Well-Integrity Operations at Prudhoe Bay, Alaska

Well integrity spans the entire life of the well. The issue of sustained casing pressure (SCP) on the annulus of a well has shaped current well-integrity practices. The well-integrity-management system used at Prudhoe Bay has been evolving since field startup in 1977. Extensive experience has resulted in the design and management of systems to ensure safe operations and compliance with industry standards, regulatory-agency requirements, and internal company policies. The full-length paper details the operational and well-intervention phases of well life and discusses evolution of the well-integrity-management system.

Introduction

BP Exploration (Alaska) Inc. is operator of the Prudhoe Bay field, on the north slope of Alaska. There are approximately 1,330 wells in the field including 416 gas lift, 591 naturally flowing, and 323 injectors. Wells produce at rates as high as 10,000 BFPD and 100 MMcf/D. Gas-injection wells inject as much as 250 MMcf/D. Tubing sizes vary from 3 1/2 to 7 in. to accommodate the range of rates. Shut-in tubing pressure on naturally flowing wells is 2,400 psi. Produced gas contains 20% CO_2, resulting in the extensive use of corrosion-resistant alloys for well tubulars. A 2,000-psi gas lift system pressure is available, resulting in as much as 2,000-psi shut-in pressure on gas lift wells and the potential for as much as 2,000 psi on well annuli. **Fig. 1** illustrates a typical completion.

Well integrity is defined in the NORSØK Standard D-010 (developed by the Norwegian petroleum industry) as the "Application of technical, operational, and organizational solutions to reduce risk of uncontrolled release of formation fluids throughout the life cycle of a well." This is a highly effective definition and has been adopted by BP in Alaska.

Well-Integrity-Program Design

Well integrity has been an ongoing effort throughout the history of Prudhoe Bay. During the design phase, all potential uses for the well should be considered, including conversion to artificial lift and injection and well-operating and -servicing requirements. Regulatory requirements and industry standards are available to guide the drilling and completion phase, but there are few guidelines for the operation, production, and workover phases.

Well-integrity engineering was managed as a component of a production engineer's job responsibilities until the mid-1980s. Because well integrity can present potential conflicts with production delivery contracts, the well-integrity programs were unified under one position, the well-integrity engineer, in 2000.

Industry standards, regulatory requirements, company standards, and local events are evaluated and incorporated into the Prudhoe Bay well-integrity system. These are summarized in the Alaska "Well Integrity System Policy." Each operational group, such as drilling, well operations, and the well-integrity team, has further refined these requirements into standard operating procedures (SOPs) used by engineers, operators, and technicians during performance of their job duties.

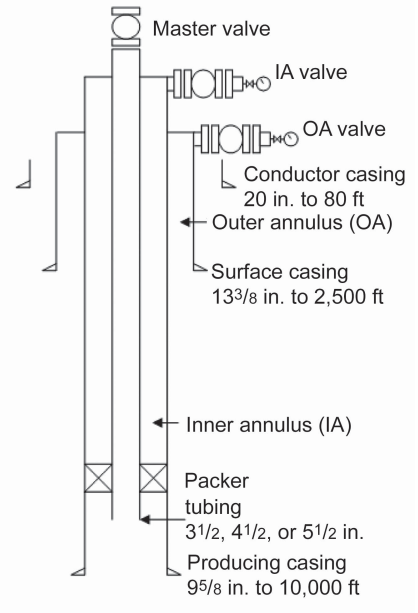

Fig. 1—Typical Prudhoe Bay well completion.

Industry Standards. Industry standards relating to well integrity are evolving. The NORSØK Standard D-010, "Well Integrity in Drilling and Well Operations," deals primarily with barrier-system design and maintenance. An American Petroleum Inst. recommended practice for annular casing-pressure management for offshore wells currently is in draft.

Company Requirements. BP has several internal standards relating to well integrity. The "Integrity Management" standard sets corporate expectations, specifying requirements such as use of qualified personnel, procedures, and management of change processes. The "Drilling and Well Operations Policy"

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For a limited time, the full-length paper is available free to SPE members at www.spe.org/jpt. The paper has not been peer reviewed.

provides specific requirements relating to well design and operations. The "BP Guidance Document for Well-Integrity Minimum Expectations" is focused on well-integrity operations and provides detailed requirements.

Regulatory Agencies. The primary regulatory agency in Alaska is the Alaska Oil and Gas Conservation Commission. Before the Well A-22 incident, regulations pertaining to well integrity were focused on injection and naturally flowing wells. After the Well A-22 incident, regulatory requirements were reviewed and additional requirements were implemented related to frequency of annulus-pressure recording, reporting of potential anomalies, and actions to take when certain pressure limits are reached.

Local Events. Incorporating lessons learned from local events into operating procedures, policies, and training materials helps reduce the chance of a reoccurrence of these events.

In August 2002, a BP Alaska field operator was injured when the surface casing on Well A-22 failed catastrophically as a result of thermally induced overpressure. An in-depth review of the well-integrity-management system was initiated after this incident, and numerous changes were made. More than 200 procedures were reviewed, and well-integrity operations were consolidated into a single operational SOP. All annulus pressures are entered daily into a database. Wells with annuli having pressures higher than the maximum-allowable working pressure (MAWP) or exhibiting other indications of mechanical anomalies are reported to the well-integrity engineers for further review.

SOPs. Specific procedures and processes to ensure implementation of the Well Integrity System Policy requirements are contained in the SOPs of each functional group. For example, drilling guidelines specify barrier-system and pressure-test requirements for new wells. Operations SOPs require pressure gauges on all annuli and specify frequency of inspection, data-entry requirements, and procedures to manage SCP.

