Working Together for a Good Working Environment

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Johan Sverdrup is one of the largest oil fields on the Norwegian continental shelf and will be one of the most important industrial projects in Norway for the next 50 years. The paper explains how the detailed design and construction partners, KBR in a joint venture with Kvaerner (K^2JV) with subcontractor, Leirvik AS, and operator, Equinor, worked together in an integrated project team to achieve the best possible working environment on the Johan Sverdrup Utilities and Living Quarters Platform, based on the Norwegian NORSOK S-002 standard.

Working environment is 'the totality of all physical, chemical, biological and psychological factors at work that may affect the employees' health and wellbeing through acute trauma or lasting exposure' (S-002). The same Equinor operator project members contributed their experience through design and construction and they will operate the installed platform; this was key to achieving the best possible working environment. A well prepared and matured concept and front end engineering design for the project, communication of the importance of working environment in design to the team, effective multidiscipline co-operation between the team members, use of the 3D model as a focal point for discussions and collaboration by the partner organisations were also important success factors.

Introduction

The aim of this paper is to describe the requirements for and methods used to provide the best possible working conditions or Working Environment (WE) during the operation of the Utilities and Living Quarters Platform (ULQP), which is part of the Johan Sverdrup (JS) oil field centre production facilities. The success factors are described and in particular, it makes the case for close collaborative working between all parties on capital projects with the continual involvement of the people who will operate the built facility, because the WE is then better.

The achievement of a good WE starts in the concept phase of a project and continues through Front End Engineering Design (FEED), although this paper is mostly concerned with detailed design and construction. Further, the WE activities were co-ordinated with those happening on the other platforms in the JS development by the overall Field Engineering activity.

Historically it has been difficult enough building and installing facilities in the North Sea and scant attention was paid to working conditions, so long as it was safe – it was a hard life for hard men, who were well rewarded.

Times have changed. It is now recognised that human performance is enhanced and one of the root causes of major accidents, human error, is reduced by providing a good WE, which is also good for the health and well-being of the workers. Companies operating in the North Sea and elsewhere prioritise WE and, in Norway, this is mandated by act of Parliament, which also requires that the people who will operate a facility are to be involved in its design. . In Norway, companies might be denied permission to operate if the WE is deficient. The requirements and expectations are outlined in the Norsok S-002 Working Environment standard. The project followed ed. 4 [Norsok, 2004] of this standard but ed. 5 has now been issued [Norsok, 2018]. In the paper text from S-002 (ed. 5, except where stated to be ed. 4) is used to illustrate requirements.

Achieving a good WE on the JS ULQP presented many challenges. An example was designing and building a 'hotel' for a maximum Personnel On Board (POB) of 560, including 110 cabins with 'turnable' beds and all rooms with en suite bathrooms and a full field control suite for 5 platforms, all of which sits on top of 3 decks of utility equipment but with noise levels below 40 dBA and 45 dBA, respectively.

The ethos of the project from the start was that the integrated team of engineers, designers, procurement personnel and support staff, etc, located in Leatherhead (UK), Jakarta, Gothenburg, Oslo and Stord (Norway) would all work by the '3Cs': 'Communication, Co-operation and Collaboration', in order to efficiently meet such challenges.

Johan Sverdrup facility description

JS is a large oil and gas field, with about 2.2 to 3.3 billion barrels of oil equivalent expected to be produced over the next 50 years. It is located in the Norwegian sector of the North Sea, about 140 km west of Stavanger.

The Phase 1 development of the JS Field Centre consists of four bridge linked platforms and connecting bridges, as shown in Figure 1. The ULQP is the westernmost of these and is connected to the Process platform via a bridge to the east. The Field Centre is the first of two planned phases for the field with the platforms having 50-year design lives. Phase 2 is soon to be in construction and includes a second process platform to be connected to the riser platform, which will also be operated from the Control Suite (CS) on the ULQP.

The ULQP platform topsides consists of two main modules: the Utility Module (UM) and the Accommodation Module (AM), which are shown in Figure 2.

Figure 1: The Johan Sverdrup Field Centre Arrangement

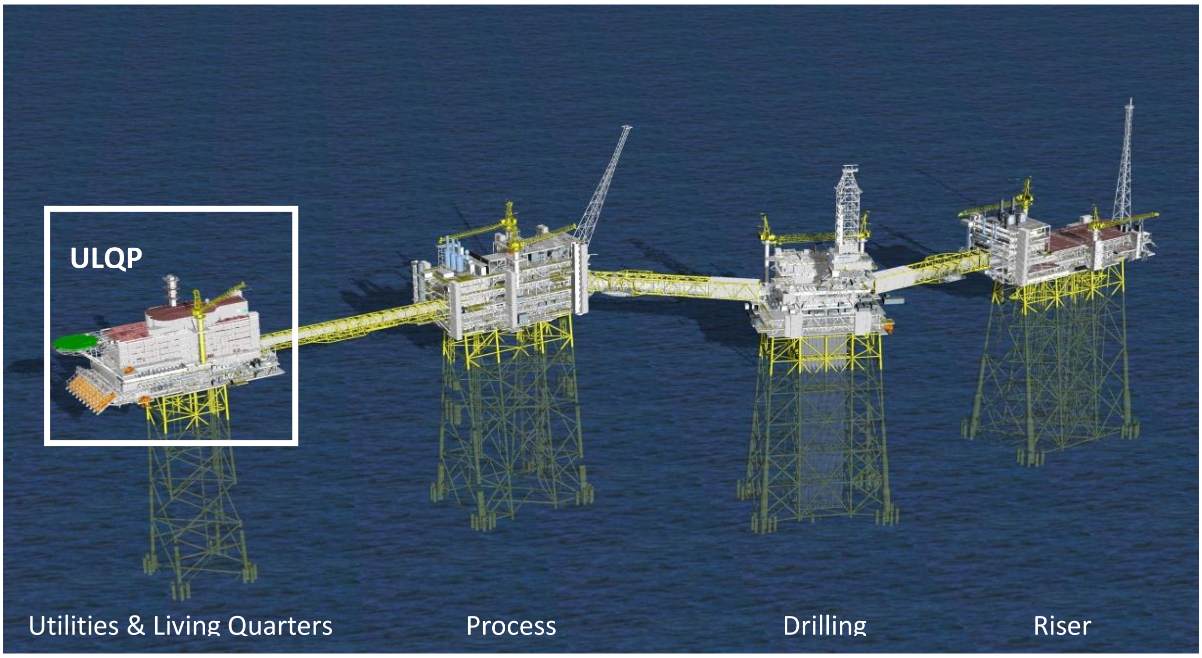
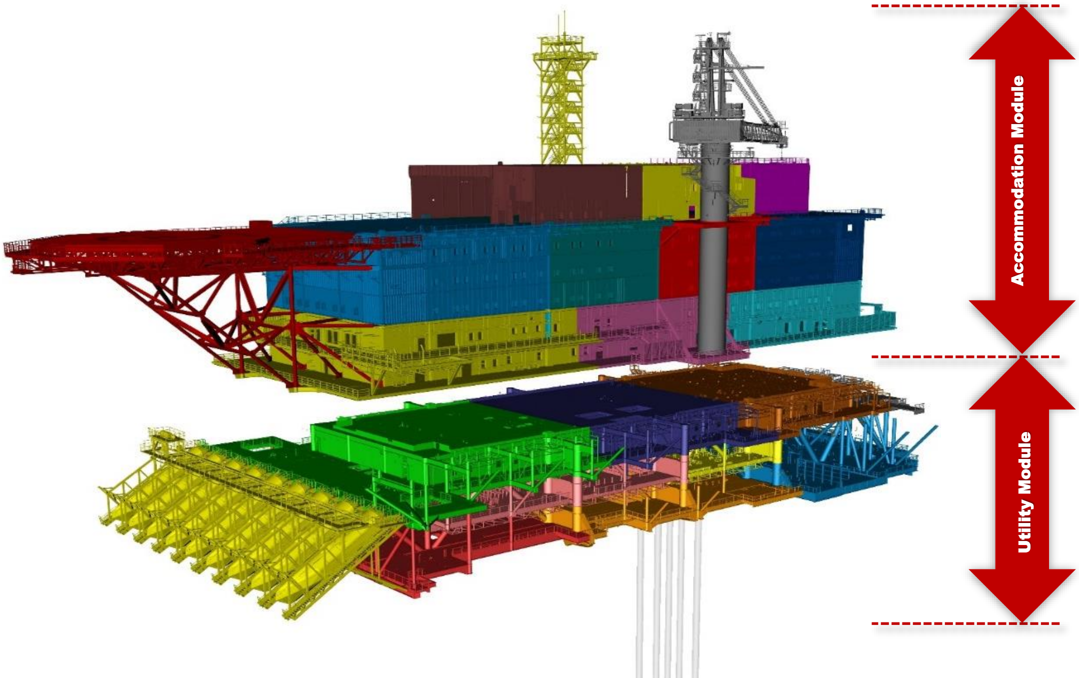


