THE APPROACH TAKEN TO THE TRANSPORTATION OF RADIOACTIVE SOURCES WITHIN A MULTI-NATIONAL OIL SERVICES COMPANY

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ABSTRACT

Baker Hughes INTEQ, a division of Baker Hughes Incorporated, provides drilling and associated services to the global oil and gas industry. A major product line uses sealed radioactive sources to obtain real-time evaluation of the formation being drilled by use of a technique called 'measurement while drilling' (MWD). INTEQ have provided MWD services in more than 50 countries from its major support bases in USA, UK, Norway, Nigeria, Dubai and Singapore. An MWD operation on a land or offshore drilling rig involves the use of a 185 GBq Am-241/Be neutron source and a 74 GBq Cs-137 gamma source. The company's operations require frequent shipments of these and other radioactive sources in Type A packages by road, sea and air between the support bases and to and from the drilling rigs. INTEQ undertakes more than 1000 shipments of these radioactive sources every year, with more than 250 involving the transport of Class 7 substances across international borders.

This paper is aimed at radiation protection professionals with an interest in the transport of Class 7 materials and assumes no prior knowledge of oilfield operations and the use of radioactive sources in drilling formation evaluation. The objective is to inform a wider audience of the nature of the work being done and to report the experience of Baker Hughes INTEQ in attempting to ensure a high standard of radiation protection in transporting radioactive materials.

INTEQ's aim is to ensure continuing safe and reliable shipment of radioactive sources, in a manner which is fully compliant with the international modal requirements and the local laws and regulations in place in the many countries in which this transport is undertaken. This paper provides details of the frequency and nature of the national and international shipments undertaken and summarises the procedures put in place by INTEQ to ensure the reliable and safe shipment of its Class 7 materials. It explains in detail the steps taken to comply with the regulatory requirements in the design of the Type A packages and their marking and labelling. The paper provides a detailed description of the design and performance of the overpack developed by INTEQ to transport its logging sources and to enable their safe storage at the rig site. The paper concludes with a discussion of several of the problems and complications which have been encountered and the lessons which can be learned from these by other consignors, carriers and by regulatory agencies involved in overseeing Class 7 shipments.

INTRODUCTION

Baker Hughes Incorporated is an oil service company providing drilling, formation evaluation and production technology to oil and gas exploration and production operations. Baker Hughes is the combination of many innovative companies that have developed and introduced technology to serve the petro-chemical industry. Their combined history dates back to the early 1900s. Every day in oil fields around the world, Baker Hughes engineers, geo-scientists and field service personnel apply the corporation's technology to find reserves, develop fields and produce oil and gas.

The global oil market had a major slump during the late 1990s, but is now showing signs of recovery. For the 12 months ending on 31 December 2000 the corporation had revenues of approximately $5.2 billion. Approximately two-thirds of these revenues come from operations outside the United States. In 1998, Baker Hughes had 36 500 employees; today this number stands at 25 000 [1].

Five of Baker Hughes's oil field operating divisions have some involvement with radioactive materials, sealed and unsealed, natural and artificial. The authors of this paper make up the Radiation Protection Department which supports the company's work with ionising radiations in the 'Eastern Hemisphere' of the global oilfield. The work involves more than 3 000 'badged' radiation workers in 50 countries. Work with radioactive materials is done in compliance with the requirements of 120 operating licences, issued by national regulatory authorities, permitting the storage, use and transport of upwards of 8 000 sealed radioactive sources.

In this paper we are going to look at one of the newer operating divisions, Baker Hughes INTEQ, which provides services related to advanced drilling technologies [2]. In particular, we are going to focus on INTEQ's 'measurement while drilling' or 'MWD' services. These provide precise well navigation information and evaluation of the formation being drilled through, in real time, to the rig operators. Prior to the development of MWD technology, such information could only be obtained by lowering equipment into the hole after the drill had been removed, using techniques known as 'wireline logging'. MWD tools carrying radioactive sources, commonly known in the oil field, albeit incorrectly, as 'nuclear tools', provide information on the density and porosity of the underground formation being drilled through.

