Expro Well Services

Well Integrity Capability

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1 Significance of Well Integrity

All Operators are aware that the loss of well availability due to well integrity issues has a direct impact on profitability, so management of well stock is fundamental to good performance.

However, well Integrity is not solely an issue of well availability. A combination of HSE, Corporate Social Responsibility and developments in government legislation are driving a renewed focus on this topic. From the wellhead to the sandface, the poor condition of wells has potential HSE consequences, as Operators have discovered. Ensuring the integrity of critical barriers in a well is of the utmost importance. While new wells cannot be ignored, particularly in challenging environments such as HPHT or deepwater, mature brownfield assets are the traditional focus for well integrity issues. For fields in long term decline, Operators are challenged as to how the decline curve can be slowed. Extending field life, however, only increases the scale of well integrity issues to be dealt with.

2 Expro's Well Integrity Services

Expro is the leading provider of services required to design, deliver, implement, manage, and support an Operator's well integrity requirements. This extends from onshore management, expertise and systems, through to well-site services, supervision and support.

Throughout the well life cycle, from initial design through to eventual abandonment, Expro Well Services (EWS) provides a broad range of integrity skills and experience to Operators. EWS are involved with well integrity at every stage. From conceptual design, through well construction and operations, to abandonment, EWS provides the services and capabilities to maximise well availability and minimise residual risk. Our high-calibre engineers are backed up by advanced processes, systems and support. Knowledge management systems ensure that our engineers have instant access to a wealth of experience. Our services are tailored to the client's needs. The engineers can either work on a stand-alone basis or as an integral part of a client team. The workscope can be on a project basis or a life of field basis.

As a global well services provider, Expro is uniquely positioned to provide a comprehensive range of services to maximise well availability and productivity whilst minimising regulatory and HSE issues. Rather than simply providing reactive services on request, Expro can provide operators with a full range of Well Integrity services from initial well completion design and well integrity management systems, through to wireline deployed diagnostic and remedial services. Combined with its Production Technology (PT) services, Expro's Well Integrity capability provides Operators with a cost-effective solution to the challenges of managing an ageing field.

Expro Well Services' well integrity offering includes:-

- GAP analysis of existing Operator's well integrity management system.
- Development and implementation of tailored client-specific Well Integrity Management Systems.
- 'SafeWells' well integrity software system to manage an Operator's entire well stock.
- Bespoke independent Well Examination services as required for internal approval or regulatory purposes.
- MAASP studies and Risk Assessments to Operator's requirements.
- Design and delivery of client-specific Well Integrity training for both well-site and office-based client personnel.
- Well Service Supervisors to manager well-site well integrity operations, including management of contractors, whether Expro or 3rd Party.
- Wireline and Cased Hole Logging Services for diagnostic and remedial services.

Expro Well Services comprises Well Integrity Engineers, Well Engineers and Well Services Completion & Intervention Supervisors. Through Expro's other services lines, including wireline (braided line, e-line and slickline) services and cased hole logging, Expro delivers the full spectrum of services required to fulfil all our client's well integrity concerns – a 'one-stop' shop. It is our belief that no other service provider has this service offering.

3 Well Integrity Management System (WIMS)

Expro Well Services has frequently reviewed existing well management processes and procedures in conjunction with legislation and industry practices. Where it is identified that management systems are not suitable, or available, we have extensive experience in developing customised wells management systems that are used by multinational and national operators. We use GAP Analysis techniques to identify current procedures and practices, determine the gaps between the current and the ideal, and make recommendations to fill the gaps. Effective management systems are created by addressing the recommendations outlined in the GAP analysis. By doing so, the system helps ensure that:-

- Zero incidents or accidents associated with Well Integrity management activities
- Zero lost production (volume) due to well integrity issues
- Zero reportable hydrocarbon spills / releases attributable to loss of well integrity
- Zero dispensations in place for more than one year
- All planned maintenance completed on time
- Well Integrity management system audit schedule on target
- All well-handover documentation – complete and delivered on-time

Expro Well Services can assist with this objective by reviewing the key elements of effective management systems such as:-

- Operating Philosophy
- Roles and Responsibilities
- Policies and Standards
- Procedures and Processes
- Audit and Feedback

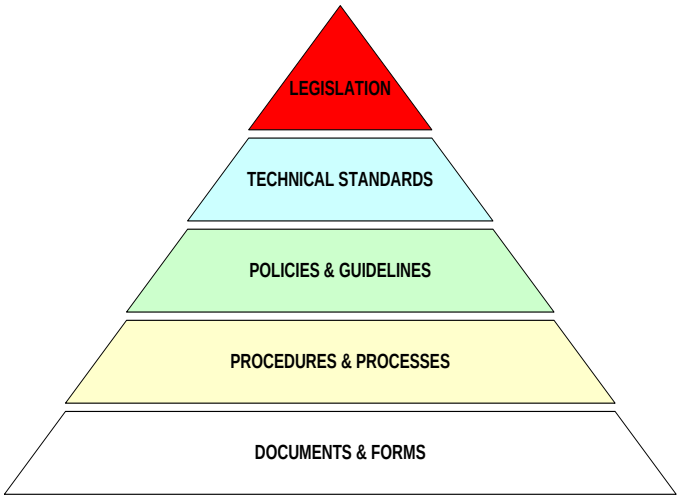
EWS's experience in reviewing existing systems ensures that integrity is being managed efficiently and demonstrates the customer's corporate and social responsibility.

3.1 Technical Standards & Procedures

A robust **Well Integrity Management System** is required to demonstrate compliance with legislation and industry best practice, and most importantly to ensure no harm to our people, the environment or equipment.

From the diagram opposite it can be seen that legislation is the overarching driver behind the system.

The technical standards are developed and are implemented / followed through the various policies and guidelines that are in place. Local procedures and processes are developed to support these. Records must be kept to demonstrate compliance with the legislation.



A well integrity management system is developed in conjunction with the well / field operator to ensure their requirements are understood and implemented into the system.

3.2 Core Elements of WIMS

As outlined, a robust WIMS system comprises of many core elements and should be considered during the implementation of the project. These are presented below for further reference.

3.2.1 Audit & Compliance

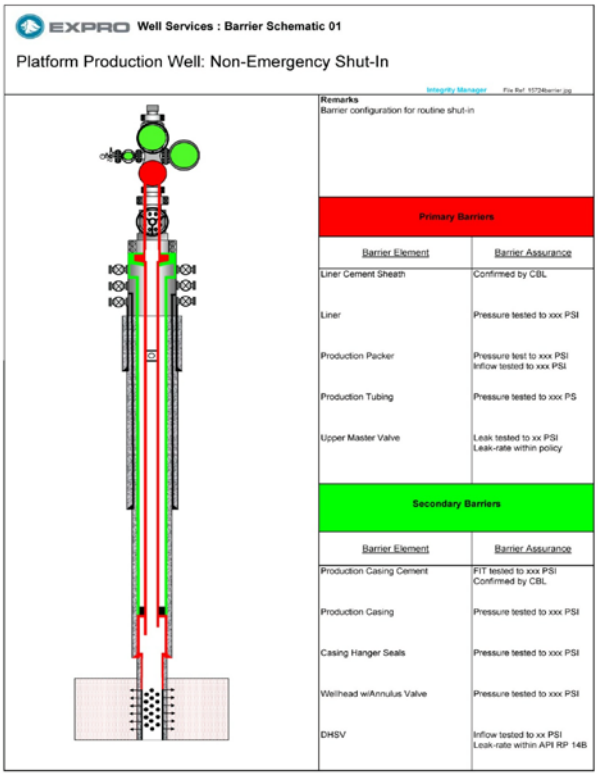
The WIMS is designed to be compliant with the ISO 9001 series. Each section shall be designed to address the compliance requirements of ISO 9001 and where required have a compliance statement. Audit is a key part of ensuring this. Audits are used as a process of quality control to assure the compliance and relevance of the WIMS and may be used to demonstrate compliance with legislation and company policies to the satisfaction of management and to external parties including Government bodies.

The other sections that ensure compliance to ISO 9001 are:-

- Management of Change
- Record Keeping
- Dispensation
- Reporting
- Performance Monitoring
- Document Control

3.2.2 Barrier Philosophy

A barrier is a protection measure or device which prevents the uncontrolled release or flow of reservoir fluids to the atmosphere / environment or an underground flow. It controls the flow to surface via the production strings or prevents the release from the reservoir or production string into the annulus or into the atmosphere via a flow line. This includes the definition of the characteristics, operational requirements, and verification of integrity and maintenance of well barriers.



Primary Barriers

These are the first in line to the well pressure. They will always have well pressure on their upstream side. Examples include:

- Production tubing
- Production packer
- Upper Master Valve (when actuated)

Secondary Barriers

These are the second in line to well pressure. They are a back-up in the event that the primary barrier fails. Examples include:

- Production Casing
- Tubing Hanger Seals
- Tree Valve Bodies
- Annulus Valves

There are various policies and procedures that fall under the Barrier Philosophy technical standard, these are;

- Annulus Management – including procedures for defining the Maximum Allowable Annulus Surface Pressure (MAASP) for each annulus.
- Xmas Tree Management
- SSSV Management
- Wellhead Management
- Communication Investigation

Within the SSSV, Xmas Tree and Wellhead Management policies and procedures there are methods identified for carrying out testing of the various valves in every well. Part of this is to identify acceptable leak rates for validating the integrity of valves which should be defined in accordance with any legislation and industry standards.

