Fuel cells, already described for use in electric cars, could be used on a larger scale for high demand periods. Gas turbines, already used as peaking power, could use hydrogen. And direct conversion cycles, such as magnetohydrodynamics, could use superheated hydrogen as a source of plasma in the production of electricity without using steam turbine generators.

Hydrogen is the perfect fuel and energy source. It is potentially unlimited in availability, reversible in production, use and recycle, and produces only water as a by-product.

Today we use fossil fuels to produce hydrogen. In the far distant future, we may have to use hydrogen to produce our hydrocarbons! Limestone, or even carbon dioxide captured from the air, might be the source of carbon most available in centuries ahead, when fossil fuels have been depleted. Then, hydrogen, which will surely be in bulk use, will be needed to re-create these complex organic molecules for us.

The challenge facing the technical community now, is to develop methods of producing hydrogen from water, making use of the second-generation nuclear fission technologies that should already be available, and the fusion power technologies that will also need hydrogen themselves for the production of unlimited energy.

Robotics: Germany

by William Engdahl

The most important area of prospective development in world industrial production today, which is essential for any crash program for the Strategic Defense Initiative, is industrial automated assembly. Industrial robotics is a vastly underutilized component of industrial assembly processes which, if fully realized, would allow exponential increases in productivity for the world's basic engineering industry. Particularly significant is the rapidly growing use of industrial lasers integrated with robots.

Developments of the past decade have placed the Federal Republic of Germany at the forefront of this work. Faced with the global crisis of soaring energy prices and usurious interest rates which began in the 1970s, the West German capital goods industry had two, quite different, responses. On the one side, productive capacities were shrunk, under the dictates of the European Community's infamous Davignon Plan for restricting steel production. Hundreds of thousands of workers were laid off in steel and industries dependent upon it. But some entrepreneurs took a different route: Beginning after the 1974 first "oil shock," a significant portion of the West German engineering industry began to invest heavily in capital-intensive productivity improvements. As a result, the West German machine tool and industrial automation technology is today the world's most advanced, with the possible exception of Japan.

The Federal Republic of Germany is the world's leading exporter of machine tools today, providing approximately 25% of the world market in 1983. Fully two-thirds of West German machine tools are exported. In the past year, the United States has become the largest import market for German engineering products, not merely because of the competitive price advantage from the rising dollar, but because of the quality differential.

Undertaking a broad-based technological investment, the German machine tool industry began 10 years ago to introduce numerically controlled machine tools. The per tool productivity increases, on average, over conventional manually operated machine tools, is 75 to 100% greater, according to the West German Machine Tool Association. Today, more

leads the world

than 42% of German machine tools are numerically controlled; Japan, 66%, the United States, 39%.

Two principal areas of concentration for the West German engineering and machine tool industry have been industrial robotics and laser machine tool applications.

In the past, most utilization of industrial robots has been relatively primitive, an "automation island" that is not integrated into any total automated production system. The concept of a total integrated industrial automated assembly is the area of most concentrated research and development in German industry. Until now, about 80% of the application of industrial robots has been in far simpler areas such as simple loading/unloading, painting, welding—mostly in automobile production. The fastest-growing area of application in the next decade is estimated to be the integrated assembly application.

The most significant research and application in the West German machine tool and robotics industry is now occurring in the area of "flexible automation." Major government-sponsored R&D projects are ongoing, as well as numerous large private sector efforts in order to allow one skilled operative to multiply his productive output by orders of magnitude through integrated automation. Flexible automation includes automation of not merely the machine tool through numerical control, but automation of the entirety of the production process, upstream and down. This means automated handling of the parts to be machined, storage, and retrieval, as well as manufacture. Machine tools are linked to industrial robots for the handling, cutting, assembly, etc. Major R&D efforts are under way across the Federal Republic, including within the major machine tool companies, such as KUKA, major electronics companies, such as Bosch, and technical universities at Aachen, Stuttgart, Munich, and Berlin. The Frauenhofer Institute in Stuttgart, under H.J. Warnecke, is involved in a number of novel industry-university-government research efforts in advanced industrial automation applications.