Figure 2: Johan Sverdrup ULQP Accommodation and Utility Modules



The UM, which has been designed and built by the K^{2}JV joint venture between KBR and Kvaerner, contains the following decks.

- Cellar: Heating Ventilation Air Conditioning (HVAC), thyristors, hot water, fresh water, diesel, air handling and other equipment, project offices, emergency generator and fire water pump engine containers, high voltage emergency room;
- Lower mezzanine: HVAC, batteries, electrical and telecommunications rooms, project offices; and
- Upper mezzanine: lifeboat access, CS, offices and meeting rooms, workshops and stores, changing rooms, dirty rest and smoking area.

There is also a walkway (or spider deck) at the top of the jacket (supporting legs), below the cellar deck, for caisson and jacket inspection.

The AM, which has been designed and built by Leirvik (formerly Apply Leirvik) contains all the clean areas, including:

- Level 1: catering laydown, food storage, galley, dining, rest and change;
- Level 2: lounge, hobbies, medical facilities and cabins;
- Level 3: cabins, linen and lockers;
- Level 4: cabins, linen, lockers and telecommunications rooms;
- Level 5: cabins, linen, lockers and activity rooms;
- Level 6: helideck, hangar, Helicopter Traffic Control Centre (HTCC), arrival and departure, HVAC;
- Level 7: lift machinery rooms, Search And Rescue (SAR) helicopter crew facilities, HVAC; and
- Roof: antennae tower, crane maintenance platform.

Systems on the ULQP serving the whole field include:

- Firewater (3 of the 5 Field Centre pumps);
- Fresh water;
- Diesel;
- Compressed air (emergency);
- Emergency power;
- Evacuation (helicopter, lifeboats);
- Search And Rescue (SAR) helicopter hangar;
- Operation of the field - Central Control Room (CCR);
- Telecommunications functions;
- Accommodation (450 cabins with capacity for 560 POB); and
- Main Field Centre workshops and stores.

Figure 3, shows the project locations, with the main engineering (detailed) design office for the project in Leatherhead, UK. Some further engineering design was done in Jakarta, Indonesia (not shown) and the living quarters was designed by Leirvik AS in Stord, Norway.

The three utilities module decks and associated components and structure were fabricated across several fabrication yards in Poland. The 7 accommodation module levels were constructed in Gothenburg, Sweden and in Stord. The individual levels and modules were combined at the construction assembly site in Stord, ready for delivery to the field. The platform topsides was installed on its jacket in a single lift using the Allseas *Pioneering Spirit* vessel in March 2019l.

The difference between occupational health and safety and technical safety

A good WE is achieved by designing for good Occupational Health and Safety (OHS). OHS is distinguished from technical safety by the scale and duration of the hazard. Whereas technical safety is about ensuring that major accident hazards, for example explosions, do not happen, OHS protects against workplace accidents, for example falls from height, and longer term effects on the health of workers, for example hearing loss due to exposure to noisy equipment. There is overlap between the two disciplines but generally workplace accidents are small scale (but might still be serious or fatal) and health effects might be caused by long-term exposure.

Even though major accidents ‘grab’ the headlines and are obviously very bad for all concerned, they do not happen often and far more people are killed, injured or made unwell by workplace accidents or exposures than by major accidents.

