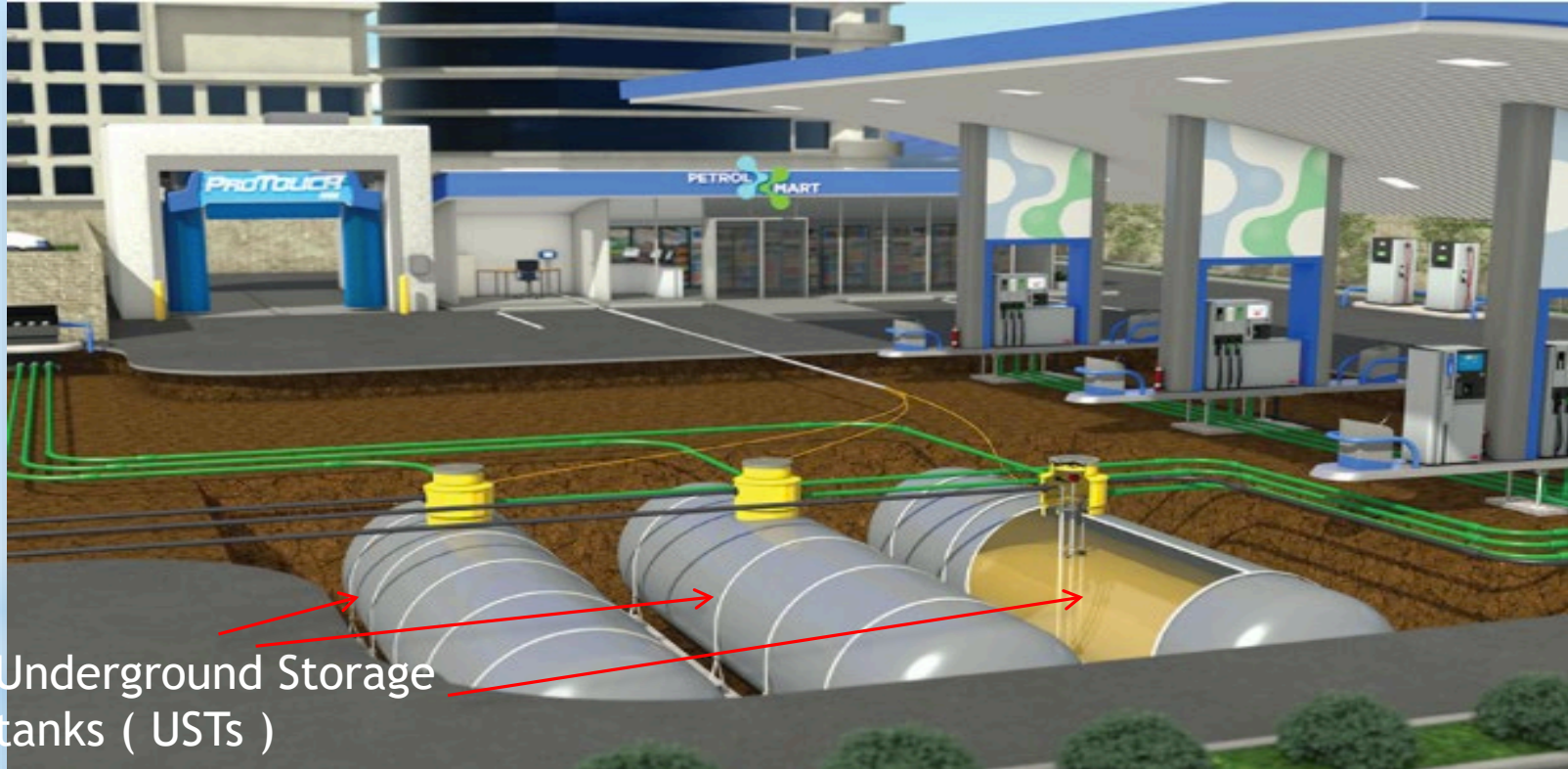
: 744

TOTAL : 4119

*Data Collection : Statistic Department
Occupational Safety & Health: June, 2016*

BACKGROUND 1a

Layout of Underground Storage Tank at Petrol Station.



Underground Storage
tanks (USTs)

Gas Station Illustrations (<https://www.behance.net/gallery/19960557/Gas-Station-Illustrations>)

ACCIDENT AT PETROL STATION



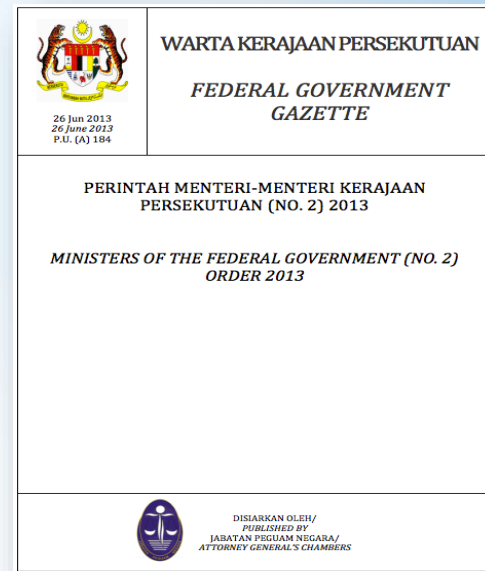
- * Accidents reported in newspaper but not registered to any government body.
- * Government decided DOSH to take charge of **PSM Act. 1984, Jun 26, 2013.**



FEDERAL GOVERNMENT GAZETTE.

P.U (A) 184 (No.2) 2013-and gazette Jun 26, 2013.

