

**Investigation of Explosion and Fire at Prudhoe Bay Well A-22  
North Slope, Alaska  
August 16, 2002**



**Alaska Oil & Gas Conservation Commission Staff Report  
November 17, 2003**

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## Acronyms

BPXA	BP Exploration (Alaska) Inc
AOGCC	Alaska Oil and Gas Conservation Commission
AAC	Alaska Administrative Code
PBU	Prudhoe Bay Unit
OA	Outer Annulus
IA	Inner Annulus
EOR	Enhanced Oil Recovery
SSV	Surface Safety Valve
TAPS	Trans Alaska Pipeline System
WIE	Well Integrity Engineer
TIO	Tubing, Inner Annulus, Outer Annulus
Psi	Pounds per square inch
SI	Shut in
DHD	Downhole Diagnostics
GC-3	Gathering Center 3
F	Fahrenheit
CO	Conservation Order
POP	Put on Production
TIFL	Tubing Integrity Fluid Level
MITOA	Mechanical Integrity Test – Outer Annulus
PPOT-IC	Positive Pressure Packoff Test – Inner Casing
MSCF	Thousand Standard Cubic Feet
AS	Alaska Statute
EWI	Edison Welding Institute

## Summary

Early in the morning of August 16, 2002 previously shut-in Prudhoe Bay Well A-22 failed catastrophically while being brought on production. A rapid release of gas from below the pad surface led to an explosion and fire that seriously injured a pad operator employed by the Prudhoe Bay Field operator, BP Exploration (Alaska), Inc. (BPXA).

A subsequent incident investigation by the Alaska Oil and Gas Conservation Commission (AOGCC or Commission) examined information gathered through field inspections, meetings, BPXA responses to AOGCC requests, public hearings, Commission review of well records, Commission review of BPXA operating policies and training programs, and interviews with operating personnel. The investigation disclosed the following:

- A-22 exhibited historical pressure in the casing annuli prior to August 2002. Approximately 1,300 psi was imposed in the inner casing annulus for artificial lift. Annulus pressure records indicated the historical outer casing annulus pressure to be approximately 600 psi.
- Pressure increased in the outer casing annulus from 600 psi to 1,900 psi sometime between July 24 and August 1, 2002; there is no pressure information between the two dates, and no information describing the cause of increased pressure in BPXA records.
- A-22 surface casing failed because internal gas pressure exceeded the casing's burst capacity. A-22 surface casing burst approximately 17 feet below the well pad surface. Excessive internal gas pressure was a direct result of well heating during start-up, acting on relatively high initial outer annulus gas pressure. No evidence suggests attempts were made to relieve initial annulus pressures from the well, reported by separate sources as ranging from 1,700 to 1,950 psi.
- High pressure gas from the A-22 outer annulus vented up the well's conductor by surface casing annulus, blowing well house wood flooring and gravel upward. Sparks from flying debris or damaged electrical equipment ignited escaping gas.
- A pad operator who had been restarting A-22 attempted to enter the well house, was caught in the blast, and received severe injuries.
- A single operator per 12-hour work shift was responsible for three production pads, containing more than 100 wells and associated facilities. Prior to the explosion, the operator found it necessary to leave the well, and the production pad, unattended.
- A BPXA internal waiver process is used to allow wells to continue in operation with annulus pressure communication. A temporary waiver was verbally issued on August 15, 2002, clearing A-22 to return to production. The waiver basis was a high fluid level in the outer casing annulus and a high imposed inner annulus pressure, which

BPXA interpreted to represent well integrity. Diagnostic testing in support of a permanent waiver was scheduled.

- No engineering analysis or other technical framework was found in BPXA's annular pressure management policies, operator training literature, or field actions leading to the A-22 restart that addresses the importance of controlling thermally induced well pressures prior to initiating well startup.
- Corrective actions to prevent future incidents similar to A-22 were initiated by BPXA and by the Commission.

## **PBU A-22 Accident Investigation August 16, 2002**

### **Incident Overview**

At about 9:37 PM on 8/15/2002, Prudhoe Bay Well A-22 (A-22) was restarted following repairs to surface production equipment. About five hours later, reported as 2:12 AM, 8/16/2002, A-22 failed catastrophically. High-pressure gas in the well's outer annulus (OA)<sup>1</sup> was released through a surface casing burst 17 feet below the well pad's surface, upward through the 20" conductor by 13-3/8" surface casing annulus<sup>2</sup>. The rapid release of annulus pressure caused loose materials in the wellhouse (gravel, foundation boards) to impact and damage the production tree, controls, and lights, resulting in an explosion and fire. The explosion seriously injured the Field Production Operator (Pad Operator) who was responsible for the well's operation. Lift gas from A-22's inner annulus (IA)<sup>3</sup> continued to jet through a damaged casing valve for several hours, until the annulus gas was depleted and response personnel regained well control.

### **Background Information**

Prudhoe Bay Well A-22 is located in the Western Operating Area (WOA), and operated by BP Exploration (Alaska) Inc. (BPXA). Sohio Alaska Petroleum Company<sup>4</sup> (Sohio) drilled A-22 in 1982 as a producing well. The well has produced nearly continuously since August 1984<sup>5</sup>. Well design includes 20" conductor casing, 13-3/8" surface casing, 9-5/8" production casing, 7" production liner, and 3-1/2" production tubing. Surface and production casing strings were successfully tested to 3,000 psi at installation. The well is configured for artificial lift, provided by injecting gas down the IA under controlled conditions. A-22 gas lift began during December 1986.

The Prudhoe Bay field is now undergoing enhanced oil recovery (EOR). Alternating volumes of water and enriched gas are injected via selected wells into the reservoir to raise pressure and sweep the producing zone of residual oil, increasing ultimate recovery. EOR began at A Pad in September 1985. Gas lift of A-22 was suspended in July 2002 since reservoir pressure had increased due to pressure support from the ongoing EOR, allowing the well to produce without gas lift.

### **AOGCC Investigative Strategy**

The A-22 incident led the Alaska Oil and Gas Conservation Commission (AOGCC or Commission) to investigate, seeking to determine (1) the incident's actual cause, (2) whether there is potential for another incident similar to A-22, and, if so, how it can be prevented, and (3) whether annular pressure regulations are needed.

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<sup>1</sup> OA – outer annulus; annular space between 13-3/8" and 9-5/8" casings in the well

<sup>2</sup> The 20" by 13-3/8" annular space is open at the casing hanger in the wellhead and is not designed to be a pressure containing barrier

<sup>3</sup> IA- inner annulus; annular space between the 9-5/8" production casing and the 3-1/2" production tubing

<sup>4</sup> Sohio later became Standard Alaska Production Company, and finally BP Exploration (Alaska) Inc.

