The ALARA Challenge in Petroleum Exploration

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Many parameters must be evaluated to determine the feasibility of continued exploration in the search of petroleum anywhere beneath the earth's surface. The days no longer exist when the decision to drill a gas or oil well was based on surface geology and lithology. This practice, known as "wildcatting," became cost prohibitive when it became necessary to drill deeper wells (>18,000 feet) to reach locations that would economically produce the desired hydrocarbons.

Current logging tool technology provides the capability to determine the bulk density of the geological formations that may be related mathematically to the porosity of the formation and the hydrogen content of the fluids present in the formation; however, this technology requires the use of sealed sources containing up to 2 Curies of Cesium-137 and 20 Curies of Am241Be, as well as neutron generators that produce 10^8 14 MeV neutrons per square centimeter per second.

These tools are used in locations where the potential for very high personnel exposures is always present; therefore, the ALARA philosophy must be implemented when the tool is in the early design stages. Additionally, the well logging engineer must know the exposure parameters of tools when handling this equipment in the very limited workspace available on the floor of an operating oil or gas drilling rig.

Introduction

Before addressing the application of the ALARA principle to the use of radioactive materials in petroleum exploration, it is appropriate to address first the manner in which sources are used. Radioactive sources are used in all aspects of the process of the discovery and ultimate extraction of oil and gas (collectively called hydrocarbons) from the earth.

The development of a well consists of several phases, primarily

1. <u>Drilling phase</u> - the well is "logged," or evaluated either periodically or continuously, and the data reduced to a data log to identify the following:

- Type of Fluid Present – utilizing electrical measurement to distinguish oil from salt water in the rocks.

- Porosity (the percentage of the formation containing fluids) – utilizing acoustic, density (using a gamma source) and neutron logs.

- Lithology (the type of rock present to determine permeability) – utilizing electrical or radioactive measurements, or by computer processing of combinations of logs.

Zonal Isolation - Achieved by filling the void between the well casing and the well bore with cement to secure the well casing in place and eliminate the possibility of movement or vibration. The Production Zone (that area of the formation that will produce hydrocarbons) is also isolated from non-productive areas of the formation to enhance the process of hydrocarbon extraction. Radioactive sources are used in both the mixing tank and flow line to measure and monitor the density of the cement used in this process to ensure that the density is sufficient to contain the pressures encountered at the depth of interest.

2. Production Enhancement - Using short-lived isotopes such as Iodine-131 as a radioactive tracer, and Iridium or Scandium in conjunction with propants to determine the effectiveness of production enhancement efforts. Production enhancement is used to increase the flow of hydrocarbons from the geological formation into the well bore. This is achieved by pumping, under very high pressure, Frac sand or glass beads into the formation to "fracture" the formation and open the pore space to increase the porosity and permeability of the formation. The propants maintain the opening after the fracturing pressure is relieved. The Iridium or Scandium is used to evaluate and monitor the effectiveness of the fracturing operation.

3. Well Completion - Conducted after the Production Zone has been identified by using the nuclear logs to a) determine the Lithology and Geology of the formation, b) identify the presence and type of hydrocarbons, and c) predict the production potential of the desired hydrocarbons. The well casing is installed into the well and cemented into place. The production zone is precisely identified in the casing by crushing Cobalt 60 beads in the casing threads at the level of the production zone. These beads allow the engineer to relocate the production zone using a gamma log to locate the region. Then the well casing and cement is perforated using shaped explosive charges to provide a pathway for the hydrocarbons to enter the completed well.

The petroleum exploration science uses the following primary isotopes:

^{60}Co – Approximately 1 microCurie beads, commonly referred to as marker beads

^{137}Cs – 1.5 to 2 Curie sealed sources used for the evaluation of formation density, porosity and lithology, formation minerals, gas zones and fluid properties, commonly referred to as the "density log".

^{241}AmBe - 4 to 20 Curie sealed sources used for the evaluation of formation porosity and to locate gas (when data is combined with the density log).

^{3}H - 300 milliCurie target used in a pulsed neutron generator used to locate potential hydrocarbons, determine hydrocarbon saturation behind casing, locate gas, oil, and water contacts, evaluate formation flow conditions, detect channeling behind the casing, and determine stratigraphy.

Various quantities of ^{137}Cs, $^{241}AmBe$, ^{nat}Th, and KUTh in natural distributions ranging from 500 nanoCuries to 500 milliCuries are used as calibration sources for the various tools.

Implementing the ALARA Philosophy

Now that the ways in which various radioactive sources are used have been addressed, we may address the challenges of using and transporting these sources in keeping with the ALARA philosophy.

The first challenge to the implementation of an effective ALARA Program arises when the adopted program must satisfy the governing regulations of the host country. The following presents the typical compliance issues associated with petroleum exploration globally.

