

**STATE OF ALASKA**  
**ALASKA OIL AND GAS CONSERVATION COMMISSION**  
**333 West 7<sup>th</sup> Avenue, Suite 100**  
**Anchorage, Alaska 99501**

Re: THE APPLICATION OF BP ) Area Injection Order No. 26A  
EXPLORATION (ALASKA) INC. for )  
modification of Area Injection Order 26 to ) Prudhoe Bay Field  
authorize underground injection of ) Schrader Bluff Oil Pool  
enriched hydrocarbon gas for enhanced oil ) Orion Development Area  
recovery in Orion Oil Pool, Prudhoe Bay )  
Field, North Slope, Alaska; and ) May 1, 2006

THE PROPOSAL initiated by the Commission to amend underground injection orders to incorporate consistent language addressing mechanical integrity of wells.

**IT APPEARING THAT:**

1. By application dated February 23, 2006 BP Exploration (Alaska) Inc. (“BPXA”), operator of the Prudhoe Bay Unit (“PBU”), requested an order from the Alaska Oil and Gas Conservation Commission (“Commission”) modifying Area Injection Order 26 (“AIO 26”) and Conservation Order 505 to authorize the injection of enriched hydrocarbon gas for enhanced oil recovery ("EOR") purposes in the Orion Oil Pool within the PBU.
2. The Commission published notice of opportunity for public hearing on BPXA’s application in the Anchorage Daily News on March 2, 2006.
3. The Commission received no requests for a public hearing.
4. The Commission received no protests or comments.
5. On its own motion, the Commission proposed to amend the rules addressing well mechanical integrity in all existing orders authorizing underground injection. The Commission published notice of opportunity for public hearing on the proposal in the Anchorage Daily News on October 3, 2004.
6. By e-mail dated October 15, 2004 BPXA suggested edits to the Commission’s proposed language addressing the mechanical integrity of injection wells.
7. The Commission received no requests for a public hearing.
8. The Commission received no protests or comments.

9. No hearing was held.

## **FINDINGS:**

1. Operator

BPXA is Operator of the Orion Development Area of the Schrader Bluff Oil Pool in the Prudhoe Bay Field, North Slope, Alaska.

2. Formations Authorized for Enhanced Recovery

Enhanced recovery injection for the Orion Development Area is proposed within the Schrader Bluff Oil Pool. The target injection zones are correlative to Prudhoe Bay Unit well V-201 between the measured depths ("MD") of 4,549 feet and 5,106 feet (Schrader Bluff formation).

3. Proposed Injection Area

BPXA requested authorization to inject fluids for the purpose of enhanced recovery operations on lands within Umiat Meridian T12N-R10E, T12N-R11E, T11N-R11E, and T11N-R12E in the Prudhoe Bay Unit.

4. Operators/Surface Owners Notification

BPXA provided operators and surface owners within one-quarter mile of the proposed area with a copy of the application for injection. The only affected operator is BPXA, operator of Prudhoe Bay Unit and the Milne Point Unit. The State of Alaska, Department of Natural Resources is the only affected surface owner.

5. Description of Operation

The contemplated operation is an EOR project using enriched gas from the Prudhoe Bay Central Gas Facility. The project involves the cyclical injection of water alternating with injection of hydrocarbon gas enriched with intermediate hydrocarbons, principally ethane and propane. Implementation of the Orion EOR project will involve connection of Orion injection wells to existing or new miscible gas injection distribution systems on L, V, and Z Pads. Enriched hydrocarbon gas injection is expected to begin in 2<sup>nd</sup> quarter 2006.

6. Hydrocarbon Recovery

The Schrader Bluff Oil Pool is estimated to contain 1,070 - 1,785 million stock tank barrels ("STB") of original oil in place ("OOIP") within the Orion Development Area, based on exploratory drilling and seismic mapping. Computer simulation indicates primary recovery within the major sands of the development area is expected to be 5% - 10% of the OOIP, and waterflood may increase recovery to 20% - 25% of the OOIP where implemented.