<sup>5</sup> "Summary by Month: Individual Well Production"; PBU A-22; AOGCC database

AOGCC Petroleum Inspectors visited the site, documented the damage to A-22, and provided early insight into events. Periodic meetings with BPXA allowed AOGCC to gather information about A-22 and monitor BPXA's internal investigation. BPXA also provided information about other wells within Greater Prudhoe Bay exhibiting annular pressures, including wells that were deemed to be most similar to A-22. These early meetings helped the Commission prioritize effort into three principal focus areas:

- (1) Other wells - Numerous wells with annular pressures exist in the Prudhoe Bay Field. After the incident BPXA shut in numerous wells and others were targeted for integrity testing, diagnostics, or monitoring to assess risks related to annular pressures. Assessing the potential for another incident similar to A-22 and determining how to prevent such were AOGCC's highest priorities.
- (2) Regulation and inspection - Domestic and international regulatory strategies were reviewed. Policies of Alaska well operators were assessed, culminating in a public hearing to determine if annular pressure regulations were appropriate. The appropriate inspection response to wells affected by annular pressures was also assessed. Pool rules were amended to address annulus pressure.
- (3) Enforcement - Investigation sought to establish if there are grounds for enforcement proceedings according to 20 AAC 25.535.

An understanding of the precise A-22 failure mechanism was critical to each of the focus areas. To determine the cause of failure, the Commission approved BPXA's request to decomplete A-22. BPXA hired Edison Welding Institute, a reputable third party with pipe failure expertise, to evaluate A-22's damaged pipe.

The Commission reviewed the following information during its A-22 investigation:

- (1) Well design - Permit to Drill and Subsequent Reports; casing and cementing records; pressure tests.
- (2) Drilling history - AOGCC records and BPXA information.
- (3) Workover history - AOGCC records and BPXA information.
- (4) Pressure history - BPXA data beginning August 2001; IA pressures imposed due to gas lift.
- (5) Safety devices - Surface safety valve (SSVs) test data.
- (6) Inspection reports - Inspections of the critical operations (equipment recovery, witnessing pressure tests) during the Well A-22 decompletion.
- (7) Casing failure analysis<sup>6</sup>.

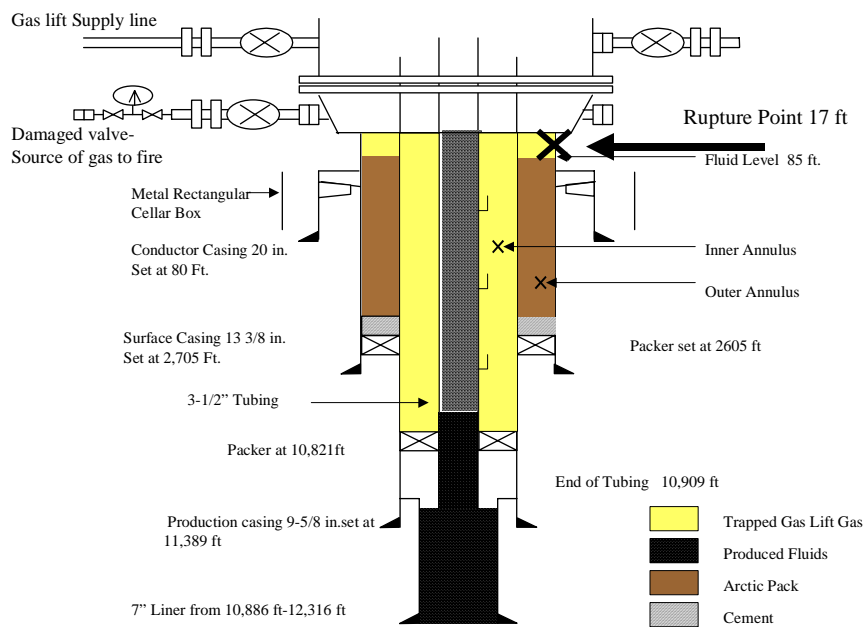
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<sup>6</sup> Edison Welding Institute, Project #46381CSP-04 – "Analysis of A-22 Casing Failure"

(8) BPXA annular pressure policies.

(9) BPXA training programs.

In addition, AOGCC interviewed several witnesses involved in pre-explosion work on A-22. The Commission aimed to assess the witnesses' knowledge of the incident and understanding of BPXA annular pressure policies then in effect. AOGCC also sought an understanding of the experience and extent of training of personnel involved in operating wells affected by annular pressures. Interviewed were the Well Integrity Engineer, two A-Pad Operators, and the Field Operations Team Leader.



**Figure 1: Well A-22 Schematic<sup>7</sup>**

<sup>7</sup> "Prudhoe Bay Well A-22 Incident Review", BP, September 17, 2002



## Discussion

Timeline. AOGCC met with BPXA periodically following the A-22 explosion, coincident with an ongoing BPXA investigation. Numerous information requests by AOGCC and responses by BPXA occurred during the early phase of this investigation. A chronology of these including a brief summary is included in the Appendix. Figure 1 is a schematic of A-22 at the time of the incident, annotated with information about the casing failure and fluids released. A timeline beginning July 24, 2002 (Table 1) for A-22 was constructed. Dates, activities, and pressures used to construct the timeline did not always agree. After initial efforts to resolve the differences, it was deemed unnecessary to devote significant additional time since the differences do not impact overall findings.

Recorded Prudhoe Bay well pressures are maintained in separate databases by BPXA engineers and by pad operators. BPXA's annular pressure database indicates no communication between A-22's casing annuli prior to July 24, 2002. The IA pressure (1300 psi) noted on July 24, 2002 was gas lift pressure, which was maintained in the IA despite gas lift not being required. OA pressure reported in the BPXA database from August 2001 to August 2002 was approximately 600 psi. BPXA interpreted the pressure differential as demonstrating well integrity. Pressure monitoring was apparently conducted each day, although data were not recorded between July 24 and August 1, 2002. IA and OA pressures in the pad operator database between August 5 and August 15, 2002 were inconsistent with information in other data sources provided by BPXA. It remains unclear if pad operator pressures are actual readings or interpolations from previous readings.<sup>8</sup>

The Trans-Alaska Pipeline System (TAPS) shut down on July 26, 2002 resulted in the shut in of A-22. Efforts to freeze protect A-22 for a short duration shut in included pressuring up the tubing with lift gas. High OA pressure was identified on August 1, 2002 with notification to the BPXA Well Integrity Engineer on August 4, 2002. It is possible that high OA pressure existed before August 1 but no information exists to confirm this. Completion of TAPS work and the restart of processing facilities allowed A-22 to be restarted on August 5, 2002 with annular pressures bled frequently during the restart. No diagnostics were performed to determine the source of the sudden OA pressure increase or evaluate the well for continued operation. It is not possible to determine, based on the information presented, if freeze protection had anything to do with the high OA pressure. There was also no explanation as to why three days elapsed between identifying high OA pressure (exceeding the 1,000-psi OA pressure threshold established in BPXA policy<sup>9</sup>) and reporting to the Well Integrity Engineer (WIE) for an engineering analysis of the change in well conditions.

