講 演
 Lecture

Development of PAG and TSB Offshore Gas Fields – The Importance of HSE along the Project Life –*

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Abstract : In oil and gas project development, almost all HSE risks can be mitigated to lower level by implementing safer design and engineered safety such as appropriate selection of technology, applying robust layer of safety protection system. However residual risks in Operation phase shall be managed properly having the facts that the actual risk increases once hydrocarbon is introduced. In the JAPT symposium, KEI shared their experience on how to manage HSE for the development of PAG and TSB Fields in Kangean block offshore north of Bali, Indonesia from initial phase of project until the Operation phase.

Keywords : HSE management system, risk assessment, risk level, process safety management / asset integrity, HSE process / plan, project phase, layer of safety protection system, latent hazard, recommended practices, lesson learned

1. Introduction

1.1 KEI

Kangean Energy Indonesia Limited (KEI) is established in 2007 with Shareholders Energi Mega Persada (EMP) 50%, Mitsubishi Corp. 25%, and JAPEX 25%. KEI is one of the PSC (Production Sharing Contractor) of Government of Indonesia which operates Kangean working area approximately 4500 km² at 120 Nautical Miles offshore north of Bali Island. The field initially discovered and developed by ARCO in late 1980's and first gas and condensate commercial production from Pagerungan (PAG) field commenced in 1994. BP became the Kangean block operator in 2000 – 2004 then EMP Kangean took over from BP in 2004 – 2007. In May 2012 Terang, Sirason and Batur (TSB) field commenced its natural gas production. All gas from PAG and TSB fields is transported via 370 km subsea East Java Gas Pipeline (EJGP) to all gas customers in east Java.

Kangean Block Map including EGJP pipe route can be seen on Fig.1 while Fig.2 and Fig.3 show the production facilities at

Fig.1 Kangean Block Map

Fig.2 Floating Production Unit (FPU) Joko Tole

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Fig.3 Pagerungan Gas Processing Facilities (PAG)

PAG and TSB field.

In 2014 total KEI gas production was at average 268 MMSCFD and it put KEI as one of the top 7 gas producers in Indonesia.

KEI has excellent safety record as of end 2014; cumulative safe manhours achieved 30.3 millions without lost time accident. KEI received award of Journey to Zero Incident 2014 from SKK Migas (Government of Indonesia's regulator for upstream business in Indonesia) .

Fig.4 Risk level reduction vs Project life cycle

1.2 HSE Concept

The importance of managing Health, Safety and Environment (HSE) over the project life from initial study/appraisal until operation phase is well understood in industries. Unfortunately catastrophic accident continues to happen in oil and gas facilities around the world which involves fire and explosion, multiple fatalities and in some cases affecting Company's reputation and existence in the business. All these happened in all continents, in all cultural background, in both upstream and downstream industry, both onshore and offshore, in both small and big company. All deals with release of hazardous / hydrocarbon material.

Risk manageability during project life cycle shows effectiveness of risk reduction in every phase of the project as illustrated at Fig.4.

Eventhough normally the risk level has been mitigated to lower level when the project entering the Operation phase, organization should not underestimate the residual risk level, some potential defects or weaknesses in design and Engineering, Procurement, Construction and Installation (EPCI) carry over to this stage. Statistically most of the major accidents happen in operation phase. This is also because once hydrocarbon is introduced into the facility, the

Fig.5 Risk Level increases in Operation phase

Fig.6 Swiss cheese Model

Source : Process Safety Management Training Manual, LebSolution,2012

actual risk level is increased significantly as illustrated in Fig.5.

Swiss cheese model introduced by James Reason (1990) as shown on Fig.6, basically illustrates accident causation as a series of events which must occur in a specific order & manner for an accident to occur, which it compares to the holes of some unique pieces of Swiss cheese lining up.

Hazards are contained by multiple protective barriers but barriers may have weaknesses or “holes”. When holes align hazard energy or chemical hydrocarbon is released, resulting in the potential for harm. Holes can be latent or unforeseen / unattended, or actively opened by people. Protective barriers and mitigation barriers maybe physical engineered containment or behavioral controls dependent on people which are normally designed and constructed in every phases of the project for example; material and equipment selection and installation, alarm and trip system, emergency shut down system, fire extinguisher system, secondary containment, operating and maintenance procedure, refuge and evacuation procedure.