Preliminary evaluations suggest that the EOR project could yield an incremental recovery to waterflood of up to 6% where implemented. These recovery estimates were obtained using an Equation of State ("EOS") developed for the nearby Polaris Oil Pool, a close analog of

the Orion Development Area. Oil from the Polaris Oil Pool has essentially identical composition and quality as that of the Orion accumulation and both accumulations have similar reservoir temperature, pressure and depth. Laboratory swell, multiple contact, and slimtube experiments were conducted using Polaris oil from W-203 and the PBU enriched gas and were used to develop a new Polaris EOS.

Fully compositional, mechanistic type pattern model simulations were conducted using the Polaris EOS for a W Pad reservoir description. In part of the project area where the reservoir oil has sufficient concentration of C7 - C13, the enriched gas forms a miscible bank with the reservoir oil through exchange of hydrocarbon components, and displaces nearly all of the contacted oil. In areas where the oil lacks sufficient concentration of C7 - C13 components to be miscible with the Prudhoe enriched gas at reservoir conditions, miscibility may not occur. Rather, a multiple contact condensing/vaporizing mass transfer mechanism between reservoir oil and the CO<sub>2</sub> and C2 - C4 in the Prudhoe enriched gas causes a significant reduction in reservoir oil viscosity. BPXA states that the magnitude of tertiary oil recovery by this "viscosity reducing, immiscible enriched gas flood" is very close to that with miscible gas injection. A fifty-fold reduction in viscosity of a 40 cp Polaris oil was found by contacting the PBU enriched gas in a single cell multiple-contact laboratory experiment conducted at reservoir conditions.

Gross utilization of Prudhoe enriched gas was estimated to be around 5.3 thousand cubic feet ("MCF") of enriched gas injected for every barrel of EOR oil. This is similar to the efficiency at other satellite Prudhoe projects and compares to an efficiency of about 15 - 20 MCF/barrel for enriched gas injection in the mature IPA EOR project area, which justifies the preferential injection of Prudhoe enriched gas into the Orion accumulation.

Approval was granted for enriched gas injection within the Polaris Oil Pool on November 28, 2005.

## 7. Geologic Information

- a. Stratigraphy: The Schrader Bluff Oil Pool encompasses reservoirs assigned to the Late Cretaceous-aged Schrader Bluff formation ("Schrader Bluff"). The Schrader Bluff is divided into two stratigraphic intervals that are designated, from deepest to shallowest, the "O sands" and the "N sands." The O and N sand intervals were deposited in marine shoreface and shallow shelf environments.

The Schrader Bluff O sands are divided into seven separate reservoir intervals that are named, from deepest to shallowest, OBf, OBe, Obd, OBc, OBb, OBa, and OA. Each of these intervals coarsens upward from non-reservoir, laminated muddy siltstone at the base to reservoir-quality sandstone at the top.

The lower portion of the Schrader Bluff N sands is dominated by mudstone and siltstone. However, the sediments coarsen upward, and fine- to medium-grained sandstone is prevalent in the upper part of the N sands. Three reservoir intervals are recognized within the N sands. They are, from oldest to youngest, Nc, Nb, and Na.

- b. Structure Overview: The structural dip ranges from 1 to 4 degrees to the east and northeast, and is broken by three sets of normal faults from Northwest to Southeast, North to South, and East to West. The Northwest to Southeast fault trend has throws up

to 200 feet. The North to South striking faults, downthrown to the west and east, have throws of up to 100 feet. East to West faults are less common, and form the reservoir trap on the southwestern side of the Orion Development Area.

- c. Confining Intervals: The upper contact between the N Sands and the overlying Prince Creek formation is generally an abrupt transition from sandstone to mudstone forming the upper confinement. The Lower Prince Creek formation (Ma-Mc sands) typically contains over 30 feet of laterally continuous shales and mudstones. Mudstones and muddy siltstones up to 1000 feet thick provide the basal confinement of the Schrader sandstones.

#### 8. Well Logs

The logs of existing injection wells are on file with the Commission.