(DOSH must adhere and take in charge of **Petroleum Safety Measurement Act 1984** which under jurisdiction and control of Department of Occupational Safety And Health Malaysia (DOSH)



P.U. (A) 184

Nama	Gelaran dan Nama Jawatan	Jabatan	Perkara
		Malaysia	menjalankan kuasa-kuasa di bawah Akta Pendaftaran Jurutera 1967
Dato' Hasan bin Malek	Menteri Perdagangan Dalam Negeri, Koperasi dan Kepenggunaan	Kementerian Perdagangan Dalam Negeri, Koperasi dan Kepenggunaan:	Mengalakkan pembangunan dan mengawal selia aktiviti perdagangan dalam negeri, termasuk transaksi secara perdagangan elektronik dan kepenggunaan
Dato' Paduka Ahmad Bashah bin Md Hanipah	Timbalan Menteri Perdagangan Dalam Negeri, Koperasi dan Kepenggunaan		Mengawal dan memantau harga barang-barang dan caj perkhidmatan, bekalan barang-barang kawalan dalam pasaran dan melarang pencatutan melalui pelesenan dan penguatkuasaan di bawah Akta Kawalan Bekalan 1961 dan Akta Kawalan Harga dan Anti Pencatutan 2011
			Penguatkuasaan subseksyen 6(3) Akta Kemajuan Petroleum 1974
			Menyelaraskan dasar keselamatan petroleum di bawah Akta Petroleum (Langkah-Langkah Keselamatan) 1984

Monitoring with Safety Policy of Petroleum under Petroleum Act.(PSMA 1984)

P.U. (A) 184

Nama	Gelaran dan Nama Jawatan	Jabatan	Perkara
			sekerja
			Menyediakan khidmat nasihat kepada pelanggan berkaitan dengan isu keselamatan sekerja
		Jabatan Tenaga Manusia (JTM)	Mentadbir, mengurus dan menyediakan akses kepada latihan kemahiran mengikut keperluan industri dan pembelajaran sepanjang hayat kepada belia lepasan sekolah dan warga kerja
			Menjalinkan kerjasama dengan industri untuk memastikan beliauan institut latihan memperoleh pekerjaan
			Membangunkan tenaga pengajar pakar melalui program peningkatan kemahiran, persijilan profesional, mengalakkan projek inovasi serta penyertaan dalam pelbagai pertandingan kemahiran dan inovasi
		Jabatan Keselamatan dan Kesihatan Pekerjaan (JKKP)	Mentadbir, melaksanakan dan menguatkuasakan perundangan dan peraturan berkaitan keselamatan dan kesihatan pekerjaan, iaitu:
			Akta Keselamatan dan Kesihatan Pekerjaan 1994
			Akta Kilang dan Jentera 1967
			Akta Petroleum (Langkah-Langkah Keselamatan) 1984
			Menjalankan kajian, penyelidikan, pembangunan dan analisis teknikal ke atas isu-isu keselamatan dan kesihatan pekerjaan di tempat kerja

Petroleum Act.(PSMA 1984)

GUA MUSANG MISHAP



April 4, 2014 - Pool fire due to fuel's overspill caused injury and property damage in Gua Musang (Kelantan, Malaysia)

- 1st reported case - investigated by DOSH, Malaysia.
- DOSH initiated - Safety Audit on Petrol Station in Malaysia.
 - DOSH aims - develop **new guidelines & improve safety in Petrol Station.**

Official Website
DEPARTMENT OF OCCUPATIONAL SAFETY AND HEALTH
Ministry Of Human Resources

SEARCH...

MAIN ABOUT DOSH SERVICES LEGISLATION COMPETENCY CONTACT US ABOUT NCOSH

Main > Statistics > Client Charter Achievement > Media & Resources > Archive > Archive News > 2014 - Archive News

STATISTIC

Occupational Accident Statistics

Client Charter Achievement

National Occupational Accident & Fatality Rate

Online Transaction Statistic

VISITORS COUNTER

11 hurt in blaze at R&R stop

TheStar Online, 3 April 2014

news 03042014 ts1

Fiery incident : The row of stalls near the petrol station being engulfed in flames.

KOTA BARU: Eleven people eating at a popular rest and recreation area near a petrol station suffered burns after fuel being unloaded to the underground container at a petrol station in Gua Musang leaked and caught fire.

The blaze occurred at 10.10pm on Wednesday while people were eating at the popular R&R stop which was adjacent to the station.

It is believed that some of the fuel leaked from the hose during the transfer. The fuel then flowed down an incline from the station, which was located on higher ground, towards the stalls before an explosion occurred seconds later.

Many patrons ran for their lives while some were seriously burnt. Other than the foodstalls, the fire also destroyed four cars and three motorcycles parked nearby.

DOSH, MALAYSIA ACTIVITIES

- ❖ Auditing Safety Operation in petrol stations under Petroleum Safety Measurement Act (PSM) 1984;
- ❖ UST(design approval, safety features and maintenance).
- ❖ Profiling on Petrol Stations(Number of USTs)
- ❖ Auditing manufacturer of UST.
- ❖ Risk engulfing Petrol Station.

*(Soft launch : Petron, Bangi : 9
Sept. 2016)*



* Issues with Petrol Stations

* Ageing Underground Storage Tank (UST) :

1. Integrity,
2. Reliable Safety features,
3. Maintenance,
4. Repair,
5. Safety from fire,
6. Piping failure,
7. Safety of Petrol Station.



* Issues with UST

Double Layer Underground Storage Tanks (USTs)	Single Layer Underground Storage Tanks (USTs)
5304 Tanks	2100 Tanks (1050@50% > 15 yrs)

(Data Collection : Statistic Department Occupational Safety & Health: June, 2016)

1. UST :

- Integrity especially more than 15 years.(USEPA 2010; New York State's Department of Environment Conservation and Public Record of UST Release (2015), UL 58, UL 1746),
 - * *buried underground.*
 - * *limited space of inspection.* (Manhole access)
 - * **cost of maintenance is too high.**
 - * **need competent person to do the maintenance.**
 - * **safety features act as accessories.**
 - * **leakage problems.**



* DEFINATION of LEAKAGE:

OXFORD Living Dictionaries means:

The accidental admission or escape of liquid or gas through a hole or crack. <https://en.oxforddictionaries.com/definition/leakage>

- * Factors of leakage could be occurred ;
- * a. Substandard product.
- * b. Substandard weldment (processing).
- * c. Poor coating.
- * e. Internal and external corrosion.
- * f. NO proper safety features in placed.



PROBLEM STATEMENT

Greater number of ageing of single layer wall of underground storage tank (> 15 years) which integrity have not been proven, no specific practice in countermeasure the outcome of disaster. Even, emerging risk of fire rarely been quantify which could pose the imminent effect of fire to the vicinity of petrol station will be massive to workers and passers by.