3.2.3 Well Life Cycle Phases

Well Life Cycle covers everything from initial design through to eventual abandonment. The life cycle phases are;

- Design.
- Construction.
- Operation and maintenance.
- Intervention and repair
- Suspension or mothball.
- Abandonment.

The purpose of defining the life cycle phases of a well is to define the required activities and assign stewardship responsibilities for each phase to ensure that all phases of a wells life cycle are considered in the design. It is critical that in each phase, the well has an 'owner', accountable for the integrity of the well.

The management of a well throughout the various life cycle phases is managed through following the various associated policies and procedures;

- Well Handover
- Well Design & Construction
- Well Verification
- Well Suspension
- Well Classification
- Well Examination

All wells must be examined to obtain assurance that it is; designed, modified, commissioned, constructed, equipped, operated, maintained, suspended and abandoned in such repair and condition, that:

- So far as is reasonably practicable, there can be no unplanned escape of fluids from the well.
- Risks to the health and safety of persons from it or anything in it, or in strata, to which it is connected, are as low as is reasonably practicable.

3.2.4 Well Operations

The operation of a well must be controlled in such a manner that the following are adhered to at all times:-

- Safely operate the wellbore within the Well Design Operating Envelope and according to any operating instructions.
- Monitor wellbore integrity.
- Monitor and maintain wellbore barriers.
- Monitor operating conditions for variances from the Wellbore Basis of Design

and potential risks to wellbore integrity.

- Identify and confirm wellbore problems affecting wellbore integrity.
- Recommend the wellbore for repair as required.

3.2.5 Wells Management

It is a requirement for well operators to operate within the bounds of an established system to manage well related activities. A Wells Management technical standard and the corresponding policies and procedures provides guidance on the processes that ensure that the construction and integrity of, and operations conducted on all wells are managed appropriately and in relation to the obligations under applicable statutory regulations and industry standards.

The management of well related activities is integrated into the overall WIMS and thus, must incorporate or take into account:-

- Compliance with company's HSE principles.
- Policies and procedures must be in place, in order to reduce the risks for all types of well activities throughout the life of the well, to the lowest practicable levels.
- Compliance with legislative requirements currently in force.
- There must be a demonstrable level of self-regulation and management control as the well operations team carry out well-related activities at any location.

The management of wells includes the following policies and procedures;

- Failed Wells
- Normal & Problem Wells
- Equipment Certification
- Inspection & Maintenance Frequency
- Pressure Testing
- Material Integrity Management
- Equipment Failure & Replacement
- Maintenance

A well which is operating outside the design envelope with known integrity issues or concerns is known as a failed well. This can be any well that has one or more of the following issues;

- External leak from the tree, wellhead or casing conductor.
- Tree and wellhead valves which fail to function or leak test.
- SSSV system fails to function or leak test.
- Tubing to casing, or casing to casing communication.
- Annuli in communication with the reservoir.
- Annulus pressure which cannot be bled off.
- Any well with tubing clearance or obstruction issues.

A Well Failure Matrix can be developed to clearly define failure types in wells and the response on one single matrix. Its purpose is to demonstrate that well failure modes have been identified and that each one has a suitable strategy in place for monitoring, testing and preventative maintenance, such that integrity is safeguarded.

3.2.6 Personnel Management

A well operator should be structured and resourced with personnel who have the experience, qualifications and skills commensurate with the roles required to support well operation activities. Each company should provide:-

- Qualified personnel that are selected and placed to meet specified job requirements.
- A competence management system.
- Personnel that have demonstrated competence, knowledge, skills and performance to fulfil the roles.
- Necessary levels of individual and collective experience and knowledge.

The recruitment of staff and contractor personnel requires that selected individuals are matched to required roles. Each job / position should have a defined set of roles, responsibilities and accountabilities in the form of a job description. Job descriptions should be provided for all members of staff.

3.2.7 Safety Management

All well operations activities shall be conducted such that the risks posed by hazards associated with the activities are reduced to a level that is As Low As Reasonably Practicable.

All well site operations are potentially hazardous by nature and accordingly, Hazard Management is integrated throughout documentation that controls well operations activities. Systems should be in place to identify sources of risk and hazards, assess their consequences and probabilities, and evaluate prevention and mitigation measures.

The conduct of comprehensive risk assessments provides essential information that permits decisions to be made of how best to reduce the risks and mitigate the consequences of health, safety and environmental incidents.

Risk assessment is the initial and most important step in risk management. It is the formal process for evaluating and quantifying the potential for harm to people, the environment or equipment / facilities.

With regards to well integrity, risk assessment is critical to the safe management of change, where change may be:

- The adoption of a new operational procedure which requires that all routine and non routine jobs should be subject to risk assessment.
- The installation or use of new equipment or consumables.
- The failure of a well component, breaching the barrier envelope.
- The operation of a well outside the design specifications envelope.
- A change in well function, for example producer to injector.

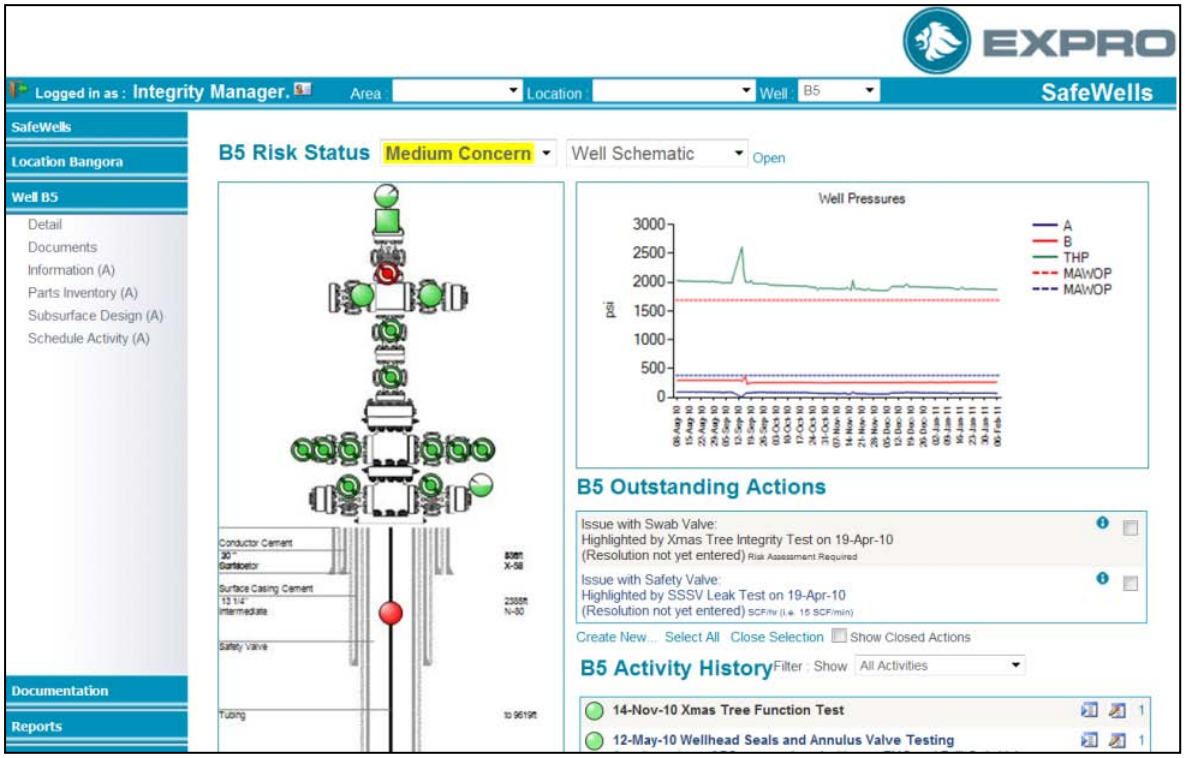
The management of hazards and risks is an ongoing process that is central to all well operations activities. This is especially critical when two or more concurrent operations are taking place.

The following key processes are used within the well operations for risk assessment & management:-

- Hazard Identification (HAZID).
- Hazard and Operability Studies (HAZOP).
- Task Risk Assessment.
- Major Hazard Risk Assessment.
- Quantitative Risk Assessment (QRA).

4 'SafeWells' Well Integrity System

SafeWells, the Expro designed bespoke software package, allows the well integrity of all wells to be monitored in real time and provides a clear overview of asset integrity across the whole organisation. The system can be easily configured to integrate with clients existing policies and procedures, allowing data to be recorded and monitored both at the well site by operational personnel and analysed onshore by engineers, management and legislative authorities alike. The emphasis has been on delivering a system which is user-friendly – it is only through this means that operators will gain the full benefits of the system.



