Well integrity; past, present and future
This is where it all began. Spindletop 1901
Spindletop, April 2013.
• Company footprint
  – Present in 25 countries as operator and partner
  – 150 + licences worldwide
  – 60+ producing fields
  – 1,700 + employees

• Africa's leading independent oil company

• Worldwide production 90,000 BOEPD
  – 100 operated wells
  – 1200 non-operated wells

• TEN project, deepwater offshore Ghana approved and bid evaluation underway

• Awaiting approval for several field developments in Uganda

• Appraisal drilling in Kenya and Ethiopia
A History of Well Integrity

1969
Santa Barbara Blow out

1970
1973
API 14B

1972
SSSV patented

1974
API 14C

1977
Ekofisk Blow out

1979
Ixtoc Blow out

1980
1990
2000

1986
NORSOK

1987
Development of Sintef equipment reliability data base

1988
Piper Alpha

1988
Ocean Odyssey

1996
DCR-96

2001

2003
Chongquing Blow out

2004

2006
Abu Dhabi SPE ATW

2005
The Hague SPE ATW

2007
Perth & Barcelona SPE ATW

2008
Abu Dhabi SPE ATW

2009
Chester, SPE ATW

2010
Macondo Blow out

2012
Elgin gas leak

2013
Edinburgh, Doha & Malaysia SPE ATW

2007
Perth & Barcelona SPE ATW

2005
The Hague SPE ATW

2008
Abu Dhabi SPE ATW

2009
Chester, SPE ATW

2010
Macondo Blow out

2012
Elgin gas leak

2013
Edinburgh, Doha & Malaysia SPE ATW

United States Patent

Taylor, Jr.

[54] WELL FLOW CONTROL VALVES AND WELL SYSTEMS UTILIZING THE SAME
[72] Inventor: Donald F. Taylor, Jr., Dallas, Tex.
[73] Assignee: Otis Engineering Corporation, Dal-

isa, Tex.

Filed: Dec. 18, 1970

Appl. No. 99,634

U.S. Cl. 166/315, 137/384.R, 166/224

Int. Cl. 137/384.R, 166/224

Field of Search 166/224, 224.S, 315,

127/384.R, 630.19

Reference Cited

UNITED STATES PATENTS

3,543,793 12/1970 Dollison

3,310,114 3/1967 Dollison

R25,471 11/1963 Fred

ABSTRACT

A valve for installation in a flow conductor for con-
trolling flow of fluids through the conductor, which may be controlled from a remote point and which may act automatically as a safety valve, including means for positively propping the valve in the open position to hold the same in such open position when desired, for performing various well service operations through the valve, for taking the valve out of operation per-
manently or for flowing the well without affecting operation of the valve, and further including means for locating and operating a supplemental flow control valve at such point in the flow conductor. Also in-
cludes a removable restraining device for holding the valve in the open position which is movable to a posi-
tion freeing the valve for normal functioning.

24 Claims, 17 Drawing Figures
Oil Reserves Per Region

- Middle East (61%)  750 x 10^9 Barrels
- South America (11%)  135 x 10^9 Barrels
- Africa (10%)  125 x 10^9 Barrels
- E Europe + FSU (8%)  100 x 10^9 Barrels
- N America (5%)  60 x 10^9 Barrels
- Asia (4%)  42 x 10^9 Barrels
- W Europe (1%)  13 x 10^9 Barrels

Worldwide Total Oil Reserves  1225 x 10^9 Barrels
Who has regulations today?

= Regulations
Active Oil + Gas Wells Per Region (2013)

North America:
- 560,000 Active Oil Wells +
- 840,000 Active Gas Wells +
- 500,000 Active Water Injection, water disposal Wells

South America:
- 70,000 Active Oil Wells

West Europe:
- 6,200 Active Oil Wells

East Europe & FSU:
- 120,000 Active Oil Wells

Asia:
- 89,000 Active Oil Wells

Middle East:
- 12,200 Active Oil Wells

Africa:
- 10,000 Active Oil Wells

Source: Gulf Publishing, EIA, EPA, IHS

+/- 870,000 oil wells +
+/- 840,000 gas wells +
+/- 500,000 water wells

33 x Co2 wells, 3 x N2 wells and 2 x Helium wells
## Consider The Environment We Work In