RESEARCH OBJECTIVES(ROs) & RESEARCH QUESTIONS(RQs)

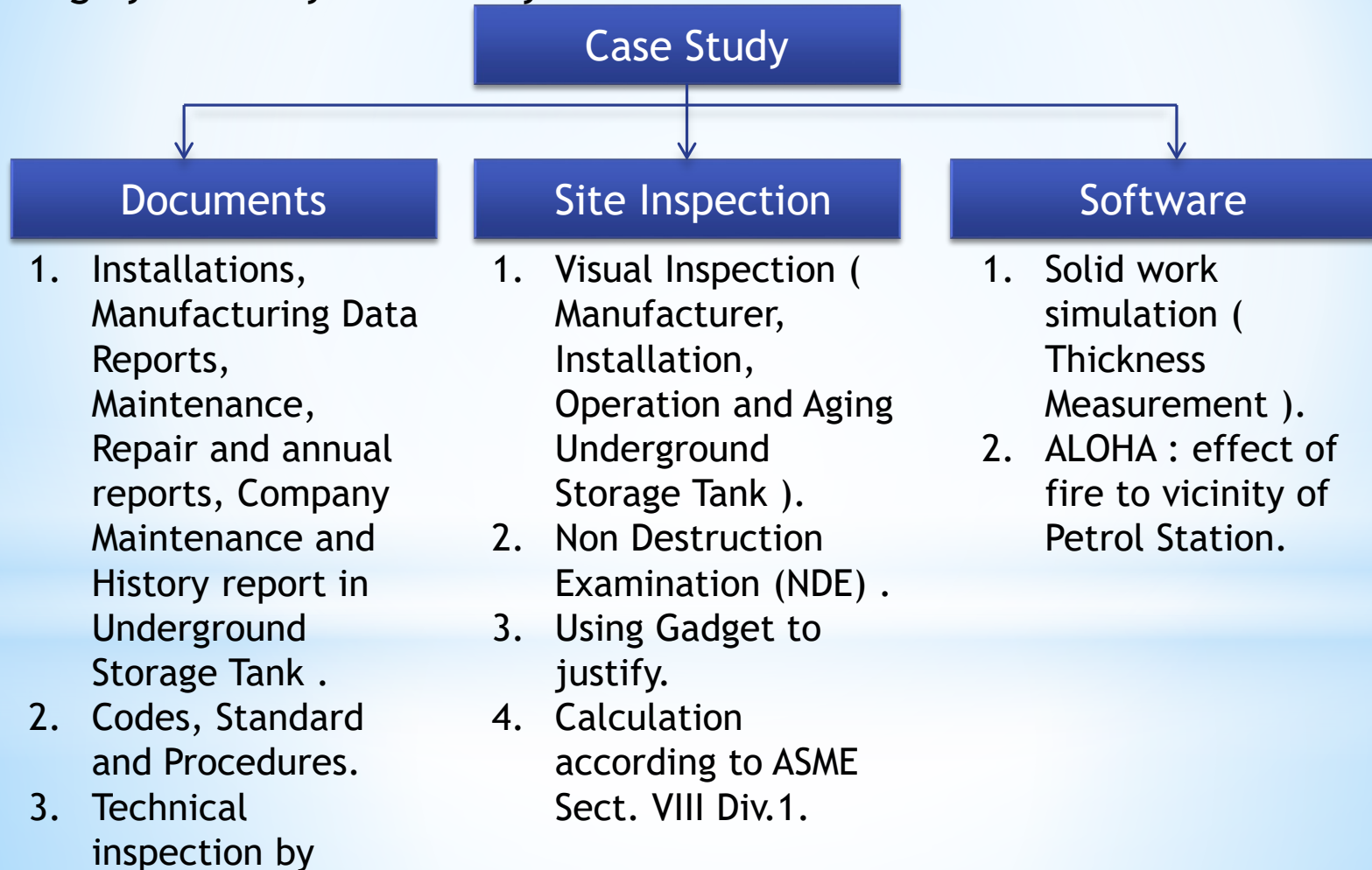
Num.	Research Objectives (ROs)	Research Questions (RQs)
1	To investigate and detecting of approaches in justifying integrity of ageing underground storage tank (15 years) which could posed fire.	How to investigate and detecting of approaches in justify integrity of ageing underground storage tank ?
2	To seek the best practices in justifying the possibility of loss integrity of ageing underground storage tank (15 years).	What & How is the best practices or methods in justifying the possibility of loss integrity of ageing underground storage tank?
3	To provide estimation(notification of risk) on the severity and effect of USTs of fire hazards on the vicinity of petrol station.	How to estimate and do notification of risk of fire on severity and effect of UST to vicinity of petrol station?



The main culprit - Fire (Lethal substances in petrol station are Ron 95, Ron 97 and Diesel)

RESEARCH METHODOLOGY

Applied Research : Aims at a finding solution for an immediate problem facing by a society or industry.



RQ1: To investigate and detecting of approaches in justifying integrity of ageing underground storage tank (UST)(15 years).

How to do investigate and detecting ? :

1. Site Visit:

- Document and technical design reviewing, investigation, measuring, detecting and analysis.
- Justify Visual Inspection and Structural Health Monitoring (SHM) by using Non Destructive Examination (NDE) approach.
- thickness measurement on actual thickness of ageing UST.



API, 2000 - API publication 581 Risk Based Inspection, base resource document

Khalid *et al.*, 2015 - Risk Based Assessment (RBA) Of Underground Storage Tank At Petrol Station

Panos *et al.*, 2015 - new generation based Inspection Methodology & Software for the Process Industry.

FEM, Fault Tree, HAZOP, HAZAN

Fit For Service (API 579)

Safe TREND, RISKWISE, Phast DNV

RQ2. To seek the best practice in justifying the possibility of loss integrity of ageing underground storage tank (UST : > 15 years).