In its 10-year service since developing its MWD technology, INTEQ have provided 'nuclear' logging services in 50 countries. In the Eastern Hemisphere, the company currently has around 200 trained radiation workers actively supporting and providing nuclear MWD services.

LOGGING SOURCES

The most active sources in use by INTEQ are the logging sources, which are loaded into the logging tools. The loaded tool is attached to the drill string and travels underground to provide real-time evaluation of the formation encountered. The porosity logging tools carry a nominally 185 GBq sealed source of amercium-241/beryllium (Am-241/Be). Backscatter of neutrons by the formation provides information on the porosity of the rock. The density logging tools carry a 74 GBq sealed source of Cs-137: the Compton scattering of the emitted gamma rays provides information on the density of the formation being drilled through.

The sealed sources used to manufacture logging sources come doubly encapsulated from the manufacturer and more than meet the standards specified internationally for oil well logging sources [3]. They are, however, encapsulated again within a third welded stainless steel plug specifically designed by Baker Hughes INTEQ. This enables the source to be manipulated with the handling tools designed by INTEQ and also enables it to be properly and securely screwed into the source port on the logging tool before it is run down hole.

The responses of the neutron and gamma detection systems on the logging tools are calibrated prior to each logging job. The responses of the detectors are then confirmed by 'verifiers', devices which contain smaller radioactive sources. The density tool verifier contains 2 small Am-241 sources (37 MBq each) and 2 Cs-137 sources (3.7 MBq and 1.85 MBq). The neutron tool verifier contains 2 Am-241/Be sources (1.11 GBq each).

The verifiers accompany the tools and logging sources to the rig site so that the detector response can be checked and confirmed prior to the commencement of the logging. This permits the application of the pre-job calibration and enables the MWD engineers to provide quantitative measures of the density and porosity of the formation being drilled through.

SOURCE TRANSPORT CONTAINERS

INTEQ would not be able to provide its MWD service on the scale it does without a reliable system for national and international transport of the radioactive sources between its main support bases and to and from the drilling rigs, on land and at sea. We will here describe the Type A packages used to facilitate the shipment of logging sources and verifiers. All of the sealed source capsules in use are covered by special form certification.

The Type A package for the density logging sources, referred to as a 'pig', weighs 50 kg. It is fabricated from a cylinder of lead, encased within a steel surround. The source is screwed into a specially designed tungsten insert at the centre of the lead. The typical dose rate present at the surface of a pig containing the 74 GBq Cs-137 source is 700 μSv/h, this being more than a thousand fold reduction from the dose rate that would be present at that distance if the source were unshielded. The loaded pig is transported as a III-Yellow category package, normally with a transport index (TI) of the order of 1.0.

For the 185 GBq Am-241/Be neutron logging source, the *Amersham* Type A package, which is called a 'keg' because of its similarity to barrels used for transporting beer, weighs 75 kg. This consists of a aluminium can filled with boron-loaded, water expanded polyester. Again, the source is screwed into a specially designed tungsten insert at the centre of the polyester. The typical neutron dose rate present at the surface of a keg is 500 μSv/h, this being the order of a five fold reduction of the dose rate that would be present at that distance if the source were unshielded. The gamma ray dose rate on contact is typically 10% of the neutron dose rate. The loaded keg is transported as a III-Yellow category package, normally with a TI of the order of 5.0. The neutron component of the dose rate at 1 m is about 90% of the total.

For the density and neutron verifiers, the body of the devices themselves have been designed and tested by Baker Hughes INTEQ to meet the requirements of Type A packages. The TI of the neutron verifier is typically of the order of 0.4, while that of the density verifier is 0.3. Both are shipped as category II-Yellow radioactive packages.

THE 'BUNKER' OVERPACK

INTEQ's sources could legitimately be transported within the specially designed Type A packages described above, although routine shipment would require the use of some form of overpack to consolidate packages and simplify handling. On oil rigs there are specific material handling and lifting requirements which necessitate that everything must be able to be lifted to and from the rig by crane.