Occupational Health and Safety Statistics

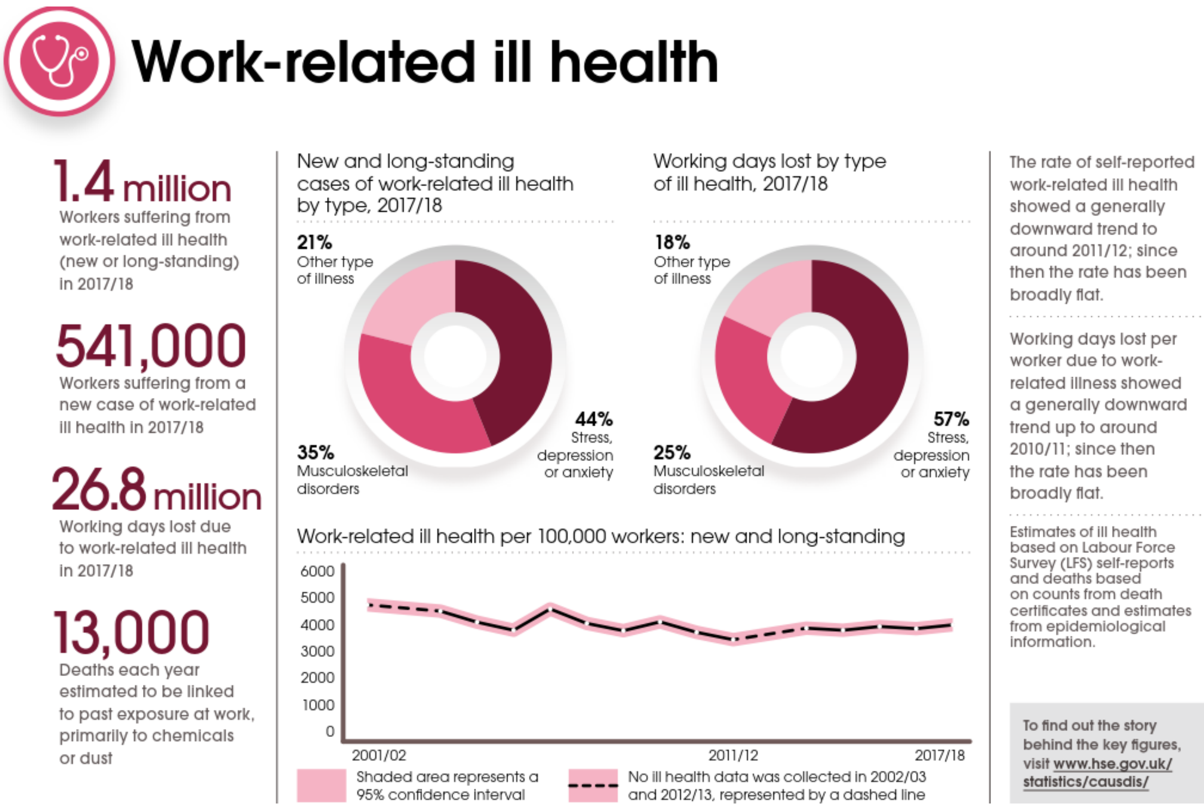
Figure 4 presents some statistics published by the UK Health and Safety Executive (HSE) [HSE, 2018]. The sheer size of the numbers indicates that workplace Health and Safety (H&S) is not good enough.

In the UK: 144 workers were killed at work and 100 members of the public were killed due to work related activities in 2017/18, but none in a major accident, whereas 13,000 UK deaths each year are estimated to be linked to past exposure at work, primarily to chemicals or dust. The annual cost to the UK is £15 billion for work-related injury (£5 billion) and new cases of ill-health (£10 billion).

However, the UK has one of the best records for H&S anywhere; other European countries are worse and other countries in the world are much worse. For example, an estimate of the global workplace cancer death rate was revised upwards from 666,000 to 742,000 people per year according to research by the International Labour Organization (ILO) and others [IOSH, 2017]. The same report highlighted that worldwide there are about 380,000 fatal accidents and 2.4 million deaths per year due to occupational diseases, including cancer.

Figure 3: ULQP Design and Construction Locations (Jakarta Not Shown)

Figure 4: UK Health and Safety Executive Occupational Health and Safety Statistics



Clearly, there is a great incentive for improving OHS, which is what designing for a good WE is about.

Analysis of accidents and incidents shows that human failure contributes to almost all accidents and exposures to substances hazardous to health [HSE, 2019]. However, as Trevor Kletz used to say, *this is not very helpful – it's a bit like saying that falls are due to gravity* [CSB, 2013]. Rather, we should design to eliminate the scope for human error or make it less likely and / or impactful, that is, as Trevor would have said, *Try to change situations, not people* [Kletz, 1985]. This is also about designing a good WE by human centred design. Moreover, good, human centred design will improve human performance, which is central to mitigating and reducing the consequence of incidents.

Working Environment (WE)

Simply put, WE is the environment for work. WE encompasses all of the factors: arrangement and access, biological, chemical, climate (indoors and outdoors), ergonomics, machinery safety, Human Factors (HF), lighting, Manual Handling (MH), noise and vibration (whole body and hand-arm), organisational, psychosocial, radiation (heat, electromagnetic and ionising) and other (do not fit in to the listed categories) that affect workers in their jobs.

The JS ULQP was destined for the Norwegian sector of the North Sea, so we followed the definition in the Norwegian, Norsok standard for WE, S-002: *The totality of all physical, chemical, biological and psychological factors at work that may affect the employees' health and wellbeing through acute trauma or lasting exposure.*

WE is closely related to HF and some organisations group the two together under the term *Human Factors Engineering*. In Norway, the S-002 standard includes methods to analyse the HF in safety-critical systems and the ergonomics as well as all the physical, chemical and biological risk factors associated with the WE. The discipline engineers expected to ensure compliance to this standard for the offshore project are: Technical Working Environment (TWE), Noise and Vibration Control and HF. These three disciplines work with Operations representatives, Procurement and the other engineering disciplines: Technical Safety, Instruments, Electrical, Mechanical, Piping and Layout, Automation, Structural and Materials.

In the UK the term Human Factors engineering often includes the TWE and HF tasks as described in the Norsok S-002 standards. In S-002 HF is defined as: *understanding of interactions between humans and other elements of a system, applying theory, principles, data and methods in design, in order to optimise human well-being and overall system performance.*

HF is often described as ergonomics but this is only a part of it. The difference between the ergonomics side of HF and WE can be illustrated by reference to the control suite design. HF analyses the layout of the displays in the control room to minimise the scope for human error; TWE and Noise and Vibration engineers make sure that the lighting, noise level, room air changes and temperature contribute to a comfortable and efficient place to work for the operators. The HF discipline develops human centred design solutions that enable human performance; whereas TWE ensures human health by reducing health risks.

Communication, Co-operation and Collaboration

The ULQP Project ethos was Communication, Co-operation and Collaboration.

WE requirements apply to all disciplines with responsibility for the design of equipment and platform areas. The TWE discipline provided advice and guidance to facilitate the achievement of the best possible WE but it was the discipline engineers and designers who implemented it. However, many of the UK project engineers were unfamiliar with WE and the importance attached to it by the Norwegian regulatory system, therefore the first task for TWE was to communicate what WE is and to engage the project discipline engineers and others.