A subsequent shut in of A-22 occurred on August 9, 2002 due to a compressor shut down at Gathering Center 3 (GC-3); that shut down lasted approximately two days. Subsequent well re-

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<sup>8</sup> "A-22 Casing Failure" – compilation of information provided by BPXA on August 23, 2002; table titled "A-Pad Well Readings"

<sup>9</sup> "Alaska Drilling and Wells, Standard Operating Procedure: Tubing/Annulus Communication and Annulus Monitoring Policy" – Sections 5.1 and 5.2. Document is part of the BPXA "Standard Operating Procedure: Annulus Communication and Monitoring Policy"; revised 3/21/01

start was interrupted after 1.7 hours because of a leaking check valve in the A-22 flow line.<sup>10</sup> No prolonged production occurred from A-22 until the well was again put on production on August 15, 2002. High OA pressure was noted on August 14, 2002 and the pad operator bled it. Notice was provided to the BPXA Well Integrity Engineer on August 15, 2002 after the OA repressured to 1,950 psi.

Date	Activity/Event	TIO Pressures (psi)	Remarks
7/24/02	Producing	238/1300/600	No gas lift (since 7/02?); last documented pressures prior to 8/1/02
7/26/02	A-22 shut in	No data	TAPS shut down
8/1/02	A-22 remains shut in	SI/2000/1900	First documented evidence of OA tracking IA pressure
8/4/02	A-Pad Operator notifies WIE of high OA pressure	SI/2000/2000	Pre-bleed pressures
	DHD crew bleeds OA pressure	SI/2000/350	Post-bleed pressures
8/5/02	A-22 put on production	300/1500/500	GC-3 restart (TAPS work completed); pressure bled frequently during restart
8/9/02	A-22 shut in	300/1350/600	GC-3 compressor K-5500 shut down
8/10/02	A-22 remains shut in	300/1350/600	
8/11/02	A-22 put on production	300/1350/600	Compressor K-5500 back on line
	A-22 shut in after 1.7 hrs production		Flow line check valve leaking (source: production records)
8/12/02	A-22 remains shut in	No data	
8/13/02	A-22 remains shut in	300/1350/600	
8/14/02	A-Pad Operator bled OA pressure (0030 – 0050 hrs)	SI/??/2000	Pre-bleed pressures
	A-22 flow line “safed out”	SI/??/200	Post-bleed pressures
8/15/02	A-22 remains shut in	SI/2000/1800	Prepare for check valve replacement
	Check valve replaced		Flow line “safed in” @ 1600 hrs
	WIE contacted by A-Pad Operator about OA		@1630 hrs; possible IA x OA communication
	OA fluid level by DHD crew		OA fluid level @ 85 ft TIO = 1840/2000/1950 psi
	WIE returns call to A-Pad Operator; “temporary waiver”		1735 hrs; ok to put on production; monitor OA; 2000 psi pressure limit
	A-Pad Operators change-out		Debrief regarding A-22 condition
	A-22 put on production @ 2135 hrs	No data	No gas lift (production records); well temp 40F
8/16/02	A-14 put on test	No data	0150 hrs per Pad Operator notes
	A-22 explosion and fire	No data	0210 hrs; Pad Operator injured

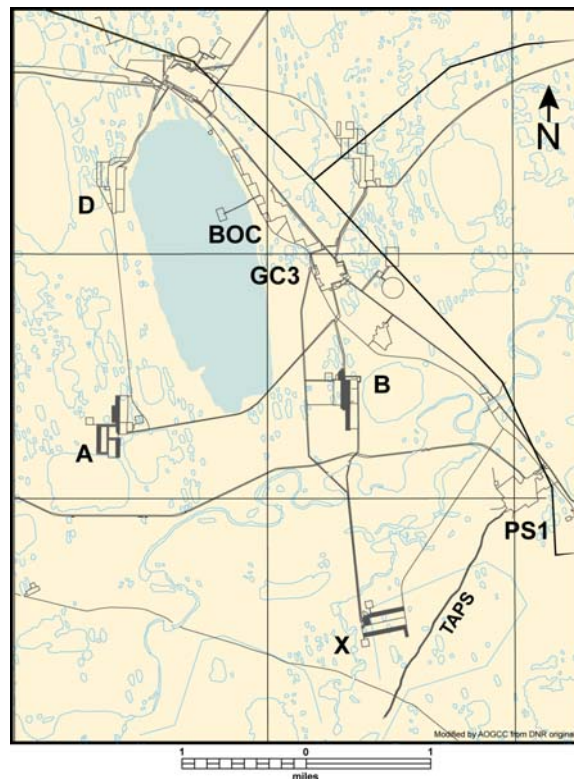
**Table 1: Well A-22 Timeline**

The WIE issued a temporary waiver (verbal) from the well operating in BPXA’s annulus pressure policy on August 15, 2002 allowing A-22 to return to production with annular pressure up

<sup>10</sup> “A-22 Casing Failure” – compilation of information provided by BPXA on August 23, 2002; Production tab - “A-22 Production Rates and SI Status”

to 2,000 psi.<sup>11</sup> BPXA’s annular pressure management program allowed issuance of a temporary waiver, leading to a full waiver allowing wells to operate with annulus pressure communication. A temporary waiver could be issued for such conditions as a high OA fluid level; a permanent waiver required further diagnostics (tubing integrity fluid level, and mechanical integrity test of the OA).<sup>12</sup> Statements made during interviews of the Pad Operator and the WIE indicate the basis for A-22’s temporary waiver was a high OA fluid level.

BPXA policy for managing annular pressures required well evaluation if the OA pressure tracks IA pressure or requires more than 2 bleeds per week to keep the OA pressure under 1,000 psi. The policy further stated: “Best effort will be made to quickly eliminate the leak” and the “well will be shut in if repairs or diagnostic work have not been initiated within 72 hours.”<sup>13</sup> Pressure was bled from A-22’s OA on August 4, again on August 11 (during startup of production) and on August 14. Rapid OA repressurization noted on August 15 was not addressed by bleeding pressure prior to restart, but clearly placed the well into the category of requiring well evaluation. Additional diagnostic tests for A-22 were ordered according to a written statement from the WIE to the BPXA Well A-22 Investigation Team dated August 22, 2002.



**Figure 2:** General area of Prudhoe Bay Pads A, B and X

<sup>11</sup> Caution tag - Control #041249; undated

<sup>12</sup> Interview with BPXA Well Integrity Engineer, June 10, 2003

<sup>13</sup> “Alaska Drilling and Wells, Standard Operating Procedure: Tubing/Annulus Communication and Annulus Monitoring Policy” – Sections 5.1 and 5.2. Document is part of the BPXA “Standard Operating Procedure: Annulus Communication and Monitoring Policy”; revised 3/21/01

Well A-22 Restart. There was no AOGCC notification or involvement in the A-22 restart. Two Pad Operators working 12-hour shifts were responsible for wells and facilities at A, B and X Pads.<sup>14</sup> An estimated four miles separate A and X Pads, with Pad B lying between A and X Pads (Figure 2). The on-duty Pad Operator (at the time of A-22 explosion) testified as to his location from the time A-22 was restarted to when he was injured. He had just begun a two-week tour of duty, beginning with a 12-hour work shift at 6:00 PM August 15, 2002. A turnover meeting was held between himself and the Pad Operator rotating off duty. The on-duty Pad Operator was advised that the WIE had verbally issued a temporary waiver clearing A-22 for restart. A-22 was placed on production at approximately 9:30 PM August 15, 2002.