<table>
<thead>
<tr>
<th>Location</th>
<th>Tree Type</th>
<th>Production Environment</th>
<th>Production Process</th>
<th>Design Hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onshore</td>
<td>Dry Trees</td>
<td>Arctic</td>
<td>Natural Production</td>
<td>Corrosion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jungle</td>
<td>Artificial Lift</td>
<td>Seismic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Desert</td>
<td>Water Injector</td>
<td>Pressure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sparsely Populated</td>
<td>Gas Injector</td>
<td>HPHT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Densely Populated</td>
<td>Co2 Injector</td>
<td>Sand</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hurricane</td>
<td>Water Disposal</td>
<td>Scale</td>
</tr>
<tr>
<td>Offshore</td>
<td>Dry Trees &amp; Wet</td>
<td>Monsoon</td>
<td>Cutting Disposal</td>
<td>Water</td>
</tr>
<tr>
<td></td>
<td>Trees</td>
<td>Manned</td>
<td>Steam</td>
<td>Weather</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unmanned</td>
<td>Coal Bed Methane</td>
<td>Paraffin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mountains</td>
<td>Fireflood</td>
<td>Asphaltene</td>
</tr>
</tbody>
</table>
Perceptions of value differ

Drillers Vs Petroleum Engineers
Well lifecycle and ownership

Design & construction  Well production  Well intervention  Well intervention  Well abandonment

Well handover  Well handover  Well handover  Well handover

0  5  10  15  20  25
Years  Years  Years  Years  Years  Years
Well integrity related software

• Tullow has mandated the use of key software packages -:
  – Well construction, workover and well intervention – **WellView**
  – Well Integrity Management System (WIMS) – **SafeWells**
  – Well failure databases – **WellMaster, RIFTS**....

• All of these are linked and form a software tree

• The Tullow Production Well Integrity Policy also sets out the standards and requirements for all well owners.
  – One Policy worldwide
    • Barriers, testing frequency of valves, responsibilities,.....
  – Compliance is monitored and reported though monthly reports and well examination
Well handover requirements

3. Well construction and flow assurance details

Detailed casing schematic to include; Casing weight, sizes, Grades, and Thread Types.

Cement (Cement types, tops, volume pumped/returned in each string), number and location of centralisers.

Detailed completion schematic complete with depths (TVD and MD) plus tubing details (tubing weights/sizes/threads/grades), cross over + component details (type/model/manufacturer & part numbers, pressure rating & thread types)

Christmas Tree and Wellhead schematic to show key components (Valves + blocks) & include: manufacturer, valve size, type, PSL rating, valve serial number manual/hydraulic, turns to open/close OR seconds to close for actuated valves, bore size, pressure rating, grease type and volume in each chamber, pressure test certificates.

SCSSSV data - Type, size, rating, valve serial number, bore size, hydraulic fluid type and volume

SCSSSV data - valve signature curve

Annulus fluids (Fluid details; type & volumes, details of inhibitors & scavengers).

MAASP/MAWOP (including the basis for calculation on each annulus) and maximum allowable tubing pressures.

Well barrier envelope showing, primary and secondary barriers their status, identification of each well barrier element its depth and associated leak or function or pressure test verification of component parts. Any failed or impaired well barrier element shall be clearly identified.

Deviation data (angle/MD/TVD, horizontal section, number of junctions)

Final Well Status at Handover (detail procedures or work that maybe required to start up a well - remove plugs, barriers)

Fish (Provide details of any fish left in the well including depths and sizes)

Final well status at abandonment (casing tops, cement plug details to include volumes, tops, pressure test details)

Seabed and site survey (wet trees only)
Well Integrity Matrix – Component Parts

- OPERATING ENVELOPE
- ELECTRONIC WELL FILES
- VALVE LEAK-TEST SCREEN
- BARRIER SCHEMATIC

SAFE WELLS ‘HOME PAGE’
WIMS = One Centralised Data Base

- Intervention Handover Docs
- Valve Change out
- Site Visit Report
- Dispensation Request
- Annulus Monitoring
- Inspection Data
- Tree/Wellhead Maint.
- Daily Prod Data
- Well Intervention Data
- Policies/Procedures
- Well Construction Data
- Barrier Diagram
- API/ISO Standards
- MAASP/MAWOP
- Well Construction & Handover Docs

25+ Different Drop Down Menus
MAASP Calculator

Well: B4  Current Annulus: A Annulus  Trigger Pressure Percentage: 80%
Type: Bangladesh Surface Tree  Change Selected Annulus: A Annulus  Minimum Pressure Percentage: 20%

Disclaimer

Please Note: The calculations provided below are based on the information entered into the calculator and should be reviewed along with the following questions before accepting the calculations:

1. Is the top of cement at the planned depth?
2. Was the cement job completed as planned with all the expected returns?
3. If a cement log was run what is the quality of the results and does this confirm quality of cement job?
4. Has the liner top packer been tested satisfactorily?
5. What is the strength of the previous casing shoe?
6. Are there multiple liner laps?
7. Is the reservoir depleted and what is the impact on the various components with weighted packer fluid and also in a gas well?
8. Do NOT exceed the maximum test pressure that the A annulus was subjected to during the completion phase.