Communication and Engagement

WE awareness presentations were made to personnel in the various project centres, in order to develop the mind-set that we are designing not only a facility to support the production of oil and gas but also a place of work, rest and recreation; and to help disciplines develop ownership of WE within their respective platform area and equipment scopes. The presentations can be encapsulated by the question: *Would you work in the workplace that you are designing?*

Equinor provided a *Working Environment Engineering Handbook* for the project, which was distributed widely amongst project engineers and equipment supplier personnel. It listed the WE requirements with explanatory pictures and references in a compact booklet that could be used as a desk information source. A similar *Working Environment Yard Handbook* was designed to fit into an overall pocket and was distributed to the construction personnel at the Kvaerner Yard in Stord.

The outcome was that project engineers and construction personnel consulted the TWE discipline BEFORE committing to a design or a course of action. They would ask: 'will this be OK?', rather than 'this will be OK, won't it?', which it might not be.

Co-Operation with Operations

Equinor and K^2JV have a shared responsibility to ensure that employees with relevant end-user experience are appropriately involved with the design throughout the project, according to S-002: *There shall also be worker participation (the safety representative).*

The object is to use employee knowledge and experience to highlight potential issues before decisions are taken on health, environment and safety matters and for the employees to influence their future WE.

The main source of end-user input has been from Equinor Operations personnel, most of whom have been located in the project offices. Good working relationships between the K^2JV TWE and other disciplines and Equinor Operations personnel were formed at the start of the project and continued throughout. Equinor Operations representatives participated in all WE reviews of the platform areas and of the equipment packages, as well as in specific reviews, for example of lighting and access to fire and gas detectors. They were also fully involved in WE inspections and verifications of the built contract object. We had a shared aim – the best possible WE on the platform - K^2JV because we wanted to do a good job and get further work and Equinor Operators, because they would have to operate the platform. Such close co-operation between operators and designers was part of the project execution plan and was not just to satisfy regulatory requirements.

Collaborative Working

The JS ULQP detail design and construction project was set-up from the start with an integrated team of K^2JV, Leirvik AS and Equinor personnel. Many of the Equinor staff were located in K^2JV or Leirvik AS offices. We had the shared aim of designing and building a great platform but as the project progressed the mutual respect that people from these three organisations had for each other developed, so that we all trusted each other, and many friendships were forged across the organisational boundaries.

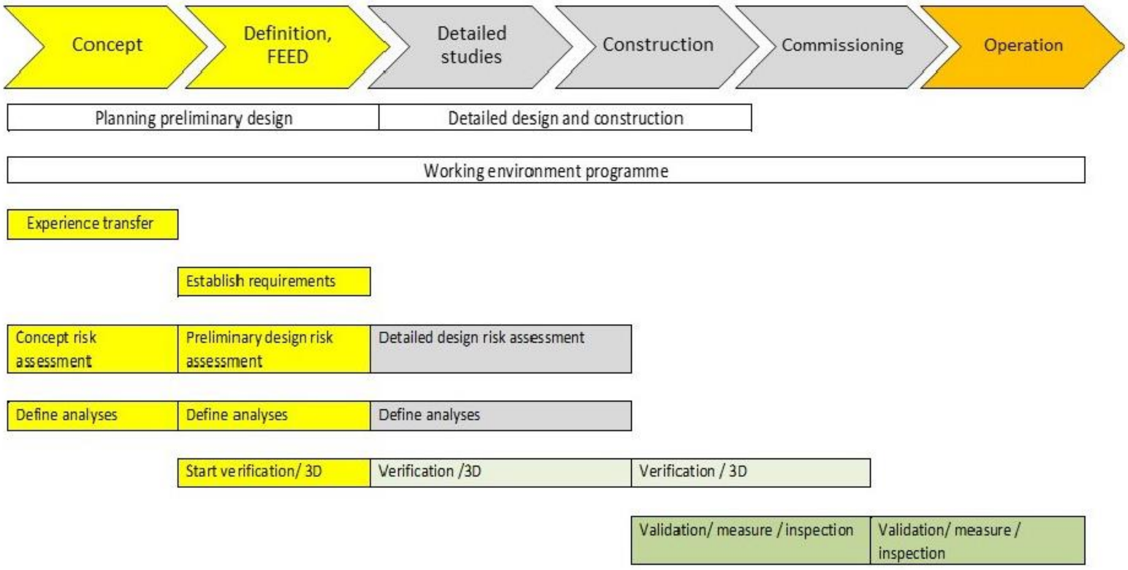
A feature of the collaboration was the many workshops in which a multi-disciplinary team from contractor and client reviewed the 3D computer model and other documents from different perspectives: technical safety, TWE, layout, etc. Indeed, the continuous availability of the live 3D model to all and the ability of disciplines to use it in their work was very powerful.

WE through the Project

S-002: *The working environment analyses shall be performed to clarify risk factors, provide input into design and develop requirements where these are not specifically stated in the other requirements documentation.*

TWE analysis is at a very high level at the concept stage and becomes more and more detailed as the design and then construction progresses. Outcome of the TWE analysis is used for design improvements to reduce WE risks and validate the chosen design. A feature of all the activities is the emphasis on some or all the '3Cs': Communication, Collaboration and Co-operation, which defined the ethos of the JS ULQP project. WE activities are listed by project stage in Figure 5, which is taken from S-002.

Figure 5: Typical timeline of activities linked to the project phases



In the concept phase the activities for the project and TWE Engineers are mostly about:

- Defining requirements and standards and the WE philosophy for the project;
- Identifying the key issues and hazards. For example, are any of the chemicals hazardous, will diving be required, what will the climate be like, etc., which will be be done mainly at a WE Impact Assessment (WEIA) workshop; and
- Prioritising measures and exposure barriers and inherently safer design principles to reduce risk and validate the selected concept.

Equinor maintain that this stage is the *best time for good ideas* and there is scope for influencing or even changing the concept; S-002 says: *provide input to concept selection and validation of the selected concept.* For example, could the facility operate without permanent staff or could any of the activities be done onshore, where the WE is better controlled?