The on-duty Pad Operator believed that a high-pressure hose would be necessary to bleed pressure from A-22 during restart. No high-pressure hose was then available on A-Pad, which the off-duty Pad Operator later confirmed. Operator discretion allowed the on-duty Pad Operator to leave A-22 unattended for several hours during restart. The on-duty Pad Operator then traveled to X-Pad to get a bleed hose. He bled high annulus pressures from several X-Pad wells and completed a “walkthrough”. BPXA records indicate that four X-Pad wells had BPXA internal waivers as of August 15, 2002: X-04, X-08, X-18 and X-25. The on-duty Pad Operator also completed a “walkthrough” at B-pad and noted six wells with high annular pressures, and then returned to A-pad. There were no BPXA waivers on any B-pad well according to information available to AOGCC.

Pad Operator notes<sup>15</sup> identify recent annulus pressure activities on other A, B, and X pads:

8/8/02	B-26; X-27; X-36	pressure bled from casing annuli;
8/11/02	X-17	hydrocarbons bubbling in well cellar;
	A-56	internal leak;
8/13/02	B-30	tubing hanger lockdown screws leaking.

The existence of several wells with internal waivers and other wells with high annular pressures appears to be consistent with statements made by the on-duty Pad Operator regarding the need to attend to X- and B-Pad wells.

Five hours after production restart, at about 2:10 AM, 8/16/02, A-22’s 13-3/8” surface casing failed about 17 feet below surface.<sup>16</sup> The on-duty Pad Operator testified he was opening the wellhouse door at approximately when the casing burst and was caught in the blast. He received severe injuries and was removed from location by BPXA’s incident response team.

Information gathered during interviews with Pad Operators and a Field Operations Team Lead, and from BPXA’s pad operator training program, confirms there was broad operator discretion provided in well restart procedures. No specific engineering analysis or guidance addresses startup procedures or when pressures should be bled. A historical understanding of a well’s “character” was one operating criterion mentioned by all those interviewed. For example, the on-duty Pad Operator stated that previous restarts of Wells X-18 and X-25 indicated that thermal effects, causing elevated pressures, were not significant for several hours. Well A-22 was considered analogous to X-18 and X-25. Both X-pad wells were operating under BPXA internal

<sup>14</sup> A-pad: 42 wells; B-pad: 36 wells; X-pad: 36 wells; facilities vary at each pad (control, manifold/valves, etc.)

<sup>15</sup> “Handover Report on B-A-X Pads”, August 8-15, 2002

<sup>16</sup> “Well Pad A-22, Final Incident Summary, Investigation Closeout Meeting 12/20/02”

waivers for IA by OA communication. There is no evidence of further analysis to determine if the X-pad wells and A-22 were in fact analogous. There was no supporting engineering analysis of well configuration, pressure history, or comparative assessment of leak paths, etc. AOGCC has seen no documentation that those responsible for the well addressed the significance of the changes in A-22 between July 24 and August 1.

It appears that A-22 conditions changed sometime prior to August 1, 2002 from manageable OA pressure (very small leak or thermal pressure remnant maintained for monitoring purposes) to high annular pressure and apparent pressure communication to the OA. It also appears that these changes were not reflected in adjustments to BPXA procedures regarding operation of the well.

Decompletion and Subsequent Study of Damaged Pipe. AOGCC approved BPXA's sundry application for decompletion and repair of A-22 on September 11, 2002. The goal was to recover damaged pipe, establish well integrity, and return the well to production. BPXA was encouraged to evaluate the other barriers and components in A-22 to "*learn as much as possible about this event so the long term decisions about operating wells with annular pressure can be improved.*"<sup>17</sup> The Commission desired to identify any failure that allowed the sudden increase of OA pressure (from 600 psi to 1,900 psi) while A-22 was shut in during the TAPS shut down. BPXA to date has not explained the source of gas in the OA.



**Figure 3:** Well A-22 tubing split

Commission inspectors witnessed critical activities of the A-22 decompletion, including recovery of the tubing and damaged casing, and pressure tests of the tubing, casing and packer. Split tubing was recovered from the well, and assessed to determine if it was a contributing factor in

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<sup>17</sup> September 11, 2002, letter forwarding approved Sundry application #302-289

the incident. BPXA stated the tubing split was the result of a string shot used to remove excess build up inside the pipe prior cutting of tubing for removal.<sup>18</sup> Photographs taken of the split tubing (Figure 3) and the fact that no liquid hydrocarbons were released from A-22 appear to confirm BPXA's assessment. Inconsistent BPXA pressure records for tubing and IA provide no useful information in determining whether pressure communication occurred due to a tubing leak.

OA pressure was bled from A-22 on at least three occasions between August 1, 2002 and August 15, 2002. There is no record of what fluids were recovered during the OA bleeds, which suggests that gas was bled. OA repressurization in a static well (no production) was likely the result of a leak in the 9-5/8" casing, allowing lift gas to communicate into the OA from the IA. Such communication remained undetected by pressure tests performed by BPXA during the decompletion and repair of A-22. There is no evidence that BPXA evaluated this possible communication as suggested in the Commission's September 11, 2002, letter approving A-22 decommissioning and repair.



**Figure 4:** Damaged surface casing recovered from Well A-22

Visual examination of recovered 13-3/8" surface casing (Figure 4) revealed no apparent corrosion or wear; both were identified as possible reasons for pipe failure early in the investigation (before the pipe was recovered). The pipe was bulged over a distance of 15 feet, with a ragged split, consistent with a high pressure burst. A 32-foot section of pipe was sent to Edison Welding Institute for detailed mechanical testing and measurement, metallography, and chemical analysis. Full scale burst testing of a downstream section of the recovered pipe was performed. The burst testing replicated the actual failure (ductile rupture) and demonstrated a measured