#### 9. Mechanical Integrity of Wells

The Commission has approved injection operations for all currently drilled Orion injectors. Mechanical integrity has been established for all injectors and wells within one-quarter mile of the Orion injectors. Cement tops are at an adequate height above the injection zone to prevent fluid from migrating out of the Orion injection zone.

#### 10. Type of Fluid / Source

Fluids requested for injection are:

- a. enriched gas from Prudhoe Bay Unit processing facilities;
- b. produced water from Prudhoe Bay Unit production facilities for the purposes of pressure maintenance and enhanced recovery;
- c. source water from the Prince Creek formation (also known as the Ugnu formation);
- d. tracer survey fluid to monitor reservoir performance;
- e. fluids injected for purposes of stimulation per 20 AAC 25.280(a)(2);
- f. source water from the Seawater Treatment Plant; and
- g. non-hazardous water collected from well-house cellars and standing ponds.

#### 11. Enriched Gas Composition and Compatibility with Formation

The enriched gas proposed for injection is a hydrocarbon with similar composition to reservoir fluids in the Orion Oil Pool and therefore no compatibility issues are anticipated. The compatibility of the injection waters was addressed in AIO 26 dated February 3, 2003.

#### 12. Injection Rates and Pressures

Maximum miscible gas injection requirements are about 60,000 MSCFD. Maximum water injection is projected at 125,000 bwpd. The average manifold injection pressure for the enriched gas will be 3000 psi, with a maximum of about 3300 psi. The average surface water injection pressure will be about 1100 psi, with a maximum of about 2000 psi. This will result in a maximum bottom hole pressure of about 4000 psi.

### 13. Fracture Information

The Commission originally ordered that injection pressures be maintained below 0.67 psi/ft to ensure that Orion injected water does not fracture or migrate out of zone, and based its decision upon BPXA's estimate of a 0.66 - 0.67 psi/ft fracture pressure for the confining mudstone using data from stress tests and dipole sonic log. Several tests conducted with the Commission's approval support BPXA's conclusion that increased injection pressures will not result in migration out of zone.

A zonal isolation test was completed in Orion well L-210 in April 2005. Sand-face pressure gauges were installed adjacent to discrete zones both above and below an isolated injection interval in order to record pressure response and reveal whether injection was breaching the confining barriers. The two perforated zones were separated by around 28 feet TVD of unperforated OA interval comprised of silty mudstone. Injection rates of up to 4200 BWPD with an injection gradient of up to 0.82 psi/ft were achieved while injecting into the lower zone. No pressure response in the adjacent zone was seen; hence, the water did not breach out of zone. Additional step rate and pulse tests in Polaris and Milne Point Schrader formations showed similar results.

On December 13, 2005 the Commission administratively approved elimination of the injection pressure limitation. However, injection pressure must be maintained such that injected fluids do not fracture the confining zones or migrate out of the approved injection stratum. BPXA will monitor each injection well and if any significant change in injectivity indicates injection out of zone, surveillance will be conducted to determine the cause of the injection anomaly.

### 14. Freshwater exemption

Aquifer Exemption Order #1, dated July 11, 1986 exempts all portions of aquifers beneath the Western Operating Area of the Prudhoe Bay Unit, including the area designated for the proposed waterflood pilot project.

### 15. Mechanical Condition of Adjacent Wells

All wells within one-quarter mile of existing proposed water-alternating-gas injectors have been reviewed for mechanical isolation. The records of cement jobs and cement bond logs were reviewed. All wells appear to have mechanical isolation between the Schrader Bluff and all other intervals.

### 16. Amendments to Rules

The Commission proposed amendments to Rules 4 and 5 and the addition of Rule 7 in order to incorporate consistent language addressing the mechanical integrity of injection wells. Various wording used in different rules creates confusion and inconsistent implementation of well integrity requirements for injection wells.