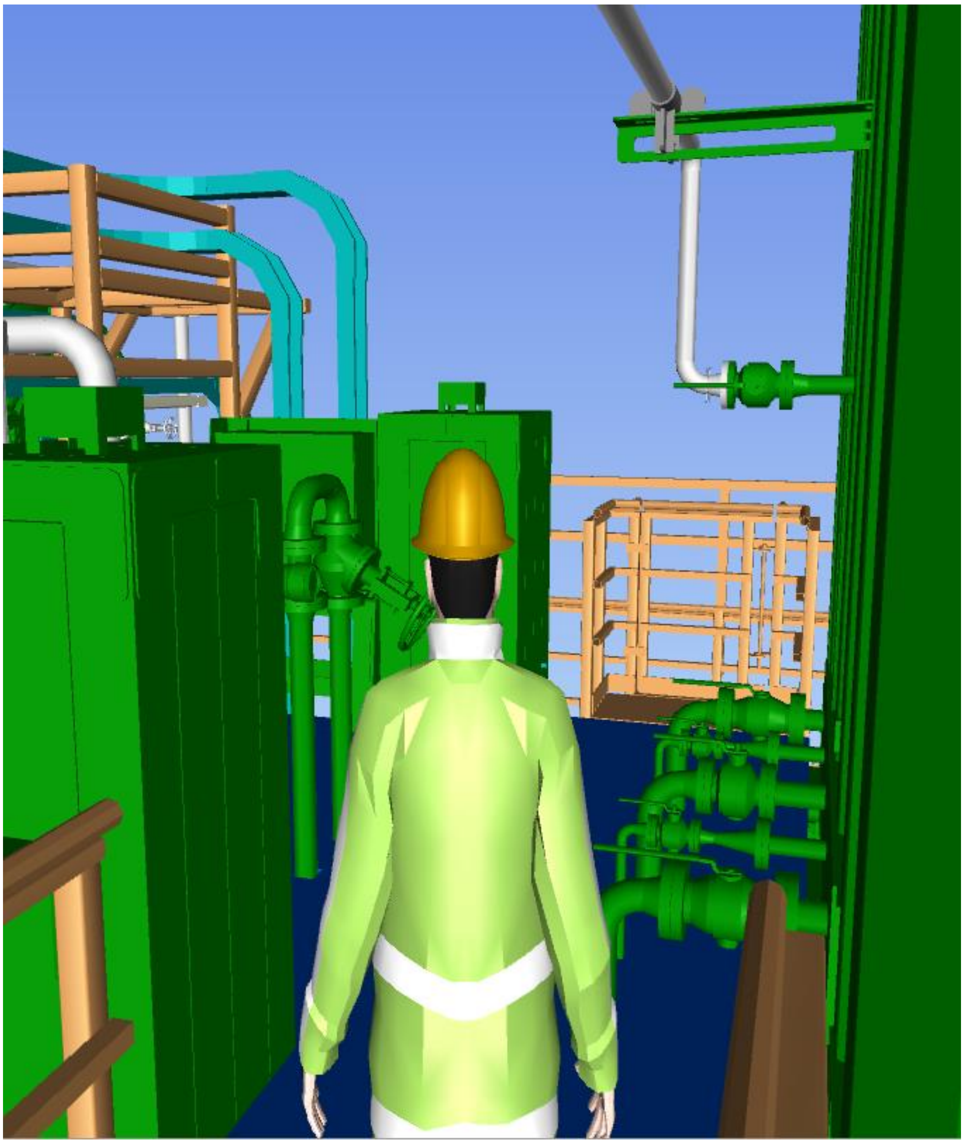
In the FEED stage there is enough definition of process, equipment and layout to make predictions for the noise and vibration levels around the facility. The process chemicals will be known and there is some knowledge of the ancillary chemicals that will be used; a Chemical Health Risk Assessment (CHRA) can be made. Another WEIA workshop is held to update and supplement the results from the previous phase. Equinor call this a WE Health Risk Assessment (WEHRA).

The ULQP detail engineering and construction project is a further development of a very well matured design developed by others in the Concept studies and FEED phase. In the detail design the FEED studies, such as the WEHRA and CHRA, were updated and made in much greater detail and further work was pursued to make the WE in the built object the best possible and such that WE risks are acceptable and As Low As Reasonably Practicable (ALARP).

Design reviews

During design development, design reviews shall be performed as necessary to verify compliance with specific WE requirements applicable to the contract object. Further validation shall be performed to ensure that design is in accordance with specific intended use. (S-002, ed. 4).

Figure 6: The 3D model was used as a basis for compliance checks for various issues



Multi-disciplinary workshop reviews of the 3D (computer) model (see Figure 6), layout drawings and related documents are an important part of all project phases and especially in detailed design. As well as participating in the project reviews, the TWE discipline organised WE reviews of the whole ULQP, area by area and included relevant engineering disciplines and Equinor Operations personnel. The 3D model was the basis for reviews of access for operation and maintenance of valves and instruments, detectors, light fixtures, HVAC heaters and dampers, filters and inspection hatches. These reviews also included assessing MH requirements - equipment, for example hoists, cranes, etc are required for weights over 25 kg, to prevent exposure to excessive manual handling workloads or risks of musculoskeletal injury. Actions to ensure compliance to requirements were proposed based on these reviews and responsible disciplines also participated in the close-out reviews for such actions. Mobile temporary access platforms were specified where possible, in order to reduce the weight of fixed access provision.

Whereas it was most often access to valves that presented non-compliance issues, it was the false or suspended ceilings that caused most problems for layout, access and noise; these were the subject of many specific reviews, involving the Architectural, Electrical, HVAC, Instruments, MH, Process, Piping and Layouts, Telecommunications and TWE disciplines, to ensure access to equipment above suspended ceilings, for example HVAC duct cleaning hatches, detectors, heaters and Public Address (PA) speakers.

Working Environment Health Risk Assessment (WEHRA)

The WEHRA is a multi-disciplinary workshop, and it is the WE equivalent of a HAZard IDentification (HAZID), which deals with major accident hazards. The output of the WEHRA is a risk and action register, such as that presented in Table 1.

WEHRAs identify personnel activities and analyse the associated hazards in as much detail as possible at the project stage and assesses whether the controls and safeguards are sufficient to reduce the risk to an acceptable level and to be in compliance with WE requirements, if not, actions are proposed to rectify the situation.

Working Environment Area Limits (WEAL) and Charts (WEAC)

The WEALs are a deliverable by the TWE discipline which established the applicable limits for the whole project on total and HVAC noise, vibration, average and escape illuminance, temperature, and air changes in an area of the platform, usually a room, external walkway or laydown, according to the function and occupancy of the area. Any discrepancies from the established WEALs are a project deviation, so the agreement on the WEALs during the FEED phase is an important task.

A WEAC was compiled for each area of the platform to record the WE information during the development of the project and they were updated as new information became available. An example WEAC is presented in Table 2. During detail engineering, predictions for noise, temperature, etc were made by the relevant disciplines and as-built measurements, verifying compliance with the specified WEALs were added during commissioning.