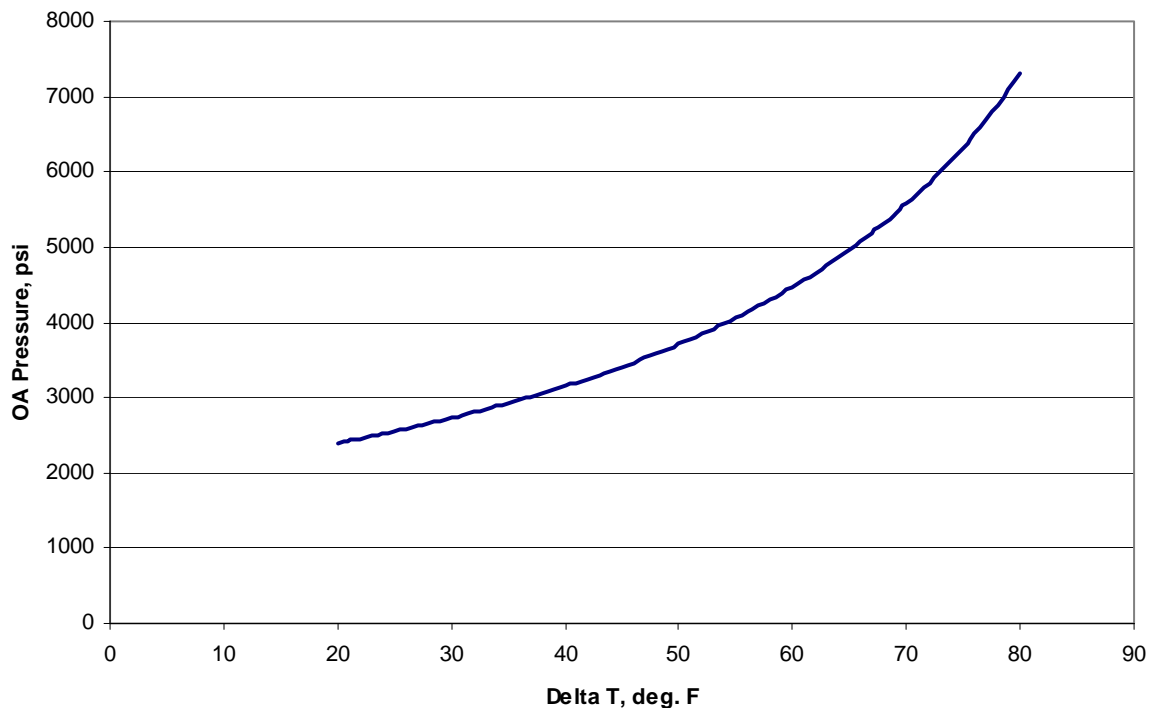
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<sup>18</sup> Email from WIE (BPXA) dated June 14, 2003



burst for the A-22 surface casing of approximately 7,700 psi.<sup>19</sup> The fact that the actual burst pressure is significantly higher than the published burst is expected, given the safety factors involved.

Why did A-22 overpressure? AOGCC evaluated the effect of temperature on annulus pressure in A-22. BPXA presented information about the thermal effects of well startup during a hearing in response to Conservation Order 483<sup>20</sup>, held to determine if regulations governing annulus pressures in Prudhoe Bay wells were appropriate. AOGCC used an in-house mathematical simulator to approximate OA pressure in A-22 as a function of temperature. AOGCC developed the simulator, which utilizes Boyle's and Charles's Laws to calculate gas pressure changes as a result of temperature and volume changes, and a coefficient of thermal expansion to calculate liquid volume changes resulting from temperature changes. The following assumptions were made: (1) rigid well casing; (2) ideal gas behavior; (3) non-varying liquid coefficient of expansion with changing pressure. AOGCC calibrated the simulator based upon observed A-22 end point pressures and temperatures. Wellbore dimensions and specifications were gathered from AOGCC well records and verified with information provided by BPXA after the explosion. A-22 OA fluids consisted of arctic pack<sup>21</sup> on top of a column of cement. The OA fluid level was measured at 85 feet below the wellhead.



**Figure 5:** A-22 OA Pressure as a Function of Temperature Change; 1,900 psi initial pressure

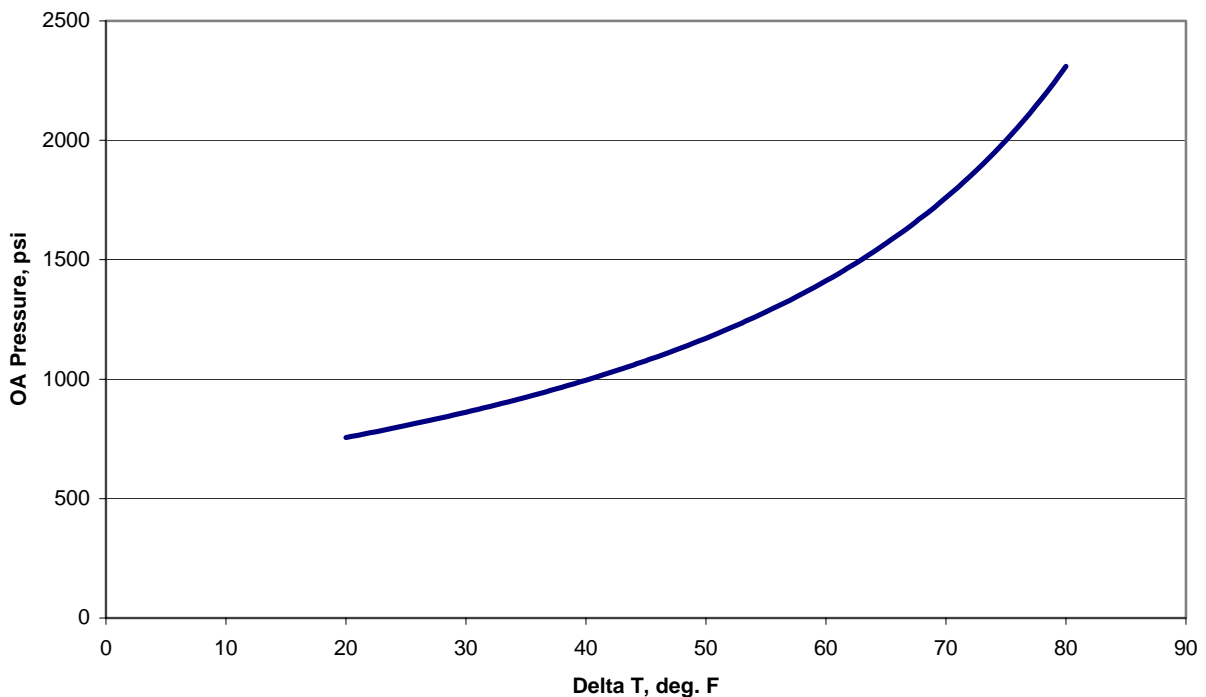
<sup>19</sup> Edison Welding Institute, Project #46381CSP-04, "Analysis of A-22 Casing Failure"

<sup>20</sup> Hearing record for CO 483

<sup>21</sup> Arctic pack – fluid mixture consisting of diesel and bentonite used to freeze protect a well through the permafrost

Figure 5 represents calculated A-22 OA pressure and temperature as the well was being started. Initial OA pressure was 1,900 psi and initial temperature was about 40° F. No pressure was bled from the well prior to startup. As warm produced fluids flowed, A-22 heated from its initial temperature to its eventual in-service temperature of about 116° F (historical information). The resulting temperature change, or delta T, was 76° F. Figure 5 reveals that as A-22 heated, the published burst pressure rating of the well’s surface casing<sup>22</sup> (5,380 psi) was exceeded at a delta T of about 68° F. In other words, the burst rating was exceeded before the well had reached its historic operating temperature.

Figure 6 illustrates the effect of a lower initial pressure on the final OA pressure at in-service temperature. The initial OA pressure of 600 psi corresponds to a final OA pressure of less than 2,500 psi at maximum delta T.