<table>
<thead>
<tr>
<th>Component</th>
<th>Component Result</th>
<th>Trigger Pressure (80%)</th>
<th>Minimum Pressure (20%)</th>
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</thead>
<tbody>
<tr>
<td>Casing to 12476 feet</td>
<td>3733 Psi</td>
<td>2986 Psi</td>
<td>747 Psi</td>
</tr>
<tr>
<td>Packer to 11816 feet</td>
<td>6502 Psi</td>
<td>5202 Psi</td>
<td>1300 Psi</td>
</tr>
<tr>
<td>SSSV to 2736 feet</td>
<td>8499 Psi</td>
<td>5199 Psi</td>
<td>1300 Psi</td>
</tr>
<tr>
<td>Tubing to 11825 feet</td>
<td>1155 Psi</td>
<td>924 Psi</td>
<td>231 Psi</td>
</tr>
</tbody>
</table>
MAASP Calculator

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Text</th>
<th>Value</th>
<th>Sequence</th>
<th>Result</th>
<th>Unit</th>
<th>Component Mapping</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>OD</td>
<td>String (Outer Diameter)</td>
<td>4.5</td>
<td>4.5</td>
<td>4.50</td>
<td>inch</td>
<td>Stake Size</td>
<td>Edit</td>
</tr>
<tr>
<td>Weight</td>
<td>String Weight</td>
<td>17</td>
<td>17.00</td>
<td>17.00</td>
<td>lbs</td>
<td>Weight</td>
<td>Edit</td>
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<tr>
<td>Grade</td>
<td>Grade</td>
<td>A40</td>
<td>14000</td>
<td>14000</td>
<td>Psi</td>
<td>Yield</td>
<td>Edit</td>
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<tr>
<td>Conn</td>
<td>Connector Type</td>
<td>TAC-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Edit</td>
</tr>
<tr>
<td>ID</td>
<td>String (Internal Diameter)</td>
<td>3.5</td>
<td>3.50</td>
<td>3.50</td>
<td>inch</td>
<td></td>
<td>Edit</td>
</tr>
<tr>
<td>Thickness</td>
<td>Thickness ((OD - ID)/2)</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>inch</td>
<td>No Mapping</td>
<td>Edit</td>
</tr>
<tr>
<td>APIBurst</td>
<td>API Burst</td>
<td>7740</td>
<td>7740</td>
<td>7740</td>
<td>Psi</td>
<td>API Burst</td>
<td>Edit</td>
</tr>
<tr>
<td>APICollapse</td>
<td>API Collapse</td>
<td>6200</td>
<td>6200</td>
<td>6200</td>
<td>Psi</td>
<td>API Collapse</td>
<td>Edit</td>
</tr>
<tr>
<td>DT</td>
<td>DT</td>
<td>4.50/5.50</td>
<td>9.00</td>
<td>9.00</td>
<td></td>
<td>No Mapping</td>
<td>Edit</td>
</tr>
<tr>
<td>ACR</td>
<td>Average Corrosion Rate</td>
<td>0.02874</td>
<td>0.03</td>
<td>0.03</td>
<td>inch/Year</td>
<td>No Mapping</td>
<td>Edit</td>
</tr>
<tr>
<td>NY</td>
<td>Number of Years</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td></td>
<td>No of yrs</td>
<td>Edit</td>
</tr>
<tr>
<td>NT</td>
<td>New Thickness</td>
<td>0.50/180.893</td>
<td>0.20</td>
<td>0.20</td>
<td>inch</td>
<td>No Mapping</td>
<td>Edit</td>
</tr>
</tbody>
</table>