2. KEI HSE management system and recommended practices implementation

Some key HSE processes and recommended practices which have been playing important role to achieve better HSE performance in PAG and TSB project development in KEI Ltd.

2.1 HSE Plan along the Project Life

HSE Process Matrix as implementation of HSE Plan along the Project Life can be seen on Table 1.

2.2 Process Safety Management (PSM)

Organization shall manage both Personal Safety and Process Safety with the same priority as illustrated by Fig.7.

Process safety itself is defined as a disciplined framework for managing the integrity of hazardous operating systems and processes by applying good design principles, engineering and operating practices. In simple word keep hydrocarbon in the pipe.

Fig.7 Personal Safety vs Process Safety

Source : http://www.woodgroup-psn.com/ThePulse/issue_033/pulse_issue_33_1h.html, Cited 05 Oct 2015)

KEI PSM Element :

- Commitment
- Pre-Start up Safety Review
- Employee Participation
- Mechanical Integrity
- Process Safety Information
- Hot Work Permit
- Process Hazard Analysis
- Management of Change
- Operating Procedures
- Accident Investigation
- Training and Competency
- Emergency Planning & Response
- Contractors
- Compliance Audit
- Purchasing

In KEI PSM manual there are key principles and requirements of each element that Company has to fulfill for PSM implementation.

2.3 Contractor Safety Management System (CSMS)

CSMS guidelines is a HSE management tool for managing contractors who will work in Company workplace, ensure the contractor's HSE awareness and capabilities are met with Company HSE requirement and standard. Structure and procedure are consisting of 2 phases and 3 steps each as shown on Table 2.

2.4 Permit to Work (PTW)

Permit to Work (PTW) or Safe System of Work (SSoW) consists of 5 elements to reduce work related risks impacted by the work being carried out:

- Plan the work
- Tasks Risks Assessment
- Control the work
- Stop unsafe works
- Learning for Improvement / audit

2.5 Job Safety Analysis (JSA)

The JSA is a detail study of each step in work procedures for new jobs, every change of work procedures and every change of job system that shall determine:

- Work step and Safety measures & prevention
- Potential hazard and hazard effect
- Responsible person
- Equipments, tools and machines
- Final assessment of residual risk

Sample of JSA is shown on Fig.8.

2.6 STOP Card

Safe Behavior Improvement by implementing Safety Training Observation Program (STOP). The aim of STOP is to identify unsafe acts and sub-standard conditions before

Table 2 CSMS Implementation

Qualification Phase	Field Implementation Phase
Risk Assessment	Pre Job Activity
Pre Qualification	Work in Progress
Selection	Final Evaluation

Table 1 Project HSE Process Matrix

No	Project HSE Plan	Appraisal	Select/Define	FEED	EPCI	Operation
A	HSE Management System					
	• Philosophy & Standard					
	• New Technology					
	• HSE Lesson Learned / Lifecycle issue					
	• Contract Strategy					
	• O&M* Philosophy & Manual					
	• Operation Recruitment/Training Strategy					
B	Safety					
	1. HSE Legislation & Permit					
	National Legislation					
	International Standard					
	Safety Case					
	2. Safer Design					
	Inherent Safety Principle					
	Risk Management (HAZID/HAZOP/SIL/QRA**)					
	Control of Work (Safe System of Work)					
	Simultaneous Operation					
	Management of Change					
	3. Construction /Commissioning					
	Constructability HSE Review					
	Construction HSE Plan					
	Commissioning HSE Plan					
	4. Emergency Preparedness & Crisis Management					
C	Environment					
	1. Permit and Consent Plan:					
	Environmental Impact Analysis Study					
	2. Environmental Management & Monitoring Plan					
	Energy Management & Emission Control					
	Waste Management					
	Emergency Preparedness (Spill)					
	Environmental Audit					
	Reinstatement/Abandonment Plan					
	3. Environmental Reporting					
D	Review and Audits					
	1. Project HSE Review					
	2. HSE Peer Review					
	3. Pre Start Up Review					

* O&M : Operation & Maintenance

** HAZID : Hazard Identification
 HAZOP : Hazard and Operability
 SIL : Safety Integrity Level
 QRA : Quantitative Risk Assessment