**Figure 6:** A-22 OA Pressure as a Function of Temperature Change; 600-psi initial pressure

If the OA pressure in A-22 had been bled to the historic value (600 psi), the final OA pressure would not approach the published burst rating of the surface casing (5,380 psi), and would have been about one-third the actual failure pressure (7,700 psi). In fact, OA pressure probably would not have exceeded the casing pressure test (3,000 psi) performed before A-22 was placed in service on August 15, 2002.

Annulus Pressure Policy. A copy of BPXA’s annulus pressure management program (policies and procedures) was provided to the Commission on August 23, 2003. The program was appli-

<sup>22</sup> API Bulletin 5C2, “Bulletin on Performance Properties of Casing and Tubing”; API grade L-80; 13-3/8”, 72 lb/ft



cable to wells in Greater Prudhoe Bay, Greater Point McIntyre, and Niakuk fields. The stated purpose of the BPXA policy was to “ensure wells with mechanical problems are identified, evaluated, and monitored in a timely and consistent manner.” BPXA’s policy includes responsibilities of key personnel, and requirements that must be demonstrated for continued well operation. The policy further establishes an internal (to BPXA) waiver process for wells that do not meet operating criteria.

The Commission reviewed BPXA’s annulus pressure policy as it relates to the events leading to A-22 failure. The engineering basis for decision criteria and pressure triggers was also assessed. Hearing testimony preliminary to CO 483 provided additional opportunity to gather information about the policy and practices used at Prudhoe Bay. Responding to questions about the policy evolution, specifically the imposed annulus pressure triggers, BPXA noted that the basis for the current pressure triggers is a combination of operating experience, BPXA and Arco well integrity practice, and the “range of operability that we were seeing on those annuluses.” Well A-22 raised questions about the decision process used to determine when a well is no longer safe to operate. Responding to questions posed by the Commissioners in the November 14, 2002 hearing, BPXA stated that their decision procedures have been developed over time with reliance on case-by-case reviews and comparison to actual experience. They further stated no formal engineering or risk assessment has been performed by BPXA as part of the policy evolution that allows leaks across multiple casing barriers and the maintenance of high annulus pressures.<sup>23</sup>

AOGCC’s review of BPXA’s policy and the statements about operating limits, coupled with the actions implemented at A-22 prior to explosion, suggests that BPXA emphasizes continued operation of wells exhibiting annular communication, by issuance of an internal waiver, in preference to repair of the wells. Further evidence of this is the diagnostic testing protocol (including types and sequence of tests, and acceptance criteria) practiced by BPXA in determining a well’s competence for continued operation.<sup>24</sup>

## **Reporting<sup>25</sup>**

On August 16, 2002 BPXA provided the Commission with verbal notice of an explosion and fire at Prudhoe Bay A-22. A written “Notification of Uncontrolled Natural Gas Release” followed later that day, summarizing the event and reporting the release of 1.035 million cubic feet of natural gas. BPXA provided Spill Reports on August 18, 2002 (initial) and September 16, 2002 (final), noting that there were no liquid hydrocarbons released during the event.

By letter dated August 27, 2002 the Commission reminded BPXA of the obligation to file a final written report within 30 days, detailing the incident. BPXA submitted a final “Notification of Uncontrolled Natural Gas Release” on September 16, 2002. An incident review report was provided on September 17, 2002, in a slide presentation format.

On December 23, 2002 the BPXA Law Department faxed to AOGCC a document titled “Key Findings of a Final A-22 Incident Investigation” with a cover letter from BPXA’s principle

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<sup>23</sup> Transcript of Proceedings, Public Hearing, November 14, 2002

<sup>24</sup> Transcript of Proceedings, Public Hearing, May 27, 2003

<sup>25</sup> 20 AAC 25.205

Commission contact regarding A-22. The letter notes that BPXA “now considers its investigation to be closed.” The “key findings” document was a paper copy of a slide presentation summarizing the incident, the response, BPXA’s investigation, contributing factors to the incident, system causes, and recommendations and action plans.

### **Potential Contributing Factors**

The immediate cause of A-22 failure and explosion was thermal expansion acting on a high annular pressure that had not been bled down before well restart. Pressure communication in A-22 resulted in an OA pressure increase from a historical value of 600 psi to 1,900 psi, a pressure that equalized with and tracked the imposed gas lift pressure in the IA. Several attempts to relieve pressures between August 4 and August 14 (while the well was static) demonstrated OA repressurization, evidence of significant pressure communication or leak (failed pressure barrier). As the well was brought into production on August 15, 2002 warm reservoir fluids created thermal expansion of the fluid in the closed annular space, increasing pressure. The thermal effects of producing the well without pressure relief resulted in an OA pressure exceeding the burst capacity<sup>26</sup> of A-22’s surface casing. Analysis shows that pipe failure was induced by overpressure.

The following potential contributing factors are noted:

1. Tubing and Casing Material Quality. Wells are designed to fail inward (collapse) such that pressures remain contained and controlled within the wellbore. Tubing integrity in A-22 was demonstrated by the lack of continued feed of gas after the explosion and the ability to withstand increasing pressures in the IA and OA during production restart. Tubing integrity does not appear to have been a contributing factor to the failure of A-22, based on the available evidence. Initial concerns about 13-3/8” casing wear (from drill pipe movement while drilling the well) and corrosion or stress cracking (induced by chemicals in drilling fluid and formation) were also eliminated as possible factors in A-22 failure based on engineering studies of the recovered pipe by Edison Welding.

2. BPXA Annular Pressure Policy and Procedures

(a) *Emphasis on Allowing Continued Operation*. BPXA statements during an annular pressure rule hearing indicate well leaks leading to elevated annular pressures are routine. Responding to Commission questions during the Conservation Order 483 hearing regarding operating a well with annular pressure communication, BPXA experts stated: “by necessity it has been a good oilfield practice simply because so many wells do have annular pressure of some type. It is just a common occurrence, and so monitoring that and then operating, having a prudent method of operation is very definitely good oilfield practice.”<sup>27</sup> The delay in notice to the Well Integrity Engineer, and apparent lack of diagnostic and engineering work in support of issuing a waiver may reflect a relatively low priority placed by BPXA on resolving annular pressure issues at the time A-22 experienced the failure.

(b) *Lack of Clarity and Understanding Related to Problem Well Restart*. Those interviewed during the investigation expressed their belief that policies were clear for wells with high OA

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<sup>26</sup> As compared to the published minimum internal yield pressure of 5,380 psi used in designing the well

<sup>27</sup> “Transcript of Proceedings”, Public Hearing in response to CO 483, November 14, 2002

pressure. However, that does not appear to be the case, particularly with regard to the role of bleeding pressures. While there were references in BPXA training program documents and policies then in place that mention bleeding pressures as a diagnostic tool, for managing pressures during well start, and for avoiding failures that would result in costly repairs, what is missing is a clear expression of the importance of bleeding pressures prior to start-up to offset the effects of well heating.