## **CONCLUSIONS:**

1. The application requirements of 20 AAC 25.402 have been met.

2. Enriched gas injection will significantly improve recovery.
3. The proposed injection operations will be conducted in permeable strata, which can reasonably be expected to accept injected fluids at pressures less than the fracture pressure of the confining strata.
4. Injected fluids will be confined within the appropriate receiving intervals by impermeable lithology, cement isolation of the wellbore and appropriate operating conditions.
5. Reservoir and well surveillance, coupled with regularly scheduled mechanical integrity tests will demonstrate appropriate performance of the enhanced oil recovery project or disclose possible abnormalities.
6. Amendments to Rules 4 and 5 and the addition of Rule 7 will provide for consistent implementation of well integrity requirements for injection wells.

**NOW, THEREFORE, IT IS ORDERED THAT:**

In addition to statewide requirements under 20 AAC 25 (to the extent not superseded by these rules), the following rules govern the underground injection of fluids for enhanced oil recovery in the Schrader Bluff Oil Pool within the affected area described below, referred to herein as the Orion Development Area, and supersede and replace the rules adopted in AIO 26 dated January 5, 2004 and AIO 26.001 dated December 13, 2005.

**Umiat Meridian**

<u>Township</u> <u>Range, UM</u>	<u>Lease</u>	<u>Sections</u>
T12N-R10E	ADL 025637	13 and 24 N/2
T12N-R11E	ADL 047446	17, 18, 19, and 20
	ADL 047447	16 S/2 and NW/4 and S/2 NE/4, 21, and 22
	ADL 028238	25 SW/4, 26, 35, and 36
	ADL 028239	27, 28, 33 E/2 and N/2 NW/4, and 34
	ADL 047449	29 N/2 and SE/4, and 30 N/2 NE/4
T11N-R11E	ADL 028240	1, 2, 11 E/2 and E/2 NW/4, and 12
	ADL 028241	3 N/2 and N/2 S/2, and 4 NE/4 N/2 SE/4
	ADL 028245	13 N/2 and SE/4, 14 E/2 NE/4, and 24 E/2

		NE/4
T11N-R12E	ADL 047450	7, and 8 S/2 and NW/4

**Rule 1: Authorized Injection Strata for Enhanced Recovery (AIO 26)**

Fluids appropriate for enhanced oil recovery may be injected for purposes of pressure maintenance and enhanced recovery within the Orion Development Area into strata that are common to, and correlate with, the interval between measured depths 4,549 feet MD and 5,106 feet MD in the PBU V-201 well and between the measured depths of 4,174 feet and 4,800 feet in Milne Point Unit well A-1.

**Rule 2: Fluid Injection Wells (AIO 26)**

The underground injection of fluids must be through a well that has been permitted for drilling as a service well for injection in conformance with 20 AAC 25.005, or through a well approved for conversion to a service well for injection in conformance with 20 AAC 25.280 and 20 AAC 25.412 (e).

**Rule 3: Authorized Fluids for Enhanced Recovery (Revised by this Order AIO 26A)**

Fluids authorized for injection include:

- a. enriched gas from the Prudhoe Bay Unit processing facilities;
- b. produced water from Prudhoe Bay Unit production facilities for the purposes of pressure maintenance and enhanced recovery;
- c. tracer survey fluid to monitor reservoir performance;
- d. source water from a sea water treatment plant;
- e. source water from the Prince Creek (Ugnu) formation; and
- f. non-hazardous filtered water collected from Schrader Bluff Oil Pool well house cellars and well pads in the Orion Development Area.

**Rule 4: Monitoring Tubing-Casing Annulus Pressure (Revised by this Order AIO 26A)**

The tubing and casing annuli pressures of each injection well must be monitored at least daily, except if prevented by extreme weather condition, emergency situations, or similar unavoidable circumstances. Monitoring results shall be documented and made available for Commission inspection.