It is clear, therefore, that regulations would permit a set of INTEQ logging sources to be transported in a simple, 'crane-able' overpack, allocated to the III-Yellow radioactive category. It was envisaged, however, that this would lead to problems when the sources arrived at the rig site. On offshore rigs in particular, space is at a premium and it would be difficult in all cases to arrange for the necessary restricted area around such a simple transport overpack. Steps would need to be taken to control the radiation exposure of the rig personnel on delivery of the sources to the rig, during any interruptions to the drilling operations, and on completion of the job prior to dispatch of the sources back to base. For this reason, the decision was taken to construct an overpack container which could be used routinely for the transport of a set of logging sources but which would also be, in effect, a portable source store.

Baker Hughes INTEQ has developed a fleet of overpacks or 'bunker' containers to ship its radioactive sources to and from rig sites around the world. These are entirely unlike anything used by any other oil service company involved in MWD or wireline logging operations and ensure the proper protection of all persons when the sources are in storage on the rig. Each consists of a 1.6 by 1.5 by 1.3 m steel shell, filled with concrete and lined with *permadex*, a proprietary neutron shielding material. This source housing is mounted onto a large area skid to spread the weight and enable it to comply with the floor loading restrictions on offshore installations. The source enclosure itself has either two or three doors; the outer one is locked to secure the sources during transport and storage. The overpack is fitted with a transponder which will enable its location to be determined in the foreseeable, but hopefully avoidable, situation that it is dropped into the sea. An empty bunker overpack weighs 7.5 tonnes.

Monitoring around a fully loaded overpack confirms that the combined neutron and gamma dose rates in contact with the outer surface are less than 5 μSv/h and the dose rates at 1 m are less than 0.5 μSv/h. The overpack, therefore, may be shipped as a category I-White enclosure. The low emitted dose rates make the overpack an ideal source store at the rig site and no additional controls for worker protection are necessary. The bunkers are also used as temporary stores at remote base locations to avoid the need for the construction of walled or underground source stores.

Because of the weight of shielding materials involved, there is always a possibility that personnel will injure themselves when handling and moving the logging source containers. In previous years the logging sources and verifiers needed to be loaded to and from the bunker overpack by hand and, because of the lack of space, only one person could physically get hold of the containers at any one time. To avoid injury, a new mechanical loading and unloading system has in the past year been installed in all of the company's overpacks. Use of the crane or 'tugger' line on a rig to move the source containers around when not in the overpack means that we have almost completely eradicated any unnecessary or individual manual handling of these bulky and heavy items.

CLASS 7 SHIPMENTS

The structure put in place by Baker Hughes INTEQ to support and deliver its 'nuclear' MWD services, and the scale of the operation, requires frequent consignment of radioactive sources for national and international transport, by road, sea and air. MWD operations in the Eastern Hemisphere are supported from the 5 maintenance and calibration facilities in the UK (Aberdeen), Norway (Stavanger), Dubai, Nigeria (Port Harcourt) and Singapore. Broadly, these respectively support MWD services in the North Sea and Europe, the Middle East, Africa, the Far East and Australasia.

Efforts have been made to keep the number of sources necessary to run these operations to a minimum, which means that there is a need to use each source as efficiently as possible. Thus the need to ship sources between these main bases and also to and from Houston, the base for INTEQ's global operation. INTEQ has developed its own database ('RadNet') to enable it to track the locations and movements of its entire radioactive source asset.

A trained and competent Radiation Protection Supervisor (RPS) at each base is responsible for receiving and shipping all radioactive sources. They select the sources to be shipped, load them into the bunker overpack or other overpack as necessary, prepare the dangerous goods notes, make the necessary notifications and consign the shipments.

In a typical year, the Eastern Hemisphere base RPSs will be responsible for the consignment of around 300 radioactive shipments and will receive at least a similar number. In a busy year like this one, 2001, the numbers will be increased. To illustrate the scale of INTEQ's transport operations, Figures 1 to 3 provide details of recent radioactive consignments from 3 of the main bases. In all cases, lowest hazard I-White category shipment of this material is only possible by use of the large bunker overpack described above.

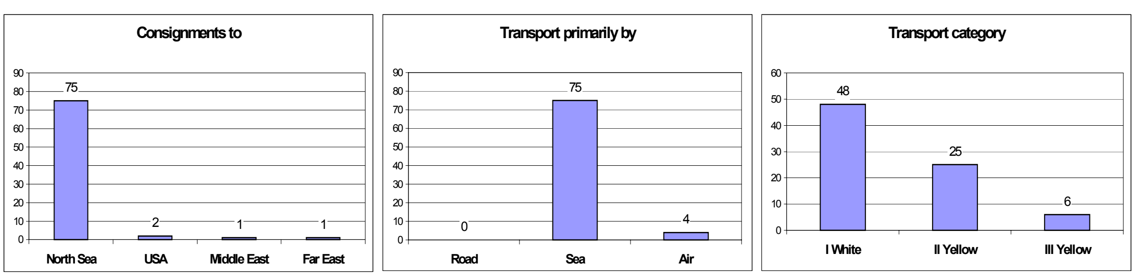

Figure 1: Stavanger - 79 consignments between January and June 2001

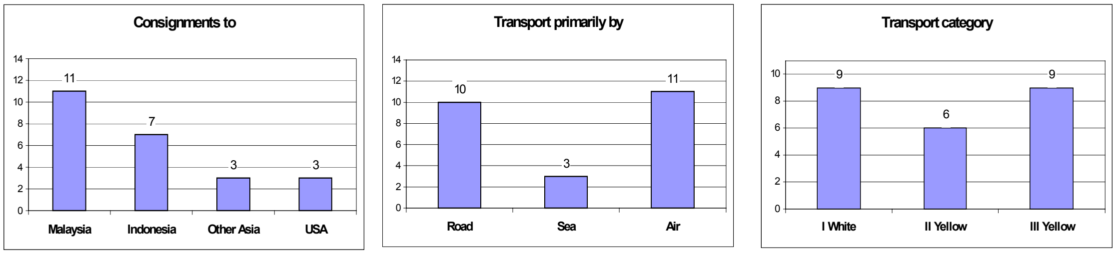

Figure 2: Singapore - 24 consignments between June 2000 and May 2001

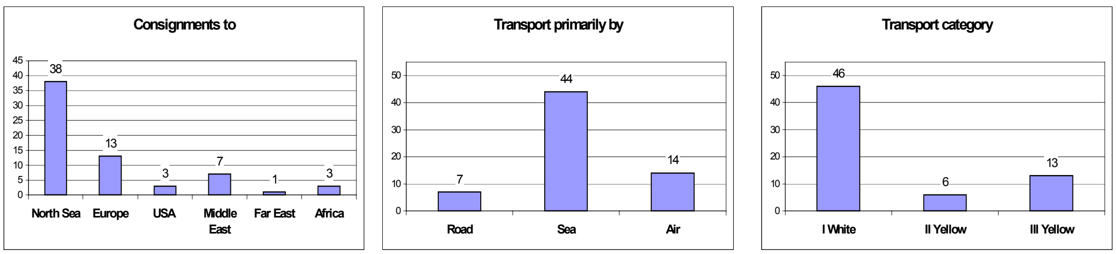

Figure 3: Aberdeen - 65 consignments between May 2000 and April 2001

The busiest base in supporting nuclear MWD operations is the one in Norway. The figures illustrate, however, that the great majority of these are routine shipments in support of offshore operations in the North Sea, primarily using the bunker overpack. The base in Aberdeen has historically been the hub of the source asset of the Hemisphere and thus, in addition to supporting routine operations in the UK sector of the North Sea, is required to consign a greater number of shipments to international destinations, by road, sea and air.

ISSUES ARISING

The scale of the operation described above illustrates the experience of Baker Hughes INTEQ's staff in transporting radioactive materials. Our knowledge of how this is done at the operational level is significant. Barriers and obstacles are encountered, sometimes daily, and speedily overcome. Several issues of wider significance are raised and discussed below.

Local regulations as barriers to efficient shipment

The international nature of our MWD operation is only possible because of the widespread international consensus on standards for the transport of radioactive materials contained within the IAEA's Regulations for the Safe Transport of Radioactive Material (TS-R-1) [4]. We would not be able to organise our work the way we do if this were not the case. A simple example illustrates how much more difficult it is for us when additional requirements apply.

Transporting radioactive materials by road across national borders within Europe is made possible by the *European agreement concerning the international carriage of dangerous goods by road* ('ADR'). One European country, however, does not subscribe to ADR with the same flexibility as other European countries. Radioactive material can only be shipped by road in that country by carriers who are licensed for this by the national authority. We can ship our materials to their border, passing through 3 or 4 other countries, using the same network of carriers that we use throughout Europe. However, when the load gets to the final border, the radioactive package needs to be removed and transferred to a local licensed carrier. This greatly complicates the logistics involved in getting the radioactive sources into and out of that country.

It is for this reason that we support the widespread application of TS-R-1. We look forward to the day when shipments done in compliance with TS-R-1 will be sufficient to permit movement in all circumstances, by all modes, in all countries, without additional requirements being added by local regulators.

Package or overpack?

We gave a detailed description above of the bunker overpack used by Baker Hughes INTEQ to transport its radioactive sources to and from rig sites. Although this contains 4 Type A packages, the largest of which is a III-Yellow category package with a TI of around 5.0, the shielding afforded by the overpack enables it to be shipped as category I-White.

The overpack has not been drop tested, stack tested or penetration tested. It has been suggested that an accident which damages the overpack could result in a carrier, organised to transport a I-White shipment, needing to stow or store in transit several II- and III-Yellow category packages. The contents of the overpack are clearly declared in the dangerous goods paperwork. Should we, in addition, ship the overpack as a III-Yellow package (with a TI of 0.0), to alert the carrier to this possibility? Alternatively, perhaps we ought to certify the overpack to Type A to show that such an incident will not occur?

An overpack is defined in TS-R-1 as being a box or bag used ‘for convenience of handling, stowage and carriage’. It is not explicit in this whether an overpack may or may not provide any radiation shielding. The INTEQ overpack clearly does, but it is our view that requiring it to be labelled to reflect the category of the packages contained, or, alternatively, that it should be certified to Type A, can equally be made against any non-shielding rigid overpack.

To explain this, consider a simple wooden crate carrying a III-Yellow package secured at the centre of the crate so that the overpack can be allocated to a lower category, say II-Yellow, on the basis of a direct measurement of the maximum radiation levels present, as permitted by TS-R-1. An incident could result in damage to the internal spacing structure holding the package. Any movement of the package towards the surface of the crate will make the overpack labelling incorrect. Thus, if it is not appropriate for INTEQ’s overpack to be labelled as category I-White, it follows that TS-R-1 should not permit the use of any rigid overpack that enables a package to be shipped in a lower category than the package itself. A significant amount of radiation shielding has been deliberately built in to the INTEQ bunker to make the shipment safer. We conclude that this does not require us to ship it in a higher category than that allocated on the basis of the radiation levels present outside, as permitted by TS-R-1.

Making the transition to TS-R-1

The changed requirements in TS-R-1 have not been as far reaching for Baker Hughes INTEQ’s operations as they have been for persons involved in the shipment of nuclear materials etc, but some significant modifications to our programme have been required. These have primarily arisen from changes to the UN numbers and proper shipping names and the changed requirements for the labelling and marking of Type A packages.

A main complication for us was associated with the different implementation dates and transition periods permitted on the different modes and in national legislation in many countries. We decided to cut over to TS-R-1 on 1 July 2001. All shipments from INTEQ's Eastern Hemisphere bases after 1 July have been made with Type A packages with new information plates and the revised UN numbers and proper shipping names were used in paperwork from that date. We conclude that INTEQ have successfully made the transition to TS-R-1, although we are aware that many shipments being made throughout the international oil field will not be in line with TS-R-1 for a significant period of time yet.

HOW GOOD IS THE GENERAL STANDARD OF COMPLIANCE IN THE TRANSPORT OF CLASS 7 MATERIALS?

Our day to day involvement with shipping agents and road, sea and air freight carriers shows that the standard of compliance with the international requirements for the transport of radioactive materials is not what it could be. Our particular knowledge, of course, comes from our involvement in the international oil field and we conclude that this is an area, in particular, where improvement is required.

We will provide some examples to illustrate this point.

Example 1: A wooden overpack carrying 4 Type A packages was successfully shipped from Africa to Europe on a passenger aircraft with no radioactive labelling or dangerous goods paperwork. If properly determined, the overpack should have been labelled as III-Yellow, with a transport index of around 5.0.

Example 2: At the other extreme, a wooden overpack carrying 8 Type A packages was shipped by passenger aircraft from the USA to the UK with 9 different II- and III-Yellow labels affixed to the outside. The consignor had mistakenly reproduced the labels affixed to the inner packages on the overpack, in addition to the label for the overpack itself (which properly described its contents and quoted the correct transport index of 6.8). The labels were attached on all 4 sides, meaning that the overpack was carrying 36 labels in all.

Example 3: An overpack carrying several Type A packages, one of which was a large Am-241/Be source, was labelled II-Yellow, with a TI of 0.5. The TI, however, was based on a radiation survey with a gamma meter only and thus failed to take account of the much larger neutron dose rates present around the container. (This failing, unfortunately, is not uncommon amongst oil service companies.) The TI of this package should really have been 3.5, clearly a III-Yellow container, and one which should be subject to much more careful radiation control during transport.

All of the examples above are clearly caused by failings within the consignor organisations, and, with regard to the oil field, this is something that operators themselves can do something to improve. It is unfortunate, however, that the ease with which such non-compliant shipments can be made will continue to act against the industry making the necessary improvements. Put cynically: why take steps to improve when it is easier, cheaper and no less reliable to continue as they have been doing for years?

The above are actual examples of the sort of errors which are being made every day in the national and international transport of radioactive materials. It should not be assumed that a successful shipment is necessarily a fully compliant one. It can be concluded that the shipping agents and carriers of these packages do not always have a sufficiently trained workforce, capable of identifying what are often quite obvious non-compliant consignments. It follows from this that the level of regulatory oversight could be improved. As can be seen from the examples given, this is often as lax in industrialised countries as it is in developing countries.

Example 1, the ‘silent’ shipment, might appear to be a more intractable problem, but it is easier to detect and prevent undeclared shipments of radioactive materials than of the other classes of dangerous goods. The radiation from such illicit shipments can easily be detected by rudimentary installed alarms or routine audits with hand-held survey meters, although the fact that many sources in use in the oil field are neutron sources must not be overlooked.

CONCLUSIONS

This paper has described Baker Hughes INTEQ’s system and organisation for the national and international shipment of radioactive materials in support of its ‘nuclear’ MWD services to the oil and gas industry. Baker Hughes INTEQ will continue to make every effort to develop its system for the reliable and safe shipment of class 7 materials. On the few occasions when mistakes occur, however, the resulting non-compliant shipments seem to get through just as efficiently as the compliant ones, whilst, on other frustrating occasions, fully compliant shipments are delayed or held up for no reason.

We conclude that there is a need for consignors involved in oil field operations to review their operations for the transport of class 7 materials and to strive to work to higher standards. There is, however, insufficient pressure from many carriers to require compliance with the various modal regulations. This could be improved by more attentive and forceful regulation. If we are going to achieve what we want, the safe, efficient and reliable transport of radioactive materials, we suggest that an increased level of attentiveness and surveillance is required by everyone involved: operators, consignors, carriers and regulators, in national and international agencies and modal authorities.

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