The number of industrial robots in use in West Germany is by far the largest in Western Europe. As of beginning 1984, German industry had 4,800 installed industrial robots operating. The world leader is Japan, with 16,500. The U.S. is number two with 8,000. But measured in the more significant parameter of what Dr.-Ing. Rolf D. Schraft of Frauenhofer Institute terms "robot-density," that is, robots per 10,000 industrial workers, West Germany is far ahead of the United States. Sweden is the world leader in robot-density, with 18.8. Japan is second, by this parameter, with 14.3, and West Germany, third with 5.6. The United States lags behind France, at 3.7 robots per 10,000 industrial operatives.

The German machine tool industry uses the most rigorous definition of what constitutes an industrial robot. It must be a "universal application, movable machine, having three or more axes of motion, and be re-programmable without human intervention." This definition immediately eliminates numerous simple pick-and-place or master-slave, loader-unloader units.

East German statistics misleadingly include the latter, for example, to inflate the actual size of their robotics industrialization. The reprogrammable aspect is essential for industries such as automobile or vehicle manufacture, where conventional tool re-fitting in the past costs billions of dollars and weeks of time to install entirely new tools. All major West German automotive makers feature intensive use of robotized welding, painting, and other production. This includes VW/AUDI, BMW, and Mercedes Benz. It is one reason West German auto exports have remained competitive in a collapsing overall world market. Only Japan at this point has a more extensive automated car assembly industry utilizing robotics.

The engineers and researchers at the Frauenhofer Institute for Production Technology and Automation (IPA), in Stuttgart, West Germany, are involved in development of workable systems for automated assembly, including computer software problems, a major bottleneck. According to the institute's head, Dr. H.J. Warnecke, given appropriate applications of robotics, results from studies made in the West German automobile industry show per-worker productivity increases in output rates of from 300 to 400% per workstation. This means one worker, operating a workstation robot, has the output of four workers at the same station with conventional tools. This, of course, is for specific applications, and details of actual company industrial productivity gains are often regarded as confidential and company proprietary for a variety of reasons. But it indicates the order of magnitude increase in output levels.

According to both the West German Machine Tool Association as well as Schraft and his colleagues at the Frauenhofer Institute, the area which is the present focus for the next expansion for the West German industrial application of robotics is in the assembly stage of the industrial production process. Schraft emphasizes, "While unit labor cost in the manufacture of parts has been brought down a long way by new materials, simplification of products, numerical control

of machines, and new production technologies, the reverse has occurred in assembling the same parts to the final product." Thus, Schraft emphasizes, "The extent to which assembly of parts can be automated will strongly determine the competitiveness of German industry." Robotics will play a central role in this automation, particularly for shorter run production of variable pieces. Currently, five West German robot manufacturers produce robots for assembly—Mantec, FWM/AEG, Bosch, Jungheinrich, and Messma Kelch. Three of these companies make up to 6-axis assembly robots.

A major development project, carried out at Frauenhofer Institute, has perfected a programmable assembly unit. In this unit, two industrial robots mount a cover, water pump, and belt pulley on a car engine, fastening them with a total of 10 screws differing in head size. Demonstrated at the 1983 Hanover Industrial Fair, the assembly system shows the future direction being now implemented for robot assembly applications in German industry.

The largest single producer of industrial robots in West Germany is the auto giant, VW, though it consumes its entire output in-house. Other major producers include KUKA, and Cloos. The Bosch Company, already a major manufacturer of industrial "turnkey" assembly systems, is rapidly moving to become a major producer of robotized modular flexible assembly systems, including hardware and software, a major step toward the semi-automated factory of the future.

Siemens, a major electronics firm, with extensive computer chip operations, has become a producer of industrial robots. It is reportedly developing a fully automated robotized assembly to manufacture the microchips, eliminating the enormous reject rate of human production, in which commonly 90% of chips are faulty. One speck of dust can destroy a micro circuit. Only robotized, fully automated production can eliminate this. A recent production plant has been completed by the Japanese Mitsubishi Corporation, in which this production from wafer to final test and assembly is fully robotized. Productivity gains are reportedly so staggering as to imply the next revolution in chip manufacture.