4.1 Key Benefits

Some of the key benefits include:-

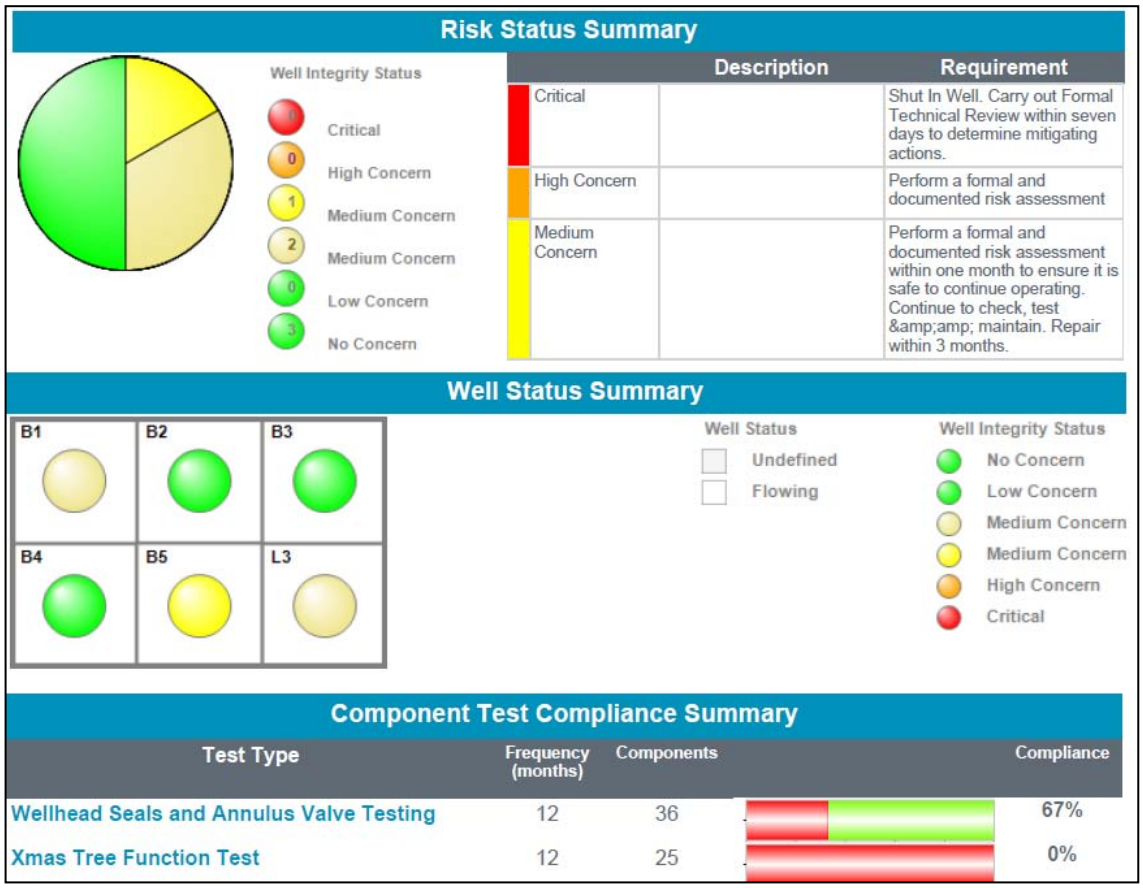
- Clear Well Integrity Overview
- Easy to Use - intuitive
- Safety Improvements
- Cost Savings
- Flexible
- Proactive Integrity Approach

Expro has developed the system to be extremely flexible. Existing paper based input forms (for example leak off test sheets) can be exactly recreated within the system. Field staff are therefore presented with an intuitive system that has a familiar look and feel.

A key benefit of the system is that acceptable leak rate criteria (in accordance with API standards or industry best practices) can be set up on the input forms. This allows wells to be categorised based upon predefined failure criteria, and presented using a “traffic light” dashboard to highlight wells with integrity related issues. Further, email notifications are sent to appointed personnel notifying them if failure parameters are exceeded.

4.2 Key Features

SafeWells integrates with existing database systems to produce live trending of production data (such as SCADA and PI systems). As a typical example, SafeWells continually monitors tubing and annulus pressures in the well. Rules are entered in accordance with client’s policy for annulus management (for example MAASP and trigger pressures), and the well is highlighted if these limits are exceeded.



Output reports provide a clear understanding of asset integrity status. Testing frequencies can be configured in accordance with company procedures, and SafeWells will highlight wells that are not compliant. An example of such a report is shown above.

Some of the many benefits that our clients are realising through use of the system include reduced operating costs through more reliable equipment selection and improved utilisation of personnel. Further, it has been reported that some of our clients' insurance overheads have also been reduced through implementation of the system.

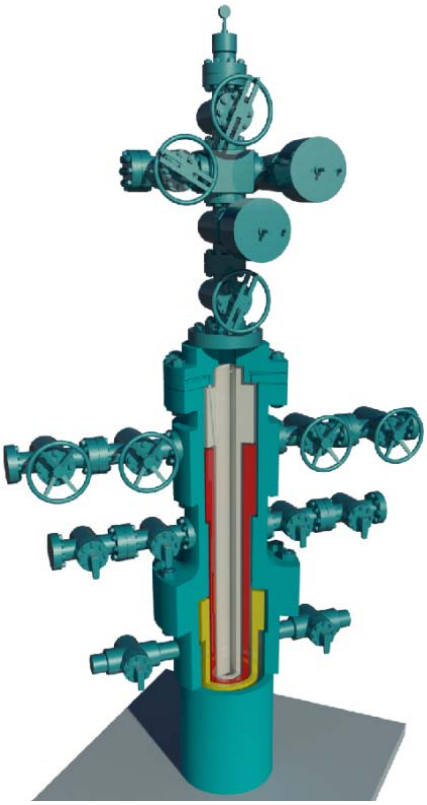
5 Risk Assessments of Wells

Expro Well Services (EWS) specialises in risk assessment projects to determine the integrity status of the well and categorising the risk to both personnel and the environment. Our methodology comprises a review of historic data and the current operating status of the well before presenting this information in a clear output report to help evaluate and mitigate the risk.

5.1 Information Assessed

A selection of the information required in performing the risk assessment is shown below:-

- Cement bond logs to evaluate cement quality.
- Corrosion logs for pipe thickness monitoring.
- Thickness checks on surface components.
- Caliper logs – pipe surface inspection.
- Annulus pressure trends.
- Design life.
- Well history.
- Defects.
- Pressure monitoring and pressure tests.
- Wellhead visual leak detection and condition check.
- Downhole video (where available).



Well Review – Historic data

All of the relevant well history data will be collated to provide a detailed “life story” of the well. This is intended to cover everything from the original well design (casing, tubing, cementing

etc.); through the drilling and construction phase - to ensure the design was fit for purpose at the time of completion to as much detail as possible on the well's operation history. This last part may involve a very large volume of data covering a wide range of topics including, but certainly not limited to production chemistry, flow rates, age, known problems etc.

Well Review – Current status

All of the current data on the well (tubular condition, temperature, pressure, chemistry, flow rate, etc.) will be reviewed to determine the well's current status which will then used be for comparison to its "as new" condition and design. At the end of this review the well will be ranked using "a traffic light ranking system" with high integrity issue wells in red, medium range in yellow and low integrity concerned wells in green.

5.2 Presentation of Results

The initial part of the report will take the form of an "evaluation matrix", followed by a detailed analysis of each well as shown below.

The matrix approach provides a specific cell for each component on each well. So that it is readily apparent which components have data missing as the cell is empty, while the 'traffic light' colour coding identifies problem components. This process gives a qualitative assessment of the wells. The matrix strategy can also be used for quantitative assessment of the well stock. Rather than entering a comment in each cell, each component will be assigned a numeric value scored against pre-set criteria. Numeric values can be weighted and manipulated to give a quantitative assessment for each well. This method is utilised when there is a requirement for Risk Ranking of the wells.

In addition to the final evaluation matrix rating of each of the wells a report will be produced for each one. This will detail the input data provided to Expro with particular attention being paid to the quality of the data and any assumptions made in the absence of inputs. Following this data review recommendations for further investigation may be made in order

to eliminate some of the assumptions made and allow a fuller understanding of the well's current condition.

Once the status of the well is fully understood, the report will then detail proposed remedial actions to reduce the risk level associated with the well (if relevant) or guide lines for the continued operation of the well in its current status. Where recommendations are made a new lower risk ranking will also be produced (assuming the success of the remedial actions) in order to illustrate the benefit from the remedial actions. In the event that the risk in the well cannot be reduced to satisfactory level consideration of well abandonment techniques may be included in the report if required.

A final report section will investigate commonalities between wells which become apparent from the evaluation matrix. Where these are identified they can act as warnings about other wells; however, due to the relatively small sample size (approximately 20 wells) it may not be possible to apply the conclusions of the study widely across the fields being investigated.