JOB SAFETY ANALYSIS

Kangean Energy Indonesia

Job Title : Piping Vibration Study
 Leader : Iman Esajito
 Crew List : Fadely Paddiyatu, Dwi Cahya

Date : December 12, 2003
 Location : All of VLP Compressor
 C-1501/1502/1503/1504

No.	Work Steps	Hazards Identified	Hazards Effect	Risk Factor			Safety Measures & Prevention	Residual Risk Factor		
				P	HE	RF		P	HE	RF
1	Work Site Preparation	Slipped	Sprained, Bruised	L	M	M4	<ul style="list-style-type: none"> - Be ensure working area clear from slippery dangers and some objects that gummed up the works, - Working carefully, focused, and do not work hastily. - Hold Toolbox Meeting before doing the activity. 	L	L	L2
2	Data acquisition and bump test	Gas	Fire/Explosion	M	H	M8	<ul style="list-style-type: none"> - Use gas detector - Standby fire watch - Standby small fire extinguisher. 	L	L	L2

Prepared by:

Reviewed by:

Approved by:

Iman esajito

Alim Subagyo 12/12/2003

Darmawan Widiyatmoko

Fig.8 Sample of Job Safety Analysis (JSA)

injuries actually arise. It develops employee's observation and communication skill to allow personnel to take positive steps to ensure a safer workplace.

2.7 Linking safety performance to individual performance

In employee yearly performance appraisal, individual safety awareness and achievement are measured and will reflect to overall individual's performance appraisal rating. Negligence against safety procedure may lead to a disciplinary action.

2.8 SRA for excellence safety performance

To maintain and continuously improve workforce's safety awareness, a spot recognition award (SRA) is given to individuals who contribute more in promoting safety culture such as the best STOP card, good idea to improve HSE, etc.

2.9 Regular plant inspection and management visit

Leadership present at site to show their commitment to HSE is very important. KEI has been performing this activity as part of regular safety audit with a clear guideline and procedure.

2.10 Fire drill and emergency response

Regular exercise to make sure readiness of emergency response team, equipment and effectiveness of procedure and communication in the event of emergency must be conducted regularly. PAG operation carried out emergency drill at least once a month with safety case scenarios having been developed and agreed in one year ahead, whilst TSB Operation performed emergency drill 4 times / months.

3. Lesson learned from incident

3.1 Pipe Burst at Inlet Line to Gas Processing Plant Train-1 at PAG

Real case high potential incident happened at PAG Gas Processing Plant on September 21, 2005 at 12:22 pm whereby a big bang noise occurred and operator saw a gas cloud.

Fig.9 Outside View of Leakage Point **Fig.10** Inside View of Leakage Point

Fig.11 Pagerungan Plant Simplified Flow Diagram

The Plant was immediately shutdown and depressurized from approx. 1,000 psig to 0 psig through flare line. After being observed it was found that 14 inch pipe elbow burst (approximately 1 inch $\times$ 3 inch) at 7 (seven) o'clock position. The appearance of the leakage point can be seen on Fig.9 and it's located just at upstream of Inlet Cooler E-1000 as shown on Fig.11.

The most likely immediate cause of failure is defective material on elbow of 14 inch-PG-5010-ME-1.

3.1.1 Possible System/Root Cause

Inadequate design criteria :

- Miscalculation of fluid composition from discharge of

High Pressure (HP) Compressor.

- Reducer (16 inch $\times$ 14 inch) directly connected to elbow causing increase fluid velocity that creates turbulence and abrasive effect as indicated on inner part of the elbow shown on Fig.10.

Inadequate inspection due to misjudgment of pipe spool and it was not included in criticality 1 pipe inspection

3.1.2 Lesson Learned

- Review criticality class of all piping system based on current fluid flow service and operating condition, and perform pipe wall thickness inspection in regular basis.
- It showed that the design defect became latent hazard in

Table 3 List of Over spans

Description	Start KP (km)	End KP (km)	Length (m)	Height (m)
Flowline #1 – 20 inch	0.896	0.938	43	0.200
Flowline #2 – 20 inch	0.951	0.995	44	0.357
	1.042	1.093	51	0.342
	1.233	1.276	43	0.222
Export Pipeline – 18 inch	0.792	0.839	47	0.233
	1.072	1.120	48	0.800
	2.379	2.415	36	0.323
	3.220	3.256	36	0.103
	8.740	8.780	40	0.800

KP : Kilometer – Post

Table 4 Project Design criteria (based on DNV-rp-f105. Fatfree ver.10.3)

No	Pipeline	Allowable free span length (m)	Fatigue Life (years)
			> 20 years
1	Flowline 20 inch	43.0	22.3
2	Export Pipeline 18 inch	35.6	34.6

operation after few years in operation.