| DTWD   | OD/NT               |                                 |          |          |      |                  |        |
| WDB    | Wear de-rated Burst | 0.875*2*Yield%(100*(DTWD))     |          |          |      |                  |        |
| TDY    | Tension Derated Yield | 110000     |          |          |      |                  |        |
| WDC    | Wear de-rated Collapse | 0.875*2*Yield%(100*(DTWD))     |          |          |      |                  |        |
| TDF    | Temperature Derated Factor | 0.95      | 0.95     | 0.95     | %/degF |                  |        |
| GTG    | Geothermal Gradient | 85     | 85       | 85       |      | No Mapping        | Edit   |
| TBDS   | Temperature De-rated Burst | 108.82*1*(1-(0.05/100)*(85-70)) | 1088.82*1*(1-(0.05/100)*(85-70)) | 1081 | Psi | No Mapping | Edit |
| TBC    | Temperature De-rated Collapse | 30185*1*(1-(0.05/100)*(85-70)) | 30185*1*(1-(0.05/100)*(85-70)) | 29950 | Psi | No Mapping | Edit |
| MB     | Burst factor in MAASP Calculation | TDB | TDB      |          |      |                  |        |
| UC     | Collapse used in MAASP Calculation | TBC | TBC      |          |      |                  |        |
| D1     | RKB to WHD | 10000 | 10000    | 10000    | Ft   |                  |        |
| DPP    | Depth of Production Pack | 0           | 0        | 0        | Ft   |                  |        |
| MGA    | Mud gradient of Annulus | 5.4   | 5.4      | 5.4      | Psi/ft | No Mapping       | Edit   |
| MCTBG  | Mud gradient of Production Pack | 12.9 | 12.9     | 12.9     | Psi/ft | No Mapping       | Edit   |
| Tubing Collapse | Tubing Collapse | 1081.100000*(5.4.12.9)/10000 | 1555 | Psi | No Mapping | Edit |

Grade Sequence:
1. H40
2. SN55
3. S55 K55
4. N50

Component Mapping:
- Stake Size
- Weight
- Yield
- Conn
- ID
- ACR
- Neue
- DT
- DTWD
- OD/NT
- WDB
- TDY
- WDC
- TDF
- GTG
- TBDS
- TBC
- MB
- UC
- D1
- DPP
- MGA
- MCTBG
- Tubing Collapse

Action:
Edit
MAASP & Annular pressure management

- **MAASP** (Calculated in SW)
- **Upper threshold**
  - (80% of MAASP)
- **Working Pressures**
- **Lower threshold**
  - (20% of MAASP or > hydrostatic for subsea wells)
- **Zero**
  - Bleed down
If it is standard practice to provide an instruction booklet for a coffee maker why shouldn’t you get an instruction booklet for a well??

Tullow mandate this requirement so that a well montage can be built.
The Well Montage

### The Well Montage

#### A Annulus (DS Inner)
#### B Annulus (DS Outer)
#### C Annulus (LS Inner)
#### A Annulus (LS Outer)
#### Safety Valve

#### Secondary

- B Annulus (DS Inner)
- B Annulus (DS Outer)
- C Annulus (LS Inner)
- A Annulus (LS Outer)
- Swab Cap
- Prod/Inj Wing Valve
- Kill Wing Valve
- C Annulus
- A Annulus (DS Outer)
- B Annulus (LS Outer)
- C Annulus (LS Inner)
- A Annulus (LS Outer)

---

**Prepared by:** EXPROGROUPcopons
**Date Printed:** 20-Feb-13

---

### Casing

<table>
<thead>
<tr>
<th>No. Centraisers</th>
<th>Set Depths (m)</th>
<th>Set Depths (TVD) (ft)</th>
<th>String (O.D) (m)</th>
<th>String Grade</th>
<th>String (ID) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casing Intermediate Casing to 2444ft</td>
<td>2</td>
<td>812</td>
<td>780</td>
<td>1 3/4</td>
<td>L80 13 1/4</td>
</tr>
<tr>
<td>Casing Production Casing to 10370ft</td>
<td>4</td>
<td>3000</td>
<td>10300</td>
<td>7”</td>
<td>L80</td>
</tr>
<tr>
<td>Casing Production Casing to 7801ft</td>
<td>10</td>
<td>11000</td>
<td>10000</td>
<td>7”</td>
<td>L80</td>
</tr>
</tbody>
</table>

### Valves

- Following mechanical failure of the completion and subsequent SRE corrosion problems, B3 was worked over and the original carbon steel completion replaced with a 15Cr completion. The upper 10 sands were also perforated at that time.