What are the best practices?:

1. Adopt **Structural Health Monitoring (SHM)**: NDE approach by using Ultra Sonic Thickness Gauge (UTTG) Model Olympus 26 MG & 27 MG.
2. UST (specifically single layer > 15 years).
 - thickness measurement on actual(Excel-ASME Sect. VIII Div.1) ,solid work (RBI process adopting API 581).
3. Codes/Standards/regulation
 - API 576, API 580, 581, OSHA 1994, PMSA 1994, ILO, OSHSAS 199 ATEX (UK), ASME Sect. VIII DIV I, NPFA 30, ISO 3100

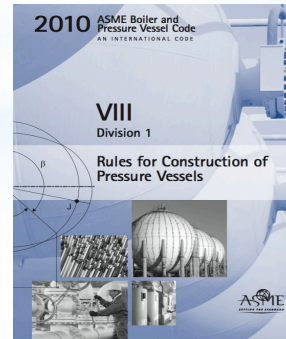
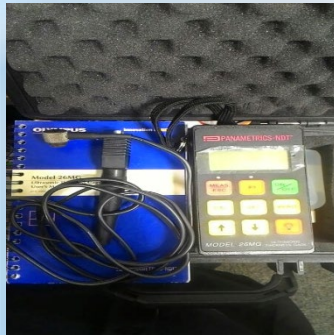
Montgomery, 1979 - Introduce a statistical control in damages of structure

Doebly *et al.*, 1996 & Sohn *et al.*, 2003 & Randhall, 2004 - NDE: Acoustic Techniques

Bentley & Hatch, 2003 - Condition Monitoring

Farar *et al.*, 2003 - Damages Prognosis Identify the damages system

Visual Inspection
Destructive Examination (NE)
Non Destructive Examination (NDE)

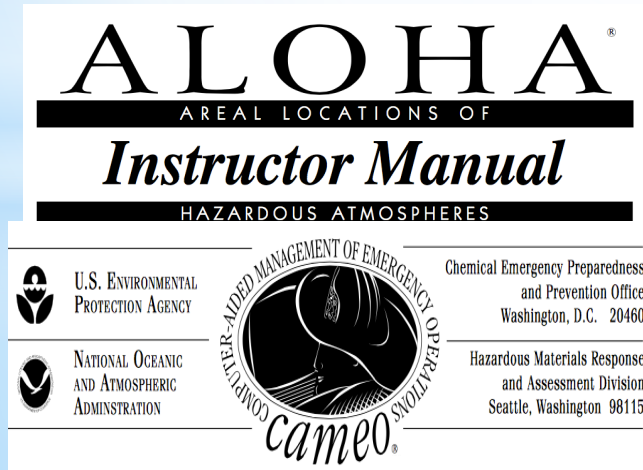


RQ3. To provide estimation (notification risk) on the severity and effect of USTs of fire hazards on the vicinity of petrol station.

How to do estimation? :

ALOHA simulation apply Loss of Containment Model;

- 1.. Parameters in the ALOHA software
2. Substance either 95 or 97.
3. Risk of fire (type of fire): outage of substance.
4. Consequences to surrounding.
5. Severity effect engulfing PS.



Papazoglu, 1992 - QRA Model -5 Steps

Zhang *et al.*, 2014 - Bayesian Network Based

Khakhad *et al.*, 2012 - Bow Tie

Guideline Safe Work Australia(SWA)

Identify risk, Analysis risk, Evaluate Risk, Control risk

Simplify using **Analysis Risk-Consequences Analysis(CA)**

Loss of Containment(LOC) :

Procedure for non-major hazard installation.

(1-LOC,2-Substance Classification,3-Quantity Release,

4-Operation Mode,5-Release Site,6-Incident cause,

7-Mitigation)

Collins & Keeley, 2003. Loss of containment(LOC) incident analysis, HSL report,HSL/2003/07

What methods required to do this research?

METHODs @ APPROACHS

Underground Storage Tank (UST)



Risk Based Inspection(RBI)

API, 2000 - API publication 581 Risk Based Inspection, base resource document.

Khalid *et al.*, 2015 - Risk Based Assessment (RBA) Of Underground Storage Tank At Petrol Station.

Panos *et al.*, 2015 - new generation based Inspection Methodology & Software for the Process Industry.

FEM, Fault Tree, HAZOP, HAZAN, Fit For Service (API 579), Safe TREND, 21 RISKWISE, Phast DNV

Structural Health Monitoring (SHM-UTTg)

Montgomery, 1979 - Introduce a statistical control in damages of structure

Doebly *et al.*, 1996 & Sohn *et al.*, 2003 & Randhall, 2004 - NDE: Acoustic Techniques

Bentley & Hatch, 2003 - Condition Monitoring

Farar *et al.*, 2003 - Damages Prognosis
Identify the damages system

Visual Inspection, Destructive Examination (NE), Non Destructive Examination (NDE)

Quantitative Risk Assessment (QRA-ALOHA)

Papazoglu, 1992 - QRA Model -5 Steps

Zhang *et al.*, 2014 - Bayesian Network Based

Khakhad *et al.*, 2012 - Bow Tie

Guideline Safe Work Australia(SWA)

Identify risk, Analysis risk, Evaluate Risk, Control risk

Simplify using Analysis Risk-Consequences Analysis(CA)

Loss of Containment(LOC) :

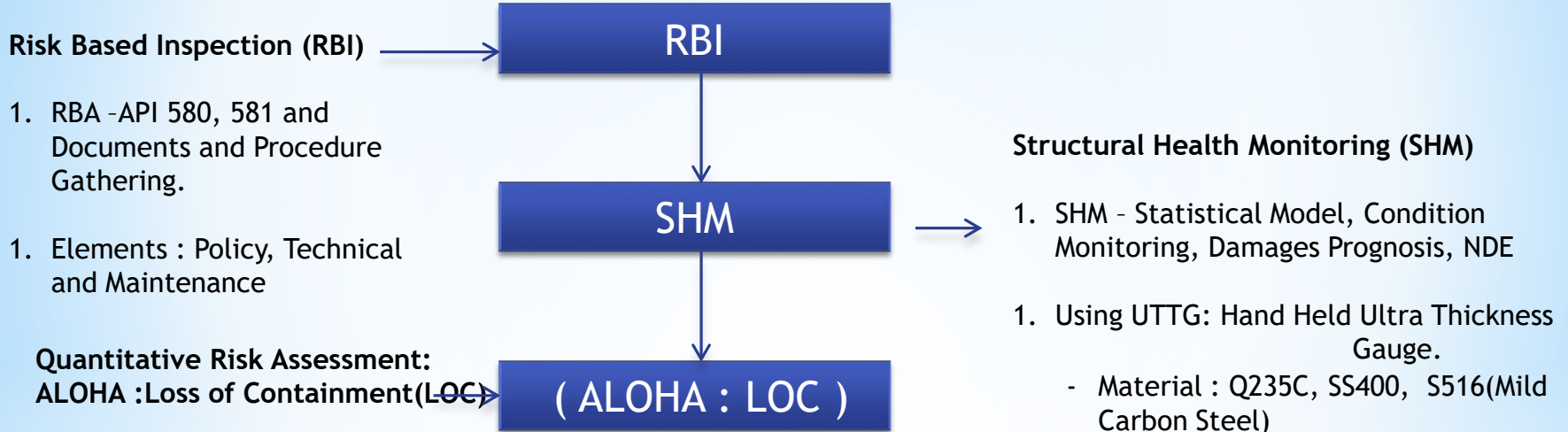
Procedure for non-major hazard installation.