It also appears that the WIE and the two Pad Operators had different understandings of the basis for allowing A-22 to be restarted with an internal BPXA waiver. For example, the off-duty Pad Operator (at the time of A-22 restart) stated an operator should remain at the location until the well is stable, meaning temperature and pressures remain constant for a period of time.<sup>28</sup> The on-duty Pad Operator referenced Wells X-18 and X-25 as providing historical experience thought to be relevant to the restart of A-22 (i.e., A-22 would behave similarly to X-18 and X-25 during restart).<sup>29,30</sup> He left A-22 after placing it on production to get a high-pressure bleed hose and attend to other duties based on his understanding and historical experience. The potential implication to the startup procedure due to the fact that the pressure characteristics had changed was not clearly addressed in the information provided to the Pad Operators.

Information provided to the Pad Operators may have been interpreted as suggesting that the annular pressures might decrease, rather than increase, as the well warmed up. There was no instruction provided regarding A-22 IA pressure (monitoring, bleed off, etc.) despite the pre-start pressure in the IA at the pressure limit (2000 psi) as established in BPXA's policy. Nothing regarding the IA pressure was noted in the temporary waiver or the caution tag prepared by the WIE. The engineering basis for statements about pressures decreasing was unsubstantiated in information provided to the Commission, and may have provided the Pad Operator additional justification for leaving A-22 unattended during startup.

(c) *Degree of Flexibility and Discretion in Implementation.* According to testimony, procedures in handling the same well conditions varied among the Pad Operators. BPXA's pressure management policies were apparently used as guidelines rather than engineering standards. BPXA's "key findings" from an internal investigation state: "*Procedures for bleeding down and monitoring annular pressures did not fully address key issues and were not consistently implemented in the field.*"<sup>31</sup> Examples of the apparent discretion in how annulus pressure management was approached included:

- Pressure thresholds (1,000 psi OA; 2,000 psi IA) that trigger actions treated as guides rather than rigid standards;
- No diagnostics for OA pressure that increased on or before August 1;
- Attempt to restart production in A-22 on August 4 without a waiver or diagnostics;
- Pressure bleed procedures as implemented by BPXA not a diagnostic tool as understood by the Commission;
- Delayed reporting of pressures exceeding pressure thresholds;

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<sup>28</sup> Interview dated July 25, 2003

<sup>29</sup> Interview dated May 27, 2003

<sup>30</sup> Wells X-18 and X-25 had internal waivers due to IA by OA communication and high pressures

<sup>31</sup> "Well Pad A-22, Final Incident Summary, Investigation Closeout Meeting 12/20/02"

- Daily pressure checks and/or reporting not conducted from July 25 through July 31 and questionable and inconsistent pressures from August 1 through August 15 (in multiple data sources reviewed by the Commission);
- No evidence of engineering analysis to predict the expected consequences from physical actions taken in the restart of A-22 (as it existed on August 15).

This level of discretion in managing well pressures, and specifically how to restart a well with high OA pressure appears to have been a contributing factor to the A-22 failure.

3. Operator Training. BPXA's training program lacked clear engineering-based guidance regarding trouble wells. Information reviewed by the Commission shows general discussions about the importance of maintaining pressures in wells, but requirements for bleeding pressures prior to well start and continuous operator presence during restart, etc., are absent from training programs.

4. Workload/Personnel Resources/Work Prioritization. The Pad Operator had simultaneous responsibility for three well pads (more than 100 wells and associated facilities – valves, controls, etc.). BPXA did not establish priorities regarding activities associated with well startup.

### **Regulatory Response to the PBU A-22 Incident**

Shortly after A-22 failed, the Commission sought and was provided information regarding other wells with annular pressures in the Prudhoe Bay Field. Because of the early emphasis on determining the cause of A-22 failure, and the priority of minimizing risk of similar occurrences, the Commission determined to impose rules at Prudhoe Bay regarding annular pressure management. The Commission deemed it inappropriate to continue self-regulated annular pressure management as was previously practiced by BPXA. Conservation Order 492, published on June 26, 2003, establishes annular pressure management requirements for the Prudhoe Bay field. Rules for other producing fields throughout the state have also been developed or are in the process of being developed. Included in CO 492 are rules requiring daily monitoring for sustained annuli pressures, notification of the Commission and corrective action when annuli pressures exceed specific triggers, and pressure relief prior to placing the well in service.

Inspection activities have also been enhanced to gather information about wells affected by annular pressures. Commission staff now has oversight, and the opportunity to validate, an operator's procedures rather than relying solely on the operator for well integrity assurance. Commission Inspectors continue to perform random inspections of well starts and the equipment used to bleed pressures from casing annuli to make sure it is maintained.

Increased surveillance and AOGCC involvement in well operation through annular pressure management rules imposed by Conservation Order should provide early warning of potential problem wells. Annulus pressure management practices that are consistent with these rules should prevent the recurrence of a failure similar to Prudhoe Bay Well A-22.

### **Enforcement**

The Commission should assess enforcement options based on the results of this investigation.

## APPENDIX

### Chronology of Meetings, Information Requests, and Responses

A series of meetings between AOGCC engineering staff and BPXA were held beginning August 16, 2002. Frequent contact was maintained with BPXA personnel during the first 2 months to address questions as they were identified in the AOGCC investigative review.

#### August 16, 2002 – Notice of Event

- AOGCC Inspector visits BPXA Incident Command Center; visits A-pad once safe to access area; photos of Well A-22 wellhouse
- AOGCC engineering staff review well file (casing and cement records); discussions with BPXA Well Integrity Engineer to gather information about incident
- Teleconference briefing by BPXA about incident; BPXA initiated investigation
  - o AOGCC invited to participate in BPXA investigation; decision made by Commission to perform independent investigation

#### August 18, 2002 – Spill report

- Initial report; no hydrocarbons spilled

#### August 19, 2002 – Teleconference Status Update

- AOGCC schedules technical meeting with BPXA
- AOGCC develops outline for technical meeting; focus on history of A-22, incident as it occurred, diagnostic procedures, policies for wells with annular pressures, other wells with similar conditions

#### August 22, 2002 – Meeting Agenda

- Forward email agenda to BPXA; technical meeting

#### August 23, 2002 – BPXA Investigation Team

- AOGCC engineering staff met with key personnel of BPXA investigation team; primary BPXA point of contact for Commission inquiries established
- Immediate cause of event identified as failure of 13-3/8” casing
  - o Baroscope confirmed split in 13-3/8” casing at ~17 ft below surface
- Draft incident report prepared by investigation team; under review by BPXA management and legal personnel
- AOGCC provided data book labeled “A-22 Casing Failure”; compilation of technical background data gathered by the Well Integrity Group (pressure history, well work history, photos of the well site, supporting information about the well and production tree, BPXA policies for wells with annular pressure communication)
- BPXA addressed points per AOGCC request
  - o 123 wells identified as having annular communication requiring BPXA internal waiver; 7 shut in to date due to rapid communication
  - o Additional shut-ins not discussed; assessing mechanical integrity of 123 wells
  - o Further technical discussions necessary as BPXA proceeds