Each well in the report is evaluated based upon various criteria, and ranked accordingly as shown below:

- Age
- CO2 percentage in gas
- H2S percentage in gas
- Free flow capability
- Production/Injection rate
- Well head flowing pressure
- Well head shut in pressure
- Water cut
- Gas oil ratio
- External Corrosion Risk

Well Number	Well Type	Hazard Review	Combined Integrity Status
121	Water dump flooder	48%	67%

Wellhead and Annulus – No recorded results of tree valve testing being carried out. Investigation of the tree reported that it is badly corroded and the integrity has failed. Reported that the tree is due for a replacement. Due to the concern with the tree integrity and no recorded results for the A1 and A2 annuli pressure (possible compromise of annuli integrity) it was marked as a high priority.

Surface Casing – 13 3/8" casing –No reports recorded on losses and or returns while carrying out the cementing operations. High possibility of contact with acquifer. Due to the corrosive nature of the acquifer the integrity of the casing could be at risk.

Production Casing – 9 5/8" casing - Past experience has shown that auto dump wells are prone to extensive corrosion. Due to the age of this well integrity issues through corrosion are a concern, although good cement across the aquifers is anticipated.

6 Operational Well Integrity Training

The primary tenet of Well Engineering is to “maintain the pressure vessel” throughout the lifecycle of a well. In addition to being a professional ethic, it is also a statutory requirement by regulatory authorities in most countries and jurisdictions.

While Well Engineers are employed in the construction, intervention and repair of wells, production personnel are principally involved in the operation and routine maintenance of the Xmas Trees, with little exposure to what lies below the tree flange. As a result, production technicians often have a limited understanding of WHY they are bleeding down / topping up of annuli etc. and the consequences of failing to maintain the well within guidelines.

Following several high profile hydrocarbon releases on the UK Continental Shelf (UKCS) suffered by a number of operating companies and service providers, Expro formed an improvement group as a pro-active preventative measure. The primary objective was to eliminate uncontrolled releases of hydrocarbons from operational activities. A comprehensive review of UK hydrocarbon releases concluded that the principal causes were

equipment failure, inadequate isolation or operator error. Further evaluation established underlying 'softer' root causes such as communication, training and supervision.

In order to address this deficit, EWS has since 2003 provided training on "Operational Well Integrity" for about 2000 people of different production disciplines from technicians, operators, engineers & management. These candidates have come from many different oil & gas companies in a variety of locations both in the UK and globally.

6.1 Course Objectives

There are four key course aims:

- Improve the delegates' appreciation of the well design and annulus construction, i.e. the well as a "pressure vessel".
- To provide the delegate with knowledge & understanding of the guidelines and standards that when observed and implemented effectively will ensure well integrity.
- Establish an increased awareness of well integrity issues and how they are controlled / managed and by whom.
- To provide the delegate with knowledge of how to maintain equipment for safe and effective operation.

From these the delegates will be able to:

- Identify well problems from available well data.
- Understand guidelines, procedures and standards.
- Appreciate design intent of completion equipment and their impact on well integrity.
- Be conversant in the care and operation of surface intervention equipment.

6.2 Course Content

The detailed course content will be agreed with the customer; however the following topics will be covered:-

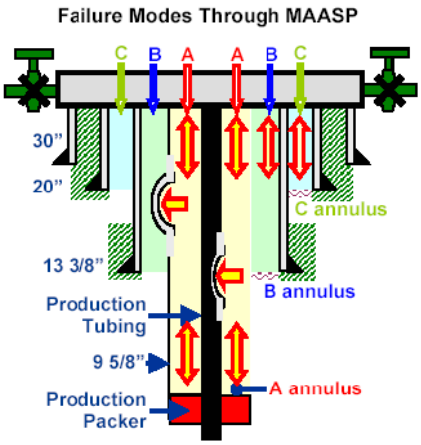
- Introduction.
- Overview of legislation, recommended practices & international standards.
- Well Construction & Completion Design (casing depths, grades & strengths and completion components).
- Threats (H2S, CO2, Sand, Wax & Asphaltenes, Hydrates).
- Xmas Trees and Wellheads (Types of wellheads and maintenance).
- Annulus Management (Pressure monitoring, fluid composition).
- Completion Management (Logging- multi fingered calliper, sonic & thermal wall thickness).
- Well Integrity Management System (What a WIMS should be).

6.2.1 Well Construction and Annulus Pressure Limits

- Casing Design
- Factors Affecting the Annulus
- Thermal Effect on Annulus Fluids
- Annulus Monitoring
- Formation Strength & MAASP
- Triggers and Working Pressures
- Hydrates, Scale, Wax & Asphaltenes
- Sand Production & Well Bean-up
- Guidelines
- Impact of H2S and CO2
- Produced Water
- Well Intervention Chemicals
- Annular Top - Ups

6.2.2 Well Completion Components

- Completion Diagrams
- Completion Components – Tubing Hanger,
- Tubing, Subsurface Safety Valves,
- Side Pocket Mandrels, Wireline Entry Guide
- Tubing Design and Function
- Wellhead Equipment
- Tubing - Annulus Relationship & Failure Modes
- Casing and Annulus Failure Modes
- A Annulus and Tubing Barriers and Failure Modes
- Methods of Pressure Equalisation



6.2.3 Practical Aspects

• Surface Tree Maintenance • Valve Requirements for ESD • Requirements for Valve Testing • Solid Block or Split Gate Valve • Valve Gates and Seals • Split Gate Valve Sealants • Filling the Body Cavity with Grease, Types of Grease and Types of Guns • Releasing Pressure and Pressure Locked Valves • Stinger Tools • Types of Buried Check valve	

6.2.4 Facilities

The course is supported by poster sessions, videos and case histories to highlight the key points raised during the day. Each of our expert trainers has over 10 years operational experience in some of the world's most hazardous environments. Training can be provided at our client's offices, in Expro's Centre of Excellence in Aberdeen or at a 3rd party facility e.g. Hotel.	

At the end of the course the delegates undertake a short test and are then presented with a certificate of attendance and a manual containing the entire course content as a personal copy.

7 Independent Well Examination Services

Expro Well Services (EWS), being totally independent from operating companies, has provided a well examination service for many years to various oil & gas companies, helping them comply with the **D**esign & **C**onstruction **R**egulations 1996 SI 913; rule 18 which states the following:-

> *2) The arrangements referred to in paragraph (1) are arrangements in writing for such examinations, by independent and competent persons, of any part of the well, or similar well, information, or work in progress, and the making of such reports and recommendations, as are suitable for ensuring (with the assistance of such other measures as the well-operator takes) that the well is so designed and constructed, and is maintained in such repair and condition, that—*
>
> *(a) so far as is reasonably practicable, there can be no unplanned escape of fluids from the well; and*
>
> *(b) risks to the health and safety of persons from it or anything in it, or in strata, to which it is connected, are as low as is reasonably practicable.*
>
> *(7) For the purpose of this regulation a person shall be regarded as independent only where:-*
>
> *(a) his examination will not involve the consideration by him of an aspect, of a thing liable to be examined, for which he bears or has borne such responsibility as might compromise his objectivity; and*
>
> *(b) he will be sufficiently independent of a management system, or of a part thereof, which bears or has borne any responsibility for an aspect, which he might consider, of a thing liable to be examined, to ensure that he will be objective in discharging his function.*

This service usually entails the examination of various programs detailing major changes which take place during intervention operations. Such operations may be Xmas tree change out, the insertion of a velocity string, tubing replacement and many other permanent changes. Normal intervention operations are not affected by this rule.

8 Gap Analysis – WIMS

8.1 Effective Management Systems

Expro Well Services (EWS) has frequently reviewed existing well integrity management processes and procedures in conjunction with legislation and industry practices. Expro uses the "Gap Analysis" process to determine if an Operator is maximising industry Well Integrity best practices to the full potential. Then once the "Gap" has been identified, Expro recommends and supplies solutions to fill that gap. Effective management systems are created by addressing the recommendations outlined in the Gap Analysis. By doing so, the system helps ensure that:-

- Zero incidents or accidents associated with Well Integrity management activities
- Zero lost production (volume) due to well integrity issues
- Zero reportable hydrocarbon spills / releases attributable to loss of well integrity
- Zero dispensations in place for more than one year
- All planned maintenance completed on time
- Well Integrity management system audit schedule on target
- All well-handover documentation – complete and delivered on-time

EWS can assist with this objective by reviewing the key elements of effective Management systems such as:-

- Operating Philosophy
- Roles and Responsibilities
- Policies and Standards
- Procedures and Processes
- Audit and Feedback

EWS has wide experience of reviewing existing systems to ensure that well integrity is being managed efficiently by Operators and this can then demonstrate the client's commitment to corporate and social responsibility.

Dependent on the client's requirements, this ranges from a brief review or audit of existing systems or processes, through to the design and implementation of a bespoke WIMS system to the Operator's requirements.