**Rule 5: Demonstration of Tubing/Casing Annulus Mechanical Integrity (Revised by this Order AIO 26A)**

The mechanical integrity of an injection well must be demonstrated before injection begins, and before returning a well to service following a workover affecting mechanical integrity. A Commission-witnessed mechanical integrity test must be performed after injection is commenced for the first time in a well, to be scheduled when injection conditions (temperature, pressure, rate, etc.) have stabilized. Subsequent tests must be performed at least once every four years thereafter. The Commission must be notified at least 24 hours in advance to enable a representative to witness mechanical integrity tests. Unless an alternate means is approved by the Commission, mechanical integrity must be demonstrated by a tubing/casing annulus

pressure test using a surface pressure of 1,500 psi or 0.25 psi/ft multiplied by the vertical depth of the packer, whichever is greater, that shows stabilizing pressure and does not change more than 10 percent during a 30 minute period. Results of mechanical integrity tests must be readily available for Commission inspection.

**Rule 6: Multiple Completion of Water Injection Wells (AIO 26)**

- a. Water injectors may be completed to allow for injection in multiple pools within the same wellbore so long as mechanical isolation between pools is demonstrated and approved by the Commission.
- b. Prior to initiation of commingled injection, the Commission must approve methods for allocation of injection to the separate pools.
- c. Results of logs or surveys used for determining the allocation of water injection between pools, if applicable, must be supplied in the annual reservoir surveillance report.
- d. An approved injection order is required prior to commencement of injection in each pool.

**Rule 7: Well Integrity Failure and Confinement (Added this Order AIO26A)**

Whenever any pressure communication, leakage or lack of injection zone isolation is indicated by injection rate, operating pressure observation, test, survey, log, or other evidence, the operator shall notify the Commission by the next business day and submit a plan of corrective action on a Form 10-403 for Commission approval. The operator shall immediately shut in the well if continued operation would be unsafe or would threaten contamination of freshwater, or if so directed by the Commission. A monthly report of daily tubing and casing annuli pressures and injection rates must be provided to the Commission for all injection wells indicating well integrity failure or lack of injection zone isolation.

**Rule 8: Notification of Improper Class II Injection (AIO 26)**

Injection of fluids other than those listed in Rule 3 without prior authorization is considered improper Class II injection. Upon discovery of such an event, the operator must immediately notify the Commission, provide details of the operation, and propose actions to prevent recurrence. Additionally, notification requirements of any other State or Federal agency remain the operator's responsibility.

**Rule 9: Plugging and Abandonment of Fluid Injection Wells (AIO 26)**

An injection well located within the affected area must not be plugged or abandoned unless approved by the Commission in accordance with 20 AAC 25.

**Rule 10: Other conditions (AIO 26)**

It is a condition of this authorization that the operator complies with all applicable Commission regulations.

The Commission may suspend, revoke, or modify this authorization if injected fluids fail to be confined within the designated injection strata.

**Rule 11: Administrative Actions (AIO 26)**

Unless notice and public hearing is otherwise required, the Commission may administratively waive the requirements of any rule stated above or administratively amend any rule as long as the change does not promote waste or jeopardize correlative rights, is based on sound engineering and geoscience principles, and will not result in an increased risk of fluid movement into freshwater.

**DONE at Anchorage, Alaska** and dated May 1, 2006.

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John K. Norman, Chairman  
Alaska Oil and Gas Conservation Commission

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Daniel T. Seamount, Jr., Commissioner  
Alaska Oil and Gas Conservation Commission

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Cathy P. Foerster, Commissioner  
Alaska Oil and Gas Conservation Commission

AS 31.05.080 provides that within 20 days after receipt of written notice of the entry of an order, a person affected by it may file with the Commission an application for rehearing. A request for rehearing must be received by 4:30 PM on the 23<sup>rd</sup> day following the date of the order, or next working day if a holiday or weekend, to be timely filed. The Commission shall grant or refuse the application in whole or in part within 10 days. The Commission can refuse an application by not acting on it within the 10-day period. An affected person has 30 days from the date the Commission refuses the application or mails (or otherwise distributes) an order upon rehearing, both being the final order of the Commission, to appeal the decision to Superior Court. Where a request for rehearing is denied by nonaction of the Commission, the 30 day period for appeal to Superior Court runs from the date on which the request is deemed denied (i.e., 10<sup>th</sup> day after the application for rehearing was filed).