## APPENDIX

### August 24, 2002 – BPXA Notification of Well Shut-ins

- BPXA notifies Commissioner Taylor of intent to shut in wells based on recommendations of their internal investigation team
  - o 9 wells shut in to date - have rapid tubing by IA communication
  - o 125-130 wells with OA pressures will be shut in;
    - Wells are currently on BPXA internal waivers

### August 27, 2002 – AOGCC letter to BPXA requesting information

- Additional information necessary to accomplish the objectives of AOGCC investigation into Well A-22 incident
  - o Cause of this incident AND how future incidents of this type can be prevented
- Requested information regarding the wells shut in by BPXA in response to Well A-22 explosion, fire, injury of pad operator; also the decision criteria for selecting wells and restarting production; diagnostics to confirm well integrity

### August 29, 2002 – BPXA Response

- Provided list of wells shut in by BPXA
- Developing decision criteria - which wells restart production; procedures for startup
  - o Will be communicated to AOGCC before production initiated

### September 3, 2002 – Status update meeting with BPXA

- Engineering staff only from AOGCC and BPXA
  - o No additional documentation provided
- Overview of BPXA investigative efforts to date
  - o Root cause analysis summarized including primary and contributing factors
  - o Still unanswered questions as to why the 13-3/8” casing failed
- Verbal summary of recommendations from BPXA investigation team
- Tentative plans by BPXA to restart production of shut-in wells

### September 4, 2002 – Information exchange by electronic mail

- BPXA advised that written procedures for diagnostic testing, startup and monitoring are required before production is restarted
- Waiver well classification used to determine which wells are shut in
- Copy of BPXA Safety Bulletin provided

### September 6, 2002 – Well diagnostics and restart procedures

- AOGCC receives and initiates review of procedures:
  - o Production well normal startup
  - o Monitoring annulus pressure
  - o Wells with annular pressure communication

### September 6, 2002 – Sundry application

- AOGCC receives and initiates review of workover for Well A-22
  - o Sundry Application Form 10-403

## APPENDIX

### September 7, 2002 – Meeting to discuss procedures

- Engineering staff only from AOGCC and BPXA
- Clarification about diagnostics, integrity testing, and startup and operating procedures
  - o Establish mechanical integrity bounds by pressure testing
    - Test to 120% of the maximum allowable operating annular pressure
      - Max allowable pressure equivalent to gas lift pressure
  - o Pressure bleed-offs; manning requirements for restarts
- AOGCC approval for subset of wells to restart production
  - o 33 wells require additional analysis before restart
- Advised that Final Incident Report per 20 AAC 25.205 is due 9/16/02

### September 9, 2002 – Written Authorization

- Engineering review completed on Well A-22 Sundry application for workover
- Written approval documenting verbal approval granted 9/7/2002 to bring subset of shut in wells and conditionally approved workover sundry application from AOGCC

### September 11, 2002 – Rig workover

- Sundry application approved; forwarding letter to BPXA
- Workover operations commence

### September 13, 2002 – Status update; more wells identified with annular pressures

- Training of field personnel (Pad Operators) completed
- 20 wells to date completed restart process
  - o Only 9 producing due to other production facility shut-ins (Gathering Center 2 and Flow Station 1)
  - o AOGCC Inspectors witnessing restarts to validate procedures implemented as described
- Well 13-34 restart did not meet criteria (IA and OA pressures tracking); well shut in
- Pad Operators report 126 additional wells with annular pressure exceeding 1,000 psi
  - o Pad Operators directed by BPXA to diagnose pressures

### September 16, 2002 – Status update

- Only 40 of 126 new wells with annular pressures have OA pressures; remaining have IA pressures only
  - o 8 wells on previous list (shut in)
- Continuing diagnostic testing
- Re-waiver all wells
  - o Tubing integrity and casing pressure tests

### September 19, 2002 – Injection wells shut in

- Confirm 137 wells shut in after A-22 incident
- Identified 8 injectors shut in as part of original 137 wells
- # wells that have completed restart sequence
  - o 47 reviewed; 25 producing – impacting 27,000 bpd
- Discuss timing for analysis of damaged casing

## APPENDIX

### September 20, 2002 – Public Hearing notice

- Consider rules governing annular pressure management at Prudhoe Bay

### October 1, 2002 – Status update

- Workover results to date
  - o Ultrasonic, camera, caliper surveys
  - o Cut and recovered 45-foot section of casing; prep part of recovered pipe for transport to Edison Welding Institute for detailed study
- Have not yet interviewed on-duty Pad Operator injured in explosion at family request; released to long term care facility; expected to be home in 3 wks
- Startup procedures are now policy compared to interpretive guideline prior to A-22
- Tubing split? BPXA has no plans to evaluate

### October 3, 2002 – Status update

- Status of original 137 wells shut in
- Additional 125 wells identified with annular pressure; not shut in
- Workover update

### October 8, 2002 – Workover completed

### October 22, 2002 – Workover report

- Report of Sundry Well Operations (Form10-404) received; summary of workover

### November 14, 2002 – Annular Pressure Rule Hearing

- Testimony by BPXA, AOGA

### December 19, 2002 – Status update

- BPXA investigation closed
- EWJ testing revealed casing failed at 7700 psi
- Will check to see if EWJ report can be released to AOGCC
- BPXA interviewed injured Pad Operator; could not remember much about accident

### December 20, 2002 – Letter to BPXA; pre-explosion events

- Questions regarding BPXA actions leading up to A-22 explosion

### December 20, 2002 – Letter to on-duty Pad Operator

- Commission would like to discuss A-22 events

### December 20, 2002 – Letter to PACE Union

- Commission available to discuss A-22 information PACE believes is relevant

### January 16, 2003 – Annular Pressure Rule for Prudhoe Bay

- CO 483 published; a rule for Greater Prudhoe Bay addressing annular pressure management practice is appropriate



## APPENDIX

February 14, 2003 – Response to December 20, 2002 letter

- Copy of EWI report provided
- Pad Operator notes provided
- Responses to questions posed by AOGCC

May 20, 2003 – Interview letters

- Letters to on- and off-duty Pad Operators, and WIE requesting interviews

May 27, 2003 – Interview with on-duty Pad Operator

June 10, 2003 – Interview with WIE

June 26, 2003 – Interview letter

- Letter to Field Operations Team Lead requesting interview

June 26, 2003 – Subpoena served to off-duty Pad Operator

June 26, 2003 – Annular Pressure Rule

- CO 492 published; annular pressure rule for Greater Prudhoe Bay
- Regulatory oversight
- Monitoring
- Pressure thresholds for notification and corrective action

July 24, 2003 – Interview with Field Operations Team Lead

July 25, 2003 – Interview with off-duty Pad Operator

August 21, 2003 – Policies, procedures and training

- BPXA provides policies, procedures and training documents in place at time of A-22 incident
- Included is information provided to State of Alaska Department of Labor and Workforce Development, Occupational Safety and Health