8.2 Example Gap Analysis Results

Gaps that have been identified for clients have included:

- not being up to date with the relevant aspects of legislation
- not using accurate maintenance & testing practices
- not restructuring reporting criteria
- below standard well life cycle management
- not having a clear and defined barrier policy
- not having an examination policy
- inadequate company Policies & Procedures

A Gap Analysis might identify these possible outcomes:-

Strengths:-

- Experienced personnel
- Good well file system
- Skilled WIMS team
- Current WIMS manual available for further development

Opportunities:-

- WIMs Improvement
- Define roles and responsibilities
- Classify and Risk Ranking of wells
- Implement industry best practices
- Improve management reporting
- Online database

Weaknesses:-

- Well Integrity envelope not defined
- Clarify roles and responsibilities within WIMS

Threats:-

- Existing corrosion issues and accelerating corrosion problems
- High annulus pressures
- Lack of available spares
- Poor documentation handover
- Staff shortages

9 Maximum Allowable Annulus Surface Pressure (MAASP)

Expro Well Services (EWS) provides services to ensure that a client's annulus well integrity is maintained in both new and existing wells. For any annulus the MAASP is the highest surface pressure that can safely be applied to that annulus without the danger of exceeding the safe operating pressure of any component within the well. In order to achieve this, a number of load cases have to be taken in to account. These will include some of the following, although not all of the cases listed below will be applicable in every annulus.

- Inner tubular collapse
- Outer tubular burst
- Formation leak-off
- Wellhead pressure rating
- Packer pressure rating
- Previous test pressures

In order to account for changes in the well condition over time it may be necessary to de-rate the tubular burst and collapse pressure ratings to account for corrosion and wear. These de-ratings can come from either inspection logs or models. In addition, changes to the fluid pressure gradients may also have to be taken into account.

The approach used for MAASP calculation within Expro Well Services was developed in conjunction with Mike Murray, head of well integrity at ExxonMobil.

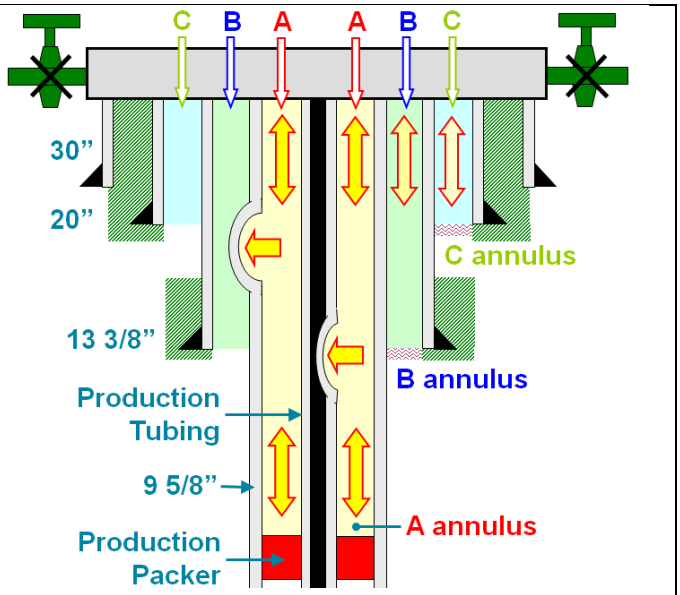
9.1 MAASP Definition

MAASPs and Acceptable Leak Rates for valve testing need to be periodically reviewed based upon changing well conditions.

It is important to consider the following when recalculating MAASP.

- Wall thickness loss (wear / corrosion)
- Fluid gradient changes
- Permeable zone pressure changes
- Equipment working pressure ratings

In order to determine the MAASPs for a well it is necessary to take a number of factors into account. These can be summarised as the pressures existing within the well and the capability of the well to resist them, with the MAASPs being the margins by which the capabilities of the well exceed the pressures within it.

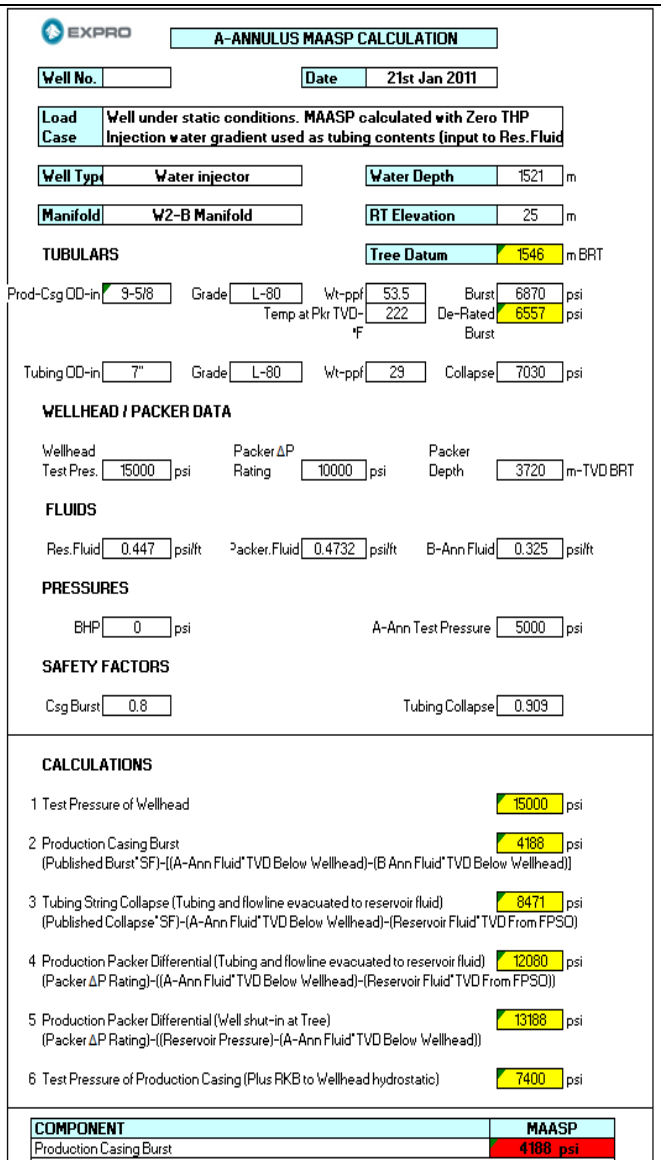


In addition the pressure regime in the formation surrounding the well and the isolation of the well from the formation need to be considered in MAASP calculations.

The pressures within a well are governed by the reservoir pressure and the hydrostatic pressure exerted by fluids within the well. Overtime the reservoir pressure may decline and the contents of the well change with each of these variations having an influence on the pressure loads within the well.

The capability of the well to resist pressure loads come from the burst and collapse pressure ratings of the tubulars, their connections, the completion equipment and the wellhead. However, a number of influences (including wear, corrosion, embrittlement, high temperatures and many more) can reduce the strength of well components and have to be taken in to account during the life of the well.

Our calculation method is shown opposite and this has been used to determine MAASP for a number of operators.



EXPRO

A-ANNULUS MAASP CALCULATION

Well No.		Date	21st Jan 2011
Load Case	Well under static conditions. MAASP calculated with Zero THP Injection water gradient used as tubing contents (input to Res.Fluid		
Well Type	Water injector	Water Depth	1521 m
Manifold	W2-B Manifold	RT Elevation	25 m
		Tree Datum	1546 m BRT

TUBULARS

Prod-Csg OD-in	9-5/8	Grade	L-80	Wt-ppf	53.5	Burst	6870 psi
				Temp at Pkr TVD-°F	222	De-Rated Burst	6557 psi
Tubing OD-in	7"	Grade	L-80	Wt-ppf	29	Collapse	7030 psi

WELLHEAD / PACKER DATA

Wellhead Test Pres.	15000 psi	Packer ΔP Rating	10000 psi	Packer Depth	3720 m-TVD BRT

FLUIDS

Res.Fluid	0.447 psi/ft	Packer.Fluid	0.4732 psi/ft	B-Ann Fluid	0.325 psi/ft

PRESSURES

BHP	0 psi	A-Ann Test Pressure	5000 psi

SAFETY FACTORS

Csg Burst	0.8	Tubing Collapse	0.909

CALCULATIONS

1	Test Pressure of Wellhead	15000 psi
2	Production Casing Burst (Published Burst*SF)-[(A-Ann Fluid*TVD Below Wellhead)-(B Ann Fluid*TVD Below Wellhead)]	4188 psi
3	Tubing String Collapse (Tubing and flowline evacuated to reservoir fluid) (Published Collapse*SF)-(A-Ann Fluid*TVD Below Wellhead)-(Reservoir Fluid*TVD From FPSO)	8471 psi
4	Production Packer Differential (Tubing and flowline evacuated to reservoir fluid) (Packer ΔP Rating)-((A-Ann Fluid*TVD Below Wellhead)-(Reservoir Fluid*TVD From FPSO))	12080 psi
5	Production Packer Differential (Well shut-in at Tree) (Packer ΔP Rating)-((Reservoir Pressure)-(A-Ann Fluid*TVD Below Wellhead))	13188 psi
6	Test Pressure of Production Casing (Plus RKB to Wellhead hydrostatic)	7400 psi

COMPONENT	MAASP
Production Casing Burst	4188 psi

9.2 MAASP Considerations

In defining a MAASP for each annulus the following considerations need to be made:-

9.2.1 Casing Wear

This can have a significant effect on downgrading burst and collapse figures. It is normally taken into account at the design stage and is monitored during well construction. Casing wear is estimated by considering the following:-

- Number of sidetracks in a well.
- The dog leg severity of the wellbore, or sidetrack.
- Speed of rotation.
- BHA round trips.
- Fluid in the hole.
- Casing grade.
- Tooljoint hardbanding.

If wear predictions have been carried out on a number of wells and compared to caliper data then a feel for the level of conservatism can be gauged and the model data used in the other wells. However the use of model data without any inspection data to verify it should be treated with caution.

9.2.2 Casing Corrosion

This can have an effect on metal loss if a continuous feed of hydrocarbons containing CO_2 and / or H_2S is introduced into an annulus. However a leak path from tubing to annulus will normally allow only a small quantity of hydrocarbons to be introduced at any one time. There then exists effectively a static annulus condition which results in more protective corrosion films than the corrosion models suggest, but reliable information to verify this is scarce. Corrosion due to oxygen ingress at surface can be a significant problem, this is normal mitigated by the use of corrosion inhibitors and oxygen scavengers in the completion fluids or positive pressure in the annulus.

9.2.3 Tubing Corrosion

During its service life the tubing in any well is continuously exposed to the produced (or injected) fluids. If these fluids contain significant amounts of water or other corrosive agents

(most commonly CO_2, H_2S or O_2) the corrosion rate on the inside of the tubing may be sufficient to greatly reduce its capability to resist pressure and leading to burst or collapse failures.

To account for the above factors reducing the wall thickness the tubular strengths used in the calculations can be reduced by or more of the following:

- By a fixed amount per well to account for wear or historic corrosion
  - Inspection data
  - Wear modelling
- By an amount per year to account for corrosion
  - Corrosion modelling
  - Inspection data
  - Data from offset wells

9.2.4 Deepest Packer

If calculating the worst case MAASP for the A annuli, then for any well the highest differential pressure will occur just above the packer. In the case of multiple packers the highest pressure will be located at the deepest packer and it is this depth that should be used.

9.2.5 Fluids

The highest 'A' annulus fluid weight possible should be used in calculations, generally this is the heaviest of the original fluid in the annulus and the formation water. The lowest bottom hole pressure and fluid weight possible in the completion (often produced gas) are also used in order to maximise the collapse load on the tubing.

The weight of the fluids present in the well also influence the burst load on the Production Casing and in this instance the lowest pressure gradient possible should be used in the B annulus with the A annulus fluid as described previously.

9.2.6 Gas lift

The presence of gas lift in part (or all) of the A annulus has a large impact on the hydrostatic pressure, which in turn has to be accounted for in the calculation of the MAASP values. In

order to account for the uncertainty in the annular liquid level and composition a number of assumptions about the hydrostatic pressure in the A annulus are made during the MAASP calculations. One approach taken for gas lifted wells is as follows:-

- Tubing contents are lift gas
- Original (pre-gas lift) A annulus contents for tubing collapse and production casing burst
- All outer annuli unaffected by lift gas

9.2.7 Physical environment

The environment the tubulars are operating in can have an influence on their pressure rating with the yield strength of steel being reduced at high temperatures and tensile loads acting to reduce the burst pressure of non-cemented tubing and casing.

10 SPE & Other Published Technical Papers

Expro Well Services (EWS) has published a number of technical papers, often jointly with our clients, to ensure that learnings are passed across the industry.

10.1 SPE Papers

- SPE 142449 “The Seven Pillars of Well Integrity Management’’, The Design and Implementation of a Well Integrity Management System in Tullow Oil. Simon J. Sparke / Tullow Oil plc, Richard Conway & Simon Copping / Expro, 2011.

- SPE 123201 “A Systematic Approach to Well Integrity Management”, Alex Annandale, Marathon Oil UK; Simon Copping, Expro, 2009.

10.2 Other Papers

- “Improving Well Integrity Management through Computerised Maintenance Systems”, A.B.M. Nor, S.S.A.B.A. Ghani, S. Copping, R. Conway and A.J.A. Fleming, Expro, 2009.

10.3 Conferences

- *Our presentation titled “Improving Well Integrity Management through Computerised Maintenance Systems” was selected as a backup presentation for Offshore Middle East, 2008.*

- *"Well Integrity: Completions & Maintenance", Pre-conference workshop and main conference presentation. IQPC, Kuala Lumpur May 2006.*

- *SPE Applied Technology Workshop "Well Integrity Management", Scheveningen, Netherlands, October / November 2005 (two presentations).*

- *SPE/ICoTA Coiled Tubing & Well Intervention Roundtable – Pre-Conference Workshop "Well Integrity Management Systems", AECC, November 2004.*

10.4 Publications

- "Well Design and Intervention", Chapter 6 in "The Technical and Legal Guide to the UK Oil and Gas Industry" Sept 2007. Edited by John Wils & Ewan C. Neilson, published by Aberlour Press.

- "Well Integrity Management – Securing the Future", Richard Conway, Simon Copping and Ian Fraser with Claire Strachan. Scandinavian Oil & Gas Magazine, No. 9/10 2006, Volume 34. P.24-26.

- "New Tool for Well Integrity Management" Richard Conway, Simon Copping and Ian Fraser. Hart's Exploration and Production, May 2006, P.85-86.

11 Clients & Track Record

Expro Well Services (EWS) has delivered Well Integrity Services to many Oil and Gas Operators and in many different countries. Further details on specific projects are available upon request. These clients include:-

12 Expro Well Services in support of Well Integrity Services

Well Integrity Services are only a part of the portfolio of services from Expro Well Services (EWS). EWS also supports well integrity through the following services:-

12.1 Well Service Supervisors

Expro Well Services provides Well Service Supervisors (WSS) to oversee wellsite operations. We currently employ more than 50 WSS's typically with over 10 years experience. Their role, typically as the Operator's representative at the well-site, although still an Expro employee, is to ensure that the operations are delivered safely, professionally, cost effectively, and without environmental harm. They are responsible for ensuring that all the client's policies, procedures and programmes are accurately followed and ensuring that all contractors, whether Expro or others, adhere to the client's expectations. They typically report to the onshore client well engineer.

The services provided cover all aspects of well servicing activity from office-based programming, planning and co-ordination to wellsite supervision. Our worldwide experience extends across different well conditions, from shallow land gas storage wells to highly complex deepwater HPHT environments. We assist with all types of well activity, including:

- Workovers.
- Completions.
- HWO (Hydraulic Workover Operations).
- Coil Tubing operations.
- Wireline operations.
- Well Testing operations.
- Downhole Stem Testing.
- Subsea operations.
- Fracturing operations.
- Stimulation operations.
- Acidizing operations.
- Completions including intelligent completions.
- Water shut-off operations.
- Abandonment operations.
- Electric line logging operations.
- Perforation (Wireline, TCP, Slickline) operations.

12.2 Wellhead Maintenance Services

Expro have been managing wellhead maintenance services since 1992. We have experience of providing routine and non-routine maintenance campaigns.

Expro has established relationships with original equipment manufacturers (OEMs) including: Cameron, McEvoy, Vetco, FMC and Seaboard Lloyd. Through Oilfield Maintenance and Repair Limited we have access to non-OEM specialist wellhead maintenance providers able to repair or replace parts to certified specifications.

12.3 Well Engineering

EWS provides well engineering services through the provision of high calibre engineers and support staff using advanced processes and systems. Our staff can be based either within the EWS offices or on secondment at the client's premises. This service is very flexible and can be customised to the needs of the client. Our well engineers will work stand alone, or embedded in the client's operations team as part of a specific project in a continuous well engineering support function.

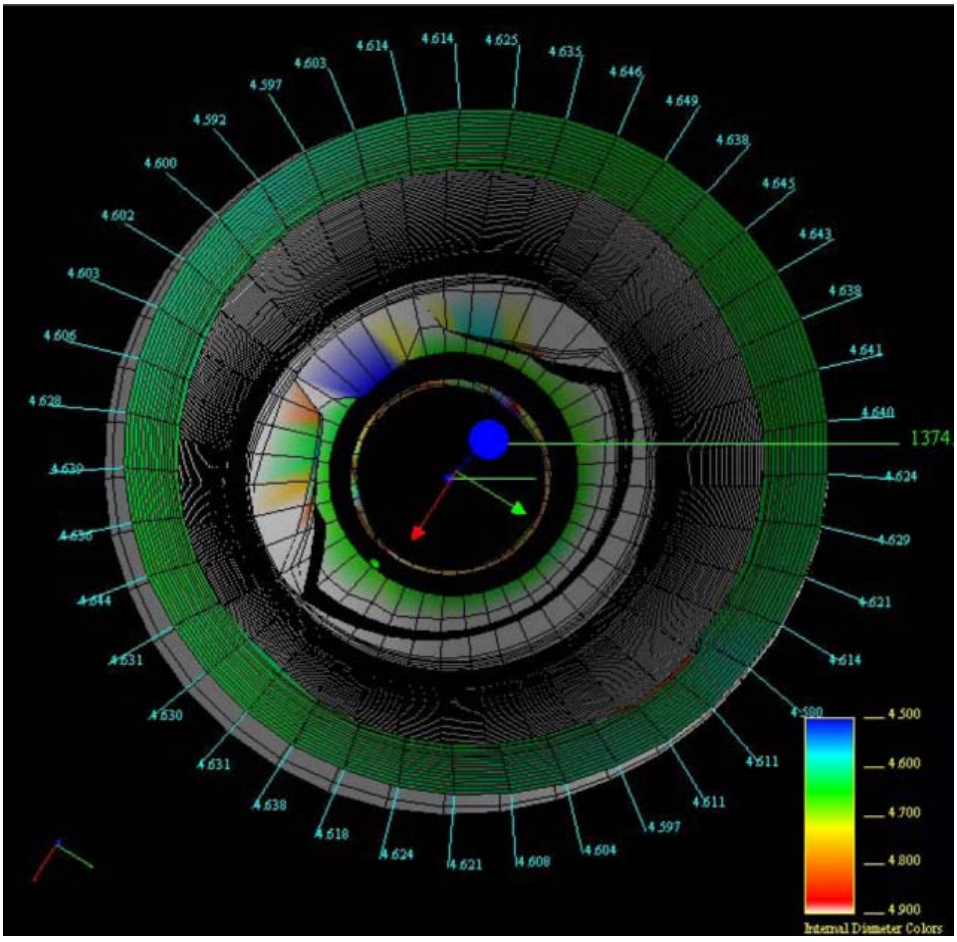
EWS Well Engineers manage, plan, design, organise and prepare well programmes for our clients across the complete range of well services activities including:-