<table>
<thead>
<tr>
<th>Valve Type</th>
<th>Acceptable Flow Rate (psi/min)</th>
<th>Manufacturer</th>
<th>Pressure Rating (psi)</th>
<th>Size</th>
<th>Test Pressure (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Annulus (DS Inner)</td>
<td>40</td>
<td>Cameron</td>
<td>10k</td>
<td>2 1/16</td>
<td></td>
</tr>
<tr>
<td>A Annulus (LS Outer)</td>
<td>40</td>
<td>Cameron</td>
<td>10k</td>
<td>2 1/6</td>
<td></td>
</tr>
<tr>
<td>A Annulus (LS Inner)</td>
<td>60</td>
<td>Cameron</td>
<td>10k</td>
<td>3 1/4</td>
<td></td>
</tr>
<tr>
<td>A Annulus (LS Outer)</td>
<td>40</td>
<td>Cameron</td>
<td>10k</td>
<td>2 1/6</td>
<td></td>
</tr>
<tr>
<td>B Annulus (DS Inner)</td>
<td>60</td>
<td>Cameron</td>
<td>5k</td>
<td>2 1/4</td>
<td></td>
</tr>
<tr>
<td>B Annulus (DS Outer)</td>
<td>60</td>
<td>Cameron</td>
<td>5k</td>
<td>2 1/4</td>
<td></td>
</tr>
<tr>
<td>B Annulus (LS Inner)</td>
<td>40</td>
<td>Cameron</td>
<td>5k</td>
<td>2 1/6</td>
<td></td>
</tr>
<tr>
<td>B Annulus (LS Outer)</td>
<td>40</td>
<td>Cameron</td>
<td>5k</td>
<td>2 1/6</td>
<td></td>
</tr>
<tr>
<td>Kill Wing Valve</td>
<td>30</td>
<td>FMC</td>
<td>10k</td>
<td>4 1/6</td>
<td>5000</td>
</tr>
<tr>
<td>Lower Master</td>
<td>30</td>
<td>FMC</td>
<td>10k</td>
<td>4 1/6</td>
<td>5000</td>
</tr>
<tr>
<td>Prod/Inj Wing Valve</td>
<td>20</td>
<td>FMC</td>
<td>10k</td>
<td>4 1/6</td>
<td>5000</td>
</tr>
<tr>
<td>Swab Valve</td>
<td>30</td>
<td>FMC</td>
<td>10k</td>
<td>4 1/6</td>
<td>5000</td>
</tr>
<tr>
<td>TRECCEU Swab Valve Block</td>
<td>30</td>
<td>FMC</td>
<td>10k</td>
<td>4 1/6</td>
<td>2000</td>
</tr>
</tbody>
</table>

### Gauges

- A Annulus
  - Last Calibrated: N/A
  - MAASP psi: 0
  - MAWOP: 1000
  - Min psi (20%): 1000
  - Trigger psi (80%): 1000
- B Annulus
  - Last Calibrated: 2006-04-01 0:0
  - MAASP psi: 0
  - MAWOP: 1000
  - Min psi (20%): 1000
  - Trigger psi (80%): 1000
- C Annulus
  - Last Calibrated: N/A
  - MAASP psi: 0
  - MAWOP: 1000
  - Min psi (20%): 1000
  - Trigger psi (80%): 1000
- TMP gauge
  - Last Calibrated: 31 August 2007
Simple add-in to collect construction data
While this may seem ideal, as an industry we could/should share more information and reduce risks further:
- Expand the well failure databases through JIP’s
- Make use of SINTEF blowout database to assist in likelihood hydrocarbon releases
- Share more information on abandonment issues
- Share more information on lessons learned

In 2014, ISO/TS 16530-2 Well Integrity Part 2, Well Integrity for the Operational Phase is published.

In 2015, EU directive on ‘Offshore Safety’ takes effect. The impact on European countries will be large, and by definition, there will NOT be a common set of rules EU wide.
The WellMaster database only has +/- 5,000 wells –
   - These are mainly North Sea with some West Africa and are principally subsea wells
   - Very few are artificial lift
   - Very few are intelligent completions
   - Limited tree or wellhead data is included

RIFTS ESP database has 100,000 well entries
RIFTS PCP database has 80,000 well entries

Why don’t we have more data available from the 2,000,000 + wells?
We have been mountain climbing in flip flops
What is next?

• Tullow Oil has taken the initiative to implement the industry sharing more of its information in a way that will help us globally build and manage the well stock more efficiently.

• Supposing you had access to a database that listed ‘0000s of wells worldwide and helped you decide what completion worked best in what environment. You could potentially reduce your workover frequency, reducing costs, maintain production/injection levels and improve the well economics, improve safety.

• Industry wide we have Wellmaster + RIFTS for ESP and PCP + George King (Sandface), and the Tullow initiative is aiming to pull much of this together in one usable package.
The initiative

- The International Technology Facilitator (ITF) is launching a JIP for a worldwide well failure database.
  - Annual fee is estimated to be +/- $50K, but more participants means lower charges
  - It is estimated that this will be functional in 1 or 2 years
- Well types to be included
  - ESP (SRP/ESP/PCP)
  - Dry and subsea wells
  - All components from christmas tree to mule shoe including sand screens, casing.....+ more
- Several international and major companies are interested
- For more details contact me simon.sparke@tullowoil.com
The future....
Competencies