(1-LOC,2-Substance Classification,3-Quantity Release, 4-Operation Mode,5-Release Site,6-Incident cause, 7-Mitigation)

Collins & Keeley, 2003. Loss of containment(LOC) incident analysis, HSL report,HSL/2003/07

Fire
(Disaster)

THE NEW PROCESS of COMBINATION RBI + SHM + LOC



Risk Based Inspection (RBI)

1. RBA -API 580, 581 and Documents and Procedure Gathering.

1. Elements : Policy, Technical and Maintenance

Quantitative Risk Assessment:

ALOHA :Loss of Containment(LOC)

1. Substance Classification
2. Quantity Release
3. Operation Mode
4. Release Rate
5. Incident Cause
6. Mitigation

Structural Health Monitoring (SHM)

1. SHM - Statistical Model, Condition Monitoring, Damages Prognosis, NDE
1. Using UTTG: Hand Held Ultra Thickness Gauge.
 - Material : Q235C, SS400, S516(Mild Carbon Steel)
 - Life-cycle- 15 years.
 - Corrosion factor (Internal and External).



**A sample of UST > 15 years
need to be measure,
process and research**

RQ1. 1nd Stage Approach : NDE : Visual Inspections and Analysis (UTTG)



a. Site Inspection



(1b) Cleaning Process



(2b) Cleaning Process



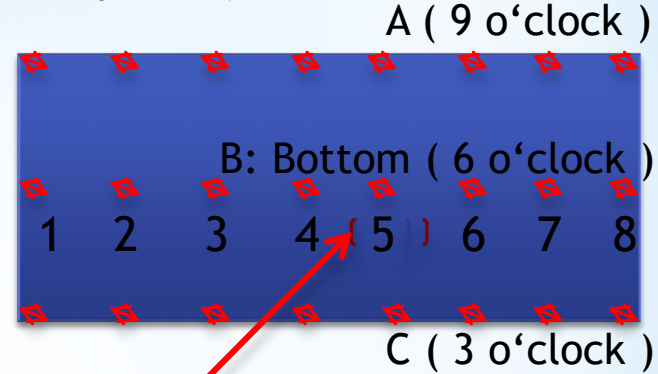
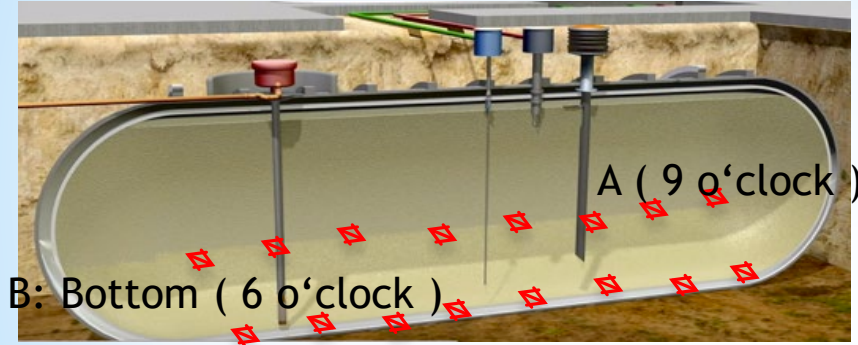
d. Leakage Occurred



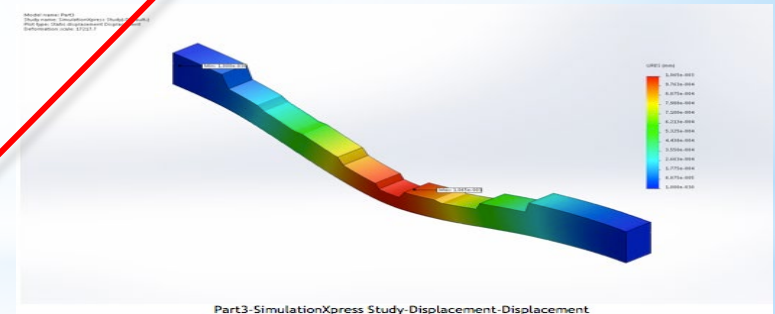
c. Internal Measurements

RQ 1 & RQ 2. 2st Stage Approach : Non Destruction Examination(NDE) and Analysis

* Sample : Inspection on old UST 18 years (> 15 years)-UTTG



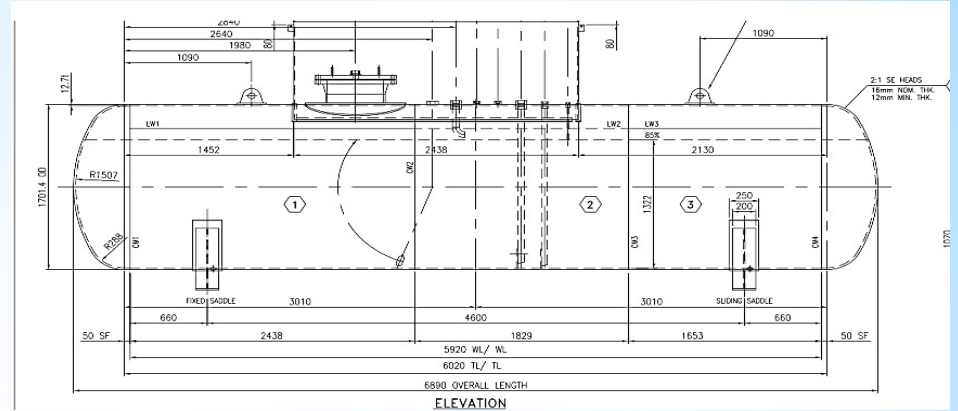
Thickness Data (on site (B))		
Location	Thickness Reading t (mm)	
1	10.20 +10.50+10.80/3	10.50
2	9.81+9.76+9.56/3	9.76
3	10.30+10.45+10.76/3	10.50
4	8.76+8.55+8.56/3	8.62
(5)	6.14+6.18+6.15/3	6.16
6	9.20+9.21+9.20/3	9.20
7	8.70+8.50+8.53/3	8.57
8	11.21+11.20+11.23/3	11.21



Location (5) : **6.15 mm**
 Localization and Corrosion occurred and possibility of Outage.

