ties. Preference is given for a downward coolant through the core. In this case the hot gas has to be directed upward again inside the core vault because the steam generator should have its gas entrance at the top. Also, the problems of inspectability and repairability of the liner of the pressure vessel are under discussion.

Another goal in addition to that of high conversion is high temperature of the core coolant, and connected with this is good thermal efficiency. The high-temperature gas-cooled reactor solves this problem. Its sensitivity against cooling disturbances is very low and at first glance its safety analysis appears to be favorable. The hot gas could be used for process heat application. The question is open as to whether this advantage is really needed in the near future. A drawback of the HTGR is its low conversion ratio, and even with special design no breeding appears to be possible.

Developing countries, nevertheless, should look into these advanced types of reactors before going deeper into a nuclear energy program. Not only are the water reactors consumers of valuable fuel that might become scarce in future times but they also have drawbacks with respect to their safety, and these have not yet been fully analyzed in all cases. The conclusion is that nowadays no nuclear energy program should be based on just one type of reactor, regardless of which reactor is chosen for the start of the program.

3. Multipurpose Nuclear Process Heat for Energy Supply in Less-Industrialized Countries, *Th. Bohn (KFA-Jülich/Germany), R. Y. Hukai (IEA/Brazil), P. Inden, D. Oesterwind (KFA-Jülich/Germany), R. T. Pessine, R. R. Pienoni (IEA/Brazil), R. Schulten (KFA-Jülich/Germany)*

This paper assesses the utilization potential of nuclear process heat on the basis of the probable economic development of less-industrialized countries. In this context, the following problems are discussed with a view to the countries concerned:

1. Description of the nuclear process heat technology and its fields of application, such as
   - a. synthesis gas (e.g., for chemical processes)
   - b. nuclear district heat and district energy (e.g., for regional agglomeration areas)
   - c. high- and low-temperature process heat (e.g., for seawater desalination, oil production from oil shale, steel production, paper industry, plastics industry, textile industry).

2. Preparation of criteria for the classification of countries in light of their possibilities to utilize nuclear process heat (e.g., the existence of sufficient resources of domestic coal for the purpose of coal gasification with nuclear process heat, etc.).

3. Assessment of the utilization potential of nuclear process heat for the fields of application specified under point 1, using Brazil as an example.

4. In conclusion, a market introduction concept on the basis of the Brazilian model is being presented for introduction of nuclear process heat, particularly where those problems that arise as a result of the rapid economic growth in Brazil are undertaken.

Thus, utilization of process heat seems particularly applicable to the conditions currently prevailing in Brazil. Two of the main potential fields of application of the high-temperature reactor (HTR) in Brazil are shale oil production and the steel industry.

Brazil has one of the largest iron ore reserves in the world (82 billion tons) of the highest grade (up to 67% iron), and its steel industry is rapidly expanding. To process the ore into steel through conventional technology Brazil will need an increasing amount of coking coal. The potential market for an HTR as a heat source to produce reducing gas for steel production from primary hydrocarbons will be described.

The other field of application in Brazil is oil production from oil shale. Brazil has the second largest world reserve of oil shale (20% of the total) and its total oil content is estimated to be 800 billion barrels. The Brazilian state-owned petroleum company has independently developed the technology to extract oil from the Brazilian shale (6 to 9.5% oil content) and has a prototype plant of 1000 bbl/day capacity. The ratio between the use to produce energy for this process is about 37%. The energy-intensive characteristic of this technology makes the application of nuclear process heat particularly suitable for dual purposes—heat and electricity from the high-temperature reactor.

The maximum temperature required to heat the processing gas for this technology is 700°C and is therefore within the present HTR state-of-the-art.

4. Energy Problems and Development of a Multipurpose VHTR in Japan, *Hiroshi Murata, Kiyoaki Taketani, Tetsuo Aochi (JAERI/Japan)*

Since the international oil crisis in 1973, Japan has strongly desired to develop nuclear energy not only for generation of electricity but to replace some of the oil energy which presently accounts for about three-fourths of the total primary energy consumption in Japan. It is also desired to secure a wide variety of energy resources and to reduce the consumption of oil as fuel.

For this purpose, nuclear energy should be obtained at a very high temperature and should be used efficiently in the appropriate fields. The very high-temperature gas-cooled reactor (VHTR) now under development is expected to meet these requirements. In the multipurpose VHTR systems, nuclear energy at a very high temperature can be used to produce a reducing gas for closed-system steel making and/or a hydrogen gas for chemical industries. The VHTR, having high thermal efficiency, can generate electricity, and a desalination process can also be included efficiently in the system.

In consideration of the energy situation in Japan, design study and research and development on an experimental multipurpose VHTR have been promoted since 1969 by the Japan Atomic Energy Research Institute with close cooperation of other domestic organizations.

The experimental VHTR, a helium-cooled graphite-moderating reactor, supplying a nominal thermal output of 50 MW and a reactor outlet coolant temperature of 1000°C, is intended to perform (a) development and demonstration tests of process heat applications, especially the production of reducing gas for steel making, (b) irradiation tests of fuel and other structural materials for high-temperature use, and (c) VHTR system safety confirmation.