Lasers and robots

The next generation of industrial robotics lies in the natural marriage of rapidly growing industrial lasers with robots. The world-acknowledged leader in this advanced area is a Hamburg firm, Rofin-Sinar, Inc., a relatively small but extremely aggressive innovator. Despite its relative small size, the 10-year-old company has developed a quality of industrial high-energy laser tool which has become the market leader in Western Europe and number three worldwide in only a few years. By developing a substantially improved geometry, known as "fast axial flow technology," in which the CO_2 gas flows parallel to the optical axis of the laser beam, Rofin-Sinar has made major quality and efficiency advances over such relative giant competitors as GTE Sylvania, which incorporate the less effective transverse model lasers.

Producing approximately 100 lasers per year, the firm, according to its founder, Samuel Simonsson, invests more than 12% of annual gross sales revenue back into future R&D. Concentrating in CO_2 industrial lasers in the power range up to 1.5 kilowatts, with a 2.5 kw model ready next year, the firm plans to be fully into the higher-power production of 10-12 kw in three to four years. Rofin-Sinar is one of only 25 firms worldwide, at present, producing commercial CO_2 industrial lasers. Less than 10 of these 25 make 50 or more lasers/year in the still labor-intensive industry. Of these 10, four are in West Germany.

Rofin-Sinar, working in tandem with a major West German robotics firm, has perfected the coupling of its laser unit, using fiber optics, to simultaneously drive three robot work stations in a production process. This takes maximum advantage of the laser's inherent flexibility. Somewhat like changing the lens on a microscope by rotating the lens, Rofin-Sinar's design is able to drive, for example, one robot doing laser cutting of metal, one robot doing welding, and one robot doing heat treatment. This takes maximum advantage of the few seconds time required to bring the next part into place, so that no time is lost and one laser can be used to work three robots, maximizing the efficiency and minimizing the cost of incorporating the laser. Incorporating the remarkable abilities of focused laser energy, Rofin-Sinar has, for example, developed new welding technologies for the German auto industry which eliminate the need for costly, heavy, and inefficient forged/machined transmission gear boxes. With laser welding, at high speeds, using robots, Rofin-Sinar is able to turn out, with minimal distortion, gear boxes with one-third the weight at one-half the cost and only one-fourth the size of the old forged/machined gear boxes. VW and Renault now incorporate this to make possible, for the first time, a 4-speed automatic transmission. Simonsson believes that the use of lasers for such welding applications will be a very fast-growing area of industrial application as companies begin to realize the advantages of high strength and low weight possible with laser welding, for example, of dissimilar metals, which is not possible with conventional welding techniques. Significantly, Rofin-Sinar's single biggest export market is Japan.

The most advanced laser machine tool known, which is presently in use in Sweden at the Volvo plant, is Rofin-Sinar's development of a 6-axis laser machine tool. This was officially unveiled on Sept. 17 at the World Machine Tool EMO Congress in Hanover. But it indicates the potentials when the remarkable qualities of lasers for metal cutting, welding, and heat treating are combined with the enormous potentials of industrial robotic automation. The impetus which will inevitably spill over from the multibillion dollar requirements of developing the sophisticated technologies for laser and related advanced anti-missile weaponry for the Strategic Defense Initiative, will catalyze rates of applications of industrial robotics and laser technologies, such as have been done only on limited scale until now by innovative firms like Rofin-Sinar or KUKA.

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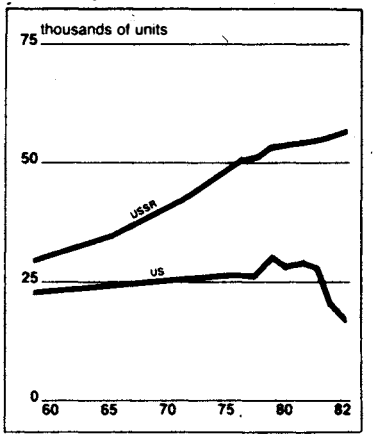
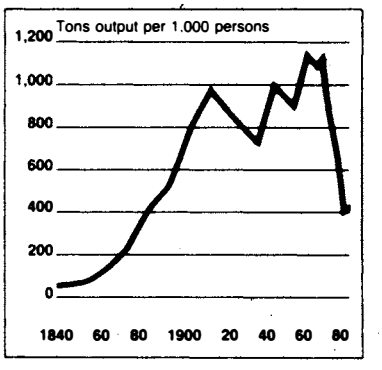
June 15, 1985

U.S. and Soviet production of power-driven metal-forming machine tools not portable by hand, 1960-82



U.S. iron output per member of the labor force



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