RQ 2. 3rd Stage Approach: Design UST and Data Analysis.

- * Design Drawing (Technical Data).
- * American Standard of Manufacturing for Engineers (ASME Sect. VIII Div. 1).
 - Underground Storage Tank (UST)
- * Formula
- * Design Technical Drawing :
- * **1.725 Mpa for 12.70 mm nom thickness suggested by manufacturer.**



- * Calculation thickness by Using Excel:
- * (UG-27), Shell Thickness : $P \cdot R / (SE - 0.6P) + C$

Circumferential Stress : $t : 13.00 \text{ mm}$

Longitudinal Stress : $t : 6.42 \text{ mm}$

(Thickness range from 6.42 - 13.00 mm)

	A	B	C	D	E	F	G	H
1	Reference Drawing No :	DM/ND/P009						
2	Equipment Name :	Underground Storage Tank(UST)						
3	Part Name :	SHELL						
4	Part No :	T						
5								
6		Shell Thickness						
7								
8	Material SA-516 Gr70							
9	Allowable stress at 120 °F,	S	=	16600	psi			
10	External Pressure Chart No. Fig. CS-2 of Section II part D							
11								
12	UG-27. Shell under internal pressure							
13								
14	Design Pressure	P	=	250.20	psi	=	1.73	
15	Allowable Stress	S	=	16600.00	psi	=	114.45	
16	Joint Efficiency of Shell	E_{shell}	=	1.00				
17	Inside Diameter	D	=	1710.00	mm	=	67.323	
18	Corroction Allowance	C	=	0.00	mm	=	0.000	
19								
20	Shell Thickness							
21	Minimum thickness							
22								
23								
24								
25								
26								
27								
28								
29								
30								
31	Required thiccknes	$t_{required}$	=	$P \cdot R / (SE - 0.6P)$			$E = 1.00$	
32			=	13.00	mm			
33			=	0.512	in			
34								
35	Required min. thickness of head		=	13.004	mm	=	0.512	
36	Proposed nominal thickness of head		=	8.000	mm	=	0.315	

- * Actual thickness 18 years old Tank : 6.16 mm
- * Design Technical Calculation thickness : 6.42 mm
- * Therefore thickness of UST might rupture and caused outage of substance to surrounding. (Fire Disaster)

RQ 3. Risk Based Inspection (RBI Technology :API 581) and Analysis

Probability of Failure(POF)=Pf(t)

Process of Probability of Failure (POF)
(Guidelines for Assigning Inspection Effectiveness)

1. General Thinning.
2. Buried Component.
3. Tank Shell Course Internal Corrosion.

RISK BASED INSPECTION(RBI)

$$R(t) = Pf(t) \cdot FC(t)$$

$Pf(t)$ - Probability of failure

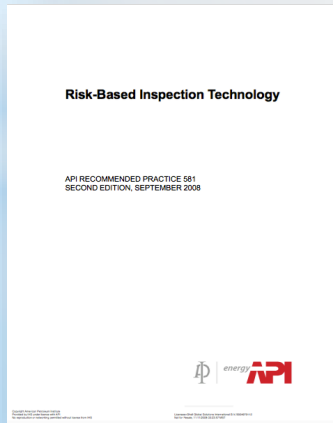
$FC(t)$ - Financial Consequences



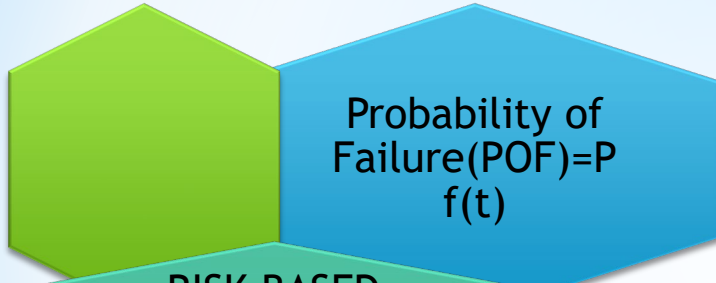
Financial Consequences(FC)=FC(t)

Process of FC (Financial Cost).

1. Production Loss.
2. Equipment + Installation.
3. Potential damage to other equipment.
4. Potential Environment clean up.
5. Staff fatality/injury.



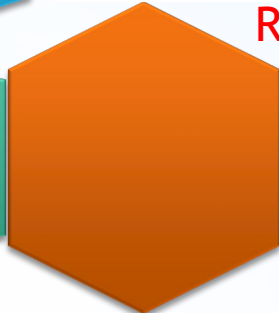
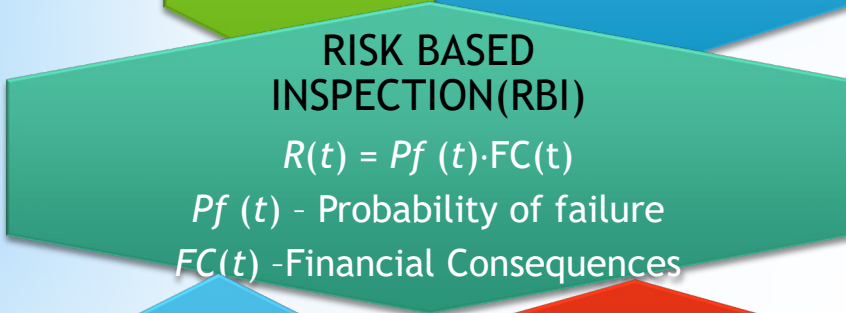
RQ3. Risk Based Inspection (RBI Technology :API 581) and Analysis



STEP 8 – Determine the damage factor for thinning, D_f^{thin} , using Equation (2.15).

$$D_f^{thin} = \frac{D_{FB}^{thin} \cdot F_{IP} \cdot F_{DL} \cdot F_{WD} \cdot F_{AM} \cdot F_{SM}}{F_{CM}}$$

