Advanced nuclear technologies can power 21st-century steel production

by Marsha Freeman, Science & Technology Editor

In order to make its requisite contributions to world development, the steel industry must quickly reach the highest possible level of productivity. What this means for U.S. steel producers in particular is to regain their technological impetus.

Today, a conventional manufacturer must use more than a ton of coal for each ton of finished steel produced. In addition to the pollution problems caused by burning fossil fuels, the cost and availability of metallurgical coking coal prevents the large-scale expansion of many nations' steel industries.

The major revolution on the horizon in steelmaking is the substitution of more advanced and efficient forms of energy for the bulk use of fossil resources. Over the next twenty years the application of advanced fission technologies can start the U.S. industry back on an upward climb of increased productivity and reduced cost of production.

Today's nuclear power plants, or light-water reactors, operate at a comparatively low temperature. The heat they can transfer from the nuclear reaction is in the range of 500-600 degrees Fahrenheit, which is too low for industrial processing.

The next-step liquid metal fast breeder reactors, which are being demonstrated commercially in France, Britain, and the Soviet Union, bring the available heat from fission up to the 900-1,100 degree range, still of only limited use. Since 1973 Japan has had a program under development to use high-temperature gas-cooled reactors (HTGRS) in the 1,700-2,000 degree range for nuclear steelmaking and other industrial processes.

Unlike the LWRs and breeders which use water and liquid sodium respectively, as coolants, the HTGR uses gaseous helium circulating around the nuclear fuel undergoing fission reactions. This gaseous coolant is well suited for the transfer of greater amounts of heat from the reactor core to water to produce super-heated steam for industry. Nuclear experts and design engineers in Japan are developing a heat exchanger system which can deliver steam at about 1,600 degrees Fahrenheit for industrial processing. In 1978, the Japanese company Ishikawajima-Harima Heavy Industry of Tokyo announced that its engineers had developed an experimental heat exchanger for that purpose.

The most advanced design for a nuclear steelmaking complex would largely eliminate the need for any fossil fuels and make use of the HTGR-produced electricity and process heat.

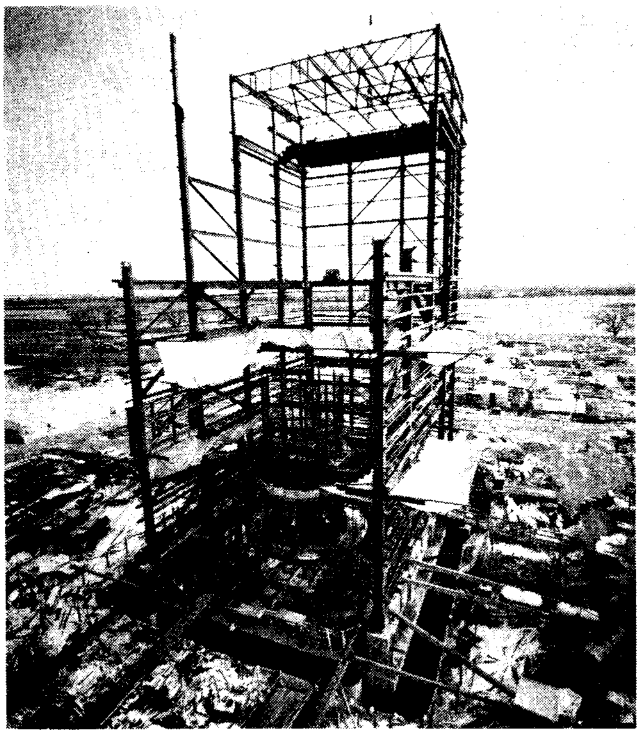
For the first stage of steel production, where the iron ore must be reduced, or purged of its oxygen, the nuclear process would eliminate the use of tons of coking coal and substitute nuclear-produced methane (natural gas) or hydrogen. The hydrogen could be produced either with the current technology of reforming methane, or better still, by using high-temperature electrolysis to free hydrogen from water. The methane or hydrogen gas would be combined with the iron ore to produce pig or sponge iron this first stage in a direct-reduction process. In the current production process, when the first-stage pig iron is ready, it is transferred to oxygen furnaces to have impurities removed and the carbon content of the iron changed to become steel.