- Good point: No ignition source in the process area, proving the effectiveness of Hazardous Area classification and management.

3.2 Free Span of TSB Flow lines

The pipe free span is one of the big risk of subsea pipeline, especially when the span is beyond allowable limit which may lead to pipe break apart. Free span illustration can be seen on Fig. 12.

Findings based on subsea inspection Dec. 2013 are listed on Table 3. Unfortunately referring to project design criteria for 20 inch flow line and 18 inch export line as shown on

Fig.12 A Pipeline Spanning The Seabed

Fig.13 Chart of Fatigue Life; 18 inch Export Pipeline with $e = 0.55$ m

Fig.14 Chart of Fatigue Life; 20 inch Infield Pipeline with $e = 0.5$ m

Table 4, we found that free span of TSB Flow lines in several locations were beyond allowable limit! Fig.13 and Fig.14 give the figure of fatigue life of 18 inch export line and 20 inch flow line respectively in variation of spans length.

3.2.1 Subsea Facilities Inspection and Pipelines Free Span Rectification

Subsea pipeline rectification work for 44 locations of free span including potential series of free span have been safely and successfully executed from 29 October – 07 December 2014. Selected pipelines rectification method was using Grout Bag. One of span condition before and after rectification is shown on Fig.15 and Fig.16.

3.2.2 The Most Likely Cause of Failure

- Unstable loose-sand sea bed condition affected by bottom sea current.

3.2.3 Lessons Learned

- Perform subsea facilities inspection in regular basis for monitoring current condition of underwater pipelines.
- Perform engineering study for predicting potential over

Fig.15 Condition Pipeline Before Free Span Rectification Program

Fig.16 Condition Pipeline After Free Span Rectification Program

free span in the future.

- Consideration of project cost and risk if applying trenching / and rocks dumping.
- Good Point : Maintaining integrity is not only a “lip service” ; pre-emptive actions before the failure.

4. Conclusion

- (1) HSE management shall be applied from initial project phase throughout the project life.
- (2) Conceptually all high risks of the project activities related to HSE can be reduced to low level risks by implementing inherently safer design, engineered safety and procedural safety / operating discipline.
- (3) Actual risk level is increased in operation phase since the hydrocarbon is introduced and the protection layers may have some holes or weaknesses. Organization has to ensure robustness of the layers of protection through proper HSE management system including managing assets integrity / process safety.
- (5) Defects in the design or poor Quality Assurance / Quality Control (QA/QC) may become latent hazard in the future that need to be attended in the first findings during facilities inspection.
- (6) Safety is a “24 hours a day / 7 days a week” business; we have to manage safety all the time through people, process and facility integrity.

Conversion to SI units

MMSCFD	×	28,316.88		= m ³ / day
psi	×	6.894757	E + 3	= Pa
inch	×	0.0254		= m

Reference

Reason J, 1990 : The Contribution of Latent Human Failures to the Breakdown of Complex Systems, *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences*, **327** (1241), Human Factors in Hazardous Situations, pp. 475-484, Published by Royal Society.

パゲルンガン海洋ガス田および TSB 海底ガス田の開発 – フィールドライフを通じた HSE の重要性 –

アフマド ブニヤミン・ダルマンシア ダウド ユスフ
イルハス ハンドヨ・熊崎 嘉人・田中 啓誉

石油・天然ガスの開発における HSE リスクマネジメントは、安全重視のデザイン、適切な技術の適用、多重安全システムの導入などで達成されるが、中でも操業段階における HSE マネジメントは、実際に可燃性の油ガスが生産設備内を流れているという点で、求められるリスクコントロールのレベルが探鉱・開発段階と比べて一段と高いものとなる。

シンポジウムでは、Pagerungan Field および TSB Field という海洋の 2 つのガス田の開発・生産操業にかかる HSE マネジメントの実際、および Lessons Learned を紹介した。