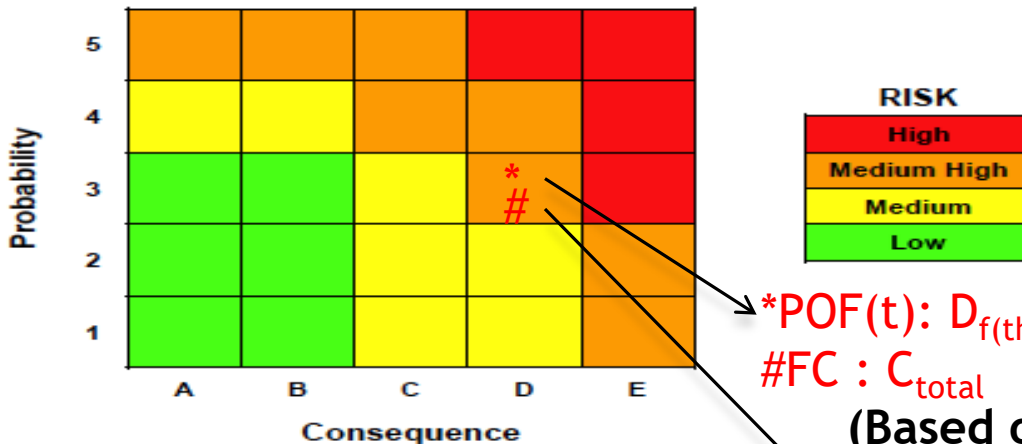
Result =POF(t): $D_{f(thinning)} : \underline{67.5}$



$$C_{total} = C_{prod. Loss} + C_{equip} + C_{main} + C_{damage} + C_{env} + C_{pers.inj}$$

Result = FC(t): $C_{total} : \underline{RM 1.2 mil.}$

RQ3. Risk Based Inspection (RBI Technology :API 581) and Analysis



*POF(t): $D_{f(thinning)}$: Category 3 = 67.5
 #FC : C_{total} : Category D = USD 1.2 mil.
 (Based on Table 4.2: API RBI 581)

DAMAGES OF OLD UST : **3D**

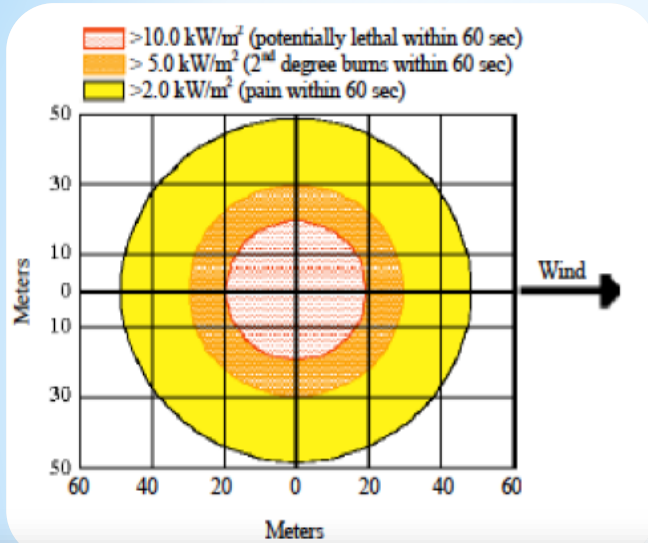
Table 4.2 – Numerical Values Associated with Probability and Financial-Based Consequence Categories in API RBI

Probability Category (1)		Consequence Category (2)	
Category	Range	Category	Range (\$)
1	$D_{f-total} \leq 2$	A	$FC \leq 10,000$
2	$2 < D_{f-total} \leq 20$	B	$10,000 < FC \leq 100,000$
3	$20 < D_{f-total} \leq 100$	C	$100,000 < FC \leq 1,000,000$
4	$100 < D_{f-total} \leq 1000$	D	$1,000,000 < FC \leq 10,000,000$
5	$100 < D_{f-total} \leq 1000$	E	$FC > 10,000,000$

Notes:

1. In terms of the total damage factor, see, Part 2, paragraph 4.4.2.
2. In terms of financial consequence, see Part 3, paragraph 5.12.

ALOHA SIMULATION: POTENTIAL FIRE HAZARD DUE TO LEAKAGE



- Red demarcation is critical area (0 - 20 m)



X (m)	Er (kW / m2)	% Death	Probability of Incident / yr
10	40.2	92%	4.20E-05
20	29.93	66%	
40	15.2	3%	



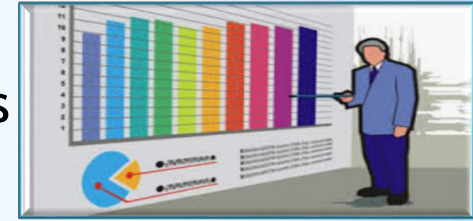
Just beside the PS. (Grocery and houses)



Less than 5km away from PS.(Houses and Indian's Temple)

CONCLUSION

- * The possibility of an early detections of any leakages on USTs (> 15 years).
- * To seek the best practices in justifying the possibility of loss integrity of ageing underground storage tank (15 years).
- * The estimation on the severity and effect of USTs of fire hazards (vicinity).
- * Provide a code of practice to oil companies and local authorities in determining the safe boundary of petrol station.