Table 2: Example Working Environment Area Chart (WEAC)

Johan Sverdrup LQ Platform
Working Environment Area Chart

Room No:	LC1206	Issue Rev.:	04	Last Update:	20/03/19	Print Date:	20/03/19	WEAC ID:	0018
Room Name:	HVAC Plant Room Utility Areas			Deck / Level:	Cellar			Manning:	U

Working Environment Area Limits

Factor	Limit	Prediction	As Built	Deviation	Notes	Status
Noise (Total) / dBA	85	79	65.8	N	**	OK
Noise (HVAC) / dBA	NS	-	-	-	-	OK
Vibration	3	3	-	NP	-	PAB
Average Illuminance / lux	200	255	300	N	-	OK
Escape Illuminance / lux	1	NA	0.59	Y	-	AR
Temperature / °C	5-35	30	-	NP	1	PAB
Air Changes per Hour / AC/h	2	2	2	N	+++	OK

General

Factor	Document No., Abreviated Title	Hazards / Non-Conformances	Decision	Notes	Status
Arrangements	NCR-BZ-0133 / NCReq4935 / NCR-C160-K2LQ-C160-H-0110-01	Void supply AHU: filter removal area, fan motors gasket reach	accept as is	4	OK (NCA)
Ergonomics	NCR-H-0214 / NCReq5142 / NCR-C160-K2LQ-C160-H-0172-01	Stiffening members 1640mm above fans in E21 extract units	accept - marked with tape	3	OK (NCA)
Human Factors	-	-	-	-	-
Technical Appliances	-	-			
Chemical Substances	-	-			
PPE	C156-KR-S-RA-05005, CHRA				

Table 1: Example Working Environment Health Risk Assessment Workshop Output

No	Deck	Area	Task / Activity	Duration	Frequency	# People (& Job Categories)	Hazards	Comments / Controls	Noise	Vibration	Climate	Ergonomics / Access	Light	Radiation	Chemical	Biological	Other	Risk Level	Previous Phase Action	Aker Close-Out Comments (Note - all actions are labelled "closed" but many have just been deferred to this phase)	Action	Responsibility
Noise : Vibration : Arrangement / Access : Machinery : Ergonomic : Human Factors : Climate (in/outdoor) : Light : Radiation : Chemical : Biological : Organisational : Psychosocial																						
Utility Module																						
1	UM Cellar	HVAC	Inspection of rotating equipment, checking leakages and general visual check	5 minutes	Once a day	1 (Process Technician)	Noise from the air handling units - at least one unit running at all times. Access - rotating equipment Casing / enclosure under pressure - crushing injuries (doors)	*Will need fan to be isolated before opening air handling unit (Statoil practice). This negates the issue of the housing being under pressure. Portholes are specified - visual confirmation is seen as useful over just instrumentation.* *Sliding doors into HVAC room prevent issues from differential pressure when entering (note, separate issue from air handling unit entry).*	2	1	1	1	1	1	1	1	1	2	Norsok S-002 defines area noise limits in HVAC rooms to be 90 dBA. Evaluate lowering this to 85 dBA. Will be evaluated further in the noise design review. Make sure structure born noise is reduced. Will be evaluated further in the noise design review. Need of physical protection (Grids in front) to the rotating parts. Part of normal design.	According to JS noise strategy 85 dB is required, ref. C160-AS-S-TA-00003. This shall be within specification for HVAC towards Suppliers. It is also a standard design.	1. HVAC package should be followed up from a noise perspective. 2. Confirm provision of suitable portholes for viewing.	J. Richards (Noise) D. Huggett (HVAC)
2	UM Cellar	HVAC	Maintenance: filter change,	12 h	Once a year	2 (Mechanic)	Dust from filters Ergonomics (heavy items) Filters are about 600x600 mm but light Access to the filters +H11(through ductwork system, despite closed damper). Hazard to personnel if someone else opens damper while filter change is in progress. PWR: not relevant, because unit is isolated, see No 1.	*Filters are only in the air intakes and the air handling units.* *Used filters are generally put into a plastic bag for disposal.* *Damper opening will be prevented by the permit to work system. May need mechanical / system lock.*	2	1	1	3	1	1	1	1	1	3	Norsok S-002 defines area noise limits in HVAC rooms to be 90 dBA. Evaluate lowering this to 85 dBA. Will be evaluated further in the noise design review. Make sure structure born noise is reduced. Will be evaluated further in the noise design review. Need for permanent access and access to laydown area when changing filters.	Door openings, size of filters needs to be followed up in detail engineering.	1. Procedural control for dampers and actuator locking to be evaluated. To be consistent with other platforms. 2. Access to be reviewed by WE discipline.	D. Huggett (HVAC) D. Edwards (WE)
3	UM Cellar	HVAC - hot water storage package in HVAC plant room.	Change of equipment (pumps, potable water heater etc.)	1 week	Every 10 years (may be more frequently, as required)	4 (Mechanic and instrument technician)	Material handling	*Tanks planned to last for design life.* *Erg. Ranking Changed. As material handling TBC.*	1	1	1	4	1	1	1	1	1	4	To be included in the material handling report.	To be included in material handling report	Confirm that this is addressed in the material handling report.	F. Thomassen (Layouts / Material Handling)
4	UM Cellar	HVAC	Maintenance: testing of fire dampers, and detectors Also follow-up maintenance.	1 h	4 times a year	4 (2 Mechanics + 1 Instruments + 1 Process Technician - not all at same time)	Ergonomics - access and material handling (ductwork at high level). Damper testing will be done manually - therefore safety system that prevents causing over/underpressures in certain rooms is disabled. Door hazards.	*Testing of dampers will be done while system is active.* *Need consistent procedures throughout field.* PWR: Any HVAC & fan must be shut down & isolated for service, see No 1	2	1	1	2	1	1	1	1	1	2	Norsok S-002 defines area noise limits in HVAC rooms to be 90 dBA. Evaluate lowering this to 85 dBA. Will be evaluated further in the noise design review. Ensure good access to the actuated dampers.	Access to dampers in the air intake will be planned for either from deck level or from platform. Access to other actuated dampers will be allowed for during design and layout. Specific reviews are recommended in detail phase. The actuated dampers are placed on the aggregate inside the room. To be followed up in detail engineering.	As item 2	D. Huggett (HVAC) D. Edwards (WE)
5	UM Cellar	HVAC	Maintenance: inspection within ductwork if problems with e.g. dampers or heaters.	1 h per item	As required (not planned)	1 (Process Technician)	Access hatches / panels in ductwork - could be hot surfaces (~130 deg C) or dampers behind that present a personnel hazard.		1	1	1	3	1	1	1	1	1	3			Suitable procedural control and system deactivation lockout to be evaluated. Similar to item 2	D. Huggett (HVAC) D. Edwards (WE)
6	UM + AM	All ducts	Cleaning of HVAC ducts (including grilles and outlets). Including extract ducts from bathrooms and smoking rooms.	4 Weeks (few days for smoking rooms)	Every 4 years approximately (every year for smoking rooms)	3 (HVAC Specialists)	Access Dust Ducts from smoking rooms may be more hazardous. Airflow isolation hazards - manually isolated. As item 4	*System isolated in sections for cleaning.* *Common inlet duct would have to be cleaned during a turnaround.* *Controls: Safe job analysis and PPE.*	1	1	1	2	1	1	1	1	1	2			1. Access to ducting for cleaning and cleaning tools / methods to be evaluated. Ensure that adequate access hatches are provided. 2. Consider smoking dust exposure in CHRA	D. Huggett (HVAC) / D Edwards (WE) D. Edwards (WE)
7	UM Upper Mezz	Welding workshop	Extract duct cleaning	1 day	Every year	3 (HVAC Specialists)	More hazardous than standard ducts as will have welding particulates.	*Controls: Safe job analysis and PPE.*	1	1	1	2	1	1	2	1	1	2			As item 6 + consider welding extract residues in CHRA.	D. Huggett (HVAC) D. Edwards (WE)
							Transfer of fumes from one room to															