Well-Integrity-Program Structure

The well-integrity program is structured around seven elements specified in the "BP Guidance Document for Well-Integrity Minimum Expectations." These elements are the following.

- Accountability and responsibility.
- Well operating procedures.
- Well intervention procedures.
- Tubing- and casing-integrity program.
- Wellhead and tree maintenance.
- Safety-valve maintenance.
- Knowledge of standards.

Accountability and Responsibility. Clear identification of responsibilities and accountabilities is key to managing well integrity. An individual is designated as the well-integrity technical authority (WITA) and is accountable for delivery of the overall well-integrity program. The wells manager is designated the WITA and also manages the well-intervention and rig-workover programs.

Implementation of the program is the responsibility of a well-integrity coordinator. The well-integrity team consists of two well-integrity engineers who respond to anomalous well reports, coordinate field crews, and execute project work such as wellhead and surface-casing repairs. A field crew of eight downhole diagnostic technicians conducts well bleeds, pressure tests, waiver compliance testing, and other well-integrity-related activities.

Responsibilities of wellsite leaders, field operators, and drilling and production engineers are contained in the SOPs used by each group. In addition, periodic audits are conducted.

Well Operating Procedures. Well operations account for the greatest portion of the life of a well. These operations are managed through a well-ownership-handover process, certified operators, effective procedures, and a corrosion-/erosion-management program. Access to well-status information allows operators to make better decisions regarding well operations.

Handover. Clear assignment of responsibility regarding well ownership is key to safe well operations. Well ownership is transferred between drilling, operations, and the well-service teams several times during the life of a well. Drilling normally "hands over" wells to operations with two competent well barrier systems. Generally, the primary well barrier system consists of the tubing, packer, jewelry such as gas lift mandrels, and competent wellhead equipment. The secondary well barrier system consists of the production casing and competent wellhead equipment. Barrier acceptance criteria for drilling are well defined, and a pressure test of both barrier systems normally is conducted.

An important process is handover documentation from the well-construction team to production operations. Any well design feature of significance to the safety or operating efficiency of the well should be identified clearly in the handover documents. Handover also occurs between operations and the well-interventions team. A "Unit Work Permit" is used to transfer ownership. The permit communicates planned activities for the well, other operations on the wellsite that may affect the well service operations, a wellsite inspection, and a hazard review. Once service operations are complete, the permit is returned to operations with any changes or potential hazards noted.

Well Startup, Operating, and Shutdown Procedures. Written operating procedures have been developed for all well types and operating scenarios. Operators are required to pass exams on all procedures and have a peer review and signoff before being authorized to operate independently.

Well-Intervention Procedures. Well interventions temporarily extend the normal pressure-containing envelope of a well by use of a lubricator or additional surface piping and choke manifolds. To manage risk associated with these operations effectively, procedures, certified personnel, well-work documentation, and contingency plans are used. All well-service operations are performed following a written job program. Standard procedures have been developed for routine well interventions. All well-intervention activities are logged into a database. A summary of each well work activity is communicated by an automatically generated e-mail each morning. Planned well work activities are communicated by a 9-day well work schedule.

Tubing- and Casing-Integrity Program. Managing the barrier status of the well inventory is an important component of the well-integrity-management system. Detecting SCP on an annulus can result in well-intervention

operations and the well being shut in. Having clearly communicated pressure limits combined with an appropriate monitoring program helps identify and manage wells with mechanical anomalies. Training of operations personnel in wellbore mechanics helps them identify anomalies and initiate appropriate actions. MAWPs are assigned to all annuli. Well designs are similar, allowing standard pressure values to be used.

All online wells have functioning, readable pressure gauges on each annulus. When an annulus pressure higher than MAWP is identified, the operator is required to initiate action. They may bleed and record the bleed event in a database. If more than two bleeds per week are required to keep the pressure less than the MAWP, it is reported to a well-integrity engineer for further evaluation. During well-intervention activities, annuli pressures are monitored continuously.

Wells With Anomalies. A report called the "Well-Integrity Diagnostics Report" is used to aid in anomaly identification and track the status of wells with potential anomalies. Once identified with an anomaly, testing is conducted to gain a better understanding of the problem and assist in a decision to repair, waiver, or shut in the well.

Identification of Wells With Anomalies. Typical anomalies include sustained pressure on the IA caused by a tubing or gas-lift-valve leak, sustained pressure on the OA caused by a production-casing leak or shallow sands communicating up an open shoe, and production- and/or surface-casing leaks.

Evaluation of Wells With Anomalies. When evaluating a well with an anomaly for continued operations, the guiding principle for evaluation of well barrier systems is "two levels of protection." Some questions need to be addressed during the review of a well with an anomaly, such as: If the current pressure-containing envelope develops a leak, where will the pressure go and how will the newly pressured components react? When is a barrier system considered competent or effective? How much can a tubing string leak and still be considered an effective barrier system?

Data Management

Identification of Potential Anomalies. At 0400 hours each day, a computer program automatically starts and scans all pressure, well-test, and other data. It generates the "Well Integrity Diagnostics Report," listing wells with potential problems. This report is distributed automatically to the well-integrity engineers and other responsible/accountable parties by e-mail each morning, identifying wells with potential anomalies. Well-integrity engineers review wells on the report, determine if additional action is warranted, and then schedule remediation activities as appropriate.

Managers accountable for a particular area are kept informed of well status through a report called the "Area Management Report." This report is generated automatically each morning and e-mailed to managers, lead operators, and other individuals responsible for well operations in a particular area, and it includes sections listing wells with pressures greater than MAWP, wells needing safety valves tested, and other key performance indicators. JPT