In a nuclear steelmaking complex of the most advanced design, this reduced iron ore would be combined with steel scrap and refined into steel in electric furnaces. Today, due to the cost of electricity, only high-valued alloy steels are made in electric furnaces. But with HTGR and nuclear-based processing, the electrical power being produced by the nuclear reactor would be on-site and cheap enough to produce even basic carbon steel with this advanced technology.

A nuclear steel complex would be a nearly self-contained production unit, with the hydrogen being made on site, and the nuclear-generated process heat and electricity contiguous to the steel mill. The only large-scale raw material needed would be the iron ore.

The Japanese are planning to demonstrate a 50-MW thermal HTGR in 1983. By 1985 they plan to have developed the design for a commercial prototype nuclear steel-making plant, and within a decade of that achievement, to build a working mill. They plan to use byproducts, such as tar from petroleum refining, which have no use today, to produce the methane and hydrogen, using the HTGR's steam to crack these byproducts. In the future the direct splitting of water to produce the hydrogen-reducing gas could be even more efficient.

Since 1977 the U.S. government, which provides bud-



The high-temperature gas reactor demonstration plant of 300 MW at Fort Saint Vrain, Colorado: new energy technologies will demand, as well as help produce, huge volumes of steel.

getary support to the advanced design and materials development work for the HTGR, has attempted to terminate the entire program. The Carter administration's excuse was the anti-nuclear bias of the entire administration, and recently the Reagan administration has attempted to cancel the effort for budgetary reasons, claiming that private enterprise will pay for this nationally vital research. This is highly unlikely, under present economic circumstances.

The Bethlehem Steel Company had an active nuclear steelmaking research and development effort until the mid-1970s when it decided that the demand for steel would not justify developing this new technology.

Fusion: the next frontier

HTGR electric plants have already been demonstrated in the United States and West Germany. The development of the higher-temperature materials and components to link the HTGR to steelmaking and other industrial processing is a technology development task which the United States could take a lead in, with an appropriate financial effort.

The real challenge in nuclear steelmaking for the first decades of the next century is to harness the intense energy of nuclear fusion to revolutionize the mining, processing, and fabrication of many kinds of materials, including steel.

Nuclear fusion, the energy source of the Sun and all stars, takes place, not at thousands, but at tens of millions of degrees. At that temperature, all materials decompose into their individual elements, makaing it a simple task to separate the oxygen from iron ore, or add carbon to pig iron. Unlike nuclear fission which can supply heat and electricity to industry, fusion fuel byproducts can also be used directly. These byproducts are in the form of plasmas, gases of charged particles at very high temperatures. The fusion process also releases various forms of radiative energy which can be optimized for various specific processes. The industrial technology known as the fusion torch is created by transferring a plasma from the fusion reactor, where it is created, through a connecting region that isolates it from the reactor, to an interaction region where materials are dissociated.

Once the materials, such as iron ore, have been reduced, a separation technique must be used to recover the desired materials. Many separation techniques have been postulated, but the one most appropriate for plasma steelmaking would be quenching, or quick cooling the plasma, to prevent the iron and oxygen atoms from recombining. Quenching can be accomplished by injecting a cooler gas into the plasma after separation, or by expanding the plasma, or by making it flow over a cooler surface. The materials and technology development for fusion-torch techniques have yet to be developed, but this should be the major challenge for the U.S. energy, materials, and steel scientists and engineers for the next decade.

No technology bottlenecks

As in the case of the HTGR, the major problem in developing fusion torch processing is not the existence of technology bottlenecks—the most immediate problem is that the federal government is pulling back from its responsibility to develop the energy source from which whole new technologies will be born.

The U.S. magnetic fusion energy program has been in a position of world leadership for the past decade. Now, when impressive achievements have been demonstrated in reaching the conditions to create energy from fusion, the Reagan administration is insisting that the nation does not need fusion power for another 70 years, and that the science and technology effort should be slowed down. Meanwhile, the Japanese government has committed its resources to demonstrate the commercial feasibility of producing energy from fusion by 1993.

If the United States slows its fusion program and loses the lead in this crucial energy technology, the Japanese will be in a position to export fusion power plants, with attendant plasma-torch steelmaking technologies, back to the United States in the next century.

The United States, with its obsolete steel industry, has no right to complain that the Japanese and others are producing cheaper steel and other materials, and will have even less right if its greatest research and development capability, the greatest in the world, is shut off. The future of the U.S. steel industry rests on its ability to marshal the required resources to leapfrog today's technology and prepare to meet the world's future needs.