Chemical Health Risk Assessment (CHRA)

Exposure to chemicals and hazardous substances was evaluated in the CHRA as follows.

Identification of chemicals and exposure - chemical usage, actual and potential exposure was identified:

- at the WEHRA workshop;
- by examining chemicals associated with operation and maintenance or present in coatings and preservatives;
- in building materials (e.g. screed, paint, glue, insulation, etc.), which were examined in collaboration with the architectural discipline; and
- exposure to hazardous substances from atmospheric vents and diesel exhaust outlet was determined by dispersion modelling.

Exposed personnel groups, with frequency, duration and likelihood of significant contact or inhalation were determined.

Hazard categorisation - each chemical is put into a hazard category, according to S-002, based upon its hazard statements given by the CLP (Classification, Labelling and Packaging) regulations [CLP, 2008].

Risk evaluation - Chemical health risk is a function of the inherent hazard and the exposure to the chemical. Risks were assessed based on the method in S-002 and input to design was made in order to ensure that the chemical health risks to personnel would be acceptable in the operation phase.

It is best to eliminate chemical hazards but, if this is not possible, then substitution of a chemical by another, which is less hazardous and still has the equivalent properties, might reduce the risk sufficiently. The final health risks due to chemicals were mitigated by exposure control. Exposure control includes closed systems, such as the biocide dosing system. Ventilation and extract systems have been assessed which provide exposure protection in areas such as the welding room and workshop. Assessing the location of the atmospheric vent outlets and exhaust outlets and making sure they are in a safe location for the workers also reduced the exposure and thereby decreased the health risk.

Dispersion modelling was used to optimise the location of the outlet of the diesel exhausts. This modelling also predicted that under certain identified unfavourable wind conditions, personnel and HVAC inlets may be exposed to exhaust fumes during engine testing and supply boat operations. A *guide* was prepared for the ULQP operation phase to inform operators, so that they could avoid potential exposure by having regard to these effects.

Modelling predicted that the proposed diesel tank vent locations on the cellar deck at the edge of the platform would expose personnel on the cellar deck to diesel vapours. The vents were relocated to beneath the cellar deck, where the plated deck would prevent the migration of vapours to the cellar deck. Although the vents are now near the spider deck, this is a normally unmanned area and there is no requirement for personnel to be there during diesel bunkering operations, therefore the health risk is acceptable.

Consequence reducing measures - The number of safety showers and eyewash stations and their locations were defined. These are required to reduce the health effects of any exposure to hazardous substances, e.g. hot or corrosive chemicals, in case the exposure barriers are not working as expected.

Construction - the correct functioning of the exposure barriers was tested and documented in the WEACs during construction and commissioning, including: measurements of exhaust fumes in air intakes, smoke tests of ventilation measures and compliance of products, including surface coatings.

Equipment reviews

All equipment suppliers were issued with a *Working Environment Design Specification* and an *HSE Checklist for Packages and Equipment* at the start of the procurement process to define the WE requirements. However, suppliers tend to design and build equipment as they have always done it, which might not comply with the project requirements. Therefore, a risk based approach was adopted and equipment packages were each assigned one of three classes, in order to guide the level of TWE assessment and follow up. MH and TWE 3D model reviews were held for all class 1 and 2 packages. Class 1 packages were subject to WE physical inspections by K^2JV TWE and Equinor TWE and Operators at 80% construction completion, to check compliance and that actions are complete and to record deficiencies. Ad hoc TWE support was provided to the Package Responsible Engineer for Class 3 packages.

Human Factors (HF)

The HF scope for the JS Field engineering and the LQ HF engineering team included: the HTCC on level 6 of the AM and the CS in the UM, from which the five JS platforms are monitored and controlled, which includes the CCR, Emergency Control Centre (ECC) and adjacent rooms. HF analyses and specifications related to the HTCC were made by the HF Team and those for the CS were made by Field Engineering and the LQ HF team.

The UM HF discipline lead the Local Control Design Group (LCDG) for the ULQP, which ensured that CS requirements were incorporated into the design, by collaborative working with the disciplines: Operations, Instruments, Safety and Automation Systems (SAS), Telecommunications, Architecture, TWE, Piping & Layout and Electrical, from K^2JV and Equinor. The LCDG also coordinated with the JS Field Centre Control Centre Design Group (CCDG).

The CCR design used an onshore Mock-Up to check the arrangement, screen technology, lighting, furniture, etc and detailed lighting simulations were used to design the lighting. HF were responsible for the Human Machine Interface (HMI) design.

The HF analyses included:

- **Function and task analyses** – collected information about the functions and operations that will be undertaken, which was used to inform room design and equipment requirements for operability, maintainability and safety. The analysis team included experienced operator input, which was integral to the success of the review.
- **Workload analysis** – was performed on the CCR, in order to predict whether the planned manning levels and job design were acceptable during all modes of operation.
- **Communications analyses** – of the methods and technologies for communication were performed to establish the functional communication needs and equipment requirements between the different control centres and specifically the HTCC.
- **CRisis Intervention and OPerability (CRIOP)** – This methodology was used to perform an independent verification and validation study of the CCR, ECC and HTCC. The CCR / ECC CRIOP was held over a two day workshop in the control suite mock-up with representatives from all affected disciplines from Equinor, K^2JV and the rest of the Field Engineering organisation. The HTCC CRIOP was held over one day with representatives from Equinor, K^2JV and Leirvik AS.

Illumination

Light levels were analysed throughout the ULQP, with particular attention given to the control rooms and other rooms where work with high visual demands takes place, where display screen equipment is used or where the work requires good visibility during various weather conditions. Areas where high risk tasks were conducted were identified by the WE discipline with Equinor Operations and the necessary illumination levels were determined.