- Completions, (land, platform and subsea).
- Workovers.
- Well tests.
- Well Intervention operations, (well maintenance, coiled tubing, Nitrogen, pumping, E- line, slickline etc).
- Well Integrity planning, scheduling and testing.
- Well Abandonment planning.
- Wellhead maintenance scheduling and planning.

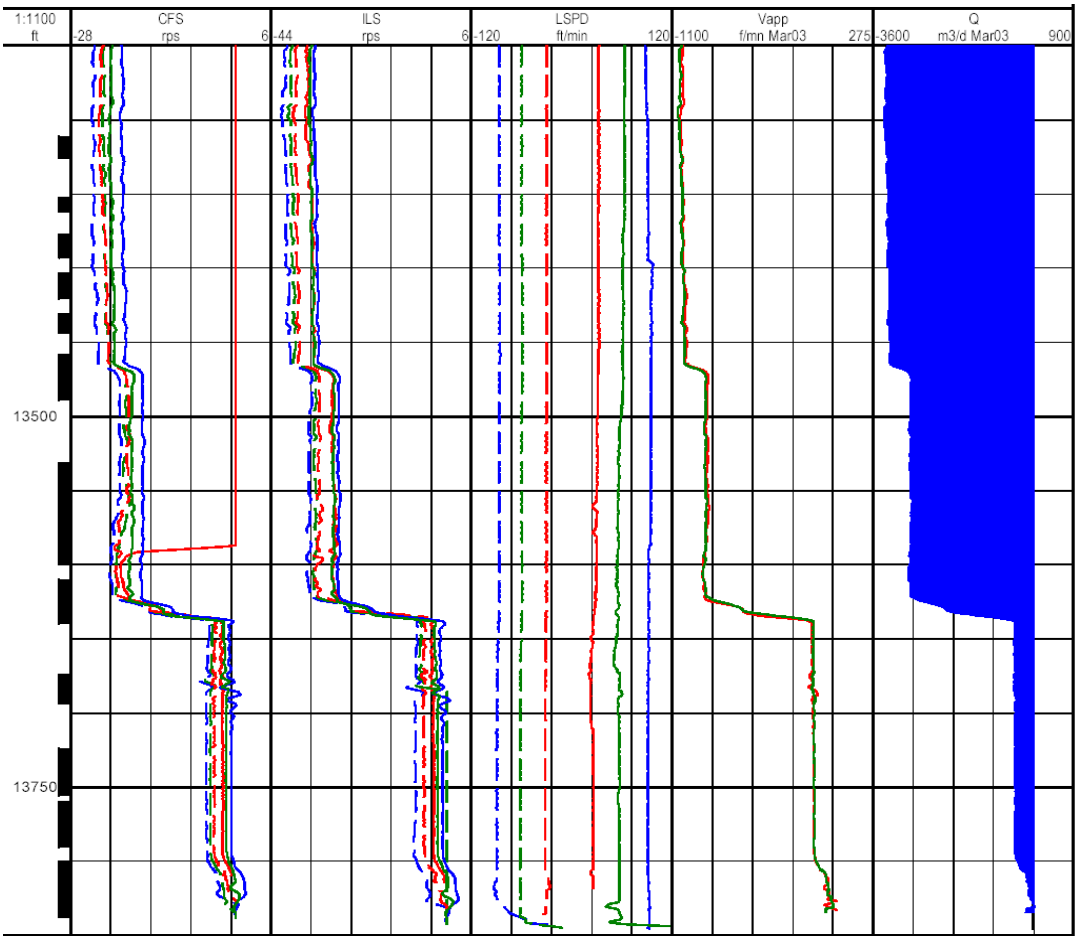
12.4 Cased Hole Logging – Data Analysis

Expro Well Services (EWS) provides data analysis and interpretation services for well integrity and production logging:-

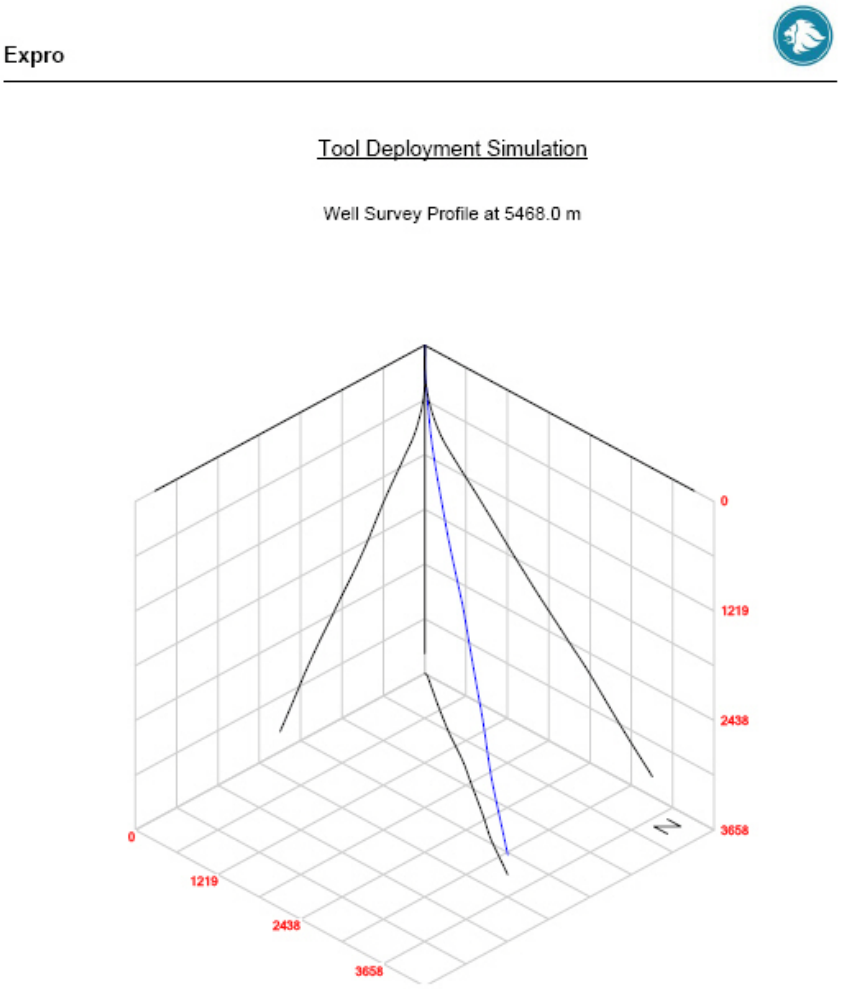
Well Integrity: Detailed reporting plus 3D imaging provides operators with precise and comprehensive visualisation of interpreted corrosion on internal tubulars. EWS uses MIPS software in the interpretation of multi-caliper data from both Expro and third party logging data.



Production Logging: Detailed 2 – and 3-phase analysis and interpretation of vertical, deviated and horizontal Production Logging data from both Expro and 3rd party raw log data. Expro uses industry standard Emerauld and PLWin software packages.



Cerberus: Expro are licensed to use Cerberus software for Wireline intervention modelling. Data collect manually during the operation is used to validate the Cerberus predictions and increase the software accuracy for future models. Using the simulation models helps to ensure cables are not needlessly placed under stress and reduces the likelihood of unproductive wireline runs



A fast turnaround service is provided, when required by the client, for all these services.

13 Expro Group in support of Well Integrity Services

Expro Group is a major service provider globally of slickline and braided line services, as well as electric line and dual-drum wireline services. These services include the latest generation wireline units and PCE and fully trained and competent personnel.

13.1 Wireline Services

Expro is a major service provider globally of slickline and braided line services, as well as electric line and dual-drum wireline services. These services include the latest generation wireline units and PCE with fully trained and competent personnel.