- 49 licenses/registrations/reciprocity agreements associated with radioactive sources and materials in approximately 32 states;

- Radioactive source inventories maintained in >50 countries worldwide;

- Necessary licenses, permits and supporting programs maintained for each country;

- >3,000 personnel worldwide are monitored by personal dosimetry and each dosimetry program must satisfy the personnel monitoring requirements for the host country;

- The master inventory numbering >14,000 radioactive sources/devices worldwide is administered in Houston, Texas. Local inventories are maintained at each facility in each country. The total inventory is maintained real-time through the use of a Company Intranet site available to selected individuals globally;

- Global responsibility and commitment to radiation safety

Program

Halliburton Energy Services has implemented, as a global standard of performance, the regulations for the control of radioactive materials prescribed by the United States Nuclear Regulatory Commission. These regulations define the minimum acceptable standard of performance for any facility operated or maintained by Halliburton Energy Services throughout the world.

If the regulations for the control and use of radioactive materials in a host country are more stringent than those of the United States, then these more restrictive regulations will be incorporated into the Halliburton program for that country. If, however, the host country regulations are less restrictive than the US regulations, we will not operate below the minimum US standards. This operating philosophy becomes the foundation for our ALARA Program.

The use of radioactive sources in petroleum exploration was first introduced in 1956 using a 600 milliCurie ^{226}RaBe source. That same year it was discovered that the sources as designed leaked, and necessary design changes were implemented.

Today's sources are designed to the criteria prescribed in ANSI N43.6, Sealed Radioactive Source Classification, and International Standard ISO 2919, Sealed Radioactive Sources – Classification.

The test criteria applied to well-logging sources are:

- Vibration: 30 minutes at 25 to 500 Hz at 5 g peak amplitude
- Puncture: 1 g (15.4 gr) from 1 m (3.28 ft)
- Temperature: - 40°C (20 minutes), + 600°C (1 hour), and thermal shock 600°C to 20°C
- Impact: 5 kg (11 lb) from 1 m
- External pressure: 25 kN/m^2 abs. to 170 MN/m^2 (24,656lb$_f$/in^2) abs.

These tests will ensure that the sources used for well logging operations will withstand the influence of the petroleum well environment. Additionally, sources that are not listed in the Sealed Source Device Registry and approved by a Competent Authority for use in well logging operations will not be used.

Job Sites

Sites involved in petroleum exploration range from drilling locations in downtown Beverly Hills, California, to barge-mounted drilling rigs on a jungle river accessible only by boat, to offshore drilling rigs accessible only by boat or helicopter. Rarely is transportation convenient and even more rare is the ability to move radioactive materials by the use of an exclusive-use vehicle.

Equipment and Applications

The Halliburton program may be broken down into three discrete parts: 1) technology development (to include research), 2) manufacturing, and 3) field operations. The ALARA principles must be applied to each aspect of our operation.

The Radiation Safety staff is closely involved in the Research and Development of new and improved tools and works closely with engineers and scientists to ensure that all aspects of the application of radioactive sources to petroleum exploration are evaluated from the ALARA perspective. For example, careful consideration is given to the isotope and quantity necessary to provide the desired data for control or evaluation purposes. Once this isotope and quantity is defined, the shielded container is designed to a) ensure that the container reduces the source radiation levels to the lowest practical levels, b) the shield will satisfy the Department of Transportation requirements for a 7A Type A container, and c) the container may be safely handled in the field application.

The designs of the source cap, the transportation container, and tools for the physical handling of the source are all considered during the Research and Development of new tools and processes. All aspects of source handling are evaluated and incorporated into the design of supporting equipment with a focus on exposure reduction to ensure that worker exposure is minimized when the tool and source combination is released for field use.

In addition to the transportation and handling aspects of the source and container, the tool with the installed source is evaluated to define the orientation of the dose field or isopleth surrounding the tool. This provides the logging engineer with the necessary information to ensure that the exposure potential to personnel on the rig floor is minimized by properly orienting the tool before entering the well bore.

During the design of a tool using a radioactive source, the most important considerations are as follows:

- To ensure that the source can be handled safely in adverse working conditions;
- That the designed shield maintains the physical security of the radioactive source;
- That the shield and source design reduces the exposure potential from the stored sources to the lowest practical level; and
- To satisfy the criteria of a certified shipping container for the source.

Close scrutiny of source applications is maintained throughout the manufacturing process. The manufacturing process includes testing the tool and source combination in actual well conditions at the manufacturing facility's test well. This testing determines not only the operating characteristics of the tool, but allows us to evaluate any unanticipated radiological conditions inherent in the design of the tool. Continuous feedback and performance monitoring is strictly maintained and user input for improvement is always considered.

The ultimate ALARA goal is to provide the logging engineer with a source, shield, and tool combination that can be safely transported and used in remote and sometimes hostile locations, incorporating all domestic and international transportation and radiation protection regulations.

Only after the well logging tools and sources have been safely transported to and used at thejobsite, and exposure to occupational an non-occupational workers on the drill rig has been maintained **ALARA**, HAS Halliburton met the ALARA challenge in petroleum exploration.

References

ANSI N43.6, Sealed Radioactive Source Classification

International Standard ISO 2919, Sealed Radioactive Sources – Classification.

10 CFR Part 39, Licenses and Radiation Safety Requirements for Well Logging

10 CFR Part 20, Standards for Protection Against Radiation

Safety Series No. 115, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources