

## Mr Robert Vance, Nuclear Development Division, Nuclear Energy Agency, OECD What can 40 Years of Red Books Tell Us?

### Background

The history of the Red Book dates back to January 1965, when the European Nuclear Energy Agency (ENEA) of the Organization for Economic Cooperation and Development (OECD) established a Study Group to examine the long-term role of nuclear energy in Western Europe. A “Working Party”, the precursor of the Uranium Group, was formed by the ENEA to compile worldwide uranium and thorium resource estimates. The Working Party, which became a joint effort between the ENEA and the International Atomic Energy Agency (IAEA) about a year later, was responsible for preparing a series of ten assessments of worldwide uranium supply between 1965 and 1982.

The first in this series of assessments of world uranium resources, “World Uranium and Thorium Resources”, had a red cover, as have all subsequent editions; hence the informal name the “Red Book”. Because of the near absence of a commercial market for thorium, the 1967 Red Book was re-titled “Uranium Resources Revised Estimates” and thorium was addressed in only a short section of the report.

By 1984, the Uranium Group included representatives from NEA member countries and a representative from the IAEA Secretariat. In 1992, non-OECD member States were invited to attend Uranium Group meetings as part of the IAEA delegation, ensuring greater availability of information on a broad range of global uranium supply and demand issues. Over the course of its history, the Uranium Group has grown from 11 members representing six countries in 1965 to 42 members from 33 countries and three international organizations in 2005. In the process it has expanded into an authoritative source of government-sponsored information on countries that have produced or used uranium for civilian purposes. A total of 107 countries have contributed data to the 21 Red Books published to date.

In 1965, there were 29 reactors in operation worldwide, with generating capacity totaling about 4500 MWe. By 2005, 440 reactors were in operation with generating capacity totaling about 369 200 MWe. Collectively, Red Books published over this period track the growth of nuclear power and provide comprehensive official government data on uranium resources, exploration and production. The 1965 Red Book included information relating to uranium resources in 16 countries with Reasonably Assured Resources (RAR) totaling some 993 000 tU. By 2005, RAR amounting to about 3 297 000 tU were reported in 44 countries.

The history of the Red Book has paralleled the growth of nuclear energy, each influenced by world events such as the

oil crisis in 1973 that increased public awareness of the potential of nuclear energy, the Three Mile Island and Chernobyl accidents that slowed the growth of nuclear power, and the end of the Cold War in 1989 that led to the inclusion of new information on the uranium industries of Central and Eastern European countries, beginning in 1991, and countries of the former USSR beginning in 1993.

The Red Book Retrospective was undertaken to collect, collate, analyze and publish all of the data in all Red Books published between 1965 and 2003. In addition to analyzing existing information, every effort was made to fill in gaps in information to ensure that Red Book Retrospective provides as complete a perspective as possible on the history of uranium supply and demand. Appendices of the consolidated raw data in spreadsheet format have been included to allow readers to perform additional analyses, if so desired. Many chapters in the report have associated appendices with spreadsheets that include the data on which charts and graphs in the report are based. With the inclusion of this supplementary information, the Red Book Retrospective is arguably the most complete record of the uranium industry available, dating from the birth of civilian nuclear energy through the dawn of the 21st-century. Some key findings with respect to the uranium industry are highlighted in this short summary of the Red Book Retrospective.

### Key Findings

#### REACTOR RELATED URANIUM REQUIREMENTS

Between 1956 and 2003, the 33 countries that have used commercial nuclear reactors had reactor-related requirements that are estimated to have totaled just over 1 500 000 tU. The top five users of uranium during that period were:

- United States - 364 000 tU, or 24.0% of the total utilized;
- France - 174 000 tU, 12%;
- Japan - 164 000 tU, 11%;
- Russian Federation - 95 000 tU, 6%;
- Germany - 74 000 tU, 5%.

#### URANIUM MARKET PRICE

The price of uranium reached its all-time peak in the 1970s, driven by a combination of military requirements and the anticipated growth of civilian nuclear power. After this peak prices dropped rapidly, and then began a steady decline over the next 20 years, driven in large part by slower than expected growth in nuclear power and a substantial supply over capacity ratio that resulted in the build-up of large inventories, particularly during the 1970s. The price hit a historic low in 2000, and then began a rebound that

continues today, as the market adjusts to the reality of declining inventory and increasing demand.

Fluctuations in the uranium market price have impacted several aspects of the uranium industry over the years including exploration, uranium resource estimates and production capacity, as well as influencing production methods (e.g., development of ISL and non-entry mining methods for very high-grade deposits). In the past, military demand for uranium distorted the market, compared to other commodities. Since the end of the Cold War, however, uranium has increasingly behaved as a typical commodity, with prices responding principally to perceptions of the supply and demand balance.

## EXPLORATION

A total of 81 countries have reported uranium exploration expenditures between 1945 and 2003 amounting to just over US\$13.0 billion. The world leaders in total uranium exploration expenditures (in current US\$) over the course of the Red Book history were:

- USSR (not including expenditures in Kazakhstan, the Russian Federation, Ukraine and Uzbekistan since 1991) - US\$3.7 billion, or 28% of total expenditures;
- United States - US\$2.5 billion, 19%;
- Germany (includes GDR) - US\$2.0 billion, 15%;
- Canada - US\$1.3 billion, 10%;
- France - US\$0.1 billion, 7%.

Exploration expenditures have closely tracked uranium market prices, with the peak in expenditures lagging the 1978 market price peak by only one year. As one might expect, the parallelism between market price and exploration expenditures was strongest in market-based economies, whereas data from centrally planned economies displayed little relationship between price and the level of exploration activity.

Exploration data from thirteen leading resource countries, which together account for 87% of global Known Conventional Resources (KCR) recoverable at <US\$ 130/kgU, show that the historic cost of discovery in these countries has amounted to less than US\$ 2.00/kgU.

## URANIUM RESOURCES

Uranium resources are reported by confidence level and production cost category. Resource categories have evolved in response to changes in the uranium market and to growing sophistication in resource calculations. The 1965 Red Book reported resources in 16 countries totaling 3.2 million tU; in 2003, 56 countries reported total resources in all confidence and cost categories of 14.4 million tU. Several factors contributed to the increase in resources, including: discovery of additional resources as the result of ongoing

exploration; an increasing number of countries participating in the reporting process, including those of the former Soviet Union; several countries, including China, Iran and India began reporting resources according to Red Book classification criteria; new resource categories were added over time, along with changes in production cost categories.

Market price influences resource assessments because it drives exploration expenditures in market-based economies as well as affecting cut-off grades and perhaps other parameters used in resource calculations. However, because of the time lag between exploration and resource reporting, these relationships are seldom readily apparent. Depletion of resources through production has not yet become a factor as far as the adequacy of supply is concerned. Despite cumulative production of more than 2.2 million tU through 2003 and a lengthy period of reduced exploration effort, additions to resource totals have kept pace with production so that overall resource levels have remained level or have increased over time. The ratio between KCR and reactor-related uranium requirements in 2003 was 52 and has averaged 47 since 1985.

## URANIUM PRODUCTION

Uranium production in 1945 is estimated to have been slightly more than 500 tU. In 1965, when the first Red Book was published, production totaled 31 630 tU. The peak in global production was achieved in 1980, amounting to 69 683 tU from 22 countries. In 2003, uranium production totaled 35 600 tU from 19 countries. Between 1945 and 2003, cumulative worldwide uranium production amounted to over 2 200 000 tU from 35 countries. The leading countries in cumulative uranium production from 1945-2003 were:

- USSR (production only to 1991) - 378 000 tU, or 17% of total production;
- Canada - 375 000 tU, 17%;
- United States - 367 000 tU, 12%;
- Germany (includes GDR production between 1946 and 1989) - 219 000 tU, 10%;
- South Africa - 158 000 tU, 7%.

Primary supply exceeded reactor-related uranium requirements until 1991, and then the relationship was reversed. The resulting gap between primary supply and uranium requirements since 1991 has been filled by secondary supplies (e.g. military and commercial inventories, enriched uranium tails, reprocessed uranium and mixed oxide fuel). In 2003 primary production almost equaled secondary supply.

Historically, uranium mines and mills around the world have operated at about 76% of total production capacity, varying within a range of 57% and 89%. The fact that production has never matched capacity is largely attributable to the uranium industry having to lower output to match demand

for primary supply. Slower growth of nuclear power and competition from secondary supply significantly reduced demand for freshly mined uranium, until very recently.

## NATURAL AND ENRICHED URANIUM STOCKS AND INVENTORIES

Between 1945 and 2003, cumulative worldwide production is estimated to have exceeded reactor requirements by almost 700 000 tU. This figure represents an upper bound of total already-mined uranium above requirements, but not necessarily a true inventory of excess material available for civilian use, since a portion will likely remain required by the military. Nevertheless, natural and enriched uranium stocks and inventories originating from this excess material represent a significant resource that has the potential to continue to supplement primary supply in the future.

Inventories of natural and enriched uranium have been reduced over time, as shown by the ratio of inventory to requirements. This ratio has decreased from about 6 in 1983 to about 1.5 since 1999, suggesting that utility-held inventories are approaching strategic levels, with much less discretionary material available to the market.

## Conclusion

While there are many lessons to be learned from the data and analyses presented in the Red Book Retrospective, two key messages deserve highlighting today as many countries consider expanding nuclear generating capacity in a manner not seen since the 1970s.

- Uranium is abundant and, in the past, it has been possible to locate deposits of economic interest at a reasonable cost.

Past exploration efforts have resulted in the delineation of a significant, low-cost resource base. A 20-year period of reduced exploration expenditures ended in late-2000. Since then, exploration expenditures have steadily increased. It can be expected that this new period of heightened exploration activity will result in the discovery of additional uranium resources, as was the case in the last round of heightened exploration activity in the 1970s.

- The analysis of annual reactor-related requirements to reported resources shows a forward looking reserves ratio that has steadily averaged about 45 over the past twenty years, despite steadily increasing requirements.

Despite reduced exploration activity for some 20 years and cumulative uranium production amounting to over 2 200 000 tU, reported uranium resources have steadily increased since the mid-1980s.

Taken together the lessons of the past provide confidence that uranium resources will remain adequate to meet projected demand, even if demand were to significantly increase.

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