Expro operates the largest fleet of rental wireline equipment in Europe and deploys the largest pool of wireline specialists operating from established support bases.

Expro boasts impressive stocks of leading edge technology and also equipment for traditional solutions which include:-

- Multi-function wireline units capable of slickline and logging operations for use in both offshore and onshore locations.
- Pressure control equipment, in bore sizes suitable for 7-3/8” completions and for HPHT wells.
- A vast array of equipment for the manipulation of downhole products.

Highly innovative and cost effective slickline cased hole logging services such as dynamic depth measurement, memory and real time production monitoring and well integrity logging, RF safe explosive initiation systems for production enhancement and abandonments.

SlimLine Double Drum Winch Unit

The SlimLine design is a single piece winch unit comprising of an integral power pack, enclosed operator cabin and double drum winch section. The winch section is fitted as standard with a 0.125” cable for slickline operation and a 7/32” braided cable for fishing operations, cable combinations can be altered to match client requirements. The system can also be utilised for cased hole logging operations using a 7/32” mono-conductor cable and a data logging cabin.

Unit features include;

- Single piece containerised design
- Four cylinder, water cooled 72hp diesel engine power pack
- ATEX certified zone 2
- Operator cab module can be fitted with a SmartMonitor
- Field proven reliable closed loop hydraulic system for superior winch control
- Capable of running speeds from 3 ft/min to 3,000 ft/min
- Double drum supplied with 0.125" Slickline and 7/32" Braided Line for fishing operations
- Sound insulated engine compartment
- Integrated drip tray
- Small foot print
- Single lift design

Pressure Control Equipment

Expro supply Pressure Control Equipment (PCE) packages ranging from 3" to 7 3/8" for slickline and braided line operations. The majority of our pressure control equipment is rated to 10,000 psi safe working pressure and suitable for H2S service. It is designed, built and tested to API 6A standards and accredited by third party verification.

Each item is clearly identifiable, with a unique identifying number and marked with maximum working pressure and temperature rating. All maintenance is performed and documented in accordance with the Expro quality system.

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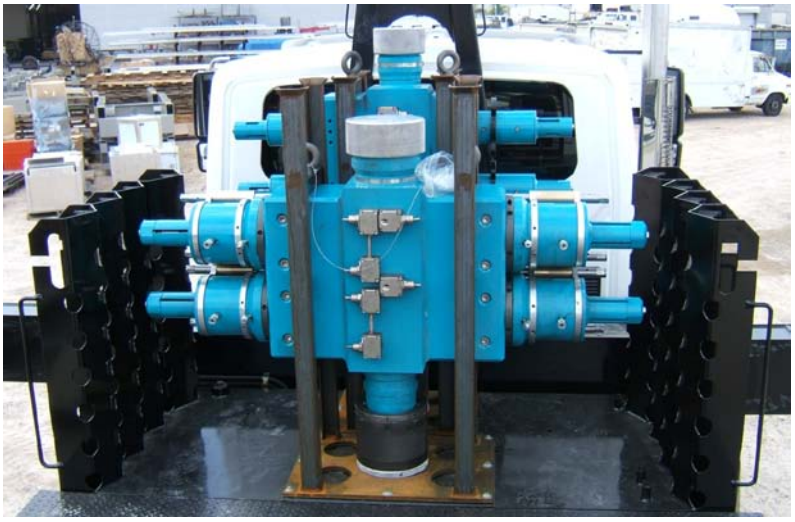


13.2 Cased Hole Services

Expro provides a range of well intervention services for proactive monitoring and problem identification. Once a problem has been diagnosed, Expro can provide a suite of wireline deployed solutions to identify and resolve well integrity issues. Expro's well integrity services can be deployed on slickline, electric line, coil tubing or well tractor depending on the application.

Multi-Finger Calipers

Expro's multi-finger calipers have been setting the standard for corrosion and deformation measurement. Expro's Kinley calipers provide a cost-effective, slickline deployed caliper measurement for tubulars from 2 3/8" to 13 3/8". The all-mechanical Kinley calipers provide high reliability and are uniquely suited to HP/HT wells with a temperature rating of 600°F. The DigiCal service provides rapid turn-around wellsite logs, enabling on the spot decision making. Complementary to Expro's suite of Kinley calipers, is its range of electronic calipers. Deployed on electric line, slickline or coil tubing these use state-of-the-art technology in the

form of either 1 11/16" 24 arm tools or 2 3/4" 40 arm tools. These provide a radial resolution of 0.005" and a vertical resolution of 0.14" at 50 feet per minute logging speed. Expro's Cased Hole Logging Data Analysis Services support both electronic and Kinley calipers, providing rapid turnaround detailed analysis using 3D imaging software. The raw data is processed to remove tool and wellbore effects to provide the operator with a three dimensional view of the tubulars plus a detailed analysis of any anomalies.

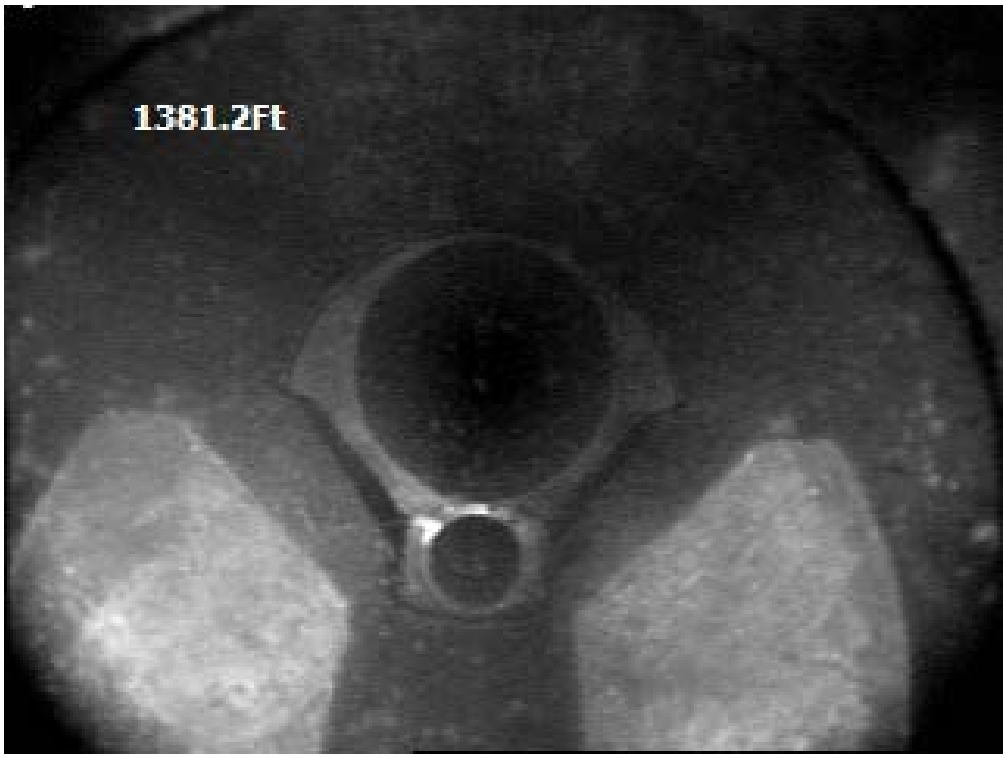
Magnetic Thickness Services

Calipers can also be combined with Magnetic Thickness Tools (MTT) to quantify the thickness of metal in the casing or tubing and thus provide an accurate internal and external profile of the wellbore. Twelve miniature magnetic sensors mounted on bowsprings investigate variations of metal thickness within the downhole tubulars. 3D visualisation software can then be used to provide powerful images of well condition, which allow both internal and external pitting and gradual wall loss to be detected.

Downhole Video Services

Whereas calipers and thickness tools provide a qualitative log which then has to be interpreted, Downhole Video gives a real picture of the wellbore. Allowing scale, perforations or holes in the tubing to be seen rather than inferred, enables correct decisions to be made first time round. Extremely portable, the HawkEye III downhole camera can be deployed on any electric line and transmits up to 1 picture per second. The slickline camera, which can take 200 pictures per run, is ideal for looking at specific objects. Expro's Downhole Video technology combined with our engineers' expertise ensures that we deliver quality downhole pictures:-

- Identifying damage and restrictions
- Locating holes and pitting
- Scale and wax build-up
- Size, location and condition of perforations
- Monitoring screen condition
- Corrosion identification
- Chemical treatment verification
- Whipstock and window inspection



CalVid Services

Expro's CalVid service combines its electric line deployed 40 arm electronic caliper with its HawkEye III video system to give a complete picture of the tubular internals. When running in the well, a picture of the wellbore is taken every second. When bottom is reached the caliper is opened and logged out of the hole, providing a traditional caliper log. If zones of interest are identified, they can be inspected in detail with the camera. Both caliper log and video can then be displayed using specialist software. The combination of visual images plus accurate caliper measurements provides a strong tool for problem qualification and quantification.

14 Contact Details – Expro Well Integrity Services

Expro Well Integrity Services is a key part of Expro Well Services and the key personnel, all based in Aberdeen, are as follows:-

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