The lighting design for the control rooms included recommendations of how to avoid reflection and glare. Light Emiting Diode (LED) homogeneous illumination is used in the CCR and a risk assessment was made in order to ensure that this type of illumination has a satisfactory influence on the working environment conditions. The proposed lighting for the CCR and ECC was tested in the CCR mock-up, and it was found that there were some distracting reflections on the large screen displays in the CCR due to their glossy surfaces. Changes were made to the light units and their set-up to eliminate reflections.

The lighting levels throughout the LQ were measured to confirm compliance with the WEALs and the results were recorded in the WEACs.

Noise and Vibration

S-002: *The [noise and vibration] analyses shall contribute decision-support documentation for the choice of design solutions, equipment and components, as well as the development of requirements for reducing noise and vibration*.

Noise regulations applicable to the project were identified, required noise limits were specified in the FEED phase for the various platform areas and were stated in the WEALs. The WEALs for the ULQP were the basis to design and dimension all the other elements of the platform having an effect on noise, vibration, structure borne noise and noise attenuation and dampening e.g HVAC ducts, mechanical and electro equipment, pipes and valves.

The noise control engineer worked with the suppliers to achieve guaranteed noise levels, by using noise Best Available Technology (BAT) and the Factory Acceptance Test (FAT). All major noise generating equipment was measured as part of a FAT process, prior to the equipment being shipped to Stord for installation. The measurements were used in the modelling and analytical work to produce predicted noise levels throughout the ULQP. Critical noise attenuating construction elements, for example the acoustically absorbent ceiling panels, the impact noise damping floor screed systems and the impact damping deck matting were all tested to confirm their acceptable performance.

The noise and vibration control discipline use computer modelling, with noise models in *SoundPlan* for: pipe noise, HVAC noise, structure borne noise calculations and *Odeon* for: Public Announcement and Control Suite noise. The models were used to calculate noise limits for equipment, validate the design and document compliance to requirements. Limits for purchased equipment, valves, orifice plates and architectural elements were calculated, advised to the relevant suppliers and guaranteed performance was confirmed.

In the utility areas, the focus of the noise control engineers work was controlling noise from piping, valves and orifices by follow-up of suppliers of noisy equipment. In the office areas the focus is HVAC noise, insulation for equipment, absorption to ensure good acoustic and wall and ceiling constructions to avoid both airborne noise from equipment nearby and vibrations and structure borne noise.

The noise generated by some valves exceeded the defined limits. These valves have been included in the piping insulation calculations, to determine the impact on area noise levels and the extent and class of acoustic insulation required to ensure that the noise from the piping will not exceed the required limit.

For the noise control engineer, multidisciplinary collaboration is vital, for example cooperation with the structural discipline on the vibration analysis and optimisation of deck stiffness and antivibration mounts. Working with Operations representatives was important - sometimes there are conflicting requirements, e.g. the easy-to-clean and hygiene requirement of the kitchen / galley makes it hard to achieve a good absorbent to ensure the best reverberation time and noise dampening possible.

High performance noise attenuating architectural materials have been widely used throughout the LQ to ensure that external noise break-in, for example from helicopters, is minimised and that acoustic absorption is maximised. The extensive use of absorbent ceiling material should ensure that a "good" acoustic environment will be experienced in all areas.

Outdoor operations

Wind wall provision for outdoor operations weather protection was analysed and decided according to the same method as in ed. 5 of S-002 in the FEED phase. The need for minor changes in the wind wall configuration was assessed qualitatively by a weather protection specialist in the detail engineering phase.

Construction Verification

S-002: *Verification of working environment during construction and commissioning. The objective is to verify conformity with requirements, validate design solutions and propose corrective measures*.

Verification of compliance with WE design and regulatory requirements (Petroleum Safety Authority Regulations and Norsok) was made by inspections at three stages of construction completion: 60%, 80% and 95%.

Equinor and K^2JV personnel took part in the inspections. Identified deficiencies were corrected and verified to be so by a small team of K^2JV construction personnel and Equinor operators or were the subject of approved non-conformance requests, if the associated risks were assessed as acceptable.

These verifications were reviewed retrospectively by the team and deemed as a very useful and an efficient exercise to ensure compliance and increase the quality while still in the construction phase and at the yard. A proposed improvement in the ULQP construction verification method is to start at 80% completion instead of 60%.

Conclusions

The paper has explained what WE is and why it is so important, not least because deficiencies in workplace occupational health and safety are responsible for far more deaths and injuries and ill health than are caused by major accidents and also provision of a good WE reduces human error. The methods for helping designers and engineers create a good WE have been outlined.

On the JS ULQP detailed design and construction project, the integrated Equinor and K^2JV TWE team successfully engaged with the project and raised the profile of WE with the project personnel. There was strong co-operation and collaboration between the engineering disciplines, equipment procurement personnel and Equinor staff, particularly the operators, who will eventually work on the platform. The ULQP 3D computer model was a key tool and reference source for the many multi-disciplinary reviews and workshops, which improved and verified the design.

In one of the last validation activities, the WE construction inspections, K^2JV Construction and TWE and Equinor TWE and Operations worked efficiently to identify and rectify any residual issues. Actions were resolved by the construction team, with very good results

References

CLP, 2008, Regulation (EC) No 1272/2008 of the European Parliament and of the Council, Classification, labelling and packaging of substances and mixtures.

CSB, 2013, CSB Video Excerpts from Dr. Trevor Kletz Tuesday, Nov 05 2013, https://www.csb.gov/videos/csb-video-excerpts-from-dr-trevor-kletz/, (accessed 14/1/19)

HSE, 2019, Human factors: Managing human failures, http://www.hse.gov.uk/humanfactors/topics/humanfail.htm, (accessed 14/1/19)

HSE, 2018, Summary Statistics 2018, http://www.hse.gov.uk/statistics/index.htm#utm_source=hse.gov.uk&utm_medium=refferal&utm_campaign=annualstats&utm_term=stats&utm_content=home-page-news, (accessed 13/1/19).

IOSH Magazine, 5 September 2017, Workplace cancer death rate higher than estimated, says new global research, https://www.ioshmagazine.com/article/workplace-cancer-death-rate-higher-estimated-says-new-global-research, (accessed 12 December 2018).

Kletz TA, 1985, An Engineer's View of Human Error, IChemE.

Norsok, 2004, S-002 Ed. 4, Working Environment.

Norsok, 2018, S-002:2018(en), Ed. 5, Working environment Arbeidsmiljø.