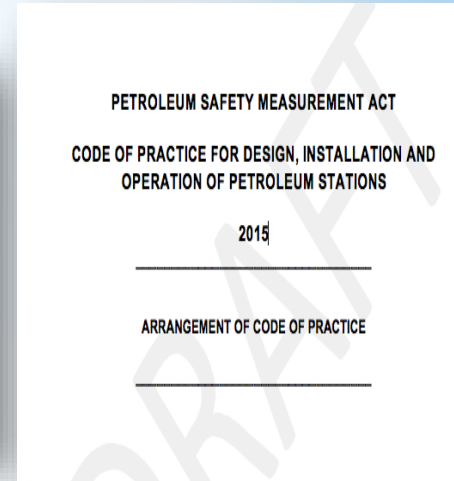
PETROLEUM SAFETY MEASUREMENT ACT
CODE OF PRACTICE FOR DESIGN, INSTALLATION AND
OPERATION OF PETROLEUM STATIONS

2015

ARRANGEMENT OF CODE OF PRACTICE



RESEARCH CONTRIBUTIONS:

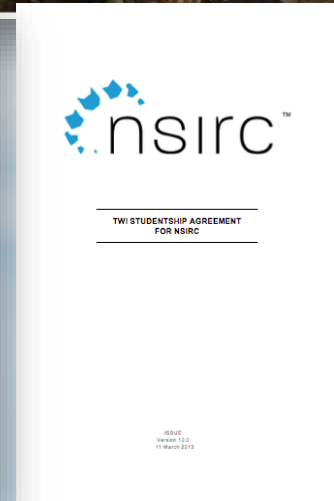


- a. Introduce a combination of **Risk Based Inspection (RBI: API 581)**, **Structural Health Monitoring (SHM: NDE + UTG)** and **Loss of Containment (LOC)**.
- b. **An alternative tool** in prediction the risk of fire in underground storage tank in Petrol Station.
- c. **Vital Element of Risk** in drafting Malaysia's code of practice: **Safety in Petrol Station**

* Attachment at **Technical Welding Institute (TWI) Ltd, Abington, Cambridge, United Kingdom(UK).**6 months: RISKWISE,API 580, API 581, API 570 and AE, GW, LRUTG & AE.

* **Code of Practice : Petrol Station Safety. (2012 -201X)(Public Comment- Sept.2018)**

- Presented 2 paper at **ICIM 2016:** Yamaguchi University & **ICIM 2018:** Shimonoseki Hotel-Yamaguchi, Japan respectively.
- **Sharing outcome PhD's research at IEM,P.J (July 2018).**



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Gua Musang Unexpected and Rarely Inferno Incident: A Case Study

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Abstract: This study is to investigate a rare case of incident which caused a pool fire accident at petrol station involving human life, property and environment. A pool fire is one of the emerging source of risk which tremendously could do harm to human. The incident caused eleven victims which nearly 60% burn and property damage. Justification of the incident has been carried out by using a software known as Area Locations of Hazardous Atmospheres (ALPHA 5.4.2) to compute from significant datas to quantify the risk and magnitude of the pool fire probability effect not just onset but offset of the vicinity which engulfing the Petrol Station (PS). The inputs including data of meteorology, chemical material of data sheet, geographical site, source data and threat zone. Investigators gathered all the information by monitored, visited, interviewed and investigated the effected site which is a petrol station, province of Gua Musang, Malaysia. Result from the software and investigation will give a crystal and vivid anecdote of the magnitude of effected scenario to human, property and environment. Furthermore, it also generated a good respond in formulate the best solution of mitigation to regards any risk emerging at petrol station and its vicinity.

Key words: Petrol station, onset and offset, pool fire, risk, mitigation

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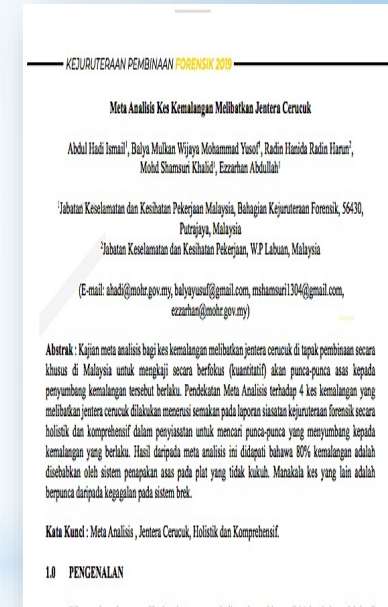
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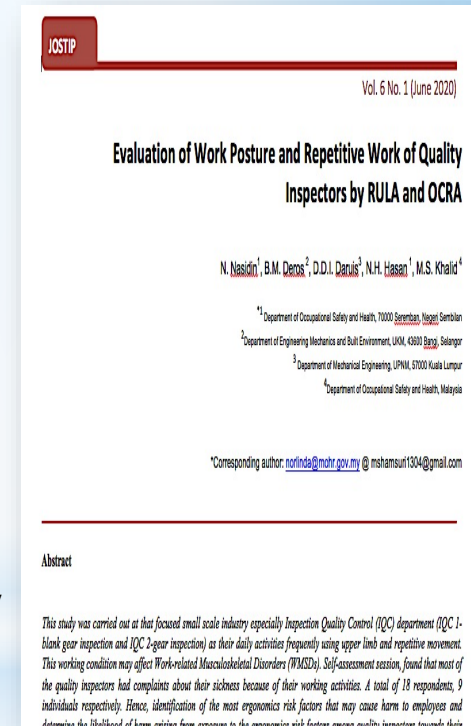
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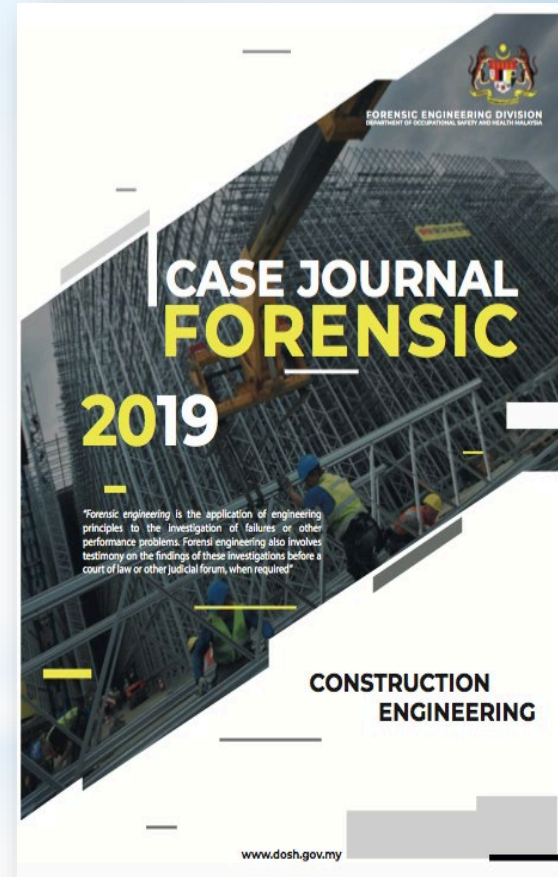
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22 JOURNALS
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Thank you. Q & A.



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